การทบทวนอนุกรมวิธานของ *Dendrobium* Sw. หมู่ *Stachyobium* Lindl. (ORCHIDACEAE) ในประเทศไทย

นายภัทธรวีร์ พรมนัส

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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TAXONOMIC REVISION OF *Dendrobium* Sw. SECTION *Stachyobium* Lindl. (ORCHIDACEAE) IN THAILAND

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Botany
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Thesis Title	TAXONOMIC REVISION OF *Dendrobium* Sw. SECTION *Stachyobium* Lindl. (ORCHIDACEAE) IN THAILAND
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ภัทธรวีร์ พรมนัส : การทบทวนอนุกรมวิธานของ *Dendrobium* Sw. หมู่ *Stachyobium* Lindl. (ORCHIDACEAE) ในประเทศไทย (TAXONOMIC REVISION OF *Dendrobium* Sw. SECTION *Stachyobium* Lindl. (ORCHIDACEAE) IN THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร.มานิต คิดอยู่, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ดร.สมราน สุดดี, 195 หน้า.

ศึกษาอนุกรมวิธานของกล้วยไม้สกุลหวาย (*Dendrobium* Sw.) หมู่เอื้องข้าวตอก (section *Stachyobium*) ในประเทศไทยตั้งแต่ปี พ.ศ. 2558-2561 โดยศึกษาตัวอย่างสดในสภาพธรรมชาติเพิ่มเติมและตัวอย่างจากพิพิธภัณฑ์พืชต่าง ๆ ทั้งในและต่างประเทศ ได้แก่ BCU, BK, BKF, BM, C, CMUB, E, K, KKU และ QBG ได้สร้างรูปวิธานระบุชนิด บรรยายลักษณะทางสัณฐานวิทยา นิเวศวิทยาพืช ภาพวาดลายเส้น และข้อมูลการกระจายพันธุ์ พบว่าในประเทศไทยมีกล้วยไม้หมู่นี้ 24 แทกซา 21 ชนิด ในจำนวนนี้มีพืชชนิดใหม่ของโลก 2 ชนิด ได้แก่ เอื้องข้าวตอกเชียงดาว (*D. chiangdaoense*)และ เอื้องข้าวตอกมรกตอบฉันท์ (*D. obchantiae*) และคาดว่าน่าจะเป็นชนิดใหม่ของโลกอีก 2 ชนิด *Dendrobium* sp.2 และ *Dendrobium* sp.3 นอกจากนี้ยังมี 1 ชนิดที่คาดว่าน่าจะเป็นพันธุ์ใหม่ คือ *Dendrobium* sp.1 จากการตรวจสอบสถานภาพพืชพบเป็นพรรณไม้ถิ่นเดียวของไทย 7 ชนิด ได้แก่ *D. confinale*, *D. dixonianum*, *D. elliottianum*, *D. garrettii*, *D. gregulus*, *D. mucronatum* และ *D. proteranthum* และเป็นพืชหายาก 6 ชนิดคือ *D. cuspidatum*, *D. denudans*, *D. kanburiense*, *D. peguanum*, *D. perpaulum* และ *D. strongylanthum* มีพืช 1 ชนิดถูกลดหน่วยอนุกรมวิธานจากชนิดลงไปเป็นหน่วยอนุกรมวิธานพันธุ์ คือ *D. venustum* var. *delacourii* (Guillaumin) Promm., Kidyoo & Suddee, *stat. nov* มีพืช 5 ชนิดที่ได้ลดสถานะเป็นชื่อพ้องของพืชชนิดอื่น ได้แก่ *D. eserre* เป็นชื่อพ้องของ *D. dixonianum* ส่วน *D. nanocompactum* และ *D. wilmsianum* เป็นชื่อพ้องของ *D. compactum*, *D. kratense* และ *D. erostelle* เป็นชื่อพ้องของ *D. incurvum* ตามลำดับ ทั้งยังพบว่า *D. eriaeflorum* และ *D. monticola* ที่มีรายงานการพบในประเทศไทย ความจริงแล้วเป็นความเข้าใจผิด ปัจจุบันทั้ง 2 ชนิดยังไม่พบกระจายพันธุ์ในประเทศไทย

ศึกษาลักษณะทางกายวิภาคศาสตร์โดยการลอกผิวใบ ฝังพาราฟิน และกล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราด พบว่าลักษณะที่สามารถนำมาใช้ในการแบ่งกลุ่มและระบุชนิดพืชบางชนิด มี 5 ลักษณะ ได้แก่ ลักษณะของผิวเคลือบคิวทิน ชนิดของปากใบ รูปแบบการกระจายตัวของปากใบ ชนิดของไทรโคม และชนิดของผลึก

ศึกษาลักษณะสัณฐานวิทยาของเรณูโดยกล้องจุลทรรศน์แบบใช้แสงและกล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราด พบว่ารูปร่างของกลุ่มเรณูของหมู่เอื้องข้าวตอกมี 2 แบบ คือ รูปทรงรีและรูปทรงกลม ชนิดของเรณูเป็นแบบสี่ก้อนรวมกัน (tetrads) ไม่มีช่องเปิด (inaperture) ลวดลายบนผนังชั้นนอกเป็นแบบเกลี้ยง (psilate) รูปแบบของการเรียงตัวของเรณูเป็นกลุ่มเรณู มี 2 แบบ 1. แบนและเป็นร่องตื้น 2. พองและเป็นร่องลึก ลักษณะเหล่านี้ช่วยในการจัดกลุ่มพืชได้

ภาควิชา พฤกษศาสตร์ ลายมือชื่อนิสิต .....

สาขาวิชา พฤกษศาสตร์ ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

ปีการศึกษา 2560 ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

5872014823 : MAJOR BOTANY
KEYWORDS: STACHYOBIUM / ANATOMY / MORPHOLOGY / PALYNOLOGY

PHATARAVEE PROMMANUT: TAXONOMIC REVISION OF *Dendrobium* Sw. SECTION *Stachyobium* Lindl. (ORCHIDACEAE) IN THAILAND. ADVISOR: ASSOC. PROF.MANIT KIDYOO, Ph.D., CO-ADVISOR: SOMRAN SUDDEE, Ph.D., 195 pp.

Taxonomic revision of *Dendrobium* Sw. section *Stachyobium* Lindl. in Thailand has been conducted from 2015–2018 based on natural habitats observation in Thailand as well as various herbaria visits, *i.e.* BCU, BK, BKF, BM, C, CMUB, E, K, KKU and QBG. Key to species, taxonomic descriptions, ecological data, illustrations and geographical distribution of all taxa are provided. Twenty four taxa with including 21 species and 3 varieties were recognized. Among these, two species namely *Dendrobium chiangdaoense* and *D. obchantiae* are new to Thailand and two species viz. *Dendrobium* sp.2 and *Dendrobium* sp.3 are being proposed as new species. Besides, *Dendrobium* sp.1 is also being proposed as new variety. Plant status was investigated, 7 species, *i.e. D. confinale, D. dixonianum, D. elliottianum, D. garrettii, D. gregulus, D. mucronatum* and *D. proteranthum* are endemic to Thailand. In addition, 6 species viz. *D. cuspidatum, D. denudans, D. kanburiense, D. peguanum, D. perpaulum* and *D. strongylanthum* are also rare species. One taxon namely *D. delacourii* is reduced from species to the rank of variety under the name *D. venustum* var. *delacourii* Promm., Kidyoo & Suddee, *stat. nov*. Furthermore, five names are recognized as synonyms. *D. eserre* is reduced to synonym of *D. dixonianum*, *D. kratense* and *D. erostelle* are reduced to be synonyms of *D. incurvum*. The other two names, *D. nanocompactum* and *D. wilmsianum* are reduced to be synonyms of *D. compactum*. Two species namely *D. eriaeflorum* and *D. monticola* were record from Thailand. In fact, they were misidentified and are not found in Thailand.

The leaf anatomical characters were examined by using epidermal peeling, paraffin embedding and scanning electron microscope (SEM). The results indicated that 5 significant anatomical characteristics for species grouping and identification of some species are cuticular ornamentations, type of stomata, distribution of stomata, type of trichomes and type of inclusions.

The palynological study by unacetolyzed pollens were investigated under light microscopy (LM) and scanning electron microscopy (SEM). The pollinia shape of the *Stachyobium* can separate into 2 types, *i.e.* obliquely ellipsoid and globose. Pollen of most species are tetrad, inaperture and the exine sculpturing are psilate. Furthermore, the degree of surface sculpturing (pitting) can be categorized into 2 types, *i.e.* 1. flattened and shallowly grooved and 2. convex and deeply grooved. These characters are useful for species grouping.

Department:	Botany	Student's Signature	.....
Field of Study:	Botany	Advisor's Signature	.....
Academic Year:	2017	Co-Advisor's Signature	.....

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CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF PLATES

CHAPTER I

GENARAL INTRODUCTION

The largest family of monocotyledon plant is Orchidaceae, which has been estimated with about 25,000−35,000 species in 796 genera, widely distributed throughout the world, especially in the tropical and subtropical zones (Dressler, 1993). They show wide range of diversity in habitats, forms, colours and sizes. In Thailand, 1,200 species with 176 genera of wild orchid were discovered and enumerated. Among these, at least 170 species are endemic to Thailand. In addition, the horticulturalists have still cultivated hybrid orchids more than 100,000 varieties up to now (Thaithong, 1999). This family has significant importance with human in many ways:

Use as food

Many of orchids are important as food such as *Vanilla planifolia* and related species are the cultivated as agriculturally valuable crop. The mature pods are steamed and fermented in order to make perfumery agents for widely used in confectionery, beverage, and sweet foods (Kalimuthu *et al*., 2006). In Australia, many orchid bulbs are consumed as food by Australian Arborigines for instance, *Dendrobium speciosum*, *Caladenia* spp. and *Gastrodia sesamoides* (holomycotrophic orchid). Whereas, *Diuris muculata* has sweet-tasting tubers. In Europe, The tubers of *Orchis mascula*, *O. maculata* and *O. latifolia*, which are terrestrial orchids widely distributed across Europe, western Asia and northern Africa, are used for nutritious drink that known as "Salep or Saloop" (Bulpitt, 2005).

Use as traditional medicine

So far, a number of orchids have been used as the herbal drugs. The famous ancient human civilization of world is the Chinese civilization, they have well-flourished healthy system. The most important drug in China is "Shihu", which made from several stem of *Dendrobium* species. It is used to relieve rehydration, anti-pyretic, and indigestion (Bulpitt, 2005). In America, *Vanilla* is used medicinally as an aphrodisiac, to relieve nausea, fevers and gastric complaints (Shiha *et al*., 2008). Furthermore, the native people in South-Eastern Thailand have used the whole plant of *Habenaria humistrata* to relieve the pain from insect bite. Roots of *Cymbidium ensifolium* is used to anti-nephropathy (Chuakul and Boonpleng, 2004).

Tradition and culture

Orchids have been associated with cultural values in several countries. For example, in the past of Thailand, *Dendrobium scabrilingue* was a forbidden object for native people in Mae Hong Son. It was used as the tribute that occupant of Mae Hong Son's territory must pay annually to the governing leader of Chiang Mai (Thaithong, 2000). Nowadays, women in northern Thailand usually use the flowers of

D. scabrilingue for hair decorating and for giving respect to the Lord Buddha (Whatthana and Pederson, 2008).

Moreover, in the Shan State, Myanmar, people offer the flowers of *D. chryseum* (the golden flower) to Lord Buddha for bringing health and happiness to their family during New Year's day celebration (Tanaka, 2003).

Classification and taxonomic features of family Orchidaceae

In 2016, the Angiosperm Phylogeny Group recognized this family in order *Asparagales* (APG IV, 2016).

Kingdom: Plantae
Division: Magnoliophyta
Class: Liliopsida
Clades: Angiosperms
Clades: Monocots
Order: Asparagales
Family: Orchidaceae

1.1 Classification of family Orchidaceae

This family has been divided into 5 subfamilies based on data from morphology, molecular, anatomy, genetics, palynology, phylogeny, evolution, ecology and paleobotany etc. (Dressler, 1993; Pridgeon *et al.*, 1999);

1.1.1 Apostasioideae

The apostasioid orchids are the most primitive group of this family. Generally, all species of subfamily are small or large terrestrial orchids, roots are swollen and simple rhizodermis, stems are usually erect or ascending, branched or simple. Leaves spirally arranged and plicate, herbaceous to papyraceous. Inflorescence raceme or simple, which develop in the terminal of shoot, erect or pendent. Flowers are also regular and spirally arranged, small to medium-sized, white, yellow or deep yellow. Sepals 3, free, midrib forming a thick ridge on the outside terminating in a subulate cusp below the incurved apical margin. Petals 2, free. Labellum similar to sepals and petals. Stamens are 2 or 3 functional anthers in their flower. Column straight to strongly curved. Ovary cylindrical or ellipsoid, usually 3 locule. Capsule thin-walled or fleshy, 3-locular; seeds very numerous, ovoid to elliptic. They consist of two genera, *Neuwiedia* and *Apostasia*.

1.1.2 Cypripedioideae

Terrestrial, lithophytic and epiphytic. Rhizomatous herbs; roots are usually succulent, fibrous and long, rhizome is short or elongate. Shoots often unbranched, short to long, erect and clustered. Leaves one to several, succulent and coriaceous, plicate or conduplicate. Inflorescence is simple or raceme, which develop in the terminal of shoot. Flower is mostly showy, concolorous or bicoloured; pedicel is obscure to short. Dorsal sepal is erect to hooded over lip. The prominent morphology is lateral sepals, which are combined at apex and forming into a synsepal. Petals usually free, flat, inflexed or reflexed. Labellum is usually pounded, in genus *Paphiopedilum* or the common name is slipper orchids, lip forming a saccate as a trap for pollinators. Column is short, stalked and porrect; anthers two, bilocular, borne on short obtuse to acute filaments; pollen powdery or viscid; staminode located at the apex of the column and forming into shield-like organ. While two fertile anthers are placed on eitherside of the column. Capsule erect or pendent, three-ribbed, cylindrical to ellipsoidal. This subfamily comprises five genera namely, *Paphiopedilum, Cypripedium, Mexipedium, Selenipedium* and *Phragmipediumand*.

1.1.3 Orchidoideae

Most of species in orchidoid orchids are terrestrials with fleshy rhizomes or root tuber, rarely epiphyte or holomycotrophic. Leaves are simple, spiral and sessile, one to many. Inflorescence is simple or raceme on the terminal of shoot, erect or nodding, one- to several flowers. Flowers are small to large, usually resupinate, flat to tubular, often showy, green, white, yellow, pink, purple or red; pedicel is usually short, often obscure. Dorsal sepal is free or often adnate to the petals to form a hood over the column. Lateral sepals are usually free, sometime connate and oblique at base to form a spur-like mentum, rerely connate to the base of column. Petals are often adnate to dorsal sepal. Labellum is the lowermost in flower usually deflexed, entire, three-or five-lobed, occasionally callose or with two basal gland, spur is saccate at the base, Column basifixed, rarely adnate to the other floral segments at the base, erect or decumbent, anther bilocular, longer than or as long as the rostellum; pollinia two or four, sectile, attached by short to elongate caudicles to one or two viscidia; staminodes two, sessile or stalked, stigma entire or two-lobe, sessile or stalked; rostellum usually two- or three-lobed, shorter than or as long as the anther. Ovary distinct, glabrous or less frequently hairy and glandular.

1.1.4 Vanilloideae

Terrestrial, perennial, monopodial or sympodial orchid, sometimes achlorophyllus, root elongate, typically fleshy, fibrous or swollen into tubers. Stem upright, grabrous, sometime elongate and climbing. Leaves one or many, alternate or whorled, often fleshy or coriaceous. Inflorescence a single terminal flower, terminal or axillary

raceme, or panicle. Flower is mostly showy, resupinate, variably fragrant. Sepals are free, glabrous or externally pubescent, mostly fleshy and spreading, yellow, white, green, pink, or brown. Petals are free, glabrous, fleshy or membranaceous, spreading or incurved. Labellum is free or fused with column, forming a floral tube, simple or more often trilobed. Column is usually slender, glabrous; stigma usually emergent; rostellum often acute and bent forward; column apex is frequently hooded; anther terminal, hyperincumbent, mobile; pollen is mostly loose, shed in monads, sometime tetrad or rarely forming true pollinia without accessory structure. Ovary unilocular or trilocular. Fruit is capsule or rarely a fleshy and indehiscent berry.

1.1.5 Epidendroideae

The epidendroid orchids are the largest group in family Orchidaceae. Epiphyte, lithophyte, terrestrail, rarely myco-heterotrophs, monopodial or sympodial orchid. Roots are often have velamen, aerial roots are generally cylindrical or flatterned. Rhizome is usually stout, creeping and elongate. Pseudobulbs are usually present, one- to several-noded, swollen or not swollen, usually covering with leaves sheaths. Leaves one to several, distichous or alternate, often fleshy or coriaceous. Inflorescence lateral, terminal, axillary raceme or panicle. Flowers one to many, mostly showy, resupinate, variably fragrant. Sepals are free, glabrous or externally pubescent, mostly fleshy and spreading, orange, yellow, white, green, pink, red, or brown, lateral sepals are often oblique. Petals are free, elliptic or oblong to linear-lanceolate, glabrous, usually thinner than sepals, spreading or incurved. Labellum is usually dominant, simple to strongly trilobed, smooth to variously pilose, spur present or lacking. Column is usually curved, glabrous, sometimes with wing-like lateral auricles or wing; stigma is usually emergent; column shorter than foot; anther terminal, hyperincumbent, mobile; pollen is mostly packed, two, four or eight. Ovary is often curved, glabrous, somewhat waxy with 6-grooved. Fruit is capsule or rarely a fleshy, indehiscent berry.

1.2 General habit of family Orchidaceae

Habit

The members of this family can be found in several habitat such as on sphagnum cushions in bogs, on the branches of tree, in floating vegetation in calcareous fern or dune slacks, on the rock near the summits of tropical mountains, in marshy areas and even on the margins of deserts. However, the majority of habit in family orchids can be divided into 4 types as follow

1.2.1 Terrestrial orchid: this type is often distributed in temperate regions, especially in Europe and Chile. In Thailand this type can be found throughout the country. In deciduous dipterocarp-oak forest or pine-deciduous dipterocarp forest, the

genera *Habenaria, Cymbidium, Pecteilis, Peristylus, Brachycorythis, Anthogonium, Pachystoma* and *Eulophia* were found on the forest floor.

1.2.2 Epiphytic orchid: the second type is very dominant in the tropics and subtropics regions. The genera *Dendrobium*, *Bulbophyllum*, *Coelogyne*, *Aerides*, *Eria*, *Vanda* and *Hygrochilus* can be found on the branches or trunks of tree in dry dipterocarp forest, hill evergreen forest and oak-pine forest.

1.2.3 Lithophytic orchid: they are usually growing on exposed rocks and cliffs. Most of the members in this group have strong roots that burrow into small fissure and absorb humidity, nutrients and organic debris. The leaves and pseudobulbs are often quite fleshy. Some species such as *Phalaenopsis pulcherrima, Eria lasiopetala* and *Bulbophyllum dayanum* are growing on boulder throughout Thailand.

1.2.4 Aquatic orchid: the last type is minor group. In Thailand, *Epipactic flava, Papilionanthe hookeriana,* and *Dipodium paludosum* can be found in floating vegetation and the edges of streams or lakes.

1.3 Classification and taxonomic history of *Dendrobium* Sw.

The genus *Dendrobium* Sw. was established in "Nova Acta Regiae Societatis Scientiarum Upsaliensis" by Olof Swartz (1799). This name came from 2 Latin words "*Dendros* = tree" and "*Bios* = life". Therefore, *Dendrobium* is referred to plants that are living on a tree (epiphytic). The type species is *Dendrobium moniliforme* (L.) Sw., which was originally described by Linnaeus in 1753 as "*Epidendrum moniliforme*". Nowadays, this genus is recognised within the tribe *Malaxideae*, subtribe *Dendrobiinae* in family Orchidaceae (Chase, M. W. *et al*., 2015) as follow:

Family: *Orchidaceae*

Subfamily: *Epidendroideae*

Tribe: *Malaxideae*

Subtribe: *Dendrobiinae*

Genus: *Dendrobium*

The genus *Dendrobium* can be separated from other genera in subtribe *Dendrobiinae* by having the flowers with 4 bright yellow pollinia in 2 pairs, each pollinium, narrowly ellipsoid, without caudicle and visidium (naked pollinia), memtum or chin is combined between the column foot and base of lateral sepals. Labellum or lip is divided into a claw and lamina, with the claw fused to the base of column foot.

Flowers are usually showy and fragrance, green, white, yellow, orange, pink, purple or red, except for pure blue and ultraviolet, single or racemose at subterminal or arising from upper part of current year's leafy stem (Figures 1.1).

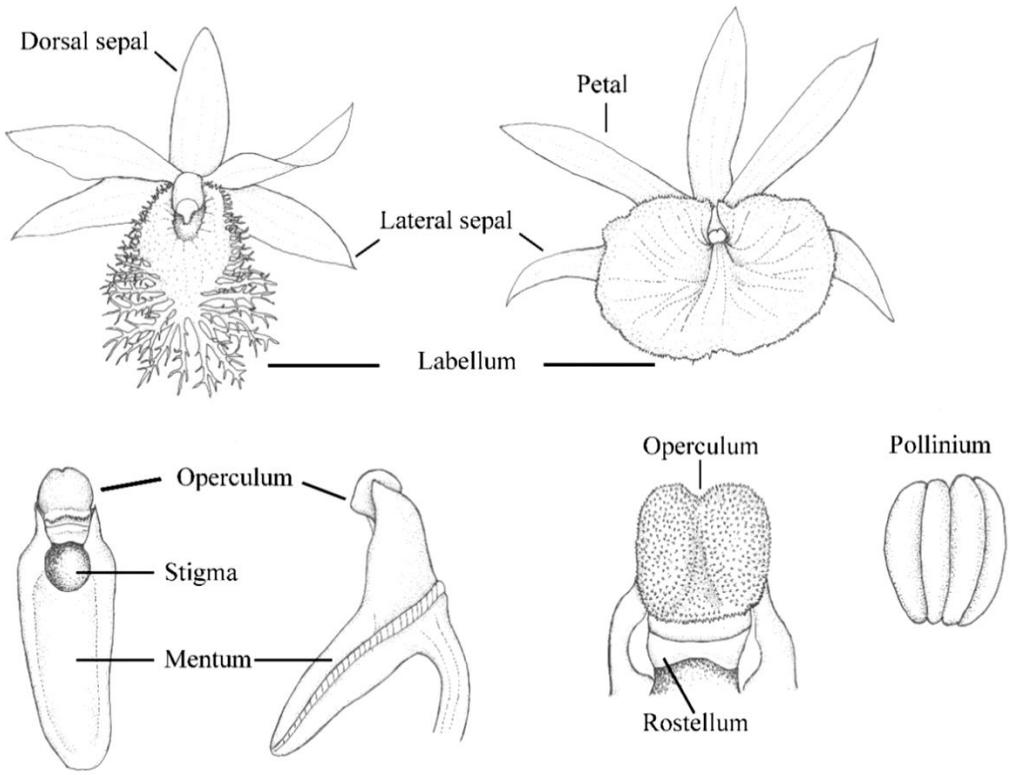


Figure 1. 1 The morphological structure of genus *Dendrobium* Sw.
Drawn by P. Prommanut.

1.4 Distribution of *Dendrobium* Sw.

This genus comprises approximately 1,500 species worldwide, distributed mainly in tropical and subtropical regions of mainland Asia and Australia, from the Himalayas to India, Nepal, Bhutan, Myanmar, China, Japan, Taiwan, Laos, Vietnam, Thailand, Cambodia, Malesian region, New Guinea, eastern Australia and the Pacific islands. They grow in habitats ranging from semi-desert to rainforest, from the hot steamy lowlands of Borneo to the cooler seasonal climates of the Himalayan foothills and the year-round cool moist conditions in the Central Ranges of New Guinea, where they have been reported at altitudes up to 3,800 m alt. (Cribb and Govaerts 2005, Garay and Sweet 1974, Lavarack *et al*. 2002, Pearce and Cribb 2002, Seidenfaden 1985, Wood 2006) (Figure 1.2).

Figure 1. 2 Distribution map of *Dendrobium* Sw. Drawn by P. Prommanut.

1.5 Literature reviews

Taxonomic history the section Stachyobium

Lindley (1844) established section *Stachyobium* in the first time in his unfinished division of *Dendrobium*. He divided genus *Dendrobium* into 4 sections, *i.e. Eudendrobium, Stachyobium, Ceratobium* and *Padilonum*. The *Stachyobium* distinguished by slender stems, thin and flat leaves, racemes inflorescence. Twenty-five species were listed in this section; *D. denudans*, *D. alpestre* (synnomym of *D. monticola*), *D. cuspidatum, D. microbolbon* and *D. pygmaeum* (synonym of *D. peguanum*) except *D. aduncum, D. formosum, D. rhombeum, D. fimbriatum, D. polyanthum, D. moschatum, D. calcaratum, D. flavescens, D. nudum, D. ramosum, D. herbaceum, D. mutabile*, D. *sclerophyllum, D. auriferum, D. barbatulum, D. lancifolium, D. bicameratum, D. elongatum, D. bicolor* and *D. catenatum,* which are not true member of this section in today.

In 1851, he published "The transparent Dendrobe (Dendrobium Transparens)". He divided *Dendrobium* into 10 sections. The section *Stachyobium* was described in Latin such as: "Folia plana, Labellum nec plumosum nec pectinatum, a. Caules elongati undique foliosi, Flores racemosi, Petala nana, Labellum brevius, dilatatum ". He recorded 30 taxa to the section, the section was divided into 2 divisions by observing the differences in the form of the lip.

In his more complete system (1859), he published "Contributions to the Orchidology of India volume 2". He maintained this arrangement with the same number of taxa. Thirteen species were listed in this section but only 8 species are true Stachyobium, *i.e. D. incurvum, D. porphyrochilum, D. eriaeflorum, D. pycnostachum, D. microbolbon, D. denudans, D. peguanum* and *D. sarcanthum* (synonym of *D. cuspidatum*).

1.6 Taxonomic literature reviewed for the section *Stachyobium* Lindl. in Thailand.

In Thailand, the most important taxonomic studies of Thai orchids were researched by Seidenfaden, who was Danish ambassador of Thailand. Between 1956-1959, he collaborated with T. Smitinand, who was a botanist from The Royal Forest Department of Thailand, to arrange orchid collecting expeditions throughout Thailand.

In 1959, they published "The Orchids of Thailand: A Preliminary List", and the description of section *Stachyobium* appeared in "The orchids of Thailand: A Preliminary List, part II, 2" (Seidenfaden and Smitinand, 1959). Thirteen species were listed in this subsection namely *Dendrobium delacourii* (= *D. venustum* var. *delacourii*), *D. trinervium* (not *Stachyobium*), *Dendrobium* sp. GT 1551 (unidentified), *D. bicameratum* (not *Stachyobium*), *D. viridulum* (not *Stachyobium*), *D. compactum*, *D. eriiflorum* (as *D. eriaeflorum*), *D. incurvum*, *D. alpestre* (a synonym of *D. monticola*), *D. confinale*, *D. kratense* (a synonym of *D. incurvum*), *D. dixonianum* and *D. wilmsianum* (synonyms of *D. compactum*). The most important of Seidenfaden's numerous works on Asiatic orchids are the series of "Orchid Genera in Thailand I-XIV", which are still the most important works for Thai orchid identification. The first volume of these series was published in 1975. The genus *Dendrobium* was published in volume XII (Seidenfaden, 1985). In this work he divided *Dendrobium* into 14 sections including section *Stachyobium*. The section is characterized by the presence of small and often tufted plant, stems of rather few internodes, inflorescences subterminal or lateral and raising in an acute angle to stem, usually with many small flowers on the rather long scape and rachis. The other important works of Seidenfaden are the works under the series "Contribution to the Orchid Flora of Thailand" volume 1-13 which were published, during 1969-1997 (Larsen, 2001).

The later taxonomic works on Thai orchids were mostly reported by botanists who worked in some specific areas. The examples of some accounts relevant to *Dendrobium* section *Stachyobium* are as follow.

Thaithong (1999) provided a list of orchid species in Thailand together with their localities based on Seidenfaden's works from 1959 to 1997. In 2000, she published her own orchid book with species descriptions and colour photographs of orchids from throughout Thailand. Members of *Dendrobium* section *Stachyobium* were included in both publications.

Boonjaras (2002) carried out taxonomic work on flowering plants in Pha Taem National Park, Ubon Ratchathani Province. He reported 28 species under 14 genera of Orchidaceae. Four species were reported under *Dendrobium*, and one of them *D. delacourii* (= *D. venustum* var. *delacourii*) belongs to section *Stachyobium*.

Boonkerd *et al.* (2003) conducted vascular plant exploration at Khun Korn Waterfall, Muang District, Chiang Rai Province. There were 77 species in 40 genera of Orchids reported. Thirteen species of *Dendrobium* were found, among these 3 species; *D. denudans, D. pycnostachyum* and *D. wilmsianum* (a synonym of *D. compactum*) belong to section *Stachyobium*.

In the same year, Suddee reported results from his taxonomic study on Orchidaceae in Pa Hin Ngam National Pak, Chiyaphum Province. Five species of *Dendrobium* were found, among these *D. compactum* member of the section *Stachyobium* was also found (Suddee, 2003).

Chantanaorrapint and Thaithong (2005) carried out a preliminary orchids study in Huey Yang Waterfall National Pak, Prachuap Khiri Khan Province. Forty-two species under 27 genera were found. Among these, *D. kanburiense* and *D. porphyrochilum*, members of section *Stachyobium*, were also found.

Pakum (2007) surveyed and studied orchids in Nam Nao National Pak, Phetchabun Province. He reported 40 species under 26 genera of Orchidaceae; 9 species of *Dendrobium* were found, among these 2 species; *D. delacourii* (= *D. venustum* var. *delacourii*) and *D. venustum*, members of section *Stachyobium* were also found.

Madaphong (2008) reported a result from his taxonomic study on Orchidaceae at Doi Phahom Pok National Park, Chiang Mai Province. Twelve species of *Dendrobium* were observed and *D. strongyanthum*, a species belongs to section *Stachyobium*.

Tokaew and Chantaranothai (2009) reported a result from a 2 years preliminary study of Orchidaceae in Nam Nao National Pak, Phetchabun Province. Fifty-six genera and 129 species were enumerated. There were 30 species of *Dendrobium* found and two of them, *D. compactum* and *D. venustum* belong to section *Stachyobium*.

Kasetluksamee and Ngernsaengsaruay (2010) studied and taxonomy of the genus *Dendrobium* Sw. at Khok Nok Kraba Area in Phu Luang Wildlife Sanctuary, Loei Province. Thirteen species were identified, including *D. compactum* and *D. proteranthum*, members of section *Stachyobium* are endemic and endangered plants of Thailand.

Markerd (2011) reported a result from his taxonomic study of Orchidaceae at Mae Wong National Park, Nakhon Sawan and Kamphaeng Phet Province. Sixty-two genera with 162 species were recorded. There were 25 species of *Dendrobium* found and four of these belong to section *Stachyobium* namely *D. compactum, D. delacourii* (= *D. venustum* var. *delacourii*), *D. denudans* and *D. porphyrochilum*.

Anuraktrakoon (2013) reported a result from diversity study on orchids in Phu Ruea Nation Park, Loei Province. Eighty-nine species within 45 genera and 3 subfamily were identified. There were 14 species of *Dendrobium* found. Among them, *D. compactum* belongs to section *Stachyobium*.

In the same year, Toonmal reported a result from his diversity study of Orchidaceae at Kaeng Krachan National Park, Phetchaburi Province. Ninety-five

species under 49 genera and three subfamily were found. There were 17 species of *Dendrobium* and one of them, *D. porphyrochilum* belongs to section *Stachyobium*. (Toonmal, 2013)

So far, the taxonomy of *Dendrobium* section *Stachyobium* in Thailand is still confused. Many of the species in these group are very similar and hard to distinguish. The details on the labellum such as the number of keel, side lobes and texture of margins must be carefully study in order to distinguish from similar species. In addition, some of the species be still proved to be present in Thailand. Thus, the taxonomic study of the *Stachyobium* in Thailand is needed to be revised.

1.7 Objective of the thesis

1.7.1 To explore a complete account of *Dendrobium* section *Stachyobium* in Thailand.

1.7.2 To clarify the taxonomic confusions of the section *Stachyobium* by using information from morphological, anatomical, palynological and ecological studies.

CHAPTER II
GENARAL MORPHOLOGY OF SECTION STACHYOBIUM

2.1 Introduction

In general, morphology provides highly reliable data for species identification, even though other data such as anatomy, cytogenetic, molecular biology have been developed by modern tool. In the past, family Zingiberaceae was recognized to have close relationship with the Orchidaceae based on differentiation of staminode to labellum. These two floral parts are comparable in position and form. Orchids, however, have their stamen and pistil combined to form a structure called a column, which is different from those of plants in the family Zingiberaceae. For Orchidaceae, labellum (resupinate or non-resupinate), pollinarium (numbers and types), shoot (monopodial or sympodial) and habit (epiphytic, lithophytic or terrestrial) are the important morphological characters used for identification. The genus *Dendrobium* is very large, comprising more than 1,500 species that are widely distributed throughout the world. Earlier taxonomists classified *Dendrobium* orchids into infrageneric ranks, *i.e.* section, subsection and subgenera, based on morphological, reproductive and distinguished vegetative parts. Over the past twenty years, six sections of the genus *Dendrobium* have been revised: *Microphytanthe* Schltr. (Reeve, 1983), *Latouria* (Blume) Miq. (Cribb, 1983), *Spatulata* Lindl. (Cribb, 1986), *Oxyglossum* Schltr. (Reeve and Wood, 1989), *Pedilonum* Blume (Dauncey, 2003) and *Formosae* (Benth. & Hook. f.) Hook. f. (Sathapattayanon, 2008).

Dendrobium section *Stachyobium* consists of c. 44 species distributed worldwide, mainly in tropical Asia and with center of diversity in Thailand (wood, 2006). The numbers of species are still unstable because of the discoveries of new species, especially from India and China. The following characteristics, small and tufted stems with rather few internodes, lateral or subterminal racemose inflorescences, several small flowers that usually arranged on a rather long scape and rachis, labellum with 1-3 keels or ornamentation on surface are traditionally used for circumscribing the section *Stachyobium*. Nevertheless, many members of the section are very similar and it is very difficult to identify them from aged type specimens in herbaria because the identification must be based on details on labellum (Seidenfaden, 1985).

2.2 General characters of *Dendrobium* section *Stachyobium* Lindl. in Thailand

2.2.1 Habit

Most species of *Dendrobium* section *Stachyobium* are epiphytic orchids. Nevertheless, some species can grow on the rock (lithophyte). *Dendrobium gregulus* and *D. elliottianum* are the examples of species which belong to this case (Plate 2.1B). They grow in several habitats, *e.g*. upper montane rain forest, pine forest, deciduous dipterocarp-oak forest, lower montane-oak forest, lower montane scrub and pine-deciduous dipterocarp forest (Plate 2.2). Furthermore, this section is restricted by specific ecological niche. They have adapted to a wide variety of habitats, from high altitudes; c. 2,565 m alt. in upper montane rain forest at Doi Inthanon, Chiang Mai Province (*D. garrettii*, *D. perpualum* and *D. porphyrochilum*) to lowland tropical forests, c. 20 m alt. in mangrove forest at Trat Province (*D. incurvum*). Some species are restricted to temperate and deciduous dipterocarp-oak forest, *e.g*. *D. peguanum* and *D. kanburiense*.

The growth habit of section *Stachyobium* is sympodial as in all other *Dendrobium* species. New shoots are produced every year.

Plate 2. 1 Habit of *Dendrobium* section *Stachyobium*. A. Epiphytic orchid (*Dendrobium strongylanthum*); B. Lithophytic orchid (*D.elliottianum*).

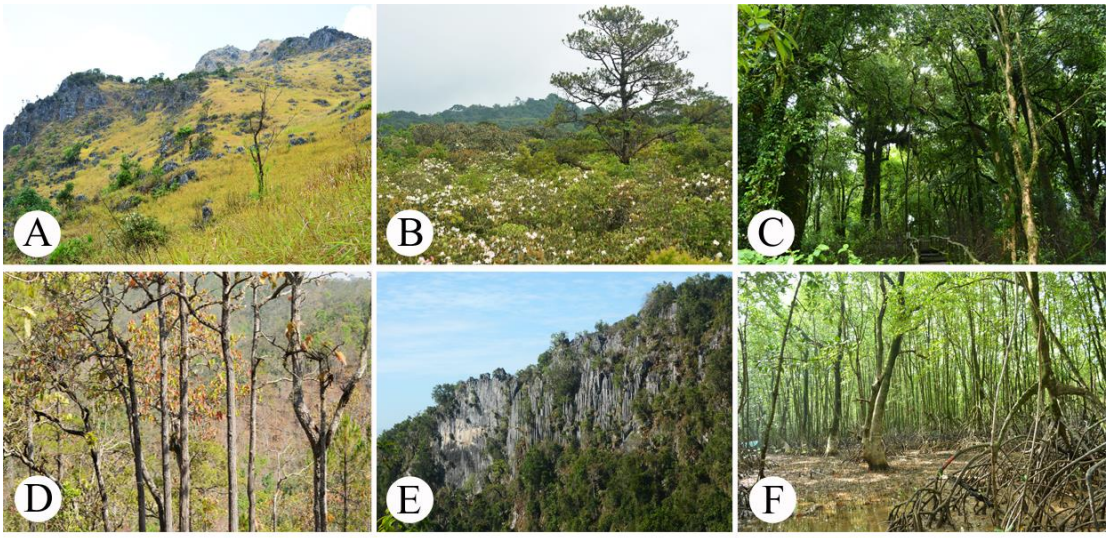


Plate 2. 2 The ecological habitat of orchids in the section *Stachyobium*: A. Upper montane forest (Doi Chiangdao, Chiang Mai Province); B. Lower montane-oak forest Phu Luang, Loei Province); C. Upper montane rain forest (Doi Inthanon, Chiang Mai Province); D. Pine-deciduous dipterocarp forest (Mae Sareinag, Mae Hong Son Province); E. Deciduous dipterocarp on limestone forest (Pha Nom Benja NP., Krabi Province); F. Mangrove forest (Makham, Chanthaburi Province).

2.2.2 Roots

Roots are generally cylindrical to flattened, slender, loosely branched or without branches, in clusters at the base of pseudobulbs. All species have a velamen, epidermis comprising several layers of cells which die as the root matures.

2.2.3 Significant stems

In most species the pseudobulbs are usually small and clustered, variable in shape. The distinguishable character of pseudobulb of the *Stachyobium* is that it is fleshy, erect or ascending with one to severally swollen internodes, usually constricted at base, covered with sheaths at leaf base, often turning yellow when dried. Certain species have orbicular or oval pseudobulbs such as *Dendrobium proteranthum*, *D. peguanum*, *D. gregulus* and *D. kanburiense*. On the other hand, some species have narrowly fusiform pseudobulbs, *i.e. D. compactum*, *D. confinale*, *D. denudans* and *D. strongylanthum*. Slender undilated pseudobulbs are also found in *D. venustum*, *D. incurvum* and *D. pycnostachyum* (Plate 2.3). The species with shortest pseudobulb in this section is *D. gregulus* (0.4–2 cm long, 3–4 mm in diameter) while *D. venustum* has the longest pseudobulb (12–40 cm long, 0.5–1 cm in diameter).

Plate 2. 3 Shape of pseudobulbs in the section *Stachyobium*. A. Orbicular or oval pseudobulbs in *Dendrobium gregulus*; B. Fusiform pseudobulb in *D. compactum*; C. Slender undilated pseudobulbs in *D. venustum*.

2.2.4 Leaves

The leaves of species in this section are simple and distichous, which is the typical situation in the majority of *Dendrobium*. Most species have close distichous leaves, for example *Dendrobium perpaulum*, *D. porphyrochilum*, *D. compactum* and *D. venustum* var. *delacourii*. Otherwise specie, such as *D. venustum* and *D. strongylanthum*, have distant distichous leaves.

Most species in these groups have 3 to 8 leaves, such as *D. venustum*, *D. denudans* and *D. incurvum*, but decreased leaf number is found in some species such as *D. proteranthum*, *D. gregulus* and *D. elliottianum.*

Leaves of all species are usually green, yellowish-green, dull green above, light green or pale green beneath, glabrous on both sides. The texture, shape, and size of leaves are variable. Most species in this section have chartaceous leaves such as *D. proteranthum* and *D. perpaulum*. However, *D. venustum* var. *delacourii*, *D. garretii* and *D. venustum*, have coriaceous leaves. The shape is usually varies from ovate, ovate-elliptic, elliptic, lanceolate, oblong, to oblong-lanceolate. The size ranges from small, 1-1.7 cm long, 0.3-0.5 cm wide in *D. dixonianum* to large, 5-13 cm long, 1.3-4 cm wide in *D. venustum*. The apex, base and margin are usually variable within this section. The leaf apex of most species are unequally bi-lobed. Otherwise resemble that of *Dendrobium* sp.1, which has acute leave. The leaf base is dilated into sheath. Furthermore, the leaf margin is entire for all species.

2.2.5 Inflorescence

The majority of the species in section *Stachyobium* have terminal or subterminal inflorescence, arising from the upper portion of stem or from upper part of current year's leafy stem. The type of inflorescence has significant value for identification. Two rather distinct types of inflorescence are found in this section.

2.2.5.1 Proteranthous: inflorescence develops on the top of vegetative shoot of which the leaves and the terminal internodes are not yet developed. In this stage, the base of shoot is covered with leaf sheath. After anthesis and during fruit setting, the leaves will develop from the base of pseudobulb. *D. proteranthum* is the only species found in this type (Plate 2.4:A).

2.2.5.2 Hysteranthous: inflorescence develops on the top of a fully developed pseudobulb with fully-grown leaves. Nearly all species in this section apart from *D. proteranthum* have hysteranthous inflorescences, for example *D. compactum*, *D. porphyrochilum* and *D. garretii* (Plate 2.4:B).

Generally, most species have raceme inflorescences with dense flowers on a rather long scape and rachis, bearing 10 to 40 flowers, for example *D. denudans* and *D. strongylanthum*, whereas only few species have lax, 2 to 5 flowers on the inflorescences, *e.g. D. kanburiense* and *D. obchantiae*. The longest inflorescence in this section is found in *D. venustum* (up to 23 cm long), while *D. peguanum* has the shortest inflorescence in this group (1.5–3 cm long).

Typically, plant in this section are mostly flowering on leaf-bearing shoot in the rainy season, for example, *D. porphyrochilum*, *D. perpualum* and *D.dixonianum*, However, some species, such as *D. gregulus*, *D. pychnostachyum* and *D. peguanum*, flower when being leafless in winter and summer.

Plate 2. 4 Types of inflorescence in section *Stachyobium*. A. Proteranthous in *Dendrobium proteranthum*; B. Hysteranthous in *D. garrettii*.

2.2.6 Flowers

The flowers of section *Stachyobium* are mostly small, fragrant, waxy, lasting for several days. The color is usually variable within the section, ranges from white in *D. compactum*, *D. cuspidatum* and *D. pycnostachyum*, whitish-pink in *D. peguanum*, dull pink in *D. elliottianum*, purplish-red in *D. denudans*, dull green in *D. pepualum*

and *D. kanburiense*, to bright yellow in *D. venustum* and *D. venustum* var. *delacourii*. In all species, the abaxial surface of sepals and petals are glabous.

2.2.7 Sepals

Generally, the sepals in most species within this section are similar in shape and size. The common shape of dorsal sepal is lanceolate, linear-lanceolate and narrow lanceolate, while falcate-lanceolate is found in all lateral sepals. Both lateral sepals and dorsal sepal have distinct keel on the abaxial surface. Sepal with truncate base and acuminate apex is the normal character found in the section *Stachyobium*. Interestingly, some species such as *D. venustum, D. venustum* var. *delacourii* and *D. porphyrochilum* have apex mucronate. Most species in this section have distinct 3– veins on dorsal and lateral sepals.

2.2.8 Petals

The distinctive petal shape of members of the section *Stachyobium* is linear-oblanceolate, which is the unique character and useful for identification (Plate 2.5). However, *D. venustum* is the only species which has linear-spatulate petal. All species have petal narrower and smaller than dorsal sepal. Petal apex is acute or acuminate. Petal base is truncate, which the common character is found in this group. Petal margin is usually entire and sometimes slightly undulate and twisted. *D. venustum* is the example. There are 3-5 visible veins.

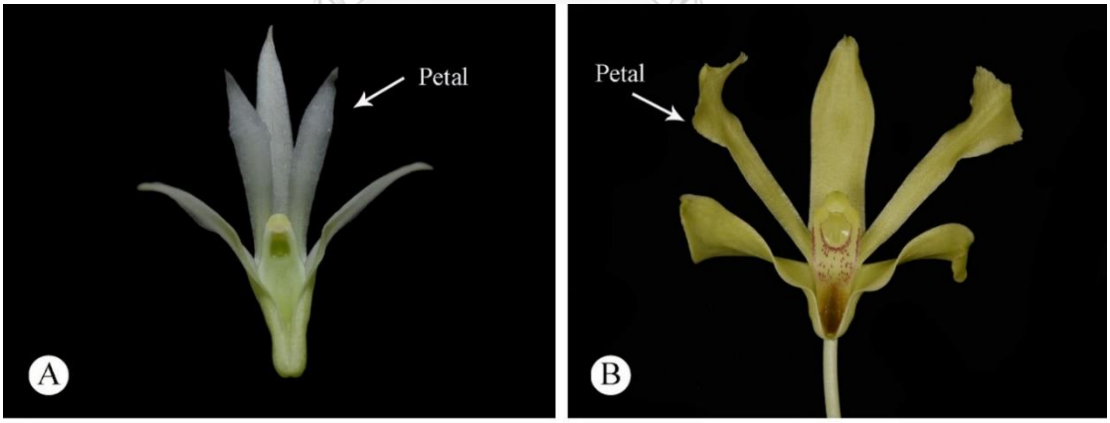


Plate 2. 5 Shapes of petals in section *Stachyobium*: A. linear-oblanceolate petal in *Dendrobium incurvum*; B. linear-spatulate petal in *D. venustum*.

2.2.9 Labellum or Lip

Labellum is the most important part for all species in the section *Stachyiobium*. Character of labellum is very useful for separating species in this section. The shape of labellum is vary from species to species. Two types of labellum are categorized as follow.

Type I: Labellum without side lobes. This type is found in *D. perpualum*, *D. porphyrochilum*, *D. proteranthum*, *D. incurvum* and *D. confinale* (Plate 2.6:A). This type is very rare in this section.

Type II: Labellum with side lobes. Most species belong to this type, for example *D. strongylanthum*, *D. denudans* and *D. garrettii* (Plate 2.6:B).

Plate 2. 6 Types of labellum in the section *Stachyobium*: A. Type I. Labellum without side lobes of *Dendrobium porphyrochilum*; B. Type II. Labellum with side lobes of *D. cuspidatum*.

In addition, the number of keels on labellum is beneficial for identification to species level. Three types of keel are categorized. Type I: Labellum with 1 keel, found in *D. compactum* (Plate 2.7:A). Type II: Labellum with 2 keels, found in 6 species, *i.e. D. gregulus*, *D. cuspidatum*, *D. elliottianum*, *D. perpualum*, *D. pycnostachyum* and *Dendrobium* sp.3 (Plate 2.7:B). Type III: Labellum with 3 keels, the common type, found in most species in section *Stachyobium* (Plate 2.7:C).

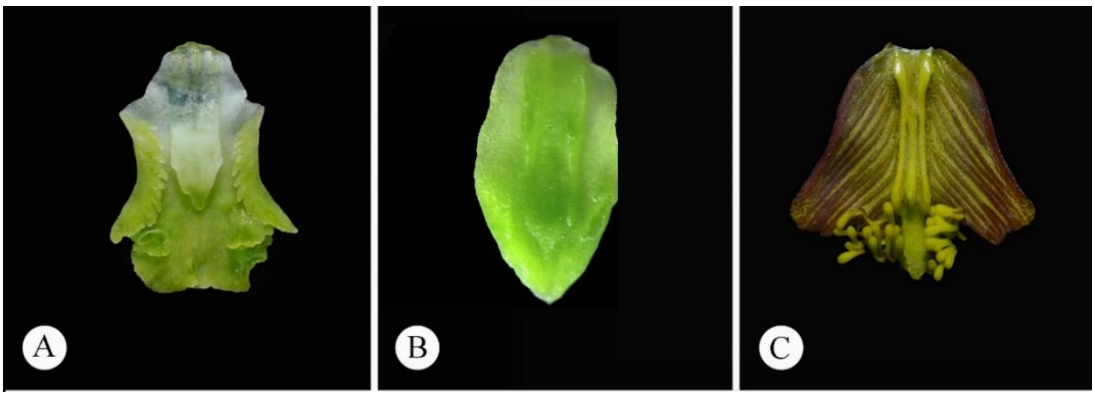


Plate 2. 7 Types of keel in section *Stachyobium*: A. Type I. One keel in *Dendrobium compactum*; B. Type II. Two keels in *D. perpualum*; C. Three keels in *D. venustum* var. *delacourii*.

Generally, the surface of labellum in this section is often smooth but in some species such as *D. compactum, D. porphyrochilum* and *D. strongylanthum* the surface is glandular-papillose. Labellum margin is varying from entire, sub-crenate, crenate-serrate to ciliate.

2.2.10 Mentum

Mentum in the section *Stachyobium* can be divided into 2 types as below:

- Type I. Broadly conical mentum (Plate 8:A) ; the mentum is very short and the edges of mentum are strongly developed to side wings. Only 4 species are found in this type namely *Dendrobium perpualum, D. kanburiense, D. proteranthum* and *D. porphyrochilum*.

- Type II. Narrowly conical mentum (Plate 8:B and C); the mentum is quite narrow from base to apex and the lateral sepals are longitudinally fused with each other, forming a spur-like structure. Most species of the section belong to this type, *e.g. D. peguanum, D. elliottianum* and *D. incurvum.*

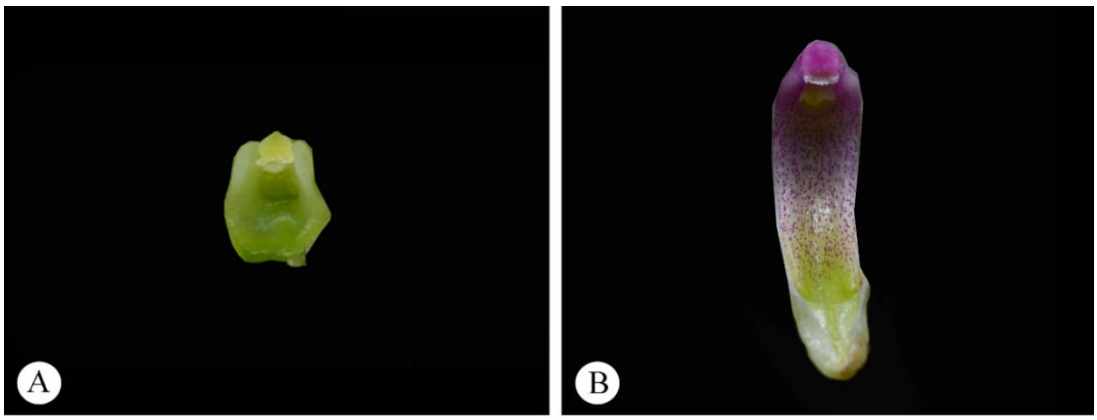


Plate 2. 8 Types of mentum in the section *Stachyobium*: Type I. A. Broadly conical mentum in *Dendrobium perpualum*; Type II. B. Narrowly conical mentum in *D. elliottianum*, respectively.

2.2.11 Ovary plus Pedicel

Normally, the ovary plus pedicel in this section is usually narrowly clavate, glabrous and somewhat waxy, with 6-longitudinal grooves. The shortest ovary plus pedicel is found in *Dendrobium perpualum* (0.8–1 mm long). In contrast, *D. venustum* has the longest ovary plus pedicel (1.8–2.1 cm long).

2.2.12 Fruits and Seeds

The fruits or termed “capsules” of this section vary from globose, ellipsoid, pear-shaped to obovoid. Surface of fruit composts of 6 obtuse keels, apex is often with persistent dried perianths. It will split or dehiscent when mature to shed dry seeds (Plate 2.9:A-B). The seed of *Stachyobium* species is similar as typical seed in the family Orchidaceae. The seeds have been called “dust seeds” due to their light weight and minute size. They usually lack endosperm. Seeds of all species are fusiform or oblong, covered with seed coat or cellular sheath. Seed coat ornamentation is reticulate (Plate 2.10:A-B).

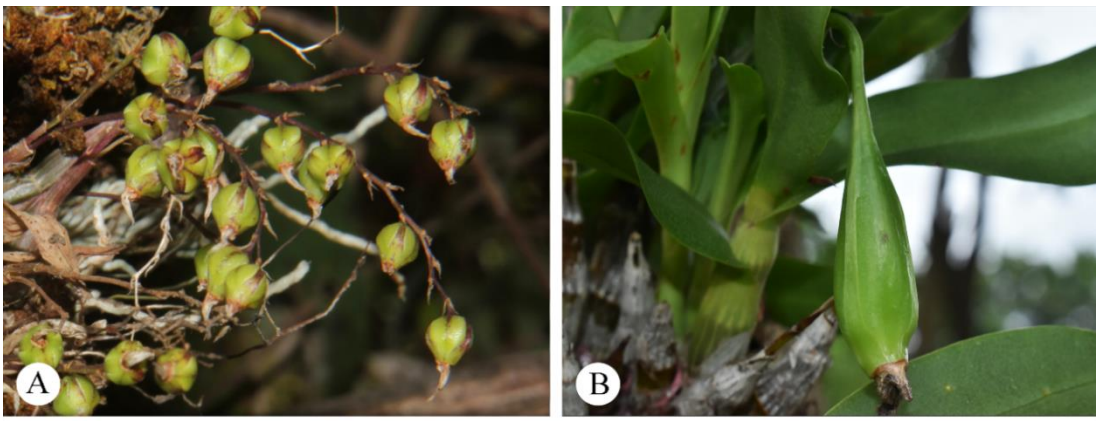


Plate 2. 9 Fruit shapes**:** A. Globose in *Dendrobium perpualum*; B. Ellipsoid in *D. venustum* var. *delacourii*, respectively.

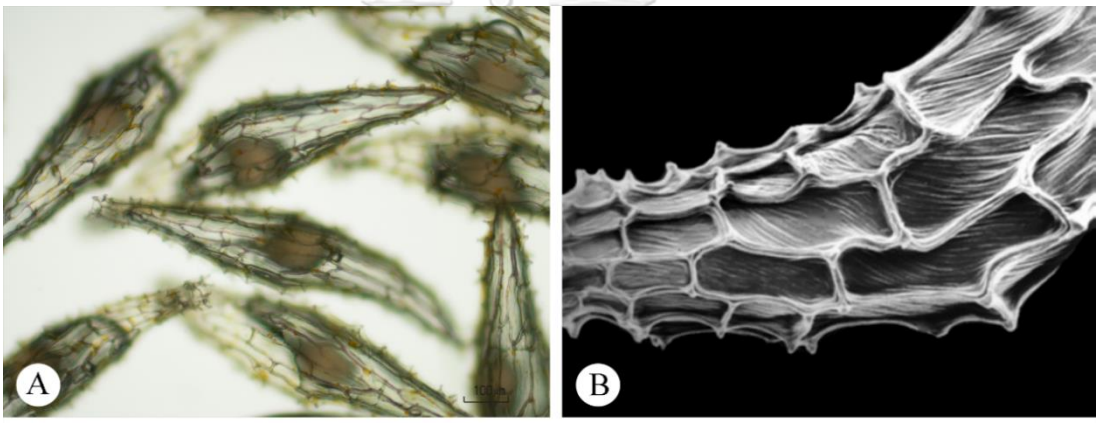


Plate 2. 10 *Stachyobium* seeds covered by cellular sheath (seed coat): A. *Dendrobium compactum*; B. SEM micrograph on seed of *D. venustum*.

2.3 General Conclusion

The section *Stachyobium* has true racemose inflorescence. Labellum is smooth or ornamented on inner surface. Both quantitative and qualitative data from reproductive and vegetative characters are very useful for identification and classification of *Dendrobium* section *Stachyobium* in Thailand.

CHAPTER III
ANATOMICAL STUDIES

3.1 Introduction

The data of anatomical characters on leaf surface have been widely used for identification and classification of plants, because they can provide important information to resolve problems (Stace, 1984). At times, anatomical study can be useful for plant determination in case that the reproductive organs are not mature or absent. Furthermore, the knowledge from vegetative anatomy enable better understanding of relationship between environment and plants, especially when these plant adapt special functions of morphology and anatomy to different environmental condition. The anatomical characters, *e.g.* trichome, type of stomata, types of crystals in leaf blade and number of palisade layers in leaf blade are greatly specific in flowering plant.

3.2 Literature review

Many scientists have attempted to examine a number of anatomical features and found these characteristics are beneficial for taxonomic classification. Anatomical study has proven its potential use and is mentioned in a lot of research as following.

In 1864, Bureau was the first botanist who applied the anatomical characters for grouping species belong to family Bignoniaceae.

Ahmad (1974) investigated the foliar epidermis and cuticle of 4 species in subfamily *Nelsonioideae* (Acanthaceae) viz. *Staurogyne longifolia*, *Elytraria acaulis* var. *acaulis*, *E. acaulis* var. *Iyrata* and *Nelsonia campestris*. He found that type of stomata, presence or absence of glandular hairs and cystoliths support the retention of *Nelsonioideae* as a subfamily of the Acanthaceae rather than its transfer to the Scrophulariaceae.

Koller and Rost (1988) examined forty-nine taxa of leaf anatomy in genus *Sansevieria* (Agavaceae) and they found leaf form of this genus depends on degrees of xeromorphic characteristics, including of cuticle thickness, stomatal depth, fiber content and fiber cell development. In addition, mesophyll in all species is divided into an outer region of chlorenchyma and a central region of colorless water-storage tissue.

Faden and Hunt (1991) used number of subsidiary cell and type of raphide canals for new classification of family Commelinaceae at generic level.

In 2004, Thitimetharoch investigated leaf anatomy in family Commelinaceae. Glandular micro-hair, raphide-canals, spherical spinulose silica bodies, patterned cuticle, continuous hypodermis and marginal sclerenchyma are useful for distinguishing each genus of this family.

Kantachot *et al.* (2006) studied the anatomy of the family Myrtaceae in Thailand. Twenty eight taxa in 12 genera of the Myrtaceae in Thailand were investigated on epidermal peel and transverse sections of leaves and petioles. The result demonstrated that isolateral or dorsiventral leaf, midrib, margin and petiole shape,

presence or absence of trichomes and hypodermis, stomatal types, number of spongy layers, epidermal cell wall, presence or absence of bundle sheath extention, shape and number of vascular bundles in the midrib and petiole, presence or absence of sclereids in the midrib and petiole, idioblast and crystal types are characteristics that could be a very useful complement to their identification.

In the same year, Saensouk revised eighteen species and 23 taxa in the genus *Alpinia* of Thailand. As a consequence, he found many features of leaf amatomy, *e.g.* type of stomata, type of inclusions, shape of subsidiary cell, trichomes and the distribution of stomata are proven useful to categorize this genus (Saensouk, 2009).

Srinual (2009) inspected anatomy of leaf epidermis from 25 species in eight genera of family Dipterocarpaceae in Thailand, including 2 species of *Anisoptera*; 4 species of *Dipterocarpus*; 7 species of *Shorea*; 8 species of *Vatica*, and 1 species of *Cotylelobium*, *Hopea*, *Neobalanocarpus* and *Parashorea* respectively, by epidermal peeling and clearing techniques. The result demonstrated that many anatomical characters, viz. types of hairs, stomatal types, presence or absence of tannin and resin canals in epidermis, druses and prismatic crystals in mesophyll and secretory cells at the end of veinlets are crucial data for species delimitation. In addition, these characters can be used to divide the family into a group.

3.2.1 Anatomical research in family Orchidaceae

The Orchidaceae is one of the largest families of flowering plants which has been confused and always difficult to classify owing to diversely morphological characters. Due to this reason, many botanists have been striving to solve the problems by using the information from alkaloids contend, chromosome numbers, palynology and seed morphology (Dressler, 1993). Apart from these, anatomical knowledge has still been used for solving taxonomic problems.

Recently, there have been many publications about the anatomy of family Orchidaceae which provide insightful studies and are worth mentioning.

Stern *et al*. (1993) investigated leaves, stems and roots of genus *Neuwiedia* and *Apostasia* (Apostasioideae). They found many characters are alike between genera, including tatracytic stomata, uniseriate velamen, cauline stegmata and root tubercles. Number of stamen is only anatomical feature which can be used to distinguish between 2 genera.

Morris *et al*. (1996) studied anatomy of leaves, stems, and roots of more than 100 species in subtribe *Dendrobiinae* (Orchidaceae). The result indicated that the anatomy of subtribe *Dendrobiinae* exhibits a high degree of morphological diversity and most of the characteristic anatomy appear to be homoplasous. When these anatomical data are gathered to obtain understanding of the systematic relationships among the genera, they pointed that genus *Dendrobium* is not monophyletic.

Phataramanon (2000) inspected leaf anatomical studies of 48 species from 27 genera in family Orchidaceae by pelling and parafin methode. The result suggest that these genera can be classified into 4 groups based on presence of trichome, fibre in mesophyll, palisade layer, cuticular sculptering, stegmata and vascular bundle sheath.

Yukawa and Stern (2002) examined the comparative vegetative anatomy and systematics of 21 species in the genus *Cymbidium*. The result showed that many anatomical characters, *e.g.* types of the distribution of stomata (amphistomatic or amphistomatic leaf), types of sub-epidermal foliar sclerenchyma and types of stomata are crucial for taxonomyof this genus.

Tokaw (2006) studied stems and leaves anatomy of 21 species from 17 genera, 5 subfamilies of terrestrial orchids in Phu Rua National Park, Loei Province, Thailand. He found that the anatomical features, *e.g.* types of stomata, types of trichome, stegmata, palisade cell and fibre in mesophyll, presence or absence of cuticular architecture and shape of silica body in the stegmata are significant characters for species classification.

Nunes *et al*. (2015) researched the comparative floral micromorphology and anatomy of six species of *Bulbophyllum* section *Napelli* in Brazilian Atlantic Rain Forest. The result indicated that types of glandular trichomes, pattern of distribution of stomata, presence or absence of vascular bundle and presence or absence crystalliferous idoblasts can be used to classify among the species.

3.2.2 The anatomical study in genus *Dendrobium* Sw.

In recent decades, many researchers have put their effort in studying the anatomy of many species of *Dendrobium*. A number of studies offering anatomical insight are mentioned below.

Yukawa *et al.* (1992) investigated the shape and size of the stomatal ledge on 153 species of the genus *Dendrobium*. The stomata may be separated into 2 types by the different shape of the outer stomatal ledge, viz. type I the dominant character is elliptical ledge with a slit like opening and has gradually sloping sides. In contrast, stomatal type II has rather circular ledge with a round to spindle-shaped opening and steep sides.

Yukawa and Uehara (1996) continued to examine vegetative diversification and radiation in subtribe *Dendrobiinae* with evidence from anatomical characters. They concluded that vegetative and anatomical characters facilitated the establishment of this group in various dry habitats. On the other hand, the modifications of size and number of parenchymatous cells substantially contributed to the vegetative diversification. This fact implies that a simple structural adjustment can result in a major modification of growth habits in the *Dendrobiinae*.

In the same year, Morris *et al.* studied anatomy of leaf, stem and root of more than 100 species in subtribe *Dendrobiinae* with a high microscope. The result demonstrated that the data from vegetative structure is very high degree of diversity and homoplasous. In addition, the data showed that the *Dendrobium* is not monophyletic.

Carlsward *et al.* (1997) examined leaf anatomy and systematic in *Dendrobium* section *Aporum* and *Rhizobium* (Orchidaceae). They found the specialized leaf anatomy of *Dendrobium* section *Aporum* and section *Rhizobium* are similar. In both sections leaves are characterized by a unifacial surface.

Mulgaonkar (2006) studied on dermal anatomy of four species of *Dendrobium* namely *D. microbulbon*, *D. mabalae*, *D. ovatum* and *D. barbatulum*. He discovered all of species are anomocytic stomata and flushed with the epidermis. Interestingly, trichomes were presented on abaxial side of *D. microbulbon* but absent in other three species.

Sathapattayanon (2008) revised *Dendrobium* section *Formosae* in Thailand and adjacent areas by using molecular phylogenetic analysis and anatomical characters of leaves. She described that the leaf surface are taxonomically useful for classifying taxa at section level. The most important and informative characters are stomatal shape, stomatal type and epidermal hairs while the cuticular sculpture can be partially used to segregate some species.

In Thailand, the data from leaf anatomy of *Dendrobium* section *Stachyobium* is still lacking because they have never been studied before. The aim of this chapter is to investigate the anatomical leaves in the section *Stachyobium* from Thailand which should be beneficial data for identification as well as classification of species.

3.3 Materials and Methods

3.3.1 Plant materials

The *Stacyobium* species are listed in Table 3.1. All of living materials were collected from throughout their natural habitats in Thailand. Besides, some species were also obtained from Kasin Suvatabhandhu Herbarium (BCU), Bangkok Herbarium (BK), The Forest Herbarium (BKF), Department of Biology, Faculty of Science, Chiang Mai University (CMUB) and Queen Sirikit Botanic Garden Herbarium (QBG). The fresh plant materials were preserved in 70% ethanol or FAA (Formalin-acetic acid-alcohol, which compose of 70 % ethanol 90 ml mixed with glacial acid 5 ml and 5 ml of commercial formalin) to prepare the Scanning electron microscopy (SEM) observation, paraffin embedding methods and epidermal peeling. The voucher specimens are deposited in Kasin Suvathabandhu Herbarium, Chulalongkorn University (BCU), Bangkok Herbarium (BK) and The Forest Herbarium (BKF). Only permanent slides are deposited at BCU.

3.3.2 Specimens for scanning electron microscopy (SEM) observation

Scanning electron microscopy is used to investigate stomata and other anatomical features on leaves. Mature leaves were cut into small pieces approximately 5 mm x 5 mm. Afterwards, these pieces were preserved in 70% ethanol or FAA for at least 24 hours. Then, they were dehydrated by alcohol series 95% and 100% ethanol for 5-10 minutes for each specimen and subsequently critical-point dried with CO_2. The dried specimens were mounted on stubs and coated with gold. Finally, both abaxial part and adaxial were observed with a JSM-6610 LV scanning electron microscope.

Several leaf characteristics such as distribution of stomata, stomatal shape and type, cuticular ornamentation and type of trichome were investigated.

3.3.3 The epidermal peeling

In preparation procedure, the mature leaf on the second from below of each specimens was cleaned with water and preserved in FAA or 70% ethanol for at least 24 hours. In case the prepared samples are susceptible and easily to be damaged, fresh leaves may be applied directly to epidermal peeling process. The samples were taken from the center area in the center of base and apex of lamina. The abaxial leaves were scraped off with razor blade and stained in 1% Safranin O approximately 5–20 minutes. After that the epidermal tissue specimens were dehydrated with 95% and 100% ethanol, respectively. Later, the epidermal tissue was washed in ethanol: xylene (1:1) and in pure xylene for 5-10 minutes each step. The samples were then mounted on slide with SP15-500 Toluene solution mounting media and were examined by a light microscope. The photographs were taken with microscopic camera (Nikon eclipse E200 and DS-Fi1 DS-Fi1/DS-L2) at last.

3.3.4 The paraffin embedding

For paraffin method, as described in Ruzin (1999), the mature leaf on the second from below of each specimens was fixed and preserved in 70% ethanol or FAA at least 24 hours. Then the prepared leaf, which include the area between midrib and leaf edge, was cut into small pieces approximately 5 x 5 mm size. After that all specimens were dehydrated in a graded tertiary butyl alcohol (TBA) or n-butyl alcohol series and embedded in paraffin. Later, sticks of paraffin were sectioned, with the sliding microtome (The Rotary Microtome HM 340 E), into roughly 15–16 micron size. Afterwards, the paraffin ribbons were fixed on slides by 0.5% gelatin and 3% formalin, toasted on slide drier at 45–50 degrees Celsius for at least 12 hours. Next, the paraffin ribbons were stained with 1% safranin O in 70% ethanol overnight then with 1% fast green in 70% ethanol for about 2–5 minutes. Subsequently, the stained ribbons were washed with 70% ethanol and then dehydrated by alcohol series 70%, 95% and 100% ethanol, respectively. Later, all slides were dipped in xylene for cleaning for about5–10 minutes and mounted with SP15-500 Toluene solution mounting media. Finally, the specimen photographs were taken with microscopic camera (Nikon eclipse E200 equipped with DS-Fi1/DS-L2) for data recording.

Table 3. 1 List of *Dendrobium* section *Stachyobium* taxa in Thailand.

No.	Species	Voucher specimens	Anatomical study	Locality
1	*D. chiangdaoense*	*W. Buddhawong* & *S. Suddee* 018 (BKF)	I, II, III	Chiang Mai, Doi Chiang Dao
2	*D. compactum*	*J. F. Maxwell* 88-1220 (BKF)	I, II, III	Chiang Mai, Doi Suthep-Doi Pui NP.
3	*D. compactum*	*N. Anuraktrakoon* 57 (BKU)	I, II, III	Loei, Phu Ruea National Park
4	*D. compactum*	*O. Thaithong* 495 (BCU)	I, II	No locality
5	*D. compactum*	*O. Thaithong* 523 (BCU)	I, II	No locality
6	*D. compactum*	*P. Prommanut* 52 (BKF)	I, II, III	Chiang Mai, Bo Luang
7	*D. compactum*	*P. Prommanut* 84 (BKF)	I, II, III	Chiang Mai, Mae Sanam Silvicultural Station
8	*D. compactum*	*P. Prommanut, S. Suddee* et al. 504 (BK)	I, II, III	Tak, Thungyai Naresuan Eastern Wildlife Sanctuary
9	*D. compactum*	*P. Prommanut* & *M. Kidyoo* 707 (BCU)	I, II, III	Chiang Mai, Doi Chiang Dao
10	*D. compactum*	*P. Prommanut* (BK)	I, II, III	Chiang Mai, Doi Suthep-Doi Pui NP.
11	*D. compactum*	*O. Thaithong* 523 (BCU)	I, II, III	No locality
12	*D. cuspidatum*	*J. Phelps* 1721 (BKF)	I, II, III	JJ Market, Bangkok
13	*D. cuspidatum*	*P. Prommanut* s.n. (BKF)	I, II, III	JJ Market, Bangkok
14	*D. denudans*	*A. Sathapattayanon* 370 (BCU)	I, II, III	Chiang Mai, Doi Ang Khang, Phang District
15	*D. denudans*	*K. K.* 1228 (BCU)	I, II, III	Chiang Rai, Khunkorn Waterfall Forest Park
16	*D. denudans*	*P. Prommanut* 620 (BK)	I, II, III	Mae Hong Son, hiking trails at Doi Ke-a Po Pho Cho
17	*D. denudans*	*P. Suksathan* & *P. Triboun* s.n. (BK)	I, II, III	Chiang Mai, Doi Ang Khang, Phang District
18	*D. denudans*	*S. Suddee* 1598 (BKF)	I, II, III	Nan, Doi Phuka NP.
19	*D. denudans*	*S. Suddee & Henrick* 1679 (BKF)	I, II, III	Chiang Mai, Doi Ang khang
20	*D. denudans*	*Wins* 019 (BKF)	I, II, III	Chiang Mai, Doi Ang khang
21	*D. denudans*	*Wins* 020 (BKF)	I, II, III	Chiang Mai, Doi Ang khang
22	*D. dixonianum*	*P. Prommanut* 474 (BK)	I, II, III	Mae Hong Son, hiking trail at rail up to Doi Ke-a Po Pho Cho
23	*D. dixonianum*	*P. Prommanut* & *W. Buddhawong* 661 (BK)	I, II, III	Chiang Mai, Doi Ang Khang
24	*D. dixonianum*	*P. Prommanut* & *M. Kidyoo* 709 (BCU)	I, II, III	Chiang Mai, Doi Ang Khang
25	*D. dixonianum*	*Put* 3383 (BK)	I, II	Chiang Mai, Doi Nangka
26	*D. dixonianum*	*T. Smitinand* 4711 (BKF)	I, II	Chiang Mai, Doi Chiang Dao
27	*D. dixonianum*	*M. Poophat* 1466 (BKF)	I, II, III	Nan, Phuwae
28	*D. dixonianum*	*P. Prommanut* s.n. (BCU)	I, II, III	Chiang Mai, Huai Nam Dang
29	*D. dixonianum*	*V. Chamchumroon* et al. 5348 (BKF)	I, II, III	Nan, Doi Phu Kha NP.
30	*D. dixonianum*	*Wins* 007 (BKF)	I, II, III	Chiang Mai, Huai Nam Dang
31	*D. elliottianum*	*P. Prommanut* et al. 594 (BK)	I, II, III	Tak, Umphang District, Doi Hua Mot
32	*D. elliottianum*	*P.Prommanut* et al. 594(BKF)	I, II, III	Tak, Umphang District, Doi Hua Mot
33	*D. garrettii*	*P. Prommanut* et al. 511 (BK)	I, II, III	Chiang Mai, Doi Inthanon NP.

No.	Species	Voucher specimens	Anatomical study	Locality
34	*D. gregulus*	*A. Sathapattayanon* 387 (BCU)	I, II	Tak, Umphang District, Doi Hua Mot,
35	*D. gregulus*	*P. Durumas* 164 (BCU)	I, II	Tak, Umphang District, Doi Hua Mot,
36	*D. gregulus*	*P. Prommanut* s.n. (BKF)	I, II	Chiang Mai, Mai Muang Nao Arboretum
37	*D. gregulus*	*P. Prommanut* 053 (BKF)	I, II, III	Chiang Mai, Mai Muang Nao Arboretum
38	*D. gregulus*	*P. Prommanut* s.n. (BCU)	I, II, III	Chiang Mai, Doi Chiang Dao
39	*D. gregulus*	*R. Pooma* 25 (BKF)	I, II	Chiang Mai, Mae Sanam
40	*D. gregulus*	*S. Suddee* 408 (BKF)	I, II	Chiang Mai, Mae Sanam
41	*D. gregulus*	*S. Suddee* s.n. (BCU)	I, II	Chiang Mai, Mae Sanam
42	*D. gregulus*	*S. Suddee* et al. 4430 (BKF)	I, II	Tak, Umphang District, Doi Hua Mot
43	*D. incurvum*	*A. F. G. Kerr* 0193 (BK)	I, II, III	Trat, Kao Saming
44	*D. incurvum*	*A. F. G. Kerr* 0666 (BK)	I, II, III	Ranong, Kraburi
45	*D. incurvum*	*Beusekom* & *T. Smitinand* 2162 (BKF)	I, II, III	Chantaburi, at the base of Khao Soi Dao
46	*D. incurvum*	*M. Chanla* s.n. (BKF)	I, II, III	Ranong, Klong-naka, Wildlife Sanctuary Headquarter
47	*D. incurvum*	*P. Prommanut* s.n. (BK)	I, II, III	Chantaburi, Makham
48	*D. incurvum*	*P. Rakthai* s.n. (BK)	I, II, III	Chantaburi, Makham
49	*D. incurvum*	*O. Thaithong* 302 (BCU)	I, II	No locality
50	*D. incurvum*	*T. Smitinand* 080(BKF)	I, II, III	Chantaburi
51	*D. incurvum*	*T. Smitinand* 3604 (BKF)	I, II, III	Chantaburi , Makham
52	*D. incurvum*	*T. Smitinand* 3639 (BKF)	I, II, III	Chantaburi, Makham
53	*D. kanburiense*	*M. Phoohat* 1335 (BKF)	I, II, III	Kanchanaburi, Sangkhlaburi, Kao Jadi
54	*D. kanburiense*	*O. Thaithong* 1419 (BCU)	I, II, III	No locality
55	*D. kanburiense*	*P. Prommanut* s.n. (BK)	I, II, III	Tak, Doi Hua Mot
56	*D. kanburiense*	*S. Suddee* et al. 4377 (BKF)	I, II, III	Tak, Road to Ban Mae La Mung Khee
57	*D. kanburiense*	*S. Suddee* et al. 5140 (BKF)	I, II, III	Tak, Tha Song Yang, Mae Moei NP.
58	*D. peguanum*	*P. Prommanut* 245 (BKF)	I, II, III	Mae Hong Son, Mae Sa Riang District
59	*D. peguanum*	*S. Rueangrea*, *S. Suddee*, *M. Roudreiw* and *C.Hemrat* 30 (BKF)	I, II, III	Chiang Mai, Mae Cham
60	*D. peguanum*	*S. Suddee* et al. s.n. (BCU)	I, II, III	Mae Hong Son, Doi Hua Mot2
61	*D. perpaulum*	*P. Prommanut* 478 (BK)	I, II, III	Mae Hon Son, Doi Ke-a Po Pho Cho
62	*D. perpaulum*	*P. Prommanut* 559 (BCU)	I, II, III	Chiang Mai, Doi Inthanon
63	*D. perpaulum*	*S. Suddee* et al. 4626 (BKF)	I, II	Mae Hon Son, Doi Ke-a Po Pho Cho
64	*D. porphyrochilum*	*A. F. G. Kerr* 0810 (BK)	I, II	Krabi , Panom Bencha
65	*D. porphyrochilum*	*B. Temboonkiat* 001 (BCU)	I, II, III	Krabi , Panom Bencha
66	*D. porphyrochilum*	*B. Temboonkiat* 002 (BCU)	I, II, III	Chiang Mai, Doi Chiang Dao
67	*D. porphyrochilum*	*K. Limkitikul* 192 (BCU)	I, II, III	Prachuap Khiri Khan, Huai Yang Waterfall NP.
68	*D. porphyrochilum*	*M. Phuphat* 1553 (BKF);	I, II, III	Chaing Mai, Doi Chiang Dao
69	*D. porphyrochilum*	*N. Toolmal* et al. 87 (BKF)	I, II, III	Phetchaburi, Kaeng Krachan NP.
70	*D. porphyrochilum*	*P. Prommanut* 645 (BCU)	I, II, III	Nan, Doi Phu Kha NP.

No.	Species	Voucher specimens	Anatomical study	Locality
71	*D. porphyrochilum*	*P. Prommanut* & *P. Triboun* s.n. (BK)	I, II, III	Chiang Mai, Doi Inthanon NP.
72	*D. porphyrochilum*	*P. Suksathan* 1022 (BCU)	I, II, III	Chaing Mai, Doi Chiang Dao
73	*D. porphyrochilum*	*S. Chantanaorrapint* s.n. (BCU)	I, II, III	Phetchaburi, Kaeng Krachan NP.
74	*D. porphyrochilum*	*S. Raksue* 94 (BKF)	I, II, III	Phetchaburi, Kaeng Krachan NP.
75	*D. pycnostachyum*	*P. Prommanut* 49 (BKF)	I, II, III	Chiang Mai, Mai Mueng Nao Arboretum
76	*D. pycnostachyum*	*P. Prommanut* 171 (BKF)	I, II, III	Mae Hong Son, Mae Um Long hotsprings
77	*D. pycnostachyum*	*P. Prommanut* 641 (BK)	I, II, III	Tak, Thungyai Narasuan Eastern Wildlife Sanctuary
78	*D. pycnostachyum*	*O. Thaithong* 793 (BCU)	I, II	No locality
79	*D. proteranthum*	*C. Kasetluksamee* & *N. Anuraktrakoon* 066 (BKU)	I, II, III	Loei, Phuluang Wildlife Sanctuary
80	*D. proteranthum*	*S. Suddee* et al. 2697 (BKF)	I, II, III	Loei, Phuluang Wildlife Sanctuary
81	*D. proteranthum*	*S. Suddee* et al. 5036 (BKF)	I, II, III	Phitsanulok, Phu Hin Rong Kla NP.
82	*D. proteranthum*	*Wichien* s.n. (BKF)	I, II	Loei, Phuluang Wildlife Sanctuary
83	*D. strongylanthum*	*P. Prommanut* & *W. Budhthiwong* 701 (BK)	I, II, III	Chiang Mai, Doi Saket, Ban Pa Meiang
84	*D. strongylanthum*	*P. Prommanut* 702 (BCU)	I, II, III	Lamphang, Chae Son National Park, Kew fin Scenic
85	*D. strongylanthum*	*S. Damapong* 92 (BKF)	I, II, III	Chiang Mai, Doi Phahom Pok NP.
86	*D. strongylanthum*	*Doi Phu Kha NP. Staff* 001 (BKF)	I, II, III	Nan, Doi Phu Kha NP.
87	*D. venustum*	*Adisai* 794 (BK)	I, II	Phetchabun, Lom Sak
88	*D. venustum*	*C. Phengklai* et al. 256 (BKF)	I, II	Kanchanaburi, Kao Pu Maklai, Nong Hoy
89	*D. venustum*	*Dee* 114 (BKF)	I, II	Loei, Phu Kradueng NP.
90	*D. venustum*	*C. Nielsen* et al. 1627 (BKF)	I, II	Nong Khai, Bungkla
91	*D. venustum*	*K. Duangdee* 36 (BCU)	I, II, III	Loei Province, Phu Kradueng NP.
92	*D. venustum*	*Pradit* 418 (BK)	I, II, III	Sakol Nakhon, Phu Phan NP.
93	*D. venustum*	*P. Prommanut* 78 (BKF)	I, II, III	Chiang Mai, Obluang NP.
94	*D. venustum*	*P. Prommanut* & *P. Triboun* s.n. (BK)	I, II, III	Lampang, Tham Phatai NP.
95	*D. venustum*	*P. Prommanut* & *M. Kidyoo* 714 (BCU)	I, II, III	Sakon Nakhon, Phu Phan NP.
96	*D. venustum*	*P. Prommanut* & *M. Kidyoo* (BCU)	I, II, III	Bueng Kan, Phu Wua Wildlife Sanctuary
97	*D. venustum*	*R. Pooma* et al. 2451 (BKF)	I, II, III	Mukdahan, Phu Pha Thoep NP.
98	*D. venustum*	*W. Somprasong* s.n. (BK)	I, II, III	Sakol Nakhon, Kusuman
99	*D. venustum* var. *delacourii*	*A. F. G Kerr* 0170 (BK)	I, II, III	Rachaburi
100	*D. venustum* var. *delacourii*	*A. F. G. Kerr* 0839 (BK)	I, II, III	Kanchanaburi
101	*D. venustum* var. *delacourii*	*A. F. G. Kerr* 0844 (BK)	I, II, III	Kanchanaburi, Ta Salao
102	*D. venustum* var. *delacourii*	*J. F. Maxwell* 76-267 (BK)	I, II, III	Uthai Thani, Huay Kha Kaeng

No.	Species	Voucher specimens	Anatomical study	Locality
103	*D. venustum* var. *delacourii*	*Kasem* 155 (BK)	I, II, III	Kanchanaburi, Srisawasdi
104	*D. venustum* var. *delacourii*	*Lackshnakara* 897 (BK)	I, II, III	Ubon rachathani, Ban Boong
105	*D. venustum* var. *delacourii*	*P. Prommanut* s.n. (BCU)	I, II, III	Mae Hong Son, Pha Bong
106	*D. venustum var.* delacourii	*P. Puudja* 1389 (BKF)	I, II	Ubon Rachathani, Khongchiam
107	*D. venustum* var. *delacourii*	*P. Triboun* 174 (BK)	I, II, III	Mae Hong Son, Huay Saew Tao
108	*D. venustum* var. *delacourii*	*S. Saema* 001 (BK)	I, II, III	Uthai Thani, Huai Kha Khaeng Wildlife Sanctuary
109	*D. venustum* var. *delacourii*	*T. Santisuk* 993 (BKF)	I, II	Chiang Mai, roadside to Mae Chaem
110	*Dendrobium* sp.1	*P. Prommanut* s.n. (BKF)	I, II, III	Kanchanaburi, Thong Pha Phum NP.
111	*Dendrobium* sp.1	*P. Prommanut* s.n. (BKF)	I, II, III	Tak, Doi Hua Mot
112	*Dendrobium* sp.2	*A. Sathapattayanon* 400 (BCU)	I, II, III	Sakonnakorn, Phu Pan NP.
113	*Dendrobium* sp.2	*A. Sathapattayanon* 401 (BCU)	I, II, III	Sakonnakorn, Phu Pan NP.
114	*Dendrobium* sp.2	*P. Prommanut* & *M. Kidyoo* 712 (BCU)	I, II, III	Sakonnakorn, Phu Pan NP.

** Note: type of anatomical study conducted on specimens;
I = Epidermal peeling
II = Transverse sectioning by paraffin embedding
III = SEM observation

3.4 Results and Discussions

3.4.1 Investigation of the Stachyobium's general character

One hundred and fourteen specimens (20 taxa) of *Dendrobium* section *Stachyobium* in Thailand were studied by epidermal peeling, paraffin embedding and SEM observation. The anatomical characteristics on leaf surface of this section demonstrate that all species are isobilateral leaf with homogeneous mesophyll layer (their mesophyll cells are not differentiated into palisade and spongy parenchyma like other monocotyledon plants). Although most of the species in this section are hypostomatous types, only 3 taxa namely *Dendrobium venustum*, *D. venustum* var. *delacourii* and *Dendrobium* sp.1 are amphistomatic species. The general characteristics of leaves in SEM observation, epidermal peeling and paraffin embedding are discussed and compared. The special anatomical structure and common characteristics are presented in Table 3.2.

Epidermal cells: The cuticle layers are thin and inconspicuous on both adaxial and abaxial for all species. The cuticular ornamentation on adaxial surface can be distinguished into 3 types

-Type I. (Striae-nett cuticle): In the cuticular layers, cuticle exhibited a range of striped pattern like net (Plate 3.1:A).

-Type II. (Long-parallel cuticle): The cuticular layers presented as parallel along cell length (Plate 3.1:B).

-Type III. (Smooth cuticle): The cuticular layers manifested a smooth pattern of cuticle cell (Plate 3.1:C).

Besides, the cuticular ornamentation on abaxial can be divided into 2 types

-Type I. (Striae-nett cuticle): the cuticular layers displayed cuticle cells with striped pattern like nett (Plate 3.2: A and B) and (Plate 3.3:A).

-Type II. (Long-parallel cuticle): the cuticular layers showed a range of pattern which all cells are parallel along their length (Plate 3.2:C and D) and (Plate 3.3:B).

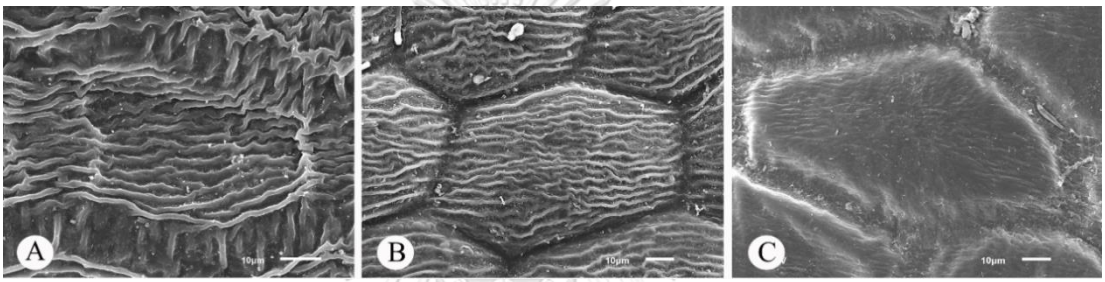


Plate 3. 1 SEM micrographs showing 3 types of cuticular ornamentation on adaxial surface: A. Striae-nett cuticle in *Dendrobium denudans*; B. Long-parallel cuticle in *D. perpualum*; C. Smooth cuticle in *D. garrettii*.

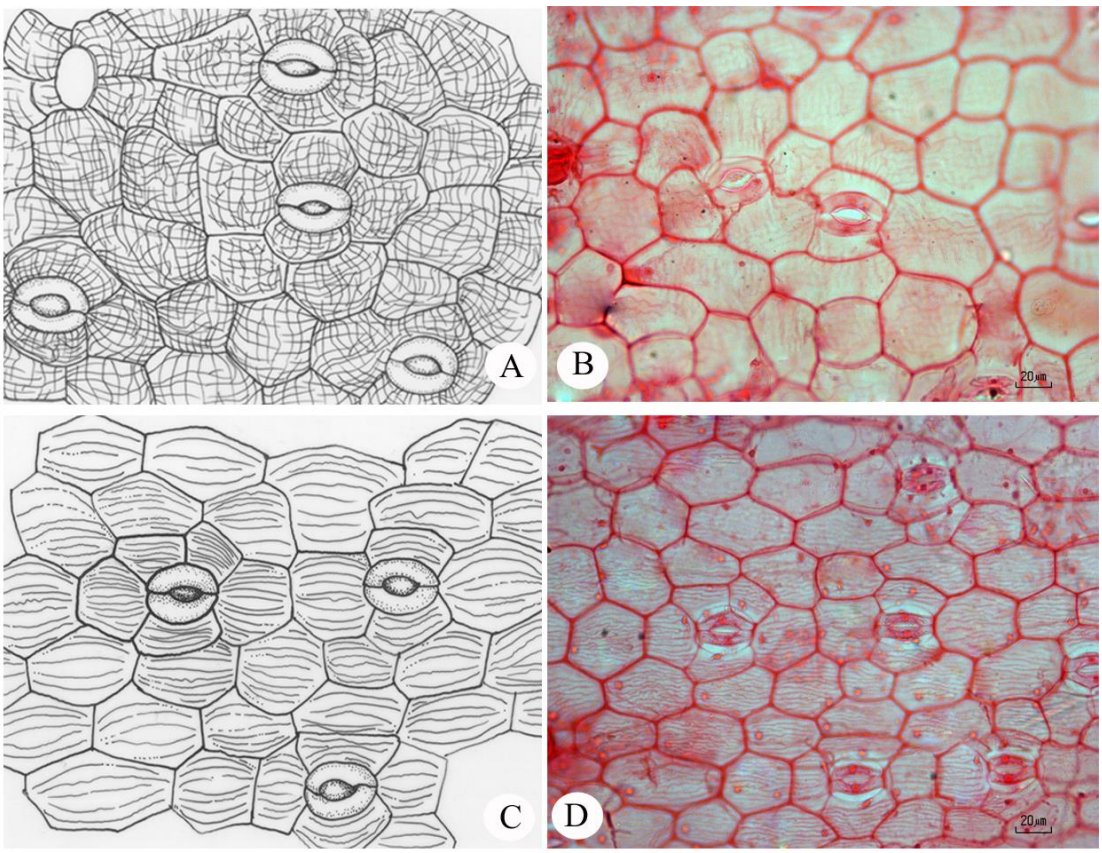


Plate 3. 2 The cuticular ornamentation on abaxial surface: Striae-nett cuticle in A. and B. Striae-nett cuticle; Long-parallel cuticle in C. and D. Drawn by P. Prommanut.

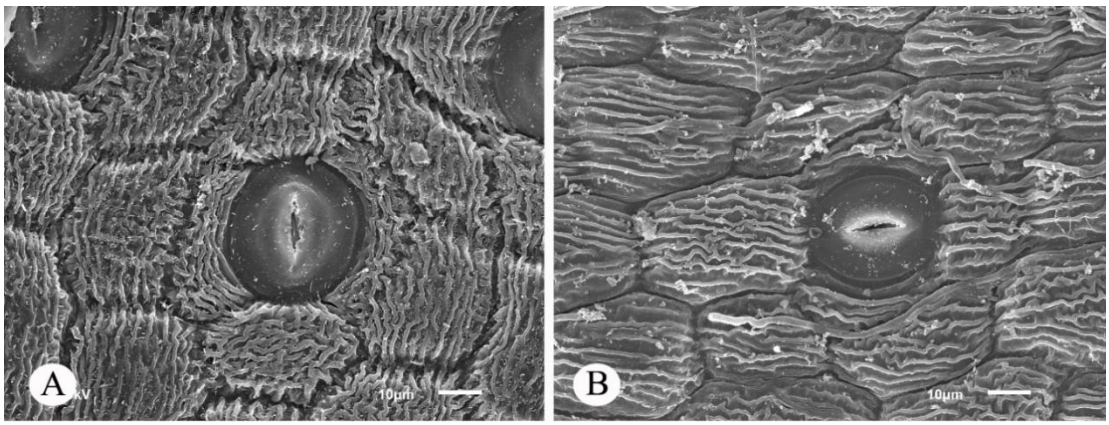


Plate 3. 3 SEM micrographs showing 2 types of cuticular ornamentation on abaxial surface. A. Striae-nett cuticle in *D. dixonianum*; B. Long-parallel cuticle in *D. chiangdaoense*.

In all specimens epidermis is a single layer but in the upper epidermal cells are larger and thicker than those of the lower epidermal cells (Plate 3.4:A-D). The shape of epidermal cells in surface view is polygonal (Plate 3.5:A and B). Whilst, the epidermal cells in transverse section are various shapes, *i.e*. dome-shape, globose, rectangular, polygonal and oval cells.

In general, the cuticular ornamentation on adaxial is rather similar with abaxial surface. Ten species in section Stachyobium, which consists of *D. compactum*, *D. cuspidatum*, *D. denudans*, *D. dixonianum*, *D. gregulus*, *D. incurvum*, *D. peguanum*, *D. venustum*, *D. venustum* var. *delacourii* and *Dendrobium* sp.2 have striae-nett cuticle on both leaf surfaces. Smooth cuticle was found only in *Dendrobium* sp.1. Whilst, other species, *i.e*. *D. chiangdaoense*, *D. kanburiense*, *D. elliottianum*, *D. perpaulum*, *D. porphyrochilum*, *D. proteranthum* and *D. pychnostachyum* have long-parallel cuticle on both adaxial and abaxial surfaces. Interestingly, adaxial and abaxial surfaces in 3 taxa, including *D. garrettii*, *D. strongylanthum* and *Dendrobium* sp.1 are different.

According to Sathapattayanon (2008) who has investigated the epidermal characters of leaf in 57 sampled species of *Dendrobium* section *Formosae*, 3 samples from section *Districhophyllum*, 2 samples from section *Conotalix* and 1 sample from section *Dendrobium* by SEM observation. She found that 46 sampled species of *Dendrobium* were striated cuticular sculpture on abaxial surface but smooth on adaxial surface. Apart from aforementioned species, only 1 species namely *D. trigonopus* has irregular on both surfaces.

Dickison (2000) mentioned that the cuticular ornamentation is the border layer of leaf which interacts between the plant body and environment. Hence, the cuticular surface of *Dendrobium* section *Stachyobium* can be varied into many types corresponding to different habitats, illuminance, altitude and humidity.

Stomatal types and distribution: Three types of stomata can be found in all species of this section viz. tatracytic, pentacytic and hexacytic stomata, because their

stoma is enclosed with four, five and six subsidiary cells, respectively (Plate 3.6:A-C). Subsidiary cells in surface view are rectangular, square, pentagon and polygonal. Whilst, the shape of subsidiary cells in transverse section are bell-like and locate at the same level as epidermal cell. In surface view, guard cells may display in three different shape: bell-shape, reniform or elliptic.

The distribution of stomata in this section can be separated into 2 types, including

-Type I. (Hypostomatic leaf): the stomata are distributed only on abaxial surface. The majority of species in the *Stachyobium* are this type (Plate 3.7:A-C).

-Type II. (Amphistomatic leaf): the stomata are distributed on both adaxial and abaxial surfaces. Notably, the most abundant of stomata were found in the abaxial surface. *Dendrobium venustum, D. venustum* var. *delacourii* and *Dendrobium* sp.1 are only 3 taxa which having amphistomatic leaf (Plate 3.8:A-C).

In previous study, Mulgaonkar (2006) has studied on the dermal anatomy of 4 species in genus *Dendrobium* namely *D. microbulbon, D. mabalae, D. ovatum* and *D. barbatulum*. He discovered that all of species are anomocytic stomata and flushed with the epidermis. Later, Sathapattayanon (2008) who examined the stomata of *Dendrobium* section *Formosae, Districhophyllum, Conotalix* and *Dendrobium*. She found most of species in these genus are tatracytic stomata but 1 species (*D. senile*) is anomocytic. Incorporated with the discoveries from this study, there are many types of stomata but none of species in section *Stachyobium* which has its own unique types of stomata. Consequently, stomata type in genus *Dendrobium* cannot be used solely to identify a single species. However, stomata type is a valuable information which may be combined with morphology to classify species in this genus.

For stomata distribution, most of species in this section have stomata distributed on abaxial surface (hypostomatous species). Whereas, 3 taxa viz. *D. venustum, D. venustum* var. *delacourii* and *Dendrobium* sp.1, have stomata on both adaxial and abaxial surfaces (amphistomatous species). This results correspond with Yukawa *et al.* in 1990, he found 148 species from 153 species in the genus *Dendrobium* have stomata on abaxial surface. Only 5 species have stomata on both surfaces. Afterwards, Sathapattayanon (2008), who researched about 57 specimens of *Dendrobium* section *Formosae*, also concluded that all species in this section are hypostomatous species. Therefore, it can be summarized that the hypostomatic type is typical stomata distribution in genus *Dendrobium*. This is the most common character in vascular plant (Dickison, 2000; Simpson, 2010).

Type of trichome: There are 2 types of trichome in *Dendrobium* section *Stachyobium* as following

-Peltate glandular trichome type I: Glandular shape is flat and rough. The size of gland is about 40–50 µm and consists of multicellular cell. Three species, namely *D. chiangdaoense*, *D. incurvum* and *D. strongylanthum*, were found in this type (Plate 3.9:A-C).

-Peltate glandular trichome type II: glandular shape is swollen and smooth. The size of gland is about 15–25 µm. Base of gland composes of many cells and is longer than type I. Most species of the section *Stachyobium* are this type (Plate 3.9:D-E).

Two types of peltate glandular trichome are distribute on both surfaces of leaf.

According to Mulgaonkar (2006) conducted on section *Dendrobium* trichomes were presented only on abaxial surface of *D. microbulbon* and absent in *D. mabalae, D. ovatum* and *D. barbatulum*. Nonetheless, this research conducted on section *Stachyobium* discovered different trichome distribution, all species have trichome distributed on both adaxial and abaxial surfaces. Thus trichome distribution has no significant meaning for species classification.

On the other hand, types of trichome can be used as supporting information for species determination.

The mesophyll: Unlike other monocotyledon plants, all species of the *Stachyobium* are homogeneous which mesophyll layer are not separated into palisade and spongy parenchyma. The spongy parenchyma, which composed of 7–10-layers, are somewhat dense and they appear in different shapes usually globose, oval and rectangular. There are both idioblasts and crystals are scattered throughout in spongy mesophyll layers (Plate 3.10:A-D).

Type of crystal: Three types of crystal can be separated in *Dendrobium* section *Stachyobium* as following

-Type I. (Raphide crystal): The needle-shaped crystal were found in only mesophyll layer (Plate 3.11:A and B).

-Type II. (Druse crystal): The crystal of calcium oxalate, silicates, or carbonates appears in both mesophyll layer and vascular bundle (Plate 3.11:C).

-Type III. (Prismatic crystal): The prism-like crytal exists only in mesophyll layer. This type of crystal is only found in three sepecies viz. *D. kanburiense, D. peguanum* and *D. pycnostachyum* (Plate 3.11:D).

Most of species in section *Stachyobium* have druse and raphide crystal in saccate idioblasts which scattered frequency throughout of mesophyll layer and vascular bundle. On the other hand, only 3 species, namely *D. kanburiense, D. peguanum* and *D. pycnostachyum* have all 3 types of crystal in mesophyll layer and vascular bundle. This study resembles Carlsward *et al.* (1997), which examined leaf anatomy and systematic in *Dendrobium* section *Aporum* and *Rhizobium*. They found mesophyll layers are undiffentiated, composed of smaller assimilatory cells and scattered. However, only raphide crystal which was found in leaves of 2 sections. As a consequence, the data from mesophyll structure do not provided any important facts for species determination. While, type of crystal can be used as supporting information together with morphology for taxonomy.

The margins: All species are acute and recurved on the upper surface. The epidermal cells are often dome-shape, globose, oval or rectangular (Plate 3.12:A. and

B.; Plate 3.14). Because all species are alike, shape of margins has no significant for classification.

The midrib: Most of the species in this section are concave on the adaxial surface. The epidermal cells are often globose, oval or rectangular (Plate 3.12:C.; Plate 3.15). All species in this section are alike thus shape of midrib has no significant meaning for classification as well.

The vascular bundles: The collateral bundles are present in all species. They are variable in both shape and size and surrounded with sclerenchyma cell (Plate 3.16). This study shows that the vascular bundle types are alike in all species. Therefore, these data are not helpful for grouping species. Nevertheless, the amount of sclerenchyma cells in vascular bundles can provide insight of relationship between plant and environmental factor. This is because sclerenchyma cells are specialized plant cells that exist to provide strength and support. For instance, *D. proteranthum* grow in lower montane forest where these ecosystems gets a high humidity and low illuminance. As a result, it has amount of sclerenchyma in vascular bundles less than *D. venustum* which species grow in dry dipterocarp forest.

3.5 Conclusions

The results of this study demonstrated that many anatomical characteristics of leaf can provide a significant knowledge for grouping taxa in *Dendrobium* section *Stachyobium* at section level. Many characteristics viz. stomata distribution, type of trichome and type of crystal are useful for species classification. While, the ornamentation cuticle and type of stomata can be regarded as supplementary information for taxonomy in some species of this section. Even though the anatomical characteristics themselves are not enough as sole classification evidence, they can be combined with information from morphology, palynology and molecular data for circumscribing species. Ultimately, these anatomical studies will always remain as the fundamental data in the genus *Dendrobium* Sw. for future reference.

Table 3. 2 Summary of leaf anatomy in *Dendrobium* section *Stachyobium* in Thailand.

No.	Taxon	Ornamentation cuticle		Stomata distribution		Type of trichome		Type of crystal		
		Upper	Lower	Upper	Lower	Type I	Type II	Druse	Raphide	Prismatic
1	*D. chiangdaoense*	LP	LP	–	✓	✓	✓	✓	✓	–
2	*D. compactum*	SN	SN	–	✓	–	✓	✓	✓	–
3	*D. cuspidatum*	SN	SN	–	✓	–	✓	✓	✓	–
4	*D. denudans*	SN	SN	–	✓	–	✓	✓	✓	–
5	*D. dixonianum*	SN	SN	–	✓	–	✓	✓	✓	–
6	*D. garrettii*	SC	SN	–	✓	–	✓	✓	✓	–
7	*D. elliottianum*	LP	LP	–	✓	–	✓	✓	✓	–
8	*D. gregulus*	SN	SN	–	✓	–	✓	✓	✓	–
9	*D. incurvum*	SN	SN	–	✓	✓	✓	✓	✓	–
10	*D. kanburiense*	LP	LP	–	✓	–	✓	✓	✓	✓
11	*D. peguanum*	SN	SN	–	✓	–	✓	✓	✓	✓
12	*D. perpaulum*	LP	LP	–	✓	–	✓	✓	✓	–
13	*D. porphyrochilum*	LP	LP	–	✓	–	✓	✓	✓	–
14	*D. pycnostachyum*	LP	LP	–	✓	–	✓	✓	✓	✓
15	*D. proteranthum*	LP	LP	–	✓	–	✓	✓	✓	–
16	*D. strongylanthum*	SC	SN	–	✓	✓	✓	✓	✓	–
17	*D. venustum*	SN	SN	✓	✓	–	✓	✓	✓	–
18	*D. venustum* var. *delacourii*	SN	SN	–	✓	–	✓	✓	✓	–
19	*Dendrobium* sp.1	SC	SC	–	✓	–	✓	✓	✓	–
20	*Dendrobium* sp.2	SN	SN	✓	✓	–	✓	✓	✓	–

** Abbreviations: LP = Long-parallel cuticle, SC = Smooth cuticle, SN = Striae-nett cuticle. Other: '–' = absent, '✓' = present.

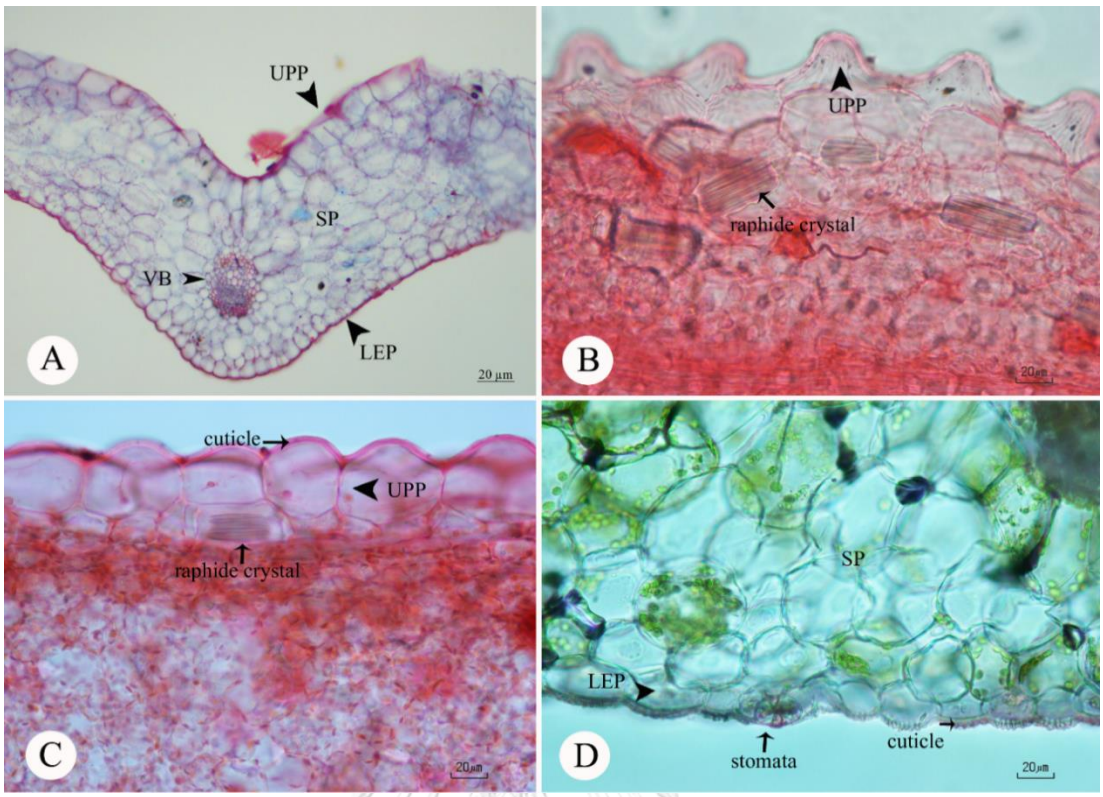


Plate 3. 4 Transverse section of leaves in the *Stachyobium*: A. Leaf of *Dendrobium denudans*; B. and C. Show cuticle, upper epidermis layer (UPP), raphilde crytals and spongy cell (SP) in *D. strongylanthum*; *D. Demonstrates* cuticle, lower epidermis layer (LEP) in *D. venustum*. Abbreviation; UPP = upper epidermis; LEP = lower epidermis; VB = vascular bundle.

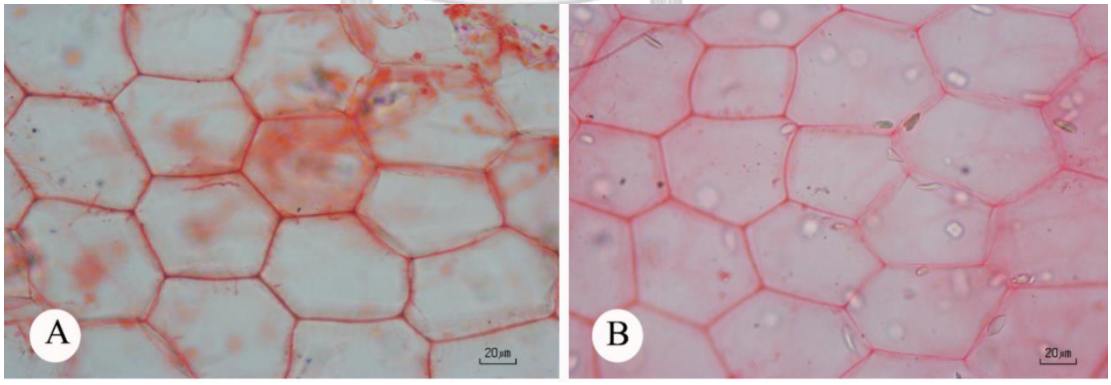


Plate 3. 5 The shapes of epidermal cell (all species are polygonal cell): A. *Dendrobium compactum*; B. *D. pycnostachyum*.

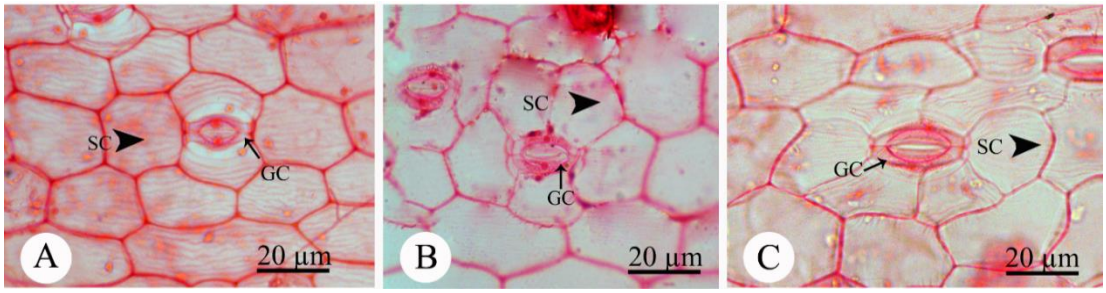


Plate 3. 6 Type of stomata: A Tatracytic in *Dendrobium chiangdaoense*; B. Pentacytic in *D. porphyrochilum*; C. hexacytic in *D. kanburiense*. Abbreviation; GC = guard cell; SC = subsidiary cell.

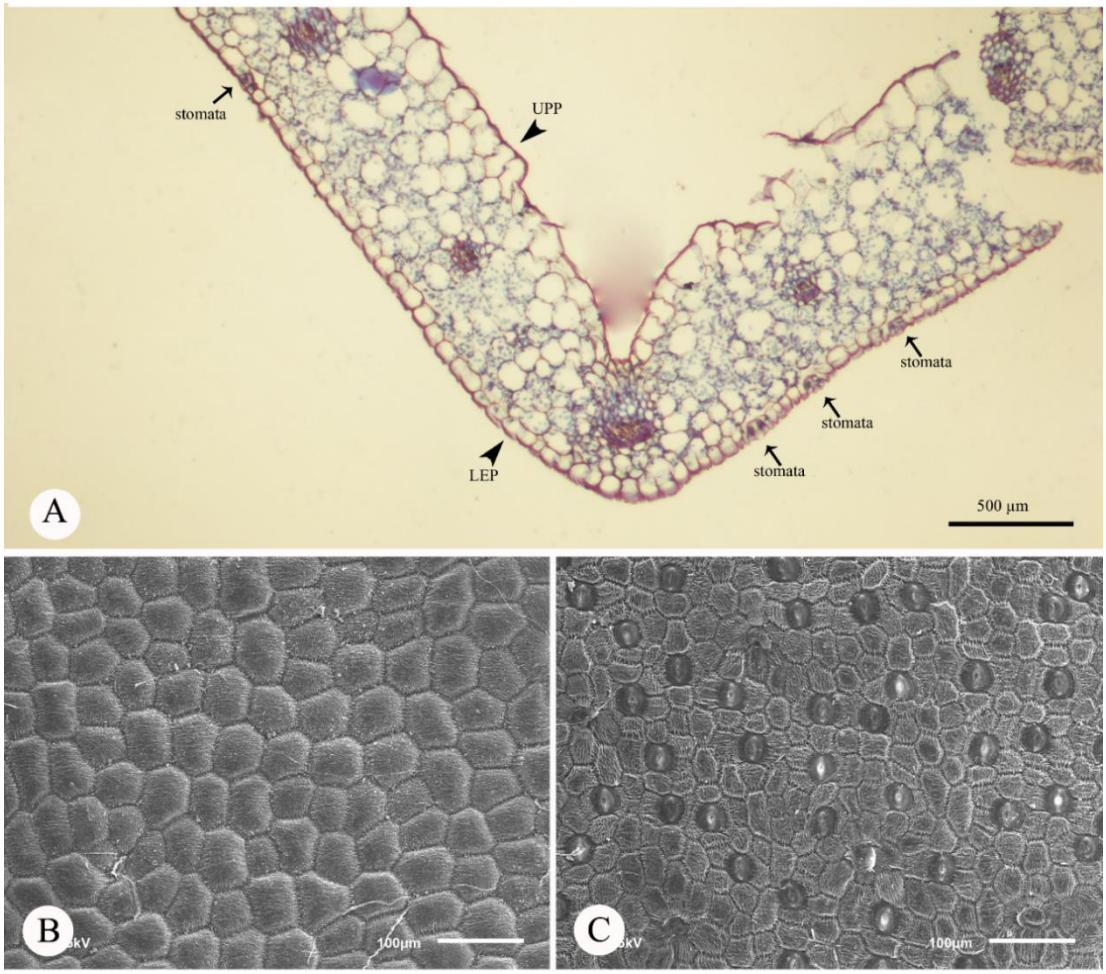


Plate 3. 7 The distribution of stomata in hypostomatic leaf: A. Transverse section of leaf in *Dendrobium dixonianum*; B. SEM micrographs on adaxial of *D. perpaulum*; C. SEM micrographs on abaxial of *D. perpaulum*. Abbreviation; UPP = upper epidermis; LEP = lower epidermis.

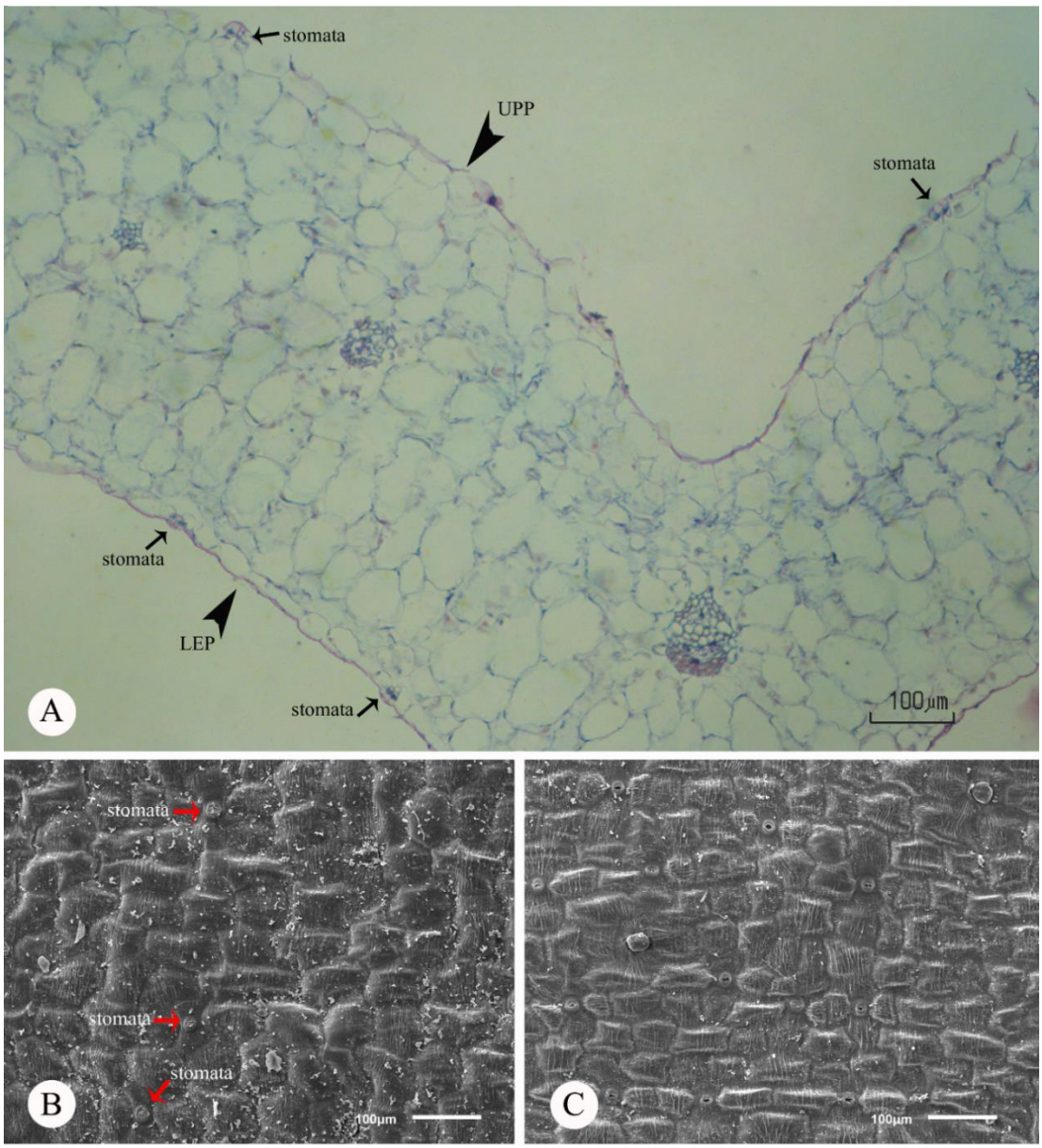


Plate 3. 8 The distribution of stomata in amphistomatic leaf: A. Transverse section of leaf in *Dendrobium venustum* var. *delacourii*; B. SEM micrographs on adaxial of *D. venustum*; C. SEM micrographs on abaxial of *D. venustum*. Abbreviation: UPP = upper epidermis; LEP = lower epidermis.

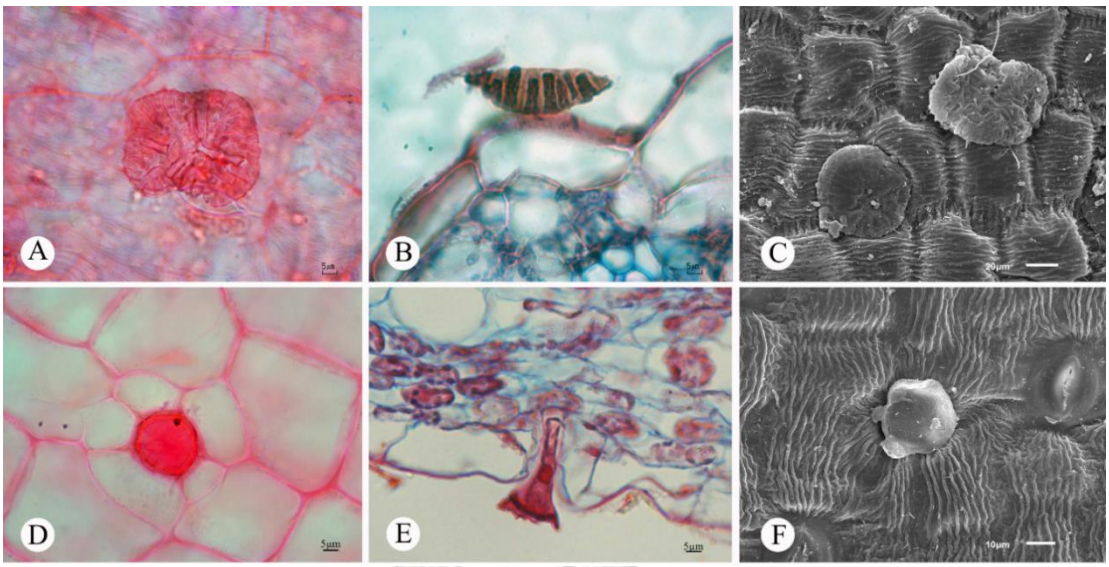


Plate 3. 9 Two types of trichome in section *Stachyobium* under different preparation: A.-C. Peltate glandular trichome type I (epidermal peeling, paraffin embedding and SEM observation, respectively); D.-F. Peltate glandular trichome type II (epidermal peeling, paraffin embedding and SEM observation, respectively).

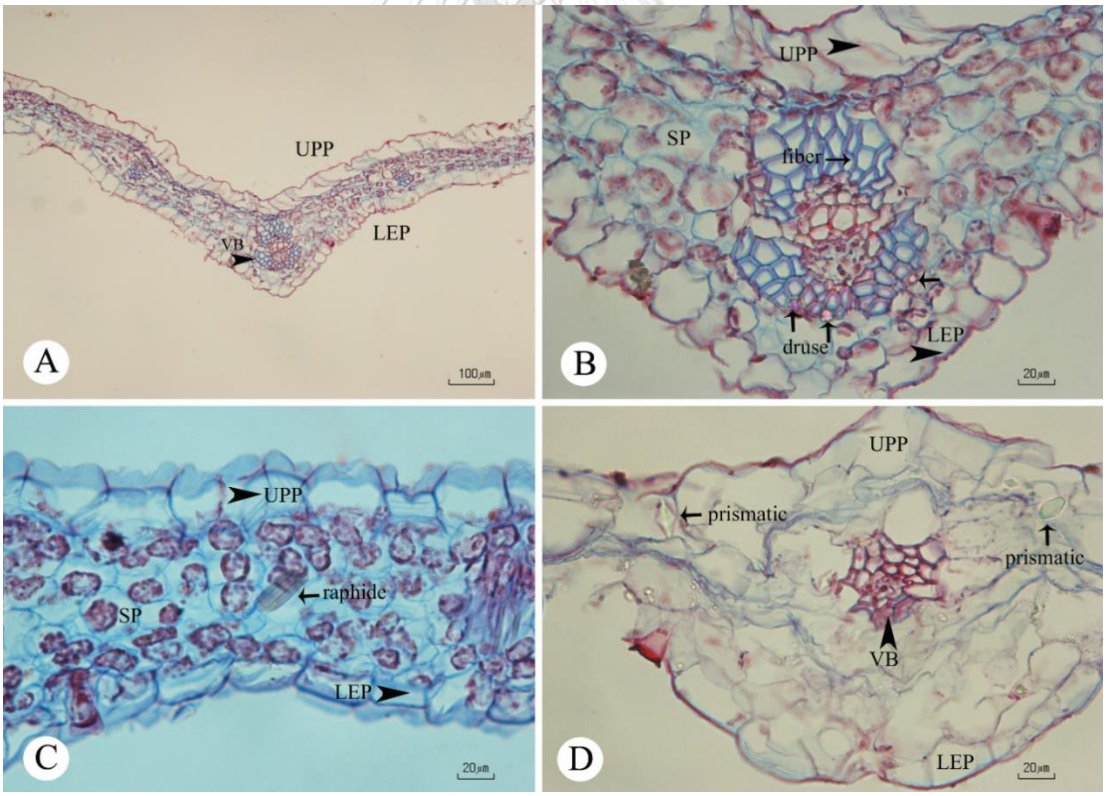


Plate 3. 10 Transverse section of leaf: A. midrib in transverse section; B. Druse crystal in close-up; C. Raphide crystal in close-up; D. Prismatic crystal in close-up. Abbreviation; UPP = upper epidermis; LEP = lower epidermis; SP = spongy cell; VB = vascular bundle.

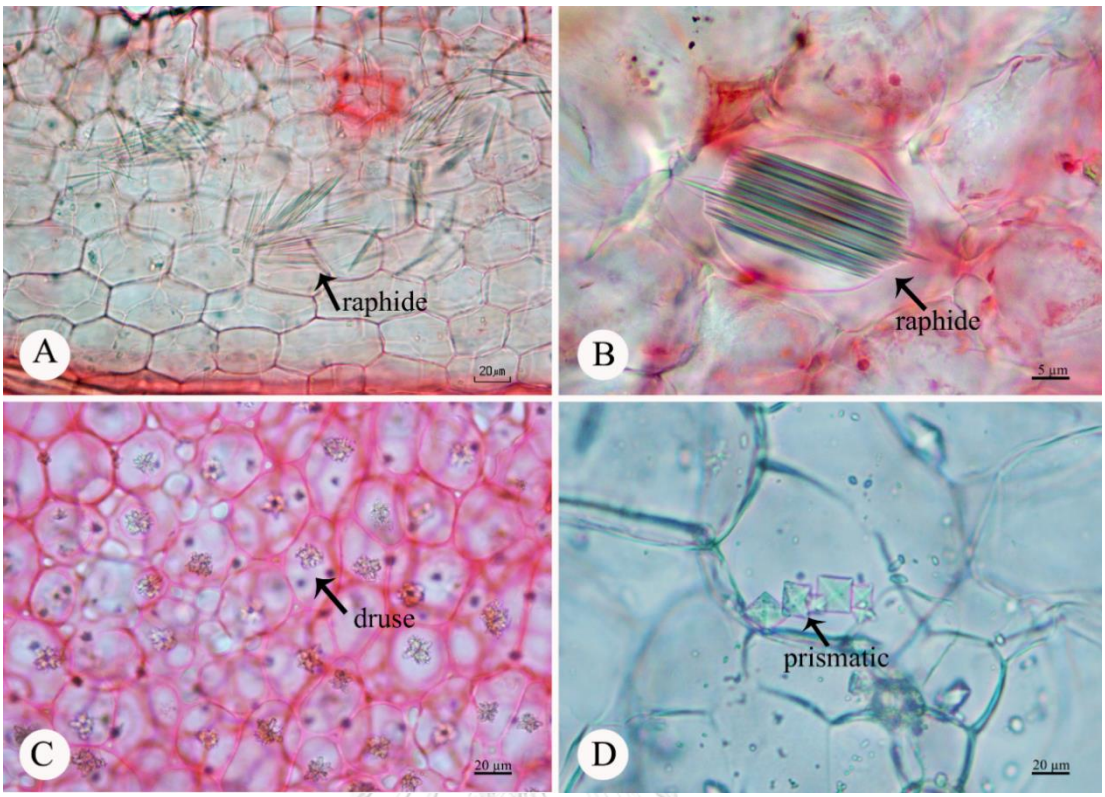


Plate 3. 11 Different types of crystal in mesophyll layer: A. and B. Raphide crystals; C. Druse crystals; D. Prismatic crystals.

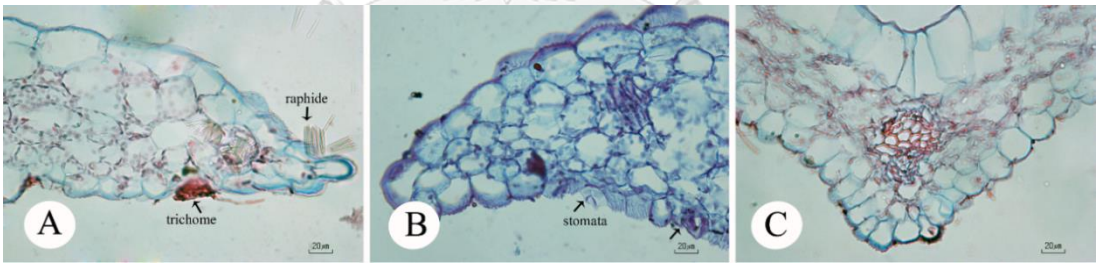


Plate 3. 12 Transverse section of leaves: A. leaf margins in *Dendrobium strongylanthum*; B. leaf margins in *D. proteranthum*; C. midribs in *D. gregulus*.

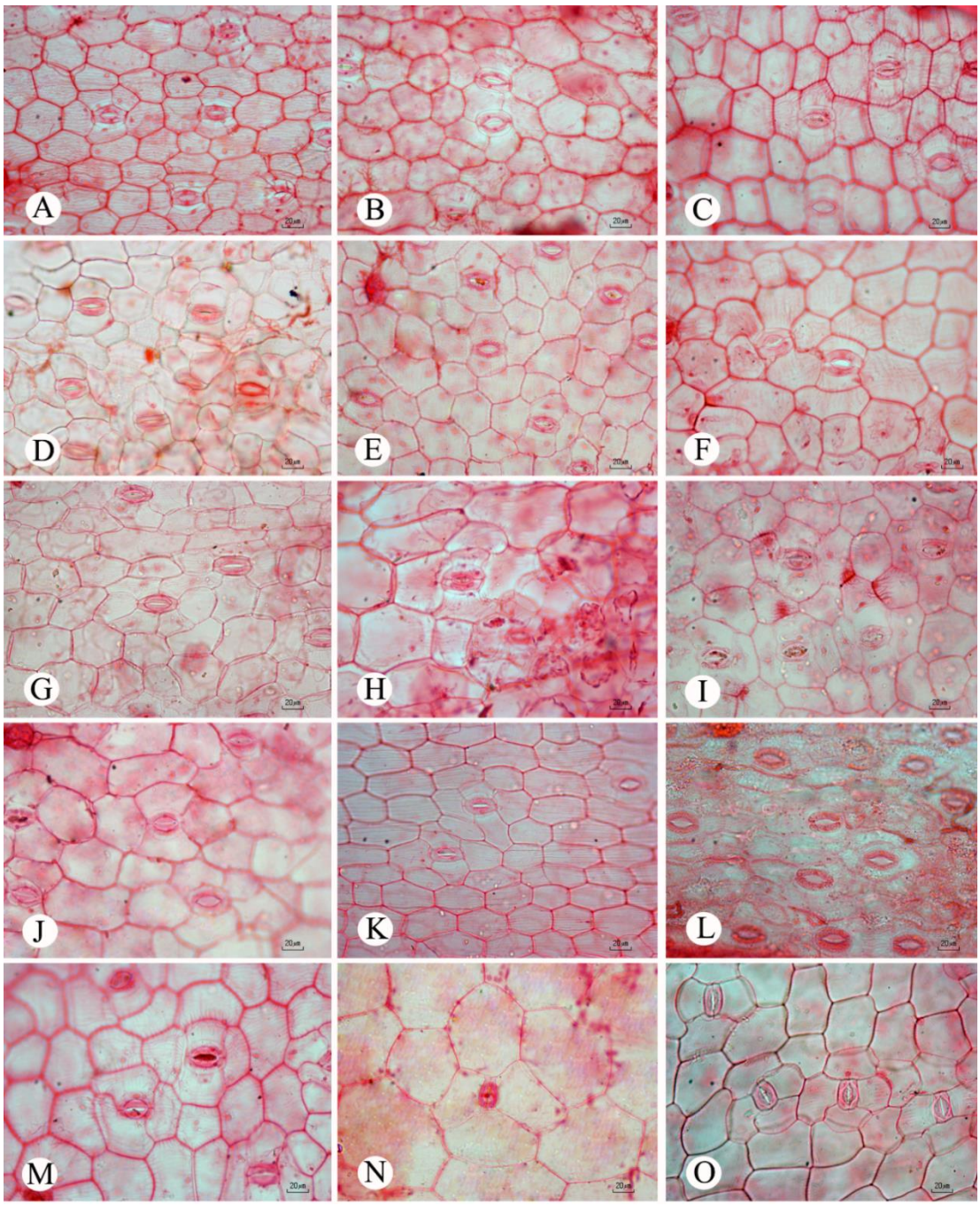


Plate 3. 13 Epidermal cells and stomata on abaxial leaf surface in the *Stachyobium*: A. *Dendrobium chiangdaoense*; B. *D. compactum*; C. *D. cuspidatum*; D. *D. denudans*; E. *D.dixonianum*; F. *D. incurvum*; G. *D. kanburiense*; H. *D. peguanum*; I. *D. perpaulum*; J. *D. porphyrochilum*; K. *D. pycnostachyum*; L. *D. proteranthum*; M. *D. strongylanthum*; N. *D. venustum* var. *delacourii*; O. *Dendrobium* sp.1.

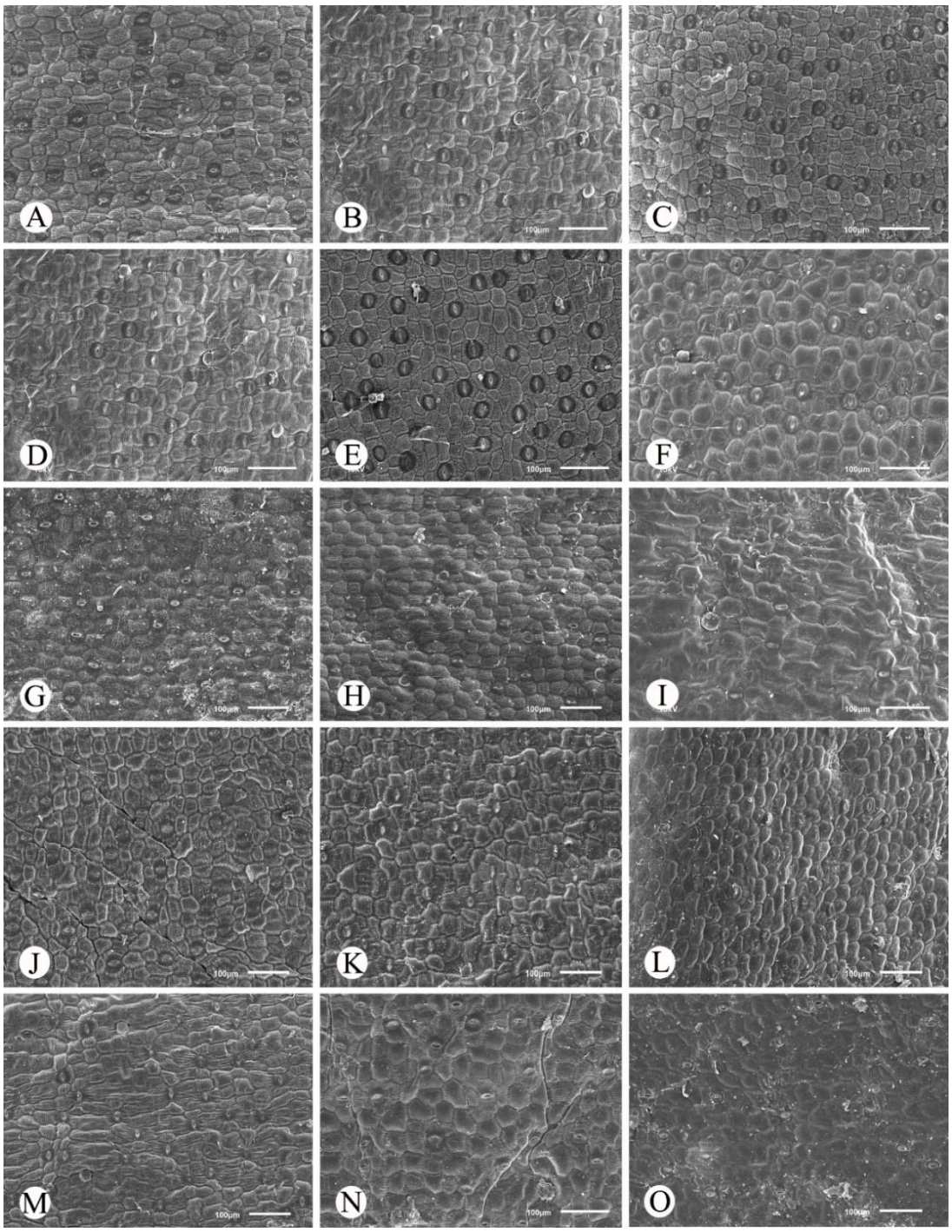


Plate 3. 14 SEM micrographs on abaxial leaf surface of leaves in the *Stachyobium*: A. *Dendrobium chiangdaoense*; B. *D. compactum*; C. *D. cuspidatum*; D. *D. denudans*; E. *D. dixonianum*; F. *D. elliottianum*; G. *D. garrettii*; H. *D. incurvum*; I. *D. kanburiense*; J. *D. peguanum*; K. *D. strongylanthum*; L. *D. venustum*; M. *D. venustum* var. *delacourii*; N. *Dendrobium* sp.1; O. *Dendrobium* sp.2.

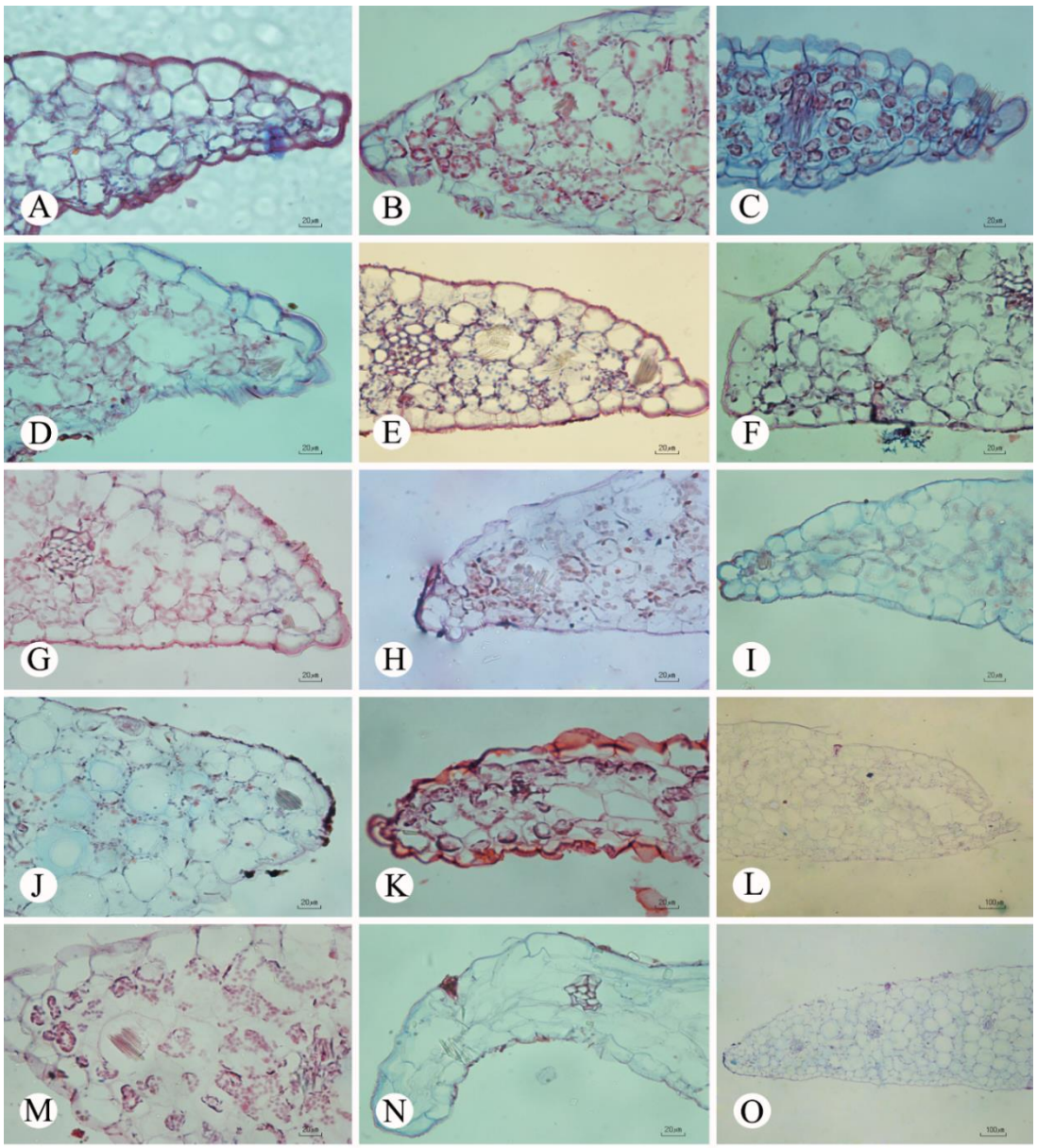


Plate 3. 15 Transverse sections of leaf margins in the *Stachyobium*: A. *Dendrobium chiangdaoense*; B. *D. compactum*; C. *D. cuspidatum*; D. *D. denudans*; E. *D. dixonianum*; F. *D. elliottianum* ; G. *D. garrettii*; H. *D. gregulus*; I. *D. incurvum*; J. *D. kanburiense*; K. *D. peguanum*; L. *D. perpaulum*; M. *D. porphyrochilum*; N. *D. pycnostachyum*; O. *D. venustum*.

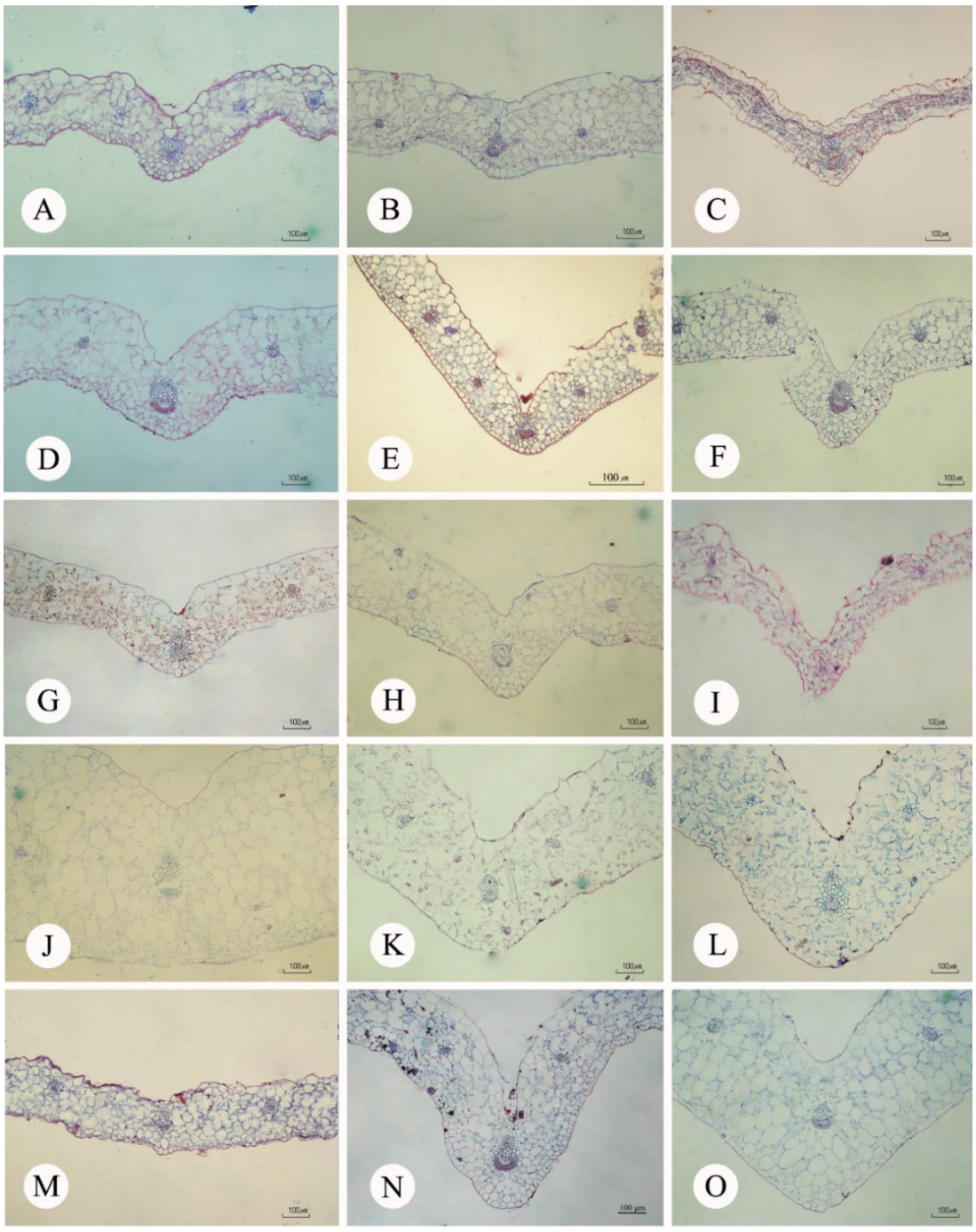


Plate 3. 16 Transverse sections of midribs in the *Stachyobium*: A. *Dendrobium chiangdaoense*; B. *D. compactum*; C. *D. cuspidatum*; D. *D. denudans*; E. *D. dixonianum*; F. *D. garrettii*; G. *D.gregulus*; H. *D.incurvum*; I. *D. kanburiense*; J. *D. peguanum*; K. *D. perpaulum*; L. *D. porphyrochilum*; M. *D. proteranthum*; N. *D. strongylanthum*; O. *D. venustum*.

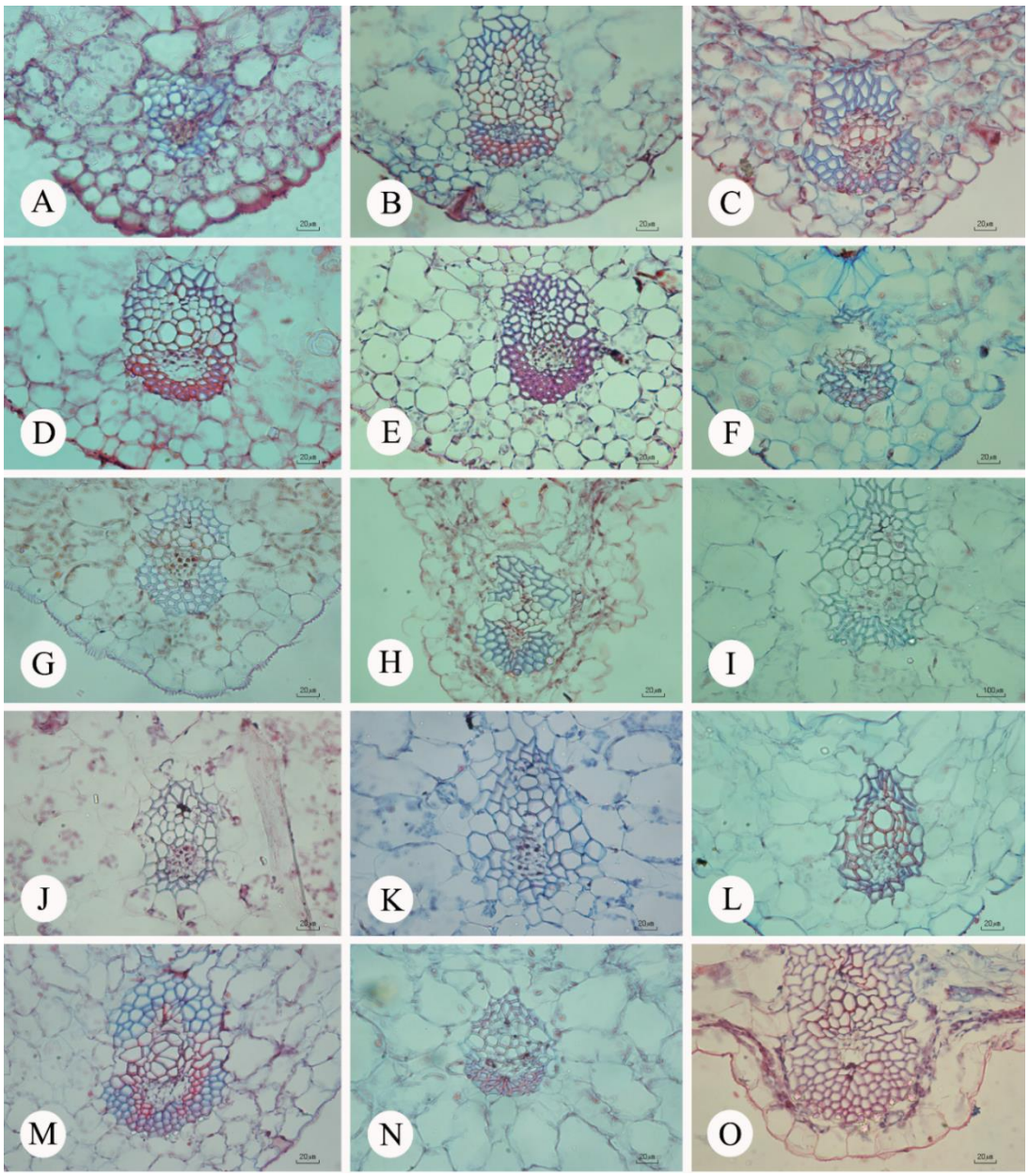


Plate 3. 17 Vascular bundle of midribs: A. *Dendrobium chiangdaoense*; B. *D. compactum*; C. *D. cuspidatum*; D. *D. denudans*; E. *D.dixonainum*; F. *D. gregulus*; G. *D. incurvum*; H. *D. kanburiense*; I. *D. peguanum*; J. *D. perpaulum*; K. *D. porphyrochilum*; L. *D. pycnostachyum*; M. *D. strongylanthum*; N. *D. venustum*; O. *Dendrobium* sp.1.

CHAPTER IV
PALYNOLOGICAL STUDIES

4.1 Introduction

Pollen morphology is a science with the primary purpose to describe and categorize pollen grains (Reitsma, 1966). The information of pollen and spores from vascular plants have numerous value in taxonomic studies because it help to understand the relationship between plants and environmental change from the past to the present (Moore *et al*., 1991). Due to their pollen trait, which are influenced by the strongly selective forces involved in severally reproductive processes, *e.g*. pollination, dispersal, and germination (Erdtman, 1952; Nowicke and Skvarla, 1979; Stuessy, 1990). Furthermore, the morphological features of pollen grains also can provide beneficial characters, such as the pollen wall and sculpture, position of aperture, shape, size and number which are usefully for classification and identification from family, generic and species levels (Simpson, 2010). Therefore, it indicates that the pollen morphology is a significant data for taxonomic study.

4.2 Literature review

The knowledge from palynology has long been used as one of tools for resolving taxonomic problems. There are a lot of previous researches which suggested that characteristic features of pollen are potential use as following.

In 1896, Chodat investigated pollen morphology of Polygalaceae and categorised into 8 genera in this family.

In the same year, Christensen studied pollen sculpturing in the family Malvaceae. More than 120 species in 40 genera of Malvaceae were examined. The result showed that the data from characteristic pollen are supported with common classification, phytogeography and cytology of the family.

Erdtman (1952) reported the pollen morphology of temperate Rubiaceae in 230 species from 120 genera and published on pollen morphology & plant taxonomy of angiosperm.

In 1968, Varghese studied the pollen features of 2 species in genus *Lindernia* (Scrophulariaceae). He found pollen shape, exine sculpture and type of aperture are helpful for species identification.

E1-Ghazaly and Chaudhary (1993) investigated pollen morphology of sixty species of the genus *Euphorbia* by LM and SEM. So they found type of pollen in this genus can separate into 7 types and revealed the evolutionary relationship between pollen types.

In 2003, Parnell explored pollen surface features of *Syzygium* (Myrtaceae) from Southeast Asia. Fifty seven species of this genus were surveyed by scanning electron

microscopy. He found all species in the genus *Syzygium* are apocolpial field but size pollen can be discriminated section *Jambosa* from other related within genus.

Pruesapan and Van Der Ham (2005) examined pollen architecture of 37 species in genus *Trichosanthes* (Cucurbitaceae) by light microscopy, scanning and transmission electron microscopy. They found exine ornamentation of pollen grains are useful for distinguishing into five types.

Krachai and Pornpongrungrueng (2011) inspected pollen morphology of genus *Lumnitzera* (Combretaceae) in Thailand and they found pollen exine sculpturing are useful for species identification.

Rodrigues *et al*. (2016) studied pollen morphology of 25 species from 14 genera in the family Apocynaceae from Amazonas, Brazil. The study indicated that exine ornamentation, shape and pollen aperture can be used for grouping and species identification.

4.2.1 Palynological study in family Orchidaceae

In recent decades, many researchers have tried to investigate pollinium morphology of Orchid family. The micromorphology of pollinium surface has been reported as following

Reichenbach was the first botanist who studied Orchid pollen in 1852 and he reported pollen grains in this family can be separated into 2 types that are monads and tetrads.

Following Schill (1974) published the first paper about pollinium surface by using scanning electron microscopy for examination. The results demonstrated that sculpturing of pollinium surface might be useful for the phylogeny and taxonomy of the Orchidaceae.

Later, Schill and Pfeiffer (1977) investigated pollen trait of 630 species in 200 genera and all subfamilies. They found the majority of pollen grains are absolutely inapurturate, while pollen grains of subfamily Cypripedioideae is colpate and porate grains is found in Neottioideae. The exine layer of Orchid family consists of only ektexine (lake of endexine). The tectate wall can separate into 2 types, *i.e.* semitectate type which occur in subfamily Neottioideae and intectate type which found in the most Orchidaceae.

In 1978, Newton and Williams observed pollen morphology of 44 species from 4 genera of subfamily Cypripedioideae and 2 genera of subfamily Apostasioideae by acetolyzed pollen. The result demonstrated that pollen sculpturing are useful for distinguishing between 2 subfamilies. Reticulate pollen grains are found in subfamily Apostasioideae, whereas the pollen grains of Cypripedioideae vary from psilate, scabrate and foveolate.

Barone Lumaga *et al.* (2006) examined exine micromorphology of 45 species from tribe Orchidieae, subfamily Orchidoideae by scanning electron microscopy. Five types of pollen exine sculpturing were found, *i.e*. psilate, reticulate, psilate-scabrate,

perforate-regulate and baculate. In addition, the data from pollen surface sculpturing can be used to support phylogenetic and evolution of this subsamily.

In 2010, Passarelli and Rolleri studied pollen grains and massulae in pollinia of four South American palustrine of *Habenaria*. They found all pollen grains of 4 species are inaperturate. Besides, shape of massulae (pyriform, triangular, tabular) and ornamentation of exine are useful for distinguishing *Habenaria gourlieana* from the other 3 species (Plate 4.1).

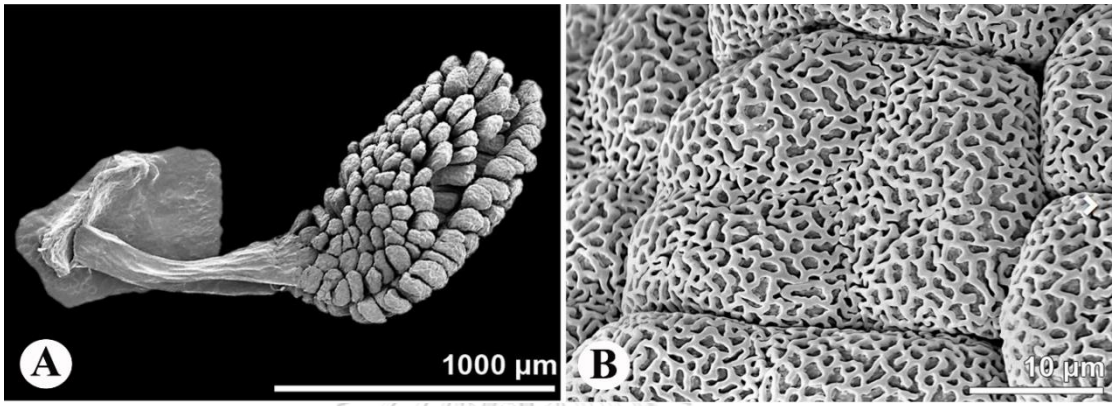


Plate 4. 1 SEM micrograph of pollinium and massulae in *Habenaria gourlieana*. A. Pollinium B. Details of massulae (micro-reticulate) from Passarelli and Rolleri (2010).

4.2.2 The palynology in genus *Dendrobium* Sw.

Types of pollen sculpturing may provide significant data for solving taxomomic problems. So far, the pollen morphology in Genus *Dendrobium* is still lacking information. Only one publication which reported the data from this genus as follow.

Chaudhary *et al.* (2012) investigated pollinia micromorphologies of 18 species of the genus *Dedrobium* belonging to section *Aporum*, *Callista*, *Dendrobium* and *Formosae* from Northern-East India. The research revealed that shape of pollinium can categorize into 6 types, while pollen sculpturing exhibited into 4 types that are psilate, regular, scabrate and psilate- scabrate. This evidences are useful for supporting the hypothesis of phylogenetic trend of exine evolution.

The purpose of this study is to investigate characteristic features of pollen of *Dendrobium* section *Stachyobium* in Thailand which can useful for grouping species.

4.3 Materials and Methods

4.3.1 Plant materials

The *Stacyobium* species are listed in table 4.1. The pollinia were collected from mature flower (bloom flower) in natural habitat. Besides, some species were obtained from Kasin Suvatabhandhu Herbarium (BCU), Bangkok Herbarium (BK) and The Forest Herbarium (BKF). The pollinia were fixed in 70% ethanol or FAA (Formalin-acetic acid-alcohol, which compose of 70 % ethanol 90 ml mixed with glacial acid 5 ml and 5 ml of commercial formalin) at least 24 hour. Then, dehydrated by alcohol series 95% and 100% ethanol for 5-10 minutes for each specimen, followed by critical-point dried with CO_2. Dried specimens were mounted on stubs and coated with gold. Finally, the pollinium surfaces were investigated with a JSM-6610 LV scanning electron microscope.

Several pollinium characters were observed that are shape, size and surface ornamentation of pollinia.

Table 4. 1 List of *Stachyobium* specimens for investigation in palynology.

No.	Species	Voucher specimens	Locality
1	*D. chiangdaoense*	*W. Buddhawong* & *S. Suddee 018* (BKF)	Chiang Mai, Doi Chiang Dao
2	*D. compactum*	*P. Prommanut 52* (BK)	Chiang Mai, Mae Sanam Silvicultural Station
3	*D. compactum*	*P. Prommanut et al. 504* (BK)	Tak, Thungyai Narasuan Eastern Wildlife Sanctuary
4	*D. cuspidatum*	*S. Pumicong 461* (QBG)	Tak, Doi Hua Mot
5	*D. denudans*	*P. Prommanut 620* (BK)	Mae Hong Son, Doi Ke-a Po Pho Cho
6	*D. denudans*	*S. Suddee* 1598 (BKF)	Nan, Doi Phuka NP.
7	*D. dixonianum*	*P. Prommanut & W. Buddhawong 661* (BK)	Chiang Mai, Doi Angkhang
8	*D. dixonianum*	*P. Prommanut 474* (BK)	Mae Hong Son, Trail up to Doi Ke-a Po Pho Cho
9	*D. elliottianum*	P. Prommanut *et al. 594* (BK)	Tak, Doi Hua Mod
10	*D. garrettii*	P. Prommanut *et al. 594* (BK)	Chiang Mai, Doi Inthanon NP.
11	*D. gregulus*	*P. Prommanut 053* (BKF);	Chiang Mai, Mae Sanam Silvicultural Station
12	*D. incurvum*	*P. Prommanut 850* (BCU)	Trat, Khao Saming
13	*D. incurvum*	*M. Chanla* s.n. (BKF)	Ranong, Klong Naka Wildlife Sanctuary
14	*D. kanburiense*	*P. Prommanut* s.n. (BK)	Tak, Doi Hua Mod
15	*D. mucronatum*	GT 8470b	Mae Hong Son, Khun Yuam
16	*D. peguanum*	*P. Prommanut 245* (BKF)	Mae Hong Son, Mae Sariang
17	*D. peguanum*	*S. Rueangrea et al. 30* (BKF)	Mae Hong Son, Doi Hua Mod 2
18	*D. perpaulum*	*P. Prommanut* 478 (BK)	Mae Hon Son, Doi Ke-a Po Pho Cho
19	*D. perpaulum*	*P. Prommanut 559* (BCU)	Chiang Mai, Doi Inthanon NP.
20	*D. porphyrochilum*	*P. Prommanut 645* (BCU)	Nan, Doi Phu Kha NP.
21	*D. porphyrochilum*	*P. Prommanut* & *P. Triboun* s.n. (BK)	Chiang Mai, Doi Inthanon NP.
22	*D. pycnostachyum*	*P. Prommanut 49* (BKF)	Chiang Mai, Mae Sanam Silvicultural Station
23	*D. strongylanthum*	*P. Prommanut* & *W. Budhthiwong 701* (BK)	Chiang Mai, Mae On-Doi Saket
24	*D. strongylanthum*	*Staff PK 001*(BKF)	Nan, Doi Phu Kha NP.
25	*D. venustum*	*P. Prommanut 78* (BKF)	Chiang Mai, Obluang NP.
26	*D. venustum*	*P. Prommanut* & *M. Kidyoo 714* (BCU)	Sakon Nakhon, Phu Phan NP.
27	*D. venustum var. delacourii*	*P. Prommanut* s.n. (BK)	Mae Hong Son, Huay Saew Tao

No.	Species	Voucher specimens	Locality
28	*D. venustum var. delacourii*	*P. Prommanut* & *M. Kidyoo* 718 (BCU)	Bueng Kan, Phu Wua Wildlife Sanctuary
29	*Dendrobium* sp.1	*P. Prommanut* & *S. Suddee* 584 (BK);	Kanchanaburi, Thong Pha Phum NP.
30	*Dendrobium* sp.1	*P. Prommanut* & *W. Buddhawong 703* (BKF).	Tak, Umphang, near the Check Point to Thi Lo Su Waterfalls
31	*Dendrobium* sp.2	*A. Sathapattayanon* 400 (BCU)	Sakonnakorn, Phu Pan NP.

4.4 Results and Discussions

4.4.1 The general structure of pollinia in *Dendrobium* section *Stachyobium*

Thirty-one specimens (29 taxa) of *Stachyobium* pollinia in Thailand were studied by SEM. The pollinia are the dispersal unite of coherent massulae pollen grains which were found in Family Orchidaceae and Apocynaceae.

Most species in the section usually have four pollinia in two unequal pairs. Each pollinium is quite flattened, one of pairs larger than another one. In addition, each pollinium is a mass of tiny rather featureless pollen grain united in tetrads (Plate 4.2: A and B). In some cases, the pollinia sculpturing on the surfaces is come from individual cells of tetrad arrangement.

Shape: The pollinia shape of the *Stachyobium* can separate into 2 types there are 1. Obliquely ellipsoid; most species are this type. 2. Globose; found in *D. mucronatum*.

Size: The pollinia size varied significantly among this section which ranging from the largest pollinia are observed in *Dendrobium venustum*, 1–1.5 mm long, 0.8–1 mm wide, whereas *D. perpualum* has the smallest pollinia , 0.3–0.5 mm long, 0.1−0.2 mm wide.

Exine: The microstructure of pollinia surface in this section is waxy, thick layer (exine) , the wall of exine composes of only tectate-imperforate and psilate type (ornamentation of pollinia is quite smooth) . While the degree of surface sculpturing (pitting) can be categorized into 2 types as described below.

- Type I. (the exterior surface is flattened and shallow) : This type appears only in *Dendrobium chiangdaoense*, *D. garrettii* and *D. incurvum* (Plate 4.3: A).

-Type II. (the exterior surface is bulge and deep): Most species of the section *Stachyobium* are this type (Plate 4.3: B).

Apertures: Most of species in this section are inapureturate like other genera in subfamily Epidendroideae.

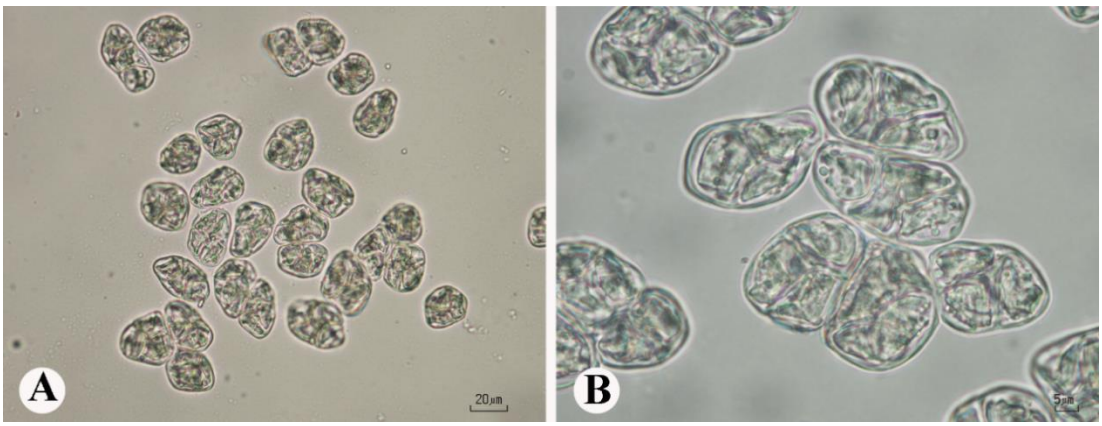


Plate 4. 2 Light microscopy showing pollen grain united in tetrad and surface sculpturing of pollinium: A. Pollen tetrad of *Dendrobium venustum*; B. Close-Up of pollen tetrad of *D. venustum*.

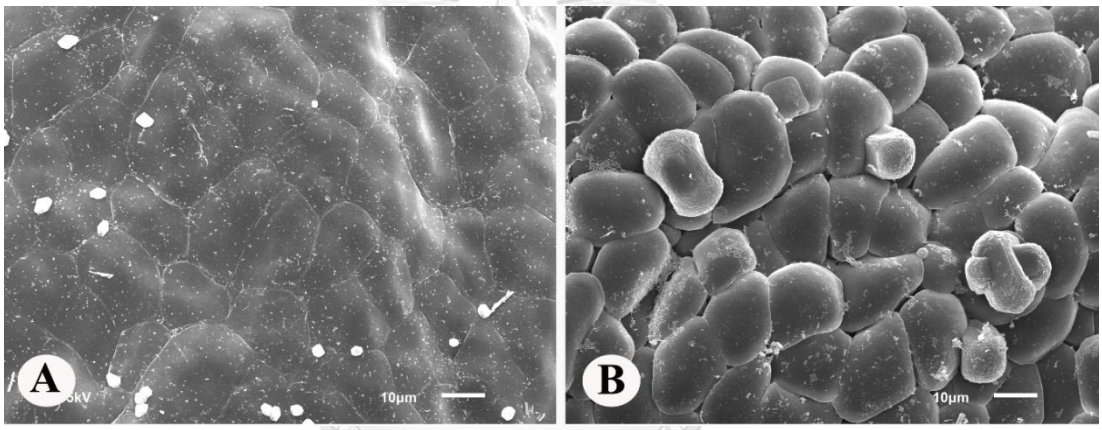


Plate 4. 3 SEM micrographs showing 2 types of surface sculpturing of pollen: A. the exterior surface is flattened and shallow in *Dendrobium garrettii* B. the exterior surface is bulge and deep in *D. peguanum*.

Pollen exine sculpturing of the *Stachyobium* agrees well with the previous studies which have examined the pollinia sculpturing from other genera in subfamily Epidendroideae (Schill & Pfeiffer, 1977; Dressler, 1993). In general, the pollen grains of subfamily Epidendroideae are tetrads and packed into pollinia, the wall of exine consists of tectate-imperforate or tectate-perforate, psilate ornamentation, loss of the foot layer and inaperturate. Whereas, the pollen grains of primitive orchid (Apostasioideae and Cypripedioideae) are usually monads, thin layer (exine), tectate-perforate, reticulate ornamentation and monosulcate similar to the most monocot plants such as Amaryllidaceae and Asparagaceae.

Nonetheless, this result is not corresponded with Chaudhary *et al.* in 2012, they reported pollen sculpturing from 18 species of *Dendrobium* are exhibited into 4 types *i.e.*, psilate, regular, scabrate and psilate-scabrate. The pollen of most species are colpate aperture, except *D. williamsonii* (section *Formosae*) which has colporate aperture. The differences of 2 studies were probably from the different section, although they being in the same genus.

4.5 Conclusions

This is the first times that the pollen morphology of *Dendrobium* section *Stachyobium* is examined in Thailand. The result indicates that shape, size and ornamentation of pollinia are not distinctively different and cannot use to identify at the species level. Nevertheless, all qualitative pollen trait might be useful for groping species in this section and can be used to analyze the relationship of evolutionary trends within genus *Dendrobium* and other genera in subfamily *Epidendroideae*.

Table 4. 2 Pollinia characters of species in *Dendrobium* section *Stachyobium* in Thailand.

No.	*Taxa*	Shape	Size	Ornamentation
1	*Dendrobium chiangdaoense*	narrowly elliptic	0.9–1 x ca. 0.5 mm	psilate type
2	*D. compactum*	obliquely elliptic	0.7–0.8 x 0.2–0.3 mm	psilate type
3	*D. cuspidatum*	obliquely elliptic	1–1.5 x ca. 0.5 mm	psilate type
4	*D. denudans*	obliquely elliptic	1–1.3 mm x 0.5–0.6 mm	psilate type
5	*D. dixonianum*	obliquely elliptic	0.8–0.9 x 0.2−0.3 mm	psilate type
6	*D. elliottianum*	obliquely elliptic	0.4–0.5 x 0.2−0.3 mm	psilate type
7	*D. garrettii*	obliquely elliptic	0.7–0.8 x 0.2–0.3 mm	psilate type
8	*D. gregulus*	obliquely elliptic	0.5–0.6 x 0.1−0.2 mm	psilate type
9	*D. incurvum*	obliquely elliptic	1–1.5 x ca. 0.5 mm	psilate type
10	*D. kanburiense*	obliquely elliptic	0.6–0.7 x 0.4–0.5 mm	psilate type
11	*D. mucronatum*	globose	0.4–0.6 x 0.2–0.3 mm	psilate type
12	*D. peguanum*	obliquely elliptic	1–1.5 x ca. 0.5 mm	psilate type
13	*D. perpaulum*	obliquely elliptic	0.3–0.5 x 0.1−0.2 mm	psilate type
14	*D. porphyrochilum*	obliquely elliptic	0.5–0.6 x 0.1−0.2 mm	psilate type
15	*D. strongylanthum*	obliquely elliptic	0.7–0.8 x 0.2–0.3 mm	psilate type
16	*D. venustum*	narrowly elliptic	1–1.6 x 0.8–1 mm	psilate type
17	*D. venustum* var. *delacourii*	obliquely elliptic	1–1.6 x 0.8–1 mm	psilate type
18	*Dendrobium* sp.1	obliquely elliptic	0.4–0.6 x 0.2–0.3 mm	psilate type
19	*Dendrobium* sp.2	obliquely elliptic	1–1.6 x 0.8–1 mm	psilate type
20	*Dendrobium* sp.3	obliquely elliptic	0.5–0.6 x 0.1−0.2 mm	psilate type

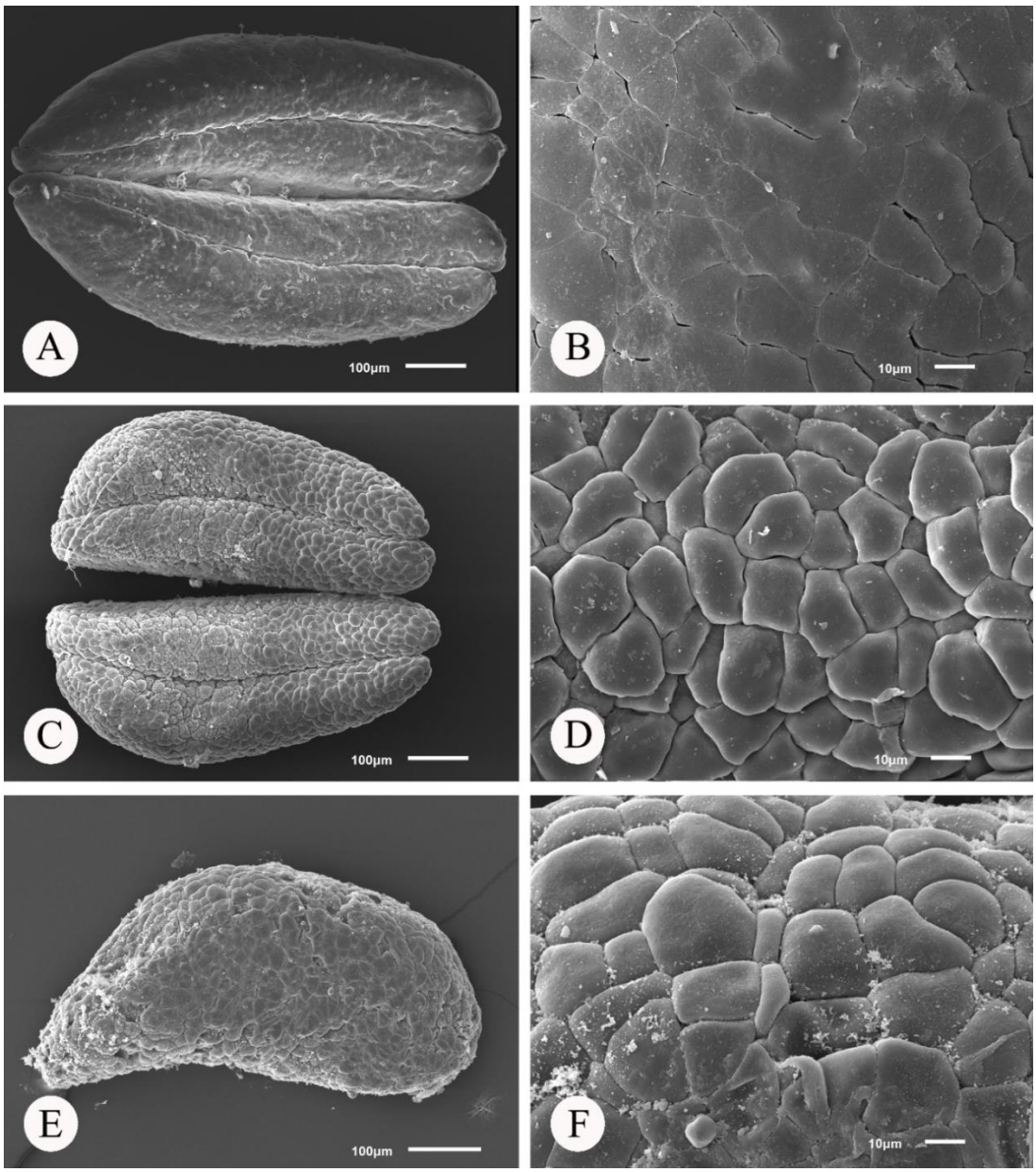


Plate 4. 4 SEM micrographs pollinia of *Dendrobium* section *Stachyobium*: A. The whole pollinium of *Dendrobium chiangdaoense*; B. Details of pollen ornamentation (exine) of *D. chiangdaoense*; C. The whole pollinium of *D. compactum*; D. Details of pollen ornamentation (exine) of *D. compactum*; E. The whole pollinium of *D. cuspidatum*; F. Details of pollen ornamentation (exine) of *D. cuspidatum*.

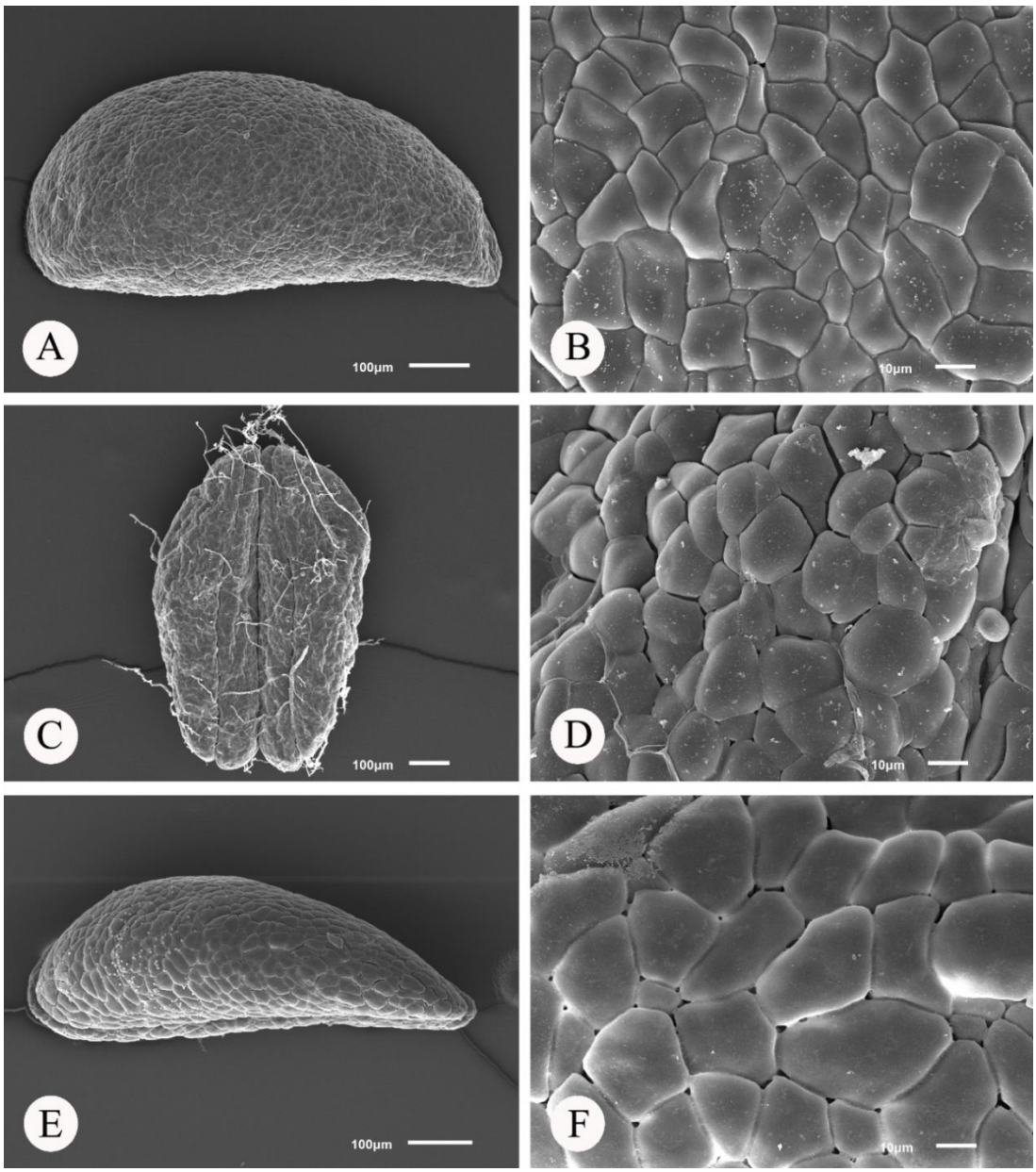


Plate 4. 5 SEM micrographs pollinia of *Dendrobium* section *Stachyobium*: A. The whole pollinium of *Dendrobium denudans*; B. Details of pollen ornamentation (exine) of *D. denudans*; C. The whole pollinium of *D. dixonianum*; D. Details of pollen ornamentation (exine) of *D. dixonianum*; E. The whole pollinium of *D. elliottianum*; F. Details of pollen ornamentation (exine) of *D. elliottianum*.

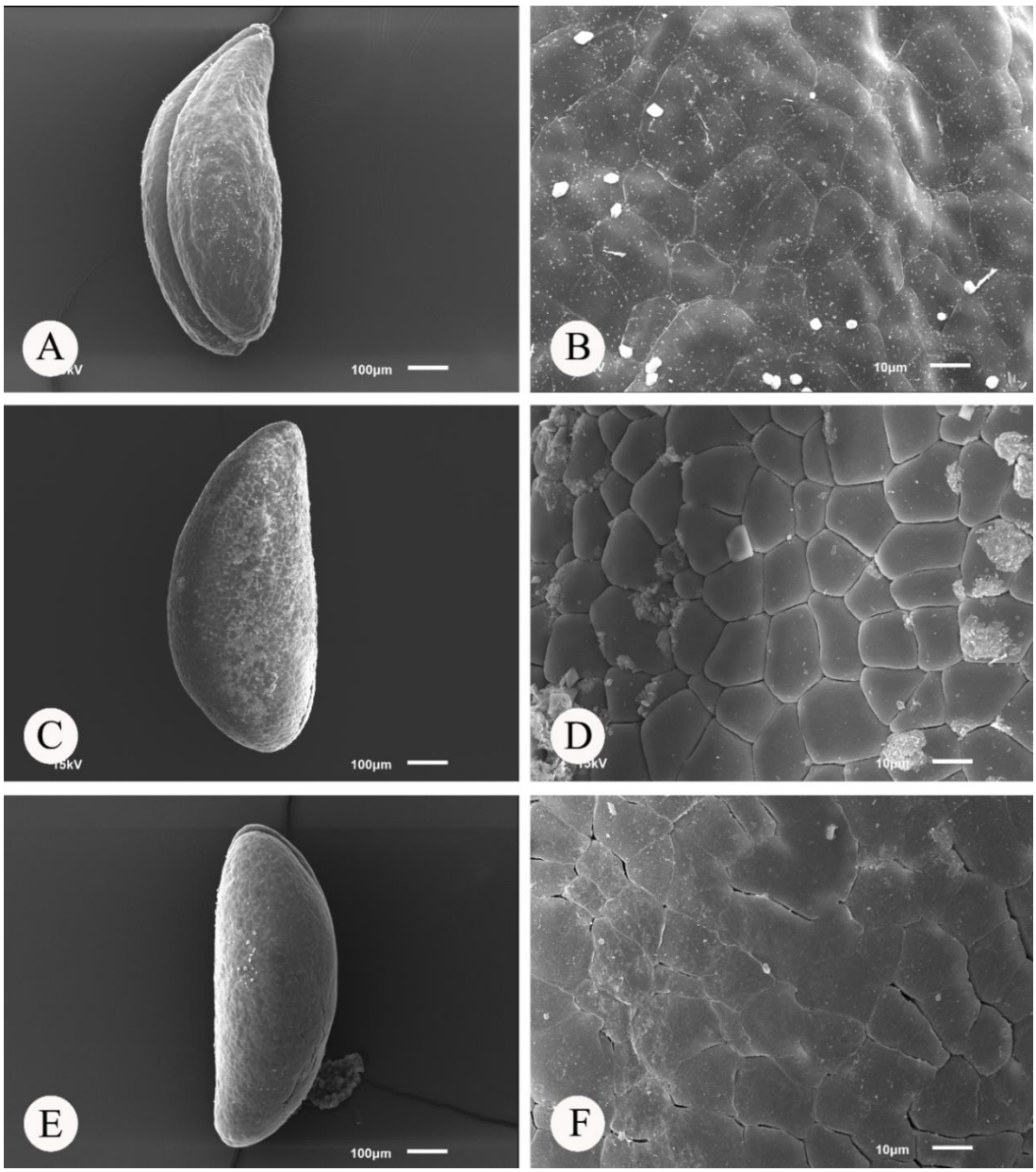


Plate 4. 6 SEM micrographs pollinia of *Dendrobium* section *Stachyobium*: A. The whole pollinium of *Dendrobium garrettii*; B. Details of pollen ornamentation (exine) of *D. garrettii*; C. The whole pollinium of *D. gregulus*; D. Details of pollen ornamentation (exine) of *D. gregulus*; E. The whole pollinium of *D. incurvum*; F. Details of pollen ornamentation (exine) of *D. incurvum*.

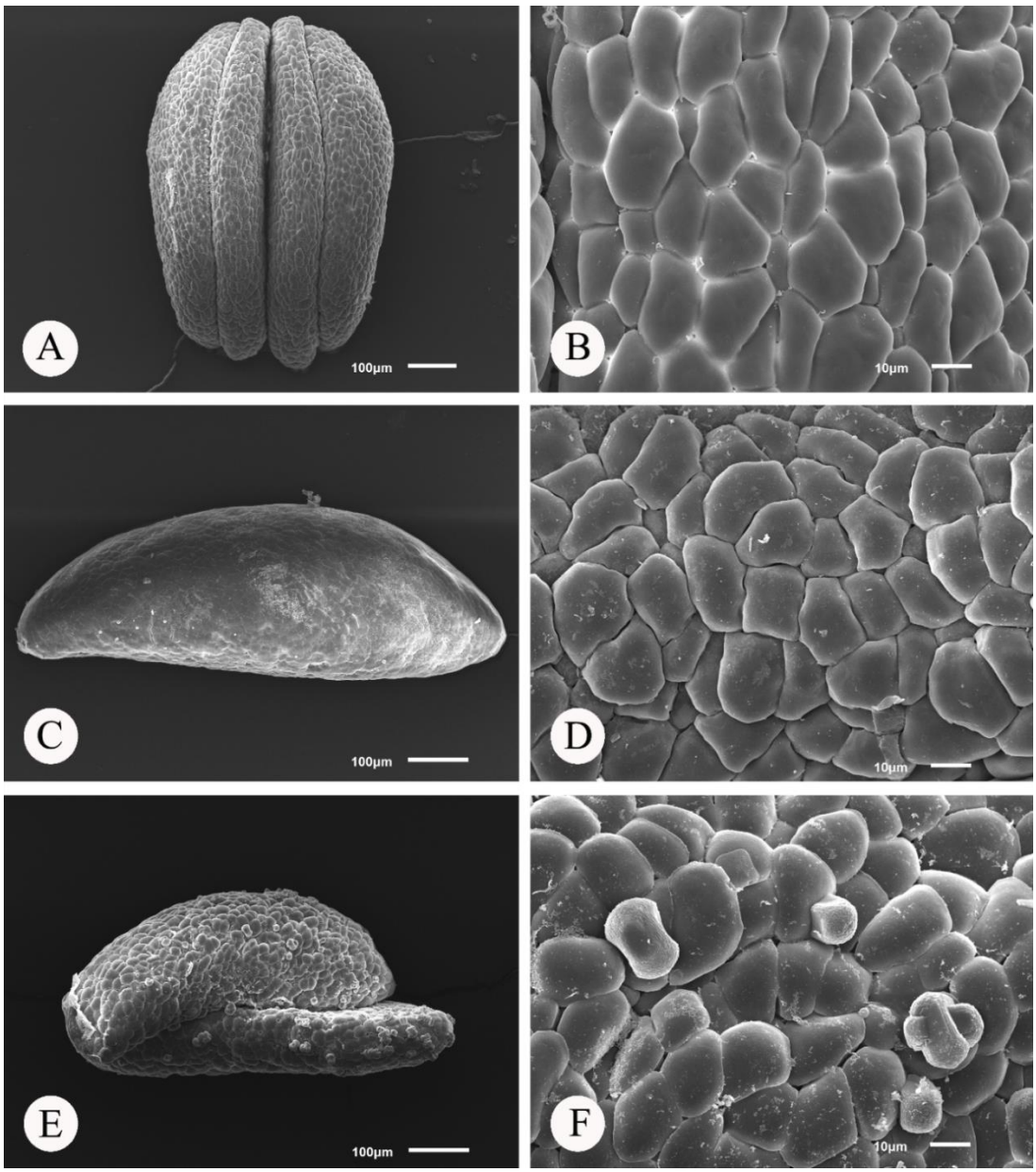


Plate 4. 7 SEM micrographs pollinia of *Dendrobium* section *Stachyobium*: A. The whole pollinium of *Dendrobium kanburiense*; B. Details of pollen ornamentation (exine) of *D. kanburiense*; C. The whole pollinium of *Dendrobium* sp1; D. Details of pollen ornamentation (exine) of *Dendrobium* sp1; E. The whole pollinium of *D. peguanum*; F. Details of pollen ornamentation (exine) of *D. peguanum*.

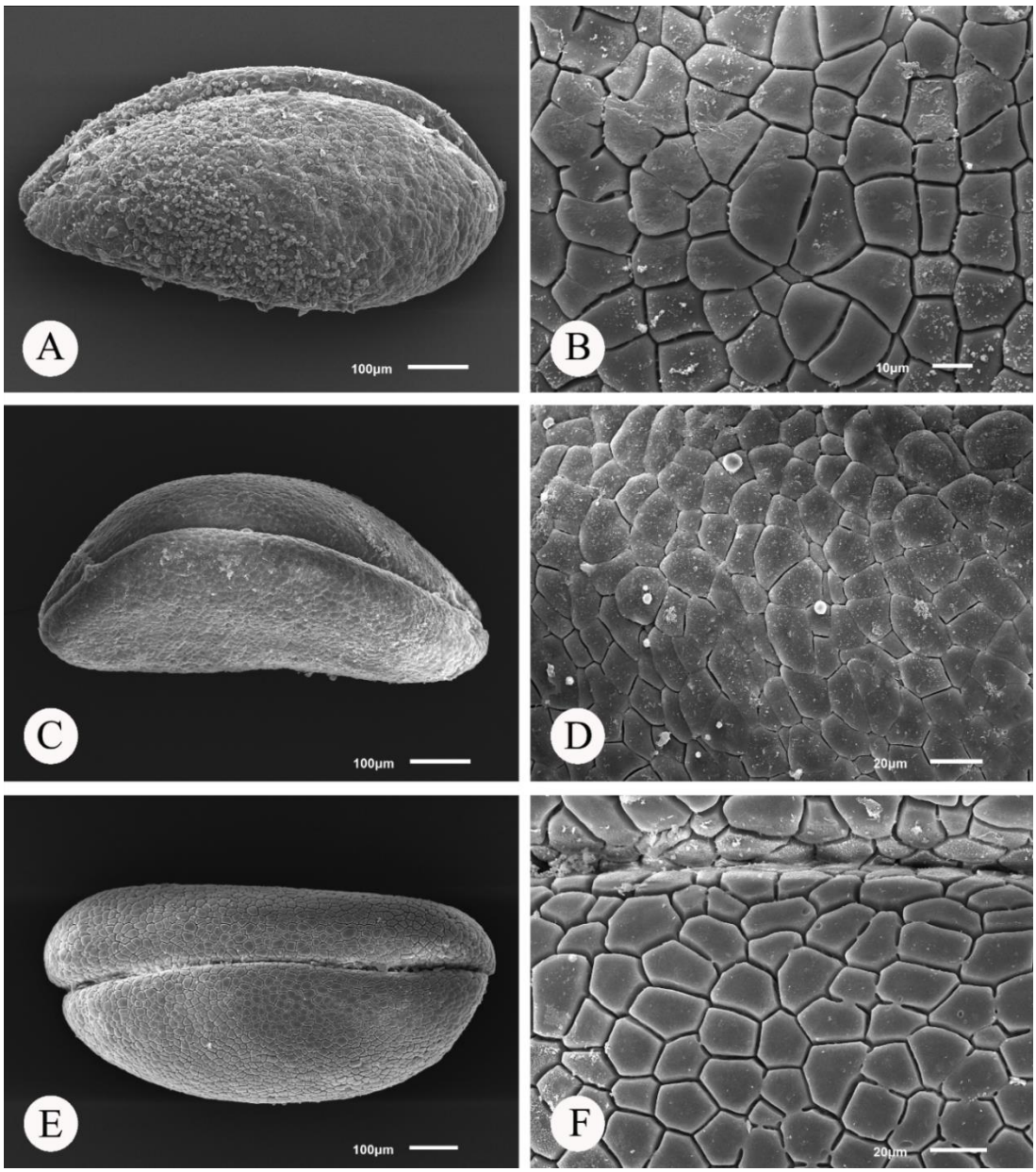


Plate 4. 8 SEM micrographs pollinia of *Dendrobium* section *Stachyobium*: A. The whole pollinium of *Dendrobium perpaulum*; B. Details of pollen ornamentation (exine) of *D. perpaulum*; C. The whole pollinium of *D. porphyrochilum*; D. Details of pollen ornamentation (exine) of *D. porphyrochilum*; E. The whole pollinium of *D. strongylanthum*; F. Details of pollen ornamentation (exine) of *D. strongylanthum*.

CHAPTER V
TAXONOMIC TREATMENTS

5.1 Introduction

The aim of this chapter is to provide the information from taxonomic revision which consists of description, morphology, distribution, ecology, utilization, vernacular names and illustration of the genus *Dendrobium* Sw. section *Stachyobium* Lindl. in Thailand.

5.2 Materials and Methods

5.2.1 Plant materials

The study of *Dendrobium* section *Stacyobium* were based on the examination of the main herbaria specimens as well as new specimen from field collections from various parts of Thailand. The herbarium specimens hold in the following herbaria were investigated: Harvard University, Oakes Ames Orchid Herbarium, United State of America (AMES) (photos and online), Kasin Suvathabandhu Herbarium, Department of Botany, Chulalongkorn University, Thailand (BCU), Bangkok Herbarium, Plant Variety Protection Office, Department of Agriculture, Bangkok, Thailand (BK), The Forest Herbarium, Department of National Park, Wildlife and Plant Conservation, Thailand (BKF), Herbarium, Department of Botany, The Natural History Museum, England (BM), Botanical Garden, Natural History Museum, University of Copenhagen, Denmark (C), Department of Biology, Faculty of Science, Chiang Mai University, Thailand (CMUB), Herbarium, Royal Botanic Garden Edinburgh, Scotland (E), Herbarium of National University of Laos, Vientiane, Lao PDR (FOF), The Herbarium of Xishuangbanna Tropical Botanical Garden (HITBC), Conseil National des Sciences, National Herbarium of Laos, Vientiane, Lao PDR (HNL), Herbarium, Royal Botanic Gardens, Kew, England (K), Department of Biology, Faculty of Science, Khon Kaen University, Thailand (KKU), Herbarium of Komarov Botanical Institute, Russian Academy of Sciences, St. Petersburg, Russian Federation (LE), Muséum National d' Histoire Naturelle, Paris, France (P), Queen Sirikit Botanic Garden Herbarium, Thailand (QBG) and Natural History Museum Vienna, Institute of Botany, University of Vienna, Austria (W).

The field investigations and collections were conducted from August 2015 to February 2018. The field area explorations were based on the original localities from type specimens and new localities that have similar ecology, especially area in the Northern, South-western, North-eastern, Eastern, Peninsular and South-Eastern Thailand. The specimens were collected together with field data record including locations, ecology, habitat, altitude, scent of flowers, colour, fruits, vernacular names and other additional information. If possible the morphological data, especially "number of keel on labellum" were studied and photographed directly from fresh material and then preserved as spirit collections with 70% ethanol or FAA for more morphological and anatomical study. The specimens were observed under light

microscope and measured by hand-ruler. The key to species, descriptions, illustrations, photographs and distribution map are also provided. The identifications base on monograph, flora, revision or other publications which relate to the section *Stachyobium* both from Thailand and neighboring areas, *e.g*. Opera Botanica, Flora of China, Flora of Nepal and flora of Malaysiana and then also compare with type specimens. Finally, the voucher specimens were deposited at BCU, BK and BKF.

5.3 Results

According to taxonomic revision of *Dendrobium* section *Stachyobium* in Thailand during August 2015 to February 2018. Twenty four taxa with 3 varieties of the *Stachyobium* were recognized. Among these two species namely *Dendrobium chiangdaoense* and *D. obchantiae* are new to Thailand and two species viz. *Dendrobium* sp.3 and *Dendrobium* sp.4 are being proposed as new species. Besides, *Dendrobium* sp.2 is also being proposed as new variety. Plant status was investigated, 7 species, *i.e. D. confinale, D. dixonianum, D. elliottianum, D. garrettii, D. gregulus, D. mucronatum and D. proteranthum* are endemic to Thailand when based on 'Thailand Red Data: Plants' (2006) and 'IUCN Red List of Threatened Plants' (1997). In addition, 6 species viz. *D. cuspidatum, D. denudans, D. kanburiense, D. peguanum, D. perpaulum* and *D. strongylanthum* are also rare species. One taxon namely *D. delacourii* is reduced from species to the rank of variety under the name *D. venustum* var. *delacourii* Promm., Kidyoo & Suddee, *stat. nov*. Furthermore, five names are recognized as synonyms. *D. eserre* is reduced to synonym of *D. dixonianum*, *D. kratense* and *D. erostelle* are reduced to be synonyms of *D. incurvum*. While, the other two names, *D. nanocompactum* and *D. wilmsianum* are reduced to be synonyms of *D. compactum*. Two species namely *D. eriaeflorum* and *D. monticola* were record from Thailand. In fact, they were misidentified and are not found in Thailand.

Dendrobium Sw. section *Stacyobium* Lindl.

Dendrobium section *Stachyobium* Lindl., Edwards's Bot. Reg., 30: 55. 1844. Type species: *Dendrobium denudans* D. Don.

Dendrobium section *Aclinia* (Griff.) Lindl., J. Linn. Soc., Bot., 3: 9. 1859. Type species: *Dendrobium aclinia* Lindl.

Dendrobium section *Stachyobium* subsection *Eriaeflorae* Benth. & Hooker. f., Gen. Pl., 3: 500. 1883. Type species: *Dendrobium eriiflorum* Griff.

Dendrobium section *Stachyobium* subsection *Humiles* Benth. & Hooker. f., Gen. Pl., 3: 499. 1883. Type species: *Dendrobium humile* Wight.

Dendrobium sebgen *Stachyobium* (Lindl.) Brieger in Schltr., Orchideen, ed. 3, 1: 697. 1981, *nom. illeg*. Type species: *Dendrobium denudans* D. Don.

Genaral description of section *Stachyobium*

Plant epiphytic orchid on tree or rarely lithophyte. **Pseudobulbs** are usually small and clustered, variable in shape which start from fusiform, ovoid, subglobose or cylindric, fleshy, erect or ascending with one to severally swollen internodes, usually constricted at base, covered with sheaths at leaf base, often turning yellow when dried. **Foliage leaves**, simple, 2–4, distichous, spreading, slightly recurved, linear-oblong, elliptic or oblong, chartaceous, trichome present both adaxial and abaxial surfaces. **Inflorescences** are true racemose type, composed of 1–7-inflorescenced, arising from the upper portion of stem or from upper part of current year's leafy stem and sub-terminal. **Flowers** are mostly small, fragrant, waxy, lasting for several days, color ranges from white, green, yellow, purple or purplish-red, many species have markings on labellum. The distinctive petal shape of members of the section *Stachyobium* is linear-oblanceolate, which is the unique character and useful for identification. **Labellum** usually present keel or other ornamentations from 1–3 keels, raising from base to middle disc. **Mentum** well-developed, long and narrow, rarely short and stout. **Column** smooth or cilia edges. **Fruit** or **capsule** dehiscent, globose, ellipsoid, pear-shaped to obovoid. **Seed** numerous, fusiform or oblong, covered with seed coat or cellular sheath. **Seed coat** ornamentation is reticulate.

Distribution.—The *Stachyobium* species distribute in mainland Asia from Sri Lanka, India, Nepal, Bhutan, Myanmar, China, Thailand, Laos, Cambodia, Vietnam, Malaysia and Lesser Sunda Island. The centre of diversity is in Thailand (Wood, 2000).

Etymology.—The name is derived from "*stachy*" that meaning "spike" and "*bios*" meaning "life". Thus, spike life maybe meaning the short, thick, spike-like pseudobulbs which grow close together on tree.

Key to the species of the Stachyobium in Thailand

1. Bracteoles longer than ovary plus pedicel

2. Labellum without keel……..……23. *Dendrobium* sp.2

2. Labellum present keel

3. Labellum with side lobes

4. One bright greenish-white or green thickened keel on labellum, apex of keel acute; petals with 3 light reddish-purple longitudinal veins; labellum bright green; plant flowering with leaf……..1. *D. chiangdaoense*
4. Three dull pink or reddish-pink thickened keels on labellum, apex of keel obtuse; petals without 3 light reddish-purple longitudinal veins; labellum reddish-pink; plant flowering when leafless…….……....14. *D. peguanum*

3. Labellum without side lobes

5. Inflorescenses proteranthous, appearing on new shoots from base of pseudobulb; sepals and petals with 3 dark purplish-red lines; 3 dull reddish-purple thickened keels on labellum; margins of column entire.....17. *D. proteranthum*

5. Inflorescenses hysteranthous, plant leaf-bearing when flowering; sepals, keels and column not as above

6. Two dull green thickened keels on labellum..……..15. *D. perpaulum*

6. Three red thickened keels on labellum

7. Petals with 1 vein and edges papillose; apex of dorsal sepal acuminate with papillose edges; labellum subglobose or broadly ovate, distinctly with 3 reddish-yellow thickened keels raising at hypochile, continuing and extending near tip of mid-lobe; pollinium globose…...12. *D. mucronatum*

7. Petals with 3 veins and edges entire; apex of dorsal sepal mucronate with entire edges; labellum sub-rhombic or elliptic, distinctly with 3 dark red thickened keels raising at hypochile, continuing and separate into 3 lobe near tip of mid-lobe; pollinium narrowly ellipsoid.....16. *D. porphyrochilum*

1. Bracteoles shorter than ovary plus pedicel

8. Mid-lobe or epichile of labellum with long fimbriate or fringed edge

9. Mid-lobe of labellum deep fringe …….....8. *D. garrettii*

9. Mid-lobe of labellum long clavate-fimbriae

10. Pseudobulbs 10–40 cm tall; flower yellow; petal spatulate and twisted; labellum with reddish-brown lines along the veins …….....20. *D. venustum*

10. Pseudobulbs less than 4 cm tall; flower white; petal oblanceolate and not twisted; labellum with pink or purple lines along the veins.....22. *Dendrobium* sp.1

8. Mid-lobe or epichile of labellum not as above, often crenate, serrate or undulate

11. Plant flowering when leafless, inflorescences terminal or rarely sub-terminal

12. Pseudobulbs cylindric, 2.7–20 cm tall; flower white; labellum with side-lobes, bright green at mid-lobe, with purplish-red veined.....18. *D. pycnostachyum*

12. Pseudobulbs ovoid, conical or globose, less than 2.5 cm tall; labellum not as above

13. Labellum indistinctly 3-lobed; flower pale pink; labellum with 2 dull pink thickened keels…….....7. *D. elliottianum*

13. Labellum without side-lobe; flower yellow or white; labellum not as above

14. Short inflorescences, 1.7–2.2 cm long, with 2–3-flowered; labellum dull green with purple edge, oblong or elliptic-oblong.....24. *Dendrobium* sp.3

14. Long inflorescences, 5–10 cm long, with 5–15-flowered; labellum light brownish-yellow with deep purplish-red lines, ovate or broadly ovate……9. *D. gregulus*

11. Plant leaf-bearing when flowering; inflorescences terminal or sub-terminal

15. Labellum with side-lobes

16. Labellum with distinct 2 greenish-yellow thickened keels; side-lobe large orbicular……..…4. *D. cuspidatum*

16. Labellum with distinct 3 thickened keels; side-lobe triangular

17. Edges of hyopchile entire or minutely undulate; labellum with distinct 3 dull green or yellowish-green thickened keels

18. Side-lobes large triangular-obovate, with vesicular on both surfaces, edge of mid-lobe cristate-corrugate…..13. *D. obchantiae*

18. Side-lobes shallowly triangular, smooth on both surface, edges of mid-lobe entire or minutely sinuate….11. *D. kanburiense*

17. Edges of hyopchile serrate or crenate-serrate; labellum with distinct 3 dull red or yellowish-green thickened keels

19. Keel on labellum raising at hypochile and separating into 3 lobes at mid-lobe; flower greenish-white; labellum yellow with 3 dark reddish-brown lines……6. *D. dixonianum*

19. Keel on labellum raising at hypochile and extending to the centre of mid-lobe; flower greenish-yellow or dull red

20. Mid-lobe thick warty crenulate, with dark maroon edges; sepals and petals lanceolate or oblong-lanceolate, surface of labellum papillose or vesicular on both sides; anther cap subglobose…..19. *D. strongylanthum*

20. Mid-lobe serrate-crisped; sepals and petals narrowly linear-oblanceolate or linear-lanceolate, surface smooth on both sides; anther capovoid……5. *D. denudans*

15. Labellum without side-lobes

21. Labellum with 1 dull green keel, apex of keel acute; margin and surface of column distinctly verrucose-papillose; anther cap papillose….2. *D. compactum*

21. Labellum with 3 keels, apex of keels obtuse; margin and surface of column not as above; anther cap smooth

22. Labellum dull green, oblong; edges of mid-lobe undulate-crispate, margin and surface of colum smooth…… 10. *D. incurvum*

22. Labellum white with purple veined, ovate; edges of mid-lobe crenate-serrate, margin and surface of column distinctly cilia-pilose ……..…..3. *D. confinale*

1. *Dendrobium chiangdaoense* Promm., Kidyoo, Buddh. & Suddee, Phytotaxa, 307(1): 84. 2017. Type: Chiang Mai Province, Chiang Dao District, road to Ban Huay Ja Khan, 800 m alt., 13 October 2015, *Buddhawong* & *Suddee* 018 (holotype **BKF!**). Figure 5.1, Plate 5.1, Map 5.1.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, light green, fusiform or cylindric, 0.9–2.2 cm tall, 4–6 mm in diameter, with 2–3 nodes, internodes 3–8 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed by leaf sheaths; leaf sheath bright creamy brown, membraneous, glabrous on both sides, previous stems dull greenish-yellow or bright yellow, naked. **Foliage leaves** 2–3, distichous, spreading, slightly recurved, linear-oblong, elliptic or oblong, 3–5 mm long, 2–3 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, lowermost smaller than upper, light green above, pale green or greenish-yellow beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme, 1–2-inflorescenced, axillary and terminal, erect, 1.3–2.5 cm long, with 3–5-flowered; peduncle and rachis glabrous, bright green, peduncle 6–9 mm long, rachis 2–7 mm long, covered with bracts; bracts pale green, slightly concave, lanceolate, 4–5 mm long, 1–1.5 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles pale green or greenish-white, narrowly lanceolate, 3–4 mm long, 1–1.2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, strongly scented, long-lasting, 6–8 mm in diameter. **Sepals** pale green with dull green at base, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal linear-lanceolate, 6.8–7 mm long, 1.4–1.5 mm wide at base, apex acuminate, base truncate, 3–4-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely falcate-triangular, 7–7.5 mm long, 5–5.2 mm wide at base, apex acuminate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** green, with 3 longitudinal light reddish-purple veins, spreading, linear-oblanceolate, 6.3–6.5 mm long, 0.9–1 mm at middle, apex acute, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** bright green with reddish-purple dots, with 3-lobed, 6–6.5 mm long, 4–4.5 mm wide across side lobes, attenuate at base; side lobes bright green, triangular, forwards and upwards pointed, ca. 1 mm long, 0.4–0.5 mm wide, margin serrate; disc narrowly oblong, surface smooth, waxy, distinctly with 1 bright greenish-white or green thickened keel, shining, raising at hypochile, continuing to base of mid-lobe, apex of keels acute and not divided to lobes; mid-lobe dull green with 3 light reddish-purple veins, triangular, recurved, apex acuminate, margins undulate-serrate. **Mentum** light green with purple dots, broadly conical, 6–6.5 mm long, 1–1.2 mm in diameter, margin and surface minute papillate, straight or incurved distally. **Column** glossy green with slight purple tinge, short, 1.9–2 mm long, 0.9–1 mm at base, margin and surface entire; foot concave, stout at base, waxy, 1–2 mm long, 0.9–1 mm wide at base; stigmatic cavity whitish-green,

elliptical shaped, stelidia acute, anther cap yellowish-green, subglobose or widely obovate, 0.9–1 mm long, 0.8–1 mm wide, apex emarginate, basal margin denticulate or ciliate, surface bullate, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.9–1 mm long, ca. 0.5 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 2.3–2.5 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** not seen.

THAILAND.—NORTERN: Chiang Mai (Doi Chiang Dao).

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In mixed deciduous forest on limestone hills; 800 m alt. Growing on *Dalbergia* sp. Flowering: October–November; fruiting: December–March.

VERNACULAR.—Ueang khao tok chiang dao.

SPECIMENS EXAMINED.—Chiang Mai Province, Chiang Dao District, road to Ban Huay Ja Khan, 800 m alt., 13 October 2015, *Buddhawong* & *Suddee* 018 (BKF).

NOTE: *Dendrobium chiangdaoense* is most similar to *D. dixonianum* but differs in having bract longer than pedicel plus ovary, inflorescences not exceeding leaves, lateral sepals obliquely falcate-triangular not recurved, labellum bright green, apex of keel acute and not divided to lobes.

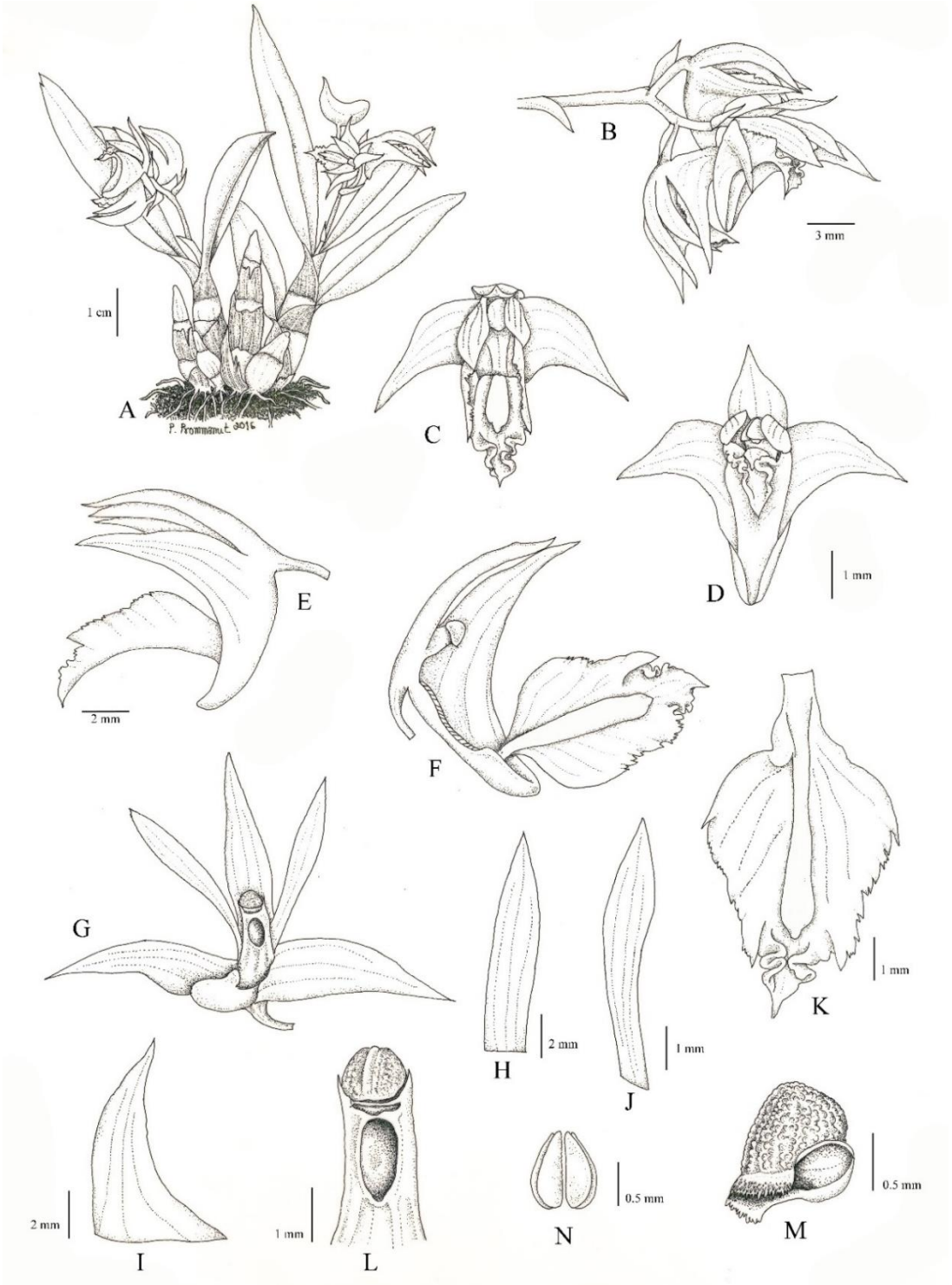


Figure 5. 1 *Dendrobium chiangdaoense* Promm., Kidyoo, Buddhawong & Suddee; A. Habit of flowering plant; B. Inflorescences; C. and D. Flower front view; E. and F. Flower side view; G. Flower without labellum; H. Dorsal sepal; I. Lateral sepal; J. Petal; K. Labellum; L. Column; M. Anther cap; N. Pollinia. Drawn from *Buddhawong* & *Suddee* 018.

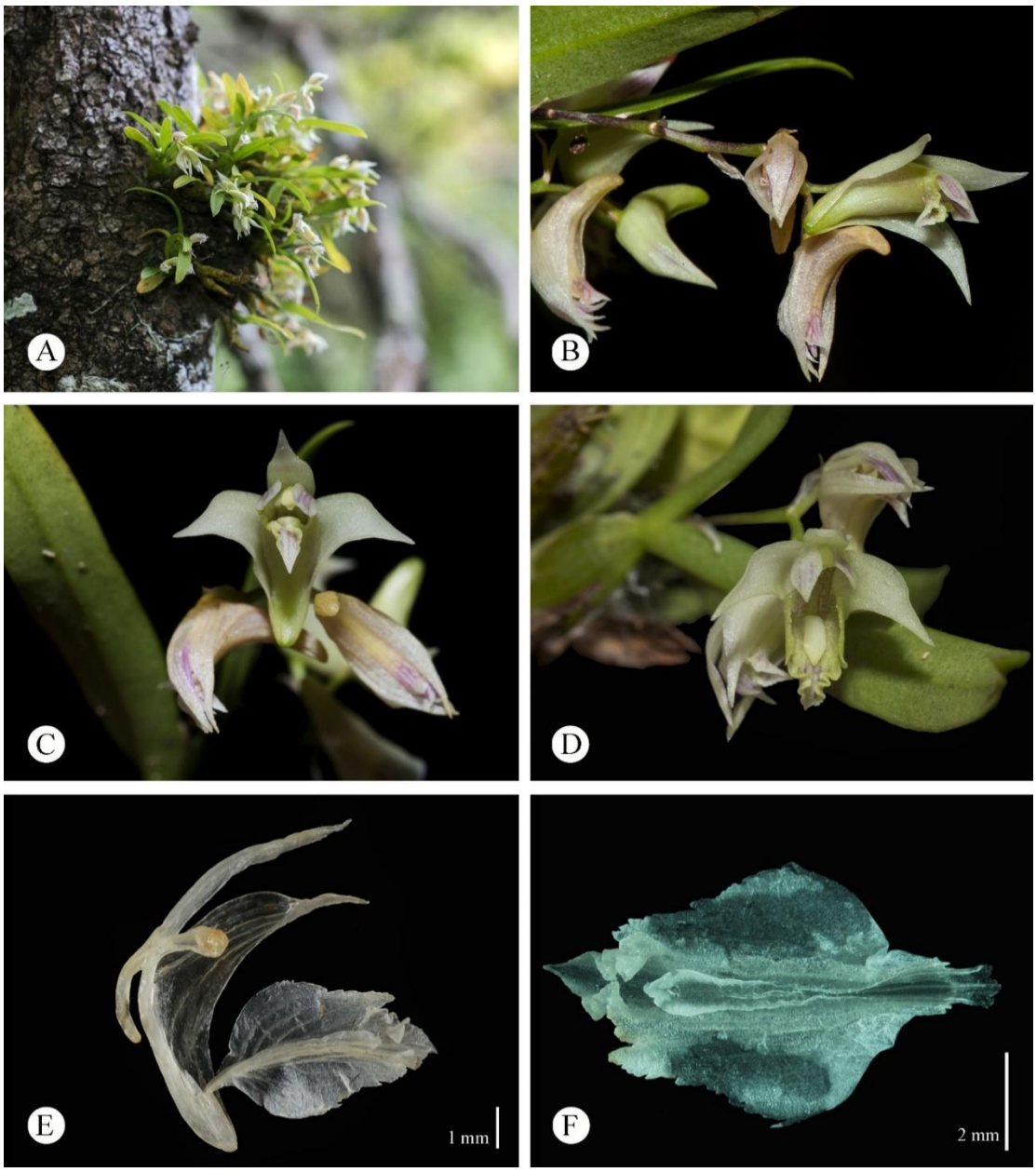


Plate 5. 1 *Dendrobium chiangdaoense* Promm., Kidyoo, Buddhawong & Suddee; A. Plant in natural habitat; B. Inflorescences; C. Flower front view; D. Flower front view and show keel on labellum; E. Flower side view and show labellum; F. Labellum from spirit collection. A, C and D photo by W. Buddhawong; B photo by T. Anek.

2. *Dendrobium compactum* Rolfe ex W. Hackett, Gard. Chron., ser. 3, 36: 400. 1904; Seidenf. & Smitinand, Orchids Thail.: 233. 1960; Seidenf., Bot. Tidsskr. 68(1): 49, f. 13. 1973; Opera Bot. 83: 145, f. 98, pl. XVIIb. 1985; G. G. Zhu, H. Ji, J. J. Wood & H. P. Wood in Z. Y. Wu *et al*. (eds), Fl. China 25: 394. 2009. Type: S China, Yunnan, *Hemptienne* s.n. (holotype **K–Herb. Hook. f.!**). Figure 5.2, Plate 5.2, Map 5.5.

Dendrobium wilmsianum Schltr., Repert. Spec. Nov. Regni Veg. 2: 86. 1906. **syn. nov**. Type: Thailand, Chiang Mai, Doi Sutep, 519 m alt., 11 December 1904, *Hosseus* 187 (holotype **K–Herb. Hook. f.!**; isotypes **BM!**).

Dendrobium nanocompactum Seidenf. Opera Bot. 124: 31. f. 19, 1995. **syn. nov**. Type: Thailand, probably from Prachin Buri, September 1988, *P. Sukhakul* 9699 (holotype **C!**).

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, green or light green, cylindric, narrowly fusiform or ovoid, 0.5–12 cm tall, 0.5–1 cm in diameter, with 2–6 nodes, internodes 0.5–3 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath pale brown, membraneous, glabrous on both sides, previous stems golden yellow or light green, naked. **Foliage leaves** 2–7, distichous, spreading, slightly recurved, oblong, elliptic-lanceolate or linear-oblong, 2.2–7 cm long, 0.5–1 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, green or light green above, pale green beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme, 1–12-inflorescenced, subterminal or arising from upper part of current year's leafy stem, suberect or nodding, 1–7 cm long, not exceeding leaves, with 2–10-flowered; peduncle and rachis glabrous, light green or yellowish-green, peduncle 0.3–2 cm long, rachis 0.5–5 cm long, covered with bracts; bracts yellowish-green or golden yellow, slightly concave, lanceolate to ovate-lanceolate, 3–3.5 cm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles green, narrowly lanceolate, 2–3 mm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, strongly scented, long-lasting, 0.5–1.3 cm in diameter. **Sepals** white, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal lanceolate, 5–8 mm long, 2–4 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely triangular-lanceolate, 5–7 mm long, 2–4 mm wide at base, apex acuminate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** white, spreading, obovate-lanceolate, 5–7 mm long, 1.7–2.5 mm wide at subterminal, apex acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** dull green or yellowish-green, surface minute papillose, slightly recurved, suborbicular, without side lobes, 5–5.5 mm long, 4.8–5 mm wide across, shortly clawed at base; disc subglobose, surface minute

papillose, waxy, distinctly with 1 whitish-green thickened keel, raising at hypochile, continuing to base of mid-lobe, 2–2.2 mm long, 1–1.5 mm wide, apex triangular, midlobe cristate-corrugate. **Mentum** white or whitish-green, narrowly conical, 3–6 mm long, 1–2 mm in diameter, margin entire, straight or incurved distally. **Column** white or pale green, 2–3 mm long, 1.7–2 mm wide at base, margin and surface distinctly verrucose-papillose; foot concave cymbiform, 3–5 mm long, 1.5–1.8 mm wide at middle; stigmatic cavity glossy whitish green, broadly ovate, stelidia acute, anther cap green or pale green, subglobose or widely obovate, 1–2 mm long, 0.8–1.2 mm wide, apex emarginated, basal margin minutely ciliate, surface papillose; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.7–0.9 mm long, 0.2–0.5 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 3–4 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, globose-ellipsoid with 3 obtuse keels, 0.8–1.4 cm long, 5–8 cm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN : Mae Hong Son (Mae Surin Waterfalls), Chiang Mai (Mae Sanam, Bo Luang, Doi Chiang Dao, Doi Pui, Doi Suthep, Omkoi), Chiang Rai (Doi Tung), Nan, Kamphaeng Phet (Chang Yen), Tak (Thungyai Narasuan Eastern Wildlife Sanctuary), Nakhon Sawan (Mae Wong); NORTERN-EASTERN: Loei (Phu Luang, Phu Ruea); EASTERN: Chaiyaphum (Pa Hin Ngam); SOUTH-WESTERN: Kanchanaburi (Huay Bankan), Ratchaburi (Khao Krachom).

DISTRIBUTION.—Myanmar, S China (type), N Vietnam.

ECOLOGY.—In pine forest, deciduous dipterocarp-oak forest, lower montane oak forest, lower montane pine-oak forest, lower montane scrub and pine-deciduous dipterocarp forest; 700–1,900 m alt. Growing on *Castanopsis argyrophylla*, *C. diversifolia*, *C. tribuloides, Lithocarpus polystachyus, L. truncates, Quercus* sp., *Shorea obtuse, Wendlandia tinctoria,* which are covered with mosses and lichens. Flowering: September–December; fruiting: December–March.

VERNACULAR.—Ueang khao tok.

SPECIMENS EXAMINED.—CHINA: Yunnan, Sjemes, W forest, 1,524 m alt., *Henry* 11752A (K, C); ibid, *Henry* 12752 (K, C). **THAILAND**: Chiang Mai, Doi Suthep, 1,524–1,676 m alt., 31 October 1909, *A. F. G. Kerr* 68 (K); Chiang Mai, Chiang Dao, 18 October 2007, *A. Keratikorkol* 149 (QBG) ; Chiang Mai, Mae Rim, 27 November 2007, *A. Keratikorkol* 376 (QBG) ; Kanchanaburi, Huay Bankan, 11 November 1971, *Beusekom* et al. 3691 (C); Chiang Mai, 8 November 1987, *Comber* 1708 (K); Chiang Mai, Mae Rit, 875 m alt., 1 November 1964, *Cumberlege* 1278 (K);

Chiang Mai, Doi Suthep, 1,500 m alt. October 1958, *G. Seidenfaden* & *T. Smitinand* 3020 (C); Loei, Phu krading, 1,050 m alt., 14 December 1960, *G. Seidenfaden* & *T. Smitinand* 3761 (C) ; Mae Hong Son, Mae Sarieng road km 53, 18 August 1964, *G. Seidenfaden* & *T. Smitinand* 5285 (C); Chiang Mai, Doi Pae Poe, 1,050–1200 m alt., 1 December 1968, *G. Seidenfaden* & *T. Smitinand* 7315 (C); Chiang Mai, Mae Sanam, 1,000 m alt., 17 December 1978, *G. Seidenfaden & T. Smitinand* 7650 (C); Chiang Mai, Omkoi, 850 m alt., 1 August 1973, *G. Seidenfaden* & *T. Smitinand* 8150 (C); Chiang Mai, Doi Pui, 1,530 m alt., 17 November 1978, *G. Seidenfaden* & *T. Smitinand* 8370 (C); Mae Hong Son, Huay Mae Surin Waterfalls, 1,260 m alt., 1 November 1978, *G. Seidenfaden* & *T. Smitinand* 8486 (C) ; Chiang Mai, Doi Sutep-Doi Pui, 1,650 m alt., 15 October 1988, *J. F. Maxwell* 88-1220 (BKF); Chiang Mai, Ban Luang, 1,100 m alt., September 1958, *K. Larsen* & *Hansen* 5265 (C) ; Chiang Mai, Doi Sutep, 1,400 m alt., 1 November 1958, *K. Larsen* & *Hansen* 5666 (C); Chiang Rai, Doi Tung, 1,410 m alt., 13 November 2010, *Martin van de Bult* 1113 (CMUB); Chiang Mai, Chiang Dao, 1,200 m alt., 9 November 1983, *Menzies* & *Du Puy* 185 (K); Loei, Phu Ruea, 1,100–1,300 m alt., 28 September 2007, *N. Anuraktrakoon* 57 (BKU); ibid, 12 September 1988, *O. Thaithong* 495 (BCU); ibid, 21 October 1988, *O. Thaithong* 523 (BCU); Chiang Rai, Doi Tung, 1,425 m alt., 19 October 2010, *P. Palee* 1034 (CMUB); Chiang Mai, Hod, Bo Luang, 1,040–1,200 m alt., 26 September 2011, *P. Prommanut* 52 (BK); ibid, Mae Sanam Silvicultural Station, 1,020 m alt., 1 October 2011, *P. Prommanut* 84 (BK); Tak, Thungyai Narasuan Eastern Wildlife Sanctuary, 1,000–1,200 m alt., 6 October 2014, *P. Prommanut, S. Suddee, S. Rueangruea, S. Mattapha, W. Khiewbang & C. Hemrat* 504 (BK); Chiang Mai, Doi Chiang Dao, 1,300 m alt., 16 October 1926, *Put* 346 (C, K); Chiang Mai, Mae Ngai-Chiang Dao, 1,200 m alt., 26 September 1999, *S. Intamusik* 60 (QBG); Chiang Mai, Mae Rim, 8 September 2006, *S. Pumicong* 463 (QBG); ibid, 7 October 2006, *S. Pumicong* 486 (QBG); Chiang Mai, Doi Pui-Doi Suthep, 1,560 m alt., 5 November 2011, *S. Watthana* 4131 (QBG); Chiang Mai, Doi Suthep, 1,500 m alt., *T. Smitinand* s.n. (C) ; Chiang Mai, 1,600 m alt., 26 November 1454, *W. Nanakorn et al.* 10020 (QBG).

LOCALITY UNKNOWN.—MYANMAR: *Entry* 100-1928 (K0009345), 28 November 1930. **CHINA**: *Tsi* 023(C03839). **THAILAND**: *Put* s.n. (K0009340), 28 October 1932; Unknown collector (BCU 008895), Chiang Dao, August 1997.

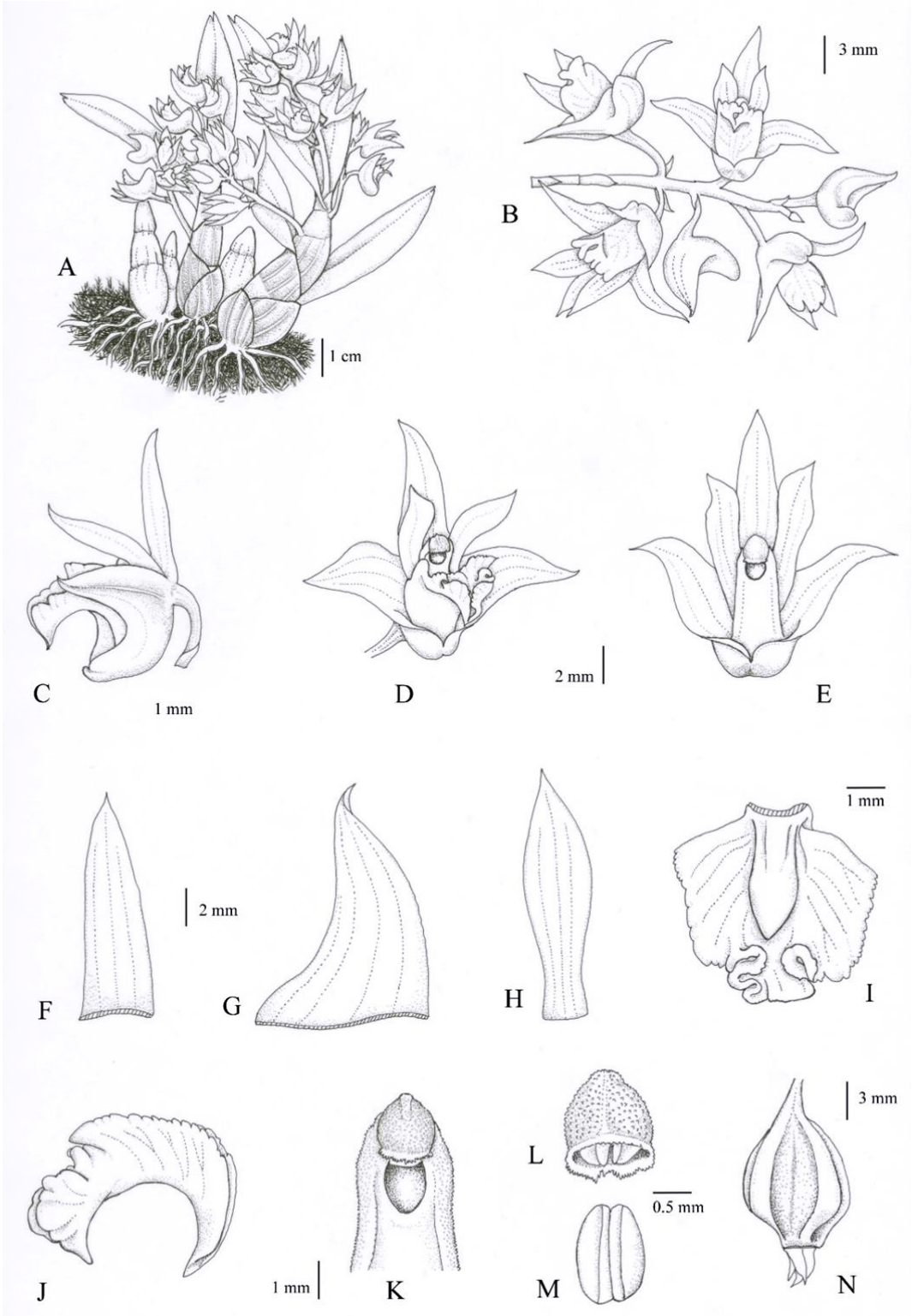


Figure 5. 2 *Dendrobium compactum* Rolfe ex W. Hackett; A. Habit of flowering plant; B. Inflorescences; C. Flower side view; D. Flower front view; E. Flower without labellum; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Labellum side view; K. Column; L. Anther cap; M. Pollinia; N. Capsule. Drawn from *P. Prommanut* 84.

Plate 5. 2 *Dendrobium compactum* Rolfe ex W. Hackett; A. Plant in natural habitat; B. Inflorescences; C. Flower side view; D. Column show margin and surface distinctly verrucose-papillose; E. Labellum with 1 keel.

3. *Dendrobium confinale* Kerr, Bull. Misc. Inform. Kew. 5: 217. 1927; Seidenf. & Smitinand, Orchids Thail. 236, 1960; Seidenf., Opera Bot. 83: 142, f. 92, 1985. Type: Thailand, Trat, Khao Saming, 400 m alt., Kerr 0218 (holotype **K–Herb. Hook. f.!**). Figure 5.3, Plate 5.3, Map 5.5.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, green or light green, cylindric, narrowly fusiform or ovoid, 4–7 cm tall, 0.5–1 cm in diameter, with 4–7 nodes, internodes 0.5–2 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath pale brown, membraneous, glabrous on both sides. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, oblong, elliptic-lanceolate or linear-oblong, 1.7–3 cm long, 4–7 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, green or light green above, pale green beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme, 2–4-inflorescenced, subterminal or arising from upper part of current year's leafy stem, suberect or nodding, 3–4 cm long, with 4–7-flowered; peduncle and rachis glabrous, peduncle 1–2 cm long, rachis 1.5–2 cm long, covered with bracts; bracts, slightly concave, ovate-oblong, 2–3.5 cm long, 2–2.3 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles, narrowly lanceolate, 1.8–2 mm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, 0.8–1 cm in diameter. **Sepals** white, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal lanceolate, 5–7 mm long, 2–3 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely triangular-falcate, 6.5–7 mm long, 2–3 mm wide at base, apex acuminate, base obliquely truncate, 3–5-viened, distinctly visible. **Petals** white, spreading, obovate-lanceolate, 6.5–7 mm long, 1.5–2 mm wide at subterminal, apex acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** white with purple veined, ovate, without side lobes, 6–6.2 mm long, 5–5.3 mm wide across, shortly clawed at base; disc subglobose, surface minute papillose, margin serrate, distinctly with 3 thickened keels, raising at hypochile, continuing to base of mid-lobe, 2–2.2 mm long, 1–1.5 mm wide, apex obtuse, mid lobe crenate-serrate. **Mentum** white, narrowly conical, 4–6 mm long, 1–2 mm in diameter, margin cilia, straight or incurved distally. **Column** white, 2.5–3 mm long, 1.7–2 mm wide at base, margin and surface distinctly cilia-pilose; foot concave cymbiform, 3–5 mm long, 1.5–1.8 mm wide at middle; stigmatic cavity broadly ovate, stelidia acute, anther cap subglobose or widely obovate, 1–2 mm long, 0.8–1.2 mm wide, apex emarginated, basal margin minutely ciliate, surface papillose; pollinia 4, in 2 pairs, each pollinium narrowly ellipsoid, 0.7–0.9 mm long, 0.2–0.5 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 4–6 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** globose-ellipsoid with 3 obtuse keels, 0.8–1 cm long, 5–7 cm wide, apex with persistent dried sepals and petals.

THAILAND.—SOUTH-EASTERN: Trat (Khao Saming).

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In evergreen forest; 400 m alt. Growing on tree, which are covered with mosses and lichens. Flowering: October–November; fruiting: December–January.

VERNACULAR.—Ueang khao tok trat.

SPECIMENS EXAMINED.**—**Trat, Khao Saming, 400 m alt., *Kerr* 0218 (K).

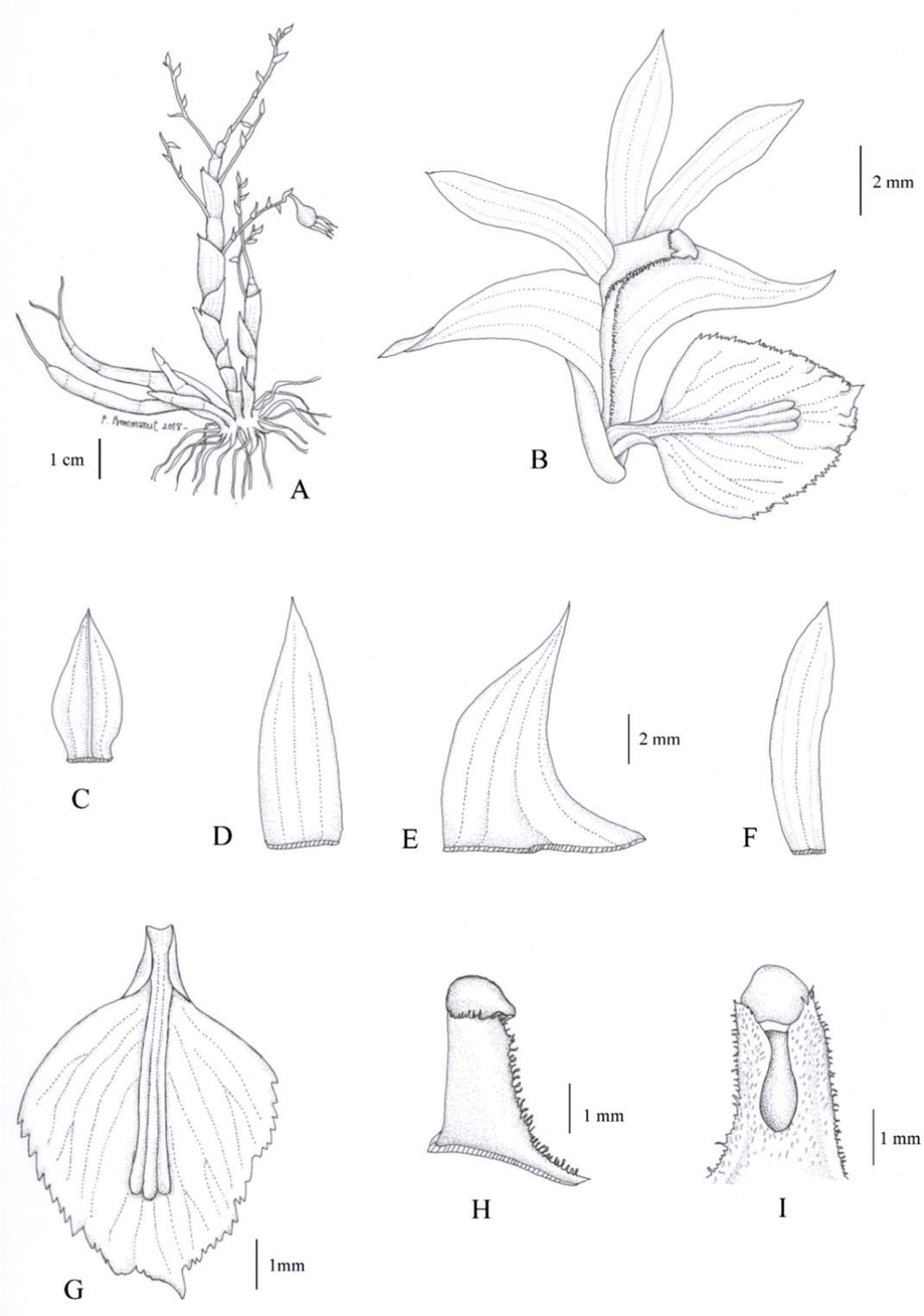


Figure 5. 3 *Dendrobium confinale* Kerr; A. Plant from type specimen; B. Flower; C. Bract; D. Dorsal sepal; E. Lateral sepal; F. Petal; G. Labellum; H. Column side view and show margin distinctly cilia-pilose; I. Anther cap and column. Drawn from *Kerr* 0218.

Plate 5. 3 *Dendrobium confinale* Kerr; A. Plant from type specimen; B. Flower and show 3 keels on labellum; C. Column side view and show margin distinctly cilia-pilose; D. Column front view and show margin distinctly cilia-pilose; E. Capsule.

4. *Dendrobium cuspidatum* Lindl., Gen. Sp. Orchid. Pl.: 84.1830; Lindl., Bot. Reg. 30: 61. 1844; Hook. f., Fl. Brit. India 5: 716. 1890; F. Kränzl., Pflanzenr. (Engler) 50 (45): 83. 1910; Seidenf., Opera Bot. 83: 140. f. 91, 1985; H. P. Wood, Dendrobiums: 619, pl. 168. 2006. Type: Myanmar, Tavoy, Wall. Cat. no. 2015 (holotype **K–Herb. Wall.!**). Figure 5.4, Plate 5.4, Map 5.4.

Callista cuspidata (Lindl.) Kuntze, Revis. Gen. Pl. 2: 654. 1891. Type: as for above.

Dendrobium sarcanthum Lindl., J. Proc. Linn. Soc., Bot. 3: 20. 1858. **syn. nov**. Type: Myanmar, Moulmein, *Lobb* 406 (holotype **K– Herb. Hook. f.!**; isotype, **BM!**; **K–Herb. Lindl.!**)

Callista sarcantha (Lindl.) Kuntze, Revis. Gen. Pl. 2: 655. 1891. Type: as for above.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, light green, cylindric, or narrowly fusiform, 4–10.5 cm tall, 4–7 mm in diameter, with 2–4 nodes, internodes 0.5–1.5 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath glabrous on both sides, gray or whitish-gray, previous year's naked stems light yellow or greenish-yellow, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, elliptic, oblong, or linear-oblong, 2.1–5.5 cm long, 5–8 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, light green or dull green above, green or pale green beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme 2–5-inflorescenced, axillary and subterminal, erect or nodding, 2.5–7 cm , exceeding leaves, densely 5- to 14-flowered; peduncle and rachis glabrous, yellowish-green, peduncle 1–3.5 cm long, rachis 1.5–4 cm long, covered with bracts; **bracts** bright reddish-brown, slightly concave, lanceolate, 3–5 mm long, 3–3.5 mm wide, apex acuminate, base truncate, margins entire, 1-veined, glabrous on both sides, distinctly keeled below, **bracteole** bright reddish-brown, narrowly lanceolate, 3–4 mm long, 2–3 mm wide, apex acuminate, base truncate, margins entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1.7–2 cm in diameter. **Sepals** greenish-white with pale cream at base, spreading, often recurved distally, margins entire, abaxial surface distinctly keeled; dorsal sepal narrowly-lanceolate, 1.3–1.5 cm long, 3–4 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely narrow-falcate, 1.3–1.4 cm long, 5–6.5 mm wide at base, apex acuminate, base obliquely truncate, 3–5-viened, distinctly visible. **Petals** greenish-white with pale cream at base, spreading, linear-oblanceolate, 1–1.2 cm long, 3–4 mm wide gently reduced at base, apex acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** bright creamy yellow with pale purple line, with 3-lobes, 1.1–1.3 cm long, 8–8.5 mm wide across side lobes; shortly clawed at base; side lobes sub-orbicular, 3–4 mm long, 3–4 mm wide, forwards and upwards pointed, margin entire; disc narrowly oblong, 5–8 mm long, 4–5 mm wide, surface minute puberulous, with distinctly 2 greenish-yellow thickened keels, shining, continuing from base to middle disc; mid-lobe triangular, 3–4.5 mm long, 3–4 mm wide, recurved, apex narrowly acuminate, margins entire; **Mentum** light creamy yellow, broadly conical, 4–5 mm long, 2–2.3 mm in diameter, straightly or incurved distal, margin and surface

entire, apex obtuse, incurved. **Column** creamy yellow, short, 1.8–2 mm long, 1.8–2 mm wide at base, margin and surface smooth; foot concave, stout at base, waxy, 2–3 long, 1.5–1.8 mm wide at base; stigmatic cavity circular or ovate, stelidia obtuse, anther cap creamy yellow, subglobose or widely obovate, 0.9–1 mm long, 0.8–1 mm wide, apex emarginated, basal margin finely serrate, surface papillous, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow or yellowish-orange, each pollinium narrowly ellipsoid, 1–1.5 mm long, 0.5 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 6–7 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, ellipsoid with 3 obtuse keels, 1.2–1.6 cm long, 0.5–0.9 cm wide, apex with persistent dried sepals and petals.

THAILAND.—SOUTH-WESTERN: Tak (Mae Ra Mat), Kanchanaburi.

DISTRIBUTION.—Myanmar (type).

ECOLOGY.—In oak-dipterocarp forest; 230–500 m alt. Growing on tree in forest, Flowering: July–December; fruiting: February–May.

VERNACULAR.—Ueang khao tok mae ra mat.

SPECIMENS EXAMINED.—THAILAND: Tak, Mae Ramat, 35 km N of Mae Sot, 230 m alt., 12 July 1972, *G. Seidenfaden* & *T. Smitinand* 7887(C); Tak, Mae Sot, 450 m alt., 15 December 1988, *G. Seidenfaden* & *T. Smitinand* 9655(C); Kanchanaburi, 8 September 2006, *S. Pumicong* 461 (QBG).

LOCALITY UNKNOWN: MYANMAR: *Lobb* 480 (BM000032779). **THAILAND**: 19 September 1994, *C. Thorut* 005 (BCU); 22 September 1985; *O. thaithong* 136 (BCU); 29 August 1992; *O. thaithong* 136 (BCU).

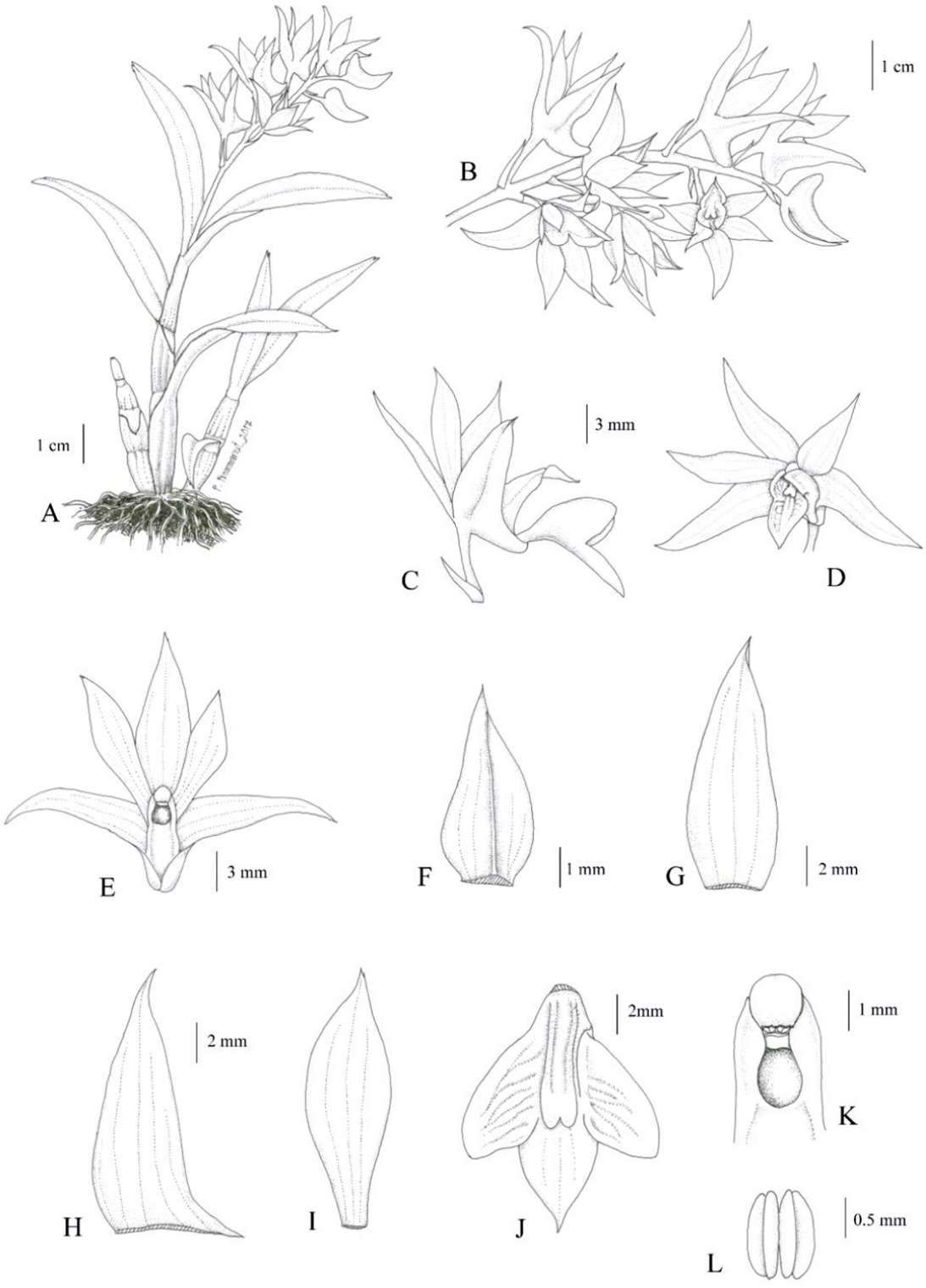


Figure 5. 4 *Dendrobium cuspidatum* Lindl.; A. Habit of flowering plant; B. Inflorescences; C. Flower side view; D. Flower front view; E. Flower without labellum; F. Bract; G. Dorsal sepal; H. Lateral sepal; I. Petal; J. Labellum; K. Column; L. Pollinia. Drawn from *Lobb* 406.

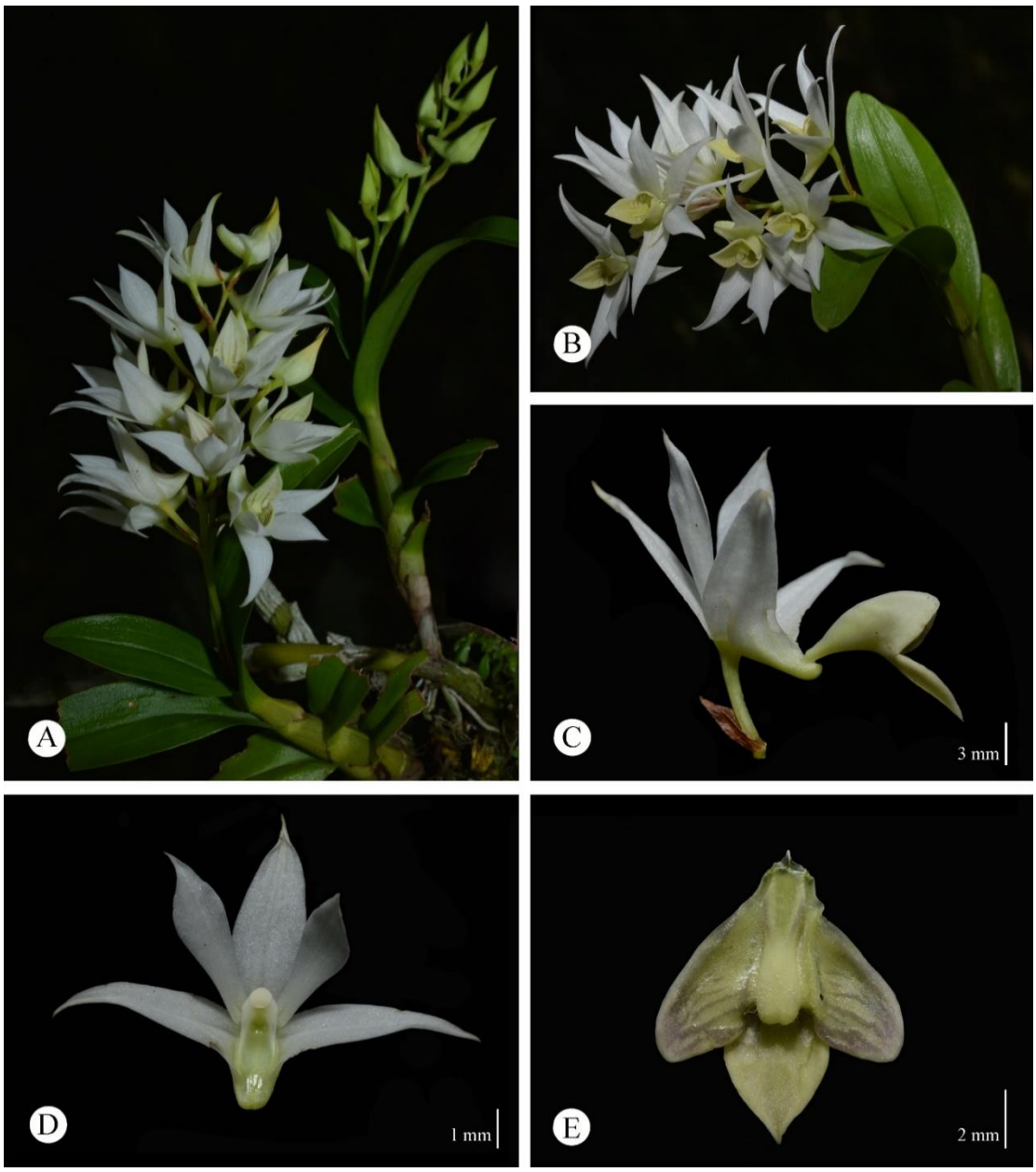


Plate 5. 4 *Dendrobium cuspitum* Lindl.; A. Plant in natural habitat; B. Inflorescences; C. Flower side view; D. Flower without labellum; E. Labellum with 2 keels.

5. *Dendrobium denudans* D. Don, Prodr. Fl. Nepal.:34, 1825; Gen. Sp. Orchid. Pl.: 85, 1830; Hook. f., Fl. Brit. India 5: 715. 1890; King & Pantl., Ann. Roy. Bot. Gard. (Calcutta) 8: 45, pl. 62. 1898; F. Kränzl., Pflanzenr. (Engler) 50 (45): 81, f.3 a-e. 1910; Seidenf., Opera Bot. 83: 148. f. 100, pl. XVIIc. 1985; K. J. White & B. Sharma, Wild Orchids Nepal: 223, pl. 86 a-e. 2000; N. Pearce & P. J. Cribb., Fl. Bhutan 3(3): 419, pl. 21. 2002; D. B. Gurung, Orchids Bhutan: 121. 2006; B. lavarack, W. Harris, G. Stocker, Dendrobium its relatives: 226, 2006; H. P. Wood, Dendrobiums: 622, pl. 169-170. 2006. Type: Nepal, Gossainthan, *N. Wallich* s.n. (holotype **BM**!; isotypes **GH**! photo seen). Figure 5.5, Plate 5.5, Map 5.4.

Callista denudans (D. Don) Kuntze, Revis. Gen. Pl. 2: 654 (1891).

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** pendent, green or light green, cylindric, terete or narrowly fusiform, 4.5–30 cm tall, 0.5–1 cm in diameter, with 3–7 nodes, internodes 1–2.2 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath gray or pale brown, membraneous, glabrous on both sides, previous year's naked stems light yellow or greenish-yellow, naked. **Foliage leaves** 2–6, distichous, spreading, slightly recurved, elliptic, oblong, or linear-oblong, 4–10 cm long, 0.8–1.5 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, light green or dull green above, green or pale green beneath, mid-vein grooved above and ribbed below, leaf-bearing when flowering. **Inflorescences** raceme 1–4-inflorescenced, axillary and terminal, pendent, 4–13.3 cm long, exceeding leaves, densely 15–30-flowered; peduncle and rachis glabrous, greenish-purple or dull purple, peduncle 1.4–5.6 cm long, rachis 2.1–10 cm long, covered with bracts; bracts bright yellow or purplish-yellow, slightly concave, lanceolate, 4–5 mm long, 1–2 mm wide, apex acuminate or acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteole bright yellow, narrowly lanceolate, 3–4 mm long, c.1 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1.5–1.7 cm in diameter. **Sepals** brownish-yellow or bright yellow with deep purple red stripe at base, becoming purplish-red when mature, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal narrowly linear-lanceolate or narrowly linear-oblanceolate, 1.2–1.5 cm long, 2–2.5 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely lanceolate or linear-falcate, 1.3–1.5 cm long, 6–7 mm wide at base, apex acuminate, base obliquely truncate, 3–5-viened, distinctly visible. **Petals** deep purple red or deep red with slight tinge of purple, spreading, narrowly linear-lanceolate or narrowly linear-oblanceolate, 1.3–1.4 cm long, 2–2.2 mm wide, apex acute or acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** purplish-red or dark red, bright yellow at centre, base greenish-yellow, with 3-lobed, 8–9 mm long, 4–5 mm wide across side lobe;

shortly clawed at base, 1–1.5 mm long, 1–1.2 mm wide, margin serrate; side lobes triangular; 1–2 mm long, 0.5–0.7 mm wide, forwards and upwards pointed, margin serrate-lacerate; disc oblong, 5–7 mm long, 2–3 mm wide, surface smooth, waxy, distinctly with 3 dull red or purplish-red thickened keels raising at hypochile, continuing to base of mid-lobe, extending to the centre of mid-lobe, margin serrate-crenate; mid-lobe recurved, triangular, 3–4 mm long, 3–3.8 mm in diameter, apex narrowly acuminate, margins serrate-crisped. **Mentum** light brownish-yellow with purplish-red dots, broadly conical, 4–5 mm long, 2.5–3 mm in diameter, margin and surface entire, apex obtuse, incurved. **Column** brownish-yellow with purplish-red dots, 2–2.3 mm long, 1.8–2 mm wide at base, margin and surface smooth; foot concave, cymbiform, 2–3 mm long, 1.5–1.8 mm wide at base, waxy; stigmatic cavity dull brown yellow, circular, stelidia obtuse, anther cap dull purplish-red, triangular, 0.9–1 mm long, 0.8–1 mm wide, apex emarginated, basal margin erose-dentate, surface minute papillous, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 1–1.5 mm long, 0.5–1 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 4–7 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule**, green or dull green, ellipsoid with 3 obtuse keels, 1.2–1.6 cm long, 5–9 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Mae Hong Son (Doi Ke-a Po Pho Cho), Chiang Mai (Doi Ang Khang), Chiang Rai (Khunkorn Waterfalls), Nan (Doi Phuka National Park), Nakhon Sawan (Mae Wong National Park).

DISTRIBUTION.—NW India, Nepal (type).

ECOLOGY.—In hill evergreen forest and open oak forest, 1,200–1,900 m alt. Growing on *Glochidion eriocarpum* and *Pinus kesiya*, which are covered with mosses. Flowering: September–November; fruiting: February–May.

VERNACULAR.—Ueang sai champa.

SPECIMENS EXAMINED.—INDIA: Darjeeling nearly Sikkim, 1,372 m alt, 13 October 1869, *H. G. Reichenbach* s.n. (BM, K); Darjeeling, 1,524 m alt, 21 September 1869, *J. D. Hooker* 9245 (BM, K); Bombay, Loddergy, 1219 m alt., 28 October 1847, *J. Lindley* s.n. (K); Sikkim, 914 m alt., October 1881, *J. S. Gamble* 9879 (K); NW Himalaya, Nainital, 1,400 m alt., November 1974, *O. Skov* s.n. (C); Kampong, 1,000 m alt., 26 August 1983, *Pradhan* 28 (C); Sikkim, 790 m alt., September 1892, *R. Pantling* 02 (K); ibid, 762 m alt., October 1892, *R. Pantling* 04 (BM). **NEPAL**: Janakpur zone, 2,550 m alt., 18 August 1985, *H. Ohba* et al 8571728 (BM); Buri Gamdaki, 1,220 m alt., 16 October 1981, *J. D. A. Staintion* 8467 (K); Malemchi Khola, 2,000 m alt., 17 September 1972, *J. H. Haas* 2801 (BM); Gad Rangchi, 1,677 m alt., 16 October 1952, *O. Pulonin, W. R. Sykes* & *L. H. J. Williams* 5757 (BM); Himalayan, Kumaon, 1,450 m alt., 31 October 1987, *R. Strachey* & *J. E. Winterbottom* 05 (K); between Mamamkhe and Kunjuri, 1,700 m alt., 30 September 1989, *S. Crawford* et al. 1118 (E, K). **THAILAND**: Chiang Mai, Doi Ang Khang, Phang District, 1,200 m alt., 26 October

2004, *A. Sathapattayanon* 370 (BCU); Chiang Rai, Mueng District, Mae Korn Sub-district, Khunkorn Waterfall Forest Park, 1,500 m alt., 16 December 1998, *K. K.* 1228 (BCU); Mae Hong Son, Mueang District, Trail up to Doi Ke-a Po Pho Cho, 1,862 m alt., 21 November 2014, *P. Prommanut* 620 (BK); Chiang Mai, Doi Ang Khang, Phang District, 1,200 m alt., 5 November 1998, *P. Suksathan* & *P. Triboun* s.n. (BK); Nan, Pua-Bua Klua District, Doi Phuka National Park, 1,300 m alt., 20 October 2002, *S. Suddee* 1598 (BKF); Chiang Mai, 17 km from southwest of Doi Ang Khang, 1,200 m alt., 6 November 2002, *S. Suddee* & *Henrick* 1679 (BKF).

LOCALITY UNKNOWN.—**NEPAL**: *Trudel* 764 (C003715).

NOTE.—*Dendrobium denudans* is related to *D. strongylanthum* in both vegetative and reproductive features. However, this species can be distinguished from *D. strongylanthum* by using many characters of flower viz. shape of sepals and petals of *D. denudans* are narrowly linear-oblanceolate or linear-lanceolate while those of *D. strongylanthum* are lanceolate or oblong-lanceolate. Both upper and lower surfaces of labellum is smooth in *D. denudans* but vesicular in *D. strongylanthum*. Shape of anther cap is triangular in *D. denudans* but subglobose in *D. strongylanthum*.

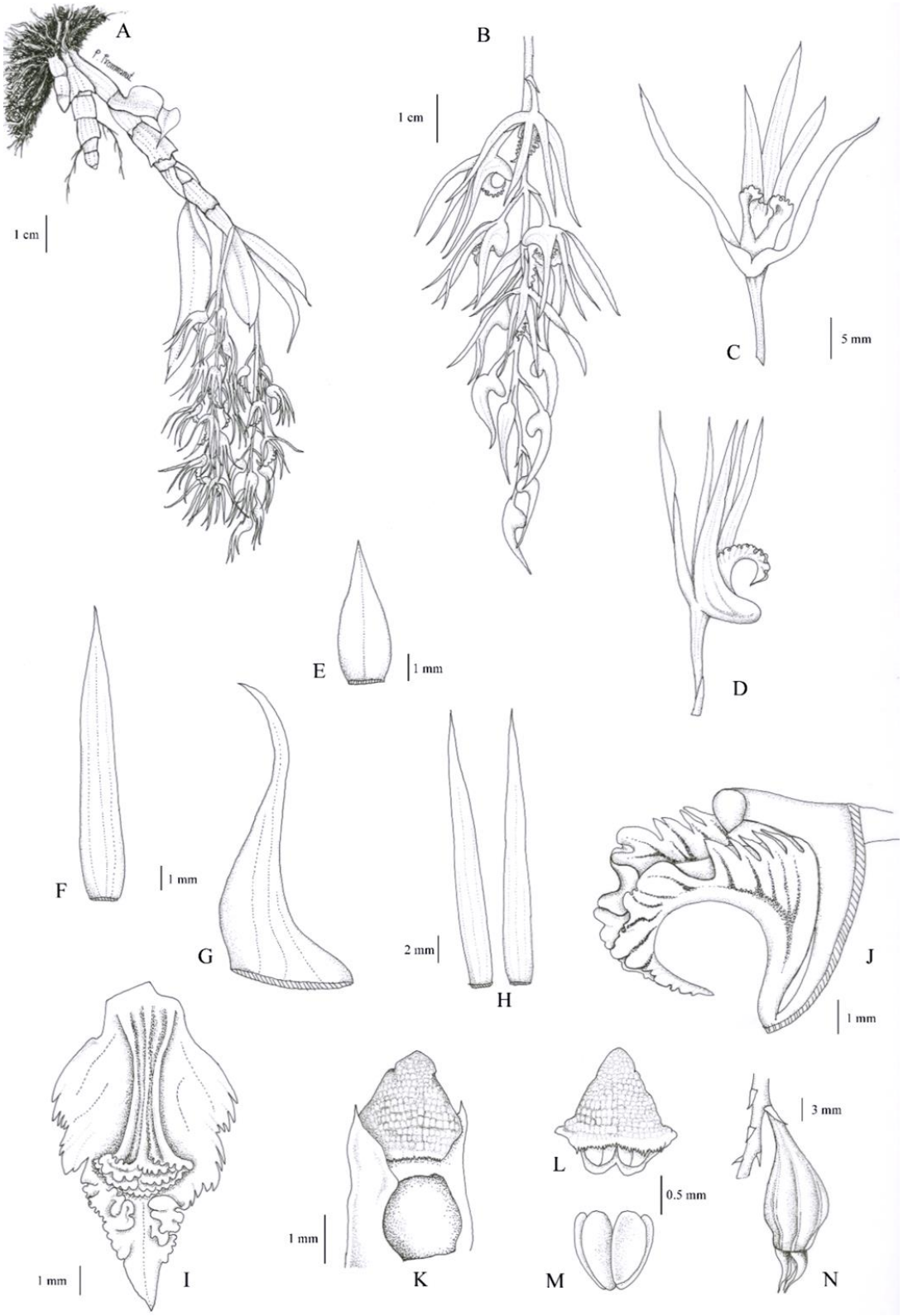


Figure 5. 5 *Dendrobium denudans* D. Don.; A. Habit of flowering plant; B. Inflorescences; C. Flower front view; D. Flower side view; E. Bract; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Column and labellum side view; K. Column; L. Anther cap; M. Pollinia; N. Capsule. Drawn from *P. Prommanut* 620.

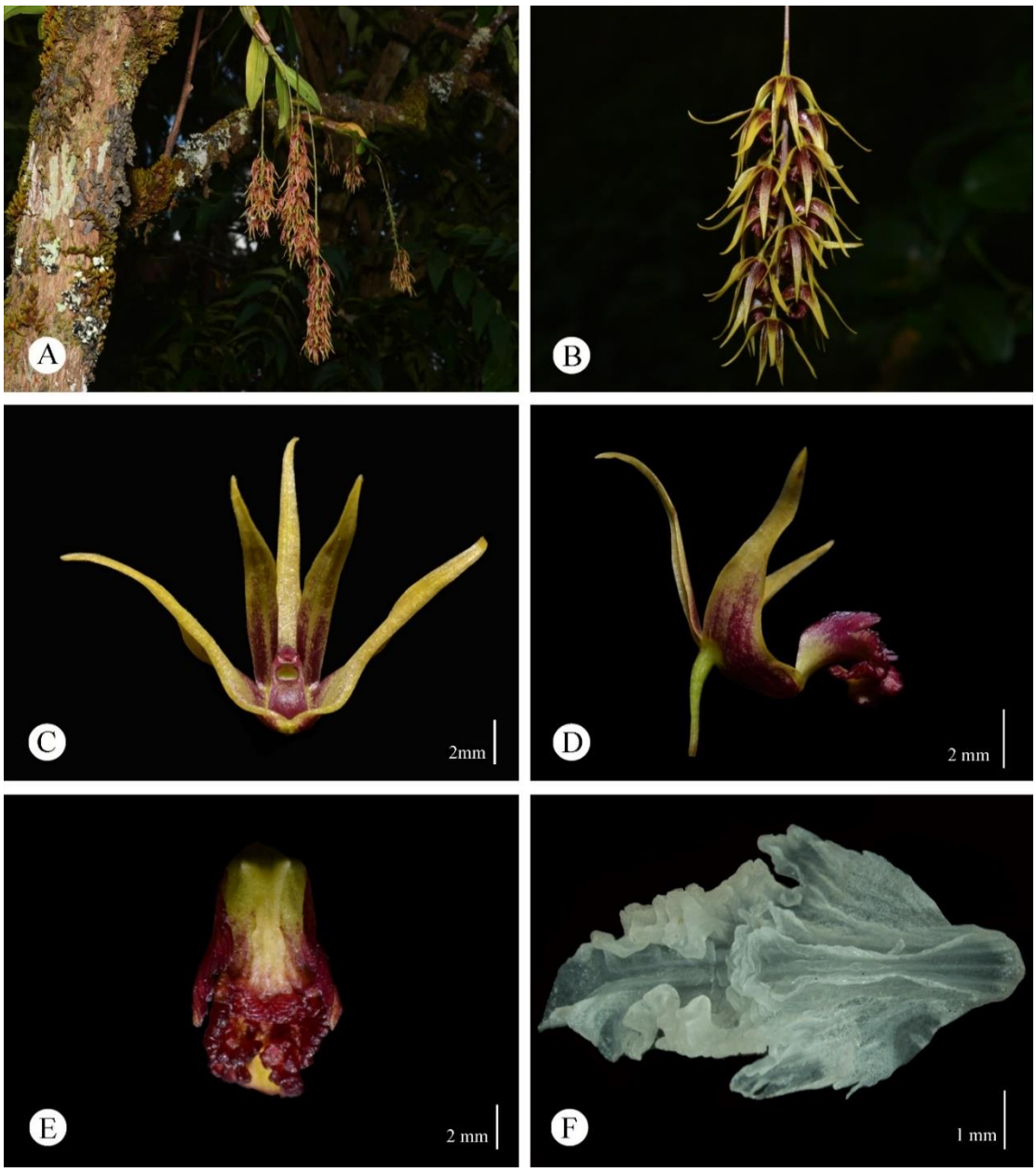


Plate 5. 5 *Dendrobium denudans* D. Don; A. Plant in natural habitat; B. Inflorescences; C. Flower front view and without labellum; D. Flower side view with labellum; E. Labellum; F. Labellum from spirit collection.

6. *Dendrobium dixonianum* Rolfe ex Downie, Bull. Misc. Inform. Kew. 9: 373. 1925; Gagnep. in Lecomte (ed.), Fl. Indo-Chine 6: 253. 1953; Seidenf., Opera Bot. 83: 137. f. 88, 1985. Type: N Thailand, Chiang Mai, Doi Chiang Dao, 1,650–1,800 m alt., *Kerr* 333 (holotype **K–Herb. Hook. f.!**). Figure 5.6, Plate 5.6, Map 5.4.

Dendrobium eserre Seidenf., Opera Bot. 83: 150. f. 102, 1985. **syn. nov**. Type: N Thailand, Mae Hong Son, Doi Chik Chong, Pai, 1,500–1,700 m alt., 10 October 1968, *G. Seidenfaden* & *T. Smitinand* 7024 (holotype **C!**).

Dendrobium eriiflorum sensu auct. Seidenf. & Smitinand 'as *eriaeflorum*' (non Griff. 1851), Orchids Thail.: 235. 1960, *pro parte. quoad Put 3383, T. Smitinand 4711*.

[The specimens cited, *Put 3383* and *T. Smitinand 4711* are in fact *D. dixonianum*]

Dendrobium wilmsianum sensu auct. Seidenf. & Smitinand, (non Schltr. 1960), Orchids Thail.: 239. 1960, *pro parte. quoad f. 181–a-e.*

[The figure 181 a-e is in fact *D. dixonianum*].

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, green or light bright green, ovoid, cylindric or fusiform, 1.2–4 cm tall, 2–6 mm in diameter, with 1–3 nodes, internodes 0.4–1.5 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath gray or pale brown, membraneous, glabrous on both sides, previous year's naked stems light yellow or greenish-yellow, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, elliptic, oblong, elliptic-lanceolate or linear-oblong, 2–4.6 cm long, 0.5–1 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, light green or dull green above, green or pale green beneath, mid-vein grooved above and ribbed below. leaf-bearing when flowering. **Inflorescences** raceme 1–2-inflorescenced, terminal, erect, 2–4.5 cm, long, exceeding leaves, with 2–10-flowered; peduncle and rachis glabrous, light green or yellowish-green, peduncle 1–2.5 cm long, rachis 2.1–4.2 cm long, covered with bracts; bracts yellowish-green or golden yellow, slightly concave, lanceolate to narrowly lanceolate, 4–5 mm long, 1–1.5 mm wide, apex acuminate or acute, base truncate, 1-veined, glabrous on both sides, margin entire, distinctly keeled below, bracteole yellowish-green or pale yellow, narrowly lanceolate, 3–4 mm long, 1–1.4 mm wide, apex acuminate, base truncate, 1-veined, glabrous on both sides, margin entire, distinctly keeled lelow. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 0.9–1.1 cm in diameter. **Sepals** greenish-white or dull greenish-yellow with dull brownish-yellow at base, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal narrowly lanceolate, 7–9 mm long, 2–3 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely falcate or triangular-lanceolate, 7–9 mm long, 5–6 mm wide at base, apex acute, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** white

with dull brownish-yellow at base, spreading, linear-oblanceolate, 6.5–7 mm long, 1.5–1.8 mm wide at middle, gently reduced at base, apex acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** dull brownish-yellow or dull yellow with deep purplish-red lines, with 3-lobed, 6.5–8.5 mm long, 4.8–5 mm wide across side lobe; shortly clawed at base, margin serrate, crenate-serrate; side lobes narrow triangular, forwards and upwards pointed, 4–4.6 mm long, 3–4 mm wide, margin crenate-serrate; disc oblong, 5–7 mm long, 2–3 mm wide, surface smooth, waxy, with distinctly 3 dull brownish-yellow thickened keels raising at hypochile, continuing to base of mid-lobe, the lateral keels shorter than the central one, apex of keel obtuse or acute; mid-lobe triangular, 2–3 mm long, 2.5–3.5 mm in diameter, acute to acuminate, margins crenate-crisped; **Mentum** orange-pink with deep red dots, broadly conical, 3.5–4 mm long, 2–2.1 mm in diameter, margin and surface entire, straightly or incurved distal. **Column** yellowish-green with deep red dots, 2–2.1 mm long, 1.4–1.5 mm wide at middle, margin and surface smooth or minute verrucose ; foot concave, cymbiform, 2–3 long, 1.5–1.8 mm wide at base, waxy; stigmatic cavity grayish-green, elliptic, stelidia obtuse, anther cap greenish-yellow with deep red dots, subglobose or widely ovate, 1–1.1 mm long, 0.9–1 mm wide, apex emarginated, basal margin denticulate or ciliate, surface minute papillous, adaxial side sulcate; pollinia 4 in 2 pairs, bright yellow or yellowish-orange, each pollinium, narrowly ellipsoid, c.1 mm long, 0.3–0.5 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 3–4 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, globose-ellipsoid with 3 obtuse keels, 1–1.2 cm long, 5–6 cm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Mae Hong Son (Doi Ke-a Po Pho Cho), Chiang Mai (Doi Ang Khang, Doi Chiang Dao, Doi Nangka), Nan (Doi Phuka National Park).

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In hill evergreen forest and open oak forest; 1,200–1,800 m alt. Growing on *Glochidion eriocarpum*, *Prunus persica* and *Quercus* sp. which are covered with mosses and lichen. Flowering: May–July; fruiting: December–March.

VERNACULAR.—Ueang khao tok bussaracum.

SPECIMENS EXAMINED.—Chaing Mai, Doi Chiang Dao, 1,800 m alt., June 1958, *K. Larsen* & *D. B. Hansen* 4198 (C); Nan, Bua Klua District, Doi Hua Suae, Doi Phuka National Park, 1,300 m alt., 10 July 2016, *M. Poophat* 1466 (BKF); Mae Hong Son, Muang District, Trail up to Doi Ke-a Po Pho Cho, 1,800 m alt., 7 August 2014, *P. Prommanut* 474; Chiang Mai, Fang District, Ban Luang, Doi Ang Khang, 1,580 m alt., 19 June 2015, *P. Prommanut* & *W. Buddhawong* 661 (BK); ibid, 1,600 m alt., 6 May 2016, *P. Prommanut* & *M. Kidyoo* 709 (BKF); Chiang Mai, Chom Thong District, Doi Inthanon, 1,200 m alt., 6 November 1980, *Put* 3383 (BK); Chiang Mai, Mae Tang District, Huai Nam Dang National Park, 6 August 2017, *S. Suddee* 5295 (BKF); Chiang Mai, Chiang Dao District, Doi Chiang Dao, 1,800 m alt., *T. Smitinand* 4711 (BKF, C).

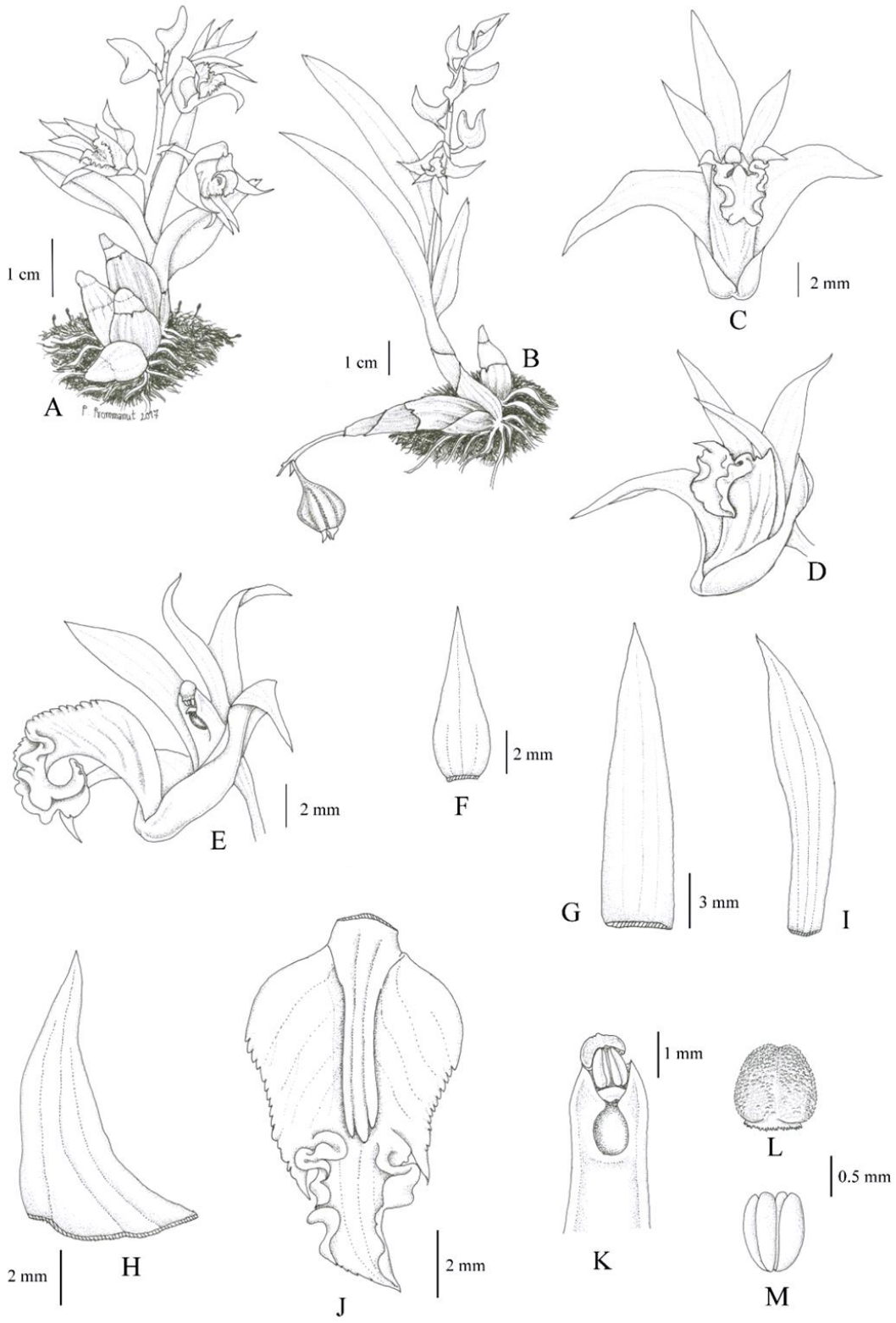


Figure 5. 6 *Dendrobium dixonianum* Rolfe ex Downie; A. Habit of flowering plant; B. Habit of flowering plant with capsule; C. Flower front view; D. and E. Flower side view; F. Bract, G. Dorsal sepal; H. Lateral sepal; I. Petal; J. Labellum; K. Column; L. Anther cap; M. Pollinia. Drawn from *P. Prommanut* 474.

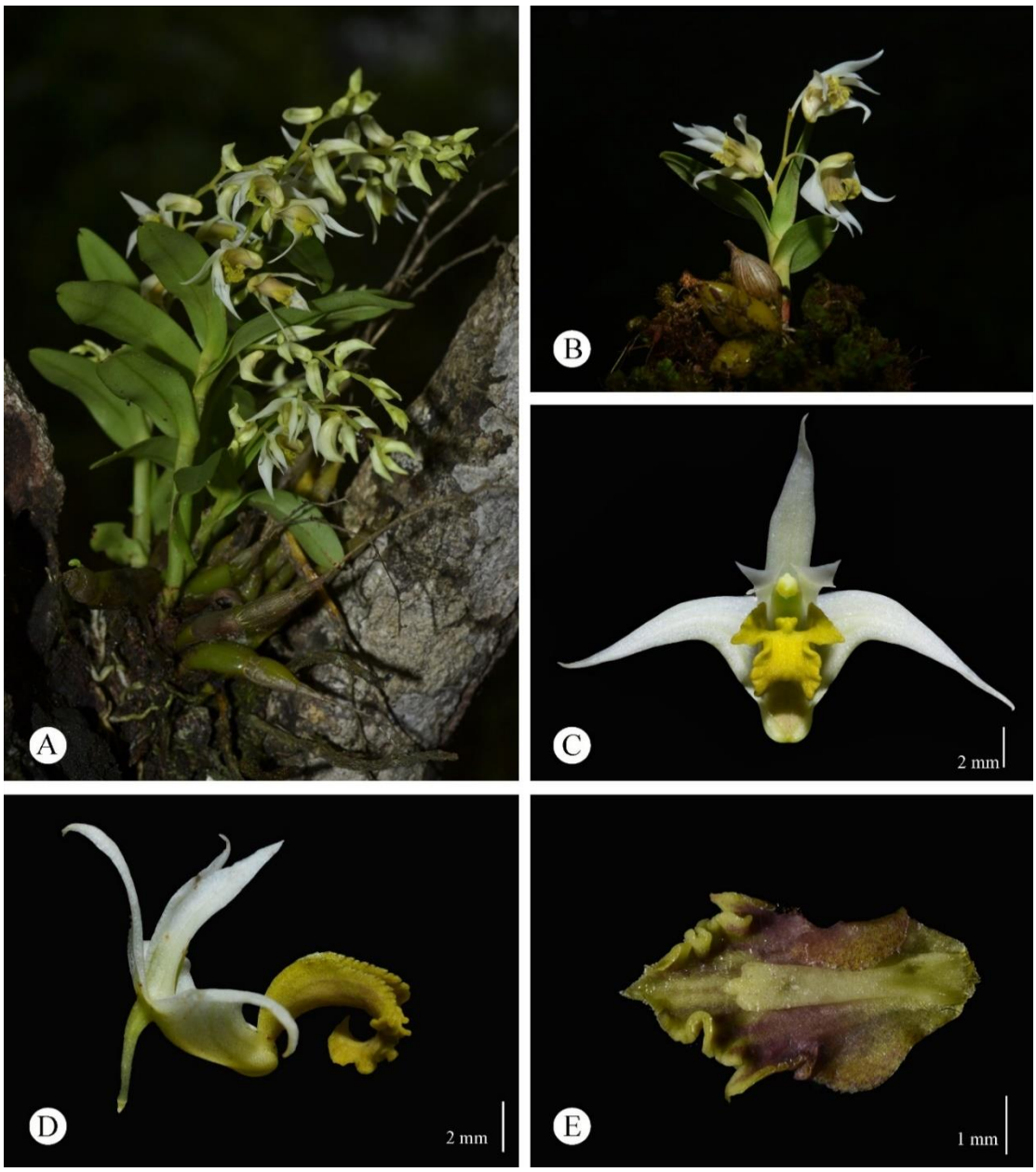


Plate 5. 6 *Dendrobium dixonianum* Rolfe ex Downie; A. and B. Plant in natural habitat; C. Flower front view; D. Flower side view; E. Labellum with 3 keels. C photo by W. Buddhawong. A. photo by M. Poophat.

7. *Dendrobium elliottianum* P. O'Byrne, Malayan Orchid Rev. 43: 96. 2009. Type: Thailand, unknown locality, cult. *J. Elliott* (Singapore). *O' Byrne* DX611 (holotype **SING!** photo seen). Figure 5.7, Plate 5.7, Map 5.3.

Plant epiphytic or litophytic, tufted with smooth roots. **Pseudobulbs** erect, green or light green, ovoid, conical or fusiform, 0.4–2.2 cm tall, 3–9 mm in diameter, with 2–5 nodes, internodes 3–6 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath gray or pale brown, membraneous, glabrous on both sides, previous year's naked stems dark purple or brownish-purple, naked. **Foliage leaves** 2–6, distichous, spreading, slightly recurved, oblong, linear or linear-oblong, 1.5–4 cm long, 2–6 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, pale yellow or dull green above, green or pale green beneath, mid-vein grooved above and ribbed below, leafless when flowering. **Inflorescences** raceme 1–2-inflorescenced, axillary and terminal, erect or suberect, 2.5–5.2 cm long, densely 3–6-flowered; peduncle and rachis glabrous, greenish-purple or dull purple, peduncle 1–1.6 cm long, rachis 0.5–1.5 cm long, covered with bracts; bracts purplish-green or pale purple, slightly concave, lanceolate, 4–5 mm long, 1.5–2 mm wide, apex acuminate or acute, base truncate, margin entire, 1–3-veined, glabrous on both sides, distinctly keeled below, bracteole pale purple, narrowly lanceolate, 3–4 mm long, 1–1.5 mm wide, apex acuminate, base truncate, margin entire, 1–3-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1.3–1.4 cm in diameter. **Sepals** white or pale pink, becoming dull pink when mature, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal dorsal sepal lanceolate or elliptical-lanceolate, 5–6.5 cm long, 1.7–2.2 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely trianular-lanceolate, 5–6 cm long, 7–8 mm wide at base, apex acuminate, base obliquely truncate, 3–5-viened, distinctly visible. **Petals** white or pale pink with pinkish-purple 3-veined, spreading, linear-oblong, 4–5.2 mm long, 1.8–2 mm wide, apex acute or acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** dull pinkish-purple or dull purple, pale green at claw, recurved, suborbicular or orbicular-flabelliform, with indistinctly 3-lobed, 6–9.6 mm long, 5–6 mm wide across side lobes; claw at base, 2–3 mm long, margin entire; side lobes erect, triangular, 2–2.5 mm long, 1–1.5 mm in diameter, apex obtuse or acute, margin crenate; disc, subglobose, 3–5 mm long, 3–3.3 mm in diameter, surface smooth, waxy, indistinctly with 2 dull pink thickened keels arising near claw and continuing to middle disc, apex acute, often notched in lateral sides, margin serrate-crenate; mid-lobe recurved, orbicular, 3–4 mm long, 2–3 mm in diameter, apex retuse, margins crenate-undulate. **Mentum** white to pale green with green marking at base and apex, narrowly conical or narrowly cylindric, 5–7 mm long, 1–2 mm in diameter, margin and surface entire, apex obtuse, incurved. **Column** dull pinkish-purple, 2–3 mm long, 1–1.8 mm

wide at base, margin and surface smooth; foot concave, cymbiform, 5–6 mm long, 1.2–1.5 mm wide at, waxy; stigmatic cavity pale pink, circular, stelidia obtuse, anther cap dull pinkish-purple, subglobose or widely obovate, 0.9–1 mm long, 0.8–1 mm wide, apex emarginated, basal margin erose-dentate, surface smooth, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.9–1 mm long, 0.5–0.9 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 5–6 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule**, green or dull green, subglobose with 3 obtuse keels, 0.9–1.2 cm long, 0.7–0.9 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Tak (Doi Hua Mot).

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In Deciduous dipterocarp-oak forest on degraded limestone hills, 860–900 m alt. Growing on moisture rock or *Quercus rex*. Flowering: October-December. Fruiting: November–February.

VERNACULAR.—Wai chedi.

SPECIMENS EXAMINED.—Tak, Umphang District, Umphang Wildlife Sanctury, Doi Hua Mot, 900 m alt., 9 October 2014, *P. Prommanut, S. Suddee, S. Rueangruea*, & *S. Muttapha* 594 (BK, BKF).

NOTE.—This species was first discovered in Doi Hua Mot. The plants of this species went on sale in Chatuchak Market, local market near the Thai-Myanmar border in Kanchanaburi Province and several nurseries in Thailand for more than 10 years.

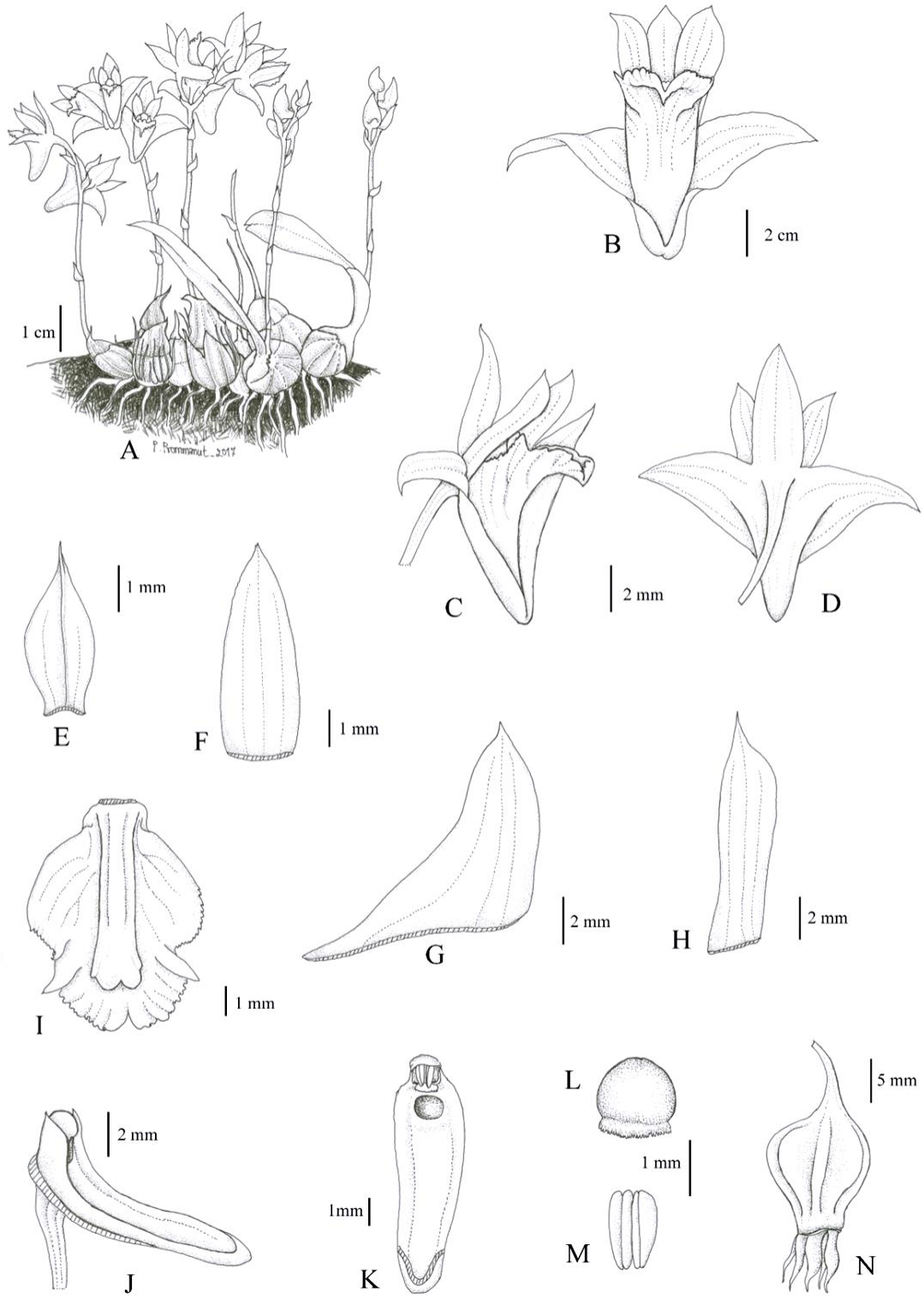


Figure 5. 7 *Dendrobium elliottianum* P. O'Byrne; A. Habit of flowering plant; B. Flower front view; C. Flower side view; D. Flower top view; E. Bract; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Column and mentum side view; K. Column and mentum front view; L. Anther cap; M. Pollinia; N. Capsule. Drawn from *P. Prommanut, S. Suddee, S. Rueangruea,* & *S. Muttapha* 594.

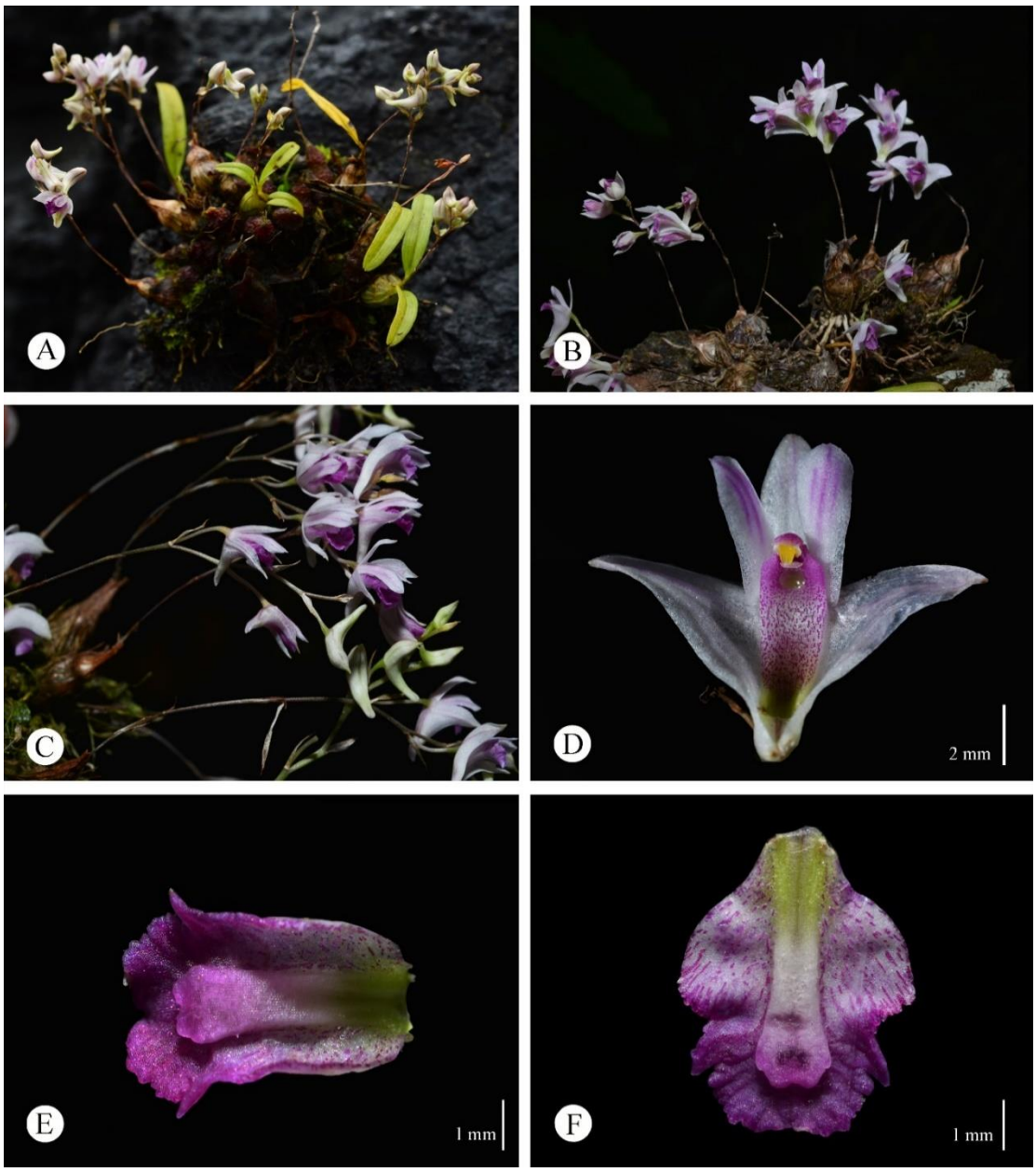


Plate 5. 7 *Dendrobium elliottianum* P. O'Byrne; A. Plant in natural habitat; B. and C. Inflorescences; D. Flower front view and without labellum; E. and F. Labellum show keel.

8. *Dendrobium garrettii* Seidenf., Opera Bot. 83: 127. 1985; 124: 30. 1995. Type: Thailand, Chiang Mai, Chom Thong, Doi Inthanon, Doi Pha Kao, southern slope near summit 1,800 m alt., 8 August 1931, *H. B. G. Garrett* 680 (holotype **K-Herb. Hook. f.!**; isotype **C!**). Figure 5.8, Plate 5.8, Map 5.3, Map 5.2.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, bright green, fusiform, globose or conical, 0.8–3 cm tall, 4–9 mm in diameter, with 1–3 nodes, internodes 3–7 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath stramineous, membraneous, glabrous on both sides, previous stems dull green or light greenish-yellow, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, orbicular, elliptic, oblong or ovate-lanceolate, 2.5–3.8 cm long, 0.6–1.7 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, coriaceous, glabrous on both sides, bright green or dull green above, pale green beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme 1-inflorescenced, terminal, erect, 2–5.5 cm long, exceeding leaves, with 3–10-flowereds; peduncle and rachis glabrous, strong pale yellow or dark purplish red, peduncle 1–3 cm long, rachis 1.2–2.5 cm long, covered with bracts; bracts strongly pale yellow or greenish-yellow, slightly concave, lanceolate to narrowly lanceolate, 5–8 mm long, 2–3 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteole, pale yellow, lanceolate, 5–6 mm long, 2–2.5 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1.5–1.8 cm in diameter. **Sepals** white, spreading, often recurved distally, margin entire or sometime slightly undulate, abaxial surface distinctly keeled; dorsal sepal narrow lanceolate, 1.1–1.5 cm long, 2–3 mm wide, apex acuminate, base truncate, mid-vein grooved above, 3-veined, distinctly visible; lateral sepals obliquely narrow-lanceolate or narrow falcate, 1.1–1.4 cm long, 5–7 mm wide at base, apex acuminate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** whitish with 2 light purple lines, recurved, oblong-oblanceolate, 1–1.2 cm long, 2–2.2 mm wide at middle, apex acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** saffron with dark red veins, margin greenish, elliptic, with 3-lobed, 1.1–1.2 cm long, c. 6 mm wide across side lobes; claw linear, c. 2 mm long, 2–2.5 mm wide, margin entire; side lobes shallowly triangular, c. 3 mm long, 1–1.5 mm wide, apex acute, margin entire; disc narrowly oblong, 7–9 mm long, 4–5 mm wide, surface smooth, waxy, distinctly with 3 dull yellow brown keels raising at hypochile, continuing to base of mid-lobe, each lobe attenuate; mid-lobe recurved, suborbicular, 5–5.5 mm long, 5–6 mm in diameter, margin fringed. **Mentum** white at upper part, brownish-yellow below, with light purple dots, narrowly conical, 5–6 mm long, 2–2.5 mm in diameter, margin and surface vesicular, apex obtuse, incurved. **Column** dull greenish-yellow with dark red dots, 2–3 mm long, 1.5–2 mm wide at base, margin and surface smooth; foot concave, cymbiform, 3–5 mm long, 1.5–1.8 mm wide

at base, waxy; stigmatic cavity dull greenish-yellow, ovate or elliptic, stelidia triangular, anther cap orange-pink with deep purple red at tip, subglobose or widely obovate, 1–1.2 mm long, c. 1 mm wide, apex emarginated, basal margin finely serrate, surface papillous, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.7–0.8 mm long, 0.2–0.3 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 5–9 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule**, green or dull green with dark purple lines, ellipsoid with 3 obtuse keels, 1.5–2 cm long, 1–1.4 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Chiang Mai (Doi Inthanon).

DISTRIBUTION.— Endemic to Thailand.

ECOLOGY.—In hill evergreen forest; 1,800–2,200 m alt. Growing on *Pinus kesiya*, *Wendlandia tinctoria* and *Dillenia* sp., which are covered with mosses and lichen. Flowering: June–August; fruiting: November–February.

VERNACULAR.—Wai karet.

SPECIMENS EXAMINED.—Chiang Mai, Mae Long, Mae Chem, 1,500 m alt., April 1990, *G. Seidenfaden* & *T. Smitinand* 9736 (C); Chiang Mai, Chom Thong District, Doi Inthanon, Doi Pha Kao, Southern slope near summit 1,800 m alt., 5 August 1931, *H. B. G. Garrett* 675 (BKF, C); ibid, Scenic view 1 km from Phra Mahathat Naphamethanidon and Nophamethanidon, 1,970 m alt., 11 July 2014, *P. Prommanut, P. Poltri, S. Suddee, S. Rueangruea* & *J. Hemrat* 511 (BK); ibid, near Kiew Mae Pan, 2,200 m alt., 1 August 2006, *P. Suksathan* 4040 (QBG); ibid, Kiew Mae Pan in front of Phra Mahathat Naphamethanidon, 2,050 m alt., 1 September 2006, *P. Suksathan* s.n. (QBG); ibid, 2,000 m alt., 5 July 2007, *S. Watthana* 2380 (QBG).

NOTE: This rare species is easily distinguished from other species in this section by epichile of labellum being coarsely fringed and very papillous anther cap.

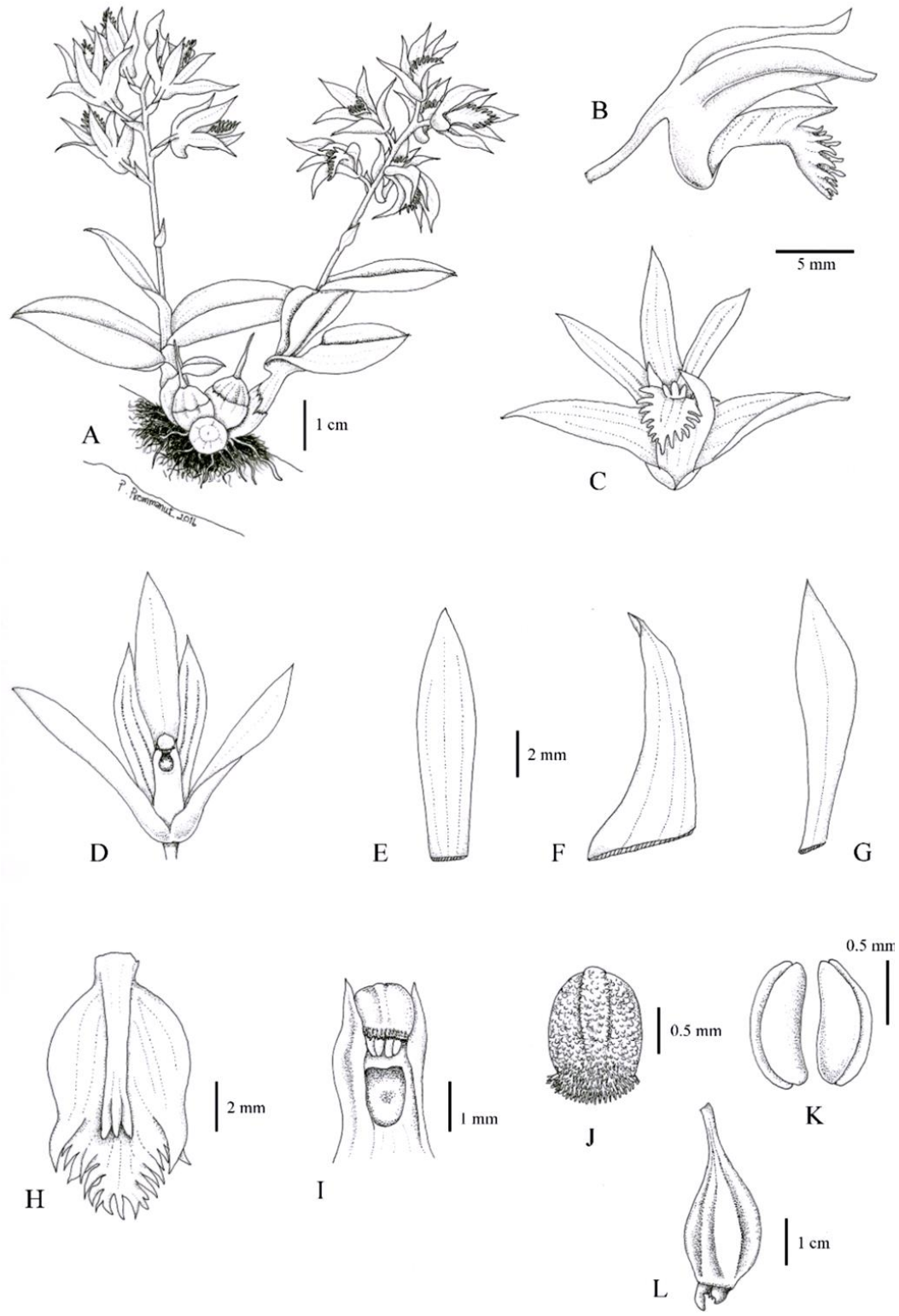


Figure 5. 8 *Dendrobium garrettii* Seidenf.; A. Habit of flowering plant; B. Flower side view; C. Flower front view; D. Flower without labellum; E. Dorsal sepal; F. Lateral sepal; G. Petal; H. Labellum; I. Column; J. Anther cap; K. Pollinia; L. Capsule. Drawn from *P. Prommanut, P. Poltri, S. Suddee, S. Rueangruea & J. Hemrat* 511.

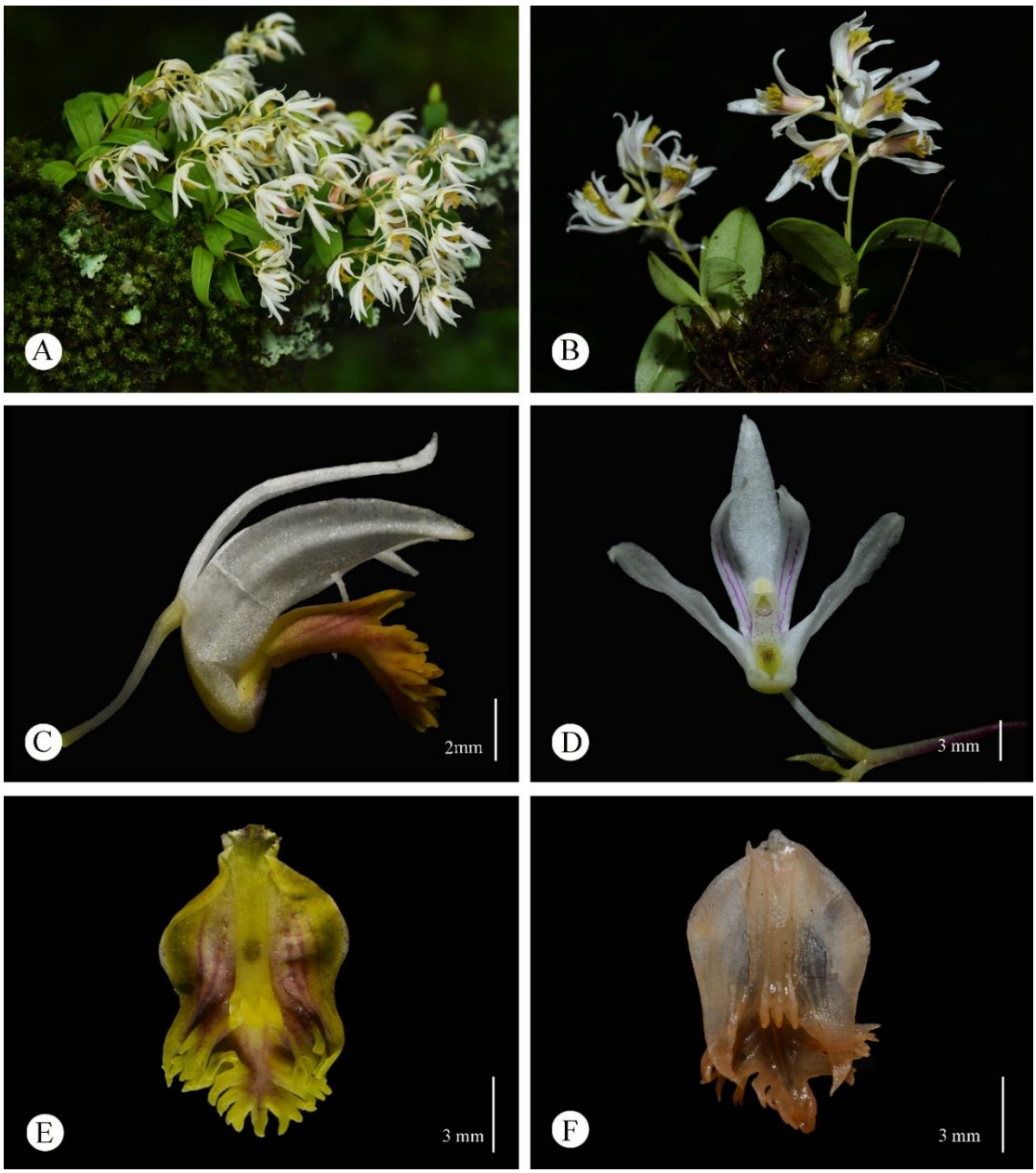


Plate 5. 8 *Dendrobium garrettii* Seidenf.; A. Plant in natural habitat; B. Inflorescences; C. Flower side view; D. Flower front view and without labellum; E. Labellum; F. Labellum from spirit collection.

9. *Dendrobium gregulus* Seidenf., Opera Bot. 83: 133. 1985. Type: N Thailand, Chiang Mai, Hod District, Bo Luang Sub-district, Mae Sanam, Pine forest station, 1,062 m alt., 5 March 1971, *G. Seidenfaden* & *T. Smitinand* 7642 (holotype **C!**). Figure 5.9, Plate 5.9, Map 5.3.

Dendrobium alpestre sensu auct. Seidenf. & Smitinand (non Royle. 1839), Orchids Thail.: 235. 1960, *pro parte. quoad f. 177.*

[The figure 177 is in fact *D. gregulus*]

Dendrobium peguanum sensu auct. Seidenf. (non Lindl. 1859), Opera Bot: 30. 1995, *pro parte. quoad Cumberlege 1303*.

[The specimens cited, *Cumberlege* 1303 is in fact *D. gregulus*].

Plant epiphytic or lithophytic, tufted, with smooth roots. **Pseudobulbs** erect, bright green, ovoid or globose, 0.8–2.5 cm tall, 0.5–1 cm in diameter, with 1–3 nodes, internodes 3–6 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath stramineous, membraneous, glabrous on both sides, previous year's naked stems dull brownish-yellow or greenish-yellow, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, linear or linear-oblong, 1–6 cm long, 3–7 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths chartaceous, glabrous on both sides, light green above, pale green beneath, mid-vein grooved above and ribbed below, flowering when leafless. **Inflorescences** raceme 1–2-inflorescenced, terminal, erect or suberect, 5.5–9.2 cm long, densely 5–15-flowered; peduncle and rachis glabrous, light purple, greenish-purple or dull yellow brown, peduncle 2.5–6 cm long, rachis 3.5–4.5 cm long, covered with bracts; bracts gray or pale brown, slightly concave, narrowly lanceolate, 6–8 mm long, 2–2.1 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteole pale brown, narrowly lanceolate, 3–4 mm long, 1–1.4 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1–1.1 cm in diameter. **Sepals** dull yellow brown, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal narrowly lanceolate or linear-lanceolate, 6.7–8 mm long, 1.9–2.1 mm wide, apex acuminate, base truncate, mid-vein grooved above, 3-veined, distinctly visible; lateral sepals obliquely falcate or triangular-lanceolate, 7–8 mm long, 4–5 mm wide at base, apex acute, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** dull yellow brown, spreading, linear-oblanceolate, 7–8 mm long, 2–2.5 mm wide at middle, gently reduced at base, apex acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** light brownish-yellow with deep purplish-red lines, slightly recurved, ovate or broadly ovate, without side lobes, 5–6 mm long, 5–5.2 mm wide, shortly clawed at base; disc ovate, surface smooth, waxy, distinctly with 2 yellow

thickened keels raising at hypochile, continuing to base of mid-lobe, each keel obtuse at apex, margin serrate-crisped. **Mentum** straw with dark purplish-red dots, broadly conical, 4–5 mm long, 2–2.6 mm in diameter, margins entire, straightly or incurved distally. **Column** dull yellowish-brown with dark purplish-red dots, especially along front edge, 2.7–3 mm long, 1–1.2 mm wide at middle, margin and surface smooth; foot concave, stout at base, waxy, 2–2.2 mm long, 1.5–2 mm wide at base; stigmatic cavity bright yellow, ovate, stelidia acute, anther cap light brownish-yellow with deep purplish-red dots, subglobose, 3–3.2 mm long, 2–2.1 mm wide, apex acute, basal margin ciliate, surface smooth, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.9–1 mm long, 0.8–1 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 3–5 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, ellipsoid with 3 obtuse keels, 0.7–1 cm long, 7–9 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Mae Hong Son (Ban Mae Lai, Mae Sariang), Chiang Mai (Chiang Dao, Mae Sanam, Bo Luang), Tak (Doi Hua Mot); SOUTH-WESTERN: Kanchanaburi.

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In dry evergreen montane forest, oak-dipterocarp forest mixed and dry deciduous dipterocarp forest on degraded limestone hills; 750-1,200 m alt. Growing on *Shorea obtusa*, *Quercus helferiana*, *Q. rex*. Flowering: December–April; fruiting: April–August.

VERNACULAR.—Ueang ma thom.

SPECIMENS EXAMINED.—Tak, Umphang District, Doi Hua Mot, *A. Sathapattayanon* 387 (BCU); Mae Hong Son, Ban Mae Lai, 1,250 m alt., *Cumberlege* 1303 (C, K); Chiang Mai, Hod District, Bo Luang, Mae Sanam, 1,100 m alt., 20 February 1983, *D. Merzies* 237 (K); Chiang Mai, Chiang Dao, 1,500 m alt., 10 March 1983, *D. Merzies* & *D. Du Puy* 185 (K); Mae Hong Son, Mae Sariang road km 45, 29 January 1964, *G. Seidenfaden* & *T. Smitinand* 5199 (C); Chiang Mai, Mae Pong, Kong Ley, 24 February 1979, *Koyama* et al. 15539 (C); Tak, Umphang District, Doi Hua Mot, 750 m alt., 13 January 2005, *P. Durumas* 164 (BCU); Chiang Mai, Hod District, Bo luang Sub-district, Mai Muang Nao Arboretum, 1,020 m alt., 20 February 2011, *P. Prommanut* s.n. (BKF); ibid, 1,100 m alt., 1 November 2012, *P. Prommanut* 053 (BKF); ibid, Mae Sanam, Pine forest station, 1,000 m alt., 6 March 1996, *R. Pooma* 25 (BKF); ibid, 1,200 m alt., 19 January 1996, *S. Suddee* 408 (BKF); ibid, January 1996, *S. Suddee* s. n. (BCU); Tak, Umphang District, Doi Hua Mot, 879 m alt., 13 March 2013, *S. Suddee, S. Rueangruea, P. Prommmanut, P. pansamrong* 4430 (BKF); Mae Hong Son, Mae Sariang, District, Huai Po cummunity forest, km 28, 900 m alt., 22

March 2006, *S. Watthana* & *M. Wongnak* 1847 (QBG); Tak, Umphang District, Doi Hua Mot, 770 m alt., 14 April 2006, *S. Watthana* 1904 (QBG); Mae Hong Son, Mae Sariang, District, Kiew Mae Han, Salawin WLS, 900 m alt., 20 February 2007, *S. Watthana* 2285(QBG); Tak, Umphang District, Ban Mae La Mung-Mae La Mung Kee, 1,000 m alt., 6 March 2007, *S. Watthana* 2313 (QBG); Tak, Umphang District, Doi Hua Mot, 800 m alt., 13 March 2011, *S. Watthana* 3730 (QBG).

LOCALITY UNKNOWN: 26 February 1995, *C. Thorat* 110 (BCU); 26 January 1996, *O. Thaithong* 1448 (BCU).

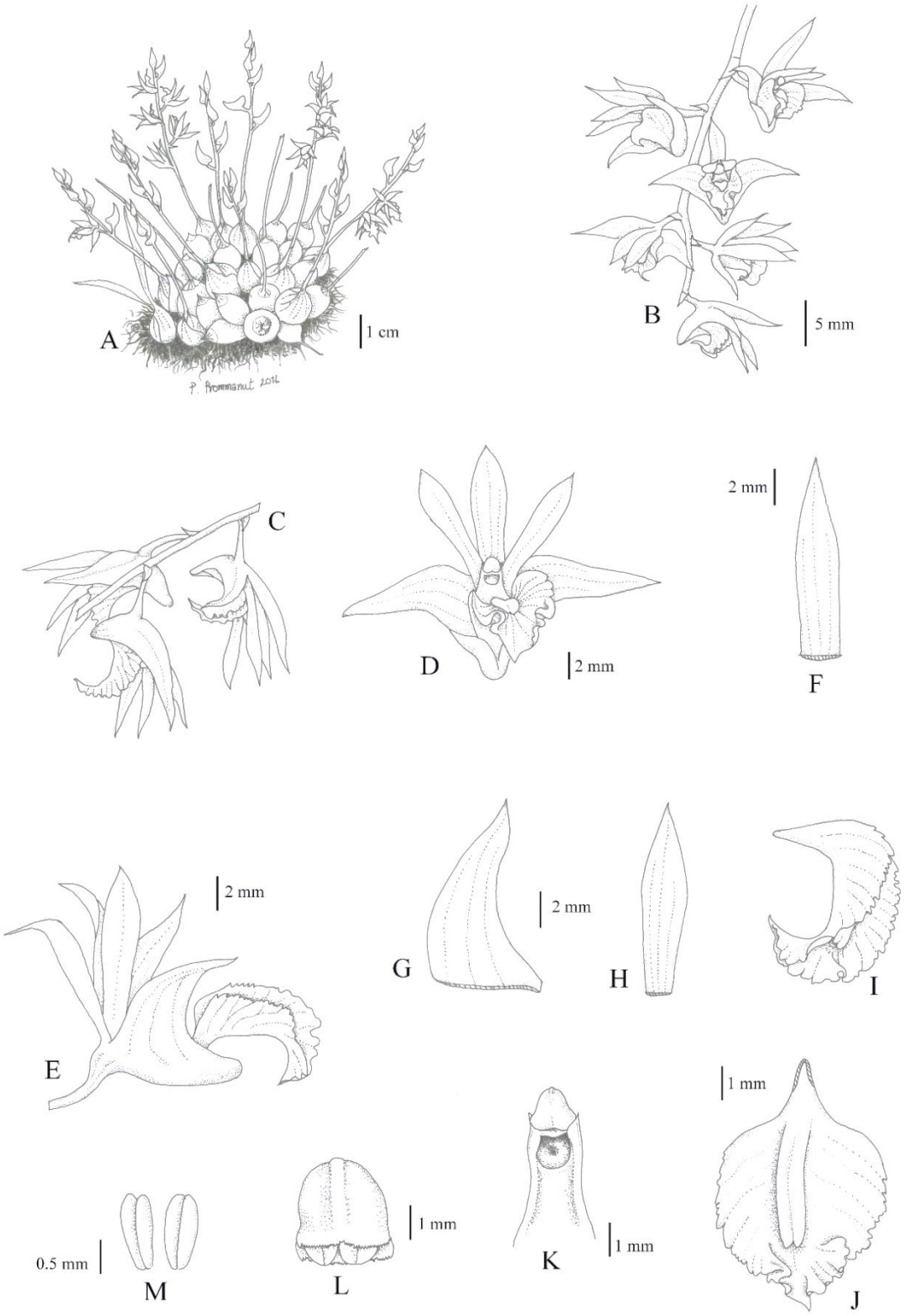


Figure 5. 9 *Dendrobium gregulus* Seidenf.; A. Habit of flowering plant; B. and C. Inflorescences. D. Flower front view; E. Flower side view; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum side view; J. Labellum; K. Column; L. Anther cap; M. Pollinia. Drawn from *P. Prommanut* 053.

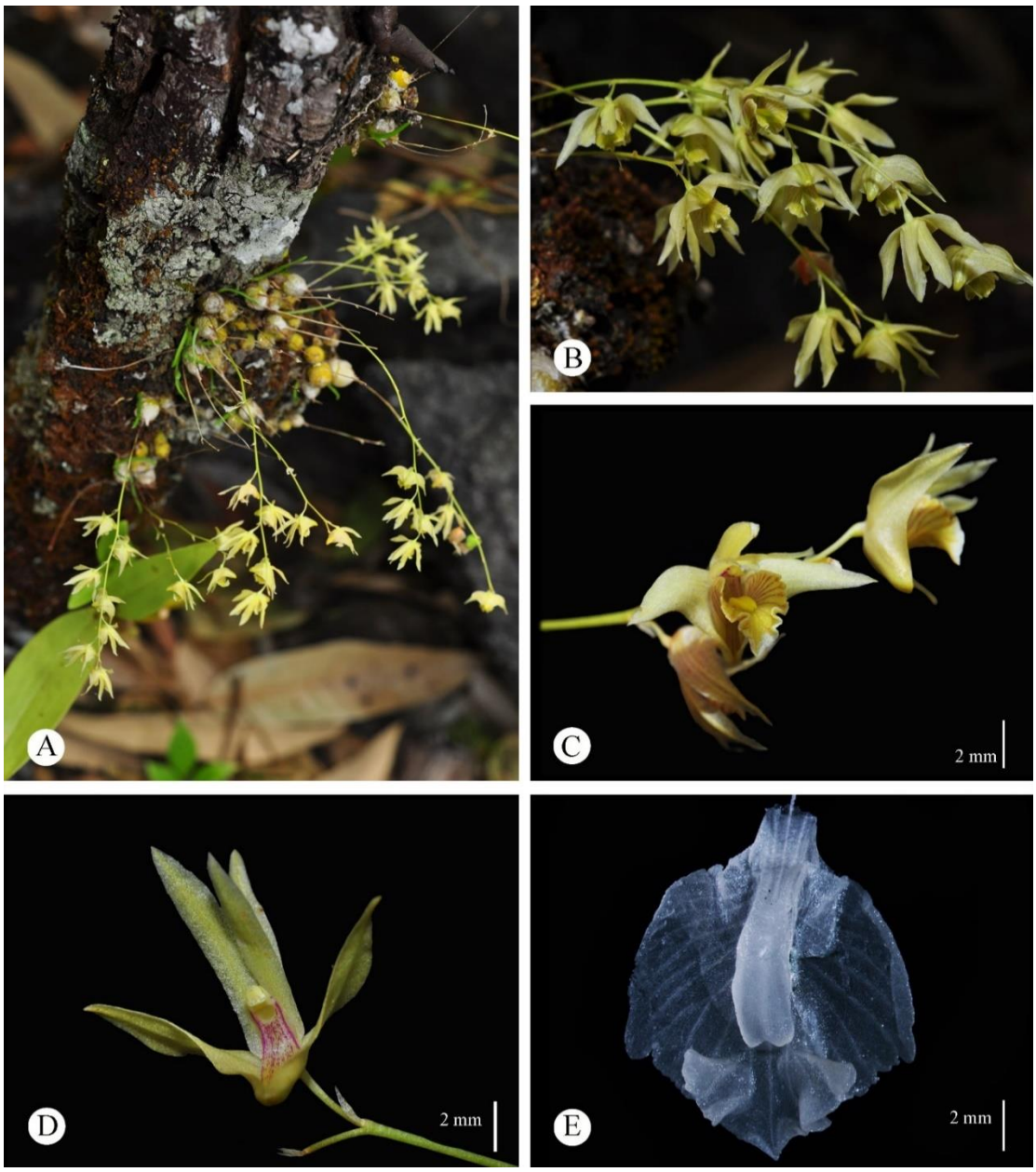


Plate 5. 9 *Dendrobium gregulus* Seidenf.; A. Plant in natural habitat; B. Inflorescences; C. Flower front view; D. Flower front view and without labellum; E. Labellum from spirit collection.

10. *Dendrobium incurvum* Lindl., J. Proc. Linn. Soc., Bot. 3: 18. 1858. Rchb., Trans. Linn. Soc. London 30(1): 137, 1874; Hook. f., Fl. Brit. India 5: 718. 1890; B. Grant, Orch. Burma: 99. 1895; F. Kränzl., Pflanzenr. (Engler) 50(45): 78. 1910; Seidenf. & Smitinand, Orchids Thail.: 235. 1960; Seidenf., Opera Bot. 83: 143. Fig. 93. 1985. Type: Myanmar, Tennesarim at Myeik, Mergui, 12°26′27″N, 98°36′42″E, *Griffith* 808 (holotype **K–Herb. Lindl.!**). Figure 5.10, Plate 5.10, Map 5.5.

Callista incurva (Lindl.) Kuntze, Revis. Gen. Pl. 2: 655. 1891. Type: as for above.

Dendrobium aclinia Lindl., J. Proc. Linn. Soc., Bot. 3: 9. 1858. *nom. illeg*.

Dendrobium kratense Kerr, Bull. Misc. Inform. Kew 1927: 217. 1927. **syn. nov**. Type: Thailand, Trat, Khao Saming, on small tree in open glade in evergreen forest, 12°21′N, 102°27′E, 20. m alt., 25 November 1924, *Kerr* 1093 (holotype **K–Herb. Hook. f.!**; isotype **BK!**).

Dendrobium erostelle Seidenf., Opera Bot. 83: 140, f. 93. 1985. **syn. nov**. Type: Thailand, Ranong, Foothills of Khao Phra Mi, *G. Seidenfaden* & *T. Smitinand* 6030 (holotype **C!**).

Dendrobium eriiflorum sensu auct. Seidenf. & Smitinand 'as *eriaeflorum*' (non Griff. 1851), Orchids Thail.: 235. 1960.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect or pendulous, bright green, fusiform or cylindric, 3–25 cm tall, 3–9 mm in diameter, with 4–10 nodes, internodes 0.5–2 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath bright creamy brown, membraneous, glabrous on both sides, previous stems dull greenish-yellow or bright yellow, naked. **Foliage leaves** 2–10, distichous, spreading, slightly recurved, linear-oblong, elliptic or oblong, 3.3–9 cm long, 0.8–1.6 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, lowermost smaller than upper, light green above, pale green or greenish-yellow beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme, 2–11-inflorescenced, axillary and sub-terminal, erect or pendulous, 2.5–5 cm long, densely 4–12-flowered; peduncle and rachis glabrous, bright green, peduncle 1.3–3 cm long, rachis 3–10 cm long, covered with bracts; bracts bright creamy brown, slightly concave, lanceolate, 4–5 mm long, 2–3 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles creamy yellow, narrowly lanceolate, 4.5–5 mm long, 1–1.5 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, strongly scented, long-lasting, 0.9–1.2 cm in diameter, not widely when bloom. **Sepals** white or pale green, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal linear-lanceolate, 1.1–1.2 cm long, 2–3 mm wide, apex acuminate, base truncate, 3-veined, distinctly

visible, mid-vein grooved above; lateral sepals obliquely narrow-falcate, 1.1–1.3 cm long, 3–5 mm wide at base, apex acuminate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** white or pale white, spreading, linear-oblanceolate, 1–1.1 cm long, 1.5–2 mm wide at middle, apex acute, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** whitish-green with strong dark green veins, recurved at apex, without side lobes, 1–1.3 cm long, 3.9–5 mm, shortly clawed at base; disc narrowly oblong, 7–9 mm long, 3.5–5 mm wide, surface smooth, waxy, distinctly with 3 bright green thickened keels raising at hypochile, continuing to base of mid-lobe, each of apex obtuse, margin undulate-crispate; mid-lobe bright green or dull green, apex acuminate, margins serrate-crenate. **Mentum** bright light, funnel shaped, 5–7 mm long, 1.2–1.8 mm in diameter, margin and surface entire, straight or incurved distally. **Column** glossy green, 2–3 mm long, 1.5–2 mm wide at base, margin and surface smooth; foot concave, cymbiform, 5–7 mm long, 1.5–1.8 mm wide at base, waxy; stigmatic cavity glossy green, circular, stelidia obtuse, anther cap pale green, subglobose or widely obovate, 0.9–1 mm long, 0.8–1 mm wide, apex emarginated, basal margin finely serrate, surface smooth, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow in 2 pairs, each pollinium narrowly ellipsoid, 1–1.2 mm long, 0.5–0.7 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 5–6 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, ellipsoid with 3 obtuse keels, 1–1.3 cm long, 5–9 mm wide, apex with persistent dried sepals and petals.

THAILAND.—SOUTH-EASTERN: Chachoengsao, Chanthaburi (Soi Dao, Makham), Trat (Khao Saming); PENINSULAR: Chumphon, Ranong (Klong Naka, Kraburi), Surat thani (Phanom, Khao Sok), Phangnga (Khao Sok), Satun (Langa).

DISTRIBUTION.—Myanmar (type), Cambodia, Malaysia.

ECOLOGY.—In mangrove forest and evergreen forest; 0–400 m alt. Growing on *Rhizophora* sp., *Avicennia* sp. and *Hopea odorata*. Flowering: October–December; fruiting: January–April.
VERNACULAR.—Wai kraten.

SPECIMENS EXAMINED.**—MYANMAR**: North Andaman Island, December 1991, *P. S. N. Rao* s.n. (C). **THAILAND**: Chumphon, 21 January 1927, *A. F. G. Kerr* 0353 (C); Ranong, Kraburi, 10 m alt., 24 December 1928, *A. F. G.* Kerr 0666 (BK); Chantaburi, Khao Soi Dao, 400 m alt., 12 November 1969, *Beusekom* & *T. Smitinand 2162* (BKF,C); Prachin Buri, 21 October1968, *C. Chermsirivathana* 1005 (BK); Surat Thani, Khao Sok National Park, 14 January 1984, *G. Seidenfaden* & *T. Smitinand* 9458 (C); ibid, 31 December 1984, *G. Seidenfaden & T. Smitinand* 9466 (C); Phang Nga, 10 km. W of Phang-nga, 17 December 1984, *G. Seidenfaden* & *T. Smitinand* 9435a (C); Trat, near sea level, 25 August 2004, *K. Phengiao* s.n. (BKF); Ranong: Klong Naka

Wildlife Sanctuary, 200 m alt., 28 November 2015, *M. Chanla* s.n. (BKF); Trat, Khao Saming, near sea level, 16 October 2016, *P. Prommanut* 850 (BCU); Chanthaburi: Makham, 30 m alt., 1 November 2015, *P. Rakthai* s.n. (BK); Chantaburi, 31 November 1962, *T. Sørensen* s.n. (C) ;Chantaburi, Khao Soi Dao, 50 m alt., 25 October 1956, *T. Smitinand* 3604 (BKF); ibid, 100 m alt., 22 November 1956, *T. Smitinand* 3639 (BKF). **MALAYSIA**: East of Malaysia, 1,700 m alt., 2 April 1979, *J. B. Comber* 1055 (K); Bukit Wang, North Kadah, *Haniff* 646 (C).

LOCALITY UNKNOWN: **THAILAND:** 31 October 1987, *O. thaithong* 302 (BCU). **CAMBODIA:** *Tixier* 7 I/63 (C).

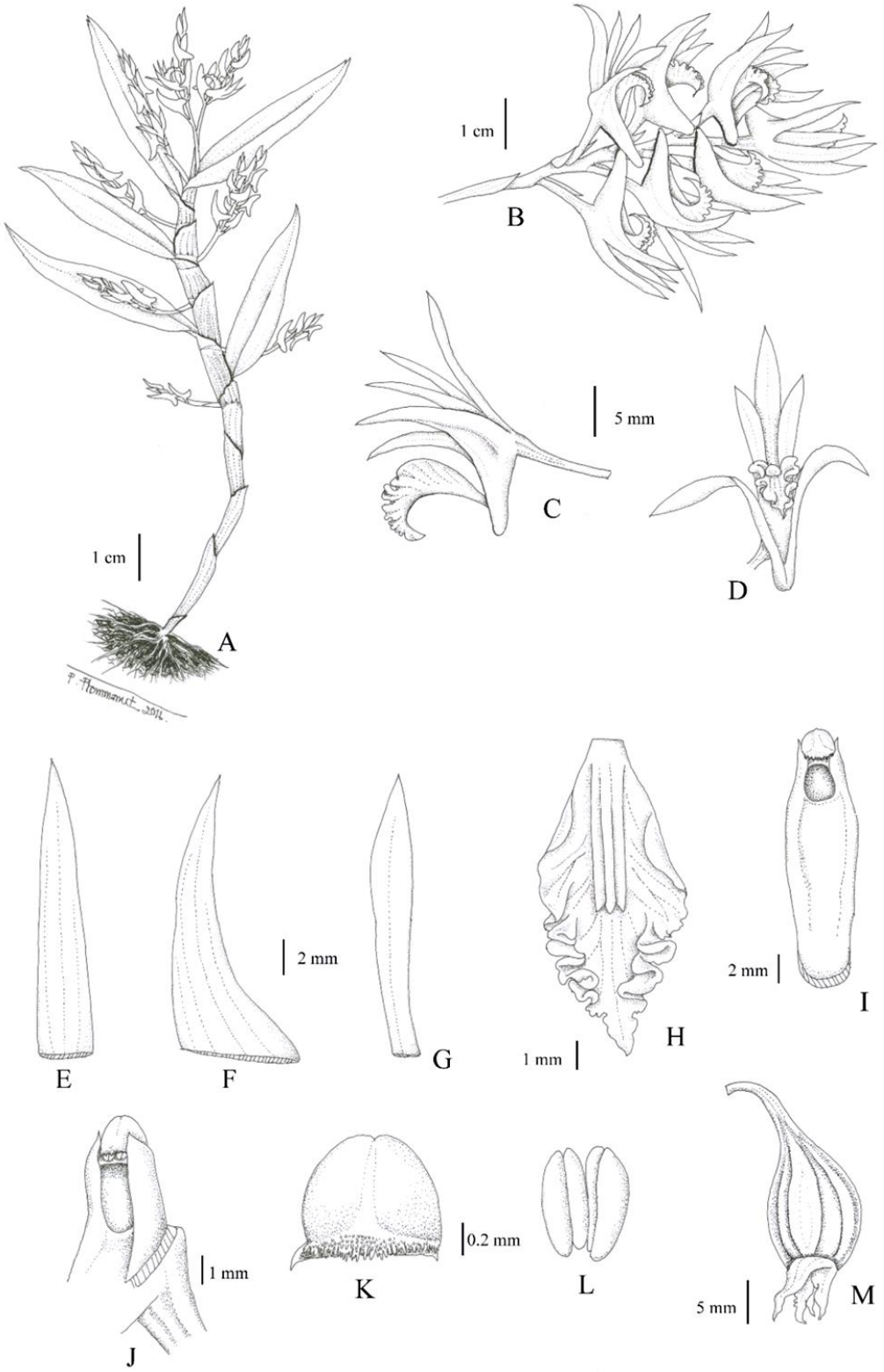


Figure 5. 10 *Dendrobium incurvum* Lindl.; A. Habit of flowering plant; B. Inflorescences; C. Flower side view; D. Flower front view; E. Dorsal sepal; F. Lateral sepal; G. Petal; H. Labellum; I. Column and mentum; J. Column side view; K. Anther cap; L. Pollinia; M. Capsule. Drawn from *P. Prommanut* 850.

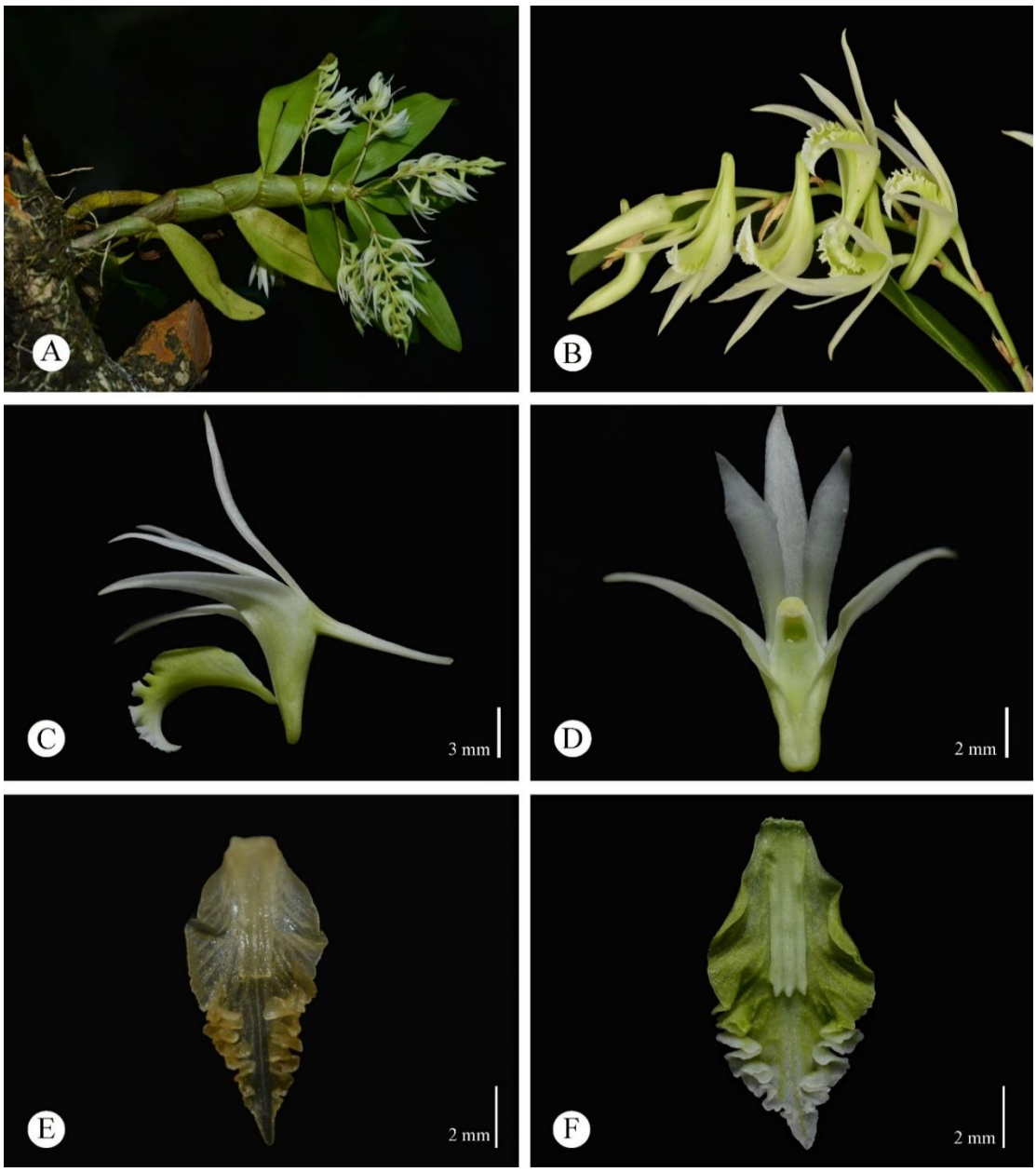


Plate 5. 10 *Dendrobium incurvum* Lindl.; A. Plant in natural habitat; B. Inflorescences; C. Flower side view; D. Flower front view and without labellum; E. Labellum from spirit collection; F. Labellum show 3 keels.

11. *Dendrobium kanburiense* Seidenf., Opera Bot. 83: 135. 1985. Type: Thailand, Kanchanaburi, Thong Pha Phum District, 300 m alt., September 1962, *G. Seidenfaden* & *T. Smitinand* 4282 (holotype **C!**). Figure 5. 11, Plate 5.1, Map 5.4.

Dendrobium sinominutiflorum S. C. Chen, J. J. Wood & H. P. Wood, Fl. China 25: 394. 2009. **syn. nov**.

Dendrobium minutiflorum S. C. Chen & Z. H. Tsi, Bull. Bot. Res., Harbin 9 (2): 27–28, f. 4–6. 1989. Type: China. *nom. illeg*.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, bright green, fusiform, globose or conical, 0.8–1.2 cm tall, 4–9 mm in diameter, with 1–3 nodes, internodes 3–6 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath stramineous, membraneous, glabrous on both sides, previous stems light greenish-yellow, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, elliptic, oblong or ovate-lanceolate, 1.8–2.7 cm long, 5–7 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, coriaceous, glabrous on both sides, bright green or dull green above, pale green beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme 1–2-inflorescenced, terminal, erect, 0.7–2 cm long, with 3–5-flowereds; peduncle and rachis glabrous, light green, peduncle 1–3 cm long, rachis 1.2–2.5 cm long, covered with bracts; bracts strongly greenish-yellow or dull green, slightly concave, lanceolate to narrowly lanceolate, 2–2.1 mm long, 1–1.2 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteole, bright green, lanceolate, 1.7–2mm long, 0.8–1 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 0.9–1.2 cm in diameter. **Sepals** dull green, spreading, often recurved distally, margin entire or sometime slightly undulate, abaxial surface distinctly keeled; dorsal sepal lanceolate, 4–6 cm long, 2–3 mm wide, apex acuminate, base truncate, mid-vein grooved above, 3-veined, distinctly visible; lateral sepals obliquely triangular, 5–5.5 cm long, 4–5 mm wide at base, apex acuminate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** dull green, recurved, oblong, 3–4.5 mm long, 1.5–1.6 mm wide at middle, apex acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** bright green, ovate, with indistinctly 3-lobed, 5–6 mm long, 5–5.2 mm wide across side lobes; claw short, 1–2 mm long, 2–2.5 mm wide, margin entire; side lobes shallowly triangular, 1–2 mm long, 1–1.5 mm wide, apex acute, margin entire; disc oblong, 3–4 mm long, 4–4.5 mm wide, surface smooth, waxy, distinctly with 3 dull green keels raising at hypochile, continuing to base of mid-lobe, each lobe attenuate; mid-lobe recurved, suborbicular, 1–2 mm long, 4–4.2 mm in diameter, margin entire or minute sinuate. **Mentum** dull green, conical, 3.5–4 mm long, 1.5–1.9 mm in diameter, margin and surfaceentire, apex obtuse, incurved. **Column** dull, 2–3 mm long, 1.5–1.9 mm wide

at base, margin and surface smooth; foot concave, cymbiform, 3–4 mm long, 1.5–1.8 mm wide at base, waxy; stigmatic cavity dull green, ovate, stelidia triangular, anther cap dull green, subglobose, 1–1.2 mm long, c.1 mm wide, apex emarginated, basal margin finely serrate, surface smooth, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.5–0.8 mm long, 0.2–0.3 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 3–4 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, obovate with 3 obtuse keels, 4–8 mm long, 5–7 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Tak (Ban Mae La Mung Khee); SOUTH-WESTERN: Kanchanaburi (Thong Pha Phum).

DISTRIBUTION.—China.

ECOLOGY.—In dry deciduous dipterocarp forest; 700–900 m alt. Growing on *Quercus* sp., *Schima wallichii* and *Shorea obtusa*, which are covered with mosses and lichen. Flowering: August–October; fruiting: November–February.

VERNACULAR.—Wai mueang kan.

SPECIMENS EXAMINED.—**THAILAND**: Kanchanaburi, Between Kriti and Kuay Bankao, 12 July 1973, *Geesink* et al. 6234 (C); Kanchanaburi, Thong Pha Phum, 26 August 1962, *G. Seidenfaden & T. Smitinand* 4282 (C); Tak, Umphang District, road to Ban Mae La Mung Khee, 720 m alt., 26 July 2012, *S. Suddee* et al. 4377 (BKF); Tak, Tha Song Yang, Mae Moei National Park, 540 m alt., 6 October 2016, *S. Suddee* et al. 5140 (BKF).

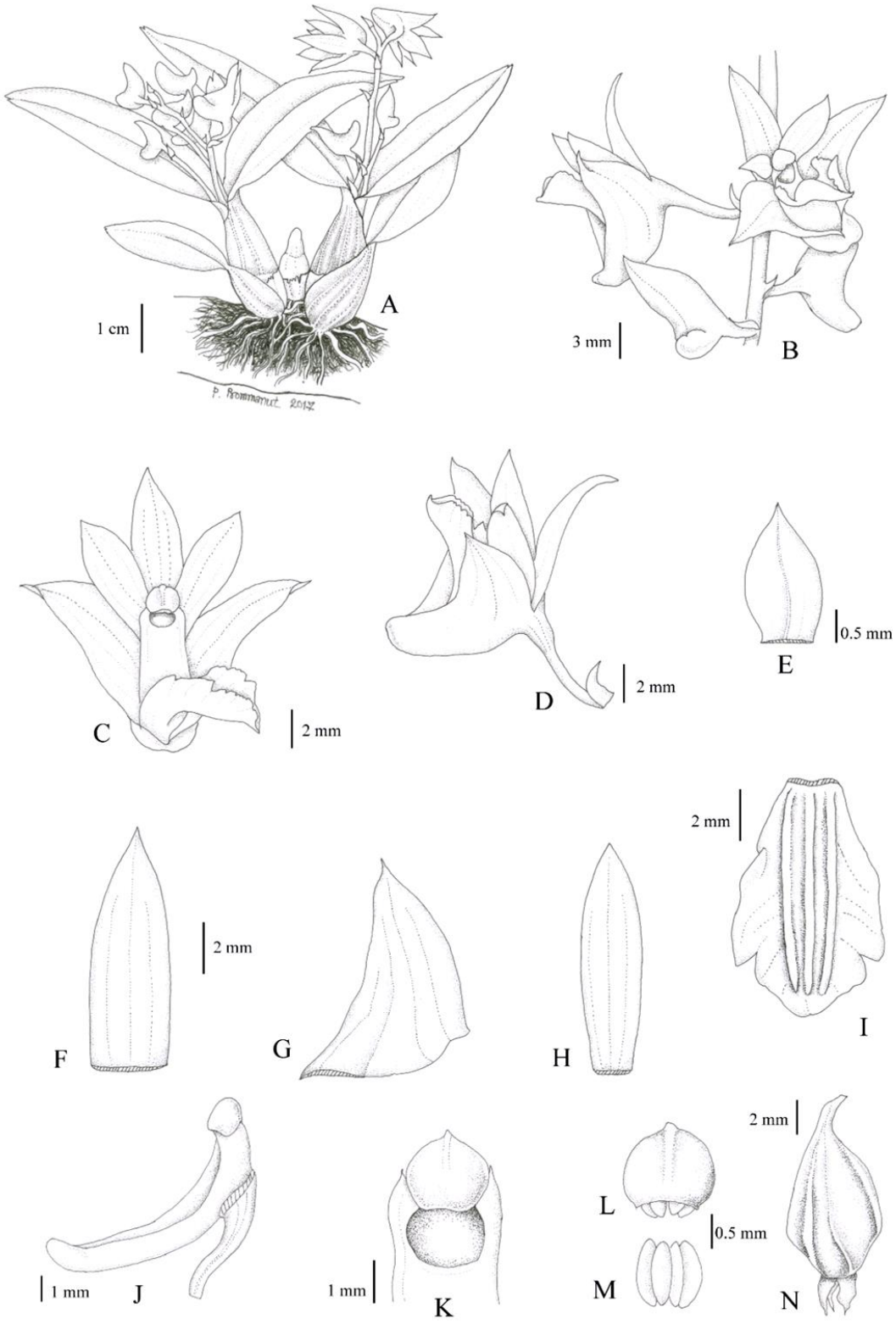


Figure 5. 11 *Dendrobium kanburiense* Seidenf.; A. Habit of flowering plant; B. Inflorescences; C. front view; D. Flower side view; E. Bract; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Column and mentum side view; K. Column; L. Anther cap; M. Pollinia; N. Capsule. Drawn from *S. Suddee et al.* 5140.

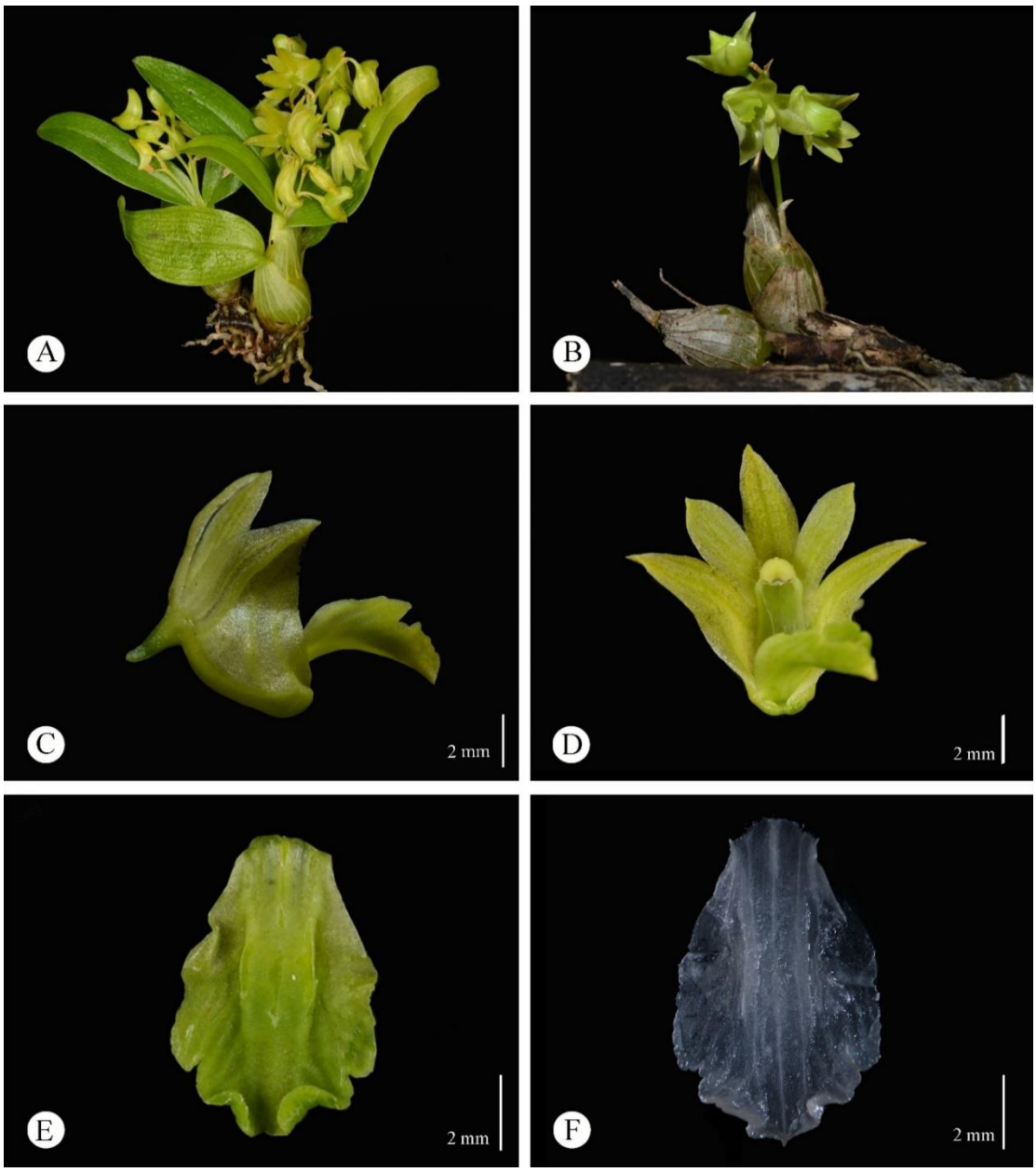


Plate 5. 11 *Dendrobium kanburiense* Seidenf.; A. and B. Plant in natural habitat; C. Flower side view; D. Flower front view; E. Labellum; F. Labellum from spirit collection.

12. *Dendrobium mucronatum* Seidenf., Opera Bot. 83: 139. f. 90, pl. XVIIa. 1985. Type: N Thailand, Mae Hong Son Province, Khao Laung, Khun Yuam, 1,600 m alt., 19 May 1978, *G. Seidenfaden* & *T. Smitinand* 8470b (holotype **C!**). Figure 5.12, Plate 5.12, Map 5.6.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, glossy green or yellowish-green, ovoid, conical, ellipsoid or fusiform, 1–1.8 cm tall, 3–9 mm in diameter, with 2–3 nodes, internodes 2–4 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath pale brown, membraneous, glabrous on both sides, previous stems dull greenish-yellow, naked. **Foliage leaves** 2–3, distichous, spreading, slightly recurved, ovate, lanceolate, narrowly lanceolate or oblong, 2.7–2.9 cm long, 1.2–1.4 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, green with purple tinted, mid-vein dark dull red, grooved above and ribbed below. **Inflorescences** hysteranthous, raceme, 1–3-inflorescenced, terminal, suberect or nodding, 1.5–2 cm long, not exceeding leaves, with 7–10-flowered; peduncle and rachis glabrous, purple or purplish-red, peduncle 4–5 mm long, rachis 7–9 mm long, covered with bracts; bracts purple or purplish-green, slightly concave, triangular to lanceolate, 2–3 mm long, 1.5–1.9 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles purplish-red, narrowly lanceolate, 1.9–2.5 mm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, 5–8 mm in diameter. **Sepals** light greenish-yellow with reddish-purple longitudinal veins, spreading, often recurved distally, margin minute papillose, abaxial surface distinctly keeled; dorsal sepal lanceolate, 3–3.5 mm long, 1.2–2 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely triangular-lanceolate, 3.8–4.2 mm long, 4–5 mm wide at base, apex mucronate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** light yellowish-brown or yellowish-green with 1 reddish purple longitudinal vein, spreading, linear-oblanceolate, 7–9 mm long, 5–7 mm wide at middle, apex acute, base truncate, margin papillose, 1-veined, distinctly visible. **Labellum** yellowish-green, surface glandular-papillose, slightly recurved at base, subglobose or broadly ovate, without side lobes, 2.4–2.6 mm long, 1.3–1.6 mm wide, shortly clawed at base; disc ovate, surface glandular-papillose, waxy, distinctly with 3 reddish-yellow thickened keels raising at hypochile, continuing and extending near tip of mid-lobe. **Mentum** pale green, very short, broadly conical, 2–3 mm long, 1–2 mm in diameter, margin sub-punctate, straight or incurved distally. **Column** green, short, with strongly developed sidewings, 1–1.2 mm long, 0.7–1 mm wide at base, margin and surface verrucose-papillose; foot concave, stout at base, waxy, 1–1.5 mm long, 1–1.4 mm wide at base; stigmatic cavity glossy green, broadly ovate, stelidia acute, anther cap pale green, subglobose, 0.5–0.7 mm long, 0.3–0.4 mm wide, apex acute, basal margin ciliate, surface papillose, adaxial side sulcate; pollinia 4, in 2

pairs, bright yellow, each pollinium globose, 0.2–0.4 mm long, 0.1–0.2 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 1–2 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** not seen.

THAILAND.—NORTERN: Mae Hong Son (Khun Yuam).

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In hills evergreen forest; 1,600 m alt. Growing on tree. Flowering: May; Fruiting: June–July.

VERNACULAR.—Ueang khao tok khun yuam.

SPECIMENS EXAMINED.—Mae Hong Son Province, Khao Laung, Khun Yuam, 1,600 m alt., 19 May 1978, *G. Seidenfaden* & *T. Smitinand* 8470b (C).

TAXONOMIC NOTE:—*Dendrobium mucronatum* is similar to *D. porphyrochilum* in having bracteoles longer than ovary (including pedicel), mucronate tip of lateral sepals, lip without distinct side lobes, but it differs by margins of sepals and petals are papillose, petals with distinctly 1-veined, lip with 3 keels extending close to a tip of mid-lobe and globose pollinium.

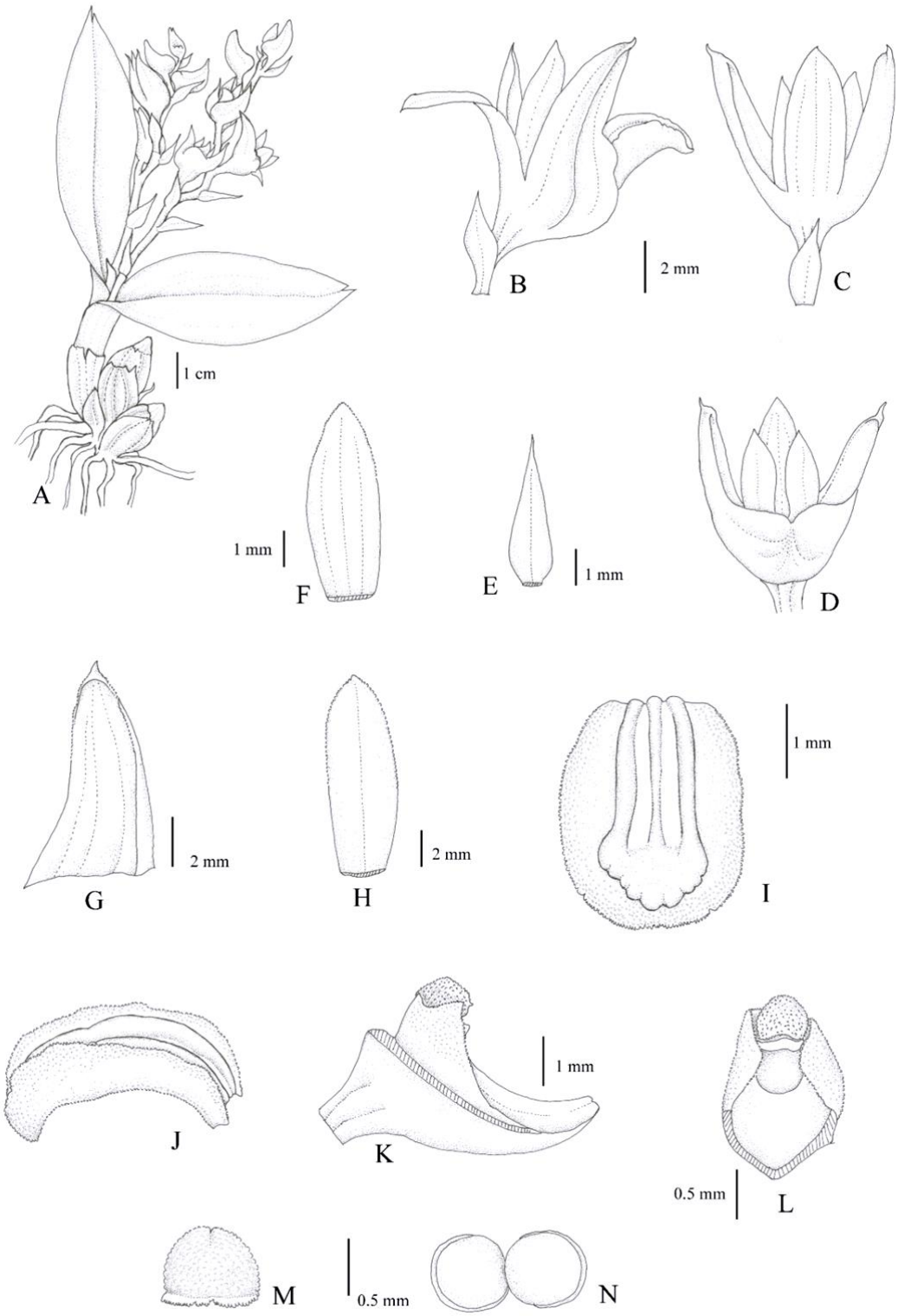


Figure 5. 12 *Dendrobium mucronatum* Seidenf.; A. Plant from type specimen; B. Flower side view; C. Flower top view; D. Flower below; E. Bract; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Labellum side view; K. Column and mentum side view; L. Colum front view; M. Anther cap; N. Pollinia. Drawn from *G. Seidenfaden* & *T. Smitinand* 8470b.

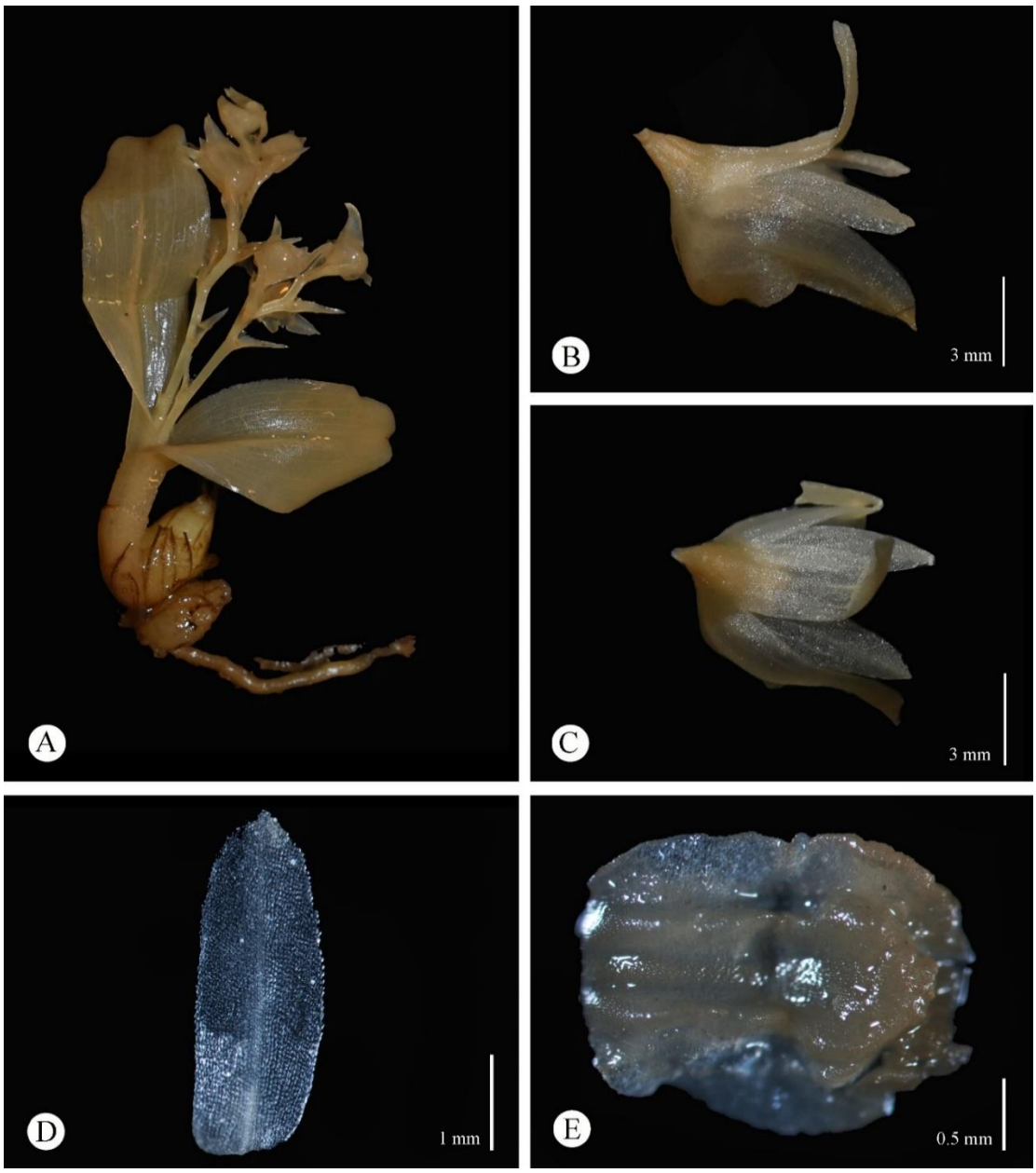


Plate 5. 12 *Dendrobium mucronatum* Seidenf.; A. Plant from type specimen; B. Flower side view; C. Flower top view; D. Petal show 1 vein and margin papillose; E. Labellum from spirit collection and show 3 keels.

13. ***Dendrobium obchantiae*** Promm., Suddee & Kidyoo, Phytotaxa, 348(2): 90–98. 2018. Type: Tak Province, Umphang District, near the Check Point to Thi Lo Su Waterfall, c. 600 m alt, 10 Oct 2014, cultivated and flowered in Chiang Mai, 25 Oct. 2015, *Prommanut* & *Buddhawong* 703 (holotype: **BKF**). Figure 5.13, Plate 5.13, Map 5.4.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, green or greenish-purple, cylindric or narrowly fusiform, 9.5–26 cm tall, 2–4 mm in diameter, with 2–8 nodes, internodes 1.6–3.7 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath stramineous, membraneous, glabrous on both sides, previous stems dull purple with pinkish-purple longitudinal lines, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, ovate, lanceolate, narrowly lanceolate or oblong-lanceolate, 4.5–8 cm long, 0.5–1.3 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, green or dull green above, pale green or purplish-green beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme 1–4-inflorescenced, subterminal and axillary, suberect or nodding, 2.5–5.5 cm, not exceeding leaves , 2–5.5 cm long, with 2–3-flowereds; peduncle and rachis glabrous, dull purple or purplish-green, peduncle 1–2 cm long, rachis 1–3 cm long, covered with bracts; bracts green or purplish-green, slightly concave, triangle to lanceolate, 3–4 mm long, 1.5–2 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteole purplish-green, lanceolate, 2–3 mm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, strongly fragrant like chocolate, long-lasting, 1.4–1.6 cm in diameter. **Sepals** greenish-yellow with 3 longitudinal purple veins, spreading, often recurved distally, margin entire or sometime slightly undulate, abaxial surface distinctly keeled; dorsal sepal elliptic-obovate, 6.5–7 mm long, 3.8–4 mm wide, apex acute, base truncate, mid-vein grooved above, 3-veined, distinctly visible; lateral sepals widely triangular or falcate-triangular, 6.5–7 mm long, 5–5.5 mm wide at base, apex acute, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** pale green or greenish-yellow, with 3 longitudinal purple veins, recurved, oblanceolate, 6.5–6.9 mm long, 1.9–2 mm wide at middle, apex acuminate, base truncate, margin entire, sometime slightly undulate at upper half, 3-veined, distinctly visible. **Labellum** bright greenish-yellow or dull green, recurved at apex, ovate or suborbicular, with 3-lobed, 7–7.5 mm long, 5–8 mm wide across side lobes, shortly clawed at base; side lobes bright greenish-yellow with dull green lines, obliquely triangular-obovate, forwards and upwards pointed, 4–5 mm long, 1.9–2 mm wide, apex acute, margin entire; disc narrowly oblong, 4–5 mm long, 4–5 mm wide, vesicular on both surfaces, waxy, distinctly with 3 bright greenish-yellow thickened keels, raising at base, continuing to base of mid-lobe, all with the same length; midlobe bright green, suborbicular, recurved, apex acuminate, margin cristate-

corrugate. **Mentum** bright green, short and stout, broadly conical shaped, 3–4 mm long, 2.5–3 mm in diameter, margins and surface entire, straight or incurved distally. **Column** bright green, short, 1.5–1.9 mm long, 2.5–2.8 mm wide at base, margin and surface smooth, sidewings strongly developed; foot concave, stout at base, waxy, 4–5 mm long, 2–2.5 mm wide at base, waxy; stigmatic cavity dull green, circular or ovate shaped, stelidia obtuse, anther cap pale green with pale brown patches, subglobose or widely obovate, 0.5–0.8 mm long, 0.8–1 mm wide, apex emarginate, basal margin minutely ciliate, surface smooth, adaxial surfaces sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium ellipsoid, 0.4–0.6 mm long, ca. 0.2 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 5–8 mm long, glabrous, quite waxy, 6-grooved. Capsule green or dull green, ellipsoid with 3 obtuse keels, 1.8–2 cm long, 0.8–1 cm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Tak (Umphang); SOUTH-WESTERN: Kanchanaburi (Thong Pha Phum).

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In mixed deciduous forest; 600–800 m alt. Growing on *Gigantochloa ridleyi*, *Wendlandia tinctoria* and *Syzygium cumini*. Flowering; October–November; fruiting: January–March.

VERNACULAR.—Ueang khao tok obchant.

SPECIMENS EXAMINED.—Kanchanaburi: Thong Pha Phum District, Thong Pha Phum National Park, Trail up to Jokkrading Waterfall, 760 m alt., 24 October 2015, *P. Prommanut* & *S. Suddee* 584 (BK); ibid, 5 January 2016, *P. Prommanut* & *S. Suddee* 674 (BCU); Tak, Umphang District, near the Check Point to Thi Lo Su Waterfall, c. 600 m alt., 25 October 2015, *P. Prommanut* & *W. Buddhawong* 703 (BKF).

NOTE: *Dendrobium obchantiae* is closely related to *D. incurvum*. They are similar in having fusiform stems, narrowly lanceolate or oblong-lanceolate leaves of chartaceous texture, inflorescences that do not exceed the leaves and three rounded keels on the inner surface of labellum. However, the new species can be clearly distinguished from *D. incurvum* by several characters as follow: *D. obchantiae* has pale green or greenish yellow flowers, lax inflorescence (2–3-flowered per inflorescence), elliptic-obovate dorsal sepal, widely triangular or obliquely triangular lateral sepals, oblanceolate petals that are narrower than sepals and recurved, an ovate or suborbicular labellum with side lobes, short and stout mentum that is broadly conical. *D. incurvum* has dense inflorescence (5–12-flowered per inflorescence), white flowers, oblong-linear dorsal sepal, narrowly falcate or obliquely falcate-lanceolate lateral sepals, linear-oblanceolate and not recurved petals, narrow lanceolate labellum without side lobes and narrowly conical mentum forming a spur.

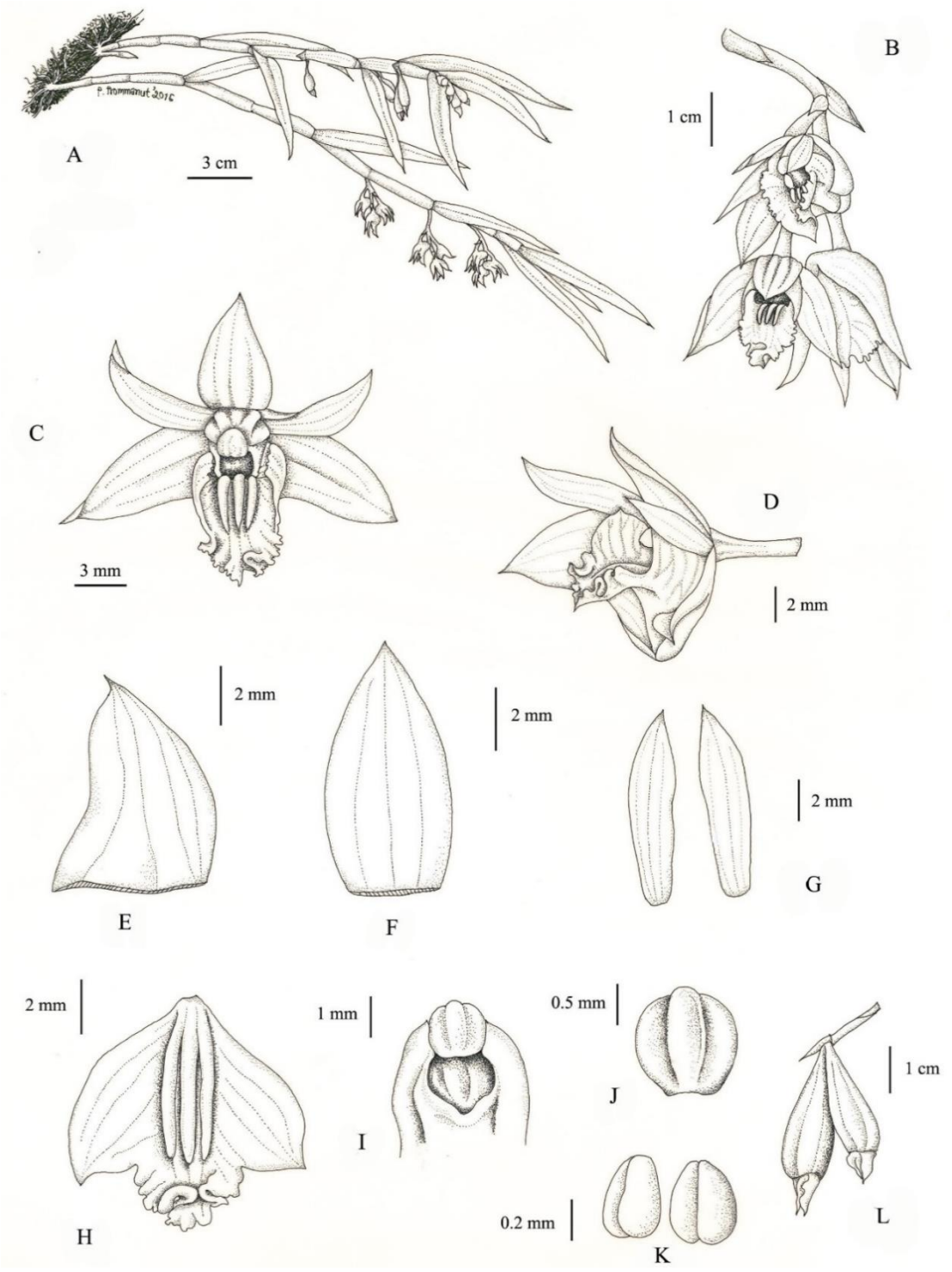


Figure 5. 13 *Dendrobium obchantiae* Promm., Suddee & Kidyoo; A. Habit of flowering plant; B. Inflorescence; C. Flower front view; D. Flower side view; E. Lateral sepal; F. Dorsal sepal; G. Petals; H. Labellum with 3 keels and side lobes; I. Column; J. Operculum; K. Pollinia; L. Capsule. Drawn from *Prommanut* & *Buddhawong* 703.

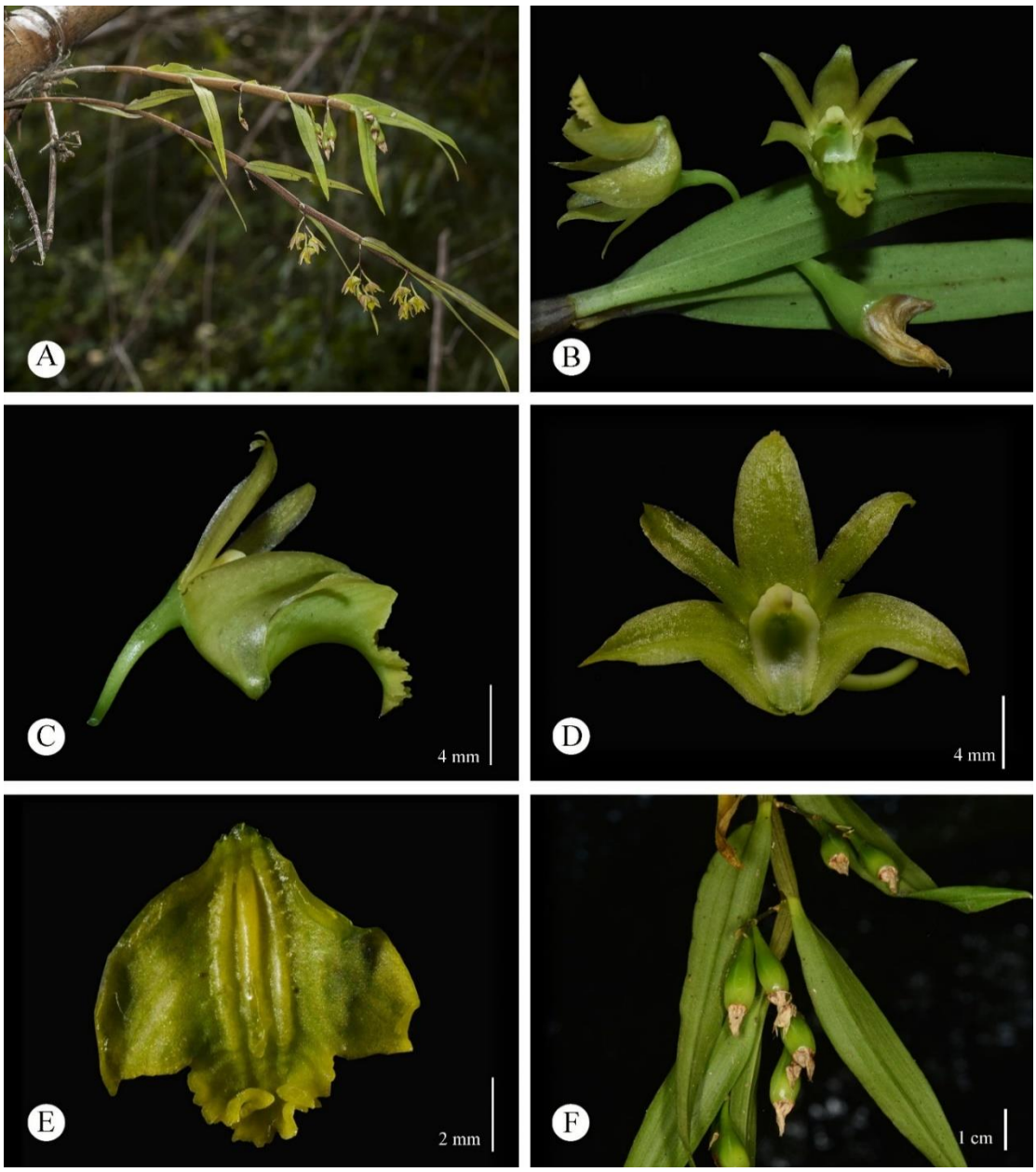


Plate 5. 13 *Dendrobium obchantiae* Promm., Suddee & Kidyoo; A. Plant in natural habitat; B. Inflorescences; C. Flower side view; D. Flower front view and without labellum; E. Labellum; F. Capsule. A photo by W. Buddhawong.

14. *Dendrobium peguanum* Lindl., J. Proc. Linn. Soc., Bot. 3: 19. 1859; Rchb., Trans. Linn. Soc. London. 30: 137. 1874; H. Santapua, R. R. Fernandes & Z. Kapadia, J. Bombay Nat. Hist. Soc. 55(3): 484, Pl. Va-h, 1958; H. Santapua & Z. Kapadia, J. Bombay Nat. Hist. Soc. 57(3): 497, Pl. XVIIIa-c, 1960; P. F. Hunt, Kew Bull. 24(1): 90. 1970; Mukerjee, Bull. Bot. Surv. India. 14: 96. 1975; H. Hara, W. T. Stearn & L. H. J. Williams, Enum. Fl. Pl. Nepal: 40. 1978; Pradhan, Indian Orchids 2: 340. 1979; Seidenf., Opera Bot. 83: 132, f. 83, 1985; Opera Bot. 124: 30, Pl. 5d, 1995; Hajra, in P. K. Hajra & D. M. Verma (eds), Fl. Sikkim 1: 61. 1996; K. J. White & B. Sharma, Wild Orchids Nepal: 223. 2000; N. Pearce & P. J. Cribb., Fl. Bhutan 3(3): 420. 2002; D. B. Gurung, Orchids Bhutan: 121. 2006; H. P. Wood, Dendrobiums: 676, Pl. 175, 2006. Type: Myanmar, Hlain Dirt, Pegu, 5 January 1854, *McLelland* s. n. (syntype **K–Herb. Hook. f.!, K–Herb. Lindl.!**). Figure 5.14, Plate 5.14, Map 5.1.

Dendrobium pygmaeum Lindl., Gen. Sp. Orchid. Pl.: 85. 1830, *nom. illeg*.; Lindl., Bot. Reg. 30: 62. 1844; Hook. f., Fl. Brit. India 5: 717. 1890; King & Pantl., Ann. Roy. Bot. Gard. (Calcutta) 8: 43, pl. 58. 1898; F. Kränzl., Pflanzenr. (Engler) 50(45): 83, f.3 L-O. 1910; T. L. Banerji, Orchids Nepal: 65. 1996, *pro parte. quoad f. 28*. Type: Myanmar, Proe, *Wall. Cat. No.* 1999. (holotype **K–W**!).

Callista pygmaea (Lindl.) Kuntze, Revis. Gen. Pl. 2: 655. 1891. Type: as for above.

Dendrobium wallichii A. D. Hawkes & A. H. Heller, Lloydia 20: 125. 1957, *nom. superfluous*.

Dendrobium fesselianum M. Wolff, Orchidee (Hamburg) 41(3): 96. 1990. Type: Thailand.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, bright green, globose or ovoid, 1–2 cm tall, 0.7–1.7 cm in diameter, with 1–3 nodes, internodes 3–4 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath pale brown, membraneous, glabrous on both sides, previous stems dull green, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, linear-oblong, elliptic or oblong, 1.9–6.5 cm long, 3–7 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, coriaceous, glabrous on both sides, light green with purplish-red dots above, pale green or greenish-yellow beneath, mid-vein grooved above and ribbed below, plants leafless when flowering. **Inflorescence** raceme, 1–2-inflorescenced, axillary and terminal, erect or suberect, 1.5–3 cm long, densely 5–12-flowered; peduncle and rachis glabrous, purplish-green or bright green with reddish-purple stripes, peduncle 0.4–1.1 cm long, rachis 0.6–1.7 cm long, covered with bracts; bracts pale brow, slightly concave, lanceolate, 6–7 mm long, 3–4 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteole creamy yellow, narrowly lanceolate, 6–6.5 mm long, 1–1.5 mm wide, apex acuminate, base truncate,

margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, strongly scented, long-lasting, 1–1.5 cm in diameter. **Sepals** white with dull greenish-yellow dots at base, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal linear-lanceolate, 0.9–1 cm long, 2 mm wide, apex acuminate, base truncate, mid-vein grooved above, 3-veined, distinctly visible; lateral sepals obliquely narrow-falcate, 0.8–1 cm long, 5–6 mm wide at base, apex acuminate, base obliquely truncate, 3–5-veined, distinctly visible. **Petals** white with greenish-yellow dots at base, spreading, linear-oblanceolate, 0.9–1 cm long, 2–3 mm wide, apex acute, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** pale brown with dark brown to purple veins, becoming deep red with a slight tinge of purple when mature, surface entire, obovate-deltoid, with 3-lobed, 0.7–1 cm long, 5–6 mm wide across side lobes; clawed linear, 3–4 mm long, margin entire or sub-crenate; side lobes broadly triangular, upwards pointed, 1–1.5 mm long, 2–2.5 mm wide, apex acute, margin entire; disc with distinctly 3 dull pink or reddish-pink thickened keels, raising at hypochile, continuing to base of mid-lobe, the lateral keels shorter and broader than the central one, apex of keels acute; mid-lobe broadly triangular, 1–2 mm long, 2–3 mm wide, apex acute, margin crisped-undulate, recurved at apex. Mentum light yellowish-green with purplish-red dots, broadly conical, 5–6 mm long, 1.9–2 mm in diameter, margin and surface entire, incurved distally or spur like. **Column** glossy green with slight tinge of purple dots, 2–3 mm long, 1.5–2 mm wide at base, margin and surface smooth; foot concave, cymbiform, 3–4 mm long, 1.3–1 mm wide at apex, waxy; stigmatic cavity glossy yellowish-green, circular, stelidia cuspidate, anther cap dark purplish-red, subglobose or widely obovate, 0.9–1 mm long, 0.8–1 mm wide, apex emarginate, basal margin denticulate or ciliate, adaxial side sulcate, surface minute colliculate; pollinia 4, in 2 pairs, bright yellow or yellowish-orange, each pollinium narrowly ellipsoid, 1–1.5 mm long, 0.5 mm wide, without caudicle and viscidium. **Ovary** (including pedicel) narrowly clavate, curved, 4–7 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, ellipsoid with 3 obtuse keels, 1.2–1.6 cm long, 5–9 mm wide, apex with persistent dried sepals and petals**.**

THAILAND.—NORTERN: Mae Hong Son (Huey Chom Phu Arboretum), Chiang Mai (Mae Chaem), Tak (Tha Song Yang).

DISTRIBUTION.— NE India, Nepal, Myanmar (type).

ECOLOGY.—In dry dipterocarp forest; 640–800 m alt. Growing on *Shorea obtusa* and *Terminalia alata*. Flowering: November–February; fruiting: April–May.

VERNACULAR.—Wai pegu.

SPECIMENS EXAMINED.**—INDIA**: Sikkim, December 1878, *Bagooza* s.n. (K); Silkkim-Himalaya, 1,000 m alt., January 1894, *R. Pantling* 23 (BM, K). **MYANMAR**:

Moulmein, January 1852, *C. Parish* 91 (C); ibid, December 1872, *C. Parish* s.n. (K); Thaton, 28 February 1927, *R. L. G. Sinlor* 82 (K). **THAILAND**: Tak, Mae Sot District, Nang Lew, 1 February 1994, *G. Seidenfaden* & *T. Smitinand* 9758 (C); Mae Hong Son, Mae Sariang District, Ban Kad Sub-district, Huey Chom Phu Arboretum, 780 m alt., 11 December 2012, *P. Prommanut* 245 (BKF); Chiang Mai, Mae Chaem District, Mae Suek Sub-district, Road to Mae Chaem from Khun Yuam, 18 6 21 N, 22 57 E, 640 m alt., 14 January 2012, *S. Rueangruea*, *S. Suddee*, *M. Roudreiw*, *C. Hemrat & N. Rittpetch* 30 (BKF).

LOCALITY UNKNOWN: MYANMAR: *R. H. Beddome* 8189 (BM). **THAILAND**: *C. Thorat* 076 (BCU), 19 December 1994; *G. Seidenfaden* & *T. Smitinand* 9743(C); *O. Thaithong* 719 (BCU), 29 December 1989; *O. Thaithong* 799 (BCU), 23 January 1990; *O. Thaithong* 1949 (BCU), January 2002; *O. Thaithong* s. n. (BCU), January 1992.

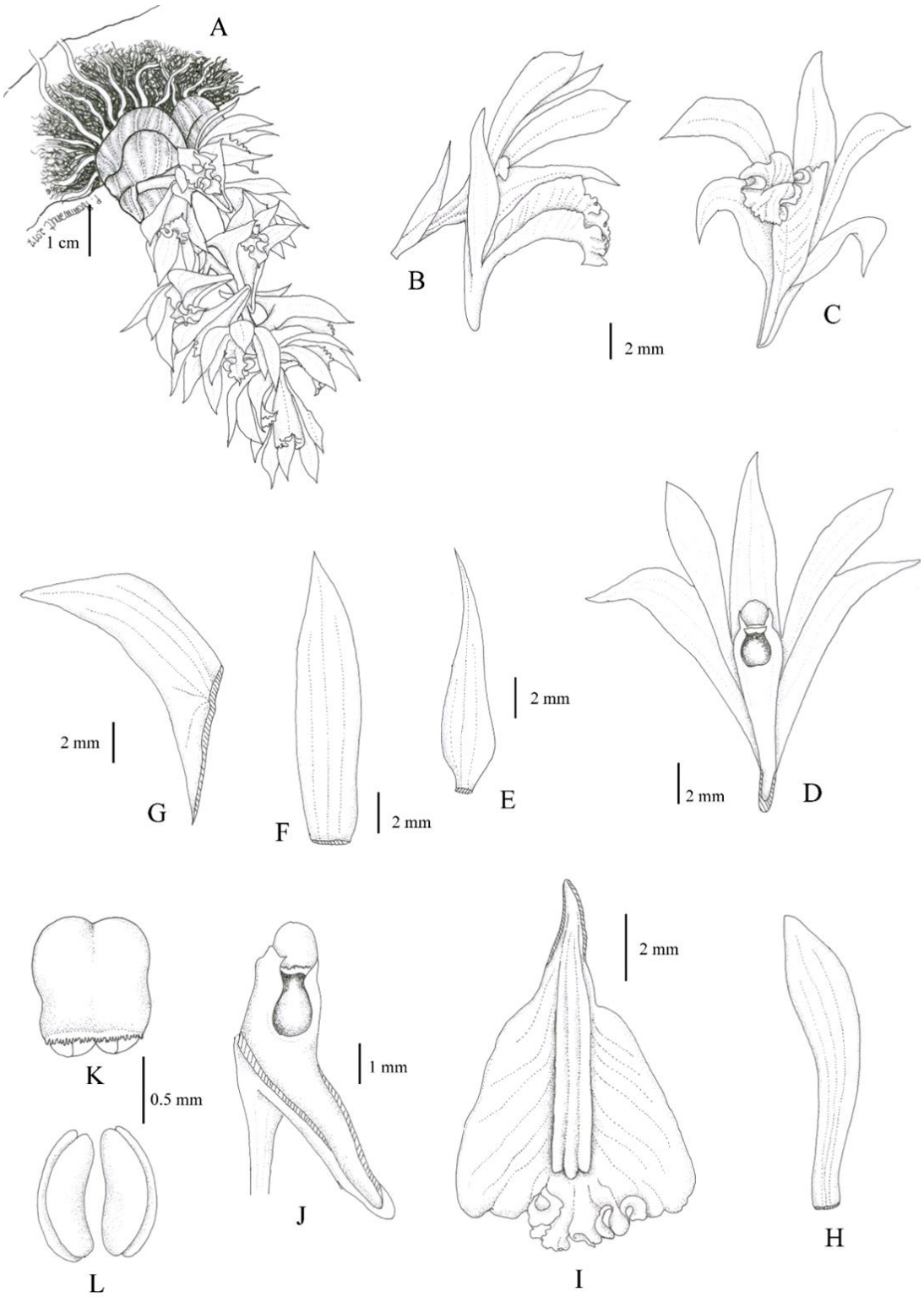


Figure 5. 14 *Dendrobium peguanum* Lindl.; A. Habit of flowering plant; B. Flower side view; C. Flower front view; D. Flower front view without labellum; E. Bract; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Column and long mentum; K. Anther cap; L. Pollinia. Drawn from *S. Rueangruea, S. Suddee, M. Roudreiw, C. Hemrat* & *N. Rittpetch* 30.

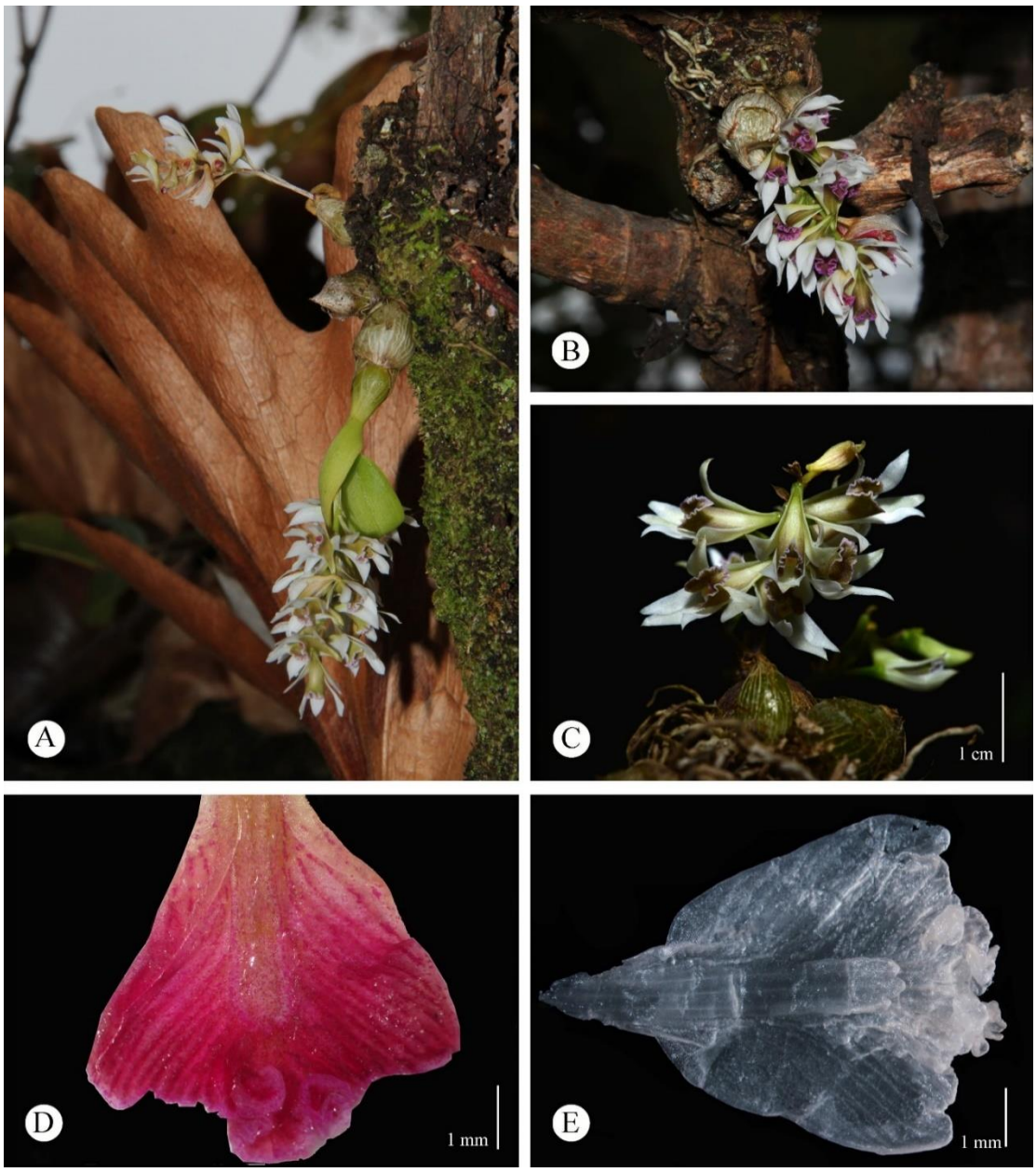


Plate 5. 14 *Dendrobium peguanum* Lindl.; A. and B. Plant in natural habitat; C. Inflorescences; D. Labellum show 3 keels; F. Labellum from spirit collection. A and B photo by S. Rueangruea.

15. *Dendrobium perpaulum* Seidenf., Opera Bot. 124: 31, Fig. 18; Pl. 6a. 1995. Type: N Thailand, Chiang Mai Province, Jomthong Distrcict, Doi Inthanon National Park, 2,000 m alt., *O. Thaithong* 512 (holotype **C!**). Figure 5.15, Plate 5.15, Map 5.6.

Dendrobium zhenyuanense D. P. Ye ex Jian W. Li, D. P. Ye & X. H. Jin, Phytotaxa. 178 (3): 217. 2014. **syn. nov**. Type. China, Yunnan Province, Zhenyuan County, on tree in broad-leaved evergreen forest, 1900 m alt., 27 September 2012, *Li* 2295 (holotype **HITBC!** photo seen).

Dendrobium minusculum Aver., Turczaninowia. 19 (3): 26. 2016. **syn. nov**. Type. Laos, Xiangkhouang province, Peak district, 1750–1850 m alt., 2 April 2015, *N. T. Hiep* et al. 925 (holotype **LE**! photo seen; isotype **HNL**!; **FOF**! photo seen.)

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, green or greenish-purple, conical, globular, cylindric or narrowly fusiform, 0.5–4 cm tall, 3–6 mm in diameter, with 2–4 nodes, internodes 2–9 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath pale brown, membraneous, glabrous on both sides, previous stems dull greenish-yellow with pinkish-purple line in longitudinal, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, ovate or lanceolate to oblong-lanceolate, 1.5–4.1 cm long, 0.5–1.1 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, green or dull green above, light green or pale green beneath, grooved above and ribbed below. **Inflorescences** hysteranthous, raceme, 1–3-inflorescenced, subterminal, suberect or nodding, 1.2–5.5 cm long, not exceeding leaves, with 7–15-flowered; peduncle and rachis glabrous, purple to purplish-maroon, peduncle 0.4–2.6 cm long, rachis 0.7–4 cm long, covered with bracts; bracts purple or purplish-green, slightly concave, lanceolate to oblong-lanceolate, 2–4 mm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles purplish-green, narrowly lanceolate, 1.9–3 mm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, strongly fragrant, long-lasting, 5–8 mm in diameter. Sepals bright green or yellowish-green, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; **dorsal sepal** lanceolate, 3–4.2 mm long, 1.2–2 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; **lateral sepals** obliquely triangular-lanceolate, 4–6 mm long, 3–5 mm wide at base, apex mucronate, base obliquely truncate, 3–4-viened, distinctly visible. Petals bright green, spreading, oblong or elliptic-oblong, 3–4.5 mm long, 1–1.7 mm wide, apex attenuate, base truncate, margin entire, 2–3-veined, distinctly visible. **Labellum** dull green, surface glandular-papillose at base, slightly recurved, elliptic, without side lobes, 2.8–3 mm long, 1.5–2 mm wide, shortly clawed at base; disc oblong,

surface minute glandular-papillose, waxy, distinctly with 2 dull green thickened keels raising at hypochile, continuing to mid-lobe. **Mentum** green, very short, broadly conical, 0.4–1.8 mm long, 1–1.5 mm in diameter, margin sub-punctate, straight or incurved distally. **Column** green, short, with strongly developed sidewings, 0.8–1 mm long, 1–1.5 mm wide at base, margin and surface smooth; foot concave, stout at base, waxy, 0.5–0.6 long, 0.9–1 mm wide at base; stigmatic cavity glossy green, broadly ovate, stelidia acute, anther cap bright green, subglobose, 0.5–0.7 mm long, 0.3–0.5 mm wide, apex acute, basal margin ciliate, surfacesmooth, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium ellipsoid, 0.2–0.4 mm long, 0.1–0.2 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 1–2 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green with pinkish-purple line in longitudinal, globose-ellipsoid with 3 obtuse keels, 3–7 mm long, 3–6 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Mae Hong Son (Doi Ke-a Po Pho Cho) and Chiang Mai (Doi Inthanon National Park, Ban Mae Lai).

DISTRIBUTION.**—**China and Laos.

ECOLOGY.—In hills evergreen forest; 1,860–1,900 m alt. Growing on *Quercus* sp., *Pinus kesiya*, *Wendlandia paniculata*, which are covered with mosses and lichen. Flowering: April–November; fruiting: December–March.

VERNACULAR.—Ueang khao tok inthanon.

SPECIMENS EXAMINED.—Chiang Mai, Ban Mae Lai, 1,200 m alt., *Cumberlege* 1308 (C); Chiang Mai, Doi Inthanon National Park, *C. Thorut* 9482 (C); Mae Hon Son, Mueang District, Trail up to Doi Ke-a Po Pho Cho, 1,900 m alt, 7 August 2014 , *P. Prommanut* 478 (BK); Chiang Mai, Mae Chaem, Doi Patido, 1,800 m alt, 23 June 2007, *P. Suksathan* 4186 (QBG); Mae Hon Son, Mueang District, Trail up to Doi Ke-a Po Pho Cho, 1,860-1,870 m alt, 24 February 2014, *Suddee, Rueangruea, W. Keiwbang* , *C. Hemrat* & *P. Pansamrong* 4626 (BKF).

TAXONOMIC NOTE:—*Dendrobium perpaulum* is similar to *D. kanburiense* in having small and greenish flower, but it differs by bracteoles longer than ovary (including pedicel), labellum without side lobes, distinctly with 2 dark green thickened keels and surface glandular-papillose at base, capsule subglobose and small.

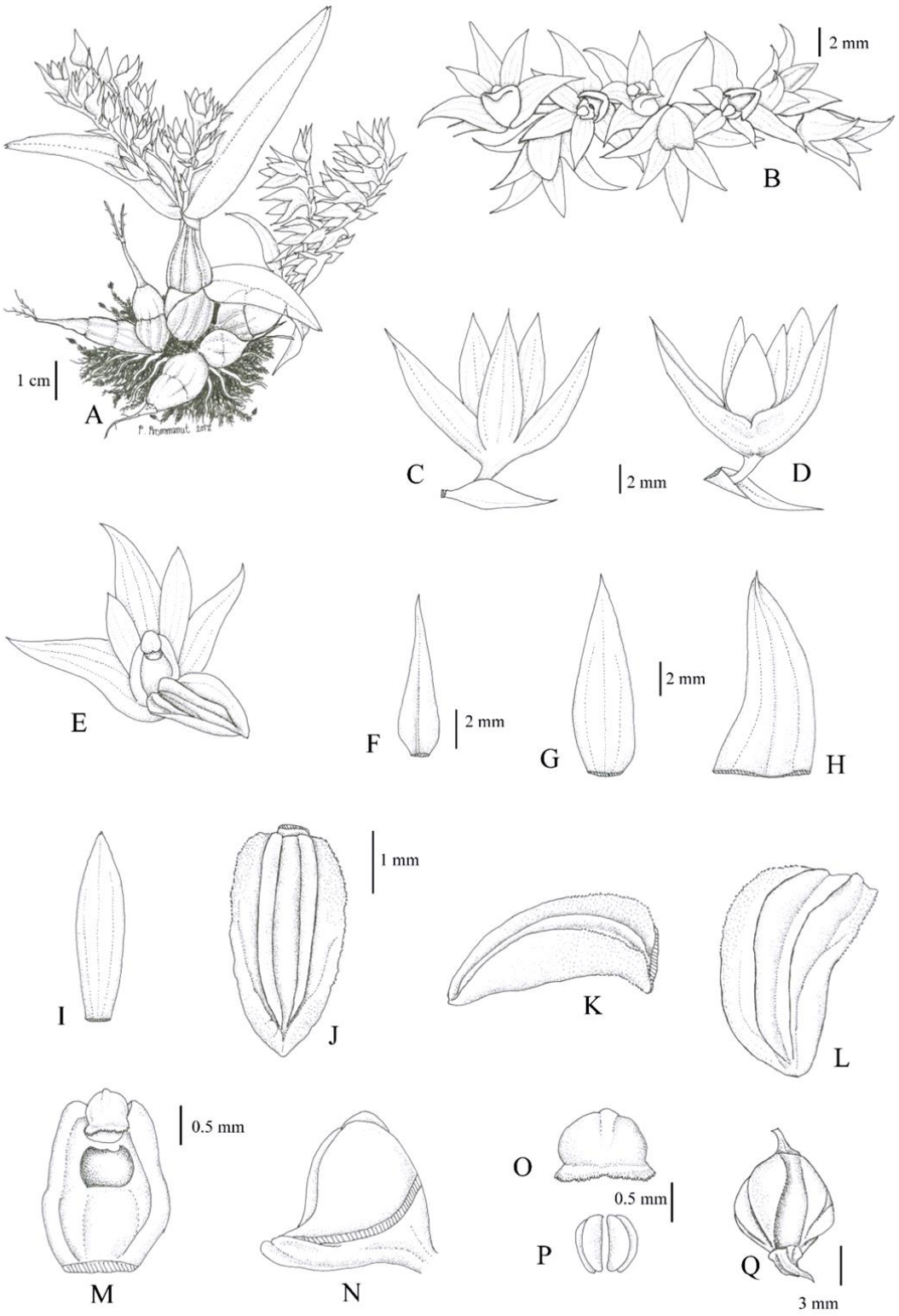


Figure 5. 15 *Dendrobium perpaulum* Seidenf.; A. Habit of flowering plant; B. Inflorescences; C. Flower top view; D. Flower below view; E. Flower front view; F. Bract; G. Dorsal sepal; H. Lateral sepal; I. Petal; J. Labellum; K. and L. Labellum side view; M. Column; N. Column side view; O. Anther cap; P. Pollinia; Q. Capsule. Drawn from *P. Prommanut* 478.

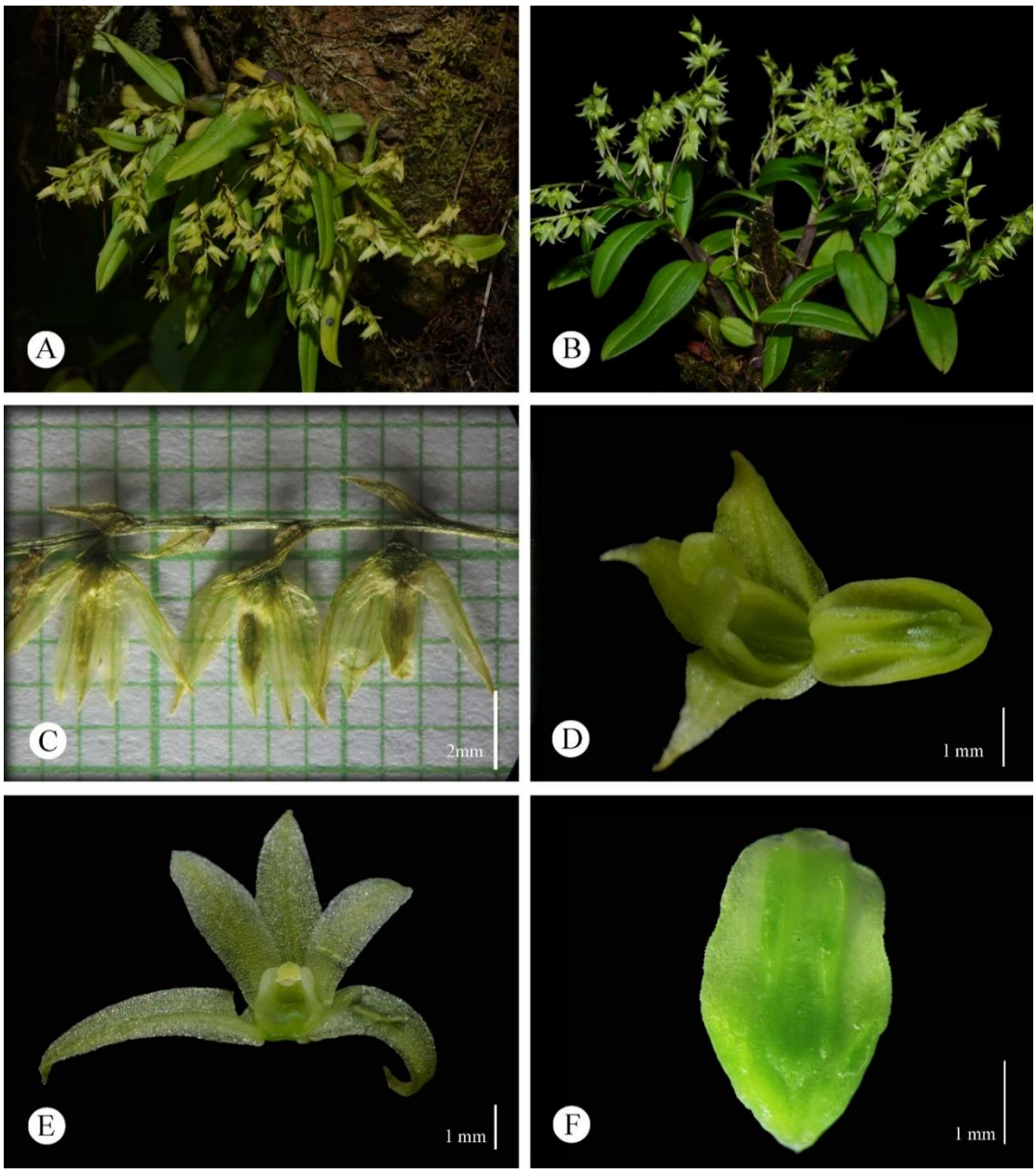


Plate 5. 15 *Dendrobium perpaulum* Seidenf.; A. Plant in natural habitat; B. Inflorescences; C. Flower and show length of bracteoles per pedicel; D. Flower side view and show 2 keels on labellum; E. Flower front view without labellum; F. Labellum with 2 keels.

16. *Dendrobium porphyrochilum* Lindl., J. Proc. Linn. Soc., Bot. 3: 18. 1858; Hook. f., Fl. Brit. India 5: 716. 1890; King & Pantl., Ann. Roy. Bot. Gard. (Calcutta) 8: 44, pl. 59. 1898; Finet, Bull. Mus. Hist. Nat. (Paris) 9: 298. 1903; F. Kränzl., Pflanzenr. (Engler) 50(45): 79, f. 3s. 1910; Mukerjee, Notes Roy. Bot. Gard. Edinburgh 21(3): 152. 1953; Deb, Bull. Bot. Surv. India 3(2): 127. 1961; H. Hara, Fl. E. Himalaya: 433. 1966; Fl. E. Himalaya: 185. 1971; Pradhan, Indian Orchids 2: 339. 1979; Seidenf., Opera Bot. 83: 138, f. 89. 1985; H. B. Naithani, Fl. Pl. India, Nepal & Bhutan: 406. 1990; Brühl, Orch. Sikkim: 55. 1993; N. Pearce & P. J. Cribb, Fl. Bhutan 3(3): 420. 2002; H. P. Wood, Dendrobiums: 680, pl. 176, 177. 2006; G. G. Zhu, Z. H. Ji, J. J. Wood & H. P. Wood in Z. Y. Wu *et al*. (eds), Fl. China 25: 393. f. 503, 2–3. 2009. Type: NE India, Khasija hill, 1,220–1,830 m alt., *Hooker* & *Thomson* 28 (syntype **K–Herb. Hook. f.!**; **K–Herb. Lindl.!**). Figure 5.16, Plate 5.16, Map 5.6.

Callista porphyrochila (Lindl.) Kuntze, Revis. Gen. Pl. 2: 655. 1891. Type: as for above.

Dendrobium caespitosum King & Pantl., J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 64(2): 332. 1895; F. Kränzl., Pflanzenr. (Engler) 50(45): 80. 1910. Type: India, Sikkim, Naru Valley, 6,000 feet, *R, Pantling* 320 (holotype **K–H!**).

Dendrobium confinale sensu auct. Seidenf. & Smitinand (non Kerr 1927), Orchids Thail.: 236. 1960, *pro parte. quoad f. 178a-e.*

[The figure 178 a-e. is in fact *D. porphyrochilum*].

Dendrobium eriiflorum sensu auct. Seidenf. & Smitinand 'as *eriaeflorum*' (non Griff. 1851), Orchids Thail.: 235. 1960, *pro parte. quoad Kerr 0810.*

[The specimens cited, *Kerr* 0810 is in fact *D. porphyrochilum*].

Dendrobium monticola sensu auct. K. J. White & B. Sharma (non P. F. Hunt & Summerh. 1961), Wild Orchids Nepal: 227. 2000, *pro parte. quoad pl. 93a-e.*

Dendrobium monticola sensu auct. Bhakta (non P. F. Hunt & Summerh. 1961), Orchids Nepal: 103. 2009.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, green or yellowish-green, ovoid, conical, ellipsoid or fusiform, 1–5.7 cm tall, 3–9 mm in diameter, with 2–5 nodes, internodes 0.5–1.3 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath pale brown, membraneous, glabrous on both sides, previous stems dull greenish-yellow, naked. **Foliage leaves** 3–7, distichous, spreading, slightly recurved, ovate, lanceolate, narrowly lanceolate or oblong, 1.7–9.5 cm long, 0.4–1.6 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, lowermost smaller than upper, dull purple when young and becoming green

or purplish-green when mature, mid-vein dark dull red, grooved above and ribbed below. **Inflorescences** hysteranthous, raceme, 1–5-inflorescenced, terminal, suberect or nodding, 3–9.3 cm long, exceeding leaves, with 7–15-flowered; peduncle and rachis glabrous, dull purple or purplish-green, peduncle 0.6–1 cm long, rachis 2.4–3.2 cm long, covered with bracts; bracts green or purplish-green, slightly concave, triangular to lanceolate, 0.5–1 cm long, 2–2.2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below**,** bracteoles green or purplish-green**,** narrowly lanceolate, 3.5–5 mm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 0.5–1.1 mm in diameter. **Sepals** light yellowish-brown or yellowish-green with 1–2 reddish-purple longitudinal veins, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal narrowly lanceolate, 5–9 mm long, 1.2–2 mm wide, apex mucronate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely triangular-lanceolate, 5–9 mm long, 2–4 mm wide at base, apex mucronate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** light yellowish-brown or yellowish-green with 2–3 reddish purple longitudinal veins, spreading, linear-oblanceolate or oblong-elliptic, 4–7 mm long, 1.3–2.5 mm wide at middle, apex acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** dark red or yellowish-green, deep purple red at centre, base brownish-yellow, surface glandular-papillose at base, slightly recurved, sub-rhombic or elliptic, without side lobes, 4–4.5 mm long, 1.3–1.8 mm wide, shortly clawed at base; disc narrowly oblong, surface smooth, waxy, distinctly with 3 dark red or reddish-yellow thickened keels, raising at hypochile, continuing to base of mid-lobe, the lateral keels shorter than the central one. **Mentum** whitish with pinkish-red dots, very short, broadly conical, 2–3 mm long, 2.5–3 mm in diameter, margin sub-punctate, straight or incurved distally. **Column** pinkish-white with reddish-purple streaks, short, with strongly developed sidewings, 1–2 mm long, 1–1.8 mm wide at base, margin and surface minutely verrucose-papillose; foot concave, stout at base, waxy, 2–3 mm long, 1.5–1.8 mm wide at base; stigmatic cavity glossy white, broadly ovate, stelidia acute, anther cap pale yellow, subglobose or widely obovate, 0.5–0.8 mm long, 0.3–0.5 mm wide, apex acute, basal margin ciliate, surface papillose, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.5–0.6 mm long, 0.1–0.2 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 3–4 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green with purple streaks, ellipsoid with 3 obtuse keels, 1.8–2 cm long, 0.8–1 cm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Mae Hong Son (Doi Chang), Chiang Mai (Doi Chiang Dao, Doi Inthanon, Omkoi), Chiang Rai (Doi Pee Pan Num), Nan (Doi Phu Kha), Tak (, Ma Sot), Kamphang Phet (Mae Wong); SOUTH-WESTERN : Uthai Thani (Huai

Kha Khaeng), Phetchaburi (Kaeng Krachan), Prachuap Khiri Khan (Huai Yang); PENINSULAR : Krabi (Panom Bencha).

DISTRIBUTION.—NE India (type), Nepal, Bhutan, Myanmar, S China & N Vietnam.

ECOLOGY.— In upper montane rain forest and lower montane-oak forest; 960–2,560 m alt. Growing on *Glochidion eriocarpum*, *Quercus* sp., *Wendlandia tinctoria* and *Saurauia nepaulensis*, which are covered with mosses and lichens. Flowering: May–September; fruiting: October–March.

VERNACULAR.—Ueang chawian.

SPECIMENS EXAMINED.—INDIA: Sikkim, Lachen Valley, 2,133 m alt., May 1895, *R. Pantling* 363 (BM, C); Trudel-Busa 936 (C). **NEPAL**: Shara, 2,438 m alt., 12 June 1954, *Staintion*, *Sykes* & *Williams* 5724 (BM); Khimti, Khola, 1,676 m alt., 26 June 1981, *Staintion* 8379 (BM), Chilim Tafu, 2,438 m alt., 8 June 1969, *Williams* 491 (BM). **MYANMAR**: North Myanmar, Kachin State, 1828.8–1981 m alt., 16 June 1953, *F. K. Ward* 20985 (BM); West Central Myanmar, Erakan, 2133 m alt., 5 September 1956, *F. K. Ward* 22670 (BM). **CHINA**: *Forrest* 26757 (C). **THAILAND**: Krabi, Panom Bencha, 28 March 1930, *A. F. G. Kerr* 810 (BK, C, K); Krabi, Khao Panom District, Khao Phanom Bencha, 18 April 2000, *B. Temboonkiat* 001 (BCU); Chiang Mai, Chiang Dao District, Chiang Dao Sub-district, Doi Chiang Dao, 10 July 2001, *B. Temboonkiat* 002 (BCU); Tak, Below Ban Ma Sot, 1,000 m alt., *G. Seidenfaden* & *T. Smitinand* 7295 (C); Chiang Mai, Omkoi District, 800–1,000 m alt., *G. Seidenfaden* & *T. Smitinand* 8175 (C); Chiang Mai, Doi Chiang Dao, 2,000 m alt., 1 July 1958, *K. Larsen* & *B. Hansen* 4231 (C); Prachuap Khiri Khan, Tub Sakae District, Huai Yang Waterfall, 1,200 m alt., 3 October 2014, *K. Limkitikul* 192 (BCU); Chaing Mai, Chiang Dao District, Chiang Dao Sub-district, Doi Chiang Dao, 1,400 m alt., 12 July 2016, *M. Poopath* 1553 (BKF); Phetchaburi, Kaeng Krachan District, Kaeng Krachan National Park, 960 m alt., May 2008, *N. Toolmal, C. Chumngoen & W. Somprasong* 87 (BKF); Chiang Mai, Chomthong District, Doi Inthanon, 2,560 m alt., 21 July 2015, *P. Prommanut* & *P. Triboun* s.n. (BK); Nan, Bo Kluea, Doi Phu Kha National Park, scenic area, trail near side-road, 1,200 m alt., 16 June 2015, *P. Prommanut* 645 (BK); Chaing Mai, Chiang Dao District, Chiang Dao Sub-district, Doi Chiang Dao, 1,500 m alt., July 1996, *P. Suksathan* 1022 (BCU); Prachuap Khiri Khan, Tub Sakae District, Huai Yang Waterfall, 1,200 m alt., 24 October 1999, *S. Chantanaorrapint* s.n. (BCU); ibid, 28 October 2000, *S. Chantanaorrapint* s.n. (BCU); Phetchaburi, Kaeng Krachan District, Kaeng Krachan National Park, 25 May 2008, *S. Raksue* 94 (BKF); Chiang Rai, Wiang Pa Pao District, Doi Pee Pan Num, 1,700 m alt., 26 June 2007, *S. Watthana* 2350 (GBG); Chiang Mai, Chiang Dao District, Chiang Dao Sub-district, Doi Chiang Dao, 12 July 2009, *S. Watthana* 3308 (QBG); Chiang Rai, Mae Suai District, Doi Chang, 2,000 m alt., 31 May 1977, *T. Santisuk* 1143 (BKF); Chiang Mai, Chiang Dao Sub-district, Doi Chiang Dao, 1,900–2,000 m alt., 17 August 1963, *T. Smitinand & H.*

Sleumer 1056 (BKF, C); Kamphang Phet, Mae Wong District, Mae Wong National Park, 1,300 m alt., *W. Markerd* 105 (Department of Biolgy, Faculty of Science, Naresuan University).

LOCALITY UNKNOWN.—NEPAL: 2,439 m alt., 12 June 2017, *Unknown collector* s.n. (BM 000505622). **THAILAND**: *P. Suksathan* 1035 (BCU); *Unknown collector* s.n. (BCU 008895), Chiang Dao, August 1997.

NOTE: *Dendrobium porphyrochilum* is very similar to *D. proteranthum* in having similar colour and shape of sepals and petals (with 2–3-reddish longitudinal purple veins), column short with developed sidewings, but differs from the latter in having hysteranthous inflorescences and labellum surface with glandular-papillose at base.

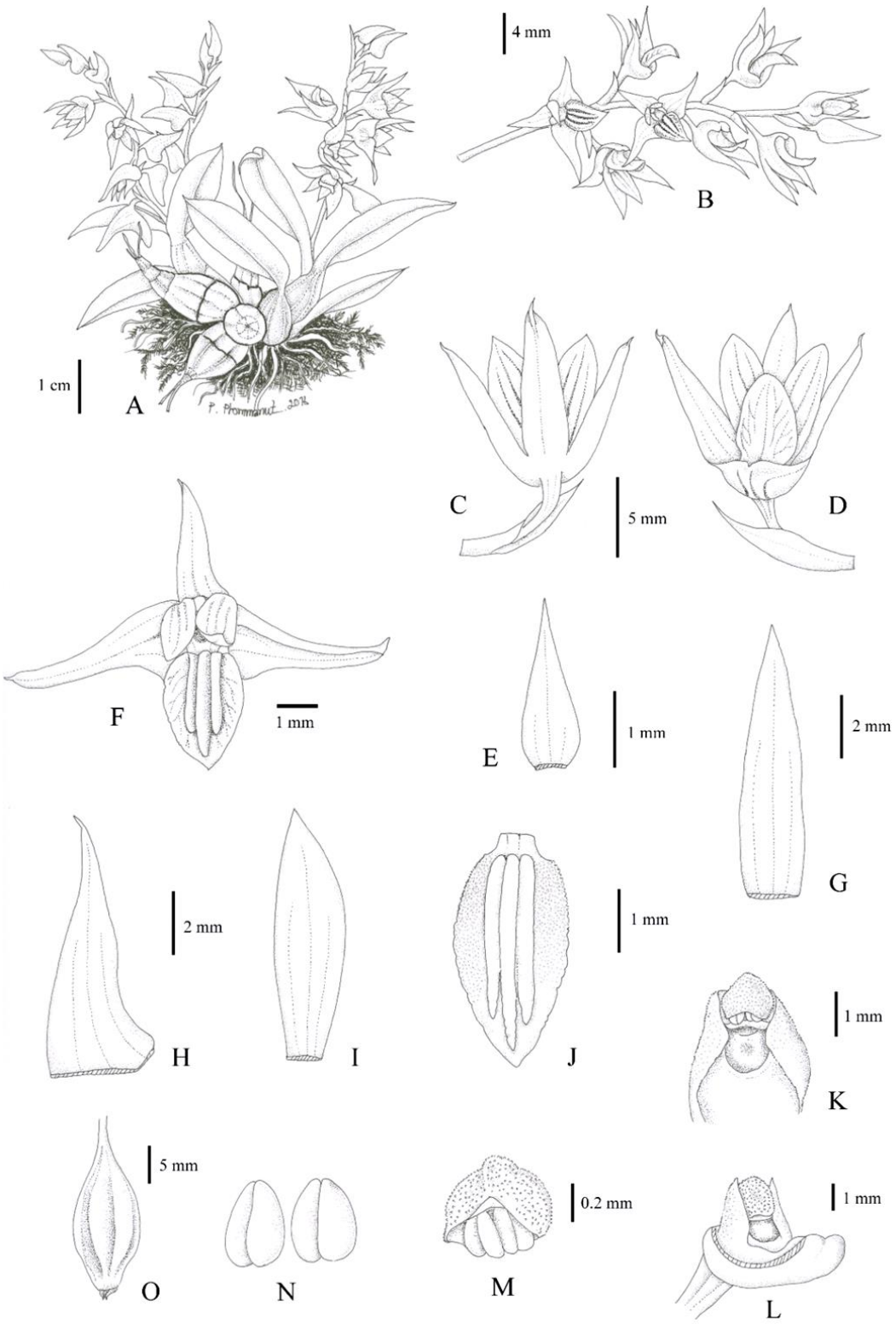


Figure 5. 16 *Dendrobium porphyrochilum* Lindl.; A. Habit of flowering plant; B. Inflorescences; C. Flower top view; D. Flower below view; E. Bract; F. Flower front view; G. Dorsal sepal; H. Lateral sepal; I. Petal; J. Labellum; K. Column front view; L. Column and mentum side view; M. Anther cap and pollinia; N. Pollinia; O. Capsule. Drawn from *P. Prommanut* 645.

Plate 5. 16 *Dendrobium porphyrochilum* Lindl.; A. Plant in natural habitat; B. Inflorescences; C. Flower top view; D. Flower front view without labellum; E. Labellum with 3 keels.

17. *Dendrobium proteranthum* Seidenf., Opera Bot. 83: 131. 1985. Type: NE Thailand, Loei Province, Phuluang District, Phuluang Wildlife Sanctuary, 1,062 m alt., 2 February 1920, *Phengkhlai* s. n. (holotype **C!**). Figure 5.17, Plate 5.17, Map 5.6.

Bulbophyllum proteranthum (Seidenf.) Seidenf., Opera Bot. 124: 41. 1995. Type: as for above.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, greyish-brown or brownish-purple, fusiform, ovate or globose, 0.8–1.5 cm tall, 3–7 mm in diameter, with 1–3 nodes, internodes 2–4 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath rust or pale brown, membraneous, glabrous on both sides, previous stems dull brownish-yellow, naked. **Foliage leaves** 3–4, distichous, spreading, slightly recurved, linear or elliptic-oblong, 2.8–3.6 cm long, 0.4–1 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, light greenish-purple or pale purple both side, mid-vein grooved above and ribbed below. **Inflorescences** proteranthous, raceme 1-inflorescenced, terminal, erect, 1.3–4.5 cm long, densely 7–15-flowered; peduncle and rachis glabrous, light purple or yellowish-purple, peduncle 0.3–1.2 cm long, rachis 1.3–1.7 cm long, covered with bracts; bracts pale yellow, slightly concave, narrowly lanceolate, 5–7 mm long, 1.8–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles yellow, narrowly lanceolate, 4–7 mm long, 1–1.4 mm wide, apex attenuate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weekly scented, long-lasting, 4–6 mm in diameter. **Sepals** brownish-yellow or pale yellow with 3 dark purplish-red lines, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal narrowly lanceolate, 4.5–5 mm long, 1.8–2 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals falcate or triangular-lanceolate, 5.5–6 mm long, 2–2.2 mm wide at base, apex acuminate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** brownish-yellow or pale yellow with 3 dark purplish-red lines, spreading, oblong, 4–4.5 mm long, 1–1.5 mm wide at middle, apex acute, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** light brownish-yellow with deep purplish-red stripe, without side lobes, 3–5 mm long, 2–2.3 mm wide, shortly clawed at base; disc oblong, surface smooth, waxy, distinctly with 3 dull reddish-purple thickened keels raising at hypochile, continuing to base of mid-lobe, apex of keels obtuse, mid-lobe bright green, triangular, recurved, apex acuminate, margins minute sinuate. **Mentum** pale yellow with dark purplish-red dots with dark purplish-red at edge, broadly conical, 2–2.2 mm long, 1–1.3 mm in diameter, margin entire, straight or incurved distally. **Column** pale yellowish-brown with dark purplish-red stripe, short, 1–1.2 mm long, 1.2–1.5 mm wide at base, margin entire; foot concave, stout at base, waxy, 1–1.1 mm long, 1.2–1.5 mm wide at base; stigmatic cavity pale yellow, circular, stelidia acute, anther cap light

brownish-yellow, subglobose, 0.5–0.6 mm long, 0.4–0.5 mm wide, apex emarginate, basal margin denticulate or ciliate, surface smooth, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow or yellowish-orange, each pollinium narrowly ellipsoid, 0.5–0.6 mm long, 0.3–0.4 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 3.5–5 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** dull purple green or blackish-purple, ellipsoid, with 3 obtuse keels, 2–6 cm long, 4–6 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Phitsanulok; NORTH-EASTERN: Loei.

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In lower montane rain forest; 1,470-1,500 m alt. Growing on *Glochidion* sp., *Lithocarpus recurvatus* and *Rhododendron simsii*. Flowering: February–March; fruiting: June–January.

VERNACULAR.—Wai noi phu luang, Khoa tok phu luang.

SPECIMENS EXAMINED.—Loei Province, Phuluang District, Phuluang Wildlife Sanctuary, Khok Nok Kraba, 1,470–1,500 m alt., *C. Kasetluksamee* & *N. Anuraktrakoon* 066 BKU (Herbarium of Department of Botany, Kasetsart University); ibid, 1,450 m alt., 9 March 2006, *S. Suddee* et al. 2697 (BKF); ibid, 1,400 m alt., 23 February 2008, *S. Watthana* 2721 (QBG); ibid, *Wichien* s. n. (BKF).

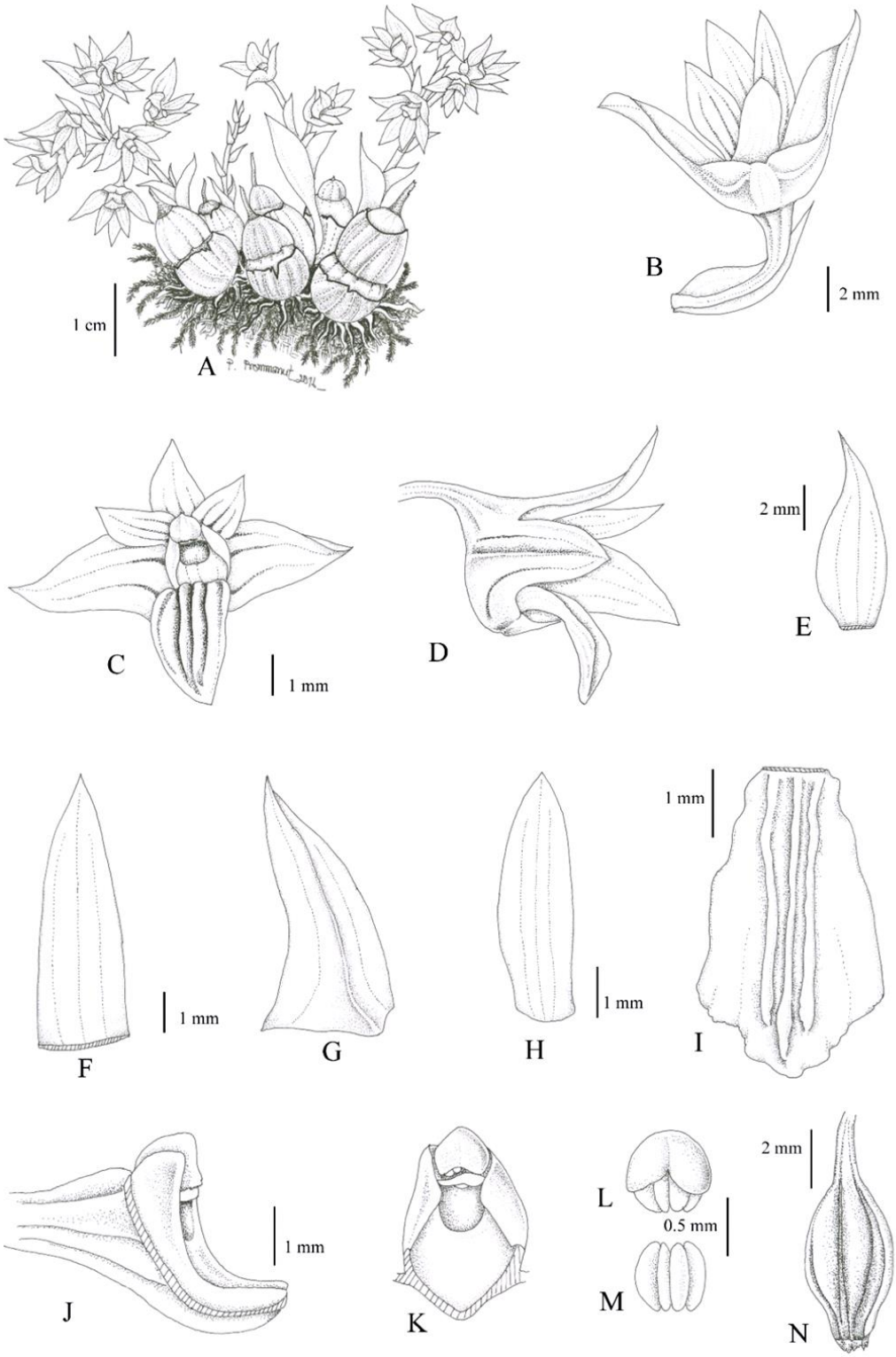


Figure 5. 17 *Dendrobium proteranthum* Seidenf.; A. Habit of flowering plant; B. Flower below view; C. Flower front view; D. Flower side view; E. Bract; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Column and mentum side view; K. Column front view; L. Anther cap; M. Pollinia; N. Capsule. Drawn from *S. Suddee et al.* 2697.

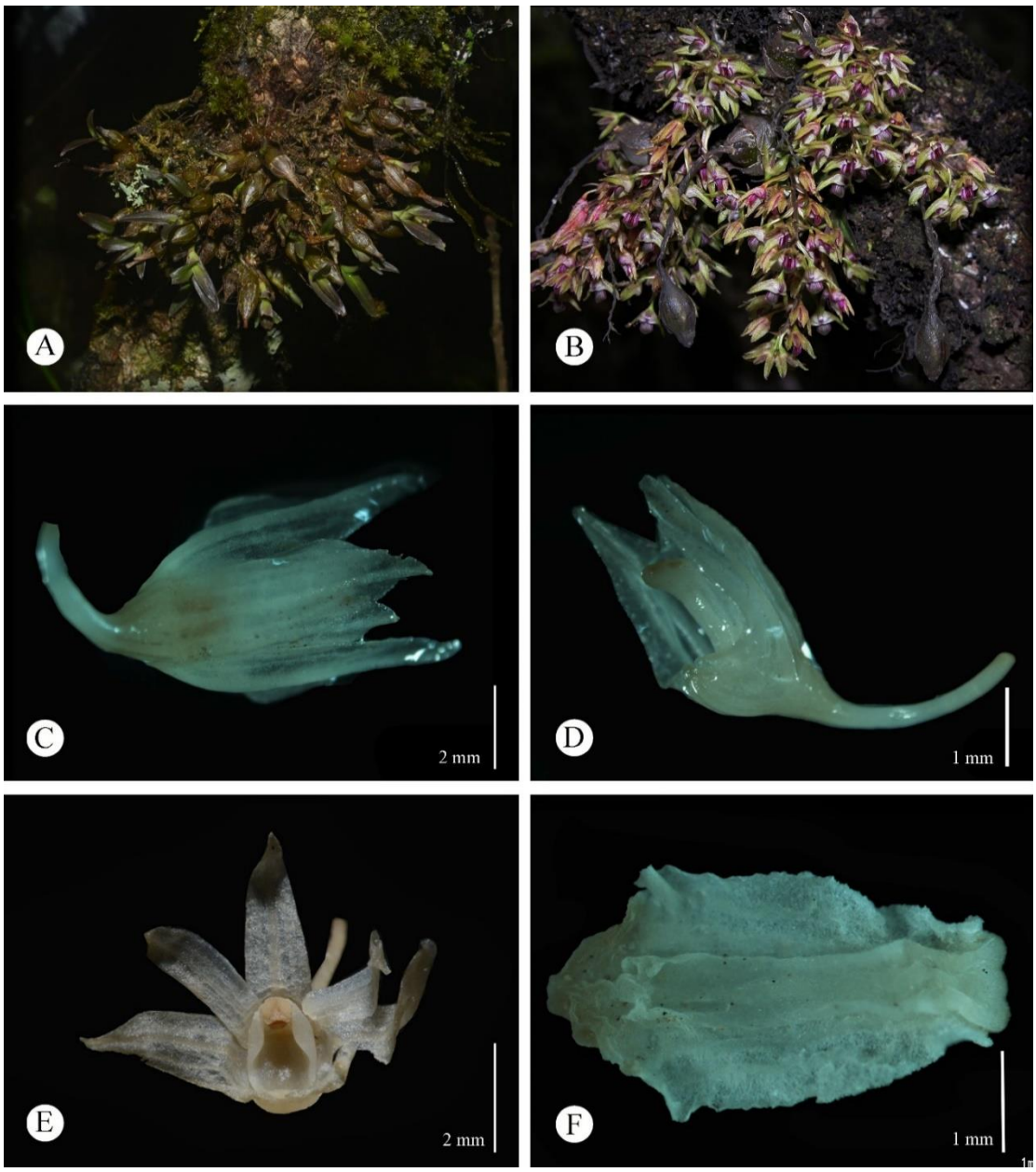


Plate 5. 17 *Dendrobium proteranthum* Seidenf.; A. Plant after flowering; B. Plant flowering in natural habitat; Flower below view; C. Flower top view; D. Flower side view; E. Flower front view; F. Labellum show 3 keels.

18. *Dendrobium pycnostachyum* Lindl., J. Proc. Linn. Soc., Bot. 3: 19. 1859; Rchb. f., Trans. Linn. Soc. London 30(1): 137, 1874; Hook. f., Fl. Brit. India 5: 718. 1890; B. Grant, Orch. Burma: 116. 1895; Kraenzl., Pflanzenr. (Engler) 50(45): 80. 1910; Seidenf., Opera Bot. 83: 152, Fig. 103, Pl. XVIId. 1985. Type: Myanmar, Tenasserim, Moulmein, *Lobb* s.n. (holotype **K–Herb. Lindl.!**). Figure 5.18, Plate 5.18, Map 5.3.

Callista pycnostachya (Lindl.) Kuntze, Revis. Gen. Pl. 2: 655. 1891. Type: as for above.

Dendrobium kratense sensu auct. H. P. Wood (non Kerr 1927), Dendrobiums: 648. 2006, *pro parte. quoad Pl. 172*.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, light green, fusiform or cylindric, 2.7–20 cm tall, 0.5–1.7 cm in diameter, with 4–8 nodes, internodes 0.8–2.5 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath bright creamy brown, membraneous, glabrous on both sides, previous stems dull greenish-yellow or bright yellow, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, linear-oblong, elliptic or oblong, 1.9–6.5 cm long, 3–7 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, lowermost smaller than upper, light green above, pale green or greenish-yellow beneath, mid-vein grooved above and ribbed below, plants leafless when flowering. **Inflorescences** raceme, 1–7-inflorescenced, axillary and subterminal, erect, 4.5–12 cm long, densely 10–40-flowered; peduncle and rachis glabrous, bright green, peduncle 1.3–3 cm long, rachis 3–10 cm long, covered with bracts; bracts bright creamy brown, slightly concave, lanceolate, 6–7 mm long, c. 3 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles creamy yellow, narrowly lanceolate, 4.5–5 mm long, 1–1.5 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, strongly scented, long-lasting, 0.9–1.5 cm in diameter. **Sepals** white with dull greenish-yellow at base, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal linear-lanceolate, 0.9–1 cm long, 1.8–2 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely narrow-falcate, 0.8–1 cm long, 5–6 mm wide at base, apex acuminate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** white with greenish-yellow at base, spreading, linear-oblanceolate, 0.9–1 cm long, 1.9–2.1 mm wide at middle, apex acute, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** white with bright green at mid-lobe, deep red to purplish-red veined, with 3-lobed, 5.9–6.3 cm long, 3–3.5 mm wide across side lobes, shortly clawed at base; side lobes bright green, triangular, forwards and upwards pointed, 1.8–2 mm long, 2–3 mm wide, margin crenate; disc narrowly oblong, surface smooth, waxy, distinctly with 2 bright greenish-white thickened keels, shining, raising at hypochile, continuing to base of mid-lobe, apex of

keels obtuse, mid-lobe bright green or dull green, triangular, recurved, apex acuminate, margins serrate-crenate. **Mentum** light yellowish-green with purplish-red dots, broadly conical, 5–6 mm long, 1.9–2 mm in diameter, margin entire, straight or incurved distally. **Column** glossy green with slight purple tinge, short, 2.2–3 mm long, 1.5–2 mm wide at base, margin entire; foot concave, stout at base, waxy, 1–2 mm long, 1.2–1.5 mm wide at base; stigmatic cavity yellowish-green, circular, stelidia obtuse, anther cap yellowish-green, subglobose or widely obovate, 0.9–1 mm long, 0.8–1 mm wide, apex emarginate, basal margin denticulate or ciliate, surface papillose, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow or yellowish-orange, each pollinium narrowly ellipsoid, 1–1.5 mm long, c. 0.5 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 4–7 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, ellipsoid, with 3 obtuse keels, 1.2–1.6 cm long, 5–9 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Mae Hong Son (Mae Um Long hotsprings), Chiang Mai (Mai Mueng Nao Arboretum, Pine Forest Station, Wat Chan), Tak (Thungyai Narasuan Eastern).

DISTRIBUTION.—India and Myanmar (type).

ECOLOGY.—In oak-dipterocarp forest and pine-dipterocarp forest; 820–1,100 m alt. Growing on *Castanopsis argyrophylla*, *Quercus kerrii* and *Glochidion eriocarpum.* Flowering: November–January; fruiting: April–May.

VERNACULAR.—Sawet sot si, Ueang sawet sot si.

SPECIMENS EXAMINED.—**INDIA**: Lushai hill, Chakang, 1,539 m alt., 1 February 1927, *Lecher* 111 (K). **MYANMAR**: Chan state, 1, 400 m alt., 15 January 1937, unknown collector (K0009371). **THAILAND**: Chiang Mai, 850–900 m alt., *Cumberlege* 1264 (C); Chiang Mai, Hod District, Mae Sanam, 1,000 m alt., 1 November 1964, *Cumberlege* 1313 (C); Chiang Mai, 6 km North of Omkoi, 900 m alt., 24 November 1964, *G. Seidenfaden* & *T. Smitinand* 5042 (C); Chiang Mai, Omkoi, 850-1,000 m alt., 27 January 1964, *G. Seidenfaden* & *T. Smitinand* 5185 (C); Chiang Mai, Hod District, Bo Luang, 1,140 m alt., 29 January 1964, *G. Seidenfaden* & *T. Smitinand* 5200 (C); Tak, Umphang road to Ma Sot, 550 m alt., 18 December 1972, *G. Seidenfaden* & *T. Smitinand* 7928 (C); Chiang Mai, Hod District, Bo Salee Sub-district, Bo Luang, Mai Mueng Nao Arboretum, 1,100 m alt., 11 January 2011, *P. Prommanut* 49 (BKF); Mae Hong Son, Mae Sariang District, Mae Sariang Sub-district, 15 km from Mae Um Long hotsprings, 820 m alt., 10 December 2012, *P. Prommanut* 171 (BKF); Chiang Mai, Hod District, Bo Salee Sub-district, Bo Luang, Pine Forest Station, 1,060 m alt., 22 Novemder 2014, 10 December 2012, *P. Prommanut* 641 (BK); Chiang Mai,

Mae Chaem District, Wat Chan, Huai Mai, 980 m alt., 29 November 2007, *P. Srisanga, P. Suksathan, P. Panyachan & A. Keratikorkul* 3089 (QBG).

LOCALITY UNKNOWN: THAILAND: *O. Thaithong* 793 (BCU), 4 January 1990. Unknown collector (K0009342), 5 January 1932.

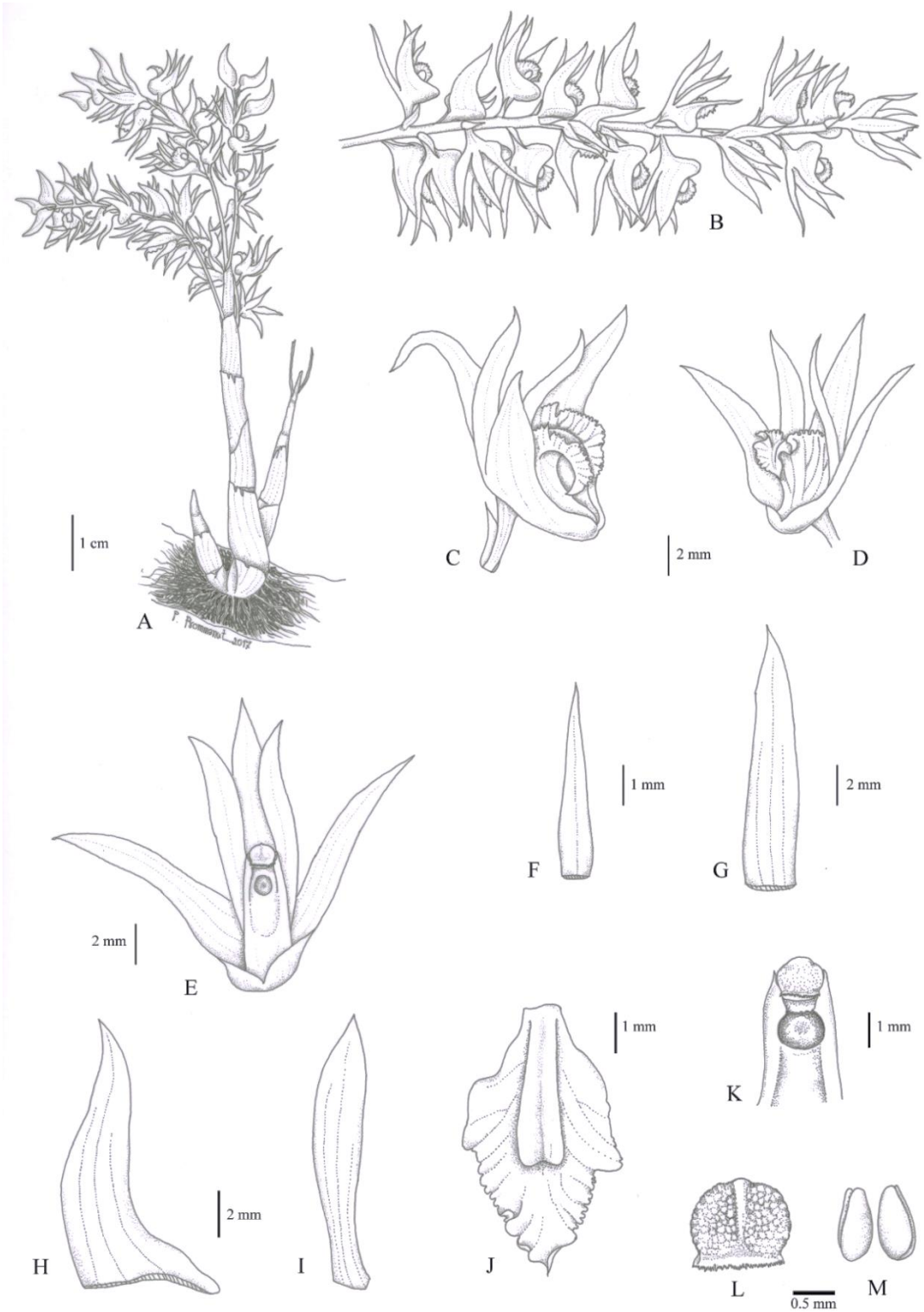


Figure 5. 18 *Dendrobium pycnostachyum* Lindl.; A. Habit of flowering plant; B. Inflorescences; C. and D. Flower side view; E. Flower front view and without labellum; F. Bract; G. Dorsal sepal; H. Lateral sepal; I. Petal; J. Labellum; K. Column; L. Anther cap; M. Pollinia. Drawn from *P. Prommanut* 641.

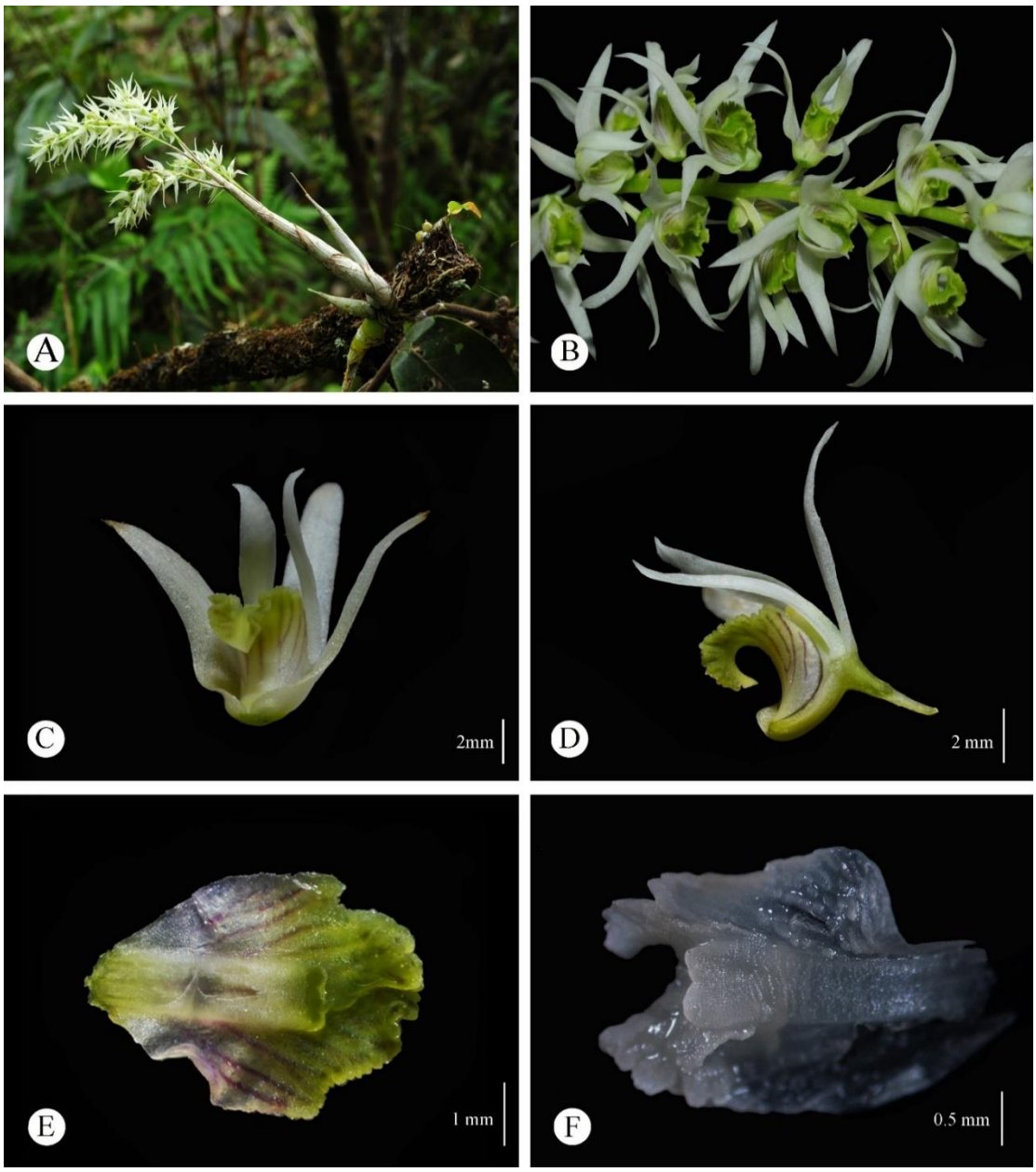


Plate 5. 18 *Dendrobium pycnostachyum* Lindl.; A. Plant in natural habitat; B. Inflorescences; C. Flower front view; D. Flower side view; E. Labellum; F. Labellum from spirit collection.

19. *Dendrobium strongylanthum* Rchb. f., Gard. Chron., 9: 462. 1878; Hook. f., Fl. Brit. India 5: 716. 1890; F. Kränzl., Pflanzenr. (Engler) 50 (45): 81. 1910; L. O. Williams, Bot. Mus. Leafl. 6: 139. 1938; Seidenf., Opera Bot. 83: 142. f. 95, 1985; G. G. Zhu, Z. H. Ji, J. J. Wood & H. P. Wood in Z. Y. Wu *et al*. (eds), Fl. China 25: 393. f. 503, 4-5, 2009. Type. Probable come from N Myanmar, *Rchb. f.* 78 (holotye **W!** photo seen). Figure 5.19, Plate 5.19, Map 5.4.

Callista strongylantha (Rchb.f.) Kuntze, Revis. Gen. Pl. 2: 655. 1891.

Dendrobium ctenoglossum Schltr., Repert. Spec. Nov. Regni Veg. 17: 66. 1921. Type: China, Yunnan: Szemao, Western-mountains, on trees, 1,677 m alt., *Henry* 12962 (holotye **K–Herb. Hook. f.!**; isotype **C!, AMES!** photo seen).

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** pendent, green or light green, cylindric or narrowly fusiform, 2.7–25 cm tall, 0.5–1.2 cm in diameter, with 3–8 nodes, internodes 0.5–2.2 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath gray or pale brown, membraneous, glabrous on both sides, previous year's naked stems light yellow or greenish-yellow, naked. **Foliage leaves** 4–9, distichous, spreading, slightly recurved, oblong-elliptic, oblong, or linear-oblong, 4–10 cm long, 0.8–1.8 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, light green or dull green above, green or pale green beneath, mid-vein grooved above and ribbed below, leaf-bearing when flowering. **Inflorescences** raceme 1–4-inflorescenced, axillary and terminal, pendent, 6.5–13 cm long, exceeding leaves, densely 10–30-flowered; peduncle and rachis glabrous, bright green or yellowish-green, peduncle 3–5 cm long, rachis 3–10 cm long, covered with bracts; bracts yellowish-green, slightly concave, lanceolate to ovate-lanceolate, 4–5 mm long, 1–1.5 mm wide, apex acuminate or acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteole bright yellow, lanceolate, 3–5 mm long, 1–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1.5–2.2 cm in diameter. **Sepals** greenish-yellow or bright yellow, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal lanceolate or oblong lanceolate, 1.2–1.5 cm long, 2.6–4 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely triangular-lanceolate, 1.5–1.6 cm long, 5–9 mm wide at base, apex acuminate, base obliquely truncate, 3–5-viened, distinctly visible. **Petals** greenish-yellow or bright yellow, spreading, lanceolate or oblong-lanceolate, 1–1.2 cm long, 2–3 mm wide, apex acute or acuminate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** yellowish-green with blackish-purple stripes, especially apex, surface papillose or vesicular on both sides, with 3-lobed, 5–5.5 mm long, 4.8–5 mm wide across side lobe; shortly clawed at base, 1–3 mm long, 1–1.5 mm wide,

margin serrate; side lobes triangular; 1–3 mm long, 1–1.5 mm wide, forwards and upwards pointed, margin serrate; disc oblong, 3–3.7 mm long, 3–4 mm wide, surface papillose, waxy, distinctly with 3 blackish-purple thickened keels raising at hypochile, continuing to base of mid-lobe, extending to the centre of mid-lobe, margin serrate-crenate; mid-lobe recurved, triangular, 2–2.7 mm long, 3–3.5 mm wide, apex narrowly acuminate, margins serrate-crisped. **Mentum** light green with purplish-red dots, broadly conical, 4–5 mm long, 4–4.5 mm in diameter, margin and surface entire or minute papillose, apex obtuse, incurved. **Column** dull green with purplish-red dots, 2.5–3 mm long, 2–2.2 mm wide at base, margin and surface smooth; foot concave, cymbiform, 3–5 mm long, 1.5–1.8 mm wide at base, waxy; stigmatic cavity dull brown yellow, circular, stelidia obtuse, anther cap dull purplish-red, subglobose, 1–1.2 mm long, 0.8–1 mm wide, apex emarginated, basal margin erose-dentate, surface minute smooth, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.7–0.9 mm long, 0.5–1 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 4–7 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule**, green or dull green, ellipsoid with 3 obtuse keels, 1.2–1.9 cm long, 5–9 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Chiang Mai (Doi Phahom Pok National Park, Doi Ang Khang, Ban Pa Meiang), Lamphang (Chae Son National Park), Nan (Doi Phu kha National Park).

DISTRIBUTION.—Myanmar (type), S China, N Vietnam.

ECOLOGY.—In hill evergreen forest and open oak forest, 1,300–1,650 m alt. Growing on *Camellia sinensis*, *Glochidion eriocarpum* and *Quercus* sp., sometimes growing on cliff rock which are covered with mosses and lichen. Flowering: September–December; fruiting: December–May.

VERNACULAR.—Ueang yoa lom, Ueang khao tok nam tan.

SPECIMENS EXAMINED.**—MYANMAR**: West central Myanmar, 1,000 m alt., 9 November 1956, *F. K. Ward* 22843 (BM); ibid, 27 November 1905, *J. O. Brein* s.n. (BM). **CHINA**: Yu, Between Meng Lien and Yu Tang Po, Tenggueh, *Rock* 7104 (C); ibid, *Rock* 7116 (C). **THAILAND**: Chiang Mai, Doi Inthanon, *Put* 3383 (C); Chiang Mai, Mae On-Doi Saket District, Ban Pa Meiang, 1,300 m alt., 1 October 2015, *P. Prommanut & W. Budhthiwong* 701 (BK); Lamphang, Chae Son District, Chae Son Sub-District, Chae Son National Park, Kew fin Scenic, 1,517 m alt., 1 October 2015, *P. Prommanut & W. Budhthiwong* 702 (BK); Chiang Mai, Fang District, Doi Phahom Pok National Park, 1,870 m alt., 28 September 2006, *S. Damapong* 92 (BKF, QBG); Chiang Mai, Fang District, Mae Ngon, Doi Ang Khang, 1,400 m alt., 9 December 2005, *S. Pumicong & P. Suksathan* 29 (QBG); ibid, 1,600 m alt., 14 October 2001, *S. Watthana* 1446; Nan, Pua District, Phu kha Sub-district, Doi Phu Kha National Park,

Trail up Dong Yah Wai, 6° 18' 8" N, 113° 31' 44" E, 1,465 m alt., 24 November 2014, *Staff PK* 001(BKF).

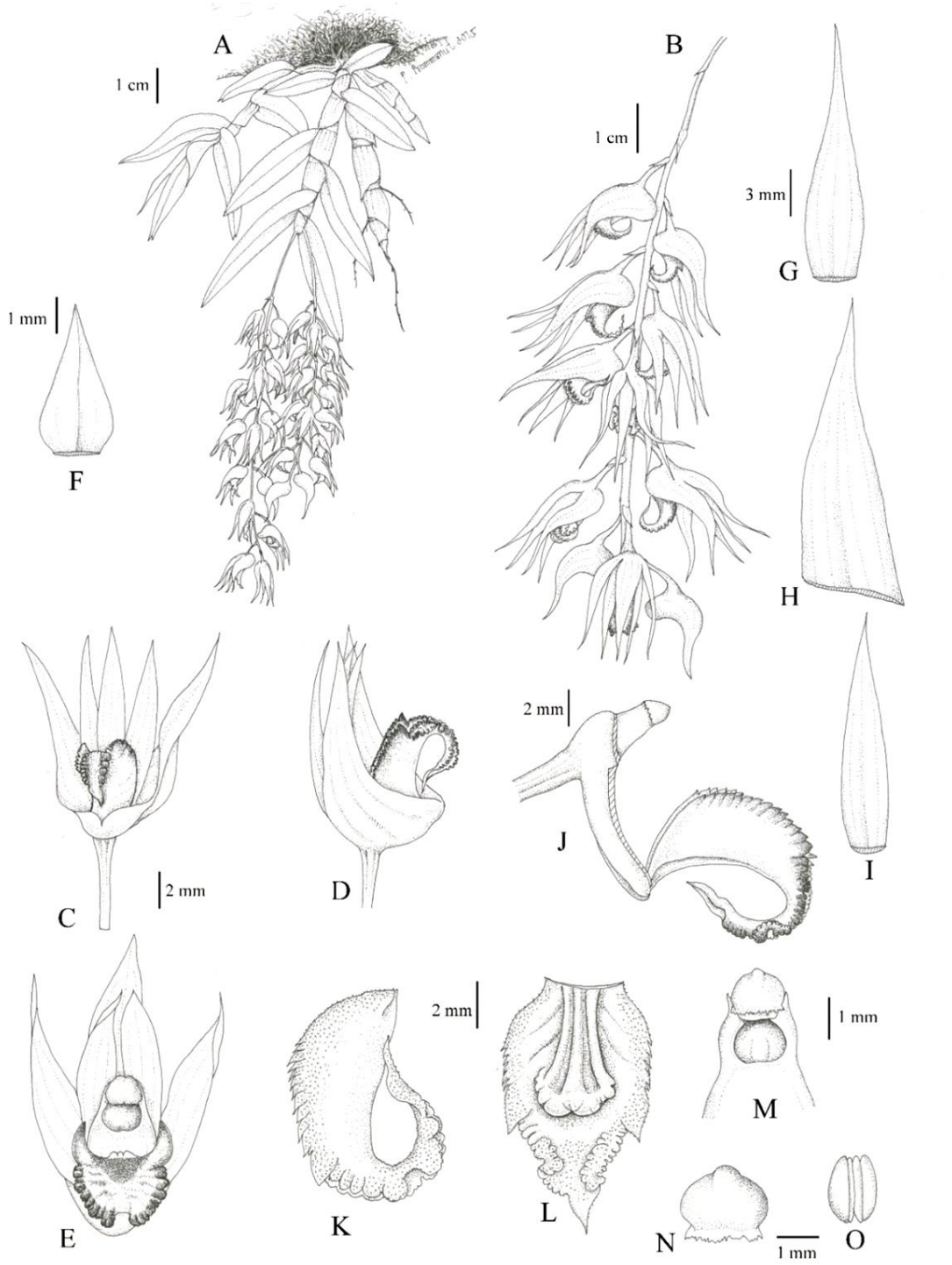


Figure 5. 19 *Dendrobium strongylanthum* Rchb. f.; A. Habit of flowering plant; B. Inflorescences; C. Flower below view; D. Flower side view; E. Flower front view; F. Bract; G. Dorsal sepal; H. Lateral sepal; I. Petal; J. Labellum and column; K. Labellum side view; L. Labellum; M Column; N. Anther cap; O. Pollinia. Drawn from *P. Prommanut & W. Budhthiwong* 702.

Plate 5. 19 *Dendrobium strongylanthum* Rchb. f.; A. Plant in natural habitat; B. Flower side view; C. Flower front view and without labellum; D. Labellum; E. Labellum from spirit collection.

20. *Dendrobium venustum* Teijsm. & Binn., Natuurk. Tijdschr. Ned.-Indië 27: 18. 1864; Seidenf. & Smitinand, Orchids Thail.: 281. 1960; Seidenf., Opera Bot. 83: 129, f. 81, Pl. XVId. 1985; Opera Bot. 114: 240. 1992; H. P. Wood, Dendrobiums: 714, Pl. 180. 2006; Type: Thailand, probably from Ratchaburi (holotype **BO** not seen).

Key to varieties

1. Pseudobulbs 10–40 cm tall, petals twisted……....a. var. *venustum*

1. Pseudobulbs less than 4 cm tall, petals not twisted……..b. var. *delacourii*

20a *Dendrobium venustum* var. *venustum*, Figure 5.20, Plate 5.20, Map 5.2.

Dendrobium ciliatum C. S. P. Parish ex Hook. f., Bot. Mag. 90: t. 5430. 1864, *nom. illeg*; Rchb. f., Trans. Linn. Soc. London 30(1) : 138. 1874; Hook. f., Fl. Brit. India 5: 719. 1890; F. Kränzl., Pflanzenr. (Engler) 50(45): 68. 1910; Gagnep. in Lecomte (ed.), Fl. Indo-Chine 6: 217, f. 19, 2-8. 1934; R. Warner & Williams, Orchid Album 10: 454. 1983. Type. Myanmar, *C. S. P. Parish* 156 (holotype **K–Herb. Hook. f.!**)

Dendrobium ciliatum var. *rupicola* Rchb. f., Otia Bot. Hamburg. 2: 36. 1878; J. T. Atwood, Amer. Peony Soc. Bull. 52: 22, f. 1-2. 1983.

Callista ciliata Kuntze, Revis. Gen. Pl. 2: 654. 1891.

Dendrobium ciliferum Bakh. f., Blumea 12: 68. 1963.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, light green, fusiform or cylindric, 9–25 cm tall, 0.5–1 cm in diameter, with 5–9 nodes, internodes 0.8–2.5 cm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath bright creamy brown, membraneous, glabrous on both sides, previous stems dull greenish-yellow or yellow, naked. **Foliage leaves** 4–13, distichous, spreading, slightly recurved, linear-oblong, elliptic or oblong, 3.2–13 cm long, 1–4 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, coriaceous, glabrous on both sides, light green above, pale green or greenish-yellow beneath, mid-vein grooved above and ribbed below. **Inflorescences** raceme, 1–5-inflorescenced, axillary and subterminal, erect, 6–26 cm long, densely 8–13-flowered; peduncle and rachis glabrous, purplish-green or bright green with magenta stripe, peduncle 2.3–14 cm long, rachis 3–15.5 cm long, covered with bracts; bracts dull reddish-brown or rusty, slightly concave, lanceolate, 4–6 mm long, 2–3 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles creamy yellow or rusty, narrowly

lanceolate, 2–3 mm long, 1.5–2 mm wide, apex acuminate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 2–2.7 cm in diameter. **Sepals** yellowish-cream or brownish-yellow, spreading, often recurved distally, margin entire or minute undulate, abaxial surface distinctly keeled; dorsal sepal elliptic-oblong 1.5–1.8 cm long, 3.5–5 mm wide, apex mucronate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely falcate, 1.4–1.5 cm long, 7–9 mm wide at base, apex mucronate, base obliquely truncate, twist, 3–4-viened, distinctly visible. **Petals** yellowish-cream or brownish-yellow, spreading, spatulate, 1.5–1.8 cm long, 3–6 mm wide at apex, apex acute, base truncate, twist, margin somewhat crenate-undulate, 3-veined, distinctly visible. **Labellum** bright yellow with reddish-brown line along the veins, flabellate, with 3-lobed 1.4–1.6 cm long, 1.3–1.5 cm wide across side lobe; clawed linear, 2–3 mm long, margin entire or sub-crenate; side lobe square, upwards pointed, 4–5 mm long, 3–4 mm wide, apex truncate, margin entire; disc oblong, surface smooth, distinctly 3 bright yellow thickened keels raising at hypochile, continuing to base of mid-lobe, apex of keels acute; mid-lobe broadly triangular, 3–4 mm long, 3–4 mm wide, apex acute, margin with long clavate fimbriae, 3–4 mm long. **Mentum** light greenish-yellow or yellowish- creamy with maroon patch, especially edge and base, broadly conical, 5–7 mm long, 3.4–4 mm in diameter, margin entire, straight or incurved distally. **Column** glossy greenish-yellow, 4–5 mm long, 2.6–3 mm wide at middle, margin entire; foot concave, waxy, 3–6 mm long, 2–3 mm wide at base; stigmatic cavity glossy creamy-yellow, circular, stelidia obtuse, with pseudo-gland inside, anther cap glossy yellowish-green, subglobose or widely obovate, 1.9–2 mm long, 2–2.3 mm wide, apex emarginate, basal margin denticulate or ciliate, surface minute vesicular, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow or yellowish-orange, each pollinium narrowly ellipsoid, 1–1.6 mm long, 0.8–1 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 1.7–2.2 cm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, ellipsoid, with 3 obtuse keels, 2–3 cm long, 5–9 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Chiang Mai (Theppanom Spring, Obluang National Park), Lampang (Tham Phatai National Park), Tak (Namtok Pha Charoen); NORTERN-EASTERN :Loei (Phu Kradueng National Park), Phetchabun (Lom Sak), Nong Khai (Bungkla), Buengkan (Phu Wua Wildlife Sanctuary), Sakol Nakhon (Kusuman, Phu Phan National Park), Mukdahan (Phu Pha Thoep National Park); SOUTH-WESTERN : Kanchanaburi (Kao Pu Maklai); CENTRAL : Saraburi (Hin Lab).

DISTRIBUTION.—Myanmar, Laos, Cambodia, Veitnam.

ECOLOGY.—In dry dipterocarp forest and oak-dipterocarp forest; 180–970 m alt. Growing on *Shorea obtusa* and *shorea siamensis*. Flowering: May–October; fruiting: June–February.

VERNACULAR.—Khao niao ling, Ueang khao niao ling, Ueang dok kham, Ueang dok ma kham.

SPECIMENS EXAMINED.—**THAILAND:** Phetchabun Province, Lom Sak District, Vung Yauw, 21 June 1964, *Adisai* 794 (BK); Kanchanaburi, Kao Pu Maklai, Nong Hoy, 250 m alt., 10 July 1987, *C. Phengklai, M. Tamura, C. Niyomdham & B. Sangkachand* 256 (BKF); Loei Province, Wang Saphung District, Phu Kradueng National Park, Sri Than, 300 m alt., 29 July 1948, *Dee* 114 (BKF); Sakol Nakhon, Phu Phan, 600 m alt., 15 October 1964, *G. Seidenfaden* & *T. Smitinand* 4490(C); Chiang Mai, Doi Inthanon, 700 m alt., May 1958, *G. Seidenfaden* & *T. Smitinand* 2340 (C); Chiang Mai, E-slope of Doi Saket, 450 m alt., 29 July 1972, *G. Seidenfaden* & *T. Smitinand* 7422 (C); Tak, Mae Ramat 35 km N of Mae Sot, 230 m alt., 12 July 1976, *G. Seidenfaden* & *T. Smitinand* 7887B (C); Nong Khai Province, Bungkla District, Nong Derm Sub-district, 17° 50' N, 103° 40' E, 460 m alt., 10 August 2004, *Ivan Christian Nielsen, C. Niyomdham, N. Hemrath & J. Rithipheth* 1627 (BKF); Loei Province, Phu Kradueng District, Sri Than Sub-district, Phu Kradueng National Park, 600 m alt., 28 June 2015, *K. Duangdee* 36 (BCU); Chiang Mai Province, Pea Uong Mong Sub-district, 1 October 1922, *Noi Mao* s.n. (BK); Sakol Nakhon Province, Phanna Nikhom-Mueang District, Phu Phan National Park, 9 August 1963, *Pradit* 418 (BK); Chiang Mai Province, Hod District, Obluang National Park, 970 m alt., 28 September 2011, *P. Prommanut* 78 (BKF); Lampang Province, Ngao District, Ban Huat, Tham Phatai National Park, 700 m alt., 26 July 2015 (blooming flower at BK, 10 August 2015), *P. Prommanut & P. Triboun* s.n. (BK); Saraburi Province, Hin Lap, 19 August 1929, *Put* 2413 (BK); Mukdahan Province, Don Tan-Mueang District, Phu Pha Thoep National Park, 16° 26' 01" N, 104° 48' 33" E, 180 m alt., 23 August 2001, *R. Pooma, W. J. J. O. de Wilde, B. E. E. Duyfjes, V. Chamchumroon & K. Phattarahirankanok* 2451 (BKF); Sakol Nakhon Province, Kusuman District, Na Phiang Sub-district, 18 September 2003, *W. Somprasong* s.n. (BK).

LOCALITY UNKNOWN: THAILAND: *A. F. G. Kerr* 83 (C); *T. Smitinand* s.n. (BKF). **LAOS:** Tixier 03 (C); **VIETNAM**: *Pierre* s.n. (C);

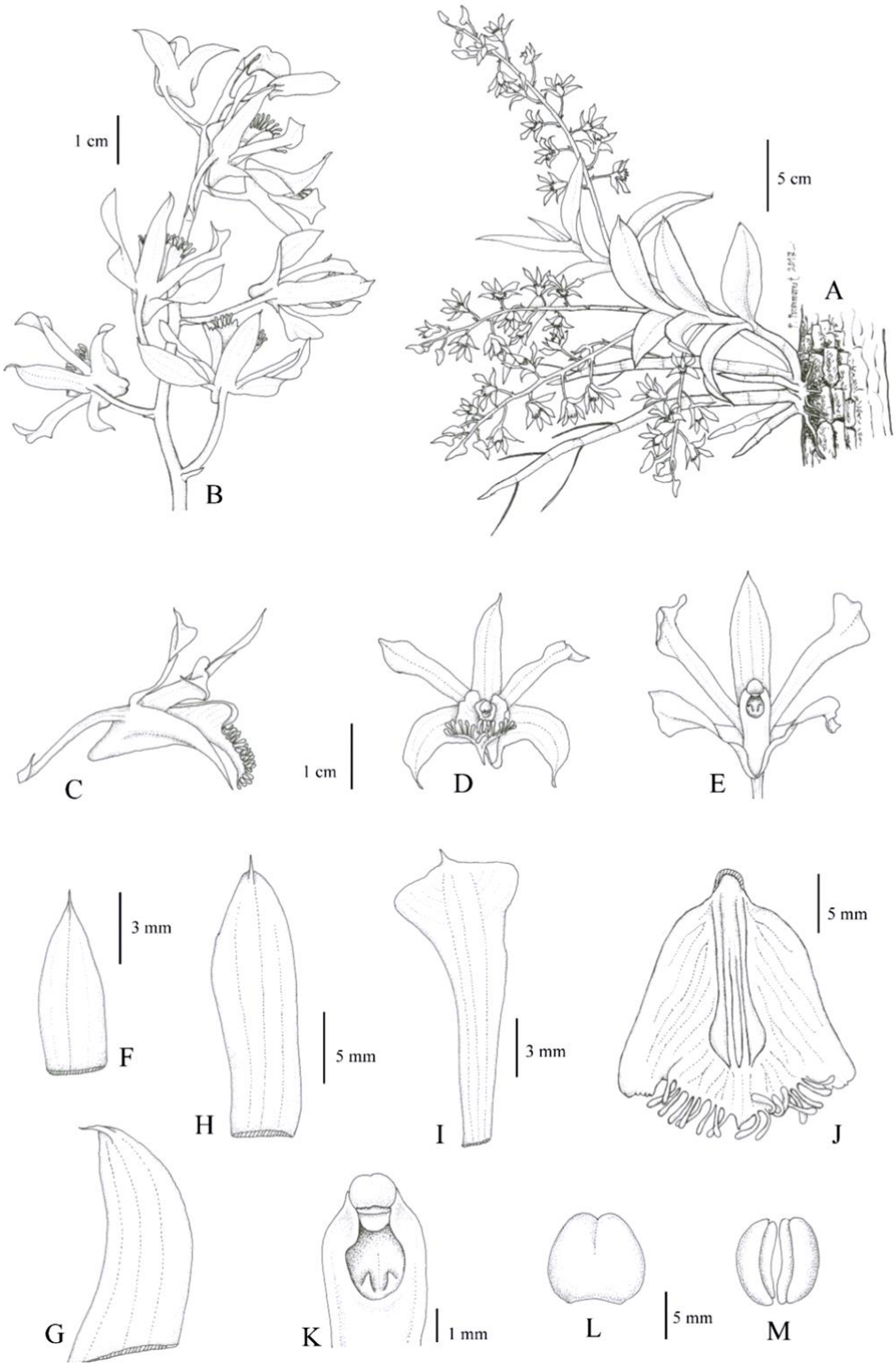


Figure 5. 20 *Dendrobium venustum* var. *venustum* Teijsm. & Binn.; A. Habit of flowering plant; B. Inflorescences; C. Flower side view; D. Flower front view; E. Flower front view without labellum; F. Bract; G. Lateral sepal; H. Dorsal sepal; I. Petal; J. Labellum; K. Column; L. Anther cap; M. Pollinia. Drawn from *Prommanut & Kidyoo* 714.

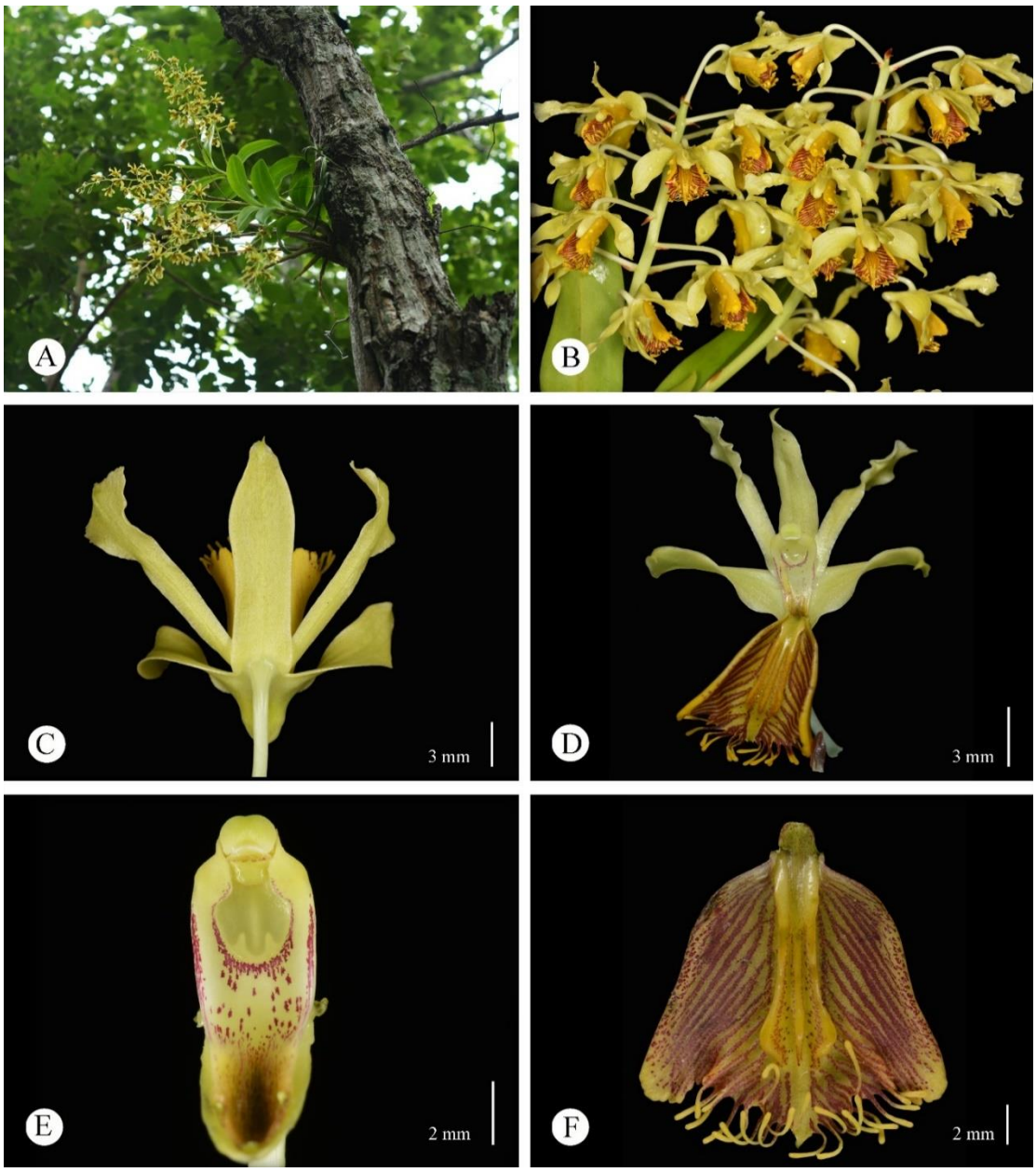


Plate 5. 20 *Dendrobium venustum* var. *venustum* Teijsm. & Binn.; A. Plant in natural habitat; B. Inflorescences; C. Flower top view; D. Flower front view; E. Column show pseudo-gland inside stigma; F. Labellum.

20b. *Dendrobium venustum* var. *delacourii* (Guillaumin) Promm., Kidyoo & Suddee, **stat. nov.** Figure 5.21, Plate 5.21, Map 5.2.

Dendrobium delacourii Guillaumin, Bull. Mus. Natl. Hist. Nat., sér. 2. 30: 522. 1924; Seidenf., Opera Bot. 83: 128. f. 80, pl. XVIc. 1985; Opera Bot. 114: 240. 1992; Type. Vietnam, Laobas, Quang Tri Province, 1924, *M. Delacour* F207 (holotype **P!** photo seen).

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, bright green, fusiform, globose or conical, 1–4 cm tall, 0.4–1.5 cm in diameter, with 2–4 nodes, internodes 3–8 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath bright creamy brown, membraneous, glabrous on both sides, previous stems dull grayish-green or light greenish-yellow, naked. **Foliage leaves** 2–6, distichous, spreading, slightly recurved, elliptic, oblong or ovate-lanceolate, 2–9 cm long, 0.6–2.5 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, coriaceous, glabrous on both sides, light green above, pale green or greenish-yellow beneath, mid-vein grooved above and ribbed below. **Inflorescences** hysteranthous, raceme, 1–2-inflorescenced, terminal, erect, 2–10 cm long, densely 5–8-flowered; peduncle and rachis glabrous, bright green or pale yellow, peduncle 1–3 cm long, rachis 1.2–3 cm long, covered with bracts; bracts pale yellow or greenish-yellow, slightly concave, lanceolate to narrowly lanceolate, 5–8 mm long, 2–3 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles creamy yellow or rusty, narrowly lanceolate, 4–5 mm long, 2–2.5 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 2–2.5 cm in diameter. **Sepals** yellowish-green or pale green, spreading, often recurved distally, margin entire or minute undulate, abaxial surface distinctly keeled; dorsal sepal elliptic-oblong, 1.1–1.5 cm long, 3–7 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely falcate, 1.4–1.7 cm long, 5–8 mm wide at base, apex mucronate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** yellowish-green, spreading, spatulate, 1.2–1.5 cm long, 4–5 mm wide at apex, apex acute, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** bright yellow with reddish-brown line along the veins, flabellate, with 3-lobed 1.2–1.7 cm long, 1.5–1.8 cm wide across side lobe; clawed linear, 1–2 mm long, margin entire or sub-crenate; side lobe obliquely square, upwards pointed, 3–3.1 mm long, 1.5–1.8 mm wide, apex truncate, margin entire; disc oblong, surface smooth, distinctly 3 bright yellow thickened keels raising at hypochile, continuing to base of mid-lobe, apex of keels acute; mid-lobe broadly triangular, 2–3 mm long, 3–3.5 mm wide, apex acute, margin with long clavate fimbriae, 1.5–2 mm long. **Mentum** light greenish-yellow or yellowish- creamy with maroon patch, especially edge and base, broadly conical, 4–5

mm long, 3–4 mm in diameter, margin entire, straight or incurved distally. **Column** glossy greenish-yellow, 3–3.5 mm long, 2.6–3 mm wide at middle, margin entire; foot concave, waxy, 4–5 mm long, 2–3 mm wide at base; stigmatic cavity glossy creamy-yellow, circular, stelidia obtuse, with pseudo-gland inside, anther cap glossy yellowish-green, subglobose or widely obovate, 1.8–2 mm long, 1.8–2 mm wide, apex emarginate, basal margin denticulate or ciliate, surface minute vesicular, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow or yellowish-orange, each pollinium narrowly ellipsoid, 1–1.3 mm long, 0.7–1 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 1.4–2 cm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, ellipsoid, with 3 obtuse keels, 2–2.5 cm long, 0.5–1.2 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTERN: Chiang Mai (Doi Luang Chiang Dao, Mae Chaem, Saluang, Bo Luang, Obluang), Mae Hong Son (Huay Saew Tao, Mae Suya Waterfalls); EASTERN: Ubon Ratchathani (Pha Taem National Park); SOUTH-WESTERN: Uthai Thani (Huai Kha Khaeng Wildlife Sanctuary), Kanchanaburi (Si sawat), Ratchaburi.

DISTRIBUTION.—Myanmar, Laos, Cambodia and Vietnam (type).

ECOLOGY.—In mixed-dipterocarp forest and oak-dipterocarp forest; 50–700 m alt. Growing on *Shorea obtusa, Dipterocarpus tuberculatus* and *Tectona grandis* Flowering: April–July; fruiting: September–November.

VERNACULAR.—Wai kao neiw ling, Ueang dok ma kham.

SPECIMENS EXAMINED.—Ratchaburi, 18 July 1924, *A. F. G. Kerr* 0170 (BKF); Kanchanaburi, 50 m alt., 12 May 1930, *A. F. G. Kerr* 0839 (BK); Kanchanaburi, Ta Salao, 10 June 1930, *A. F. G. Kerr* 0844 (BK); Uthai Thani, Ban Rai District, Huay Kha Kaeng, near the Hin Dang Station, 200 m alt., 22 April 1976, *J. F. Maxwell* 76-267 (BK); Kanchanaburi, Si Sawat District, 19 May 1962, *Kasem* 155 (BK); Ubon Ratchathani, Ban Boong, 11 June 1932, *Lackshnakara* 897 (BK); Mae Hong Son, Mueang District, Huai Pha Sub-district, Mae Suya Waterfalls, Thamwua, 10 June 2014, *M. Norsaengsri* 11238 (QBG); Ubon Rachathani, Khong chiam District, 26 May 2005, *P. Puudja* 1389 (BKF); Mae Hong Son, Huay Saew Tao, 1 June 1998, 250 m alt., *P. Triboun* 174 (BK); Chaing Mai, Saluang, 30 May 2006, *S. Pumicong & S. Watthana* 319 (QBG); Chaing Mai, Chiang Dao District, Chiang Dao Sub-district, Doi Luang Chiang Dao, 1,300 m alt., 12 July 2006, *S. Pumicong & M. Wongnak* 382 (QBG); Uthai Thani, Huai Kha Khaeng Wildlife Sanctuary, *S. Saema* 001 (BK); Ubon Rachathani, Pha Team National Park, Khong Chiam District, April 2001, c. 250 m alt., *T. Boonjaras* 290 (BCU) ; Chiang Mai, in route to Mae Chaem, 500 m alt., 15 May 1977, *T. Santisuk* 993 (BKF); Ubon Rachathani, 4 August 1990, *W. Songkakul* 104 (BKF).

LOCALITY UNKNOW: *K. Chankeaw* 001 (BKF), 25 June 2003; *O. Thaithong* s.n. (BCU), August 1991.

NOTE: After I studied a great number of specimens both from many herbaria and natural habitat, I found that *Dendrobium delacourii* is similar to *D. venustum*, differing in only varing much shorter pseudobulbs and untwisted petals. Therefore, it should be reduced to rank of variety of *D. venustum*.

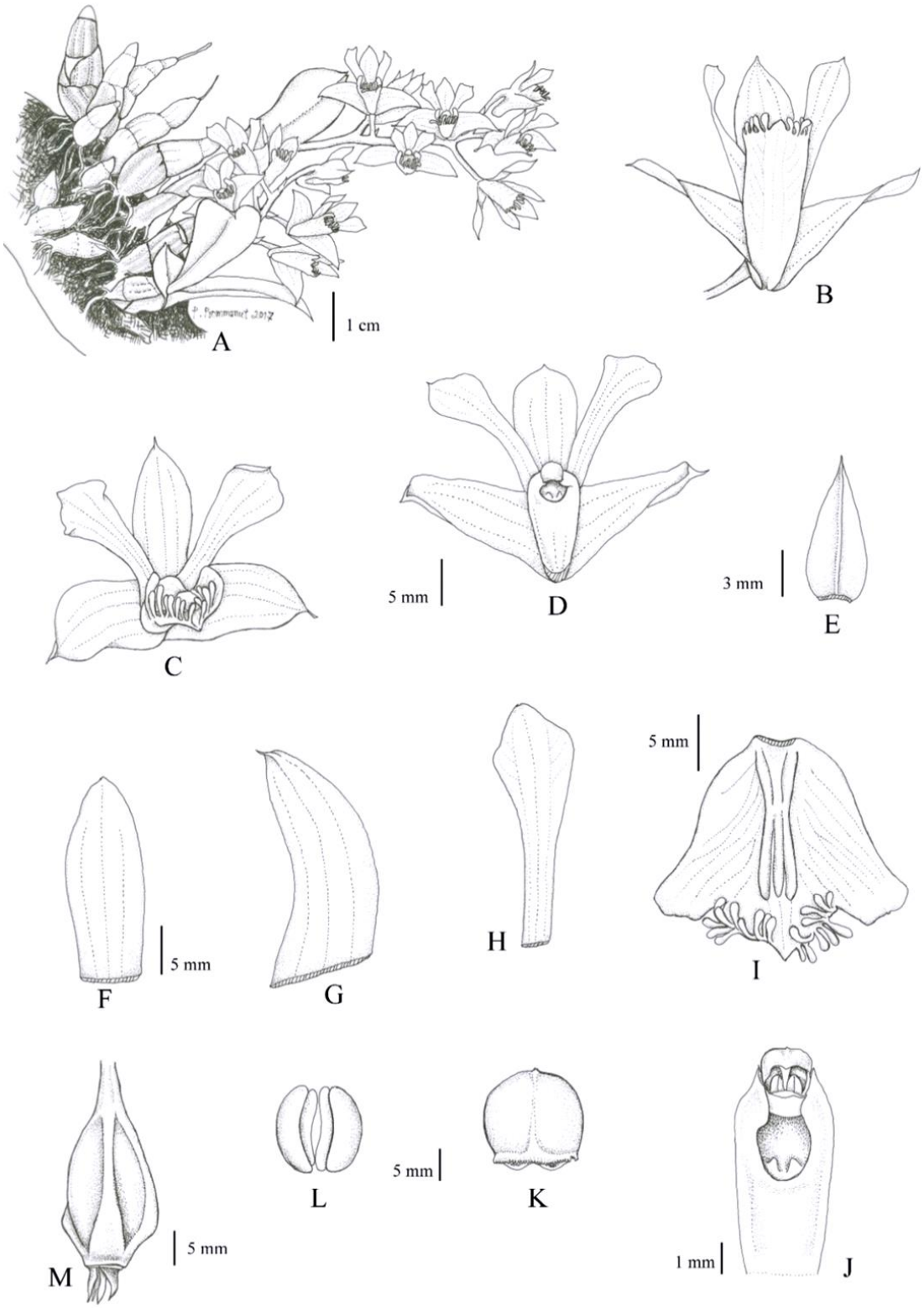


Figure 5. 21 *Dendrobium venustum* var. *delacourii* stat. nov.; A. Habit of flowering plant; B. Flower below view; C. Flower front view; D. flower side view without labellum; E. Bract; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Column; K. Anther cap; L. Pollinia; M. Capsule. Drawn from *P. Triboun* 174.

Plate 5. 21 *Dendrobium venustum* var. *delacourii* stat. nov.; A. Plant in natural habitat; B. Inflorescences; C. Flower below view; D. Flower top view; E. flower front view; F. Labellum.

22. *Dendrobium* sp.1. Figure 5.22, Plate 5.22, Map 5.2.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, bright green with purple pinkish-purple longitudinal lines, fusiform, globose or conical, 1–3 cm tall, 0.4–1.4 cm in diameter, with 1–3 nodes, internodes 4–5 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath bright creamy brown, membraneous, glabrous on both sides, previous stems dull grayish-green or light greenish-yellow, naked. **Foliage leaves** 2–6, distichous, spreading, slightly recurved, elliptic, oblong or ovate-lanceolate, 2.7–5.5 cm long, 0.8–1.9 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, coriaceous, glabrous on both sides, green or purplish-green above, pale green or reddish-green beneath, dull purple at edges and mid-vein, mid-vein grooved above and ribbed below. **Inflorescences** hysteranthous, raceme, 1-inflorescenced, terminal, erect, 1.9–2.5 cm long, densely 3–5-flowered; peduncle and rachis glabrous, greenish-purple or purple, peduncle 3–5 mm long, rachis 2–3 mm long, covered with bracts; bracts pale green or greenish-purple, slightly concave, lanceolate to narrowly lanceolate, 1.9–2 mm long, 0.9–1 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles purple, or greenish-purple, narrowly lanceolate, 1.5–2 mm long, 0.9–1 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1–1.5 cm in diameter. **Sepals** purplish-white, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal elliptic-oblong, 1–1.1 cm long, 2.8–3 mm wide, apex acuminate, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely falcate, 1–1.1 cm long, 4–5 mm wide at base, apex mucronate, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** purplish-white, spreading, oblanceolate, 0.9–1 cm long, 2.8–3 mm wide at apex, apex acute, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** white with pink or purple line along the veins, flabellate, with 3-lobed 1.1–1.2 cm long, 7–8 mm wide across side lobe; clawed linear, 1–2 mm long, margin entire or sub-crenate; side lobe obovoid, upwards pointed, 2–2.1 mm long, 2.8–3 mm wide, apex obtuse, margin entire; disc oblong, surface smooth, distinctly 3 pale green thickened keels raising at hypochile, continuing to base of mid-lobe, apex of keels obtuse; mid-lobe broadly triangular, 2–2.1 mm long, 3–3.2 mm wide, apex acute, margin with long clavate fimbriae, 1.5–2 mm long. **Mentum** glossy white with pink patch, especially edge and base, broadly conical, 4–5 mm long, 1.9–2 mm in diameter, margin entire, straight or incurved distally. **Column** glossy white with purple patch at edges, 2–2.1 mm long, 1.9–2 mm wide at middle, margin entire; foot concave, waxy, 1–2 mm long, 2–2.1 mm wide at base; stigmatic cavity glossy white, circular with pseudo-gland inside, stelidia obtuse, anther cap white, subglobose or widely obovate, 1.8–2 mm long, 1.5–1.9 mm wide, apex emarginate, basal margin denticulate or ciliate, surface smooth, adaxial side sulcate;

pollinia 4, in 2 pairs, bright yellow or yellowish-orange, each pollinium narrowly ellipsoid, 0.7–0.9 mm long, 0.4–0.8 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 6–8 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, ellipsoid, with 3 obtuse keels, 1.5–1.8 cm long, 5–8 mm wide, apex with persistent dried sepals and petals.

THAILAND.—NORTH-EASTERN: Sakon Nakorn (Phu Phan National Park).

DISTRIBUTION.—Only known from Thailand.

ECOLOGY.—In mixed-dipterocarp forest; 300–500 m alt. Growing on *Phyllanthus emblica, Shorea obtusa, Terminalia* sp. and *Vitex* sp. Flowering: July–August; fruiting: August–October.

VERNACULAR.—.

SPECIMENS EXAMINED.**—**Sakol Nakon, Phu Phan district, Phu Phan National Park, *A. Sathapattayanon* 400 (BCU); ibid, 300–500 m alt., 11 August 2016, *P. Prommanut* & *M. Kidyoo* 712 (BCU).

NOTE: This species is similar to *D. venustum* var. *delacourii* in having short pseudobulbs, labellum with 3 thickened keels, stigma with pseudo-gland inside but differ from flower having white with purple veins, oblanceolate petal and side lobes obtuse.

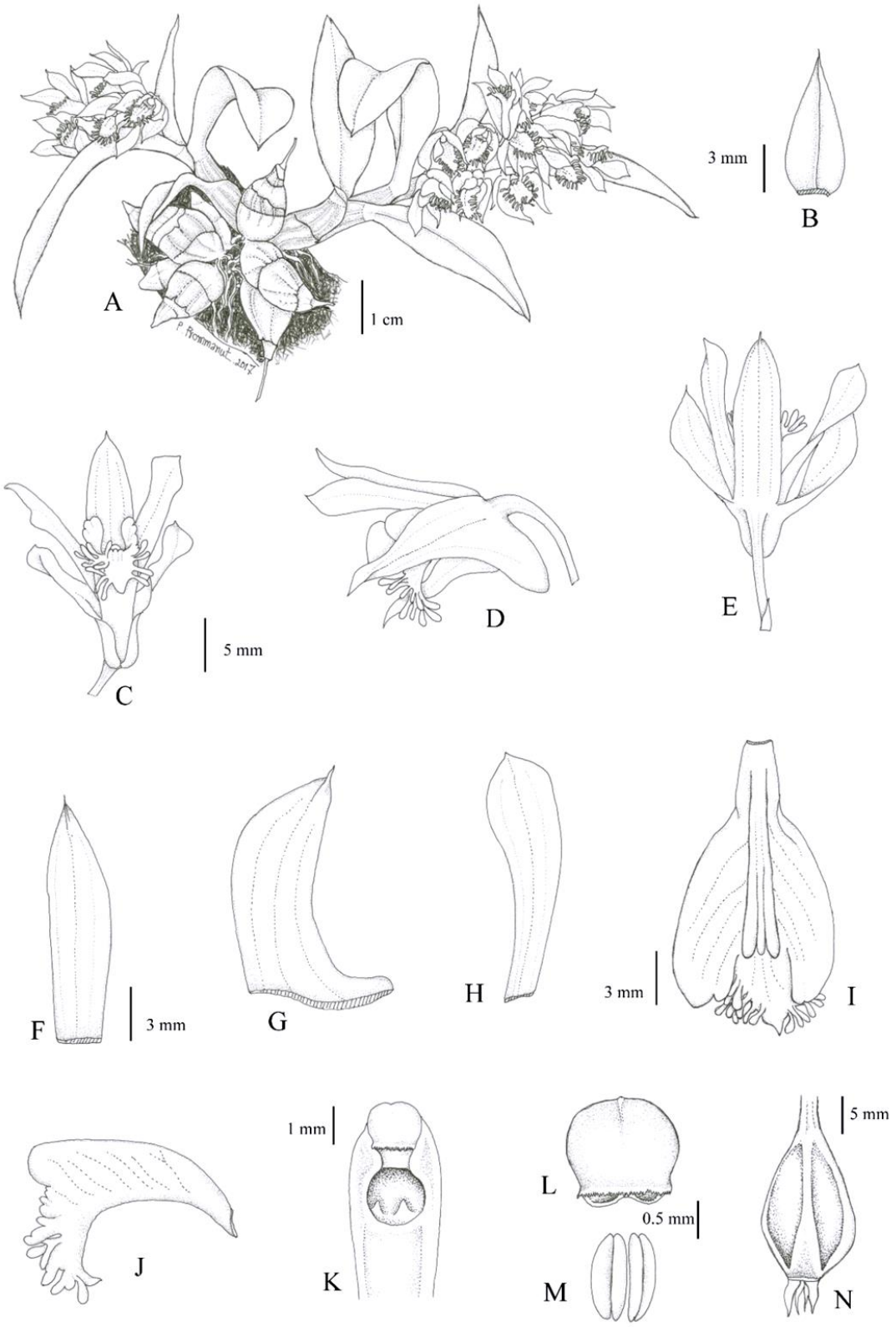


Figure 5. 22 *Dendrobium* sp.1; A. Habit of flowering plant; B. Bract; C. Flower front view; D. flower side view; E. Flower top view; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Labellum side view; K. Column; L. Anther cap; M. Pollinia; N. Capsule. Drwan from *P. Prommanut* & *M. Kidyoo* 712.

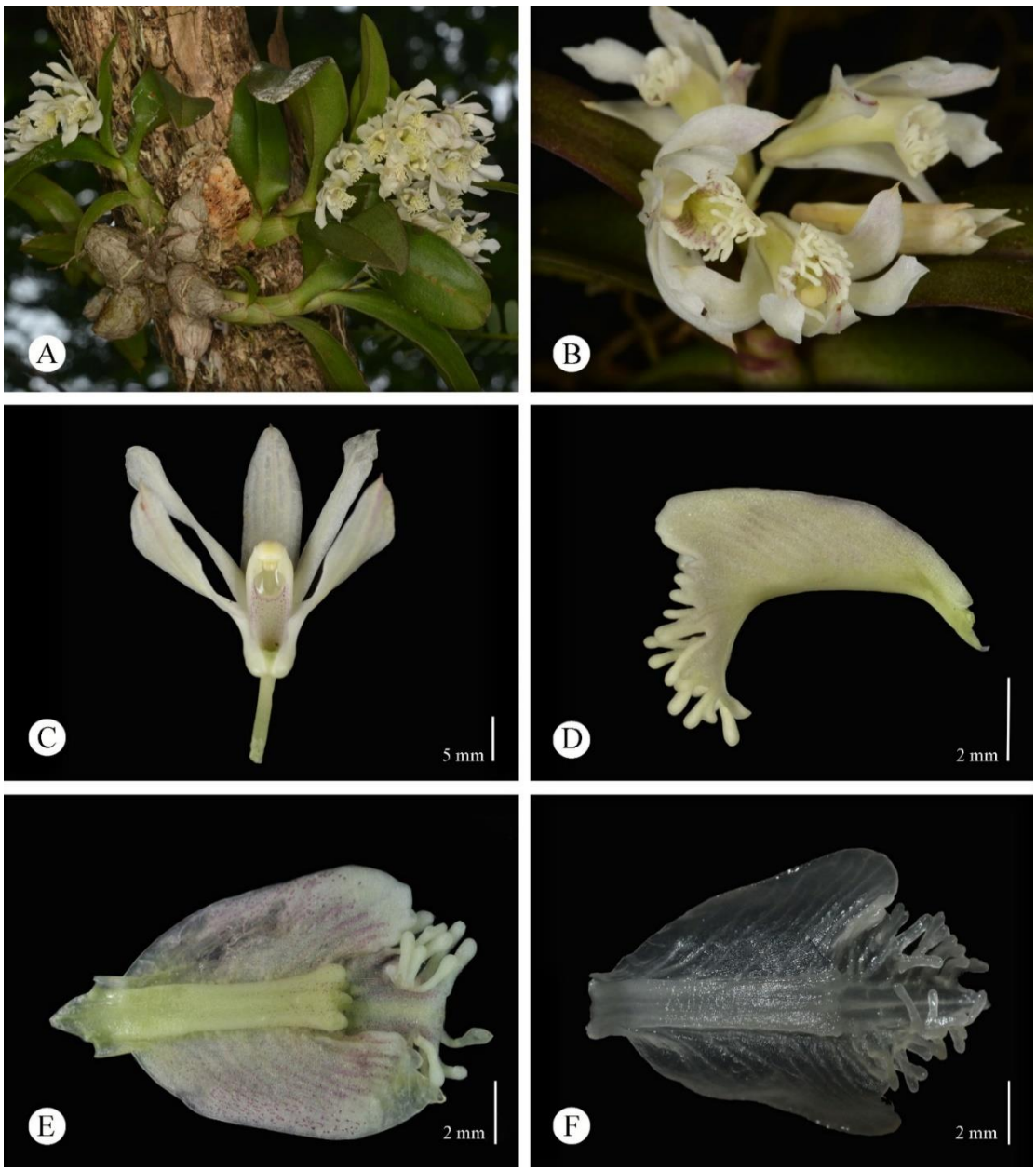


Plate 5. 22 *Dendrobium* sp.1; A Plant in natural habitat; B. Inflorescences; C. Flower front view without labellum; D. Labellum side view; E. Labellum; F. Labellum from spirit collection.

23. *Dendrobium* sp.2. Figure 5.23, Plate 5.23, Map 5.1.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, green or light green, cylindric, narrowly fusiform or ovoid, 0.8–2 cm tall, 0.5–1 cm in diameter, with 2–3 nodes, internodes 5–7 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath pale brown, membraneous, glabrous on both sides, previous stems golden yellow or light green, naked. **Foliage leaves** 2–4, distichous, spreading, slightly recurved, oblong, elliptic-lanceolate or linear-oblong, 2.2–4 cm long, 3–8 cm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths, chartaceous, glabrous on both sides, green or light green above, pale green beneath, mid-vein grooved above and ribbed below, flowering when leafless. **Inflorescences** raceme, 1–4-inflorescenced, subterminal or arising from upper part of current year's leafy stem, suberect or nodding, 0.5–1 cm long, with 2–10-flowered; peduncle and rachis glabrous, light green or yellowish-green, peduncle 2–2.1 mm long, rachis 1–2 mm long, covered with bracts; bracts yellowish-green or green, slightly concave, lanceolate, 3–4 cm long, 1–2 mm wide, apex attenuate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteoles green, narrowly lanceolate, 3.4–4 mm long, 1–2 mm wide, apex attenuate, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1–1.2 cm in diameter. **Sepals** yellowish-green, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal lanceolate, 6.5–7 mm long, 1.9–2.1 mm wide, apex acute, base truncate, 3-veined, distinctly visible, mid-vein grooved above; lateral sepals obliquely triangular-lanceolate, 7–8 mm long, 5–5 mm wide at base, apex acute, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** yellowish-green, spreading, obovate-lanceolate, 6.8–7 mm long, 1.9–2 mm wide at subterminal, apex acute, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** dull green with 1 dark purple blotch, surface papillose, slightly recurved, ovate or suborbicular, without side lobes, 5.8–6 mm long, 3.8–4 mm wide across, shortly clawed at base; disc ovate, surface papillose, waxy; midlobe triangular, margin undulate-crenulate. **Mentum** green, narrowly conical, 4–5 mm long, 1.5–2 mm in diameter, margin entire, straight or incurved distally. **Column** green, 2–3 mm long, 1–1.5 mm wide at base, margin and surface smooth; foot concave cymbiform, 1–2 mm long, 1.5–1.8 mm wide at middle; stigmatic cavity glossy green, broadly ovate, stelidia acute, anther cap green, ovate, 1–1.5 mm long, 0.8–1 mm wide, apex emarginated, basal margin minutely ciliate, surface smooth; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.7–0.9 mm long, 0.2–0.5 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 2–2.5 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** green or dull green, subglobose with 3 obtuse keels, 1–1.5 cm long, 1.2–1.5 cm wide, apex with persistent dried sepals and petals.

THAILAND.—SOUTH-WESTERN: Kanchanaburi (Thong Pha Phum National Park).

DISTRIBUTION.—Endemic to Thailand.

ECOLOGY.—In hill evergreen forest; 1,200-1,300 m alt. Growing on *Schima wallichii*, which are covered with mosses and lichens. Flowering: January–February; fruiting: February–March.

VERNACULAR.—Ueang khao tok thong pha phum.

SPECIMENS EXAMINED.—Kanchanaburi, Thong Pha Phum District, Thong Pha Phum National Park, 1,000 m alt., 5 January 2016, *P. Prommanut* & *S. Suddee* 704 (BKF); ibid, January 2017, *P. Srisom* & *S. Suddee* s.n. (BKF).

NOTE: The species is distinguished by having 1 dark purple blotch on labellum, surface papillose and labellum without keels unlike any species in this section.

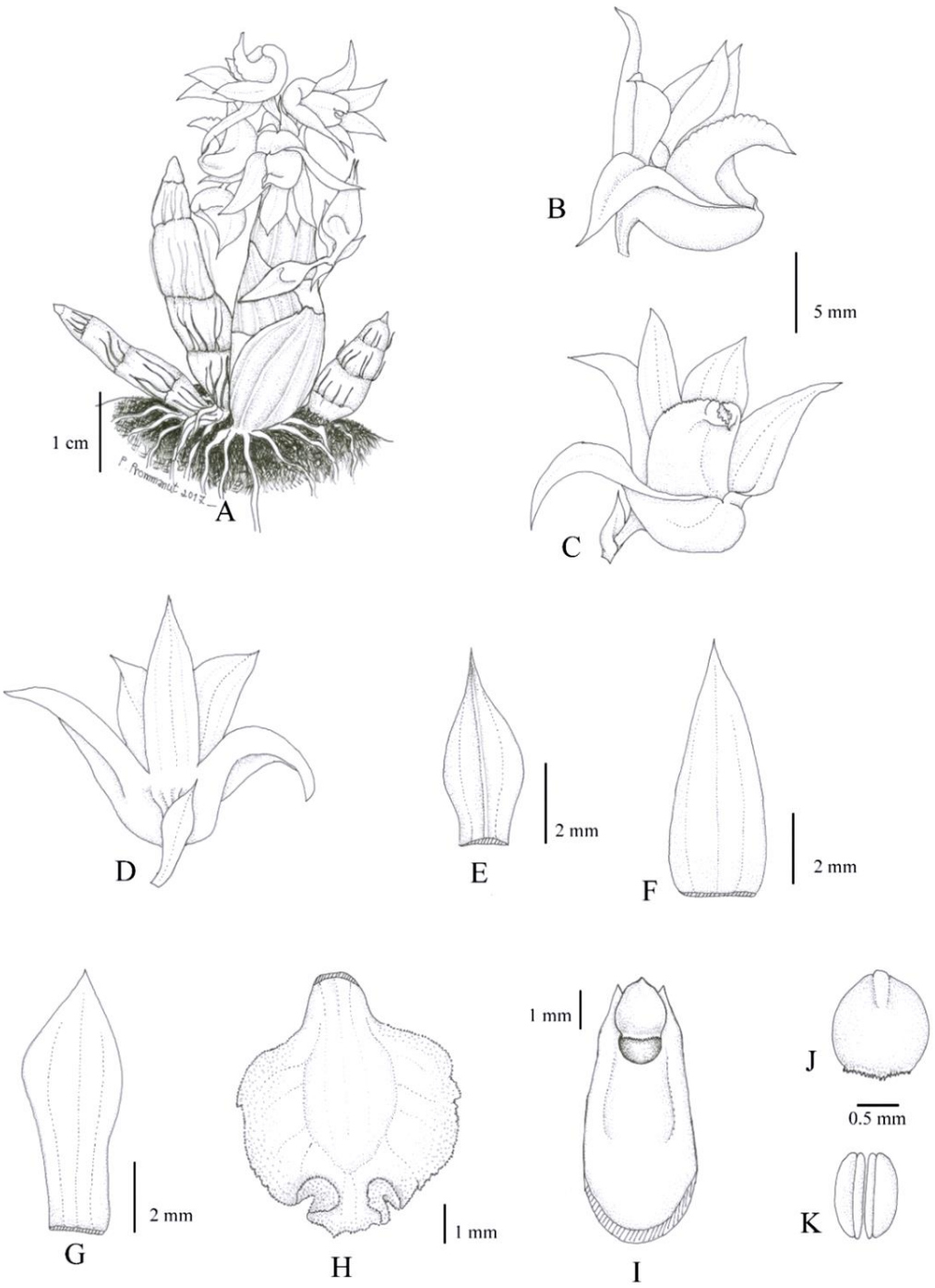


Figure 5. 23 *Dendrobium* sp.2; A. Habit of flowering plant; B. Flower side view; C. Flower front view; D. Flower top view; E. Bract; F. Dorsal sepal; G. Petal; H. Labellum; I. Column; J. Anther cap; K. Pollinia. Drawn from *P. Prommanut & S. Suddee* 704.

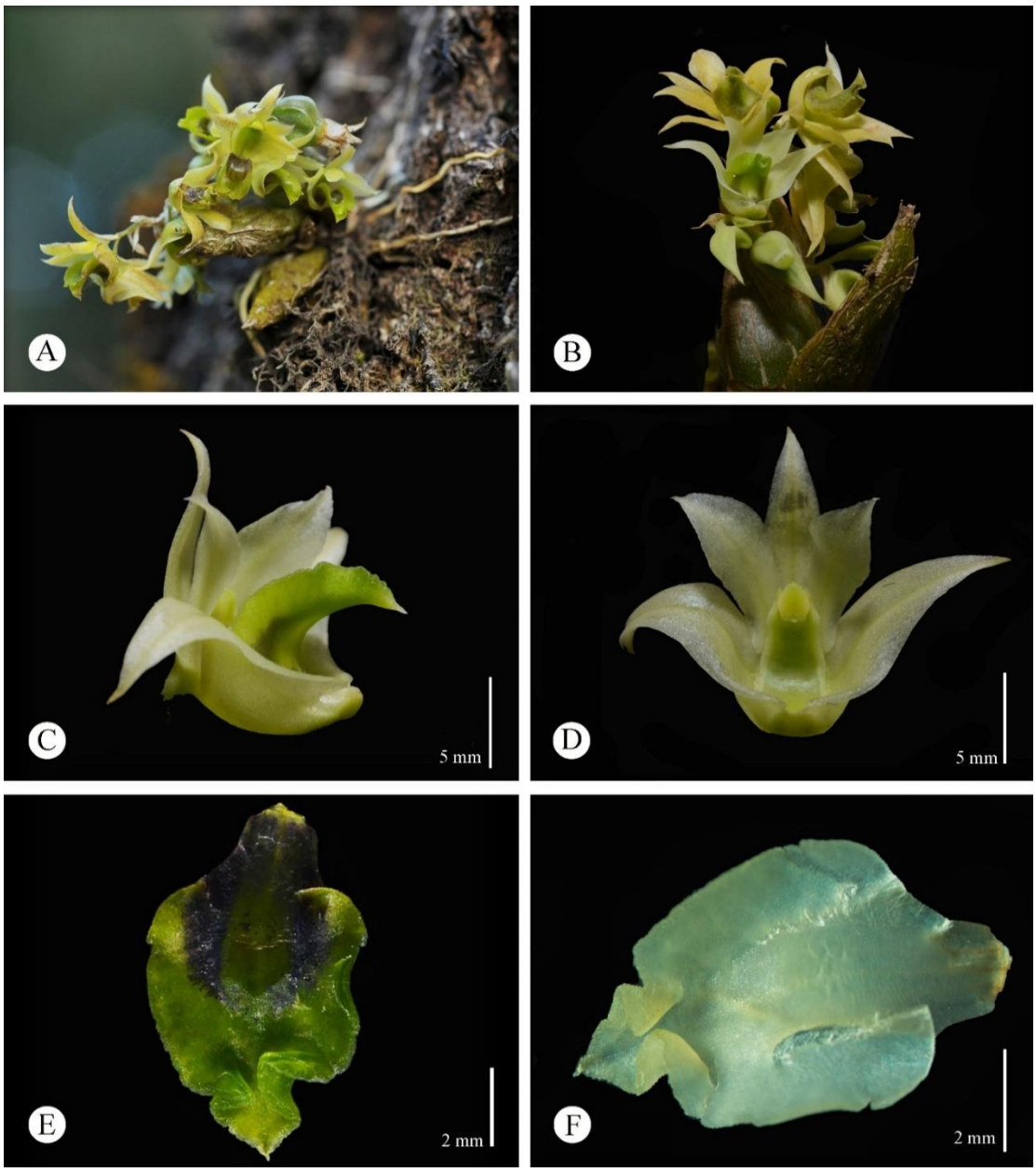


Plate 5. 23 *Dendrobium* sp.2; A Plant in natural habitat; B. Inflorescences; C. Flower side view; C. Flower front view; D. Flower front view without labellum; E. Labellum; F. from spirit collection. A photo by P. Srisom.

24. *Dendrobium* sp.3. Figure 5.24, Plate 5.24, Map 5.3.

Plant epiphytic, tufted, with smooth roots. **Pseudobulbs** erect, bright green, ovoid or globose, 0.8–1.2 cm tall, 4–6 mm in diameter, with 1–2 nodes, internodes 3–4 mm long, base slightly contracted, become narrowed toward apex above middle, sulcate, fleshy, current stems enclosed in leaf sheaths; leaf sheath stramineous, membraneous, glabrous on both sides, previous year's naked stems dull green, naked. **Foliage leaves** 2–3, distichous, spreading, slightly recurved, linear or linear-oblong, 2–4 cm long, 3–4 mm wide, apex unequally bi-lobed, each lobe acute, base dilated into sheaths chartaceous, glabrous on both sides, light green above, pale green beneath, mid-vein grooved above and ribbed below, flowering when leafless. **Inflorescences** raceme 1-inflorescenced, terminal, erect or suberect, 1.7–2.2 cm long, with 2–3-flowered; peduncle and rachis glabrous, light green, peduncle 1–1.3 cm long, rachis 0.8–1 cm long, covered with bracts; bracts green, slightly concave, lanceolate, 2–3 mm long, 1–1.1 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below, bracteole green, narrowly lanceolate, 2–2.2 mm long, c. 1 mm wide, apex acute, base truncate, margin entire, 1-veined, glabrous on both sides, distinctly keeled below. **Flowers** resupinate, waxy and polished, weakly scented, long-lasting, 1.2–1.5 cm in diameter. **Sepals** white, spreading, often recurved distally, margin entire, abaxial surface distinctly keeled; dorsal sepal narrowly lanceolate, 7–8 mm long, 1.9–2 mm wide, apex attenuate, base truncate, mid-vein grooved above, 3-veined, distinctly visible; lateral sepals obliquely falcate or triangular-lanceolate, 7–7.2 mm long, 6–6.5 mm wide at base, apex acute, base obliquely truncate, 3–4-viened, distinctly visible. **Petals** white, spreading, linear-oblanceolate, 6.5–7 mm long, 1.5–1.8 mm wide at middle, gently reduced at base, apex attenuate, base truncate, margin entire, 3-veined, distinctly visible. **Labellum** dull green with purple at edges, slightly recurved, oblong or elliptic-oblong, without side lobes, 0.9–1 cm long, 4–4.2 mm wide, shortly clawed at base; disc oblong, surface smooth, waxy, distinctly with 2 dull green thickened keels raising at hypochile, continuing to base of mid-lobe, each keel obtuse at apex, margin serrate-crisped. **Mentum** green, broadly conical, 4–5 mm long, 2–2.3 mm in diameter, margins entire, straightly or incurved distally. **Column** dull green, 2–2.1 mm long, c. 2 mm wide at middle, margin and surface smooth; foot concave, stout at base, waxy, 2–2.2 mm long, 1.5–2 mm wide at base; stigmatic cavity bright green, ovate, stelidia acute, anther cap light green, subglobose, 1–1.5 mm long, 0.8–0.9 mm wide, apex acute, basal margin ciliate, surface smooth, adaxial side sulcate; pollinia 4, in 2 pairs, bright yellow, each pollinium narrowly ellipsoid, 0.8–0.9 mm long, 0.8–1 mm wide, without caudicle and visidium. **Ovary** (including pedicel) narrowly clavate, curved, 3–4 mm long, glabrous, somewhat waxy, 6-grooved. **Capsule** not seen.

THAILAND.—Data deficit.

DISTRIBUTION.—Probably occurs in Kanchanaburi and Tak in Thailand.

ECOLOGY.—No habitat details are known. Flowering: November–December; fruiting: January–March.

VERNACULAR.—.

SPECIMENS EXAMINED.—Thailand, from Chatuchak Market, 12 December 2015, *P. Prommanut* s.n. (BK).

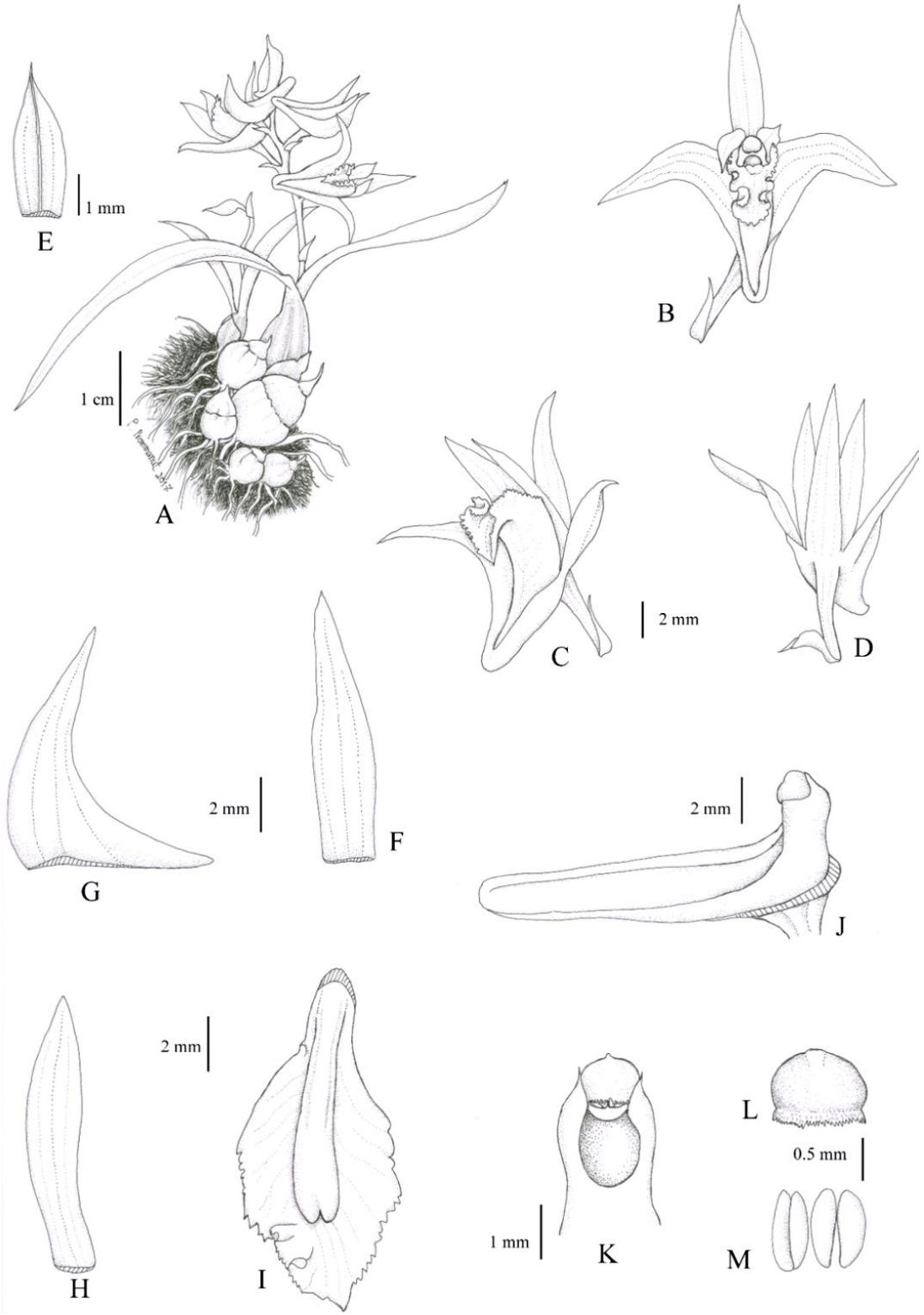
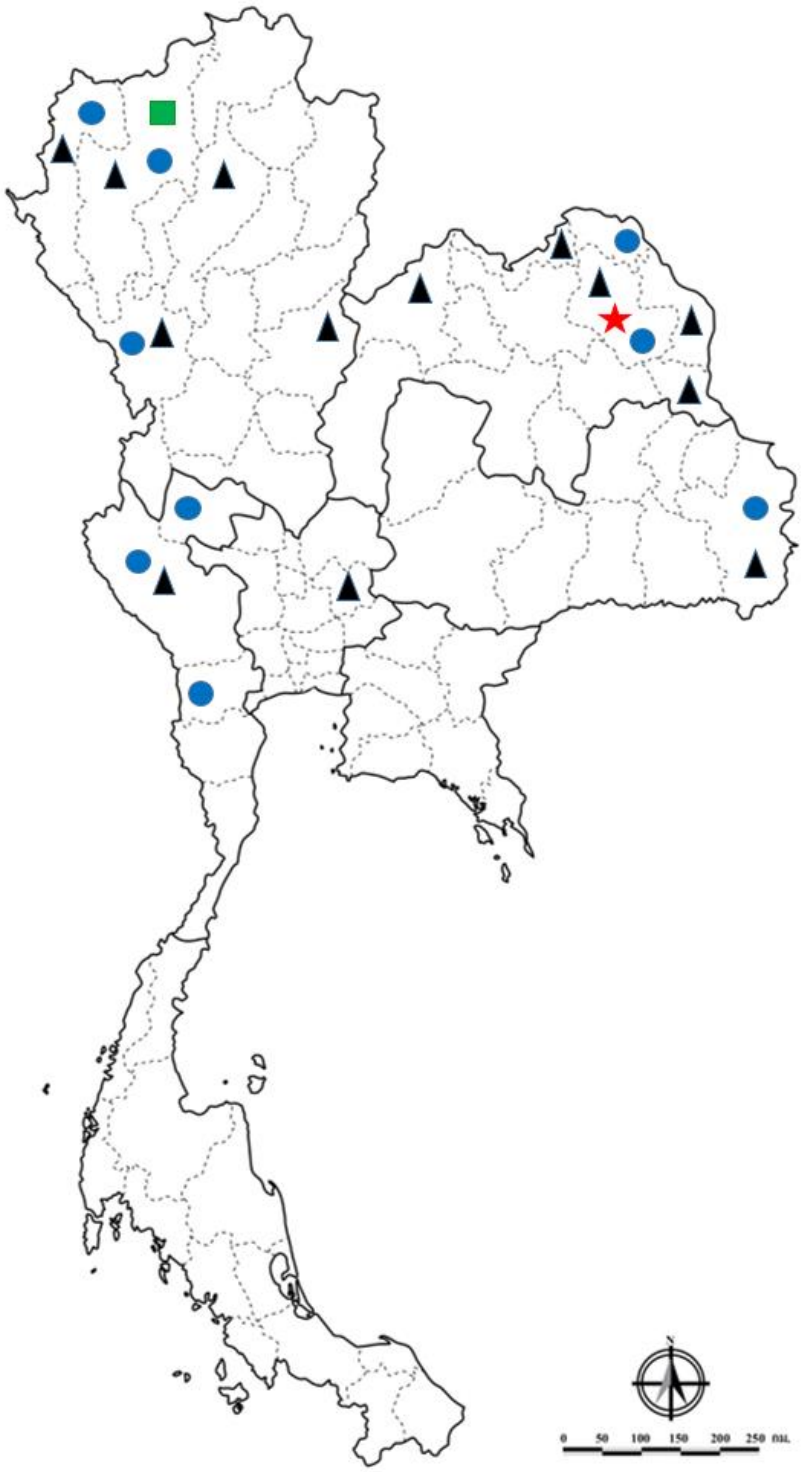


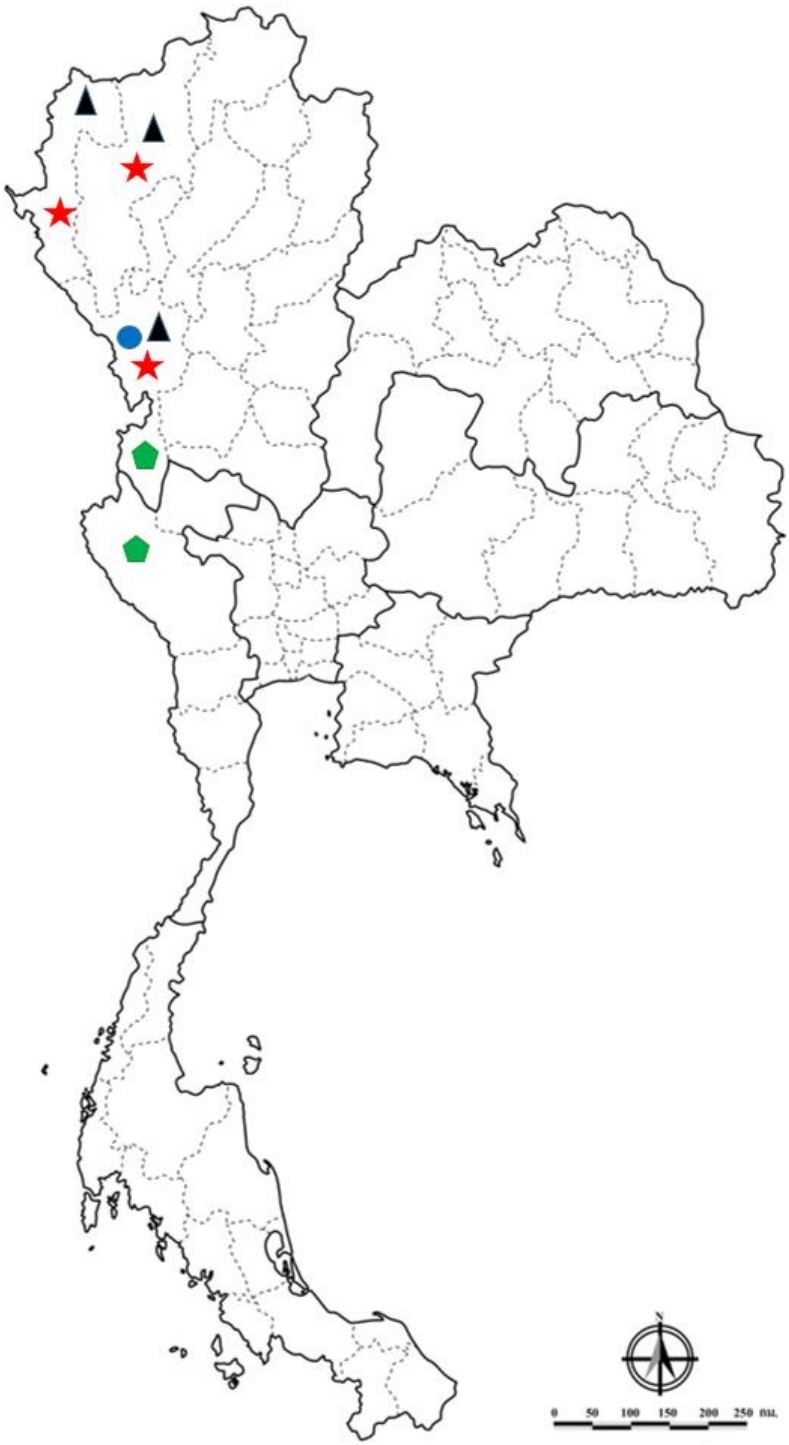
Figure 5. 24 *Dendrobium* sp.3; A. Habit of flowering plant; B. Flower front view; C. Flower side view; D. Flower top view; E. Bract; F. Dorsal sepal; G. Lateral sepal; H. Petal; I. Labellum; J. Column and mentum side view; K. Column front view; L. Anther cap; M. Pollinia. Drawn from *P. Prommanut* s.n.

Plate 5. 24 *Dendrobium* sp.3; A. Plant from culture; B. Inflorescences; C. Flower front view; D. Flower without labellum from spirit collection; E. Labellum show 2 keels; F. Labellum from spirit collection.

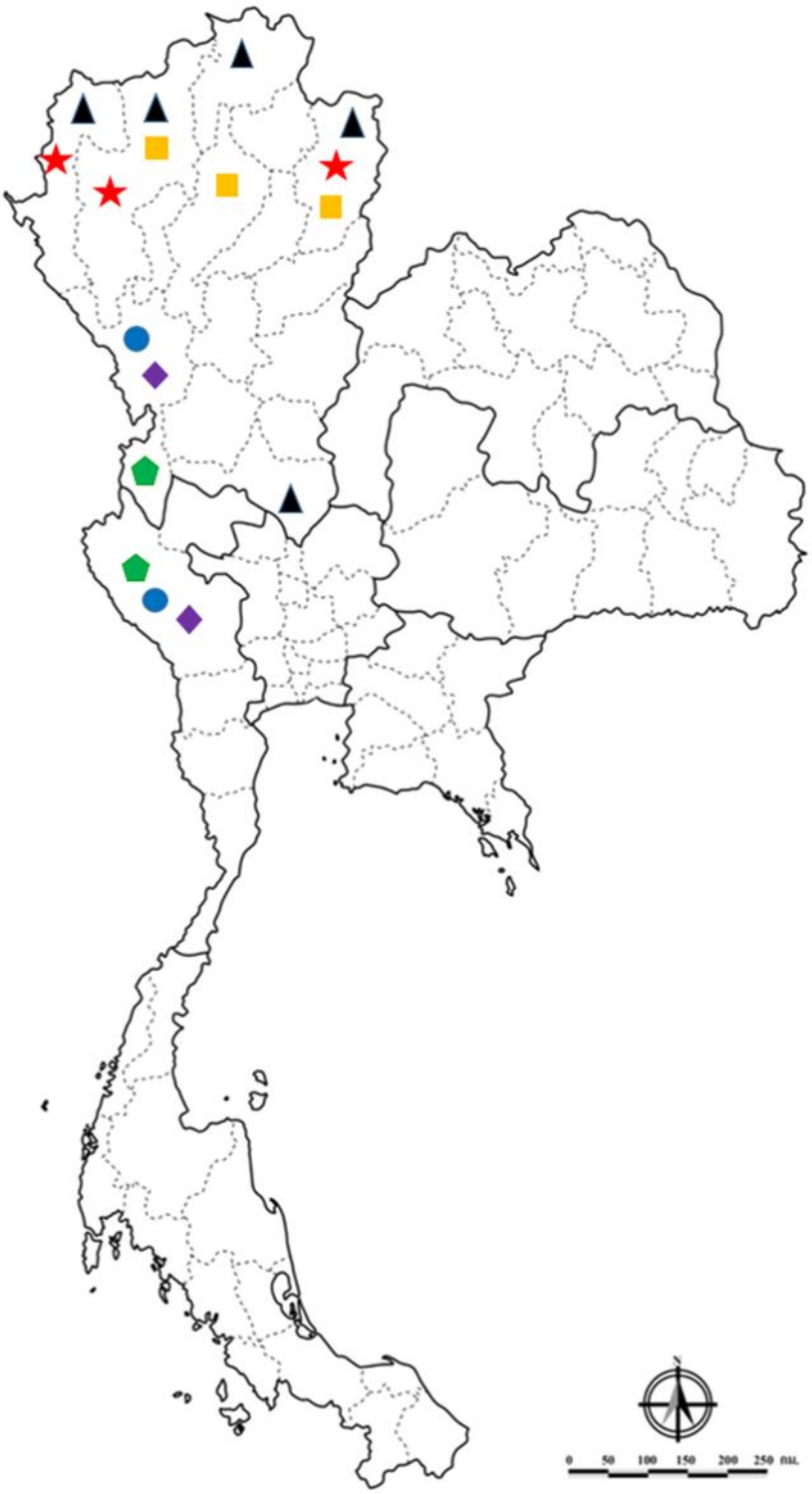
Map 5. 1 Distribution of *Dendrobium chiangdaoense; D. peguanum; Dendrobium* sp.2.
Abbreviation; *Dendrobium chiangdaoense* = ▲; *D. peguanum* = ●
; *Dendrobium* sp.2 = ★



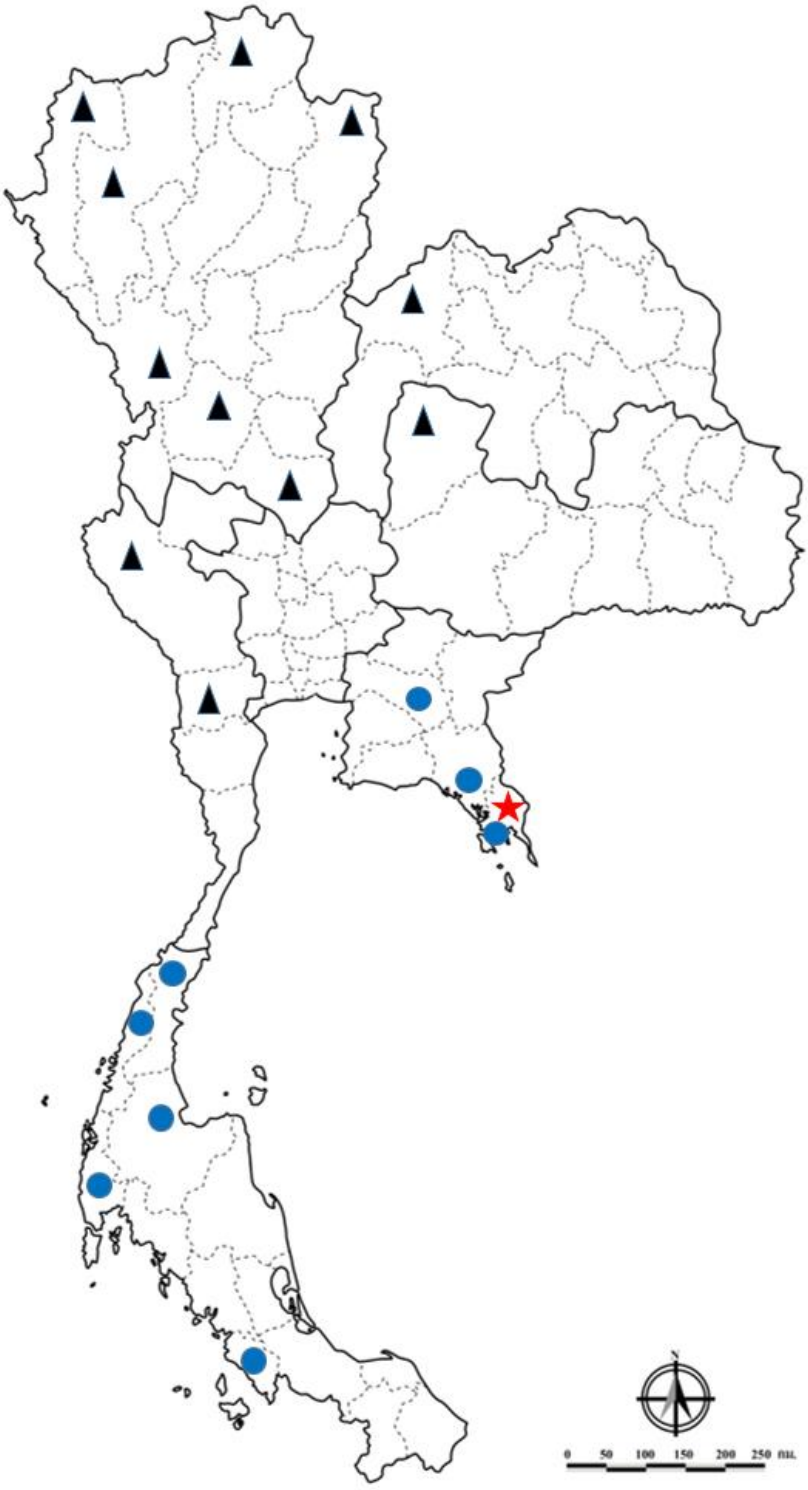
Map 5. 2 Distribution of *Dendrobium garrettii*; *D. venustum* var. *delacourii; D. venustum* var. *venustum; Dendrobium* sp.1.
Abbreviation; *Dendrobium garrettii* = ■ ; *D. venustum* var. *delacourii* = ● ; *D. venustum* var. *venustum* = ▲ ; *Dendrobium* sp.1 = ★



Map 5. 3 Distribution of *Dendrobium elliottianum; D. gregulus; D. pycnostachyum; Dendrobium* sp.3.
Abbreviation; *Dendrobium elliottianum* = ● ; *D. gregulus* = ▲ ; *D. pycnostachyum* = ★ ; *Dendrobium* sp.3 = ⬟



Map 5. 4 Distribution of *Dendrobium cuspidatum; D. denudans; D. dixonianum; D. kanburiense; D. strongylanthaum; Dendrobium obchantiae.*
Abbreviation; *Dendrobium cuspidatum* = ● ; *D. denudans* = ▲ ; *D. dixonianum* = ★ ; *D. kanburiense* = ◆ ; *D. strongylanthaum* = ■ ; *Dendrobium obchantiae* = ⬟



Map 5. 5 Distribution of *Dendrobium compactum; D. confinale; D. incurvum.*
Abbreviation; *Dendrobium compactum* = ▲ ; *D. confinale* = ★
; *D. incurvum* = ●

Map 5. 6 Distribution of *Dendrobium mucronatum; D. perpaulum; D. porphyrochilum; D. proteranthum.*
Abbreviation; *Dendrobium mucronatum* = ● ; *D. perpaulum* = ★ ; *D. porphyrochilum* = ▲ ; *D. proteranthum* = ⬟

5.4 Discussion and conclusions

5.4.1 The account of the *Dendrobium* section *Stachyobium* Lindl. in Thailand

The updated taxonomic revision of the section *Stachyobium* in Thailand was provided based on specimen examination and fieldtrips. Twenty four taxa are recognized in this section. Most of the species are distributed in the northern Thailand (19 species) whereas the southeastern and peninsular Thailand are the areas which have the lowest number of species (2 species). Interestingly, 11 species namely *Dendrobium chiangdaoense, D. cuspidatum, D. denudans, D. dixonianum, D. elliottianum, D. garrettii, D. mucronatum, D. peguanum, D. perpaulum, D. pycnostachyum* and *D. strongylanthum* are restricted to the specific ecological niches in upper montane rainforest, pine forest, deciduous dipterocarp-oak forest, lower montane-oak forest, lower montane scrub and pine-deciduous dipterocarp forest in northern Thailand. *Dendrobium incurvum* can be found in mangrove forest and tropical rain forest in southeastern and peninsular Thailand (table 5.1).

Table 5. 1 Summary of distribution areas of *Dendrobium* section *Stachyobium* in Thailand.

Taxa	Floristic Regions of Thailand							Altitude (m)
	N	NE	E	SW	C	SE	PE	
1. *D. chiangdaoense**	✓	–	–	–	–	–	–	750–800
2. *D. compactum*	✓	✓	✓	✓	–	–	–	1,200–1,800
3. *D. confinale**	–	–	–	–	–	✓	–	200–300
4. *D. cuspidatum*	✓	–	–	–	–	–	–	c. 700
5. *D. denudans*	✓	–	–	–	–	–	–	1,500–1,800
6. *D. dixonianum**	✓	–	–	–	–	–	–	1,400–1,600
7. *D. elliottianum**	✓	–	–	–	–	–	–	750–800
8. *D. garrettii**	✓	–	–	–	–	–	–	1,700–1,900
9. *D. gregulus**	✓	–	–	✓	–	–	–	700–1,800
10. *D. incurvum*	–	–	–	–	–	✓	✓	50–200
11. *D. kanburiense*	✓	–	–	✓	–	–	–	500–700
12. *D. mucronatum**	✓	–	–	–	–	–	–	c. 1,700
13. *D. obchantiae**	✓	–	–	✓	–	–	–	800–1,100

Taxa	Floristic Regions of Thailand							Altitude (m)
	N	NE	E	SW	C	SE	PE	
14. *D. peguanum*	✓	–	–	–	–	–	–	900–1,100
15. *D. perpaulum*	✓	–	–	–	–	–	–	1,600–1,900
16. *D. porphyrochilum*	✓	–	–	✓	–	–	✓	800–2,000
17. *D. proteranthum*	✓	✓	–	–	–	–	–	1,470–1,500
18. *D. pycnostachyum*	✓	–	–	–	–	–	–	900–1,200
19. *D. strongylanthum*	✓	–	–	–	–	–	–	1,200–1,500
20. *D. venustum* var. *venustum*	✓	✓	✓	✓	–	–	–	400–800
21. *Dendrobium* var. *delacourii*	✓	✓	✓	✓	–	–	–	400–600
22. *Dendrobium* sp.1	–	✓	–	–	–	–	–	400–600
23. *Dendrobium* sp.2*	–	–	–	✓	–	–	–	1,200–1,300
24. *Dendrobium* sp.3*	✓	–	–	✓	–	–	–	c. 1,000
total	20	5	3	9	0	2	2	

Notes: N = Northern, NE = Northeastern, E = Eastern, SW = Southwestern, C = Central, SE = Southeastern, PE = Peninsular, ✓ = present, – = absent, * = species endemic to Thailand.

In the present study, the number of species in section *Stachyobium* accounts for more than that reported by Seidenfaden (1985, 1995) . Five names are recognized as synonyms including *D. eserre*, which is reduced to synonym of *D. dixonianum*, *D. kratense* and *D. erostelle*, which are reduced to synonyms of *D. incurvum*, *D. nanocompactum* and *D. wilmsianum*, which are reduced to synonyms of *D. compactum*. Furthermore, it is found after intensively study, these species that 2 species namely *D. monticola* and *D. eriaeflorum* reported in Opera Botanica (1985), which were collected by Hosseus s.n. (for *D. monticola*) and Seidenfaden & Smitinand 5042, 5185, 5200 and 7928 (for *D. eriaeflorum*) from Doi Suthep and Bo Luang, Chiang Mai Province, were misidentified. The specimen of Hosseus s.n. which was labeled as *D. monticola* is in fact *D. compactum*, whlil the four specimens of Seidenfaden & Smitinand are actually *D. pycnostachyum*. These species are distributed in India, Nepal, China, Laos and Vietnam. Moreover, *D. elliottianum*, a new species deceribed from a specimen obtained from Chatuchak market is now discovered in a natural habitat at Doi Hua Mot, Umphang District, Tak Province.

Table 5. 2 Summary of *Dendrobium* section *Stachyobium* accounts in Thailand in this study compared to those of previous studies.

Taxa	Seidenfaden (1985, 1995)	Present study (2018)	*Note
1. *D. chiangdaoense*	–	✓	new species
2. *D. compactum*	✓	✓	
3. *D. confinale*	✓	✓	
4. *D. cuspidatum*	✓	✓	
5. *D. denudans*	✓	✓	
6. *D. delacourii*	✓	*	= *D. venustum* var. *delacourii*
7. *D. dixonianum*	✓	✓	
8. *D. elliottianum*	–	✓	new species (malayan orchid rev. 2009.)
9. *D. erostelle*	✓	*	= *D. incurvum*
10. *D. eserre*	✓	*	= *D. dixonianum*
11. *D. eriaeflorum*	✓	–	misidentified specimens
12. *D. garrettii*	✓	✓	
13. *D. gregulus*	✓	✓	
14. *D. incurvum*	✓	✓	
15. *D. kanburiense*	✓	✓	
16. *D. kratense*	✓	*	= *D. incurvum*
17. *D. monticola*	✓	–	misidentified specimens
18. *D. mucronatum*	✓	✓	
19. *D. nanocompactum*	✓	*	= *D. compactum*
20. *D. obchantiae*	✓	✓	
21. *D. peguanum*	✓	✓	
22. *D. perpaulum*	✓	✓	
23. *D. porphyrochilum*	✓	✓	
24. *D. pycnostachyum*	✓	✓	
25. *D. strongylanthum*	✓	✓	
26. *D. venustum*	✓	✓	
27. *D. wilmsianum*	–	*	= *D. compactum*

Taxa	Seidenfaden (1985, 1995)	Present study (2018)	*Note
28. *Dendrobium* sp.1	–	✓	new variety
29. *Dendrobium* sp.2	–	✓	new species
30. *Dendrobium* sp.3	–	✓	new species

5.4.2 Species with new ranks

Guillaumin (1924) described a new species namely *Dendrobium delacourii* from Vietnam, Laobas, Quang Tri Province. Careful study of the type specimen and the specimens collected from natural habitat showed that this species is similar to *D. venustum* in having yellow flower, bright yellow flabellate labellum with reddish-brown lines along the veins and distinct 3 bright yellow thickened keels raising at hypochile and continuing to the base of mid-lobe, obliquely square side lobes, margin of the mid-lobe with long clavate fimbriae, pseudo-gland present inside the stigma. However, *D. delacourii* differs from *D. venustum* by having short pseudobulbs and untwisted petals. In addition, the data from leaf anatomy supported that these 2 species are closely related. Both species have amphistomatic stomata (stomata distributed on adaxial and abaxial surfaces). The other species in this section have hypostomatic stomata (stomata distributed only on abaxial surfaces). From this information, *D. delacourii* is reduced from species rank to variety rank and named as *D. venustum* var. *delacourii* stat. nov.

5.4.3 New species and new variety of the *Sthacyobium* in Thailand

There are four new species and one new variety as follows:
1. *Dendrobium chiangdaoense* Promm., Kidyoo, Buddhawong & Suddee is found in mixed deciduous forest at ca. 800 m alt. on limestone hills in Chiang Dao District, Chiang Mai Province. This species is most similar to *D. dixonianum* but differs in having bract longer than pedicel plus ovary, inflorescences not exceeding leaves, obliquely falcate-triangular and not recurved lateral sepals, bright green labellum, apex of keel being acute and not divided to lobes.
2. *Dendrobium obchantiae* Promm., Suddee & Kidyoo is discovered in mixed deciduous forest near the Check Point to Thi Lo Su Waterfall, Umphang District, Tak Province. *Dendrobium obchantiae* is similar to *D. incurvum* in having slender stem, bracteoles shorter than pedicel plus ovary and labellum with three keels, but the former is distinguished by its pale green or greenish yellow flowers with 3–4 longitudinal purple veins on sepals and petals, elliptic-obovate dorsal sepal, widely triangular or falcate-triangular lateral sepals, ovate or suborbicular labellum with three distinct lobes, obliquely triangular-obovate and raised sidelobes, and a short stout mentum.
3. *Dendrobium* sp.1 is found in mixed-dipterocarp forest at 300–500 m alt. in Sakol Nakorn Province.
4. *Dendrobium* sp.2 is found in hill evergreen forest at 1,200–1,300 m alt. in Kanchanaburi Province.

5. *Dendrobium* sp.3 is found for the first time at Chatuchak market. The plant probably occurs in Kanchanaburi and Tak Provinces in Thailand. More investigation is still needed.

5.4.4 Endemic and rare species of the Sthacyobium in Thailand

Seven species are endemic to Thailand:

1. *D. confinale* is only found in Khao Saming District, Trat Province. It is known only from type specimen kept at Kew herbarium (K).

2. *D. dixonianum* is found in Mae Hong Son, Chiang Mai and Nan Province.

3. *D. elliottianum* is only found at Doi Hua Mot, Tak Province. It is now threatened from tourists' activities and cattle grazzing.

4. *D. garrettii* is only found in Doi Inthanon, Chiang Mai Province. It has been threatened from illegal trade and human activities.

5. *D. gregulus* is found in Mae Hong Son, Chiang Mai, Tak and Kanchanaburi Province.

6. *D. mucronatum* is only found in Khun Yuam, Mae Hong Son Province. It is khown only from type specimen which is kept at Copenhagen herbarium (C).

7. *D. proteranthum* is found in Phitsanulok and Loei Province. The populations in natural habitat are decreasing.

Additionally, when based on 'Thailand Red Data: Plants' (2001) and 'IUCN Red List of Threatened Plants' (1997), 6 species are rare.

1. *D. cuspidatum* is only found in Mae Ra Mat, Tak and Kanchanaburi Province. Currently, it is rare in natural habitat, but the plants, possibly brought from Myanmar, can be found in orchid farms and Chatuchak market.
2. *D. denudans* is found in Mae Hong Son, Chiang Mai, Chiang Rai, Nan and Nakhon Sawan Province.
3. *D. kanburiense* is found in Kanchanaburi and Tak Province. In fact, this species was described as endemic to Thailand, but after carefully studied it is also found in China under the name "*D. sinominutiflorum*".
4. *D. peguanum* is found in Mae Hong Son, Chiang Mai and Tak Province. At present, it is over collected from natural habitats, due to its beautiful and fragrant flowers.
5. *D. perpaulum* is found in Mae Hong Son and Chiang Mai Province. This species was described as endemic to Thailand, but after circumspectly examined, it is also distributed in China (under the name "*D. zhenyuanense*") and Laos (under the name "*D. minusculum*").
6. *D. strongylanthum* is found in Chiang Mai, Lamphang and Nan Province.

CHAPTER VI
GENARAL CONCLUSIONS

Taxonomic revision of *Dendrobium* section *Stchyobium* Lindl. in Thailand base on morphological, ecological, anatomical and palynological studies were investigated. A complete account of this section can resolve taxonomic problems in this section. This research aims to find new characters which are useful for species identification.

6.1 Morphological study

The morphological study was based on sample collections both from natural habitat and from many herbaria in Thailand and abroad. The significant morphological characters that are useful for species identification, *i.e.* shape of pseudobulb (orbicular, oval, narrowly fusiform and slender undilated), length of bracteoles per pedicel plus ovary (bracteoles shorter than pedicel plus ovary and longer than pedicel plus ovary, type of inflorescence (proteranthous and hysteranthous), apex of sepals (mucronate, acute or acuminate), shape of petals (In general, linear-oblanceolate is a unique character of this section but twisted linear-spatulate can be found in *Dendrobium venustum* and spatulate in *D. venustum* var. *delacourii*), type of labellum (labellum with side-lobes and without side-lobes), number of keels on labellum (one, two and three or absent); this character is beneficial for identification to species level, type of mentum (broadly conical and narrowly conical), type of edge column (smooth, cilia-pilose and verrucose-papillose) and shape of capsule (globose, ellipsoid and pear-shaped to obovoid).

6.2 Diversity and geographical distribution of the Stachyobium

Most of the species in this section are found in various forest type in Northern, North-Eastern and South-Western Thailand viz. upper montane rain forest, pine forest, deciduous dipterocarp-oak forest, lower montane-oak forest, lower montane scrub and pine-deciduous dipterocarp (20 species namely *Dendrobium chiangdaoense, D. cuspidatum, D. denudans, D. dixonianum, D. elliottianum, D. garrettii, D. kanburiense, D. mucronatum, D. obchantiae, D. peguanum, D. perpaulum, D. porphyrochilum, D. proteranthum, D. pycnostachyum, D. strongylanthum, D. venustum* var. *veuustum*, D. *venustum* var. *delacourii*, *Dendrobium* sp.1, *Dendrobium* sp.2 and *Dendrobium* sp.3, while a few species occur in mangrove forest and tropical rain forest in south-eastern

and peninsular Thailand (*D. confinale* and *D. incurvum*). This information is quite useful for distinguishing species in case they looking similar such as *D. garrettii* is similar to *Dendrobium* sp.1 or *D. venustum* var. *delacourii* but *D. garrettii* can be distinguished from the 2 species by its upper montane rain forest habitat while the 2 species are grown in dipterocarp forest.

6.3 Anatomical study

The study provided some anatomical features which are useful for species grouping and identification of Thai *Stachyobium* viz. cuticular ornamentations (striae-nett cuticle, long-parallel cuticle, smooth cuticle), type of stomata (tatracytic, pentacytic and hexacytic stomata), type of stomatal distribution (hypostomatic and amphistomatic leaf), type of trichomes (peltate glandular trichome type I and type II) and type of inclusions (raphide crystal, druse crystal and prismatic crystal).

6.4 Palynological study

The pollinia shape of the *Stachyobium* can be divided into 2 types, 1. obliquely ellipsoid and 2. globose. Pollen of most species are tetrad, inaperture and the exine sculpturing are psilate. Furthermore, the degree of surface sculpturing (pitting) can be categorized into 2 types, *i.e.* 1. The exterior surface is flattened and shallow and 2. The exterior surface is bulge and deep. These characters are useful for species grouping.

6.5 The total account of the *Dendrobium* section *Stachyobium* in Thailand

Twenty four taxa with including 21 species and 3 varieties of the *Stachyobium* were recognized. Among these two species namely *Dendrobium chiangdaoense* and *D. obchantiae*, is new to Thailand and two species viz. *Dendrobium* sp.2 and *Dendrobium* sp.3 are being proposed as new species. Besides, *Dendrobium* sp.1 is also being proposed as new variety. Plant status was investigated based on 'Thailand Red Data: Plants' (2006) and 'IUCN Red List of Threatened Plants' (1997). Seven species, *i.e. D. confinale, D. dixonianum, D. elliottianum, D. garrettii, D. gregulus, D. mucronatum* and *D. proteranthum* are endemic to Thailand. In addition, 6 species viz. *D. cuspidatum, D. denudans, D. kanburiense, D. peguanum, D. perpaulum* and *D. strongylanthum* are rare species.

One taxon namely *D. delacourii* is reduced from species level to the rank of variety under the name *D. venustum* var. *delacourii* Promm., Kidyoo & Suddee, *stat. nov.*

Furthermore, five names are recognized as synonyms including *D. eserre* is reduced to be a synonym of *D. dixonianum*. *D. kratense* and *D. erostelle* are reduced to be synonyms of *D. incurvum*. The other two names, *D. nanocompactum* and *D. wilmsianum* are reduced to be synonyms of *D. compactum*. Two species namely *D. eriaeflorum* and *D. monticola* were recorded from Thailand by Seidenfaden (1985). In fact, they were misidentified and are not found in Thailand.

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APPENDIX

VITA

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1. Wittaya Graduate Fund

2. The 90th Anniversary of Chulalongkorn University Fund (Ratchadaphisek somphot Endowment Fund)

3. Overseas Research Experience Scholarship for Graduate Student (for study type specimens at Denmark and United Kingdom)

RESEARCH PUBLICATIONS

1. Prommanut, P., Kidyoo, M., Buddhawong, W. and Suddee, S. 2017. Dendrobium chiangdaoense (Orchidaceae), a new species from Thailand. Phytotaxa 307 (1): 84–88.

2. Prommanut, P., Kidyoo, M. and Suddee, S. 2018. A narrow endemic new species of Dendrobium sect. Stachyobium from Thailand (Orchidaceae: Malaxideae). Phytotaxa 348 (2): 90–98.

AWARDS

1. The 1st runner-up award for oral presentation at the 11th Botanical Conference of Thailand, 14th–16th June 2017, Faculty of Science, Mahidol University, Bangkok. Thailand.

2. 1st Place in the Student Outstanding Award (Oral Presentation) in the 17th Flora of Thailand Conference, 21th–25th August 2017, Krabi, Thailand, and presented a paper entitled: Taxonomic revision of Dendrobium Sw. Section Stachyobium Lindl. in Thailand.

3. 1st Place in the Student Outstanding Award (Oral Presentation) for oral presentation at the 12th Botanical Conference of Thailand, 14th–16th June 2018, Faculty of Science, Mahasarakham University, Mahasarakham. Thailand.