Taxonomic Study of the Family Daltoniaceae (Bryophyta) in Thailand

Wanwisa Juengprayoon

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Botany

Prince of Songkla University

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ชื่อวิทยานิพนธ์ การศึกษาอนุกรมวิธานของมอสส์วงศ์ Daltoniaceae (Bryophyta) ในประเทศไทย
ผู้เขียน นางสาววันวิสาข์ จึงประยูร
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บทคัดย่อ

การศึกษาอนุกรมวิธานของมอสส์วงศ์ Daltoniaceae Schimp. ในประเทศไทย จากตัวอย่างที่สำรวจและเก็บรวบรวมในภาคสนาม จากเขตพรรณพฤกษชาติต่างๆ ของประเทศไทย ระหว่างเดือนมกราคม พ.ศ. 2557 ถึงเดือนธันวาคม พ.ศ. 2559 และตัวอย่างที่เก็บรักษาไว้ในพิพิธภัณฑ์พืชต่างๆ ได้แก่ BCU, BKF, CMUB, HYO, PSU, และ SING พบมอสส์วงศ์นี้ทั้งหมด 22 ชนิด 3 พันธุ์ ใน 5 สกุล ได้แก่ *Calyptrochaeta* Desv., *Daltonia* Hook. & Taylor, *Distichophyllum* Dozy & Molk., *Ephemeropsis* K.I.Goebel และ *Leskeodon* Broth.ในจำนวนนี้จัดเป็นชนิดที่รายงานพบครั้งแรกในประเทศไทย 3 ชนิด ได้แก่ *Distichophyllum obtusifolium* Thér., *D. osterwaldii* M. Fleisch. และ *D. subnigricaule* Broth. มีมอสส์ 3 ชนิด ถูกตัดออกจากพรรณพฤกษชาติของประเทศไทย ได้แก่ *Daltonia carinata* (Dixon & W.E. Nicholson) B.C. Ho & L. Pokorny, *Distichophyllum decolyi* Gangulee และ *D. obovatum* (Griff.) Paris ได้จัดทำรูปวิธานจำแนกชนิด คำบรรยายลักษณะ และภาพวาดลายเส้น พร้อมทั้งข้อมูลสภาพถิ่นอาศัย ลักษณะทางนิเวศวิทยา และการกระจายพันธุ์ของแต่ละชนิด วงศ์ Daltoniaceae ในประเทศไทยสามารถพบได้ในที่อยู่อาศัยที่หลากหลายทั้งก้อนหิน พื้นดิน ลำต้น กิ่งไม้ และใบไม้ ในจำนวนนี้พบส่วนใหญ่เป็นพืชอิงอาศัยเจริญบนลำต้นหรือกิ่งไม้ ซึ่งพบได้ตั้งแต่ที่ความสูงใกล้ระดับน้ำทะเลจนถึงที่ระดับความสูงมากกว่า 2000 เมตรจากระดับน้ำทะเล มอสส์วงศ์ Daltoniaceae ในประเทศไทยส่วนใหญ่พบในป่าดิบชื้นที่ความสูงระหว่าง 800 ถึง 1600 เมตรจากระดับน้ำทะเล เขตคาบสมุทรไทยพบจำนวนชนิดมากที่สุด คือ 14 ชนิด 3 พันธุ์ รองลงมาคือในภาคเหนือพบ 10 ชนิด *Calyptrochaeta remotifolia* (Müll. Hal.) Z. Iwats. *et al.* มีการกระจายพันธุ์ในประเทศไทยกว้างที่สุดพบได้ 5 เขตพรรณพฤกษชาติ

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ABSTRACT

A taxonomic study of the family Daltoniaceae Schimp. in Thailand is presented, based on the materials from field surveys in various floristic regions of the country from January 2014 to December 2016 as well as the herbarium specimens from BCU, BKF, CMUB, HYO, PSU, and SING herbaria. Twenty-two species and three varieties in five genera are recognized, namely *Calyptrochaeta* Desv., *Daltonia* Hook. & Taylor, *Distichophyllum* Dozy & Molk., *Ephemeropsis* K.I.Goebel, and *Leskeodon* Broth. Of these, three species are newly recorded for Thailand *viz. Distichophyllum obtusifolium* Thér., *D. osterwaldii* M. Fleisch. and *D. subnigricaule* Broth. Three species are excluded from Thai flora: *Daltonia carinata* (Dixon & W.E. Nicholson) B.C. Ho & L. Pokorny, *Distichophyllum decolyi* Gangulee, and *D. obovatum* (Griff.) Paris. A key to species, descriptions and illustrations are provided. Habitats, ecology, and geographical distribution of the species are also noted. Among the currently recognized taxa of Daltoniaceae in Thailand were collected from various habitats such as rocks, soils, trunks, twigs and living leaves. The majority of the species are epiphytes either corticolous or ramicolous. The total altitudinal range of the family extends from near sea level to over 2000 m in elevation. The lower montane rain forests at altitudes between 800 and 1600 m contain the highest species numbers. The greatest diversity of Thai Daltoniaceae is found in the Peninsular region with 14 species 3 varieties, followed by 10 species in the Northern region. *Calyptrochaeta remotifolia* (Müll. Hal.) Z. Iwats. *et al.* is the most common species and widely spread in Thailand which is distributed in five floristic regions.

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CHAPTER 1

INTRODUCTION

The family Daltoniaceae, a member of the order Hookeriales, was first described by Schimper in 1860 based on the genus *Daltonia* Hook. & Taylor. It comprises approximately 200 species in 14 genera and mainly distributed in tropical and subtropical regions (Frey & Stech, 2009; Ho *et al*., 2012). Members of the family can be found growing in a wide range of habitats from terrestrial to epiphytic and occasionally epiphyllous, and prefer the humid forest. The family is characterized by: 1) plants usually forming complanate foliate; 2) leaves with one costa (unicostate), rarely none (ecostate only in *Distichophyllidium* M.Fleisch.), 3) marginal laminal cells mostly differentiated as a distinct border of elongate cells (limbate); and 4) the mitriform calyptra with fringed hairs at the base (Ho *et al*., 2012).

Thailand is well-known as one of the richest areas of bryophyte diversity (e.g. He *et al.*, 2012; Chantanaorrapint & Sridith, 2014; Inuthai *et al*., 2014, 2015; Chantanaorrapint, 2015; Promma & Chantanaorrapint, 2015). The country is located in both the Indo-Burmese and Sundaland hotspots (Myers *et al.*, 2000), and includes area identified as the overlapping zone of Sino-Himalayan and Malesian floristic regions (Smitinand, 1989). Although several publications have contributed to the knowledge of the Asiatic species of Daltoniaceae (e.g. Gangulee, 1977; Tan & Robinson, 1990; Mohamed & Robinson, 1991; Lin & Tan, 1995), there are few reports of this family from Thailand, probably due to the rareness of bryological surveys in this country (Sukkharak & Chantanaorrapint, 2014). The first report of Daltoniaceae species in Thailand was published by Brotherus (1901) who described a new species, *Distichophyllum schmidtii* Broth., based on a collection made by J. Schmidt from Koh Chang (Island), Trat province. The latest checklist of Thai moss contains 10 species in 4 genera of family Daltoniaceae (He, 1998). In recent years, some additional species have been reported for Thai flora (Akiyama, 2006; Ho *et al.*, 2010; Akiyama *et al*., 2011; Printarakul *et al*. 2013). More new records of species are expected in the unexplored areas, especially in the southern part of the country. Moreover, the identification of the species is difficult due to morphological variations

and the taxonomic statuses of Daltoniaceae species in Thailand are still unclear; several species have been treated as a synonym or seem to be erroneous identification.

The purposes of the present study is to revise the current knowledge on family Daltoniaceae in Thailand based on herbarium specimens and recent collections from field surveys. The morphology, habitat and ecology, and phytogeography are noted. Description of family, genera, and species as well as key to genera and species are provided.

Objectives:

1. To revise and account the family Daltoniaceae Schimp. in Thailand.

2. To examine the taxonomic status of members of Thai Daltoniaceae.

3. To construct keys to genera, species and varieties of the family Daltoniaceae in Thailand with detailed descriptions and line drawing.

CHAPTER 2

LITERATURE REVIEW

2.1 The history of family Daltoniaceae

The family Daltoniaceae is a member of the order Hookeriales M.Fleisch. This family was first described by Schimper (1860) as "Daltonieae", based on the genus *Daltonia* Hook. & Taylor.

Subsequently, Fleischer (1908) proposed four families of suborder Hookerineae including Nemataceae Broth., Pilotrichaceae Kindb., Hookeriaceae, and Hypopterygiaceae Mitt. In this study, He did not recognize the family Daltoniaceae and treated the genus *Daltonia* as a part of family Hookeriaceae Schimp. He divided Hookeriaceae into four tribes, consisting of Daltonieae (*Bellia* Broth. (= *Crosbya* Vitt.) and *Daltonia*), Distichophylleae, Hookerieae, and Hypnelleae. In 1920, Fleischer described the order Hookeriales and divided it into two suborders: Nematacineae (Nemataceae) and Hookeriineae (Pilotrichaceae, Hookeriaceae, Symphyodontaceae M.Fleisch., Leucomiaceae Broth., and Hypopterygiaceae) (Fleischer, 1920).

Later, Fleischer (1923) proposed six families of Hookeriales that consisted of Nemataceae, Pilotrichaceae, Hookeriaceae, Symphyodontaceae, Leucomiaceae, and Hypopterygiaceae. Brotherus (1925) followed Fleischer's classifications and raised Fleischer's tribes to subfamilies level. The family Hookeriaceae was divided into four subfamilies *viz*.: Daltonioideae, Distichophylloideae, Hookerioideae, and Hypnelloideae. The Daltonioideae composted of two genera *Bellia* and *Daltonia*. The subfamily Distichophylloideae consisted of six genera, i.e., *Adelothecium* Mitt., *Distichophyllidium* M.Fleisch., *Distichophyllum* Doxy & Molk., *Eriopus* Brid. (= *Calyptrochaeta* Desv.), *Leskeodon* Broth, and *Pterygophyllum* Brid. (= *Achrophyllum* Vitt & Crosby).

Miller (1971) recognized nine families in Hookeriales and hypothesized the directions of morphological evolution. He expanded the Fleischer-Brotherus concept

of subfamily Daltonioideae became a family level consisted of *Daltonia* and *Bellia* (= *Crosbya* Vitt.). Distichophyllaceae was described as a new family that consisted of *Adelothecium*, *Distichophyllidium*, *Distichophyllum*, *Leskeodon*, *Leskeodontopsis* Zanten, and *Pterygophyllum*. Moreover, the genus *Eriopus* (= *Calyptrochaeta*) was transferred to the subfamily Hookerioideae by the characters of leaf with a double costa and narrowly bordered.

Crosby (1974) proposed a new classification that emphasizing the features of sporophyte. Order Hookeriales was divided into two families: Daltoniaceae (13 genera) and Hookeriaceae (38 genera), separated by outer exostome surface ornamentation. Exostomes with the outer surfaces cross-striate are termed ‘‘hookeriaceous type”, whereas those completely papillose are termed ‘‘daltoniaceous type’’. The arrangement of thirteen daltoniaceous genera were recognized in four subgroups (Actinodontioid, Helicoblepharoid, Daltonioid, and Catharomnioid), based on some characters of gametophyte.

Buck (1987, 1988) proposed five families of Hookeriales consisting Adelotheciaceae W.R. Buck, Callicostaceae H.A. Crum, Daltoniaceae, Hookeriaceae, and Leucomiaceae. He discussed about interfamilial relationships with emphasizing gametophytic rather than sporophytic features. Furthermore, he re-circumscribed Daltoniaceae to include the genus *Ephemeropsis* K.I.Goebel (by gametophytes consisting of persistent protonemata, and a hookeriaceous peristome). The members of Daltoniaceae consisted of *Calyptrochaeta*, *Crosbya*, *Daltonia*, *Distichophyllidium*, *Distichophyllum*, *Ephemeropsis*, *Leskeodon*, and *Leskeodontopsis*. Moreover, the other genera of Daltoniaceae which had been classified by Crosby were transferred to family Callicostaceae such as *Actinodontium* Schwägr., *Crossomitrium* Müll. Hal., *Helicoblepharum* (Spruce ex Mitt.) Broth., and *Stenodesmus* (Mitt.) A. Jaeger, based on the features of gametophyte.

Whittemore and Allen (1989) classified Hookeriales in three families (Daltoniaceae, Hookeriaceae, and Ephemeropsidaceae W. Schultze-Motel) based on the similarity of sporophyte and gametophyte characters. Furthermore, they retained genus *Ephemeropsis* in a family of its own (Ephemeropsidaceae). This classification the family Daltoniaceae composted of twelve genera, *viz.* *Achrophyllum*,

Adelothecium, *Bryobrothera*, *Calyptrochaeta*, *Crosbya*, *Cyathophorum* P. Beauv., *Cyathophorella* M. Fleisch., *Daltonia*, *Distichophyllidium*, *Distichophyllum*, *Leskeodon*, and *Leskeodontopsis*.

Later, Buck *et al.* (2005) recognized seven families into order Hookeriales on the basis of phylogenetic analyses with molecular data from four genes (chloroplast trnL-trnF and rps4, mitochondrial nad5, and nuclear 26S). The family Daltoniaceae consisted of fourteen genera, including *Achrophyllum*, *Adelothecium*, *Beeveria* Fife, *Benitotania* H.Akiy., T.Yamag. & Suleiman, *Bryobrothera* Thér, *Calyptrochaeta*, *Crosbya*, *Daltonia*, *Distichophyllidium*, *Distichophyllum*, *Ephemeropsis*, *Leskeodon*, *Leskeodontopsis*, and *Metadistichophyllum* Nog. & Z.Iwats.

Recently, the intergeneric relationships among the members of Daltoniaceae were studied by Pokorny *et al.* (2011, 2012) and Ho *et al.* (2012). However, the circumscription of Daltoniaceae and the relationships among genera are not entirely settled. In particular, the inclusion of *Calyptrochaeta* in the family still awaits confirmation. The relationships between *Achrophyllum*, *Calyptrochaeta* and the rest of Daltoniaceae are uncertain. Furthermore, infrageneric relationships within *Achrophyllum* have never been assessed. A first approach exists for *Calyptrochaeta* (Pokorny, *et al.* 2011). Within the well-supported core Daltoniaceae (i.e. Daltoniaceae excluding *Calyptrochaeta* and *Achrophyllum*), relationships among the genera, especially with regard to the species-rich *Distichophyllum*, are still in question. Therefore, the understanding of morphological evolution in these mosses requires a better understanding of phylogenetic relationships.

The historical classification of the order Hookeriales was summarized following table 2.1.

Table 2.1 Historical classification of the order Hookeriales

Brotherus (1925)
Hookeriales
Suborder Nematacineae
- Nemataceae
Ephemeropsis

Suborder Hookeriineae
- Pilotrichaceae
Pilotrichidium
Pilotrichum

- Hookeriaceae
:Daltonioideae
Bellia
Daltonia

:Distichophylloideae
Adelothecium
Distichophyllidium
Distichophyllum
Eriopus
(= *Calyptrochaeta*)
Leskeodon
Pterygophyllum
(= *Achrophyllum*)

:Hookerioideae
Actinodontium
Amblytropsis
Callicostella
Cyclodictyon
Hookeria
Hookeriopsis
Lamprophyllum
(= *Schymperobryum*)
Lepidopilidium
Tetrastichium

:Hypnelloideae
Callicostellopsis
Chaetomitriopsis
Chaetomitrium
Dimorphocladon
Harpophyllum
(= *Hemiragis*)
Helicoblepharum
Hypnella
Orontobryum
Philophyllum
Pseudohypnella
Rhynchostegiopsis
Sauloma
Stenodesmus
Stenodictyon
Thamniopsis

- Symphyodontaceae
Symphyodon

- Leucomiaceae
Leucomium
Vesicullariopsis

- Hypopterygiaceae
:Hypopterygioideae
Catharomnium
Hypopterygium
Lopidium

:Cyathophoroideae
Cyathophorella
Cyathophorum

Miller (1971)
Hookeriales
Suborder Hookeriineae
- Pilotrichaceae
Acrohypnella
(=*Vesicullariopsis*)
Callicostellopsis
Chaetomitriopsis
Chaetomitrium
Dimorphocladon
Diploneuron
Helicoblepharum
Hemiragis
Hypnella
Neohypnella
Orontobryum
Pilotrichidium
Pilotrichum
Stenodictyon
Thamniopsis

- Hookeriaceae
:Hookeriopsidoideae
Actinodontium
Amblytropis
Archboldiella
Callicostella
Cyclodictyon
Hookeriopsis
Lepidopillidium
Lepidopilum

:Hookerioideae
Crossomitrium
Eriopus
(= *Calyptrochaeta*)
Hookeria
Schimperobryum
Tetrastichium

- Distichophyllaceae
Pterygophyllum
Distichophyllum
Distichophyllidium
Leskeodon
Leskeodontopsis
Adelothecium?

- Daltoniaceae
Bellia (= *Crosbya*)
Daltonia

- Symphyodontaceae
Symphyodon

- Leucomiaceae
Vesicullariopsis
Philophyllum
Sauloma
Leucomium
Pulvinella
Stenodesmus
Rhynchostegiopsis

Suborder Ephemeropsidineae
- Ephemeropsidaceae
Ephemeropsis

Suborder Hypopterygiineae
- Hypopterygiaceae
Lopidium
Hypopterygium
Catharomnium
Cyathophoraceae
Cyathophorum
Cyathophorella

Crosby (1974)
Hookeriales
- Daltoniaceae
Actinodontioid group
Actinodontium
Crossomitrium
Isodrepanium
Lepidopilum
Stenodesmus

Helicoblepharoid group
Helicoblepharum
Pilotrichum

Daltonioid group
Daltonia
Distichophyllidium
Leskeodon
Leskeodontopsis

Catharomnioid group
Catharomnion
Cyathophorella

Genera incertae sedis
Amblytropis
Symphyodon

- Hookeriaceae
Distichophylloid group
Acrophyllum
Distichophyllum

Adelothecium group
Adelothecium
Bellia (= *Crosbya*)

Cyathophoroid group
Calyptrochaeta
Cyathophorum
Dendrocyathophorum
Hypopterygium
Lopidium

Hookerioid group
Hookeria
Schimperobryum
Tetrastichium

Hemiragoid group
Dimorphocladon
Hemiragis
Philophyllum
Rhynchostegiopsis
Sauloma

Hookeriopsoid group
Callicostella
Cyclodictyon
Hookeriopsis
Lepidopilidium
Stenodictyon
Thamniopsis

Pilotrichidioid group
Diploneuron
Pilotrichidium
Ephemeropsoid group
Ephemeropsis

Genera incerta sedis
Chaetomitrium
Cyathophorella
Chaetomitriopsis
Pulvinella
Vesicullariopsis

Excluded genera
Orontobryum
Hypnella
Neohypnella
Pseudohypnella
Leucomium
Phillodon
Schizomitrium

Buck (1987, 1988)
Hookeriales
- Adelotheciaceae
Adelothecium
Bryobrothera?

- Callicostaceae
Actinodontium
Amblytropis
Brymela
Callicosta
Callicostellopsis
Crossomitrium
Cyclodictyon
Diploneuron
Helicoblepharum
Hemiragis
Hookeriopsis
Hypnella
Lepidopilidium
Lepidopilum
Philophyllum
Pilotrichidium
Sauloma
Schizomitrium
(= *Callicostella*)
Stenodesmus
Stenodictyon
Tetrastichium
Thamniopsis
Trachyxiphium
Vesicullariopsis

- Daltoniaceae
Calyptrochaeta
Crosbya
Daltonia
Distichophyllidium
Distichophyllum
Ephemeropsis
Leskeodon
Leskeodontopsis

- Hookeriaceae
Achrophyllum
Cyathophorella
Cyathophorum
Dendrocyathophorum
Hookeria
Schimperobryum

- Leucomiaceae
Leucomium
Rhynchostegiopsis

Excluded genera
Chaetomitrium
Chaetomitriopsis
Dimorphocladon
(=*Hypopterigiaceae* were transferred to the Bryales (Buck & Vitt, 1986))

Whittemore & Allen (1989)
Hookeriales
- Daltoniaceae
Achrophyllum
Adelothecium
Bryobrothera
Calyptrochaeta
Crosbya
Cyathophorum
Cyathophorella
Daltonia
Distichophyllidium
Distichophyllum
Leskeodon
Leskeodontopsis

- Hookeriaceae
Actinodontium
Amblyotropis
Brymela
Callicostellopsis
Crossomitrium
Cyclodictyon
Diploneuron
Helicoblepharum
Hemiragis
Hookeria
Hookeriopsis
Hypnella
Lepidopilidium
Lepidopilum
Leucomium
Philophyllum
Pilotrichidium
Rhynchostegiopsis
Sauloma
Schimperobryum
Schizomitrium
Stenodesmus
Stenodictyon
Tetrastichium
Thamniopsis

- Ephemeropsidaceae
Ephemeropsis

Buck *et al*. (2005)
Hookeriales
- Daltoniaceae
Achrophyllum
Adelothecium
Beeveria
Benitotania
Bryobrothera
Calyptrochaeta?
Crosbya
Daltonia
Distichophyllidium
Distichophyllum
Ephemeropsis
Leskeodon
Leskeodontopsis
Metadistichophyllum

- Hookeriaceae
Hookeria
Crossomitrium?

- Hypopterygiaceae
Arbusculohypopterigium
Canalohypopterigium
Catharomnium
Cyathoforum
Cyathophorella?
Dendrocyathoforum
Hypopterigium
Lopidium

- Leucomiaceae
Leucomium
Rhynchostegiopsis
Tetrastichium

- Pilotrichaceae
Actinodontium
Brymela
Callicostella
Callicostellopsis
Cyclodictyon
Hemiragis
Hypnella
Lepidopilidium
Lepidopilum
Philophyllum ?
Pilotrichidium
Pilotrichum
Stenodictyon
Thamniopsis
Trachyxiphium

- Saulomataceae
Ancistrodes
Sauloma
Vesicullariopsis?

- Schimperobryaceae
Schimperobryum

2.2 Previous studies of the family Daltoniaceae in Thailand

The first information of Daltoniaceae species in Thailand was published by Brotherus (1901) who described a new species, *Distichophyllum schmidtii* Broth., based on a collection made by J. Schmidt from Koh Chang (Island), Trat province.

Based on the previous publications and Kerr's collections, Dixon (1932) published the first checklist of moss in Thailand and reported three species of Daltoniaceae including *Distichophyllum mittenii* Bosch & Sande Lac. from Chanthaburi province, *D. schmidtii* Broth. from Surat Thani province, and *Ephemeropsis tjibodensis* K.I.Goebel. from Chanthaburi, Surat Thani, and Pattani province. Two years later, Dixon (1935) updated his checklist and added two more additional species for Thai bryoflora *viz*. *Distichophyllum cuspidatum* (Dozy & Molk) Dozy & Molk. and *D. sinuosulum* Dixon. (= *D. nigricaule* Mitt. ex Bosch & Sande Lac. var. *elmeri* (Broth.) B.C. Tan & H. Rob.).

Touw (1968) reported two species of the family in Thailand, including *Distichophyllum tortile* Dozy & Molk. ex Bosch & Sande Lac. and *Eriopus remotifolius* Müll. Hal. (= *Calyptrochaeta remotifolia* (Müll. Hal.) Z. Iwats., B.C. Tan & Touw) from Nakhon Si Thammarat province.

Tixier (1970) studies bryophytes in Ranong province and reported two members of the family *viz*. *Ephemeropsis tjibodensis* and *Leskeodon acuminatus* (Bosch & Sande Lac.) M. Fleisch.

Based on the previous publications between 1900 and 1970, Sornsamran and Thaithong (1995) published a checklist of bryophytes in Thailand, including 644 species of mosses. Of these species belong to Daltoniaceae.

The latest catalogue of Thai mosses was published by He (1998), based on herbarium specimens and literature reviewed. He listed 620 species and 31 subspecific taxa distributed in 190 genera and 52 families. Of these contain 10 species in four genera of Daltoniaceae: *Calyptrochaeta* Desv., *Ephemeropsis* K.I.Goebel, *Distichophyllum* Dozy & Molk., and *Leskeodon* Broth.

After that the other reports of Daltoniaceae in Thailand have been done in some particular areas such as Doi Inthanon National Park, Chiang Mai province

(Akiyama, 2006; Nathi, 2009; Akiyama *et al.*, 2011; Printarakul *et al.*, 2013); Doi Suthep-Pui National Park, Chiang Mai province (Printarakul, 2016); Khao Soi Dao wildlife sanctuary, Chanthaburi province (Sukkharak *et al.*, 2014); Khao Luang, Huai Yang Waterfall National Park, Prachuap Khiri Khan province (Chantanaorrapint *et al.*, 2004); and Khao Nan National Park, Nakhon Si Thammarat province (Chantanaorrapint, 2010)

In addition, seven new recorded species of Daltoniaceae in Thailand were reported by Ho *et al*. (2010) *viz. Distichophyllum brevicuspis* M. Fleisch., *D. carinatum* Dixon & W.E. Nicholson (= *Daltonia carinata* (Dixon & W.E. Nicholson) B.C. Ho & L. Pokorny), *D. collenchymatosum* Cardot, *D. jungermannioides* (Müll. Hal.) Bosch & Sande Lac., *D. maibarae* Besch. (= *Leskeodon maibarae* (Besch.) B.C.Ho & L. Porkorny), *D. spathulatum* (Dozy & Molk.) Dozy & Molk., and *D. wanianum* B.C. Tan & P.J. Lin (= *Daltonia waniana* (B.C.Tan & P.J.Lin) B.C.Ho & L.Pokorny). In summarized, 22 species and three varieties in five genera of Daltoniaceae have been previously reported in Thailand (Brotherus, 1901; Dixon, 1932, 1935; Touw, 1968; Tixier, 1970; He, 1998; Chantanaorrapint *et al.*, 2004; Akiyama, 2006; Nathi, 2009; Ho *et al*., 2010; Akiyama *et al*., 2011; Printarakul *et al.*, 2013; Sukkharak *et al.*, 2014; Pócs & Podani, 2015).

2.3 Study area

Thailand is situated in mainland Southeast Asia between the latitudes 5–21° N and longitudes 97–106° E. The country is sharing border with Myanmar (Burma) in west and northwest, Laos in the northeast, Cambodia in the southeast, and Malaysia in the south. The country is about 1620 km long, 750 km wide and covers a total area of 513,115 square kilometers (Santisuk, 2007). Thailand exhibits a diverse landscape, ranging from sea level to 2565 m in elevation. The most of conspicuous terrain features of Thailand contain several high mountains covering most of north and extending along western border with Myanmar down into Malay Peninsula.

The climate is characterized by tropical monsoon system that reverses its cycle seasonably (He, 1998; Maxwell, 2004). The region is under the influence of northeast

and southwest monsoons. The northeast monsoon (dry) is from October-November to February-March and the southwest monsoon (wet) lasts from April–May to October. Influence of monsoons creates two distinct seasons: wet and dry; except northern part of the country has three distinct seasons, *viz.* rainy (May–October), cool–dry (November–February), hot-dry (March–April). The amount of rainfall in the peninsula, southeast and Ranong province is 3000–4500 mm per year with shortest dry period (3–8 weeks) and rainfall decreases to 1000–2000 mm per year towards the north and northeast with increasing dry period (3–5 months). Temperatures vary considerably with the seasons, latitude, and elevation. The highest temperatures occur between March and April reaching to over 40°C, whilst the lowest temperatures are usually recorded in November to February.

Thailand is covered by two main types of forest, especially for tropical evergreen forest and tropical deciduous forest (Maxwell, 2004; Santisuk, 2007). Based on these two main forest types, Santisuk (2007) divided the vegetation in Thailand to several forest types. Evergreen forest consists of 14 types, *viz.* tropical evergreen rain forest or tropical rain forest, seasonal rain forest or semi-evergreen forest or dry evergreen forest, lower montane rain forest, lower montane oak forest, lower montane pine-oak forest, lower montane coniferous forest, lower montane scrub, upper montane rain forest or cloud forest, upper montane scrub, montane peat bog or sphagnum bog, mangrove forest, peat swamp forest, freshwater swamp forest, and strand vegetation. Deciduous forest comprises 3 types, *viz.* mixed deciduous forest, deciduous dipterocarp forest or dry dipterocarp forest, and pine-deciduous dipterocarp forest. This variability in topography and climate has produced a diverse vegetation that includes a large number of mosses, representing one of the richest bryoflora in the tropical Asia (He, 1998).

Unfortunately, the natural forest has been widely disturbed throughout the country by human activities over the last 50 years. A large amount of forest cover has been transformed to various agricultural usages such as rubber and oil palm plantations in the south and crop plantations in the north. Currently, the only undisturbed forests can be found in the mountainous regions where agriculture is not

economically viable. During the past century the forest cover of Thailand has been reduced to 15% (Maxwell, 2004).

Phytogeographical regions in Thailand

Thailand is well known as one of the richest areas of bryophyte diversity (e.g. He *et al.*, 2012; Chantanaorrapint & Sridith, 2014; Inuthai *et al.*, 2014, 2015; Chantanaorrapint, 2015; Promma & Chantanaorrapint, 2015). This area is located in both the Indo-Burma and Sundaland biodiversity hot spots (Myers *et al.*, 2000), and includes areas identified as a transition zone between the Indo-Chinese and Malesian floristic regions (Smitinand, 1989). The variability in topography and climate has produced a diverse vegetation that includes a large number of mosses, representing one of the richest bryoflora in the tropical Asia (He, 1998).

Formerly, Thailand can be divided into seven floristic regions according to topography, vegetation type, and climatic data (Smitinand, 1958) (Fig. 2.1). They are the Northern, North-eastern, Eastern, Central, South-eastern, South-western, and Peninsular regions. Recently, Van Welzen *et al.* (2011) recognized only four floristic regions including the Northern, Eastern, Central and Southern regions. However, most of botanists still use seven floristic regions in framework of the Flora of Thailand project. The characteristic of the regions can be summarized as follows table 2.2.

Table 2.2 The characteristic of seven Thai floristic regions divided by Smitinand (1958).

Thai Floristic Regions	**Influenced floristic elements**	**Vegetations**
Northern	Indo-Burmese	dry deciduous forest, dry hill evergreen forest, and montane temperate forest
North-eastern	Indo-Chinese	dry deciduous to mixed deciduous forest with large tracts of dry evergreen forest

Thai Floristic Regions	Influenced floristic elements	Vegetations
Eastern	Central and Southern Indo-Chinese	dry dipterocarp forest
South-eastern	Indochinese and Malesian	tropical rain forest, mangrove swamps and tidal forest
Central	Mainly cultivated with only small remnants of original forests	mangrove
South-western	Tenasserim or lower Burmese	bamboo forest, mixed deciduous, dry dipterocarp forest, mangroves
Peninsular	Malesian, Burmese (northern part)	tropical rain forest, mangrove forest, peat swamps

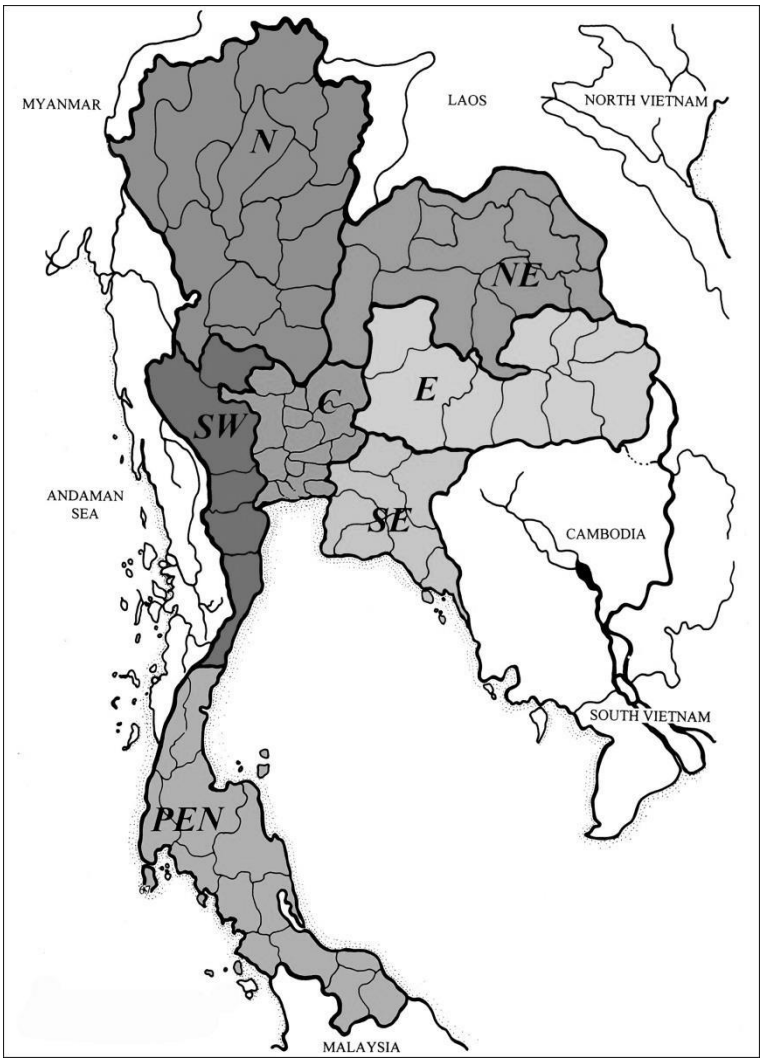

Figure 2.1 The phytogeographical regions in Thailand by Smitinand (1958) (N = Northern, NE = North-Eastern, E = Eastern, SW = South-Western, C = Central, SE = South-Eastern, and PEN = Peninsular).

CHAPTER 3

MATERIALS AND METHODS

Plant materials

Approximately 520 specimens of Daltoniaceae were examined in the present study, including the recent collections from field surveys as well as herbarium specimens. Herbarium specimens of Daltoniaceae from Thailand and neighboring countries housed in the herbaria BCU, BKF, CMUB, HYO, PSU, and SING were consulted.

Methodology

Literature review

Reviewed literatures dealing with the family Daltoniaceae emphasized, which distributed in Thailand and neighboring countries such as China, India, Indonesia, Malaysia, Philippines, and Singapore in order to use as guidance for further study and collection. The herbarium specimens of Daltoniaceae in Thailand were loaned from various herbaria such as BCU, BKF, CMUB, HYO, and SING.

Field survey

Field collections were carried out between August 2014 and December 2016. All fresh specimens were collected from selected places in seven Thai floristic regions (Table 3.1) (Smitinand, 1958). The study sites were selected based on previous records of bryophytes in Thailand as well as other places, where possesses an appropriate habitat and have never been explored (Fig. 3.1). Methods in field surveys and collecting specimens were followed the process of Schofield (1985). The specimens were collected from various substrates including soil, rocks, base of tree trunks, twigs, and living leaves. GPS (Garmin 62SC) receiver was used for marking the localities. Field notes of ecological data and some diagnostic characters were made. In addition, plants in their natural habitats were photographed.

Laboratory study

All specimens of Daltoniaceae were examined. For the description of all other aspects, the specimens were observed, measured, photographed by Olympus SZX12 stereo microscope and Olympus BX51 light microscope with an attached camera. Line drawings were made with an Olympus SZX12 stereo microscope with attached Olympus SZX-DA Drawing tube and Nikon OPTIPHOT-2 with attached Nikon Drawing tube.

Vegetative and reproductive structures were taken from mature plants such as shoot, stem, axillary hair, leaf, calyptra and sporophyte.

Plant height and width were measured when the plants were turgid. Shoot width was measured as the width between opposite leaf apices, and height was measured from rhizoids surface between the plants to the highest point reached by the leaves (Fig. 3.2A). The stem width was examined by both measuring the distance of diameter and counting number of cells along the diameter (Fig. 3.2B).

Axillary hairs were taken from the young leaf axils or at the shoot. Axillary hair was examined by both measuring from basal cell to terminal cell and counting number of cells along the length (Fig. 3.2C). Leaf length was measured as the distance from leaf base to apex. Leaf width was measured perpendicularly to its length from the widest area of leaf (Fig. 3.2D). The length of leaf cells was defined as the greatest distance between opposite of the middle lamellae or the middle of cell walls. Width was measured perpendicularly to length (Fig. 3.2E). Length of seta was measured between the insertion of seta on capsule and the insertion of seta on the innovation (Fig. 3.2F). Capsule length is the longest distance measured from the basal insertion of capsule on the seta to the apex (including neck) and the width was measured perpendicularly to length at the middle of capsule (Fig. 3.2F). Calyptra length was measured from the base with fringed hairs to the apex (Fig. 3.2G).

Furthermore, mature spores were dissected from sporangia and mounted on double-stick cellophane adhesive tape affixed on stubs. Spores were then plated with a thin layer of gold and examined with a FEI Quanta 400 scanning electron

microscope. Surface of peristome teeth were also examined by scanning electron microscope.

The full descriptions and line drawings are provided. The key to genera and key to species of Thai taxa are constructed. Ecological data and their distributions were retrieved from herbarium labels, literature and the recent observation. Author names are abbreviated according Brummitt and Powell (1992), and herbarium abbreviations follow Index herbariorum (Holmgren *et al*., 1990). The terminology used in this thesis was followed Malcolm and Malcolm (2000, 2006).

All recent specimens of Daltoniaceae from field surveys were deposited at The Prince of Songkla University Herbarium (PSU) and The Forest Herbarium, Department of National Park, Wildlife and Plant Conservation (BKF).

Table 3.1 The selected study site

Thai floristic regions	**Locality**	**Province**
Northern	1. Doi Inthanon National Park	Chiang Mai
	2. Doi Suthep–Pui National Park	Chiang Mai
	3. Doi Pha Hom Pok National Park	Chiang Mai
	4. Doi Chiang Dao	Chiang Mai
	5. Phu Hin Rong Kla National Park	Phitsanulok
	6. Thi Lo Su Waterfall	Tak
North-eastern	7. Phu Kradung National Park	Loei
	8. Phu Luang Wildlife Sanctuary	Loei
	9. Phu Ruea National Park	Loei
Eastern	10. Phu Khiao Wildlife Sanctuary	Bueng Kan
	11. Nam Nao National Park	Bueng Kan
	12. Phu Chong–Na Yoi National Park	Ubon Ratchathani
	13. Pha Taem National Park	Ubon Ratchathani
South-western	14. Huai Yang Waterfall National Park	Prachuap Khiri Khan
South-eastern	15. Khao Yai National Park	Prachinburi

Thai floristic regions	Locality	Province
	16. Khao Soi Dao wildlife sanctuary	Chanthaburi
	17. Mu Ko Chang National Park	Trat
Peninsular	18. Ngao Waterfall National Park	Ranong
	19. Si Phang-nga National Park	Phang Nga
	20. Khao Lampi–Hat Thai Mueang National Park	Phang Nga
	21. Sa Nang Manora Forest Park	Phang Nga
	22. Emerald Pool	Krabi
	23. Khao Nan National Park	Nakhon Si Thammarat
	24. Khao Luang National Park	Nakhon Si Thammarat
	25. Khao Ramrome	Nakhon Si Thammarat
	26. Khao Plai Dum	Nakhon Si Thammarat
	27. Krung Ching National Park	Nakhon Si Thammarat
	28. Khao Sam Phu	Phatthalung
	29. Khao Ched Yod	Trang
	30. Tarutao Island	Satun
	31. Ton Nga-Chang wildlife Sanctuary	Songkhla
	32. Khao Nam Khang National Park	Songkhla
	33. Ban Chulabhorn Patana 10	Yala
	34. Hala-Bala Wildlife Research Station	Narathiwat

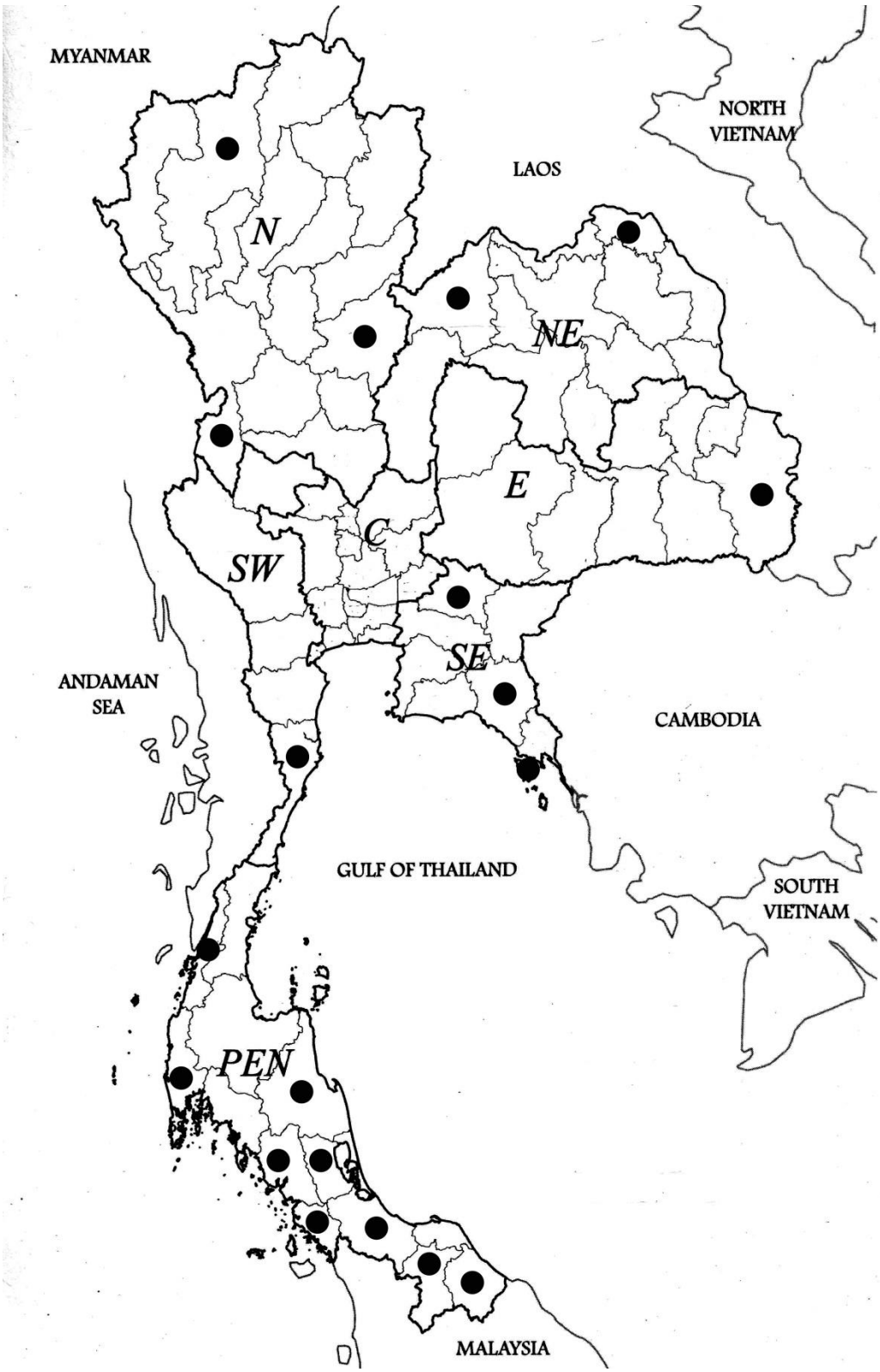

Figure 3.1 Map of Thailand showing localities of the study sites in seven Thai floristic regions: N = Northern, NE = North-eastern, E = Eastern, SW = South-western, C = Central, SE = South-eastern, and PEN = Peninsular.

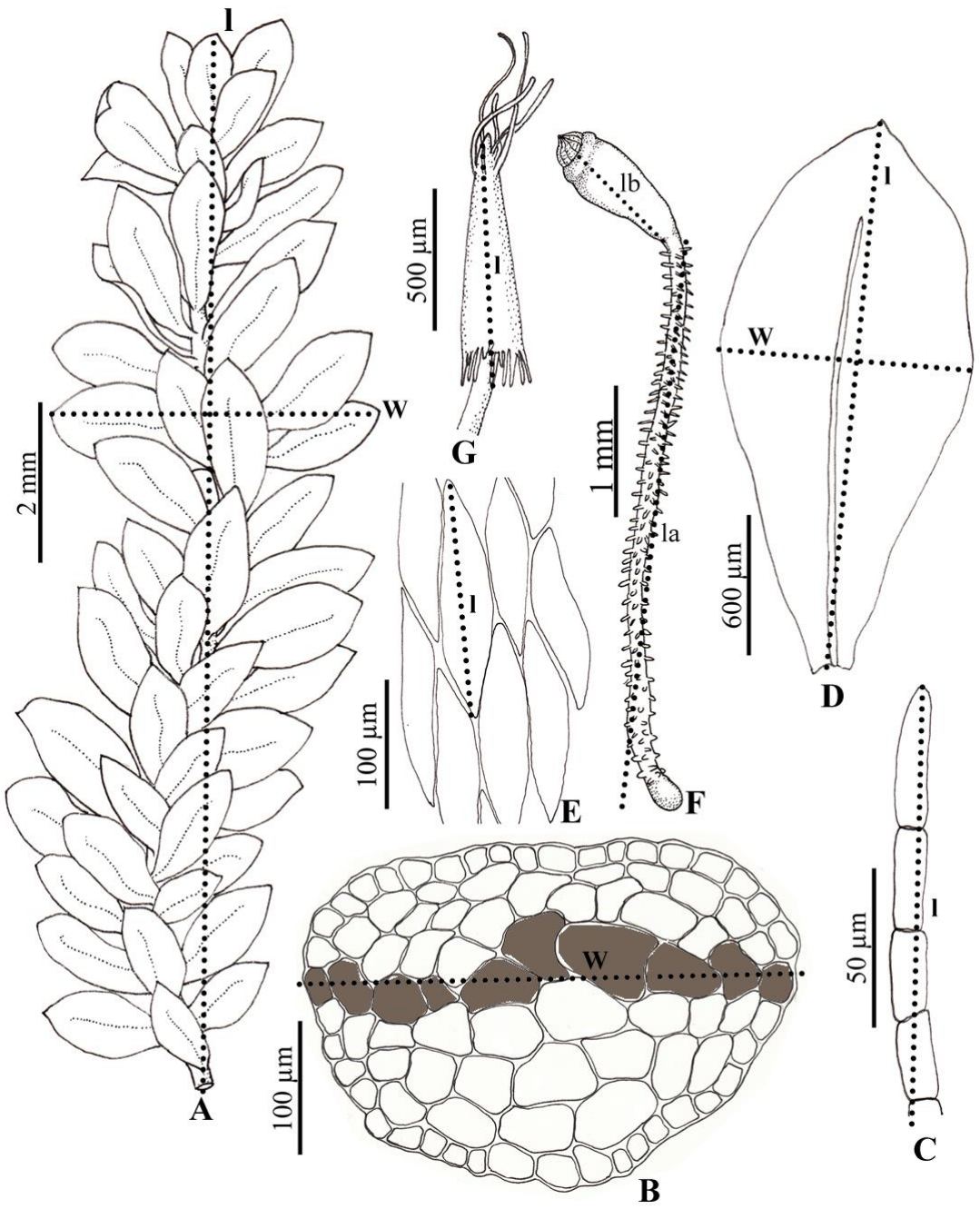

Figure 3.2 Methods of measurement in Daltoniaceae. A. Portion of plant, ventral view; w = plants width; l = plant length. B. Cross-section of stem; w = stem width by measured the distance of diameter, gray color = stem width by counting the number of cells along the diameter. C. Axillary hair; l = axillary hair length. D. Leaf, ventral view; w = leaf width, l = leaf length. E. Leaf cells; l = leaf cell length. F. Sporophyte; la = seta length; lb = capsule length. G. Calyptra; l = calyptra length.

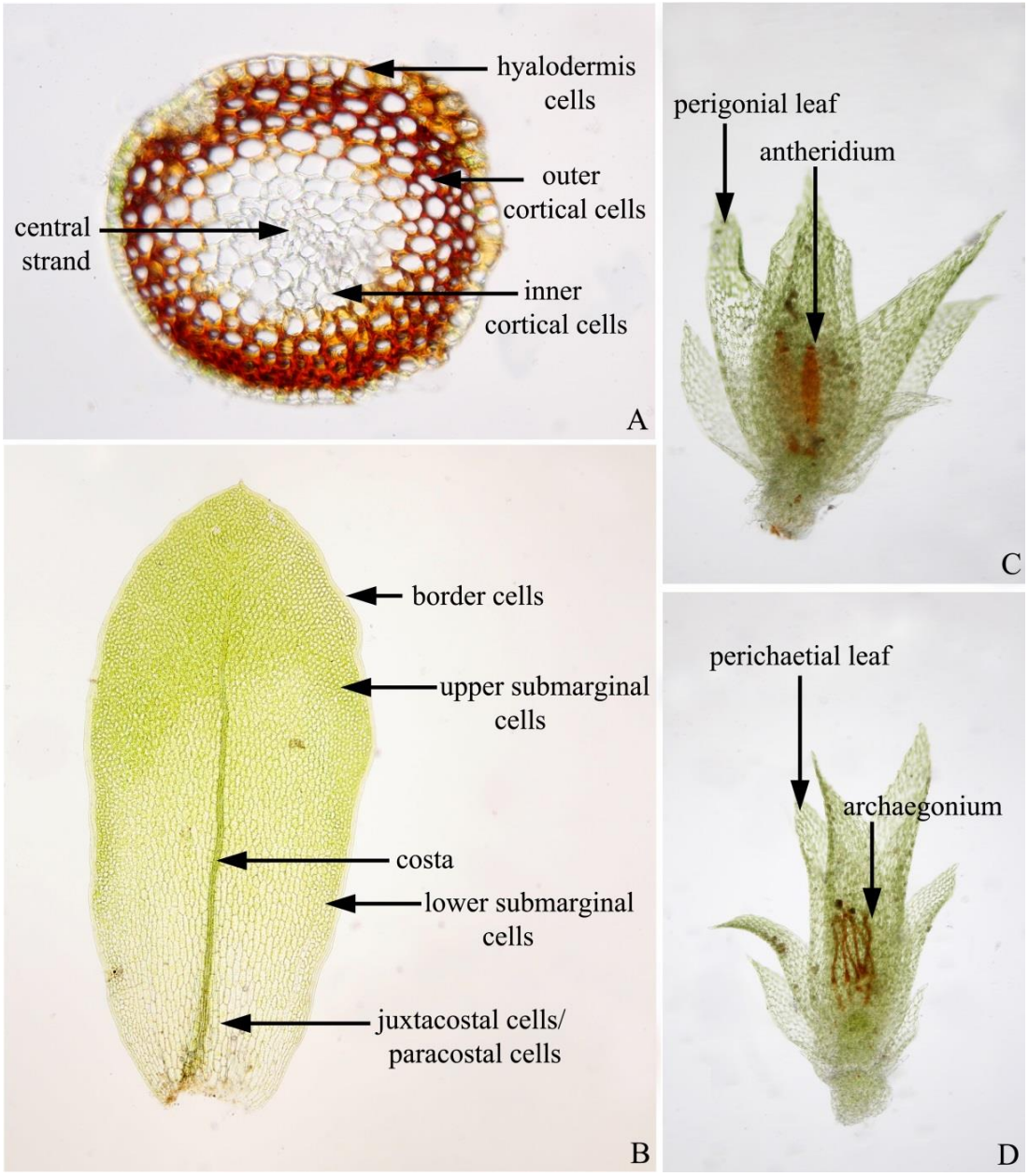

Figure 3.3 Diagram of some structures in Daltoniaceae. A. Cross section of stem in *Calyptrochaeta remotifolia*. B. Lateral leaf in *Distichophyllum schmidtii*. C. Perigonium in *Distichophyllum collenchymatosum*. D. Perichaetium in *Distichophyllum collenchymatosum*.

CHAPTER 4

RESULTS

In this study about 520 specimens of Thai Daltoniaceae were examined including fresh materials as well as herbarium specimens. There are twenty-two species and three varieties of Daltoniaceae in Thailand are recognized (Table 4.1). Of these, three species are newly recorded for Thailand. The descriptions of family, genera, and species are provided. Key to genera and species are proposed. In addition, distribution, habitat and ecology, and examined specimens of each species are noted.

Table 4.1 List of Daltoniaceae in Thailand and their distribution.
Thai floristic Regions: N = Northern, NE = North-eastern, E = Eastern, SE = South-eastern, C = Central, SW = South-western, PEN = Peninsular. * = new record.

Taxa	Thai Floristic Regions						
	N	**NE**	**E**	**SE**	**C**	**SW**	**PEN**
Calyptrochaeta Desv.							
1. *C. remotifolia* (Müll. Hal.) Z. Iwats., B.C. Tan & Touw	x	x		x		x	x
2. *C. spinosa* (Nog.) Ninh	x						
Daltonia Hook. & Tayl.							
3. *D. angustifolia* Dozy & Molk.	x					x	
4. *D. apiculata* Mitt.	x						
5. *D. aristifolia* Renauld & Cardot.	x						
6. *D. semitorta* Mitt.	x						
7. *D. waniana* (B.C. Tan & P.J. Lin) B.C. Ho & L. Pokorny	x	x		x		x	
Distichophyllum Dozy & Molk.							
8. *D. armatum* (E.B. Bartram) B.C. Ho & L. Pokorny							x

Taxa	Thai Floristic Regions						
	N	**NE**	**E**	**SE**	**C**	**SW**	**PEN**
9. *D. brevicuspes* M. Fleisch.							x
10. *D. collenchymatosum* Cardot.	x	x				x	
11. *D. cuspidatum* (Dozy & Molk.) Dozy & Molk.							x
12. *D. jungermannioides* (Müll. Hal.) Bosch & Sande Lac.							x
13. *D. mittenii* Bosch & Sande Lac.		x				x	x
14. *D. nigricaule* Mitt. ex Bosch & Sande Lac. var. *nigricaule*						x	x
15 *D. nigricaule* Mitt. ex Bosch & Sande Lac. var. *cirratum* (Renauld & Cardot) M. Fleisch.		x		x			x
16. *D. nigricaule* Mitt. ex Bosch & Sande Lac.var. *elmeri* (Broth.) B.C. Tan & H. Rob.		x					x
17. *D. obtusifolium* Thér.*		x					
18. *D. osterwaldii* M. Fleisch.*							x
19. *D. schmidtii* Broth.		x		x		x	x
20. *D. spathulatum* (Dozy & Molk.) Dozy & Molk.						x	x
21. *D. subnigricaule* Broth.*							x
22. *D. tortile* Dozy & Molk. ex Bosch & Sande Lac.							x
Ephemeropsis K.I.Goebel							
23. *E. tjibodensis* K.I.Goebel	x			x			x
Leskeodon Broth.							
24. *L. maibarae* (Besch.) B.C. Ho & L. Pokorny	x	x				x	x

MORPHOLOGY AND ANATOMY

Growth form

The gametophytes of Thai Daltoniaceae are usually well developed consisting of leaves and stems; excepted *Ephemeropsis tjibodensis*, the gametophore (mature gametophyte) is very reduced lacking vegetative leaves, its protonema is persistant forming dense mats or protonemal form (Fig. 4.1H) appressed to the substrates. The well-developed gametophytes species grow loose to dense colonies on various substrates such as barks, rotten woods, living leaves, rocks and soils. They are simple to complanately branched forming the fan-like or frond. They may be erect in relation to the substrate or, if the fronds are longer, become pendent. The species, growing on horizontal substrates, usually form short or long turfs with rarely branches (Fig. 4.1A–B). While the species, growing on inclined or vertical substrates are usually fans to pendents with fairly branches (Fig. 4.1C–G).

Color and size

Plants are yellowish green to dark green or rarely greenish brown (*Ephemeropsis tjibodensis*) when fresh, becoming yellowish green to yellow-brown or dark brown when dry. In *Distichophyllum jungermanioides* and *D. subnigricaule* are light to yellowish green and distinctly glossy leaves both features can be recognized to the species, becoming yellowish brown and glossy when dry. The sizes of the plants are very variable from minute to large depending on the species or genera. Whenever size is relevant for the identification of species or genera, exact measurements are given; in other cases size is indicated by the following categories: 1) minute, gametophyte is very reduce (*Ephemeropsis tjibodensis*); 2) small sized, 0.2–0.26 cm wide with leaves; 3) medium sized, 0.28–0.45 cm wide with leaves; and 4) large sized, 0.43–1.0 cm wide with leaves.

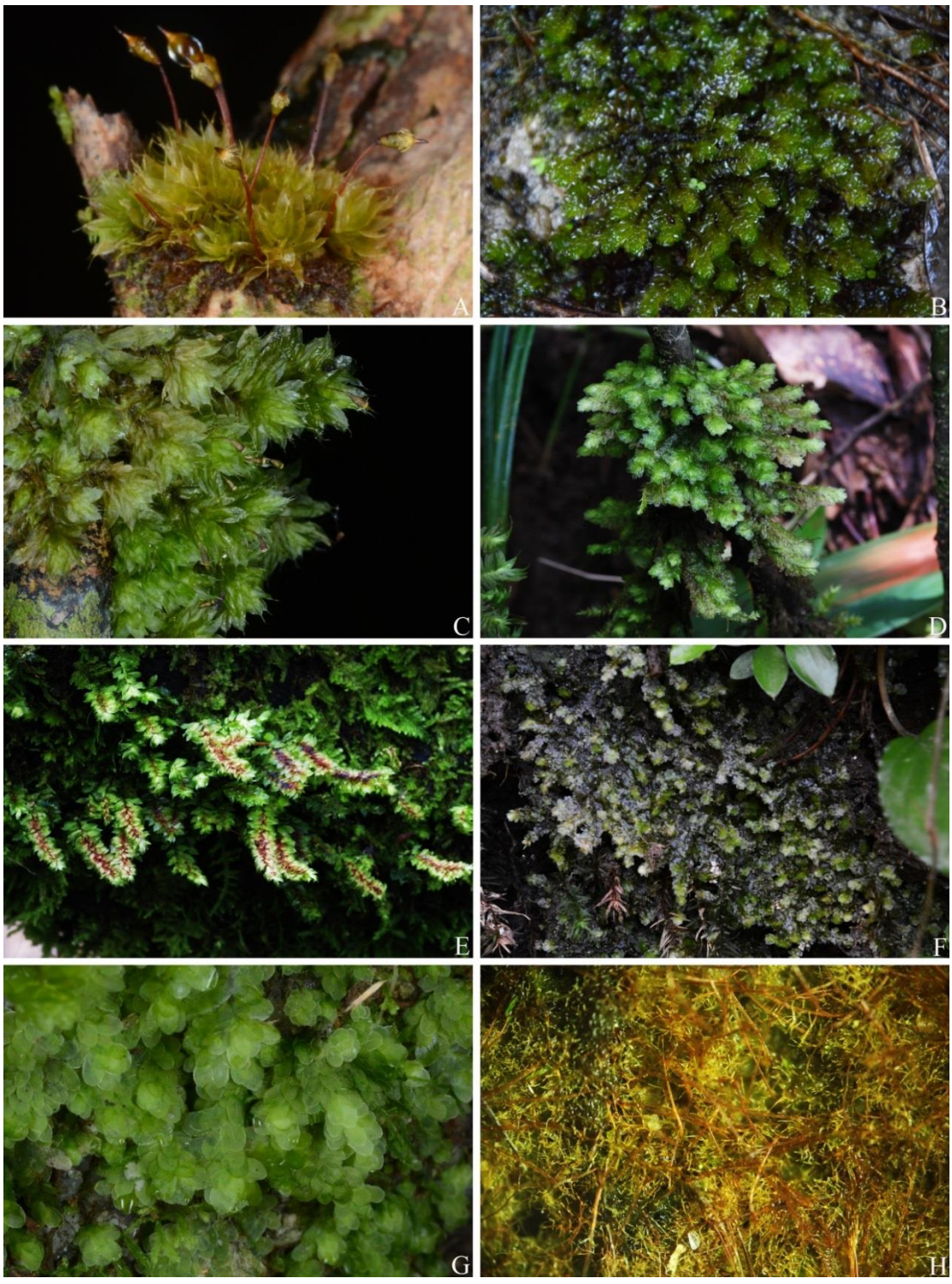

Figure 4.1 The variations of the growth forms. A–B. Tufts form on horizontal substrate; A. *Daltonia angustifolia*, B. *Distichophyllum tortile*. C–G. Fans to pendent forms on inclined or vertical substrates; C *Distichophyllum cuspidatum*, D. *Distichophyllum schmidtii*, E. *Calyptochaeta remotifolia*, F. *Distichophyllum nigricaule* var. *nigricaule*, G. *Distichophyllum nigricaule* var. *emeri*. H. Protonemal form; *Ephemeropsis tjibodensis*.

Gametophyte

Rhizoids

Rhizoids are produced from epidermal cells of the axis immediately below the leaf bases and usually restricted at base of stems, but may occur along the ventral surface of stems and branches. Rhizoids of Thai Daltoniaceae are multicellular with oblique cross walls and having smooth surface. They are usually reddish, purple to magenta in color, but may be colorless at their tips. Most rhizoids of Thai species are sparsely to irregularly branched.

Stem structure

The stems of plants in Thai Daltoniaceae are brown to reddish brown in color and almost oval in cross-section varying from 130 to 450 μm in diameter. According to observations of stem anatomy, three parts in the cross-section of a stem are recognized: epidermal layer, cortex and central strand. Based on the three parts of stem mentioned above, four types of stem structure are classified in present study.

1) Stem differentiates into 4 layers: 1) the epidermis; 2) outer cortex, consisting of 4–5 layers of small and thick-walled cells; 3) inner cortex, consisting of larger and thin-walled cells; and 4) a central strand (Fig.4.2A), in *Calyptrochaeta remotifolia*.

2) Stem differentiates into 3 layers: the epidermis; 2) outer cortex, consisting of 1–2 layers of small and thick-walled cells; and 3) inner cortex, consisting of larger and thin-walled cells, lacking a central strand (Fig. 4.2B), in *Calyptrochaeta spinosa*.

3) Stem differentiates into 2 layers: epidermis and cortex. The epidermis consists of 1–2 layers of small and thick-walled cells. The cortex cells are larger in size and thin-walled (Fig. 4.2C). This type is common in Thai species.

4) Stem differentiates into 2 layers. The epidermis consists of 1–2 layers of small and thin-walled cells. The cortex cells are also thin-walled but larger

in size. This type is found in *Distichophyllum collenchymatosum* (Fig. 4.2D).

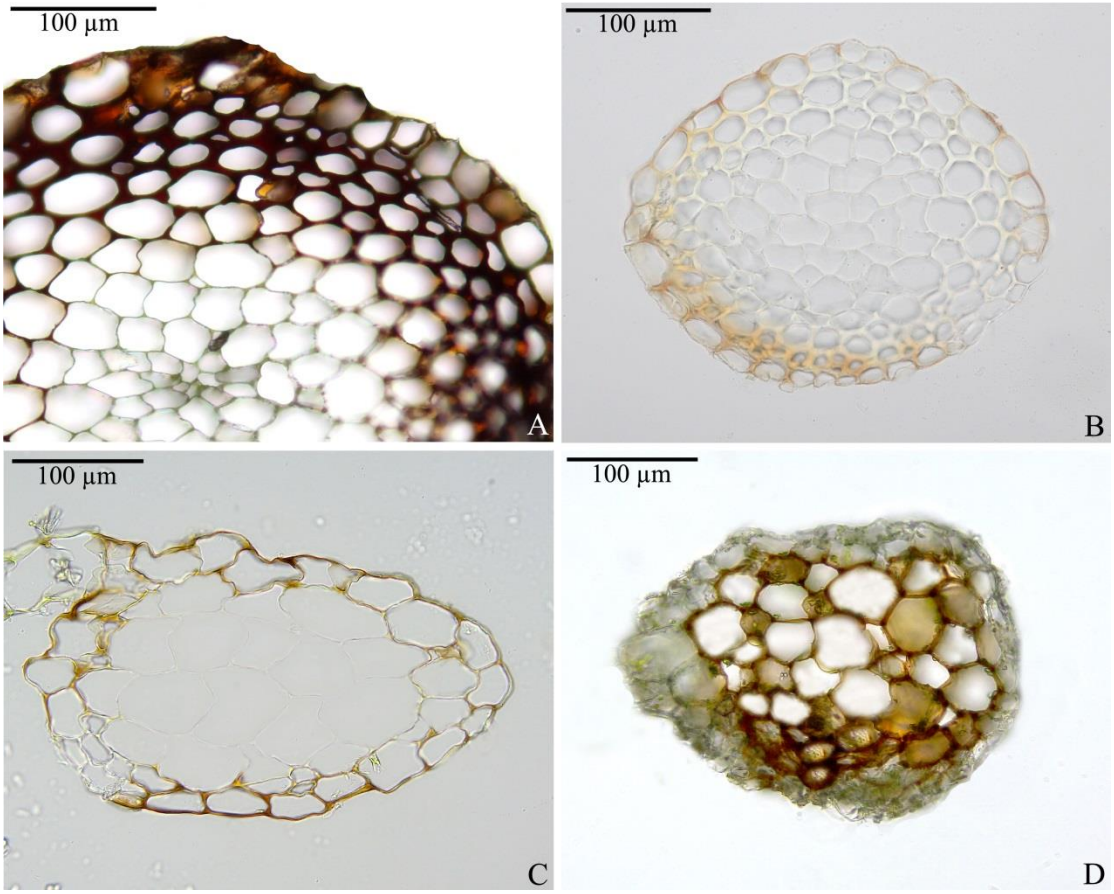

Figure 4.2 Cross-sections of stems. A. Stem differentiates into epidermis, outer cortex, inner cortex, and central strand (*Calyptrochaeta remotifolia*). B. Stem differentiates into epidermis, outer cortex, and inner cortex (*C. spinosa*). C. Stem differentiates into epidermis and cortex, the epidermal cells thick-walled and smaller than the cortex cells (*Distichophyllum nigricaule* var. *nigricaule*). D. Stem differentiates into epidermis and cortex, the epidermal cells thin-walled and smaller than the cortex cells (*Distichophyllum collenchymatosum*).

Axillary hairs

The axillary hairs are filiform and uniseriate structures situated on the axes of the mature gametophyte (gametophore). Each axillary hair produces from a cell, which belongs to a row of cells that is located in the leaf axil just above the base of associated leaf. The number of cells in that row bearing an axillary hair is variable,

and may vary between leaves and species. The number of axillary hairs per associated leaf is also variable. In Daltoniaceae axillary hairs are persistent and consist of three parts *viz*. 1) a basal cell, 2) intermediate cells and 3) a terminal cell. The basal cell is normally hyaline but sometimes pale brown. The number of intermediate cell is variable depended on genus and species, usually different from the basal once. The terminal cell may show considerable variation in length and shape between genus and species. Consequently, axillary hairs provide useful character states for distinguished taxa, especially at the generic level. According to present observation, five types of the axillary hair can be classified:

Type I: Axillary hairs are very small in size, composed of 2–3 cells, 30–50 µm long. The terminal cell is strongly inflated and longer than the lower once (Fig. 4.3A). This type is found in member of genus *Daltonia* and *Districhophyllum armatum*.

Type II: Axillary hairs consist of 3–4 cells, ranging from 70–150 µm long. The terminal cell is nearly inflated or somewhat claviform and clearly longer than intermediate cells (Fig. 4.3B). This type is found in *Leskeodon maibarae*.

Type III: Axillary hairs consist of (3)4–5 cells, ranging from 40–150 µm long. The terminal cell is not inflated and as long as the intermediate cells (Fig. 4.3C). This type is common in genera *Calyptrochaeta* and *Distichophyllum*.

Type IV Axillary hairs consist of 3–5 cells, ranging from 90–150 µm long. The terminal cell is not inflated and shorter than the intermediate cells (Fig. 4.3D). This type is found in *Distichophyllum brevicuspes*.

Type V Axillary hairs are rather long consisting of about 11 cells and ranging from 100–450 µm long. The terminal cell is inflated and as long as the intermediate cells. The intermediate cells are irregularly in shape and size (Fig. 4.3E). This type is found in *Distichophyllum cuspidatum*.

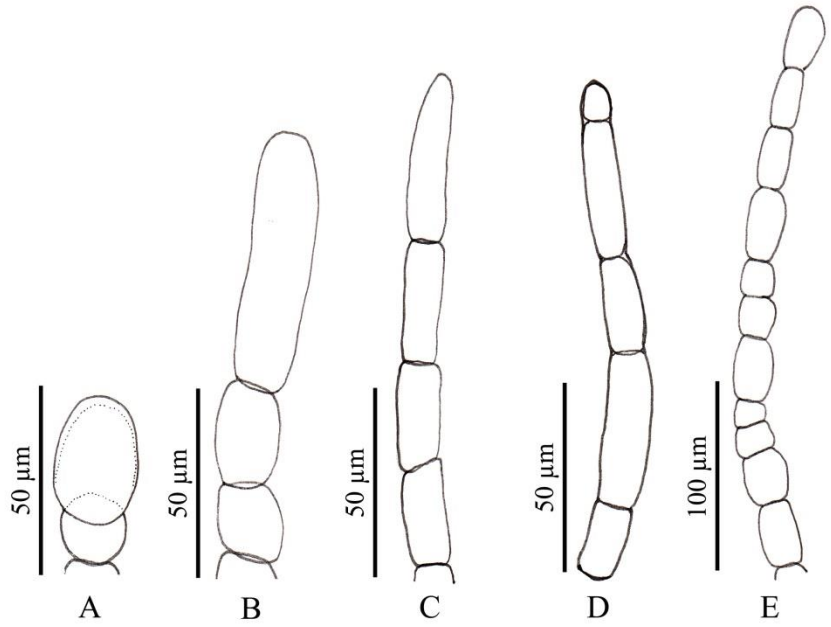

Figure 4.3 The variations of the axillary hairs. A. Type I (*Districhophyllum armatum*). B. Type II (*Leskeodon maibarae*). C. Type III (*Distichophyllum schmidtii*). D. Type IV (*Distichophyllum brevicuspes*). E. Type V (*Distichophyllum cuspidatum*).

Phyllotaxy

The phyllotaxy in Daltoniaceae are sprially arranged, shown terete or complanate branches. Most members of Daltoniaceae have complanate leaves being octastichous arrangrement. In this study, the commplanate form is common in *Calyptrochaeta*, *Distichophyllum* and *Leskeodon*, but the terete form is found in all members of genus *Daltonia*, *Distichophyllum armatum* and *D. cuspidatum*.

Vegetative leaves

The vegetative leaves of Thai Daltoniaceae are various in size and shape. Most of Thai species have symmetry leaves, except the member of *Calyptrochaeta* which are more or less asymmetry. Leave are monomorphic or dimorphic. The monomorphic leaf can be observed in member of *Daltonia*, *Distichophyllum armatum* and *D. cuspidatum*. But they are dimorphic in genera *Calyptrochaeta*, *Leskeodon* and most *Distichophyllum* species. The leaves are usually flexuose, crisped to contorted

when dry and plane, slightly carinate along costa or erecto-spreading when moist. Leaves are varying from small to large in size. Leaf shapes are very various from lanceolate, elliptic, elliptic-oblong, oblong, oblong-lingulate, obovate, spathulate, broadly ovate, to suborbicular (Fig. 4.4A–H). The margins are usually entire in Thai species, however the dentate margins can be observed in member of genus *Calyptrochaeta*. Thus, this dentate margin is a good character to separate *Calyptrochaeta* from the rest of genera. The apices are also variable from round, mucronate, acute, acuminate, apiculate, attenuate, to cuspidate (Fig. 4.4A–H).

Generally, the vegetative leaf of Daltoniaceae has a single costa, bordered and lamina. The costae vary from very short to nearly percurrent. Costa of the genus *Calyptrochaeta* is the shortest, restricted at leaf base, and fork at leaf apex. The leaf borders of Thai species are usually differentiated into 1–5 rows of linear cells surrounding the leaf lamina. However, the leaf border of *Distichiphyllum obtusifolium* and *D. osterwaldii* are not well developed at the apex. The lamina cells vary in shapes and sizes depending on genera, species and their position such as isodiametric, hexagonal or rhomboidal (Fig. 4.4I–K). The lamina cells are heterogeneous in genera *Daltonia*, *Distichophyllum* and *Leskeodon*, but more or less homogeneous in *Calyptrochaeta* spp. and *Distichophyllum armatum*.

Sexuality

The majority of Thai Daltoniaceae (14 species and 3 varieties) are dioicous. Six species are autoicous, *viz. Daltonia angustifolia, D. aristifolia, Distichophyllum collenchymatosum, D. cuspidatum, D. osterwaldii,* and *Ephemeropsis tjibodensis.* The heteroicous is found only in *Distichophyllum mittenii*.

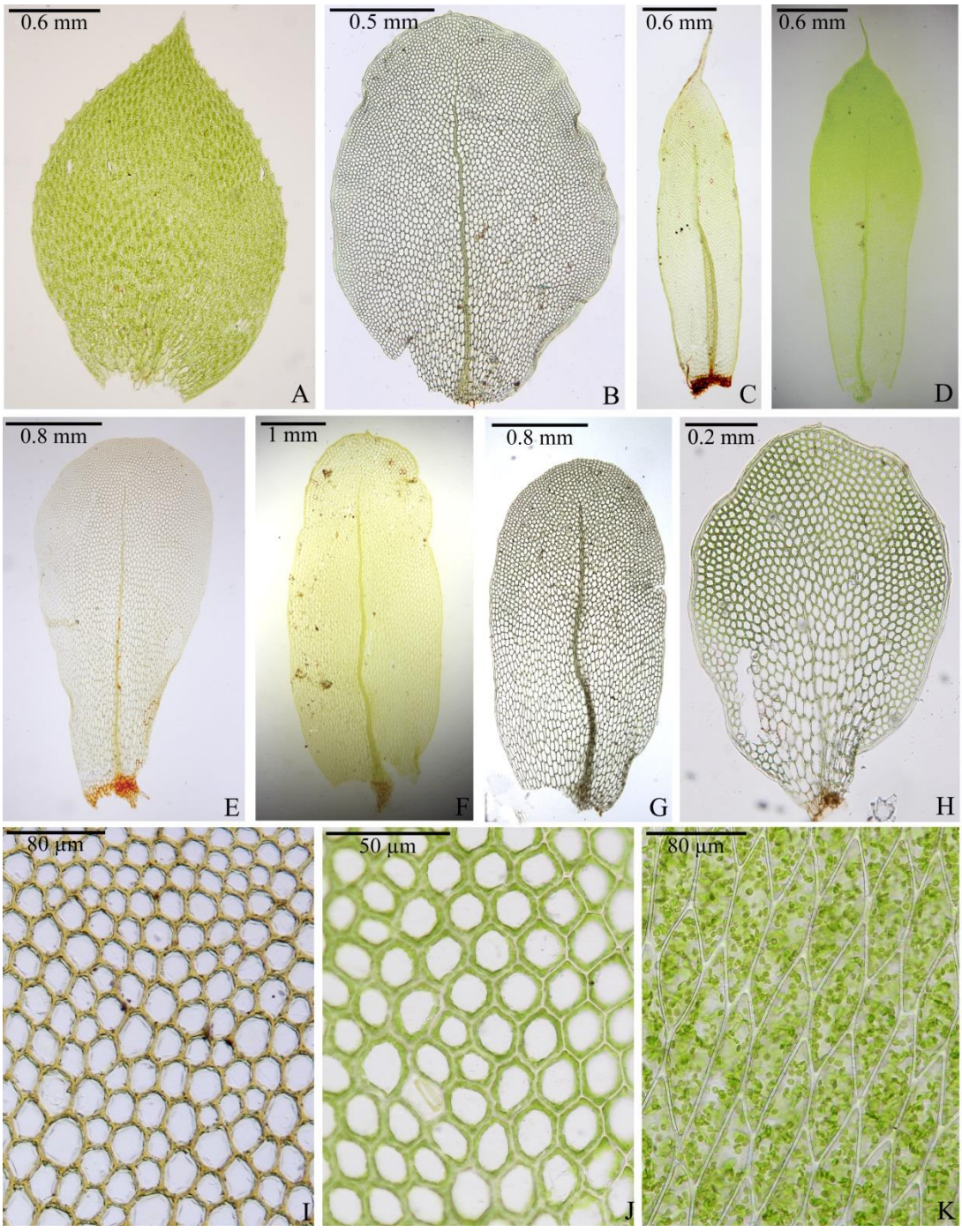

Figure 4.4 The variations of leaf shape and leaf cells. A–H. Leaf shape: A. broadly ovate with acute apex, B. broadly elliptic with mucronate apex, C. narrowly oblong with acuminate apex, D. narrowly oblong with cuspidate apex, E. spathulate with bunt apex, F. oblong-lingulate with acute apex, G. obovate with round apex, H. suborbicular with shortly mucronate apex. I–K. Leaf cells: I. *Distichophyllum spathulatum* showing nearly round and thick walled cells. J. *Distichophyllum subnigricaule* showing hexagonal and thin walled cells. K. *Calyptrochaeta spinosa* showing rhomboidal and thin walled cells.

Perigonia

The perigonia are produced on the upper half of stem and main branches. They are gemmiform (approximately 1 mm high) without paraphyses (Fig. 3.3C). The perigonial leaves are smaller than vegetative leaves, ecostate with entire margin. The shape of perigonial leaves are varied from ovate, oblong, elliptic to lanceolate, and gradually narrowed upward to an acute or narrowly acuminate apex. However, the round leaf apex can be found in *Daltonia waniana* and *Distichophyllum spathulatum*.

Perichaetia

The perichaetia are also produced on the upper half of stem and main branches. They are gemmiform (approximately 1 mm high) without paraphyses (Fig. 3.3D). The perichaetia leaves usually similar to the perigonial leaves. They are also smaller than vegetative leaves, ecostate with entire margin. The shape of perichaetial leaves are varied from ovate, oblong, elliptic, to lanceolate, and gradually narrowed upward to an acute or narrowly acuminate apex. However, *Distichophyllum obtusifolium* has round leaf apex.

Calyptra

The calyptrae are mitriform and bearing strongly fringed hairs at base. The surface of calyptrae varied from smooth, papillose to hairy at the apex (Fig. 4.6D–G).

Sporophyte

The sporophytes of Daltoniaceae are produced on the short lateral branches. The mature sporophyte is composed of a foot, a stalk or a seta and a capsule. In the present study, the sporophyte characters have been observed in *Calyptrochaeta remotifolia*, *C. spinosa*, *Daltonia angustifolia*, *D. apiculata*, *D. aristifolia*, *D. semitorta*, *D. waniana*, *Distichophyllum armatum*, *D. collenchymatosum*, *D. cuspidatum*, *D. mittenii*, *D. nigricaule* var. *cirratum*, *D. osterwaldii*, *D. schmidtii*, D. *spathulatum*, *Ephemeropsis tjibodensis*, and *Leskeodon maibarae*.

Seta

Setae are usually erect, slender and brownish green to dark green, ranging from 1 to 7 mm. In *Ephemeropsis tjibodensis* has the shortest seta (1–1.2 mm long). Their surfaces varied from smooth, scabrous, papillose, spinose, or hairy (Fig. 4.5A–E). In this study, the surface of most Thai species are smooth. The papillose setae are found in *Distichophyllum schmidtii*, while *Daltonia angustifolia* and *Distichophyllum armatum* have smooth surface in the lower part and scabrous above. The setae of *Distichophyllum mittenii*, *D. osterwaldii*, and *D. spathulatum* are distinctly spinose. In addition, the hairy seta is a good character to separate *Calyptrochaeta* from the other genera.

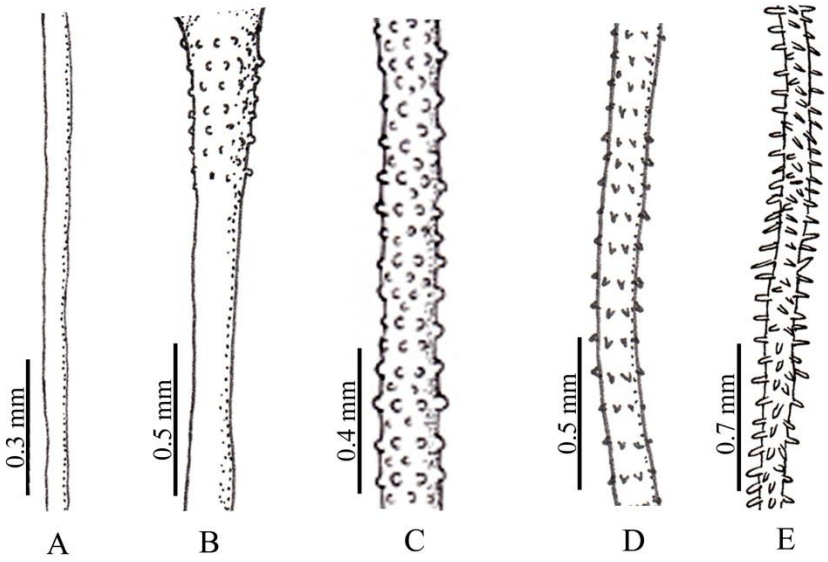

Figure 4.5 The variations of seta surface. A. Smooth. B. Smooth below and scabrous above. C. Papillose. D. Spinose. E. Hairy.

Capsule

The capsule is ovoid to elliptic-oblong, erect or slightly inclined and it has a smooth exothecium (Fig. 4.6A–B). The colour is light brown or dark brown. Exothecium cells varied from quadrate, short rectangular, pentagonal, hexagonal to

isodiametric (Fig. 4.7A–O). Most species have thick-walled and strongly nodulose at the corner or distinctly collenchymatous, except *Ephemeropsis tjibodensis* and *Leskeodon maibare* have thin-walled with small corner thickening (Fig. 4.7N–O). All observation species have few paneroporous stoma in the apophysis (Fig. 4.6C).

Operculum

In this study, the mature operculum (Fig. 4.6A–B) was found in 16 species. They are rostrate from a conical base and length varies between 0.2–0.6 mm. The rostrum is straight and erect. In the most species, the operculum is long-rostrate, i.e. the rostrum is longer than the conical part (Fig. 4.6B). In *Calyptrochaeta spinosa* the operculum is short-rostrate, i.e. the rostrum is approximately equally long as the conical part (Fig. 4.6A).

Peristome

The peristome of the Daltoniaceae is diplolepidous and double. A complete peristome consisting of an exostome with 16 teeth and an endostome with 16 processes. The peristomes provide useful character states for distinguished taxa, especially at the generic level. According to Crosby's classification, two types of the peristomes are observed in Thai species: hookeriaceous and daltoniaceous.

Hookeriaceous type: The exostome teeth (or outer peristome) have horizontally cross-striolate on the outer surfaces near their bases (Fig. 4.8A–B, E–H), the inner surface are well developed ventral lamellae from base to tip. The endostome are lanceolate with high basal membranes and finely papillose segments and cilia absent. These features are found in *Calyptrochaeta*, *Distichophyllum, Ephemeropsis* and *Leskeodon.*

Daltoniaceous type: The exostome teeth are papillose throughout (Fig. 4.8C–D), the inner surface is developed ventral lamellae with slightly papillose from base to tip. The endostomes lanceolate with high basal membranes and finely papillose segments and without cilia. These features are found in the genus *Daltonia*.

Spore

The spores of Thai Daltoniaceae are mostly green inside and yellowish on the surface and somewhat spherical in shape. They are generally unicellular and exosporic germaination. The spores of almost species studied range between 10 and 15 μm in diameter and have fine to distinctly papillose ornamentation (Fig. 4.9A–K). While *Ephemeropsis tjibodensis* has smallest spores of about 1 μm in diameter, its ornamentation is nearly psilate (Fig. 4.9G–I).

Asexual reproduction

Vegetative reproduction in Daltoniaceae occurs by gemmae or fragments of leaves. After the gemmae and fragments have released and dispersed, they form new protonemata in suitable habitat, which, form new mature gametophytes. Among the 24 taxa in Thailand, asexual reproduction is known in 15 taxa. The type of asexual reproduction may be summarized as follows:

1. Caducous leaves: leaf usually falls or fragments then produce shoot primordia and grow into new small plantlets on them. In present study, this character is found only in *Distichophyllum jungermannioides*.

2. Gemmae: the gemmae are usually simple and consist of uniseriate filament of a few to several cells. They can be produced from protonemata (in *Ephemeropsis*) (Fig. 4.10A), in the leaf axil (e.g. *Calyptrochaeta remotifolia*, *C. spinosa*, *Distichophyllum armatum*, *D. brevicuspes*, *D. jungermannioides*, *D. mittenii*, *D. nigricaule* var. *nigricaule*, *D. nigricaule* var. *cirratum*, *D. nigricaule* var. *emeri*, *D. obtusifolium*, *D. schmidtii*, *D. tortile* and *Leskeodon maibarae*) (Fig. 4.10B), on tip of costa (e.g. *Daltonia apiculata* and *D. waniana*) (Fig. 4.10D), and on basal part of costa (e.g. *Distichophyllum tortile*) (Fig. 4.10E). The gemmae may cluster on the epidermal cells or form on specialized structure, referred to as gemmaphores (Fig. 4.10C, F).

Habitats and Ecology

The presently 24 taxa were collected from lowland to montane forests, in various habitats such as soil, rocks, twigs, tree trunk, and living leaves. Several species can grow on more than one substrate types. The majority habitats (16 species) are epiphytes, growing on tree trunks (corticolous) or branches and twigs (ramicolous), or both habitats. There are many species restricted on rocks and soil (11 species and 3 varieties).

The members of the family were recorded ranging from 56 to 2500 m elevation. The almost species of the Thai Daltoniaceae usually occur in lower montane forest at altitude between 600 to 1800 m. In some species (genus *Daltonia*) were found in montane forest up to 2500 m above sea level (Table 5.1).

Figure 4.6 Capsules and calyptrae. A. Capsule with short-rostrate operculum (*Calyptrochaeta spinosa*). B. Capsule with long-rostrate operculum (*Distichophyllum spathulatum*). C. Paneroporous stomata in apophysis (*Calyptrochaeta remotifolia*). D–G. The features of calyptrae surface: D. Smooth (*Distichophyllum cuspidatum*), E. Papillose (*Distichophyllum spathulatum*). F. Hairy throutout (*Calyptrochaeta remotifolia*), G. Hairy at the apex (*Leskeodon maibarae*).

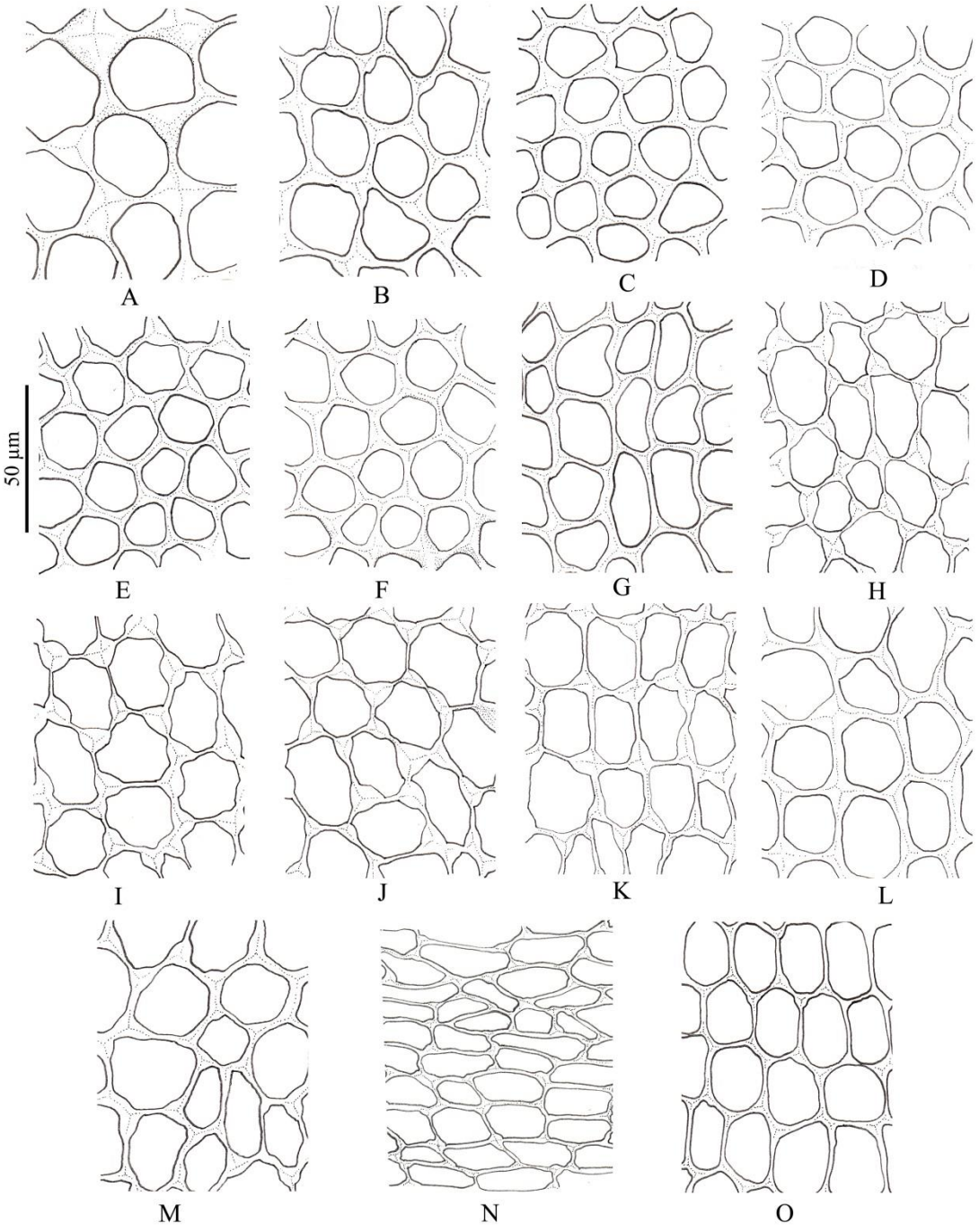

Figure 4.7 Exothecium cells. A–M. thick-walled and strongly nodulose or collenchymatous: A. *Calyptrochaeta remotifolia,* B. *C. spinosa*, C. *Daltonia angustifolia,* D. *D. apiculata*, E. *D. aristifolia*, F. *D. semitorta*, G. *D. waniana*, H. *Distichophyllum collenchymatosum,* I. *D. cuspidatum,* J. *D. mittenii,* K. *D. osterwadii*, L. *D. schmidtii*, M. *D. spathulatum.* N–O. thin-walled with small corner thickening: N. *Ephemeropsis tjibodensis*, O. *Leskeodon maibarae*.

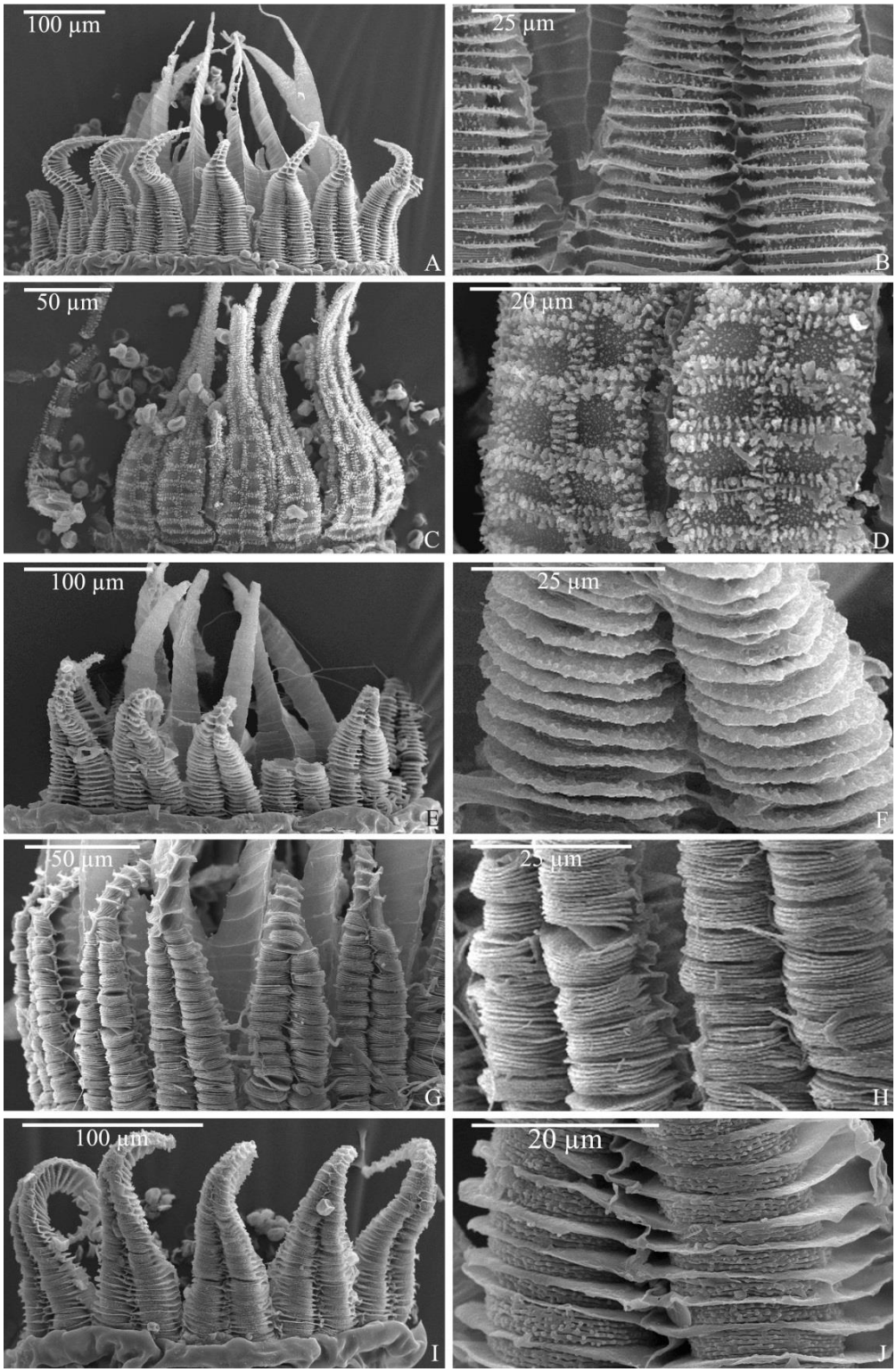

Figure 4.8 Outer surface of peristome teeth. A–B., E–J. Hookeriaceous type: A–B. *Calyptrochaeta remotifolia*, E–F. *Distichophyllum cuspidatum*, G–H. *Ephemeropsis tjibodensis*, I–J. *Leskeodon maibarae*. Daltoniaceous type: C–D. *Daltonia angustifolia*.

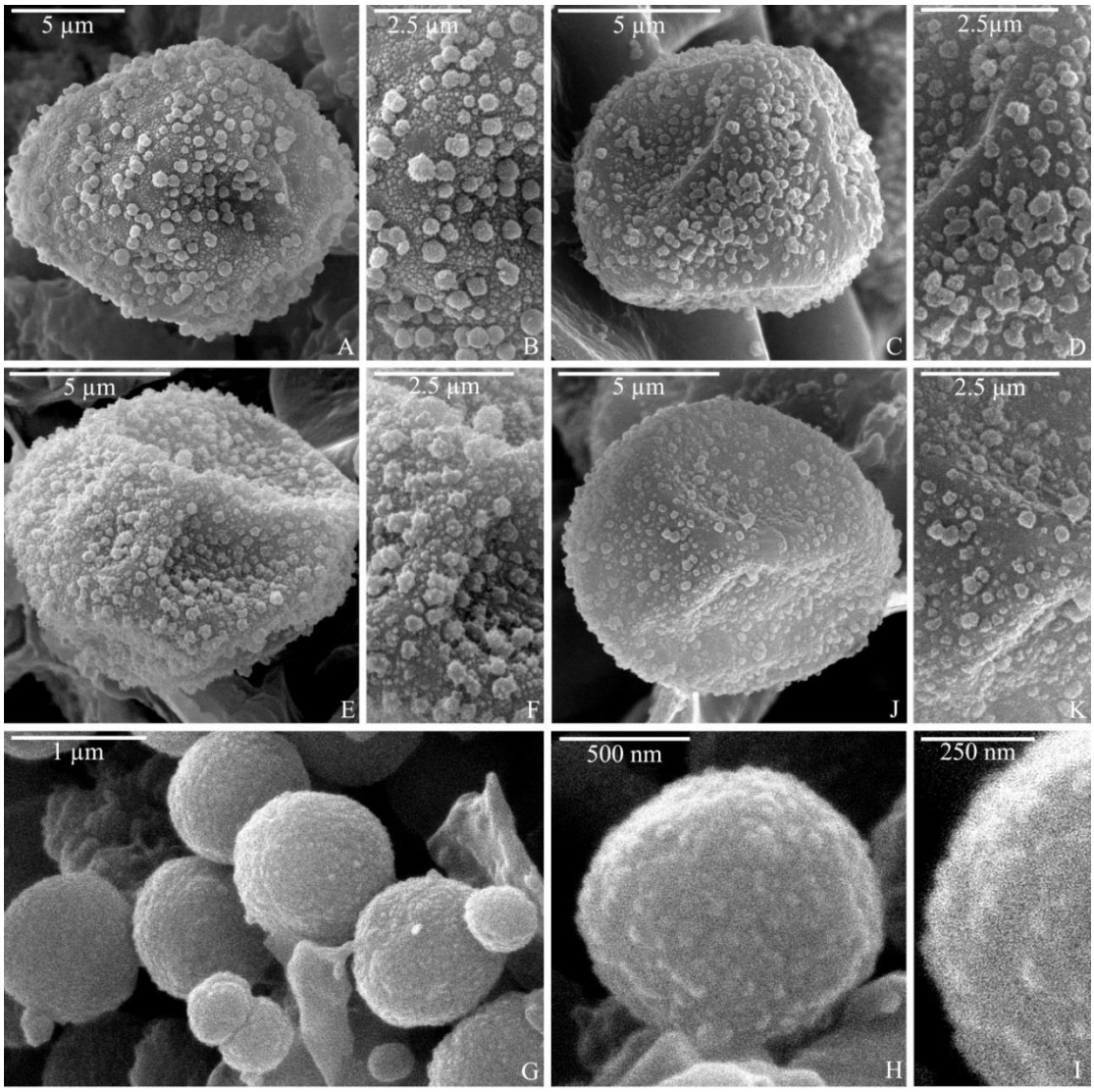

Figure 4.9 Variation of spores. A–K. Papillose ornamentation: A–B. *Calyptrochaeta remotifolia*. C–D. *Daltonia angustifolia*. E–F. *Distichophyllum cuspidatum*, J–K. *Leskeodon maibarae*. Smooth ornamentation: G–I. *Ephemeropsis tjibodensis*.

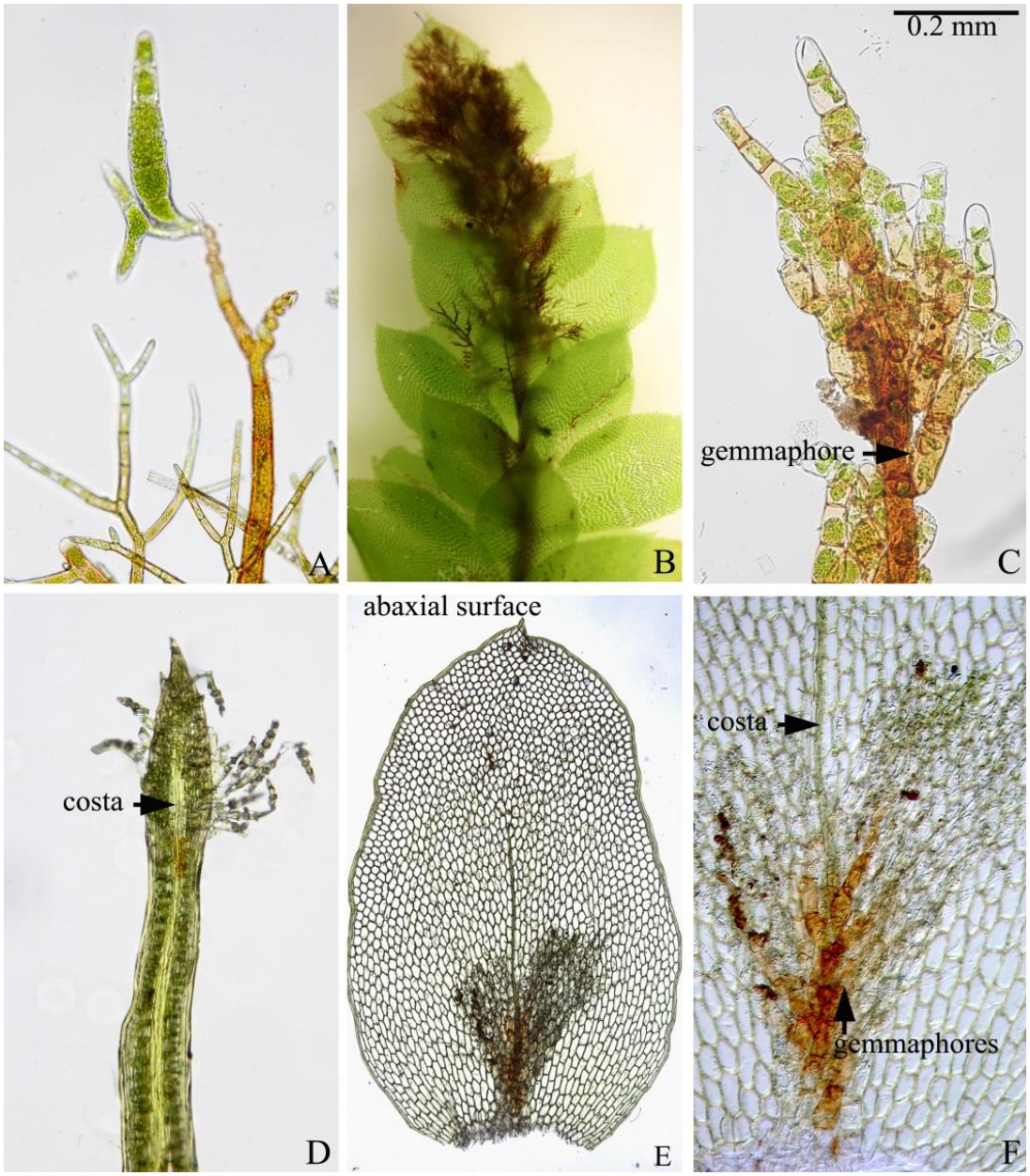

Figure 4.10 The position of gemmae. A. on the tips of mature chloronemal filaments (*Ephemeropsis tjibodensis*). B–C. on leaf axiles (*Calyptrochaeta spinosa*). D. on the tip of costa near leaf apex at adaxial surface of leaf (*Daltonia apiculata*). E–F. on gemmaphore at abaxial surface of leaf (*Distichophyllum tortile*).

Daltoniaceae

Schimp., Syn. Musc. Eur. 478. 1860.

Plants small to large in size yellowish green to dark green, turning to brownish green to brownish yellow in herbarium specimens; protonemata usually ephemeral, rarely persistant. **Rhizoids** reddish, purple to magenta, dense at base of stem, slightly along ventral surface of stem. **Stems** erect to prostrate, simple or sparsely and irregularly branched, dark green to reddish brown; hyalodermis and central stand present or absent. **Axillary hairs** uniseriate, consisting of (2)3–12 cells long; basal cell pale brown or colorless. **Leaves** monomorphic or dimorphic, complanate or terete; flxuose, crisped or contorted when dry, usually plane, slightly carinate along costa or erecto-spreading when moist; margins often limbate, entire or dentate to serrate or ciliate; costa single or double, rarely ecosta (in *Distichophyllidium*); lamina cells isodiametric, hexagonal or rhomboidal.

Dioicous, autoicous or heteroicous**. Perigonial** leaves, green to yellowish green, narrowly ovate to ligulate; apex acute, acuminate, or bunt; margin entire; antheridia few to numerous per androecium. **Perichaetial** leaves, green to yellowish green, narrowly ovate to elliptic; apex acute, acuminate to bunt; margin entire; archegonia usually numerous per gynoecium. **Sporophyte** lateral or terminal. **Seta** slender, greenish yellow to reddish brown, smooth, papillose or hairy. **Capsule** ovoid or oblong, erect, horizontal to inclined; exothecial cells small to medium in size, irregular polygonal, thin walled or collenchymatous; operculum rostrate; peristome teeth double, outer peristome teeth yellow to yellowish orange, lanceolate, narrowly furrowed, transversely striolate or papillose; inner peristome teeth as long as outer ones, with high basal membrane; operculum conical to rostate. **Spores** small to medium in size, slightly papillose, germination rarely endosporic. **Calyptra** mitriform, smooth or papillose, covering all of the theca or only the operculum, strongly fringed hairs at the base or not. **Asexual reproduction** by caducous leaves or gemmae.

This family composted of about 200 species worldwide in 14 genera (Ho *et al*., 2012), of which 5 genera are found in Thailand. The plants are lithophytes, epiphytes or epiphyllous, in lowland to montane forest.

Key to the genera of the family Daltoniaceae in Thailand

1. Gametophyte very reduced, protonema persistent ..... *Ephemeropsis*
1. Gametophytes well developed, protonema not persistent .....2.
2. Leaves more or less asymmetry, margins toothed; costae very short, forked ....*Calyptrochaeta*
2. Leaves symmetry, margins entire, rarely denticulate; costae at least 1/3 as long as leaf length, unbranched .....3.
3. Stem not complanate-foliate. Leaves monomorphic, oblong-lanceolate to lanceolate-linear, rarely spathulate. Outer peristome teeth papillose .....*Daltonia*
3. Stem complanate-foliate. Leaves usually dimorphic, rarely monomorphic, ovate-oblong to spathulate. Outer peristome teeth deeply furrowed, striolate .....4.
4. Calyptra with hair at the tip. Exothecial cells of capsule parenchymatous .... *Leskeodon*
4. Calyptra without hair at the tip. Exothecial cells of capsule collenchymatous ....*Distichophylum*

Calyptrochaeta

Desv., Mém. Soc. Linn. Paris 3: 226. 1825. — *Eriopus* Brid., Bryol. Univ. 2: 788. 1827. Type: *Calyptrochaeta cristata* (Hedw.) Desv. [≡ *Leskea cristata* Hedw.].

Plants usually epiphytic and rarely terrestrial, medium to large in size, loosely tufted, yellowish green to dark green. **Rhizoids** dark reddish to older reddish brown, dense at base of stem. **Stems** compost of primary and foliate stems, dull dark green to

yellowish brown. Primary stems short, creeping and tightly adherent to substrate. Foliate stems various in size, erect or pendent, simple or branched, green to greenish brown, in cross section without or with a differentiated central strand, hyalodermis present. **Axillary hairs** filiform, 3–5 cells long, terminal cell as long as lower ones. **Leaves** asymmetry, dimorphic, complanate, 2 rows of lateral leaves, 2 dorsal rows and 2 ventral rows, widely spreading, slightly undulate when dry, straight when moist; lateral leaves, medium to large, orbicular, ovate to oblong, apices acute to apiculate, margins weakly to coarsely dentate near apex, border all around with 2–7 rows of linear cells; costa short, frequently weak, irregularly forked; dorsal and ventral leaves usually smaller than lateral leaves, broadly ovate to elliptic, apices broadly acute, margins plan to weakly dentate in upper half. Lamina cells median to large size, thin walled, apical cells short hexagonal to rhomboidal; submarginal and median cells oblong hexagonal to pentagonal; basal cells oblong hexagonal to irregularly pentagonal.

Dioicous or autoicous. **Perigonial** leaves narrowly ovate to lanceolate, apices bunt to acute, entire, ecostate. Antheridia few to numerous per androecium. **Perichaetial** leaves, similar to perigonial leaves, but usually shouldered. Archegonia usually numerous per gynoecium. **Sprophyte** lateral. **Seta** slender, dark green to reddish brown, papillose to hairy. **Capsule** ovoid, erect or inclined; exothecial cells collenchymatous, thin to slightly thick walled with medium trigones; operculum long or short rostrate; outer peristome teeth, lanceolate, narrowly furrowed, transversely striolate; inner peristome teeth as long as outer peristome, with high basal membrane. **Spores** medium to large in size, slightly papillose. **Calyptra** mostly mitriform, fringed hairs at the base. **Asexual reproduction** by gemmae, gemmae reddish brown.

Calyptrochaeta comprises approximately 30 species (Streimann, 2000; Frey & Stech, 2009), which are usually growing on humus, decaying wood and tree bases in montane forest. The genus is distributed mainly in tropical regions of the world (Ho & Kruijer, 2007). There are two species of *Calyptrochaeta* occurring in Thailand.

Key to the species of the genus *Calyptrochaeta* in Thailand

1. Foliate stems up to 5.5 cm tall, with rounded apex when gemmiferous; stems in cross section with a central strand. Leaf margins strongly toothed, bordered by 3–4 rows of linear cells ..... *C. remotifolia*
1. Foliate stems up to 3 cm tall, with attenuated apex when gemmiferous; stems in cross section without a central strand. Leaf margins weakly toothed, bordered by 1–2 rows of linear cells ..... *C. spinosa*

1. *Calyptrochaeta remotifolia* (Müll. Hal.) Z. Iwats., B.C. Tan & Touw, J. Hattori Bot. Lab. 44: 150. 1978. Fig. 4.11

≡ *Eriopus remotifolius* Müll. Hal., Bot. Zeitung (Berlin) 5: 828. 1847. — *Hookeria remotifolia* (Müll. Hal.) Müll. Hal., Syn. Musc. Frond. 2: 207. 1851. Type: INDONESIA. Java, "monte Gédé supra terram humosam et lapides", *Reinwardt s.n.* (holotype: B).

= *Hookeria cristata* Hornsch. & Reinw., Nova Acta Phys. Med. Acad. Caes. Leop.–Carol. Nat. Cur. 14, Suppl. II: 718, t.40 f.b. 1829. non (Hedw.) Hook. & Grev.

Plants light to dark green, glossy, turning to brownish yellow in herbarium specimens. **Rhizoids** dark reddish, dense on primary stem. **Primary stems** short tightly attached to substrata, bearing a number of aerial foliate stems. **Foliate stems** erect, large in size, 2.5–5.5 cm long, 0.8–1.0 cm wide with leaves, usually unbranched, dark green to reddish brown; in cross section 24–28 cells across; hyalodermis distinct, consisting of 1 layer of large, thin-walled cell; outer cortical cells consisting of 4–5 layers of small, thick-walled; inner cortical cells large, thin-walled; central strand well-developed. **Axillary hairs** filiform, consisting 3–5 cells long (100–150 µm), terminal cell not inflated, 40–50 µm long, basal and intermediate cells ca. 40–48 µm long. **Leaves** widely spreading, somewhat rugose when dry, straight when moist; lateral leaves large, ovate to oblong, 4.2–5.0 mm long, 1.5–2.0 mm wide, apices broadly acute, margins coarsely dentate in upper half with strongly toothed, distinctly bordered all around with 3–4 rows of linear cells; costa short and fork, 0.5–1.0 mm long; dorsal and ventral leaves smaller than lateral leaves, mostly broadly ovate to elliptic, 2.5–3.5 mm long, 1.3–1.7 mm wide; apices broadly acute,

margins weakly dentate in upper half. Lamina cells homogeneous, thin walled; apical cells short hexagonal to rhomboidal, 80–125 × 20–35 µm; median and submarginal cells oblong hexagonal to irregularly pentagonal, 100–150 × 25–45 µm; basal cells oblong hexagonal to irregularly pentagonal, 140–180 × 25–50 µm.

Dioicous. Perigonial leaves, yellowish green, narrowly ovate to elliptic, 0.8–1.2 mm long, 0.5–0.8 mm wide, acute, entire. Antheridia 600–650 µm long. **Perichaetial** leaves, yellowish green, narrowly ovate to elliptic, 0.7–1.0 mm long, 0.4–0.6 mm wide, round, entire. **Seta** slender, 4–7 mm long, reddish brown, hairy; hair 5–10 µm long. **Capsule** ovoid-oblong, horizontal, 1.0–1.8 mm long; exothecial cells large in size, irregular hexagonal, 35–45 µm in diameter, collenchymatous, thin walled with medium trigones; operculum long rostrate, beak ca. 0.5 mm long; outer peristome teeth orange to reddish, lanceolate, narrowly furrowed, transversely striolate, inner surface with well-developed ventral lamellae from base to tip; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, ca. 1 mm long, 0.65 mm wide at base, slightly hairy above, strongly fringed hairs at the base. **Gemmae** brownish green to reddish brown, filiform, bearing on gemmaphore, present along distal part of foliate stem among leaves.

Habitat and ecology: In Thailand, *Calyptrochaeta remotifolia* were found growing amongst other bryophytes such as *Distichophyllum cuspidatum* (Dozy & Molk.) Dozy & Molk., *Heteroscyphus coalitus* (Hook.) Schiffn., *Jubula* sp., *Pyrrhobryum spiniforme* (Hedw.) Mitt., and *Thuidium* sp., on wet rocks, tree trunks and rotten woods in lower montane forest, at altitude between 1000 and 1630 m.

Distribution: India, Indonesia (Bali, Ceram, Flores, Java, Kalimantan, New Guinea, Papua and Sumatra), Malaysia (Sabah, Sarawak), Philippines and Thailand (Gangulee, 1977; Tan & Robinson, 1990; Mohamed & Robinson, 1991).

Specimens examined: **Chiang Mai**, Doi Inthanon National Park, 15 ha Plot, near Check Point 2, 1600–1700 m, 18°31'20.40"N, 98°24'28.20"E, 31 Dec. 2008, *H.*

Akiyama, M. Kanzaki, T. Irie & N. Ando 239 (HYO); 6 Jan. 2009, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 407* (HYO); 10 Mar. 2011, *N. Printarakul 2673, 3654* (CMUB, O). **Phitsanulok**, Phu Hin Rong Kla National Park, 1624 m, 16°55'51.41"N, 101°03'04.41"E, 9 Jul. 2015, *W. Juengprayoon 552, 556, 559, 573* (PSU). **Loei**, Phu Hin Rong Kla National Park, Man Dang Waterfall, 1615 m, 16°56'45.99"N, 101°03'24.52"E, 9 Dec. 2013, *S. Chantanaorrapint, J. Inuthai & C. Promma 3422* (PSU); Phu Ruea district, Phu Luang Wildlife Sanctuary, 1151 m, 17°30'00.08"N, 101°20'09.54"E, 5 Jul. 2015, *W. Juengprayoon 474* (PSU); 1517 m, 17°16'48.4"N, 101°31'31.8"E, 6 Jul. 2015, *M. Poopath 1165 1166, 1171, 1173, 1177, 1192* (BKF, PSU). **Prachuap Khiri Khan**, Huai Yang Waterfall National Park, 1072 m, 11°38'50.91"N, 099°34'57.37"E, 3 Mar. 2016, *S. Chantanaorrapint, W. Juengprayoon & O. Suwanmala 109* (PSU). **Nakhorn Si Thammarat**, Khao Nan National Park, Khao Nan Mt., 1000–1300 m, 21 Apr. 2007, *S. Chantanaorrapint 1622* (PSU); Khao Luang National Park, Khao Luang Mt., 4 Feb. 1966, *A. Touw 11612* (L), 1308 m, 08°32'51.01"N, 099°44'15.44"E, 21 Apr. 2014, *W. Juengprayoon 115, 116A* (PSU); 1484 m, 08°32'31.95"N, 099°44'13.98"E, 22 Apr. 2014, *W. Juengprayoon 120, 121B, 122A, 124* (PSU); 1537 m, 08°32'23.30"N, 099°44'12.19"E, 22 Apr. 2014, *W. Juengprayoon 126, 127A, 128, 129B* (PSU); 1403 m, 08°32'10.18"N, 099°45'05.45"E, 23 Apr. 2014, *W. Juengprayoon 135A, 137A* (PSU); 1264 m, 08°32'53.40"N, 099°44'16.71"E, 25 Jun. 2015, *W. Juengprayoon 363, 364, 367* (PSU); 1326 m, 08°32'51.01"N, 099°44'15.44"E, 26 Jun. 2015, *W. Juengprayoon 390, 392, 396, 397, 411, 414, 415, 422, 424, 427, 428A, 434, 442, 443B, 446* (PSU); Khao Ramrome Mt., 945 m, 07°00'28.51"N, 100°29'58.08"E; 10 Feb. 2016, *W. Juengprayoon 722* (PSU). 10 Apr. 2016 *W. Juengprayoon 741* (PSU). **Trang**, Khao Ched Yod Mt., 1116 m, 07°19'18.4"N, 099°54'39.3"E, 21 May 2012, *S. Chantanaorrapint, J. Inuthai & C. Promma 1215A* (PSU); 1067 m, 07°19'18.86"N, 099°54'40.48"E, 2 May 2014, *W. Juengprayoon 152* (PSU).

Additional descriptions: Dozy & Molkenboer (1861: 34), Bartram (1939: 263 as *Eriopus remotifolius*), Gangulee (1977: 1495), Tan & Robinson (1990: 10), Mohamed & Robinson (1991: 9).

Additional illustrations: Dozy & Molkenboer (1861: fig. CLVIII), Gangulee (1977: 1497, fig. 748), Tan & Robinson (1990: 8, figs 5–6), Mohamed & Robinson (1991: 8, figs. 16–22).

Taxonomic notes: The distinctive features of *C. remotifolia* are 1) medium to large plant size, 2) the presence of central strand in stem cross-section, 3) leaf margins strongly toothed above, 4) leaf border consisting of 3–4 rows of linear cells near the apex, and 5) perichaetial leaves with blunt or round apex.

2. *Calyptrochaeta spinosa* (Nog.) Ninh, Acta Bot. Acad. Sci. Hung. 27: 159. 1981.

Fig. 4.12

≡ *Eriopus spinosus* Nog., J. Sci. Hiroshima Univ., Ser. B, Div. 2, Bot. 3: 51, f. 6. 1937. — *Calyptrochaeta ramosa* (M. Fleisch.) B.C. Tan & H. Rob. subsp. *spinosa* (Nog.) P.J. Lin & B.C. Tan, Harvard Pap. Bot. 7: 29. 1995. Type: FORMOSA (=Taiwan), prov. Taihoku (=Taipei), Mt. Taihei, ca. 2200 m, August 1932, *A. Noguchi 6601a* (holotype: HIRO, missing). Lectotype: Nog. J. Sci. Hiroshima Univ., Ser. B, Div. 2, Bot. 3: 51, f. 6. 1937 (here designated).

= *Calyptrochaeta pocsii* Ninh, Acta Bot. Acad. Scientiarum Hung. 27: 157. 1981. Type: VIETNAM. Tamdao, lower montane evergreen forest, 1350 m, on decaying wood, *Tr. Ninh 68–202a* (holotype: HNU n.v.; isotype: SINU).

Plants yellowish green to dark green, glossy, turning to greenish brown in herbarium specimens. **Rhizoids** dark reddish, dense on primary stem. **Primary stems** short, creeping and tightly adherent to substrate. **Foliate stems** erect, medium in size, 1.5–3.0 cm long, 0.25–0.4 cm wide with leaves, simple or branched, dark green to reddish brown; in cross section 17–20 cells across; hyalodermis distinct, consisting of 1 layer of large, thin-walled cell; outer cortical cells consisting of 1–2 layers of small, thick-walled; inner cortical cells large, thin-walled; central strand not differentiated. **Axillary hairs** filiform, consisting 3–4 cells long, terminal cell not inflated, 30–40 µm long, basal and intermediate cells 25–38 µm long. **Leaves** widely spreading,

somewhat curved when dry, straight when moist; lateral leaves large, short ovate to oblong, 2.2–3.5 mm long, 1.3–1.8 mm wide, apices broadly acute, margins dentate, bordered all around with 1–2 rows of linear cells; costa very short and fork, 0.3–0.5 mm long; dorsal and ventral leaves smaller than lateral leaves, mostly broadly ovate, 1.3–1.5 mm long, 1.0–1.2 mm wide, apices broadly acute, margins slightly dentate in upper half. Lamina cells homogeneous, thin walled; apical cells short hexagonal, 30–45 ×15–20 μm; median and submarginal cells oblong hexagonal to irregularly pentagonal, 50–90 × 25–40 μm; basal cells oblong hexagonal to irregularly pentagonal, 120–150 × 45–50 μm.

Dioicous. **Perigonial** leaves yellowish green to light green, narrowly ovate to lanceolate, 0.5–0.7 mm long, 0.15–0.2 mm wide, acuminate, entire. Antheridia 300–450 μm long. **Perichaetial** leaves yellowish green, broadly ovate, 0.7–1.0 mm long, 0.4–0.5 mm wide, acuminate, entire. **Seta** slender, 2.5–3.0 mm long, dark green to reddish brown, papillose, projection 2–4 μm long. **Capsule** ovoid, erect or inclined, 0.5–0.8 mm long; exothecial cells medium to large in size, irregular hexagonal, 30–45 μm in diameter, collenchymatous, thin walled with medium trigones; operculum short rostrate, ca. 0.25 mm high; outer peristome teeth orange to reddish, lanceolate, narrowly furrowed, transversely striolate, inner surface with well-developed ventral lamellae from base to tip; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform ca. 0.5 mm long, 0.45 mm wide at base, slightly hairy above, strongly fringed hairs at the base. **Gemmae** brownish green, filiform, bearing on gemmaphore, present along distal part of foliate stem among leaves.

Habitat and ecology: The species were found growing amongst other bryophytes, such as *Bazzania* spp., *Calycularia crispula* Mitt., *Plagiochila* spp., and *Thamniopsis utacamundiana* (Mont.) W.R. Buck, on tree trunks in upper montane forest, between 1900 and 2543 m.

Distribution: China (Guangxi, Guangdong, Guizhou, Hainan, Sichuan, Yunnan), India, Nepal, Taiwan, Thailand, and Vietnam (Gangulee, 1977; Lin & Tan, 1995).

Specimens examined: **Chiang Mai**, Doi Inthanon National Park, 2300 m, 20 Dec. 1965, *A. Touw 10126* (L); 10 Dec. 1969, *V. Beusekom B187* (L); Ang Ka, 2545 m, 18°35'18.06"N, 98°29'8.16"E, 23 Jul. 2007, *Y. Nathi 145* (BCU); 2580 m, 18°35'16.32"N, 98°29'13.98"E, 9 Feb. 2008, *Y. Nathi 746* (BCU); 2214 m, 18°33'28.44"N, 98°28'85.38"E, 13 May 2008, *Y. Nathi 1032* (BCU); 1900–2543 m, 18°35'20.10"N, 098°29'05.60"E, 31 Oct. 2015, *W. Juengprayoon 603, 607, 610A* (PSU); 15 ha Plot, near Check Point 2, 1600–1650 m, 18°31'20.40"N, 98°24'28.20"E, 28 Dec. 2008, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 132* (HYO); 31 Dec. 2008, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 249* (HYO); 2 Jan. 2009, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 306* (HYO); 10 Mar. 2011, *N. Printarakul 3669, 3670* (CMUB); near Plot E–07, 2300 m, 18°34'4.80"N, 98°29'6.00"E, 11 Mar. 2011, *H. Akiyama & N. Printarakul 1531* (HYO); Kew Mae Pan, 2167 m, 18°33'38.02"N, 098°28'32.45"E, 28 Jun. 2007, *Y. Nathi 1182* (BCU); 2214 m, 18°33'27.42"N, 98°28'51.42"E, 13 May 2008, *Y. Nathi 1032* (BCU); 2167 m, 18°33'38.02"N, 098°28'32.45"E, 1 Nov. 2015, *W. Juengprayoon 617, 618A, 619A, 622B, 623, 624A, 625, 627, 628A* (PSU); Doi Pha Hom Pok National Park, 1922 m, 20°02'42.97"N, 099°08'43.43"E, 2 Nov. 2015, *W. Juengprayoon 641, 643, 644* (PSU); 2000 m, 9 Nov. 2016, *S. Chantanaorrapint & O. Suwanmala 581, 587* (PSU).

Additional descriptions: Noguchi (1937: 15), Gangulee (1977: 1497), Lin & Tan (1995: 29).

Additional illustrations: Noguchi (1937: 16, fig. 6), Gangulee (1977: 1497, fig. 749), Lin & Tan (1995: 53, fig. 23).

Taxonomic notes: The main diagnostic character of *C. spinosa* are plant size small to medium, the absence of central strand in stem cross-section, leaf margins weakly toothed above, leaf border consisting of 1–2 rows of linear cells, and perichaetial leaves with acuminate apex. Tan and Robison (1990) suggested that *C. spinosa* might be a juvenile form of *C. ramosa* (M. Fleisch.) B.C. Tan & H. Rob. Later, Lin and Tan

(1995) reduced *C. spinosa* as a subspecies of *C. ramosa*. However, our examination of the various specimens of both species reveals that *C. spinosa* is quite different from *C. ramosa* and thus cannot be a juvenile form of *C. ramosa*. Therefore, the author agrees with Redfearn *et al.* (1996) who had first reinstated *C. spinosa* as a distinct species after Lin and Tan (1995).

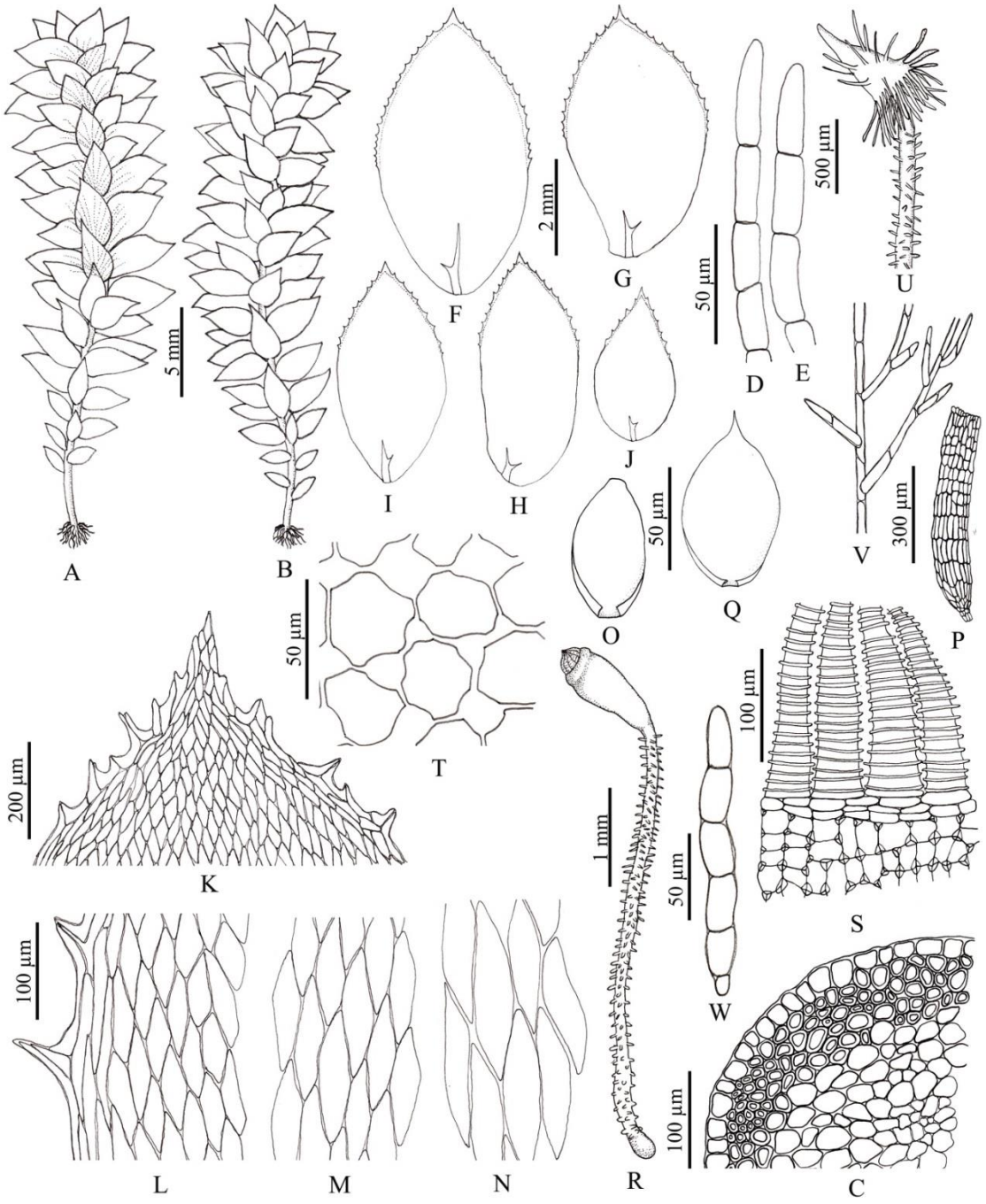

Figure 4.11 *Calyptrochaeta remotifolia* (Müll. Hal.) Z. Iwats., B.C. Tan & Touw. A–B. Sterile gametophytes. C. Cross section of stem. D–E. Axillary hairs. F–G. Lateral leaves. H–J. Dorsal leaves. K. Cells of upper part of leaf. L. Cells at leaf margin. M. Cells at leaf median part of leaf. N. Cells at leaf base. O. Perigonial leaf. P. Antheridium (old). Q. Perichaetial leaf. R. Sporophyte. S. Part of exostome. T. Exothecial cells. U. Calyptra on a developing capsule. V. Gemmaphore. W. Gemma. All from *W. Juengprayoon 424* (PSU).

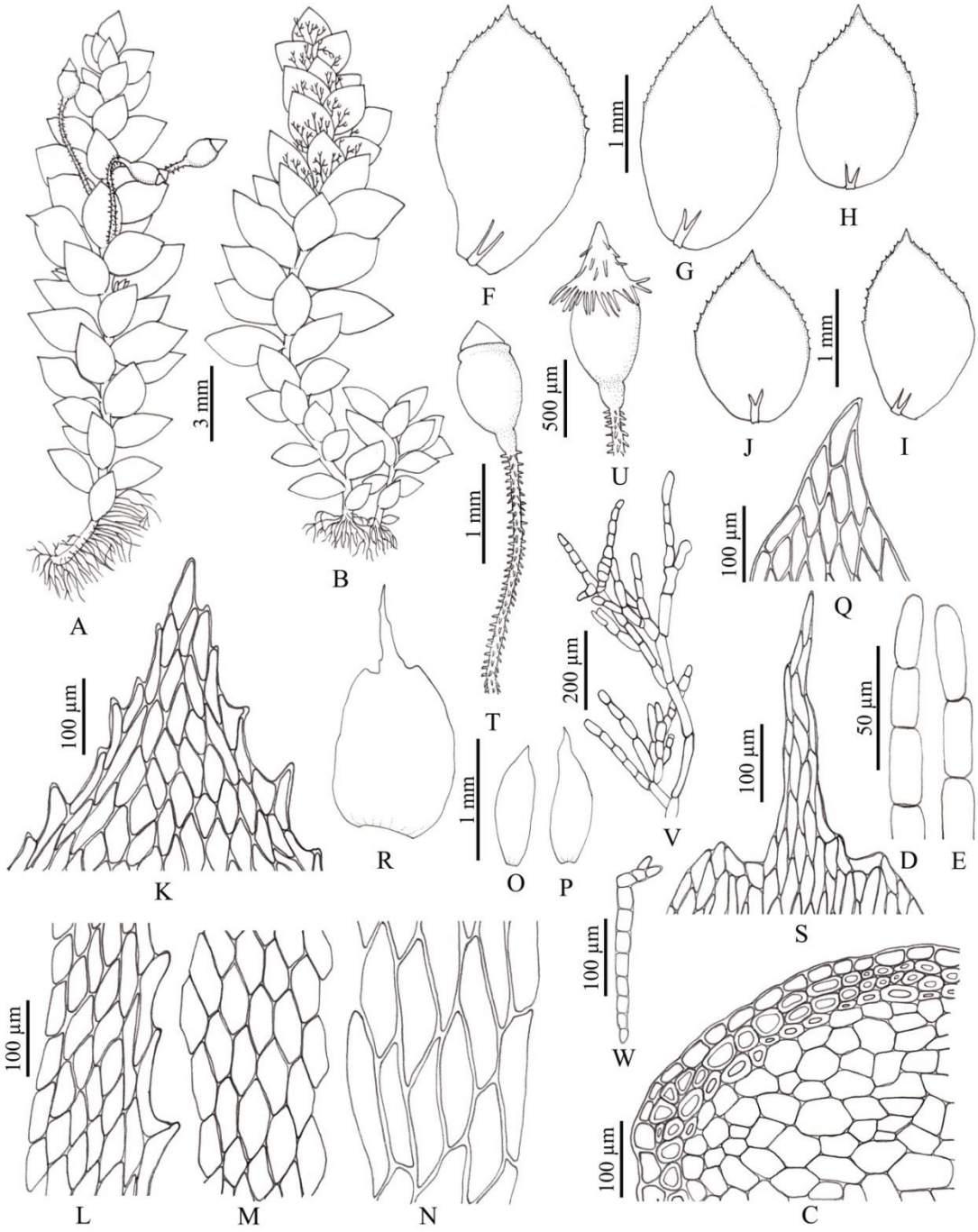

Figure 4.12 *Calyptrochaeta spinosa* (Nog.) Ninh. A. Gametophyte with sporophytes, B. Gametophyte with gemmae. C. Cross section of stem. D–E. Axillary hairs. F–G. Lateral leaves. H–J. Dorsal leaves. K. Cells at leaf apex. L. Cells at leaf margin. M. Cells at median part of leaf. N. Cells at leaf base. O–P. Perigonial leaves. Q. Cells at leaf apex part of perigonial leaf. R. Perichaetial leaf. S. Cells at leaf apex part of perichaetial leaf. T. Upper part of sporophyte. U. Capsule with calyptra. V. Gemmaphore with gemmae. W. Gemma. All from *W. Juengprayoon 603* (PSU).

Daltonia

Hook. & Taylor, Musci Brit. 80. 1818, nom. cons. Type: *Neckera splachnoides* Sm. [= *Daltonia splachnoides* (Sm.) Hook. & Tayl.].

Plants usually epiphytic and rarely epiphyllous, small to medium in size, usually tuft form, yellowish green to greenish brown, simple or rarely branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** dark green to reddish brown, in cross section without central strand. **Axillary hairs** filiform, terminal cell longer than basal and intermediate cells. **Leaves** monomorphic, not complanate, crowed or dense leaves, somewhat flexuous to concave when dry, erecto-patent, plane to slightly carinated when moist; narrowly oblong to lanceolate, rarely spathulate; apices acute to acuminate, rarely rounded; margins entire with 2–4 rows of linear cells; costa single, weakly, about 3/5–4/5 of leaf length. Lamina cells hetero-(homogeneous), small to medium in size, thin-walled, oblong pentagonal, hexagonal to polygonal.

Dioicous or autoicous. **Perigonial** leaves yellowish green, ovate to broadly ovate, acute to acuminate, entire. **Perichaetial** leaves usually similar to perigonial leaves. **Sporophytes** lateral or terminal. **Seta** slender, reddish brown, smooth to scabrous above. **Capsule** ovoid-oblong, horizontal to inclined, exothecial cells, small to medium in size, irregular hexagonal, collenchymatous, thick walled with large trigones; operculum long rostrate; outer peristome teeth yellow to orange, triangular lanceolate, papillose; inner peristome teeth as long as outer peristome, with high basal membrane. **Spores** medium in size, slightly papillose. **Calyptra** mitriform, fringed hairs at the base. **Asexual reproduction** by gemmae; gemmae filiform, usually yellowish green, mostly present on costa near the leaf tips.

The genus *Daltonia* includes approximately 59 species worldwide and widely distributed in tropical regions (Frey & Stech, 2009). The plants are epiphytes usually growing on twigs, branches or sometime on tree trunks from lower montane to upper montane forests. There are five species in Thailand.

Key to the species of the genus *Daltonia* in Thailand

1. Plants medium in size, 0.62–1.5 cm tall. Leaves spathulate to obovate with rounded apex.....*D. waniana*
1. Plants small in size, 0.2–0.65 cm tall. Leaves narrowly ovate to lanceolate with acute, acuminate, or cuspidate apices 2
2. Leaf apex strongly cuspidate .....*D. aristifolia*
2. Leaf apex acute to acuminate 3
3. Leaves strongly carinated along the costa, acute at apex about 70–100 µm long.....
   ..... *D. semitorta*
3. Leaves plane to slightly carinated along the costa, acuminate at apex 130–200 µm long.....4.
4. Leaf narrowly oblong to lanceolate, 3.5–4.0 mm long, 0.7–1.0 mm wide, apex about 150–200 µm long. Seta smooth below and scabrous above. ...*D. angustifolia*
4. Leaf narrowly lanceolate, 1.7–2.2 mm long, 0.45–0.7 mm wide, apex 130–160 µm long. Seta smooth throughout .....*D. apiculata*

1. ***Daltonia angustifolia*** Dozy & Molk., Ann. Sci. Nat., Bot., sér. 3, 2: 302. 1844. Fig. 4.13

Type: INDONESIA. Borneo, sine loco., *Korthals s.n.* (holotype: NY).

Plants yellowish green to greenish brown, turning to brownish yellow in herbarium specimens, erect, short, small in size, 3.5–6.0 mm tall, 2.0–2.5 mm wide with leaves, simple or rarely branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** dark green to reddish brown, in cross section 8–12 cells across; epidermal cells 1–2 layers, thick-walled; cortex cells larger, thin-walled. **Axillary hairs** filiform, consisting of 2–3 cells long; terminal cell inflated, 25–30 µm long; basal and intermediate cells smaller, ca. 10 µm long. **Leaves** somewhat flexuose when dry, erecto-patent when moist; slightly carinated, narrowly oblong to lanceolate, 3.5–4.0 mm long, 0.7–1.0 mm wide, apex gradually acuminate, 150–200 µm long, margins

entire; border distinct, consisting of 2–4 rows of linear cells; costa weakly, about 3/5–2/3 of leaf length. Lamina cells heterogeneous, thin walled; apical cells narrowly rhomboidal, 30–42 × 10–25 µm; paracostal and upper submarginal cells, rectangular to hexagonal, 35–45 × 15–28 µm; basal and lower submarginal cells, oblong rectangular, 40–80 × 18–30 µm.

Synoicous. Perigonial leaves yellowish green, narrowly ovate, 0.15–0.2 mm long, 0.08-0.1 mm wide, acuminate, entire. **Perichaetial** leaves similar to perigonial leaves. **Seta** slender, 4.3–5 mm long, reddish brown, smooth below and scabrous above. **Capsule** ovoid-oblong, horizontal, 1.0–1.5 mm long; exothecial cells irregular hexagonal, 20–25 µm in diameter, collenchymatous, thick walled with large trigones; operculum long rostrate, beak ca. 0.6 mm long; outer peristome teeth orange to reddish, triangular lanceolate, papillose; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, ca. 1 mm long, 0.5 mm wide at base, fringed hairs at the base. **Asexual reproduction** not seen.

Habitat and ecology: In Thailand, *Daltonia angustifolia* usually grows on twigs and branches amongst other bryophytes, in lower to upper montane forest, at altitude between 1100 and 2550 m.

Distribution: Indonesia (Borneo, Java), Malaysia, Nepal, New Zealand, Philippines, Sri Lanka, Vietnam, Thailand, and also in Central Africa, and Madagascar (Mohamed & Robinson, 1991).

Specimens examined: **Chiang Mai**, Doi Inthanon National Park, 2550 m, 5 Dec. 2000, *H. Akiyama Th-10* (HYO), Above the Check Point 2, 1800 m, 8 Dec. 2000, *H. Akiyama Th-187* (HYO), Chomthong, Kew Mae Pan, 2233–2234 m, 18°33'592"N, 098°28'548"E, 8 Oct. 2007, *Y. Nathi 460*, *546* (BCU), 2 Oct. 2008, *Y. Nathi 987* (BCU), 2300 m, 15 Jan. 2010, *N. Printarakul 2730*, *2759* (CMUB, O), Angka, 2543 m, 18°35'20.10"N, 098°29'05.60"E, 31 Oct. 2015, *W. Juengprayoon 602A*, *605*,*615* (PSU), 2167 m, 18°33'21.13"N, 098°28'56.90"E, 1 Nov. 2015, *W. Juengprayoon*

628B, *629A* (PSU), 1922 m, 20°02'42.97"N, 099°08'43.43"E, 2 Nov. 2015, *W. Juengprayoon 631*, *632*, *633*, *634*, *635A*, *636*, *637*, *638* (PSU), 3 Nov. 2015, *W. Juengprayoon 640*, *642B* (PSU), 2529 m, 7 Nov. 2016, *S. Chantanaorrapint & O. Suwanmala 509*, *510C*, *517A* (PSU); Fang, Doi Pha Hom Pok National Park, 1945 m, 9 Nov. 2016, *S. Chantanaorrapint & O. Suwanmala 563*, *564*, *566*, *570* (PSU); Doi Chiang Dao, 2141 m, 12 Nov. 2016, *W. Juengprayoon 501*, *502* (PSU). **Prachuap Khiri Khan**, Huai Yang Waterfall National Park, 1194 m, 3 Mar. 2016, *S. Chantanaorrapint*, *W. Juengprayoon & O. Suwanmala 95* (PSU).

Additional descriptions: Dozy & Molkenboer (1861: 30), Fleischer (1908: 956), Gangulee (1977: 1476), Bartram (1939: 256), Tan & Robinson (1990: 12), Mohamed & Robinson (1991: 13), Lin & Tan (1995: 31).
Additional illustrations: Fleischer (1908: 957, fig. 165), Gangulee (1977: 1477, fig. 735), Tan & Robinson (1990: 12, figs. 11–14), Mohamed & Robinson (1991: 14, fig. 23–29), Lin & Tan (1995: 55, fig. 25).

Taxonomic notes: *Daltonia angustifolia* is the smallest species of this genus in Thailand. It is characterized by being synoicous, leaves slightly carinate and leaves apices with narrowly acuminate. This species usually developed sporophytes and distinct in having seta which is smooth below and scabrous above.

2. ***Daltonia apiculata*** Mitt., J. Proc. Linn. Soc., Bot., Suppl. 2: 145. 1859. Fig. 4.14

Type: NEPAL. sine loco., *Wallich s.n.* (holotype: NY).

Plants yellowish green, turning to brownish yellow in herbarium specimens, erect, small in size, 3.0–6.5 mm tall, 2.0–2.3 mm wide with leaves, simple or rarely branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** green to dark green, in cross section 5–8 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells larger in size and thin-walled. **Axillary hairs** filiform, consisting of 2–3 cells

long; terminal cell inflated, 25–35 µm long; basal and intermediate cells ca. 10 µm long. **Leaves** plane to concave when dry, erecto-spreading when moist; narrowly lanceolate, 1.7–2.2 mm long, 0.45–0.7 mm wide, apex acute to acuminate, margins entire; border distinct consisting of 2–3 rows of linear cells; costa weakly, extending about 4/5 of leaf length. Lamina cells heterogeneous, thin walled; apical cells hexagonal to rectangular, 16–20 × 8–10 µm; paracostal cells hexagonal to rectangular, 22–30 × 15–20 µm; submarginal cells hexagonal bigger than paracostal cells, 35–50 × 17–25 µm; basal cells oblong rectangular, 40–75 × 18–30 µm.

Dioicous. Perigonial leaves not seen. **Perichaetial** leaves yellowish green, oblong to narrowly ovate, 0.65–0.78 mm long, 0.15–0.2 mm wide, broadly acute, entire. **Seta** slender, 0.3–0.5 mm long, greenish brown, smooth. **Capsule** ovate-oblong, inclined or erect, 1.2–1.6 mm long; exothecial cells irregular pentagonal to polygonal, 16–20 µm wide in diameter, collenchymatous, thick walled with large trigones; operculum long rostrate, beak 0.5–0.6 mm long; outer peristome teeth orange, triangular lanceolate, papillose; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, 0.7–0.8 mm long, ca. 0.4 mm wide at base, fringed hairs at the base. **Gemmae** yellowish green, fusiform, 50–70 µm long, occurring on costa near the leaf tips.

Habitat and ecology: *Daltonia apiculata* mostly growing on twigs, branches and rarely on living leaves, in upper montane forest, at altitude between 1600 and 2500 m.

Distribution: Eastern India, Eastern Nepal and Thailand (Chiang Mai) (Gangulee, 1977).

Specimens examined: **Chiang Mai**, Doi Inthanon National park, 15 ha Plot, Near Check Point 15, 1600–1650 m, 18°31'20.40"N, 098°24'28.20"E, 28 Dec. 2008, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 120* (HYO), 6 Jan. 2009, *H. Akiyama 400, 401* (HYO), 22 Nov. 2009, *N. Ando s.n.* (HYO), Near Check Point 10–11, 14 Jan. 2010, *H. Akiyama, T. Irie, N. Printarakul & M. Kanzaki 1130, 1131* (HYO), 2280 m,

18°33'55.00"N, 098°29'12.00"E, 20 Jan. 2010, *H. Akiyama, T. Irie, N. Printarakul & M. Kanzaki 1353* (HYO), 2300–2500 m, 18°30'60.00"N, 098°29'12.00"E, 11 Mar. 2011, *H. Akiyama & N. Printarakul 1496, 1536, 1555–a* (HYO), 20 Jan. 2010, *N. Printarakul 2982* (CMUB, O), 11 Mar. 2011, *N. Printarakul 3695* (CMUB, O), Chomthong, Kew Mae Pan, 2167 m, 18°33'38.02"N, 098°28'32.45"E, 1 Nov. 2015, *W. Juengprayoon 629C* (PSU), 2529 m, 7 Nov. 2016, *S. Chantanaorrapint & O. Suwanmala 506, 510A, 517B* (PSU), Fang, Doi Pha Hom Pok National Park, 1922 m, 20°02'42.97"N, 099°08'43.43"E, 2 Nov. 2015, *W. Juengprayoon 634B, 635B* (PSU), 3 Nov. 2015, *W. Juengprayoon 642B* (PSU). **Prachuap Khiri Khan**, Huai Yang Waterfall National Park, 1194 m, 3 Mar. 2016, *S. Chantanaorrapint, W. Juengprayoon & O. Suwanmala 95* (PSU).

Additional descriptions: Mitten (1859: 145), Gangulee (1977: 1477).
Additional illustrations: Gangulee (1977: 1478, fig. 736).

Taxonomic notes: This species can be recognized by its narrowly lanceolate leaf with acute to acuminate apex. Unfortunately, the specimens from field survey are mostly immature plants and without gemma. Therefore, this study mostly based on the mature specimens were collected by Akiyama and his team from Thailand.

3. ***Daltonia aristifolia*** Renauld & Cardot., Rev. Bryol. 23: 105. 1896. Fig. 4.15

Type: INDONESIA. Java, Tjibodas, *Massart inter 1395* (BR).

= *Daltonia perlaxiretis* Dixon., J. Bombay Nat. Hist. Soc. 39: 786, 1 f, 13. 1937. Type: INDIA. Assam, Piri, Aka Hills, 2500 m alt., 17 Nov. 1934, *Bor 264* (holotype: BM).

Plants green to yellowish green, turning to greenish brown in herbarium specimens, erect, small in size, 5.4–6.5 mm tall, 2.4–2.6 mm wide with leaves, simple or rarely branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** dark green to

reddish brown, in cross section 8–12 cells across; epidermal cells 1–3 layers, thick-walled; cortex cells large in size and thin-walled. **Axillary hairs** filiform, consisting of 2–3 cells long; terminal cell inflated, 25–36 µm long; basal and intermediate cells ca. 10 µm long. **Leaves** plane to recurved when dry, erecto-spreading when moist; narrowly lanceolate, 3.0–3.5 mm long, 0.6–0.75 mm wide, apex cuspidate, about 250–350 µm long, margins entire; border distinct, consisting of 2–3 rows of linear cells; costa, extending about 4/5 of leaf length. Lamina cells heterogeneous, thin walled; apical cells shortly hexagonal, 8–15 × 6–7.6 µm; paracostal cells narrowly rectangular, 40–55 × 17–22 µm; upper submarginal cells shortly rhomboidal, 40–48 × 14–20 µm; lower submarginal and basal cells, oblong hexagonal, 55–90 × 15–30 µm.

Autoicous. Perigonial leaves yellowish green, ovate, 0.45–0.6 mm long, 0.24–0.35 mm wide, broadly acute, entire. **Perichaetial** leaves yellowish green, ovate, 0.5–0.67 mm long, 0.20–0.31 mm wide, acute to acuminate, entire. **Seta** slender, 1.0–1.5 mm long, greenish brown, smooth. **Capsule** oblong, erect, 0.6–0.75 mm long; exothecial cells irregular pentagonal to polygonal, 15–23 µm in diameter collenchymatous, thick walled with large trigones; operculum long rostrate, beak ca. 0.38 mm long; outer peristome teeth orange, triangular lanceolate, papillose; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, 0.5–1 mm long, ca. 0.25 mm wide, covering only long rostrate operculum, fringed hairs at the base. **Asexual reproduction** not seen.

Habitat and ecology: *Daltonia aristifolia* usually grow on twigs and branches among the other bryophytes such as *Daltonia angustifolia*, in upper montane forest, at altitude between 1900 and 2500 m.

Distribution: China, India (Assam, Darjeeling), Indonesia (Java, New Guinea), Philippines, Nepal, Vietnam, Taiwan, Thailand (Chiang Mai) (Noguchi, 1986; Lin & Tan, 1995; Akiyama *et al.*, 2011).

Specimens examined: **Chiang Mai**, Doi Inthanon National park, Angka, 2500 m, 11 Mar. 2011, *N. Printarakul 3762* (CMUB, O), 2543 m, 098°29'05.60"E, 18°35'20.10"N, 31 Dec. 2015, *W. Juengprayoon 602B, 604* (PSU), Fang, Doi Pha Hom Pok National Park, 1922 m, 20°02'42.97"N, 099°08'43.43"E, 2 Nov. 2015, *W. Juengprayoon 630* (PSU).

Additional descriptions: Fleischer (1908: 963), Gangulee (1977: 1467), Noguchi (1986: 264), Tan & Robinson (1990: 13), Lin & Tan (1995: 32).
Additional illustrations: Fleischer (1908: 965, fig. 166), Gangulee (1977: 1468, fig. 728), Noguchi (1986: 263, fig. 5), Tan & Robinson (1990: 12, figs 11–14), Lin & Tan (1995: 56, fig. 26).

Taxonomic notes: This species is easily separated from other Thai species by having leaves with long hairpoints or cuspidate at the apices. The sporophytes are smooth setae with oblong and erect capsules. *Daltonia aristifolia* can be confused with *D. angustifolia* which also has long-acuminate leaf apices. However, the arista of *D. aristifolia* is made up of several thick-walled, linear cells, similar to the leaf border cells. In *D. angustifolia*, the long leaf apex consists of cells that are not different from other upper leaf cells.

4. ***Daltonia semitorta*** Mitt., J. Proc. Linn. Soc., Bot., Suppl. 2: 146. 1859. Fig. 4.16

Type: INDIA, Sikkim, Mt. Singalelah (= Singalila), 11000 ft, *J. D. Hooker s.n.* (holotype: NY, isotype: BM).

Plants light to yellowish green, erect, small in size, 4.2–5.6 mm tall, 2.2–2.5 mm wide with leaves, simple or rarely branched. **Rhizoids** dark reddish, dense at base of stem. **Stems**, dark green to reddish brown, in cross section 8–10 cells across; epidermal cells 1–2 layers, thick walled; cortex cells larger in size and thin-walled. **Axillary hairs** filiform, consisting of 2–3 cells long; terminal cell inflated, 25–30 µm

long; basal and intermediate cells ca. 10 µm long. **Leaves** strongly twisted at the leaf tip and flexuous when dry, erecto-spreading and strongly carinate along the costa when moist; leaves medium, broadly lanceolate to lanceolate, 2.2–3.1 mm long, 0.6–0.8 mm wide; apex acute, 70–100 µm long; margins entire, border distinct, consisting of 1–2 rows of cells above, 3–5 rows of cells at base; costa strongly, extending 2/3–4/5 of leaf length. Lamina cells heterogeneous, slightly thick walled; apical cells shortly hexagonal, 15–20 × 8–10.5 µm; paracostal cells shortly rhomboidal, 20–25 × 10–16 µm; submarginal cells polygonal, 18–23 × 10–14 µm; basal cells oblong hexagonal, 22–26 × 14–17 µm; paracostal and basal cells larger than other area.

Dioicous. **Perigonial** leaves not seen. **Perichaetial** leaves yellowish green, broadly ovate, 0.5–0.6 mm long, 0.3–0.35 mm wide, broadly acute, entire. **Seta** slender, 4.5–5.0 mm long, reddish brown, smooth. **Capsule** elliptic-ovate, inclined, 0.7–0.9 mm long; exothecial cells irregular pentagonal to polygonal, 15–19 µm in diameter, collenchymatous, thick walled with large trigones; operculum long rostrate, beak ca. 0.5 mm long; outer peristome teeth yellowish orange, triangular lanceolate, papillose; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, ca. 0.7 mm long, 0.5 mm wide at base, fringed hairs at the base. **Asexual reproduction** not seen.

Habitat and ecology: This species usually grow on twigs with other bryophytes such as *D. angustifolia* and *D. apiculata*, in upper montane forest, at altitude about 2100 m.

Distribution: Nepal (Dhankuta), India (Darjeeling), Thailand (Chiang Mai) (Noguchi, 1986).

Specimens examined: **Chiang Mai**, Doi Inthanon National park, Chomthong, Kew Mae Pan, 2167 m, 18°33'21.13"N, 098°28'56.90"E, 1 Nov. 2015, *W. Juengprayoon 628C, 629C* (PSU), 2529 m, 7 Nov. 2016, *S. Chantanaorrapint* & *O. Suwanmala 510B* (PSU).

Additional descriptions: Gangulee (1977: 1475), Noguchi (1986: 264), Lin & Tan (1995: 32).

Additional illustrations: Gangulee (1977: 1476, fig 794), Noguchi (1986: 265, fig. 6).

Taxonomic notes: The distinctive features of *Daltonia semitorta* are the broadly lanceolate to lanceolate leaves, strongly carinate along the costa, and sporophyte with broadly oblong capsule.

5. ***Daltonia waniana*** (B.C. Tan & P.J. Lin) B.C. Ho & L. Pokorny., Bot. J. Linn. Soc. 170: 172. 2012. Fig. 4.17

≡ *Distichophyllum wanianum* B.C. Tan & P.J. Lin., Trop. Bryol. 10: 57. f. 1, 13–18. 1995. Type: CHINA. Yunnan, Luchun, on branches, *M. Zhang 550* (holotype: IBSC; isotype: FH, KUN).

Plants green to yellowish green, turning to greenish brown in herbarium specimens, erect, medium in size, 0.62–1.5 cm tall, 0.3–0.5 cm wide with leaves, sparingly branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** dark green, in cross section 8–10 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells larger in size and thin–walled. **Axillary hairs** filiform, consisting of 5-6 cells long; terminal cell not inflated, 23-31 µm long; intermediate cells 10-35 µm long; basal cell smallest, 5–8 µm long. **Leaves** strongly crisped when dry, erecto–spreading when moist; broadly spathulate to obovate, 1.3–1.9 mm long, 0.3–0.6 mm wide, apex rounded, margins entire; border distinct, consisting of 1–2 rows of cells at apex, 2–3 rows of linear cells below; costa weakly, extending near the apex, about 4/5 of leaf length. Lamina cells heterogeneous, thin walled; apical cells quadrate to shortly polygonal, 12–15 × 6–9.8 µm; paracostal and submarginal cells shortly polygonal, 20–31 × 17–25 µm; basal cells broadly rectangular to polygonal, 49–69 × 25–38 µm.

Dioicous. Perigonial leaves yellowish green, broadly ovate, 0.4–0.53 mm long, 0.3–0.38 mm wide, rounded, entire. **Perichaetial** leaves yellowish green, narrowly ovate, 0.48–0.6 mm long, 0.3–0.42 mm wide, obtuse, entire. **Seta** slender, 3.5–4.0 mm long, reddish brown, smooth, slightly scabrous above. **Capsule** ovoid, inclined or erect, 1.2–1.5 mm long; exothecial cells, medium to large in size, 25–32 µm in diameter, irregular pentagonal to polygonal, collenchymatous, thick walled with medium trigones; operculum long rostrate, beak ca. 0.7 mm long; outer peristome teeth yellowish orange, lanceolate, papillose; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, ca. 0.75 mm long, 0.4–0.5 mm wide at base, covering only long rostrate operculum, fringed hairs at the base. **Gemmae** dark green, fuliform, 180–200 µm long, occuring on costa near the leaf tips.

Habitat and ecology: *Daltonia waniana* usually grow on branches and tree trunks in lower to upper montane forest, at altitude between 1200 and 2500 m.

Distribution: China (Guangdong, Hainan, Yunnan), India (Darjeeling), and Thailand (Ho *et al*., 2010).

Specimens examined: **Chiang Mai**, Doi Inthanon National park, 2250–2570 m, 15°45'31.45"N, 101°32'16.64"E, 18 Dec. 1965, *A. Touw 9771* (BKF), 20 Dec. 1965, *A. Touw 10169* (BKF), 5 Dec. 2000, *H. Akiyama Th–22, Th–52* (HYO), 4 Mar. 2008, *H. Akiyama 21547* (HYO), 2543 m, 18°35'20.10"N, 098°29'05.60"E, 31 Oct. 2015, *W. Juengprayoon 609, 611* (PSU), 15 ha Plot, Near Check Point 2, 1600–1650 m, 18°31'20.40"N, 098°24'28.20"E, 27 Dec. 2008, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 22* (HYO), 28 Dec. 2008, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 122*, *134* (HYO), 2 Jan. 2009, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 317* (HYO), 2250–2300 m, 11 Jan. 2010, *H. Akiyama, T. Irie, N. Printarakul & M. Kanzaki 1085* (HYO), 17 Jan. 2010, *H. Akiyama, T. Irie, N. Printarakul & M. Kanzai 1254* (HYO), Chomthong, Kew Mae Pan, 2189–2553 m, 18°35'354"N, 098°29'106"E, 22 Jul. 2007,

Y. Nathi 99 (BCU), 23 Jul. 2007, *Y. Nathi 138*, *164* (BCU), 18°33'368"N, 098°28'932"E, 24 Jul. 2007, *Y. Nathi 181, 204, 256* (BCU), 1 Dec. 2007, *Y. Nathi 772* (BCU), 1700–2500 m, 14 Jan. 2010, *N. Printarakul 2653* (CMUB, O), *N. Printarakul 2684* (CMUB, O, SIN), 2300 m, 11 Mar. 2010, *N. Printarakul 3735, 3764* (CMUB, O), 2167 m, 18°33'38.02"N, 098°28'32.45"E, 1 Nov. 2015, *W. Juengprayoon 616, 619B, 620, 621, 622A, 624B, 626, 628C* (PSU), 2529 m, 7 Nov. 2016, *S. Chantanaorrapint & O. Suwanmala 533, 534* (PSU). **Loei,** Phu Luang National Park, 1517 m, 17°16'48.4"N, 101°31'31.8"E, 6 Jul. 2015, *M. Poopath 1187, 1189, 1193* (BKF). **Chanthaburi**, Khao Soi Dao Wildlife Sanctuary, 1365 m, 16°3'51.21"N, 097°45'50.22"E, 7 Apr. 2012, *S. Chantanaorrapint, J. Innuthai & C. Promma 889* (PSU), 1420 m, 15°0'1.22"N, 099°59'22.89"E, 8 Apr. 2012, *S. Chantanaorrapint, J. Innuthai & C. Promma 903* (PSU). **Prachuap Khiri Khan**, Huai Yang Waterfall National Park, 1212 m, *S. Chantanaorrapint, W. Juengprayoon & O. Suwanmala 84* (PSU).

Additional descriptions: Lin & Tan (1995: 43), Ho *et al.* (2010: 120).
Additional illustrations: Lin & Tan (1995: 65, fig. 35), Ho *et al.* (2010: 121, fig. 7).

Taxonomic notes: *Daltonia waniana* is unique among the members of Thai *Daltonia*. It is the largest species of the genus and easy recognized by broadly spathulate leaf with round apex and axillary hairs consisting of 5–6 cells long with non–inflated terminal cell.

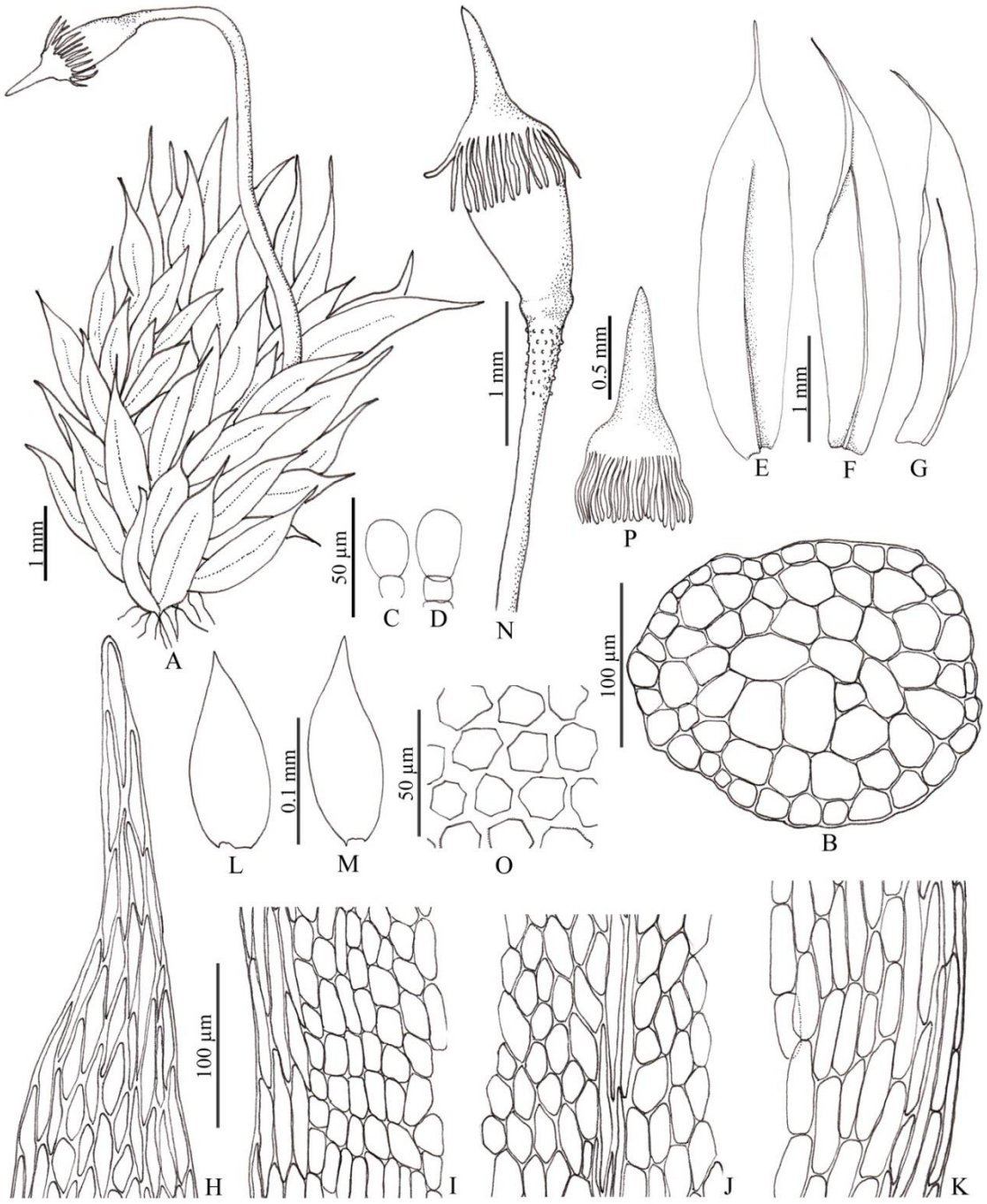

Figure 4.13 *Daltonia angustifolia* Dozy & Molk. A. Gametophyte. B. Cross section of stem. C–D. Axillary hairs. E–G. Leaves. H. Cells at leaf apex. I. Cells at leaf margin. J. Cells at median part of leaf. K. Cells at leaf base. L. Perigonial leaf. M. Perichaetial leaf. N. Upper part of sporophyte. O. Exothecial cells of capsule. P. Calyptra. All from *W. Juengprayoon 640* (PSU).

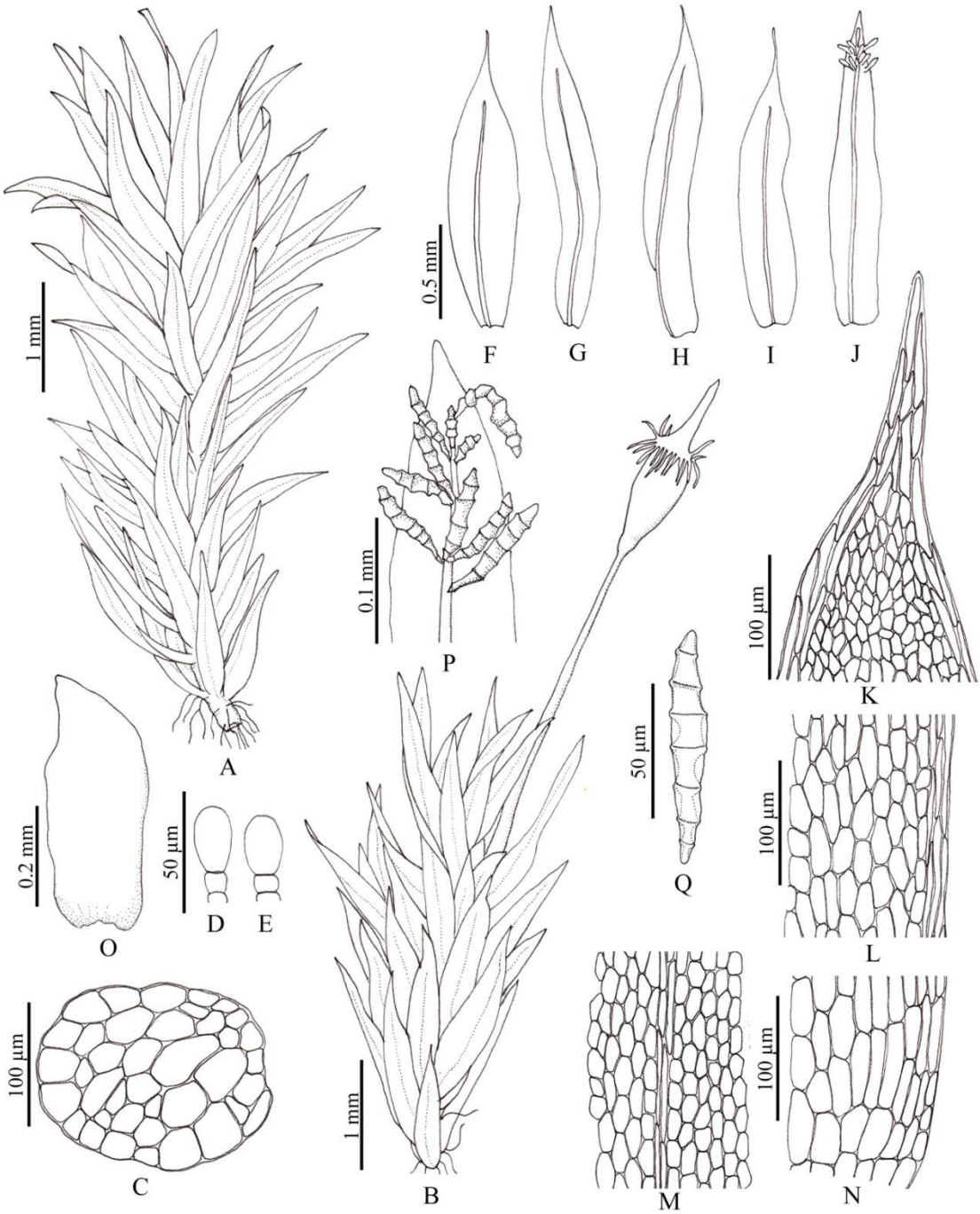

Figure 4.14 *Daltonia apiculata* Mitt. A. Gametophyte. B. Gametophyte with sporophyte. C. Cross section of stem. D–E. Axillary hairs. F–J. Leaves. K. Cells at leaf apex. L. Cells at leaf margin. M. Cells leaf median part of leaf. N. Cells at leaf base. O. Perichaetial leaf. P. Leaf apex with gemmae. Q. Gemma. All from *H. Akiyama 120* (HYO).

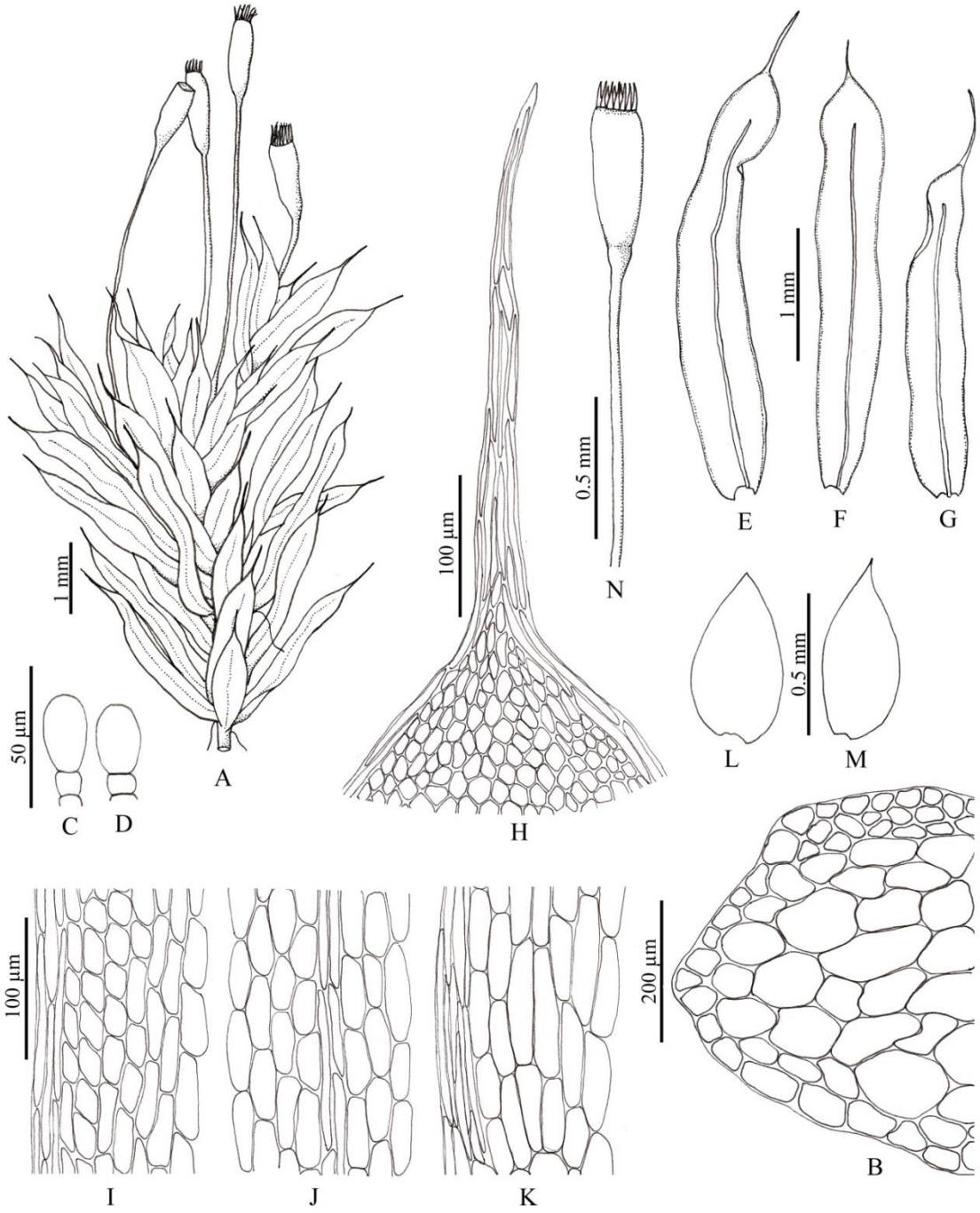

Figure 4.15 *Daltonia aristifolia* Renauld & Cardot. A. Gametophyte with sporophytes. B. Cross section of stem. C–D. Axillary hairs. E–G. Leaves. H. Cells at leaf apex. I. Cells at leaf margin. J. Cells at median part of leaf. K. Cells at leaf base. L. Perigonial leaf. M. Perichaetial leaf. N. Part of sporophyte. All from *N. Printarakul 3762* (CMUB, O).

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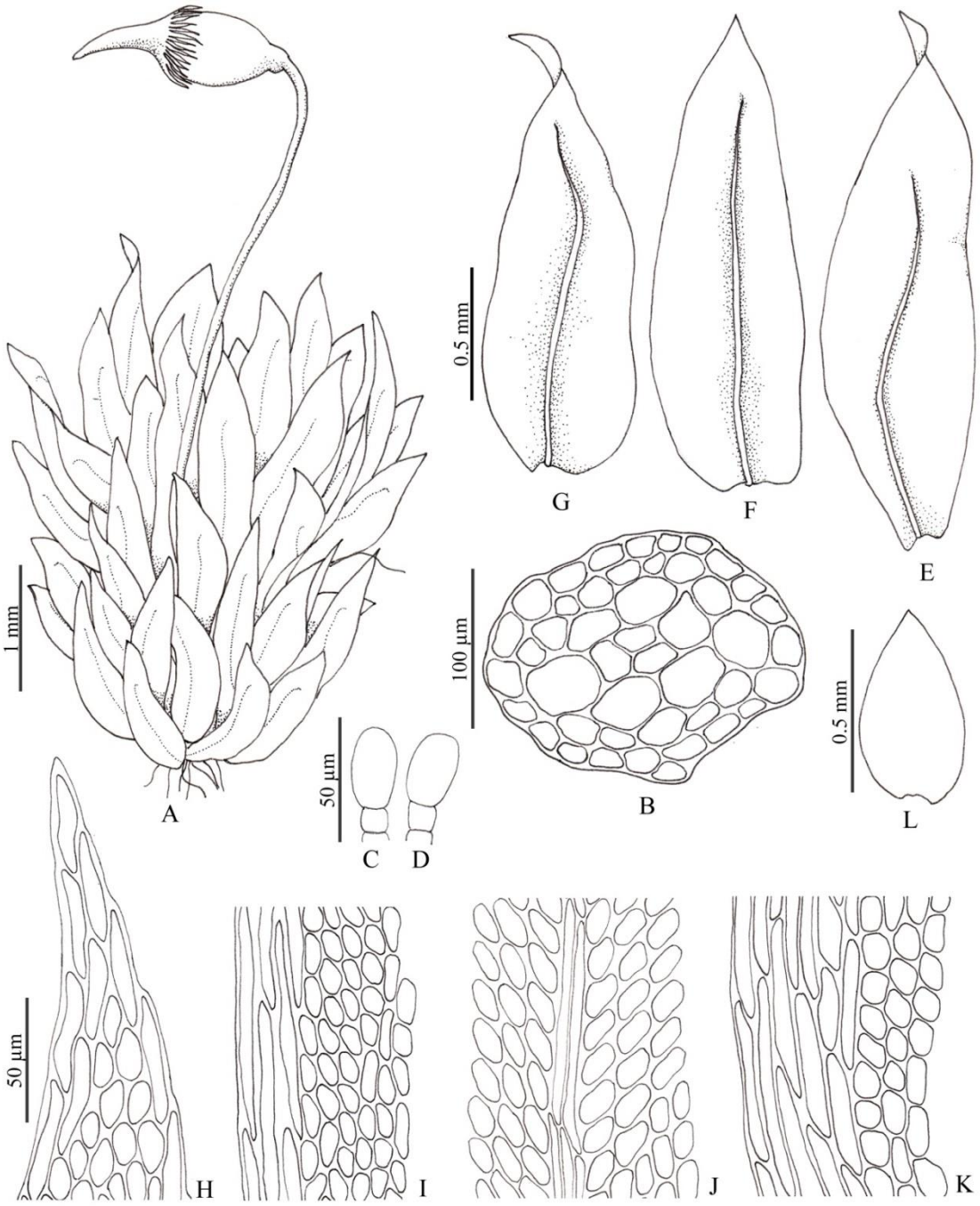

Figure 4.16 *Daltonia semitorta* Mitt. A. Gametophyte with sporophytes. B. Cross section of stem. C–D. Axillary hairs. E–G. Leaves. H. Cells at leaf apex. I. Cells at leaf margin. J. Cells at median part of leaf. K. Cells at leaf base. L. Perichaetial leaf. All from *W. Juengprayoon 629B* (PSU).

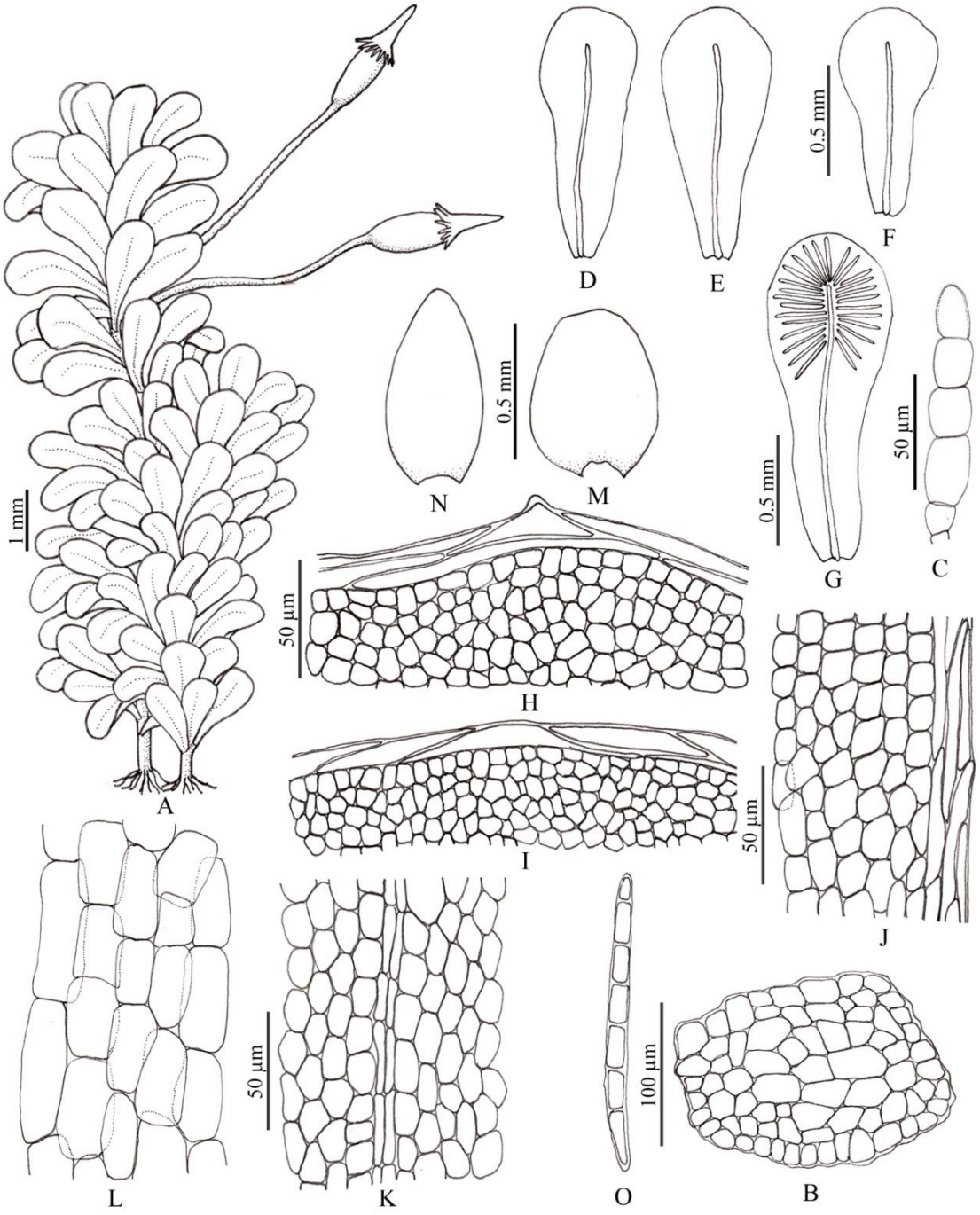

Figure 4.17 *Daltonia waniana* (B.C. Tan & P.J. Lin) B.C. Ho & L. Pokorny. A. Gametophytes with sporophytes, B. Cross section of stem, C. Axillary hair. D–H. Leaves. I. Cells at leaf apex. J. Cells at leaf margin. K. Cells at median part of leaf. L. Cells at leaf base. M. Perigonial leaf. N. Perichaetial leaf. O. Gemma. All from *W. Juengprayoon 628C* (PSU).

Distichophyllum

Dozy & Molk., Musc. Frond. Ined. Archip. Ind. 99. 1846. Type: *Distichophyllum spathulatum* (Dozy & Molk.) Dozy & Molk. [≡ *Hookeria spathulata* Dozy & Molk.].

Plants usually epiphytic or terrestrial, dark green to yellowish green, turning to brownish green or brownish yellow in herbarium specimens, erect, small to large in size, simple or sparingly branched. **Rhizoids** reddish, purple to magenta, dense at base of stem, slightly along ventral surface of stem. **Stems** dark green to reddish brown, in cross section without central strand. **Axillary hairs** filiform, 2–4(–11) cells long, terminal cell mostly as long as intermediate cells. **Leaves** dimorphic or rarely monomorphic, complanate to nearly terete, laxly foliate, flxuose, crisped or concave when dry, usually plane, slightly carinate along costa or erecto-spreading when moist; elliptic, elliptic-oblong, obovate, spathulate, rarely broadly ovate, oblong-lingulate or suborbicular; apices acute, acuminate, apiculate, attenuate, cuspidate, mucronate or round; margins entire, mostly bordered all around with (1–)2–4(–5) rows of linear cells, costa single, weakly or strongly, about (1/2–)2/3–4/5 of leaf length; lamina cells hetero- or homogeneously, small to large size, thin to slightly thick walled.

Dioicous or autoicous (rarely heteroicous). **Perigonial** leaves yellowish green, narrowly ovate to ligulate, acute or bunt, entire. **Perichaetial** leaves yellowish green, narrowly ovate to elliptic, acuminate to bunt, entire. **Sporophyte** lateral. **Seta** slender, greenish yellow, smooth, scabrous, papillose or spinose. **Capsule** ovoid or oblong, horizontal to inclined; exothecial cells, small to medium in size, irregular polygonal, collenchymatous, thin walled with large trigons, operculum long rostrate; outer peristome teeth yellow to yellowish orange, lanceolate, narrowly furrowed, transversely striolate; inner peristome teeth as long as outer peristome, with high basal membrane. **Spores** small to medium in size, slightly papillose. **Calyptra** mitriform, entire or papillose, mostly covering all of the theca, strongly fringed hairs at the base. **Asexual reproduction** by caducous leaves or gemmae.

Distichophyllum is the largest genus of the family Daltoniaceae, consisting of 103 species worldwide and distributed mainly in tropical Asia and America (Frey &

Stech, 2009). The members of the genus are usually grown on humus soil, rocks and tree trunks in lowland to montane forest. There are 13 species and 3 varieties in Thailand.

Key to the species of the genus *Distichophyllum* in Thailand

1. Leaf apices long acuminate to attenuate or cuspidate, the acumen more than 150 µm long .....2.
1. Leaf apices round, obtuse, mucronate, apiculate or acute, the acumen less than 100 µm long .....3.
2. Autoicous. Leaf apices cuspidate. Lamina cells heterogeneous, thick walled. Axillary hairs consisting of 6–11 cells long. .....*D. cuspidatum*
2. Dioicous. Leaf apices long acuminate to attenuate. Lamina cells somewhat homogeneous, rhomboidal to oblong hexagonal, thin walled. Axillary hairs consisting of 2–3 cells.....*D. armatum*
3. Leaf border not well developed at the apex .....4.
3. Leaf border well developed all around .....5.
4. Leaf apex finely denticulate by prominent cell angles. Cells in upper half of leaf heterogeneous. Axillary hairs consisting of 3–4 cells, terminal cell not inflated and as long as intermediate and basal cells. Dioicous .....*D. obtusifolium*
4. Leaf apex entire. Cells in upper half of leaf more or less homogeneous. Axillary hairs consisting of 2–3 cells, terminal cell inflated and longer than intermediate and basal cells. Synoicous.....*D. osterwaldii*
5. Axillary hairs consisting of 2–3 cells, terminal cell inflated. Costa weakly, reaching midleaf.....6.
5. Axillary hairs consisting of 3–4(5) cells, terminal cell not inflated. Costa reaching at least 2/3 of leaf length.....7.
6. Plant small, 1.5–2 mm wide with leaves. Leaves rarely caducous. Lamina cells loose areolation, paracostal cells 28–35 µm wide. .....*D. subnigricaule*

6. Plant larger, 2.8–3 mm wide with leaves. Leaves usually caducous. Lamina cells dense areolation, paracostal cells 15–24 µm wide. .....*D. jungermannioides*
7. Leaves spathulate to obovate. Outer surface of calyptra papillose or slightly spinose. Setae papillose to spinose throughout. .....8.
7. Leaves elliptic, elliptic-oblong, obovate, broadly ovate, or oblong-lingulate. Outer surface of calyptra smooth. Setae smooth to scabrous. .....9.
8. Dioicous. Leaf apex round. Perigonial leaf blunt or round perichaetium leaf acute at the apex. .....*D. spathulatum*
8. Heteroicous. Leaf apex shortly apiculate. Bisexual perichaetium leaf acute at the apex. .....*D. mittenii*
9. Cells in upper one third of leaf heterogeneous; submarginal cells much smaller than the inner ones .....*D. nigricaule*
9. Cells in upper one third of leaf more or less homogeneous; submarginal cells not distinctly smaller than the inner ones.....10.
10. Leaves often carinate along costa near base; lamina cells distinctly collenchymatous. The terminal cell of axillary hair shorter than the intermediate cells .....*D. brevicuspes*
10. Leaves not carinate along costa, lamina cells thin walled or slightly collenchymatous. The terminal cell of axillary hair as long as the intermediate cells. .....11.
11. Leaves less than 2.5 mm long; lamina cells slightly collenchymatous. Seta smooth .....*D. collenchymatosum*
11. Leaves more than 2.5 mm long, lamina cells thin-walled. Seta scabrous to papillose. .....12.
12. Plant rarely branched, laxly foliate, 6–9 mm wide with leaves. Leaf crisped when dry. Median leaf cells 20–24 µm wide. .....*D. tortile*
12. Plant usually branched, forming densely foliate, 4.3–6 mm wide with leaves. Leaf strongly flxuose when dry. Median leaf cells 30–35 µm wide. .....*D. schmidtii*

1. *Distichophyllum armatum* (E.B. Bartram) B.C. Ho & L. Pokorny, Bot. J. Linn. Soc. 170: 172. 2012. Fig. 4.18

≡ *Daltonia armata* E.B. Bartram., Farlowia. 1: 508. figs. 21–24. 1939. Type: PHILIPPINES. Mindanao, Lanao Prov., vicinity of Dansalan (= Marawi), Sacred Mountain, alt. 700–800 m, on culm of climbing bamboo, 3 Nov. 1938, *Zwickey 638*, (holotype: FH; isotype: FH, MICH).

Plants dark green to yellowish green, turning to brownish green in herbarium specimens, medium in size, 0.65–1.2 cm long, 0.3–0.4 cm wide with leaves, rarely branched. **Rhizoids** reddish brown to magenta, dense at base of stem, slightly along ventral surface of stem, except apex. **Stems** dark green to brown, in cross section 8–12 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells larger in size and thin-walled. **Axillary hairs** filiform, consisting of 2–3 cells long; terminal cell inflated, 25–32 µm long; basal and intermediate cells smaller, ca. 12–18 µm long**. Leaves** nearly terete, slightly recured to flexuose when dry, erecto-spreading, strongly carinate at base when moist; lateral leaves narrowly elliptic to oblanceolate, 2.5–4.3 mm long, 0.7–1.2 mm wide; apex long acuminate to attenuate, acumen 320–400 µm long; margins entire; border weakly defined, consisting of 1–2 rows of linear cells; costa weakly, about 3/5–2/3 of leaf length; dorsal and ventral leaves similar to lateral leaves, narrowly elliptic to oblanceolate, 2.5–4.3 mm long, 0.7–1.2 mm wide. Lamina cells somewhat homogeneous, thin walled, rhomboidal to oblong hexagonal; cells in upper half of leaf 80–97 × 20–25 µm; cells in lower half longer, 102–130 × 23–27 µm.

Dioicous. Perigonial leaves not seen. **Perichaetial** leaves yellowish green, narrowly ovate, 0.4–0.45 mm long, 0.1–0.12 mm wide, acute to acuminate, entire. **Seta** slender, 6.2–7.1 mm long, reddish brown, smooth below, slightly scabrous above. **Capsule** oblong, erect, about 2–2.5 mm long; operculum long rostrate, ca. 0.7 mm long; outer peristome teeth yellowish orange, lanceolate, papillose; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra**

mitriform, ca. 1 mm, fringed hairs at the base. **Asexual reproduction** by gemma; gemma light green, filiform, 320–345 µm long, occurring on adaxial surface of leaf bases.

Habitat and ecology: This species usually grow on bamboo nodes, in lower montane forest, at altitude about 1000 m.

Distribution: Indonesia (Ceram, Sumatra), Malaysia (Pahang, Sabah), Philippines (Mindanao), and Thailand (Nakhon Si Thammarat) (Tan & Robinson, 1990; Ho *et al*., 2010).

Specimens examined: **Nakhon Si Thammarat**, Ron Phibun, Khao Ramrome, 945 m, 07°00'28.51"N, 100°29'58.08"E, 28 Feb. 2015, *W. Juengprayoon 205* (PSU), 28 May 2015, *W. Juengprayoon 221* (PSU), 10 Apr. 2016, *W. Juengprayoon 747* (PSU).

Additional descriptions: Tan & Robinson (1990: 13 as *Daltonia armata*), Mohamed & Robinson (1991: 13 as *Daltonia armata*), Ho *et al.* (2010: 107 as *Daltonia armata*).

Additional illustrations: Tan & Robinson (1990: 12, figs. 11–14 as *Daltonia armata*), Mohamed & Robinson (1991: 16, figs. 37–42 as *Daltonia armata*), Ho *et al.* (2010: 108, fig. 1 as *Daltonia armata*).

Taxonomic notes: *Distichophyllum armata* was first described as *Daltonia armata* E.B. Bartram based on collection from Mindanao, Philippines (Bartram, 1944). Recently, Ho *et al.* (2012) transferred it to the genus *Distichophyllum*. The distinctive characters of *Distichophyllum armata* are 1) nearly terete plants with monomorphic leaves, 2) leaves somewhat carinate at base, 3) long acuminate to attenuate leaf apex, 4) leaf boarders and costa weakly defined, 5) rhomboidal to long hexagonal leaf cells, and 6) axillary hairs consisting of 2–3 short cells.

2. *Distichophyllum brevicuspes* M. Fleisch., Musci Buitenzorg 3: 979. 1908.

Fig. 4.19

Type: INDONESIA. West Java, am Poentjak Pass steril, 1350 m, *Fleischer s.n.* (lectotype: FH) designated by Tan & Robinson (1990); West Java, bei Tjibodas, 1450 m, *Fleischer s.n.* (syntype: FH).

Plants green to yellowish green, turning to greenish yellowish in herbarium specimens, small in size, 0.5–0.98 cm long, 0.2–0.25 cm wide with leaves, rarely branched. **Rhizoids** reddish brown, dense at base of stem, slightly along ventral surface of stem, except apex. **Stems** usually greenish brown, in cross section 5–7 cells across; epidermal cells about 1 layer, slightly thick walled; cortex cells larger in size and thin walled. **Axillary hairs** filiform, consisting of ca. 5 cells long; terminal cell not inflated, 10–18 µm long; basal and intermediate cells 10–45 µm long. **Leaves** criped and flexuosed when dry, plane and somwhat carinate at base when moist; lateral leaves small to medium, elliptic-oblong, 0.8–1.2 mm long, 0.6–0.78 mm wide; apices acute to cuspidate, acumen 50–65 µm long; margins entire, border consisting of 1–2 rows of linear at the apex, 2–3 rows of cells below; costa distinct about 3/5(–2/3) of leaf length; dorsal and ventral leaves smaller or similar to lateral leaves, elliptic to ovate, 0.5–1.1 mm long, 0.5–0.6 mm wide, apices acute to cuspidate, margins entire. Lamina cells heterogeneous; apical cells thick walled, hexagonal to polygonal, 18–23 × 16–20 µm; paracostal cells thick walled, hexagonal, 20–30 × 18–22 µm; submarginal cells slightly thick walled, hexagonal to polygonal, 18–25 × 16–20 µm; basal cells thin walled, broadly hexagonal, 48–58 × 25–30 µm, bigger than other area.

Dioicous. Perigonial leaves yellowish green, narrowly ovate to oblong, 0.4–0.5 mm long, 100–120 mm wide, acute to acuminate, entire. **Perichaetial** leaves, similar to perigonial leaves. **Sporophytes** not seen. **Asexual reproduction** by gemma; gemma yellowish green, filiform, 102–130 µm long, present on adaxial surface of leaves base.

Habitat and ecology: This species is usually grown on tree trunks, in lower montane forest, at altitude between 1300 and 1400 m.

Distribution: Indonesia (Java, Kalimantan, Sumatra), Malaysia (Pahang, Sabah), Philippines (Luzon), Thailand (Nakhon Si Thammarat) (Ho *et al.*, 2010).

Specimens examined: **Nakhon Si Thammarat**, Khao Luang National Park, Phamee Mt., 1400 m, 1 May 2009, *S. Chantanaorrapint KL7/4a* (PSU), Promlok, 1326 m, 08°32'51.01"N, 099°44'15.44"E, 26 Jun. 2015. *W. Juengprayoon 420B, 421, 437, 443A* (PSU).

Additional descriptions: Fleischer (1908: 979), Tan & Robinson (1990: 17), Mohamed & Robinson (1991: 19), Ho *et al.* (2010: 109).

Additional illustrations: Tan & Robinson (1990: 14, figs. 17–18).

Taxonomic notes: *Distichophyllum brevicuspes* is characterized by 1) a somewhat carinate leaf base, 2) its rather homogenous upper leaf cells, and 3) filiform axillary hairs consisting of 5 cells long. The species is similar to *D. subcarinatum* Nog. & Z. Iwats. in general apperence. Tan and Robinson (1990) suggested that the later might be conspecific with the former. Later, Akiyama and Yamaguchi (1999), however, reduced *D. subcarinatum* as a synonym of *D. subcuspidatum* Nog. & Z.Iwats. Ho *et al.* (2010) also noted that the type specimen of *D. torquatifolium* Dixon is probably conspecific with *D. subcuspidatum*. However, more samples of these four *Distichophyllum* need to be examined for understanding of their status.

3. *Distichophyllum collenchymatosum* Cardot., Bull. Soc. Bot. Genève, sér. 2, 3: 278. 1911. Fig. 4.20

Type: JAPAN. Yakushima, *Faurie 1156* in part (holotype: PC).

= *Distichophyllum cavaleriei* Thér., Monde Pl. ser. 2, 9: 22. 1907. Type: CHINA. Guizhou, Tong Tcheou, 1904, *Cavalerie s.n.* (lectotype: PC) designated by Lin & Tan (1995); *ibid*, Pin-fa, 1909, *Cavalerie s.n.* (syntype: PC).

= *Distichophyllum sinense* Dixon, Hong Kong Natural. Suppl. 2: 22. 1933. Type: CHINA. Guangdong, White Cloud Mountain, *Herklots 302C* (holotype: BM).

Plants dark green, turning to yellowish green in herbarium specimens, medium in size, 1.6–3.5 cm long, 0.2–0.3 cm wide with leaves, rarely branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** dark green to reddish brown, in cross section 13–15 cells across; epidermal cells 1–2 layers, thin walled; cortex cells larger in size and thick walled. **Axillary hairs** filiform, consisting of 3–4 cells long, terminal cell not inflated, 30–38 µm long; basal and intermediate cells 15–35 µm long. **Leaves** widely spreading, slightly crisped to curved when dry, straight when moist; lateral leaves elliptic to obovate, 2.0–2.3 mm long, 0.6–0.8 mm wide; apices acute to apiculate, acumen 35–48 µm long; margins entire, border consisting of 2–3 rows of linear cells; costa slender, about 2/3 of leaf length; dorsal and ventral leaves smaller or similar to lateral leaves, elliptic to obovate, 0.8–1.2 mm long, 0.5–0.65 mm wide; apices acute, 50–63(–70) µm long, margins entire. Lamina cells heterogeneous; apical cells slightly thick walled, shortly pentagonal, 18–28 × 16–17 µm; paracostal cells thin walled, rectangular, 17–20 × 18–23 µm; submarginal cells thin walled, shortly hexagonal, 18–24 × 18–22 µm; basal cells thin walled, oblong rectangular, 80–110 × 30–46 µm.

Autoicous. Perigonial leaves yellowish green, narrowly ovate to ligulate, 0.8–1.0 mm long, 0.25–0.4 mm wide, acuminate, entire. Antheridia 350–400 µm long. **Perichaetial** leaves, yellowish green, narrowly ovate to elliptic, 0.7–0.9 mm long, 0.20–0.38 mm wide, acuminate, entire. Archegonia 320–520 µm long. **Seta** slender, 4.2–5.0 mm long, greenish yellow, smooth. **Capsule** ovoid, horizontal to inclined, about 0.45 mm long; exothecial cells, small to medium in size, irregular polygonal, 17–23 µm in diameter, collenchymatous, thin walled with large trigons; operculum not seen; outer peristome teeth yellow, lanceolate, narrowly furrowed, transversely

striolate; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** not seen. **Asexual reproduction** not seen.

Habitat and ecology: *Distichophyllum collenchymatosum* was occurred on tree trunks and rocks amongst other bryophytes such as *Callicostella* sp. in lower to upper montane forest, at altitude between 1300 and 2540 m.

Distribution: Bhutan (Geylegphug (= Sarphag)), India (Darjeeling), Indonesia (Java), Nepal (Kangchenjunga), Philippines (Negros), Thailand (Ho *et al.*, 2010).

Specimens examined: **Chiang Mai**, Doi Inthanon National Park, Chomthong, Kew Mae Pan, 2142 m, 18°33'210"N, 98°28'656"E, 10 Feb. 2008, *Y. Nathi 98*, *946* (BCU), 2194 m, 18°33'327"N, 98°28'559"E, 28 Jun. 2008, *Y. Nathi 1040, 1153* (BCU), Angka, 2547 m, 18°35'228"N, 98°29'223"E, 12 May 2008, *Y. Nathi 992* (BCU), 12 May 2008, *Y. Nathi 1154* (BCU), Angka , 2543 m, 18°35'20.10"N, 098°29'05.60"E, 4 Apr. 2014, *W. Juengprayoon 81* (PSU). **Loei**, Phu Ruea, Phu Luang National Park, 1332 m, 17°17'53.41"N, 101°31'21.79"E, 20 Feb. 2016, *W. Juengprayoon 735* (PSU).**Prachuap Khiri Khan**, Huai Yang Waterfall National Park, 1072 m, 11°38'50.91"N, 099°34'57.37"E, 3 Mar. 2016, *S. Chantanaorrapint, W. Juengprayoon & O. Suwanmala 107* (PSU).

Additional descriptions: Cardot (1911: 278), Tan & Robinson (1990: 17), Noguchi (1991: 744), Lin & Tan (1995: 36), Ho *et al.*, (2010: 110).
Additional illustrations: Noguchi (1991: 745, fig. 328), Lin & Tan (1995: 58, fig. 28), Ho *et al.*, (2010: 111, fig. 3).

Taxonomic notes: The distinctive characters of *Distichophyllum collenchymatosum* are 1) leaves elliptic to obovate in outline with acute to apiculate tips, 2) the distinct leaf borders consist of 2–3 rows of linear cells reaching up to leaf apex, and 3) cells in the upper half of hexagonal to round, slightly collenchymatous.

4. *Distichophyllum cuspidatum* (Dozy & Molk.) Dozy & Molk., Musc. Frond. Ined. Archip. Ind. 4: 101. 33. 1846. Fig. 4.21

≡ *Hookeria cuspidata* Dozy & Molk., Ann. Sci. Nat., Bot., sér. 3, 2: 305. 1844. Type: INDONESIA. Java, prope Limbang, Zippelius, *Korthals s.n.* (syntype: NY).

Plants yellowish green, turning to yellow to brownish yellow in herbarium specimens, medium in size, 1.5–3.0 cm long, 0.3–0.45 cm wide with leaves, sparsely branched. **Rhizoids** reddish, purple to magenta, dense at base of stem. **Stems** dark brown, in cross section 12–15 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells larger in size and thin walled. **Axillary hairs** filiform, consisting of 6–11 cells long; terminal cell somewhat inflated, 18–25 µm long; basal and intermediate cells 15–23 µm long. **Leaves** slightly complanate, densely foliate, slightly crisped to twisted when dry, plane and straight when moist; lateral leaf narrowly obovate, 3.2–4.0 mm long, 0.1–1.5 mm wide; apices long cuspidate, acumen 450–600 µm long; border consisting of 2–3(–4) rows of linear cells; costa single, about 2/3–3/4 of leaf length; lateral leaves similar to lateral leaves, narrowly obovate, 3.2–4.0 mm long, 0.1–1.5 mm wide. Lamina cells heterogeneous; apical cells thick walled, collenchymatous, round-hexagonal, 24–30 × 20–28; paracostal cells thin walled, round-hexagonal, 40–45 × 35–38 µm; submargianl cells thin walled, round-hexagonal, 30–45 × 25–33 µm; basal cells thin walled, oblong-hexagonal, 120–150 × 50–64 µm.

Autoicous. Perigonial leaves yellowish green, narrowly ovate, 0.5–0.68 mm long, 0.23–0.3 mm wide, narrowly acuminate, entire. **Perichaetial** leaves similar to perigonial leaves. **Seta** slender, 5–6.3 mm long, greenish yellow, smooth below and slightly scabrous above. **Capsule** ovoid, inclined, about 0.7–1.2 mm long; operculum long rostrate, ca. 0.5 mm long; outer peristome teeth yellowish orange, lanceolate, narrowly furrowed, transversely striolate; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, about 0.7–1 mm long strongly fringed hairs at the base. **Asexual reproduction** not seen.

Habitat and ecology: *Distichophyllum cuspidatum* usually occurs on tree trunks, and branches, in lower montane forest, at altitude between 940 and 1530 m.

Distribution: Indonesia (Java, Sumatra), Japan, Malaysia (Borneo), New Caledonia, Papua New Guinea, Philippines, Sri Lanka, Taiwan, and Thailand (Nakhon Si Thammarat) (Mohamed & Robinson, 1991).

Specimens examined: **Nakhon Si Thammarat**, Khao Nan National Park, San Yen, 1000 m, 20 Apr. 2007, *S. Chantanaorrapint 1560* (PSU), Khao Luang National Park, Lan Saka, 1308 m, 08°32'51.01"N, 099°44'15.44"E, 21 Apr. 2014, *W. Juengprayoon 116B, 117* (PSU), 1484 m, 22 Apr. 2014, *W. Juengprayoon 129A* (PSU), 1326 m, 08°32'51.01"N, 099°44'15.44"E, 26 Jun. 2015, *W. Juengprayoon 384, 385, 389, 395, 405, 409, 410, 416, 420A, 422* (PSU), Ron Phibun, Khao Ramrome, 945 m, 07°00'28.51"N, 100°29'58.08"E, 28 Feb. 2015, *W. Juengprayoon 203, 204, 209, 210, 211, 215,216, 217, 218, 224B* (PSU), 10 Feb. 2016, *W. Juengprayoon 712, 720, 727, 729, 732* (PSU). **Phatthalung**, Pa Bon, Khao Sam Phu, 944 m, 1 Jun. 2016, *S. Chantanaorrapint & O. suwanmala 443* (PSU). **Trang**, Palian, Khao Chedyod, 1116 m, 07°19'18.4"N, 099°54'39.3"E, 21 May 2012, *S. Chantanaorrapint, J. Innuthai & C. Promma 1203A, 1213D, 1215B* (PSU), 1095 m, 07°19'16.43"N, 099°54'33.87"E, 1 May 2014, *W. Juengprayoon 143, 144, 147, 149, 150, 151* (PSU), 1067 m, 07°19'18.56"N, 099°54'40.48"E, 2 May 2014, *W. Juengprayoon 155, 156B, 157, 158A, 160* (PSU).

Additional descriptions: Dozy & Molkenboer (1846: 101), Dozy & Molkenboer (1861: 19), Fleischer (1908: 987), Bartram (1939: 258), Mohamed & Robinson (1991: 19), Lin & Tan (1995: 38), Streimann (1999: 96), Ho *et al.*, (2015: 3).

Additional illustrations: Dozy & Molkenboer (1846: fig. TAB. XXXIII), Fleischer (1908: 988, fig. 169), Mohamed & Robinson (1991: 20, figs. 43–49), Lin & Tan (1995: 56, fig. 26), Streimann (1999: 97, fig. 3).

Taxonomic notes: It is easily separated from the other species of *Distichophyllum* in Thailand by long-cuspidate leaf apices, collenchymatous lamina cells, costa ending just below the apex, and its axillary hairs very long consisting of 6–11 cells. Without sporophytes, *Distichophyllum cuspidatum* might be confused with *Daltonia aristifolia*, which also has a long-cuspidate leaf apex. However, the leaf apex of *Daltonia aristifolia* gradually narrows into the long acumen whilst that of *Distichophyllum cuspidatum* contracts into the long acumen. Lamina cells of *Daltonia aristifolia* are narrowly hexagonal to rectangular, whereas those of *Distichophyllum cuspidatum* are uniformly round-hexagonal. Moreover, their axillary hairs also differ in shape and sized.

5. *Distichophyllum jungermannioides* (Müll. Hal.) Bosch & Sande Lac., Bryol. Jav. 2: 22. 1861. Fig. 4.22

≡ *Mniadelphus jungermannioides* Müll. Hal., Syn. Musc. Frond. 2: 660. 1851. Type: INDONESIA. Java, *Blume s.n.* (holotype: B, destroyed).

= *Distichophyllum nanum* Dozy & Molk. in Zollinger, Syst. Verz. 32. 1854. Type: INDONESIA. Java, Herb. van den Bosch (syntype: P).

= *Distichophyllum ulukahiense* Damanhuri & Mohamed., J. Bryol. 14: 329. f. 2. 1986. Type: MALAYSIA. Pahang, Gunung Ulu Kali, 1750 m, 17 Nov. 1983, *Damanhuri 2645* (holotype: KLU).

Plants light to yellowish green, turning to yellow to brownish yellow in herbarium specimens, medium in size, 0.6–1.2 cm long, 0.28–0.3 cm wide with leaves, usually branched. **Rhizoids** reddish, purple to magenta, dense at base and slightly along ventral surface of stem. **Stems** dark brown, in cross section 6–8 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells larger in size and thin walled. **Axillary hairs** filiform, consisting of 2 cells long; terminal cell inflated, 40–57 µm long; basal stalk shorter, 10–15 µm long. **Leaves** complanate, glossy and

fragile, widely spreading, slightly crisped to concave and easily caducous when dry, plane and slightly carinate along costa when moist; lateral leaves spathulate to obovate, 1.2–1.6 mm long, 0.7–0.9 mm wide; apices short apiculate, (65–)70–90 µm long; margins entire, border consisting of 2–3 rows of linear cells; costa short, 1/3–1/2(–3/5) of leaf length; dorsal and ventral leaves smaller than lateral leaves, shortly obovate or broadly elliptic, 0.65–0.8 mm long, 0.6–0.68 mm wide; apices shortly apiculate, acumen (50–)60–70 µm long; margins entire. Lamina cells heterogeneous; apical cells thin walled, shortly hexagonal, 8–20 × 7.2–15 µm; paracostal cells thin walled, hexagonal, 25–40 × 15–24 µm; submarginal cells similar to paracostal cells, thin walled, hexagonal, 8–35 × 7.5–20 µm; basal cells thin walled, oblong-hexagonal, 25–67 × 22–35 µm.

Dioicous. Perigonial leaves not seen. **Perichaetial** leaves yellowish green, narrowly ovate to lanceolate, 0.4–0.52 mm long, about 0.15 mm wide, narrowly acuminate, entire. **Sporophytes** not seen. **Asexual reproduction** by caducous leaves and gemmae; gemmae yellowish green, filiform, 60–80 µm long, present on leaf base or leaf axial.

Habitat and ecology: In Thailand, *Distichophyllum jungermannioides* mostly grow on tree trunks and branches. This species usually found in lower montane forest ranging from 940 to 1500 m elevation.

Distribution: Indonesia (Ceram, Java, Sumbawa), Malaysia (Malay Peninsula, Sabah, Sarawak), Papua New Guinea, Taiwan, and Thailand (Mohamed & Robinson, 1991; Ho *et al.*, 2010).

Specimens examined: **Nakhon Si Thammarat**, Khao Nan National Park, San Yen, 1000–1300 m, 19 Apr. 2007, *S. Chantanaorrapint 1486* (PSU), Khao Luang, Pharmee Mt., 1400 m, 30 Apr. 2009, *S. Chantanaorrapint KL6/9a* (PSU), 1296–1703 m, 08°32'23.30"N, 099°44'12.19"E, 18 Mar. 2013, *S. Chantanaorrapint & C. promma 2292* (PSU), 19 Mar. 2013, *S. Chantanaorrapint & C. promma 2401* (PSU), 1537 m,

08°32'23.30"N, 099°44'12.19"E, 22 Apr. 2014, *W. Juengprayoon, 123A, 125, 127B* (PSU), Promlok, 1326 m, 08°32'51.01"N, 099°44'15.44"E, 26 Jun. 2015, *W. Juengprayoon 386, 387, 394* (PSU), Khao Ramrome, Ron Phibun, 945 m, 07°00'28.51"N, 100°29'58.08"E, 28 Feb. 2015, *W. Juengprayoon 207, 208, 224A* (PSU), 10 Feb. 2016, *W. Juengprayoon 721* (PSU). **Phatthalung**, Ta Mode, Khao Sam Phu, 944 m, 1 Jul. 2016, *S. Chantanaorrapint & O. suwanmala 440B, 437, 449, 495* (PSU). **Trang**, Khao Chedyod, Palian, 1110 m, 07°19'18.4"N, 099°54'39.3"E, 21 May 2012, *S. Chantanaorrapint, J. Innuthai & C. Promma 1188, 1213C* (PSU), 1067 m, 07°19'18.86"N, 099°54'40.48"E, 2 May 2014, *W. Juengprayoon 154, 156A, 158C* (PSU), 1048 m, 07°19'24.56"N, 099°53'32.11"E, 3 May 2014, *W. Juengprayoon 168, 169* (PSU).

Additional descriptions: Dozy & Molkenboer (1861: 22), Fleischer (1908: 977), Mohamed & Robinson (1991: 22), Ho *et al.* (2010: 113)**.**

Additional illustrations: Fleischer (1908: 978, fig. 168), Mohamed & Robinson (1991: 23, figs. 58–64).

Taxonomic notes: *Distichophyllum jungermannioides* is easily to recognised by 1) having a spathulate or obovate leaf outline with narrow base, 2) short apiculate leaf apex, 3) short costa, and 4) more or less homogenous cells in the upper half of the leaf. *Distichophyllum jungermannioides* somwhat resembles *Distichophyllum brevicupes* in general apperence. However, the later differs from the former in having much smaller leaves which are distinctly carinate along the costa and median cells which are collenchymatous.

6. *Distichophyllum mittenii* Bosch & Sande Lac., Bryol. Jav. 2: 25. 149. 1861.

Fig. 4.23

Type: INDONESIA. Java, sine loco, *Teysman s.n.* (syntype: L); *Holle s.n.* (syntype: L); prope Toegoe, pr. Bogor, *Amann s.n.* (syntype: L).

Plants light to yellowish green, turning to brownish yellow in herbarium specimens, medium in size, 1.8–2.9 cm long, 0.3–0.45 cm wide with leaves, rarely branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** dark green to reddish brown, in cross section 9–13 cells across; epidermal cells 1–2 layers, thin walled; cortex cells larger in size and thick walled. **Axillary hairs** filiform, consisting of 3–4 cells long; terminal cell not inflated, 33–35 µm long; basal and intermediate cells 20–28 µm long. **Leaves** complanate, widely spreading, slightly crisped to wrinkled when dry, plane and straight when moist; lateral leaves medium, narrowly spathulate, 1.8–2.5 mm long, 0.6–0.75 mm wide; apices broadly round to shortly apiculate, less than 16–20 µm long; margins entire, bordered consisting of only 1 row of linear cells at the apex, 1–2 rows of cells below, costa slender, extending about 4/5 of leaf length; dorsal and ventral leaves smaller than lateral ones, broadly obovate, 0.8–1.5 mm long, 0.6–0.7 mm wide; apices shortly apiculate, margins entire. Lamina cells heterogeneous; apical cells slightly thick walled, square to shortly rhomboidal, 12–16 × 8–10 µm; paracostal cells thin walled, hexagonal, 25–32 × 18–23 µm; submarginal cells slightly thick walled, hexagonal, 20–25 × 14–15 µm; basal cells thin walled, oblong hexagonal, 35–46 × 22–30 µm.

Heteroicous. Perigonial leaves yellowish green, narrowly ovate to lanceolate, 0.6–0.9 mm long, 0.1–0.2 mm wide, acute, entire. Antheridia 300–400 µm long. **Bisexual perichaetial** leaves similar to perigonial leaves. Archegonia 310–420 µm long. **Seta** slender, 4.2–6.0 mm long, reddish brown, scabrous to tiny spinose throughout. **Capsule** ovoid, horizontal to inclined, about 0.5 mm long; exothecial cells, small to medium in size, irregular polygonal, 21–25 µm in diameter, collenchymatous, thin walled with large trigons to mamillose; operculum long rostrate, 0.35-0.45 mm; outer peristome teeth orange to reddish, lanceolate, narrowly furrowed, transversely striolate; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, 0.6–0.7 mm, slightly papillose above, strongly fringed hairs at the base. **Asexual reproduction** by gemma; gemma yellowish green, filiform, 120–140 µm long, present on adaxial surface of leaves base.

Habitat and ecology: *Distichophyllum mittenii* mostly occurred on branches, tree trunks and rarely on wet rocks amongst other mosses such as *Fissidens* sp. in lowland evergreen to lower montane forest, at altitude between 60 and 1400 m.

Distribution: Australia (Queenland), Indonesia (Flores, Java, Kalimantan Timur, Papua, Sulawesi, Sumatra), Japan, Sri Lanka, Taiwan, and Thailand (Mohamed & Robinson, 1991; Ho *et al.*, 2010).

Specimens examined: **Mae Hong Son**, Khun Yuam, 550 m, 10° 4'29.01"N, 102°20'36.38"E, 29 Dec. 1965, *A. Touw 11323* (BKF). **Prachuap Khiri Khan**, 1072 m, 11°38'50.91"N, 099°34'57.37"E, 3 Mar. 2016, *S. Chantanaorrapint, W. Juengprayoon & O. Suwanmala* 102B (PSU). **Nakhon Si Thammarat**, Khao Luang National Park, 900–1000 m, 13°31'30.32"N, 099°31'41.25"E, 4 Feb. 1966, *A. Touw 11578* (BKF), 6 Feb. 1966, *A. Touw 11578, 11927, 11958, 11970* (BKF), 1442 m, 08°44'34.50"N, 099°44'11.14"E, 21 Apr. 2014, *W. Juengprayoon 112A* (PSU), 743 m, 08°33'14.22"N, 099°44'50.66"E, 25 Jun. 2015, *W. Juengprayoon 322*, *355*, *356B* (PSU), 1326 m, 08°32'51.01"N, 099°44'15.44"E, 26 Jun. 2015, *W. Juengprayoon 391* (PSU), Ron Phibun, Khao Ramrome, 945 m, 07°00'28.51"N, 100°29'58.08"E, 28 May 2015, *W. Juengprayoon 222* (PSU), 10 Apr. 2016, *W. Juengprayoon 742* (PSU). **Trang**, Palian, Khao Ched Yod, 1116 m, 07°19'18.4"N, 099°54'39.3"E, 21 May 2012, *S. Chantanaorrapint, J. Innuthai & C. Promma 1203B*, *1199* (PSU). **Yala**, Betong, 358 m, 10°4'50.61"N, 097°14'38.80"E, 4 Dec. 2011, *S. Chantanaorrapint & C. promma 582* (PSU). **Narathiwat**, Waeng, Hala-Bala Wildlife Research Station, 69 m, 05°48'04.49"N, 101°46'26.55"E, 1 Jan. 2016, *W. Juengprayoon 692* (PSU).

Additional descriptions: Dozy & Molkenboer (1861: 25), Bartram (1939: 261), Noguchi & Iwatsuki (1972: 475), Tan & Robinson (1990: 19), Mohamed & Robinson (1991: 25), Lin & Tan (1995: 40), Ho *et al.*, (2010: 116).

Additional illustrations: Dozy & Molkenboer (1861: fig. TAB. CXLLX), Mohamed & Robinson (1991: 24, figs. 65–72), Lin & Tan (1995: 61, fig. 31), Ho *et al.*, (2010: 111, fig. 3).

Taxonomic notes: The distinctive features of *Distichophyllum mittenii* are 1) heteroicous (consisting of bisexual perichaetia and male perigonia), 2) leaves more or less spathulate, 3) setae mostly spinose throughout, and 4) calyptra papillose above. *Distichophyllum mittenii* is morphologically close to *D. spathulatum*, which also has a spathulate leaf with thin border consisting of 1(–2) row of cells at apex and a distinct band of smaller laminal cells near the margin in the upper half of the leaves. *Distichophyllum spathulatum*, however, is distinguished from *D. mittenii* by larger in sized, dioicous sexuality, and broadly round leaf apex.

7. *Distichophyllum nigricaule* Mitt. ex Bosch & Sande Lac., Bryol. Jav., 2: 20. 1861.

Distichophyllum nigricaule is one of the common and variable species of this genus in Thailand. Because of its great morphological plasticity, three varieties are recognized in this study.

Key to the varieties of *Distichophyllum nigricaule* in Thailand

1. Leaf apex obtuse or bunt with a shortly mucronate. Lamina cells thin walled throughout..... *D. nigricaule* var. *emeri*
1. Leaf apex acute or apiculate. Upper lamina cells somewhat thick walled.....2
2. Leaves slightly crisped to concave when dry, with a few rows of smaller submarginal cells in the upper 2/3 of leaves. Costa reaching 2/3–3/4 of the leaf length. .....*D. nigricaule* var. *nigricaule*
2. Leaves usually strongly crisped to flexuous when dry, with several rows of smaller submarginal cells in the upper 2/3 of leaves. Costa usually reaching more than 4/5 of the leaf length. .....*D. nigricaule* var. *cirratum*

7a. *Distichophyllum nigricaule* Mitt. ex Bosch & Sande Lac. **var. *nigricaule***

Fig. 4.24

Types: INDONESIA. Java. Pangerango Mt., *Motley s.n*. (lectotype: NY) designated by Tan & Robinson (1990); sine loco, *Teymann s.n*. (syntypes: BO, L).

= *Distichophyllum gracilicaule* M. Fleisch., Musci Fl. Buitenz., 3: 983. 1908. Type: INDONESIA. West Java. Tjibodas. am Gedeh, *Fleischer s.n*. (lectotype: FH) designated by Tan & Robinson (1990); am Poentjak, *Fleischer s.n*. (syntype: FH).

Plants dark green, turning to yellowish green in herbarium specimens. medium in size, 0.5–3.2 cm long, 0.3–0.4 cm wide with leaves, sparingly branched. **Rhizoids** reddish magenta, dense at base of stem. **Stems** dark green to reddish brown, in cross section10–12 cells across; epidermal cells 1(–2) layers, slightly thick walled; cortex cells large in size and thin walled. **Axillary hairs** filiform, consisting 3–4 cells; terminal cell not inflated, 24–30 µm long; basal and intermediate cells ca. 23–28 µm long. **Leaves** complanate, laxly foliate, slightly crisped to flexuous when dry, plane when moist; lateral leaves medium, obovate, 2.1–2.5 mm long, 1.0–1.5 mm wide; apices apiculate, the apiculus 30–40 µm long; margins entire, bordered all around with 2–3 rows of linear cells; costa reaching 2/3–3/4 of leaf length, never percurrent; dorsal and ventral leaves smaller than lateral leaves, broadly elliptic, 1.2–1.4 mm long, 0.5–0.8 mm wide; apices shortly apiculate, margin entire. Lamina cells heterogeneous; apical cells thin walled, quadrate , 20–25 × 18–23 µm; paracostal cells thin walled, hexagonal, 25–50 × 23–40 µm; submarginal cells thin walled, quadrate, 24–28 × 20–25 µm; basal cells thin walled, rectangular, 50–80 × 45–53 µm.

Dioicous. Perigonial leaves not seen. **Perichaetial** leaves, yellowish green, broadly ovate, about 0.5 mm long, 0.3 mm wide, apiculate, entire. **Sporophyte** not seen. **Asexual reproduction** by gemma; gemma yellowish green, filiform, 140–160 µm long, present on adaxial surface of leaves base.

Habitat and ecology: This variety often grow on rocks and humus in lowland to lower montane forest, at altitude between 560 and1480 m.

Distribution: China (Hainan), Indonesia (Bali, Ceram, Java, Sumatra), Japan (Ryukyu), Malaysia, Nepal, Papua New Guinea, Philippines (Batan, Luzon, Palawan), Singapore, Taiwan, Thailand, and Vietnam (Mohamed & Robinson, 1991; Ho *et al.*, 2010).

Specimens examined: **Nakhon Si Thammarat**, Khao Luang National Park, 575 m, 08°33'25.22"N, 099°45'47.00"E, 20 Apr. 2014, *W. Juengprayoon 84B* (PSU), 1403–1484 m, 08°44'34.50"N, 099°44'11.14"E, 21 Apr. 2014, *W. Juengprayoon 109, 114* (PSU), 22 Apr. 2014, *W. Juengprayoon 120B* (PSU), 23 Apr. 2014, *W. Juengprayoon 133A* (PSU), 743–1134 m, 08°33'14.22"N, 099°44'50.66"E, 25 Jun. 2015, *W. Juengprayoon 325, 328, 333, 334, 335, 336, 337A, 338, 340, 343, 344A, 346, 347, 348, 351B, 356A*, (PSU), 1326 m, 08°32'51.01"N, 099°44'15.44"E, 26 Jun. 2015, *W. Juengprayoon 371, 382, 398, 400, 402, 403, 412, 425, 438, 440, 445, 447* (PSU), Ron Phibun, Khao Ramrome, 945 m, 07°00'28.51"N, 100°29'58.08"E, 28 Feb. 2015, *W. Juengprayoon 201, 212, 220* (PSU), 10 Feb. 2016, *W. Juengprayoon 717, 718, 726, 730, 743, 744, 746*, (PSU). **Phatthalung**, Kong Ra, Khao Ched Yod, 618 m, 07°20'42.34"N, 099°55'28.09"E, 28 May 2016, *S. Chantanaorrapint & O. suwanmala 287, 289* (PSU). **Trang**, Palian, Khao Ched Yod, 1095 m, 07°19'16.43"N, 099°54'33.87"E, 1 May 2014, *W. Juengprayoon 141, 142* (PSU). **Songkhla**, Ton Plew water fall, 564 m, 06°59'01.11"N, 100°12'54.35"E, 31 Jan. 2015, *W. Juengprayoon 187, 188* (PSU).

Additional descriptions: Dozy & Molkenboer (1861, 20 as *Distichophyllum nigricaule*), Fleischer (1908: 980 as *Distichophyllum nigricaule*), Bartram (1939: 258 as *Distichophyllum nigricaule*), Tan & Robinson (1990: 20), Mohamed & Robinson (1991: 25 as *Distichophyllum nigricaule*), Ho *et al.*, (2010: 118).

Additional illustrations: Dozy & Molkenboer (1861, fig. TAB. CXLVII as *Distichophyllum nigricaule*), Tan & Robinson (1990: 21, figs. 23–28), Mohamed & Robinson (1991: 21, figs. 50–57 as *Distichophyllum nigricaule*).

Taxonomic notes: This variety is characterized by 1) its leaves slightly crispate when dry, a nearly percurrent costa and homogenous size of the leaf cells in the upper half of the leaf.

7b. *Distichophyllum nigricaule* Mitt. ex Bosch & Sande Lac. **var. *cirratum*** (Renauld & Cardot) M. Fleisch., Musci Buitenzorg 3: 982. 1908. Fig. 4.25

≡ *Distichophyllum cirratum* Renauld & Cardot., Rev. Bryol. 23: 104. 1896. Type: INDONESIA. Java, Tjibodas, *Massart 1397* (isotype: FH).

= *Distichophyllum perundulatum* Dixon, J. Linn. Soc., Bot. 50: 106. 1935. Type: North Borneo, Sarawak, Ulu Koyan, Oxford Exped. *No. 1863* (holotype: BM).

Plants yellowish green, turning to greenish yellow in herbarium specimens, medium in size, 0.3–2.9 cm long, 0.3–0.45 cm wide with leaves, usually branched. **Rhizoids** reddish brown, dense at base of stem. **Stems** dark green to reddish brown, in cross section10–12 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells large in size and thin walled. **Axillary hairs** filiform, consisting 3–4 cells; terminal cell not inflated, 20–25 µm long; basal and intermediate cells ca. 18–25 µm long. **Leaves** complanate, laxly foliate, strongly crisped when dry, plane and slightly concave when moist; lateral leaves medium, elliptic oblong, 2.8–3.5 mm long, 1.3–2.1 mm wide; apices acuminate, acumen 40–80 µm long; margins entire, bordered all around with 2–3(–4) rows of linear cells; costa more than 4/5 of leaf length sometimes percurrent; dorsal and ventral leaves smaller than lateral leaves, elliptic oblong, 1.3–1.7 mm long, 0.8–1.0 mm wide; apices shortly apiculate; margin entire. Lamina cells heterogeneous; apical cells thick walled, square, 24–28 × 15–20 µm; paracostal cells slightly thick walled, pentagonal, 30–35 × 28–30 µm; submarginal cells square, thick walled, 24–30 × 15–22 µm; basal cells thin walled, rectangular, 52–90 × 22–26 µm.

Dioicous. **Perigonial** leaves not seen. **Perichaetial** leaves, light to yellowish green, broadly ovate, 0.6–0.8 mm long, 0.3–0.4 mm wide, apiculate, entire. **Seta** slender, 2.2–2.5 mm long, yellowish to brownish green, entire. **Capsule** oblong, horizontal, about 0.5–0.6 mm long; operculum long rostrate; outer peristome teeth yellowish orange, lanceolate, narrowly furrowed, transversely striolate; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** not seen. **Asexual reproduction** by gemma; gemma yellowish green, filiform, 180–200 µm long, present on adaxial surface of leaves base.

Habitat and ecology: *Distichophyllum nigricaule* var. *cirratum* usually found on soil, in shady area, sometime on rocks amongst other mosses such as *Fissidens* spp. and *Distichophyllum* spp. in lowland to lower montane forest, at altitude between 560 and 1400 m.

Distribution: Indonesia (Ceram, Java, Sumatra), Japan (Ryukyu), Malaysia (Perak, Pahang, Sabah, Sarawak), Nepal, Philippines (Luzon), Taiwan, and Thailand (Mohamed & Robinson, 1991; Ho *et al.*, 2010).

Specimens examined: **Loei**, Phu ruea, Phu Luang wildlife Sanctuary, 1070 m, 17°18'45.6"N, 101°30'32.6"E, 7 Jun. 2015, *M. Poopath 1234* (BKF). **Nakhon Si Thammarat**, Khao Luang National Park, 1703 m, 08°29'35.66"N, 099°44'33.47"E, 18 March 2013, *S. Chantanaorrapint & C. promma 2294* (PSU), 1442 m, 08°44'34.50"N, 099°44'11.14"E, 21 Apr. 2014, *W. Juengprayoon 111*, *112B*, *113*, *114* (PSU), 1403 m, 08°32'10.18"N, 099°45'05.45"E, 23 Apr. 2014, *W. Juengprayoon 131*, *133A* (PSU), 743 m, 08°31'33.28"N, 099°45'23.31"E, 24 May 2015, *W. Juengprayoon 318* (PSU), 1024–1264 m, 08°33'05.95"N, 099°44'35.40"E, 25 Jun. 2015, *W. Juengprayoon 339*, *340*, *351A*, *358*, *365* (PSU), 1326 m, 08°32'51.01"N, 099°44'15.44"E, 26 Jun. 2015, *W. Juengprayoon 393*, *401*, *426*, *435*, *436* (PSU), Ron Phibun, Khao Ramrome, 945 m, 07°00'28.51"N, 100°29'58.08"E, 28 Feb. 2015, *W. Juengprayoon 202*, *205* (PSU). **Trang**, Palian, Khao Ched Yod, 1067–1190 m, 07°19'16.43"N, 099°54'33.87"E, 1 May 2014, *W. Juengprayoon 142* (PSU), 2 May

2014, *W. Juengprayoon* 153 (PSU), 3 May 2014, *W. Juengprayoon 159, 170* (PSU). **Songkhla**, Ton Nga-Chang wildlife Sanctuary, 827 m, 06°57'46.22"N, 100°13'19.18"E, 23 May 2014, *S. Chantanaorrapint & C. Promma 3854* (PSU), Ton Plew Waterfall, 564 m, 06°59'01.11"N, 100°12'54.35"E, 31 Jan. 2015. *W. Juengprayoon 186, 188* (PSU).

Additional descriptions: Fleischer (1908: 982), Tan & Robinson (1990: 20), Mohamed & Robinson (1991: 19 as *Distichophyllum cirratum*), Ho *et al.*, (2010: 118).

Additional illustrations: Bosch & Sande Lacoste (1861: fig. TAB. CXLLX), Tan & Robinson (1990: 21, figs. 23–28), Mohamed & Robinson (1991: 21, figs. 50–57 as *Distichophyllum cirratum*).

Taxonomic notes*:* This variety is very similar to var. *nigricaule*, however it differs by its leaves strongly crisped and contorted when dry and having several rows of distinctly smaller submarginal leaf cells.

7c. *Distichophyllum nigricaule* Mitt. ex Bosch & Sande Lac. **var. *elmeri*** (Broth.) B.C. Tan & H. Rob., Smithsonian Contr. Bot. 75: 22. 1990. Fig. 4.26

≡ *Distichophyllum elmeri* Broth., Leafl. Philipp. Bot. 2: 656. 1909. Type: PHILIPPINES. Luzon. Baguio. Benguet Prov., *Elmer 10453* (holotype: H).

= *Distichophyllum sinuosulum* Dixon, J. Siam Soc., Nat. Hist. Suppl. 10(1): 15. 1935. Type: MALAYSIA. Perak. Binch's Hill. *Burkill 12606* (holotype: BM).

Plants light to yellowish green, turning to greenish yellow in herbarium specimens, medium in size, 0.35–2.0 cm long, 0.32–0.45 cm wide with leaves, sparingly branched. **Rhizoids** reddish brown, dense at base of stem. **Stems** dark green to reddish brown, in cross section 10–12 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells large in size and thin walled. **Axillary hairs** filiform, consisting 3(–4) cells; terminal cell not inflated, 20–30 µm long; basal and

intermediate cells ca. 20–25 µm long. **Leaves** complanate, laxly foliate, crisped to flexuous when dry, plane or slightly curved when moist; lateral leaves medium, broadly elliptic, 1.8–2.1 mm long, 1.1–1.6 mm wide; apices bunt to shortly mucronate, the acumen 5–8 µm long; margins entire, bordered all around with 2–3 rows of linear cells, costa usually reaching2/3–3/4 of leaf length, rarely percurrent; dorsal and ventral leaves smaller than lateral leaves, elliptic-oblong, 1.0–1.3 mm long, 0.6–0.8 mm wide; apices bunt to shortly mucronate; margin entire. Lamina cells heterogeneous, thin walled; apical cells hexagonal, 20–36 × 16–20 µm; paracostal hexagonal, 30–45 × 20–25 µm; submarginal cells hexagonal, 20–43 × 18–21 µm; and basal cells rectangular to oblong-hexagonal, 80–105 × 42–50 µm.

Dioicous. **Perigonial** leaves, yellowish green, broadly ovate, about 0.8–1 mm long, 0.3–0.38 mm wide, acute, entire. **Perichaetial** leaves, yellowish green, narrowly ovate, about 0.8–1.2 mm long, 0.2–0.25 mm wide, acute to acuminate, entire. **Sporophyte** not seen. **Asexual reproduction** by gemma; gemma light green, filiform, 250–350 µm long, occurring on adaxial surface of leaf bases.

Habitat and ecology: *Distichophyllum nigricaule* var. *elmeri* was found on rocks and soil in shady area. This species usually occurs from lowland to lower montane forest ranging from 740 to 1700 m elevation.

Distribution: China, Philippines, Taiwan, Thailand (Tan & Robinson, 1990; Lin & Tan, 1995, Redfearn et al., 1996).

Specimens examined: **Loei**, Phu Kradueng National Park, 1150–1200 m, 16°49'60.00"N, 101°45'0.00"E, 15 Jan. 1966, *A. Touw 11031* (BKF). **Nakhon Si Thammarat**, Khao Luang National Park, 1530–1700 m, 08°30'0.00"N, 099°45'0.00"E, 5 Feb. 1966, *A. Touw 11871* (BKF), 1027 m, 08°29'11.57"N, 099°45'5.14"E, 16 Mar. 2013, *S. Chantanaorrapint & C. Promma 2170* (PSU), 861 m, 08°33'10.12"N, 099°44'41.61"E, 21 Apr. 2014, *W. Juengprayoon 91, 92B, 95, 97, 108C* (PSU), 1484 m, 08°32'31.95"N, 099°44'13.98"E, 22 Apr. 2014, *W.*

Juengprayoon 119 (PSU), 23 Apr. 2014, *W. Juengprayoon 132A* (PSU), 743 m, 08°31'33.28"N, 099°45'23.31"E, 24 Jun. 2015, *W. Juengprayoon 318* (PSU), 1134 m, 08°32'53.40"N, 099°44'16.71"E, 25 Jun. 2015, *W. Juengprayoon 352, 353, 354, 357, 368, 361A* (PSU), 1326 m, 08°32'51.01"N, 099°44'15.44"E, 16 Jun. 2015, *W. Juengprayoon 381, 404, 406, 426* (PSU). **Phatthalung**, Ta Mode, Khao Sam Phu, 411 m, 07°13'14.73"N, 100°01'16.29"E, 30 Jun. 2016, *S. Chantanaorrapint & O. Suwanmala 413* (PSU). **Trang**, Palian, Khao Ched Yod, 1116 m, 07°19'18.4"N, 099°54'39.3"E, 21 May 2012, *S. Chantanaorrapint, J. Inuthai & C. Promma 1277* (PSU), 1048 m, 07°19'24.56"N, 099°53'32.11"E, 2 May 2014, *W. Juengprayoon 167* (PSU).

Additional descriptions: Tan & Robinson (1990: 22), Lin & Tan (1995, 36 as *Distichophyllum cirratum* var. *elmeri*), Tan & He (1966: 211).
Additional illustrations: Tan & Robinson (1990: 21, figs. 23–28).

Taxonomic notes*:* This variety similar to var. *cirratum* in habit, size and leaf shape. The submarginal cells of leaf are also clearly smaller than the paracostal cells. However, var. *elmeri* differs from var. *cirratum* by obtuse leaf apex, having more number of rows of smaller submarginal cells in the upper 2/3 of leaves and its costa rarely reaching the leaf tip.

8. *Distichophyllum obtusifolium* Thér., Monde Pl. 9(45): 22. 1907. Fig. 4.27

Type: JAPAN. Amami-oshima, Naze, Nov. 1899, *Ferrie s.n.* (syntype: PC).

Plants dark to emerald green, turning to yellowish green in herbarium specimens, erect, medium in size, 0.8–1.2 cm long, 0.3–0.34 cm wide with leaves, rarely branched. **Rhizoids** reddish brown, dense at base of stem. **Stems** brownish green, in cross section 10–12 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells larger and thin walled. **Axillary hairs** filiform, consisting of 3–4

cells long; terminal cell not inflated, 26–35 µm long; basal and intermediate cells 20–30 µm long. **Leaves** complanate, loosely foliate, criped when dry, plane when moist; lateral leaves spathulate to narrowly obovate, 1.8–2.0 mm long, 0.8–1.2 mm wide; apices denticulate; margins entire, narrowly bordered only lower half of leaves with 1–2 rows of linear cells; costa distinct, extending about 3/4 of leaf length; dorsal and ventral leaves smaller than lateral leaves, obovate, 1.6–1.75 mm long, 0.5–0.78 mm wide; apices denticulate; margin entire. Lamina cells heterogeneous; apical cells thick walled, shortly pentagonal, 25–30 × 12–20 µm; paracostal cells thin walled, pentagonal, 40–75 × 20–25 µm; submarginal cells thin walled, pentagonal, 38–45 × 17–20 µm; basal cells thin walled, rectangular, 55–91 × 20–28 µm.

Dioicous. **Perigonial** leaves not seen. **Perichaetial** leaves green, narrowly lingulate, 0.75–0.98 mm long, 0.25–0.3 mm wide, round, entire. **Sporophyte** not seen. **Asexual reproduction** by gemma; gemma yellowish green, filiform, present at adaxial surface of leaf base.

Habitat and ecology: In Thailand, *Distichophyllum obtusifolium* was found on rocks in lower montane forest at altitude about 1500 m.

Distribution: China (Hainan), Hong Kong, Japan, Philippine, Taiwan (Tan & Robinson, 1990; Lin & Tan, 1995), **New to Thailand.**

Specimens examined: **Loei**, Phu ruea, Phu Luang wildlife Sanctuary, Pha Chang Phan nature trail, 1517 m, 17°16'48.4"N, 101°31'31.8"E, 6 Jul. 2015, *M. Poopath 1183, 1184A, 1185A, 1186, 1190, 1200, 1201B* (BKF).

Additional descriptions: Tan & Robinson (1990: 22), Noguchi (1991: 746).

Additional illustrations: Ho *et al.* (2010: 112, fig. 4), Noguchi (1991: 749, fig. 329A).

Taxonomic notes: The main characters of *Distichophyllum obtusifolium* include 1) its leaves being obovate to spathulate with denticulate apice and 2) narrow leaf borders, consisting of 1–2 rows of linear cells below, weakly differentiated into one row of short pentagonal cells near the apex. This species may be confused with *Distichiphyllum osterwaldii* because of the similar leaf morphology. However, the latter species is easily separated by a larger plant with entire leaf margins and the lacking of a differentiated border in the leaf apex.

9. *Distichophyllum osterwaldii* M. Fleisch., Musci Buitenzorg 3: 994. 170a–g. 1908. Fig. 4.28

Type: INDONESIA. West-Java, Gedehgebirge bei Tjibodas, 1500 m, Fleischer *s.n.* (syntype: FH).

Plants yellowish green, turning to brownish green in herbarium specimens, erect, medium in size, 1.8–3.2 cm long, 0.3–0.42 cm wide with leaves, rarely branched. **Rhizoids** reddish brown, dense at base of stem. **Stems** dark brown, in cross section 10–14 cells across; epidermal cells 1–2 layers, thick walled; cortex cells larger in size and thin walled. **Axillary hairs** filiform, consisting of 2(–3) cells long; terminal cell somewhat inflated, 23–25 µm long; basal and intermediate cells 10–18 µm long. **Leaves** complanate, laxly foliate, slightly concave or criped when dry, plane when moist; lateral leaves spathulate, 2.1–2.6 mm long, 0.8–1.2 mm wide, apices broadly round, margins entire, bordered only lower half of leaves with 1–2 rows of linear cells; costa distinct, about 2/3–3/4 of leaf length; dorsal and ventral leaves smaller than lateral leaves, obovate, 1.85–2.0 mm long, 0.5–0.9 mm wide; apices round or blunt, margin entire. Lamina cells heterogeneous; apical cells slightly thick walled square, 12–22 × 8–13 µm; paracostal cells thin walled, square, 25–41 × 15–19 µm; submarginal cells thin walled, broadly pentagonal, 28–45 × 18–22 µm; basal cells thin walled, oblong pentagonal, 82–95 × 26–37 µm.

Synoicous. **Bisexual** perichaetial leaves, yellowish green, narrowly ovate, 0.8–1.1 mm long, 0.3–0.5 mm wide. **Seta** slender, 2.5–3.2 mm long, brownish green to dark green, papillose to spinose throughout. **Capsule** ovoid to oblong, erect, about

0.7–1.0 mm long; operculum long rostrate, ca. 0.6 mm long; outer peristome teeth yellowish orange, lanceolate, narrowly furrowed, transversely striolate; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, ca. 1 mm long, slightly spinose or papillose above, strongly fringed hairs at the base. **Asexual reproduction** not seen.

Habitat and ecology: In Thailand, *Distichophyllum osterwaldii* was occurred on rocks. This species was found in lower montane forest at altitude about 1480 m.

Distribution: China, Indonesia (Borneo, Java), Japan, Malaysia, Philippines, and Taiwan (Noguchi & Iwatsuki, 1972; Mohamed & Robinson, 1991), **New to Thailand**.

Specimens examined: **Nakhon Si Thammarat**, Khao Luang National Park, 1480 m, 08°32'31.95"N, 099°44'13.98"E, 22 Apr. 2014, *W. Juengprayoon 120* (PSU).

Additional descriptions: Fleischer (1908: 994), Bartram (1939: 260), Noguchi & Iwatsuki (1972: 475), Tan & Robinson (1990: 23), Mohamed & Robinson (1991: 26), Noguchi (1991: 748), Tan & Lin (1995: 42).

Additional illustrations: Fleischer (1908: 996, fig. 170), Mohamed & Robinson (1991: 27, figs. 73–79), Noguchi (1991: 749, fig. 329B), Tan & Lin (1995: 42, figs. 12–20), Ho *et al.* (2010: 112, fig. 4).

Taxonomic notes: The distinctive features of *Distichophyllum osterwaldii* are robust plant with obovate to spathulate leaves, and undifferentiated border in the leaf apex. This species is morphologically similar to *Distichophyllum denticulatum* Dixon and *Distichophyllum obtusifolium*, however, the latter two species differ in being much smaller in size and in having at least one row of differentiated cells at the apex.

10. *Distichophyllum schmidtii* Broth. Bot. Tidsskr. 24: 122. 1901. Fig. 4.29

Type: THAILAND. Ins. Koh Chang, ad rupos irror in silvos, *J. Schmidt 1900*, (holotype: P).

Plants yellowish green to dark green, turning to yellow to yellowish brown in herbarium specimens, erect, large in size, 2.9–4 cm long, 0.43–0.6 cm wide with leaves, usually branched. **Rhizoids** reddish brown, dense at base of stem. **Stems** dark brown, in cross section 12–16 cells across; epidermal cells 2–3 layers, slightly thick walled; cortex cells larger in size and thin walled. **Axillary hairs** filiform, medium in size, consisting of 3–5 cells long; terminal cell not inflated, 25–27 µm long; intermediate cells as long as terminal one; basal cell short, 10–15 µm long. **Leaves** complanate, densely foliate, somewhat crisped when dry, plane or straight when moist; lateral leaves medium to large, obovate, 4.8–6.0 mm long, 2.0–2.3 mm wide; apices broadly acute, 50–70(–80); margins entire, bordered all around with 2–3(–4) rows of linear cells; costa distinct, extending about 3/4–4/5 of leaf length; dorsal and ventral leaves smaller than lateral leaves, obovate, 2.3–2.8 mm long, 1.6–1.9 mm wide; apices broadly acute, margins entire. Lamina cells heterogeneous; apical cells thin walled, hexagonal, 35–50 ×28–30 µm; paracostal thin walled, hexagonal, 40–50 ×30–35 µm; submarginal cells thin walled, pentagonal, 35–50 ×27–32 µm; basal cells thin walled, rectangular, 70–98 × 35–40 µm, and longer than other area.

Dioicous. Perigonial leaves yellowish green, narrowly ovate, 0.9–1.2 mm long, 0.34–0.4 mm wide, margin entire, apex acuminate. **Perichaetial** leaves light green to yellowish green, lingulate, 0.98–1.3 mm long, 0.32–0.36 mm wide, margin entire, apex acute. Archegonia 85–120 µm long. **Seta** slender, dark green to brownish green, strongly scabrous to papillose. **Capsule** ovoid, inclined, 0.7–1 mm long; exothecial cells large in size, polygonal to round, 36–48 µm in diameter, collenchymatous, thin walled with medium trigones; operculum long rostrate, ca. 0.7 mm long; outer peristome teeth orange to yellowish, lanceolate, narrowly furrowed, transversely striolate; inner peristome teeth as long as outer peristome, with high basal

membrane. **Calyptra** mitriform, ca. 1 mm long, strongly fringed hairs at base. **Asexual repoduction** not seen.

Habitat and ecology: This species is usually occurs on wet rock, soil and tree trunks in lowland to lower montane forest at altitude between 60 to 1600 m.

Distribution: Bangladesh, Malaysia, Singapore, and Thailand (Mohamed & Robinson, 1991).

Specimens examined: **Loei**, Phu Luang wildlife Sanctuary, 1517 m, 17°16'48.4"N, 101°31'31.8"E, 7 Jul. 2015, *M. Poopath 1201B* (BKF). **Prachinburi**, Hnong Pling Waterfall, Khao Yai National Park, 694 m, 14°22'53.20"N, 101°22'49.48"E, 31 May 2015, *W. Juengprayoon 289* (PSU). **Phang Nga**, Takua Pa, Tam Nang waterfall, Si Phang-nga National Park, 80 m, 07°00'25.93"N, 100°29'55.15"E, 8 Oct. 2015, *W. Juengprayoon 587, 589, 590* (PSU), 56–61 m, 08°59'49.28"N, 098°19'16.84"E, 9 Oct. 2015, *W. Juengprayoon 597, 599* (PSU). **Nakhon Si Thammarat**, Khao Nan National Park, San Yen, 600 m, 17 Apr. 2007, *S. Chantanaorrapint 1459* (PSU), 1100 m, 17 Feb. 2009, *S. Chantanaorrapint s.n.* (PSU), 24 Jul. 2010, *S. Chantanaorrapint 2242* (PSU), Khao Luang National Park, 1446-1594 m, 11°5' 1.70"N, 099°13'29.60"E, 18 Mar. 2013, *S. Chantanaorrapint & C. Promma 2233, 2276* (PSU), 799 m, 10°14'36.91"N, 099°36'41.42"E, 19 Mar. 2013, *S. Chantanaorrapint & C. Promma 2425* (PSU), 573–577 m, 20 Apr. 2014, 08°33'25.22"N, 099°45'47.00"E, *W. Juengprayoon 82, 83, 84A* (PSU), 21 Apr. 2014, *W. Juengprayoon 89B* (PSU), 495 m, 08°31'33.28"N, 099°45'23.31"E, 24 Jun. 2015, *W. Juengprayoon, 315A, 316* (PSU), 778 m, 08°33'14.22"N, 099°44'50.66"E, 25 Jun. 2015, *W. Juengprayoon, 329, 342, 345* (PSU), 1326 m, 08°32'51.01"N, 099°44'15.44"E, 26 Jun. 2015, *W. Juengprayoon* 439 (PSU),Ron Phibun, Khao Ramrome, 945 m, 07°00'28.51"N, 100°29'58.08"E, 28 May 2015, *W. Juengprayoon 223* (PSU). **Phatthalung**, Pa Bon, Khao Sam Phu, 552 m, 07°13'13.03"N, 100°00'15.11"E, 2 Jul. 2016, *C. Promma* & *O. Suwanmala* 500 (PSU). **Trang**, Palian, Khao Chedyod, 1116 m, 07°19'18.4"N,

099°54'39.3"E, 21 May 2012, *S. Chantanaorrapint, J. Inuthai & C. Promma 1201* (PSU), 585 m, 07°19'49.60"N, 099°53'45.53"E, 30 Apr. 2014, *W. Juengprayoon 139* (PSU), 1 May 2014, 1098 m, 07°19'16.43"N, 099°54'33.87"E, *W. Juengprayoon 146* (PSU), 347 m, 07°19'45.55"N, 099°52'37.78"E, 3 May 2014, *W. Juengprayoon 175* (PSU). **Satun**, Tarutao Island, Lao Pao waterfall, 200 m, *S. Chantanaorrapint 2080* (PSU). **Songkhla**, Ton Nga Chang Wildlife Sanctuary, 827 m, 06°57'46.22"N, 100°13'19.18"E, 24 May 2014, *S. Chantanaorrapint & C. Promma 3878A*, 15 Jan. 2016, *W. Juengprayoon 711* (PSU), 25 Feb. 2016, *W. Juengprayoon 739* (PSU), 485-488 m, 06°50'44.08"N, 100°18'16.27"E, 4 Oct. 2014, *W. Juengprayoon 184* (PSU), 21 Jul. 2015, *W. Juengprayoon 580*, *581* (PSU), Ton Plew water fall, 564 m, 06°59'01.11"N, 100°12'54.35"E, 31 Feb. 2015, *W. Juengprayoon 185*, *189*, *190*, *191*, *192*, *193* (PSU), Sadao, Pha Dam National Park Protection, 4 Feb. 2014, *S. Chantanaorrapint & C. Promma 3481* (PSU), 306 m, 06°46'02.19"N, 100°12'46.58"E, 1 Mar. 2015, *W. Juengprayoon 226*, *227* (PSU). **Yala**, Betong, Klong Wang Suda, 326 m, 6 Dec. 2011, *J. Wai 2120* (PSU). **Narathiwat**, Waeng, Hala-Bala Wildlife Research Station, 74 m, 07°00'25.77"N, 100°29'54.90"E, 30 Dec. 2015, *W. Juengprayoon 650* (PSU), 69–540 m, 05°48'04.49"N, 101°46'26.55"E, 1 Jan. 2016, *W. Juengprayoon 677*, *678*, *688*, *691* (PSU), 2 Jan. 2016, *W. Juengprayoon 695*, *698* (PSU), 2 Jan. 2016, *W. Juengprayoon 707* (PSU), Sukhirin, 366 m, 05°48'04.48"N, 101°46'24.85"E, 31 Dec. 2015, *W. Juengprayoon 671*, *672* (PSU).

Additional descriptions: Brotherus (1901: 122), Gangulee (1977: 1491), Mohamed & Robinson (1991: 26).

Additional illustrations: Gangulee (1977: 1492, fig. 746), Mohamed & Robinson (1991: 20, fig. 80–86).

Taxonomic notes: *Distichophyllum schmidtii* is widely distributed in Thailand. It is easily recognized by plant is large in size, frequently branched, densly foliate, acute leaf apex, and scabrous seta. This species may be confused with *Distichophyllum tortile* in general appearance, but the latter is distinguished from the former by the

plant bigger in sized, loosely foliate, leaf strongly criped and wavy when dry, and the presence of gemmae on abaxial surface of dorsal leaves.

11. ***Distichophyllum spathulatum*** (Dozy & Molk.) Dozy & Molk., Musc. Frond. Ined. Archip. Ind. 4: 103. 34, 35A. 1846. Fig. 4.30

≡ *Hookeria spathulata* Dozy & Molk. Ann. Sci. Nat., Bot., sér. 3 2: 305. 1844. Type: INDONESIA. West-Java, Buitenzog, Miquel (syntype: NY).

Plants yellowish green, turning to yellow to brownish yellow in herbarium specimens, erect, large in size, 4.5–5.3 cm long, 0.6–0.8 cm wide with leaves, rarely branched,. **Rhizoids** reddish brown, dense at base of stem. **Stems** dark brown, in cross section 14–17 cells across; epidermal cells 1–2 layers, slightly thick walled; cortex cells larger in size and thin walled. **Axillary hairs** filiform, consisting of 4(–5) cells long; terminal cell not inflated, 25–30 µm long; basal and intermediate cells as long as terminal one. **Leaves** complanate, glossy, densely foliate, slightly concave when dry, plane and somewhat carinate along costa when moist; lateral leaves large, spathulate, 3.8–4.9 mm long, 1.2–1.6 mm wide; apex round; margins entire, bordered all around with 2–3 rows of linear cells, only 1 row at the apex; costa distinct, about 3/4 of leaf length; dorsal and ventral leaves smaller than lateral leaves, shortly spathulate, 2.5–3.4 mm long, 1.0–1.3 mm wide; apices round; margin entire. Lamina cells heterogeneous; apical cells thick walled, round-hexagonal, 12–15 × 8–14 µm in diameter; paracostal cells thin walled, oblong hexagonal, 28–52 × 19–23 µm; submarginal cells distincted, slightly thick walled, round-hexagonal, 2–4 rows, 12–14 × 6–12 µm; basal cells thin walled, oblong hexagonal, 86–130 × 28–35 µm.

Dioicous. **Perigonial** leaves yellowish green, narrowly ovate to lingulate, 0.9–1.3 mm long, 0.4–0.5 mm wide; apex round, margin entire. **Perichaetial** leaves green, narrowly ovate, 0.7–1.0 mm long, 0.3–0.4 mm wide, apex acute, margin entire. **Seta** slender, 3.5–6.2 mm long, brownish green to dark green, papillose to spinose throughout. **Capsule** ovoid inclined or horizontal, about 0.6–1.3 mm long; operculum long rostrate, mm 0.7–0.8 mm long; outer peristome teeth yellowish orange,

lanceolate, narrowly furrowed, transversely striolate; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, ca. 0.9 mm long, slightly spinose or papillose above, strongly fringed hairs at the base. **Asexual reproduction** not seen.

Habitat and ecology: *Distichophyllum spathulatum* usually rocks and soil, This species was found from lowland to lower montane forest ranging from 700 to 1440 m elevation.

Distribution: Indonesia (Java, Kalimantan, Sumatra, Sumbawa), Malaysia (Pahang, Perak, Sabah), New Caledonia, Philippines (Camiguin Is.), Society Is. (Tahiti), Taiwan, and Thailand (Mohamed & Robinson, 1991; Ho *et al.*, 2010).

Specimens examined: Prachuap Khiri Khan, 1072 m, 11°38'50.91"N, 099°34'57.37"E, 3 Mar. 2016, *S. Chantanaorrapint, W. Juengprayoon & O. Suwanmala 104B* (PSU). **Nakhon Si Thammarat**, Khao Nan National Park, San Yen, 1000-1300 m, 18 Apr. 2007, *S. Chantanaorrapint 1472, 1570* (PSU), Khao Luang National Park, 1442 m, 08°32'34.50"N, 099°44'11.14"E, 21 Apr. 2014, *W. Juengprayoon 107* (PSU), 1436 m, 08°32'10.18"N, 099°45'05.45"E, 23 Apr. 2014, *W. Juengprayoon 132B, 138A* (PSU), 778 m, 08°33'14.22"N, 099°44'50.66"E, 25 Jun. 2015, *W. Juengprayoon 330* (PSU), Ron Phibun, Khao Ramrome, 945 m, 07°00'28.51"N, 100°29'58.08"E, 28 Feb. 2015, *W. Juengprayoon 206* (PSU), 10 Feb. 2016, *W. Juengprayoon 715* (PSU).

Additional descriptions: Dozy & Molkenboer (1846: 105), Mohamed & Robinson (1991: 29), Ho *et al.*, (2010: 119), Ho *et al.*, (2015: 3).

Additional illustrations: Dozy & Molkenboer (1846, fig. TAB. XXXIV), Mohamed & Robinson (1991: 20, figs. 87–93), Ho *et al.*, (2010: 117, fig. 6).

Taxonomic notes: *Distichophyllum spathulatum* is characterized by plant rather large, dioicous, leaves spathulate, perigonial leaves with blunt or round apex, and setae mostly spinose throughout. *Distichophyllum spathulatum* is very similar to *Distichophyllum mittenii*. For separation from the similar *D. mittenii*, see there.

12. *Distichophyllum subnigricaule* Broth., Philipp. J. Sci. 31: 289. 1926. Fig. 4.31

Type: PHILIPPINES. Mindanao, Zamboanga, *Merrill 8324* (isotypes: BM, FH).

= *Distichophyllum laxirete* Nog. & Z. Iwats., J. Hattori Bot. Lab. 36: 475. f. 4: a–d. 1972. Type: MALAYSIA. Borneo, Sabah, Kinabalu Mt., near Ulu Liwagu, 2500 m, *Mizutani 3604C* (holotype: NICH).

= *Distichophyllum rotundatum* Nog. & Z. Iwats., J. Hattori Bot. Lab. 36: 476. f. 3: g–l. 1972. Type: MALAYSIA. Sabah, Kinabalu Mt., in forest between Hot Spring, Poring and Royal Soc. Bungalow, alt. 600–1100 m, 28 May 1963, *Iwatsuki 1711a* (holotype: NICH).

Plants light to yellowish green, turning to greenish yellow to yellow in herbarium specimens, erect, small in size, 0.5–0.78 cm long, 0.15–0.2 cm wide with leaves, rarely branched. **Rhizoids** reddish brown, dense at base of stem, slightly along ventral surface of stem. **Stems** brownish green, in cross section 5-6 cells across; epidermal cells only 1 layer, slightly thick walled; cortex cells larger in size and thin walled. **Axillary hairs** filiform, 2–3 cells long, terminal cell somewhat inflated, 18–20 µm long; intermediate cells not inflated, 10–15 cells µm long; basal cell smallest, ca. 10 µm long. **Leaves** complanate, laxly foliate, slightly concave when dry, plane when moist; lateral leaves small to medium, suborbicular, 0.9–1.0 mm long, 0.67–0.8 mm wide; apex round or with shortly mucronate, less than 10 µm long; margins entire; border narrow, consisting of 1–2(–3) rows of linear cells; costa distinct, about 1/2–2/3 of leaf length; dorsal and ventral leaves smaller than lateral leaves, suborbicular, 0.68–0.8 mm long, 0.56–0.6 mm wide; apices round or with shortly mucronate, margin entire. Lamina cells heterogeneous; apical thin walled, hexagonal, 18–30 × 14–18 µm; paracostal cells thin walled, hexagonal, 20–25 × 28–30 µm;

submarginal cells thin walled, hexagonal, 18–35 × 15–20 µm; basal cells thin walled, oblong hexagonal, 38–56 × 28–32 µm.

Reproductive organs not seen.

Habitat and ecology: *Distichophyllum subnigricaule* was found on rocks in lowland evergreen forest at altitude about 700 m.

Distribution: China (Hainan, Yunnan), Malaysia (North Borneo), and Philippines (Mohamed & Robinson, 1990), **New to Thailand**.

Specimens examined: **Nakhon Si Thammarat**, Promlok, Khao Luang National Park, 778 m, 08°33'14.22"N, 099°44'50.66"E, 25 Jun. 2015, *W. Juengprayoon 332* (PSU).

Additional descriptions: Bartram (1939: 259), Noguchi & Iwatsuki (1972: 476 as *Distichophyllum rotundatum*), Tan & Robinson (1990: 23).
Additional illustrations: Noguchi & Iwatsuki (1972: 473, fig. 3 as *Distichophyllum rotundatum*).

Taxonomic notes: The distinctive characters of *Distichophyllum subnigricaule* are nearly orbicular to broadly obovate leaves with slightly mucronate at the apex and its very lax leaf cell areolation. This species is similar to *Distichophyllum hattorii* but is distinguished by its more stout plant, leaves apiculate, non-undulate, shortly costate leaves, and very loose areolation.

13. *Distichophyllum tortile* Dozy & Molk. ex Bosch & Sande Lac., Bryol. Jav. 2: 27. 152. 1862. Fig. 4.32

Type: INDONESIA. Banca, sine loco, *Amann s.n.* (syntype: NY).

Plants dark green, turning to greenish brown in herbarium specimens, erect, large in size, 3.5–5.8 cm long, 0.6–0.9 cm wide with leaves, rarely branched. **Rhizoids** reddish brown, dense at base of stem. **Stems** dark brown, in cross section 8–14 cells across; cortical cells 1–2 layers, thick walled; medullary cells larger in size and slightly thin walled. **Axillary hairs** filiform, consisting of 3–4 cells long, terminal cell not inflated, 30–40 µm long; basal and intermediate cells as long as terminal once. **Leaves** complanate, laxly foliate, strongly flexuose when dry, plane or slightly wavy when moist; lateral leaves medium to large, oblong-lingulate, 3.6–4.3 mm long, 2.0–2.4 mm wide; apices broadly acut to apiculate; margins entire, bordered all around with 2–4(–5) rows of linear cells; costa distinct, about 3/4–4/5 of leaf length; dorsal and ventral leaves smaller than lateral leaves, broadly ovate, 1.8–2.5 mm long, 1–2 mm wide; apices broadly acute; margins entire. Lamina cells heterogeneous; cells in upper half of leaf slightly thick walled, shortly rhomboidal to pentagonal, 18–22 ×20–24 µm; cells in lower half of leaf thin walled, oblong hexagonal to rectangular, 30–60 × 25–33 µm.

Dioicous. Perigonial leaves not seen. **Perichaetial** leaves, light green, narrowly lingulate, 0.8–1.2 mm long, 0.20–0.25 mm wide; apex acute; margin entire. Archegonia 210–220 µm long. **Sporophytes** not seen. **Gemmae** yellowish green, filiform, bearing on gemmaphore, attaching at abaxial surface of leaf base and lower half of dorsal leaves.

Habitat and ecology: This species is usually occurs on wet rock along stream in lowland to lower montane forests at altitude between 340 and 1400 m.

Distribution:, India (Banka), Indonesia (Borneo, Java), Philippines (Luzon), and Thailand (Mohamed & Robinson, 1991).

Specimens examined: **Nakhon Si Thammarat**, Khao Nan National Park, Khao Nom, Klong Kan waterfall, 800 m, 1 Mar. 2008, *S. Chantanaorrapint* (PSU), Khao

Luang National Park, 700-800 m, 08°30'0.00"N, 099°45'0.00"E, 7 Feb. 1966, *A. Touw 11979* (BKF), 575 m, 08°33'25.22"N, 099°45'47.00"E, 20 Apr. 2014, *W. Juengprayoon 84A, 85, 86, 87* (PSU), 577–1442 m, 21 Apr. 2014, *W. Juengprayoon 89A, 90, 93, 94, 96, 98, 105, 106* (PSU), Promlok, 743 m, 08°33'14.22"N, 099°44'50.66"E, 25 Jun. 2015, *W. Juengprayoon 321* (PSU), 27 Jun. 2015, *W. Juengprayoon 458, 465, 466, 467, 468* (PSU). **Phatthalung**, Kong Ra, Khao Ched Yod, 618 m, 07°20'42.34"N, 099°55'28.09"E, 28 May 2016, *S. Chantanaorrapint & O. suwanmala 288* (PSU). **Trang**, Palian, Khao Ched Yod, 888 m, 07°19'12.87"N, 099°54'17.67"E, 3 May 2014, *W. Juengprayoon 172, 173, 174, 176* (PSU).

Additional descriptions: Dozy & Molkenboer (1862: 27), Fleischer (1908: 997), Bartram (1939: 261), Tan & Robinson (1990: 24), Mohamed & Robinson (1991: 29), Lin & Tan (1995: 43).

Additional illustrations: Dozy & Molkenboer (1862: fig. TAB. CLII), Fleischer (1908: 996, fig. 170), Tan & Robinson (1990: 24), Mohamed & Robinson (1991: 31, figs. 94–98), Lin & Tan (1995: 64, fig. 34).

Taxonomic notes: *Distichophyllum tortile* is the largest in size among the other species of genus *Distichophyllum* in Thailand. The species is characterized by 1) its large plant size, leaves strongly criped or wavy when dry, oblong to broadly lingulate leaves with acute to apiculate apices, and the lax and thin-walled leaf areolation.

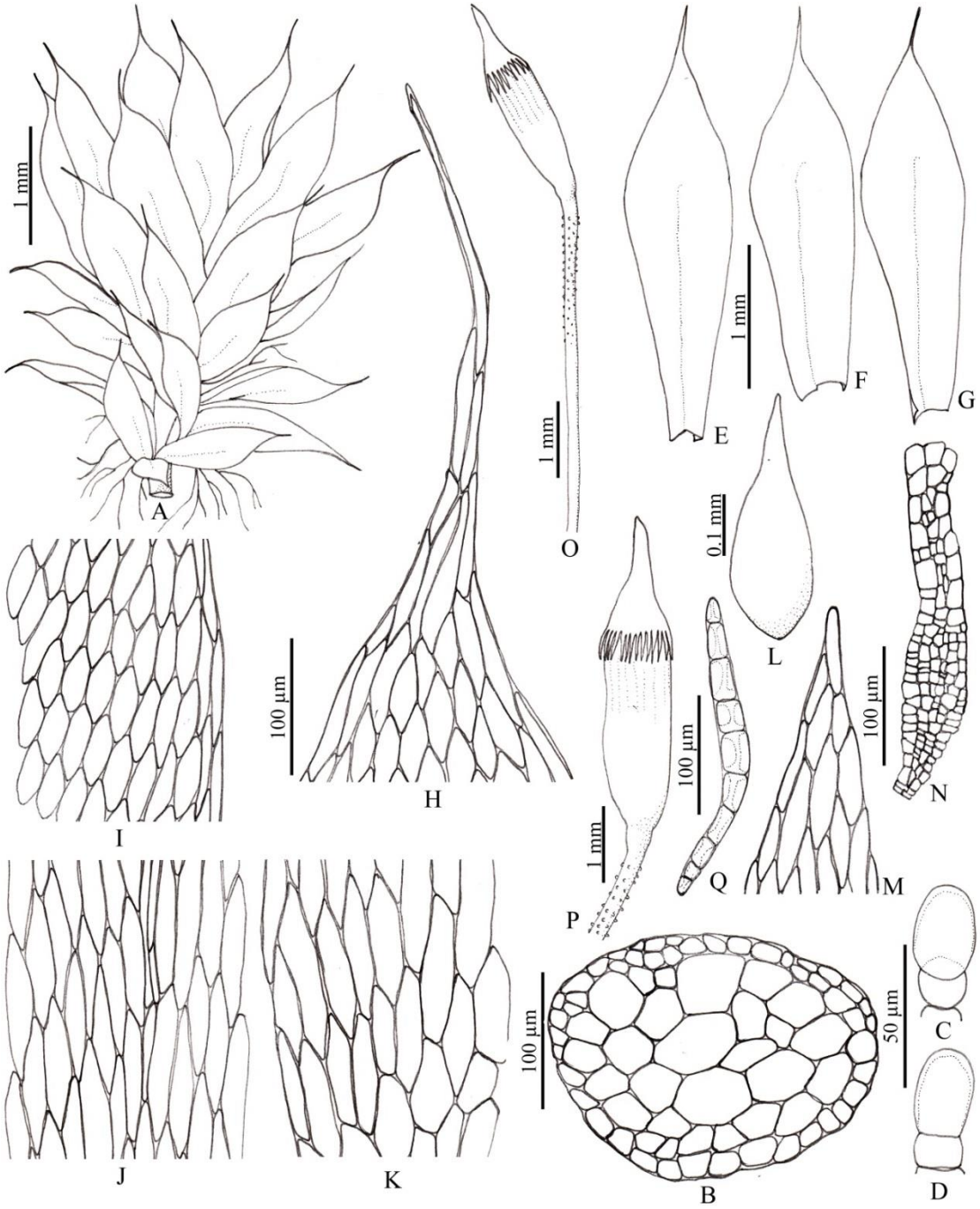

Figure 4.18 *Distichophyllum armatum* (E.B. Bartram) B.C. Ho & L. Pokorny. A. Gametophyte. B. Cross section of stem. C–E. Leaves. F. Cells at leaf apex. G. Cells at leaf margin. H. Cells at median part of leaf. I. Cells at leaf base. J–K. Axillary hairs. L. Perichaetial leaf. M. Apical part of perichaetial. N. Archegonium. O. Upper part of sporophyte. P. Capsule with calyptra, Q. Gemma. All from *W. Juengprayoon 713* (PSU).

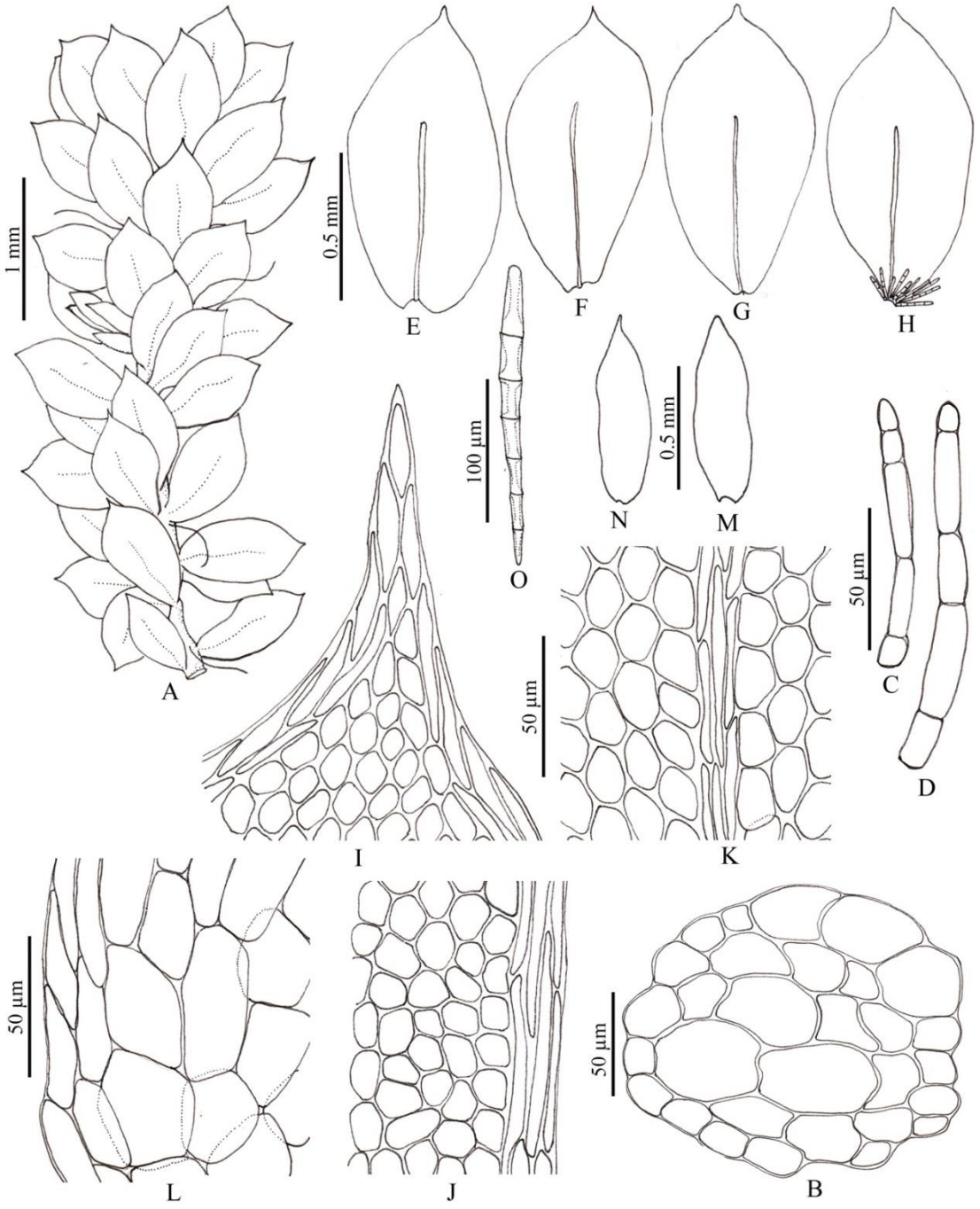

Figure 4.19 *Distichophyllum brevicuspes* M. Fleisch. A. Gametophyte. B. Cross section of stem. C–D. Axillary hairs. E–G. Lateral leaves. H. Dorsal leaf with gemmae. I. Cells at leaf apex. J. Cells at leaf margin. K. Cells at median part of leaf. L. Cells at leaf base. M. Perigonial leaf. N. Perichaetial leaf. O. Gemma. All from *W. Juengprayoon 443* (PSU).

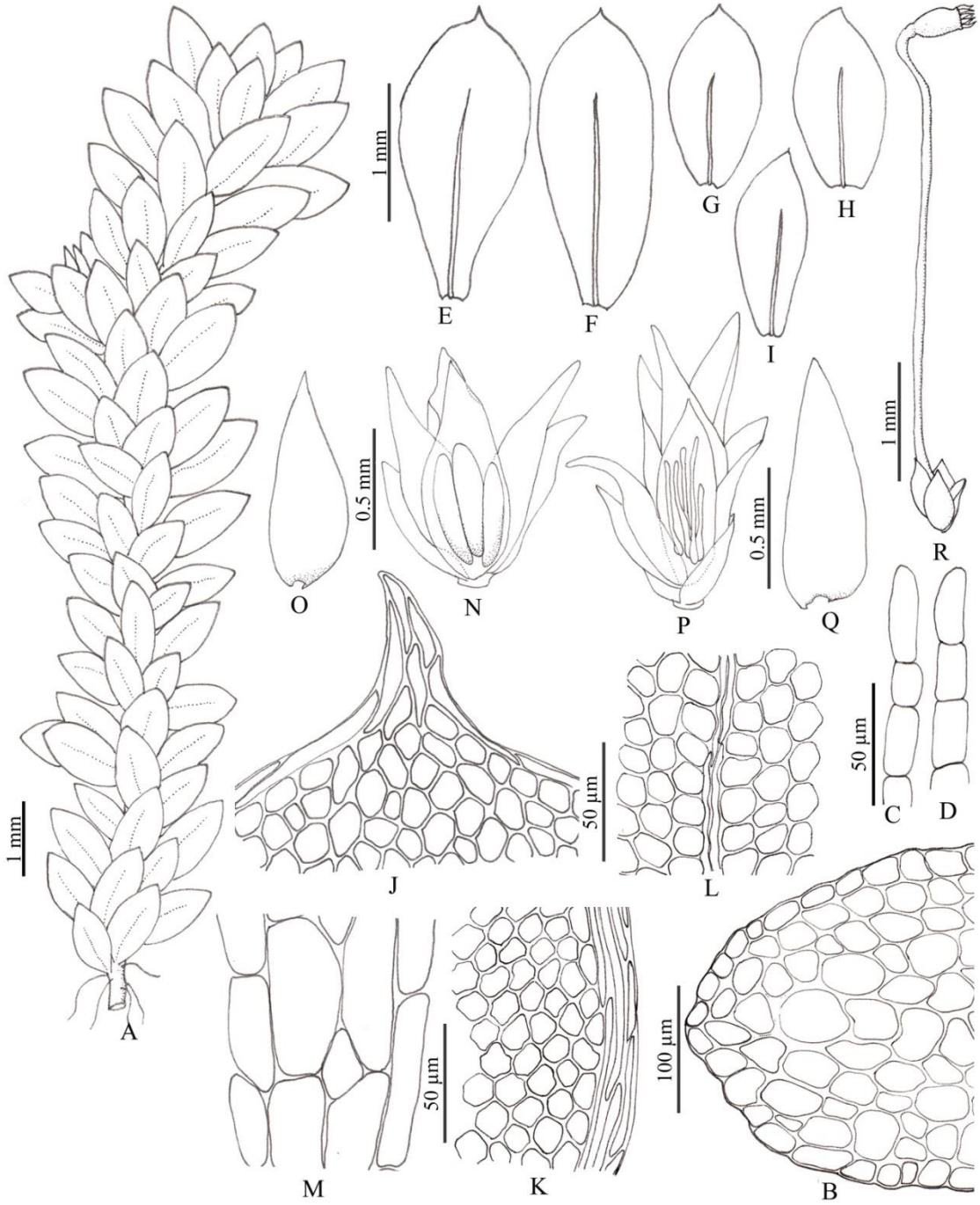

Figure 4.20 *Distichophyllum collenchymatosum* Cardot. A. Gametophyte. B. Cross section of stem, C–D. Axillary hairs. E–F. Lateral leaves. G–H. Dorsal leaves. I. Ventral leaf. J. Cells at leaf apex. K. Cells at leaf margin. L. Cells at median part of leaf. M. Cells at leaf base. N. Perigonium. O. Perigonial leaf. P. Perichaetium. Q. Perichaetial leaf. R. Sporophyte. All from *W. Juengprayoon 735* (PSU).

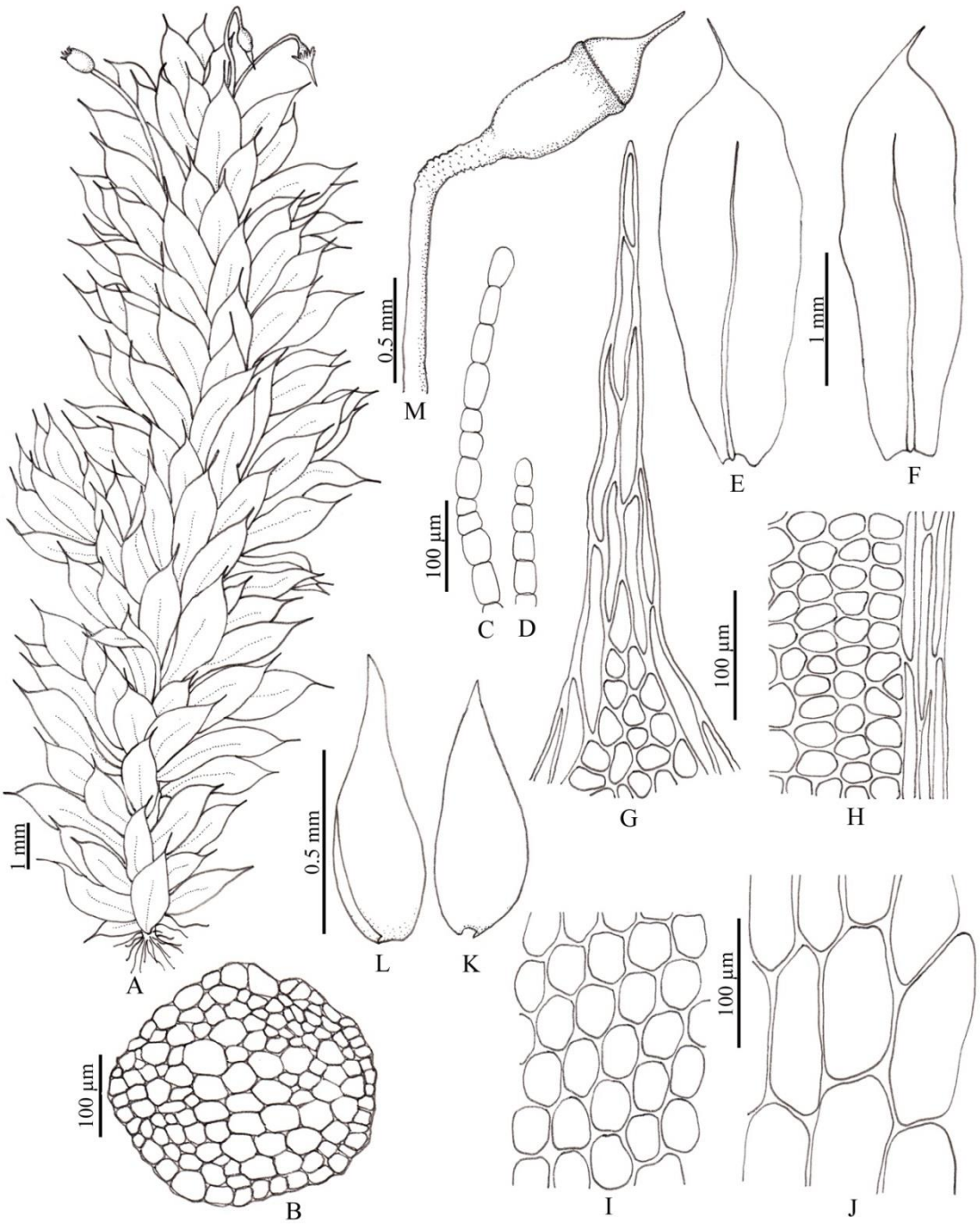

Figure 4.21 *Distichophyllum cuspidatum* (Dozy & Molk.) Dozy & Molk. A. Gametophyte with sporophytes. B. Cross section of stem. C–D. Axillary hairs. E–F. Leaves. G. Cells at leaf apex. H. Cells at leaf margin. I. Cells at median part of leaf. J. Cells at leaf base. K. Perigonial leaf. L. Perichaetial leaf. M. Upper part of sporophyte. All from *W. Juengprayoon 211* (PSU).

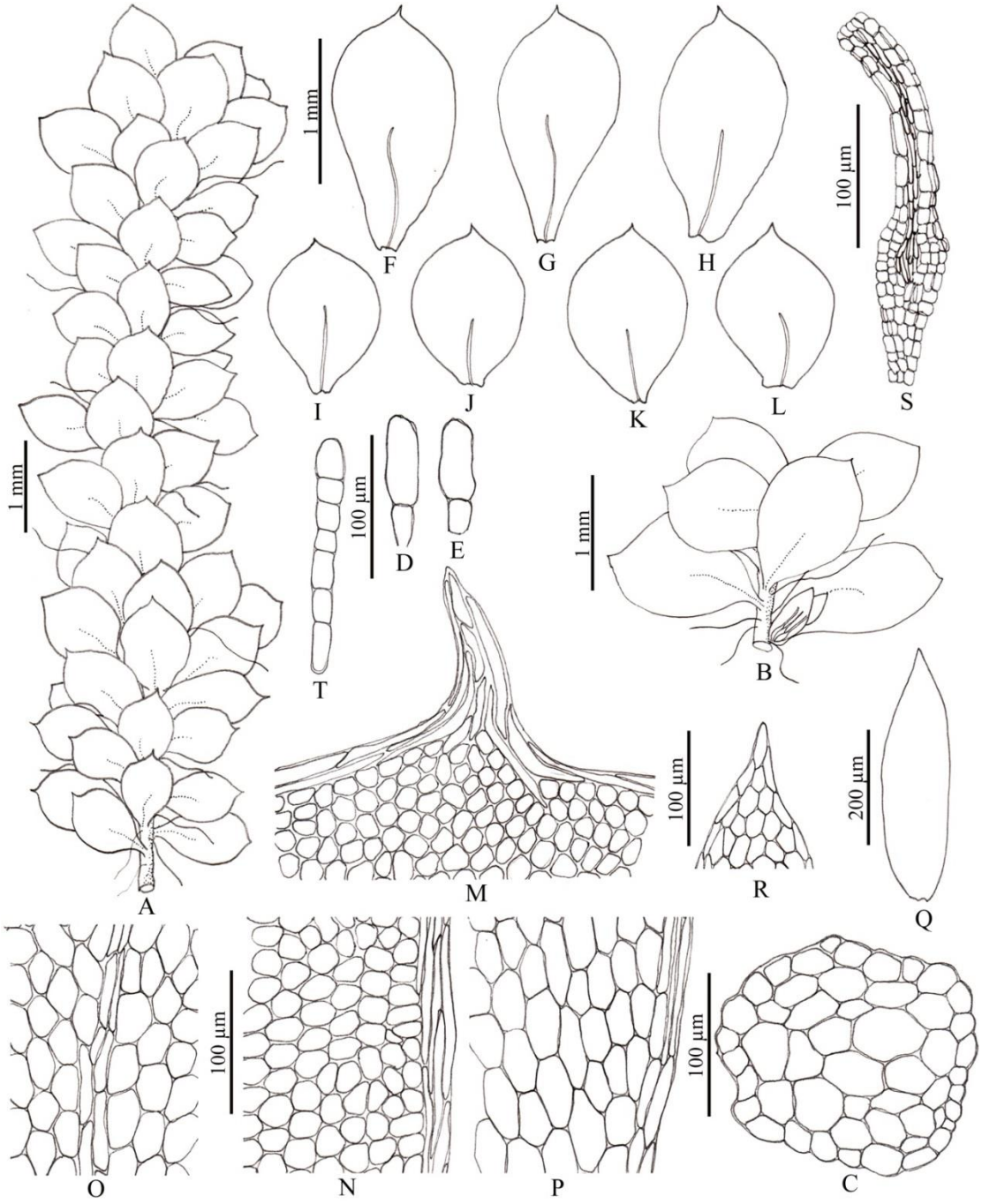

Figure 4.22 *Distichophyllum jungermannioides* (Müll. Hal.) Bosch & Sande Lac. A. Gametophyte. B. Part of gametophyte with perichaetium. C. Cross section of stem. D–E. Axillary hairs. F–H. Lateral leaves. I–J. Dorsal leaves. K–L. Ventral leaves. M. Cells at leaf apex. N. Cells at leaf margin. O. Cells at median part of leaf. P. Cells at leaf base. Q. Perichaetial leaf. R. Apical part of perichaetial leaf. S. Archaegonium. T. Gemma. All from *W. Juengprayoon 721* (PSU).

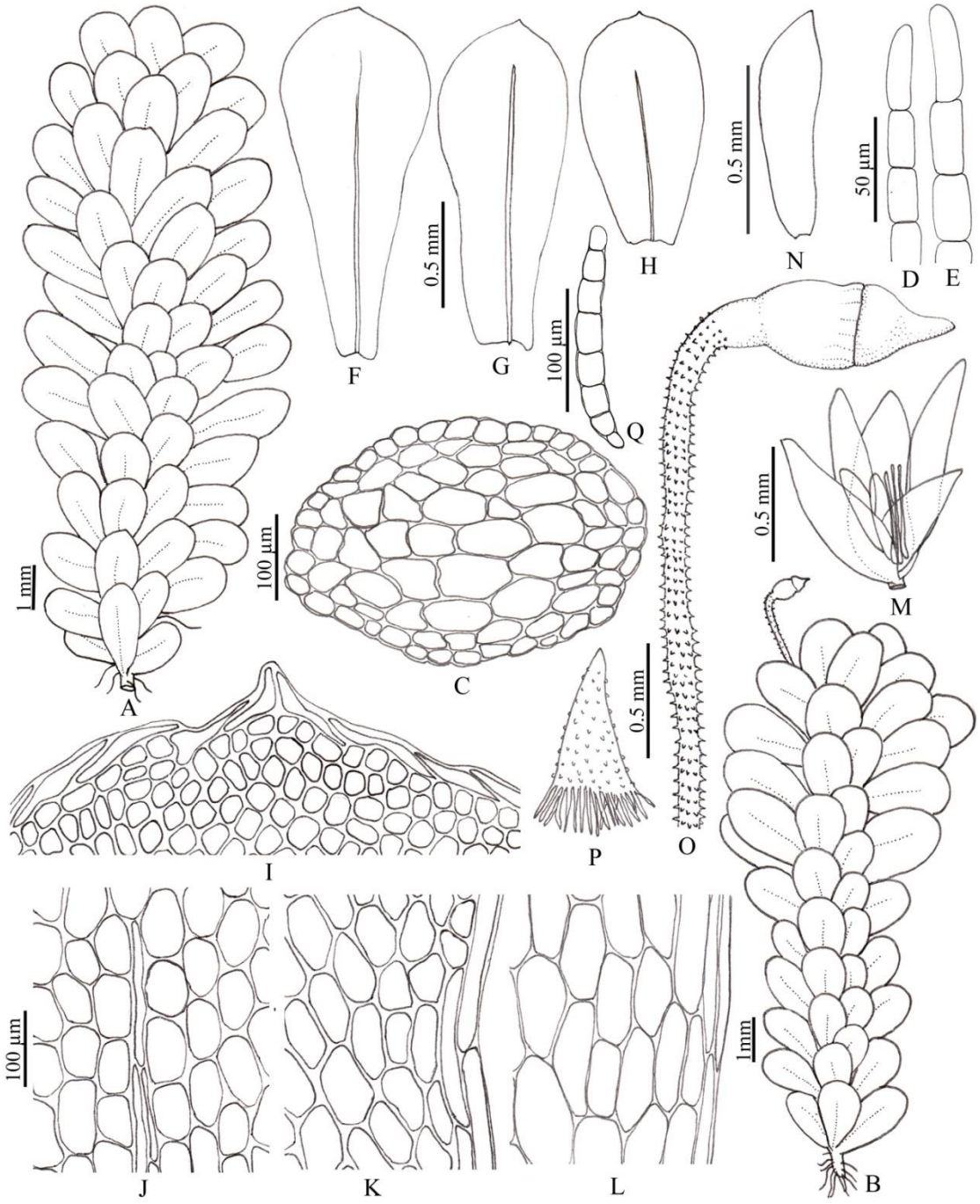

Figure 4.23 *Distichophyllum mittenii* Bosch & Sande Lac. A. Gametophyte. B. Gametophyte with sporophyte. C. Cross section of stem. D–E. Axillary hairs. F–G. Lateral leaves. H. Dorsal leaves. I. Cells at leaf apex. J. Cells at leaf margin. K. Cells at median part of leaf. L. Cells at leaf base. K–L. M. Bisexual perichaetium. N. Bisexual perichaetial leaf. O. Upper part of Sporophyte. P. Calyptra. All from *W. Juengprayoon 692* (PSU).

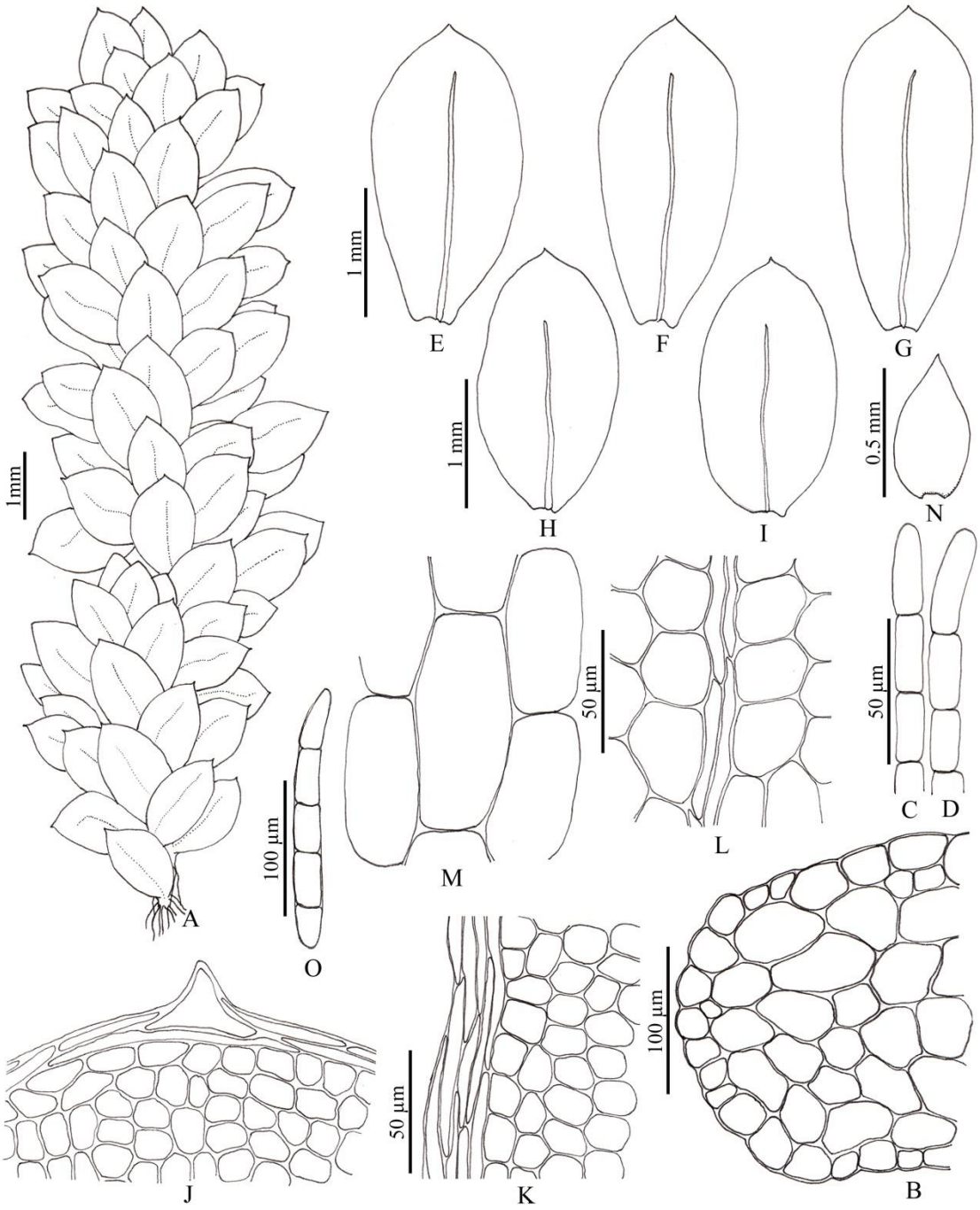

Figure 4.24 *Distichophyllum nigricaule* Mitt. ex Bosch & Sande Lac. var. *nigricaule* A. Gametophyte. B. Cross section of stem. C–D. Axillary hairs. E–G. Lateral leaves. H–I. Dorsal leaf. J. Cells at leaf apex. K. Cells at leaf margin. L. Cells at median part of leaf. M. Cells at leaf base. N. Perichaetial leaf. O. Gemma. All from *W. Juengprayoon 403* (PSU).

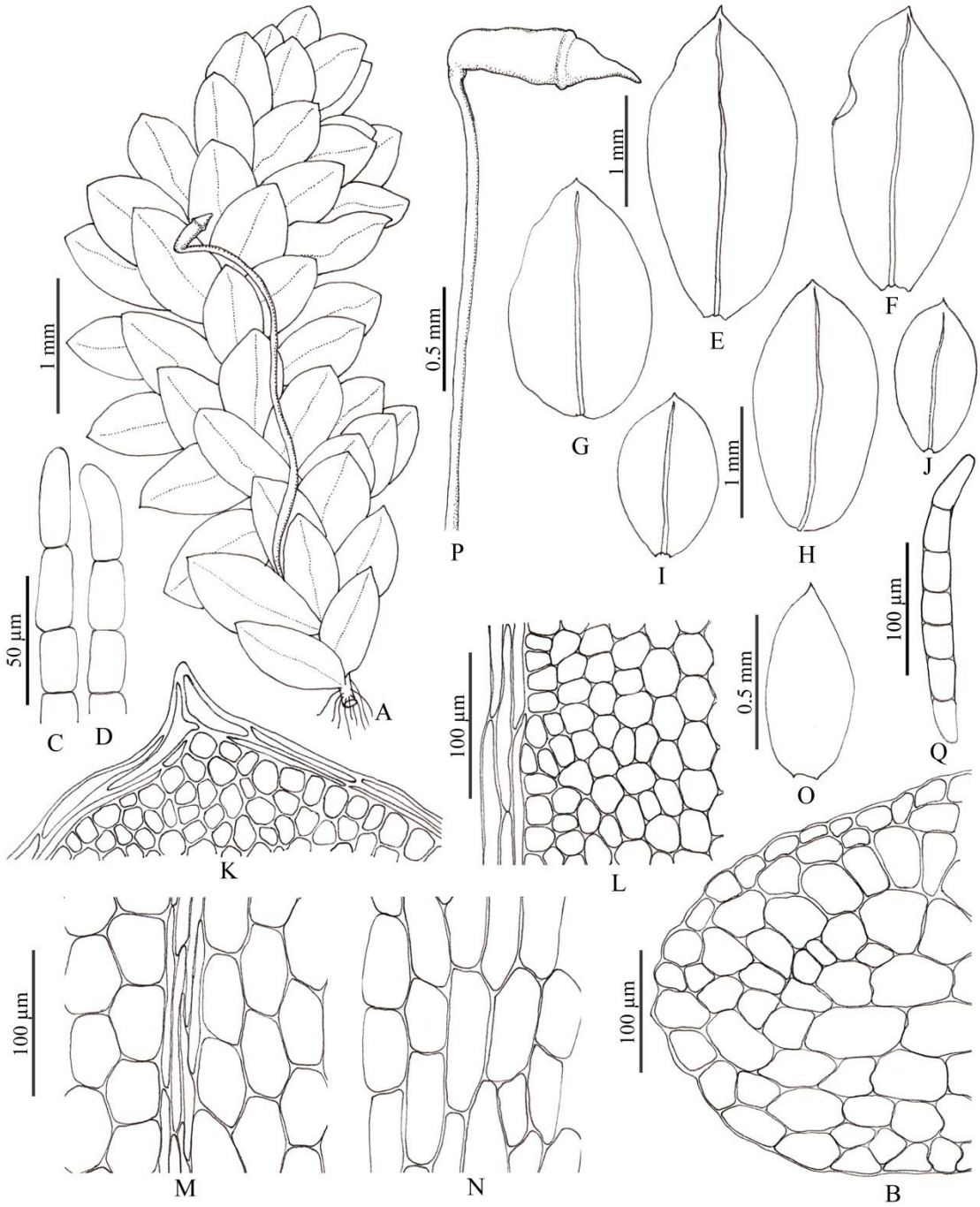

Figure 4.25 *Distichophyllum nigricaule* Mitt. ex Bosch & Sande Lac. var. *cirratum* (Renauld & Cardot) M. Fleisch. A. Gametophyte with sporophyte. B. Cross section of stem. C–D. Axillary hairs. E–H. Lateral leaves. I. Dorsal leaf. J. Ventral leaves. K. Cells at leaf apex. L. Cells at leaf margin. M. Cells at median part of leaf. N. Cells at leaf base. O. Perichaetial leaf. P. Upper part of Sporophyte. Q. Gemma. All from *W. Juengprayoon 112B* (PSU).

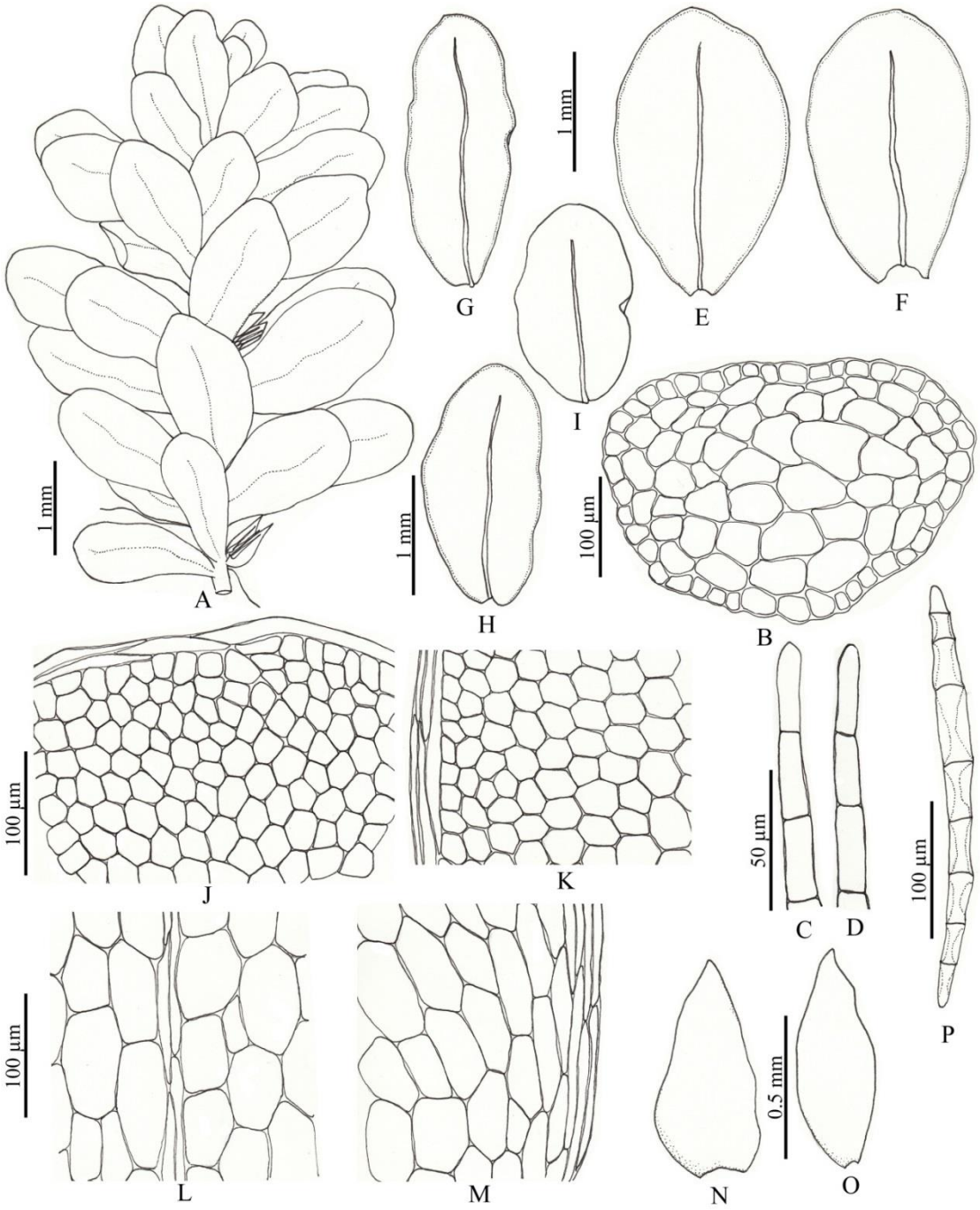

Figure 4.26 *Distichophyllum nigricaule* Mitt. ex Bosch & Sande Lac. var. *elmeri* (Broth.) P.J. Lin & B.C. Tan. A. Gametophyte. B. Cross section of stem. C–D. Axillary hairs. E–F. Lateral leaves. G–I. Dorsal leaves. J. Cells at leaf apex. K. Cells at leaf margin. L. Cells at median part of leaf. M. Cells at leaf base. N. Perigonial leaf. O. Perichaetial leaf. P. Gemma. All from *W. Juengprayoon 381* (PSU).

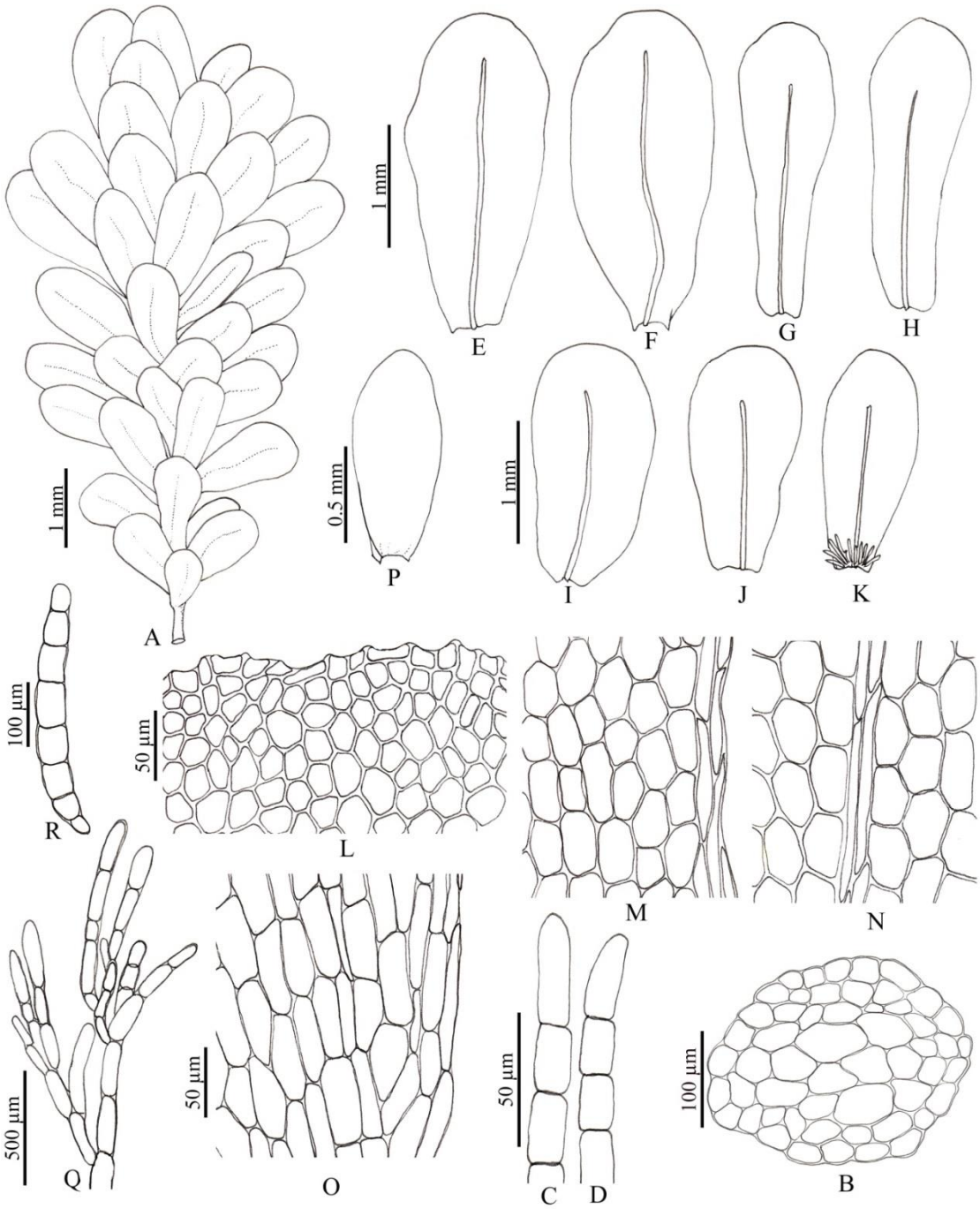

Figure 4.27 *Distichophyllum obtusifolium* Thér. A. Gametophyte, B. Cross section of stem. C–D. Axillary hairs. E–H. Lateral leaves. I–K. Dorsal leaves. L. Cells at leaf apex. M. Cells at leaf margin. N. Cells at median part of leaf. O. Cells at leaf base. P. Perichaetial leaf. Q. Gemmaphore. R. Gemma. All from *M. Poopath 1190* (BKF).

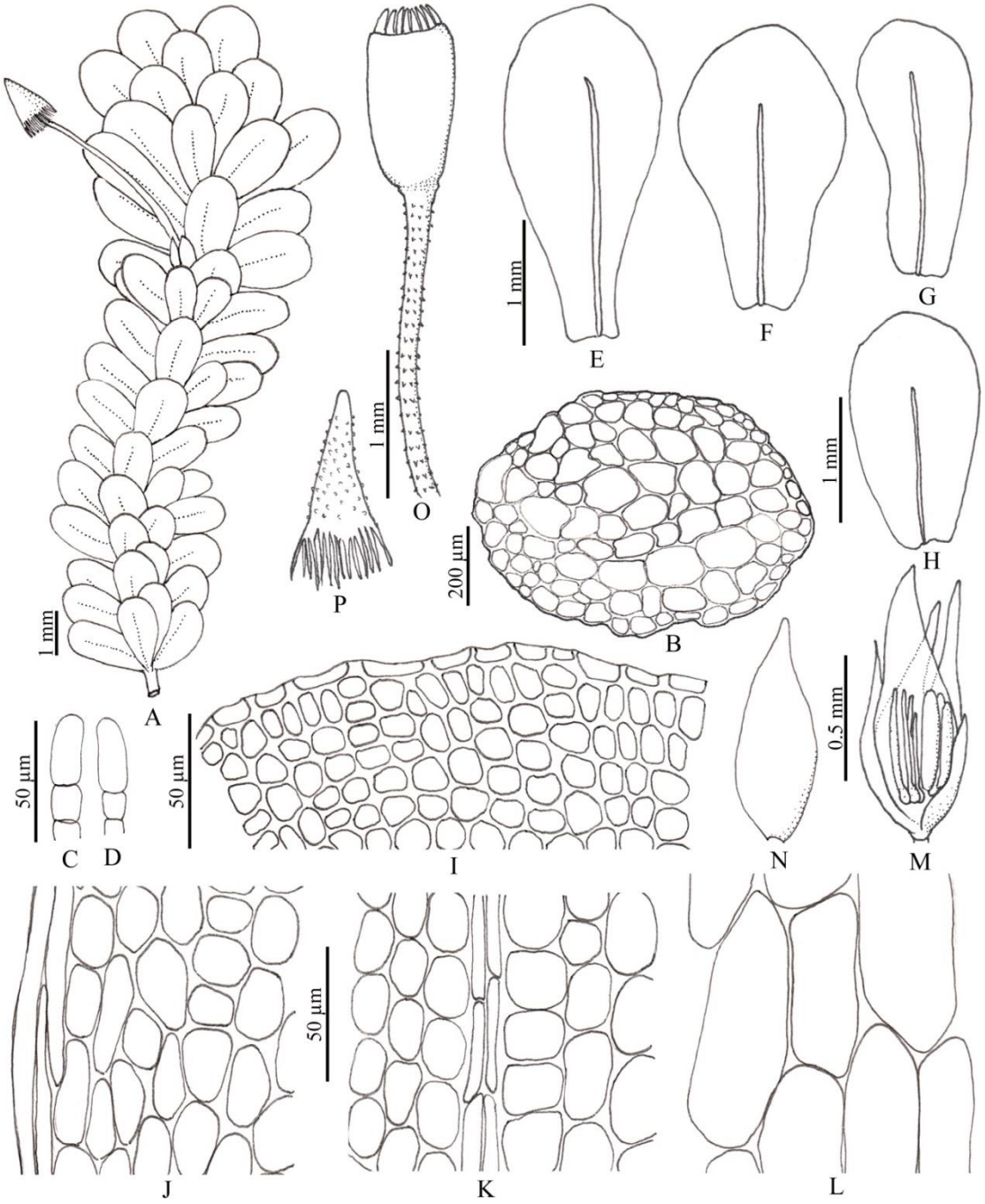

Figure 4.28 *Distichophyllum osterwaldii* M. Fleisch. A. Gametophyte with sporophyte. B. Cross section of stem. C–D. Axillary hairs. E–F. Lateral leaves. G–H. Dorsal leaves. I. Cells at leaf apex. J. Cells at leaf margin. K. Cells at median part of leaf. L. Cells at leaf base. M. Bisexual perichaetium. N. Bisexual perichaetial leaf. O. Upper part of sporophyte. P. Calyptra. All from *W. Juengprayoon 120A* (PSU).

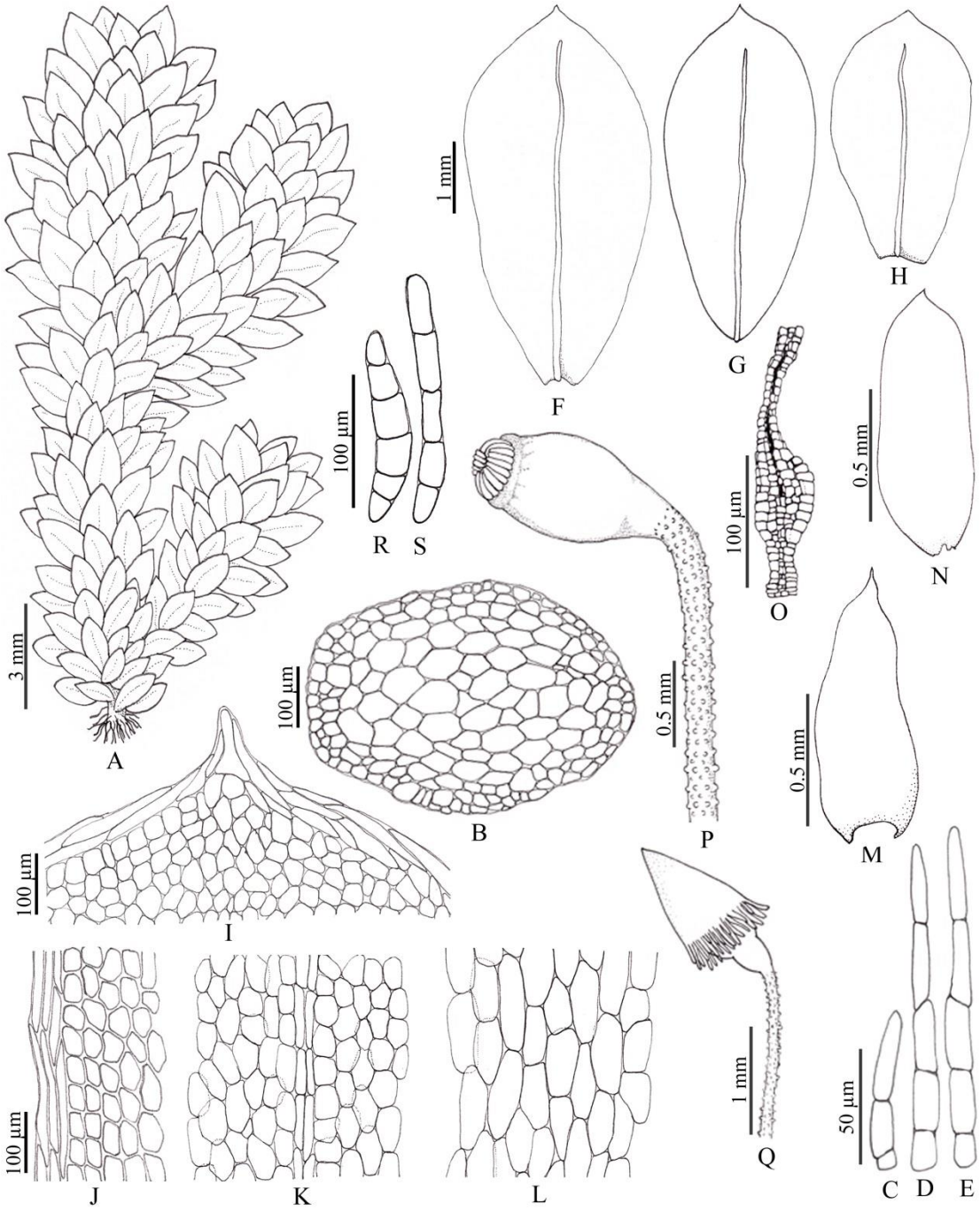

Figure 4.29 *Distichophyllum schmidtii* Broth. A. Gametophyte. B. Cross section of stem. C–E. Axillary hairs. F–G. Lateral leaves. H. Dorsal leaf. I. Cells at leaf apex. J. Cells at leaf margin. K. Cells at median part of leaf. L. Cells at leaf base. M. Pergonial leaf. N. Perichaetial leaf, O. Perichaetium, P. Upper part of sporophyte. Q. Capsule with calyptra. R–S. Gemmae. All from *W. Juengprayoon 581* (PSU).

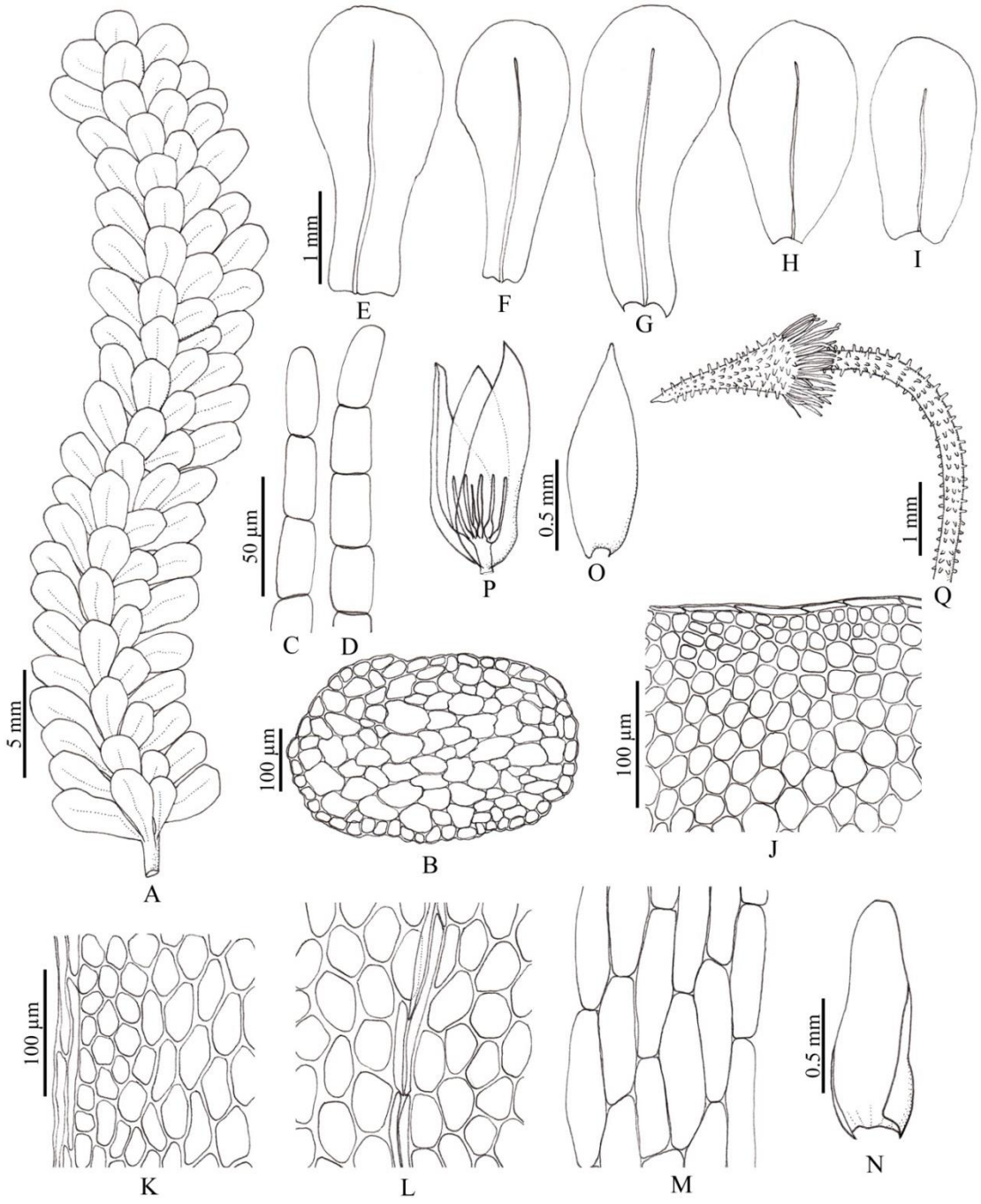

Figure 4.30 *Distichophyllum spathulatum* (Dozy & Molk.) Dozy & Molk. A. Gametophyte. B. Cross section of stem. C–D. Axillary hairs. E–G. Lateral leaves. H. Dorsal leaf. I. Ventral leaf. J. Cells at leaf apex. K. Cells at leaf margin. L. Cells at median part of leaf. M. Cells at leaf base. N. Perigonial leaf. O. Perichaetium. P. Perichaetial leaf. Q. Upper part of sporophyte. All from *W. Juengprayoon 107* (PSU).

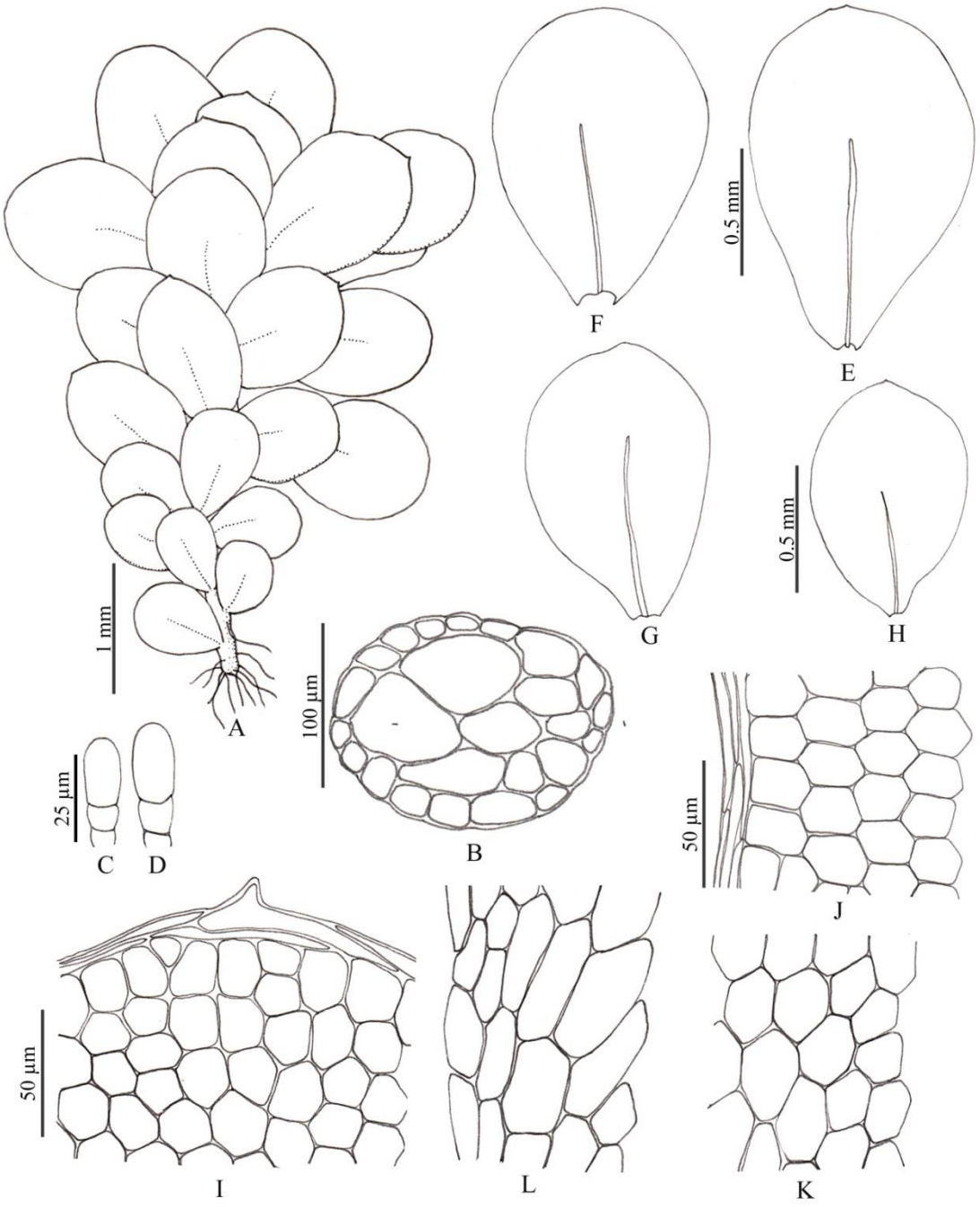

Figure 4.31 *Distichophyllum subnigricaule* Broth. A. Gametophyte, B. Cross section of stem. C–D. Axillary hairs. E–F. Lateral leaves. G–H. Dorsal leaves. I. Cells at leaf apex. J. Cells at leaf margin. K. Cells at median part of leaf. L. Cells at leaf base. All from *W. Juengprayoon 332* (PSU).

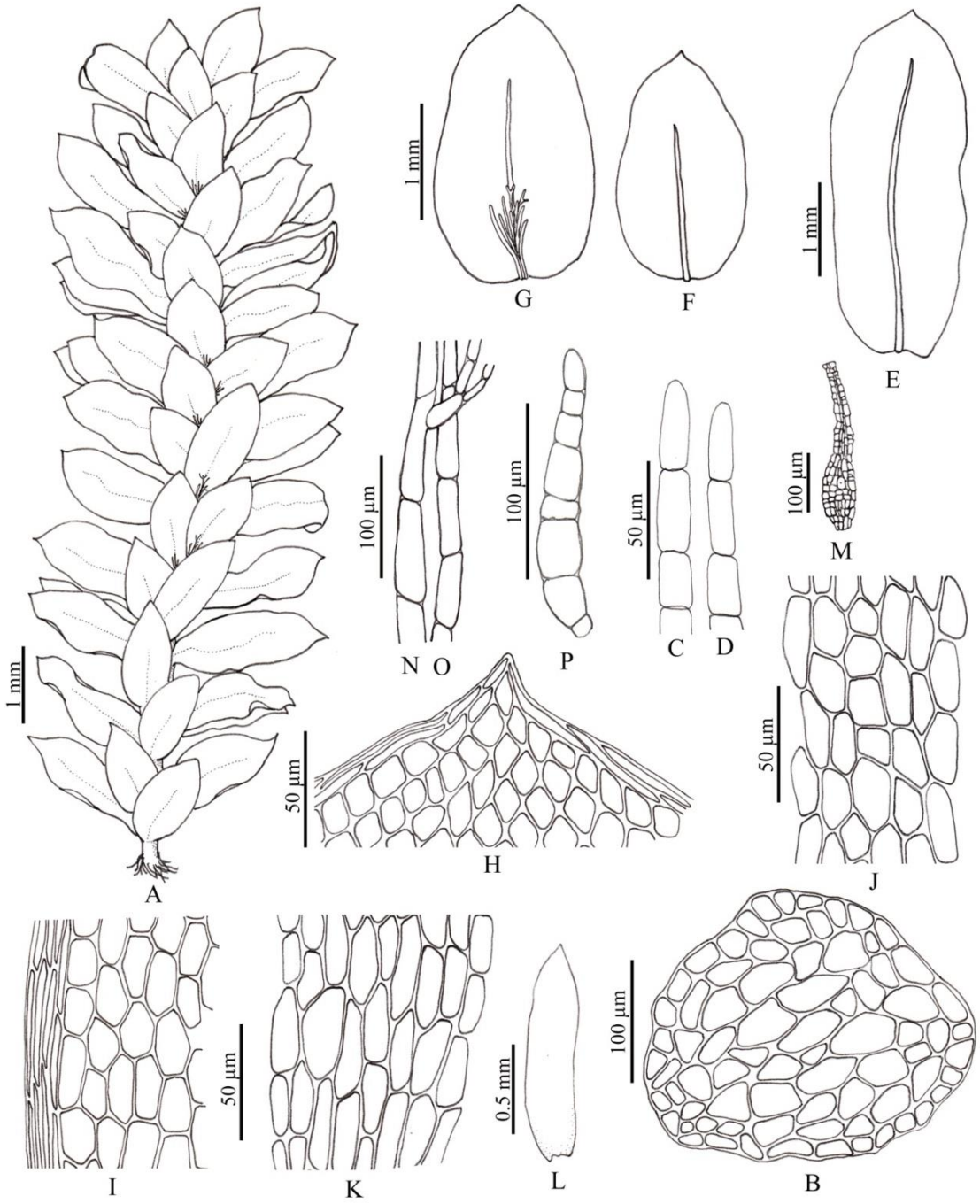

Figure 4.32 *Distichophyllum tortile* Dozy & Molk. ex Bosch & Sande Lac. A. Gametophyte. B. Cross section of stem. C–D. Axillary hairs. E. Lateral leaf. F–G. Dorsal leaves. H. Cells at leaf apex. I. Cells at leaf margin. J. Cells at median part of leaf. K. Cells at leaf base. L. Perichaetial leaf. M. Archegonium. N–O. Gemmaphores. P. Gemma All from *W. Juengprayoon 468* (PSU).

Ephemeropsis

K.I.Goebel., Flora 76: 98. 1892. Type: *Ephemeropsis tjibodensis* K.I.Goebel

Plants epiphyllous or epiphytic on twigs, small in size, greenish brown. **Protonemata** persistent protonema which resembles the algae, irregularly branched, consisting of main axes or caulonemata and side branches or chloronemata. **Caulonemata** greenish brown to dark brown, sparing branched, thick walled cells. **Chloronemata** usually smaller than caulonemata, yellowish green, spreading branched, thin walled cells.

Autoicous. **Perigonial** leaves broadly ovate, acute, entire to slightly dentate. **Perichaetial** leaves similar to perigonial leaves. **Seta** slender, smooth to slightly scabrous. **Capsule** ovoid to oblong, horizontal; operculum long rostrate; outer peristome teeth, orange to reddish brown, lanceolate-triangular, narrowly furrowed, outer surface with transversely striate to quadrate, inner surface with well-developed ventral lamellae from base to tip; inner peristome shorter to as long as outer peristome. **Spores** germination exo-or endosporic, small in size, rounded, nearly smooth. **Calyptra** mitriform, short to long fringed hairs at the base. **Asexual reproduction** by gemmae, fusiform or globose.

The genus is mainly distributed in tropical Asia, Australasia and Fiji (Frey & Stech, 2009). One species is known in Thailand.

Ephemeropsis tjibodensis K.I.Goebel, Flora 76: 116. 1892. Fig. 4.33

Type: INDONESIA. Java, Tjibodas, 1450–2000 m, *Fleischer s.n.*, (holotype: M; isotype: H).

Plants usually epiphyllous, very small in size, greenish brown. **Protonemata** persistent with very reduced gametophores, spreading irregularly branched, consisting of main axes (caulonemata) and 3 types of side branches (chloronemata, bristales, and hepteres) about 19–30 µm diameter with narrower side branches. **Caulonemata**

greenish brown to dark brown, sparing branched with elongate cells, 19–30 × 80–130 µm, thick walled, having less chloroplast than chloronemata cells. **Chloronemata** smaller than caulonemata, light green to yellowish green, spreading branched with short cells, 10–15 × 20–40 µm, thin walled. **Bristles** or vertical spines yellowish brown, 700–900 µm long, erect with elongate cells, 18–29 × 80–100 µm, a mature protonema producing numerous bristles emerging above the chloronemal mat. **Hapteres** or rhizoid–like structures adherent to substratum, with short celled less than 120 mm long, simple or sparingly branched.

Autoicous. Perigonial leaves, yellowish green to reddish brown, broadly ovate, 0.25–0.5 mm long, 0.2–0.3 mm wide, acute, entire to slightly dentate; antheridia 50–80 µm long. **Perichaetial** leaves yellowish green, similar to perigonial leaves; archegonium not seen. **Seta** slender, yellowish green to green, 1.0–1.2 mm long, smooth. **Capsule** ovoid-oblong, horizontal, 150–250 µm long; operculum long rostrate, beak ca. 0.35 mm long; peristome double; outer peristome teeth 16, orange to reddish brown, lanceolate-triangular, narrowly furrowed, outer surface with transversely striate, inner surface with well-developed ventral lamellae from base to tip; inner peristome as long as outer peristome, with high basal membrane. **Calyptra** mitriform, ca. 0.7 mm long, 0.3 mm wide, slightly hairy above, strongly fringed hairs at the base. **Gemmae** fusiform (5–7 celled), uniseriate, 150–200 µm long, produced at the tips of mature chloronemal filaments or attenuated main axes.

Habitat and ecology: In Thailand, *E. tjibodensis* were found growing associated with the members of Lejeuneaceae and *Radula* spp., on living leaves or sometimes on twigs in lowland to lower montane forests, between 50 and 1700 m alt.

Distribution: Indonesia (Boneo, Java, New Guinea, Sumatra,), Laos, New Caledonia, northern Queensland, Philippines, Thailand, and Vietnam (Bartlett & Iwatsuki, 1985; Pressel & Duckett, 2009).

Specimens examined: **Chiang Mai**, Doi Inthanon National park, 15 ha Plot, Near Check Point 2, 1600–1650 m, 18°31'20.40"N, 98°24'28.20"E, 27 Dec. 2008, *H. Akiyama et al. 37* (HYO), 31 Dec. 2008, *H. Akiyama et al. 250* (HYO), 1700 m, 14 Jan. 2010, *N. Printarakul 2685* (CMUB, O). **Prachuap Khiri Khan**, Huai Yang Waterfall National Park, Khao Luang Mt, ca 1200 m alt, 16 May 2011, *S. Chantanaorrapint 2425* (PSU). **Chanthaburi**, Khao Soi Dao Wildlife Sanctuary, 1549 m, 12°55'22.62"N, 102°11'43.91"E, 8 Apr. 2012, *S. Chantanaorrapint, J. Inuthai & C. Promma 961* (PSU). **Phang Nga**, Takua Pa, Si Phang-nga National Park, Ton Dang waterfall, 65 m, 08°59'38.9"N, 98°28'12.8"E, 2 Mar. 2015, *W. Juengprayoon 228* (PSU), 56 m, 08°59'49.28"N, 098°19'16.84"E 9 Oct. 2015, *W. Juengprayoon 592, 593, 594, 595, 596* (PSU), Mueang Phang-nga, Sa Nang Manora Forest Park, 55 m, 08°26'12.13"N, 098°18'33.89"E, 11 Oct. 2015, *W. Juengprayoon 600, 601* (PSU). **Nakhon Si Thammarat**, San Yen, Khao Nan National Park, 10 Jul. 2010, *S. Chantanaorrapint & C. Promma 2274* (PSU). **Trang**, Khao Chedyod Mt., 1048 m, 09°19'14.71"N, 099°54'32.11"E, 2 May 2014, *S. Chantanaorrapint & C. Promma 3789D* (PSU), *W. Juengprayoon 161, 162, 163, 164, 165, 166* (PSU), 888 m, 07°19'12.87"N, 099°54'17.67"E, 3 May 2014, *W. Juengprayoon 171* (PSU). **Yala**, Betong, Ban Chulabhorn Pattana 10, 547 m, 06°01'14.86"N, 101°16'40.42"E, 10, 3 Jul. 2014, *W. Juengprayoon 181, 182* (PSU), 543 m, 27 Dec. 2016, *S. Chantanaorrapint, W. Juengprayoon & O. Suwanmala 805, 806, 807, 811, 814, 818* (PSU). **Narathiwat**, Waeng, Hala-Bala Wildlife Research, Station, 540 m, 05°48'04.49"N, 101°46'24.55"E, 2 Jan. 2016, *W. Juengprayoon 694* (PSU).

Additional descriptions: Fleischer (1908: 945), Bartlett & Iwatsuki (1985: 179).
Additional illustrations: Fleischer (1908: 946, fig. 164).

Taxonomic notes: *Ephemeropsis tjibodensis* is characterized by the presence of bristles or vertical spines of well-developed protonema, the occurring of fusiform gemmae, and the smooth setae. In contrast, the protonema of *E. trentepohlioides* has no vertical spines, and globose gemmae. Moreover, its setae are slightly scabrous (Bartlett & Iwatsuki, 1985).

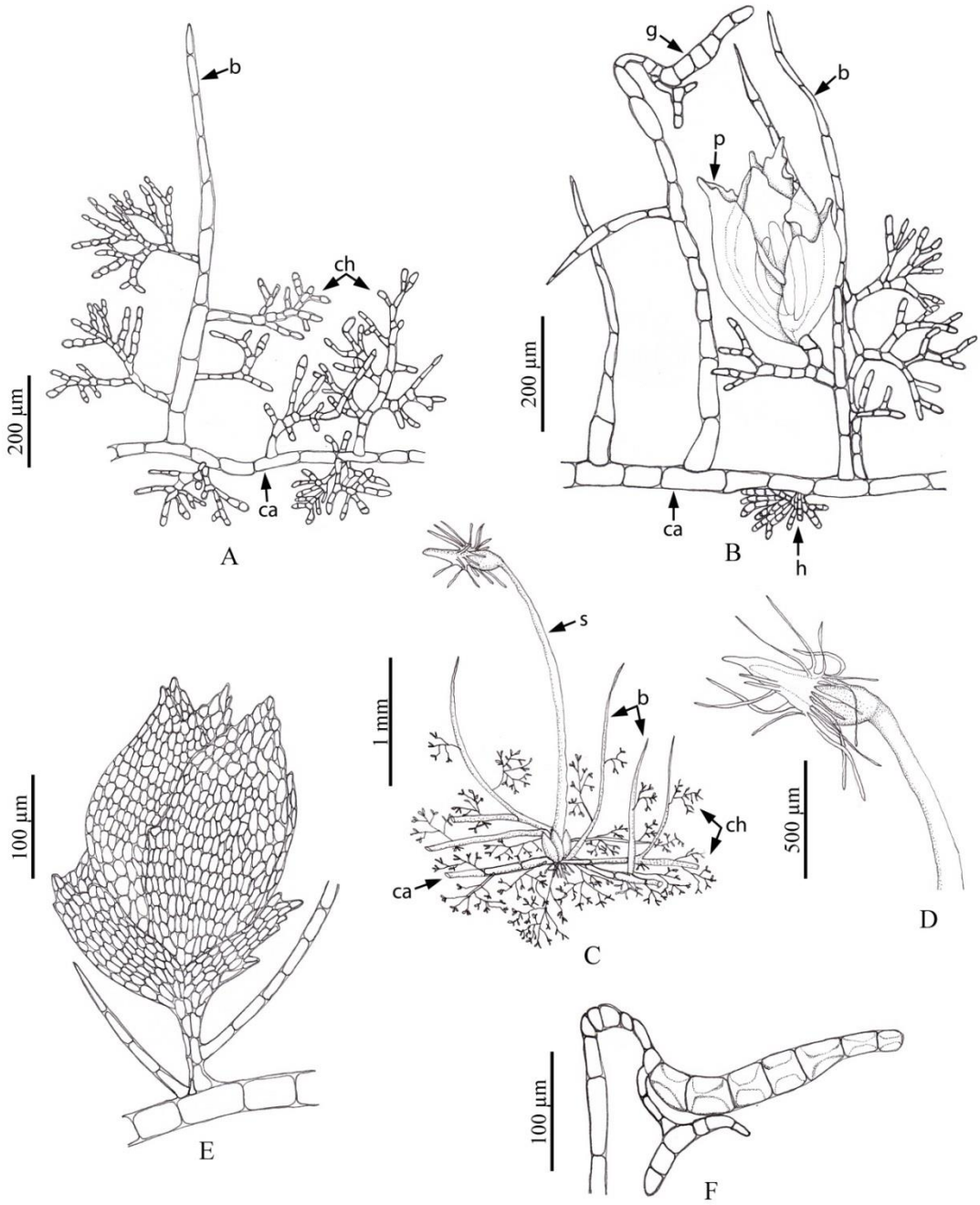

Figure 4.33 *Ephemeropsis tjibodensis* K.I.Goebel. A. Protonema showing caulonema (ca) or main axis. chloronema (ch) filaments, and bristle (b) or ventral spine; B. Protonema with gemma (g), perigonium (p), and heptera (h). C. Protonema with sporophyte (s). D. Capsule with calyptra. E. Perigonium (andoecium). F. Gemma. All from *Juengprayoon 228* (PSU).

Leskeodon

Broth., Nat. Pflanzenfam.1(3): 925. 1907. Type: *Leskeodon auratus* (Müll. Hal.) Broth. [≡ *Mniadelphus auratus* Müll. Hal.].

Plants light green to green, medium in size, simple or sparingly branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** dark green to reddish brown, in cross section without central strand. **Axillary hairs** filiorm, medium in size, terminal cell longer than basal and intermediate cells. **Leaves** complanate, widely spreading, somewhat crisped when dry, straight and plane when moist, dimorphic; lateral leaves large, ovate-oblong, obovate to shortly spathulate, apices shortly apiculate, acute, to acuminate, margins entire, border differentiated; costa single, slender, ending below the apex or percurrent; dorsal and ventral leaves smaller than lateral ones, broadly ovate to ovate-oblong; apices shortly apiculate, margins entire. Lamina cells heterogeneous, smooth, thin walled; mostly subhexagonal, hexagonal to rhomboidal.

Autoicous or dioicous. **Perigonial** leaves yellowish green, narrowly ovate, acute, entire. **Perichaetial** leaves yellowish green, narrowly ovate to elliptic, acuminate, entire. **Sporophyte** lateral. **Seta** erect, slender, reddish brown, smooth or scabrous above. **Capsule** ovoid, fragile, inclined; exothecial cells, small to medium in size, oblong rectangular to irregular polygonal, mostly non-collonchymatous, thin-walled; operculum rostrate; outer peristome teeth yellowish orange, lanceolate, papillose or narrowly furrowed, outer surface with transversely striolate, inner surface with well-developed ventral lamellae from base to tip; inner peristome teeth as long as outer peristome, with high basal membrane. **Spores** small to medium in size, slightly papillose. **Calyptra** mitriform, hairy at the tip, smooth below, fringed hairs at the base. **Asexual reproduction** by gemmae, gemmae shortly filiform or branced, present at leaf axils.

Leskeodon composes of 21 species, which are distributed mainly in Neotropic, Malesia, New Caledonia and South East Asia (Frey & Stech, 2009). One species is known in Thailand.

Leskeodon maibarae (Besch.) B.C. Ho & L. Pokorny, Bot. J. Linn. Soc. 170: 172. 2012. Fig. 4.34

≡ *Distichophyllum maibarae* Besch. J. Bot. (Morot) 13: 40. 1899. Type: JAPAN. Nippon central (= Honshu), Maibara, 7 Nov. 1893, *Faurie 11130* (holotype: BM; isotype: FH, H-Br).

= *Distichophyllum decolyi* Gangulee, Mosses E. India 6: 1488. f. 744. 1977. Type: INDIA. Darjeeling district, Kurseong, Chuttakpur, *Decoly & Schaul s.n. (Bryoth. Levier 2542)* (holotype: BM; isotype: BM).

Plants light green to green, turning to yellowish green in herbarium specimens, medium in size, 1.4–1.8 cm long, 0.3–0.45 cm wide with leaves, sparingly branched. **Rhizoids** dark reddish, dense at base of stem. **Stems** dark green to reddish brown, in cross section 10–12 cells across; epidermal cells 1–2 layers of small, somewhat thick-walled; cortex cells larger than epidermal ones, thin-walled. **Axillary hairs** filiform, consisting 3–4 cells long; terminal cell inflated, 48–55 µm long; basal and intermediate cells similar, ca. 20–30 µm long. **Leaves** widely spreading, fragile, somewhat crisped when dry, straight when moist; lateral leaves large, ovate-oblong to shortly spathulate, 2.0–2.5 mm long, 1.0–2.0 mm wide, apices shortly apiculate, 39–70 µm long; margins bordered by 1–2 rows of linear cells; costa single, about 3/5–2/3 of leaf length; dorsal and ventral leaves smaller than lateral ones, broadly ovate to ovate-oblong, 1.5–1.8 mm long, 0.9–1.1 mm wide; apices shortly apiculate, 35–65 µm long. Lamina cells heterogeneous, thin walled; apical cells subhexagonal, 16–34 × 9–25 µm; paracostal cells and submarginal cells in upper half hexagonal, 16–38 × 10–30 µm; paracostal cells in lower half and basal cells larger than other area, rectangular to irregularly pentagonal, 40–100 × 35–45 µm.

Dioicous. Perigonial leaves yellowish green, narrowly ovate, 0.6–0.7 mm long, 0.30–0.35 mm wide, acute. Antheridia 300–350 µm long. **Perichaetial** leaves yellowish green, narrowly ovate to elliptic, 0.7–1.0 mm long, 0.35–0.40 mm wide, acuminate. **Seta** slender, 3.5–4.0 mm long, reddish brown, smooth. **Capsule** ovoid, inclined, 0.6–0.8 mm long; exothecial cells oblong rectangular to irregular polygonal,

25–30 µm wide, thin-walled, mostly nodulose; operculum long rostrate, beak ca. 0.7 mm long; outer peristome teeth yellowish orange, lanceolate, narrowly furrowed, inner surface with well-developed ventral lamellae from base to tip; inner peristome teeth as long as outer peristome, with high basal membrane. **Calyptra** mitriform, ca. 1 mm long, 0.5 mm wide at base, hairy at the apex, smooth below, fringed hairs at the base. **Gemmae** yellowish green, shortly filiform, ca. 100–150 µm long, bearing on gemmaphore, present at leaf axil.

Habitat and ecology: In Thailand, *Leskeodon maibarae* usually occurs on wet rocks, in lower to upper montane forest, at altitude between 1000 and 2520 m.

Distribution: China, India (Chuttapur), Indonesia (Java), Japan, Malaysia (Pahang, Sabah), Philippines (Luzon, Bantan Is.), Taiwan, Thailand, and Vietnam (Noguchi *et al.*, 1991; Wu *et al.*, 2002; Ho *et al.*, 2010).

Specimens examined: Chiang Mai, Doi Inthanon National Park, 2550 m, 5 Dec. 2000, *H. Akiyama Th-24* (HYO), 15 ha Plot, Near Check Point 2, 1600–1650 m, 18°31'20.40"N, 98°24'28.20"E, 31 Dec. 2008, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 229*, *230*, *231*, *237*, *243*, *246* (HYO), 2 Jan. 2009, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando* 269 (HYO), 5 Jan. 2009, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 377* (HYO), 6 Jan. 2009, *H. Akiyama, M. Kanzaki, T. Irie & N. Ando 399* (HYO), Chomthong, Kew Mae Pan, 2146 m, 18°33'208"N, 98°28'659"E, 10 Feb. 2008, *Y. Nathi 640*, *652*, *689* (BCU, SING), *947* (BCU), 2521 m, 18°35'228"N, 98°29'242"E, 12 May 2008, *Y. Nathi 993* (BCU), 2217 m, 18°33'359"N, 98°28'666"E, 3 Dec. 2007, *Y. Nathi 1025* (BCU, SING), 2520 m, 18°35'228"N, 98°29'242"E, 12 May 2008, *Y. Nathi 1152* (BCU), 1700 m, 14 Jan. 2010, *N. Printarakul 2689* (CMUB, O), 2300 m, 18 Jan. 2010, *N. Printaraku 2900* (CMUB, O), 20 Jan. 2010, *N. Printarakul 2981* (CMUB, O), 1650 m, 10 Mar. 2011, *N. Printarakul 3667* (CMUB, O), Angka, 2543 m, 18°35'20.10"N, 098°29'05.60"E, 31 Oct. 2015, *W. Juengprayoon 608, 613* (PSU). **Phitsanulok**, Phu Hin Rong Kla National Park, 1624 m, 16°55'51.41"N, 101°03'04.47"E, 9 Jul. 2015, *W. Juengprayoon 572* (PSU). **Loei**, Phu ruea, Phu Luang

National Park, 1300–1350 m, 11° 2'14.52"N, 99°11'37.76"E, 9 Jan. 1966, *A. Touw 10640* (BKF), 1517 m, 17°16'48.4"N, 101°31'31.8"E, 6–7 Jul. 2015, *M. Poopath 1181, 1201A* (BKF). **Prachuap Khiri Khan**, Bang Saphan, Huai Yang Waterfall National Park, 1072 m, 11°38'50.91"N, 099°34'57.37"E, 3 Mar. 2016, *S. Chantanaorrapint, W. Juengprayoon & O. Suwanmala 102A, 104A* (PSU). **Nakhon Si Thammarat**, Khao Nan National Park, San Yen, 1000–1300 m, 20 Apr. 2007, *S. Chantanaorrapint 1591* (PSU), Khao Luang National Park, 1442 m, 08°32'34.50"N, 099°44'11.14"E, 21 Apr. 2014, *W. Juengprayoon 108A* (PSU), 1403 m, 08°32'10.18"N, 099°45'05.45"E, 24 Apr. 2014, *W. Juengprayoon 133B, 135B* (PSU).

Additional descriptions: Bescherelle (1899: 40 as *Di. maibarae*), Gangulee (1977: 1488 as *Di. decolyi*), Tan & Robinson (1990: 19), Noguchi (1991: 744 as *Di. maibarae*), Mohamed & Robinson (1991: 22), Tan & Lin (1991: 308), Lin & Tan (1995: 39), Ho *et al.*, (2010: 114 as *Di. maibarae*), Nathi (2009, 79), Yoon *et al.* (2015: 40).

Additional illustrations: Gangulee (1977: 1489, fig. 744 as *Di. decolyi*), Noguchi (1991: 745, fig. 327 as *Di. maibarae*), Lin & Tan (1995: 59, fig. 29), Ho *et al.* (2010: 115, fig. 5 as *Di. maibarae*).

Taxonomic notes: The distinctive features of *Leskeodon maibarae* are 1) the presence of long erect hairs at calyptra apex, 2) epidermal cells of capsule thin-walled and mammillose, 3) leaf bordered by 1–2 rows of elongate cells, 4) cells at the upper part of leaf homogeneous, small, usually round to short hexagonal, and 5) terminal cell of axillary hair longer than the basal onces.

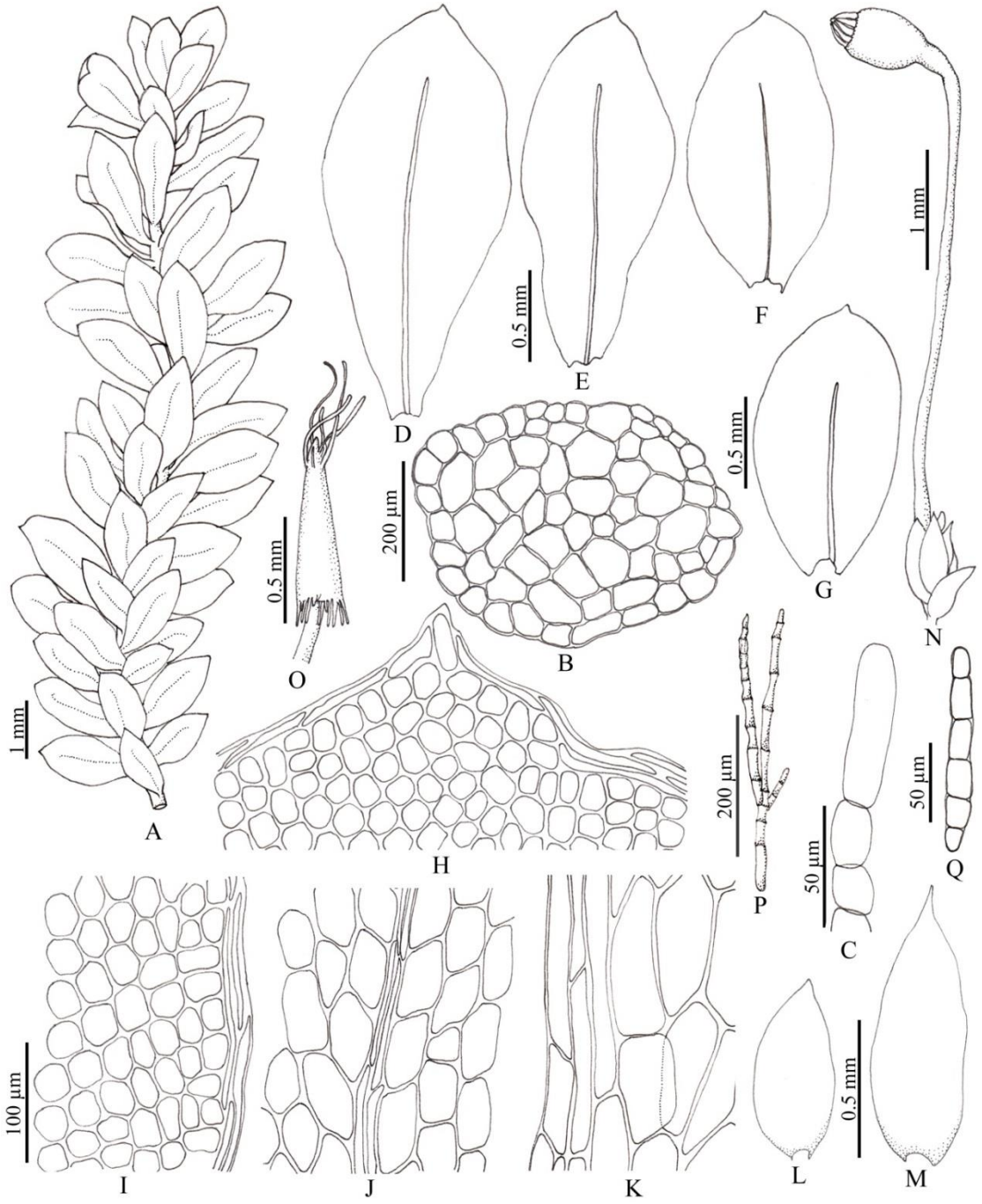

Figure 4.34 *Leskeodon maibarae* (Besch.) B.C. Ho & L. Pokorny. A. Gametophyte. B. Cross section of stem. C. Axillary hair. D–E. Lateral leaves. F. Dorsal leaf. G. Ventral leaf. H. Cells at leaf apex. I. Cells at leaf margin. J. Cells at median part of leaf. K. Cells at leaf base. L. Perigonial leaf. M. Perichaetial leaf. N. Mature sporophyte. O. Calyptra on a developing capsule. P. Gemmaphore. Q. Gemma. All from *W. Juengprayoon 608* (PSU).

CHAPTER 5

DISCUSSIONS AND CONCLUSION

5.1 Diversity of Daltoniaceae in Thailand

In this study, 22 species and 3 varieties in 5 genera of Daltoniaceae were recognized for Thailand. In comparison with the previously studies (e.g. He, 1995; Akiyama, 2006; Ho *et al.*, 2010; Akiyama *et al.*, 2011; Printarakul *et al.*, 2013), 21 taxa are similar and three species are newly recorded. In addition, four names are excluded from Thai flora.

The previous studies of Daltoniaceae in Thailand are rarely known, reflected on the few bryophyte studies for the country (Sukkharak & Chantanaorrapint, 2014). Most of data based on the studies of bryophytes in some particular areas. In the present study, the family was surveyed and collected practically in both previously reported areas and unexplored areas. Moreover, several names have been treated as a synonym or seem to be erroneous identification. Thus, it is not surprise that three new recorded species were found and four names are excluded for Thailand.

The continuous discovery of new species and new records of bryophytes from Thailand (e.g. He *et al.*, 2012; Kornochalert *et al.*, 2012; Chantanaorrapint, 2014, 2015; Inuthai *et al.*, 2014, 2015; Chantanaorrapint & Sridith, 2014; Promma & Chantanaorrapint, 2015; Sukkharak & He, 2015; Juengprayoon *et al.*, 2016) suggests that many bryophyte taxa await discovery in this country. More detailed investigations of the bryophytes of Thailand, particularly in the northern and southern parts of the country, should prove rewarding and are likely to lead to the discovery of interesting new taxa.

New records

From the results of this study, there are 3 species of genus *Distichophyllum* which have not been recorded before from Thailand following below.

1. *Distichophyllum obtusifolium* Thér.

This species has been reported from China (Hainan), Japan, Philippines, Taiwan (Tan & Robinson, 1990; Lin & Tan, 1995). In Thailand this species is only known from Phu Luang wildlife Sanctuary, Loei province, in montane forest at altitudes of 1517 m.

2. *Distichophyllum osterwaldii* M. Fleisch.

This species has been found in China, Indonesia (Java), Japan, Malaysia, Philippines, and Taiwan (Noguchi & Iwatsuki, 1972; Mohamed & Robinson, 1991). In Thailand this species is only known from Khao Luang National Park, Nakhon Si Thammarat province, growing on rock in montane forest at altitude about 1480 m.

3. *Distichophyllum subnigricaule* Broth.

This species is reported from China (Hainan, Yunnan), Malaysia, North Borneo, and Philippines (Mohamed & Robinson, 1990). In Thailand, *D. subnigricaule* was found on rocks in lowland at altitude about 780 m only from Khao Luang National Park, Nakhon Si Thammarat province.

Doubtful and excluded records

1. *Leskeodon acuminatus* (Bosch & Sande Lac.) M. Fleisch., Musci Buitenzorg 3: 971. 1908.

≡ *Distichophyllum acuminatum* Bosch & Sande Lac., Bryol. Jav. 2: 26. 150. 1861. Type: INDONESIA, Java, Mt. Gedeh, *Teymann s.n.* (syntype: NY).

Descriptions: Tan & Robinson (1990: 27).

Illustrations: Dozy & Molkenboer. (1861: TAB. CI).

Leskeodon acuminatus has been reported in Thailand by Tixier (1970) based on his collection from Ranong province. Unfortunately, this specimen was not available for the present study. Based on the recent field survays we can not find any other collections of *L. acuminatus* in Thailand. *Leskeodon acuminatus* might be confused with *Distichophyllum schmidtii*, the common species in southern Thailand,

in general appearance. Therefore, *L. acuminatus* in Thailand should be considered doubtful and Tixer's specimen (no. 4015) needs to be re-examined.

2. *Daltonia carinata* (Dixon & W.E. Nicholson) B.C. Ho & L. Pokorny, Bot. J. Linn. Soc. 170: 171. 2012.

= *Distichophyllum carinatum* Dixon & W.E. Nicholson, Rev. Bryol. 36: 24. f. 1–7. 1909. Type: AUSTRIA, 700 m, 3 Aug. 1908, *Dixon s.n.* (holotype: MO).

Descriptions: Dixon & Nicholson (1909: 24), Lin & Tan (1995: 15).

Illustrations: Dixon & Nicholson (1909: 26, fig. 1–7).

This species has been recorded from Austria, China, Japan, and Thailand (Ho *et al*, 2010). *Daltonia carinata* was first reported in Thailand by Nathi (2009) as *Distichophyllum carinatum* based on a single collection (*Y. Nathi 460* BCU!, SING!) from Doi Inthanon National Park, Chiang Mai province. However, after re-examination, this collection was identified as *Daltonia angustifolia*. Thus, the recorded of this species should be excluded from Thailand.

3. *Distichophyllum decolyi* Gangulee, Mosses E. India. 6: 1488. f. 744. 1977. Type: INDIA. Darjeeling district, Kurseong, Chuttakpur, *Decoly & Schaul s.n. (Bryoth. Levier 2542)* (holotype: BM; isotype: BM).

Descriptions: Gangulee (1997: 1488).

Illustrations: Gangulee (1997: 1489, fig. 744).

Distichophyllum decolyi was previously considered as an Indian endemic and earlier reported from Thailand by Akiyama (2006). However, this name has been proposed earlier to be a synonym of *D. maibarae* (Tan & Lin, 1991). Recently, *Distichophyllum maibarae* has been transferred to the genus *Leskeodon* (Ho *et al*., 2012).

4. *Distichophyllum obovatum* (Griff.) Paris, Index Bryol. 390. 1896. Type: INDIA. Khasia, *Griffith s.n.* (syntype: NY).

Descriptions: Gangulee (1997: 1483).

Illustrations: Gangulee (1997: 1484, fig. 740).

This species was earlier reported from Thailand by Akiyama (2006) based on his collection from Doi Inthanon National Park, Chiang Mai province. However, Ho *et al.* (2010) had studied Akiyama' collection and identified as *Districhophyllum wanianum* B.C. Tan & P.J. Lin. After re-examination this specimen, we agree with Ho *et al.* (2010). In last few years, Ho *et al.* (2012) transferred this plant to the genus *Daltonia*, as *Daltonia waniana*.

5.2 Distribution of Daltoniaceae in Thailand

According to the phytogeography of Thailand, the country has been classified into seven floristic regions (Smitinand, 1958), that is used in the Flora of Thailand Project. Base on the present study, the Daltoniaceae in Thailand is found in five regions (Fig. 5.1) *viz.* Northern, North-eastern, South-western, South-eastern, Peninsular, except Eastern and Central regions. The greatest diversity is found in the Peninsular region with 16 taxa (67%). There are 10, 9, 9, and 3 taxa in Northern, North-eastern, South-western, and South-eastern Thailand, respectively. The high number of species recorded in the Peninsular region is probably due to this area contains undisturbed evergreen rain forests which seem to provide optimal growth conditions for Thai Daltoniaceae species. From field observations, most of Thai Daltoniaceae are growing in the moist lowland evergreen and humid montane forests. These forest types are abundant in southern and eastern parts of the country, and in the highland areas or top of the mountains in other parts of country. Therefore, it is not surprise that can not find Daltoniaeace taxa in Central and Eastern regions, because most forest types in these regions belong to deciduous or dry evergreen forests.

Calypytrochaeta remotifolia is the most common species and widely spread in Thailand, distributed in five floristic regions (Northern, North-eastern, South-eastern, South-western and Peninsular), while 12 species are restricted in particular floristic region (Table 4.1). There are seven species restricted in the Peninsular region i.e., *Distichophyllum armatum*, *D. brevicuspes*, *D. cuspidatum*, *D. jungermannioides*, *D. osterwaldii*, *D. subnigricaule*, and *D. tortile*. Four species, *Calypytrochaeta spinosa*, *Daltonia apiculata*, *D. aristifolia*, and *D. semitorta* were found only in the Northern

region. *Distichophyllum obtusifolium* was currently known only from North-eastern region.

Following the critical observations, six species have been recognized as the rare species, *viz. Daltonia semitorta*, *Distichophyllum armatum*, *D. brevicuspes, D. obtusifolium*, *D. osterwaldii* and *D. subnigricaule*. These six species have been known only small populations with a narrow spread in Thailand.

5.3. Altitudinal distribution

Altogether 24 taxa in five genera were encountered in the present study in the altitude range of 50 to 2500 m (Table 5.1). Most of Daltoniaceae species in Thailand are occurred in lower montane forest at altitudes between 800 and 1600 m. Some of the species are occurring in a wide range of elevation, e.g. *Daltonia waniana, Distichophyllum mittenii, Ephemeropsis tjibodensis,* etc., while few species have a restricted in upper montane forests ranging from 1800–2500 m elevation, *viz. Calyptrochaeta spinosa*, *Daltonia aristifolia*, and *Daltonia semitorta*. Seven species are restricted in lower mountain forest ranging from 800 to 1600 m elevation *viz. Calyptrochaeta remotifolia, Distichophyllum armatum, D. brevicuspes, D. cuspidatum*, *D. jungermannioides*, *D. obtusifolium*, and *D. osterwaldii*. Moreover, *Distichophyllum subnigricaule* is a restricted in lowland evergreen forest ranging from 50 to 700 m elevation.

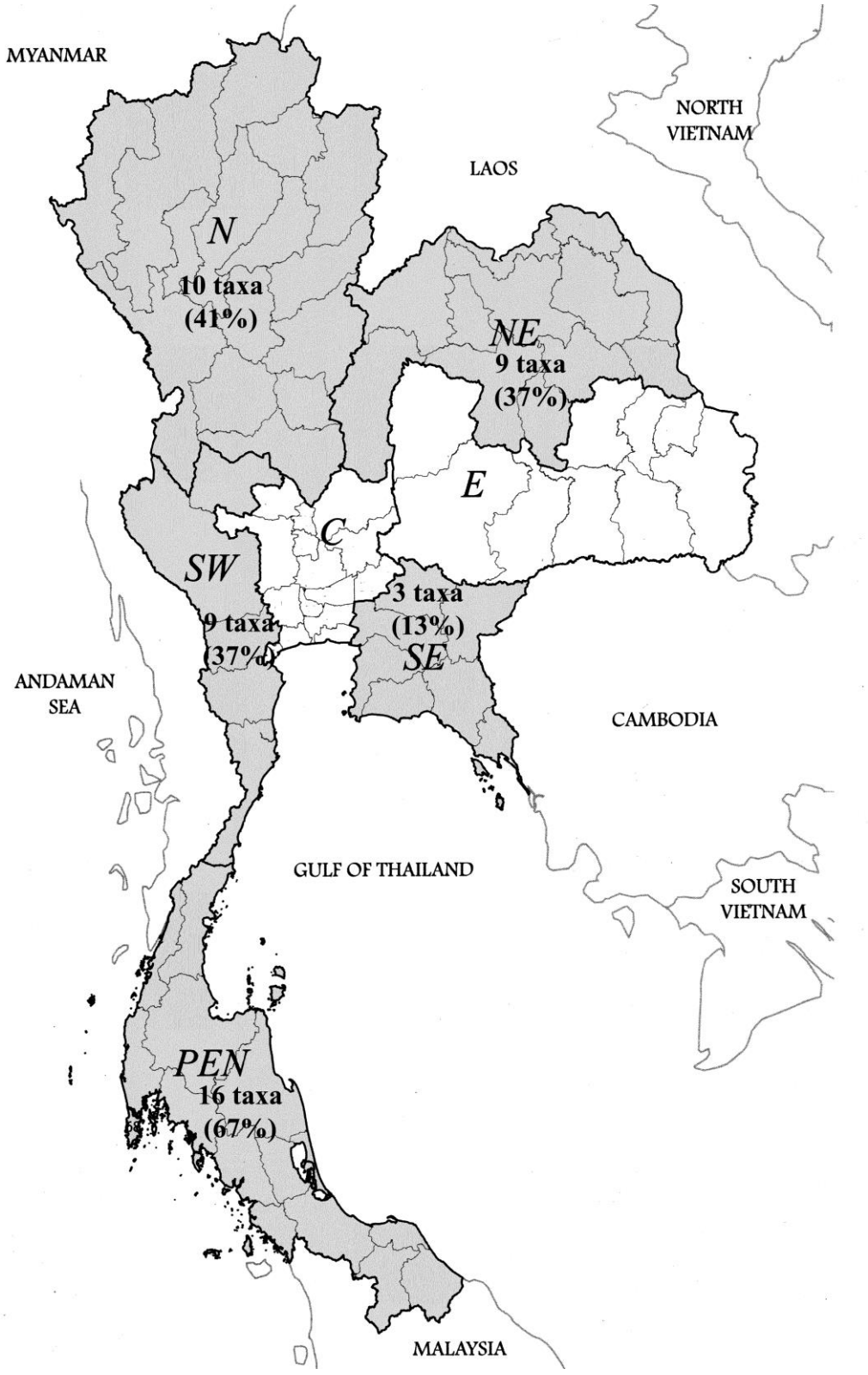

Figure 5.1 Number and percentages of Daltoniaceae taxa recorded in floristic regions of Thailand: N = Northern, NE = North-eastern, E = Eastern, SW = South-western, C = Central, SE = South-eastern, and PEN = Peninsular.

5.4 Microhabitats

Daltoniaceae speices in Thailand were collected in various habitats such as soil, rocks, rotten woods, tree trunks, branches, twigs, and living leaves (Table 5.1). Some species are specific to their habitats, whereas, several species grow on more than one substrate types. Among these, fifteen taxa are epiphytes, growing on tree trunks (corticolous, 10 species), branches or twigs (ramicolous, 6 species), and living leaves (epiphyllous, 1 species); and thirteen taxa are terrestrials occurring on rocks (saxicolous) or soil (terricolous). On large horizontal trunks or branches, the humus and debris of all kind accumulate are more than on other parts of the tree. This is one reason why the bryophytes usually found on the base of trees. Whereas, the epiphytic and epiphyllous mosses on the upper branches of tree are dependent on only the minute of mineral nutrients in rain water, air-borne dust, small animals and blue green algae (Richards, 1984).

Concerning to the habitat preference, most of the species in genus *Daltonia* (except *D. waniana*) usually grow on small branches in the open areas of upper montane forest. Most of species in this genus are very small with densely spiral shoot and yellowish brown in color. These characters may help water retention in plants, and to protect them from high light intensity, respectively. Most of saxicolous and terricolous species belonging to the genus *Distichophyllum*, they are medium to large in size with complanate foliate leaves and usually found along the stream in in shady and undisturbed areas. The fan life form may help to incress ability of photo reception in low light intensity condition (Bates, 1998). Consequently, the members of Daltoniaceae seem to be restricted to the humid habitates in primary forests from lowland to the summit of the moutains.

Table 5.1 Habitats, elevations and forest types of Daltoniaceae taxa recorded in Thailand.

Microhabitats: C = corticolous; R = ramicolous; E = epiphyllous; S = saxicolous; T = terricolous. Forest type: lef = lowland evergreen forest; lmf = lower montane forest; umf = upper montane forest. Phytogeography: 1 = Paleotropical (Africa–Asia Tropical–Australasia); 2 = Asia Tropical and Subtropical–Australasia–Pacific; 3 = Asia Temperate–Asia Tropical; 4 = Himalayan region; 5 = Malesian region

Taxa	Microhabitats					Elevations (m)	Forest types	Phytogeography
	C	R	E	S	T			
1. *Calyptrochaeta remotifolia*	✓			✓		1000–1630	lmf	3
2. *Calyptrochaeta spinosa*	✓					1900–2580	umf	4
3. *Daltonia angustifolia*		✓				1100–2550	lmf, umf	1
4. *Daltonia apiculata*		✓				1600–2500	lmf, umf	4
5. *Daltonia aristifolia*		✓				1900–2500	umf	3
6. *Daltonia semitorta*		✓				2100	umf	4
7. *Daltonia waniana*	✓	✓				1200–2500	lmf, umf	4
8. *Distichophyllum armatum*	✓					1000	lmf	5
9. *Distichophyllum brevicuspes*	✓					1300–1400	lmf	5
10. *Distichophyllum collenchymatosum*	✓			✓		1300–2540	lmf, umf	3
11. *Distichophyllum cuspidatum*	✓					940–1530	lmf	3
12. *Distichophyllum jungermannioides*	✓					940–1500	lmf	3
13. *Distichophyllum mittenii*	✓			✓		60–1400	lef, lmf	2

Taxa	Microhabitats					Elevations (m)	Forest types	Phytogeography
	C	R	E	S	T			
14. *Distichophyllum nigricaule* var. *nigricaule*				✓	✓	560–1480	lef, lmf	3
15. *Distichophyllum nigricaule* var. *cirratum*				✓	✓	560–1400	lef, lmf	3
16. *Distichophyllum nigricaule* var. *elmeri*				✓	✓	740–1700	lef, lmf	3
17. *Distichophyllum obtusifolium*				✓		1500	lmf	3
18. *Distichophyllum osterwaldii*				✓		1480	lmf	3
19. *Distichophyllum schmidtii*	✓			✓	✓	60–1600	lef, lmf	5
20. *Distichophyllum spathulatum*				✓	✓	700–1440	lef, lmf	3
21. *Distichophyllum subnigricaule*				✓		700	lef	3
22. *Distichophyllum tortile*				✓		340–1400	lef, lmf	3
23. *Ephemeropsis tjibodensis*		✓	✓			50–1700	lef, lmf	2
24. *Leskeodon maibarae*				✓		1000–2520	lmf, umf	3

5.5 Phytogeography

The comparing to neighboring countries or regions, the members of Daltoniaceae, found in Thailand have been recorded from adjacent countries, *viz.* India, China, Japan, Vietnam, Philippines, Malaysia, Borneo, Sumatra, Sulawesi, Micronesia, and Australia. The number of taxa from the neighboring countries shared with Thai Daltoniaceae and the percentages of Similarity Index was summarized in Table 5.2. The Daltoniaceae in Thailand is most similar to Malaysian species by 71.79 % of Similarity Index and it is also similar to species from China by 69.76 %. They are less similarity in Australia, Micronesia and Sulawesi by 10.53%, 8.33 % and 8%, respectively. The Similarity Index supported that species composition of Thai Daltoniaceae has been affected by the flora of neighboring countries. Moreover, this result shows an overlapping zone of the species distributed from both the Sino-Himalayan and Malesian floristic regions.

Table 5.2 Daltoniaceae taxa recorded in neighboring countries, number of taxa shared with Thai Daltoniaceae, and Sørensen's Similarity Index.

Country/ regions	Number of taxa recorded	Number of taxa shared with Thai Daltoniaceae	Sørensen's Similarity Index (%)
India (Gangulee, 1977; Dandotiya *et al*., 2011; Alam *et al*., 2015)	24	11	47.82
China (Lin & Tan, 1995, 2002; Redfearn *et al*., 1996; Ho, 2013)	21	15	69.76
Japan (Noguchi, 1991)	6	3	21.43
Vietnam (Ninh, 1981; Ho *et al*., 2015)	7	3	20.69
Philippines (Bartram, 1939; Tan & Robinson, 1990)	27	13	53.06
Malaysia (Mohamed & Robinson, 1991)	17	14	71.79
Borneo (Noguchi & Iwatsuki, 1972; Touw, 1978; Akiyama & Suleiman, 2015)	29	13	50.98
Sumatra (Ho *et al*., 2006)	13	8	45.71
Sulawesi (Gradstein *et al*., 2005)	3	1	8
Micronesia (Smith, 1976)	2	1	8.33
Australia (Streimann, 1999; 2000)	16	2	10.52

Twenty-two species and three varieties of Daltoniaceae in Thailand can be divided into six phytogeographical groups based on their geographical ranges (Fig. 5.2; Table 5.3).

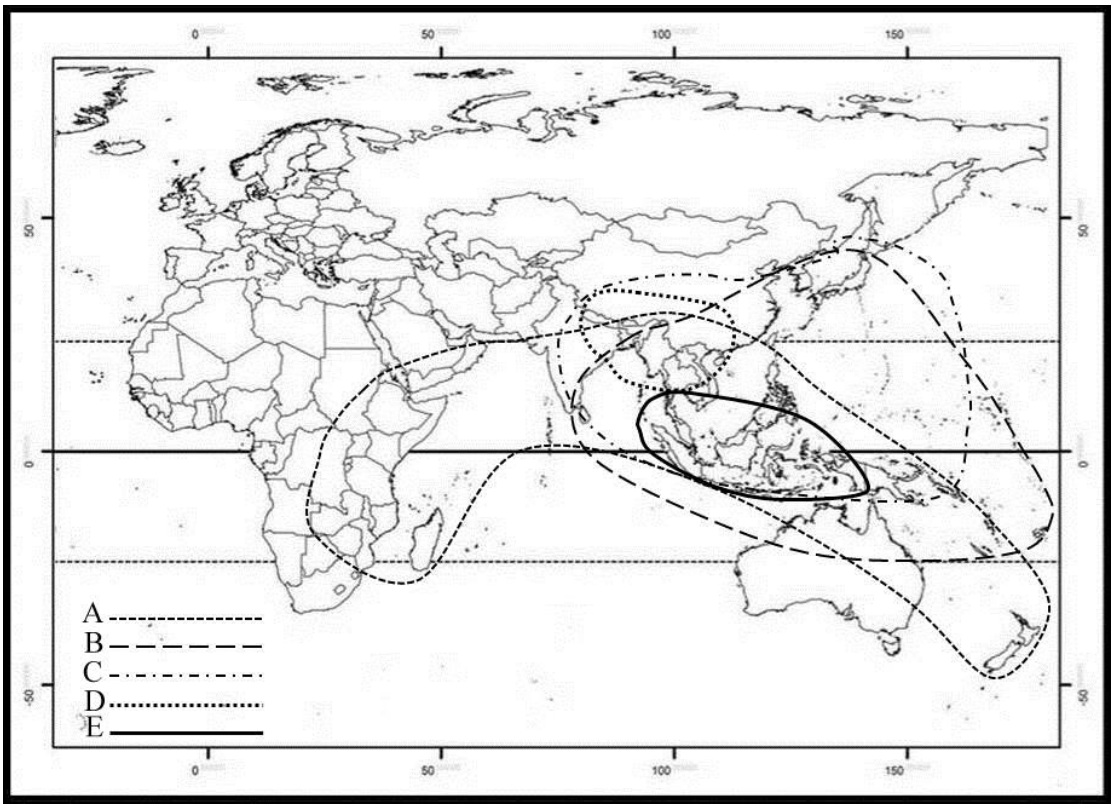

Figure 5.2 The distribution patterns of Daltoniaceae species in Thailand. A. Paleotropical (Africa–Asia Tropical–Australasia). B. Asia Tropical and Subtropical–Australasia– Pacific. C. Asia Temperate–Asia Tropical. D. Himalayan region. E. Malesian region.

Table 5.3 Number of Daltoniaceae taxa per phytogeographical groups in Thailand.

Distribution type	Number of taxa	Percentage (%)
1. Paleotropical (Africa–Asia Tropical–Australasia)	1	4
2. Asia Tropical and Subtropical–Australasia–Pacific	2	8
3. Asia Temperate–Asia Tropical	14	58
4. Himalayan region	4	17
5. Malesian region	3	12
Total	24	100

1. Paleotropical (Africa–Asia Tropical–Australasia)

This group includes only *Daltonia angustifolia* widely distributed species ranging from Africa (Central Africa, Madagascar), Nepal, Sri Lanka, Thailand, Malaysia, Vietnam, Indonesia (Borneo, Java), Philippines, and New Zealand. The widespread distribution of this species is probably due to the small plant size. In addition, their ability to produce sporophytes and spores may increase the probability of successful long-distance dispersal. Regarding to maturity of size, the organism with a smaller final size always has a higher reproductive rate (Angilletta *et al*., 2004).

2. Asia Tropical and Subtropical–Australasia–Pacific

The species are distributed from Sri Lanka, Thailand, Indochina, Indonesia (Flores, Java, Kalimantan Timur, Papua, Sulawesi, Sumatra), Taiwan, Japan, Melanesia, Polynesia, Japan to Australia (Queenland). There are two species distributed throughout this region, i.e., *Ephemeropsis tjibodensis* and *Distichophyllum mittenii*. The adaptation ability, including the high reproductive rate by producing gemmae, and the ability to grow from the lowland to the montane forest may also be reasons to support wide ranges of both species.

3. Asia Temperate–Asia Tropical

The species are ranging from Indian Subcontinent, China, Indo-China, Eastern Asia, and southward to Malesia and Papuasia. This region contains the largest number of Daltoniaceae in Thailand (12 species and 3 varieties which are accounting for 58%). Daltoniaceae species which are distributed in this region mostly belong to genus *Distichophyllum* (except *Calyptrochaeta remotifolia*, *Daltonia aristifolia* and *Leskeodon maibarae*). Following the critical observation, several species trends to show the distribution patterns from Malaysia region distribute straight upwards in the northeastern direction to the Indochina (Cambodia, Laos, and Vietnam) and Southern China (Hainan and Taiwan). This phenomenon occurs probably due to the climatic data and forest type. However, there are some distribution patterns of species which range from Indonesia and Malaysia towards South China, but they cannot be found in Cambodia, Laos include central and southern of Vietnam. The occurring of disjunct distribution patterns in this case probably due to the lack of data collections.

4. Himalayan region

The species are distributed from the Himalaya area, India, South China, to northern Thailand. There are four species distributed throughout this region, i.e., *Calyptrochaeta spinosa*, *Daltonia apiculata*, *D. semitorta* and *D. waniana*. The northern part of Thailand seems to be the southernmost limited of these four species. As mentions above about the seasonal monsoons in Southeast Asia, and the northeast monsoon may influences the species from Nepal and mainland China spread southwards to the northern Thailand. Thus, it causes the new southern limits of species.

5. Malesian region

This region encompasses the Southeast Asia and the Peninsular Malaysia, extending as far east as Indonesia. Three species of Daltoniaceae can be found restricted in this region, i.e., *Distichophyllum armatum*, *D. brevicuspes*, and *D. schmidtii*. Based on historical distribution, Daltoniaceae species in this area trend to be distributed from Java and Sumatra upwards to the Malay Peninsula, Thailand, and the Philippines.

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List of Publication and Proceeding

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