TAXONOMIC REVISION AND POLLINATION BIOLOGY OF ORCHID GENERA *Crepidium* Blume AND *Dienia* Lindl. (MALAXIDINAE, ORCHIDACEAE) IN THAILAND

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A Dissertation Submitted in Partial Fulfillment of the Requirements
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การทบทวนอนุกรมวิธานและชีววิทยาการถ่ายเรณูของกล้วยไม้สกุล *Crepidium* Blume และ *Dienia* Lindl. (MALAXIDINAE, ORCHIDACEAE) ในประเทศไทย

น.ส.อัญชลี น่วมมี

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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Dissertation Title	TAXONOMIC REVISION AND POLLINATION BIOLOGY OF ORCHID GENERA *Crepidium* Blume AND *Dienia* Lindl. (MALAXIDINAE, ORCHIDACEAE) IN THAILAND
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อัญชลี น่วมมี : การทบทวนอนุกรมวิธานและชีววิทยาการถ่ายเรณูของกล้วยไม้สกุล *Crepidium* Blume และ *Dienia* Lindl. (MALAXIDINAE, ORCHIDACEAE) ในประเทศไทย. (TAXONOMIC REVISION AND POLLINATION BIOLOGY OF ORCHID GENERA *Crepidium* Blume AND *Dienia* Lindl. (MALAXIDINAE, ORCHIDACEAE) IN THAILAND) อ.ที่ปรึกษาหลัก : ผศ. ดร.ต่อศักดิ์ สีลานันท์, อ.ที่ปรึกษาร่วม : Dr.Henrik Æ. Pedersen

กล้วยไม้ดินสกุล *Crepidium* Blume และ *Dienia* Lindl. ได้มีการรายงานในประเทศไทยโดย Gunnar Seidenfaden ภายใต้สกุล *Malaxis* ซึ่งรายงานเพียงรูปวิธานและภาพวาดลายเส้น แต่ขาดคำบรรยายลักษณะชนิด จึงทำให้ยากแก่การกำหนดขอบเขตชนิดที่ชัดเจน นอกจากนี้มีการค้นพบกล้วยไม้ชนิดใหม่เพิ่มเติม จึงทำให้จำนวนชนิดที่ไม่มีความแน่นอน ดังนั้น การศึกษาทบทวนอนุกรมวิธานของกล้วยไม้สกุล *Crepidium* และ *Dienia* ในประเทศไทยจึงมีความจำเป็นอย่างยิ่ง ผลการศึกษาพบว่าลักษณะของเส้าเกสรและแคลลัสบนกลีบปากเป็นลักษณะสำคัญที่สามารถนำมาใช้ในการกำหนดขอบเขตระดับสกุลของกล้วยไม้สองสกุลนี้ นอกจากนี้ลักษณะทางสัณฐานวิทยา ได้แก่ ลักษณะของลำต้นและใบ รูปร่างของกลีบปาก ติ่งกลีบปาก ขอบและจำนวนซี่ฟันของกลีบปาก รวมทั้งสันนูนบนโพรงกลีบปากเป็นลักษณะสำคัญที่สามารถนำมาใช้ในการจัดจำแนกและระบุชนิดได้ การศึกษาทบทวนทางอนุกรมวิธานพบกล้วยไม้สกุล *Dienia* เพียง 1 ชนิด และสกุล *Crepidium* จำนวน 25 ชนิด ซึ่งเป็นชนิดที่ไม่เคยมีรายงานในประเทศไทย 4 ชนิด คือ *C. bahanense* (Hand.-Mazz.) S. C. Chen & J. J. Wood, *C. josephianum* (Rchb. f.) Marg., *C. maximowiczianum* (King & Pantl.) Szlach. และ *C. micranthum* (Hook. f.) Szlach. และพืชชนิดใหม่ของโลก 1 ชนิด คือ *C. falcifolium* Nuammee, Seelanan & H. A. Pedersen นอกจากนี้ยังมีชนิดที่ย้ายจากสกุลอื่นมา 2 ชนิด คือ *C. chamaeorchis* (Schltr.) Nuammee, Seelanan, Suddee & H. A. Pedersen และ *C. szemaoense* (Tang & F. T. Wang) Nuammee, Seelanan, Suddee & H. A. Pedersen.

การศึกษาชีววิทยาการถ่ายเรณูของ *C. acuminatum* (D. Don) Szlach. และ *D. ophrydis* (J. Koenig) Ormerod & Seidenf. พบว่า *C. acuminatum* เป็นกล้วยไม้ที่ถ่ายเรณูข้ามต้นและต้องพึ่งพาแมลงพาหะในการถ่ายเรณู ส่วน *D. ophrydis* เป็นกล้วยไม้ที่ถ่ายเรณูในต้นเดียวกัน โดยอาศัยกลไกการถ่ายเรณูด้วยน้ำฝน ผ่านกระบวนการการสร้าง viscous drop และแรงดึงของน้ำ โดยทั้ง *C. acuminatum* และ *D. ophrydis* สามารถสร้างน้ำต้อยเพื่อดึงดูดแมลงพาหะ สำหรับปริมาณการติดฝักตามธรรมชาติ *C. acuminatum* มีการติดฝักที่ต่ำมาก อาจเนื่องมาจากไม่สามารถถ่ายเรณูในต้นเดียวกันได้ ปัจจัยจำกัดมาจากแมลงพาหะและปัจจัยอื่น ๆ จากสิ่งแวดล้อม ในขณะที่ *D. ophrydis* อาจจะใช้น้ำต้อยเพื่อเพิ่มโอกาสในการถ่ายเรณูข้ามต้น แต่กลไกการถ่ายเรณูด้วยน้ำฝนกลับเป็นยุทธวิธีที่สำคัญที่สามารถรับประกันการติดฝักในเวลาที่แมลงพาหะในธรรมชาติขาดแคลน

สาขาวิชา พฤกษศาสตร์
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ลายมือชื่อนิสิต ....
ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
ลายมือชื่อ อ.ที่ปรึกษาร่วม ....

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Anchalee Nuammee : TAXONOMIC REVISION AND POLLINATION BIOLOGY OF ORCHID GENERA *Crepidium* Blume AND *Dienia* Lindl. (MALAXIDINAE, ORCHIDACEAE) IN THAILAND. Advisor: Asst. Prof. Tosak Seelanan, Ph.D., Henrik Æ. Pedersen, Ph.D.

The terrestrial orchid *Crepidium* Blume and *Dienia* Lindl. in Thailand were enumerated by Gunnar Seidenfaden under *Malaxis* with key and drawings. Because of no species descriptions in publication, it is difficult to delimit species boundary. Moreover, recent discovery of new species results in unreliable assessment of species, therefore, the taxonomic revision of *Crepidium* and *Dienia* in Thailand should be carried out. The results indicated that the column and transversal callus on labellum are taxonomically important characters to delimit these two genera. In addition, morphological characters, i.e. stem and leaf morphology, labellum auricles, margins and number of teeth on distal margin of labellum, and high ridges on labellum cavity, are useful characters to classify and identify to species. It is suggested that only 1 species of *Dienia* and 25 species of *Crepidium* are distributed in Thailand. Four species are new records for Thailand, namely, *C. bahanense* (Hand.-Mazz.) S. C. Chen & J. J. Wood, *C. josephianum* (Rchb. f.) Marg., *C. maximowiczianum* (King & Pantl.) Szlach. and *C. micranthum* (Hook. f.) Szlach. and a new species, *C. falcifolium* Nuammee, Seelanan & H. A. Pedersen. Furthermore, the two new combinations are made and substantiated, i.e. *C. chamaeorchis* (Schltr.) Nuammee, Seelanan, Suddee & H. A. Pedersen and *C. szemaoense* (Tang & F. T. Wang) Nuammee, Seelanan, Suddee & H. A. Pedersen.

The investigation on pollination biology of *C. acuminatum* (D. Don) Szlach and *D. ophrydis* (J. Koenig) Ormerod & Seidenf. indicated that *C. acuminatum* is likely cross-pollinated orchid that relies on pollinators for successful pollination. In contrary, *D. ophrydis* is autonomous self-pollination assisted by rain whose pollination mechanism was assisted by viscous drops and water adhesion. Both *C. acuminatum* and *D. ophrydis* produced and secreted nectar to possibly attract pollinators. The much lower percentages of natural fruit set of *C. acuminatum* may be due to self-incompatibility, pollinator limitation, coupling with other environmental factors. Whilst, *D. ophrydis* may employ nectar as attractant to pollinators in order to increasing chance for outcrossing but autonomous self-pollination assisted by rain thus seem to be an important strategy that guarantees fruit set when pollinator's visits are scarce.

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Student's Signature ....
Advisor's Signature ....
Co-advisor's Signature ....

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Anchalee Nuammee

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CHAPTER I
INTRODUCTION

1.1 Background and rationales

In Thailand, species in *Crepidium* and *Dienia* were reported by Seidenfaden (1978) under *Malaxis*. Later on Seidenfaden (1997) revised and transferred 19 species of *Malaxis* to *Crepidium* and one species to *Dienia*, following Szlachetko generic concept (Szlachetko, 1995). Since then, only Margońska (2005b) reported a new species from Thailand namely *Crepidium klimkoanum* Marg. Although the taxonomic works of Seidenfaden were excellent, not only providing key to species but also drawings and numerous notes, however, his compilation did not provide any species description.

In addition, from field surveys and preliminary study of some herbarium specimens of *Crepidium* it was found that many specimens could not be ascertained by key to species of Seidenfaden (1978). It can be seen that species accounts of *Crepidium* throughout Thailand are incomplete and still uncertain. Therefore, taxonomic works of *Crepidium* in Thailand are still in much needed.

For *D. ophrydis*, only a few specimens from Thailand were examined. Despite *D. ophrydis* was reported as only one species of *Dienia* in Thailand by Seidenfaden (1978; 1997), however, this species is extremely variable in term of morphology such as greenish-yellow to dark purple flowers and leaf size. More field works are needed to study the variation within *D. ophrydis* populations in Thailand.

Another aspect within these two genera is reproductive biology. Flowers of *Crepidium* and *Dienia* are small and labellum positioned above column, i.e. non-resupinate flower thus lacking any horizontal supports to facilitate potential pollinators, e.g. insects, birds or small animals, to land on flowers to transfer pollinia from one flower to another. Yet, some authors suggest that *Dienia* is self-pollination (Ibrahim *et al.*, 2011) and some small insects such as those in Hymenoptera or Diptera may involve in pollination of *Crepidium* (Margońska, 2005a). However, there have not been any reports based on field experiment. Preliminary field observation revealed that there are many flowers of *Dienia ophrydis* (J. Koenig) Ormerod & Seidenf., whose pollinia had been placed on stigma cavity. The first hypothesis is *D. ophrydis* may be self-pollination through rain-assisted autogamy, because this mechanism can be found in other various tropical orchids (Pansarin *et al.*, 2008b). The second hypothesis, based on short observation, is that some small insects may walk directly on the inflorescence, somehow detach, carry and transfer pollinia to the same flower or another flower in order to verify which hypothesis is more likely. Details study in the field is needed.

Furthermore, the different success of fruit setting in different species have been observed in the field (Tosak Seelanan, unpublished data). Most *D. ophrydis* plants have high percentage of natural fruit set, nearly the whole inflorescence carrying fruits, whereas *Crepidium* species have much lower in fruit set, approximately 1–4 fruits/inflorescence. It is, therefore, of interests to conduct field observation so that it may reveal the information on reproductive biology of some species and may shed some light that may be applicable to other members of these two genera.

It can be seen that the taxonomy of *Crepidium* and *Dienia* in Thailand is still uncertain. In addition, the knowledge of pollination biology within both genera is still poor. Consequently, this research aims to revise taxonomy of *Crepidium* and *Dienia* by using morphological characters together with field data in order to provide complete species descriptions and other information. Additionally, field observation will employed to reveal information about pollination biology of some species in *Crepidium* and *Dienia* in Thailand.

1.2 Aim of this study

1. To compile taxonomic accounts on *Crepidium* and *Dienia* in Thailand.
2. To investigate the pollination biology of some species in *Crepidium* and *Dienia*.

1.3 Anticipated benefits

The results of this research will be beneficial to the completion for the Flora of Thailand–Orchidaceae, and to accommodate the model for future taxonomic study and pollination biology in tropical members of Orchidaceae.

CHAPTER II
LITERATURE REVIEWS

2.1 Orchid characters and classifications

2.1.1 General morphological characters of the Orchidaceae

The Orchidaceae is one of the largest and most diverse families of plants. Naturally, the orchids share many features with related groups of monocot e.g. scattered vascular bundles, parallel leaf venation, flower parts in threes and inferior ovary (Dressler, 1981). However, the general morphology and the major distinguishing features of orchids can be found as below.

Plant habit and habitat

Because orchids can adapt vegetative morphology to response to adverse environmental conditions, in particular the problems of water conservation, so that orchids can be found worldwide and almost every habitat types, e.g. on the permanently moist floor of the lowland tropical rain forest, in the uppermost branches of tall forest trees, on rocks near the summit of tropical mountains, in grassy and marshy areas, on land slips and roadsides, and even on the margins of deserts (Pridgeon *et al.*, 1999).

Orchids can be terrestrial (Fig. 2.1A), epiphytic (Fig. 2.1B) and lithophytic (Fig. 2.1C). However, some lithophytic orchid can grow close to streams with markedly varying water level that they become submerged for several months each year and can tolerate to this habit. This orchids are known as rheophytic orchids (Fig. 2.1D), it seems that only a few orchids are rheophytic such as *Epipactis flava* Seidenf. (Pedersen *et al.*, 2013). In the tropics, the majority of orchids are epiphytic on forest trees, or lithophytic on the rocks and cliffs, but a significant minority is terrestrial, growing on the forest ground. The epiphytes can be lithophytic where the rainfall is sufficient. It is not uncommon to find the same species growing on trees and rocks in the same locality. In such cases orchids that are usually epiphytic can grow terrestrially. In temperate region orchids predominate in the terrestrial habit, especially in grassland and woodland as well as wet meadows, fens, and bogs. Some orchids can grow in floating vegetation mats near the edges of ponds and streams. Some of terrestrial orchids are achlorophyllous, bearing only scale leaves or lacking leaves altogether and reliant on their mycorrhizal fungi for nutrients throughout their life and most appear above ground only at flowering time for pollination and seed dispersal. These orchids are usually referred as mycoheterotrophic orchids (Fig. 2.1E) (Dressler, 1981; Pridgeon *et al.*, 1999).

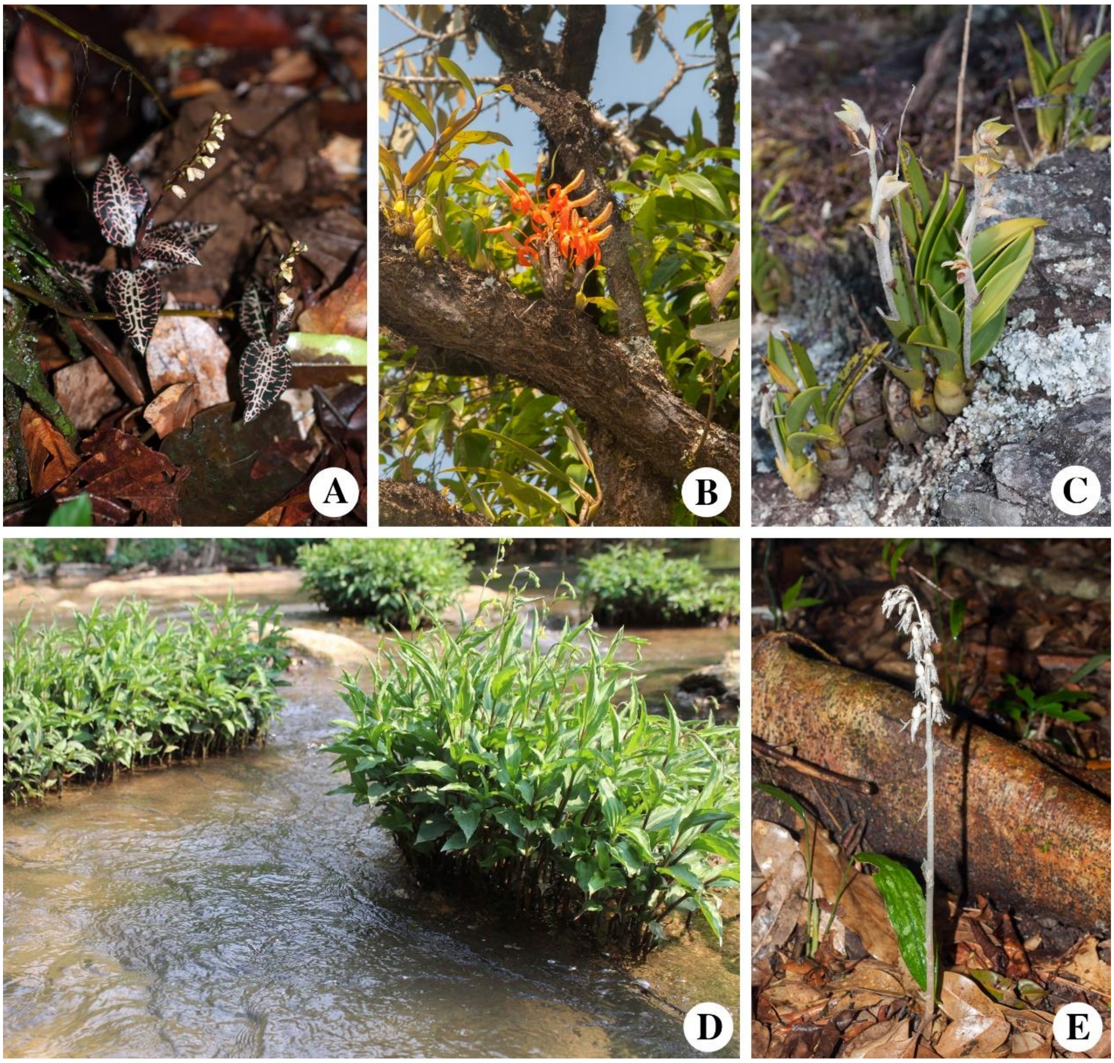

Figure 2.1 Habit of orchids. **A:** Terrestrial orchids. **B:** Epiphytic orchids. **C:** Lithophytic orchids. **D:** Rheophytic orchids (Photo by Yanisa Punsung). **E:** Mycoheterotrophic orchids.

Roots

Orchid roots may have one or more functions, e.g. attachment to the substrate, anchorage in substrate, absorption of water and nutrients, photosynthesis, litter-gathering, and as a link between orchid and mycorrhizal fungus (Pridgeon *et al.*, 1999). Orchid roots, being monocots, never have a taproot or primary root like that of most dicots. The entire root system is made up of adventitious roots that arise from the stem. These can vary greatly in thickness. Although most terrestrial orchids have a simple rhizodermis, some terrestrials and virtually all epiphytes have a velamen. The velamen is usually a spongy, whitish sheath around the root, multiple epidermis, comprising one to eighteen layer of cells which die as the root matures, separated from the cortex by an exodermis (Fig. 2.2A–B). The structure and physiology of the velamen and underlying exodermis are adapted for attachment to the substrate and water, and nutrient uptake in a periodically dry environment (Pridgeon, 1987). The velamen is most obvious in epiphytic orchids, but it is also present in most terrestrial orchids as well as in some Liliaceae and Araceae (Dressler, 1981; 1993).

Epiphytic orchids can have several types of roots. Aerial roots are generally cylindrical, whereas those on the substrate are dorsoventrally flatted roots. In many terrestrial orchids the roots are storage organs and consequently are swollen and often tuberous, whereas roots of some mycoheterotrophic orchids can be abbreviated and vestigial. In *Neottia* coralloid roots are present, and *Corallorhiza* coralloid rhizome are present, in which the main absorptive function is assumed by the mycorrhizal fungi (Fig. 2.2C). Furthermore, many orchids have photosynthetic roots such as in some vandaceous orchids and in the leafless orchids of such genera as *Taeniophyllum* (Fig. 2.2D) and *Chiloschista*, the roots have entirely taken over the photosynthetic function (Pridgeon *et al.*, 1999).

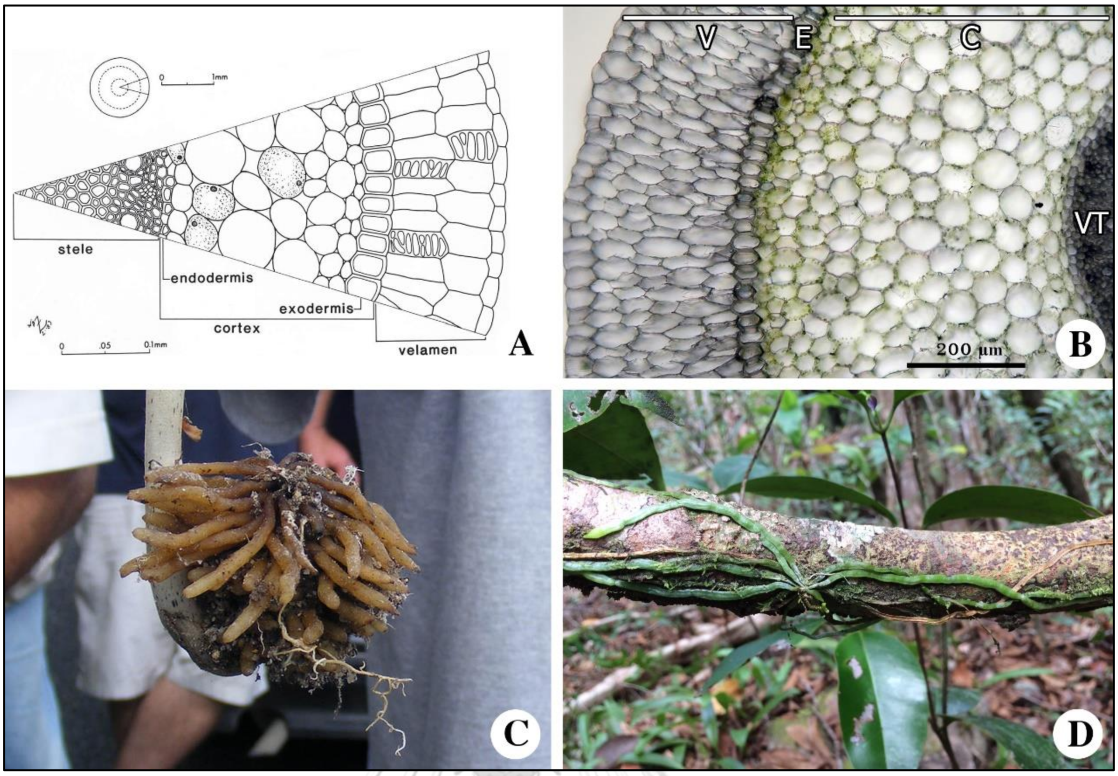

Figure 2.2 Root of orchids. **A:** Drawing from *Restrepiella ophiocephala* by Wendy Zomlefer showing typical root tissue zones of epiphytic orchids (Stern, 2014). **B:** Multiple velamen of orchid root (Courtesy of Dr. Chumpol Khunwasi; V = Velamen, E = Exodermis, C = Cortex, VT = Vascular tissue). **C:** Root system of *Neottia nidus-avis* (Courtesy of Susan Walter). **D:** Photosynthetic roots of *Taeniophyllum*.

Stems

Orchids can have one of two growth patterns, either sympodial or monopodial. In sympodial growth the apex of each shoot terminates in a flowering axis, the subsequent vegetative shoot emerges from a node below the apex of the new shoot. Usually the new growth is produced annually or seasonally. In monopodial growth, the stem apex is of indeterminate growth and the inflorescences are borne laterally. Monopodial growth is found in vanilloid and vandoid orchids (Dressler, 1981; 1993; Pridgeon *et al.*, 1999).

Rhizomes are horizontal or ascending stem of sympodial orchids, either below or on the substrate surface. Along the rhizomes are distichously arranged scale leaves and the renewal bud which develop as aerial or erect shoot and may become pseudobulbous. Pseudobulbs are swollen or thickened stems, essentially water-storage organs of sympodial orchids. A pseudobulb may be made up of a single thickened internode (heteroblastic) or several (homoblastic). On the other hand, corms are underground swollen storage organs in such genera *Eulophia* and *Spathoglottis*. In many orchids the pseudobulbs or stems are green and photosynthetic. The leaves of some species are so small that the pseudobulb functions as the main photosynthetic organ (Pridgeon *et al.*, 1999).

Leaves

The leaves of orchids perform the main photosynthetic function in most species. In most orchids, the leaves are arranged distichously. However, in some species can be spirally arranged on the stem or reduced to a single terminal leaf. In a few orchids the leaves are borne opposite one another (Pridgeon *et al.*, 1999).

Orchid leaves are typical monocotyledon leaves with parallel longitudinal venation, usually linked by less obvious commissural veins. However, reticulate venation is rare in orchids, it only found in genus *Epistephium* and *Clematepistephium* from south American and the new Caledonian, respectively (Cameron, 1998). Leaf venation can be systematically informative.

Leaf vernation has been used as a systematically useful character. Among the primitive groups the developing leaves are rolled, or convolute. Leaves that are convolute in development may be either plicate or soft herbaceous. In the plicate, or pleated condition, several veins are prominent and the leaf is usually folded at each vein. In many orchid species, especially among the epiphytes, the leaves are duplicate during development, or folded once with each half flat. So that leaves always become conduplicate, that is, with a single fold at the mid-vein and broadly V-shaped in cross-section, the veins of the leaf blade all being similar in size and not prominent. The leaves plicate vernation are usually found in most terrestrial orchids and conduplicate vernation are found among epiphytes (Dressler, 1981; 1993).

Leaf shape in orchids is relatively uniform for many genera. Most orchids have simple, linear, lanceolate, oblanceolate, ovate, or elliptic leaves. However, fan-shaped and palmate leaves are found in a few orchid species. In many orchids the leaves have sheathing base which closely clasps the stem. Leaf articulation is found only in subfamily Epidendroideae. The abscission layer is usually between the leaf blade and leaf sheath (Pridgeon *et al.*, 1999).

Inflorescences

Inflorescences of orchids may be produced from any part of the stem. The ancestral state is terminal inflorescence of a shoot axis. The derived status is inflorescence borne lateral, produced from the side or base of shoot or from a rhizome. The most common inflorescence type is the raceme. However, compound raceme inflorescences or panicles are not uncommon in orchids, in particular panicles occur in many epiphytic genera but rare among terrestrials. The other inflorescence type is the cyme, found in some genera such as *Lockhartia* (Pridgeon *et al.*, 1999).

Moreover, solitary flowers that borne one at a time, either sessile or on a shorter or longer peduncle, are found in many genera such as *Bulbophyllum*, *Corybas* and some species of *Paphiopedilum* (Pridgeon *et al.*, 1999).

Flowers

Normally, the labellum lies uppermost and column lowermost in bud. The condition when the labellum is lowermost in opening orchid flowers can originate in a number of ways, e.g. by 180° twisting of the ovary and pedicel, by the inflorescence being pendulous, and by the flower bud tipping over on the time of anthesis (Ames, 1938). This phenomenon provides labellum as the landing platform for pollinators. However, some orchid flowers are nonresupinate, i.e. pedicel and ovary either do not twist during development (e.g. *Satyrium*) or else twist through 360° (e.g. *Angraecum*), so that the labellum is still uppermost. There are many examples of nonresupinate flowers in Orchidoideae and Epidendroideae (Pridgeon *et al.*, 1999).

The floral structure of orchids are characterized by two whorls of three perianths, and a gynostemium, a flowers is epigynous. The outer whorl of perianth is calyx, which consists of three sepals. The two lateral sepals differ slightly from the third median sepal, called dorsal sepal. In some orchids such as *Dendrobium*, *Bulbophyllum* and *Eria*, the lateral sepals are united at base forming the mentum. In Cypripedioideae the lateral sepal are united from base to apex, forming a synsepal (Dressler, 1981; 1993; Pridgeon *et al.*, 1999).

The corolla comprises of three petals. The two lateral petals differ markedly from the third median petal, which lies at the lowermost of the flowers in resupinate flowers. The lateral petals are often showy and coloured. The third petal, called labellum or lip, is highly modified. It is the import adaptation to facilitate cross-pollination. The labellum, including visual cues and fragrance glands, acts as an attractant and/or landing platform. Labellum shape and its features can be diagnostic in orchid classification (Dressler, 1981; 1993; Pridgeon *et al.*, 1999).

The reproductive organs of orchid shows the greatest modifications from the basic of monocotyledon. Androecium and the style and stigma are fused into a single structure, called column or gynostemium. However, in Apostasioideae, only filaments and style are fused; *Neuwiedia* has three functional stamens but in *Apostasia* where the median stamen is sterile or absent. Similarly, only two lateral stamens in Cypripedioideae are fertile. In other orchids, a single median stamen lies at the apex of column with the other two either sterile or absent (Dressler, 1981; 1993; Pridgeon *et al.*, 1999).

The anther of orchids does not contain powdery pollen as in other angiosperms but forms is discrete waxy masses called pollinia. The pollinia are attached to a stalk to a well-defined sticky organ, called viscidium. Pollen stalks that attach the pollinia to the viscidium can have various origins. Those that originate in the anther are called caudicles. Most vandoid orchids have a strap of non-sticky tissue, called the stipe, derived from rostellar tissue instead of anther tissue. The pollinia, pollen stalk and viscidium together comprise a pollination unit termed pollinarium which carried by pollinator. Normally, pollinarium is covered by the anther (Dressler, 1981; 1993; Pridgeon *et al.*, 1999).

The stigma of orchids is positioned on the ventral surface of the column. The stigma is a sticky lobed situated below and behind the anther, but in some terrestrial orchids such as *Habenaria*, the stigma is bilobed with the receptive surface at the apex of each lobe. In many species, the pollinia are transferred to the pollinators by a modified lobe of the stigma called the rostellum, which acts as the projecting flap that catches the pollinia and directs pollinia into the stigmatic cavity (Dressler, 1981; 1993; Pridgeon *et al.*, 1999).

Fruits

Orchid fruit develops from ovary into capsule that is dehiscent by 3 or 6 longitudinal slits. Orchid capsules can be variously ornamented with papillae, setae, spines, ridges or beaks. The young, developing capsules are usually green and photosynthetic. Mature capsules of terrestrial orchids are generally erect, thin-walled rather dry and papery whereas those of epiphytes are usually pendent, thicker-walled, and often fleshy (Dressler, 1981; 1993).

Seeds

Orchid seeds are generally almost microscopic and very numerous, in some species over a million per capsule. Most orchids have a loose, rather thin-textured seed coat around the embryo and lacking endosperm, usually ranging from 8–10 µm up to 5 mm in length (Stoutamire, 1974; Dressler, 1981; Arditti, 1992). Because of lacking endosperm, the seeds have to enter symbiotic relationships with various mycorrhizal fungi that provide them necessary nutrients to germinate.

2.1.2 Taxonomic history and classification of Orchidaceae

The first study of orchid appeared by Pedanius Dioscorides who described an orchid as "*Orchis*" in his De Materia Medica (c. 70 AD). This orchid was mentioned by the testicle-like tubers. "Orchis" is the Greek word that means testicles of man.

However, the taxonomy of the orchids started during the last 150 years ago by Carolus Linnaeus (1753) who first recognized 69 species of orchids in 8 genera, namely *Orchis*, *Satyrium*, *Ophrys*, *Serapias*, *Limodorum*, *Arethusa*, *Cypripedium* and *Epidendrum*, published in the well-known book **Species Plantarum**. However, Linnaeus did not design the family name of these plants.

Until in 1789, Antonie Laurent de Jussieu recognized the family name Orchidaceae and published in his **Gernera Plantarum** (Jussieu, 1789).

In 1800, Olaf Swartz was the first specialist of orchid taxonomy; he published a critical review in orchid literature, a morphological analysis, and a classification with key to 25 genera of orchids in **Afhandling om Orkidernes slägter och deras systemmatiska indenlning**. Moreover, he also was the first who separated orchids into 2 groups, namely monandrous and diandrous orchids. He mentioned that most orchids had one stamen whereas slipper orchids had two stamens (Swartz, 1800).

At the beginning of the nineteenth century the knowledge of tropical orchids grew quickly with the works of many botanists such as Brown (1810), du Petit-Thouars (1809; 1822), Richard (1817), and Blume (1825a; 1825b). They studied orchids in tropics and added characters as new genera.

In the next period of orchid studies, orchid systematics was emphasized on evolution of orchids. John Lindley (1826–1840), who was generally known as the father of modern orchid classification, was the first using a category in classification and recognized 4 tribes of orchids (namely Neottieae, Orchideae, Epidendreae and Cypripedieae) in **Orchidearum Sceletos** (Lindley, 1826). He also published **Genera and Species of Orchidaceous Plants** which described 1,980 species and classified into 7 tribes, i.e. Malaxeae, Epidendreae, Vandeae, Ophreae, Arethuseae, Neottieae and Cypripedieae (Lindley, 1830).

In 1881, George Bentham published a new classification, modified from Lindley’s system. He classified Orchidaceae into 5 tribes, i.e. Cypripedieae, Ophrydeae, Neottieae, Epidendreae, and Vandeae. Bentham used caudicles and other characters in orchid for classification at the tribal level and introduced the term stipes for pollinium stalk in the Vandeae .

Friedrich Richard Rudolf Schlechter (1926) recognized 2 subfamilies, Cypripedioideae and Orchidoideae, in 610 genera. However, he separated Apostasiaceae as a family in **Das System der Orchidaceen**.

In the essay **On the origin of Orchidaceae** of Leslie Garay (1960), he divided orchids into 5 subfamilies including Apostasioideae, Cypripedioideae, Orchidoideae, Neottioideae, and Epidendroideae.

Robert Louis Dressler (1981) published the new classification system in **The Orchids: Nature History and Classification** which is widely accepted by many botanists. Then, it has been modified in his second book on orchid classification namely **Phylogeny and Classification of Orchid family** (Dressler, 1993). Dressler considered in evolution and interrelationships of the subfamilies. He recognized 5 subfamilies, namely Apostasioideae, Cypripedioideae, Spiranthoideae, Orchidoideae and Epidendroideae, and at lower rank are classified into 22 tribes, 70 subtribes, 850 genera and about 30,000 species.

In the recent orchid classification by Alec M. Pridgeon, Phillip J. Cribb, Mark W. Chase and Finn N. Rasmussen in **Genera Orchidacearum**, Orchidaceae is classified into 5 subfamilies, namely, Apostasioideae, Cypripedioideae, Orchidoideae, Vanilloideae and Epidendroideae, based on morphological characters, molecular data, phylogeny and evolution (Pridgeon *et al.*, 1999; 2001; 2003; 2005; 2009; 2014).

Presently, the family Orchidaceae is currently placed in the order Asparagales (APG IV, 2016) which is recognized as 5 subfamilies including Apostasioideae, Vanilloideae, Cypripedioideae, Orchidoideae and Epidendroideae (Chase *et al.*, 2015). In this classification system, it is similar to Pridgon *et al*. (1999–2014) except the position of subfamily Vanilloideae is relocated (Fig. 2.3).

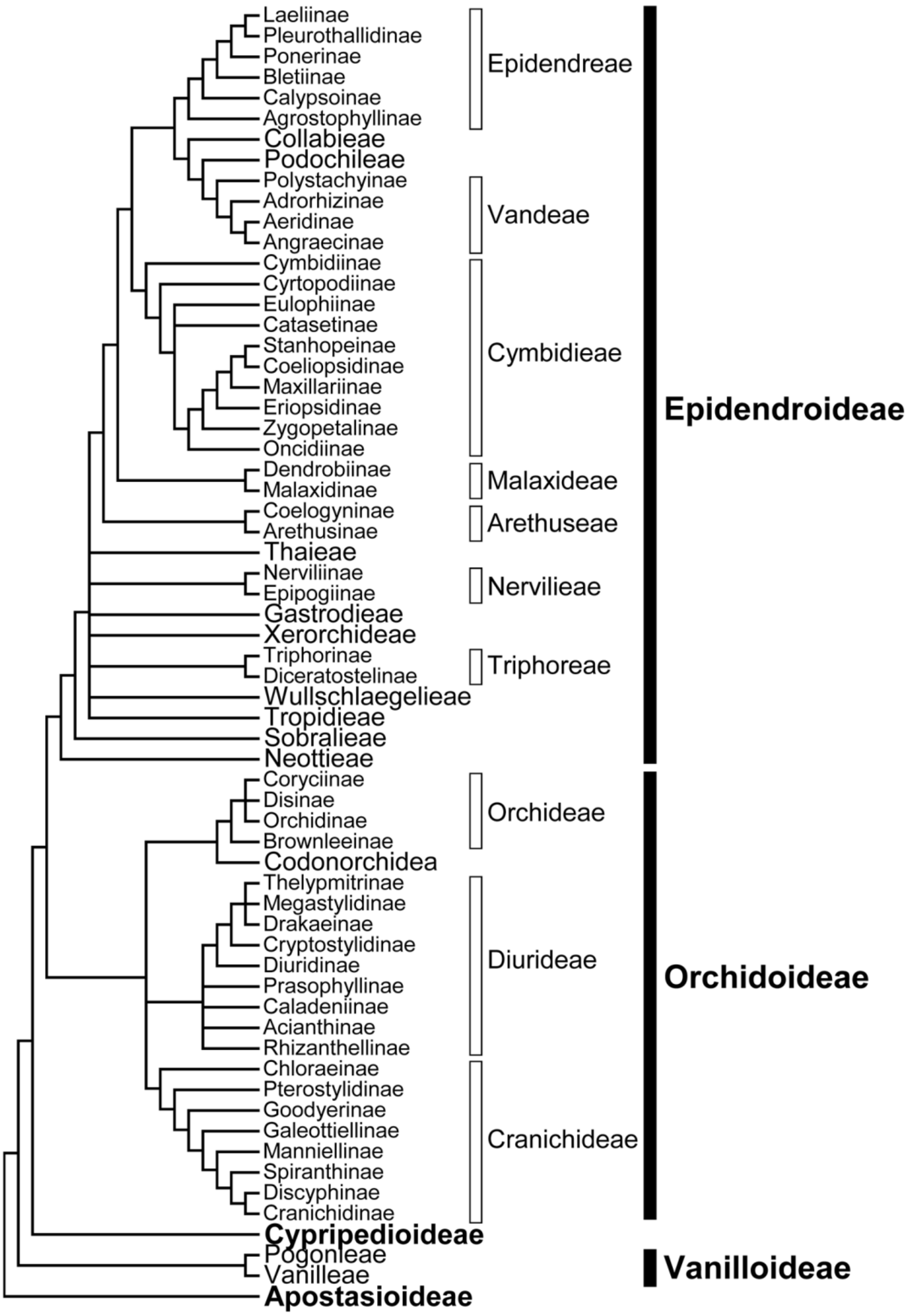

Figure 2.3 A classification summary tree for the subfamilies, tribes and subtribe of Orchidaceae (adapted from Chase *et al*., 2015).

2.1.3 General morphological characters of tribe Malaxideae and subtribe Malaxidinae

Tribe Malaxideae is characterized by naked pollinia without caudicles. Pollinia are four often clavate in shape in two pairs, and lack or with tiny visidium. Most taxa are terrestrial or epiphytic, rarely lithophytic. *Stem* are cylindrical to swollen pseudobulous or cormous with one or several internodes, or creeping rhizome. *Roots* have velamen, usually of the *Malaxis* type. *Leaves* have only one to several, thin-textured to fleshy, plicate or conduplicate, dorsiventrally flattened or iridiform, rarely terete, alternate to distichous, sheathing at base, articulated or not near base. *Inflorescences* occur on terminal shoot, racemose or subumbellate type, unbranched, flowers arranged in spiral, whorl or distichous. *Flowers* are small to medium-small, resupinate or non-resupinate, usually thin-textured and translucent. Sepals are usually free and spreading but sometimes lateral sepals may be fused. Petals are free and usually reflexed, often smaller than sepals. *Labellum* are entire to lobed, lacking a spur, usually bearing a callus of ridges or mounds, and labellum base are often auriculate. *Column* are short or elongate, often winged at apex and lacking a foot. *Anther* are terminal or subdorsal, two-celled, motile, incumbent or more or less erect. *Pollinia* are four in two pairs, often of unequal size, oblong to clavate, lacking a visidium or with one or two visidia. *Stigma* is entire and ventral. *Rostellum* is flap-like, often emarginated or seldom elongated. *Ovary* is cylindrical and rarely papillose. *Capsules* are fusiform to suborbicular (Dressler, 1993; Pridgeon *et al.*, 2005).

Subtribe Malaxidinae Benth. & Hook. f. is characterized by leaves usually being plicate, sometimes convolute, thin-textured, gathered at the apex of pseudobulb. Columns are short and massive, or slender, erect or arcuate. Anthers are erect to incumbent (Bentham and Hooker, 1883).

2.2 Taxonomic history and taxonomic works relevant to *Crepidium* and *Dienia*

2.2.1 Taxonomic history of *Crepidium* and *Dienia*

Crepidium Blume and *Dienia* Lindl. are closely related genera belonging to subfamily Epidendroideae, tribe Malaxidae and subtribe Malaxidinae. *Dienia* was established by Lindley (1824) on the basis of *D. congesta*. It was characterized by terrestrial plant with plicate leaves, column short and straight, labellum 3-lobed, distinctly concaved, parallel to column, and without auricles. He recognized 7 species of the genus (Lindley, 1830). Until in 1996, Clements and Jones raised *Dienia* as a generic level and recognized 6 species of the genus (Clements and Jones, 1996).

Recently, taxonomic revision by Margońska and Kowalkowska (2008) of *Dienia* in Asia and Australia suggested that there are only two accepted species, i.e. *D. ophrydis* (J. Koenig) Seidenf. and *D. seidenfadeniana* Szlach., Marg. & Rutk. These two species are widely distributed from Asia to Australia and the Pacific islands. One species, *D. ophrydis*, is widely distributed throughout Thailand.

Crepidium was erected later by Blume (1825b) on the basis of *C. rheedei*. Then, it was demoted to section within the older genus *Microstylis* (Ridley, 1888). In 1978, Seidenfaden later transferred taxa in *Crepidium* to *Malaxis* Sol. ex Sw. (Swartz, 1778) which is the closely related genus in the same subtribe Malaxidinae. Seidenfaden recognized 6 section of *Malaxis*, i.e. section *Malaxis*, *Oberoniiflora* Seidenf., *Gastroglottis* (Blume) Seidenf., *Glossochilus* (Schltr.) Seidenf., *Commelinodes* (Schltr.) Seidenf. and *Crepidium* (Blume) Seidenf.

Until in 1995, Szlachetko reinstated *Dienia* and *Crepidium*, and provided distinguished characters to separate them from *Malaxis*, namely, shape of lip, size and shape of column. However, these characters and other reproductive floral structures found among these genera are similar and cause confusion. Some authors accepted the Szlachetko's conception whereas others refuted. Presently, most taxonomists accepted that *Crepidium* and *Dienia* should be separated from *Malaxis* (Cameron, 2005; Pridgeon *et al.*, 2005; Chen and Wood, 2009a; 2009b; Govaerts, 2011).

The taxonomy works of Szlachetko (1995) on *Crepidium* recognized 167 species and divided into 2 subgenus, viz. *Crepidium* Blume subgenus *Crepidium* and *Crepidium* Blume subgenus *Pseudoliparis* (Finet) Szlach. Moreover, he also recognized two sections within subgenus *Crepidium* i.e. section *Crepidium* and *Commelinoides* (Schltr.) Szlach.

Furthermore, Margońska (2005a) transferred a section *Hololobus* Schltr. of *Microstylis* to *Crepidium.* Nowaday, *Crepidium* can be recognized in 3 sections, i.e. section *Crepidium* is characterized by its erect pseudobulbs and labellum with distinctly toothed distal margins, section *Commelinoides* (Schltr.) Szlach. is characterized by creeping rhizome and labellum with distinctly toothed distal margins, and section *Hololobus* (Schltr.) Marg. is characterized by erect pseudobulbs and labellum with entire distal margins or bilobed at apex (Margońska, 2005b).

In the later year, Margońska (2006) published a new genus, *Seidenforchis*, by transferring 3 species of *Crepidium* that have underground pseudobulbs and leaf blades horizontally flatted situated close to or above ground surface. However, most taxonomists have not accepted Margońska' proposition (Chen and Wood, 2009a; Govaerts, 2011).

In addition, the taxonomic ranks at subsection level within genus *Crepidium* were further assigned by Margońska and Szlachetko from 2005 to 2010. Section *Hololobus* (Schltr.) Marg. were divided into 3 subsections, i.e. *Hololobus*, Maximowiczianae Marg. (Margońska, 2005b), *Prasinae* Marg. (Margońska, 2005c). Whilst section *Commelinodes* Schltr. (Szlach.) were divided into 2 subsections, i.e. *Commelinodes* and *Lowiae* Marg. (Margońska and Szlachetko, 2010).

2.2.2 Taxonomic works of orchids relevant to *Crepidium* and *Dienia* in Thailand and adjacent areas

The terrestrial orchid genera *Crepidium* and *Dienia* are widely distributed in tropical and subtropical regions from India, Himalayas, China, Southeast Asia to Australia (Pridgeon *et al.*, 2005). No members of these two genera are reported from America or Africa, but it has only been reported about the closely related genus, *Malaxis* and *Microstylis*, in those continents.

The taxonomic works of *Crepidium* and *Dienia* were usually reported in the part of Floras or the studies of orchid diversity, for instances, **Flora of British India** (Hooker, 1890), **The orchid of the Sikkim-Himalaya** (King and Pantling, 1898), **Flora of Bhutan** (Pearce and Cribb, 2002), **Flora of China** (Chen and Wood, 2009a; 2009b), **The wild orchids of Hong Kong** (Barretto *et al.*, 2011), **The orchid of Burma** (Grant, 1895), **Flora of Vietnam** (Averyanov, 2013), **The Orchids of Peninsular Malaysia and Singapore** (Seidenfaden and Wood, 1992), **Flora of Malaya** (Holttum, 1964), **Die Orchideen von Java** (Smith, 1905), **Orchids of Sumatra** (Comber, 2001), **Orchids of Sarawak** (Beaman *et al.*, 2001), and **Orchids of Papua New Guinea** (Millar, 1978). However, these publications reported under the outdated names or synonyms, viz. *Malaxis* or *Microstylis*.

Owing the last two decades, many new species of *Crepidium* were discovered from India, Thailand, Philippines, Sumatra, Borneo, West Java, Australia, New Guinea and Solomon Islands, including *C. christinae* Marg. & Szlach., *C. comberi* Szlach. & Marg., *C. cribbianum* Szlach. & Marg., *C. dewildeanum* Szlach. & Marg., *C. dresslerianum* Marg. & Szlach., *C. flammeum* Szlach. & Marg., *C. flavovirens* D.L. Jones & M.A. Clem., *C. klimkoanum* Marg., *C. lyroglossum* Szlach. & Marg., *C. maaikeae* Marg., Szlach. and Kubala, *C. mariae* Szlach. & Marg., *C. meghalayensis* M. Murugesan, Sushil K. Singh & A.A. Mao., *C. mieczyslawi* Marg., *C. novoguineense* Marg., Szlach. & Kubala, *C. ochyreanum* Szlach. & Marg., *C. ravanii* Marg., *C. sarawakense* Szlach. & Marg., *C. sundaicum* Szlach. & Marg., *C. szlachetkianum* Marg., *C. vermeulenianum* Szlach. & Marg., *C. witkowskianum* Szlach. & Marg., and *C. woodianum* Szlach. & Marg. (Jones and Clements, 1997; Szlachetko and Margońska, 1998a; 1998b; 1998c; Margońska *et al.*, 1999; Szlachetko and Margońska, 2000a; 2000b; Margońska and Szlachetko, 2001a; 2001b; Margońska, 2002; Szlachetko and Margońska, 2002; Margońska, 2005b; 2014; Singh *et al.*, 2016). On the other hand, *Dienia* was reported only one species of *D. seidenfadeniana* Szlach., Marg. & Rulk. from Sumatra, Indonesia (Szlachetko *et al.*, 1999).

In Thailand, the first taxonomic account of family Orchidaceae was reported in Flora of Koh Chang by Kraenzlin (1900). The specimens were collected from Koh Chang and nearby islands, and identified as 31 species in 21 genera of orchids, one of them was *Malaxis congesta* (Lindl.) Deb (which is a synonym of *D. ophrydis* (J. Koenig) Ormerod & Seidenf.).

Besides, the important taxonomic works of Thai orchids were provided by Gunnar Seidenfaden and Tem Smitinand during 1959-1965. They explored and collected specimens throughout Thailand and published 858 species of Thai orchids in **The Orchids of Thailand: A Preliminary list** (Seidenfaden and Smitinand, 1959a; 1959b; 1960; 1961; 1963; 1965).

The taxonomic account of *Crepidium* and *Dienia* was initially reported under *Malaxis* by Seidenfaden and Smitinand (1959b). They recognized 17 taxa in their publication. However, some taxa were uncertain and they further mentioned some notes in volume four (Seidenfaden and Smitinand, 1965). In 1969-1970, Seidenfaden worked continuously on *Malaxis*, and published new species and new combinations in **Contribution to the orchid Flora of Thailand 1-2**, i.e. *Malaxis godefroyi* (Rchb. f.) Seidenf. and *M. concava* Seidenf. (Seidenfaden, 1969; 1970).

In 1978, Seidenfaden revised the taxonomic account of *Malaxis*; he recognized 22 species of *Malaxis* as occurring in Thailand and provided key to species, drawings and notes, however, the species and generic descriptions were not included. Later on followed the revised generic classification of Malaxideae proposed by Szlachetko (1995), Seidenfaden (1997) revised and transferred 19 species of *Malaxis* to *Crepidium*, and three species, one each to *Dienia, Glossochilopsis* Szlach. and *Oberonioides* Szlach.

Upon the request from the Office of Natural Resources and Environmental Policy and Planning, Thaithong (1999) enumerated all orchids of Thailand based on scientific publication at the time, and no new taxa of *Crepidium* and *Dienia*, other than those published in Siedenfaden's work (1959-1997), was listed. Later on, however, *Crepidium klimkoanum* Marg., the new species from Thailand, was described by Margońska (2005b).

During the past two decades many taxonomic works on Thai orchids have been published, some relevant to *Crepidium* and *Dienia*, by Thai botanists who studied orchid diversity in area-based exploration around Thailand. The examples of these researches as follow (arranged in chronological order):

Chantanaorrapint and Thaithong (2005) surveyed orchids at Huai Yang Waterfall National Park, Prachuap Khiri Khan Province. Fifty specimens were collected and they belong to 42 species in 27 genera. Two species of *Crepidium*, i.e. *C. macrochilum* (Rolfe) Szlach. and *C. polyodon* (Hook. f.) Szlach., were reported.

Buakhlai *et al.* (2005) studied diversity of orchids at Khao Khiao area in Khao Yai National Park, Nakhon Ratchasima Province. One hundred and six species were identified, and *D. ophrydis* (J. Koenig) Ormerod & Seidenf. was reported.

Damapong (2007) worked on taxonomic study of Orchidaceae at Doi Phahom Pok National Park, Chiang Mai Province. Eighty-five species in thirty-three genera were found and of these, *D. ophrydis* (J. Koenig) Ormerod & Seidenf., *Malaxis acuminata* D. Don [=*Crepidium acuminatum*], *M. calophylla* (Rchb. f.) Kuntze [=*C. calophylla*], and *M. orbicularis* W. W. Sm. & Jeffrey. [=*C. orbicularis*] occur in the area.

Fupunya and Suwanthada (2008) surveyed the rare terrestrial orchids of *Liparis* and *Malaxis* in some forest areas of Khun Mae Kwuang National Reserved Forest. They found three species of *Malaxis* distributed in those areas i.e. *Malaxis acuminata* D. Don [=*C. acuminatum*], *M. calophylla* (Rchb. f.) Kuntze [=*C. calophyllum*] and *M. latifoli*a Sm. [=*D. ophrydis*].

Tippayasri and Ngernsaengsaruay (2008) studied some terrestrial orchid species in Phu Hin Rong Kla National Park, Phitsanulok Province. They reported 24 species in 18 genera of terrestrial orchids and recorded *C. acuminatum* (D. Don) Szlach. grow along the edge of forest, while *D. ophrydis* (J. Koenig) Ormerod & Seidenf. grow in bamboo forest.

Buanaka *et al.* (2009) studied diversity of terrestrial orchids at Pine Camping Area in Phu Soi Dao National Park, Uttaradit Province. They reported 23 species in 23 genera in this area and only *C. orbicularum* (W. W. Sm. & Jeffrey) Seidenf. were recorded for *Crepidium*.

Makerd (2011) worked on taxonomic study of Orchidaceae at Mae Wong National Park, Nakhon Sawan and Kamphaeng Phet Provinces. Sixty-two genera with 162 species were found *Malaxis acuminatum* D. Don [=*Crepidium acuminatum*] was recorded.

Duangdee (2015) worked on orchid diversity along trails to the plateau of Phu Kradueng National Park, Loei Province. Seventy nine species were identified, and one of them was *D. ophrydis* (J. Koenig) Ormerod & Seidenf.

Limkittikul *et al.* (2016) reported species diversity and conservational status of orchids in Huai Yang Waterfall National Park, Prachuap Khiri Khan Province. They reported 25 genera and 27 species of orchid from the areas. Four species of *Crepidium* were recorded, namely *C. acuminatum* (D. Don) Szlach., *C. macrochilum* (Rolfe) Szlach., *C. polyodon* (Hook. f.) Szlach. and *Crepidium* sp.

Rojchana-umpawam *et al.* (2016) studied species diversity of orchids in Ton Nga Chang Wildlife Sanctuary. One hundred and twenty-two species in 69 genera were found. Only one species of *Crepidium*, *C. calophyllum* (Rchb. f.) Szlach., and one species of *Dienia*, *D. ophrydis* (J. Koenig) Ormerod & Seidenf. were recorded.

2.3 Pollination biology of Orchidaceae

2.3.1 History of pollination studies, breeding system and main pollinators in orchids

The orchid family is one of the largest family of angiosperms which contains about 25,000 species widespread in the tropics and temperate (Dressler, 2005; Simpson, 2010). The orchid flowers are highly diverse in morphological features although they are in the same genus because orchids have adaptation of their flowers for pollinated by various insects. Pollination biology of orchids began largely with the work of Charles Darwin (1862), who concentrated mainly on the European species. He described a number of the pollination mechanisms and pollination vectors. After a long period, Neiland and Wilcock (1998) reviewed publication based on field observations of 117 species worldwide on orchid pollinations in several genera. Typically, biotic pollinators of orchids are mainly bees, butterflies, ants, moths, flies, wasps, beetles and birds whereas abiotic pollinators are rain drop and wind.

Based on pollination biology works by Charles Darwin and other biologists from the past to the present years for more than 200 year (Micheneau *et al.*, 2009), the orchid pollination can be mainly divided into two group. The first group exhibits pollinator-dependent pollination with nectar, mimic or deceit reward (Oh *et al.*, 2001). The strategy of most orchids usually offers nectar rewards to pollinators such as some species of *Angraecum*, *Satyrium*, *Acrolophia cochlearis* and *Sedirea japonica* that pollinated by Hawkmoth, sunbirds, *Colletes claripes* and *Bombus diversus diversus*, respectively (Nilsson *et al.*, 1987; Johnson, 1996; Peter and Johnson, 2009a; Suetsugu and Tanaka, 2013).

However, as many as one-third of orchids have not offered any reward to attract pollinators but used mimicry or deception strategies (Cozzolino and Widmer, 2005) such as generalized food deception of *Cyrtopodium polyphyllum* (Pansarin *et al.*, 2008a), food-deceptive floral mimicry of *Coelogyne fimbriata* (Cheng *et al.*, 2009) and *Luisia curtisii* Seidenf. (Pedersen *et al.*, 2012) and sexual deception of many orchids (Jersáková *et al.*, 2006; Gaskett, 2011) which there are different in details of mechanisms in individual species.

In the second group of orchids exhibits pollinator-independent pollination because some orchid species can promote self-pollination such as *Holcoglossum amesianum* (Liu *et al.*, 2006), rain-assisted autogamy of *Liparis loeselii* (Catling, 1980) and the reducing of rostellum enhance self-pollination in *Pogonia minor* (Suetsugu, 2015). However, Neiland and Wilcock (1998) suggested that nectariferous orchids are more successful in fruit set than nectarless species and the provision of nectar as a reward are doubles of the probability of fruit set.

Another aspect on pollination biology of orchids are breeding system which there is the one of important indicator for reproductive success of individual species. Breeding system was recorded in three types, e.g. panmixis or cross-fertilization, self-fertilization (autogamy or geitonogamy) and asexuality (Richards, 1997). Orchids may exhibits only one breeding system or in combination of these. Asexual reproductive mode of orchids have been documented about agamospermy/apomixis in some species of tribe Cranichidae (Fryxell, 1957). In particular, breeding system is the main factor to limit number of fruit set in some species affected by self-incompatibility (Cheng *et al.*, 2009).

During the last decade several studies of orchid pollination have been conducted in Asia, especially in China, e.g. *Cypripedium guttatum*, *Cypripedium plectrochilum*, *Paphiopedilum barbigerum* and South America, especially, in Brazil e.g. *Epidendrum secundum*, *Cyrtopodium polyphyllum* and some species of *Stanhopea*. Information on pollination biology in orchids included habitats, details of floral and vegetative morphology and breeding systems (Banziger *et al.*, 2005; Li *et al.*, 2008; Pansarin and Amaral, 2008; Pansarin *et al.*, 2008a; Pansarin and Amaral, 2009; Shi *et al.*, 2009). In all cases, fruit set was taken as indicator for reproductive success of individual species. Moreover, lip anatomy and lip micromorphology were investigated to reveal attractant that orchids produced from specific structures as reward to their pollinators such as nectar, oils, and fragrances (Stpiczyńska *et al.*, 2003; Teixeira *et al.*, 2004; Ascensao *et al.*, 2005; Kowalkowska and Margońska, 2009; Gomiz *et al.*, 2013).

2.3.2 Pollination studies in tribe Malaxideae

The knowledge on reproductive biology, pollination mechanism of subtribe Malaxidinae have only been reported in genera *Malaxis* and *Liparis*, for instances *M. paludosa* was self-compatible and has fungus gnats, *Phronia digitata* Hackman (Diptera, Mycetophilidae), as pollinators with pollinia attaching on the ventral-anterior part of the thorax behind the mouthparts (Reeves and Reeves, 1984; Argue, 2012) whereas *M. massonii* was self-incompatible and was completely pollinator-dependent for fruit and seed production. Natural pollination of *M. massonii* yielded a fruit set of 1.8% and increased fruit set in hand cross-pollination to 29% (Aragón and Ackerman, 2001).

In *Liparis*, *L. loeselii* was self-compatible and pollinated by rain-assisted autogamy (Catling, 1980). Pollination mechanism was described as droplets fall on anther cap that forced anther cap quickly downward and pushed the pollinia onto the stigmatic surface. However, the pollinia were also pulled onto the stigma by cohesive forces of water (Argue, 2012). while *L. liliifolia* was self-incompatible and might be pollinated casually by a number of unspecialized insects (Catling, 1984). Moreover, Oh *et al.* (2001) reported that *L. kumokiri* was self-compatible, but *L. makinoana* was self-incompatible. In addition, the much lower percentage of fruit set of *L. makinoana* may reflect combined effects of pollinator limitation and self-incompatibility.

Because flowers of *Crepidium* and *Dienia* are small and non-resupinate, resulting in labellum positioned above column, lack any horizontal supports to facilitate potential pollinators, e.g. insects, birds or small animals, to land on flowers to transfer pollinia from one flower to another. Yet, some authors suggest that *Dienia* is self-pollination (Ibrahim *et al.*, 2011) and some small insects such as Order Hymenoptera or Diptera may involve in pollination of *Crepidium* (Margońska, 2005a; Kowalkowska and Margońska, 2009). However, there have not been any reports based on experiment in field observation.

Consequenly, this research is also carried out on pollination biology of *Crepidium* and *Dienia* to investigate on floral phenology, pattern of breeding system, type of pollinator, pollinator behaviors as well as estimation of pollination success based on experiment in field observation.

CHAPTER III

MATERIALS AND METHODS

This study was divided into two parts: part 1 deals with morphological and taxonomic studies and part 2 is about pollination biology. The results of the former is presented in Chapter 4 while those of the latter is in Chapter 5.

3.1 Morphological and taxonomic studies

3.1.1 Materials and Chemicals

3.1.1.1 Materials for specimen collection

- Spade, pruner and knife
- Plastic bags and zipper bags (various sizes)
- Digital camera
- The global positioning system (GPS) receiver model Garmin GPSMap 60CSx
- Collector number cards
- Field note, pencils and eraser
- Fly sheet, tent, hammock and other hiking equipment

3.1.1.2 Materials for herbarium specimen preparation

- Plant presses (30 × 45 cm) and ropes
- Sheets of newspapers
- Corrugated cardboards
- Hot air oven (40–55 °C)
- Deep freezer (–30 °C)
- Genus cover papers, 30 × 42 cm
- Species cover papers, 30 × 42 cm
- Mounting papers, 30 × 42 cm
- Mounting glue (latex glue)

- Needle and cotton thread
- Glass bottles and vial (various sizes)
- Ethyl alcohol 70%
- Herbarium label

3.1.1.3 Materials for study morphological and taxonomic characters

- Stereoscopic microscope
- Compound light microscope
- Camera Lucida
- Dissecting needles
- Fine tipped forceps
- Petri dishes
- Droppers
- Razor blades
- Drawing papers and pencils
- Tracing papers and drawing pens
- Taxonomic literatures, e.g. Floras, monographs, research articles, manual of orchids, etc.

3.1.2 Methodology

3.1.2.1 Review taxonomic literature

Taxonomic bibliography of *Crepidium* Blume, *Dienia* Lindl. and other related genera e.g. *Microstylis* (Nutt.) Eaton and *Malaxis* Sol. ex Sw. both in Thailand and neighboring countries were gathered and investigated. The number of *Crepidium* species previously recording in Thailand, ecological data, locality and distribution were compiled and noted.

3.1.2.2 Gather plant specimens from field exploration

The living specimens of species in *Crepidium* and *Dienia* were collected from all floristic regions throughout Thailand. Details of living specimens (e.g. color of flowers, habit) and ecology (e. g. habitat) of each species were noted and photographed.

Herbarium specimens and spirit collections were prepared according to standard procedures for herbarium materials (Bridson and Forman, 1998). All specimens were kept at the Professor Kasin Suvatabhundbu Herbarium, Department of Botany, Chulalongkorn University (BCU) and at the Forest Herbarium (BKF), Department of National Parks, Wildlife and Plant Conservation, Bangkok, Thailand.

The initial identification followed taxonomic keys and some description of orchid genera/species in Thailand and adjacent areas (Seidenfaden, 1978; Seidenfaden and Wood, 1992; Szlachetko and Margońska, 2002; Chen and Wood, 2009a; 2009b).

3.1.2.3 Investigate herbarium specimens from main herbaria in Thailand and abroad

Herbarium specimens and specimen in spirit collections deposited in main herbaria in Thailand and abroad were examined including Professor Kasin Suvatanhandhu Herbarium, Department of Botany, Chulalongkorn University, Bangkok, Thailand (BCU); Herbarium, Botanical Section, Department of Agriculture, Bangkok, Forest Herbarium, Thailand (BK); Forest Herbarium (BKF), Department of National Parks, Wildlife and Plant Conservation, Bangkok, Thailand; Natural History Museum of Denmark, University of Copenhagen, Denmark (C); Royal Botanic Gardens, Kew Herbarium, England (K); National Herbarium Netherland University of Leiden branch, The Netherlands (L); Singapore Botanic Gardens, Singapore (SING) and Queen Sirikit Botanic Garden, Herbarium, Thailand (QBG).

Besides, the digital images of specimens accessed online available from another herbarium were observed including Department of Systematic Botany, University of Aarhus, Denmark (AAU); Harvard University, Oakes Ames Orchid Herbarium, United States of America (AMES); British Natural History Museum Herbarium, England (BM); Royal Botanic Garden, Edinburgh, U.K. Scotland (E); Linnaean herbarium, England (LINN); Herbarium, School of Forestry and Resource

Conservation National Taiwan University (NTUF); The New York Botanical Garden Herbarium, USA (NY); Muséum national d'Histoire naturelle, Paris, France (P); Institute of Ecology and Evolutionary Biology, College of Life Science, National Taiwan University (TAI); Naturhistorisches Museum Wien, Austria (W); Institute of Botany, University of Vienna, Austria (WU). Also, the type specimens of species were examined. Below are the list of URL for obtaining some digital images of herbarium specimens:

AAU	http://www.aubot.dk/search_form.php
AMES	http://kiki.huh.harvard.edu/databases/specimen_index.html
BM	http://data.nhm.ac.uk/
LINN	http://linnean-online.org/linnaean_herbarium.html
NTUF	http://ntuf.cc.ntu.edu.tw/search.htm
NY	http://sweetgum.nybg.org/science/vh/
P	https://science.mnhn.fr/institution/mnhn/collection/p/item/search/
TAI	http://tai2.ntu.edu.tw/Specimen/species-specimen.php
WU	http://herbarium.univie.ac.at/database/search.php

3.1.2.4 Investigate morphological characters applicable to taxonomic treatment of *Crepidium* and *Dienia*

All specimens were investigated for both vegetative and reproductive characters. Measurements of quantitative vegetative character (e.g. lamina, petioles, stems, rhizomes, pseudobulbs, etc.) and reproductive character (e.g. inflorescence, sepals, petals, labellum, column, etc.) were carried out using digital caliper. Qualitative characters in each specimen include habits, shape of lamina, color of flowers, shape of sepals, petals and labellum, mid-lobe of labellum, shape of column, etc., were examined using stereoscopic microscope and light compound microscope.

3.1.2.5 Carry out taxonomic treatment

Taxonomic entities of each species was based on the existing diagnostic characters available from the first publication together with Floras or manuals of orchids in Thailand or neighboring countries. Then, botanical name of specimens were confirmed by comparing specimens to the type specimens. The comprehensive morphological description of each species were described, illustrated and documented by photos as well as key to species were constructed. Besides, ecological, and geographical data were noted.

3.2 Materials and Methods for pollination biology

3.2.1 Materials and Chemicals

3.2.1.1 Materials for study floral features

- Digital camera and video camera
- Digital caliper
- Compound light microscope
- Field note, pencils and eraser
- Refractometer bellingham and Stanley ^{TM} model 45-81
- Neutral Red
- Sudan Red
- Ethyl alcohol 95%
- Glycerin
- Distilled water

3.2.1.2 Materials for study pollinators and visitors

- Digital camera, video camera, flats and accessories
- Computers and external hard disks
- Batteries
- Plastic bottles and vial in any sizes
- Insect aspirator
- Ethyl alcohol 70%
- Label sheets
- Fly sheets, hammock, and other hiking equipment\

3.2.1.3 Materials for study breeding system

- Optivisor Headband Magnifier, 7x and 10x
- Dissecting needles
- Forceps
- Tulle bags
- Needles and thread in any colours
- Scissors
- Pruner and knife
- Flashlights
- Plastic labeling tags
- Petri dishes
- Droppers
- Slides and microscope cover slips

3.2.2 Methodology for pollination biology

3.2.2.1 Selected species

The criteria for choosing model species of *Crepidium* and *Dienia* included population size of plant at least 50–100 plants or inflorescences, accessibility to and stability of population or plants in the area, permission to access area and to carry out the experiment. Therefore, *C. acuminatum* (D. Don) Szlach. and *D. ophrydis* (J. Koenig) Ormerod & Seidenf. were chosen as both species are widely distributed ranging from the northern to the southern part of Thailand, occur in a large population in Thailand, yield the large number of flowers are enough to estimate breeding system, pollination process and reproductive success and are relatively easy to get the permission for entering areas to conduct experiments.

Moreover, *C. acuminatum* and *D. ophrydis* are similar in having non-resupinate flowers. The flowers of *C. acuminatum* are larger than other *Crepidium* species in Thailand, but they produced very low fruit set (1–3 fruits/inflorescence) whereas *D. ophrydis* have a large number of small flowers on its inflorescences and it showed high fruit set in natural habitat (Fig. 3.1). Hence, it is very interesting to reveal limitation factors that limited number of fruit set in these two orchid species.

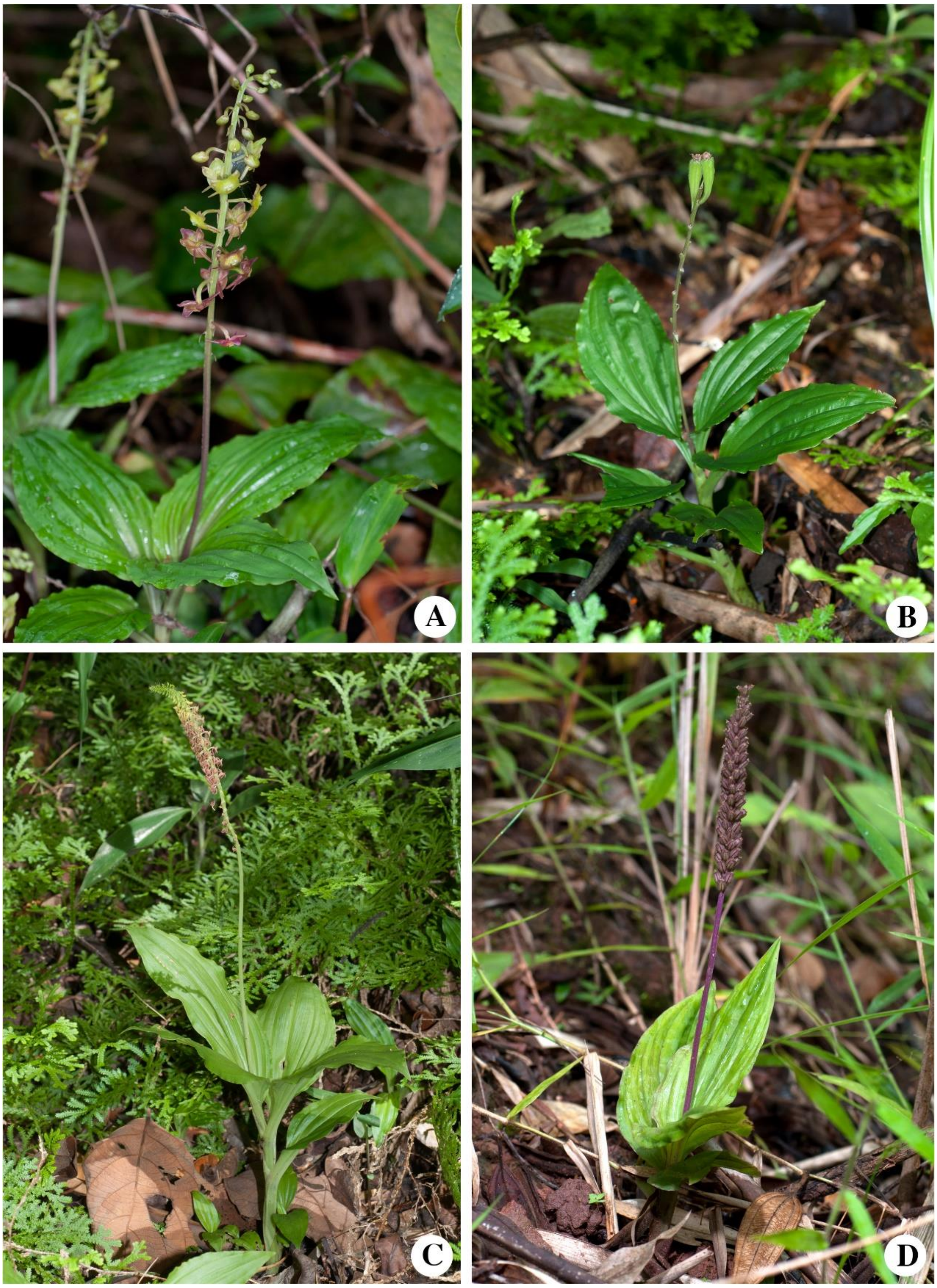

Figure 3.1 *Crepidium acuminatum* and *Dienia ophrydis*. **A:** Plant and inflorescence of *C. acuminatum*. **B:** Two fruits on infructescence of *C. acuminatum*. **C:** Plant and inflorescences of *D. ophrydis*. **D:** Many fruits on infructescence of *D. ophrydis*.

3.2.2.2 Study sites

Phu Hin Rong Kla National Park

The pollination biology of *C. acuminatum* were studied in open areas in the hill evergreen forest and coniferous forest in Phu Hin Rong Kla National Park (approx. 17° 00' 14.3" N, 100° 59' 40.0" E) (Fig. 3.2). The national park covers area located in Loei, Phitsanulok and Phetchabun Provinces of Thailand. The National Park is mountainous terrain, occupies an area of 307 km^2 with elevation from 800–1,800 m. In the past, this national park was stronghold for Communist Party of Thailand (Office of National Park; Department of National Parks Wlidlife and Plant Conservation, 2017) . The season can be divided into three seasons including summer, winter and rainy season. The average annaul rainfall is about 1,737 mm, and the average temperature about 18–25 °C (Chimyam, 1999; Phu Hin Rong Kla National Park, 2017). The observations and experiments were conducted in three populations including the trail of Romklao-Pharadon waterfall, the trail near roadside at the school of Political and Military, and the trail between Lan Hin Pum to Pha Chu Thong viewpoint (Fig. 3.3 and 3.4A–D). All of trails are situated in Phitsanulok province.

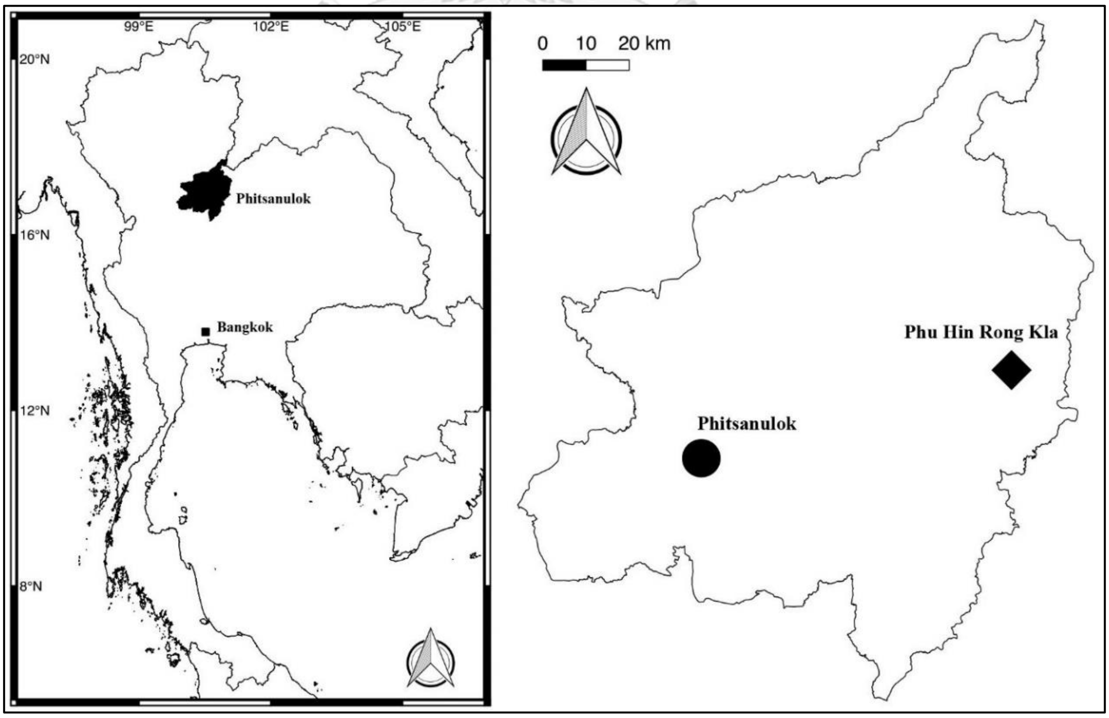

Figure 3.2 Location of Phu Hin Rong Kla National Park, Phitsanulok province.

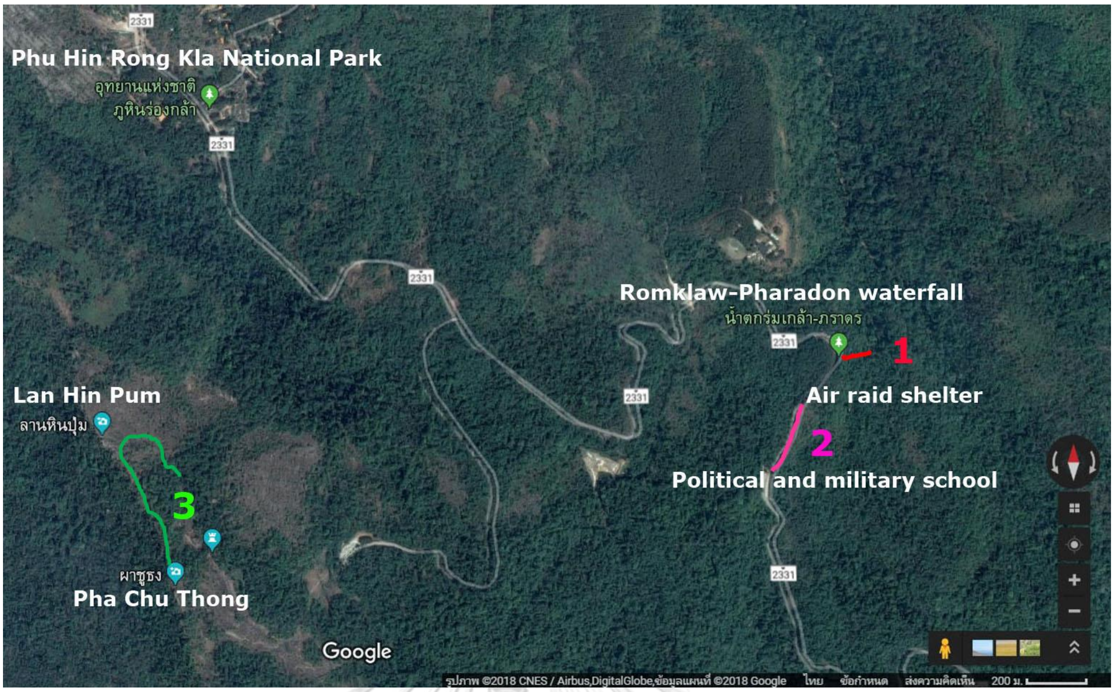

Figure 3.3 Location of three populations of *C. acuminatum* in three natural trails.

Figure 3.4 Landscape of study sites in Phu Hin Rong Kla National Park. **A:** The trail of Romklaw-Pharadon waterfalls. **B:** The trail near roadside at the school of Political and Military. **C–D:** The trail between Lan Hin Pum to Pha Chu Thong viewpoint.

Ko Kut

The pollination biology of *D. ophrydis* were studied in understory areas of lowland evergreen rain forest at Ko Kut, Trat province (approx. 11° 39' 30" N, 102° 32' 32" E). The island is 25 km long and 12 km wide covering an area of approximately 105 km^2. The topography is mountains and coastal plains where many streams originate and become waterfalls. The season can be divided as three seasons including summer, rainy and short winter season. The average annaul rainfall is about 4,398 mm, and the average temperature about 26–29 C° (Ko Kut, 2017). The observations and experiments were conducted in one population in the natural trail of Khao Ruea Rob (Fig. 3.5 and 3.6A–D).

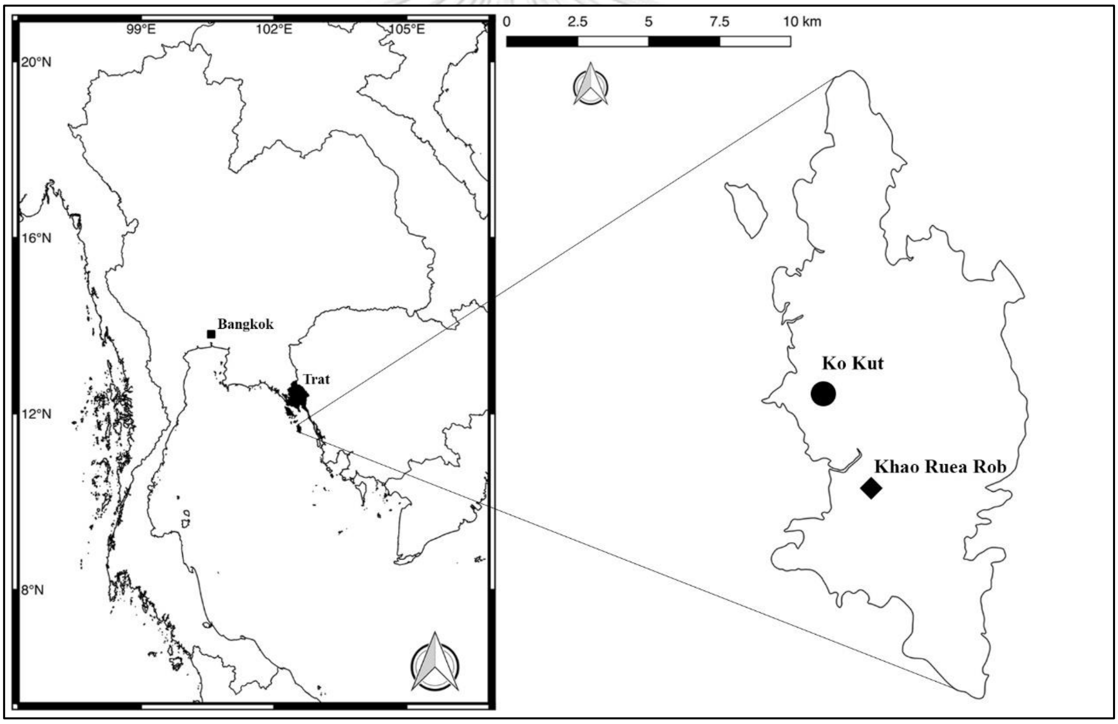

Figure 3.5 Location of Ko Kut and Khao Ruea Rob, Trat province.

3.2.2.3 Plant phenology and floral features

Field observation were carried out for three seasons, from April 2014 to December 2017. Data on phenology, the production of pseudoblubs, leaves and inflorescences were recorded from 100 plants in each seasons. Also, data on the features of flowers before, during and after anthesis were recorded from 10 flowers using photography and video recording.

Nectar of *C. acuminatum* were collected by micropipette (83 flowers, from 15 plants). In *D. ophrydis*, a small flower were cut and put in the microtube and then centrifuge to extract nectar (150 flowers, from 15 plants). Sugar concentration in nectar was determined using the refractometer. The labellum anatomy were investigated using method of Stern *et al.* (1986). The presence of osmophores and lipids after staining with Neutral Red and Sudan Red, respectively were observed under compound light microscope and photographs were taken.

3.2.2.4 Pollinators/Visitors to flower during anthesis

Pollinators and visitors were observed in natural populations. The details of pollination process, visitation frequencies and pollinator behavior on flowers were documented by means of field notes, photography and video recording during day and night (Fig. 3.7A–D). The observations were carried out from 10 to 12 June, 16 to 21 June, 26 to 28 June 2016, totalling 96 hour and from 28 to 30 May, 9 to 11 June and 20 to 24 June 2017, totalling 196 hour for *C. acuminatum*. In addition, *D. ophrydis* were observed from 11 to 12 July, 17 to 23 July 2016, totalling 55 hour and from 2 to 4 July 2017, totalling 60 hour. The observation period of daytime was observed from 07:00 to 18:00 and with one video camera was taken all 24 hour to detect possible nocturnal pollination.

Some insects visited to flowers were captured by insect aspirator (Borror *et al.*, 1989) or plastic bags and then preserved in 70% alcohol for further taxonomic identification. Insects were identified using handbooks for insect identification (Oldroyd, 1970; Michener, 2007) and deposited at Chulalongkorn University Museum of Natural History, Department of Biology, Faculty of science.

Figure 3.6 Landscape of study sites in Khao Ruea Rob, Ko Kut, Trat province.

Figure 3.7 Pollinator observations. **A–B:** Pollinator observations of *C. acuminatum* at Phu Hin Rong Kla. **C–D:** Pollinator observations of *D. ophrydis* at Ko Kut.

3.2.2.5 Breeding system and natural fruit set

The experiments to investigate the breeding system of *C. acuminatum* were conducted during three flowering seasons under natural conditions (2014 to 2016) whereas *D. ohrydis* were conducted during two flowering seasons under natural conditions (2015 to 2016). A control for open-pollination treatments was used to observe natural fruit set. A total number of flowers per inflorescence was recored and the pollinated flowers were also tagged with white thread to futher follow fruit setting (Fig. 3.8A–D and 3.14A–D).

In addition, hand-pollination treatments were randomly appiled for five pollination trials, as modified from Oh *et al.* (2001), Humaña *et al.* (2008) and Pansarin *et al.* (2008a), to determine breeding system using flowers in the first day of anthesis. The experiment is as following:

(i) For unmanipulated flowers, the whole young inflorescences were covered with tulle bags to test autonomous self-pollination and to measure pollinator-dependent (Fig. 3.9A–D and 3.15A–D).

(ii) For unbagged emasculation, pollinia were removed from the anther and flowers were not covered by tulle bag to verify outcrossing pollination (Fig. 3.10A–D and 3.16A–D).

(iii) For bagged emasculation, pollinia were removed from the anther and flowers were covered by tulle bags to test for agamospermy and to evaluate the rate of nonsexual reproduction (Fig. 3.11A–D and 3.17A–D).

(iv) For hand self-pollination, pollinia were pollinated within the same flower to test self-incompatibility (Fig. 3.12A–D and 3.18A–D).

(v) For hand cross-pollination, pollinia were pollinated with the different inflorescences > 5 m apart to verify self-incompatibility and estimate efficiency of pollinators for natural fruit set (Fig. 3.13A–D and 3.19A–D). At the end of individual treatment, the flowers or inflorescences were covered with tulle bags to exclude any possible insect pollination. Number of inflorescences and flowers were randomly assigned to open pollination and hand pollination treatments as shown in Table 3.1. Fruit set were recorded during fruit setting and when fruits were dehiscent.

Seed examination to test seed viability was performed on fruits obtained through open-pollination, hand self-pollination and hand cross-pollination. Seeds were placed on slide and observed under compound light microscope. Samples of 500 seed per fruit were scored for seed viability with criterion that seed with well-developed embryos were considered viable, whereas seed with rudimentary or no embryos were considered nonviable (Pansarin *et al.,* 2008a).

3.2.2.6 Analyze and describe for pollination biology

The result of breeding system and natural fruit were analyzed. The pollination mechanism was described including type of pollinator (biotic pollinator or abiotic pollinator), pollinator behavior, and pollination success.

3.3 Publish manuscripts and write dissertation

Table 3.1 Number of plants and flowers of *C. acuminatum* and *D. ophrydis* for breeding system treatments.

Species	***C. acuminatum***						***D. ophrydis***			
Year	**2014**		**2015**		**2016**		**2015**		**2016**	
Treatment	No. inflores-cences	No. flowers	No. inflores-cences	No. flowers	No. inflores-cences	No. flowers	No. inflores-cences	No. flowers	No. inflores-cences	No. flowers
(A) Open pollination	37	645	43	745	74	1,635	50	5,613	75	7,357
(B) Hand pollination										
- (B1) Unmanipulated flowers	5	39	5	50	6	55	5	310	10	991
- (B2) Unbagged emasculation	2	10	6	29	8	45	3	62	5	277
- (B3) Bagged emasculation	2	11	6	29	5	42	3	89	4	187
- (B4) Hand self-pollination	5	22	16	92	15	92	3	97	6	343
- (B5) Hand cross-pollination	8	28	16	94	20	105	3	100	5	445

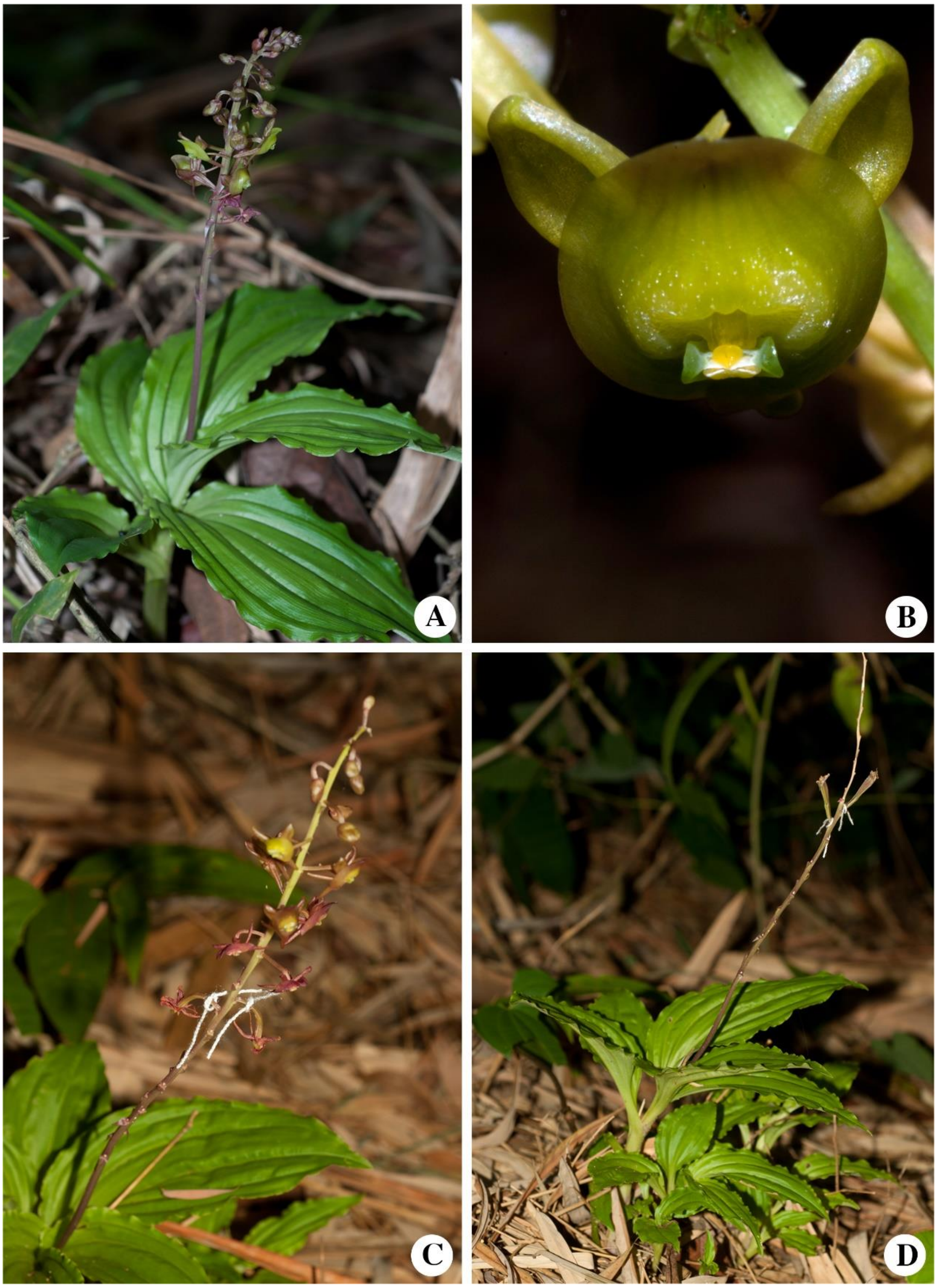

Figure 3.8 Open pollination of *C. acuminatum*. **A:** A total number of flower/plant was recorded. **B–C:** Pollinated flowers were tagged with white thread. **D:** Following fruit setting and fruit development.

Figure 3.9 Unmanipulated flowers of *C. acuminatum*. **A:** The young inflorescences before flower anthesis. **B**–**D:** The whole young inflorescences were covered with tulle bags.

Figure 3.10 Unbagged emasculation of *C. acuminatum.* **A:** Flowers in the first day of anthesis. **B:** Pollinia were removed from the anther by needle. **C**–**D:** Emasculated flowers were tagged with thread without covered with tulle bags.

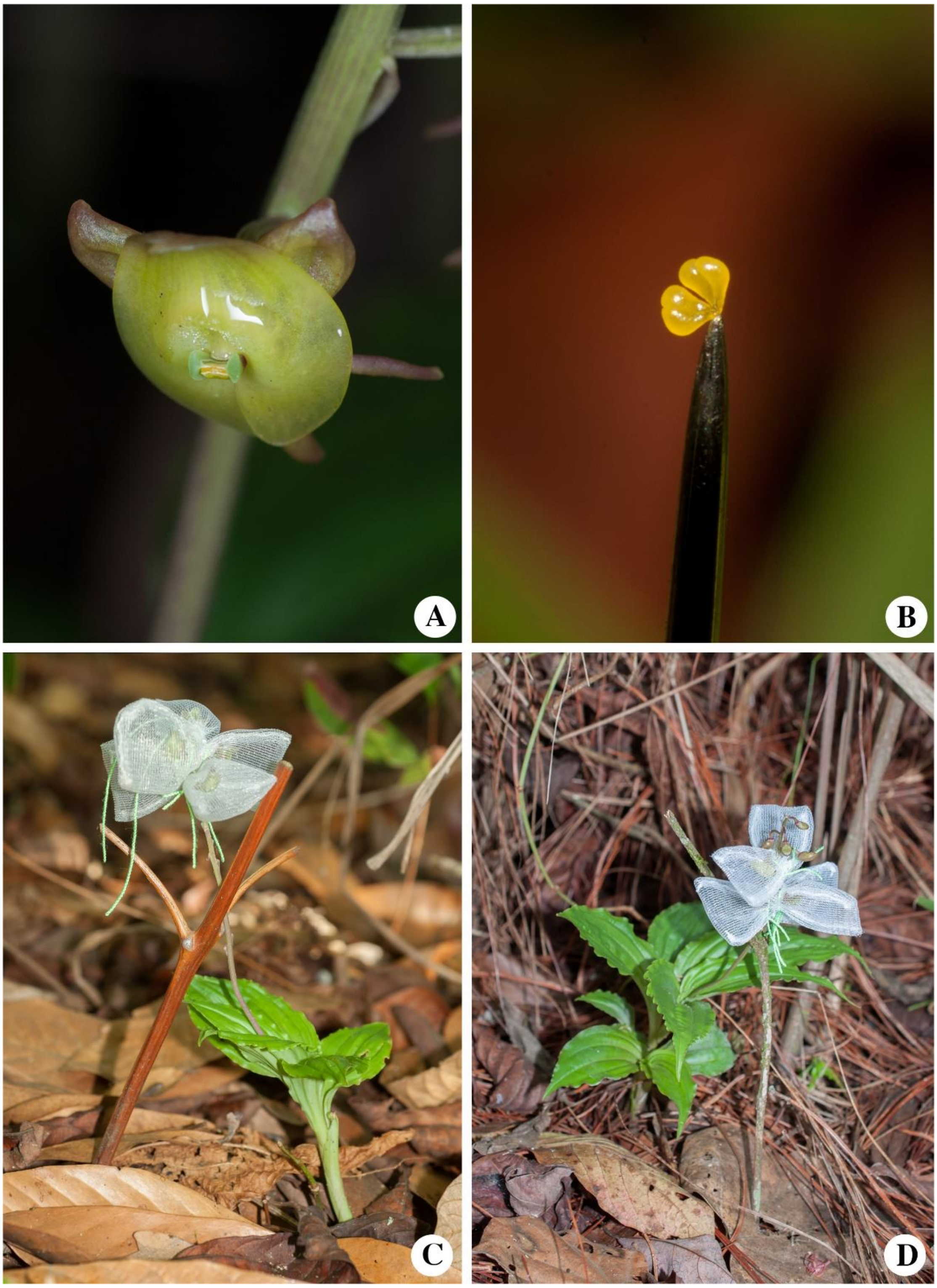

Figure 3.11 Bagged emasculation of *C. acuminatum.* **A:** Flowers in the first day of anthesis. **B:** Pollinia were removed from the anther by needle. **C**–**D:** Emasculated flowers were covered with tulle bags.

Figure 3.12 Hand self-pollination of *C. acuminatum.* **A:** Pollinia were transferred to stigma cavity within the same flower. **B–D:** Hand self-pollinated flowers were covered with tulle bags.

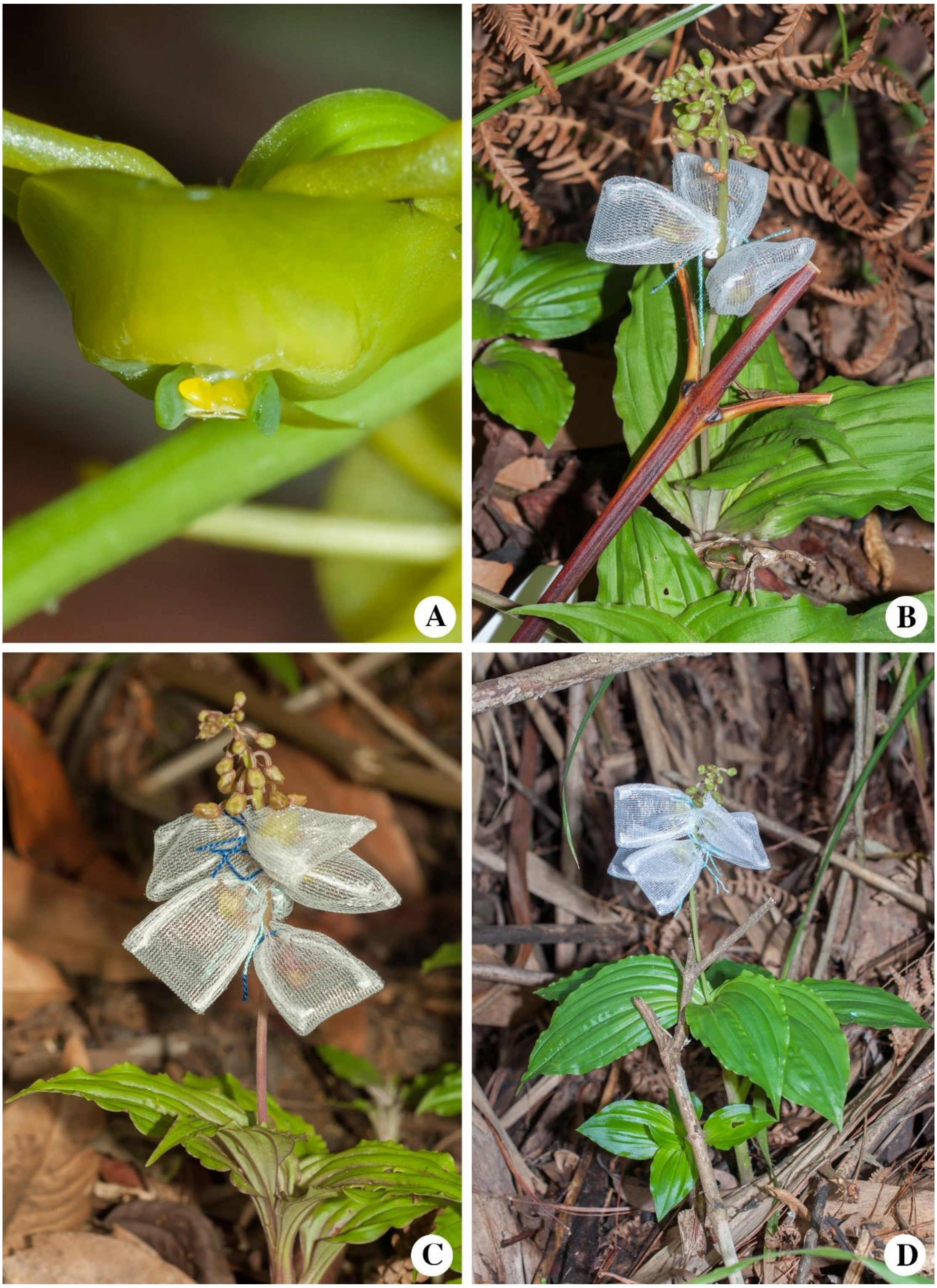

Figure 3.13 Hand cross-pollination of *C. acuminatum.* **A:** Pollinia were transferred to stigma cavity from different plants. **B**–**D:** Hand cross-pollinated flowers were covered with tulle bags.

Figure 3.14 Open pollination of *D. ophrydis.* **A:** A total number of flowers/plant was recorded. **B:** Fruit setting/plant was recorded. **C–D:** Following fruit development.

Figure 3.15 Unmanipulated flowers of *D. ophrydis*. **A:** The young inflorescence before flower anthesis. **B–D:** The whole young inflorescence was covered with tulle bags.

Figure 3.16 Unbagged emasculation of *D. ophrydis.* **A:** Flowers in the first day of anthesis. **B:** Pollinia were removed from the anther. **C**–**D:** Emasculated flowers were tagged with thread without covered with tulle bag. **E:** Fruit setting of unbagged emasculation.

Figure 3.17 Bagged emasculation of *D. ophrydis*. **A:** Pollinia of flowers in the first day of anthesis were removed from the anther by needle. **B–D:** Emasculated flowers were covered with tulle bags.

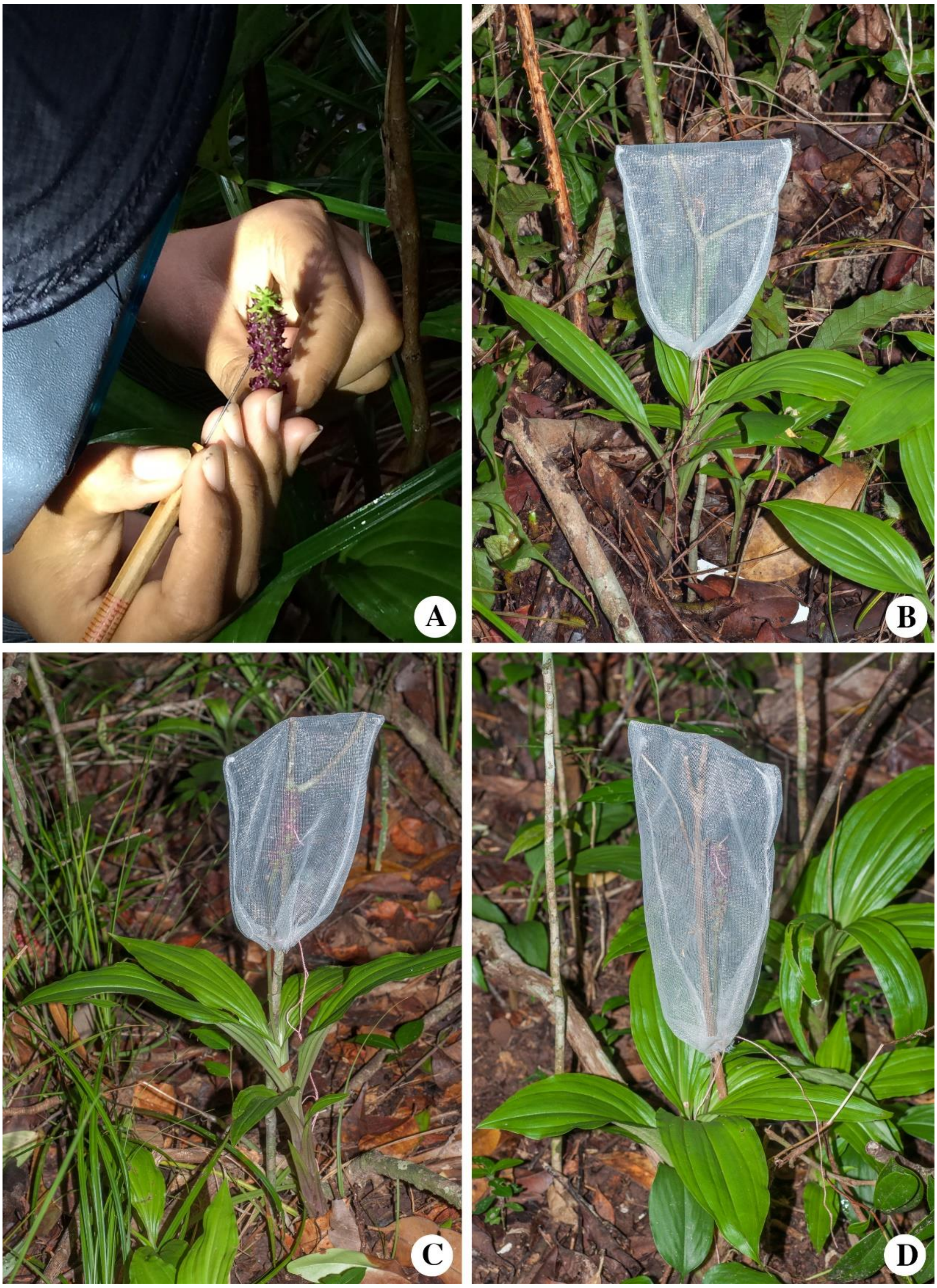

Figure 3.18 Hand self-pollination of *D. ophrydis*. **A:** Pollinia were transferred to stigma cavity within the same flower. **B–D:** Hand self-pollinated flowers were covered with tulle bags.

Figure 3.19 Hand cross-pollination of *D. ophrydis*. **A:** Pollinia were transferred to stigma cavity from different plants. **B**–**D:** Hand cross-pollinated flowers were covered with tulle bags.

CHAPTER IV
TAXONOMIC REVISION

4.1 Morphological characters of *Crepidium* Blume and *Dienia* Lindl.

Habit and habitat

Most of *Crepidium* and *Dienia* species are terrestrial orchids, usually grow on humus-rich soil in the shade areas. However, some species can grow on limestone areas (lithophytes) or also grow on lower trees trunk (epiphytes). For example, *D. ophrydis* is common terrestrial orchids within these two genera (Fig. 4.1A). *C. acuminatum* can be found in all three habitat (Fig. 4.1B–D). Moreover, *C. luniferum* can be found on lower trees trunk that covered with moss and ferns (Fig. 4.1E). *C. szemaoense* is often grow on limestone hills that covered with humus (Fig. 4.1F).

The growth habit of *Crepidium* and *Dienia* are sympodial orchids with strongly condensed rhizome or creeping rhizome which produces the new shoot every year.

Stems

Stem of *Crepidium* and *Dienia* can be classified as stem with creeping rhizome, never produces pseudobulb (Fig. 4.2A) and stem with strongly condensed rhizome, produces pseudobulb above ground (Fig. 4.2B) or corm underground (Fig. 4.2C).

After flowering season of *Crepidium* species that have stem creeping rhizome, the inflorescence decays and the stem gradually becomes prostrate. However, the proximal part of the stem and its leaves can survive in the dry season and don’t disappear until the next year, a new young flowering shoot is produced from one of the lower leaf axils. It is contrary to *Crepidium* and *Dienia* species that producing pseudobulb or corm, leave will be dried after fruit development and survive in the dry season as a leafless corm or pseudobulb.

Leaves

Leaves arrangement of *Crepidium* and *Dienia* species are alternate, subdistichous or subspiral. Leaves are usually plicate. Most species are ascending, erect or spreading leaves. However, some species are appressed to the ground surface (Fig. 4.2D).

Inflorescences

The inflorescences are borne on terminal of flowering shoot, pseudobulb or corm. It is usually a long raceme with long peduncle and rachis, bearing many small flowers.

Flowers

The flowers of *Crepidium* and *Dienia* are non-resupinate. Sepals are often broader than petals. Labellum of these two genera are usually 3-lobed (Fig. 4.3A–B), but some species are obscurely 3-lobed or without labellum auricles (Fig. 4.3C). Distal part of labellum can be divided into 3 groups, including entire (Fig. 4.3B), retuse or bilobed (Fig. 4.3D–E) and dentate (Fig. 4.3F–I). The number of teeth on distal margins are different in individual species. Moreover, the basal part to central part of labellum are form as a small cavity which is called labellum cavity (Fig. 4.3J–L). The high ridges that is often flanked labellum cavity may be present (Fig. 4.3J–K) or absent (Fig. 4.3L). Column of *Crepidium* and *Dienia* species are mostly the same but they may be different in shape of staminodes.

Fruits and seeds

The fruit of *Crepidium* and *Dienia* species are typical fruit of the family Orchidaceae, rather dry and dehiscent at maturity. Mature capsules are generally erect and pedicellate. Capsules are usually ornamented with 6-longidinal ridges. The apex of fruit is usually with persistent dried perianths and column (Fig. 4.4A–D).

Seeds of *Crepidium* and *Dienia* species are nearly fusiform shape. They have a loose and rather thin-textured seed coat around the embryo and lacking endosperm (Fig. 4.4E–F).

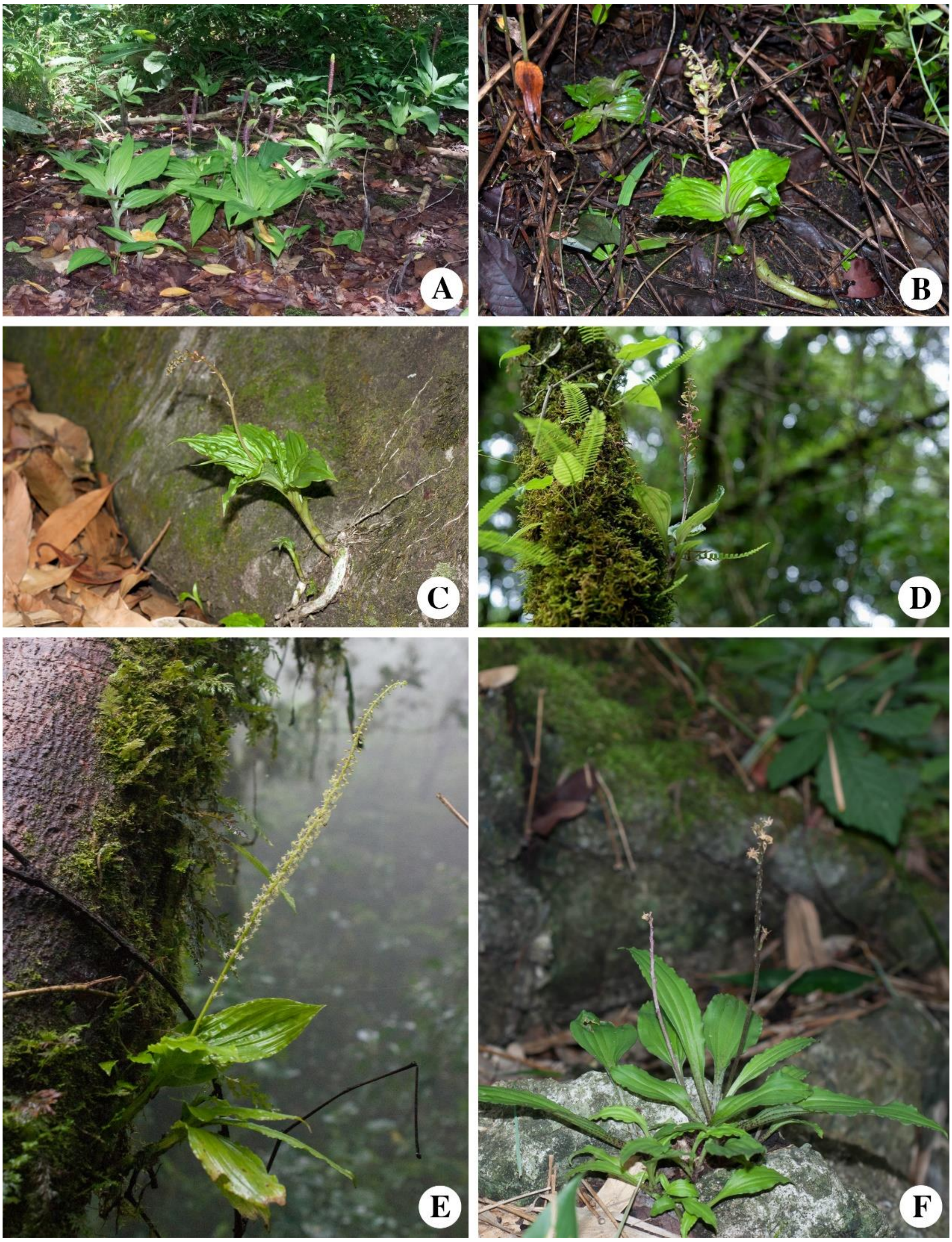

Figure 4.1 Habit and habitat of *Crepidium* and *Dienia* species. **A:** *D. ophrydis* (Ko Kut, 27 May 2018). **B:** *C. acuminatum* grow on ground (Phu Hin Rong Kla, 28 June 2013). **C:** *C. acuminatum* grow on rock (Phu Hin Rong Kla, 9 June 2015). **D:** *C. acuminatum* grow on the lower part of trees trunk (Photo by Wins Buddhawong, Huay Nam Dung, July 2016). **E:** *C. luniferum* grow on the lower part of trees trunk (Khao Luang, 23 July 2014). **F:** *C. szemaoense* grow on limestone hills (Doi Chiang Dao, 20 June 2014).

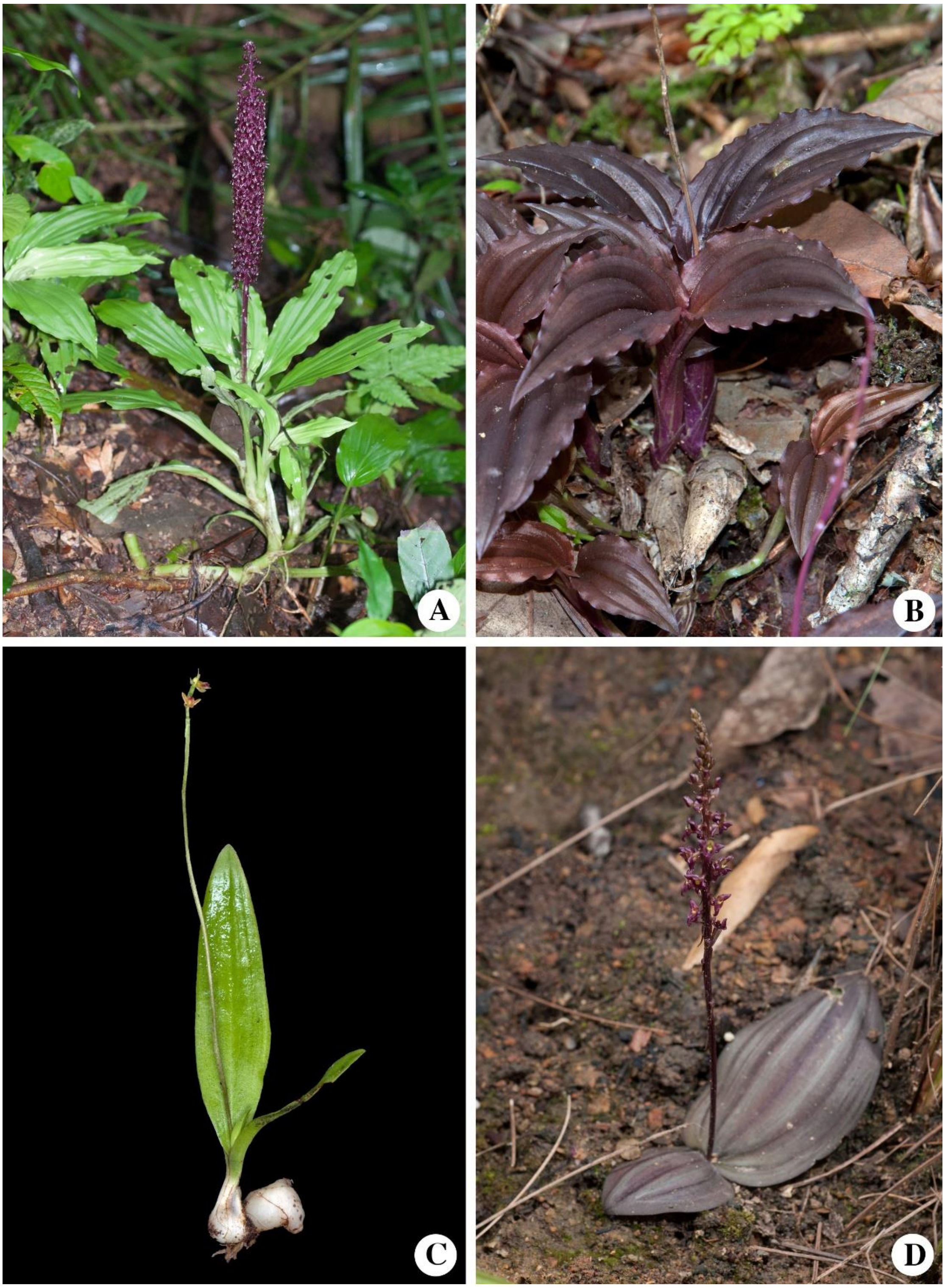

Figure 4.2 Stem characters of *Crepidium* and *Dienia*. **A:** Plant with creeping rhizome (Khao Luang, 15 November 2013). **B:** Plant with pseudobulb above ground (Phu Luang, 15 June 2013). **C:** Plant with corm underground (Phu Ruea, 30 May 2014). **D:** Plant with laves appressed to the ground surface (Doi Suthep, 27 September 2014).

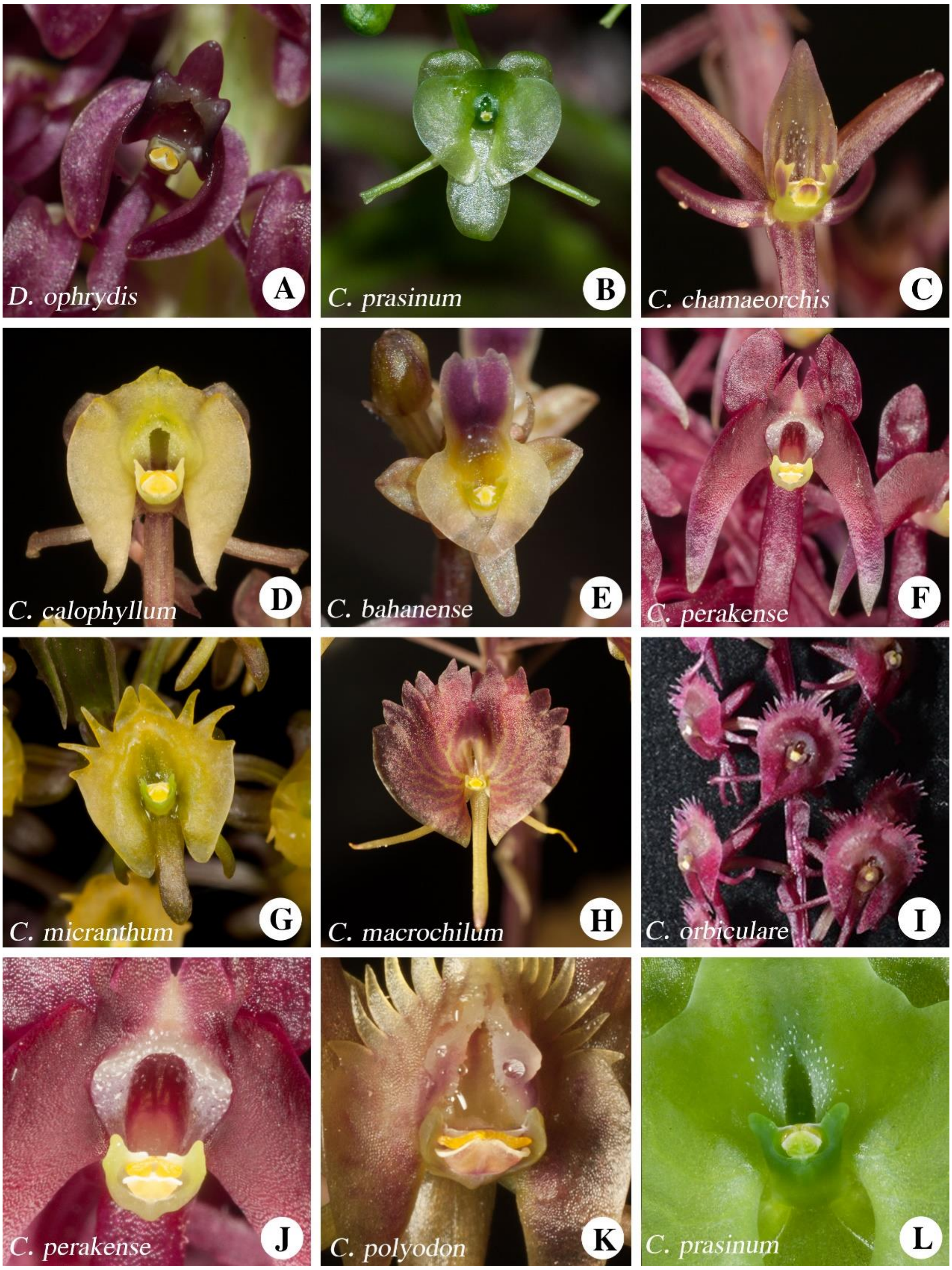

Figure 4.3 Flowers variation of *Crepidium* and *Dienia*. **A–B:** Labellum distinctly 3-lobed. **C:** Labellum obscurely 3-lobed and without labellum auricles. **D–E:** Distal part of labellum retuse or bilobed. **F–I:** Distal part of labellum dentate. **J–K:** High ridges flanking labellum cavity. **L:** Labellum cavity without high ridges.

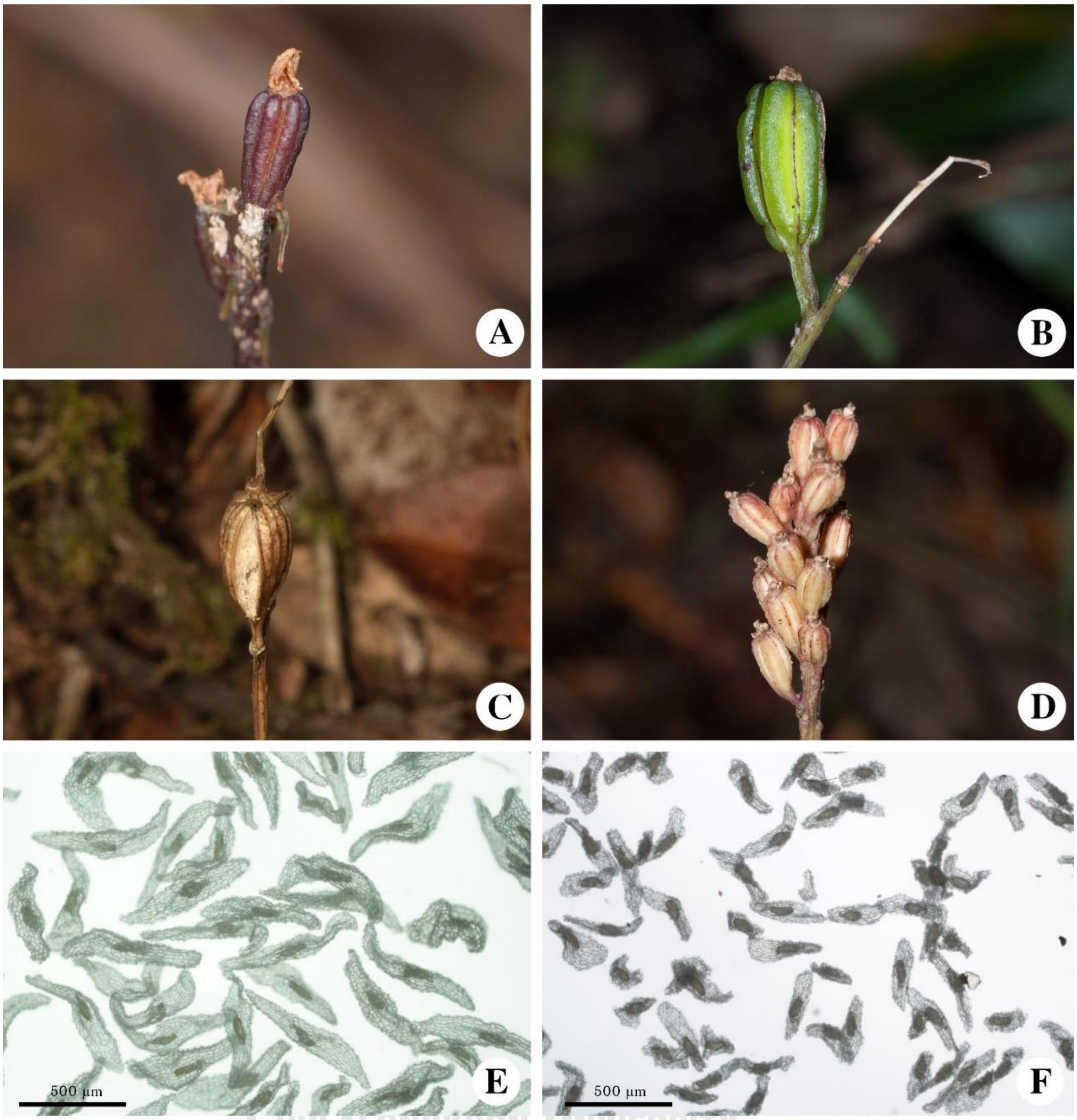

Figure 4.4 Fruits and seeds of *Crepidium* and *Dienia*. **A:** Fruits of *C. klimkoanum* (Doi Suthep, 27 September 2014). **B:** Fruits of *C. acuminatum* (Phu Hin Rong Kla, 1 November 2015). **C:** Mature fruits of *C. calophyllum* (Phu Ruea, 3 May 2015). **D:** Fruits of *D. ophrydis* (Ko Kut, 28 June 2013). **E:** Seeds of *C. acuminatum*. **E:** Seeds of *D. ophrydis*.

4.2 Taxonomic treatment of genera *Crepidium* Blume and *Dienia* Lindl.

The field exploration and herbarium specimen studies suggested that only 1 species of *Dienia* and 25 species of *Crepidium* are distributed in Thailand.

KEY TO GENERA

1. Distal part of labellum entire, bifid, dentate or obscurely 3-lobed; basal part without a high, transverse callus just in front of the column.............**1. Crepidium**
1. Distal part of labellum entire or distinctly 3-lobed; basal part ornamented by a high, transverse callus just in front of the column………………………**2. Dienia**

1. CREPIDIUM

Blume, Bijdr. Fl. Ned. Ind.: 387. 1825; Szlach., Fragm. Flor. Geobot., Suppl. 3: 123. 1995; Szlach. & Marg., Acta Bot. Fenn. 173: 70. 2002; Pridgeon et al. (eds.), Gen. Orchid. 4: 457. 2005.— *Pterochilus* Hook. & Arn., Bot. Beechey Voy.: t. 17. 1832.— *Pseudoliparis* Finet, Bull. Soc. Bot. France 54: 536. 1907.— *Glossochilopsis* Szlach., Fragm. Flor. Geobot., Suppl. 3: 122. 1995.— *Seidenfia* Szlach., Fragm. Flor. Geobot., Suppl. 3: 122. 1995.— *Fingardia* Szlach., Fragm. Flor. Geobot., Suppl. 3: 134. 1995.— *Saurolophorkis* Marg. & Szlach., Polish Bot. J. 46: 7. 2001.— *Seidenforchis* Marg., Acta Soc. Bot. Poloniae 75: 302. 2006. **Type species:** *C. reedii* Blume

Sympodial, usually terrestrial, rarely lithophytic or epiphytic *herbs*. *Rhizome* condensed, bearing an erect, pseudobulbous/cormous flowering shoot distally and 1–2 decaying pseudobulbs/corms behind; rarely creeping, devoid of pseudobulbs/corms and producing a flowering shoot that is erect from a decumbent base. *Roots* arising from the basal part of the pseudobulb or at node of the rhizome. *Foliage leaves* 2 to several, dorsoventrally flattened, plicate (sometimes obscurely so), sheathing at base. *Inflorescence* terminal, erect, racemose, elongating during flowering; bracts persistent, often recurved or reflexed, setose to triangular, lanceolate or ovate. *Flowers* usually non-resupinate, green, brown, yellow or purple. *Sepals* free (or lateral sepals connate), spreading to reflexed, glabrous. *Petals* free, spreading to reflexed or revolute, often narrower than sepals; *Labellum* perpendicular to column, flat to bowl-shaped, usually strongly auriculate at base, distal margin entire to lobed or toothed, spurless but usually with a small, basal to central cavity that is often flanked by 2 or bordered by 1 ridge. *Column* erect, as long as broad or slightly longer, with 2 lateral staminodes, foot absent; anther incumbent, versatile, more than twice as wide as connective; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard; rostellum transversely rectangular, truncate to obtuse, sometimes producing a minute viscidium; fertile stigma part (transversely) rectangular to elliptic or subovate. *Ovary* (fusiform-)cylindrical with 6 longitudinal ridges, glabrous. *Fruit* a pedicelled capsule dehiscing by longitudinal slits.

A genus of c. 280 species distributed throughout Indo-Malesia to Queensland and the W Pacific islands, with a few species in temperate E Asia; 25 species in Thailand.

KEY TO THE SPECIES

1. Labellum devoid of auricle..**7. C. chamaeorchis**

1. Labellum markedly cordate-auriculate to sagittate-auriculate; auricles stretching backwards or embracing column

  2. Distal part of labellum conspicuously several-dentate to laciniate

    3. Plant with a creeping rhizome; flowering shoot erect from a decumbent base. Foliage leaves (3–)5–14

      4. Labellum more than 6.5 mm long. Flowers reddish-purple to dark purple...**21. C. perakense**

      4. Labellum less than 6.5 mm long. Flowers (greenish-)yellow to orange, sometimes flushed purple

        5. Distal margin of labellum with 2 teeth on either side of the apex...**2. C. aschistum**

        5. Distal margin of labellum with 3–5 teeth on either side of the apex

          6. Labellum with a triangular, bifid mid-lobe, flanked by smaller teeth; labellum cavity narrowly triangular to rectangular in outline, shallow, with flat or insignificantly thickened margins...**18. C. micranthum**

          6. Labellum distally rounded, dentate; labellum cavity obovate in outline, deep, bordered by a prominent, horseshoe-shaped ridge........................**4. C. bancanum**

3\. Plant with a pseudobulb above ground; flowering shoot erect. Foliage leaves 2–5

7\. Distal margin of labellum laciniate-dentate with at least 20 teeth/laciniae..**20. C. orbiculare**

7\. Distal margin of labellum dentate with less than 20 teeth

8\. Dorsal sepal more than twice as long as labellum auricles. Labellum cavity narrowly triangular in outline. Leaves brown-spotted

9\. Labellum distinctly longer than wide, usually with fewer than 5 teeth on either side of the apex. Column larger than the largest marginal labellum teeth..**19. C. octodentatum**

9\. Labellum approximately as long as wide, usually with more than 5 teeth on either side of the apex. Column smaller than the largest marginal labellum teeth ....**15. C. macrochilum**

8\. Dorsal sepal less than twice as long as labellum auricles. Labellum cavity orbicular, (ob)ovate, elliptic or triangular in outline. Leaves unspotted

10\. Labellum with at least 5 teeth on either side; auricles falcate.......**22. C. polyodon**

10\. Labellum with less than 5 teeth on either side; auricles obliquely triangular

11\. Inflorescence more than 25 cm long, producing more than 100 flowers Pseudobulb terete. Petiole green, unspotted.............................**13. C. luniferum**

11\. Inflorescence less than 22 cm long, producing less than 70 flowers. Pseudobulb ovoid to conical. Petiole green with tiny red-purple markings..**25. C. szemaoense**

2\. Distal part of labellum never several-dentate (but sometimes lobed or emarginate)

12\. Plant with an underground corm. Foliage leaves 2(–3)

13\. Leaves ascending to erect; lamina bearing numerous white papillae on the adaxial side when young (later glabrous)…………………………..……….**3. C. bahanense**

13\. Leaves horizontally spreading just above the soil surface, consistently glabrous

14\. Labellum ovate with prominently sagittate-auriculate base, distally cleft for up to 1/4 of its length……………………………………..………**12. C. klimkoanum**

14\. Labellum (triangular-)oblong with prominently sagittate-auriculate base, distally emarginated…………………………………………………**14. C. mackinnonii**

12\. Plant with a pseudobulb above ground. Foliage leaves 3–7

15\. Labellum constricted (by locally revolute margins) at the middle

16\. Leaves lustrous greyish-green, obliquely ovate-elliptic to subfalcately lanceolate Distal part of labellum bilobed; lobules truncate to retuse...........**11. C. khasianum**

16. Leaves green, (narrowly) lanceolate, often falcate. Distal part of labellum bilobed; lobules rounded to obtuse..**9. C. falcifolium**

15. Labellum usually not constricted at the middle (rarely constricted by a pair of lateral indentations)

17. Labellum distinctly bowl-shaped in its natural conformation

18. Flowers less than 4 mm in diameter, green. Labellum obtuse and with sagittate-auriculate base; auricles (sub)acute...............................**16. C. maximowiczianum**

18. Flowers more than 4 mm in diameter, (brownish-)yellow tinged or marked with purple or reddish-brown. Labellum truncate to emarginate and with cordate-auriculate base; auricles rounded to obtuse

19. Flowers less than 8 mm in diameter, yellow tinged with purple. Labellum cavity laterally flanked by 2 prominent, obliquely triangular ridges..................... ....**8. C. concavum**

19. Flowers more than 8 mm in diameter, brownish-yellow with reddish-brown or purplish markings on basal part of labellum. Labellum cavity laterally flanked by 2 low, linear ridges…………………………………...**10. C. josephianum**

17. Labellum flat or nearly flat in its natural conformation

20. Labellum retuse to bilobed

21. Leaves pale brown to greenish-brown or dull brownish-purple with white to ligth green (often spotted) marginal bands. Distal part of labellum (rounded-) truncate with a small triangular cleft apex...............................**6. C. calophyllum**

21. Leaves green; petiole more or less suffused with purple. Distal part of labellum not (rounded-)truncate with a small, triangular apex

22. Labellum with a pair of lateral indentations that distinctly set off the bilobed distal part from the rest of the labellum...............................**24. C. purpureum**

22. Labellum devoid of lateral indentations, distally retuse to emarginate............. ....**1. C. acuminatum**

20. Labellum acute to rounded

23. Labellum distinctly longer than wide. Labellum cavity laterally flanked by prominent, obliquely triangular ridges. Staminodes blackish-purple, subclavate ....**5. C. biauritum**

23. Labellum at least as wide as long. Labellum cavity not laterally flanked by prominent ridges. Staminodes greenish, oblongoid

24. Labellum more than 3 mm across, distinctly 3-lobed.............**23. C. prasinum**

24. Labellum less than 3 mm across, obscurely 3-lobed...........**17. C. merapiense**

1. Crepidium acuminatum (D. Don) Szlach., Fragm. Florist. Geobot., Suppl. 3: 123. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; Nanakorn & Watthana, Queen Sirikit Bot. Gard. (Thai Native Orchids 1): 194 (incl. colour photos). 2008; S. C. Chen & J. J. Wood in Z. Wu et al. (eds.), Fl. China 25: 233. 2009.— *Malaxis acuminata* D. Don, Prodr. Fl. Nepal.: 29. 1825; Seidenf., Dansk Bot. Arkiv 33(1): 55 p.p., figs. 43(a–e, g), 44. 1978; Opera Bot. 114: 147. 1992; Thaithong, Thai Orchids: 275 (colour photos on pp. 274–275). 2000; N. Pearce & P. J. Cribb, Fl. Bhutan 3(3): 213, t. 7(bottom left). 2002. **Type:** Nepal, Gossainthan, sine anno, *Wallich s.n.* (not seen).

— *Microstylis wallichii* Lindl., Gen. Sp. Orchid. Pl.: 20. 1830; Ridl., J. Linn. Soc., Bot. 24: 337. 1888; Hook. f., Fl. Brit. India 5: 686. 1890.— *Malaxis wallichii* (Lindl.) Deb, Bull. Bot. Surv. India 3: 128. 1962. **Type:** Nepal, sine loco, sine anno, *Wallich. 1938A* [holotype **K!**, isotypes **C! E**! **G! L! P!**].

— *Microstylis biloba* Lindl., Gen. Sp. Orchid. Pl.: 20. 1830; Ridl., J. Linn. Soc., Bot. 24: 337. 1888.— *Microstylis wallichii* Lindl. var. *biloba* (Lindl.) Hook. f., Fl. Brit. India 5: 686. 1890.— *Malaxis biloba* (Lindl.) Ames, Orchidaceae 2: 122. 1908; Seidenf. & Smitinand, Orchids Thailand: 149. 1959; Seidenf., Bot. Tidsskr. 65: 320, fig. 5 p.p. 1970.— *Malaxis acuminata* D. Don var. *biloba* (Lindl.) Ames in Merr., Enum. Philipp. Fl. Pl. 1: 302. 1924.— *Malaxis acuminata* D. Don f. *biloba* (Lindl.) Tuyama, Fl. E. Himalaya: 443. 1966.— *Crepidium bilobum* (Lindl.) Szlach. ex Lucksom, Orchids Sikkim N. E. Himalaya: 323. 2007. **Type:** Nepal, sine loco, sine anno, *Wallich 1940* [holotype **K!**, isotype **C!**].

— *Microstylis wallichii* Lindl. var. *omphaloides* C. S. P. Parish ex Ridl., J. Linn. Soc. 24: 338. 1888; Hook. f., Fl. Brit. India 5: 686. 1890. **Type:** Myanmar, Moulmein, 1862, *Parish 147* [holotype **K!**].

— *Microstylis pierrei* Finet., Bull. Soc. Bot. France 54: 534, t. 12. 1907.— *Malaxis pierrei* (Finet) Tang & F. T. Wang, Acta Phytotax. Sin. 1: 74. 1951. **Type:** Vietnam, Cochinchine, Déon-ba, 28 April 1866, *Pierre s.n.* [syntype **P!**]; Vietnam, Cochinchine, Mt. Dinh, July 1867, *Pierre s.n.* [syntype **P!**]; Vietnam, Cochinchine, Cai Cong, August 1884, *Regnier 360* [syntype **P!**]; Cambodia, Mt. Knang-Krépeuh, 28 May 1870, *Pierre s.n.* [syntype **P!**]. Indonesia, Gebok Klakka, 8 November 1844, *Zollinger 2536* [syntype **P**!].

— *Microstylis pierrei* Finet var. *rotundata* Finet, Bull. Soc. Bot. France 54: 535. 1907. **Type:** Cambodia, Tpong, Mt. Tamir, 15 May 1870, *Pierre s.n.* [syntype **P**!]; Cambodia, Kampot, Mt. Cam-chay, May 1874, *Pierre s.n.* [syntype **P**!]; Vietnam, Cochinchine, Mt. Tay ninh, May 1866, *Pierre s.n.* [syntype **P**!].

— *Microstylis trigonocardia* Schltr., Repert. Spec. Nov. Regni Veg. Beih. 4: 62. 1919. **Type:** China, Yunnan, 1900, *Henry 12284* [holotype **K!**].

— *Microstylis siamensis* Rolfe ex Downie, Bull. Misc. Inform. Kew 1925: 368. 1925.— *Malaxis siamensis* (Rolfe ex Downie) Seidenf. & Smitinand, Orchids Thailand: 150, fig. 117. 1959. **Type:** Thailand, Chiang Mai, Doi Suthep, 5 June 1909, *Kerr 100* [holotype **K!**, isotype **P!**].

— *Malaxis allanii* S. Y. Hu & Barretto, Chung Chi J. 13(2): 18. 1976. **Type:** China, Hong Kong, 25 March 1975, *Hu 13551* [holotype **K!**, isotype **A!**].

Terrestrial (rarely lithophytic or epiphytic), sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, 13.5–41 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* several, slender, arising from the basal part of the pseudobulbs, 1–10 cm long. *Pseudobulb* green, terete from a fusiform base, 5–15.5 cm long, 0.6–1.3 cm in diameter, consisting of 5–7 internodes. *Cataphylls* 3–5, broadly triangular to lanceolate-oblong (the lowermost tubular), acute to acuminate 0.5–5 by 0.7–1.6 cm. *Foliage leaves* 3–6, ascending to spreading or erect, petiolate, petiole sheathing at base, free part 0.5–3.5 cm long, green, more or less suffused with purple; lamina plicate, green, unspotted ovate to lanceolate or elliptic with slightly asymmetrical base, acute to acuminate, 1.8–17 by 0.8–7 cm, 3- to 9-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 8–30 cm long, elongating gradually during flowering; peduncle green, 3.5–12 cm long, 0.1–0.4 cm in diameter; rachis densely many-flowered; floral bracts persistent, pale green to purple, strongly recurved, lanceolate to triangular, acute to acuminate, entire, 3–10 by 1–2.5 mm, shorter than ovaries. *Flowers* yellowish-green, yellow tinged with red-purple or pink-purple, 4.5–13 mm in diameter. *Sepals* obtuse, glabrous, margins revolute; dorsal sepal spreading, (oblong-)lanceolate, 5.5–10 by 2.5–4.5 mm; lateral sepals spreading to reflexed, broadly and obliquely ovate to elliptic, 4.5–8.5 by 3–5 mm. *Petals* reflexed, linear, rounded to obtuse, 5–10 by 1–1.5 mm, margins revolute. *Labellum* (nearly) flat, 5–13 by 4–10 mm (maximum dimensions), longer than wide, ovate to obovate in outline (not constricted at the middle) with a strongly sagittate-auriculate base, distally retuse to emarginate with obtuse to acute lobes; basal part forming a cavity that is rectangular to nearly oblong in outline, subdivied by a longitudinal keel, and bordered by a more or less horseshoe-shaped ridge; auricles obliquely triangular to ovate, acute to rounded, 2.5–5 by 1.5–4 mm. *Column* pale green, erect, 1–2.5 mm long; staminodes fleshy, broadly and obliquely oblong, obtuse to truncate; anther incumbent, versatile, orange-yellow, broadly ovate, rounded to retuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.6–1 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) green, fusiform-cylindrical, with 6 longitudinal ridges, 4–11 mm long, glabrous. *Capsule* clavate-oblong, 0.8–1.5 cm long, 0.2–0.6 cm in diameter; fruit pedicel 0.8–0.9 cm long. Figures 4.5, 4.6 and 4.7.

Thailand.— NORTHERN: Mae Hong Son, Chiang Mai (Doi Sutep, Doi Inthanon, Doi Chiang dao), Chiang Rai, Nan (Phu Kha), Lumphun, Phitsanulok (Phu Hin Rong Kha); NORTH-EASTERN: Loei (Phu Ruea); SOUTH-WESTERN: Phetchaburi (Kaeng Krachan), Prachuap Khiri Khan (Huay Yang); PENINSULAR: Krabi (Khao Panom Bencha).

Distribution.— India, Nepal, Bhutan, Myanmar, China, Taiwan, Japan, Loas, Vietnam, Cambodia, Indonesia and Philippines.

Ecology.— *Crepidium acuminatum* grows in humus-rich soil, less often on mossy rocks and on the lower part of tree trunks, in tropical rain forest, hill evergreen forest and seasonal evergreen forest; 660–1,800 m alt. Flowering: May–July.

Vernacular.— Hoo Sua (หูเสือ).

Note.— This species is highly polymorphic especially in the shape of its labellum, not least the retuse to deeply emarginate distal part (cf. Seidenfaden 1978: fig. 43).

Specimens examined.— **THAILAND:** *C.F. van Beusekom & C. Phengklai 1282* (BKF, C, L), Chiang Mai, Doi Suthep, 16 June 1968; *S. Damapong 37* (QBG), Chiang Mai, Doi Phahom Pok, 27 May 2006; *H.B.G. Garrett 404* (K, P), Chiang Mai, Doi Ang Ka, 3 July 1927; *R. Geesink et al. 5896* (C, L), Chiang Mai, Bo Luang, 12 June 1973; *T. Havananda 066* (QBG), Chiang Mai, 19 July 1998; *A.F.G. Kerr 100* (K), Chiang Mai, Doi Suthep, 5 June 1909; *A.F.G. Kerr 321* (K), Prachuap Khiri Khan, Khao Laung, 4 July 1924; *A.F.G. Kerr 437* (K), Chiang Mai, Doi Chiang Dao, 13 June 1927; *A.F.G. Kerr 445* (K), Chiang Mai, Kao Ngao, Muang Lom, 3 May 1922; *A.F.G. Kerr 872* (C, K), Krabi, Khao Panom Bencha, 4 June 1921; *H. Koyama T-61151* (BKF), Chiang Mai, Mae Pan waterfalls, Doi Inthanon, 29 July 1988; *W. La-ongsri et al. 4144* (QBG), Lampang, Ngao, 22 May 2015; *K. Larsen & B. Hansen 3769* (BKF, C), Chiang Mai, Doi Suthep, 28 June 1958; *J.F. Maxwell 88-976* (BKF, L), Chiang Mai, Doi Suthep, 8 August 1988; *J.F. Maxwell 93-502* (L), Chiang Mai, Doi Saket, 25 May 1993; *J.F. Maxwell 93-600* (L), Lamphun, Doi Khun Tan, 7 June 1993; *J.F. Maxwell 02-147* (L), Chiang Mai, Mae Awn, Sahngampang, 29 May 2002; *D.J. Middleton et al. 1771* (BKF), Phetchaburi, Kaeng Krachan, 28 March 2003; *D.J. Middleton et al. 3363* (BKF), Phetchaburi, Kaeng Krachan, 10 May 2005; *W. Nanakorn et al. 11258* (QBG), Chiang Mai, Doi Suthep, 2 January 1998; *M. Norsaengsri & N. Tathana* 7923 (QBG), Chiang Rai, Mae Sai, Khun Nam Nang Norn, 26 May 2011; *A. Nuammee 377* (BCU, BKF), Phitsanulok, Phu Hin Rong Kha, 28 June 2013; *A. Nuammee 398* (BCU), Loei, Phu Ruea, 4 May 2014; *A. Nuammee 429* (BCU), Prachuap Khiri Khan, Huay Yang waterfalls, 3 August 2014; *A. Nuammee 438* (BCU, BKF), Prachuap Khiri Khan, Huay Yang waterfalls, 8 May 2015; *P. Palee 233* (BKF), Chiang Mai, Doi Suthep, 17 July 1994; *G. Seidenfaden & T. Smitinand GT 2595* (C), Chiang Mai, Doi Suthep, 1 July 1958; *G. Seidenfaden & T. Smitinand GT 2813* (C), Chiang Mai, Doi Suthep, 1 June 1958; *P. Suksathan 4206* (QBG), Chiang Mai, Mae Chaem, 23 June 2007; *S. Watthana 1985* (QBG), Nan, Phu Kha, 6 June 2006.

India: *C.M. Arora 70815* (C), Maith, 31 July 1980; *C.M. Arora 70828* (C), Dafia Dhoora, Pithoragarh; *P. Mackinnon 21775* (K), sine loco, July 1998; *C.A. Barber 2045* (K), Nilgiris, Sepember 1900; *T.R. Chand 7850* (K), Mawphlang, Khasia Hills, 14 July 1954; *J.M. Cowan s.n.* (K), Darjeeling, 5 July 1993; *J.R. Drummond s.n.* (K), Punjab, sine anno; *H. Falconer 1012* (K, L), E. India, 1864; *H. Falconer 1015* (K), Sine loco, sine anno; *J.S. Gamble 8981* (K), Darjeeling, July 1880; *A. Henry 398* (K), sine loco, 10 October 1886; *H. Homuasji 21778* (K), Mawphlang, Khasia Hills, 17 July 1998; *J.D. Hooker s.n.* (K), Mt. Khasia, sine anno; *J.D. Hooker s.n.* (L), Meghalaya, Khasia hills, sine anno; *Inaijat 24116* (K), W Himalaya, 22 July 1900; *King's collectors 187* (L), Sikkim Himalaya, sine anno; *W.N. Koelz 33243a* (K), Mawphlang, Khasia Hills, 30 June 1953; *W.N. Koelz 33298* (K), Mawphlang, Khasia Hills, 7 June 1953; *S. Kurz s.n.* (SING), Sikkim, Tonglu, sine anno; *R.N. Parker 2032* (K), Almora, 29 June 1923; *R. Pantling 448* (K, L), Sikkim Himalaya, June 1986; *H.H. Rich 258* (K), sine loco, sine anno; *Sine coll. s.n.* (K), sine loco, sine anno; *R.R. Stewart 10968* (K), NW Himalaya, 9 July 1930; *T. Thomson 9169* (K), Himalaya, sine anno; *C.K. Treutler 584* (K), Punjab, 13 August 1874; *N. Wallich 1938* (K), Sylhet, sine anno; *Watt s.n.* (C), Simla, sine anno.

Nepal: *J.F. Royle 1940* (K), sine loco, sine anno; *N. Wallich. 1938A* (C, E, K, L, P), sine loco, sine anno; *N. Wallich 1940* (C, K), sine loco, sine anno; *G. Wilson & Phillips 240* (K), Mulkharka, 30 June 1973; *G. Wilson & Phillips 294* (K), Lumle, 18 July 1973; *A.D. Schilling 575*, Kathmandu, 23 July 1965; *M. Farille et al. 847263* (K), Ganesh Himal, Sathigaon, 1919.

Myanmar: *R.E. Cooper 6051* (E), Mt. Victoria, 1924; *J.H. Lace 149* (E), Maymyo, July, 1916; *C.S.P. Parish 115* (K), Moulmein, sine anno; *C.S.P. Parish 147* (K), Moulmein, 1862; *C.S.P. Parish 13552* (K), Maymyo; 23 July 1935; *F.E.W. Venning 14* (K), Chin Hills, 23 July 1910.

China: *G. Barretto s.n.* (K), Hong Kong, September 1969; *J.M. Delavay s.n.* (P), Les marais de Nien Kla Se près de Ta pin tze, 20 August 1885; *A. Henry 12284* (K), Yunnan, 1900; *S.Y. Hu 12451* (K), Hong Kong, 8 November 1972; *S.Y. Hu 13551* (K, P), Hong Kong, 25 March 1975; *E.H. Wilson 5319* (K, P), W. China, Mt. Omi, July 1904.

Vietnam: *A.C. Alleizette s.n.* (L), Khanh Hoa, Nha Trang, 6 June 1909; *L. Pierre s.n.* (P), Cochinchine, Tay ninh, May 1866; *L. Pierre s.n.* (P), Cochinchine, Deon-ba, 28 April 1866; *L. Pierre s.n.* (P), Cochinchine, Ad montem Dinh, Baria aust., July 1867; *E. Poilane 4871* (C, P), Nhatrang, 4 September 1922; *A. Regnier 360* (P), Cai Cong, August 1884; *P. Tixier 59* (C, P), Chute de Dantania, 1958.

Cambodia: *L. Pierre s.n.* (P), Tpong, Mt. Tamir, 15 May 1870; *L. Pierre s.n.* (P), Knang-Krepeuh; 28 May 1870; *L. Pierre s.n.* (P), Kampot, Mt. Cam-chay, May 1874.

Indonesia: *Hagerup s.n.* (C), Toba, sine anno; *S.H. Koorders 38097* (L), Java, Jawa Timur, Gunung, 11 November 1999; *H. Zollinger 2536* (C, P), Gebok Klakka, 8 November 1844; *J.B. Comber 1016* (K), E. Java, Magetan, 26 November 1978; *J.B. Comber 1115* (K), E. Java, Kediri, Malang 28 October 1979; *J.B. Comber 1144* (K), E. Java, Batu, 1 January 1980; *J.B. Comber 1542* (K), E. Java, Arjuno-Tretes, 17 November 1983.

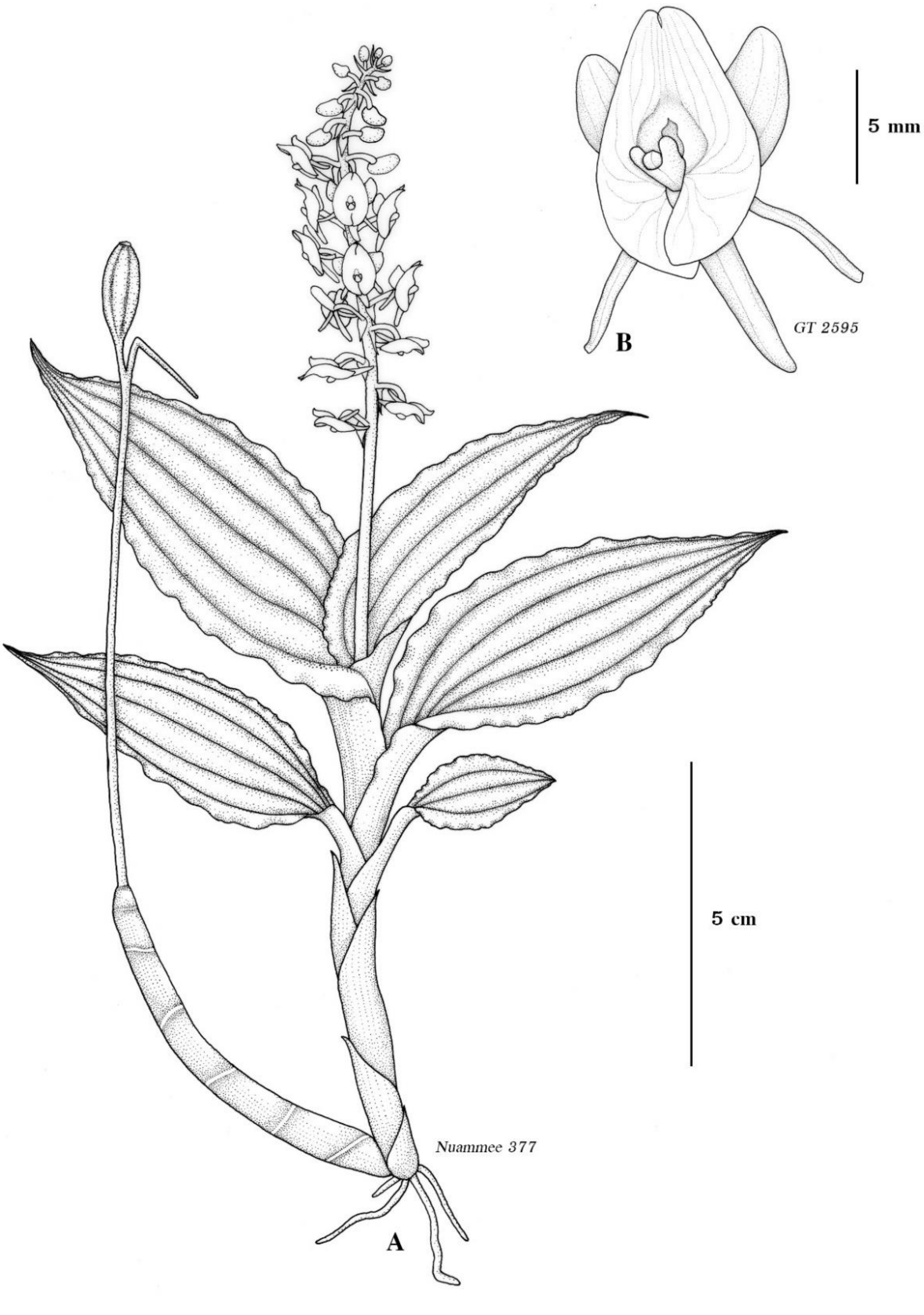

Figure 4.5 *Crepidium acuminatum* (D. Don) Szlach. **A:** Habit. **B:** Flower, front view. Drawing from *Nuammee 377* (A); *GT 2595* (B).

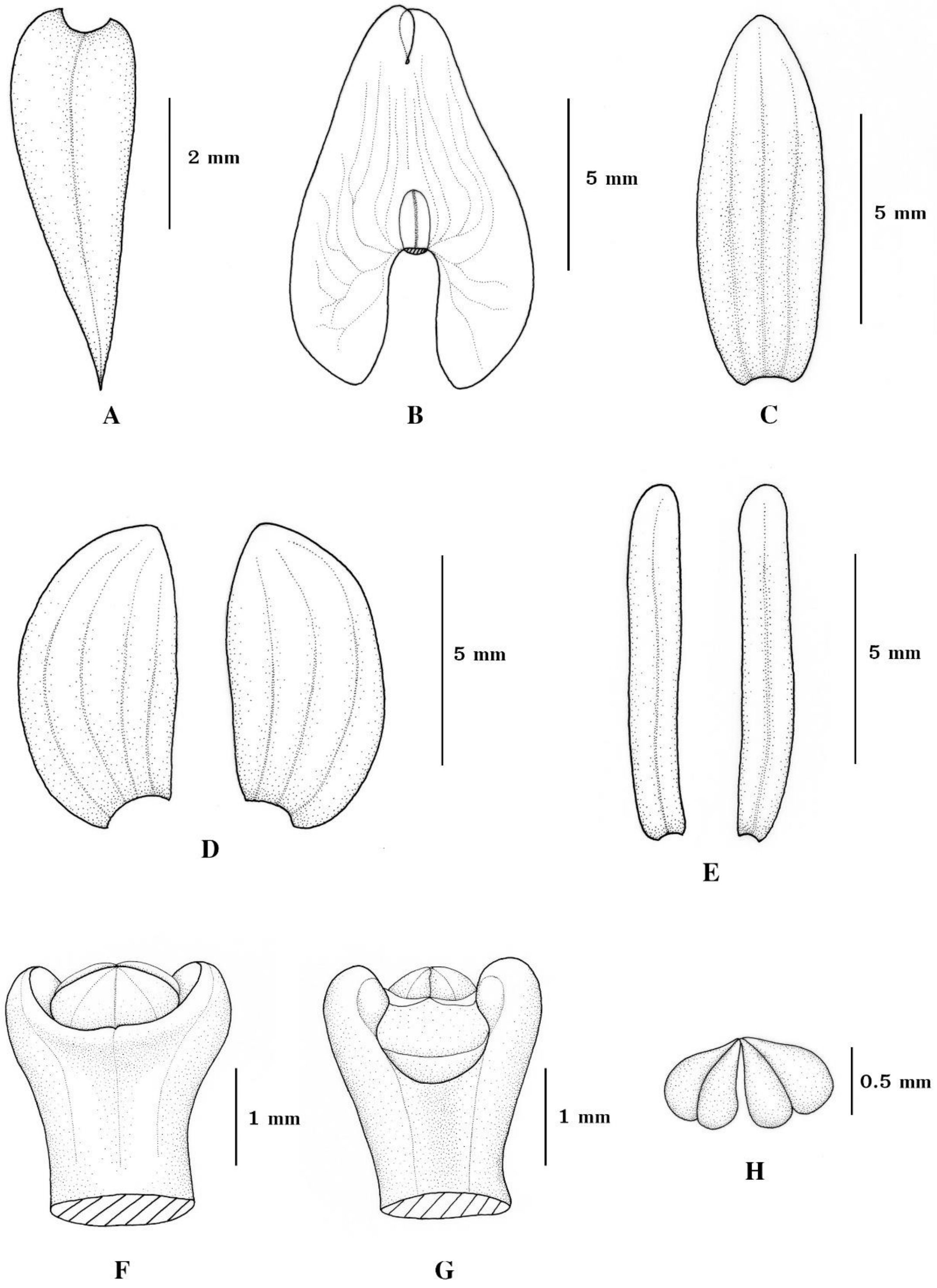

Figure 4.6 *Crepidium acuminatum* (D. Don) Szlach. **A:** Floral bract. **B:** Labellum, front view. **C:** Dorsal sepal. **D:** Lateral sepals. **E:** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *GT 2595* (A–H).

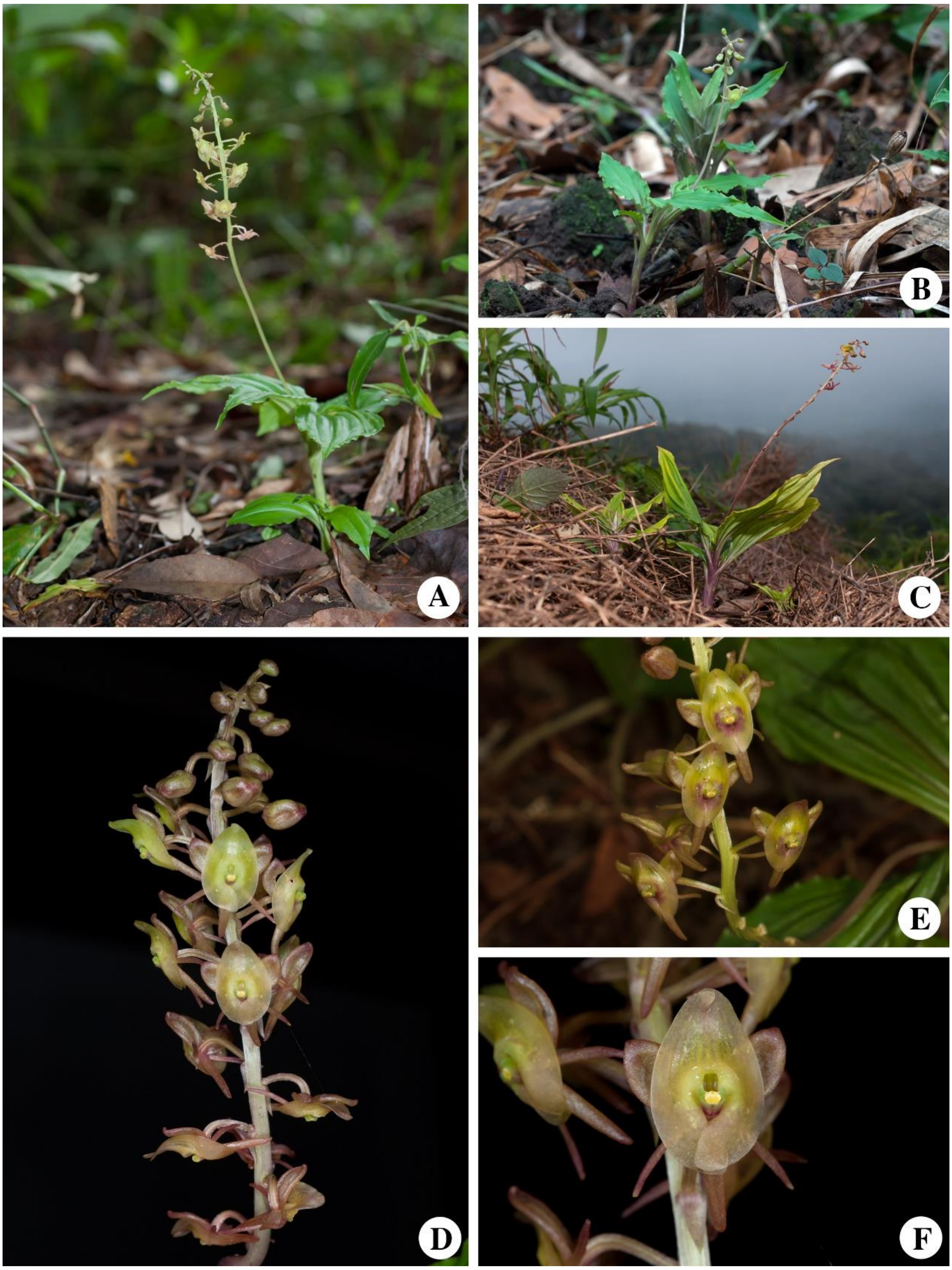

Figure 4.7 *Crepidium acuminatum* (D. Don) Szlach. **A–C:** Habit. **D:** Inflorescence. **E–F:** Flower, front view. A was photographed from Phitsanulok, Phu Hin Rong Kla, 12 June 2016, B was photographed from from Loei, Phu Ruea, 04 May 2014; C and E were photographed from Prachuap Khiri Khan, Huay Yang waterfalls, 9 May 2015; D and F were photographed from Phitsanulok, Phu Hin Rong Kla, 28 June 2013.

2. Crepidium aschistum (Seidenf.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 124. 1995.— *Malaxis aschista* Seidenf., Dansk Bot. Arkiv 33(1): 72, fig. 51. 1978. **Type:** Thailand, Narathiwat, Su-ngai Padi, *Larsen et al. 4042* [holotype **AAU**, isotype **K!**].

Terrestrial, sympodial herb with a creeping rhizome terminally producing a 16–38 cm tall flowering shoot that is erect from a decumbent base. *Rhizome* green to green-brown, terete, 2.5–11 cm long, 0.3–0.4 cm in diameter, internodes 0.6–0.9 cm long. *Roots* several, 1–2 arising from each node of the rhizome and from the lower nodes of the stem, 2–4.5 cm long. *Foliage leaves* 9–12, ascending to spreading, petiolate, petiole sheathing at base, free part 1–2.2 cm long, greenish-brown, more or less suffused with purple; lamina greenish-brown, unspotted, ovate to lanceolate with asymmetrical base, acute, 5–10 by 1.5–3 cm, 3- to 5-veined, glabrous, margins undulate. *Inflorescence* terminal on the young shoot, racemose, erect, 17–26 cm long, elongating gradually during flowering; peduncle green, 8–10 cm long, 0.1–0.2 cm in diameter; rachis densely many-flowered; floral bracts persistent, green, reflexed, ovate to narrowly triangular, acute to acuminate, entire, 2.5–7 by 0.5–1.5 mm, shorter than ovaries. *Flowers* yellow to orange, sometimes flushed purple, 3–4 mm in diameter. *Sepals* obtuse to rounded, glabrous, margins recurved; dorsal sepal spreading, ovate, 2.5–3 by 1.5–2 mm; lateral sepals, spreading to reflexed, ovate to suborbicular, 2.5–3 by 2–2.5 mm. *Petals* reflexed, linear, truncate, 2.5–3 by 0.5–1 mm, margins recurved. *Labellum* nearly flat, 3.5–4 by c. 3 mm (maximum dimensions), longer than wide, broadly ovate (not constricted at the middle) with a strongly sagittate-auriculate base, distally obtuse to bifid with unevenly 2 teeth on either side of the apex; basal/central part forming a small and shallow cavity that is narrowly triangular in outline, with flat margins; auricles broadly and obliquely triangular, obtuse, c. 1.5 by 1–1.5 mm. *Column* yellow to orange, erect, slender, c. 1 mm long, larger than the largest marginal teeth of the labellum; staminodes flat, triangular, obtuse; anther incumbent, versatile, orange-yellow, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, 0.3–0.4 mm long; rostellum transversely rectangular, truncate, flat; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) yellowish-green, cylindrical, 3–5 mm long, glabrous. *Capsule* oblongoid-ellipsoid, 0.6–0.9 cm long, 0.2–0.3 cm in diameter; fruit pedicel 0.4–0.7 cm long. Figures 4.8, 4.9 and 4.10.

Thailand.— PENINSULAR: Yala (Betong), Narathiwat (Su-ngai Padi).

Distribution.— Endemic.

Ecology.— *Crepidium aschistum* grows in humus-rich soil along streams in evergreen forest at c. 1,000 m. Flowering: August–September.

Note.— This species resembles *C. oculata* (Rchb. f.) Szlach. from Sumatra and Java in both vegetative and floral characters, and the mutual delimitation of the two taxa is in need of further study.

Specimens examined.— **THAILAND:** *Ahdhabhan s.n.* (BCU), Yala, Betong, 13 August 2003; *K. Larsen et al. 4042* (AAU, K), Narathiwat, Su-ngai Padi, Chatvarin waterfalls, 18 October 1970, 6' 04" N, 101' 52" E.

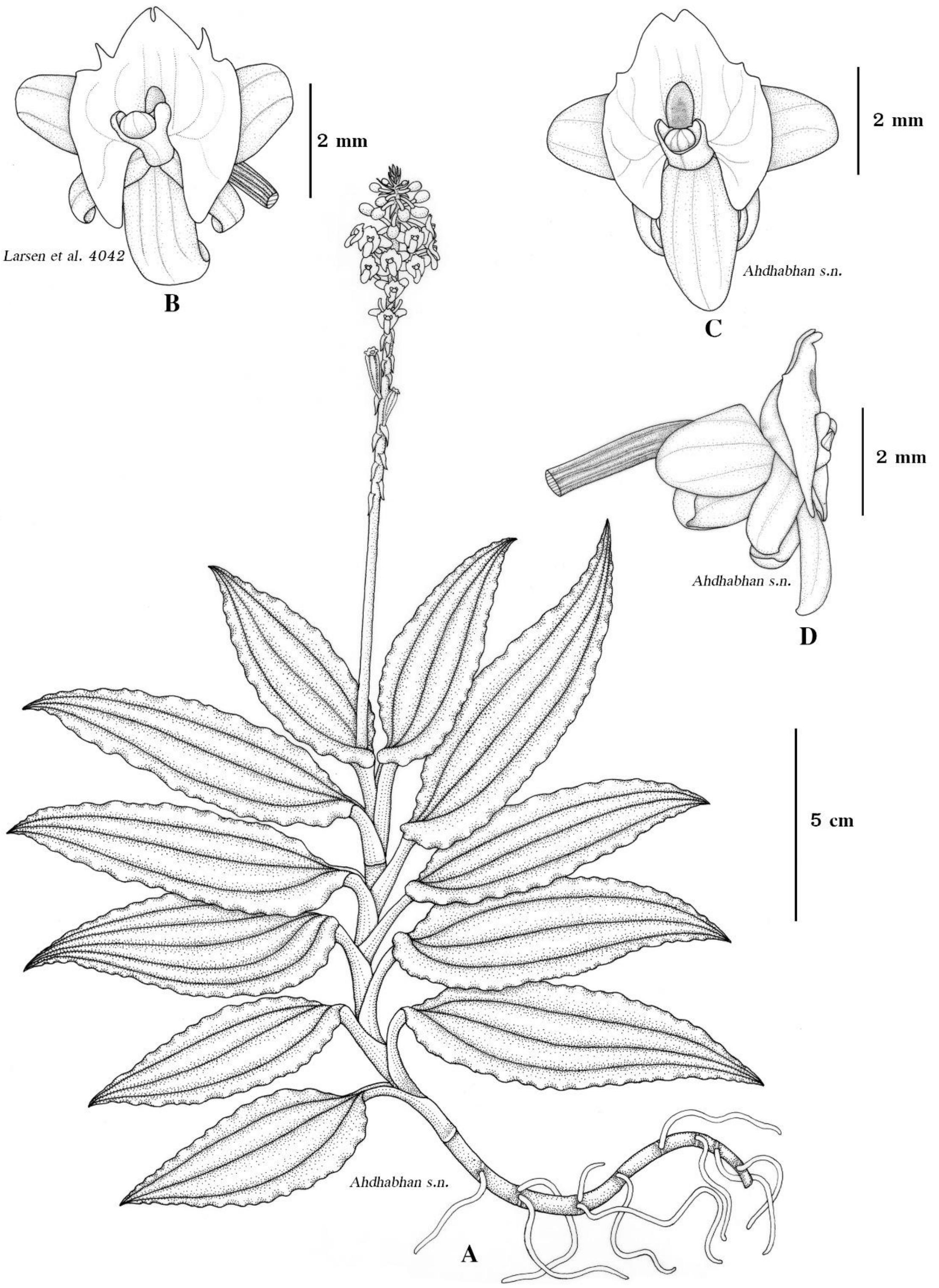

Figure 4.8 *Crepidium aschistum* (Seidenf.) Szlach. **A:** Habit. **B–C:** Flower, front view. **D:** Flower, lateral view. Drawing from *Ahdhabhan s.n.* (A, C, D); *Larsen et al. 4042* (B).

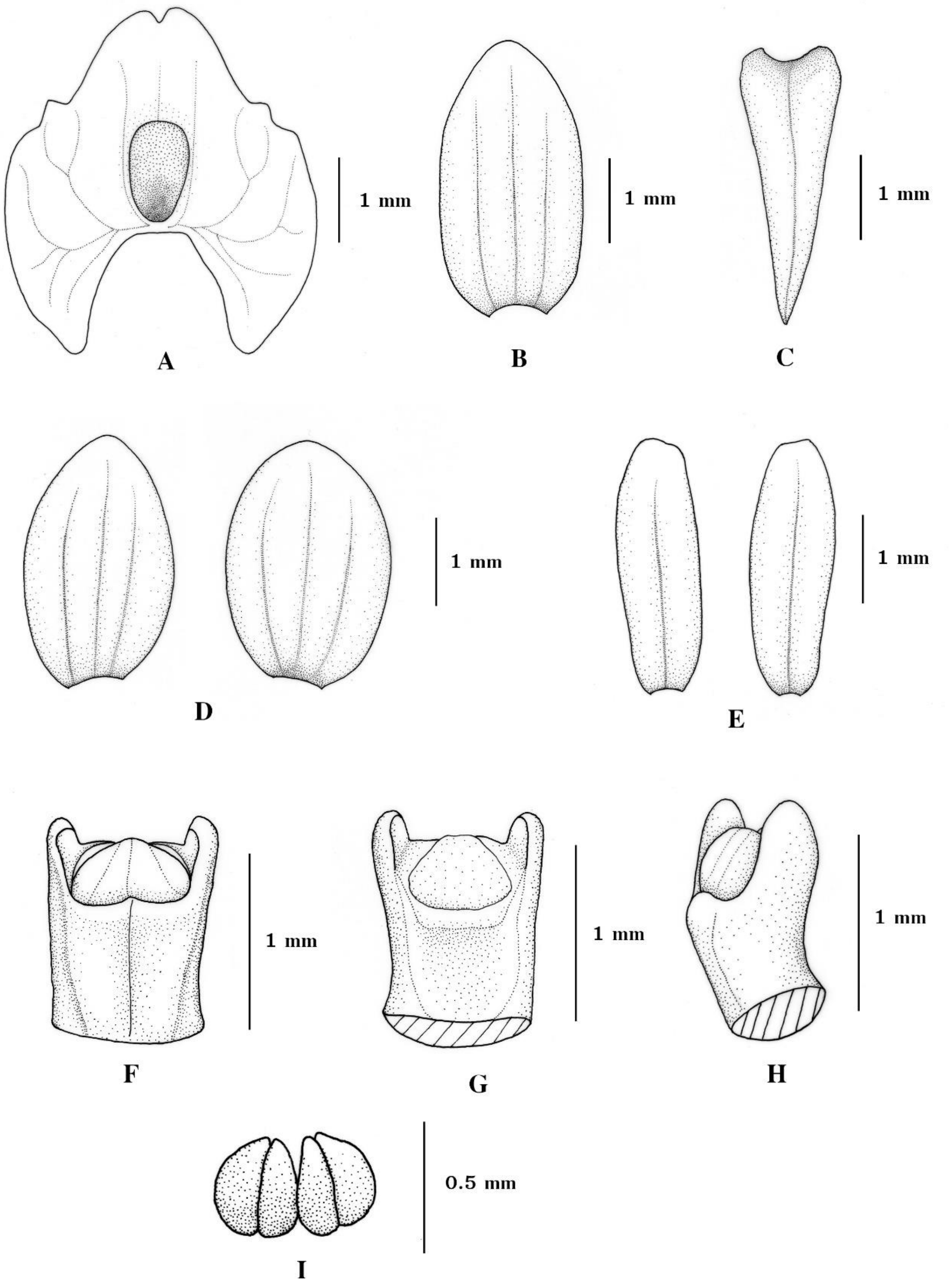

Figure 4.9 *Crepidium aschistum* (Seidenf.) Szlach. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bract. **D:** Lateral sepals. **E:** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Column, lateral view. **I:** Two pairs of pollinia. Drawing from *Ahdhabhan s.n*. (A–I).

Figure 4.10 *Crepidium aschistum* (Seidenf.) Szlach. **A:** Habit. **B–C:** Inflorescence. **D:** Flower, front view. All were photographed by Mr. Ahdhabhan from Yala, Betong, 13 August 2003.

3. Crepidium bahanense (Hand.-Mazz.) S. C. Chen & J. J. Wood in Z. Wu et al. (eds), Fl. China 25: 232. 2009.— *Microstylis bahanensis* Hand.-Mazz. Symb. Sin. 7: 1350. 1936.— *Malaxis bahanensis* (Hand.-Mazz.) Tang & F. T. Wang: Acta Phytotax. Sin. 1: 71. 1951. **Type:** China, Yunnan, sine loco, 21 July 1916, *Handel-Mazzetti 9574* [holotype **WU!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect cormous, 10–20 cm tall flowering shoot distally and 1–2 decaying corms behind. *Roots* 3–5, arising from the basal part of the corms, 0.5–1 cm long. *Corms* white, subglobose, 0.6–1.1 cm long, 0.5–1.5 cm in diameter, consisting of 2–4 internodes. *Cataphylls* few, oblong to oblong-lanceolate, subacute to acute, 0.8–3 by 0.4–0.7 cm. *Foliage leaves* 2(–3), ascending to erect, petiolate, petiole sheathing at base, free part 0.8–2 cm long, green; lamina subplicate, green, unspotted, lanceolate-oblong to ovate-oblong or ovate with symmetrical base, obtuse to acute, sometimes slightly apiculate, 3–7.5 by 1–2.5 cm, 1- to 3-veined, with numerous scattered white papillae on the adaxial side when young (later glabrous), margins entire to slightly undulate. *Inflorescence* terminal on the young corm, racemose, erect, 9–17 cm long, elongating gradually during flowering; peduncle brownish-purple to greenish-brown or green, 6–9 cm long, c. 0.1 cm in diameter; rachis laxly 10- to 30-flowered; floral bracts persistent, creamy-yellow to yellowish-green, reflexed, (linear-)triangular, acute to acuminate, entire, 2–5.5 by 1.1–1.2 mm, equal to longer than ovaries. *Flowers* creamy-yellow with more or less purple lip mid-lobe, 4–4.5 mm in diameter. *Sepals* spreading, rounded to obtuse, glabrous, margins revolute; dorsal sepal ovate to elliptic, c. 2.5 by c. 1.5 mm, less than twice as long as labellum auricles; lateral sepals concave, obliquely ovate, c. 2.5 by 1.8–2 mm. *Petals* revolute, linear-ligulate, truncate, 2–2.2 by 0.5–0.6 mm, margins recurved to revolute. *Labellum* (nearly) flat, c. 4.5 by 2.5–3 mm (maximum dimensions), longer than wide, oblong, constricted at the middle, with a widened, strongly sagittate-auriculate base, distally bilobed with obtuse to retuse lobes, basal part forming a cavity that is broadly ovate to suborbicular in outline and bordered by a more or less horseshoe-shaped ridges, distally prolonged; auricles obliquely triangular to ovate, obtuse, c. 1.5 by c. 1 mm. *Column* yellow, erect, stout, 1–1.5 mm long; staminodes fleshy, oblong, truncate; anther incumbent, versatile, orange-yellow, broadly ovate, retuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.4–0.5 mm; rostellum transversely rectangular, truncate; fertile part of stigma elliptic, flat, concave at base. *Ovary* (including pedicel) greenish-yellow, fusiform-cylindrical, with 6 longitudinal ridges, 2–2.5 mm long, glabrous. *Capsule* ellipsoid, 0.5–0.7 cm long, 0.2–0.4 cm in diameter; fruit pedicel 0.1–0.2 cm long. Figures 4.11, 4.12 and 4.13.

Thailand.— NORTH-EASTERN: Loei (Phu Ruea).

Distribution.— China (Yunnan).

Ecology.— *Crepidium bahanense* grows in sandy soil along streams and shallow moist depressions in open grassland at c. 1,200 m alt. Flowering: June to July.

Vernacular.— Hoo Sua Chiuw Bui Tuang (หูเสือจิ๋วใบตั้ง)

Note.— Unpublished photos taken by Panu Ruangjan in 2008 suggest that *C. bahanense* may also occur in Chanthaburi in south-eastern Thailand. However, no herbarium specimen is available to unequivocally document this occurrence.

Specimens examined.— **Thailand:** *A. Nuammee 380* (BCU, BKF), Loei, Phu Ruea, 20 July 2013; *A. Nuammee 415* (BCU, BKF), Loei, Phu Ruea, 2 July 2014. **China:** *Handel-Mazzetti 9574* (WU), Yunnan, sine loco, 21 July 1916.

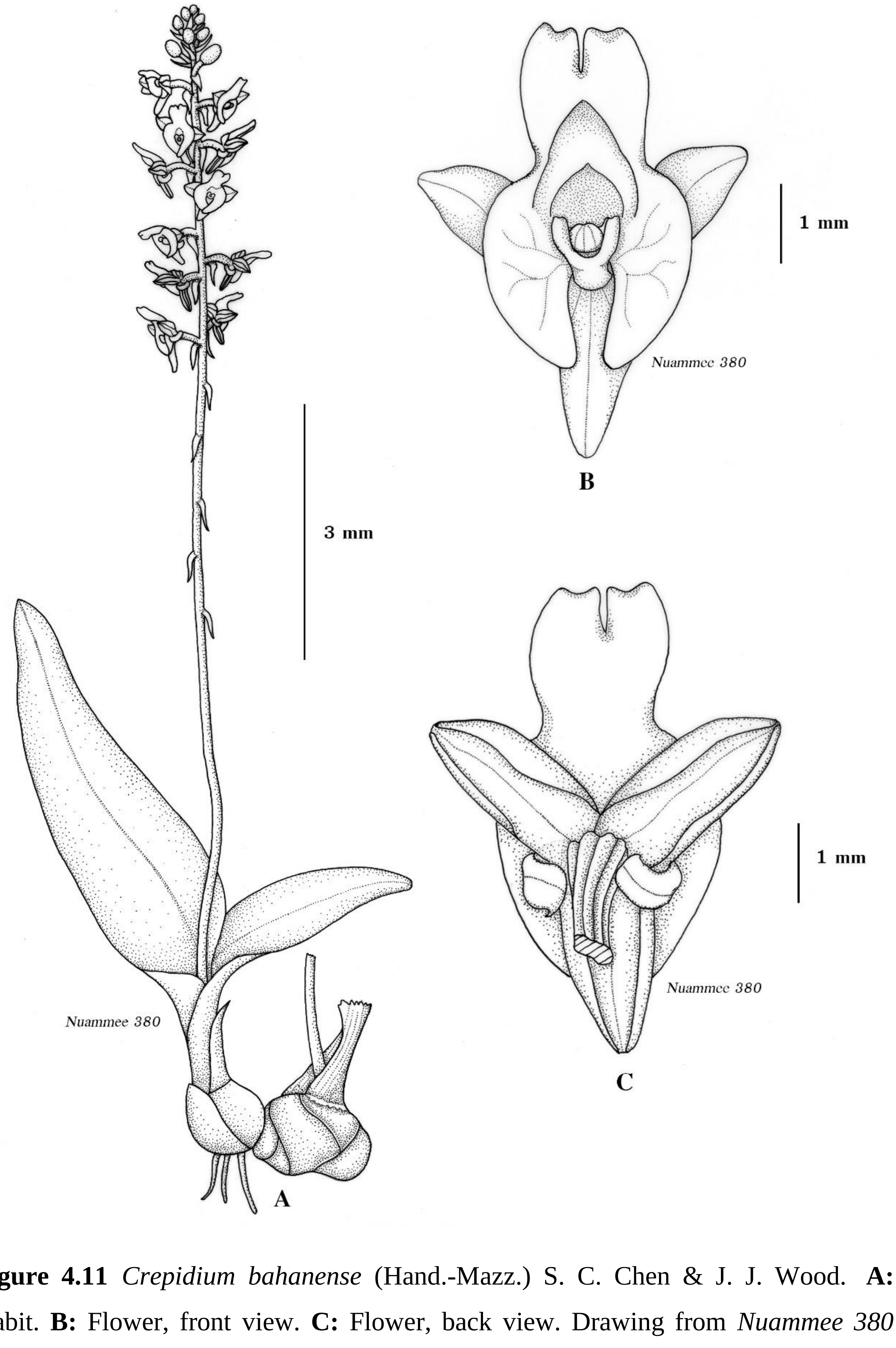

Figure 4.11 *Crepidium bahanense* (Hand.-Mazz.) S. C. Chen & J. J. Wood. **A:** Habit. **B:** Flower, front view. **C:** Flower, back view. Drawing from *Nuammee 380* (A–C).

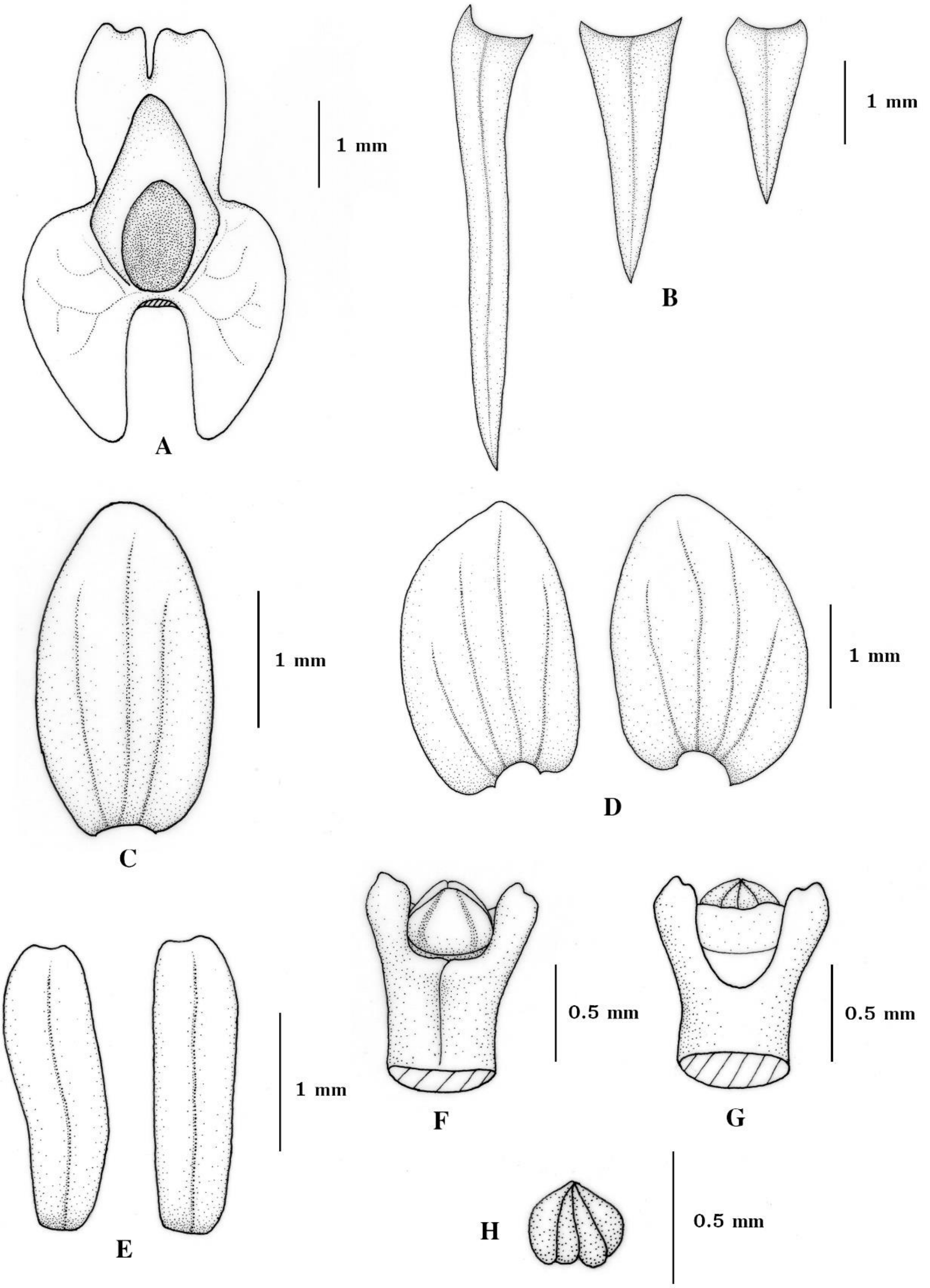

Figure 4.12 *Crepidium bahanense* (Hand.-Mazz.) S. C. Chen & J. J. Wood. **A:** Labellum, front view. **B:** Floral bracts. **C:** Dorsal sepal. **D:** Lateral sepals. **E:** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *Nuammee 380* (A–H).

Figure 4.13 *Crepidium bahanense* (Hand.-Mazz.) S. C. Chen & J. J. Wood. **A–B:** Habit. **C:** White papillae on young leaves. **D:** Inflorescence. **E** Flower, front and lateral view. **F:** Flower, front view. A, B and E were photographed from Loei, Phu Ruea, 20 July 2013; C, D and F were photographed from Loei, Phu Ruea, 2 July 2014.

4. Crepidium bancanum (Ridl.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 124. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997.— *Microstylis bancana* Ridl., J. Linn. Soc., 24: 343. 1888.— *Malaxis bancana* (Ridl.) Kuntze, Revis. Gen. Pl. 2: 673. 1891; Seidenf., Dansk Bot. Arkiv 33(1): 76, fig. 53. 1978; J. B. Comber, Orchids of Sumatra: 175. 2001. **Type:** Indonesia, Bangka, sine anno, *Horsfield s.n.* [holotype **BM!**].

Terrestrial, sympodial herb with a creeping rhizome terminally producing a flowering shoot that is erect from a decumbent base. *Rhizome* terete, 8–10 cm long, internodes 0.8–1 cm long. *Roots* several, 1–2 arising from each node of the rhizome and from the lower nodes of the stem. *Foliage leaves* (3–)5–8, ascending to spreading or erect, petiolate, petiole sheathing at base, free part 2–5 cm long; lamina lanceolate to (oblong-)elliptic with asymmetrical base, acuminate, 13–15 by 3.5–4.1 cm, 5-veined, glabrous, margins undulate. *Inflorescence* terminal on the young shoot, racemose, erect, 16–30 cm long, elongating gradually during flowering; peduncle 6.5–15 cm long, c. 0.2 cm in diameter; rachis laxly many-flowered; floral bracts persistent, reflexed, linear-triangular to lanceolate, acuminate, entire, 5–10 by 1.5–2 mm, longer than ovaries. *Flowers* yellow to orange, sometimes flushed purple, 5–7 mm in diameter. *Sepals* spreading, rounded, glabrous; dorsal sepal broadly lanceolate to oblong, 3.5–4 by c. 2 mm; usually more than twice as long as labellum auricles; lateral sepals obliquely ovate, 2.5–3 by 1.5–2 mm. *Petals* spreading, oblong, obtuse, c. 4 by c. 1.5 mm. *Labellum* (nearly) flat, 3.5–4.5 by 2.5–3 mm (maximum dimensions), longer than wide, nearly elliptic (not constricted at the middle) with cordate-auriculate base, distally rounded with coarsely and unevenly 8- to 10-dentate margin (4- to 5-dentate teeth on either side); basal/central part forming a deeply cavity that is obovate in outline, bordered by a prominent horseshoe-shaped ridge; auricles obliquely ovate, obtuse to rounded, 1–2 by 1–1.5 mm. *Column* erect, c. 1 mm long, larger than the largest marginal teeth of the labellum; staminodes flat, transversely rectangular, truncate; anther incumbent, versatile, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.3–0.4 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) cylindrical, with

6 longitudinal ridges, 2–3 mm long, glabrous. *Capsule* not seen. Figures 4.14 and 4.15.

Thailand.— PENINSULAR: Yala (Khao Kala Kriri).

Distribution.— Indonesia (Bangka).

Ecology.— *Crepidium bancanum* grows on rocks in evergreen forest at c. 800 m alt. Flowering: recorded in August.

Note.— The morphological description above has been prepared partly from the sole, incomplete Thai specimen, partly from the equally poor type specimen from Bangka.

Specimens examined.— **Thailand:** *A.F.G. Kerr 0567* (K), Yala, Khao Kala Khiri, 2 August 1925. **Indonesia:** *T. Horsfield s.n.* (BM), Bangka, Nearest named place, sine anno.

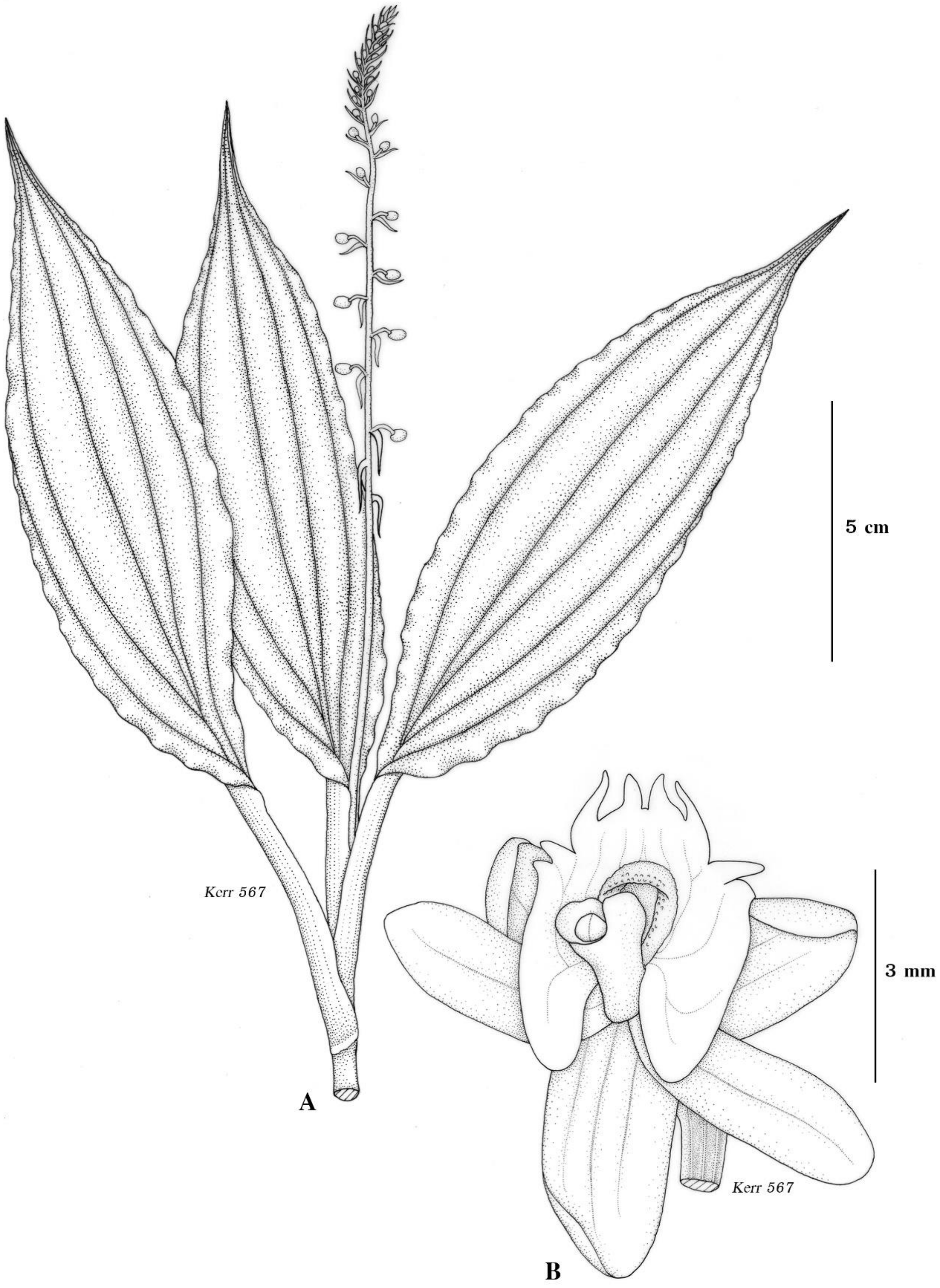

Figure 4.14 *Crepidium bancanum* (Ridl.) Szlach. **A:** Habit. **B:** Flower, front view. Drawing from *Kerr 567* (A–B).

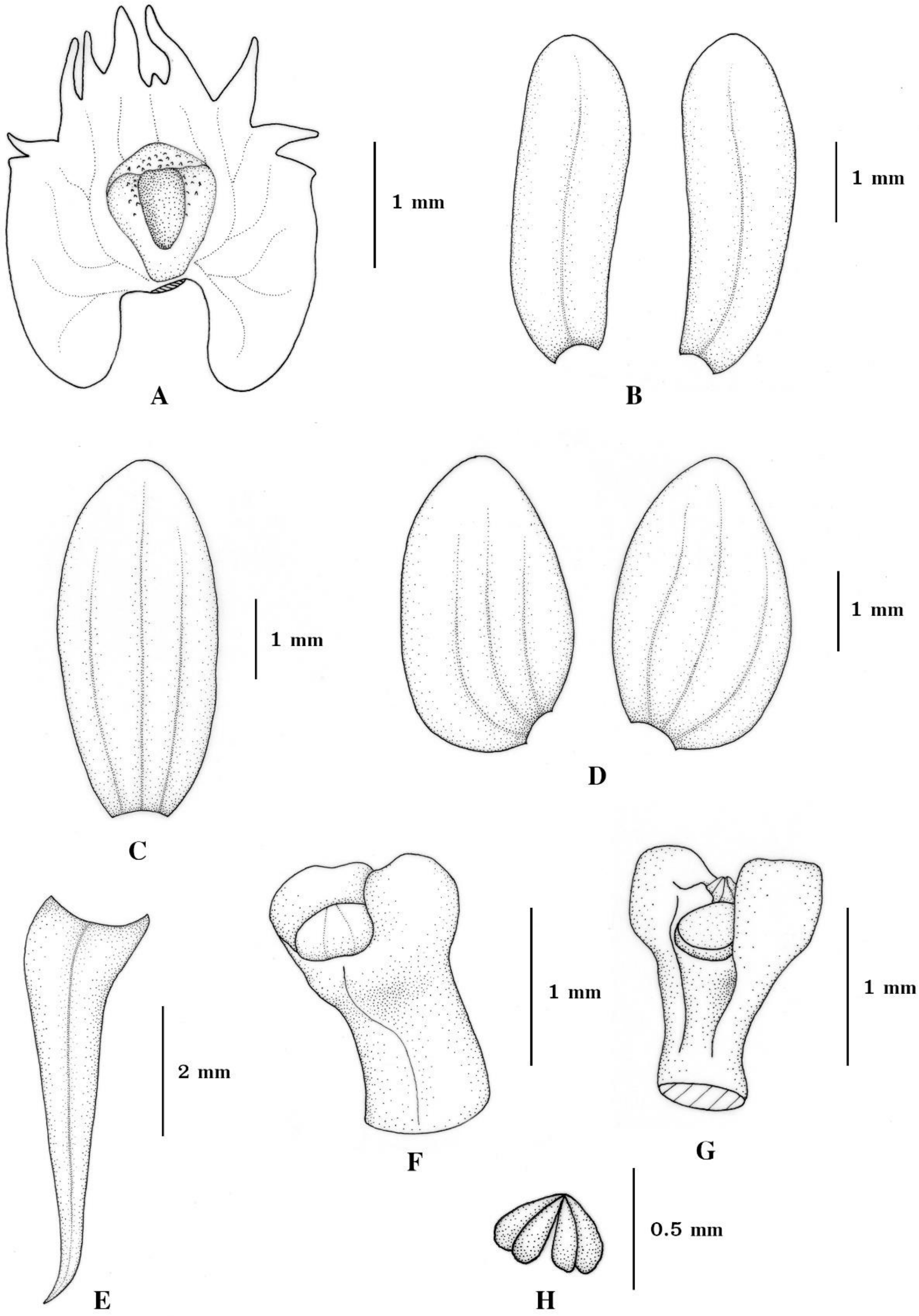

Figure 4.15 *Crepidium bancanum* (Ridl.) Szlach. **A:** Labellum, front view. **B:** Petals. **C:** Dorsal sepal. **D:** Lateral sepals. **E:** Floral bract. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *Kerr 567* (A–H).

5. Crepidium biauritum (Lindl.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 124. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; S. C. Chen et al., Native Orchids China Colour: 290 (incl. colour photos). 1999; S. C. Chen & J. J. Wood in Z. Wu et al. (eds.), Fl. China 25: 232. 2009.— *Microstylis biaurita* Lindl., Gen. Sp. Orchid. Pl. 20. 1830; Ridl., J. Linn. Soc., Bot. 24: 335. 1888; Hook. f., Fl. Brit. India 5: 687. 1890.— *Malaxis biaurita* (Lindl.) Kuntze, Revis. Gen. Pl. 2: 673. 1891; Seidenf., Bot. Tidsskr. 65: 125, fig. 16. 1969; Dansk Bot. Arkiv 33(1): 67, fig. 46. 1978; Opera Bot. 114: 147. 1992; Vaddhanaphuti, Field Guide Wild Orchids Thailand, ed. 4: 181 (incl. colour photo). 2005. **Type:** Khasia, Pundua, De Silva, *Wallich 1941* [holotype **K!**, isotype **C!**].

— *Microstylis andamanica* King & Pantl., J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 66: 582. 1897.— *Malaxis andamanica* (King & Pantl.) N. P. Balakr. & Vasudeva Rao, Bull. Bot. Surv. India 21: 177. 1981.— *Crepidium andamanicum* (King & Pantl.) Marg. & Szlach., Polish Bot. J. 46: 43. 2001. **Type:** India, Andaman and Nicobar Islands, 1884, *King's collectors 306* [holotype **K!**, isotype **L! P!**].

— *Microstylis thorelii* Finet, Bull. Soc. Bot. France 54: 536. 1907. **Type:** Laos, Palai, Lukhon, sine anno, *Thorel s.n.* [holotype **P!**, isotype **P!**].

— *Microstylis sutepensis* Rolfe ex Downie, Bull. Misc. Inform. Kew 1925: 369. 1925.— *Malaxis sutepensis* (Rolfe ex Downie) Seidenf. & Smitinand, Orchids Thailand: 148. 1959. **Type:** Thailand, Chiang Mai, Doi Suthep, 20 May, 1912, *Kerr 329* [holotype **K!**, isotype **C!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, 12–23 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* several, slender, arising from the basal part of the pseudobulbs, 1–6.5 cm long. *Pseudobulbs* green to dark dull green, ovoid to terete from a fusiform base, 2.5–4.2 cm long, 0.5–1.3 cm in diameter, consisting of 3–5 internodes, sometimes covered by cataphylls or leaf sheaths. *Cataphylls* 2–4, (triangular-)ovate to lanceolate-oblong (the lowermost tubular), acute to acuminate 0.8–4 by 0.9–6 cm. *Foliage leaves* 3–4, ascending to spreading or erect, sessile to short-petiolate; petiole sheathing at base, free part up to 1 cm long, green; lamina plicate, green, unspotted, (oblong-)ovate or elliptic (sometimes broadly so) with slightly asymmetrical base, acute to short-acuminate, 2.2–9 by 1.2–5.8 cm, 3- to 8-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 8.5–20 cm long; peduncle light green, 4–7 cm long, 0.1–0.2 cm in diameter; rachis subdensely 14- to 45-flowered; floral bracts persistent, light green, strongly recurved, (linear-)lanceolate, acuminate, entire, 1.5–8 by 0.5–1.8 mm, slightly shorter to longer than ovaries. *Flowers* yellowish-green to pale yellowish-brown, 2.5–4 mm in diameter. *Sepals* spreading to reflexed, rounded to obtuse, glabrous, margins revolute; dorsal sepal (oblong-)lanceolate, 4.5–6.5 by 1–2 mm, less than twice as long as labellum auricles; lateral sepals obliquely and narrowly ovate to elliptic, 3.7–5.5 by 1.8–3.5 mm. *Petals* reflexed, linear, obtuse, 4–5.5 by 0.5–1 mm, margins revolute. *Labellum* (nearly) flat, 4.5–7 by 2.5–4 mm (maximum dimensions), distinctly longer than wide, ovate (not constricted at the middle) with a strongly sagittate-auriculate to cordate-auriculate base, distally obtuse to subacuminate, usually incurved, basal/central part forming a cavity that is narrowly oblong in outline, subdivied by a longitudinal keel, laterally flanked by prominent, obliquely triangular ridges; auricles obliquely ovate to narrowly triangular, acute(to obtuse), 2.5–5 by 1.5–4 mm. *Column* yellowish-green with blacklish-purple on staminodes, erect, 1.2–2 mm long; staminodes, fleshy, blackish-purple, subclavate, rounded(to truncate); anther incumbent, versatile, broadly ovate, pollinia 4 in 2 pairs, obliquely clavate, 0.5–0.7 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely elliptic. *Ovary* (including pedicel) green, fusiform-cylindrical, with 6 longitudinal ridges, 3.5–7 mm long, glabrous. *Capsule* clavate-oblongoid to oblongoid-elliptisoid, 0.7–1.5 cm long, 0.3–0.6 cm in diameter; fruit pedicel 0.3–0.6 cm long. Figures 4.16 and 4.17.

Thailand.— NORTHERN: Chiang Mai (Doi Suthep), Lumpang (Doi Khun Tan); NORTH-EASTERN: Phetchabun (Nam Nao), Loei (Phu Khadueng); EASTERN: Nakhon Ratchasima (Khao Yai).

Distribution.— India, Nepal, China (Yunnan), Myanmar, Laos.

Ecology.— *Crepidium biauritum* grows on humus rich sandy slopes, shade areas in hill evergreen forest margins at 660–2,200 m alt. Flowering: May–June.

Note.— This species is easily recognized by its blacklish purple staminodes on column, with a thickened and obliquely triangular ridges on either side of cavity and the ornaments of obscure transverse ridge on labellum.

Specimens examined.— **Thailand:** *Cumberlege 658* (C), Lampang, Doi Khun Tan, sine anno; *J.F. Maxwell 88-695* (BKF, L), Chiang Mai, Doi Suthep, 28 May 1988; *A.F.G. Kerr 329* (C, K, P), Chiang Mai, Doi Suthep, 20 May 1912; *A.F.G. Kerr s.n.* (C, P), Chiang Mai, Doi Suthep, 21 June 1914; *J.F. Maxwell 89-722* (L), Chiang Mai, Doi Suthep, 7 June 1989; *G. Seidenfaden & T. Smitinand GT 3724* (C), Loei, Phu Khadueng, June 1960; *G. Seidenfaden & T. Smitinand GT 4365* (C), Nakhon Ratchasima, Khao Yai, October 1962; *G. Seidenfaden & T. Smitinand GT 5027* (C), Chiang Mai, 6 km south of omkoi, 3 May 1964; *T. Smitinand 534* (C, P), Phetchabun, Nam Nao, 23 May 1951.

India: *S. Deva 8529* (C), India, Laxmansiah, Dehra Dun, sine anno; *S. Deva 10645* (J. Renz herbarium), India, Uttar Pradesh-Dehra Dun, 8 July 1983; *King's collectors 306* (L), Andaman and Nicobar Islands, 1884; *S. Kurz s.n.* (K), south Andaman, 23 September 1967; *N. Wallich 1914* (K), Pundua, 1832. **China:** *A. Henry 12284A* (K), Yunnan, sine anno; *A. Henry 13543* (K), Yunnan, Yiwu, 1901. **Laos:** *C. Thorel s.n.* (P), Palai, Lukhon, sine anno.

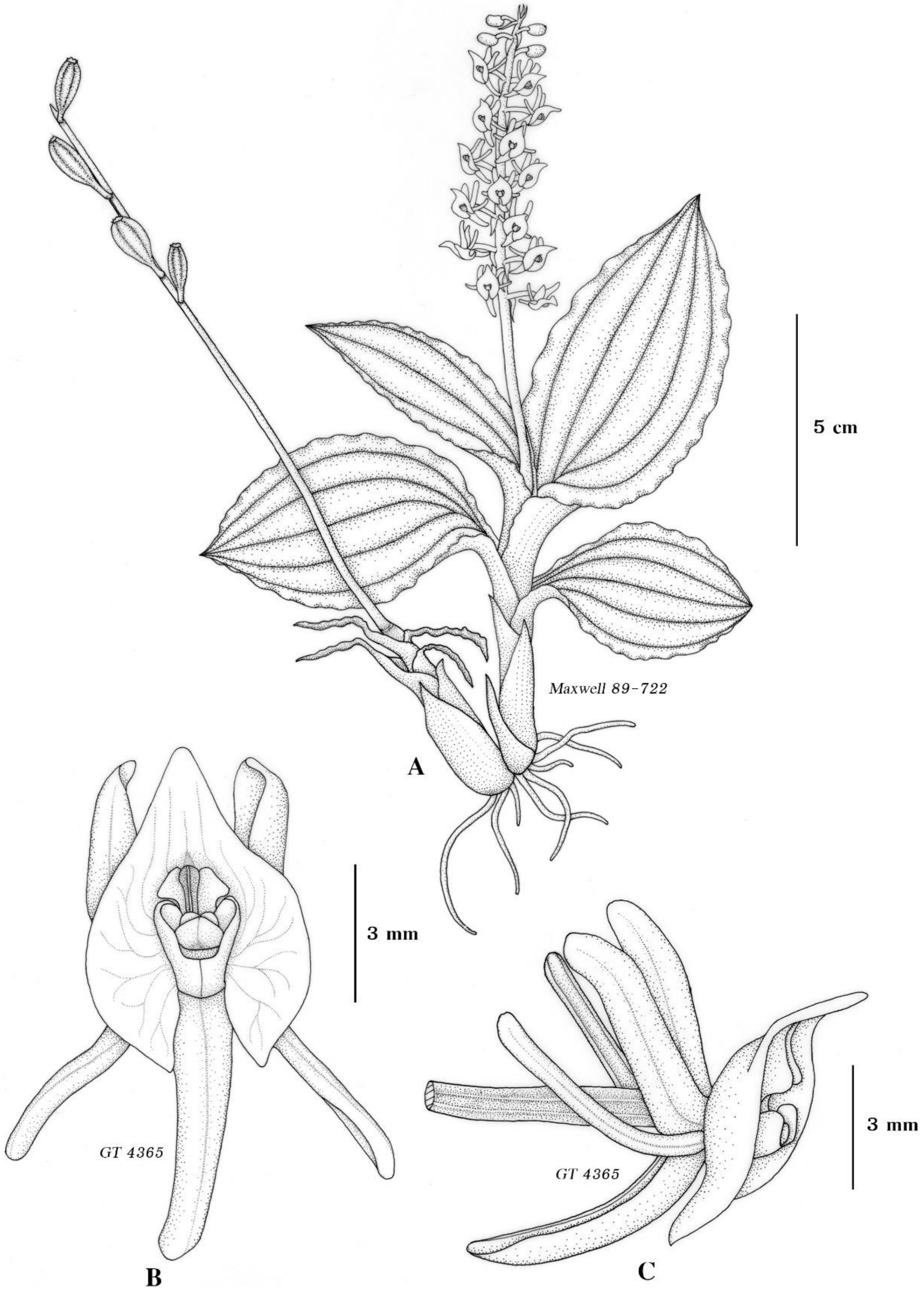

Figure 4.16 *Crepidium biauritum* (Lindl.) Szlach. **A:** Habit. **B:** Flower, front view. **C:** Flower, lateral view. Drawing from *Maxwell 89-722* (A); *GT 4365* (B–C).

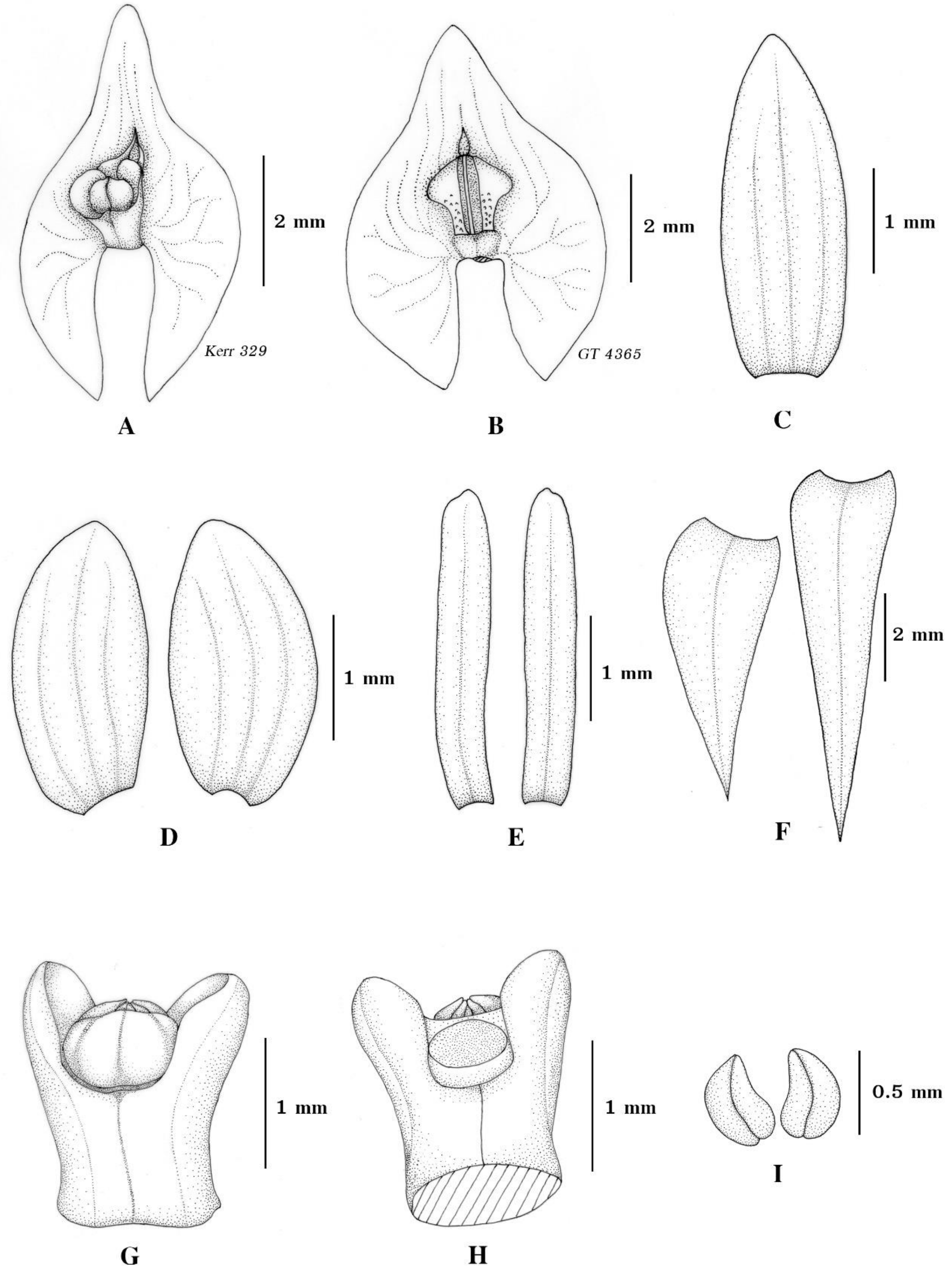

Figure 4.17 *Crepidium biauritum* (Lindl.) Szlach. **A:** Labellum with column, front view. **B:** Labellum, front view. **C:** Dorsal sepal. **D:** Lateral sepals. **E:** Petals. **F:** Floral bracts. **G:** Column, back view. **H:** Column, front view. **I:** Two pairs of pollinia. Drawing from *Kerr 329* (A); *GT 4365* (B–I).

6. Crepidium calophyllum (Rchb. f.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 125. 1995; Thaithong, Thai Orchids: 276, colour photos on pp. 276–277. 2000; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; S. C. Chen & J. J. Wood in Z. Wu et al. (eds.), Fl. China 25: 232. 2009.— *Microstylis calophylla* Rchb. f., Gard. Chron., new ser., 12: 718. 1879; Ridl., J. Linn. Soc., Bot. 24: 340. 1888.— *Malaxis calophylla* (Rchb. f.) Kuntze, Revis. Gen. Pl. 2: 673. 1891; Seidenf. & Smitinand, Orchids Thailand: 149, 761. 1959–1965; Seidenf., Bot. Tidsskr. 65: 327, fig. 8. 1970; Dansk Bot. Arkiv 33(1): 54, fig. 42. 1978; Opera Bot. 114: 147. 1992; Seidenf. & J. J. Wood, Orchids Penins. Malaysia Singapore: 223, fig. 94c–d. 1992; N. Pearce & P. J. Cribb, Fl. Bhutan 3(3): 215. 2002; Aver., Turczaninowia 16: 128, fig. 63e. 2013. **Type:** Malasia, sine loco, sine anno, *Reichenbach s.n.* [Reichenbach herbarium (**W**): not seen].

— *Microstylis wallichii* Lindl. var. *brachycheila* Hook. f., Fl. Brit. India 5: 686. 1890.— *Malaxis calophylla* (Rchb. f.) Kuntze var. *brachycheila* (Hook. f.) Tang & F. T. Wang, Acta Phytotax. Sin. 1: 71. 1951. **Type:** Myanmar, Moulmein, sine anno, *C. S. P. Parish 191* [holotype **K!**].

— *Microstylis scottii* Hook. f., Fl. Brit. India 5: 687. 1890; King & Pantl., Ann. Roy. Bot. Gard. (Calcutta) 8: 17, t. 20. 1898.— *Malaxis scottii* (Hook. f.) Kuntze, Revis. Gen. Pl. 2: 673. 1891. **Type:** Drawing by W. Fitch from a plant which discovered by Mr. John Scott from Rangoon in Pegu (Myanmar) and flowering in Royal Bot. Gard., Kew [drawing in the library of K!; see reproduction in Bot. Mag. 118: t. 7268. 1892].

— *Malaxis biloba* auct. non (Lindl.) Ames: Seidenf. & Smitinand, Orchids Thailand: 761, fig. 567. 1965.

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, 6.5–25 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* several, arising from the basal part of the pseudobulbs, 1–6.5 cm long. *Pseudobulbs* greenish-purple to dull purple, (oblongoid-)ovoid, to terete from a fusiform base, 2–7 cm long, 0.4–1.2 cm in diameter, consisting of 4–6 internodes; sometimes covered by cataphylls or leaf sheaths. *Cataphylls* 2–4, (triangular-)ovate to lanceolate-oblong (the lowermost tubular), acute to acuminate 1–4 by 0.8–6 cm.

Foliage leaves 3–5, ascending to spreading or erect, sessile to short-petiolate, petiole sheathing at the base, free part up to 1 cm long; lamina plicate, pale (greenish-)brown to dull brownish-purple with white to light green (often spotted) marginal bands, ovate to ovate-lanceolate with slightly asymmetrical base, acuminate, 1–7.5 by 0.5–4 cm, 3- to 7-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 5.5–18 cm long, elongating gradually during flowering; peduncle pale purple, 2.5–10 cm long, 0.1–0.2 cm in diameter; rachis subdensely 10- to many-flowered; floral bracts persistent, pale purple, reflexed, linear-triangular to lanceolate, acuminate, entire, 1.5–5.5 by 0.5–1.5 mm, shorter to longer than ovaries. *Flowers* greenish-yellow or pale yellow with purplish sepals and petals, 4–5 mm in diameter. *Sepals* spreading to reflexed, glabrous, margins revolute; dorsal sepal (lanceolate-)oblong to ovate, obtuse, 4–5.5 by 1.5–2.5 mm, up to twice as long as labellum auricles; lateral sepals obliquely and broadly elliptic to ovate, rounded, 3–4 mm by 1.8–3 mm. *Petals* spreading to reflexed, linear-ligulate, truncate or retuse, 4–6 by 0.5–1 mm, margins revolute. *Labellum* (nearly) flat, 4.5–7.5 by 3–4.5 mm (maximum dimensions), longer than wide, more or less obovate (not constricted at the middle), strongly sagittate-auriculate at base, distally (rounded-)truncate with a small triangular cleft apex; basal/central part forming a cavity that is suborbicular to obovate (to linear-lanceolate) in outline, and bordered by more or less horseshoe-shaped ridge; auricles obliquely falcately triangular, acute to obtuse, 2–4 mm by 1–2 mm. *Column* greenish-yellow, erect, very stout, 1–2.2 mm long; staminodes flat, oblong, truncate; anther incumbent, versatile, broadly ovate, obtuse to rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.5–0.6 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) pale green to greenish-purple, fusiform-cylindrical, with 6 longitudinal ridges, 3–4.5 mm long, glabrous. *Capsule* obovoid-ellipsoid, 1–1.5 cm long, 0.5–0.7 cm in diameter; fruit pedicel 0.2–0.4 cm long. Figures 4.18, 4.19 and 4.20.

Thailand.— NORTHERN: Mae Hong Son, Chiang Mai, Chiang Rai; NORTH-EASTERN: Phetchabun (Nam Nao), Loei (Phu Luang), Buengkan (Phu Wua); PENINSULAR: Chumpon (Langsuan), Songkhla (Ton Nya Chang).

Distribution.— NE India, Nepal, Bangladesh, Myanmar, China (Hainan, Yunnan), Vietnam, Cambodia, Peninsular Malaysia, Borneo.

Ecology.— *Crepidium calophyllum* grows in sandy, humus-rich soil in hill evergreen forest at 550–1,500 m alt. Flowering: May–June.

Vernacular.— Haew Moo Pha (แห้วหมูป่า).

Note.— In living condition, this species is easily recognized by its leaves having a markedly lighter band along the slightly wavy margins, whereas this feature is rarely preserved in herbarium specimens. Variation in labellum morphology is considerable, cf. Seidenfaden (1978: fig. 42). Reichenbach noted that type specimen was collected from Dutch India (no locality) and said that he also provided drawing for this species. However, Seidenfaden and we have never seen any Reichenbach's type specimen and drawing that might be probably destroyed.

Specimens examined.— **Thailand:** *C.T. s.n.* (BCU), sine loco, 1 June 1994; *Curtis s.n.* (K), Tongka, 17 July 1895; *S. Damapong 188* (BKF), Chiang Mai, Doi Phahom Pok, 6 June 2007; *A.F.G. Kerr 276* (K), Chiang Mai, Doi Suthep, 24 June 1911; *K. Jatupol 08-418* (QBG), Chiang Mai, Samoeng, Ban Pa Kar, 6 August 2008; *J.F. Maxwell 08-133* (QBG, L), Mae Hong Son, Nong Kow Klang village, 23 June 2008; *A. Nuammee 436* (BCU), Loei, Phu Luang, 3 May 2015; *P.V. 216* (BCU), sine loco, 14 April 2002; *Put 1695* (K), Chumpon, Langsuan, Tako, 16 June 1928; *G. Seidenfaden & T. Smitinand GT 3710* (C), Loei, Phu Khadueng, July 1959; *T. Smitinand 533* (C), Phetchabun, Nam Nao, sine anno; *S. Suddee s.n.* (BKF), Songkhla, Ton Nya Chang waterfalls, sine anno; *S. Suddee et al. 4506* (BKF), Buengkan, Phu Wua, 13 June 2013; *P. Suksathan 4246* (QBG), Mae Hong Son, Pang Ung, 5 July 2007; *O. Thaithong 715* (BCU), sine loco, 1 August 1989; *O. Thaithong 1678* (BCU), sine loco, 24 May 1996.

India: *R. Pantling 220* (K, P), Sikkim, Tista Valley, July 1894; *Sine coll. s.n.* (K), sine loco, 1898. **Myanmar:** *C.S.P. Parish 191* (K), Moulmein, sine anno; *A.*

Samuel 13677 (K), Maymyo, sine anno. **Laos:** *A.D. Kerr 1312* (C), Vientiane Plain, sine anno. **Cambodia:** *F.F. Godefroy 442* (C, K), Mt. Mursat, sine anno.

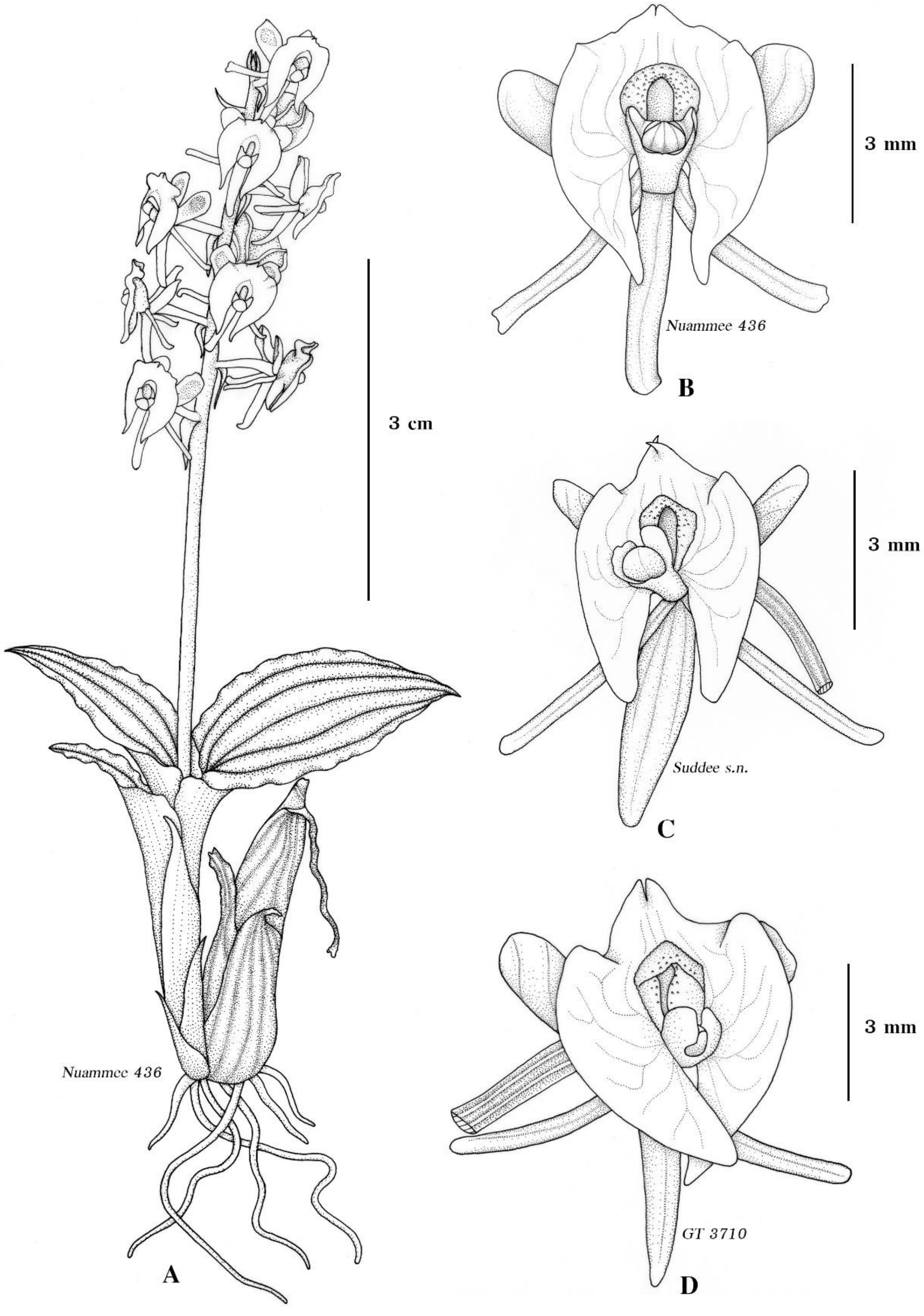

Figure 4.18 *Crepidium calophyllum* (Rchb. f.) Szlach. **A:** Habit. **B–D:** Flower, front view. Drawing from *Nuammee 436* (A–B); *Suddee s.n.* (C); *GT 3710* (D).

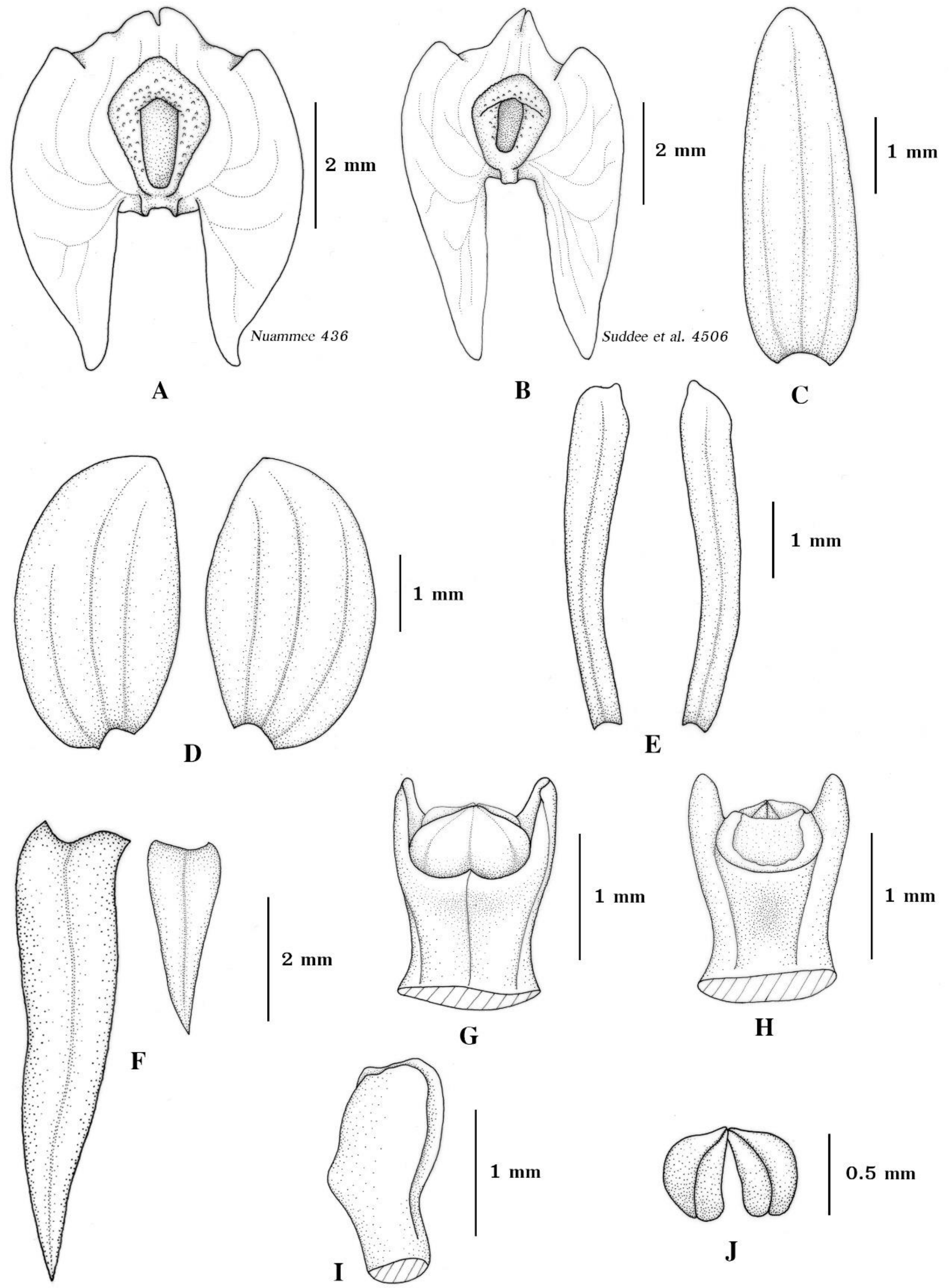

Figure 4.19 *Crepidium calophyllum* (Rchb. f.) Szlach. **A–B:** Labellum, front view. **C:** Dorsal sepal. **D:** Lateral sepals. **E:** Petals. **F:** Floral bracts. **G:** Column, back view. **H:** Column, front view. **I:** Column, lateral view. **J:** Two pairs of pollinia. Drawing from *Nuammee 436* (A, C–J); *Suddee et al. 4506* (B).

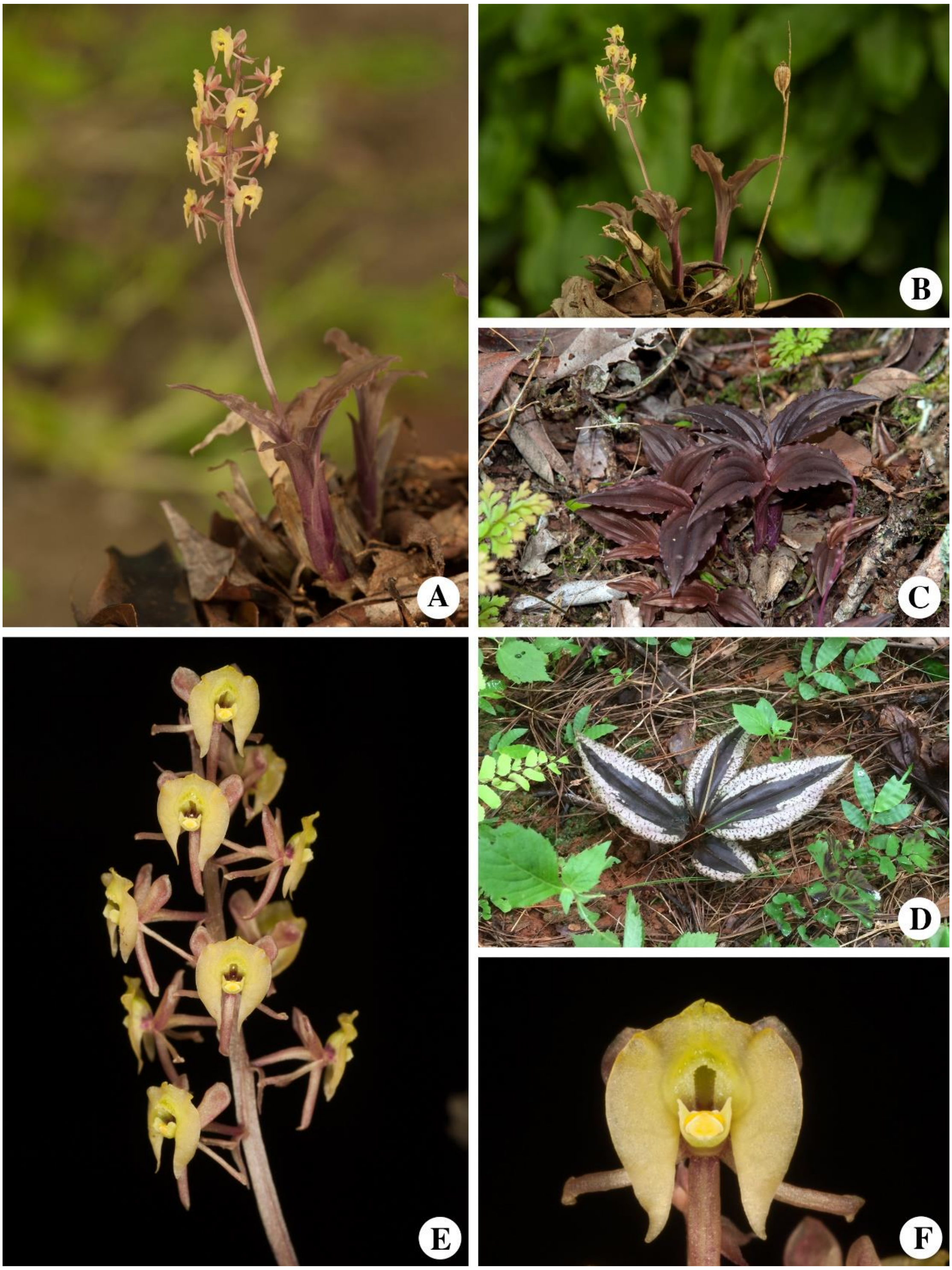

Figure 4.20 *Crepidium calophyllum* (Rchb. f.) Szlach. **A–D:** Habit. **D:** Inflorescence. **F:** Flower, front view. A, B, E and F were photographed from Loei, Phu Luang, 12 May 2015; C was photographed from Loei, Phu Luang, 15 June 2013; D was photographed from Chiang Rai, Doi Thung, 8 August 2016.

7. Crepidium chamaeorchis (Schltr.) Nuammee, Seelanan, Suddee & H. A. Pedersen, Thai Forest Bull. (Bot.) 44: 36, fig. 1A–B. 2016.— *Microstylis chamaeorchis* Schltr., Bot. Jahrb. Syst. 45, Beibl. 104: 11. 1911.— *Malaxis carnosula* auct. non (Rolfe) Seidenf. & Smitinand: P. F. Cumberlege & V. M. S. Cumberlege, Nat. Hist. Bull. Siam Soc. 20: 161, fig. 19. 1963.— *Malaxis chamaeorchis* (Schltr.) Seidenf., Bot. Tidsskr. 65: 316, fig. 2. 1970; Seidenf., Dansk Bot. Arkiv 33(1): 48, fig. 36. 1978; Seidenf. & J. J. Wood, Orchids Penins. Malaysia Singapore: 220, fig. 93d. 1992.— *Glossochilopsis chamaeorchis* (Schltr.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 123. 1995. **Type:** Indonesia, West Sumatra, Gunung Marapi, 24 January 1907, *Schlechter 15942* [holotype **B**, probably destroyed; isotypes **AMES! C! K! L! NSW**, **P!**].

Terrestrial (sometimes epiphyte), sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, 10–18.5 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* several, arising from the basal part of the pseudobulbs, 0.5–2 cm long. *Pseudobulbs* green-purple, ovoid, pyriform to subglobose, 0.5–1.5 cm long, 0.8–1.5 cm in diameter, consisting of 3–4 internodes. *Cataphylls* few, broadly triangular-ovate to lanceolate-oblong (the lowermost tubular), acute, 1.2–3 by 1–1.5 cm. *Foliage leaves* 2–3, ascending to erect, sessile, sheathing at the base; lamina plicate, green to greenish-purple, purple-veined beneath, unspotted, lanceolate to ovate or elliptic with slightly asymmetrical base, acute, 1.5–5.5 by 0.5–1.5 cm, 3-veined, glabrous, margins straight. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 8–16 cm long, elongating gradually during flowering; peduncle purplish-red, 2–5 cm long, 0.1–0.3 cm in diameter; rachis laxly 10- to many-flowered; floral bracts persistent, green with purplish-red, reflexed, triangular to lanceolate, acuminate, entire, 2.5–5 by 0.4–0.5 mm, shorter than ovaries. *Flowers* purplish-red with greenish-yellow veins, 3–4 mm in diameter. *Sepals* spreading, glabrous, margins recurved; dorsal sepal oblong to ovate, rounded, 2–3.5 by 1–2 mm; lateral sepals oblong to elliptic or broadly ovate, rounded, 2.5–3 mm by 1–3 mm. *Petals* reflexed, linear, rounded, 2–3 by 0.3–0.5 mm, margins recurved. *Labellum* (nearly) flat, 2–2.5 by 1–1.5 mm (maximum dimensions), longer than wide, ovate to lanceolate, devoid of auricles, distally obtuse to subacute; basal/central part forming a small and shallow cavity, with flat margins. *Column* greenish-yellow with purplish staminodes, erect, stout, 1–1.5 mm long; staminodes fleshy, oblong, retuse; anther incumbent, versatile, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.3–0.4 mm long; rostellum transversely (sub)rectangular, truncate; fertile part of stigma transversely (sub)elliptic, flat, concave at base. *Ovary* (including pedicel) reddish-purple, cylindrical, with 6 longitudinal ridges, 2.5–5 mm long, glabrous. *Capsule* not seen. Figures 4.21, 4.22 and 4.23.

Thailand.— EASTERN: Nakhon Ratchasima (Khao Yai); SOUTH-EASTERN: Trat (Khao Kaup).

Distribution.— Peninsular Malaysia, Sumatra.

Ecology.— *Crepidium chamaeorchis* grows in humus-rich soil, on mossy rocks or as an epiphyte on the lower part of tree trunks at 1,200–1,400 m alt. Flowering: May–July.

Vernacular.— Hoo Sua Khaer (หูเสือแคระ).

Note.— *Crepidium chamaeorchis* is recognized by labellum with no auricles and the distinctly long column. Also, the condition of new combination for this species can be found in Nuammee *et al.* (2016). However, the thai plants have staminodes branching while the staminodes of type specimens have not brancing.

Specimens examined.— **Thailand:** *Cumberlege 891* (K), Nakhon Ratchasima, Khao Yai, July 1964; *A. Nuammee 442* (BCU, BKF), Nakhon Ratchasima, Khao Yai, 11 July 2015; *Put 2906* (K), Trat, Kao Kaup, 21 May 1980. **Malay Peninsula:** *R.E. Holtum 14859* (SING), Kedah Peak, 1 April 1925. **Indonesia:** *F.R.R. Schlechter 163* (L), W. Sumatra, Padang Bovenlanden, 18 April 1907; *F.R.R. Schlechter 15942* (AMES, B, C, K, L, NSW, P), W. Sumatra, Gunung Marapi, 24 January 1907.

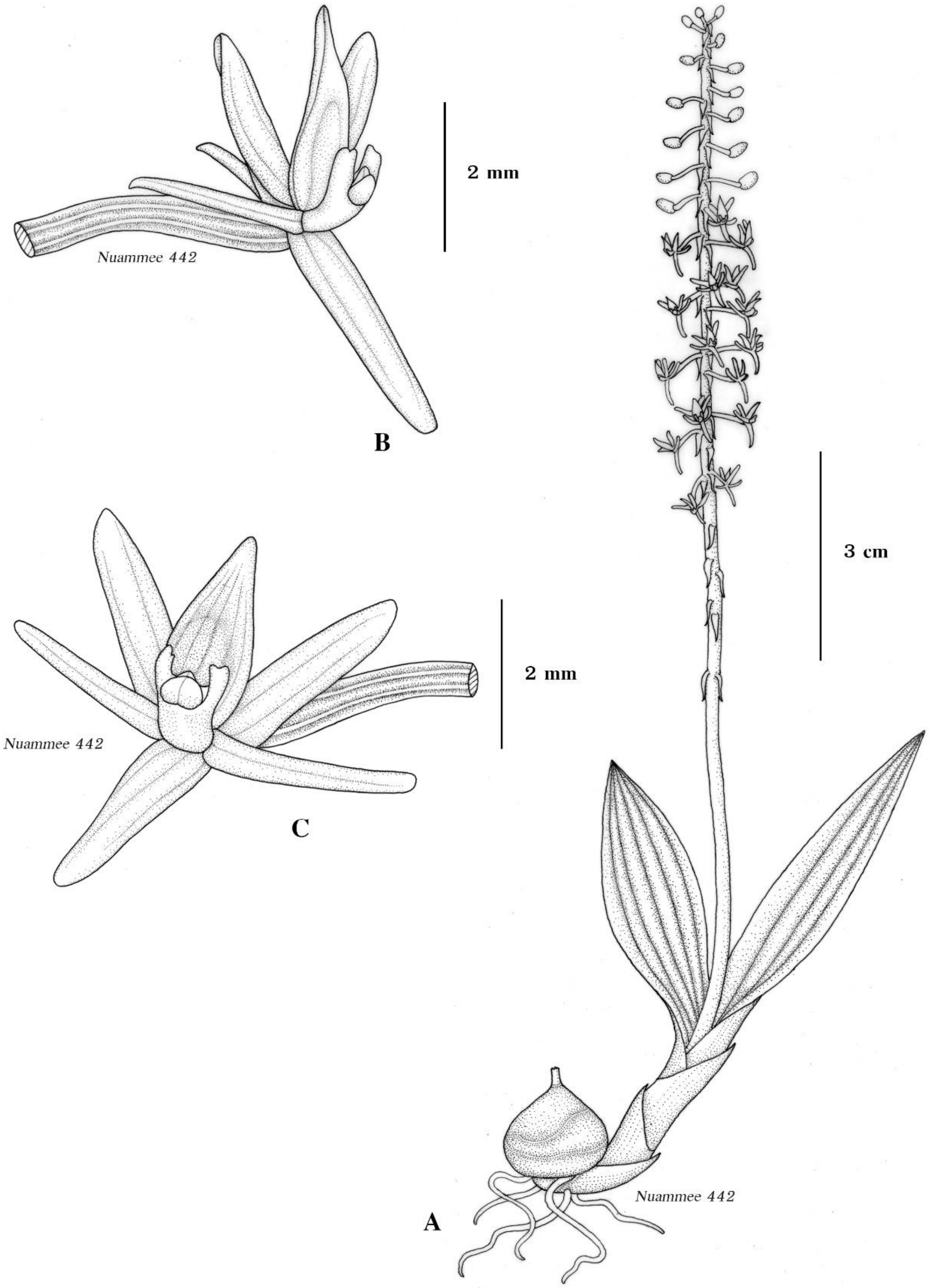

Figure 4.21 *Crepidium chamaeorchis* (Schltr.) Nuammee, Seelanan, Suddee & H. A. Pedersen. **A:** Habit. **B:** Flower, lateral view. **C:** Flower, front view. Drawing from *Nuammee 442* (A–C).

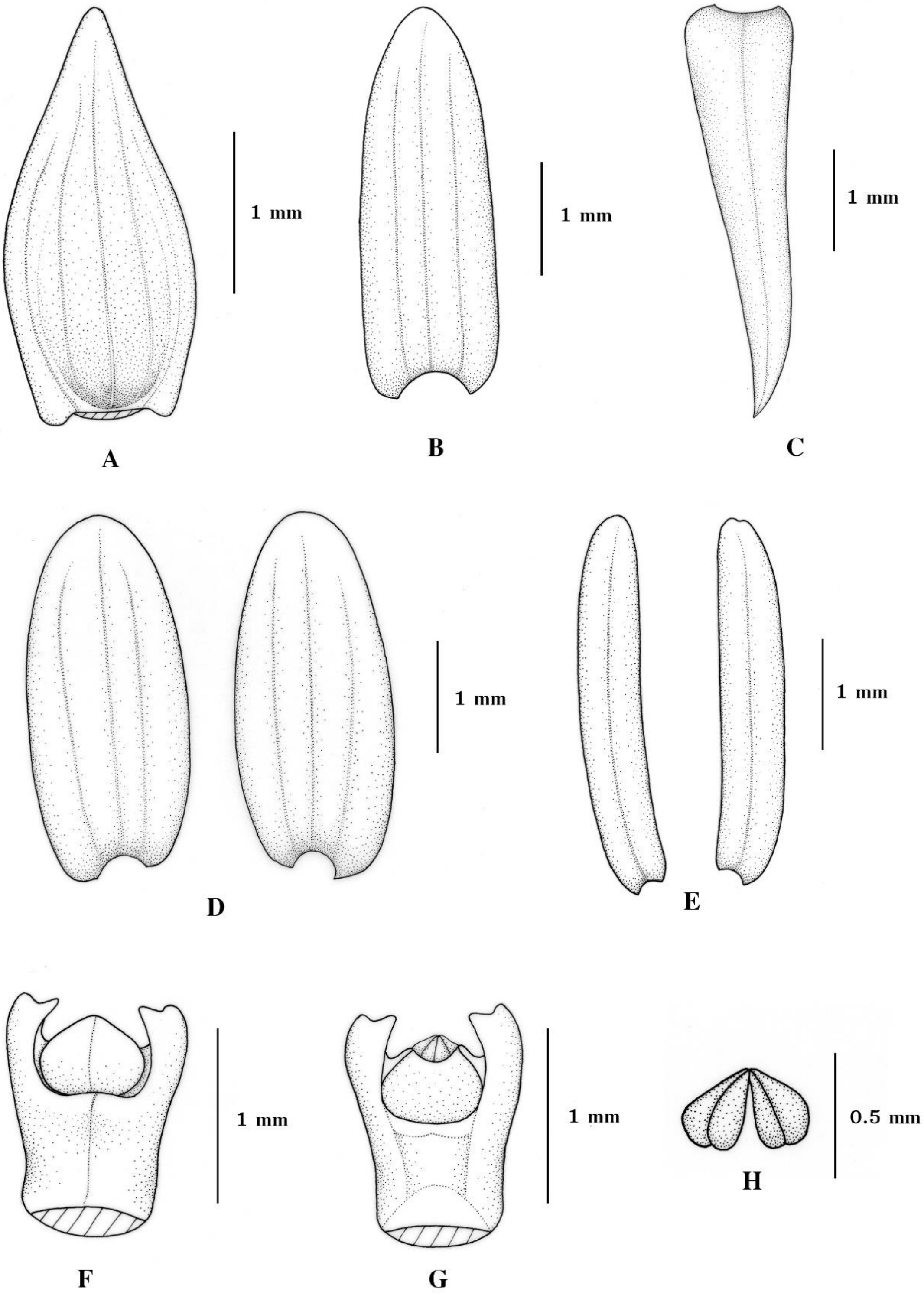

Figure 4.22 *Crepidium chamaeorchis* (Schltr.) Nuammee, Seelanan, Suddee & H. A. Pedersen. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bract. **D:** Lateral sepals. **E:** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *Nuammee 442* (A–H).

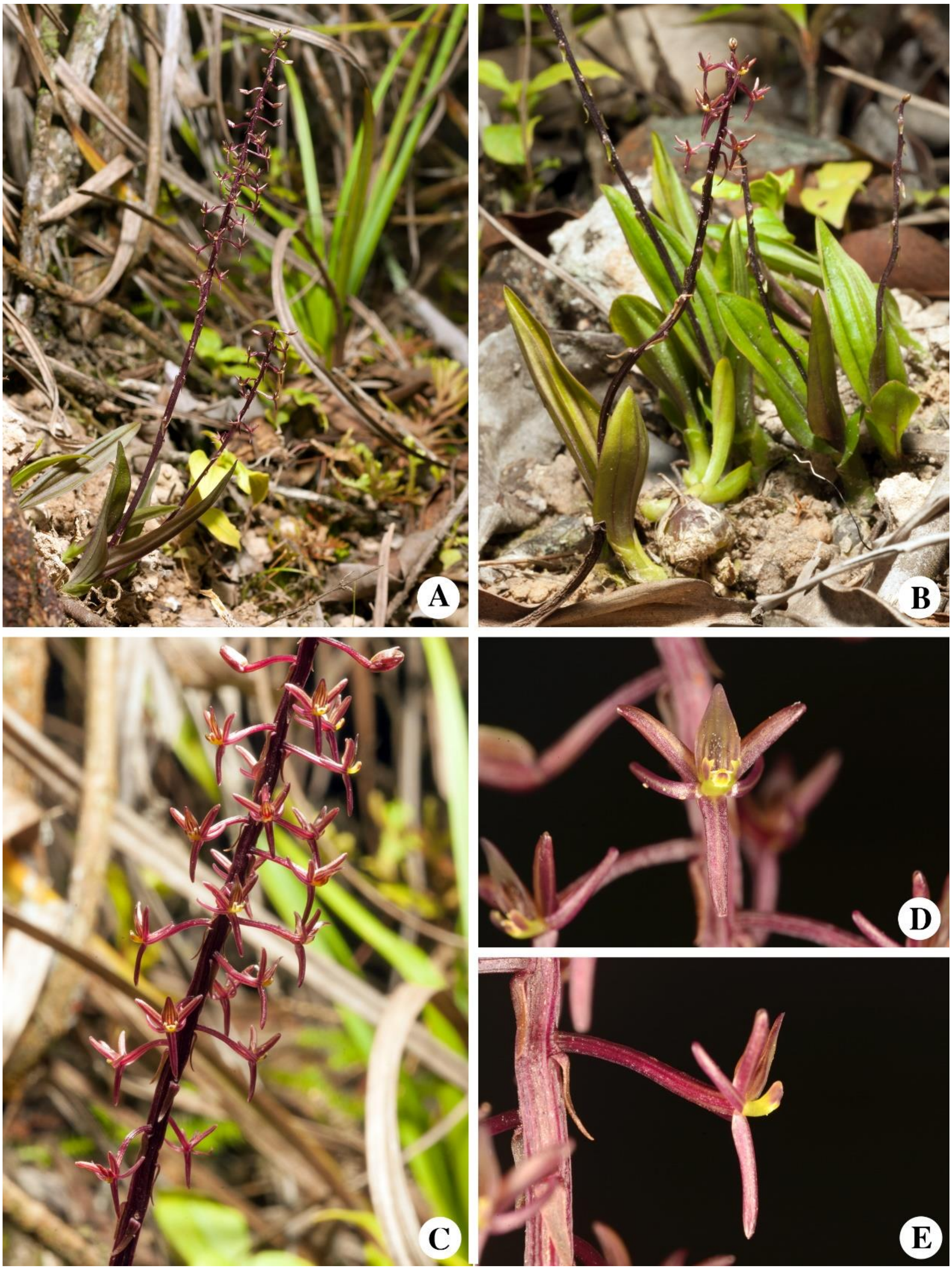

Figure 4.23 *Crepidium chamaeorchis* (Schltr.) Nuammee, Seelanan, Suddee & H. A. Pedersen. **A–B:** Habit. **C:** Inflorescence. **D:** Flower, front view. **E:** Flower, lateral view. All were photographed from Nakhon Ratchasima, Khao Yai, 11 July 2015.

8. Crepidium concavum (Seidenf.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 125. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997.— *Malaxis concava* Seidenf., Bot. Tidsskr. 65: 325, fig. 7. 1970; Dansk Bot. Arkiv 33(1): 54, fig. 41. 1978. **Type:** Thailand, Kanchanaburi, Thunng Kang Yang foothills, 7 July 1963, *Danish Botanists (Sørensen, Larsen & Hansen) DB 10592* [holotype **C!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, 9–15 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* several, slender, arising from the basal part of the pseudobulbs, 1–2 cm long. *Pseudobulbs* green, narrowly ovoid to terete from a fusiform base, 2–3.1 cm long, 0.5–0.8 cm in diameter, consisting of 3–4 internodes. *Cataphylls* 3–4, triangular to oblong-lanceolate (the lowermost tubular), acute to acuminate 0.8–3 by 0.5–1 cm. *Foliage leaves* 3–4, ascending to spreading, subsessile, sheathing at the base; lamina plicate, green, unspotted, ovate to lanceolate with slightly asymmetrical base, acuminate, 3.5–8.5 by 1.2–3.2 cm, 4- to 5-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 7–11 cm long, elongating gradually during flowering; peduncle green, 4–6 cm long, 0.1–0.2 cm in diameter; rachis laxly 6- to 10-flowered; floral bracts persistent, green, reflexed, lanceolate, acuminate, entire, 3.5–6 by 0.8–2 mm, shorter than ovaries. *Flowers* yellow tinged with purple, 5–6 mm in diameter. *Sepals* spreading, obtuse, glabrous, margins recurved; dorsal sepal oblong-lanceolate, 8–8.5 by 2–2.5 mm, more than twice as long as labellum auricles; lateral sepals obliquely and narrowly ovate, 6–6.5 by 2–2.5 mm. *Petals* spreading, linear-ligulate, obtuse to retuse, 7.5–8 by c. 1 mm, margins revolute. *Labellum* distinctly bowl-shaped, 7.5–8 by 5–6 mm (maximum dimensions), longer than wide, oblong-ovate (not constricted at the middle) with a strongly cordate-auriculate base, distally truncate to retuse; basal part forming a cavity that is narrowly oblong in outline, subdivided by a longitudinal keel, laterally flanked by 2 prominent, obliquely triangular ridges; auricles obliquely triangular-ovate, rounded to obtuse, c. 2.5 by 2.5–3 mm. *Column* erect, c. 1 mm long; staminodes flat, oblong, rounded; anther incumbent, versatile, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.5–0.6 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely rectangular, flat, concave at base. *Ovary* (including pedicel) fusiform-cylindrical, with 6 longitudinal ridges, 5–6 mm long, glabrous. *Capsule* not seen. Figures 4.24 and 4.25.

Thailand.— SOUTH-WESTERN: Kanchanaburi (Thunng Kang Yang, Thong Phaphum).

Distribution.— China (Yunnan)

Ecology.— *Crepidium concavum* grows in humus-rich soil in limestone forests or bamboo-dominated mixed deciduous forest at 400–500 m alt. Flowering: recorded in July.

Vernacular.— Hoo Sua Thong Pha Phum (หูเสือทองผาภูมิ) (here proposed).

Note.— This species can be recognized by the slightly hood-shape labellum and its high triangular ridges on either side of cavity. However, living specimens have not seen. The colour of leaves and flowers based on Seidenfaden' s description.

Specimens examined.— **Thailand:** *R. Geesink 6103* (C, L), Kanchanaburi, Thong Phaphum, Huay Ban Kaw, 4 July 1973; *J.F. Maxwell 73-142* (C), Kanchanaburi, Thong Phaphum, sine anno; *Danish Botanists (Th. Sørensen, K. Larsen & B. Hansen) DB 10592* (C), Kanchanaburi, Sai Yok, Thunng Kang Yang foothills, 7 July 1963.

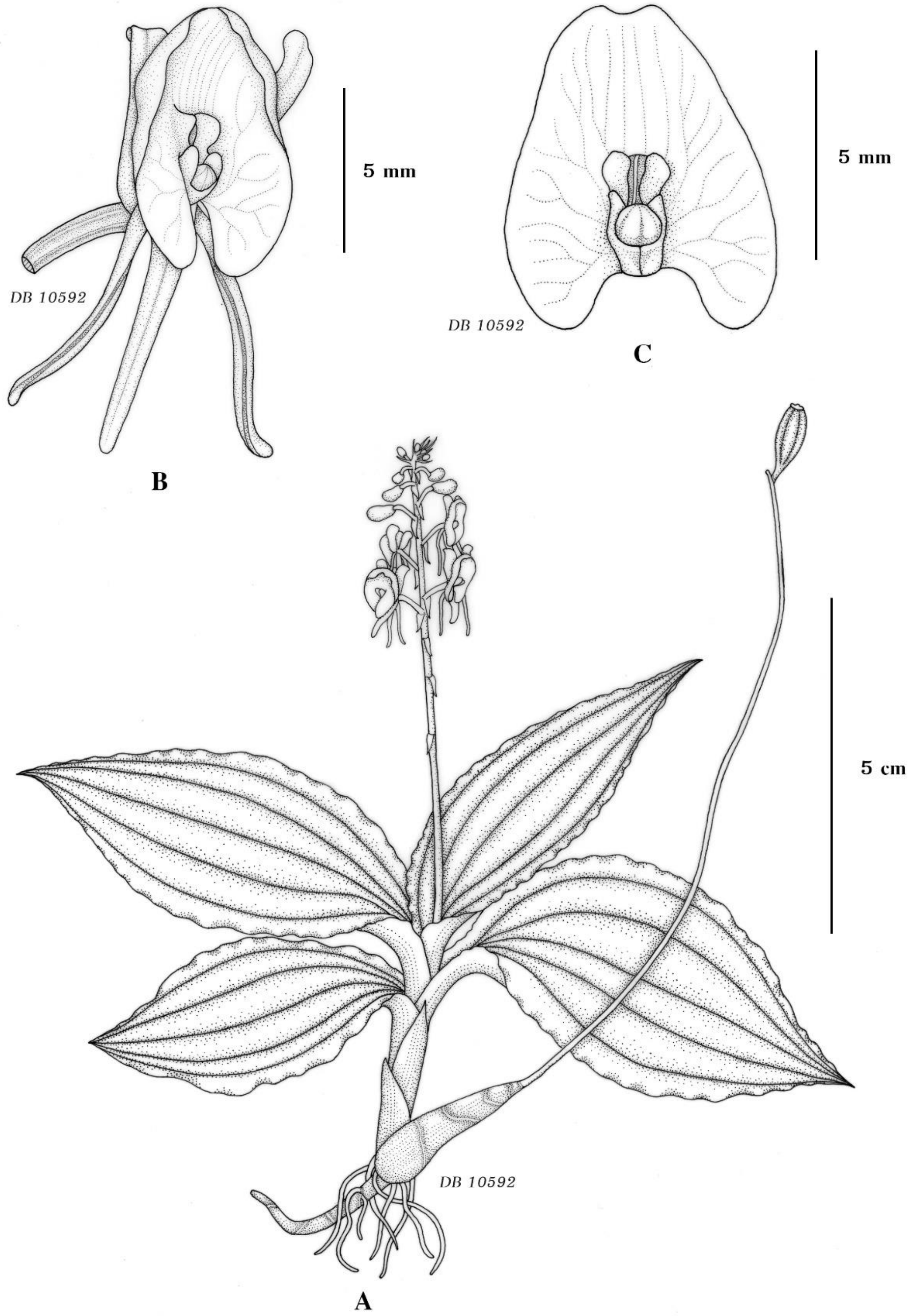

Figure 4.24 *Crepidium concavum* (Seidenf.) Szlach. **A:** Habit. **B:** Flower, lateral view. **C:** Labellum with column, front view. Drawing from *DB 10592* (A–C).

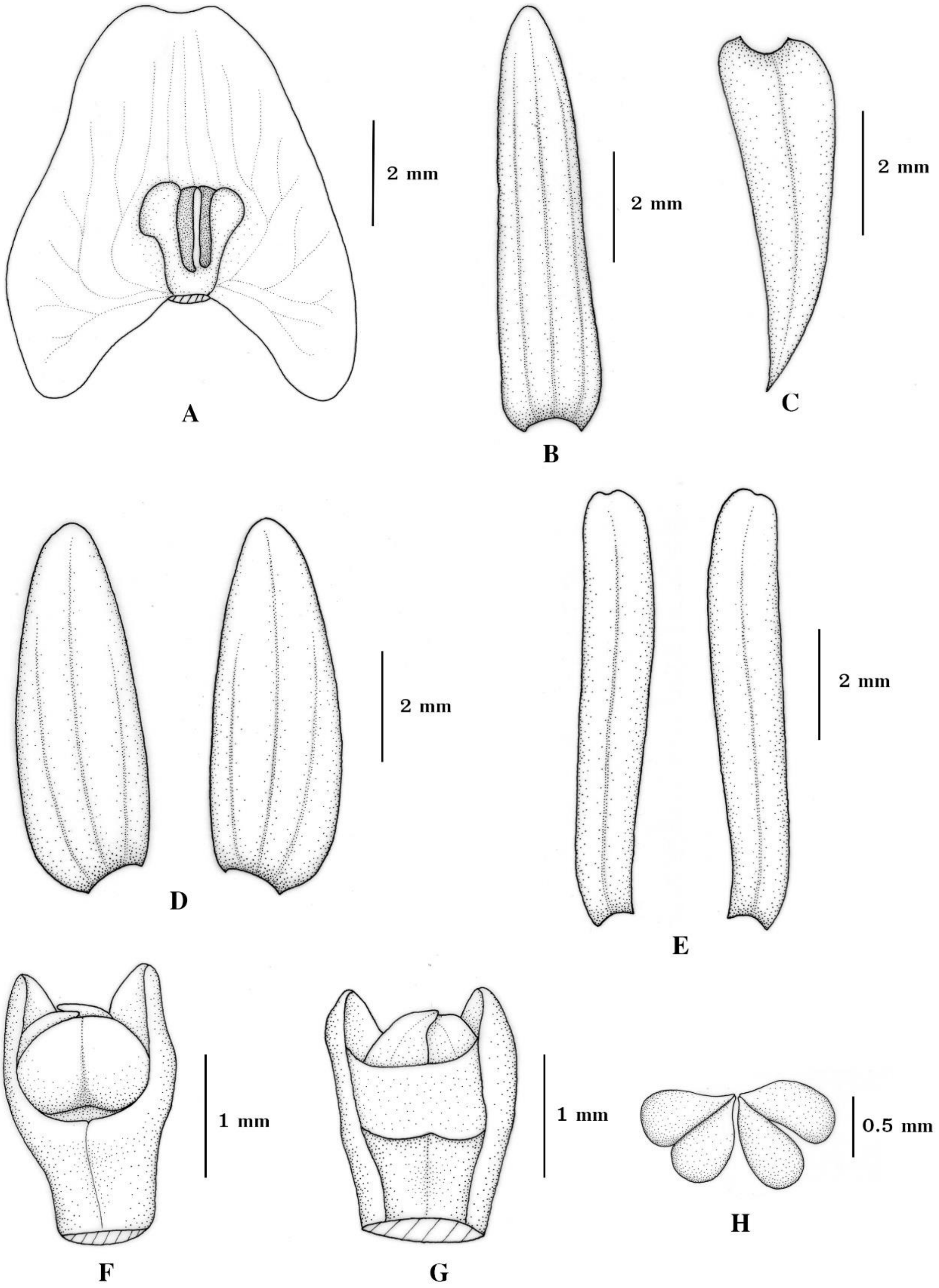

Figure 4.25 *Crepidium concavum* (Seidenf.) Szlach. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bract. **D:** Lateral sepals. **E:** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *DB 10592* (A–H).

9. Crepidium falcifolium Nuammee, Seelanan & H. A. Pedersen, Syst. Bot. 43(4): 950. 2018.— *Malaxis godefroyi* auct. non (Rchb. f.) Kuntze: Seidenf., Bot. Tidsskr. 65: 127 p.p., fig. 18. 1969; Dansk Bot. Arkiv 33(1): 54 p.p., fig. 40. 1978. Type: Thailand, Nakhon Si Thammarat, Krung Ching, Khao Pon, 19 October 2015, *Nuammee 452*; [holotype **BCU!**, isotype **BKF!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, 7–27 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* several, slender, arising from the basal part of the pseudobulbs, 0.5–4 cm long. *Pseudobulbs* green, slenderly obconical to terete from a fusiform base or cylindrical, 3–6.5 cm long, 0.2–0.7 cm in diameter, consisting of 4–6 internodes; internodes 0.3–1 cm long, sometimes covered by cataphylls or leaf sheaths. *Cataphylls* 3–4, ovate-lanceolate (the lowermost tubular), acute to shortly acuminate, 0.5–2 × 0.2–1 cm. *Foliage leaves* 4–7, ascending to spreading or erect, petiolate, petiole sheathing at the base, free part 0.5–1.5 cm long, green or tinged with purple on edges; lamina plicate, green, falcate to narrowly lanceolate with slightly asymmetrical base, acuminate, 1.2–7.2 by 0.3–1.9 cm, 1- to 4-veined, mostly 3-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 7–21 cm long, elongating gradually during flowering; peduncle dull purple, 4–8 cm long, c. 0.1 cm in diameter; rachis laxly 15- to 35-flowered; floral bracts persistent, green, more or less tinged with purple, spreading to reflexed, ovate to triangular, acuminate, entire, 2–5 by 0.5–1.8 mm, shorter than ovaries. *Flowers* light green to yellowish-green, sometimes more or less tinged with purple, 1.5–4 mm in diameter. *Sepals* glabrous, margins recurved; dorsal sepal spreading, ovate-elliptic to oblong, acute 2–3.5 by 1–2.5 mm; lateral sepals reflexed, broadly and obliquely ovate to elliptic, subacute to obtuse or rounded, concave in their central part 2–3 × 1.5–2.1 mm. *Petals* spreading, linear-oblong, rounded to obliquely retuse, 2–3.5 by 0.5–2 mm, margins revolute. *Labellum* (nearly) flat, 5–7 by 1.5–3.8 mm (maximum dimensions), longer than wide, elliptic to elliptic-oblong, constricted at the middle (by means of locally revolute margins) and with a strongly sagittate-auriculate base, distally bilobed with rounded lobes, usually incurved; basal part forming a cavity that is oblong-elliptic to triangular in outline, with the edges distally raising to form a minute rounded transversal ridge; auricles obliquely triangular-ovate, obtuse, 1–2.2 mm by 1–1.8 mm. *Column* green, erect, 0.5–1 mm long; staminodes oblong, rounded; anther incumbent, versatile, broadly ovate, rounded to retuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.3–0.4 mm long; rostellum transversely rectangular, truncate; fertile stigma part transversely elliptic, flat, concave at base. *Ovary* (including pedicel) green tinged with purple, fusiform-cylindrical, with 6 longitudinal ridges, 4–5 mm long, glabrous. *Capsule* not seen. Figures 4.26, 4.27 and 4.28.

Thailand.— PENINSULAR: Surat Thani (Khao Phra Rahu), Nakhon Si Thammarat (Khao Pon).

Distribution.— Endemic

Ecology.— *Crepidium falcifolium* grows in humus-rich soil in shaded areas of mixed deciduous forest on limestone hills at 200–250 m alt. Flowering: September–October.

Vernacular.— Hoo Sua Bui Khiew (หูเสือใบเคียว).

Note.— *Crepidium falcifolium* is more similar to *C. khasianum*, but differs in both vegetative and floral characters. *C. falcifolium* has green, distinctly falcate to narrowly lanceolate, less than 2 cm broad leaves, and a labellum shallowly bilobed at apex with rounded lobes. In comparison, *C. khasianum* has lustrous greyish green, ovate to ovate-elliptic or lanceolate, 2–5 cm broad leaves, and a labellum with broad and rounded to shallowly bilobed at apex with subentire to erose, truncate to retuse lobes.

Specimens examined.— **Thailand:** *A. Nuammee 390*, (BCU, BKF), Nakhon Si Thammarat, Krung Ching, Khao Pon, 27 October 2013; *A. Nuammee 452*, (BCU, BKF), Nakhon Si Thammarat, Krung Ching, Khao Pon, 19 October 2015; *T. Smitinand & H. Sleumer 1160* (K, L), Surat Thani, Khao Phra Rahu, 20 September 1963; *P. Tripetch 028* (QBG), Nakhon Si Thammarat, Krung Ching, Khao Pon, 20 September 2009.

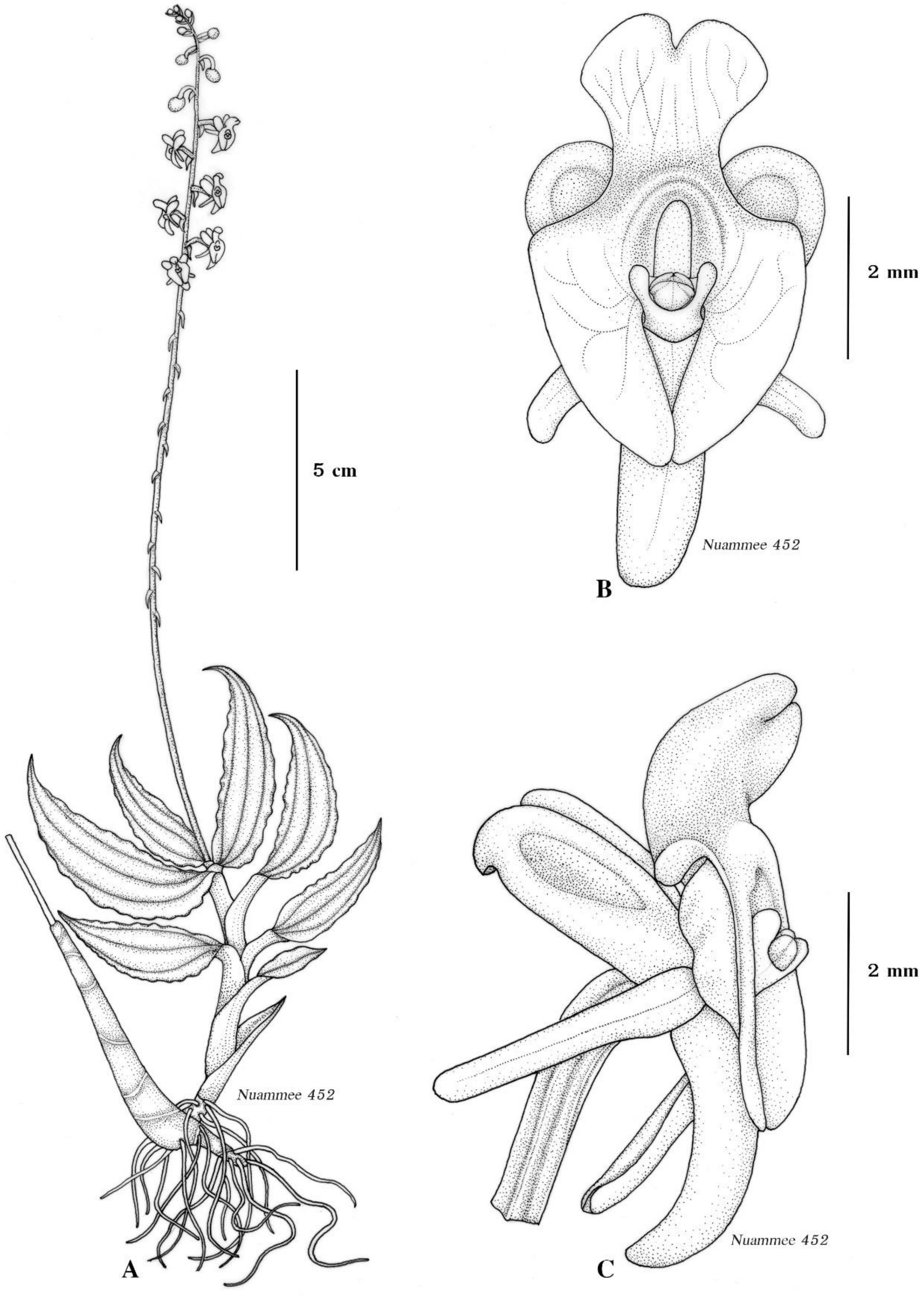

Figure 4.26 *Crepidium falcifolium* Nuammee, Seelanan & H. A. Pedersen. **A:** Habit. **B:** Flower, front view. **C:** Flower, lateral view. Drawing from *Nuammee 452* (A–C).

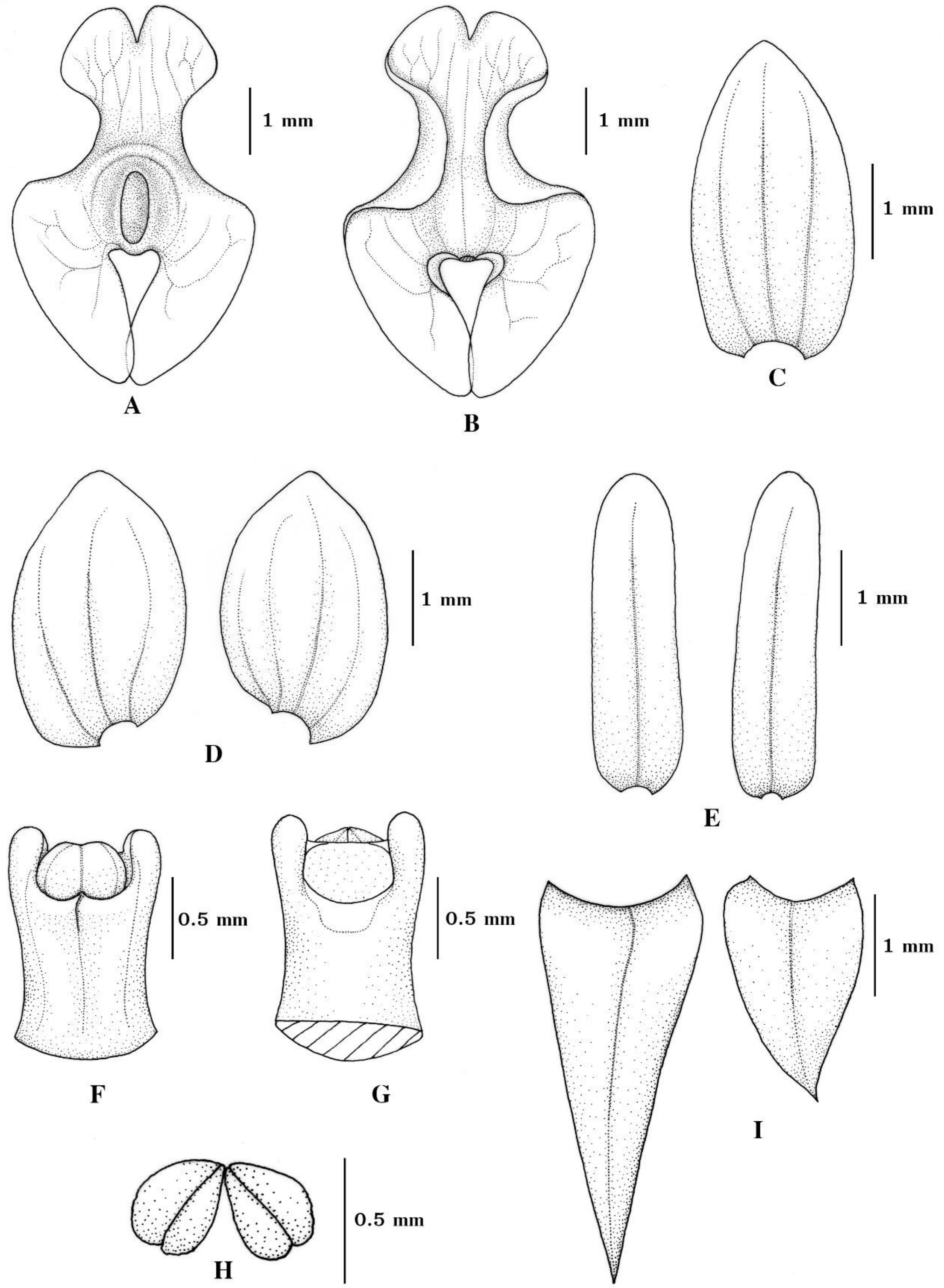

Figure 4.27 *Crepidium falcifolium* Nuammee, Seelanan & H. A. Pedersen. **A:** Labellum, front view. **B:** Labellum, back view. **C:** Dorsal sepal. **D:** Lateral sepals. **E:** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. **I:** Floral bracts. Drawing from *Nuammee 452* (A–I).

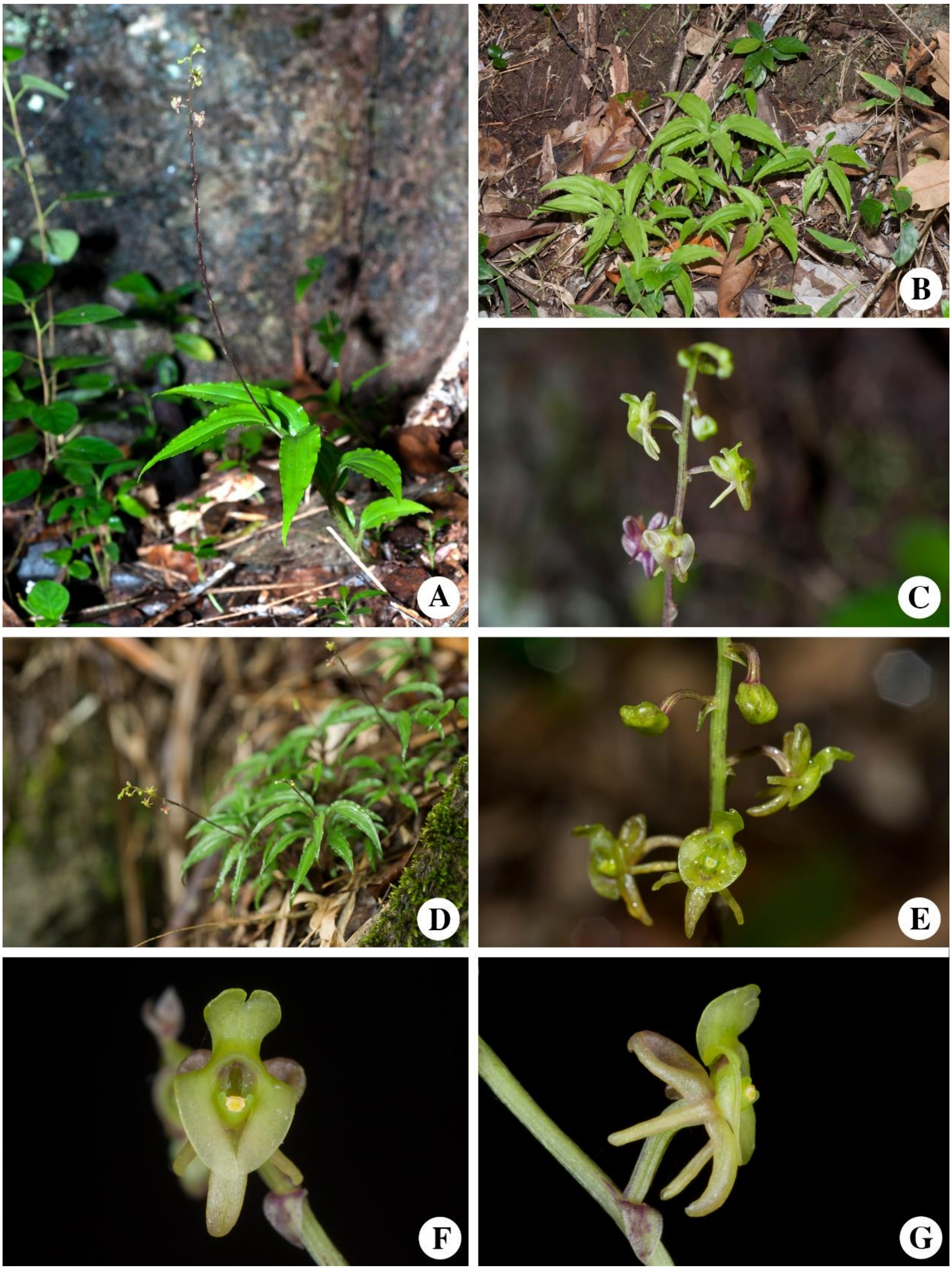

Figure 4.28 *Crepidium falcifolium* Nuammee, Seelanan & H. A. Pedersen. **A–C:** Habit and inflorescence (from Nakhon Si Thammarat). **D–E:** Habit and inflorescence (from Surat Thani). **F:** Flower, front view. **G:** Flower, lateral view. A, B, C, F and G were photographed from Nakhon Si Thammarat, Krung Ching, Khao Pon, 19 October 2015; D and E were photographed by Wins Buddhawong, Surat Thani, August 2016.

10. Crepidium josephianum (Rchb. f.) Marg., Ann. Bot. Fenn. 39: 65. 2002; Nuammee et al., Thai Forest Bull., Bot. 44: 39, fig. 3C–D. 2016.— *Microstylis josephiana* Rchb. f., Bot. Mag. 103: t. 6325. 1877; Ridl., J. Linn. Soc., Bot. 24: 336. 1888; Hook. f., Fl. Brit. India 5: 687. 1890; King & Pantl., Ann. Roy. Bot. Gard. (Calcutta) 8: 21, t. 27. 1898.— *Malaxis josephiana* (Rchb. f.) Kuntze, Revis. Gen. Pl. 2: 673. 1891. **Type:** Drawing by W. Fitch from a plant sent by Gammie from Sikkim (India) and flowering in Royal Bot. Gard., Kew [lectotype in the library of **K!**; see reproduction in Bot. Mag. 103: t. 6325. 1877].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, up to 15 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* several, arising from the basal part of the pseudobulbs, 1–3 cm long. *Pseudobulbs* green, oblong-fusiform, 5–6 cm long, 1–1.5 cm in diameter, consisting of 4–5 internodes. *Cataphylls* 2–3, triangular-ovate to lanceolate-oblong (the lowermost tubular), acute 1.5–5 by 0.8–1 cm. *Foliage leaves* 3–5, ascending to erect, sessile, sheathing at the base; lamina plicate, pale purplish-brown with purple veins beneath, unspotted, ovate to elliptic-lanceolate with slightly asymmetrical base, acuminate, 6–7 by 3.3–3.8 cm, 5- to 6-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 8–10 cm long, elongating gradually during flowering; peduncle pale purplish-brown, 5–6 cm long, 0.2–0.3 cm in diameter; rachis densely 6- to 12-flowered; floral bracts persistent, purplish-brown, patent to reflexed, triangular to triangular-ovate, acuminate, entire, 3.5–4 by 1.5–2 mm, shorter than ovaries. *Flowers* (light) brownish-yellow with red-brown or purplish-red markings on the basal part of the labellum, 10–12 mm in diameter. *Sepals* obtuse, glabrous, margins recurved; dorsal sepal revolute, ovate, 10–12 by 4–5.5 mm, 4-veined, more than twice as long as labellum auricles; lateral sepals broadly elliptic, recurved, 10–11 mm by 6–7 mm, 5-veined. *Petals* spreading, linear, rounded, 10–11 by c. 2 mm, margins revolute. *Labellum* distinctly bowl-shaped, 12–14 by 14–16.5 mm (maximum dimensions), slightly longer than wide, broadly elliptic (not constricted at the middle) with a strongly cordate-auriculate base, distally emarginate; basal part forming a cavity that is narrowly rectangular in outline, laterally flanked by 2 low linear ridges; auricles broadly and obliquely elliptic-oblong, rounded, 4–5 mm by 6–7 mm. *Column* green, erect, very stout, c. 2 mm long, c. 2.2 mm in diameter; staminodes fleshy, oblong, truncate; anther incumbent, versatile, broadly ovate, obtuse to rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 10–12 mm long; rostellum transversely rectangular, truncate; fertile stigma part transversely elliptic, flat, concave at base. *Ovary* (including pedicel) greenish-cream, tinged with purple, cylindrical, with 6 longitudinal ridges, 3–5 mm long, glabrous. *Capsule* not seen. Figures 4.29, 4.30 and 4.31.

Thailand.— NORTH-EASTERN: Loei (Phu Luang).

Distribution.— Nepal, NE India.

Ecology.— *Crepidium josephianum* grows in humus-rich soil in hill evergreen forest at c. 1,400 m alt. Flowering: recorded in May.

Vernacular.— Haew Moo Pha Sikkim (แห้วหมูป่าสิกขิม).

Note.— A few plants within a small population of this species was discovered in a shaded area near Khok Nokkaba Forest Protection Unit.

Specimens examined.— **Thailand:** *A. Nuammee 435* (BCU), Loei, Phu Luang, 2 May 2015. **India:** *C.B. Clarke 35077* (BM, K), Darjeeling, 27 May 1884; *C.B. Clarke 35483* (BM, K), Darjeeling, 25 May 1884; *R. Pantling 312* (BM, K), Sikkim Himalaya, May 1896.

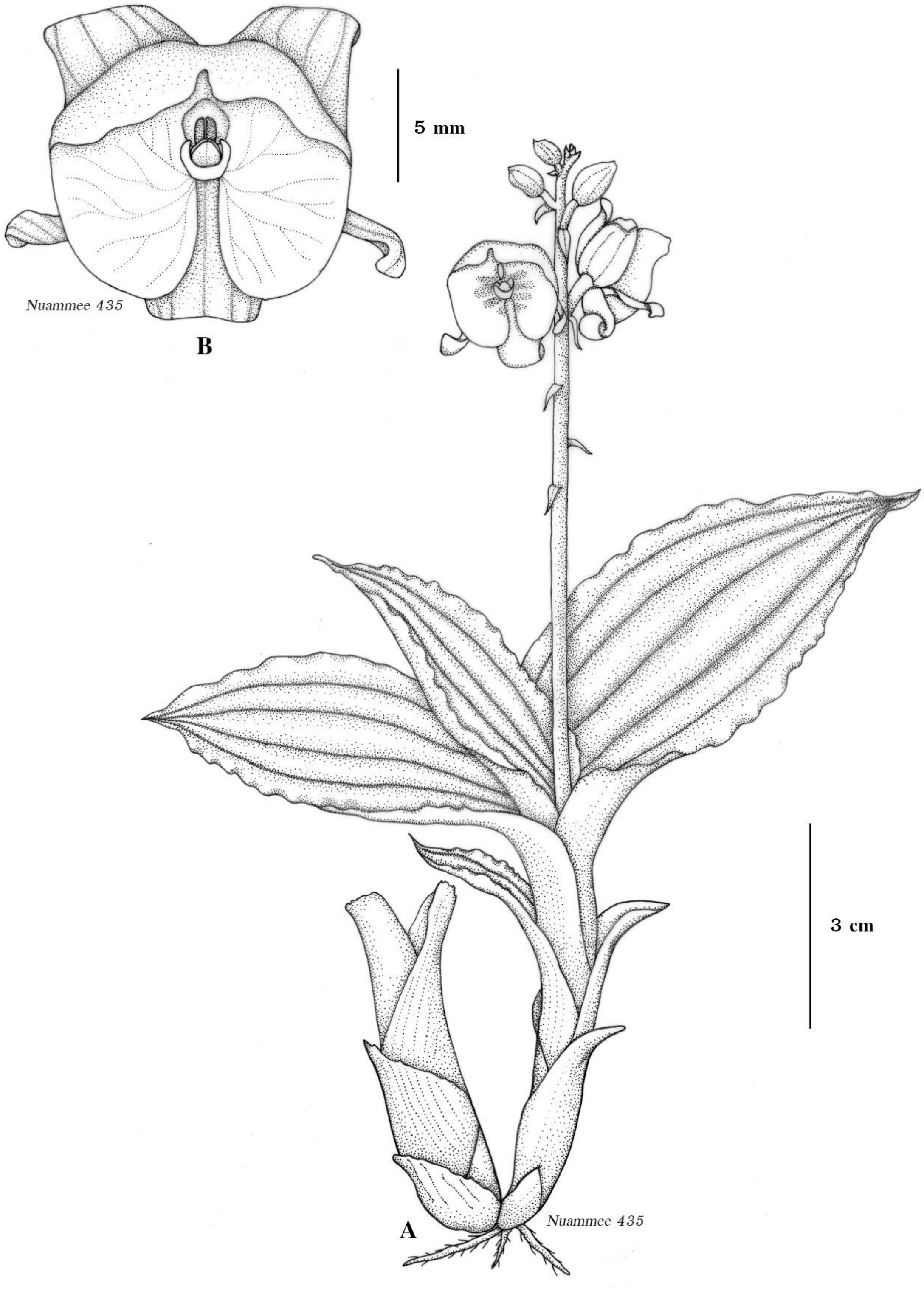

Figure 4.29 *Crepidium josephianum* (Rchb. f.) Marg. **A:** Habit. **B:** Flower, front view. Drawing from *Nuammee 435* (A–B).

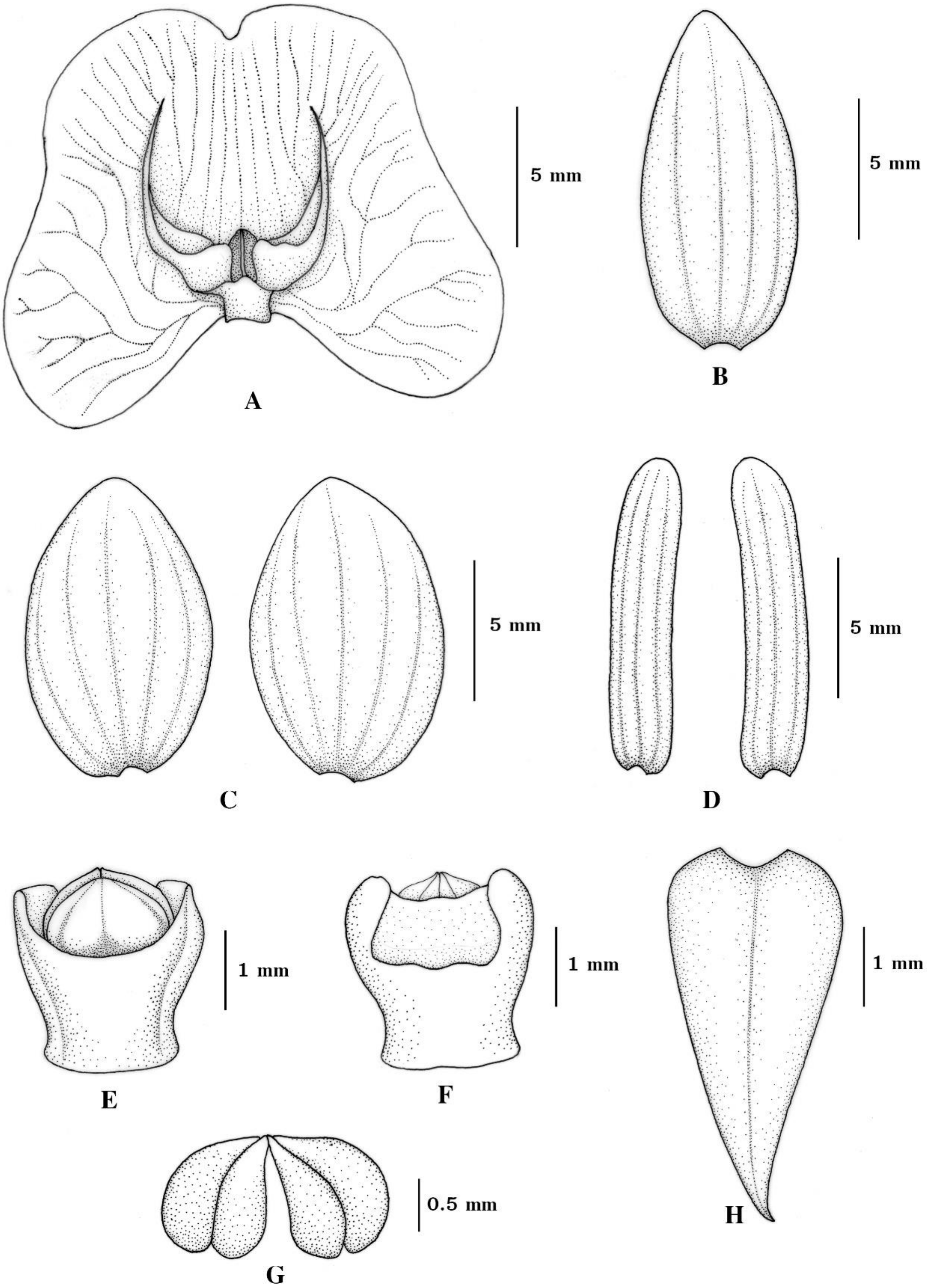

Figure 4.30 *Crepidium josephianum* (Rchb. f.) Marg. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Lateral sepals. **D:** Petals. **E:** Column, back view. **F:** Column, front view. **G:** Two pairs of pollinia. **H:** Floral bract. Drawing from *Nuammee 435* (A–H).

Figure 4.31 *Crepidium josephianum* (Rchb. f.) Marg. **A–B:** Habit. **C:** Flower, lateral view. **D:** Habit and inflorescence. **E:** Flower, front view. All were photographed from Loei, Phu Luang, 2 May 2015.

11. Crepidium khasianum (Hook. f.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 127. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; S. C. Chen & J. J. Wood in Z. Wu et al. (eds.), Fl. China 25: 233. 2009; Zhihui Xu, Wild Orchids Yunnan: 164, figs. 215a–215b. 2010.— *Microstylis khasiana* Hook. f., Fl. Brit. India 5: 686. 1890; King & Pantl., Ann. Roy. Bot. Gard. (Calcutta) 8: 15, t. 17. 1898.— *Malaxis khasiana* (Hook. f.) Kuntze, Revis. Gen. Pl. 2: 673. 1891; Seidenf., Dansk Bot. Arkiv 33(1): 52, fig. 39. 1978; N. Pearce & P. J. Cribb, Fl. Bhutan 3(3): 216. 2002; Aver., Turczaninowia 16: 125, fig. 63a. 2013. **Type:** India, Khasia, sine loco, sine anno, *Lobb s.n.* [holotype **K!**].

Terrestrial or lithophytic, sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, 18–25 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* 3–7, arising from the basal part of the pseudobulbs, 0.3–4.5 cm long. *Pseudobulbs* purplish-green, conical-cylindrical to terete from a fusiform base, 4.5–5.2 cm long, 0.4–0.6 cm in diameter, consisting of 4–5 internodes. *Cataphylls* 2–3, (triangular-)ovate to lanceolate-oblong (the lowermost tubular), acute 1–3.2 by 0.5–0.6 cm. *Foliage leaves* 4–5, ascending to spreading, petiolate, petiole sheathing at the base, free part 0.5–1.8 cm long; lamina plicate, lustrous greyish-green, more or less flushed with purple, unspotted, obliquely ovate-elliptic to lanceolate or subfalcately lanceolate with slightly asymmetrical base, acute to short-acuminate, 3–10.7 by 1–3.6 cm, 3- to 6-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 10–20 cm long, elongating gradually during flowering; peduncle greenish-purple to dull purple, 4.5–5.5 cm long, 0.1–0.2 cm in diameter; rachis laxly 5- to 35-flowered; floral bracts persistent, greenish-purple to dull purple, reflexed, triangular to lanceolate, acuminate, entire, 4–8 by 2–2.5 mm, shorter to longer than ovaries. *Flowers* greenish-yellow (to greenish-purple with yellow labellum), 4–5 mm in diameter. *Sepals* incurved, glabrous, margins recurved; dorsal sepal revolute at apex, ovate-elliptic, acute, 4–4.5 by 2–2.3 mm, up to twice as long as labellum auricles; lateral sepals ovate, obtuse to rounded, strongly concave, 3.5–4 by 1–1.2 mm. *Petals* spreading, linear-ligulate, rounded, 10–11 by c. 2 mm, margins revolute. *Labellum* (nearly) flat, 6.5–7 by 4–4.5 mm (maximum dimensions), longer than wide, broadly oblong, constricted (by means of locally revolute margins) at the middle and with strongly sagittate-auriculate base, distally rounded with more or less erose margin, to bilobed with truncate to retuse lobes, usually incurved; basal part forming a cavity that is oblong-elliptic in outline, bordered by more or less horseshoe-shaped ridge; auricles obliquely to subfalcately ovate, rounded to obtuse, 2–2.5 by 1.8–2 mm. *Column* greenish-yellow, erect, 1–1.5 mm long; staminodes stout, oblong, rounded; anther incumbent, versatile, broadly ovate, rounded to retuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, c. 0.3 mm long; rostellum transversely rectangular, truncate; fertile stigma part transversely elliptic, flat, concave at base. *Ovary* (including pedicel) greenish-purple, fusiform-cylindrical, with 6 longitudinal ridges, 5–6 mm long, glabrous. *Capsule* not seen. Figures 4.32, 4.33 and 4.34.

Thailand.— NORTHERN: Chiang Mai.

Distribution.— Nepal, NE India, China (Yunnan).

Ecology.— *Crepidium khasianum* grows in humus-rich soil in shaded areas in pine forest or on limestone, c. 1,700–1,900 m alt. Flowering: June–July.

Note.— This species has a slight variation in terminal lobe of the labellum. In some plants the lobe is almost rounded and erose, or rounded and minutely bifid, while in others it is somewhat truncate and bifid and there are intermediate characters between these.

Specimens examined.— **Thailand:** *A. Nuammee 411* (BCU, BKF), Chiang Mai, Doi Ang Khang, 23 June 2014; *T. Smitinand & H. Sleumer 1051* (BKF, L), Chiang Mai, Doi Chiang Dao, 17 August 1963. **China:** *G. Forrest 8627* (C, K), Yunnan, Shweli-Tengyueh Divide, sine anno; *G. Forrest 18268* (K), Yunnan, sine anno; *G. Forrest 18463* (K), Yunnan, sine anno. **India:** *T.R. Chand 3520* (K), Assam, Naga hills, 30 August 1950; *C. Curtis s.n.* (K), Assam, Khasia hills, July 1890; *J.D. Hooker & T. Thomson 1653* (K), Khasia, sine anno; *R. Pantling 283* (K), Sikkim Himalaya, July 1893; *Pradhan 31* (C), sine loco, sine anno.

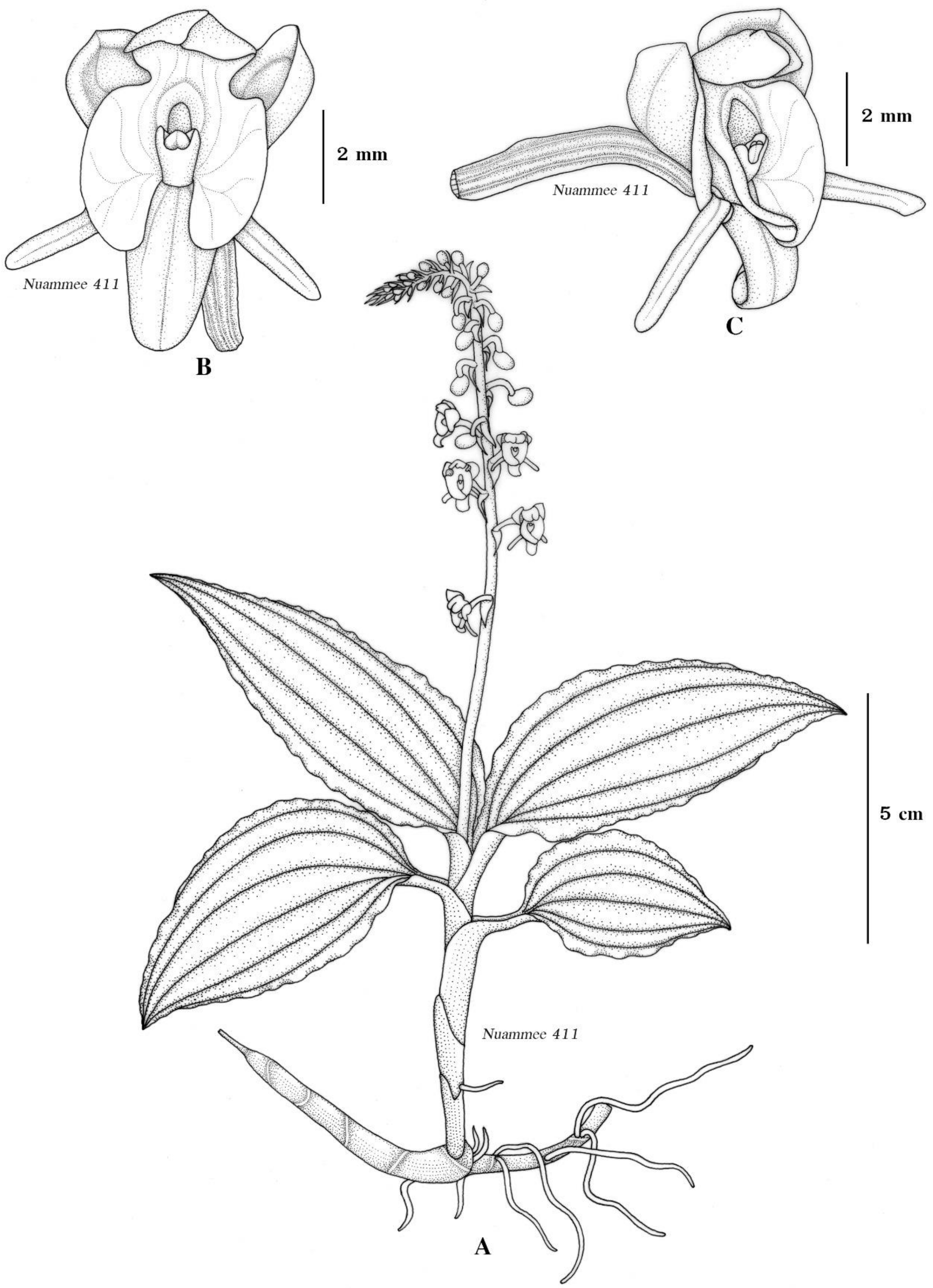

Figure 4.32 *Crepidium khasianum* (Hook. f.) Szlach. **A:** Habit. **B:** Flower, front view. **C:** Flower, lateral view. Drawing from *Nuammee 411* (A–C).

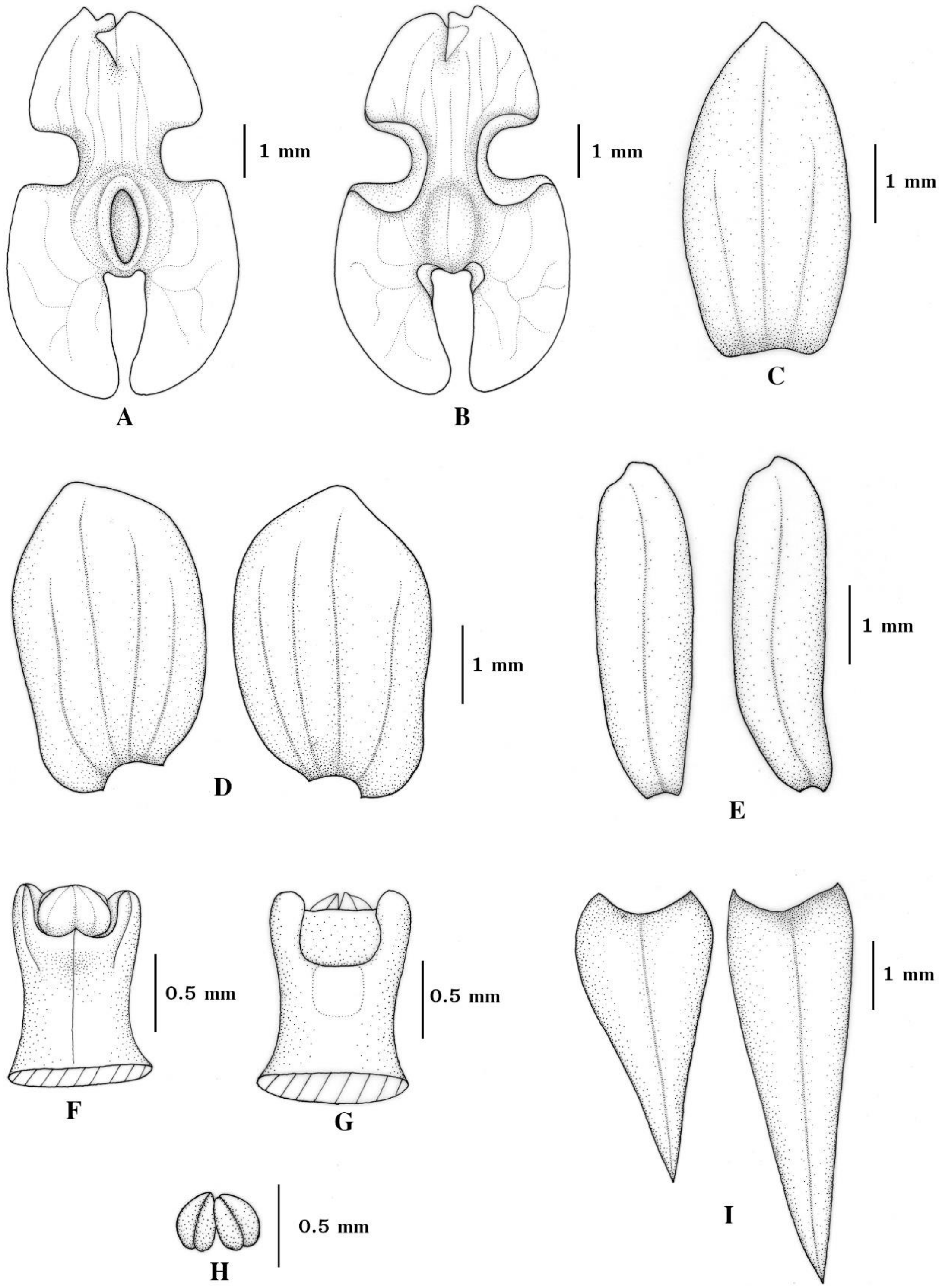

Figure 4.33 *Crepidium khasianum* (Hook. f.) Szlach. **A:** Labellum, front view. **B:** Labellum, back view. **C:** Dorsal sepal. **D:** Lateral sepals. **E:** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. **I:** Floral bracts. Drawing from *Nuammee 411* (A–I).

Figure 4.34 *Crepidium khasianum* (Hook. f.) Szlach. **A–B:** Habit. **C:** Inflorescence. **D:** Flower, front view. **E:** Flower, lateral view. All were photographed from Chiang Mai, Doi Ang Khang, 23 June 2014.

12. Crepidium klimkoanum Marg., Candollea 60: 374. 2005.— *Malaxis mackinnonii* auct. non (Duthie) Ames: Seidenf., Bot. Tidsskr. 65: 121 p.p. 1969; Dansk Bot. Arkiv 33(1): 50 p.p. 1978.— *Seidenforchis klimkoana* (Marg.) Marg., Acta Soc. Bot. Poloniae 75: 306. 2006. **Type:** Thailand, Chiang Mai, Chiang Dao, September 1958*, Seidenfaden & Smitinand GT 3031* [holotype **C!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect cormous, 9–15 cm tall flowering shoots distally and 1 decaying corm behind. *Roots* 2 to several, arising from the basal part of the corms, 0.3–2 cm long. *Corms* white, ovoid to almost oblong, 0.6–3 cm long, 0.5–0.8 cm in diameter, consisting of 3–4 internodes. *Cataphylls* few, triangular-ovate to lanceolate-oblong (the lowermost tubular), acute, 1–3.3 by 0.6–1 cm. *Foliage leaves* 2(–3), horizontally spreading just above the soil surface, subopposite, sessile, sheathing at base, lamina subplicate, uniformly green to purple or green with reddish-purple veins, unspotted, broadly ovate to lanceolate or elliptic with symmetrical base, acute, 2.2–6.5 by 1–5 cm, 3- to 5-veined, glabrous, margins flat. *Inflorescence* terminal on the young corm, racemose, erect, 8–12 cm long, elongating gradually during flowering; peduncle dark purple to greenish-purple, 4–7.5 cm long, 0.1–0.2 cm in diameter; rachis laxly 10- to 30-flowered; floral bracts persistent, purple to purplish-green, reflexed, (linear-)lanceolate or ovate, acute to acuminate, entire, 2–7 by 0.5–1.5 mm, equal to longer than ovaries. *Flowers* purple with green labellum mid-lobe to cremmy-yellow with purple labellum mid-lobe, 2.5–5 mm in diameter. *Sepals* spreading, acute to rounded, glabrous, margins recurved; dorsal sepal ovate to lanceolate, 2.5–3.5 by 1.5–1.8 mm, usually more than twice as long as labellum auricles; lateral sepals slightly concave, obliquely ovate, 2.5–3 by 1.5–3 mm. *Petals* spreading to revolute, linear, obtuse to truncate, 2.5–3 by 0.5–0.8 mm, margins recurved. *Labellum* (nearly) flat, 3–4 mm by 2–3 mm (maximum dimensions), longer than wide, ovate (constricted at the middle) with prominently sagittate-auriculate base, distally triangular, cleft for up to 1/4 of its length; basal/central part forming a cavity that is shallowly ovate in outline, bordered by a more or less horseshoe-shaped ridge; auricles obliquely ovate-triangular to ovate, obtuse to rounded, 1–1.5 by 0.7–1 mm. *Column* creamy-yellow to greenish-purple, erect, stout, 1–1.5 mm long; staminodes fleshy, oblong, retuse; anther incumbent, versatile, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, c. 0.3 mm long; rostellum transversely rectangular, truncate; fertile stigma part transversely elliptic, flat, concave at base. *Ovary* (including pedicel) greenish yellow tined with purple, cylindrical to fusiform-cylindrical, with 6 longitudinal ridges, 1.5–3 mm long, glabrous. *Capsule* not seen. Figures 4.35, 4.36 and 4.37.

Thailand.— NORTHERN: Chiang Mai (Chiang Dao, Doi Sutep).

Distribution.— Endemic.

Ecology.— *Crepidium klimkoanum* grows in sandy clay in open grassland, dry deciduous dipterocarp forest at 800–1,200 m alt. Flowering: August–September.

Vernacular.— Hoo Sua Chiuw (หูเสือจิ๋ว).

Specimens examined.— **Thailand:** *A. Nuammee 430* (BCU), Chiang Mai, Doi Suthep, 27 September 2014; *S. Pumicong* (QBG), Chiang Mai, Mae Rim, 17 August 2006; *G. Seidenfaden & T. Smitinand GT 3031* (C), Chiang Mai, Chiang Dao, September 1958; *G. Seidenfaden & T. Smitinand GT 3042* (C), Chiang Mai, Doi Suthep, September 1958; *O. Thaithong 471* (BCU), sine loco, 8 August 1988; *S. Watthana 4202* (QBG), Chiang Mai, Chiang Dao, 20 August 2014.

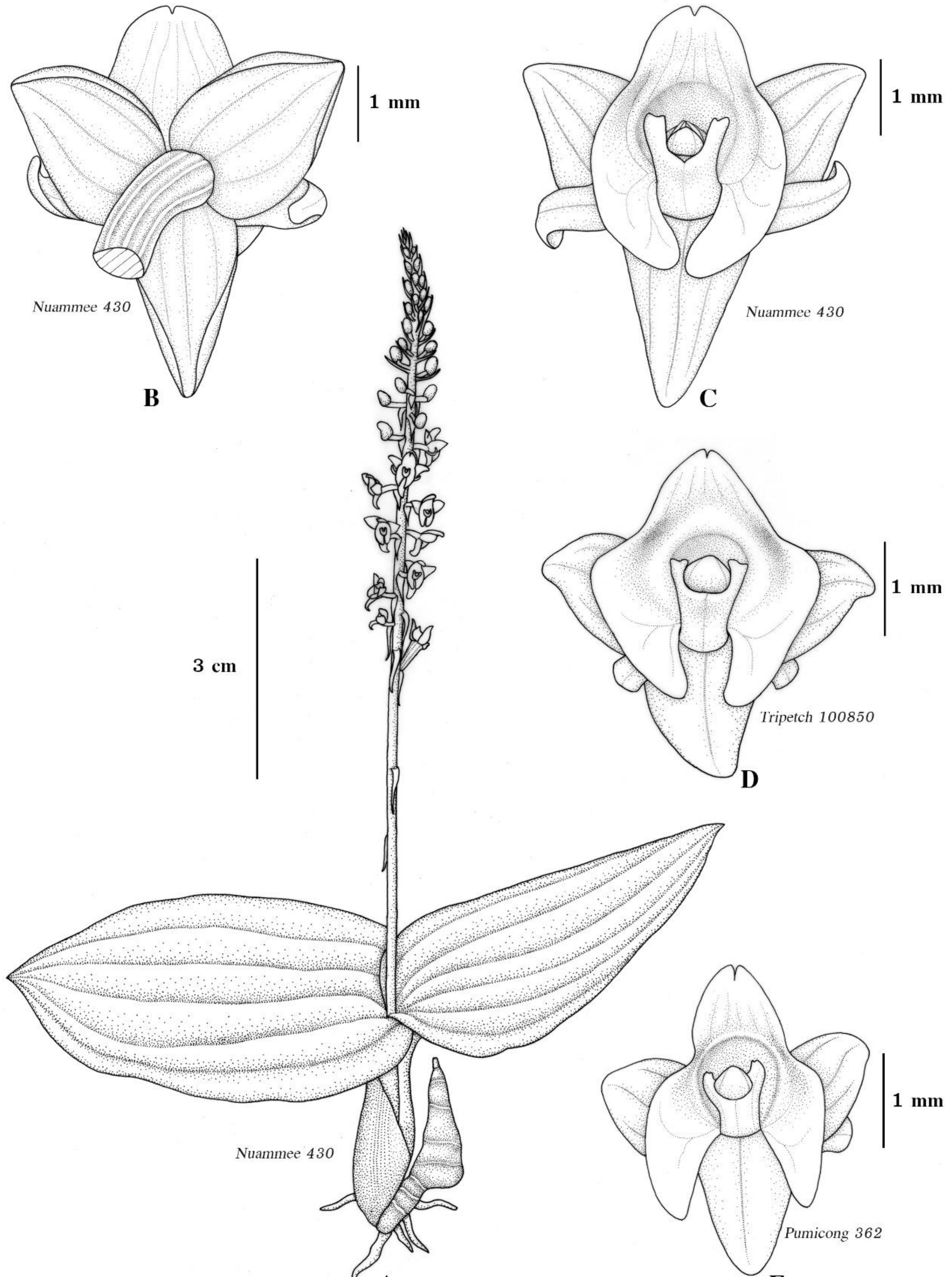

Figure 4.35 *Crepidium klimkoanum* Marg. **A:** Habit. **B:** Flower, back view. **C–E:** Flower, front view. Drawing from *Nuammee 430* (A–C); *Tripetch 100850* (D); *Pumicong 362* (E).

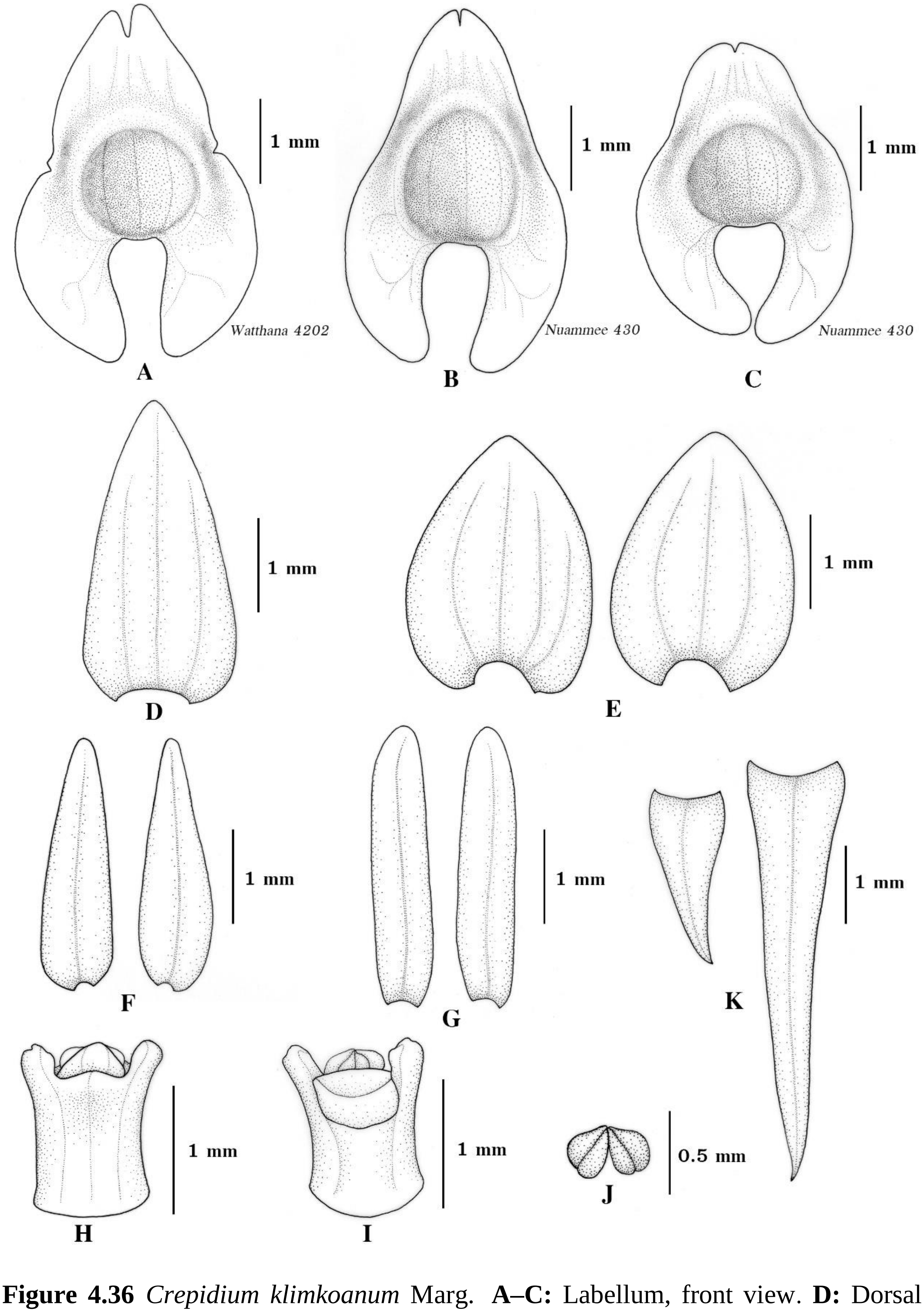

Figure 4.36 *Crepidium klimkoanum* Marg. **A–C:** Labellum, front view. **D:** Dorsal sepal. **E:** Lateral sepals. **F–G:** Petals. **H:** Column, back view. **I:** Column, front view. **J:** Two pairs of pollinia. **K:** Floral bracts. Drawing from *Watthana 4202* (A); *Nuammee 430* (B–J).

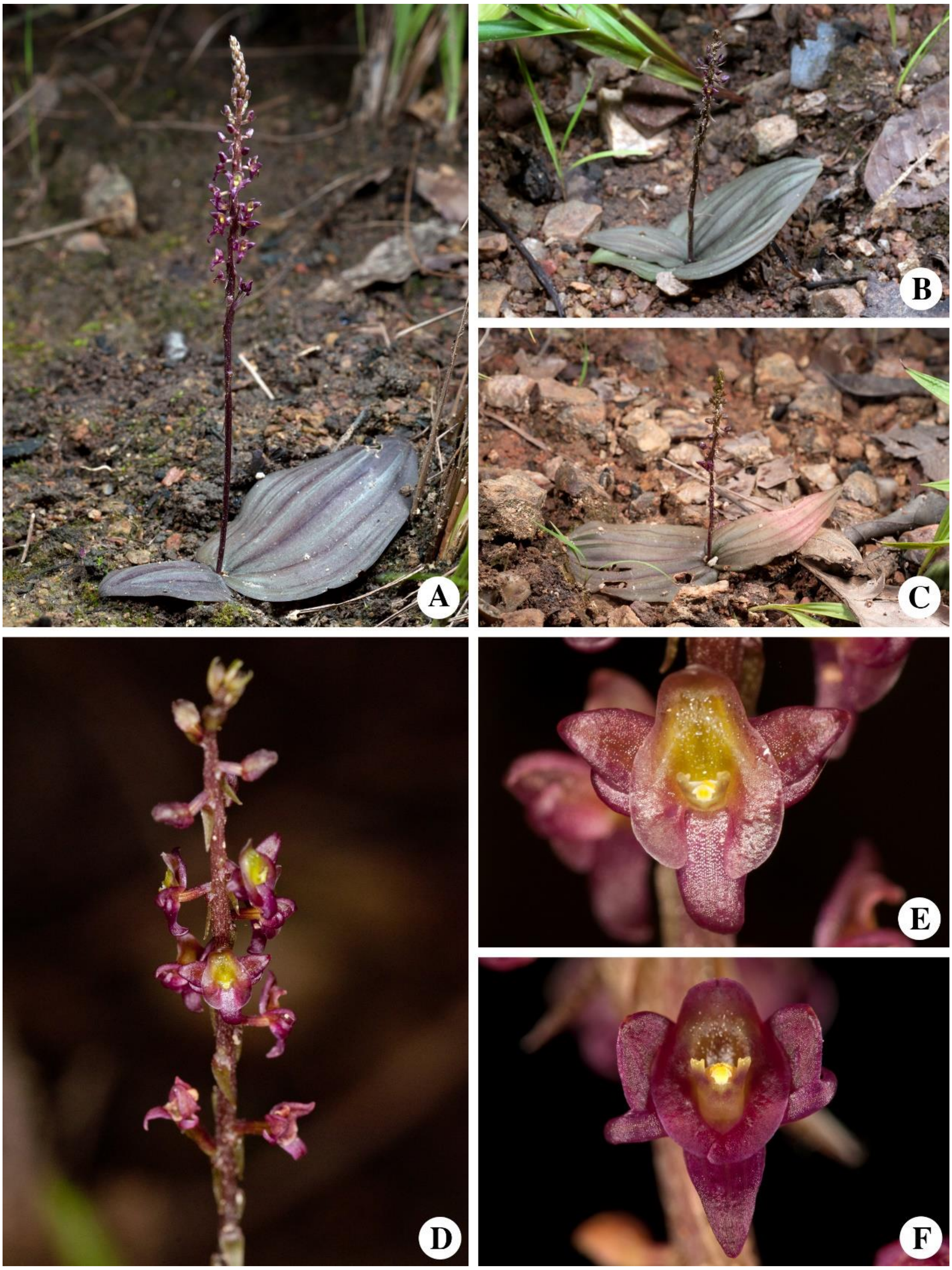

Figure 4.37 *Crepidium klimkoanum* Marg. **A–C:** Habit. **D:** Inflorescence. **E–F:** Flower, front view. All were photographed from Chiang Mai, Doi Suthep, 27 September 2014.

13. Crepidium luniferum (J. J. Sm.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 128. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997.— *Microstylis lunifera* J. J. Sm., Bull. Jard. Bot. Buitenzorg sér. 3, 10: 39. 1928.— *Malaxis* sp. [*Kerr 0446*, *Phloenchit 406*]: Seidenf. & Smitinand, Orchids Thailand: 152, fig. 120. 1959.— *M. quadridens* auct. non (Schltr.) P. F. Hunt: Seidenf., Bot. Tidsskr. 65: 329, fig. 9. 1970.— *M. lunifera* (J. J. Sm.) Seidenf., Dansk Bot. Arkiv 33(1): 79, fig. 54. 1978. **Type:** Indonesia, Sumatra, Gunung Kerintji, 12 March 1920, *Bünnemeijer 8716* [holotype **L!**, isotypes **C! K!**].

Terrestrial (occasionally lithophytic or epiphytic), sympodial herb with a long creeping rhizome, bearing an erect, slenderly pseudobulbous, 20–56 cm tall flowering shoot distally 1–2 decaying pseudobulb behind. *Roots* several, 1–3 arising from each node of the rhizome and from the lower nodes of the pseudobulbs, 1–15 cm long. *Pseudobulbs* green, terete, 2.5–5 cm long, 0.7–1.2 cm in diameter, consisting of 5–7 internodes. *Foliage leaves* (2–)4–5, ascending to spreading or erect, petiolate, petiole green, sheathing at base, free part 1–5 cm long; lamina plicate, green, unspotted, lanceolate, ovate to elliptic, oblong or oblong-lanceolate with asymmetrical base, acuminate, 5.5–18 by 2–7 cm, 5- to 7-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 28–50 cm long, elongating gradually during flowering; peduncle green, 10–13 cm long, 0.1–0.5 cm in diameter, bearing a few linear-triangular sterile bracts; rachis densely many-flowered (bearing more than 100 flowers); floral bracts green, reflexed, linear-lanceolate, acuminate, 3–10 by 1–2 mm, longer than ovaries. *Flowers* green, 3–5 mm in diameter. *Sepals* rounded to acute, glabrous, margins revolute; dorsal sepal spreading, oblong to oblong-lanceolate, 2.5–4 by 1–1.5 mm, less than twice as long as labellum auricles; lateral sepals reflexed, broadly and obliquely ovate to elliptic, 2–3.5 by 1.2–2 mm. *Petals* spreading, linear to linear-ligulate, truncate or retuse, 2.5–3.5 by 0.5–1 mm, margins revolute. *Labellum* (nearly) flat, 3.5–5 by 3–4 mm (maximum dimensions), usually longer than wide, obovate (not constricted at the middle) with a strongly sagittate-auriculate base, distally rounded with distally rounded with 2–4 irregular teeth on either side of the apex; basal/central part forming a deep cavity that is obovate to elliptic or orbicular in outline, bordered by a prominent horseshoe-shaped high ridges; auricles obliquely triangular, acute to obtuse, 1.5–2.5 by 0.8–1.5 mm. *Column* green, erect, stout, 1–1.5 mm long; staminodes oblong, truncate to rounded; anther incumbent, versatile, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.2–0.3 mm long; rostellum transversely rectangular, truncate; fertile stigma part transversely elliptic, flat, concave at base. *Ovary* (including pedicel) green to purple, cylindrical, with 6 longitudinal ridges, 3–6 mm long, glabrous. *Capsule* clavate-oblong, 0.5–1 cm long, c. 0.5 cm in diameter; fruit pedicel 0.4–0.5 cm long. Figures 4.38, 4.39 and 4.40.

Thailand.— PENINSULAR: Surat Thani (Khao Nong), Nakhon Si Thammarat (Khao Luang).

Distribution.— Indonesia, New Guinea.

Ecology.— *Crepidium luniferum* grows on mossy rocks in shaded areas along streams and on the lower part of tree trunks in evergreen forest at 900–1,600 m alt. Flowering: July–September.

Vernacular.— Hoo Sua Chan Thon (หูเสือจันทร).

Note.— During collecting living specimens, I found further variation of labellum with differ from Seidenfaden notes. Seidenfaden noted that the middle large triangular of labellum are bifid, but the collected specimens have the middle large triangular acute, not bifid.

Specimens examined.— **Thailand:** *K. Iwatsuki et al.* 840, Nakhon Si Thammarat, Khao Luang, 23 August 1967; *A.F.G. Kerr 446* (C, K), Surat Thani, Khao Nong, 10 August 1927; *A. Nuammee 419* (BCU), Nakhon Si Thammarat, Khao Luang, 24 July 2014; *A. Nuammee 420* (BCU, BKF), Nakhon Si Thammarat, Khao Luang, 24 July 2014; *A. Nuammee 446* (BCU, BKF), Nakhon Si Thammarat, Khao Luang, 21 September 2015; *Phloenchit 406* (BKF), Nakhon Si Thammarat, Khao

Luang, 30 August 1955; *P. Srisom 33* (BKF), Nakhon Si Thammarat, Khao Luang, 30 September 2014.

Indonesia: *H.A.B. Bünnemeijer 8616* (L), Sumatra, Gunung Kerintji, 8 March 1920; *H.A.B. Bünnemeijer 8716* (C, L, K), Sumatra, Gunung Kerintji, 12 March 1920; *H.A.B. Bünnemeijer 8753* (L), Sumatra, Gunung Kerintji, 13 March 1920; *H.A.B. Bünnemeijer 8890* (L, P, SING), Sumatra, Gunung Kerintji, 16 March 1920; *H.A.B. Bünnemeijer 9066* (L), Sumatra, Gunung Kerintji-Mt. Tudjuh, 22 March 1920; *H.A.B. Bünnemeijer 9022* (L), Sumatra, Gunung Kerintji, 20 March 1920; *Herb. Hort. Bot. Bog. 1431* (L), Sumatra, sine anno; *M. Jacobs 4438* (L), Sumatra, Gunung Kerintji, 1 August 1956; *J.A.J. Verheijen 882* (L), Lesser Sunda Islands, Manggarai, sine anno; *J.A.J. Verheijen 1770* (L), Lesser Sunda Islands, sine anno. **New Guinea**: *C.E. Carr 16970* (L), Isuarava, 31 January 1936.

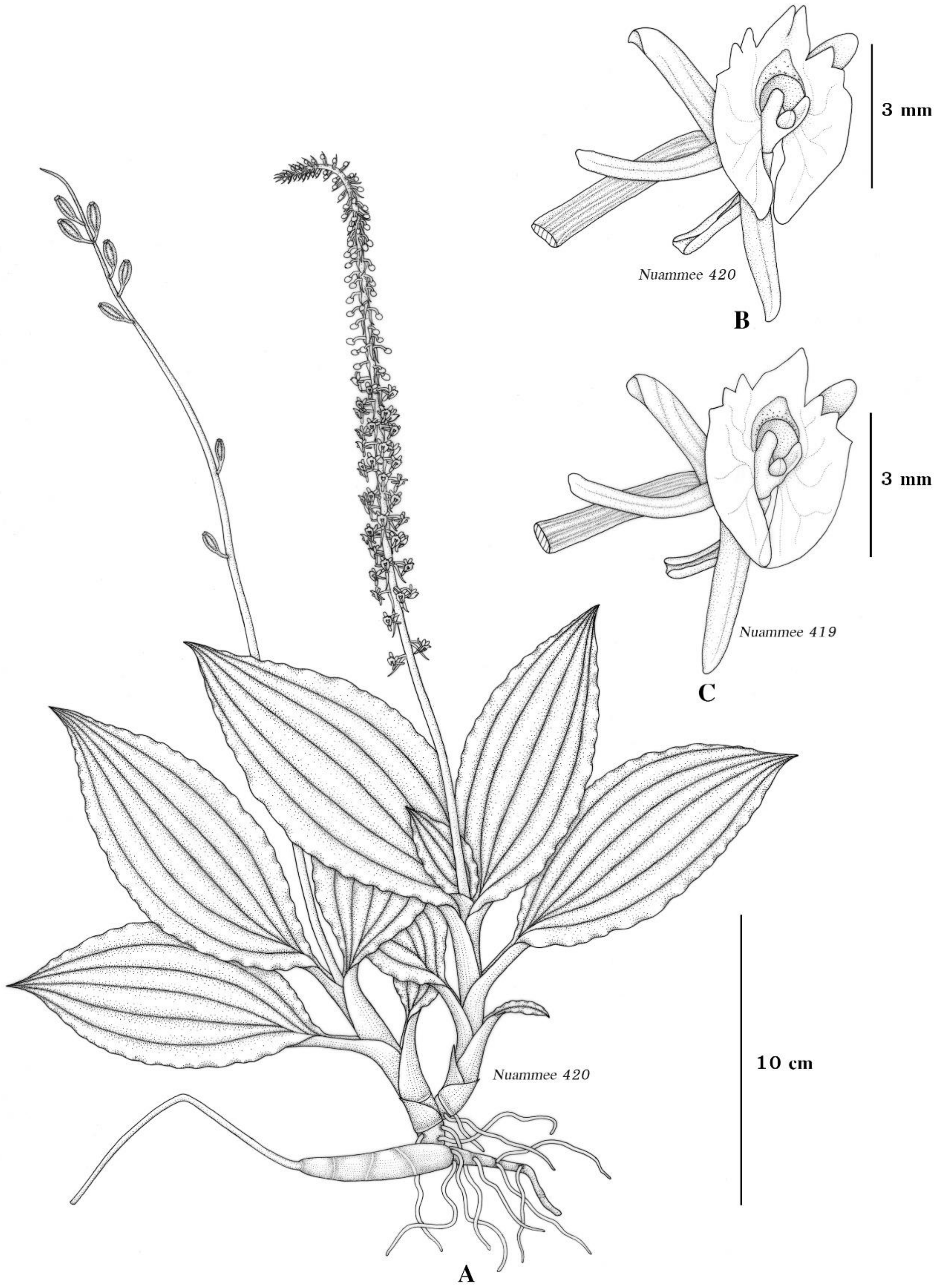

Figure 4.38 *Crepidium luniferum* (J. J. Sm.) Szlach. **A:** Habit. **B–C:** Flower, front view. Drawing from *Nuammee 420* (A–B); *Nuammee 419* (C).

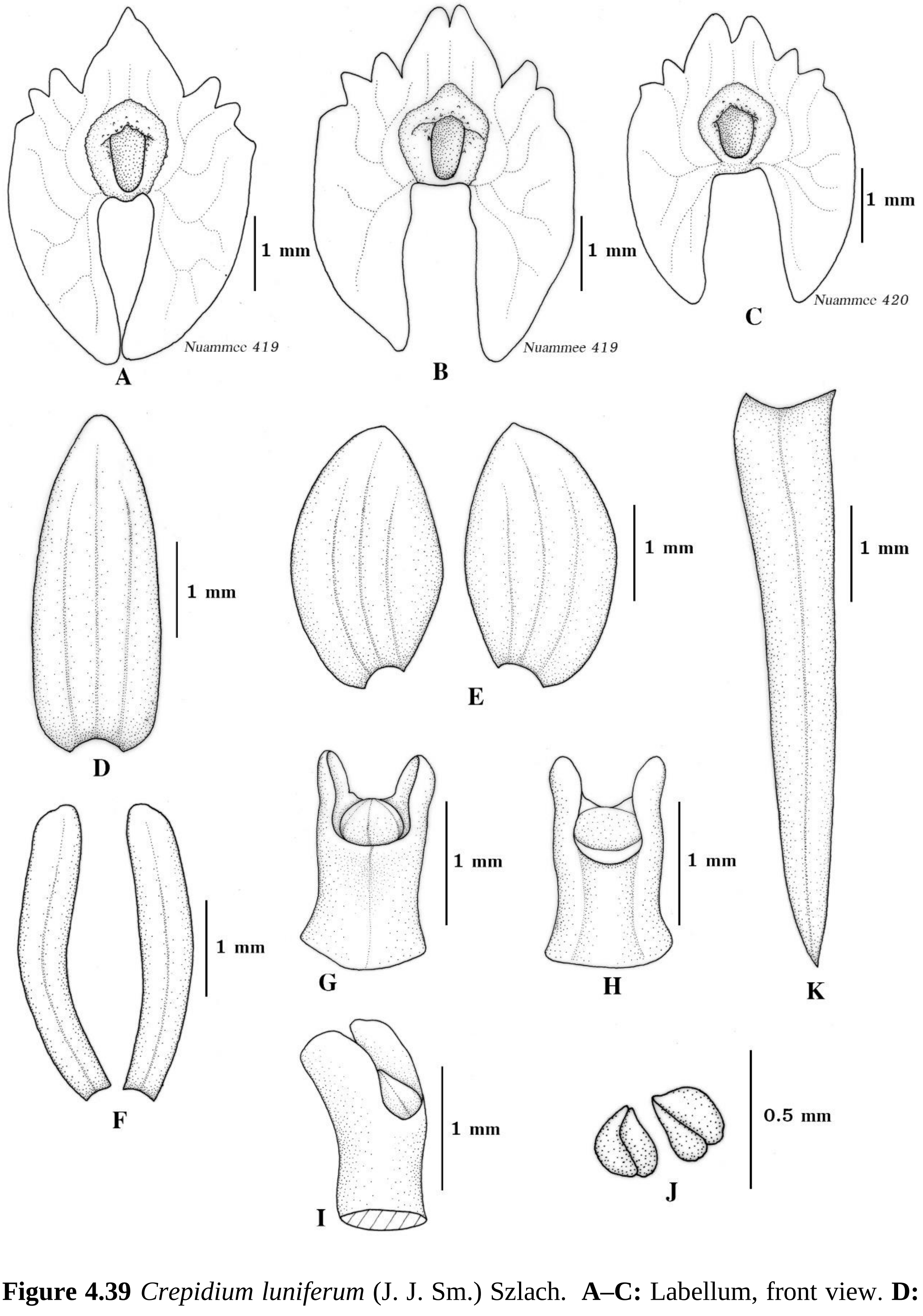

Figure 4.39 *Crepidium luniferum* (J. J. Sm.) Szlach. **A–C:** Labellum, front view. **D:** Dorsal sepal. **E:** Lateral sepals. **F:** Petals. **G:** Column, back view. **H:** Column, front view. **I:** Column, lateral view. **J:** Two pairs of pollinia. **K:** Floral bract. Drawing from *Nuammee 419* (A–B, D–K); *Nuammee 420* (C).

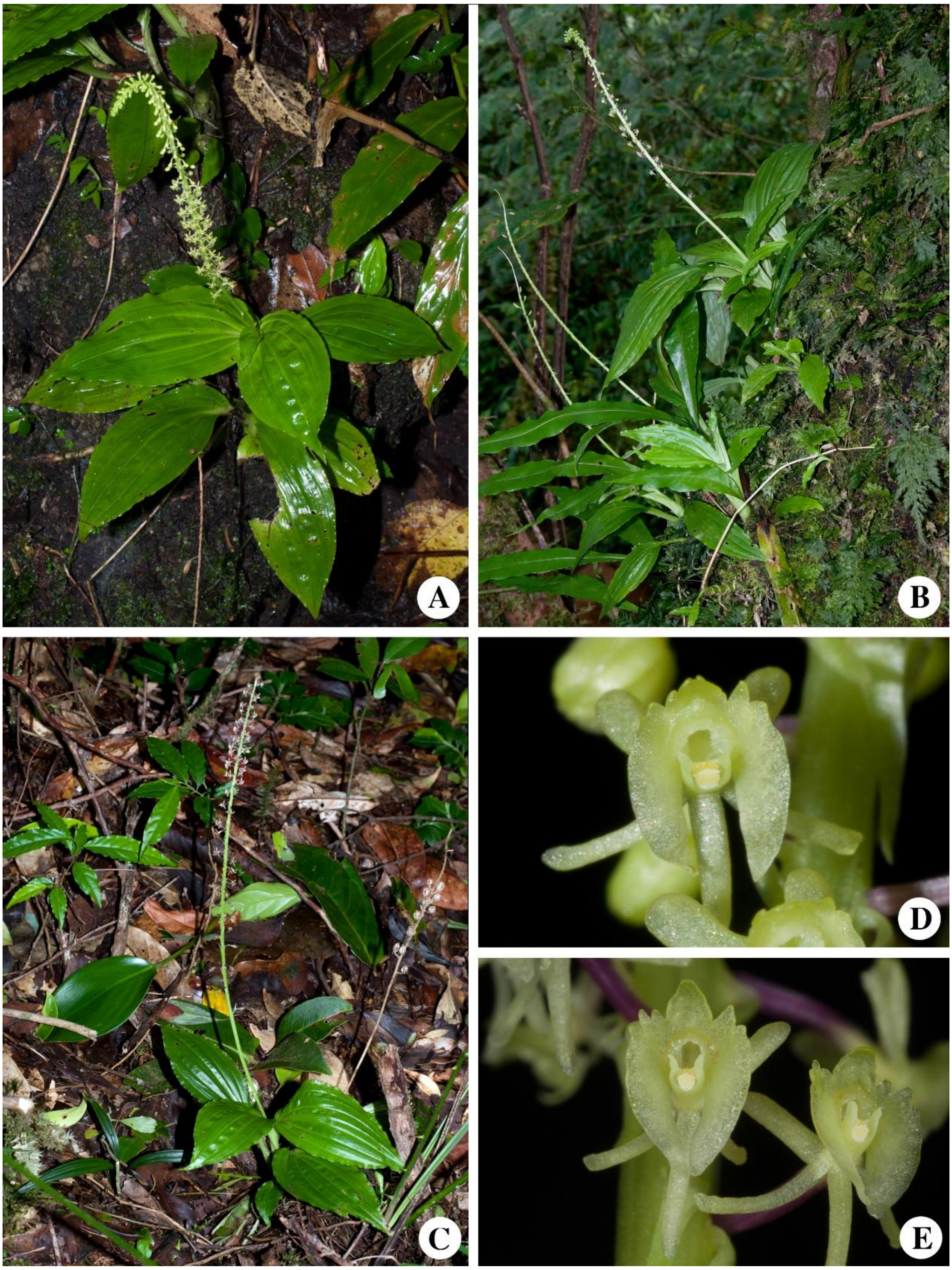

Figure 4.40 *Crepidium luniferum* (J. J. Sm.) Szlach. **A:** Habit, grow on rock. **B:** Habit, grow on the lower part of trees trunk. **D:** Habit, grow on ground. **E–F:** Flower, front view. All were photographed from Nakhon Si Thammarat, Khao Luang, 21 September 2015.

14. Crepidium mackinnonii (Duthie) Szlach., Fragm. Florist. Geobot., Suppl. 3: 128. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 17. 1997; S. C. Chen & J. J. Wood in Z. Wu et al. (eds.), Fl. China 25: 232. 2009.— *Microstylis mackinnonii* Duthie, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 71: 37. 1902.— *M. cardonii* Prain, Bengal Pl.: 1004. 1903.— *Malaxis mackinnonii* (Duthie) Ames, Orchidaceae 6: 289. 1920; Seidenf., Bot. Tidsskr. 65: 121 p.p., fig. 15. 1969; Dansk Bot. Arkiv 33(1): 50 p.p., fig. 38. 1978; Vaddhanaphuti, Field Guide Wild Orchids Thailand, ed. 4: 182 (incl. colour photo). 2005.— *M. sutepensis* auct. non (Rolfe ex Downie) Seidenf. & Smitinand: Seidenf. & Smitinand, Orchids Thailand: fig. 114. 1959.— *Seidenforchis mackinnonii* (Duthie) Marg., Acta Soc. Bot. Poloniae 75: 303. 2006. **Type:** India, NW Himalaya, Musoorie, 28 July 1899, *Mackinnon 25429* [holotype **K!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect cormous, 8–25 cm tall flowering shoots distally and 1 decaying corm behind. *Roots* 2 to several, arising from the basal part of the corms, 0.5–2 cm long. *Corms* white, ovoid to subglobose, 1–2 cm long, 0.5–1 cm in diameter, consisting of 3–4 internodes. *Cataphylls* few, triangular to ovate, acute to acuminate 1–1.5 by 0.5–0.6 cm. *Foliage leaves* 2(–3), horizontally spreading just above the soil surface, subopposite, sessile, sheathing at base; lamina subplicate, brownish-purple to dark purple, unspotted, broadly ovate with symmetrical base, acute, 3–5.5 by 1–4.5 cm, 3- to 7-veined, glabrous, margins entire. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 6–22 cm long, elongating gradually during flowering; peduncle brownish-purple to reddish-purple or greenish-yellow, 3–7 cm long, 0.1–0.2 cm in diameter; rachis laxly 10- to 30-flowered; floral bracts persistent, purplish-green to yellowish-green, reflexed, (linear-)lanceolate, acuminate, entire, 2–5 by 0.5–1.5 mm, longer than ovaries. *Flowers* pale greenish-yellow to pale reddish-purple, 4–5 mm in diameter. *Sepals* spreading, obtuse to rounded, glabrous, margins recurved to revolute; dorsal sepal oblong-elliptic to oblong-ovate, 2.5–3 by 1.2–1.5 mm, at least twice as long as labellum auricles; lateral sepals concave, obliquely ovate, 2.2–2.6 by 1.8–2 mm. *Petals* revolute, linear, obtuse, 2.2–2.5 by 0.5–0.8 mm, margins revolute. *Labellum* (nearly) flat, 4–5.5 mm by 2.8–3.2 mm (maximum dimensions), longer than wide, (triangular-)oblong (more or less constricted at the middle) with a widened, strongly sagittate-auriculate base, distally emarginate with obtuse to acute lobules; basal/central part forming a cavity that is broadly ovate in outline and bordered by a more or less horseshoe-shaped ridge; auricles obliquely ovate-triangular, obtuse, 1–1.5 by 0.7–1 mm. *Column* greenish-yellow, erect, stout, 1–1.5 mm long; staminodes fleshy, oblong, retuse; anther incumbent, versatile, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, c. 0.3 mm long; rostellum transversely rectangular, truncate; fertile stigma part transversely elliptic, flat, concave at base. *Ovary* (including pedicel) greenish-yellow to reddish-purple, cylindrical to fusiform-cylindrical, with 6 longitudinal ridges, 2–3 mm long, glabrous. *Capsule* not seen. Figures 4.41 and 4.42.

Thailand.— NORTHERN: Mae Hong Son, Chiang Mai; NORTH-EASTERN: Loei.

Distribution.— India, Bangladesh, China (Yunnan).

Ecology.— *Crepidium mackinnonii* grows in sandy clay in open grassland, dry deciduous dipterocarp forest at 800–1,200 m alt. Flowering: August–September.

Vernacular.— Hoo Sua Chiuw (หูเสือจิ๋ว).

Note.— The leaves and psuedobulb morphology of *C. mackinnonii* is much similar to *C. klimkoanum.* The colour of leaves and flowers are overlaped between these two species. However, There are differences in term of the labellum shape, *C. mackinnonii* can be recognized by the mid-lobe of labellum oblong and deeply bilobed.

Specimens examined.— **Thailand:** *H. Kurzweil 2082* (QBG), Chiang Mai, Mae Rim, 9 September 2009; *S. Wathana & S. Pumicong 2070* (QBG, SING), Chiang Mai, Mae Rim, 24 June 2008.

India: *G.S. Deb 3108* (K), Sambalpur, Kalahandi, 27 August 1948; *J.F. Duthie 22974* (K), NW Himalaya, Mussoorie, 28 July, 1899; *H.F. Mooney 4010* (K), Sambalpur, 13 September, 1950; *P.W. Mackinnon 22974* (K, P), NW Himalaya, Musoorie, 28 July 1899; *P.W. Mackinnon 25429* (K, P), Dehra Dun, Kalanga, 20 August 1901. **Nepal:** *B.R. Sharma s.n.* (K), Sahid Smarak, Hetauda, 25 July 2003.

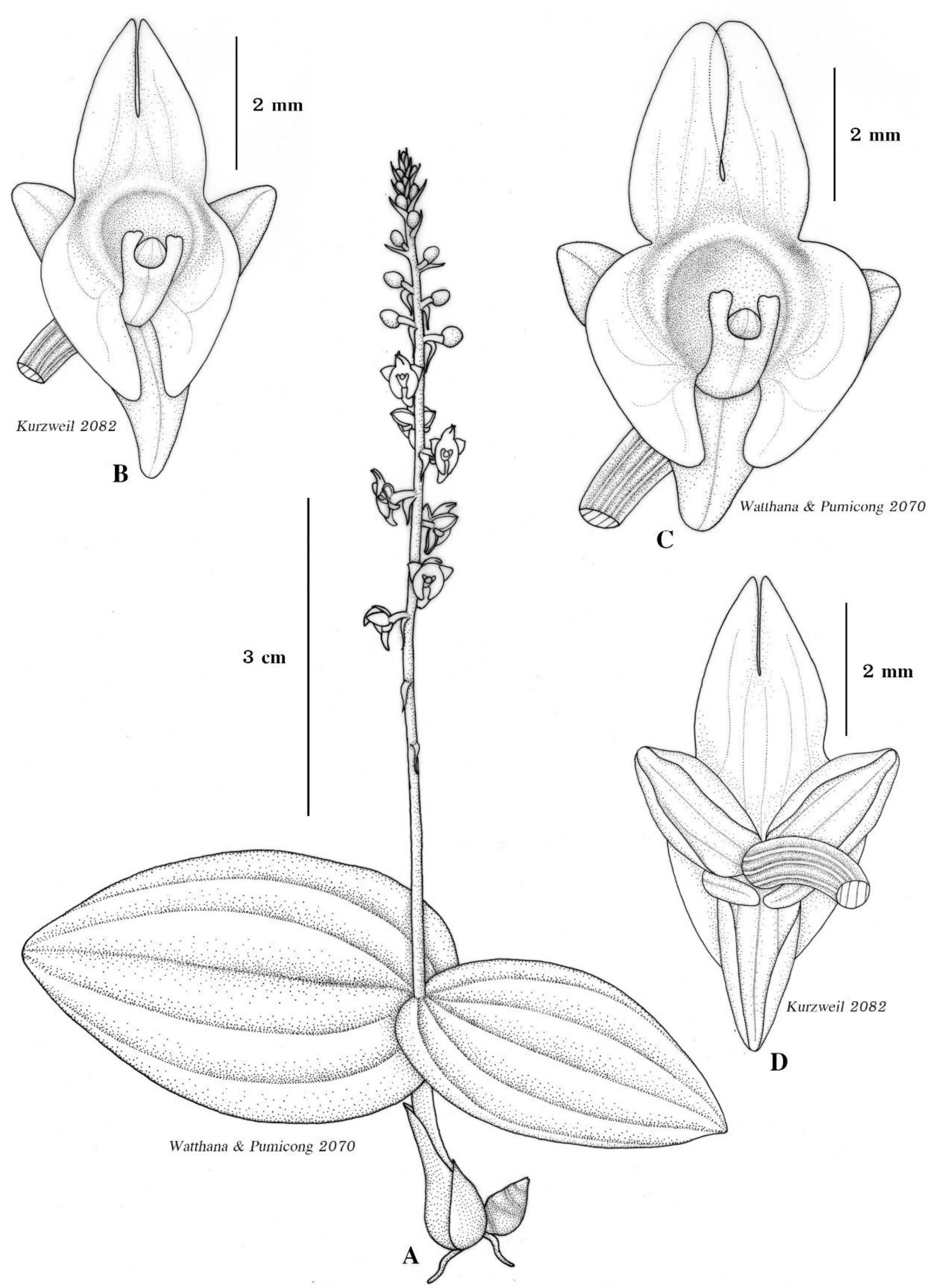

Figure 4.41 *Crepidium mackinnonii* (Duthie) Szlach. **A:** Habit. **B–C:** Flower, front view. **D:** Flower, back view. Drawing from *Watthana & Pumicong 2070* (A, C); *Kurzweil 2082* (B, D).

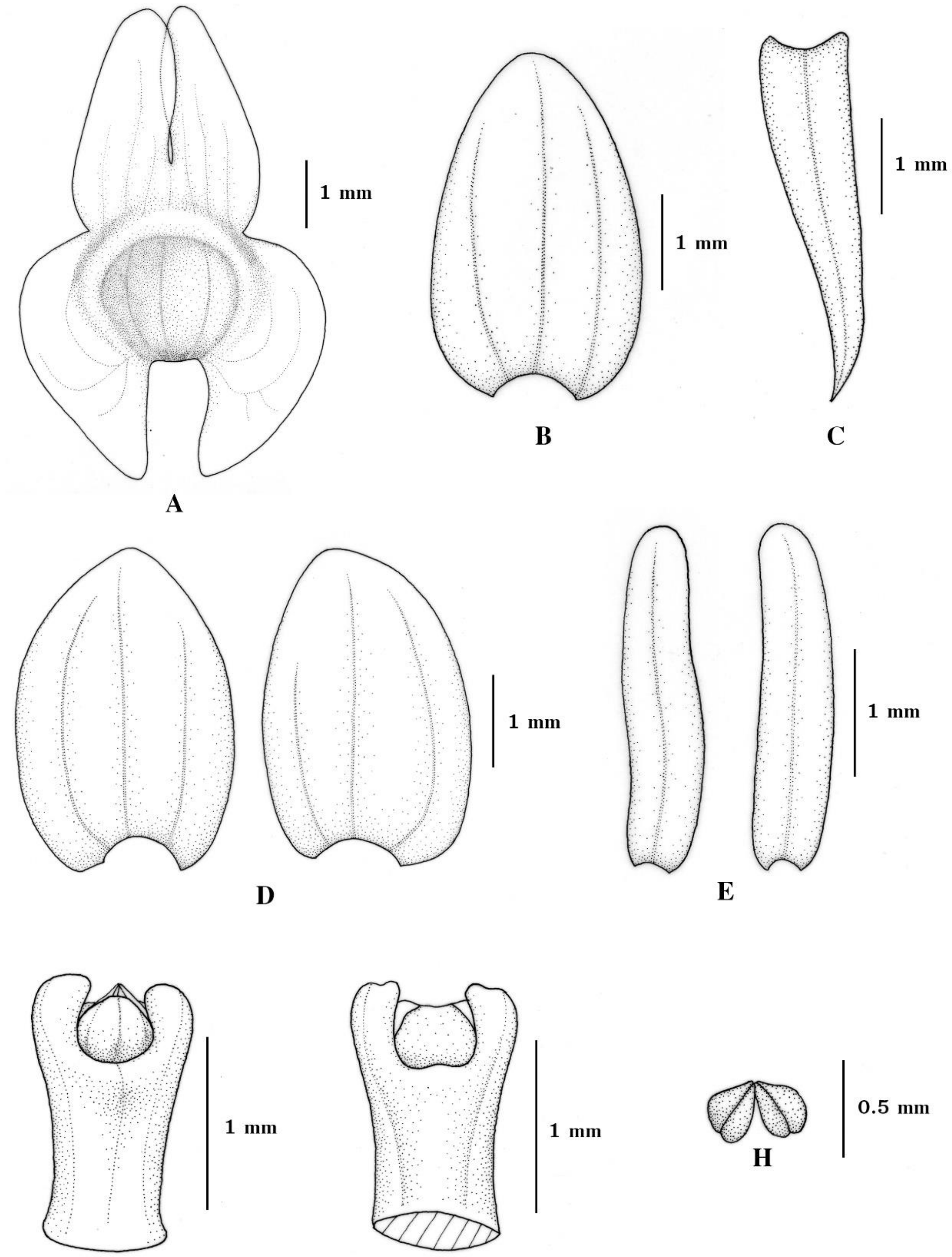

Figure 4.42 *Crepidium mackinnonii* (Duthie) Szlach. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bract. **D:** Lateral sepals. **E:** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *Wathana & Pumicong 2070* (A–H).

15. Crepidium macrochilum (Rolfe) Szlach., Fragm. Florist. Geobot., Suppl. 3: 128. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997.— *Microstylis macrochila* Rolfe, Bull. Misc. Inform. Kew 1895: 6. 1895.— *Malaxis macrochila* (Rolfe) Holttum, Gard. Bull. Singapore 11: 282. 1947; Seidenf. & Smitinand, Orchids Thailand: 149. 1959; Seidenf., Bot. Tidsskr. 65: 331, fig. 11. 1970; Dansk Bot. Arkiv 33(1): 79, fig. 56. 1978. **Type:** Thailand, Phangnga, sine loco, 1894, *Curtis s.n.* [holotype **K!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect pseudobulbous, 12–25 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* 5 to 7, slender, arising from the basal part of the pseudobulbs, 0.3–3.5 cm long. *Pseudobulbs* green, slenderly ovoid to oblong-fusiform, 4–6.5 cm long, 0.8–1 cm in diameter, consisting of 4–5 internodes. *Cataphylls* 3–4, (triangular-)ovate to lanceolate-oblong (the lowermost tubular), acute, 0.5–5 by 0.5–1.2 cm. *Foliage leaves* 2–3, ascending to erect, sessile, sheathing at base; lamina plicate, pale brownish-green to purplish-brown with brown spots, ovate to elliptic or oblong-lanceolate with slightly asymmetrical base, acute to acuminate, 4.5–12 by 2–6.5 cm, 5- to 7-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 6.5–16.5 cm long, elongating gradually during flowering; peduncle purplish-brown to dull purple, 4–7.5 cm long, 0.1–0.2 cm in diameter; rachis laxly to densely 25- to 40-flowered; floral bracts persistent, green to pale purple, reflexed, ovate-triangular to lanceolate, acute to acuminate, entire, 3–11 by 1–3 mm, much shorter than ovaries. *Flowers* purplish-green to purple, 8–13 mm in diameter. *Sepals* spreading, obtuse to rounded, glabrous, margins revolute; dorsal sepal oblong to oblong-lanceolate, 9–13.5 by 2–2.8 mm, more than twice as long as labellum auricles; lateral sepals obliquely oblong to elliptic, 5–8 by 2.5–3.5 mm. *Petals* spreading, linear, obtuse to truncate or retuse, 7.5–12 by 0.8–1 mm, margins revolute. *Labellum* (nearly) flat, 9–13 by 8–13 mm (maximum dimensions), approximately as long as wide, obovate (not constricted at the middle) with a strongly sagittate-auriculate base, distally rounded to subtruncate with with 4–7 coarse teeth on either side of the apex, basal part forming a cavity that is narrowly triangular in outline, bordered by an oblong-elliptic ridge; auricles obliquely triangular to ovate, acute, 2.5–4.5 by 2.5–4 mm. *Column* pale green, erect, 1–2.5 mm long, smaller than the largest marginal labellum teeth; staminodes flat, triangular-ovate, truncate; anther incumbent, versatile, broadly ovate, obtuse to rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.6–0.8 mm long; rostellum transversely rectangular, truncate; fertile stigma part transversely elliptic to subovate, flat, concave at base. *Ovary* (including pedicel) pale purple, slender, cylindrical, with 6 longitudinal ridges, 11–17 mm long, glabrous. *Capsule* ellipsoid, 1–1.5 cm long, 0.3–0.4 cm in diameter; fruit pedicel 0.8–0.9 cm long. Figures 4.43, 4.44 and 4.45.

Thailand.— SOUTH-WESTERN: Prachuap Khiri Khan; PENINSULAR: Phangnga, Surat Thani.

Distribution.— Endemic.

Ecology.— *Crepidium macrochilum* grows in humus-rich soil in shaded area in mixed deciduous forest and dry evergreen forest at 400–1,000 m alt. Flowering: April–May.

Vernacular.— Haew Moo Pha Pak Yak (แห้วหมูป่าปากหยัก).

Note.— The type specimen of Curtis consists only inflorescence with many flowers. There are no leaves and pseudobulbs. Haniff’s specimens and Kerr’s specimens at Kew herbarium have been seen the leaves morphology e.g. shape and colour, and pseudobulb morphology of this species are much similar to *C. octodentatum*. However, there are a few differrent features in labellum morphology. The labellum length of *C. macrochilum* is as long as labellum broad and with a high number of teeth on distal margins while *C. octodentatum* has a few teeth on distal margins.

Specimens examined.— **Thailand:** *C. Curtis s.n.*, (K), Phangnga, sine loco, 1894; *C. Curtis s.n.*, (K), Surat Thani, Kawp Kep, 27 June 1925; *K. Limkitikul 92* (BCU), Prachuap Khiri Khan, Huay Yang waterfalls, 15 June 2014; *A. Nuammee 440* (BCU, BKF), Prachuap Khiri Khan, Huay Yang waterfalls, 9 May 2015; *H.N. Ridley s.n.* (SING), sine loco, June 1895; *S. Ruksue 91* (BKF), Phetchaburi, Kaeng Krachan km 38, 10 May 2008; *O. Thaithong et al. s.n.* (BCU), Prachuap Khiri Khan, Huay Yang waterfalls, 20 May 1999; *Sine coll. s.n.* (K), sine loco, sine anno.

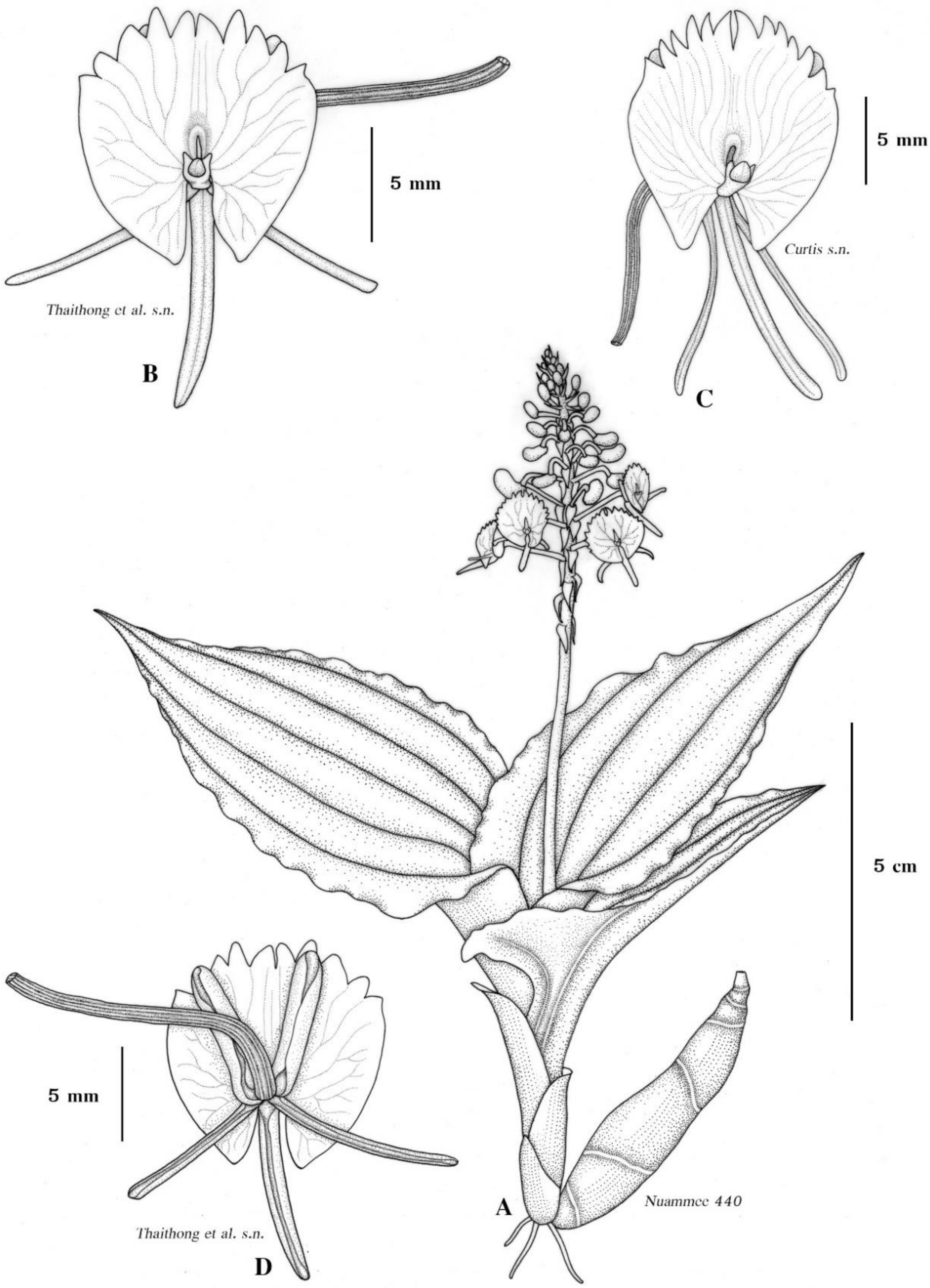

Figure 4.43 *Crepidium macrochilum* (Rolfe) Szlach. **A:** Habit. **B–C:** Flower, front view. **D:** Flower, back view. Drawing from *Nuammee 440* (A); *Thaithong et al. s.n.* (B, D); *Curtis s.n.* (C).

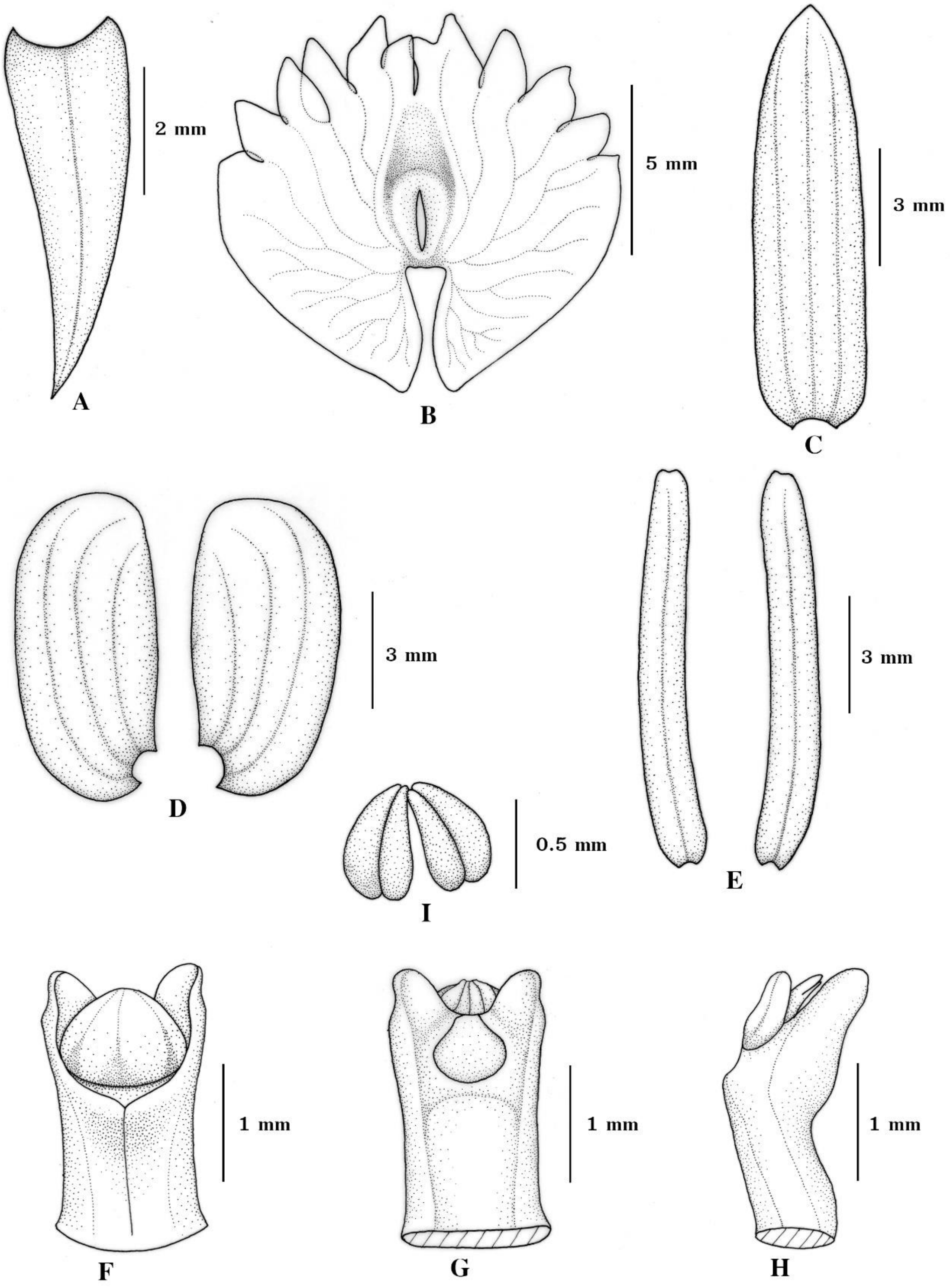

Figure 4.44 *Crepidium macrochilum* (Rolfe) Szlach. **A:** Floral bract. **B:** Labellum, front view. **C:** Dorsal sepal. **D:** Lateral sepals. **E.** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Column, lateral view. **I:** Two pairs of pollinia. Drawing from *Nuammee 440* (A–H).

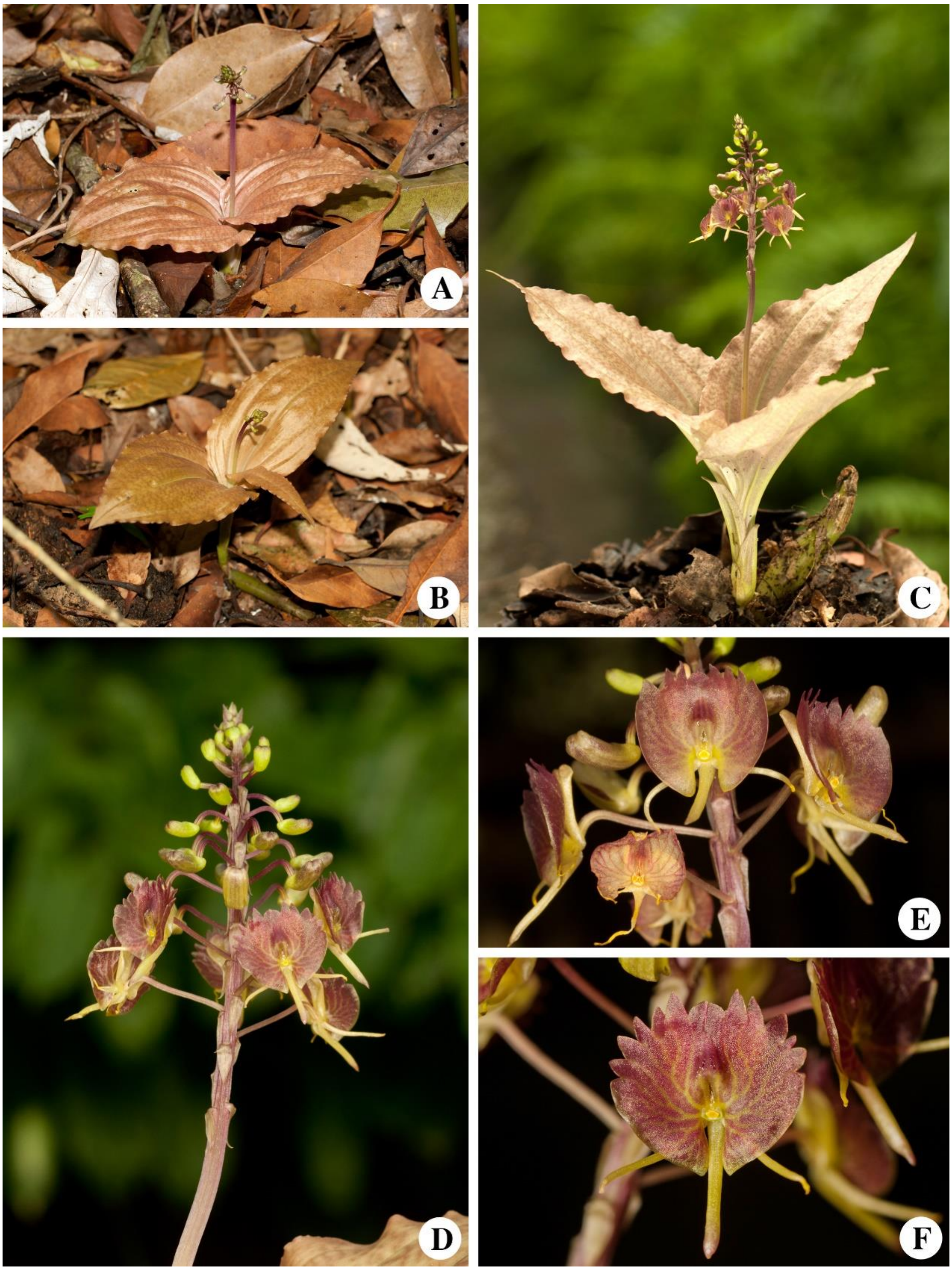

Figure 4.45 *Crepidium macrochilum* (Rolfe) Szlach. **A–C:** Habit. **D:** Inflorescence. **E–F:** Flower, front view. All were photographed from Prachuap Khiri Khan, Huay Yang waterfalls, 9 May 2015.

16. Crepidium maximowiczianum (King & Pantl.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 129. 1995; Nuammee et al., Thai Forest Bull. (Bot.) 44: 41, fig. 4A–B. 2016.— *Microstylis maximowicziana* King & Pantl., J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 64: 329. 1895; Ann. Roy. Bot. Gard. (Calcutta) 8: 21, t. 26. 1898; Marg., Edinburgh J. Bot. 62: 175. fig. 5. 2005.— *Malaxis maximowicziana* (King & Pantl.) Tang & F. T. Wang, Acta Phytotax. Sin. 1: 72. 1951. **Type:** India, West Bengal, Mungpoo Cinchona Plantation, July 1892, *Pantling 226* [holotype **BM!**, isotype **K!**].

Terrestrial, sympodial herb with a condensed rhizome, bearing a robust, erect pseudobulbous, up to 30 cm tall flowering shoots distally and 1 decaying pseudobulb behind. *Roots* several, arising from the basal part of the pseudobulbs, 1–7 cm long. *Pseudobulbs* green, terete from a fusiform base, c. 10 cm long, 0.7–0.8 cm in diameter, consisting of 5–7 internodes. *Cataphylls* 2–3, lanceolate-oblong (the lowermost tubular), acute to acuminate, 3–7 by 0.7–1.4 cm. *Foliage leaves* 5–6, ascending to spreading, petiolate, petiole sheathing at base, free part 2–3 cm long; lamina plicate, green, unspotted, elliptic to elliptic-lanceolate or ovate with slightly asymmetrical base, acuminate, 9–17 by 4.8–6.5 cm, 7- to 9-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, c. 20 cm long, elongating gradually during flowering; peduncle green, 8–9 cm long, 0.2–0.3 cm in diameter; rachis densely many-flowered; floral bracts persistent, green, strongly recurved, linear-lanceolate, acuminate, entire, 3.5–8 by 0.7–1.2 mm, shorter to longer than ovaries. *Flowers* green, 2–3 mm in diameter. *Sepals* spreading to reflexed, rounded to acute, glabrous, margins revolute; dorsal sepal lanceolate to oblong-lanceolate, 4.2–4.3 by c. 1.5 mm, much more than twice as long as labellum auricles; lateral sepals concave, broadly and obliquely elliptic, 3–3.5 by 1.9–2 mm. *Petals* reflexed, linear, rounded to obtuse, 3.6–4 by 0.5–0.7 mm, margins revolute. *Labellum* distinctly bowl-shaped, 2.7–3 by 3–3.7 mm (maximum dimensions), wider than long, semicircular to transversely rectangular when flattened (not constricted at the middle) with a sagittate-auriculate base, distally (truncate-)rounded with a slightly thickened, recurved, and subcrenate apiculum; basal/central part forming a cavity that is ovate to elliptic in outline, subdivied by a longitudinal keel and bordered by a more or less horseshoe-shaped ridge; auricles obliquely to subfalcately triangular, (sub)acute, 0.6–

1 by 0.5–1 mm. *Column* green, erect, 1.5–1.8 mm long; staminodes flat, broadly and obliquely oblong, obtuse to truncate, overarching and partly hiding the anther; anther incumbent, versatile, pale yellow, broadly ovate to (sub)rectangular, rounded to obliquely retuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.5–0.6 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) green, fusiform-cylindrical, with 6 longitudinal ridges, 3–4 mm long, glabrous. *Capsule* ellipsoid, 0.5–0.7 cm long, 0.2–0.4 cm in diameter; fruit pedicel 0.1–0.2 cm long. Figures 4.46, 4.47 and 4.48.

Thailand.— NORTHERN: Chiang Mai (Doi Ang Khang).

Distribution.— NE India.

Ecology.— *Crepidium maximowiczianum* grows in humus-rich soil in shaded areas in pine forest, c. 1,700 m alt. Flowering: June to July.

Vernacular.— Hoo Sua Morakot (หูเสือมรกต).

Note.— During field surveys, a small population of this species was discovered near Royal Agricultural Station Ang Khang. This species is easily recognized by small green flowers with distinctly hood-shape labellum, auricle acute and parallel backward.

Specimens examined.— **Thailand:** *P. Pongkai 100* (BCU), Chiang Mai, Doi Ang Khang, 23 June 2014. **India:** *J.D. Hooker 99* (K), Khasia, sine anno; *W.N. Koelz 30344* (K), Assam, Khasia hills, 25 June 1952; *R. Pantling 226* (BM, K), Sikkim Himalaya, July 1892.

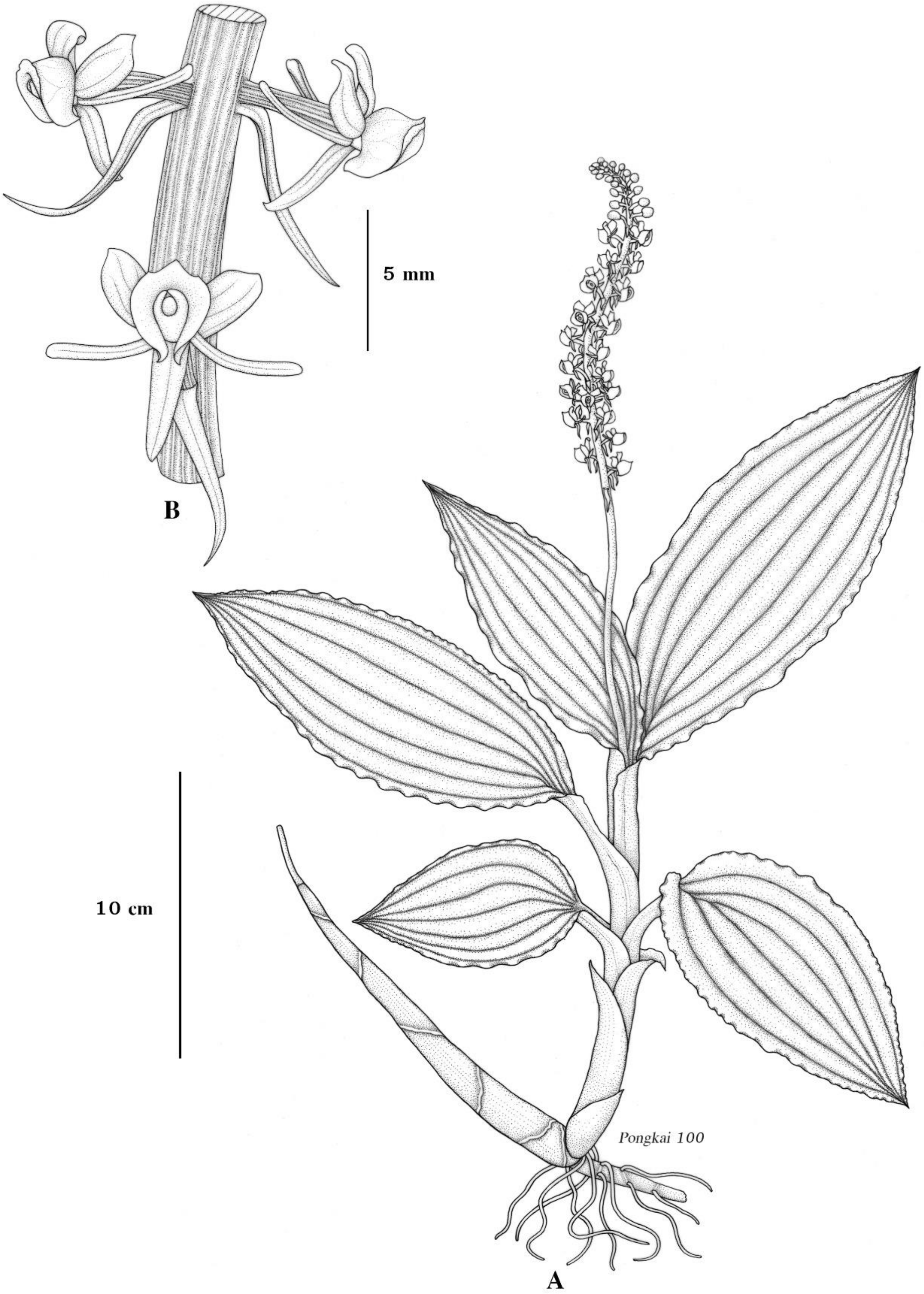

Figure 4.46 *Crepidium maximowiczianum* (King & Pantl.) Szlach. **A:** Habit. **B:** Flowers, front view and lateral view on rachis. Drawing from *Pongkai 100* (A–B).

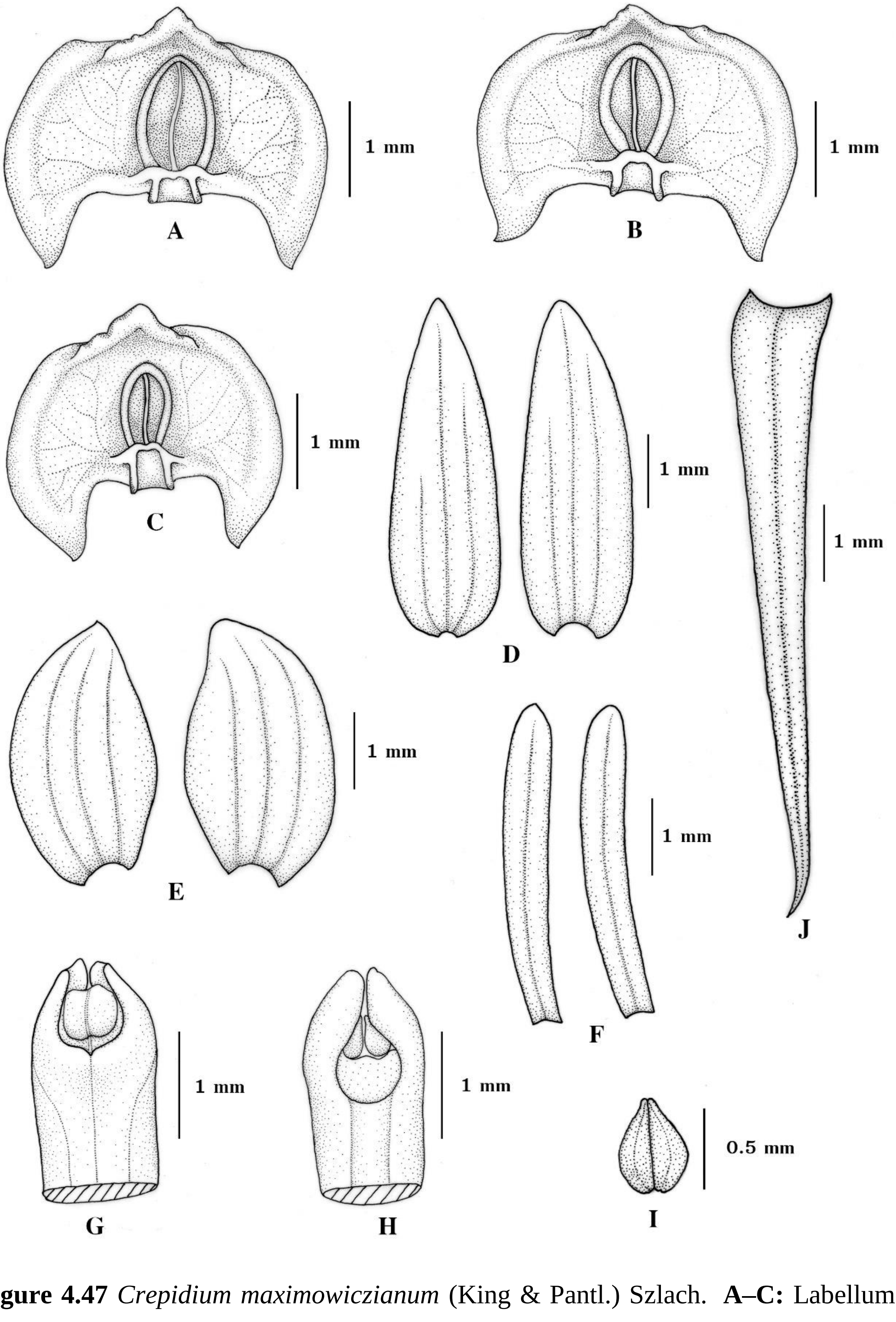

Figure 4.47 *Crepidium maximowiczianum* (King & Pantl.) Szlach. **A–C:** Labellum, front view. **D:** Dorsal sepal. **E:** Lateral sepals. **F.** Petals. **G:** Column, back view. **H:** Column, front view. **I:** Two pairs of pollinia. **J:** Floral bract. Drawing from *Pongkai 100* (A–J).

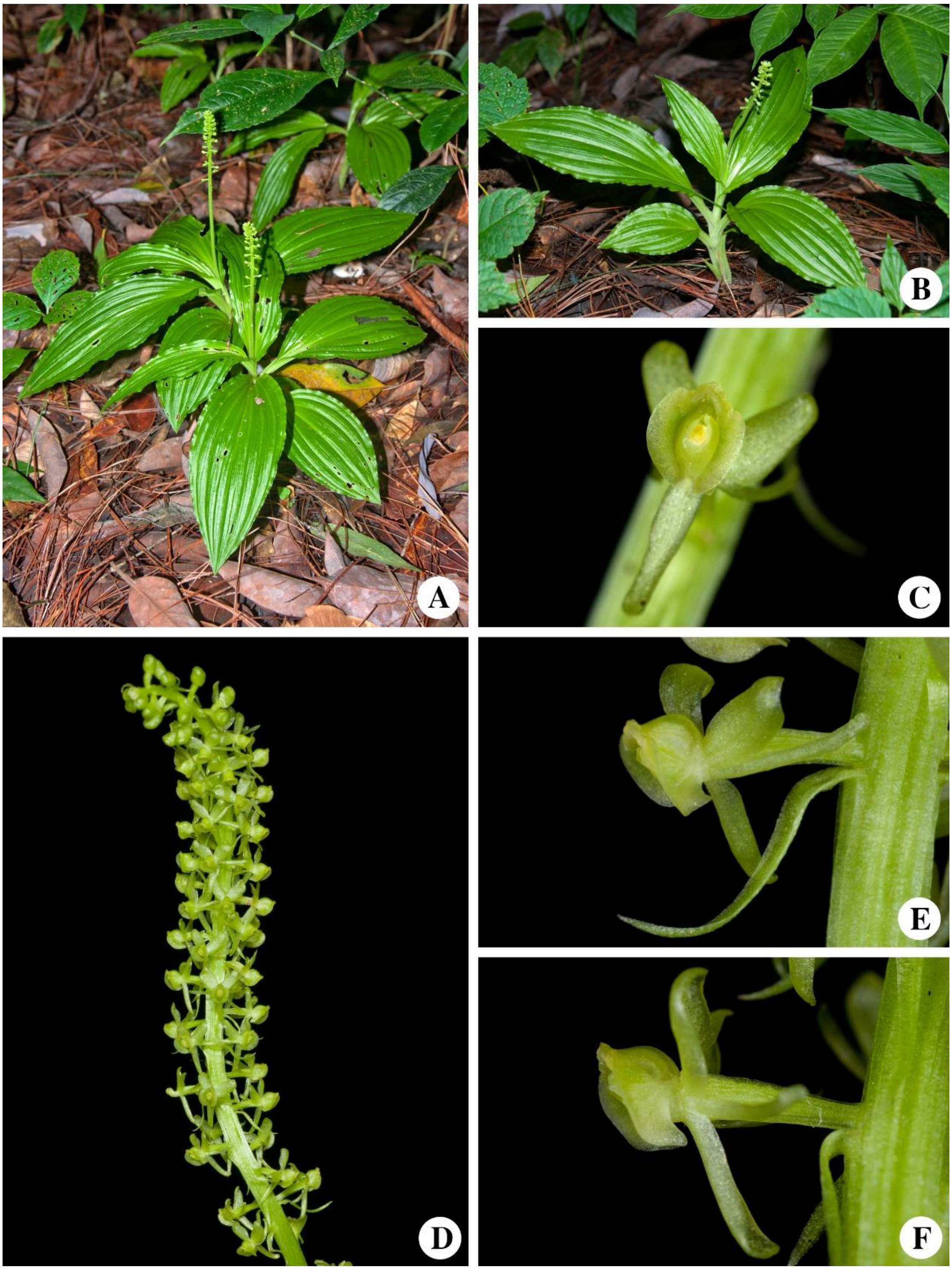

Figure 4.48 *Crepidium maximowiczianum* (King & Pantl.) Szlach. **A–B:** Habit. **C:** Flower, front view. **D:** Inflorescence. **E–F:** Flower, lateral view. All were photographed from Chiang Mai, Doi Ang Khang, 23 June 2014.

17. Crepidium merapiense (Schltr.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 129. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997.— *Microstylis merapiensis* Schltr., Bot. Jahrb. Syst. 45: 12. 1911.— *Malaxis* sp. [*Kerr 0452*]: Seidenf. & Smitinand, Orchids Thailand: 148, fig. 148. 1959.— *M. merapiensis* (Schltr.) Seidenf., Bot. Tidsskr. 65: 318, fig. 4. 1970; Vaddhanaphuti, Field Guide Wild Orchids Thailand, ed. 4: 182 (incl. colour photo). **Type:** Indonesia, W. Sumatra, Gunung Marapi, *Schlechter 15943* [not seen].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect, pseudobulbous, 11–23 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* 2 to several, slender, arising from the basal part of the pseudobulbs, 1–11 cm long. *Pseudobulbs* green with purple, ovoid to oblong-fusiform, 2–5 cm long, 0.5–1.5 cm in diameter, consisting of 4–6 internodes, sometimes covered by cataphylls or leaf sheaths. *Cataphylls* 2–3, broadly ovate to lanceolate-oblong (the lowermost tubular), acute to acuminate 0.5–3.1 by 0.4–1.2 cm. *Foliage leaves* 3–5, ascending to erect, petiolate, petiole sheathing at base, free part 0.6–3.2 cm long; lamina plicate, green with more or less suffused with purple and with dull purple veins above and beneath, ovate to lanceolate or elliptic with slightly asymmetrical base, acute to acuminate, 2–13 by 1–3.5 cm, 3- to 6-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 6–18 cm long, elongating gradually during flowering; peduncle dull purple, 4–12 cm long, 0.1–0.2 cm in diameter; rachis densely 12- to 35-flowered; floral bracts persistent, green, strongly recurved, triangular to lanceolate, acuminate, entire, 1.5–5 by 0.5–1.5 mm, much shorter than ovaries. *Flowers* green, 2.5–3.5 mm in diameter. *Sepals* spreading, obtuse, glabrous, margins recurved; dorsal sepal oblong to elliptic, 2–3 by 0.8–1.7 mm, usually less than twice as long as labellum auricles; lateral sepals obliquely ovate to elliptic, 1.7–2.5 by 0.7–1.5 mm. *Petals* spreading, linear-ligulate, obtuse to rounded, 2–2.8 by 0.4–0.6 mm, margins revolute. *Labellum* (nearly) flat, 2.3–2.7 by 2–2.5 mm (maximum dimensions), at least as wide as long, ovate to reniform (not constricted at the middle), obscurely 3-lobed, with strongly cordate-auriculate base, distally obtuse to acute; basal/central part forming a cavity that is obliquely rectangular in outline, with slightly thickened margins; auricles obliquely triangular, obtuse to rounded, 0.7–2 by 0.5–1 mm. *Column* green, erect, 0.6–1.1 mm long; staminodes stout, oblongoid, obtuse; anther incumbent, versatile, yellowish-white to greenish-white, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.3–0.5 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) green, cylindrical, with 6 longitudinal ridges, 4–8 mm long, glabrous. *Capsule* clavate-oblongoid, 0.9–1 cm long, 0.3–0.4 cm in diameter; fruit pedicel 1–1.5 cm long. Figures 4.49 and 4.50.

Thailand.— PENINSULAR: Surat Thani (Ban Kawp Kep), Phangnga (Phangnga Bay), Trang (Nam Tai).

Distribution.— Sumatra.

Ecology.— *Crepidium merapiense* grows in humus-rich soil in shaded areas on limestone hills and occurs on limestone in mangrove areas, 200–300 m alt. Flowering: recorded in May and September.

Note.— The vegetative characters of *C. merapiense* are similar to *C. prasinum* but most of them are smaller than those of *C. prasinum*. The flowers of *C. merapiense* are also smaller than *C. prasinum.*

Specimens examined.— **Thailand:** *N. Fukuoka T-35839* (K), Phangnga, Phangnga Bay, 3 September 1984; *A.F.G. Kerr 452* (C, K), Surat Thani, Ban Kawp Kep, 16 May 1927; *K. Larsen et al. 3650* (K), Trang, Nam Tai, 11 October 1970.

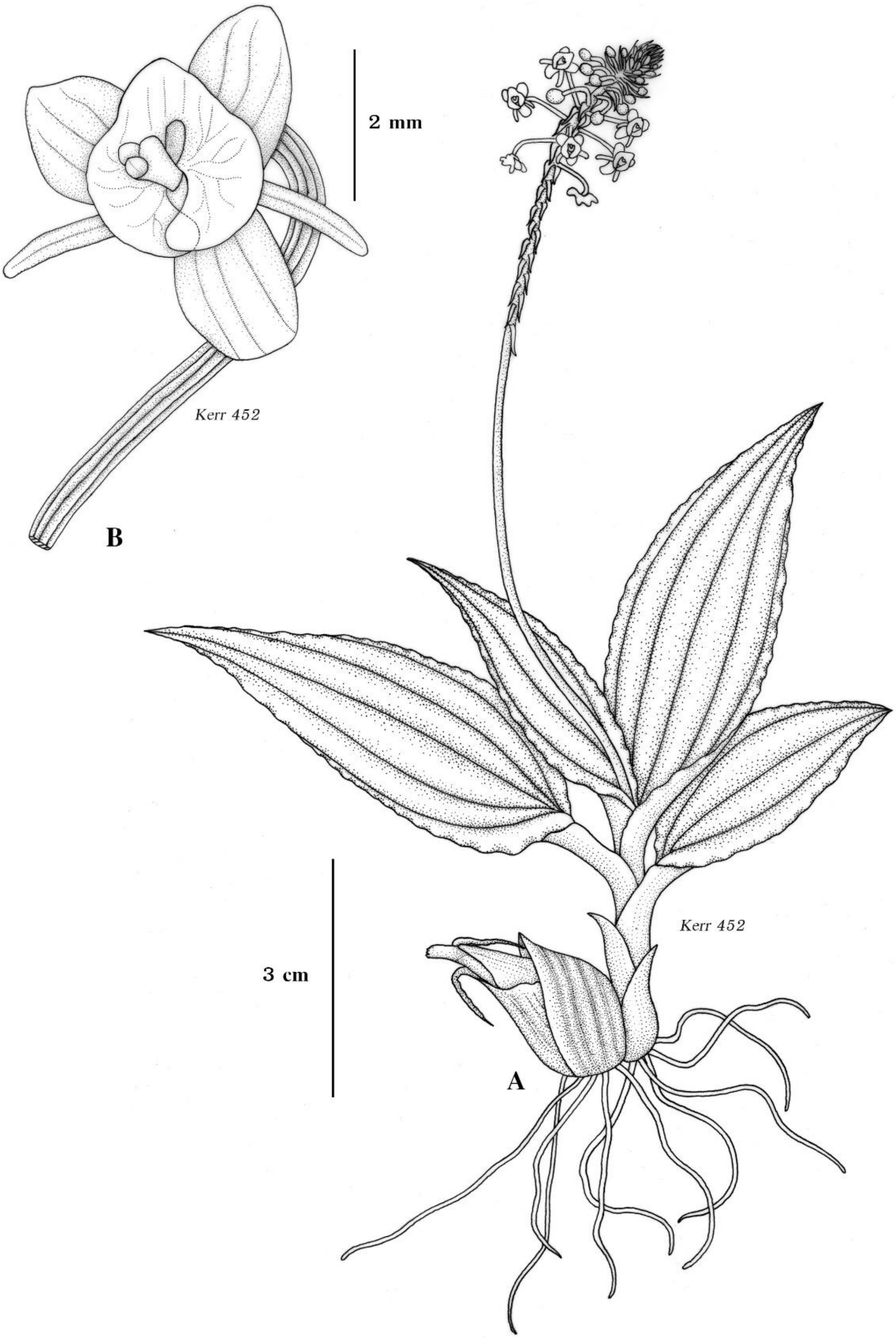

Figure 4.49 *Crepidium merapiense* (Schltr.) Szlach. **A:** Habit. **B:** Flower, front view. Drawing from *Kerr 452* (A–B).

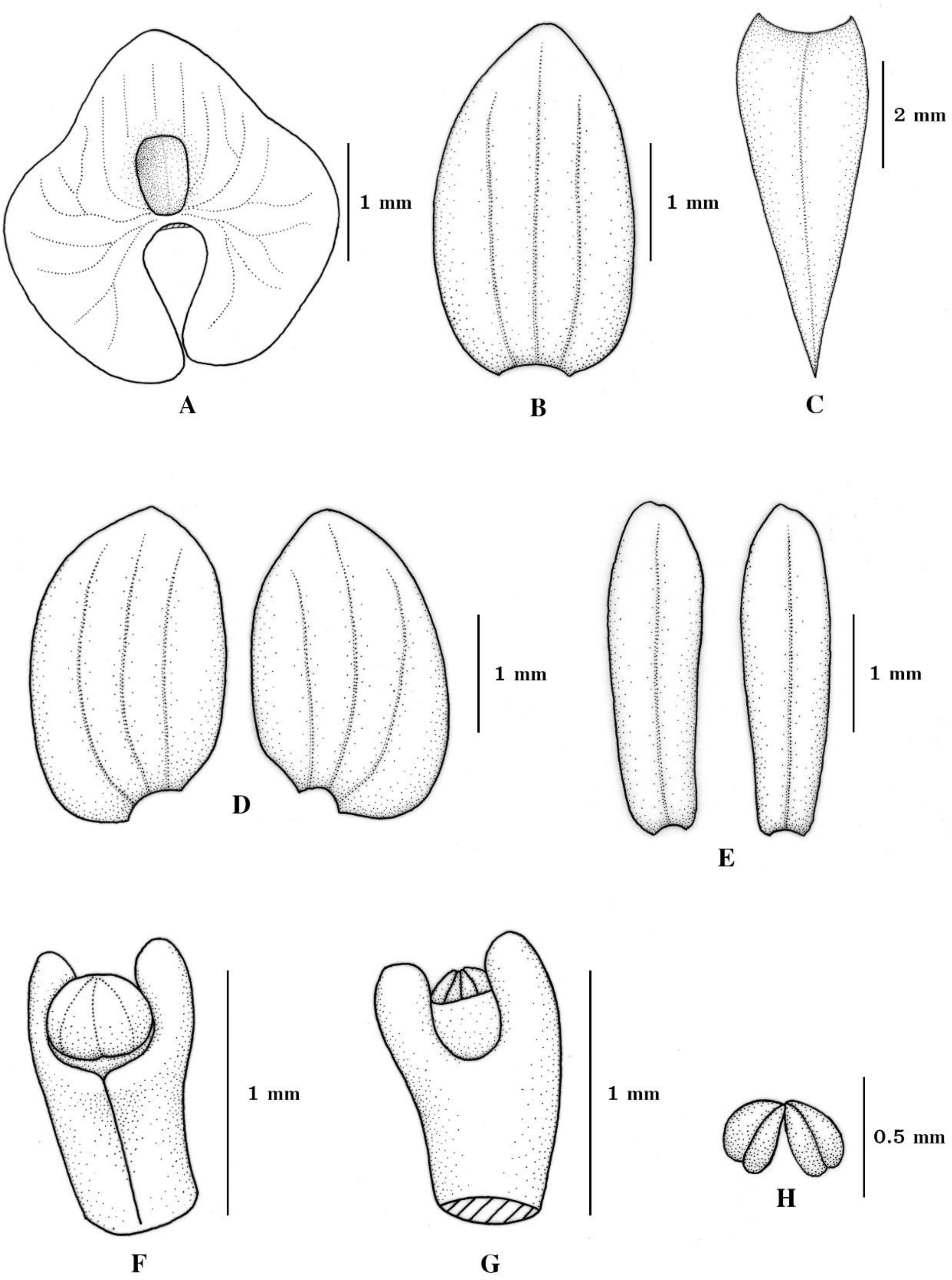

Figure 4.50 *Crepidium merapiense* (Schltr.) Szlach. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bract. **D:** Lateral sepals. **E.** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *Kerr 452* (A–H).

18. Crepidium micranthum (Hook. f.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 129. 1995.— *Microstylis micrantha* Hook. f., Hooker's Icon. Pl. 19: t. 1834. 1889; Fl. Brit. India 5: 688. 1890.— *Malaxis micrantha* (Hook. f.) Kuntze, Revis. Gen. Pl. 2: 673. 1891; Seidenf., Dansk Bot. Arkiv 33(1): 76, fig. 52. 1978; Seidenf. & J. J. Wood, Orchids Penins. Malaysia Singapore: 225, fig. 95c–d. 1992. **Type:** Malaysia, Peninsular Malaysia, Perak, "Taiping Hills", sine anno, *Scortechini 581* [holotype **K!**].

— *Microstylis flavoviridis* Ridl., J. Straits Branch Roy. Asiat. Soc. 61: 37. 1912. **Type:** Malaysia, Peninsular Malaysia, Perak, Gunung Korbu, sine anno, *Haniff 3982* [holotype **K!**].

— *Microstylis trinervia* Ridl., Bull. Misc. Inform. Kew 1926: 84. 1926. **Type:** Indonesia, W. Sumatra, Mentawi Islands, Sipura, sine anno, *Boden Kloss 14655* [holotype **K!**].

Terrestrial plant with a creeping rhizome terminating in a 15–37 cm tall flowering shoot that is erect from a decumbent base. *Rhizome* green to green-brown, terete, 8–20 cm long, 0.3–0.8 cm in diameter, internodes c. 1 cm long. *Roots* several, 1–3 arising from each node of the rhizome and from the lower nodes of the stem, 1–7 cm long. *Foliage leaves* 6–14, ascending to speading or erect, petiolate, petiole sheathing at base, free part 1–2.5 cm long, light green to greenish-purple; lamina plicate, green to purplish-brown, unspotted, lanceolate to ovate-lanceolate or elliptic with asymmetrical base, acuminate, 5–12 by 2–4.5 cm, 3- to 5-veined, glabrous, margins undulate. *Inflorescence* terminal on the young shoot, racemose, erect, 15–30 cm long, elongating gradually during flowering; peduncle green to purplish-brown, 8–10 cm long, 0.2–0.3 cm in diameter, bearing a few lanceolate sterile bracts; rachis laxly many-flowered; floral bracts persistent, green to purplish-brown, reflexed, lanceolate, acuminate, entire, 4–12.5 by 1–2.5 mm, longer than ovaries. *Flowers* greenish-yellow, more or less flushed with purple, 4–5 mm in diameter. *Sepals* spreading to reflexed, rounded to acute, glabrous, margins revolute; dorsal sepal ovate, 2.5–4 by 1.5–2 mm, more than twice as wide as labellum auricles; lateral sepals broadly and obliquely ovate, 2.5–3.5 by 1.5–2.5 mm. *Petals* spreading, linear, obtuse to rounded, 2.5–3 by 0.5–1 mm, margins revolute. *Labellum* (nearly) flat, 4.5–6 by 4–

5 mm (maximum dimensions), slightly longer than wide, reniform to nearly semicircular (not constricted at the middle) with a strongly sagittate-auriculate base, distally with a large, triangular bifid mid-lobe flanked by 2–4 smaller teeth on either side, usually incurved apiculum; basal/central part forming a small and shallow cavity that is narrowly triangular to rectangular in outline, with flat or insignificantly thickened margins; auricles obliquely (ovate-)triangular, obtuse, 1–2 by 1–2 mm. *Column* greenish-yellow, erect, stout, 1–1.5 mm long, usually smaller than the largest marginal labellum teeth; staminodes flat, broadly and obliquely triangular-oblong, rounded to obtuse; anther incumbent, versatile, yellow, broadly ovate, obtuse to rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, c. 0.5 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) green to purplish-brown, cylindrical, with 6 longitudinal ridges, 3–5 mm long, glabrous. *Capsule* oblongoid-ellipsoid, 0.7–0.9 cm long, 0.3–0.5 cm in diameter; fruit pedicel 0.2–0.3 cm long. Figures 4.51, 4.52 and 4.53.

Thailand.— PENINSULAR: Krabi (Khao Phanombenja), Nakhon Si Thammarat (Khao Luang).

Distribution.— Peninsular Malaysia, Indonesia, New Guinea and Pacific Islands.

Ecology.— *Crepidium micranthum* grows in humus-rich soil in shaded areas along streams in evergreen forest at 800–1,200 m alt. Flowering: September–October. After flowering, the inflorescence decays and the stem gradually becomes prostrate. However, at least the proximal part of the stem – and its leaves – survive the dry season and do not disappear until a new, young, erect, potentially flowering shoot has been produced from one of the lower leaf axils.

Vernacular.— Muang Korn Lueang Thin Tai (มังกรเหลืองถิ่นใต้).

Specimens examined.— **Thailand:** *A. Nuammee 444* (BCU, BKF), Nakhon Si Thammarat, Khao Luang, 19 September 2015; *A. Nuammee 445* (BCU, BKF), Nakhon Si Thammarat, Khao Luang, 19 September 2015; *P. Tripetch 100534* (QBG), Krabi, Khao Phanombenja, 1 May 2010.

Malaysia: *C.E. Carr 209* (SING), Peninsular Malaysia, Pahang, "Fraser Hills", October 1929; *Haniff* 3982 (K), Peninsular Malaysia, Perak, Gunung Korbu, sine anno; *Mat s.n.* (SING), Peninsular Malaysia, Johor, Gunung Palai,1892; *Ngadiman s.n.* (SING), Peninsular Malaysia, Johor, Pontian, 4 July 1939; *H.N. Ridley s.n.* (SING), Peninsular Malaysia, Perak, "Maxwells hills", June 1893; *H.N. Ridley s.n.* (SING), Peninsular Malaysia, Johor, "Tempayang River", 1908; *B. Scortechini 581* (K), Peninsular Malaysia, Perak, "Taiping Hills", sine anno; *Dyg. Awa & B. Lee 50840* (K), Sarawak, Bario, October 1991; *C. Hansen 186* (C), Sarawak, Gunung Mulu, 28 January 1978; *J.W. Purseglove & M. Shah 4521* (SING), Sarawak, Lundu, Gunung Gading, 19 September 1955; *J.W. Purseglove 4978* (K, L); Sarawak, Telok Asam, Bako, 18 May 1956.

Indonesia: *C. Boden Kloss 14655* (K, SING), W. Sumatra, Mentawi Islands, Sipura, sine anno; *J.B. Comber 1502* (K), N. Sumatra, Sialang, 20 July 1983; *Hort. Bot. Singapore 1523* (L), Sumatra, sine loco, sine anno; *C. Kalkman 3654* (L), Demta, Waisiniwai, 10 December 1956; *C.G. Matthew s.n.* (K), Mt. Barisan, 28 December 1913; *P.J. Martin 39294* (K), Bali, Gunung Batur, 1 February 1983; *E. Schmutz 4526* (L), Maggarai, Lesser Sunda Islands, 27 February 1979; *R. Schlechter 20541*, Sulawesi, 10 December 1909.

New Guinea: *L.J. Brass 29475* (L), Gurakor, 8 May 1959; *L.J. Brass 29503* (L), Gurakor, 9 May 1959; *K. Dissing & S. Olsen 2010* (L), sine loco, 1962; *A.N. Millar 22511* (L), Patep, Morobe, 6 April 1965; *C.E. Ridsdale & Galore 33432* (L), Kiunga, 21 July 1967; *L.J. Brass 25415* (L), Normanby Islands, 14 April 1956; *D.B. Foreman 45680* (L), Bougainville Island, Tonolei Harbour, 22 August 1969.

Pacific Islands: *P.E. Hunt 2262* (L), Solomon Islands, 27 August 1965; *P.E. Hunt 2444* (L), Solomon Islands, 27 August 1965.

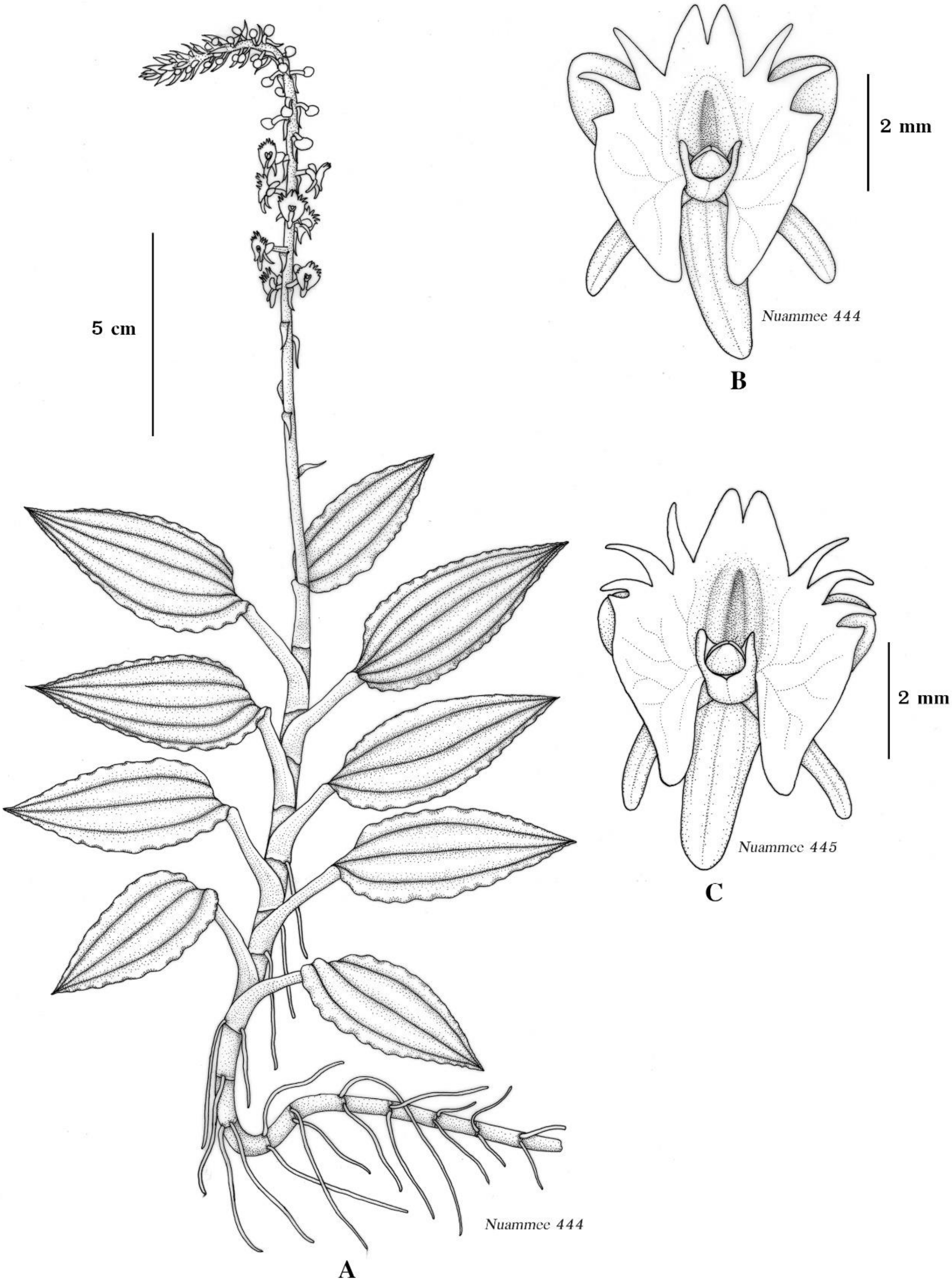

Figure 4.51 *Crepidium micranthum* (Hook. f.) Szlach. **A:** Habit. **B**–C**:** Flower, front view. Drawing from *Nuammee 444* (A–B); *Nuammee 445* (C).

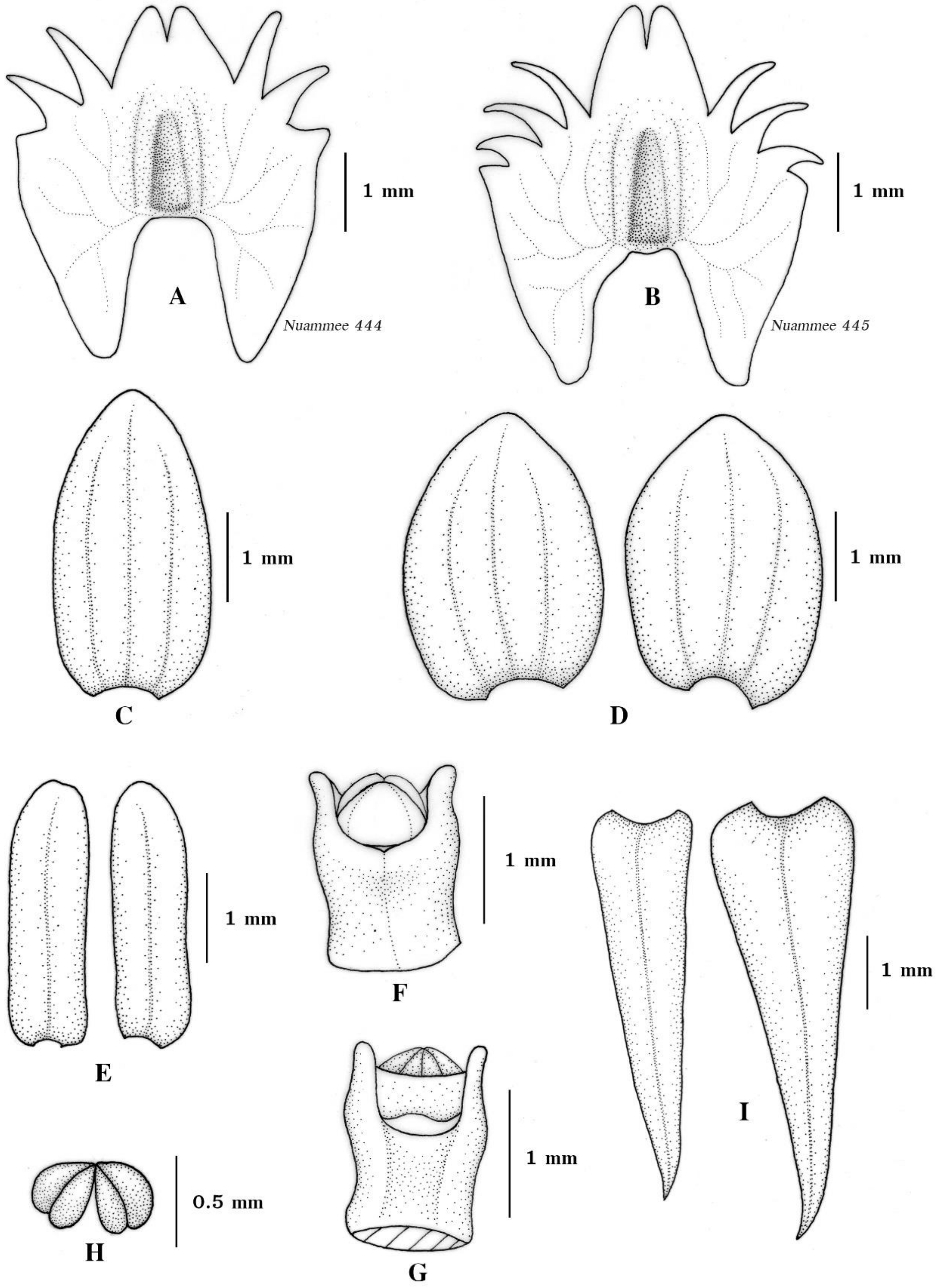

Figure 4.52 *Crepidium micranthum* (Hook. f.) Szlach. **A–B:** Labellum, front view. **C:** Dorsal sepal. **D:** Lateral sepals. **E.** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. **I:** Floral bracts. Drawing from *Nuammee 444* (A, C–I); *Nuammee 445* (B).

Figure 4.53 *Crepidium micranthum* (Hook. f.) Szlach. **A–B:** Habit. **C–D:** Flower, front and lateral view. All were photographed from Nakhon Si Thammarat, Khao Luang, 19 September 2015.

19. Crepidium octodentatum (Seidenf.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 130. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; Sitthisajjadham, Wild Orchids Thailand: 174 (incl. colour photos). 2006.— *Malaxis octodentata* Seidenf., Dansk Bot. Arkiv 33(1): 81, fig. 58. 1978; Opera Bot. 114: 149, t. Xb. 1992; Aver., Turczaninowia 16: 129, fig. 63g. 2013.— *Malaxis* sp. [*Seidenfaden & Smitinand GT 3564*]: Seidenf. & Smitinand, Orchids Thailand: 154, fig. 122. 1959. **Type:** Trat, Ko Kut, April 1959, *Seidenfaden & Smitinand GT 3564* [holotype **C!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect, pseudobulbous, 9–20 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* 4 to several, slender, arising from the basal part of the pseudobulbs, 0.2–3.5 cm long. *Pseudobulbs* green, slenderly ovoid to oblong-fusiform, 3–4 cm long, 0.6–1 cm in diameter, consisting of 4–6 internodes. *Cataphylls* 3–5, (triangular-)ovate to lanceolate-oblong (the lowermost tubular), acute to acuminate, 0.5–4 by 0.3–1 cm. *Foliage leaves* 2–3(–4), ascending to erect, sessile, sheathing at base; lamina plicate, pale brownish-green to purplish-brown with brown spots, ovate to oblong-lanceolate with slightly asymmetrical base, acuminate, 2–9 by 1–5 cm, 3- to 7-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 6.5–16.5 cm long, elongating gradually during flowering; peduncle dull purple, 4–7.5 cm long, 0.1–0.2 cm in diameter; rachis laxly 6- to 25-flowered; floral bracts persistent, green to pale purple, reflexed, ovate-triangular to lanceolate, acuminate, entire, 3–11 by 1–3 mm, much shorter than ovaries. *Flowers* purplish-green to purple, 5–8 mm in diameter. *Sepals* spreading to reflexed, glabrous, obtuse to subacute, margins revolute; dorsal sepal oblong, 6–10 by 1.5–2.2 mm, more than twice as long as labellum auricles; lateral sepals obliquely oblanceolate, 4.5–7 by 2–3 mm. *Petals* pendulous to spreading, linear, rounded, 5–11 by 0.5–1 mm, margins revolute. *Labellum* (nearly) flat, 7.5–10 by 5–8 mm (maximum dimensions), obovate (not constricted at the middle) with a strongly sagittate-auriculate base, distally rounded to subtruncate with 3–5 coarse teeth on either side of the apex, the two median teeths more or less overlapping, basal part forming a cavity that is narrowly triangular in outline, bordered by an oblong-elliptic ridge, glabrous; auricles obliquely triangular, acute to obtuse, 1.5–4 by 1.5–3 mm. *Column* pale green, erect, 1–2.5 mm long, larger than the largest marginal labellum teeth; staminodes flat, broadly triangular-ovate, truncate; anther incumbent, versatile, more than twice as wide as connective, orange-yellow, broadly ovate, obtuse to rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, c. 1 mm long; rostellum transversely rectangular, truncate; fertile part of stigma subovate, flat, concave at base. *Ovary* (including pedicel) pale purple, slender, cylindrical, with 6 longitudinal ridges, 6.5–16 mm long, glabrous. *Capsule* ellipsoid, 1–1.5 cm long, 0.3–0.4 cm in diameter; fruit pedicel 0.8–0.9 cm long. Figures 4.54, 4.55 and 4.56.

Thailand.— EASTERN: Nakhon Ratchasima (Pak Thong Chai); SOUTH-WESTERN: Phachuap Khiri Khun (Huay Yang); SOUTH-EASTERN: Trat (Ko Kut).

Distribution.— Cambodia, Vietnam.

Ecology.— *Crepidium octodentatum* grows in humus-rich soil in shaded areas in dry evergreen forest at 50–1,000 m alt. Flowering: April–May.

Note.— The leaves morphology e.g. shape and colour, and pseudobulb morphology of *C. octodentatum* is much similar to *C. macrochilum*. However, there are a few differrent features in labellum morphology. The labellum length of *C. octodentatum* is longer than labellum width and with a few number of teeth on distal margins.

Specimens examined.— **Thailand:** *C.F. van Beusekorn & T. Santisuk 3225* (C, L), Trat, Ko Kut, 15 March 1970; *A. Nuammee 433* (BCU, BKF), Trat, Ko Kut, 13 April 2015; *A. Nuammee 434* (BCU, BKF), Trat, Ko Kut, 14 April 2015; *A.F.G. Kerr 318* (C, K), Phachuap Khiri Khun, Huay Yang waterfalls, 2 July 1914; *G. Seidenfaden & T. Smitinand GT 3564* (K), Trat, Ko Kut, April 1959; *T. Smitinand s.n.* (C), Trat, Ko Kut, May 1968. **Cambodia:** *L. Pierre 1454* (P), Montibus Cam Chay, May 1874; *L. Pierre s.n.* (C, P), Cam chay, 1867; *L. Pierre s.n.* (C, P), Mt. Dith, Bavia, sine anno. **Vietnam:** *L. Averyanov & E. Kudryavtzeva 428* (C), Vuuqtau-Couolao, Bay Cauh, 17 June 1989.

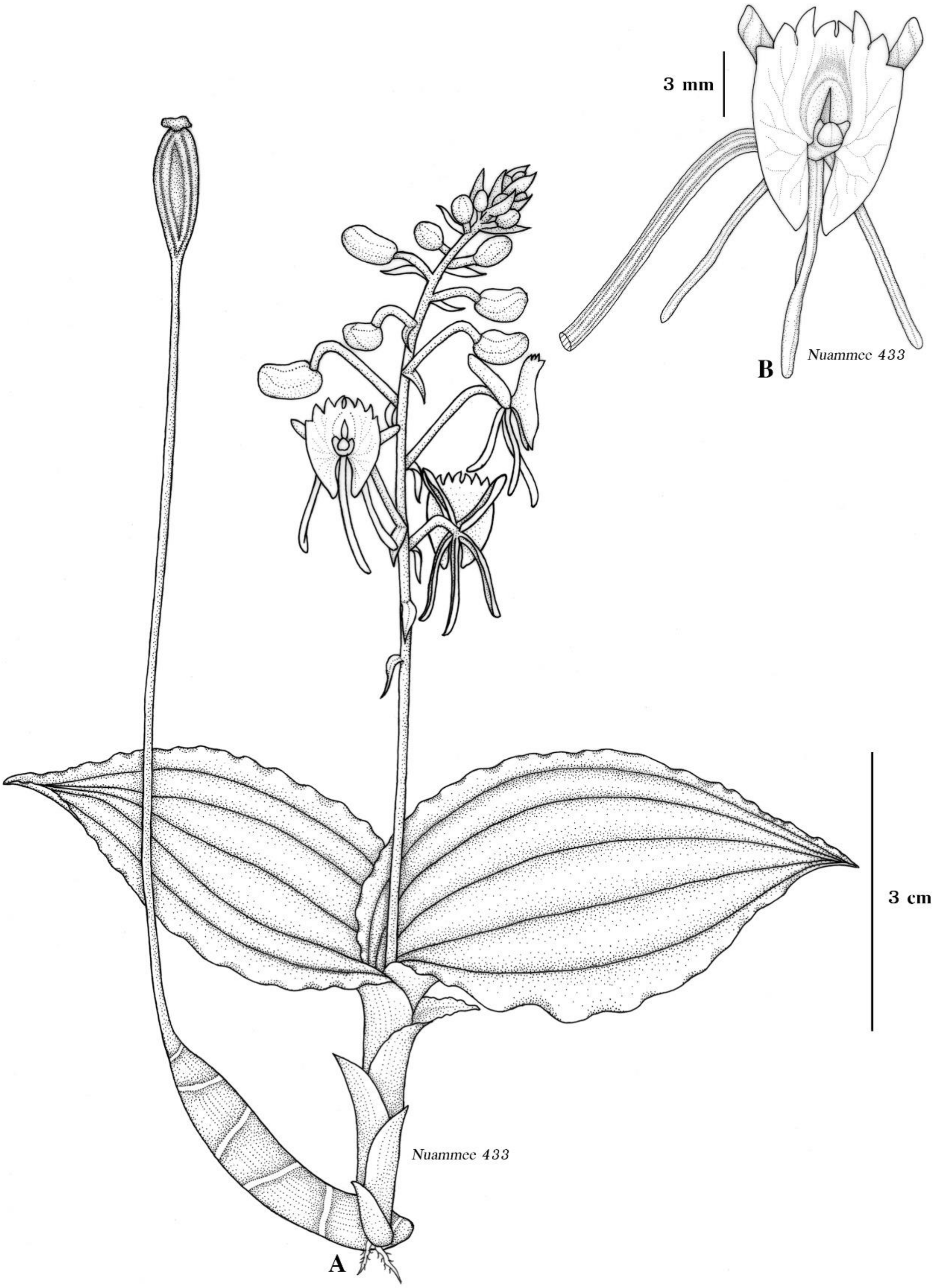

Figure 4.54 *Crepidium octodentatum* (Seidenf.) Szlach. **A:** Habit. **B:** Flower, front view. Drawing from *Nuammee 433* (A–B).

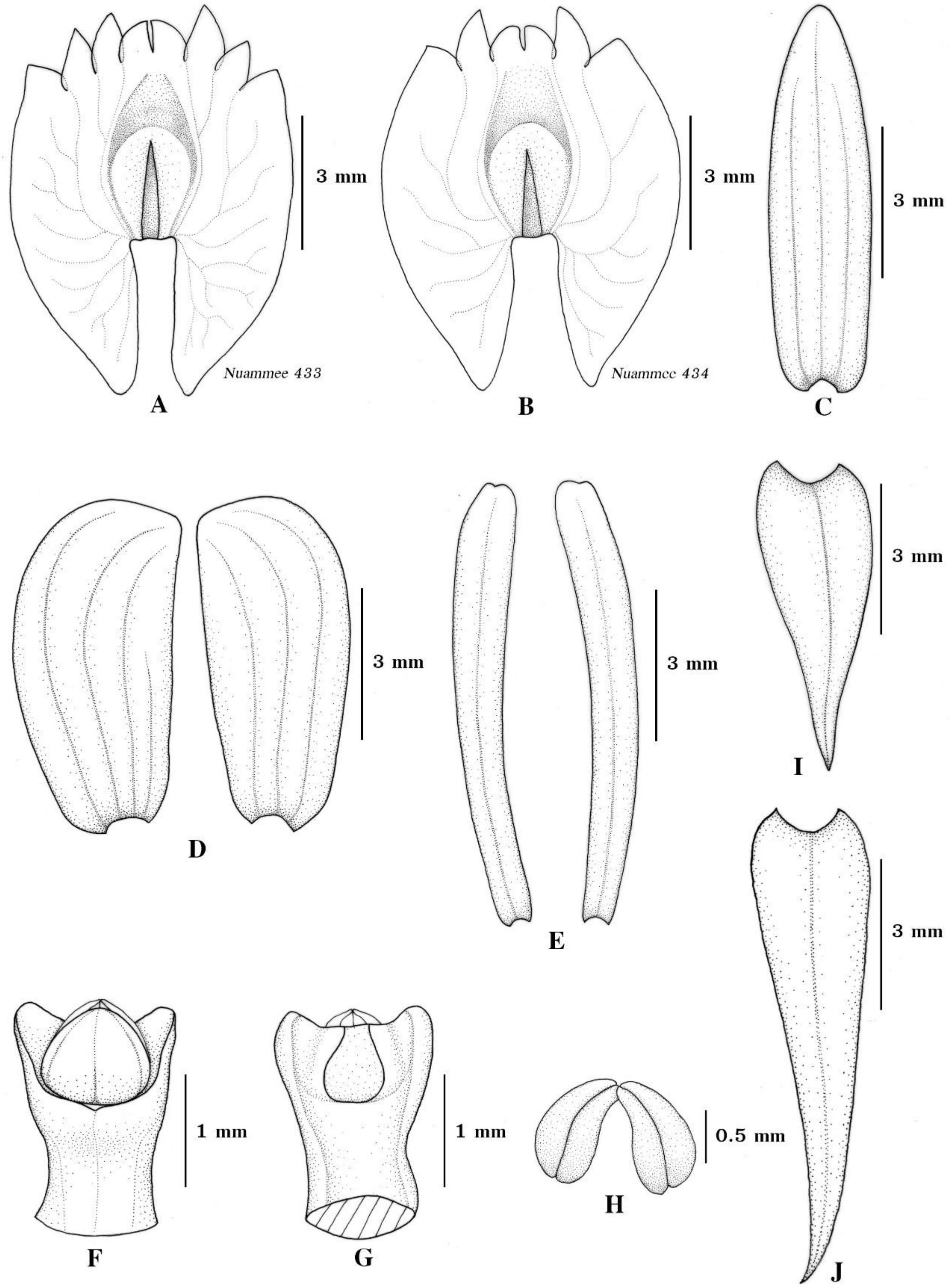

Figure 4.55 *Crepidium octodentatum* (Seidenf.) Szlach. **A–B:** Labellum, front view. **C:** Dorsal sepal. **D:** Lateral sepals. **E.** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. **I–J:** Floral bracts. Drawing from *Nuammee 433* (A, C–J); *Nuammee 434* (B).

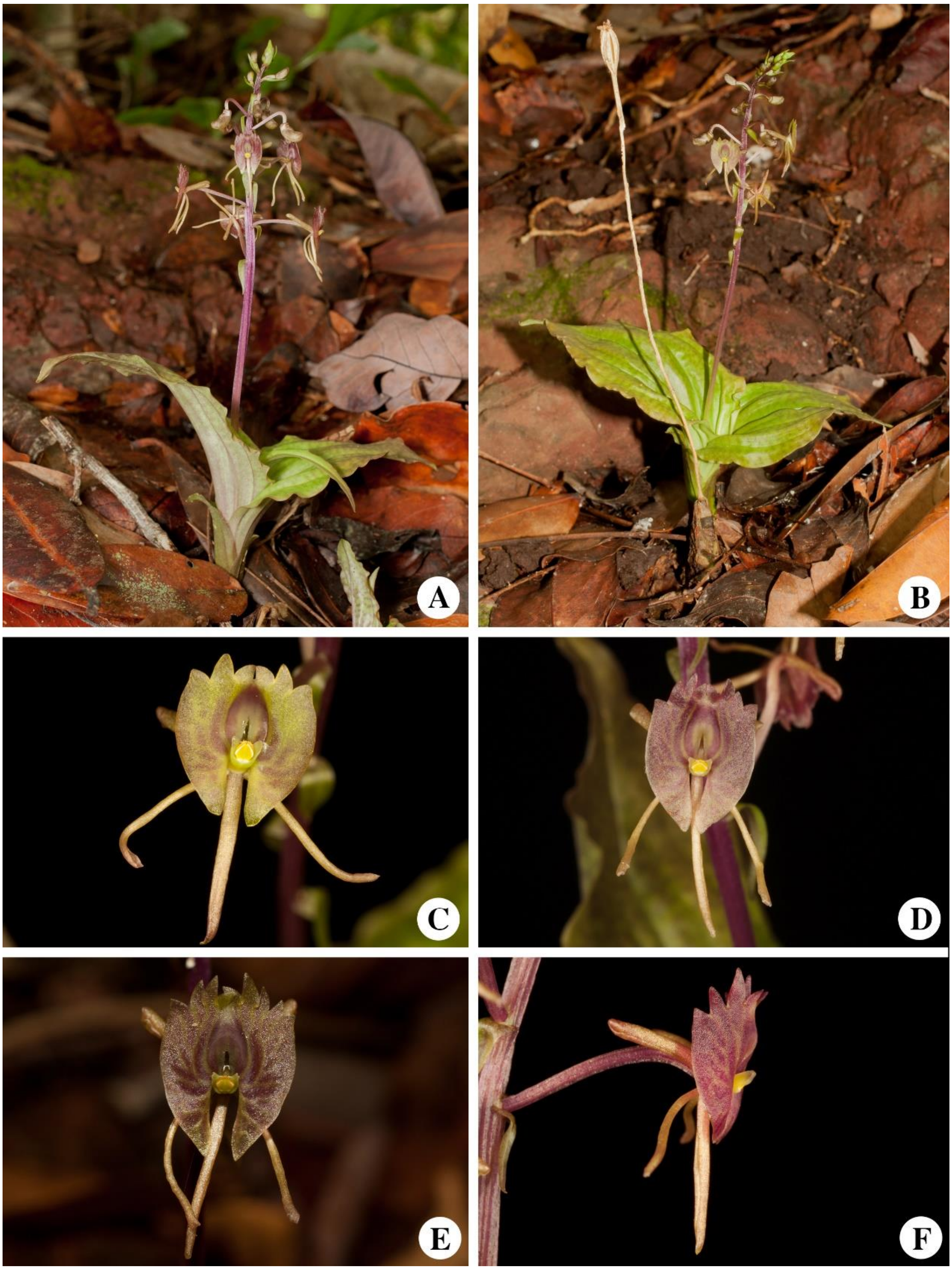

Figure 4.56 *Crepidium octodentatum* (Seidenf.) Szlach. **A–B:** Habit. **C–E:** Flower, front view; **C:** 6 teeth on distal margin; **D–E:** 8 teeth on distal margin. **F:** Flower, lateral view. All were photographed from Trat, Ko Kut, 13 April 2015.

20. Crepidium orbiculare (W. W. Sm. & Jeffrey) Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; Sitthisajjadham, Wild Orchids Thailand: 175 (incl. colour photos). 2006; Nanakorn & Watthana, Queen Sirikit Bot. Gard. (Thai Native Orchids 1): 195 (incl. colour photos). 2008; S. C. Chen & J. J. Wood in Z. Wu et al. (eds.), Fl. China 25: 231. 2009.— *Microstylis orbicularis* W. W. Sm. & Jeffrey, Notes Roy. Bot. Gard. Edinburgh 9: 111. 1916.— *Malaxis orbicularis* (W. W. Sm. & Jeffrey) Tang & F. T. Wang, Acta Phytotax. Sin. 1: 73. 1951; Seidenf. & Smitinand, Orchids Thailand: 150, fig. 118, t. V(2706). 1959; Seidenf., Dansk Bot. Arkiv 33(1): 85, fig. 59. 1978; Opera Bot. 114: 150. 1992; Aver., Turczaninowia 16: 129, fig. 63f. 2013. **Type:** China, Yunnan, Tengyueh, *Howell 334* [holotype **E**!].

— *M. tenebrosa* Rolfe ex Downie, Bull. Misc. Inform. Kew 1925: 369. 1925. **Type:** Chiang Mai, Doi Sutep, 5 September 1909, *Kerr 209* [holotype **K!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect, pseudobulbous, 18–45 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* several, arising from the basal part of the pseudobulbs, 1–8 cm long. *Pseudobulbs* green, ovoid to fusiform, 1–5 cm long, 0.6–1.3 cm in diameter, consisting of 3–4 internodes. *Cataphylls* 2–4, triangular to ovate or lanceolate-oblong (the lowermost tubular), acute to acuminate 1.2–5.5 by 0.5–1.5 cm. *Foliage leaves* 3–4, ascending to spreading or erect, petiolate, petiole sheathing at base, free part 1.2–4.5 cm long; lamina plicate, green, unspotted, broadly ovate to lanceolate or (oblong-)elliptic with slightly asymmetrical base, attenuate to acuminate, 2.2–18 by 1.2–5.5 cm, 5- to 7-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 16–38 cm long, elongating gradually during flowering; peduncle dark purple, 8–20 cm long, 0.1–0.3 cm in diameter; rachis laxly 10- to 45-flowered; floral bracts persistent, pale green to red-purple or dark purple, strongly recurved, lanceolate, acuminate, entire, 3–12 by 0.8–2.5 mm, shorter than ovaries. *Flowers* greenish-purple, red-purple to dark purple or maroon, 4–10 mm in diameter. *Sepals* spreading to reflexed, obtuse, rounded or truncate, glabrous, margins revolute; dorsal sepal oblong, 5–7.5 by 1–2.5 mm, about twice as long as labellum auricles; lateral sepals oblong to obovate or elliptic, 3–5 by 2–3.5 mm. *Petals* spreading to reflexed, linear, obtuse, 5–7.5 by 0.5–1 mm, margins revolute. *Labellum* (nearly) flat, 6.5–9 by 5–10 mm (maximum dimensions), about as long as wide, suborbicular (not constricted at the middle) with a strongly sagittate-auriculate base, distally rounded with 20–40 variously sized teeth/laciniae; basal part forming a cavity that is elliptic to suborbicular in outline, bordered by a more or less horseshoe-shaped ridge; auricles obliquely and broadly (ovate-)triangular to lanceolate, obtuse to acute, 2.5–4 by 2–3.5 mm. *Column* pale green, greenish-purple to dark purple, erect, 1.5–2 mm long, larger than the largest marginal labellum teeth; staminodes (sub)oblong, obtuse to rounded; anther incumbent, versatile, orange-yellow to greenish-yellow, broadly ovate, rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.4–0.5 mm long; rostellum transversely rectangular, obtuse; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) green, greenish-purple to dark purple, fusiform-cylindrical, with 6 longitudinal ridges, 5–10 mm long, glabrous. *Capsule* clavate-oblongoid, 0.8–1 cm long, 0.3–0.5 cm in diameter; fruit pedicel 0.5–0.7 cm long. Figures 4.57, 4.58 and 4.59.

Thailand.— NORTHERN: Chiang Mai, Tak (Umphang).

Distribution.— China (Yunnan), Vietnam.

Ecology.— *Crepidium orbiculare* grows in shaded areas and open grassland in primary hill evergreen forest on granite bedrock; 1,000–1,800 m alt. Flowering: June–September.

Vernacular.— Muang Korn Dang (มังกรแดง).

Note.— This species is easily recognized by semiorbicular labellum with more than 20-fimbriate teeth on distal margins and flowers are red purple to dark purple.

Specimens examined.— **Thailand:** *Danish Botanists (Th. Sørensen, K. Larsen & B. Hansen) DB 4643* (C), Chiang Mai, Doi Suthep, 31 August 1958; *H.B.G. Garrett 880* (BKF, K, P) Chiang Mai, Doi Angka, Doi Phamon, 7 July 1934; *A.F.G. Kerr 209* (K), Chiang Mai, Doi Suthep, 5 September 1909; *A.F.G. Kerr 490* (K), Chiang Mai, Mae Cham, 15 July 1922; *G. Seidenfaden & T. Smitinand 2706* (C), Chiang Mai, Doi Suthep, 12 August 1958; *G. Seidenfaden & T. Smitinand 4529* (C), sine loco, 1963; *T. Smitinand 8304* (C) Chiang Mai, Doi Suthep, 19 August 1963; *J.F. Maxwell 88-978* (BKF, L), Chiang Mai, Doi Suthep, 8 August 1988; *J.F. Maxwell 89-7* (L), Chiang Mai, Doi Suthep, 1 July 1989; *P. Palee 23*2 (L), Chiang Mai, Doi Suthep, 17 July 1994; *W. Songkakul 68* (BKF), Chiang Mai, Doi Pui, 14 July 1989; *S. Pumicong 335* (QBG), Chiang Mai, Doi Chiang Dao, 25 July 2006; *A. Keratikorkol 492* (QBG), Tak, Umphang, Ban Palatha, 27 June 2008; *W. Nanakorn et al. 11382* (QBG), Chiang Mai, Doi Suthep-Pui, 24 June 1998; *W. Nanakorn et al. 12633* (QBG), Chiang Mai, Doi Suthep, 12 September 1998; *S. Intamusik 32* (QBG) Chiang Mai, Doi Suthep, 8 July 1998; *S. Watthana & W. La-ongsri 4185* (QBG), Chiang Mai, Doi Suthep, 15 July 2014; *S. Watthana & K. Kertsawang 4196* (QBG), Chiang Mai, Doi Pha Hom Pok, 19 July 2014; *D.J. Middleton et al. 4469* (BKF), Chiang Mai, Doi Suthep-Pui, 17 September 2008.

China: *G. Forrest 18446* (K), Yunnan, sine loco, 1919; *E.B. Howell 334* (E), Yunnan, Tengyueh, 1912.

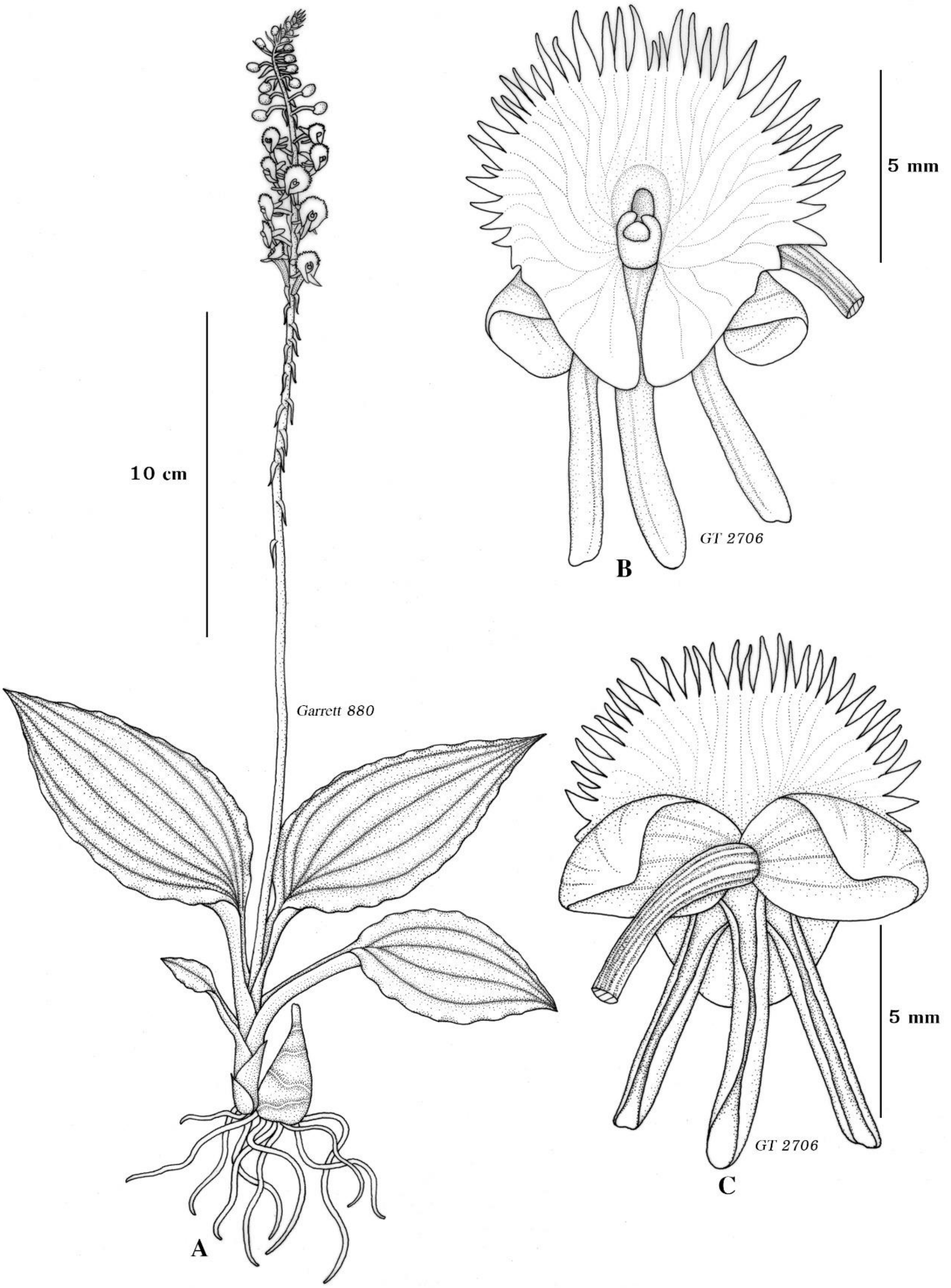

Figure 4.57 *Crepidium orbiculare* (W. W. Sm. & Jeffrey) Seidenf. **A:** Habit. **B:** Flower, front view. **C:** Flower, back view. Drawing from *Garrett 880* (A); *GT 2706* (B–C).

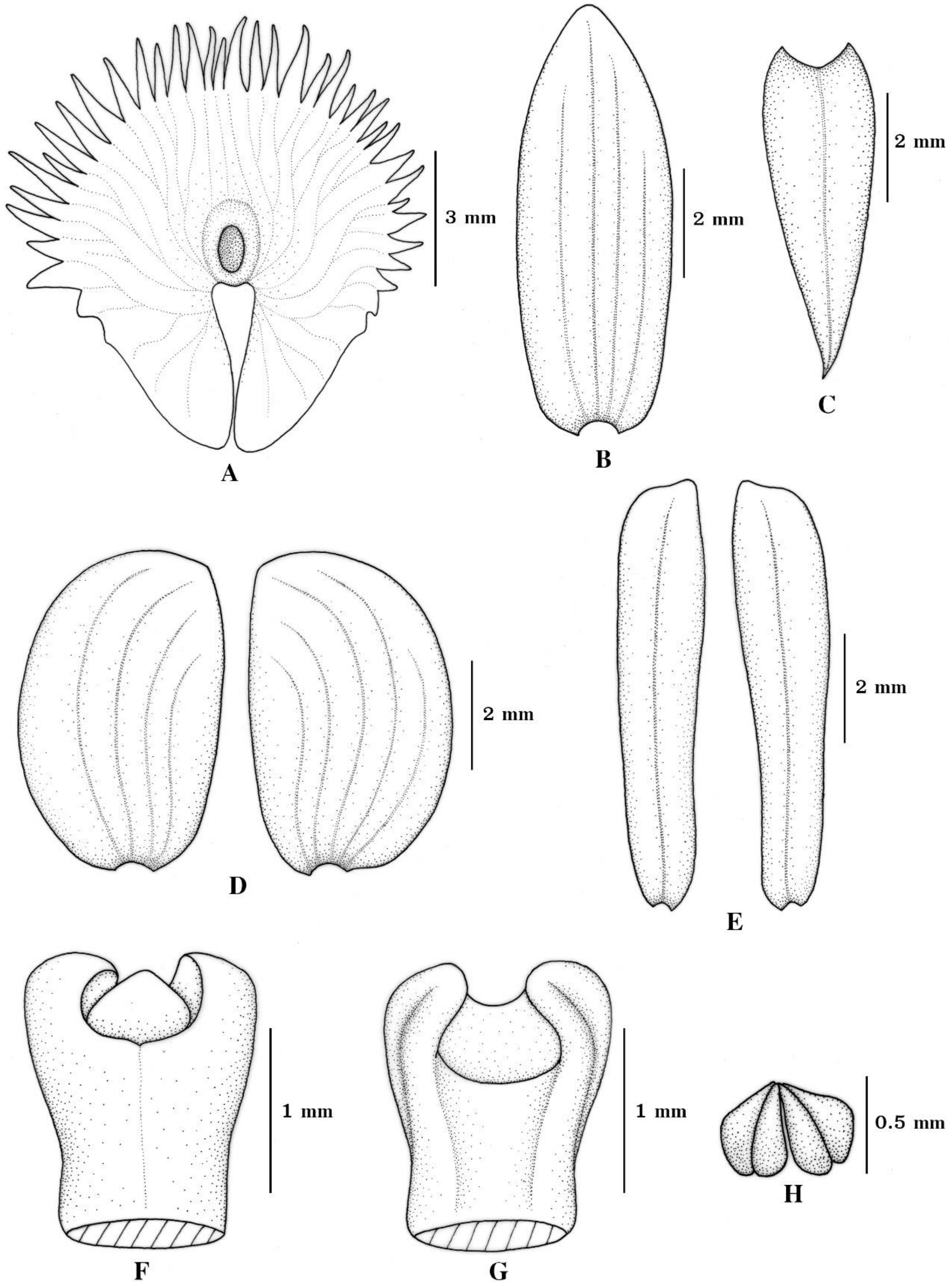

Figure 4.58 *Crepidium orbiculare* (W. W. Sm. & Jeffrey) Seidenf. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bract. **D:** Lateral sepals. **E.** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *GT 2706* (A–H).

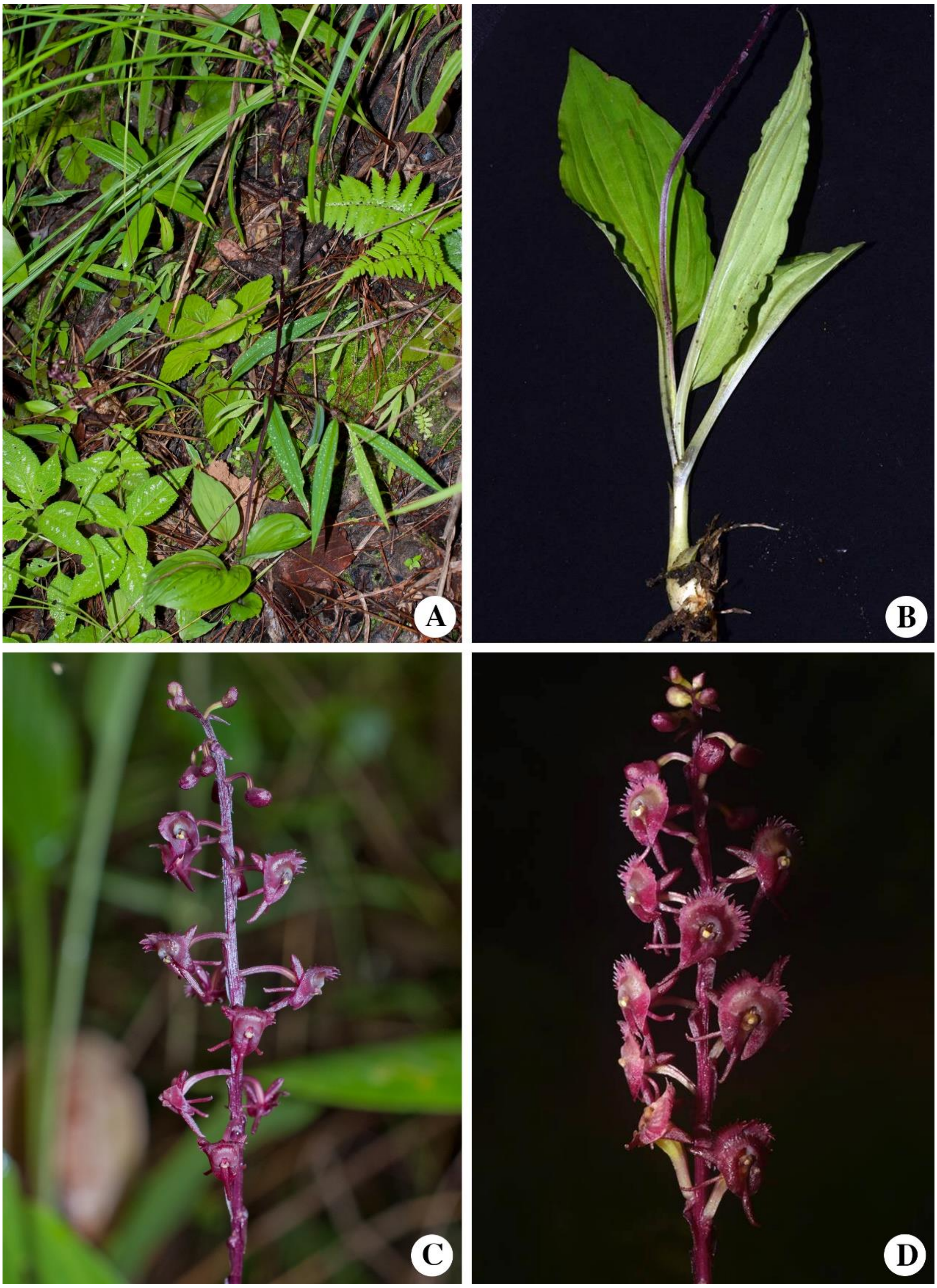

Figure 4.59 *Crepidium orbiculare* (W. W. Sm. & Jeffrey) Seidenf. **A–C:** Habit. **D:** Inflorescence. (A and C were photographed from Chiang Mai, Doi Chiang Dao, 26 July 2012; B and D were photographed by Phattaravee Prommanut, from Chiang Mai, Doi Ang Khang).

21. Crepidium perakense (Ridl.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 130. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; J. J. Wood et al., Orchids Mt. Kinabalu 2: 237, fig. 2.126, t. 17B. 2011.— *Microstylis perakensis* Ridl., J. Linn. Soc., Bot. 32: 222. 1896.— *Malaxis perakensis* (Ridl.) Holttum, Gard. Bull. Singapore 11: 283. 1947; Seidenf. & Smitinand, Orchids Thailand: 154, fig. 123. 1959; Seidenf., Bot. Tidsskr. 65: 125, fig. 17. 1969; Dansk Bot. Arkiv 33(1): 69, fig. 49. 1978; J. B. Comber, Orchids Java: 145 (incl. colour photo). 1990; Seidenf. & J. J. Wood, Orchids Penins. Malaysia Singapore: 223, fig. 95a, t. 13c. 1992. **Type:** Malaysia, Perak, Batu Kurau, *Curtis s.n.* [holotype **SING!**].

— *Malaxis wenzelii* Ames, Philipp. J. Sci., C 8: 412. 1914.— *Crepidium wenzelii* (Ames) Szlach., Fragm. Florist. Geobot., Suppl. 3: 133. 1995. **Type:** Philippines, Leyte, Dagami, 21 October, 1912, *Wenzel 34* [holotype **AMES!**, isotypes **AMES! K! NY! SING!**].

— *Microstylis spectabilis* Ridl., J. Fed. Malay States Mus. 5: 166. 1915.— *M. spectabilis* (Ridl.) Seidenf. & Smitinand, Orchids Thailand: 155. 1959. **Type:** Thailand, Surat Thani, Ko Pennan, 25 May 1913, *Robinson 5790* [holotype **K!**, isotypes **AMES! C! P!**].

— *Microstylis longidens* J. J. Sm., Bull. Jard. Bot. Buitenzorg, sér. 2, 26: 25. 1918.— *Malaxis longidens* (J. J. Sm.) Ames, Univ. Calif. Publ. Bot. 15: 37. 1929. **Type:** Java, Piangan, *Backer 12* [not seen; see reproduction in Bull. Jard. Bot. Buitenzorg, sér. 3, 5: t. 33. fig. 5. 1922].

Terrestrial, sympodial herb with a creeping rhizome terminating in a 25–40 cm tall flowering shoot that is erect from a decumbent base. *Rhizome* green, terete, 3–25 cm long, 0.6–1 cm in diameter, internodes 0.7–2 cm long. *Roots* several, 2–7 arising from each node of the rhizome and from the lower nodes of the stem, 1.5–15 cm long. *Foliage leaves* 7–10, ascending to spreading, petiolate, petiole sheathing at base, free part 1–6 cm long, green; lamina plicate, green, unspotted, lanceolate to ovate, elliptic or oblong with asymmetrical base, acuminate, 4.5–17 by 1.5–5 cm, 3- to 5-veined, glabrous, margins slightly undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 20–30 cm long, elongating gradually during flowering; peduncle dark purple, 8–14 cm long, 0.3–0.4 cm in diameter, bearing a few lanceolate sterile bracts; rachis densely many-flowered (sometimes bearing more than 100 flowers); floral bracts persistent, dark purple, reflexed, lanceolate to triangular or narrowly ovate, acute to acuminate, entire, 3.5–8.5 by 1–2.5 mm, shorter than ovaries. *Flowers* reddish-purple to dark purple, 5–6.5 mm in diameter. *Sepals* spreading to subreflexed, acute to obtuse, glabrous, margins recurved; dorsal sepal broadly oblong to oblong-lanceolate, 4.5–6.5 by 1.8–2.3 mm; lateral sepals broadly and obliquely ovate to elliptic, 3.5–5.2 by 2.5–3 mm. *Petals* reflexed, linear to linear-ligulate, truncate to obtuse or slightly retuse, 4–6 by 0.7–1.5 mm, margins slightly recurved. *Labellum* (nearly) flat, 7–11 by 5.5–7 mm (maximum dimensions), longer than wide, obovate to elliptic (sometimes constricted at the middle) with a strongly sagittate-auriculate base, distally with 4–6 variously sized teeth/laciniae; basal/central part forming cavity that is elliptic in outline, bordered by a high horseshoe-shaped ridge; auricles narrowly and obliquely to falcately triangular, acute to obtuse, 3.5–6 by 2–2.5 mm. *Column* green, erect, 2–5.5 mm long; staminodes oblong, rounded; anther incumbent, versatile, orange-yellow, broadly ovate, obtuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.5–0.7 mm long; rostellum transversely rectangular, emarginate; fertile part of stigma (sub)triangular, flat, concave at base. *Ovary* (including pedicel) dark purple, cylindrical, with 6 longitudinal ridges, 4–9 mm long, glabrous. *Capsule* not seen. Figures 4.60, 4.61 and 4.62.

Thailand.— PENINSULAR: Surat Thani, Nakhon Si Thammarat (Khao Luang), Phattalung (Tha Mot).

Distribution.— Peninsular Malaysia, Sumatra, Java, Borneo, Philippines.

Ecology.— *Crepidium perakense* grows in humus-rich soil in shaded areas and on rocks along streams in evergreen forest at 200–800 m alt. Flowering: August–December.

Vernacular.— Muang Korn Dum (มังกรดำ).

Specimens examined.— **Thailand:** *A.F.G. Kerr 438* (BK, C, K), Surat Thani, Khao Nong, 8 August 1927; *K. Larsen et al. 44167* (AAU, C, SING), Phattalung, Tha Mot, NW. Hat Yai, 31 October 1993; *K. Larsen et al. 42149* (AAU), Phattalung, Tha Mot, 5 October 1991; *T. Smitinand 987* (BKF), Nakhon Si Thammarat, Khao Luang, 23 October 1994; *A. Nuammee 394* (BCU, BKF), Nakhon Si Thammarat, Khao Luang, 12 December 2013; *A. Nuammee 432* (BCU, BKF), Nakhon Si Thammarat, Khao Luang, 19 November 2014; *A. Nuammee 449* (BCU, BKF), Nakhon Si Thammarat, Khao Luang, 21 September 2015; *H.C. Robinson 5790* (AMES, C, K, P). Surat Thani, Ko Pha-ngan, 25 May 1913.

Peninsular Malaysia: *C. Curtis s.n.* (SING), Perak, Batu Kurau, September 1893; *C.E. Carr 163* (SING), Pahang, Gunung Senyum, September 1929; *C.E. Carr 358* (SING), Pahang, Batu Balai, November 1930; *Haniff 14245* (SING), Perak, Jor, 14 September 1924; *R.E. Holttum 9825* (C, SING), Negeri Sembilan, Ulu Bendel, 30 November 1922; *King's collectors 10858* (SING), Perak, sine loco, September 1886; *King's collectors 10436* (K), Perak, sine loco, July 1886; S.P. Lim et al. 685 (SING), Sarawak, Sabah, Madai-Baturong, 10 June 1996; *P.T. Ong 64077* (L), Pahang, Temerluh, Krau, 13 October 2008; *H.N. Ridley s.n.* (C), Perak, Telok Pinang, Ipoh, 1890; *H.N. Ridley s.n.* (C), Pahang, Ulu Telom, 1908; *B. Scortechini 1212* (K), Perak, sine loco, 16 August 1888; *B. Scortechini s.n.* (SING), Pahang, Gunung Batu, 1893.

Indonesia: *S.M. Latif 69* (L), Sumatra, S.W.K. Anaistroomgebied, November, 1934; *C.N.A. de Voogd 1172* (L), Sumatra, sine loco, 11 September 1931; *W.J.J.O. de Wilde & B.E.E. de Wilde-Duyfies 12276* (L), N. Sumatra, Gunung Lesser, Lau Ketambe, 22 May 1972; *W.J.J.O. de Wilde & B.E.E. de Wilde-Duyfies 12715* (L), N. Sumatra, Gunung Lesser, Lau Ketambe, 8 June 1972; *W.J.J.O. de Wilde & B.E.E. de Wilde-Duyfies 13603* (L), N. Sumatra, Gunung Lesser, Lau Ketambe, 14 July 1972; *W.J.J.O. de Wilde & B.E.E. de Wilde-Duyfies 13842* (L), N. Sumatra, Gunung Lesser, W. Kutacane, 29 June 1979; *W.J.J.O. de Wilde & B.E.E. de Wilde-Duyfies 18225* (L), N. Sumatra, Gunung Lesser, Lau Ketambe, 20 July 1972; *W.J.J.O. de Wilde & B.E.E. de Wilde-Duyfies 18360* (L), N. Sumatra, Gunung Lesser, W. Kutacane, 22 June 1979.

Philippines: *C.A. Wenzel 34* (AMES, K, NY, SING), Leyte, Dagami, 21 October 1912.

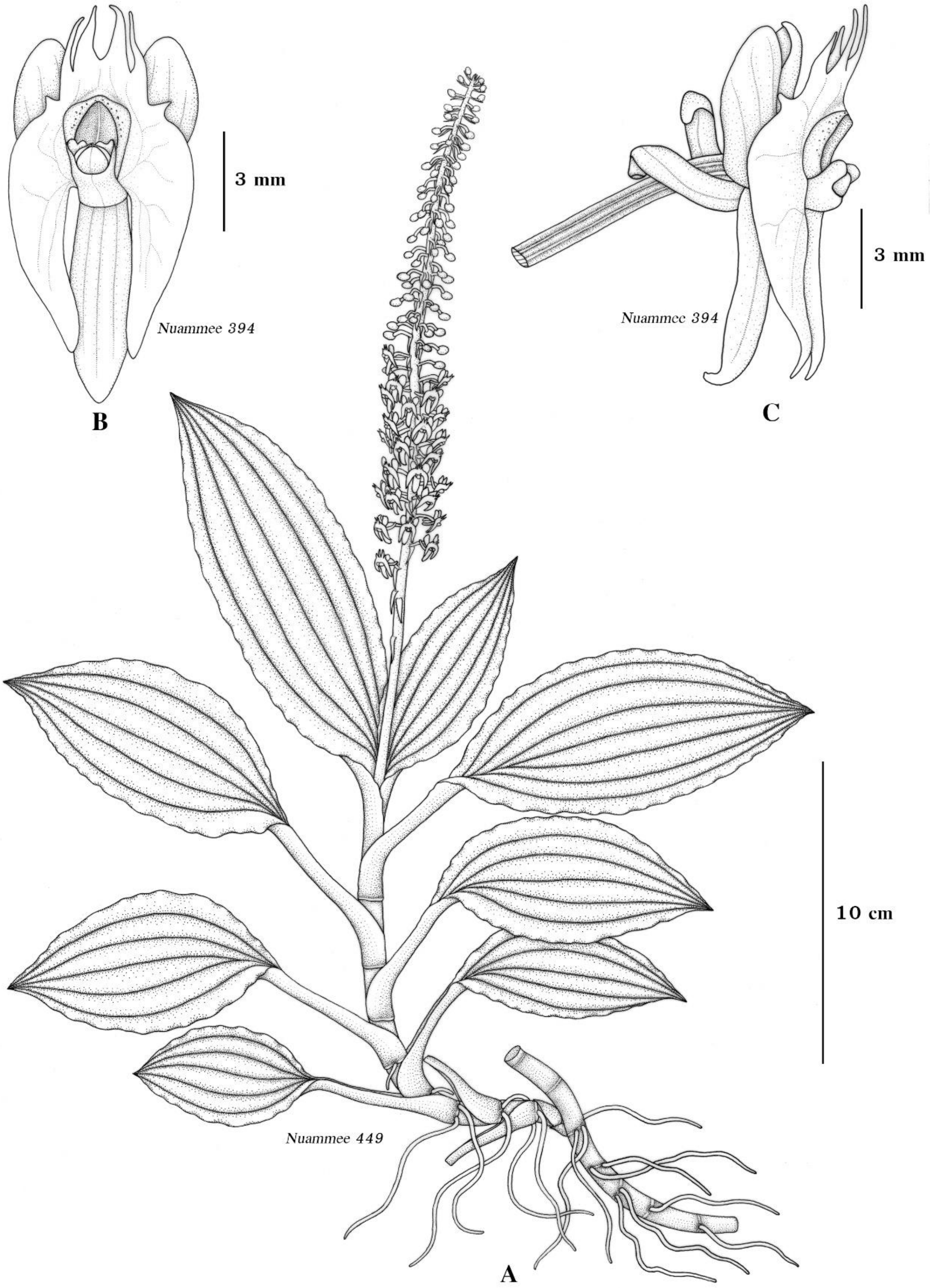

Figure 4.60 *Crepidium perakense* (Ridl.) Szlach. **A:** Habit. **B:** Flower, front view. **C:** Flower, lateral view. Drawing from *Nuammee 449* (A); *Nuammee 394* (B–C).

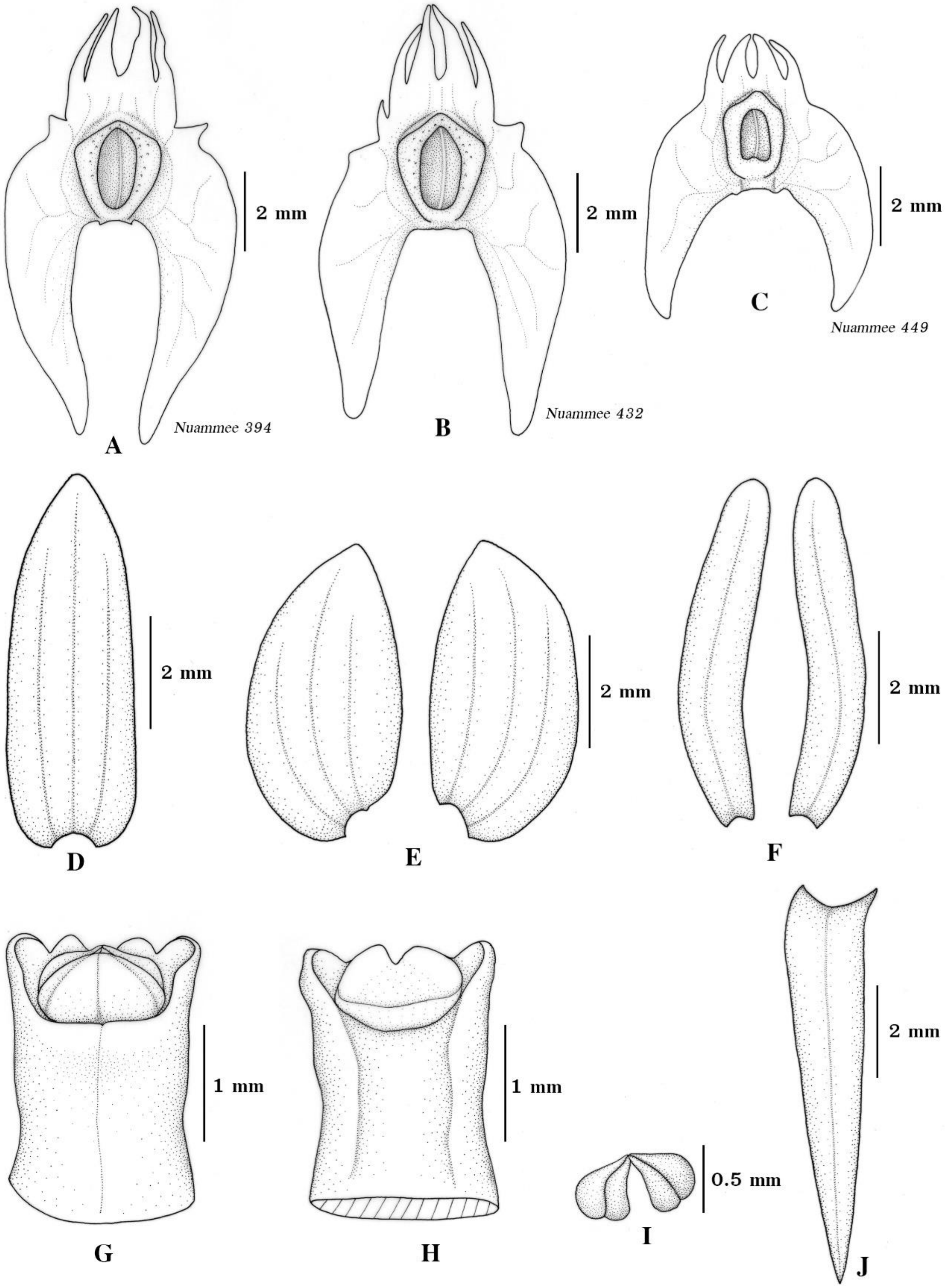

Figure 4.61 *Crepidium perakense* (Ridl.) Szlach. **A–C:** Labellum, front view. **D:** Dorsal sepal. **E:** Lateral sepals. **F.** Petals. **G:** Column, back view. **H:** Column, front view. **I:** Two pairs of pollinia. **J:** Floral bract. Drawing from *Nuammee 394* (A); *Nuammee 432* (B, D–J); *Nuammee 449* (C).

Figure 4.62 *Crepidium perakense* (Ridl.) Szlach. **A–B:** Habit. **C:** Inflorescence. **D:** Flower, front view. All were photographed from Nakhon Si Thammarat, Khao Luang, 16 November 2014.

22. Crepidium polyodon (Hook. f.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 130. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997.— *Microstylis polyodon* Hook. f., Fl. Brit. India 5: 688. 1890.— *Malaxis polyodon* (Hook. f.) Kuntze, Revis. Gen. Pl. 2: 673. 1891; Seidenf. & Smitinand, Orchids Thailand: 152, fig. 121. 1959; Seidenf., Dansk Bot. Arkiv 33(1): 81, fig. 57. 1978; Opera Bot. 114: 148. 1992; Aver., Turczaninowia 16: 129, fig. 63h-j. 2013. **Type:** Myanmar, Moulmein, *Parish 215* [holotype **K!**].

Terrestrial, with a condensed rhizome bearing an erect, pseudobulbous, 24–42 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* several, slender, arising from the basal part of the pseudobulbs, 1–8 cm long. *Pseudobulbs* green, terete from a fusiform base, 15–19 cm long, 0.6–1 cm in diameter, consisting of 6–7 internodes. *Cataphylls* 4–6, broadly triangular-ovate to lanceolate-oblong (the lowermost tubular), acute to acuminate 0.7–13 by 1–2.2 cm. *Foliage leaves* 4–5, ascending to erect, sessile to distinctly petiolate, petiole sheathing at base, free part up to 3 cm long; lamina plicate, green, unspotted, elliptic to lanceolate or broadly ovate with slightly asymmetrical base, acuminate, 5–17 by 1.5–6.5 cm, 5- to 11-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 13–32 cm long, elongating gradually during flowering; peduncle pale green to pale purplish-brown, 7.5–10 cm long, 0.2–0.4 cm in diameter; rachis densely 20- to many-flowered; floral bracts pale green with purplish-brown, reflexed, linear-lanceolate, acuminate, entire, 3.5–6.5 by 1–1.5 mm, shorter than ovaries. *Flowers* (brownish-)yellow to green, more or less tinged with purple, 4–6.5 mm in diameter. *Sepals* spreading to reflexed, obtuse to acute, glabrous, margins revolute; dorsal sepal oblong to oblong-elliptic, 4–7 by 1.5–2.5 mm; lateral sepals obliquely and broadly elliptic, 3.5–5 by 2–3.5 mm. *Petals* spreading to reflexed, linear-filiform, rounded to retuse, 4.5–6.7 by 0.5–0.7 mm, margins revolute. *Labellum* (nearly) flat, 5–8 by 3–4.5 mm (maximum dimensions), longer than wide, ovate (not constricted at the middle) with a strongly sagittate-auriculate base, distally rounded with 6–9 coarse teeth on either side of the apex, the two median teeths more or less overlapping; basal/central part forming a cavity that is triangular to elliptic in outline, flanked by thickened, obliquely triangular ridge on either side; auricles falcate, acute to obtuse, 2.5–5 by 1–

2 mm. *Column* pale green with purple, erect, 2–2.5 mm long, larger than the largest marginal labellum teeth; staminodes oblong, rounded; anther incumbent, versatile, pale yellowish-purple, broadly ovate, subtruncate to rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.5–0.6 mm long; rostellum broadly triangular, obtuse to rounded; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) pale green tinged with more or less brownish-purple, slender, cylindrical, with 6 longitudinal ridges, 4–8 mm long, glabrous. *Capsule* not seen. Figures 4.63, 4.64 and 4.65.

Thailand.— NORTHERN: Nakhon Sawan (Me Wong); NORTH-EASTERN: Loei (Na Haeo); SOUTH-WESTERN: Prachuap Kriri Khan (Huay Yang); PENINSULAR: Phangnga.

Distribution.— Myanmar, Laos.

Ecology.— *Crepidium polyodon* grows in humus-rich soil in a shaded areas in dry evergreen forest at 200–1,000 m alt. Flowering: May–July.

Note.— Due to the similarity of vegetative morphology, young plants of *C. polyodon* with flowers buds can be mistaken for *Dienia ophrydis* (J. Koenig) Szlach.

Specimens examined.— **Thailand:** *R. Geesink & T. Santisuk 5159* (C, L), Pangnga, Khao Pawta Luang Keow, 2 May 1973; *A.F.G. Kerr 457* (K), Nakhon Sawan, Mae Wong, 28 May 1922; *A. Nuammee 437* (BCU, BKF), Prachuap Kriri Khan, Huay Yang, 5 May 2015; *O. Thaithong et al. 009074* (BCU), Prachuap Kriri Khan, Huay Yang, 20 May 1999; *T. Pingyot et al. 102* (QBG), Loei, Na Haeo, 20 April 2017.

Myanmar: *Parish 215* (C, K), Moulmein, sine anno. **Laos:** *A.F.G. Kerr 986* (SING), Wiang Chan, Nam Fuak, 25 Apirl 1932.

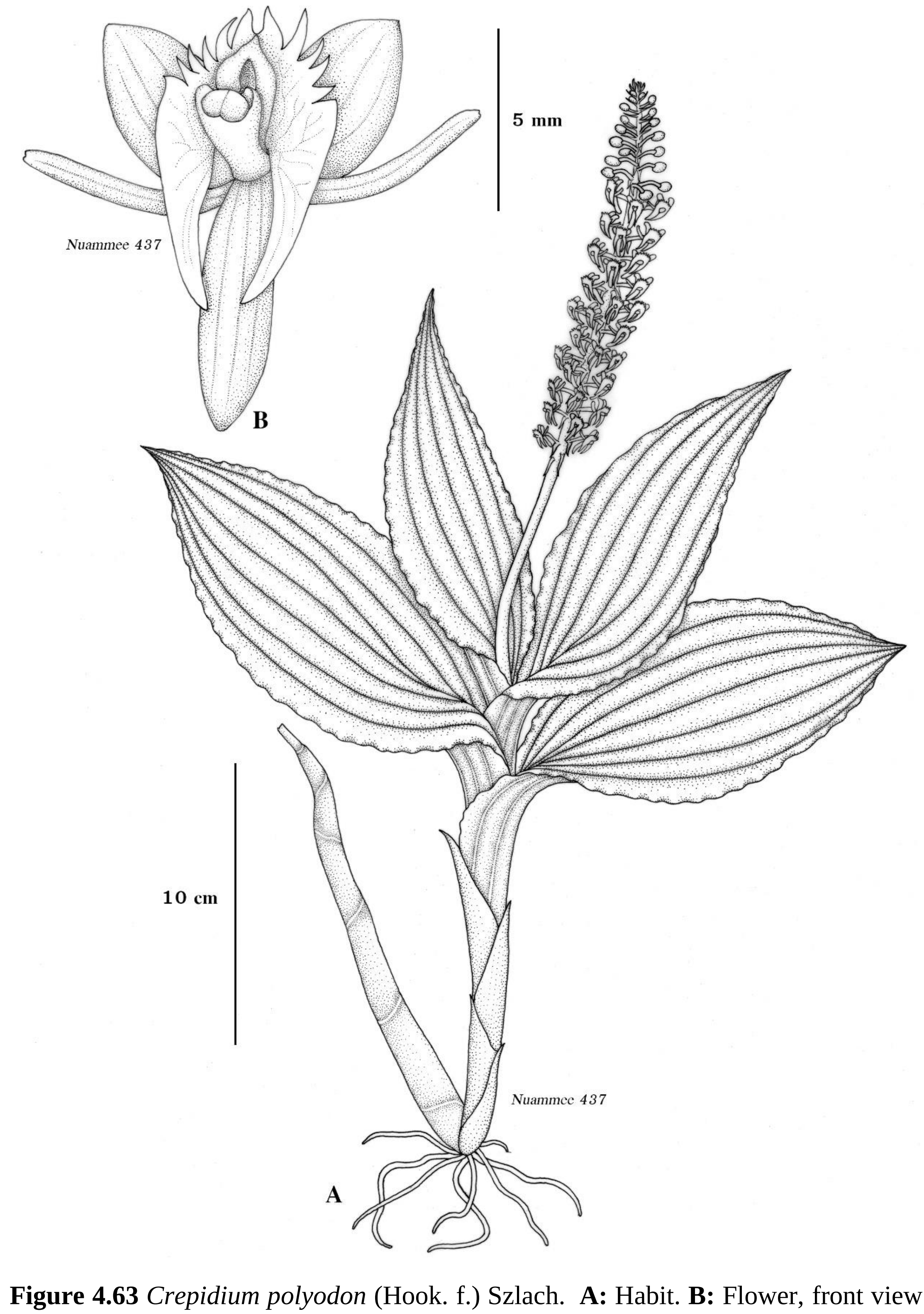

Figure 4.63 *Crepidium polyodon* (Hook. f.) Szlach. **A:** Habit. **B:** Flower, front view. Drawing from *Nuammee 432* (A–B).

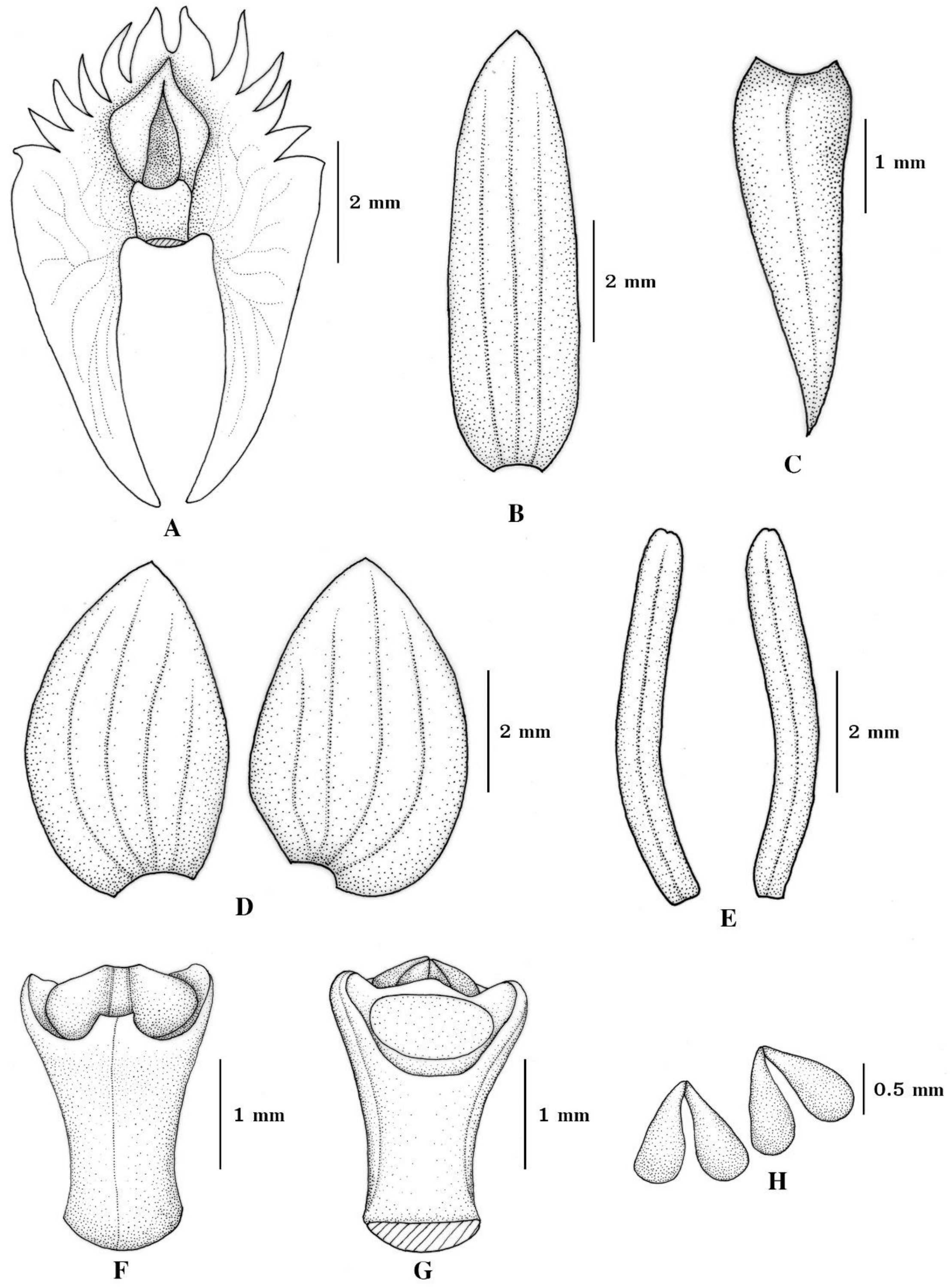

Figure 4.64 *Crepidium polyodon* (Hook. f.) Szlach. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bracts. **D:** Lateral sepals. **E.** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *Nuammee 437* (A–H).

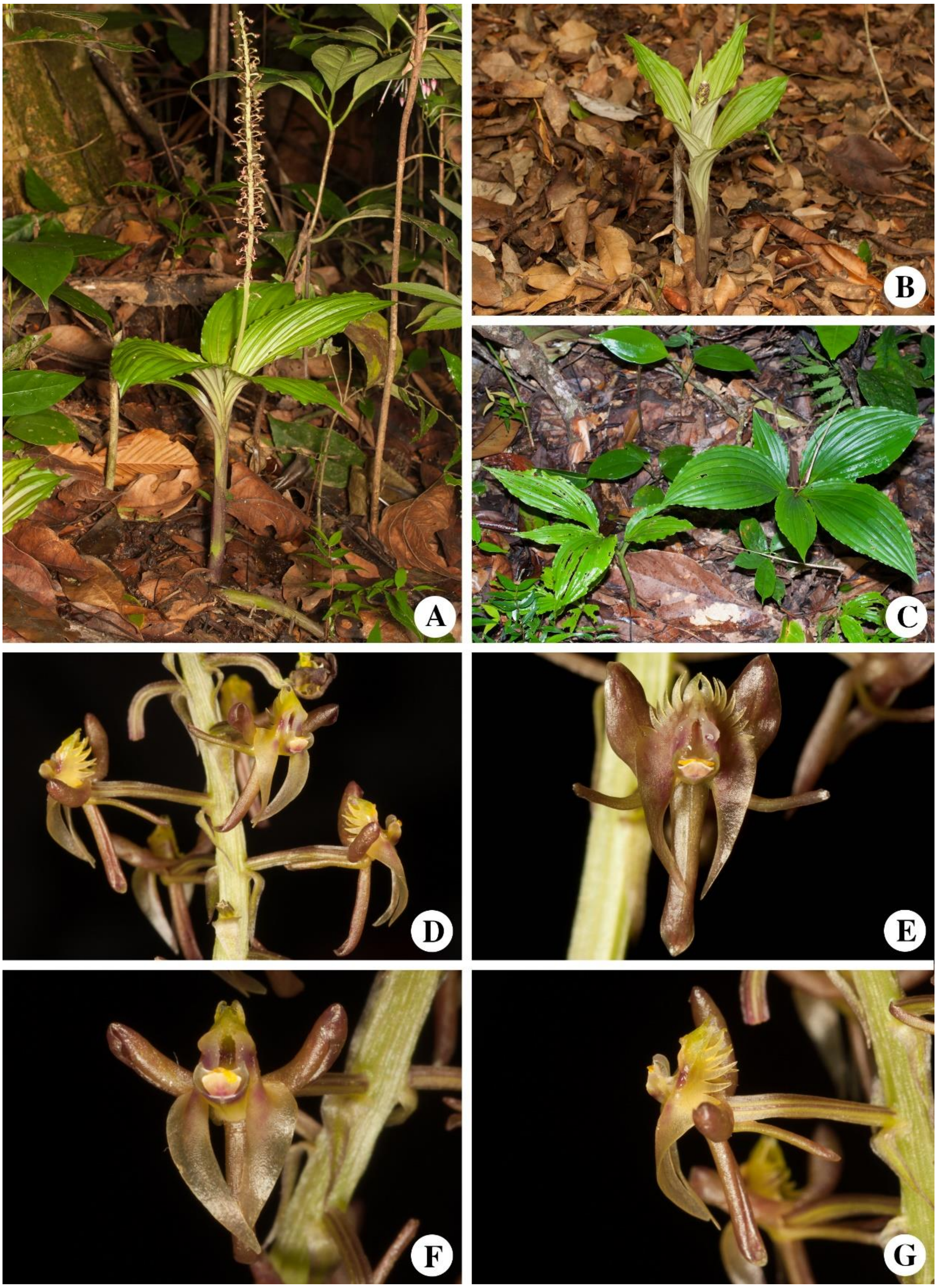

Figure 4.65 *Crepidium polyodon* (Hook. f.) Szlach. **A–C:** Habit. **D:** Flowers. **E–F:** Flower, front view. G: Flower, lateral view. All were photographed from Prachuap Khiri Khan, Huay Yang waterfalls, 5 May 2015.

23. Crepidium prasinum (Ridl.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 130. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; Sitthisajjadham, Orchid Guide Book 2: 113, colour photo on p. 38 (bottom right). 2007.— *Microstylis prasina* Ridl., J. Linn. Soc., Bot. 32: 223. 1896.— *Malaxis prasina* (Ridl.) Seidenf. & Smitinand, Orchids Thailand 2: 149. 1959; Seidenf., Bot. Tidsskr. 65: 318, fig. 3. 1970; Dansk Bot. Arkiv 33(1): 68, fig. 47. 1978; Opera Bot. 114: 148. 1992; Seidenf. & J. J. Wood, Orchids Penins. Malaysia Singapore: 221, fig. 94a–b. 1992; Sitthisajjadham & Tripetch, Wild Orchids Thailand 2: 332, colour photos on pp. 332–333. 2009. **Type:** Thailand, Phuket, Tongkah, 1894, *Ridley s.n.* [holotype **SING!**, isotype **BM!]**.

— *Microstylis reniloba* Carr, Gard. Bull. Straits Settlem. 7: 4. 1932.— *Malaxis reniloba* (Carr) Holttum, Gard. Bull. Singapore 11: 283. 1947; Seidenf. & Smitinand, Orchids Thailand 2: 148, fig. 113. 1959. **Type:** Peninsular Malaysia, Perlis, November 1929, *Henderson s.n.* [holotype **SING!**].

Terrestrial, sympodial herb with a condensed rhizome bearing an erect, pseudobulbous, 12–20 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* several, slender, arising from the basal part of the pseudobulbs, 0.5–8.5 cm long. *Pseudobulbs* green, obconical, oblong-fusiform, 1.5–6 cm long, 0.8–1.5 cm in diameter, consisting of 4–6 internodes. *Foliage leaves* 3–5, ascending to erect, petiolate, petiole sheathing at base, free part 0.5–3.5 cm long; lamina plicate, green, more or less suffused with purple and dull purple-veined above and beneath, lanceolate to broadly ovate or elliptic with slightly asymmetrical base, acute to acuminate, 2–15 by 0.5–7.5 cm, 3- to 6-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 5–20 cm long, elongating gradually during flowering; peduncle dull purple, 3–10 cm long, 0.1–0.3 cm in diameter; rachis densely 20- to 45-flowered; floral bracts persistent, green, strongly recurved, lanceolate to ovate, acuminate, 2–6 by 0.5–2 mm, much shorter than ovaries. *Flowers* green, 4.5–8.5 mm in diameter. *Sepals* spreading, glabrous, margins recurved; dorsal sepal broadly oblong to elliptic, obtuse to rounded, 3.5–7 by 1.5–3.5 mm, more than twice as long as labellum auricles; lateral sepals broadly and obliquely ovate or elliptic, rounded to acute, 3.5–6 by 2–4 mm. *Petals* spreading, linear-ligulate, rounded to subacute, 4–6.5 by 0.5–1.5 mm, margins revolute. *Labellum* (nearly) flat, 4.5–6.5 by 4.5–8.5 mm (maximum dimensions), at least as wide as long, reniform to almost obovate (not constricted at the middle) with strongly cordate-auriculate base, distinctly 3-lobed, disally rounded to obtuse; basal/central part forming a cavity that is elliptic to rectangular in outline, with flat margins; auricles obliquely triangular to ovate or suborbicular, obtuse to rounded, 1.5–3 by 1.5–3.5 mm. *Column* green, erect, 1–2 mm long; staminodes greenish, slender, oblongoid, obtuse to rounded; anther incumbent, versatile, pale green, broadly ovate, obtuse to rounded, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.4–0.5 mm long; rostellum transversely rectangular, retuse; fertile part of stigma transversely elliptic, flat, concave at base. *Ovary* (including pedicel) green, cylindrical, with 6 longitudinal ridges, 8–17.5 mm long, glabrous. *Capsule* ellipsoid to oblongoid, 0.8–1 cm long, 0.3–0.5 cm in diameter; fruit pedicel 1–1.6 cm long. Figures 4.66, 4.67 and 4.68.

Thailand.— PENINSULAR: Chumphon (Sapil), Surat Thani, Phuket, Trang, Nakhon Si Thammarat.

Distribution.— Laos, Peninsular Malaysia.

Ecology.— *Crepidium prasinum* grows in humus-rich soil in shaded areas on limestone hills at 200–300 m alt. Flowering: September– October.

Vernacular.— Haew Moo Pha Thin Tai (แห้วหมูป่าถิ่นใต้).

Note.— The leaves and pseudobulb morphology of *C. prasinum* is similar to *C. merapiensis*. However, the flowers of *C. prasinum* are distincly 3-lobed and larger than 4 mm. The morphology of mid-lobe labellum is highly variable; some populations have large mid-lobe labellum, semiorbicular and rounded apex, but some populations have small mid-lobe labellum, triangular and acute apex.

Specimens examined.— **Thailand:** *A.F.G. Kerr 873* (C, K), Trang, 21 June 1930; *D.J. Middleton et al. 4343* (BKF), Surat Thani, Khlong Phanom, 7 September 2008; *A. Nuammee 387* (BCU, BKF), Nakhon Si Thammarat, Krung Ching, Khao Pon, 27 October 2013; *A. Nuammee 451* (BCU, BKF), Nakhon Si Thammarat, Krung Ching, Khao Pon, 19 October 2015; *Put 1005* (C, K), Chumpon, Sapil, 8 September 1927; *Put 4113* (C, K), Surat Thani, Kantuli, 6 September 1931; *Rabil 100* (C, K), Nakhon Si Thammarat, Thung song, Khao Chem, 20 July 1929; *H.N. Ridley s.n.*, Phuket, Tongkah, 1894, (BM, SING); *P. Tripetch 091041* (QBG), Nakhon Si Thammarat, Krung Ching, Khao Pon, 23 October 2009.

Peninsular Malaysia: *M.R. Henderson s.n.* (SING), Perlis, November 1929; *W. Yong 335* (SING), Perlis, Perlis State Park, 10 August 2004. **Indonesia:** *W. Leewan 13079* (L), Java, Larangan, 9 January 1930.

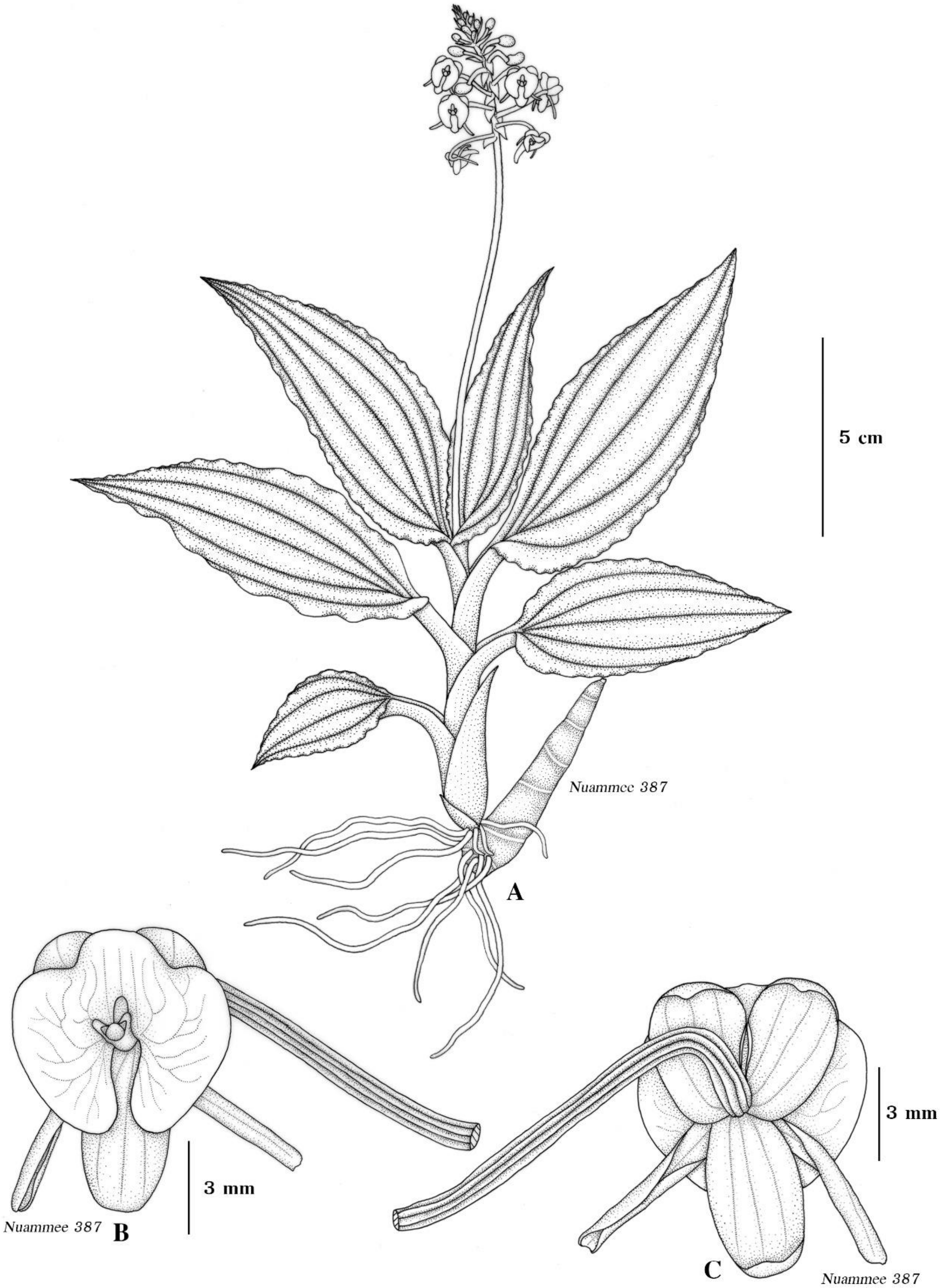

Figure 4.66 *Crepidium prasinum* (Ridl.) Szlach. **A:** Habit. **B:** Flower, front view. **C:** Flower, back view. Drawing from *Nuammee 387* (A–C).

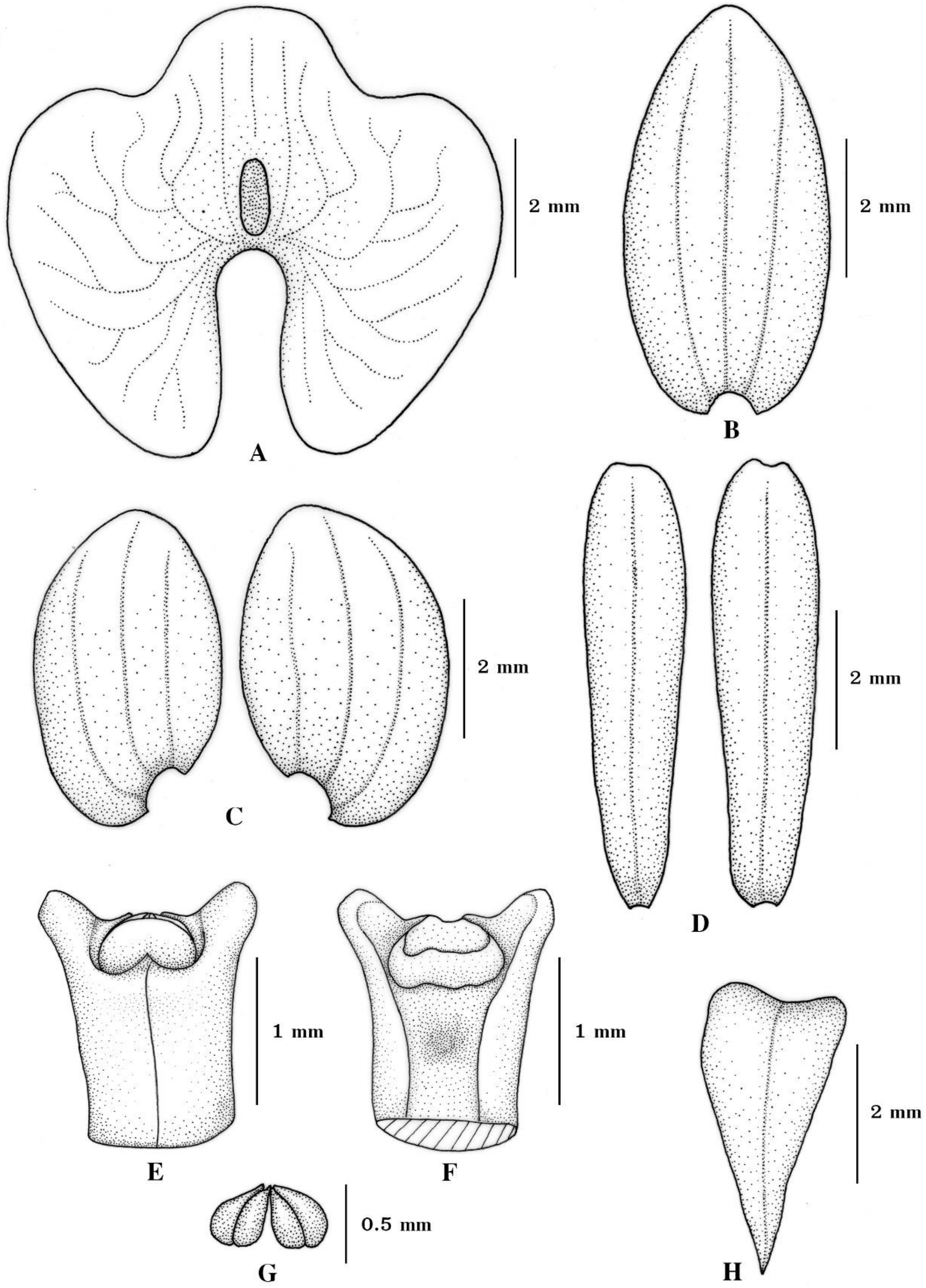

Figure 4.67 *Crepidium prasinum* (Ridl.) Szlach. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Lateral sepals. **D.** Petals. **E:** Column, back view. **F:** Column, front view. **G:** Two pairs of pollinia. **H:** Floral bract. Drawing from *Nuammee 387* (A–H).

Figure 4.68 *Crepidium prasinum* (Ridl.) Szlach. **A–C:** Habit. **B:** Inflorescence. **E:** Flowers. **F:** Flower, front view. A, D and F were photographed from Nakhon Si Thammarat, Krung Ching, Khao Pon, 27 October 2013; B and C were photographed from Nakhon Si Thammarat, Krung Ching, Khao Pon, 19 October 2015.

24. Crepidium purpureum (Lindl.) Szlach., Fragm. Florist. Geobot., Suppl. 3: 131. 1995; Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; S. C. Chen & J. J. Wood in Z. Wu et al. (eds.), Fl. China 25: 234. 2009; Zhihui Xu, Wild Orchids Yunnan: 168, figs. 219a–219b. 2010.— *Microstylis purpurea* Lindl., Gen. Sp. Orchid. Pl. 20. 1830; Ridl., J. Linn. Soc., Bot. 24: 340 p.p. 1888; Hook. f., Fl. Brit. India 5: 687. 1890.— *Malaxis purpurea* (Lindl.) Kuntze, Revis. Gen. Pl. 2: 673. 1891; Seidenf., Bot. Tidsskr. 65: 325, fig. 6. 1970; Dansk Bot. Arkiv 33(1): 63, figs. 43f, 45. 1978; Opera Bot. 114: 147. 1992; N. Pearce & P. J. Cribb, Fl. Bhutan 3(3): 216. 2002; Aver., Turczaninowia 16: 128, fig. 63e. 2013. **Type:** Sri Lanka**,** near Galle, *Macrae s.n.* [not seen].

— *Microstylis wallichii* Lindl. var. *biloba* King & Pantl., Ann. Roy. Bot. Gard. (Calcutta) 8: 16, t. 19. 1898. **Type:** Sikkim Himalaya, tropical Himalayan valleys, June 1891, *Pantling 37* [holotype **W**, isotypes **C! K! L! M**].

— *Malaxis rizalensis* Ames, Philipp. J. Sci., C 6: 46. 1911. **Type:** Philippines, Luzon, Rizal, Bosoboso, August 1907, *Ramos 4561* [holotype **AMES!**, isotype **C!**].

Terrestrial, sympodial herb with a strongly condensed rhizome bearing an erect, pseudobulbous, 12–44 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* several, slender, arising from the basal part of the pseudobulbs, 1–10 cm long. *Pseudobulbs* green, conical, 2–4.5 cm long, 0.6–2 cm in diameter, consisting of 3–6 internodes. *Cataphylls* 1–3, broadly (triangular-)ovate to lanceolate-oblong (the lowermost tubular), acute to acuminate, 1–5 by 0.5–3 cm. *Foliage leaves* 4–5, ascending to spreading or erect, petiolate, petiole sheathing at base, free part 0.5–5.5 cm long, green, more or less suffused with purple; lamina plicate, green, unspotted, ovate, lanceolate to elliptic or oblong with slightly asymmetrical base, acute to acuminate, 3.8–19 by 2–5.5 cm, 3- to 6-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 9–40 cm long, elongating gradually during flowering; peduncle green, 6–17 cm long, 0.1–0.4 cm in diameter; rachis laxly or densely 6- to many-flowered; floral bracts persistent, pale green to purplish-red, strongly recurved, ovate to narrowly triangular or lanceolate, acuminate, 2–12 by 1–3.5 mm, shorter or longer than ovaries. *Flowers* yellow to yellowish-brown, yellowish-green to purplish-red, 5–8 mm in diameter.

Sepals spreading, obtuse to subacute, glabrous, margins revolute; dorsal sepal lanceolate to oblong, 5–6 by 2–3 mm, less than twice as long as labellum auricles; lateral sepals broadly and obliquely obovate, ovate to elliptic, 4–5 by 2–3 mm. *Petals* spreading to reflexed, linear, rounded to retuse, 5–6 by 0.8–1 mm, margins revolute. *Labellum* (nearly) flat, 6–9 by 4–6 mm (maximum dimensions), longer than wide, (oblong-)ovate, constricted at the middle and with a strongly sagittate-auriculate base, distally deeply bilobed, 1.5–2 mm depth, with obtuse to retuse or acute lobes; basal/central part forming a cavity that is shallow and small ovate to elliptic in outline, bordered by a more or less horseshoe-shaped ridge; auricles obliquely triangular to ovate, obtuse or acute, 3–4 by 2–2.5 mm; anther incumbent, versatile, greenish-yellow to pale green, broadly ovate, obtuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, c. 0.5 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely elliptic, flat, concave at base. *Column* pale green to purple, erect, 1–1.5 mm long; staminodes very short. *Ovary* (including pedicel) green, fusiform-cylindrical, with 6 longitudinal ridges, 4–10 mm long, glabrous. *Capsule* clavate-oblongoid, 1.5–2 cm long, 0.5–0.8 cm in diameter; fruit pedicel 0.2–0.4 cm long. Figures 4.69, 4.70 and 4.71.

Thailand.— NORTHERN: Chiang Mai, Chiang Rai (Doi Thung), Phitsanulok (Phu Hin Rong Kla).

Distribution.— N India, Sri Lanka, S China, Taiwan, Japan (Ryukyu Islands), Laos, Vietnam, Philippines, Sulawesi.

Ecology.— *Crepidium purpureum* grows in humus-rich soil in shaded areas in mixed evergreen or deciduous forest, and in open areas on slopes in pine forest at 550–1,500 m alt. Flowering: July– August.

Note.— *C. purpureum* is similar to *C. acuminatum*. However, the labellum of *C. purpureum* is completely different from *C. acuminatum*. It does not have indentation on margins and the bilobulate apex is shallow while *C. purpureum* have indentation on margins at the base of apical part, seperated the bilobulate apex from sidelobes and the apex is deeply bilobed.

Specimens examined.— **Thailand:** *A.F.G. Kerr 232* (K), Chiang Mai, Mea Sa, 25 July 1915; *J.F. Maxwell 89-919* (L), Chiang Mai, Doi Chiang Dao, Ban Yang Pong Luang, 22 July 1989; *W. Nanakorn et al. 11256* (QBG), Chiang Mai, Doi Suthep, 2 June 1998; *W. Nanakorn et al. 11425* (QBG), Chiang Mai, Doi Suthep, 6 July 1998; *M. Norsaengsri 7125* (QBG), Tak, Mae Tho, Ban Muser Mai, 22 August 2010; *A. Nuammee 416* (BKF), Phitsanulok, Phu Hin Rong Kla, 10 July 2014; *A. Nuammee 453* (BCU), Chiang Rai, Doi Thung, 9 October 2016; *S. Tsugaru T-61712* (BKF, L), Chiang Mai, Doi Inthanon, 22 July 1988.

India: *C.M. Arora 38895* (L) Kumaon, Pithoragarh, 29 July 1969; *E. Barnes 2289* (K), Nadugani, Nilgiri-Wynaad, July 1940; *E. Barnes 2290* (K), Nadugani, Nilgiri-Wynaad, July 1940; *E. Barnes 2291* (K), Nadugani, Nilgiri-Wynaad, July 1940; *E. Barnes 2292* (K), Nadugani, Nilgiri-Wynaad, July 1940; *R. Plantling 37* (C, L), Sikkim Himalaya, tropical Himalayan valleys, June 1891; *RHT 4224* (C), Salem, Yercoud, sine anno.

Sri Lanka: *G.H.K. Thwaites CP 3768* (C, K, P), Hinidoon Patta, 1867.

China: *G. Barretto 2* (K), Hong Kong, Taimoshan, 9 June 1966; *G. Barretto 9* (K), Hong Kong, Taimoshan, June 1973; *G. Barretto 317* (C), Hong Kong, 25 June 1976; *G. Barretto s.n.* (C), Hong Kong, June 1976; *W.P. Fang 2134* (K), Szechuan, 12 July 1928; *A. Henry 13131* (K), Yunnan, sine loco, 1901; *R.H. Mobbs s.n. (*K), Fukien, Hillide, 29 July 1931.

Taiwan: W.M. Lin s.n. (TAI), Yenchao, 3 July 2008.

Laos: *A.D. Kerr 2610* (C), Vientiane, Ban Noi, That Luang Rd., 12 July 1968.

Philippines: *Ahern 1468* (C, K), Luzon, Batan, Lamao River, Mt. Mariveles, August 1905; *Ahern 3244* (C, K), Luzon, Rizal, August 1905; *T. Lobb s.n.* (K), Luzon, sine anno; *A. Loher 442* (K), Luzon, sine anno; *M. Ramos 1472* (K), Luzon, September 1906; *M. Ramos 4561* (AMES, C), Luzon, Rizal, Bosoboso, August 1907; *M. Ramos 4562* (L), Luzon, Rizal, Bosoboso, August 1907; *M. Ramos 21337* (K), Luzon, Rizal, August 1913; *M. Ramos s.n.* (K, L), Luzon, Laguna, San Antonio, Febuary 1918; *M. Ramos & G. Edano 29515* (K), Luzon, Rizal, Antipolo, July 1917.

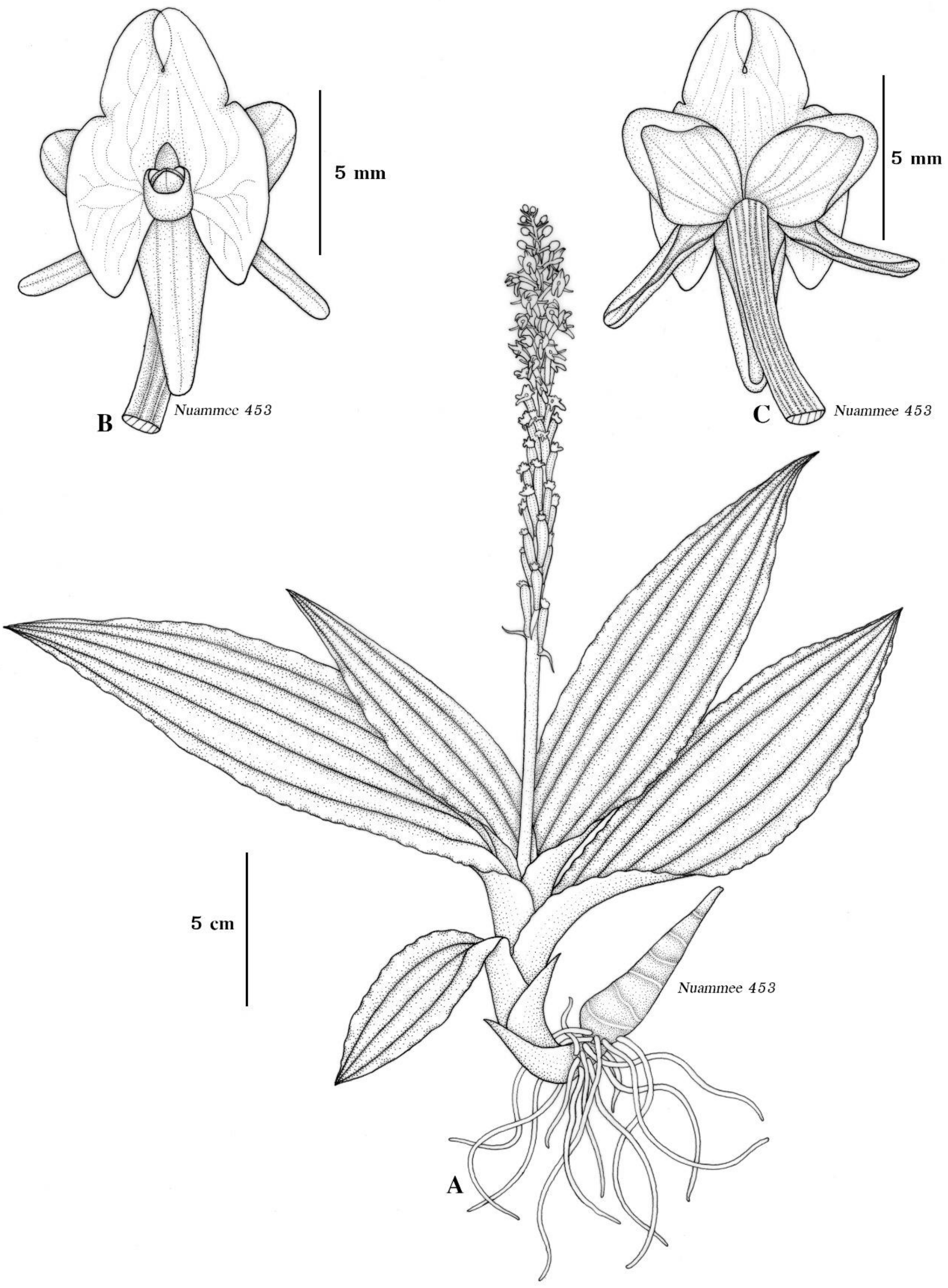

Figure 4.69 *Crepidium purpureum* (Lindl.) Szlach. **A:** Habit. **B:** Flower, front view. **C:** Flower, back view. Drawing from *Nuammee 453* (A–C).

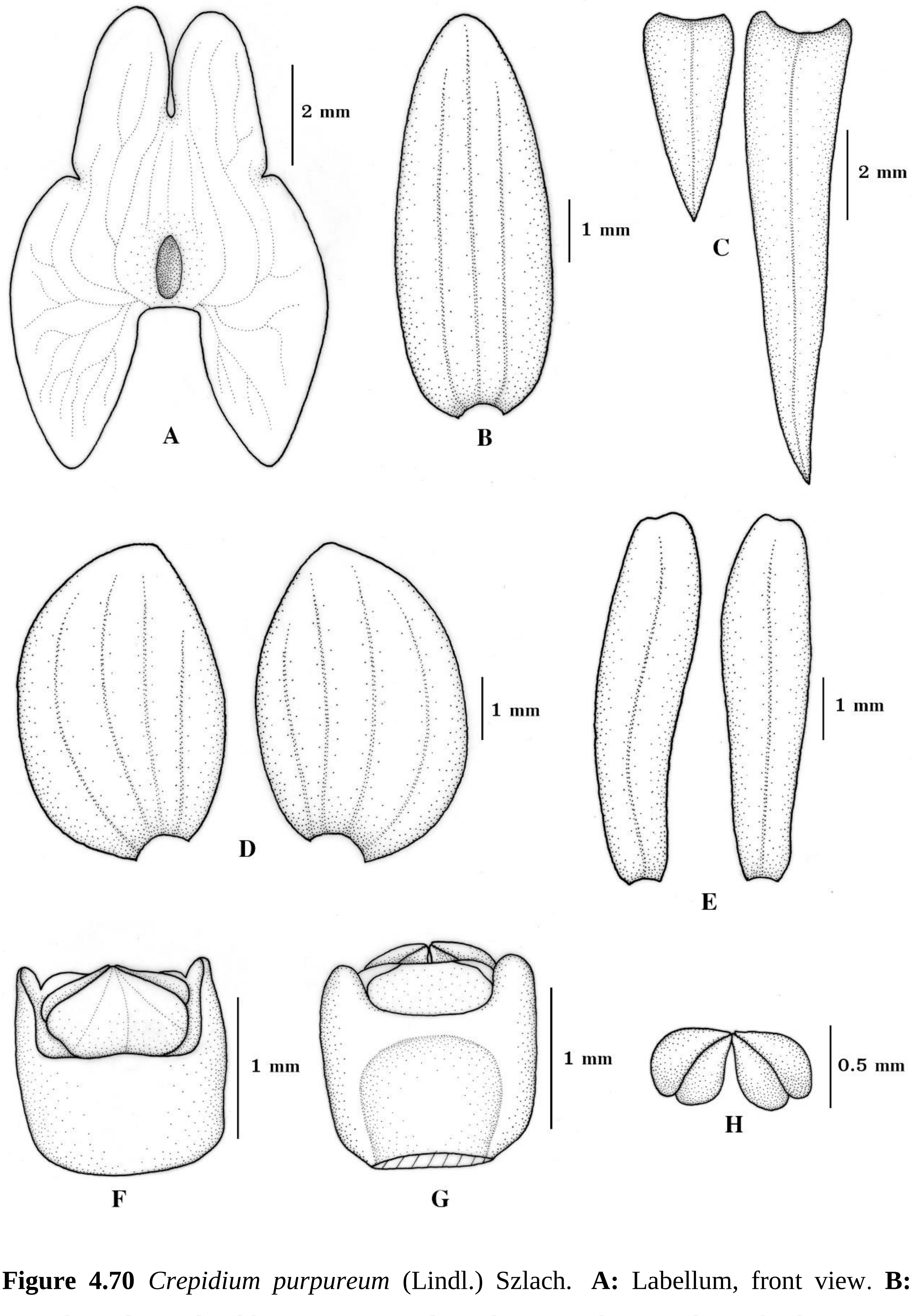

Figure 4.70 *Crepidium purpureum* (Lindl.) Szlach. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bracts. **D:** Lateral sepals. **E.** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Two pairs of pollinia. Drawing from *Nuammee 453* (A–H).

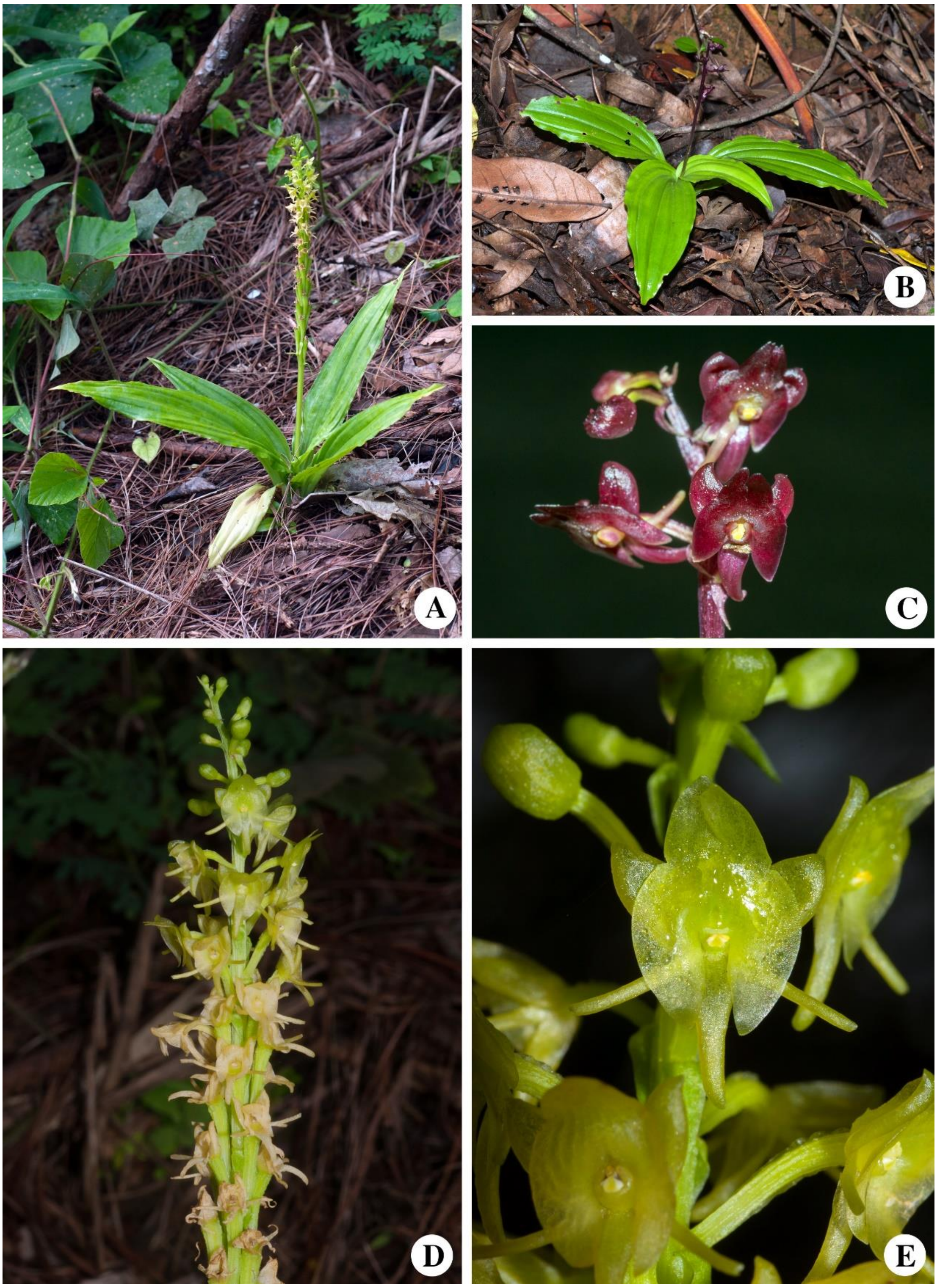

Figure 4.71 *Crepidium purpureum* (Lindl.) Szlach. **A–B:** Habit. **C:** Flowers. **D:** Inflorescence. **E:** Flower, front view. B and C were photographed from Phitsanulok, Phu Hin Rong Kla, 10 July 2014; A, D and E were photographed from Chiang Rai, Doi Thung, 9 October 2016.

25. Crepidium szemaoense (Tang & F. T. Wang) Nuammee, Seelanan, Suddee & H. A. Pedersen, Thai Forest Bull. (Bot.) 44: 36, fig. 1C–D. 2016.— *Malaxis szemaoensis* Tang & F. T. Wang, Acta Phytotax. Sin. 1: 75. 1951.— *M. verruculosa* auct. non (J. J. Sm.) Seidenf., Bot. Tidsskr. 65: 330. 1970.— *M. ovalisepala* auct. non (J. J. Sm.) Seidenf.: Seidenf., Dansk Bot. Arkiv 33(1): 79 p.p., fig. 55. 1978. **Type:** China, Yunnan, Szemao, "N.W. Mts.", 1901, *Henry 13128* [holotype **K!**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect, pseudobulbous, 7–22 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* several, slender, arising from the basal part of the pseudobulbs, 0.5–5 cm long. *Pseudobulbs* green, ovoid to conical, 0.7–3.5 cm long, 0.5–1.3 cm in diameter, consisting of 3–5 internodes. *Cataphylls* 2–4, broadly (triangular-)ovate to lanceolate-oblong (the lowermost tubular), acute, 0.5–5 by 0.3–1.2 cm. *Foliage leaves* 2–4, ascending to spreading, petiolate, petiole sheathing at base, free part 0.5–4.5 cm long, green with tiny red-purple markings, lamina plicate, green to purplish-brown, unspotted, ovate to lanceolate or obovate with slightly asymmetrical base, acute to short-acuminate, 1.2–10 by 1.1–4.7 cm, 3- to 9-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 6–20 cm long, elongating gradually during flowering; peduncle green to greenish-purple, 4.5–12 cm long, 0.1–0.3 cm in diameter; rachis subdensely 8- to 40-flowered; floral bracts persistent, greenish-purple, strongly recurved, (linear-)laceolate to ovate, acuminate, entire, 1.5–8.5 by 0.5–1.5 mm, shorter than ovaries. *Flowers* green (with more or less purple sepals), 4–5 mm in diameter. *Sepals* spreading, obtuse (to truncate), glabrous, margins revolute; dorsal sepal oblong to oblong-lanceolate, 3.5–4 by 1.3–1.5 mm, less than twice as long as labellum auricles; lateral sepals broadly and obliquely ovate to elliptic, 2.5–3 by 1.5–2 mm. *Petals* reflexed, linear-ligulate, truncate, 3.5–4 by 0.4–0.7 mm, margins revolute. *Labellum* (nearly) flat, 4–6 by 3.5–4.5 mm (maximum dimensions), longer than wide, obovate (not constricted at the middle) with a strongly sagittate-auriculate base, distally obtuse to rounded with 3–4(–5) coarse teeth on either side of the apex; basal/central part forming a cavity that is elliptic in outline, bordered by a more or less horseshoe-shaped ridge; auricles obliquely triangular, acute to obtuse, 2.5–3.5 by 1–1.5 mm.

Column pale green, erect, 1–1.5 mm long; staminodes oblong, truncate; anther incumbent, versatile, more than twice as wide as connective, light yellow to pale green, broadly ovate, obtuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.4–0.5 mm long; rostellum transversely rectangular, truncate; fertile part of stigma transversely (sub)elliptic, flat, concave at base. *Ovary* (including pedicel) green to greenish purple, fusiform-cylindrical, with 6 longitudinal ridges, 3–5 mm long, glabrous. *Capsule* clavate, 0.7–1 cm long, 0.3–0.5 cm in diameter; fruit pedicel 0.3–0.5 cm long. Figures 4.72, 4.73 and 4.74.

Thailand.— NORTHERN: Chiang Mai (Doi Chiang Dao), Nan (Tham Sakoen).

Distribution.— China (Yunnan).

Ecology.— *Crepidium szemaoense* grows in humus-rich soil on rock in limestone forest at 900–2,150 m alt. Flowering: June–July.

Vernacular.— Hoo Sua Pak Yak (หูเสือปากหยัก), Hoo Sua Chiang Dao (หูเสือเชียงดาว).

Specimens examined.— **Thailand:** *G. Seidenfaden & T. Smitinand GT 2643* (C), Chiang Mai, Chiang Dao, July 1958; *T. Smitinand 4693* (BKF, C), Chiang Mai, Chiang Dao, 15 July 1958; *P.S. 1017* (BCU), Chiang Mai, Chiang Dao, July 1996; *A. Nuammee 384* (BCU), Chiang Mai, Chiang Dao, 18 October 2013; *A. Nuammee 404* (BCU, BKF), Chiang Mai, Chiang Dao, 23 June 2014; *A. Nuammee 408* (BCU, BKF), Chiang Mai, Chiang Dao, 23 June 2014; *W. La-ongsri et al. 1878* (QBG), Nan, Tham Sakoen, 28 July 2011. **China:** *A. Henry 13128* (K), Yunnan, Szemao, "N.W. Mts.", c. 1525 m alt. 1901.

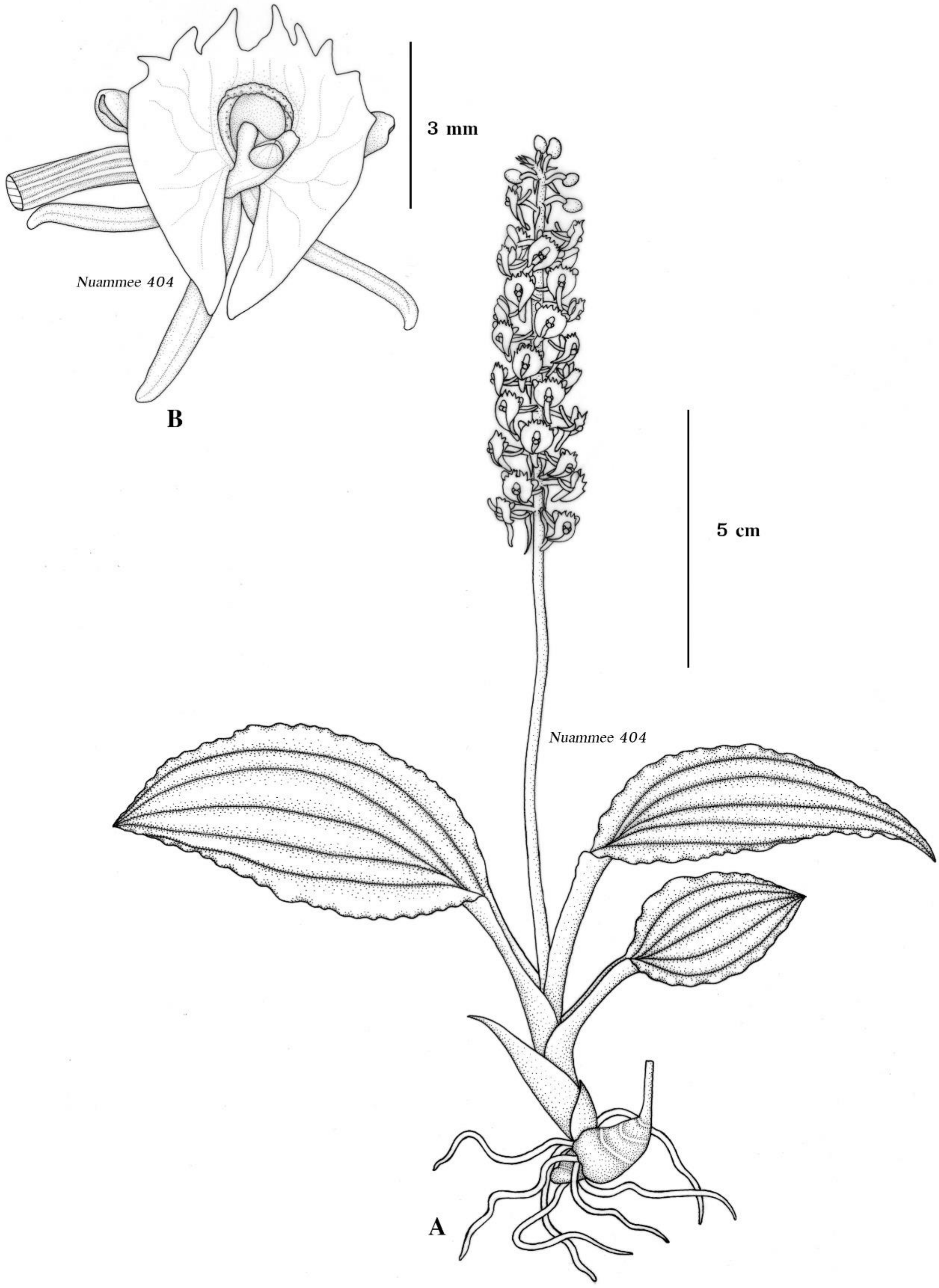

Figure 4.72 *Crepidium szemaoense* (Tang & F. T. Wang) Nuammee, Seelanan, Suddee & H. A. Pedersen. **A:** Habit. **B:** Flower, front view. Drawing from *Nuammee 404* (A–B).

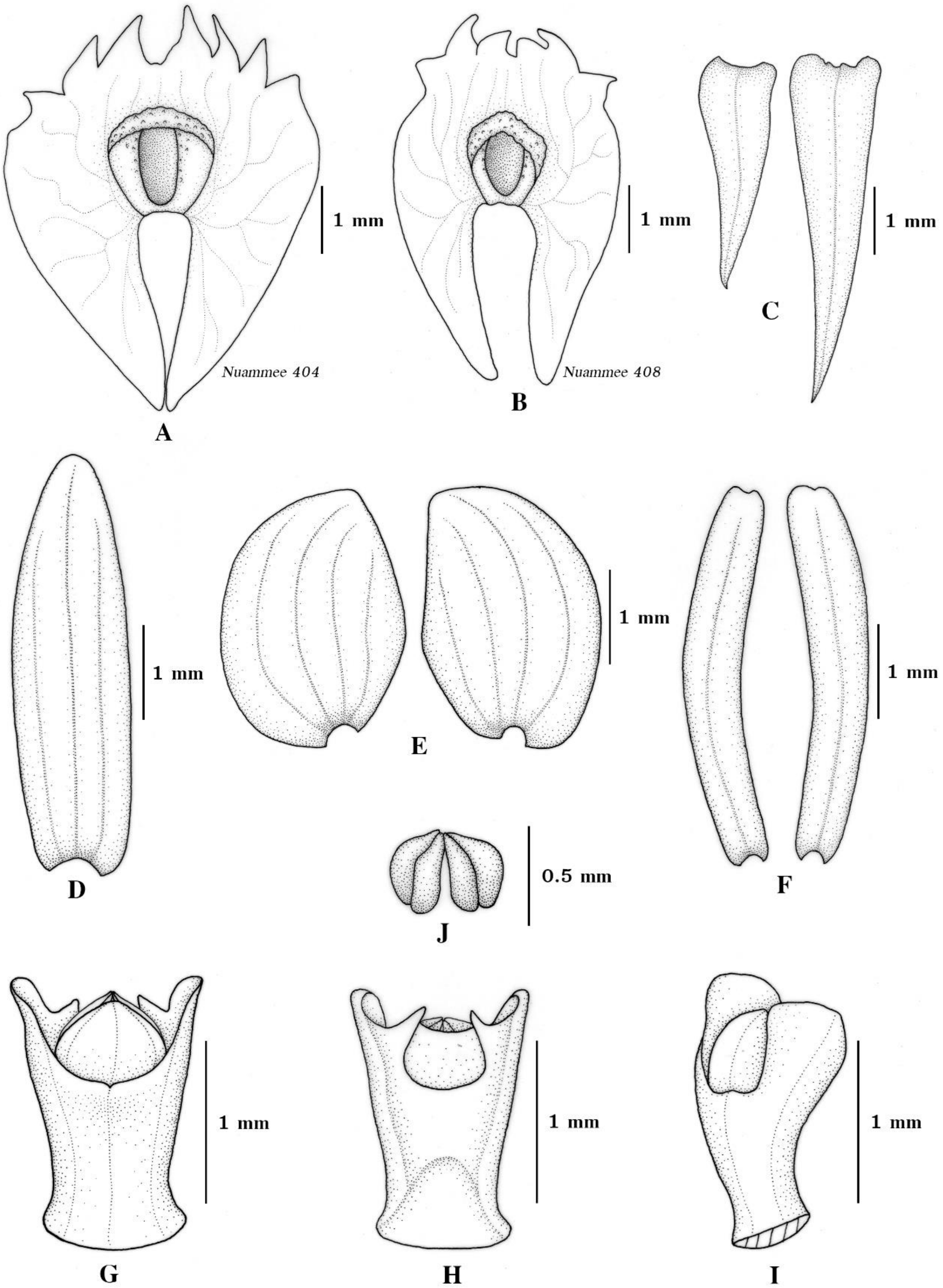

Figure 4.73 *Crepidium szemaoense* (Tang & F. T. Wang) Nuammee, Seelanan, Suddee & H. A. Pedersen. **A–B:** Labellum, front view. **C:** Floral bracts. **D:** Dorsal sepal. **E:** Lateral sepals. **F.** Petals. **G:** Column, back view. **H:** Column, front view. **I:** Column, lateral view. **J:** Two pairs of pollinia. Drawing from *Nuammee 404* (A, C–J); *Nuammee 408* (B).

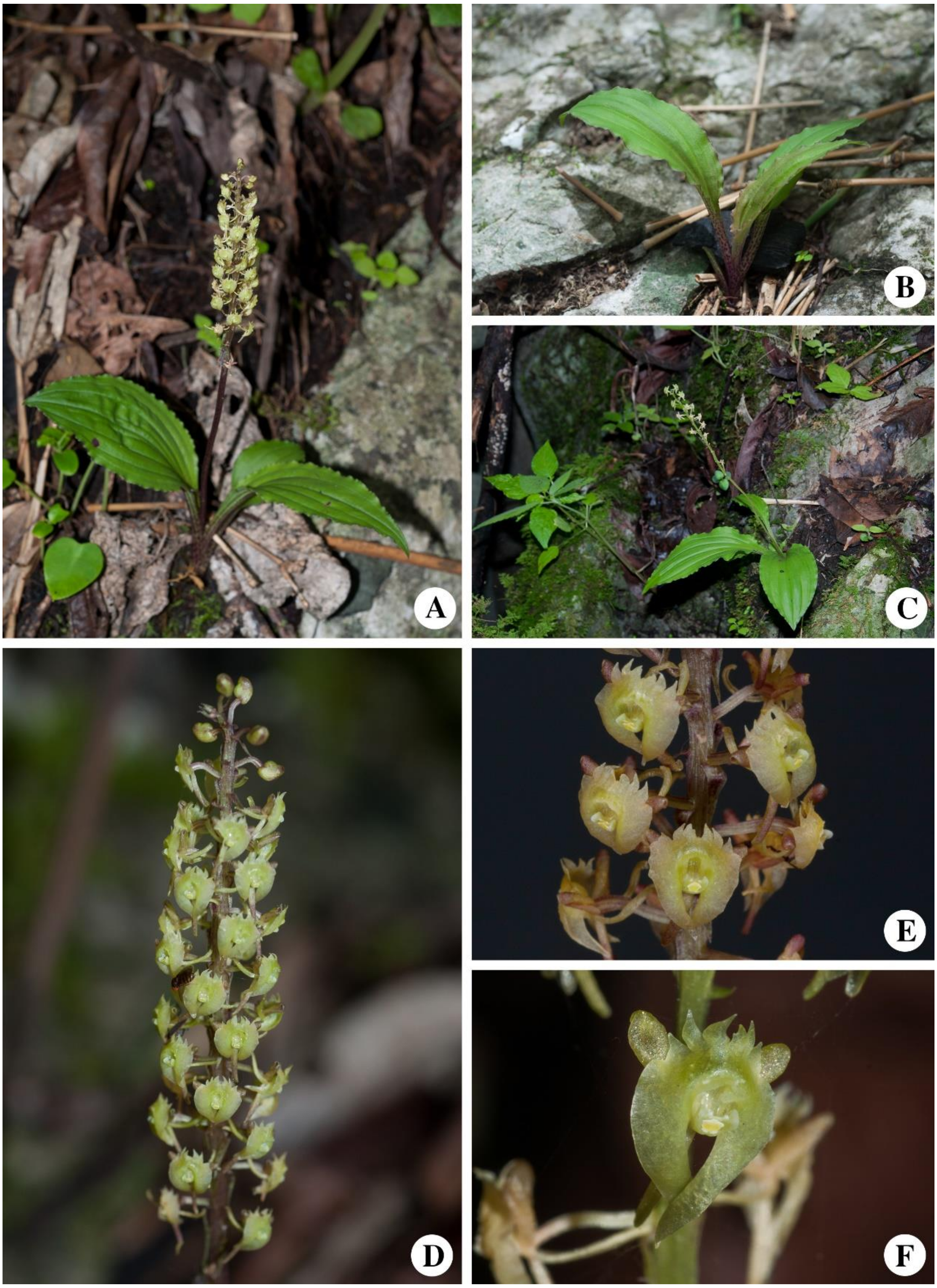

Figure 4.74 *Crepidium szemaoense* (Tang & F. T. Wang) Nuammee, Seelanan, Suddee & H. A. Pedersen. **A–C:** Habit. **D:** Inflorescence. **E–F:** Flower, front view. All were photographed from Chiang Mai, Doi Chiang Dao, 23 June 2014.

2. DIENIA

Lindl., Bot. Reg. 10: t. 825. 1824; Szlach. & Marg., Acta Bot. Fenn. 173: 73. 2002; Pridgeon et al. (eds.), Gen. Orchid. 4: 460. 2005; Marg. & Kowalk., Ann. Bot. Fenn. 45: 98. 2008.— *Gastroglottis* Blume, Bijdr. Fl. Ned. Ind.: 397. 1825.— *Anaphora* Gagnep., Bull. Mus. Natl. Hist. Nat., sér. 2, 4: 592. 1932. **Type species:** *D. congesta* Lindl. [=*D. ophrydis* (J. Koenig) Ormerod & Seidenf.]

Terrestrial, less often epiphytic, sympodial herbs. *Stem* creeping or pseudobulbous. *Roots* arising from the basal part of the pseudobulb or from node of the rhizome. *Foliage leaves* 2 to several, plicate, sessile to petiolate, petiole sheathing at base. *Inflorescence* terminal, erect, racemose, elongating gradually during flowering; floral bracts persistent, often recurved or reflexed, lanceolate, triangular or ovate. *Flowers* usually non-resupinated, green, brown, yellow or purple. *Sepals* free, spreading to reflexed. *Petals* free, spreading, often narrower than sepals. *Labellum* parallel to column, sometimes concave at base, the distal margin entire or distinctly 3-lobed, unadorned or ornamented by an obscure transverse ridge. *Column* erect, stout, straight or nearly so, devoid of a foot, but bearing 2 arm-like wings in its distal part; anther incumbent, versatile, attached by a connective less than half as wide, locules opening ventrally; pollinia 4 in 2 pairs, almost equal in size, obliquely clavate, lacking caudicles; rostellum transversely rectangular, obtuse, producing a minute viscidium; fertile part of stigma semicircular or transversely elliptic. *Ovary* (including pedicel) cylindrical, with 6 longitudinal ridges, glabrous. *Fruit* a distinctly pedicelled capsule dehiscing by longitudinal slits.

A genus of c. 4 species are widely distributed from mainland S/SE Asia across Malesia to Queensland and the SW Pacific islands; 1 species in Thailand.

1. Dienia ophrydis (J. Koenig) Ormerod & Seidenf. in Seidenf., Contr. Orchid Fl. Thailand XIII: 18. 1997; S. C. Chen & J. J. Wood in Z. Wu et al. (eds.), Fl. China 25: 235. 2009; Barretto et al., Wild Orchids Hong Kong: 327, figs. 272–275. 2011; Srisom & Rayangkool, Orchids Huai Kha Khaeng: 263, colour photos on pp. 260–263. 2015.— *Epidendrum ophrydis* J. Koenig in Retz., Observ. Bot. 6: 46. 1791.— *Malaxis ophrydis* (J. Koenig) Ormerod in Seidenf., Descr. Epidendrorum J. G. König:

18. 1995; J. B. Comber, Orchids Sumatra: 172. 2001; T. E. Beaman et al., Orchids Sarawak: 345. 2001; N. Pearce & P. J. Cribb, Fl. Bhutan 3(3): 49. 2002.— *Crepidium ophrydis* (J. Koenig) M. A. Clem. & D. L. Jones, Lasianthera 1: 38. 1996.— *Gastroglottis ophrydis* (J. Koenig) A. N. Rao, Bull. Arunachal Forest Res. 26: 103. 2010. **Type:** India, sine loco, sine anno, *Koenig s.n.* [lectotype **K!**].

— *Malaxis latifolia* Sm. in Rees, Cycl. 22: no. 3. 1819; Seidenf. & Smitinand, Orchids Thailand: 146, 761, fig. 112. 1959–1965; Holttum, Orchids Malaya 1: 195. 1964; Deva & H. B. Naithani, Orchids Fl. North West Himalaya: 315. fig. 179. 1986; Seidenf., Dansk Bot. Arkiv 33(1): 45, fig. 35. 1978; Seidenf., Opera Bot. 114: 146. 1992; Seidenf. & J. J. Wood, Orchids Penins. Malaysia Singapore: 219, fig. 93a–c, t. 13b. 1992; Thaithong, Thai Orchids: 278, colour photos on pp. 278–279. 2000.— *Microstylis latifolia* (Sm.) J. J. Sm., Fl. Buitenz. 6: 248. fig. 185. 1905; J. J. Sm., Orchids Java: 248. 1905.— *Gastroglottis latifolia* (Sm.) Szlach., Fragm. Florist. Geobot. Suppl. 3: 123. 1995.— *Dienia latifolia* (Sm.) M. A. Clem. & D. L. Jones, Lasianthera 1: 38. 1996. **Type:** Nepal, sine loco, 1806, *Buchanan-Hamilton s.n.* in Herb. J. E. Smith *1396.3.1* [holotype **LINN!**].

— *Dienia congesta* Lindl., Bot. Reg. 10: t. 825. 1824.— *Microstylis congesta* (Lindl.) Rchb. f. in Walp., Ann. Bot. Syst. 6: 206. 1861; Hook. f., Fl. Brit. India 5: 689. 1890; B. Grant, Orchids Burma: 16. 1895; King & Pantl., Ann. Roy. Bot. Gard. (Calcutta) 8: 19, fig. 23. 1898.— *Malaxis congesta* (Lindl.) Deb, Bull. Bot. Surv. India 3: 128. 1962. **Type:** Nepal, Narainhetty, 1821, *Wallich 1936* [holotype **K!**, isotypes **E! L!**].

— *Gastroglottis montana* Blume, Bijdr. Fl. Ned. Ind.: 397. 1825.— *Dienia montana* (Blume) M. A. Clem. & D. L. Jones, Lasianthera 1: 41. 1996. **Type:** Indonesia, Java, sine anno, *Blume s.n.* [holotype **L!**].

— *Neottia plantaginea* D. Don, Prodr. Fl. Nepal: 27. 1825, *nom. illeg.*— *Spiranthes plantaginea* (D. Don) Spreng., Syst. Veg. 3: 708. 1826.— *Gyrostrachys plantaginea* (D. Don ex Spreng.) Kuntze, Revis. Gen. Pl. 2: 664. 1891. **Type:** Nepal, Hab. in Gosaingsthan Napalensium, *Wallich s.n.* [not seen].

— *Dienia fusca* Lindl., Gen. Sp. Orchid. Pl. 22: 1830.— *Microstylis fusca* (Lindl.) Rchb. f., Ann. Bot. Syst. 6: 207. 1861.— *Microstylis congesta* var. *fusca* (Lindl.) Ridl., J. Linn. Soc. 24: 335. 1888.— *Microstylis latifolia* var. *fusca* (Lindl.)

Ames, Phil. J. Sci. 6: 45. 1911. **Type:** Sri Lanka, sine loco, 1829, *Macrae 7* [holotype **K!**, isotype **L!**].

— *Malaxis plicata* Roxb., Hort. Bengal. 68. 1814, *nom. nud.*, Fl. Ind. ed. 1832, 3: 456. 1832. **Type:** Indonesia, Sumatra, sine loco, 1804, *Roxburgh s.n.* [not seen].

— *Microstylis trilobulata* Kurz, Rep. Veg. Andaman Island, App. B: 19. 1870. **Type:** India**,** Andaman Islands, sine anno, *Berkeley s.n.* [holotype **K!**].

— *Microstylis bernaysii* F. Muell., Fragm. Phyt. Austr. 11: 21. 1878.— *Liparis bernaysii* (F. Muell.) F. M. Bailey, Syn. Queensl. Fl.: 508. 1883. **Type:** Australia, Trinity Bay, 1878, *Bailey s.n.* [holotype **MEL**, isotype **BM**].

— *Malaxis curranii* Ames, Philipp. J. Sci., C 6: 44. 1911.— *Dienia curranii* (Ames) M. A. Clem. & D. L. Jones, Lasianthera 1: 41. 1996. **Type:** Philippines, Luzon, Benguet, 1906, *Curran s.n.* [holotype **AMES!**, isotype **K!**].

— *Microstylis volkensii* Schltr., Bot. Jahrb. Syst. 56: 458. 1921.— *Malaxis volkensii* (Schltr.) Fosberg & Sachet, Micronesica, 20(1–2): 143. 1987.— *Dienia volkensii* (Schltr.) M. A. Clem. & D. L. Jones, Lasianthera 1: 42. 1996. **Type:** Palau Islands, 1914, *Ledermann 14571* [syntype **B**]; Caroline Islands, Yap Island Mashabal, *Volkens 174* [syntype **B**].

— *Microstylis carnosula* Rolfe ex Downie, Bull. Misc. Inform. Kew 1925: 368. 1925.— *Malaxis carnosula* (Rolfe ex Downie) Seidenf. & Smitinand, Orchids Thailand: 146. 1959.— *Glossochilopsis carnosula* (Rolfe ex Downie) Szlach. & Marg., Polish Bot. J. 46: 114. 2001. **Type:** Thailand, Chiang Mai, Doi Suthep, 27 August 1911, *Kerr 278* [holotype **K!**, isotype **K!**].

— *Liparis krempfii* Gagnep., Bull. Soc. Bot. France 76: 514. 1929. **Type:** Vietnam, Ton Ha Sui, August 1912, *Krempf 1570* [holotype **P!**].

— *Liparis turfosa* Gagnep., Bull. Soc. Bot. France 76: 515. 1929. **Type:** Vietnam, Massif de la Mere et de l'Enfant, Nhatrang, 24 May 1923, *Poilane 6822* [holotype **P!**].

— *Anaphora liparioides* Gagnep., Bull. Mus. Natl. Hist. Nat., II, 4: 592. 1932. **Type:** Vietnam, Tourane, 13 September 1923, *Poilane 7941* [holotype **P!**].

— *Microstylis kizanensis* Masam., Ann. Rep. Kaihoku Bot. Garden 3: 75. 1933.— *Malaxis kizanensis* (Masam.) Hatsusima, Fl. Ryukyus: 863. 1971. **Type:**

Taiwan, Yilan, Kueishan Island, 3 July 1932, *Masamune & Suzaki s.n.* [holotype **TAI!**].

— *Microstylis ishigakensis* Ohwi, J. Jap. Bot. 13: 439. 1937. **Type:** Japan, Ryukyu, Ishigaki Island, sine anno, *Koidznmi s.n.* [holotype **KYO**].

— *Microstylis dalatensis* Guillaumin, Bull. Mus. Natl. Hist. Nat. II, 27: 397. 1955. **Type:** Vietnam, Annam, Dalat, 1955, *C.R.S.T. 38* [holotype **P!**].

— *Malaxis parvissima* S. Y. Hu & Barretto, Chung Chi J. 13(2): 22. 1976. **Type:** Hong Kong, New Territories, Tai Mo Shan, 28 June 1972, *Hu 12453* [holotype **K!**, isotype **CUH**].

— *Malaxis shuicae* S. S. Ying, J. Jap. Bot. 62: 70. 1987.— *Dienia shuicae* (S. S. Ying) T. P. Lin, Lin et al., Taiwania 61(2): 95. 2016. **Type:** Taiwan, Pingtung, Shui-Ca Kaohsuing Hsien, 14 February 1986, *Ying s.n.* [holotype **NTUF!**].

— *Malaxis sampoae* T. P. Lin & W. M. Lin, Taiwania 56(4): 319. fig. 4. 2011. **Type:** Taiwan, Shouka, Pingtung, 21 July 2010, *Lin s.n.* [holotype **TAI**].

Terrestrial, sympodial herb with a strongly condensed rhizome, bearing an erect, pseudobulbous, 20–60 cm tall flowering shoot distally and 1 decaying pseudobulb behind. *Roots* several, arising from the basal part of the pseudobulbs, 0.5–10 cm long. *Pseudobulbs* green, fleshy, cylindrical to terete from turbinate base, 5–20 cm long, 0.5–2 cm in diameter, consisting of 5–7 internodes. *Cataphylls* 3–5, broadly triangular-ovate to lanceolate-oblong (the lowermost tubular), acute to acuminate 1–14 by 0.6–5 cm. *Foliage leaves* (3)4–6, ascending to spreading or erect, petiolate, sheathing at base; petiole pale green with more or less purple-veined, 0.5–3.5 cm long; lamina plicate, green with more or less purplish veins beneath, unspotted, broadly elliptic to (oblong-)ovate or lanceolate with slightly asymmetrical base, acute to acuminate, 7–25 by 2–10 cm, 5- to 9-veined, glabrous, margins undulate. *Inflorescence* terminal on the young pseudobulb, racemose, erect, 10–40 cm long; peduncle light green to brownish-purple, 5–25 cm long, 0.1–0.6 cm in diameter, elongating gradually during flowering; rachis densely 20-to 300-flowered; floral bracts pale green, strongly recurved, (linear-)lanceolate, acuminate, entire, 2–7 by 0.5–1 mm, longer than ovaries. *Flowers* greenish-yellow, green or purplish-green when young, and turning into greenish-yellow, pink, red-purple, to dark violet with age, 3–6 mm in diameter, usually facing downwards. *Sepals* subacute to rounded, glabrous, margins recurved; dorsal sepal slightly incurved, oblong to oblong-lanceolate, 3–4 by 1–1.8 mm; lateral sepals curved inward and forward, obliquely ovate to elliptic, 3–3.5 by 1.5–2 mm. *Petals* incurved, narrowly oblanceolate to linear, subacute to rounded, 2.2–3.5 by 0.4–1 mm, margins recurved. *Labellum* parallel to column, strongly concave in its basal/central part, 2–3 by 3.5–4.5 mm, suborbicular to subcordate, 3-lobed in its distal part, mid-lobe narrowly ovate to oblong, subacute to obtuse; basal/central part forming a strongly concave cavity that is ovate to suborbicular in outline, bordered by 2 convex nerves, labellum base attached to the base of column. *Column* pale green, cylindrical, erect, 1–2 mm long; staminodes small and very short, subacute; anther incumbent, versatile, more than twice as wide as connective, orange-yellow, broadly ovate, obtuse, 2-chambered; pollinia 4 in 2 pairs, (sub)equal in size, obliquely clavate, hard, 0.3–0.4 mm long; rostellum transversely rectangular, obtuse, producing a minute viscidium; fertile part of stigma transversely elliptic, flat. *Ovary* (including pedicel) pale green, cylindrical, with 6 longitudinal ridges, 3–5 mm long, glabrous. *Capsule* obovoid to ellipsoid, 0.4–1 cm long, 0.2–0.5 cm in diameter; fruit pedicel 0.2–0.3 cm long. Figures 4.75, 4.76 and 4.77.

Thailand.— NORTHERN: Mae Hong Son, Chiang Mai, Chiang Rai, Lampang, Nan (Doi Phu Kha, Pua), Phitsanulok, Nakhon Sawan; NORTH-EASTERN: Loei (Phu Luang); EASTERN: Nakhon Ratchasima (Khao Yai); SOUTH-WESTERN: Tak, Uthai Thani (Huai Kha Khaeng), Kanchanaburi (Thong Pha Phum), Prachuap Kriri Khan; SOUTH-EASTERN: Chanthaburi, Trat; PENINSULAR: Chumphon, Surat Thani (Ko Pa-ngan), Phangnga, Krabi, Nakhon Si Thammarat, Satun (Ko Talutao), Songkhla (Padang Besar), Yala (Betong), Narathiwat.

Distribution.— India, Sri Lanka, Nepal, Bhutan, Myanmar, China, Taiwan, Japan (Ryukyu Islands), Vietnam, Laos, Cambodia, Malaysia, Indonesia, Brunei, Philippines, New Guinea, Queensland and the SW Pacific islands.

Ecology.— Terrestrial on sand, clay or humus-rich soil, somestimes on mossy rocks or in leaf-litter on rocks; tolerates both open and shaded habitats (e.g. grassy road sides, forest edges and wet stream banks in forest). Tropical rain forest, bamboo thickets and hill evergreen forest; 0–2000 m alt. Flowering: June–July.

Note.— *Dienia ophrydis* is one of the most common and widely distributed species within the tribe Malaxideae. Mainly due to its remarkably wide range of variation in flower colour and in size of the whole plant as well as the individual organs, the species has been described more than 20 times. However, *D. ophrydis* can be recognized by a number of floral traits. Thus, the flowers are usually facing downwards, the sepals and petals are curved inwards and forwards, the labellum is markedly concave and distally 3-lobed, and the column is cylindrical with only very short arm-like wings.

Specimens examined.— **Thailand:** *M. van de Bult 1080* (BKF), Chiang Rai, Mae Fa Luang, Doi Tung, 13 October 2010; *K. Chayamarit et al. 1400* (BKF), Loei, Phu Luang, 14 May 1998; *Cumberlege 905* (K), Nakhon Ratchasima, Khao Yai, sine anno; *Cumberlege 1194* (C), Nakhon Ratchasima, Khao Yai, sine anno; *Cumberlege 1358* (C), Prachuap Khiri Khan, Ban Klong Loi, 9 July 1966; *Camberlege s.n*. (L), Chiang Mai, Ang Ka, 29 June 1909; *R. Geesink et al. 7337* (L), Satun, Ko Talutao waterfalls, 20 June 1974; *A.F.G. Kerr 230* (K), Chiang Mai, Mae Sa, 24 July 1915; *A.F.G. Kerr 231* (K), Chiang Mai, 3 July 1922; *A.F.G. Kerr 251* (K), Chiang Mai, Doi Suthep, 10 July 1910; *A.F.G. Kerr 278* (K), Chiang Mai, Doi Suthep, 27 August 1911; *A.F.G. Kerr 371* (K), Yala, Batong, 23 May 1919; *A.F.G. Kerr 459* (K), Nakhon Sawan, Khao Pado, 4 June 1922; *A.F.G. Kerr s.n.* (K), Chiang Mai, Doi Suthep, 2 July 1921; *A.F.G. Kerr s.n.* (K), Bangkok, 7 September 1927; *A.F.G. Kerr s.n.* (K), sine loco, 5 August 1928; *Khontohai 176* (BKF), Chiang Mai, Doi Chiang Dao, 21 June 1955; *K. Larsen et al. 42999* (AUU, C, P), Narathiwat, Pong Pong Falls, 19 June 1992; *J.F. Maxwell 72-237* (L), Chanthaburi, Lam Sing, Pliew Falls, 28 May 1972; *J.F. Maxwell 96-738* (BKF, L), Lampang, Mueng Pan, 28 May 1996; *J.F. Maxwell 06-467* (QBG, L), Chiang Rai, Mae Fa Luang, Doi Tung, 20 July 2006; *J.F. Maxwell 07-379* (QBG, L), Chiang Rai, Doi Tung, 2 June 2007; *J.F.*

Maxwell 08-231 (QBG), Chiang Rai, Mae Fa Luang, Mt. Pu Du Kaw, 27 November 2008; *G. Murata et al. T-17446* (BKF), Trat, Ko Chang, 2 August 1973; *W. Nanakorn et al. 11243* (QBG), Chiang Mai, Mae Rim, Huai Poo, 18 May 1998; *C. Niomdham & Veachiraka 1927* (C), Narathiwat, Tak Bai, Kun Jun, sine anno; *M. Norsaengsri 1614* (QBG), Chiang Mai, Wieng Haeng, Ban Lao Wa, 18 July 2001; *A. Nuammee 400* (BKF), Nakhon Ratchasima, Khao Yai, 24 May 2014; *A. Nuammee 402* (BKF), Trat, Ko Chang, 5 December 2013; *A. Nuammee 456* (BCU), Trat, Ko Kut, 10 June 2018; *C. Phengklai et al. 4132* (BKF), Chiang Mai, Ang Ka Noi, 26 June 1978; *C. Phengklai et al. 6937* (BKF), Chiang Mai, Doi Inthanon, 26 July 1988; *C. Phengklai et al. 15475* (BKF), Trat, Ko Kut, 3 December 2006; *S. Pumicong 285* (QBG), sine loco, sine anno; *P. Suksathan 4243* (QBG), Mae Hong Son, Nong Pla Laam, Ban Rak Thai, sine anno; *R. Pooma et al. 1953* (BKF), Satun, Thale Ban, 3 June 2001; *Put 765* (K, L), Surat Thani, Ko Pha-ngan, 3 June 1927; *Rabie 36* (K), Trat, Ko Chang, Salak Khok, 6 June 1925; *Sanan 507* (BKF), Surat Thani, Ban Na San, Krasum, 15 October 1954; *G. Seidenfaden & T. Smitinand GT 2697* (C), Chiang Mai, Doi Suthep, August 1958; *G. Seidenfaden & T. Smitinand GT 3562* (C), Trat, Ko Kut, June 1959; *G. Seidenfaden & T. Smitinand GT 5026* (C), Chiang Mai, 6 km North of Omkoi, 9 June 1964; *G. Seidenfaden & T. Smitinand GT 5027* (C), Chiang Mai, 6 km North of Omkoi, 21 June 1968; *G. Seidenfaden & T. Smitinand GT 5263* (C), Chiang Mai, Bo Luang, 12 June 1965; *G. Seidenfaden & T. Smitinand GT 6238* (C), Krabi, Khao Thong Tai, 4 July 1968; *G. Seidenfaden & T. Smitinand GT 7348* (C), Tak, 90 km South of Tak, 28 June 1968; *P. Srisanga 940* (BKF, QBG), Nan, Doi Phu Kha, 26 July 1999; *P. Srisanga 1925* (QBG), Nan, Doi Phu Kha, Tham Pha Khaw, 5 July 2001; *S. Watthana 665* (QBG), Chiang Rai, Chom Thong, Doi Song Mai, 21 August 1999; *S. Watthana & S. Pumicong 2065* (QBG), Phangnga, Tabpud, 24 June 2006; *S. Watthana 2354* (BKF, QBG), Chiang Rai, Wiang Pa Pao, Doi Pee Pan Nam, 26 June 2007.

Nepal: *Buchanan-Hamilton s.n.* (LINN in Herb. J.E. Smith *1396.3.1*), sine loco, 1806; *Sine coll. s.n.* (K), Narainhetty, 12 August 1802; B.R. *Sharma s.n.* (K), Sahid Smarak, Hetauda, 25 July 2003; *G. Wilson & Phillips 134A* (K), Gulbannjyang, N. Kathmandu, 2,600 m alt., 25 June 1973; *N. Wallich 1936*, (K, L), Narainhetty, 1821, 1829.

India: *A. Abraham 3150* (K), S. India, Jrivandrum, 25 June 1956; *N.E. Berkeley s.n.* (K), Andaman Islands, sine anno; *T.R. Chand 3427* (K), Assam, Takubama, Naga Hills, 13 August 1950; *C.B. Clarke 20204* (K), Chota Nagpur Plateau, Mt. Parasnath, 3 December 1873; *C.B. Clarke 36589* (K), Sikkim Terai, Dulkayhar, 15 October 1884; *C.B. Clarke 42327* (K), Mrokoo, 30 November 1885; *W.G. Craib 514* (P), N. Cachar, Assam, Haflong, 28 August 1908; *Herb. Griffith 5366* (K), E. Bengal, Khasia Hills, sine anno; *J.D. Hooker & T. Thomson 1073* (K), Mt. Khasia, 22 July 1950; *J.D. Hooker & T. Thomson 1795* (K), Mt. Khasia, 19 July 1950; *J.D. Hooker s.n.* (K), Sikkim, sine anno; *J.D. Hooker s.n.* (K), Sikkim, sine anno; *King's collectors s.n.* (P), Sikkim Himalaya, Namga, August 1886; *J. G. König s.n.* (K), sine loco, sine anno; *H. Kurzweil* 143 (K), W. Bengal, Darjeeling, Kalimpong, 3 July 1983; *Lobb. s.n.* (K), Khasia hills, sine anno; *Lobb. s.n.* (K), Khasia Hills, sine anno; *N.G. Nair s.n.* (SING), Andamans-Nicobar Islands, Mt. Harriet, 16 January 1974; *R. Pantling 89* (K, L, P), Sikkim Himalaya, tropical valleys, July 1891; *Pradhan 5* (C), West Bengal, Darjeeling, Kalimpong, sine anno; *N. Wallich 1832* (K), sine loco, 14 September 1936.

Sri Lanka: *Macrae 7* (K, L), sine loco, 1829.

China: *G. Barretto s.n.* (K), Hong Kong, New Territories, Mt. Lead Mine Pass, June 1968; *G. Barretto s.n.* (K), Hong Kong, New Territories, Ma On Shan, 26 September 1968; *Bons d'Anty 448* (P), Yunnan, Kien Kanhong, 28 August 1897; *C.E. Carr s.n.* (SING), Hong Kong, Victoria Peak, 10 November 1934; *A. Henry 12336* (K), Yunan, Szemao, 1900; *S.Y. Hu 10520* (K), Hong Kong, New Territories, Ma On Shan, 30 June 1970; *S.Y. Hu 10734* (K), Hong Kong, New Territories, Jubilee Reservoir, 28 July 1970; *S.Y. Hu 12453* (K), Hong Kong, New Territories, Tai Mo Shan, 28 June 1972; *W.T. Tsang 451* (K), Hainan, Sha Po Shan, 23 June 1928; *W.T. Tsang 26836* (K), Kwangtung, Kung P'ing Shan, 18 September 1936.

Taiwan: *H.-Y. Chen 273* (TAI), Pingtung, Shouka, 23 August 1998; *S.-F. Cheng 471* (TAI), Nantou, Lungfeng waterfalls, 19 August 2006; *A. Henry 835* (K), Formosa, sine anno; *S.F. Huang 4818* (TAI), Taoyuan, Kuanhsi-Fusing, 1 June 1992; *C.M. Kuo 5388* (TAI), Taipei, Wanli, 26 June 1974; *W. Lin s.n.* (TAI), Pingtung, Silingashan, 13 August 2008; *G. Masamune & S. Suzaki s.n.* (TAI), Yilan, Kueishan Island, 3 July 1932; *T. Sata 1160* (TAI), Taitung, Lanyu, Langtao-Shasheshan, 7

August 1932; *T. Sata 1161* (TAI), Taitung, Lanyu, Langtao-Shasheshan, 7 August 1932; *S.S. Ying s.n.* (NTUF), Pingtung, Shui-Ca Kaohsuing Hsien, 14 February 1986.

Japan: *M. Furuse 4031* (K), Ryukyu, Ishigaki Island, Mt. Omoto, 13 February 1973; *M. Furuse 4032* (K), Ryukyu, Ishigaki Island, Mt. Omoto, 16 September 1973; *M. Furuse 4506* (K), Ryukyu, Iriomote Island, Mt. Omoto, 5 November 1973.

Vietnam: *C.R.S.T. 38* (C, P), Annam, Dalat, 1955; *E. Contest-Lacour 78* (P), IIe de Phu- Quôc, September 1874; *N.V. Du et al. HNK 2289* (K), Ban Pieng, Ngoc Chien, Son La, 3 October 2008; *P.A. Eberhardt 81b* (P), Annam, 12 December 1912; *F.J. Harmand s.n.* (P), Poulo-Condor, sine anno; *B. Hayata s.n.* (P), Dran, 14 June 1921; *A. Krempf 1570* (P), Ton Ha Sui, August 1912; *L. Pierre s.n.* (P), Phu-Quoc, 1 September 1874; *E. Poilane 6822* (P), Massif de la Mere et de l’Enfant, Nhatrang, 24 May 1923; *E. Poilane 7941* (P), Tourane, 13 September 1923 *E. Poilane 18478* (P), Annam, Kontum, Dak Ha et Dak Tô, 3 October 1930.

Laos: *A.D. Kerr 1168* (C), Vientiane, sine anno; *A.D. Kerr 1173* (C), Phone Hong, Thalat Rd., sine anno; *L. Vaughan 8124* (C), sine loco, sine anno; *L. Vaughan 8126* (C), sine loco, sine anno.

Cambodia: *F.F. Godefroy 534* (P), Mont de Pursat, 20 June 1875; *Gourgand s.n.* (P), sine loco, sine anno; *L. Pierre s.n.* (P), Angkor, July 1875; *C. Thorel 2101* (P), Angkor, sine anno.

Malaysia: *V.M. Alvins 1668* (SING), Malacca, Chabau, 26 September 1885; *B. & K. Bremer 1601* (L), Pahang, Bentong, 22 September 1979; *J. & M.S. Clemens 27005* (K, L), Borneo, Kinabalu, 31 July 1931; *C. Curtis s.n.* (SING), Langkawi, sine anno; *C. Curtis s.n.* (SING), Pulau Penang, Pulau Betong, June 1892; *C. Curtis s.n.* (SING), Siamese Island, May 1894; *C. Curtis s.n.* (SING), Pulau Penang, May 1898; *C. Curtis s.n.* (SING), Langkawi, September 1900; *C. Curtis 3121* (K, SING), Pulau Penang, Pulau Betong, September 1894; *C.E. Carr 27366* (SING), N. Borneo, Dallas, Kinabalu, 10 May 1933; *R. Derry 100* (SING), Malacca, Sungei Udang Reserve, December 1886; *R. Derry 162* (SING), Malacca, Sungei Udang Reserve, December 1889; *J.S. Goodenough 1408* (SING), Malacca, Ayer Panas, 1893; *J.S. Goodenough 1486* (SING), Malacca, September 1893; *Hort Bot Singapore SBGO 3571* (L, SING), Perak, Maxwell Hills, sine anno; *M.R. Henderson s.n.* (SING), Kedah, Pulau Langkawi, Selat Punchor, November 1934; *M.R. Henderson s.n.* (K), Pulau

Langkawi, Selat Panchor, November 1934; *A. Ibrahim & R. Kiew 520* (SING), Sabah, Labuk Sugut, Ulu Sapapayun, 2 September 1999; *M. Jutta 54226* (K, SING), Perak, Hulu Perak, Bintang Hijau, 15 May 2007; *M. Jutta 54237* (L), Perak, Hulu Perak, Bintang Hijau, 13 June 2007; *E. Langlassé* 163 (P), Borneo, Foret de Kianji, 8 August 1894; *C.W. Lek 149* (SING), Langkawi, Dayang Bunting, 16 May 1957; *L. Lugas 2879* (K), Sabah, Kota Belud, Kampung Melangkap Tomis, 27 July 1998; *A.C. Maingay 1601*, sine loco, sine anno; *L. Madani et al. 133069* (L), Borneo, Sabah, Ulu Keleng, 18 September 1991; *H.N. Ridley 7060* (SING), Penang, sine loco, December 1895; *H.N. Ridley s.n.* (SING), Perak, Maxwell Hill, 1892; *H.N. Ridley s.n.* (SING), Malacca, Bukit Bata Tiga, July 1889; *H.N. Ridley s.n.* (SING), Penang, sine loco, June 1898; *H.N. Ridley s.n.* (SING), Perlis, sine loco, 1910; *H.N. Ridley s.n.* (K), Sarawak, sine loco, June 1915; *S. Sambuling 73* (K), Sabah, Kota Belud, Kampung Melangkap Tomis, 3 December 1993; *B.C. Stone 14813* (L), Palau Langkawi, Gunung Raya, 13 November 1979; *P.M. Synge 46* (K), Sarawak, Marudi, 27 July 1932; *L. Vaughan 9* (C), Kedah Peak, October 1981; *L. Vaughan 8104* (C), Penang Hills, sine anno; *L. Vaughan 8105* (C), Penang Hills, sine anno; *E.F. de Vogel 1492* (L), Sarawak, Mt. Hose, 13 March 1974; *Sine coll. 3121* (K), Pulau Penang, September 1894; *Sine coll. 3922* (K), Chau Chu Kay, 1892; *Sine coll. s.n.* (K), Pulau Penang, Penang Hill, June 1900.

Indonesia: *A.G.L. Adelbert 506* (L), W. Java, Banten, Mt. Pulosari, 12 February 1954; *C.A. Backer 6248* (L), Java, Tjibodas, 29 November; *C. Boden-Kloss 14654* (K, SING), Sumatra, Sipora, 9 October 1924; *Berley s.n.* (K), Java, sine loco 14 March 1911; *Boerlage s.n.* (L), W. Java, Buitenzorg, 1914; *C.L. Blume 849* (L), Java, sine loco, sine anno; *C.L. Blume s.n.* (L), Java, sine loco, sine anno; *R. Brinkman 818* (L), Java, Kedoe, Sempor bij Gombong, 23 December 1936; *H.A.B. Bünnemeijer 2323* (L), Sumatra, Bangka, Tjiibodas, December 1917; *H.A.B. Bünnemeijer 2392* (L), Sumatra, Banka, Pl. Lepar, A. Bajam, 12 December 1917; *J. Elbert 4484* (L), Lesser Sunda Islands, Pulau Wetar, Lepakumug bei Laswerang, 18 June 1910; *A. Elsener H 64* (L), N. Borneo, Kalimantan Barat, Njarumkop, 12 November 1964; *Fontes 56* (L), Sulawesi, sine loco, sine anno; *Hort Bot Singapore SBGO 3380* (L, SING), Sulawesi, Sulawesi Selatan, Rantepao-Paloppo, sine anno; *Hort Bot Singapore SBGO 5896* (L), Sulawesi, Sulawesi Tengah, Poso, sine anno; *H. Kuhl s.n.* (L), Java, sine loco, October 1903; *H. Kuhl s.n.* (L), Java, sine loco, sine anno; *H. Kuhl s.n.* (L), Sumatra, sine loco, sine anno; *H.J. Lam 3119* (L), Moluku, Talaud eil, Salibaboe, Z. helling Gunung Ajambana, 22 May 1926; *Lobb. s.n.* (K), Borneo, sine loco, sine anno; *J. Motley 322* (K), Borneo, Bangarmassing, 1857; *H.N. Ridley s.n.* (K), Java, Jalar, 14 July 1915; *E. Schmutz 4465* (L), Lesser Sunda Islands, Manggarai, 12 December 1979; *E. Schmutz 4502* (L), Lesser Sunda Islands, Manggarai, 20 December 1979; *J.J. Vermeulen 2490* (L), Sulawesi, Sulawesi Selatan, Mangkutane-Pendolo Divide, 4 February 2004; *E.F. de Vogel 2973* (L), W. Sumatra, Barisan Range, Tapa-sungai Penuh Rd., 13 March 1974; *W.J.J.O. de Wilde & B.E.E. de Wilde-Duyfies 12667* (K, L), N. Sumatra, Gunung Leuser, Mt. Guhra, 7 June 1972; *H. Zollinger 116* (C), Tjikoya, 1842.

Brunei: *J.H. Bernstein 198* (K), Bang Ligi, 1 October 1992.

Philippines: *H.M. Curran s.n.* (AMES, K), Luzon, Benguet, 1906; *A.D.E. Elmer 15220* (K, L, P), Luzon, Sorsogon, Irosin (Mt. Bulusan), April 1916; *E. Fenix 12721* (K, P), Luzon, Benguet, Sablang, November 1910; *Y. Kondo & G. Edaño 40850* (K), Siasi, Mt. Bayao, 1957; *C. Mabesa 26912* (K), Luzon, Laguna, Los Banos, August 1917; *Medicilo et al. 29317* (K, L), Luzon, Cavite, Mt. Palaypalay Mataas na Gulod, 26 November 1996; *A. Loher 444* (K), Luzon, Benguet, sine anno; *A. Loher 445* (K), Luzon, sine loco, sine anno; *A. Loher 5291* (K), sine loco, 1906; *M. Ramos & G. Edano 44249* (K), Sulu, Tawi-Tawi, July 1924; *M. Vanoverbergh 1351* (K, L, P, SING), Luzon, Bontoc, July 1911; *M. Vanoverbergh 3678* (L), Luzon, Bontoc, May 1913; *C.A. Wenzel 10002* (L, SING), S. Mindanao, Juhud Places, 21 September 1926;

New Guinea: *T.G. Hartley 10381* (K), Morobe, Waria River, 20 June 1962; *A.N. Millar 23360* (L), Morobe, above Wampit River, 4 March 1964; *J.J.F.E de Wilde 1158* (L), Biak, Kampong Landbouw, 7 June 1972; *A. Zippelius s.n.* (L), N. New Guinea, sine loco, October 1903.

Micronesia: *M.V. Cushing 470* (P), Caroline Islands, W. Summi, Mt. Matade, 25 July 1965; *F.R. Fosberg 60047* (K), Caroline Islands, Tabiwol, Bulochang abandoned village, 5 August 1980; *Herbst et al. 9409* (K), Babeldaob Island, Ngetpang, Nkebeduul River, 16 July 1991.

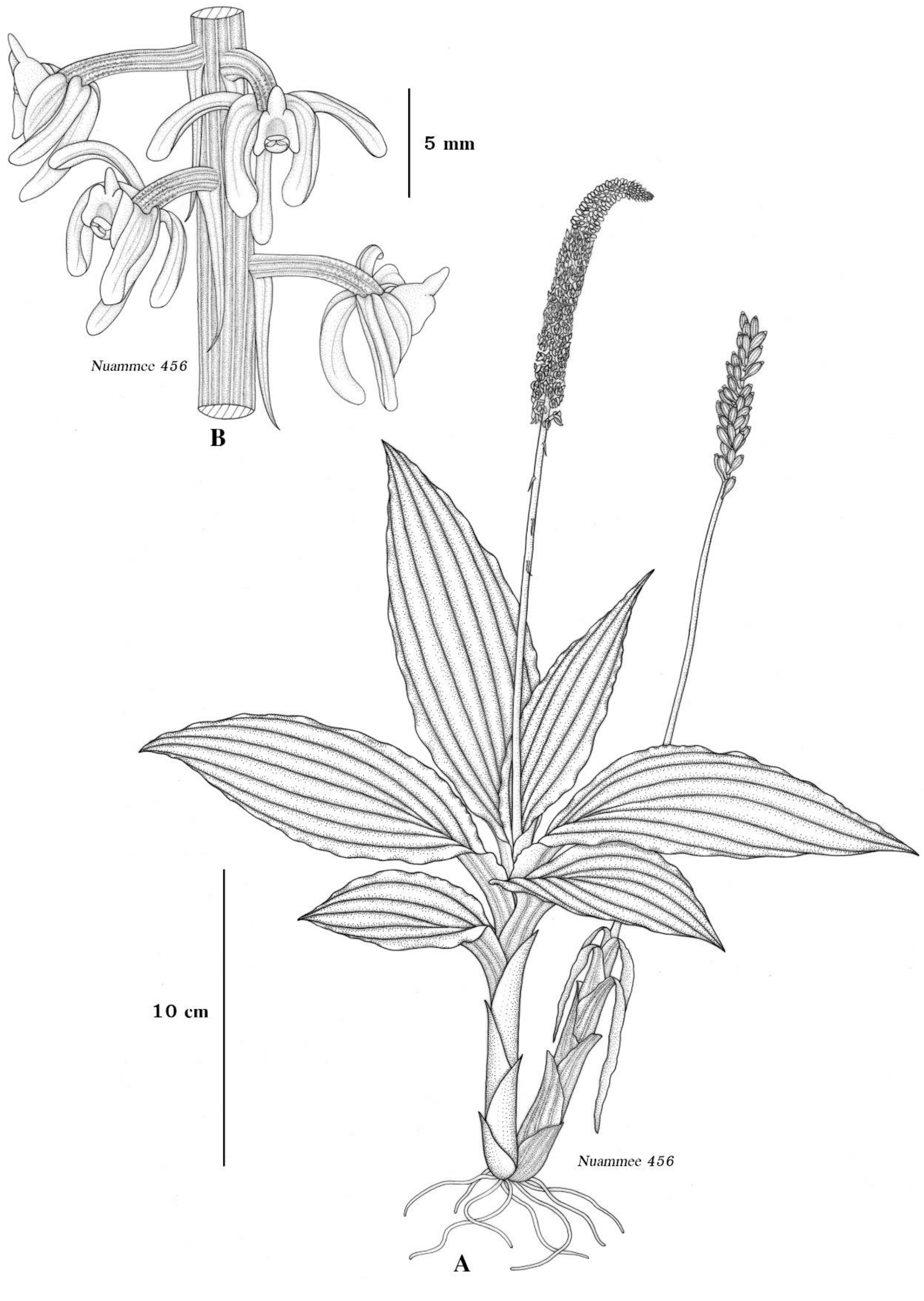

Figure 4.75 *Dienia ophrydis* (J. Koenig) Ormerod & Seidenf. **A:** Habit. **B:** Flowers, front view and lateral view on rachis. Drawing from *Nuammee 456* (A–B).

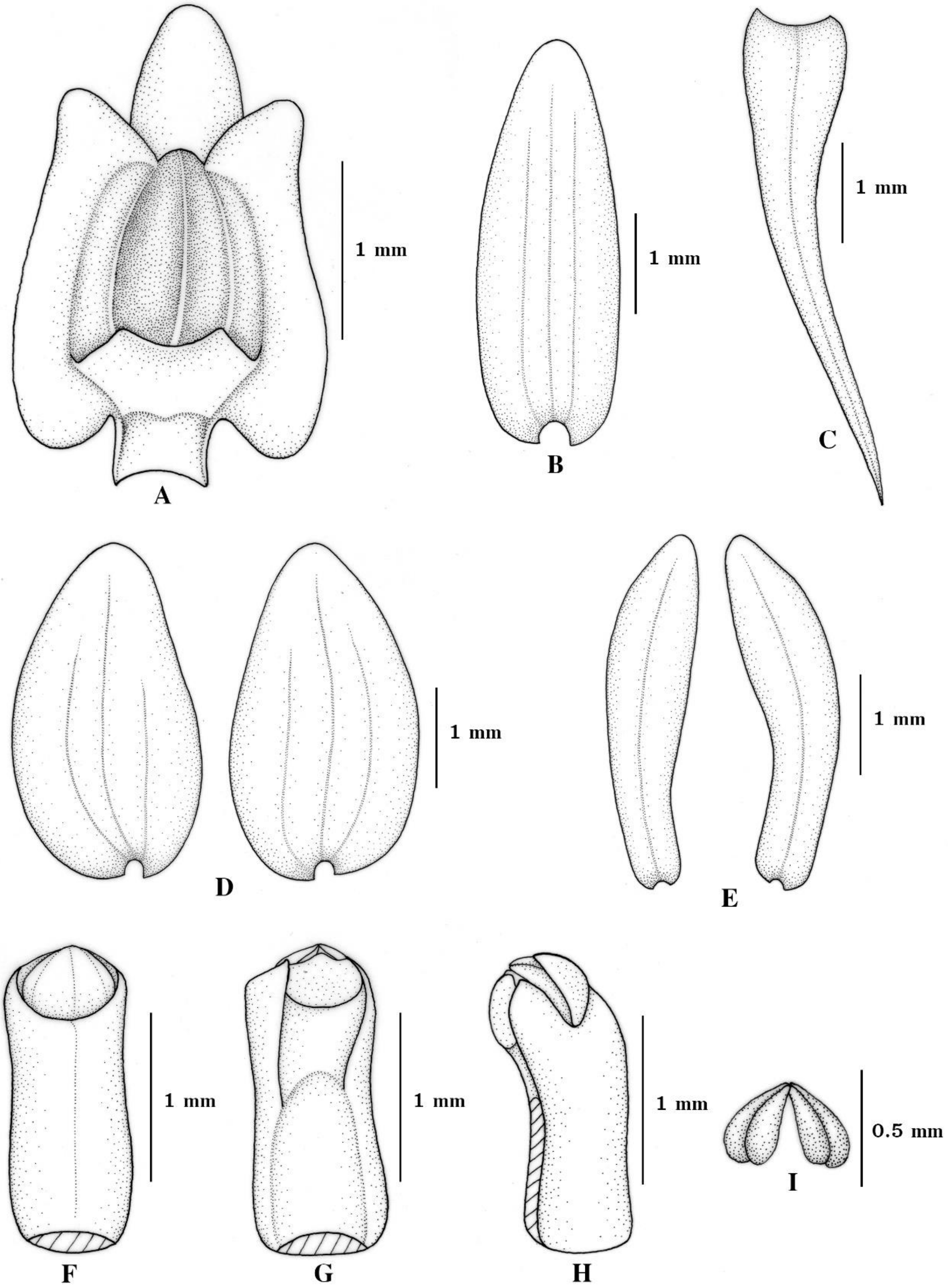

Figure 4.76 *Dienia ophrydis* (J. Koenig) Ormerod & Seidenf. **A:** Labellum, front view. **B:** Dorsal sepal. **C:** Floral bract. **D:** Lateral sepals. **E.** Petals. **F:** Column, back view. **G:** Column, front view. **H:** Column, lateral view. **I:** Two pairs of pollinia. Drawing from *Nuammee 456* (A–I).

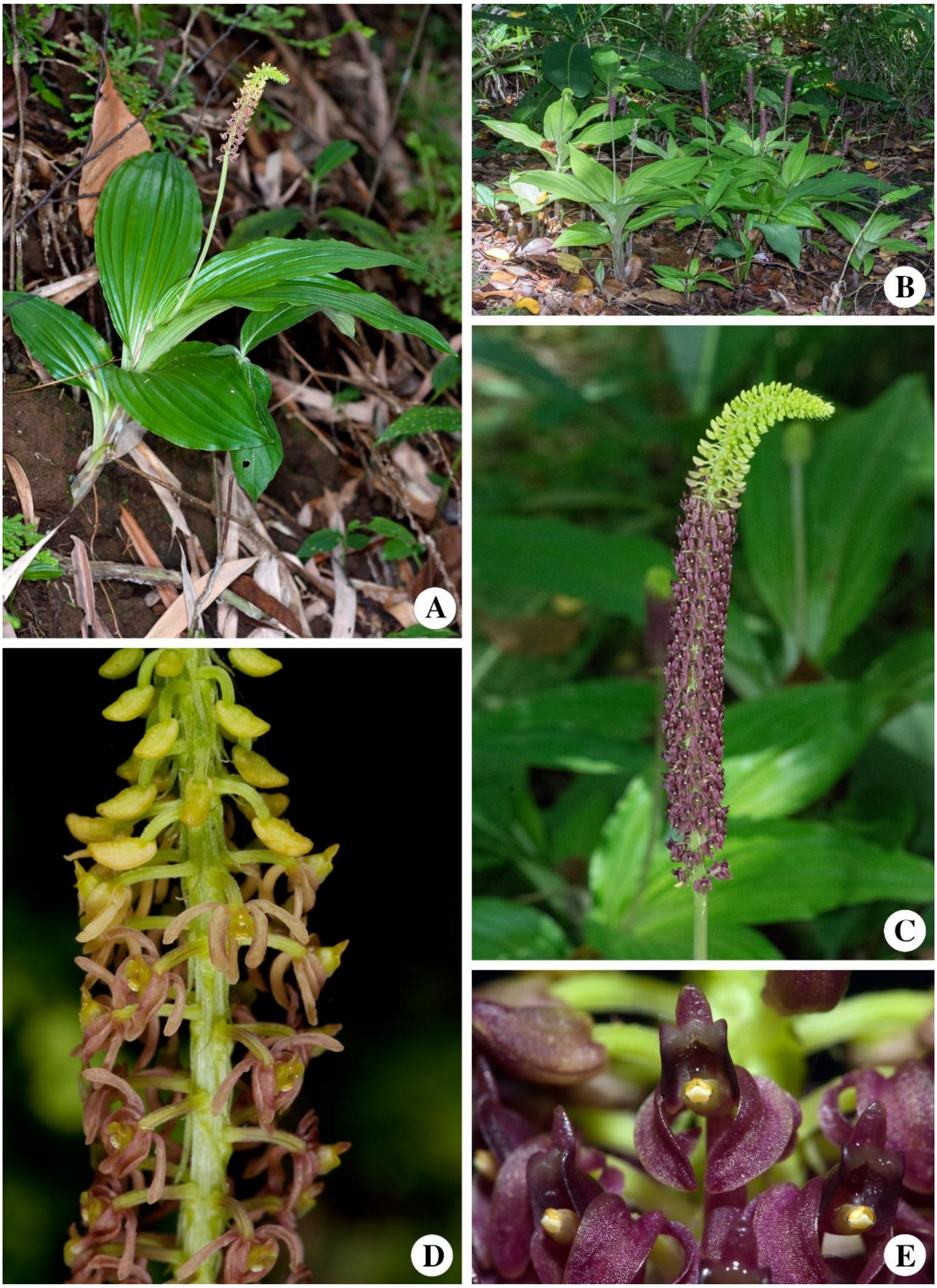

Figure 4.77 *Dienia ophrydis* (J. Koenig) Ormerod & Seidenf. **A–B:** Habit. **C–D:** Inflorescence. **E:** Flower, front view. A was photographed from Phitsanulok, Phu Hin Rong Kla, 2 June 2014; D was photographed from Nakhon Ratchasima, Khao Yai, 24 May 2014; B, C and D were photographed from Trat, Ko Kut, 10 June 2018.

CHAPTER V

POLLINATION BIOLOGY

5.1 Pollination biology of *Crepidium acuminatum* (D. Don) Szlach.

5.1.1 Plant phenology and floral features

Crepidium acuminatum is a terrestrial orchid, grows in humus-rich soil or mossy rock, and usually occurs in small patches of about 5–20 plants (Fig. 5.1A–B). In late April, each plant of *C. acuminatum* developed new pseudobulbs (Fig. 5.2A–B), then, leaves and inflorescences were also developed until May. The flowering period was started from early May to June but some plants were still flowering until early July (Fig. 5.2C–D). The inflorescences of *C. acuminatum* were 15–30 cm in length and comprised about 10–50 flowers. After flowering period around 7–15 day, fruits occurred and continuously developed (Fig. 5.2E). Mature fruits of *C. acuminatum* dehisced on late December to January. After that, *C. acuminatum* plants entered the dormancy stage in dry season around Febuary to April (Fig. 5.2F).

C. acuminatum flowers were anthesis from late afternoon and fully open in early morning of the next day. (Fig. 5.3A–H). Nectar was produced on labellum base and labellum cavity right from the beginning of anthesis which could persist for 48–72 hours.

Figure 5.1 Populations of *C. acuminatum* (D. Don) Szlach. **A–B:** The small patches of *C. acuminatum* in natural populations.

Figure 5.2 Phenology of *C. acuminatum*. **A–B:** New pseudobulbs were produced in late April. **C:** Leaves and inflorescences were developed. **D:** Flowers bloomed in the flowering period. **E:** Fruits were developing. **F:** Mature fruits dehisced and plant entered the dormancy stage.

Figure 5.3 The anthesis of *C. acuminatum* flower. **A:** 4.00 p.m. **B:** 6.00 p.m. **C:** 8.00 p.m. **D:** 10 p.m. **E:** midnight **F:** 2.00 a.m. **G:** 5.00 a.m. **H:** 8.00 a.m. Note on nectar production on a labellum from 4 p.m. till 8 a.m. of the next day.

The amount of nectar (collected from 83 flowers) was 1–6.5 µl (with mean of 2.5 µl) and nectar concentration was 4–17% brix (with mean of 11.5% brix), it is suggested that the main nectar components of *C. acuminatum* may be sucrose.

The result from labellum anatomy showed that the nectary of *C. acuminatum* located on the adaxial surface of labellum which consisted of opening in epidermis layer around labellum cavity (Fig. 5.4A–C). Most of the opening were encircled by needle-shaped crystals of calcium oxalate or raphides (Fig. 5.4D). Parenchyma cells contained chromoplast, chloroplast (Fig. 5.4E) and anthocyanin (Fig. 5.4F) so that the labellum colour was yellowish green with more or less purple tint. Moreover, two or three layer below epidermis have dense cytoplasm (Fig. 5.4G).

Neutral red was used to detect osmorphores (Stern *et al.*, 1986), which are stained to pink-red colour in two or three layers of cell from adaxial epidermis in labellum cavity and flanking tissue (Fig. 5.5 A–D). The result could be indicated that osmophores may located on adaxial epidermis around and inside labellum cavity. The adaxial epidermis around labellum cavity contained short cone-shaped cells whose surface were rugose (Fig. 5.5E–F) and had large nucleus (Fig. 5.5G).

Sudan red was used to detect oil or fat body in cells, and the results showed that the cuticle layer of epidermis of the labellum was stained in red (Fig. 5.6A–D) and it was also found that some oil droplets were presented in cell of the adaxial epidermis around labellum cavity (Fig. 5.6E–G).

The pollination strategies of *C. acuminatum* revealed that *C. acuminatum* produced nectar as reward to pollinators. The nectary was a single layer epidermis which consisted of openings in epidermis and two or three layers of subepidermal cells. The dense cytoplasm of two or three layer lower epidermis indicated that nectar may be produced and accumulated in this areas. The secretory epidermis has few openings and encircled by raphides. The osmophores of *C. acuminatum* may be presented on adaxial epidermis of labellum and it was short cone-shaped whose the surface was rugose.

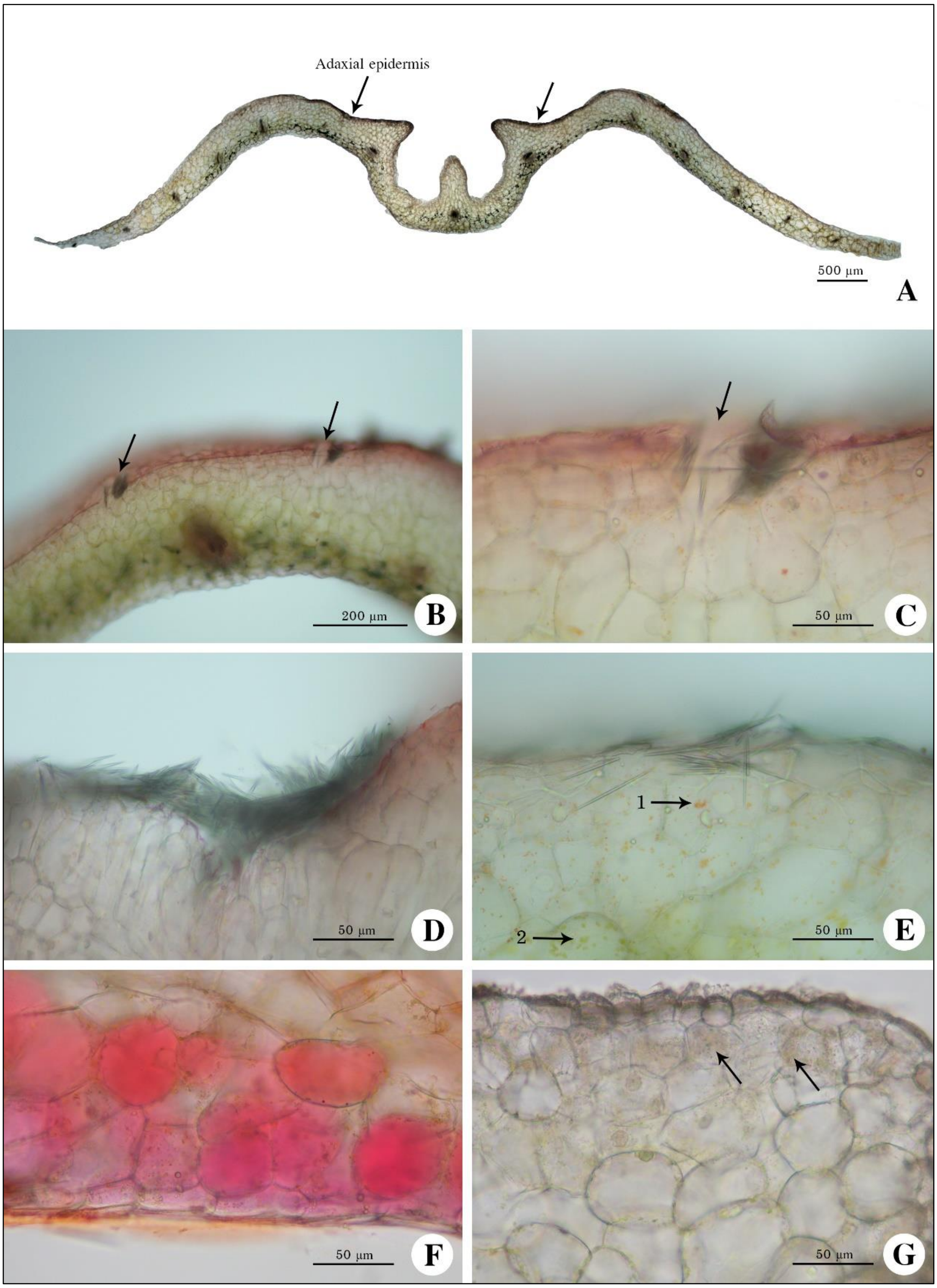

Figure 5.4 Labellum anatomy of *C. acuminatum* in distilled water. **A:** Cross-sections of labellum. **B–C:** Opening in epidermis (arrows). **D:** Raphides. **E:** Chromoplast (arrow 1) and chloroplast in cells (arrow 2). **F:** Anthocyanin in parenchyma cells. **G:** Dense cytoplasm in two or three layer of cells below epidermis.

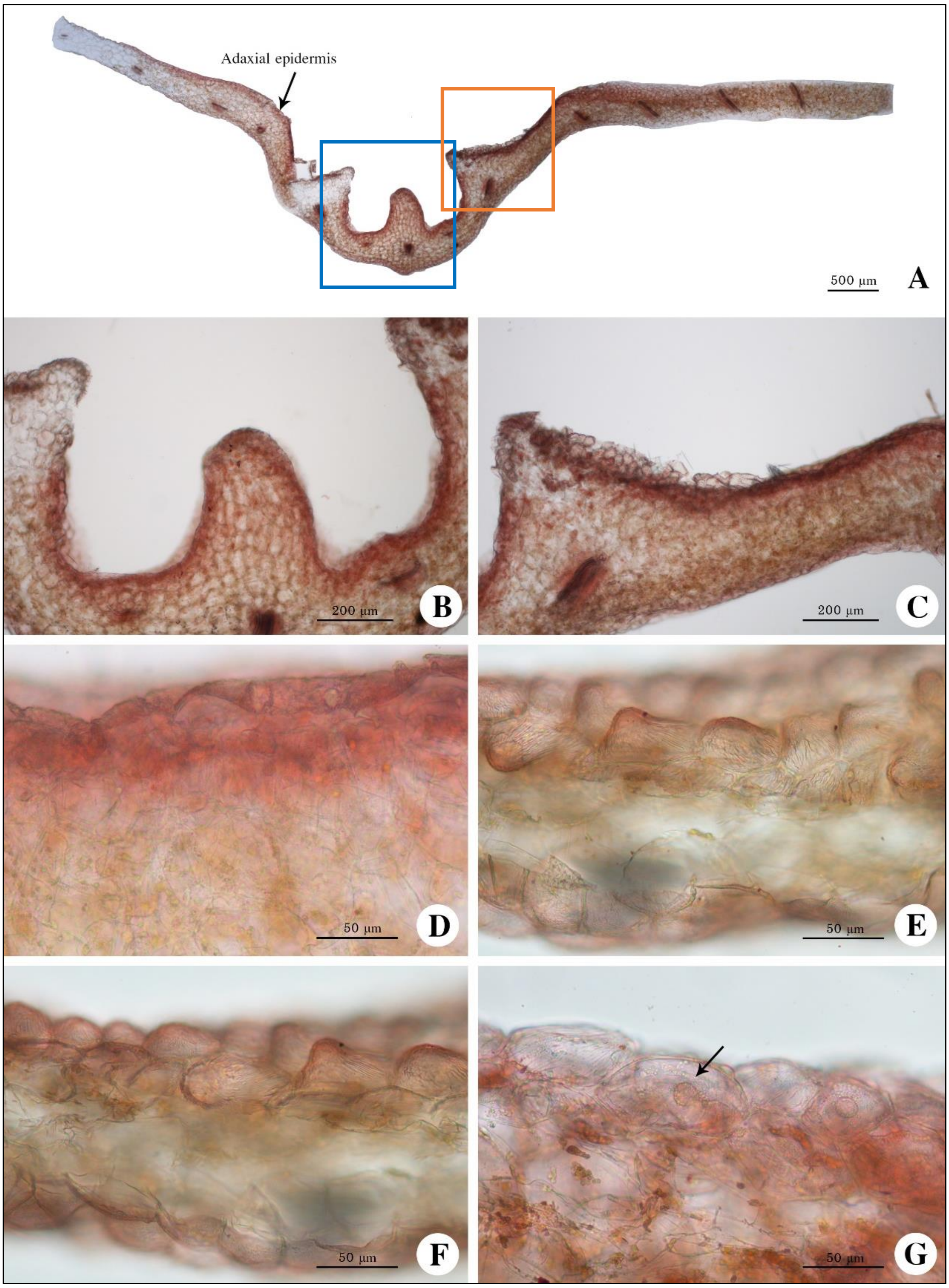

Figure 5.5 Labellum anatomy of *C. acuminatum* stained with Neutral red. **A:** Cross-sections of labellum, Blue box area is enlarged in B; Orange box area is enlarged in C. **B:** Adaxial epidermis in labellum cavity. **C:** Adaxial epidermis flanking labellum cavity. **D:** Two or three layer of subepidermal cells. **E–F:** Short cone-shape epidermis. **G:** Large nucleus in epidermis (arrow).

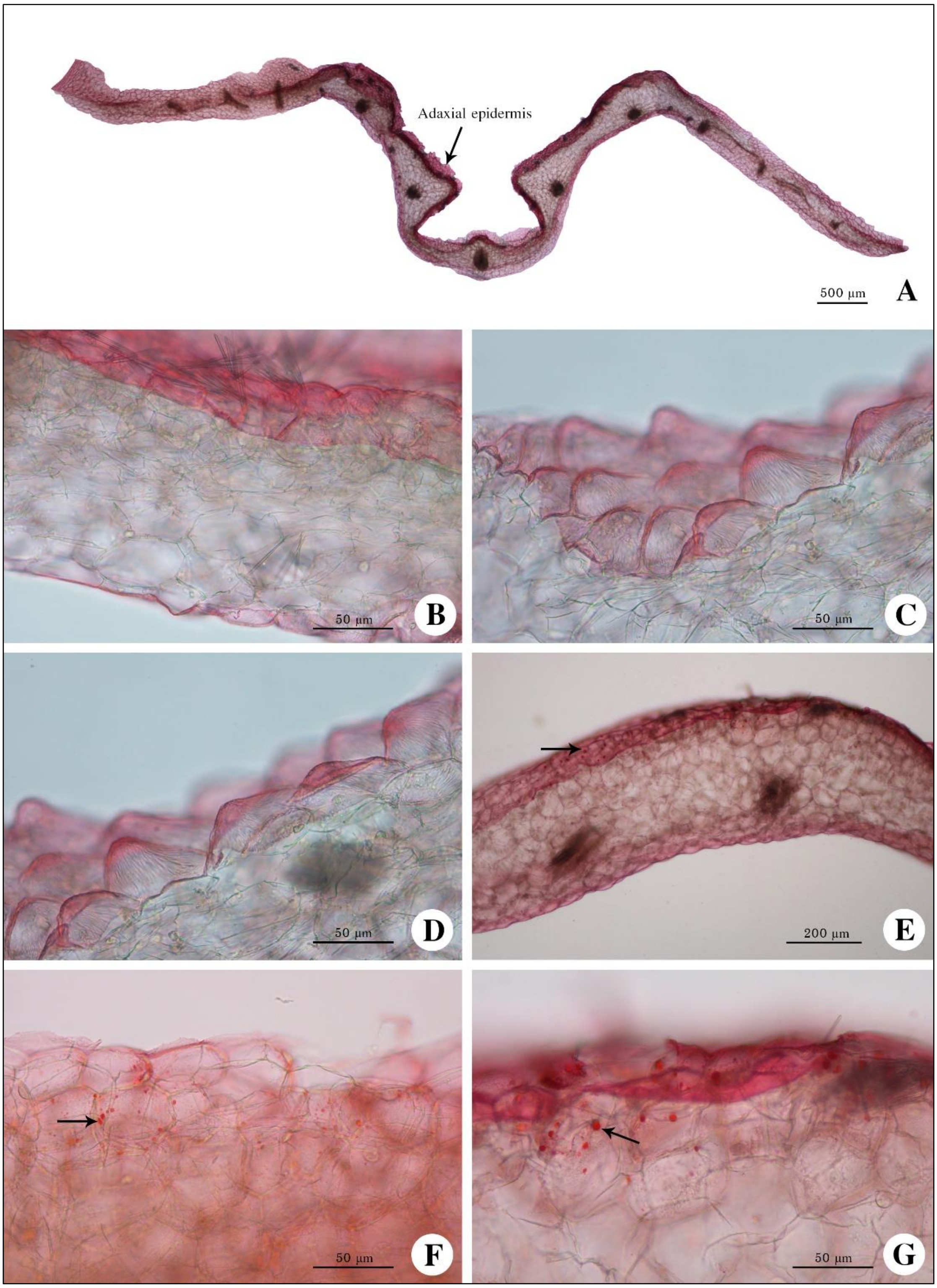

Figure 5.6 Labellum anatomy of *C. acuminatum* stained with Sudan red. **A:** Cross-sections of labellum. **B:** Cuticle of epidermis stained to red colour by Sudan red. **C–D:** Short cone-shape epidermal cells. **E:** Location of oil droplets (arrow). **F–G:** Sudan red staining cuticle and oil droplets in osmophore cells.

5.1.2 Breeding system, natural fruit sets and seed viability

The summary of the experiment was showed in Tabel 5.1. The observations showed that no fruit set were produced in most plants from open pollination treament. Only 1–2 fruit sets/inflorescence were produced in a few plants (Fig. 5.7A–D). The natural fruit set from open pollinations was very low in all three seasons, with mean of 1.1%–2.3%. The experiments revealed that no fruit set from unmanipulated flowers (Fig. 5.8A–B), unbagged emasculation (Fig. 5.8C–D) and bagged emasculation (Fig. 5.9A–D). No fruit set from unmanipulated flowers suggested that *C. acuminatum* is not an autonomous self-pollination and may rely on pollinators for successful pollination. No fruit set from unbagged emasculation suggested that no pollinator carry pollinia from other flowers to deposit on emasculated flowers. No fruit set from bagged emasculation suggested that agamospermy – development of fruits and seeds without fertilization – is not present in *C. acuminatum*. In addition, fruit set from hand self-pollination was very low in the second year (4.4%) but no fruit set from the first and third year (Fig. 5.10A–E). The highest fruit set was observed from hand cross-pollination in all three seasons (Fig. 5.11A–E and Table 5.1). Results from both experiments suggest that *C. acuminatum* is partly self-incompatible and rely on pollinators for successful cross pollination.

When compared the number of fruit setting and fruit dehiscence, the results showed that the number of fruit dehiscence was lower than fruit setting because some fruits were destroyed by some insects and larvae (Fig 5.12A–B).

Seeds of *C. acuminatum* are nearly fusiform shape and about 600–800 µm long. Each seed has a loose and rather thin-textured seed coat enclosing the embryo and lack endosperm (Fig 5.12C–D). Fruits obtained from open pollination, hand self-pollination and hand cross-pollination showed different percentage of viable seeds. Seed viability showed much higher percentages in cross pollination (94%–98%, n=10 fruits) and open pollination (53%–98%, n=10 fruits) than self-pollination (22.5%–28%, n=3 fruits), possibly due to inbreeding depression (Fig 5.12E–H).

Table 5.1 Fruit sets of *C. acuminatum* from all experiments in three seasons.

Year	**2014**			**2015**				**2016**			
Treatment	No. flowers	No. fruit sets	% fruit sets	No. flowers	No. fruit sets	% fruit sets	No. fruit dehiscence	No. flowers	No. fruit sets	% fruit sets	No. fruit dehiscence
(A) Open pollination	645	7	**1.1%**	745	9	**1.2%**	6	1,635	38	**2.3%**	30
(B) Hand pollination											
- (B1) Unmanipulated flowers	39	0	0	50	0	0	-	55	0	0	-
- (B2) Unbagged emasculation	10	0	0	29	0	0	-	45	0	0	-
- (B3) Bagged emasculation	11	0	0	29	0	0	-	42	0	0	-
- (B4) Hand self-pollination	22	0	0	92	4	4.4%	3	92	0	0	-
- (B5) Hand cross-pollination	28	14	**50%**	94	78	**83%**	65	105	98	**93%**	73

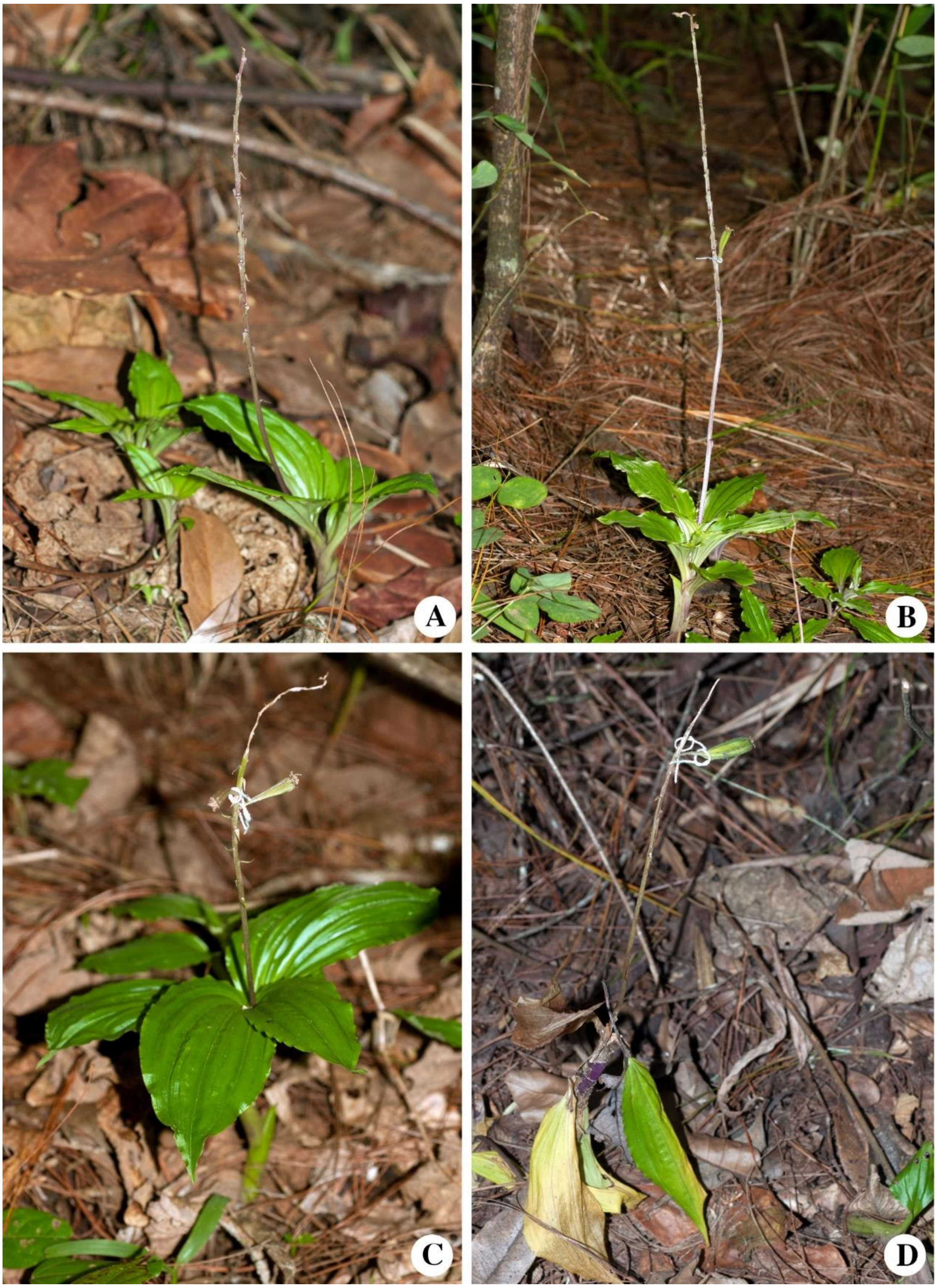

Figure 5.7 The natural fruit set from open pollination of *C. acuminatum*. **A:** No fruit set in most plants. **B–D:** A few plants yielded 1–2 fruit set/inflorescence.

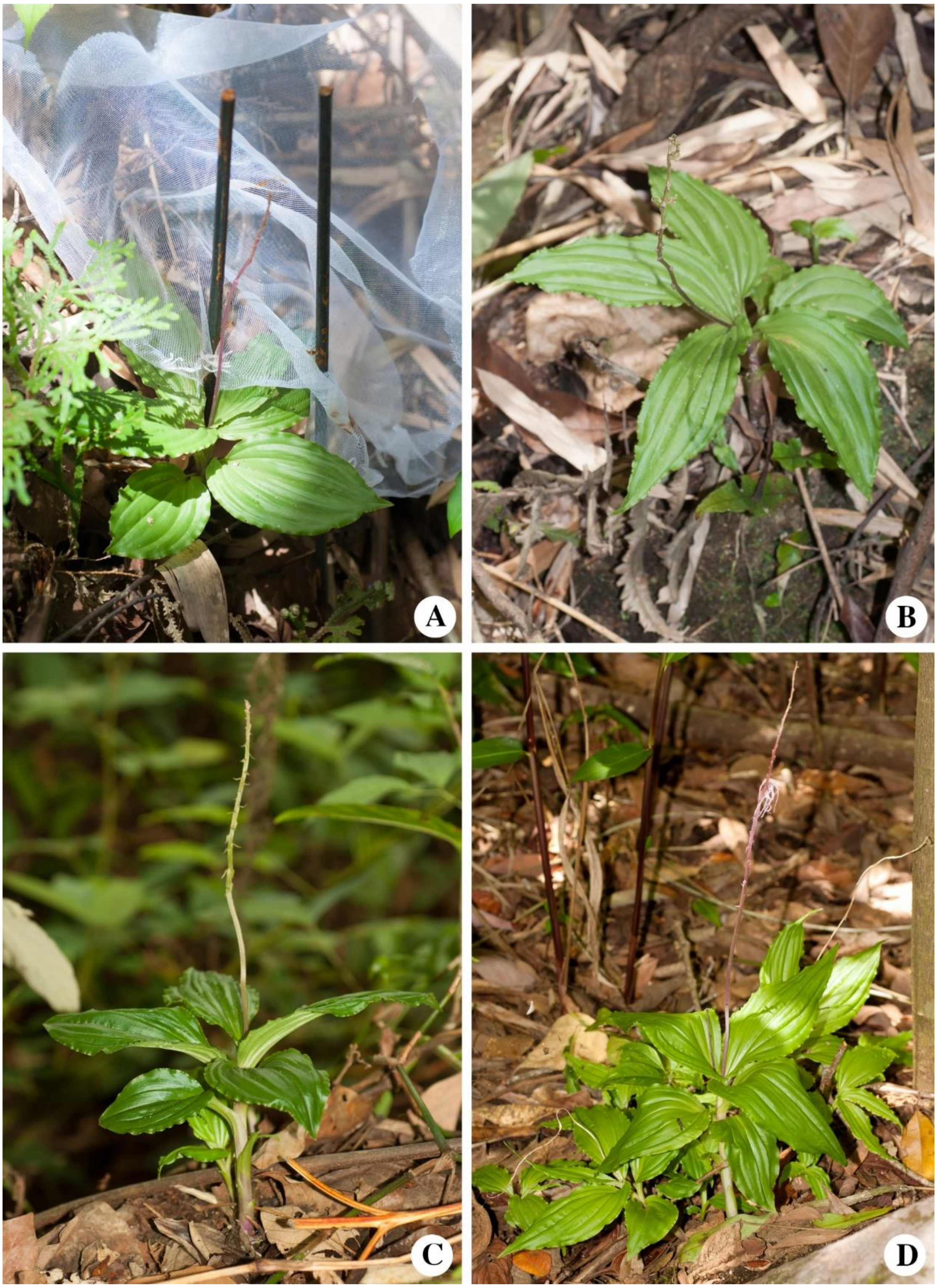

Figure 5.8 Unmanipulated flowers and unbagged emasculation of *C. acuminatum*. **A–B:** No fruit set from unmanipulated flowers. **C–D:** No fruit set from unbagged emasculation.

Figure 5.9 Bagged emasculation of *C. acuminatum*. **A–D:** No fruit set from bagged emasculation.

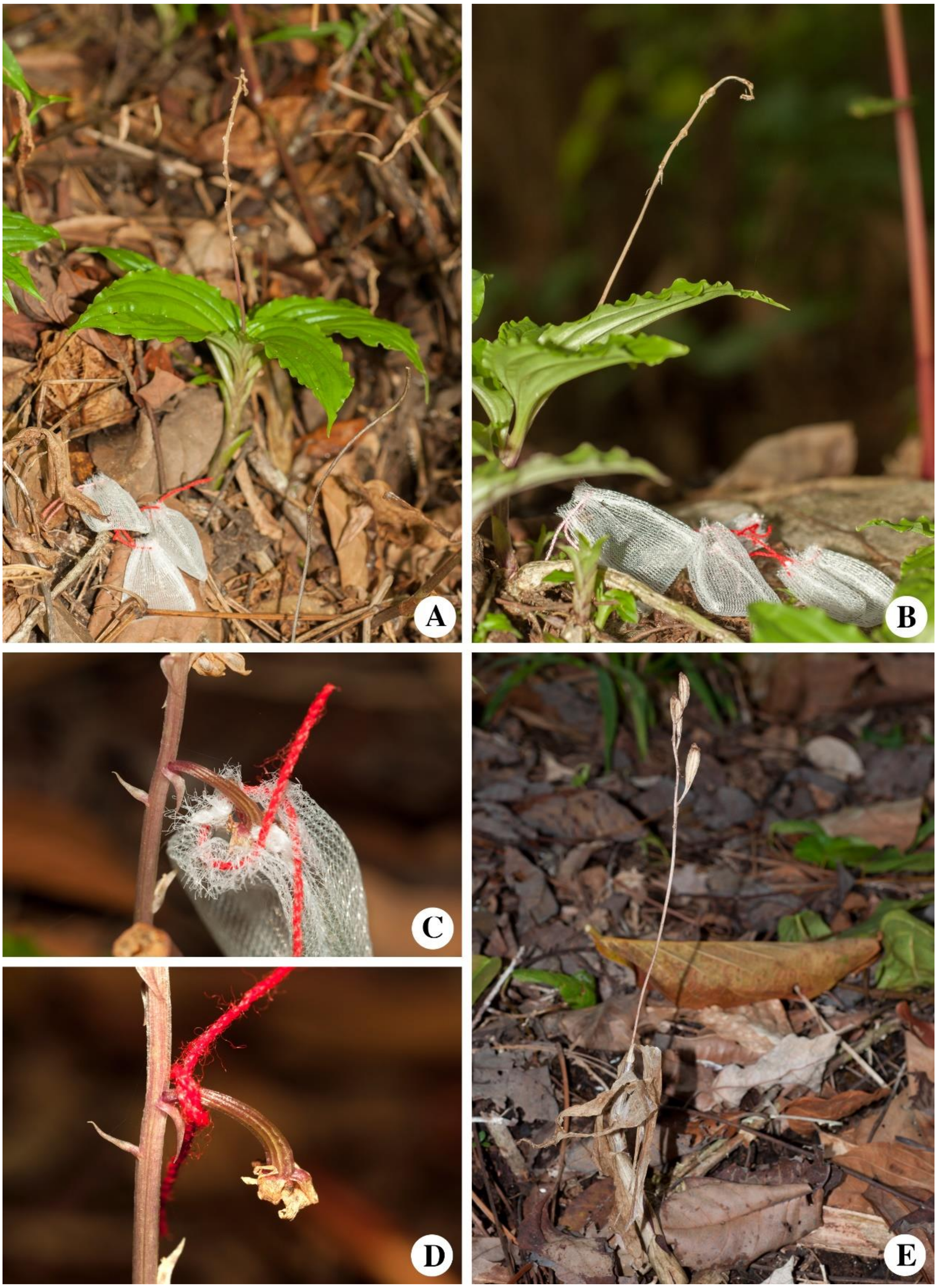

Figure 5.10 Hand self-pollination of *C. acuminatum*. **A–B:** No fruit set in most plants from the first and third seasons. **C–E:** A few fruit set were produced in the second season.

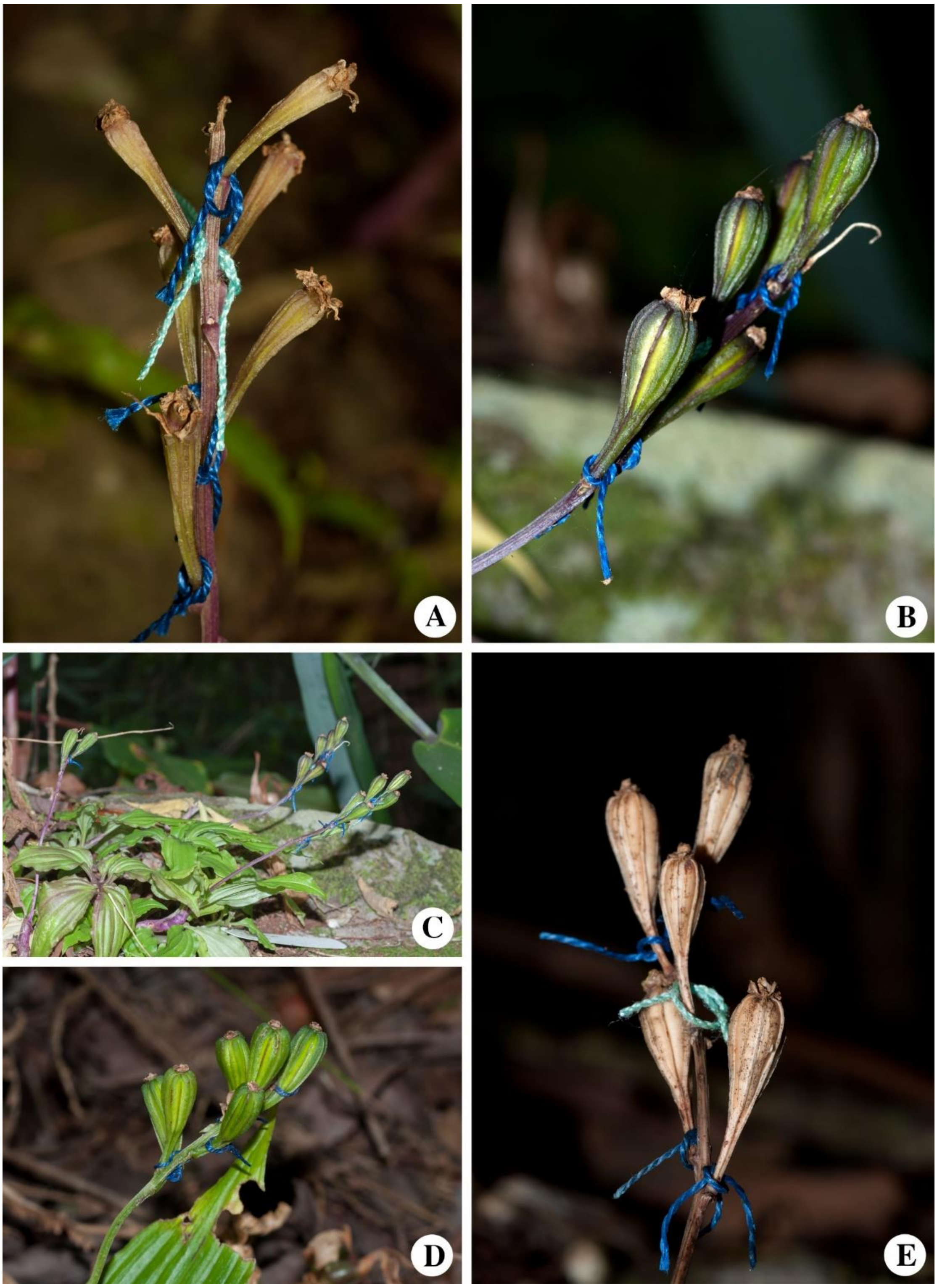

Figure 5.11 Hand cross-pollination of *C. acuminatum*. **A–E:** The highest fruit set were produced from hand cross-pollination in all three seasons.

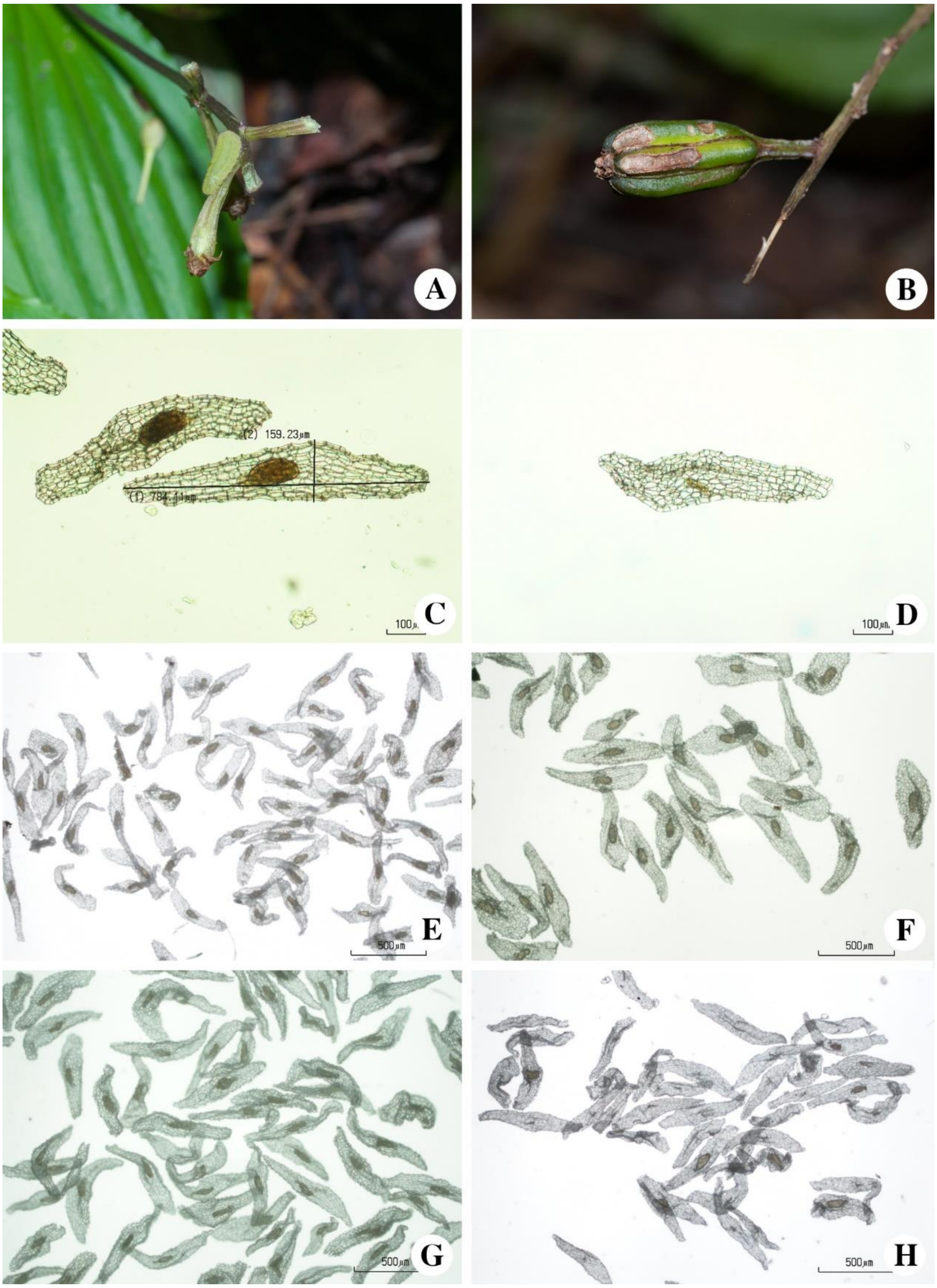

Figure 5.12 Fruits and seeds of *C. acuminatum*. **A–B:** Fruits were destroyed by insects and larvae. **C:** Seeds with embryo. **D:** Seed without embryo. **E–F:** Seeds from open pollination. **G:** Seeds from cross pollination. **H:** Seeds from self-pollination.

5.1.3 Pollinators and pollination process

Flowers of *C. acuminatum* were frequently visited by various diurnal insects e.g. Diptera (hoverflies, and fungus gnats), Hymenoptera (honey bees, ants), Orthoperta (crickets) and Coleoptera (beetles), which searched and fed nectar from labellum base and labellum cavity. The observations found that visits to flowers of *C. acuminatum* were fairly rare, one to five per day, and occurred at irregular intervals, but mainly between 9.00–11.00 a.m. and 2.00–4.00 p.m. Insects visited only on cloudy or sunny days, as rainfall restricted the insect foraging activity. Four species of insects (i.e. cf. *Meliscaeva cinctella*, *Apis* sp., fungus gnats and crickets) may act as pollinators because they did succeed in removing pollinia (Table 5.2).

During visits, honey bees (*Apis* sp.) landed and held directly on flowers (Fig. 5.13A). They tried to feed nectar by insertion its proboscis in labellum cavity (Fig. 5.13B). While accessing nectar in labellum cavity, pollinia attached on legs of honey bees which carried to other flowers (Fig. 5.13C), but pollinia were deposited on labellum base which is considered a failed pollination (Fig. 5.13D).

Hoverflies (cf. *Meliscaeva cinctella*) landed and held directly on flowers similar to honey bees. While accessing nectar in labellum cavity, pollinia were removed and attached by its proboscis and legs (Fig. 5.13E–H). However, if pollinia attached on proboscis, at which appear to be the suitable position, the chance is higher for pollination success. Another species in the same family, cf. *Baccha elongata* was the highest frequent visitors to flowers *C. acuminatum*. During visits to flowers, cf. *Baccha elongata* inserted proboscis into labellum cavity (Fig. 5.14F–G) but they did not succeed in removing any pollinium. It may be due to how cf. *Baccha elongata* approaching flowers make its part of or whole body placement not suitable for removing the pollinium.

Fungus gnats was very small insects which long legs. During visits to flowers, gnats inserted its head into labellum cavity to feed nectar (Fig. 5.14A). Pollinia were attached on an anterior ventral thorax of gnats (Fig. 5.14B). This process is similar to the previous pollination report of *Malaxis paludosa* that is pollinated by fungus gnats and its pollinia are attached on anterior ventral thorax of fungus gnats (Reeves and Reeves, 1984; Argue, 2012).

The various species of small crickets also visited to flowers of *C. acuminatum*. They walked directly on inflorescences to search and feed on nectar by inserting its head into labellum cavity (Fig. 5.14C–D). However, it was only one incident that they did succeed in removing pollinia which was attached on its anterior ventral thorax (Fig. 5.14E).

Ants also visited flowers of *C. acuminatum* both at day and night time. It showed ants had high rate of visitation number but they did not succeed in removing pollinia because their body size were too small to remove pollinia and they only feed nectar on labellum base (Fig. 5.14H).

In addition, other files and beetles also visited flowers of *C. acuminatum* but in low rate of visitation number, only one or two times and they did not removed any pollinium (Fig. 5.15A–D).

Table 5.2 Insects and number of visits to flowers of *C. acuminatum.*

Insect species	Number of visits	Frequency of carrying or removing pollinia
Honey bees (*Apis* sp., Family Apidae)	12	1
Hoverflies (cf. *Meliscaeva cinctella*, Family Syrphidae)	44	3
Hoverflies (cf. *Baccha elongata*, Family Syrphidae)	51	0
Fungus gnats (Family Sciaridae)	3	1
Crickets (Family Gryllidae)	7	1
Ants (Family Formicidae)	23	0

Table 5.3 The efficiency of pollinators visit to flowers of *C. acuminatum.*

No. flowers	No. flowers were not removed	No. flowers pollinia were removed	No. pollinated flowers	No. fruit sets
98	77	21	6	1

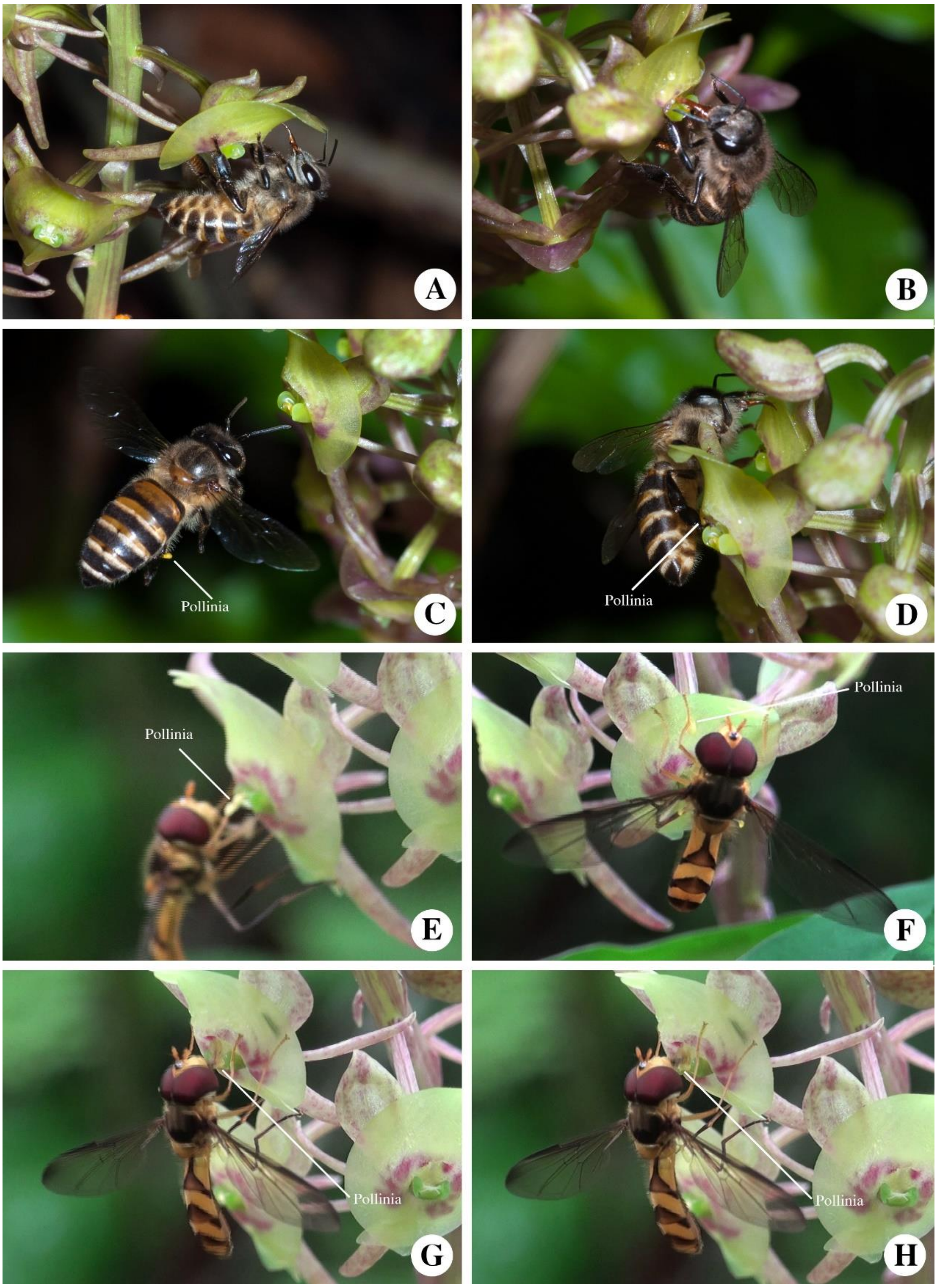

Figure 5.13 Pollinators and visitors of *C. acuminatum*. **A–B:** Honey bee visited to flowers and inserted proboscis into labellum cavity. **C:** Pollinia attached on a leg of honey bee. **D:** Honey bee deposited pollinia on labellum base. **E–F:** Pollinia attached on the legs of cf. *Meliscaeva cinctella*. **G–H:** Pollinia attached on proboscis of cf. *M. cinctella*.

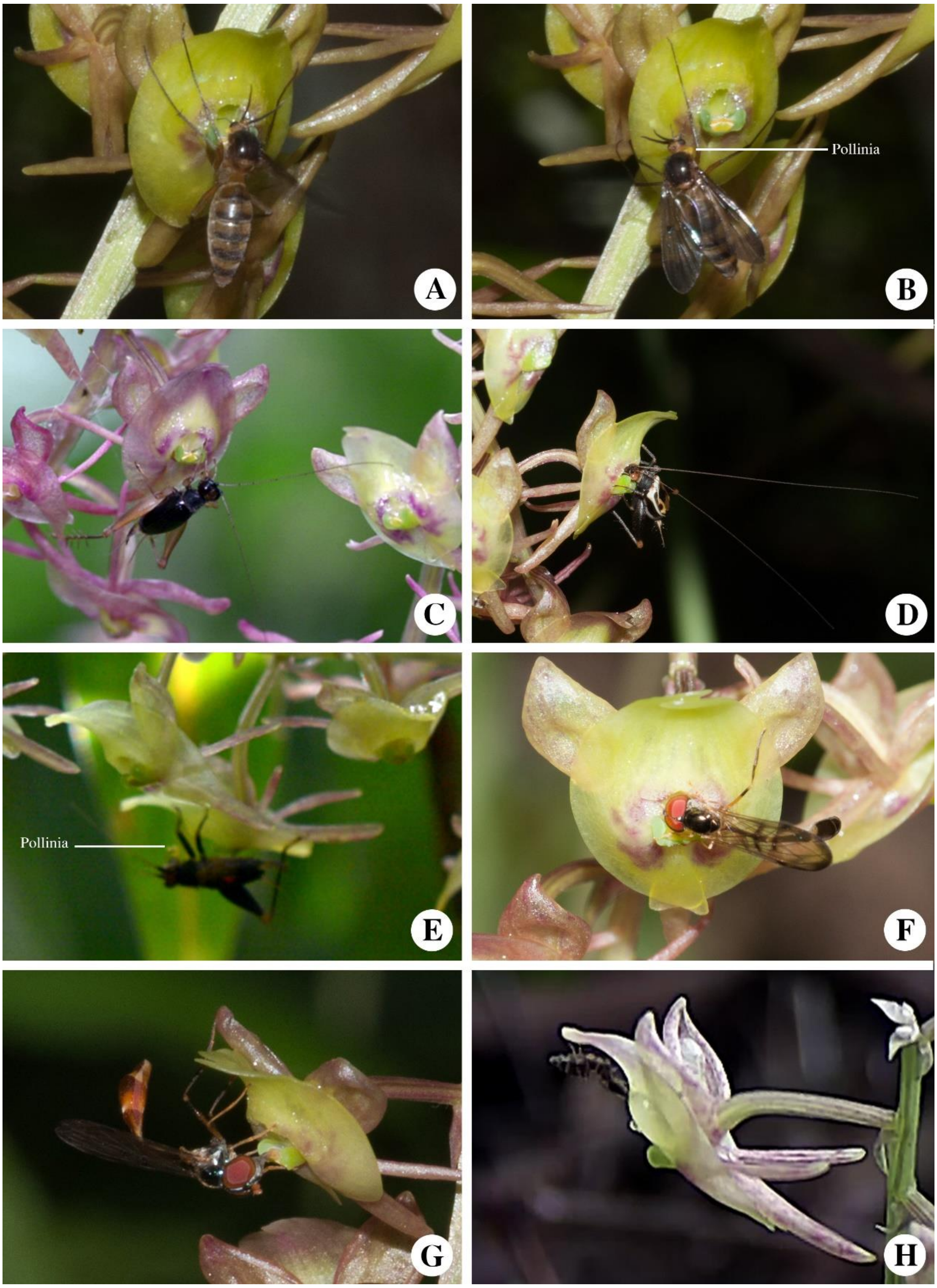

Figure 5.14 Pollinators and visitors of *C. acuminatum*. **A–B:** Fungus gnat visited to flowers and pollinia attached on an anterior ventral thorax. **C–E:** Cricket visited to flowers, and pollinia attached on anterior ventral thorax. **F–G:** cf. *Baccha elongata* feeding nectar by proboscis. **H:** Ant feeding nectar on labellum base.

Figure 5.15 Pollinators and visitors of *C. acuminatum*. **A–C:** Some flies visiting and feeding nectar by proboscis. **D:** Beetle visiting and feeding nectar.

5.1.4 Pollinator efficiency

The observation on pollinator visits to flowers of *C. acuminatum* in one populations in 2016 (Table 5.3) found that for a total of 98 openning flowers observed, pollinia were not removed. The result may imply that few pollinators visit to flowers or pollinaors did not succeed in removing pollinia (Fig. 5.16A). Twenty-one flowers whose pollinia were removed from anthers (Fig. 5.16B–C) but only 6 flowers were pollinated (Fig. 5.16D–E) and some pollinia were deposited on labellum base or tepals (Fig. 5.16F–H). The result suggested that it may be due to low efficiency of pollinators because most of pollinia were lost during transfer process. Moreover, of six pollinated flowers, only one can developed to fruit, suggesting self-incompatibility. This observation indicated that the much low percentage of natural fruit sets of *C. acuminatum* were limited by low pollinators in the natural habitats, low efficiency of pollinators and self-incompatibility.

Figure 5.16 The observation on pollinator efficiency of *C. acuminatum*. **A:** Presumably no visitors. **B–C:** Flowers were removed pollinia from the anther. **D–E:** Flowers were pollinated (E: flower were pollinated when its pollinia still in anther). **F–H:** Pollinia were deposited on labellum base or tepals which are failed pollination.

5.2 Pollination biology of *Dienia ophrydis* (J. Koenig) Ormerod & Seidenf.

5.2.1 Plant phenology and floral features

Dienia ophrydis is a terrestrial orchid, grows in humus-rich soil and usually occurs in small patches of about 5–20 plants to large population of more than 50 plants (Fig. 5.17 A–D). In early April, each plant of *D. ophrydis* developed new pseudobulbs, then, leaves and inflorescences were also developed until May (Fig. 5.18A–B). Later on the flowering period was started from late May to July. The inflorescences of *D. ophrydis* were 10–40 cm in length and comprised about 20–300 flowers (Fig. 5.18C–D). After the flowering period around 7–15 day, fruits occurred and continuously developed (Fig. 5.18E). Mature fruits of *D. ophrydis* dehisced in January of the following year. After that, *D. ophrydis* entered the dormancy stage in dry season around January to April (Fig. 5.18F).

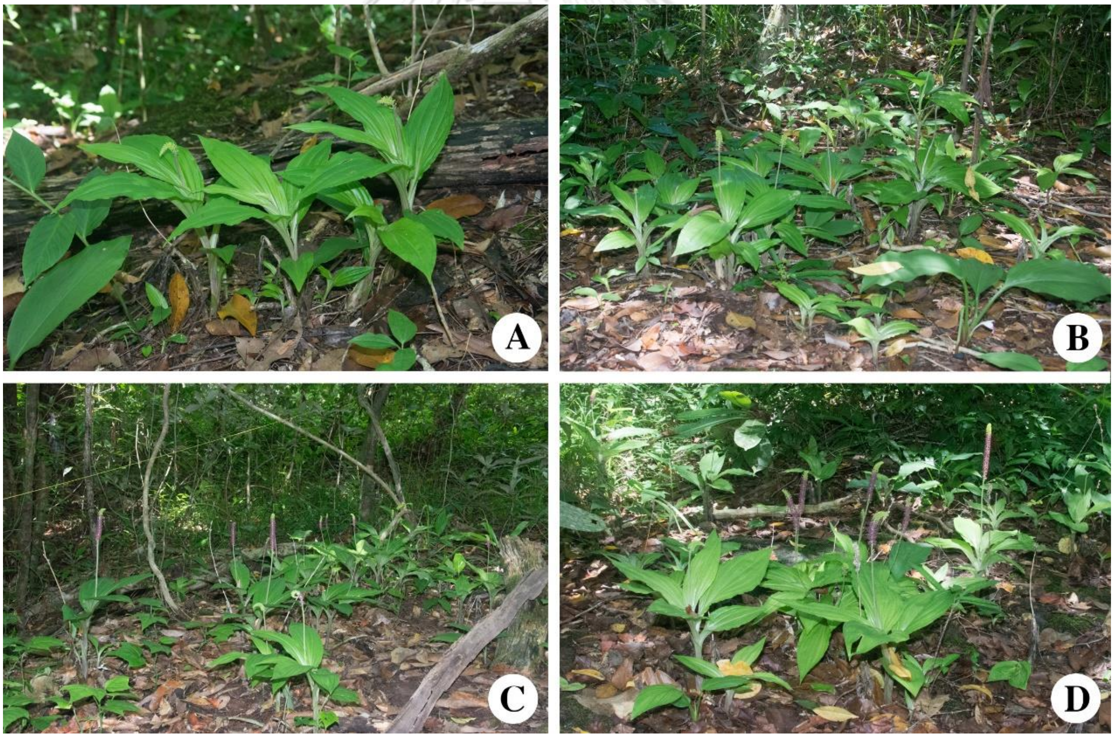

Figure 5.17 The population of *D. ophrydis* (J. Koenig) Ormerod & Seidenf. **A–D:** The small patches to large population of *D. ophrydis* in natural habitats.

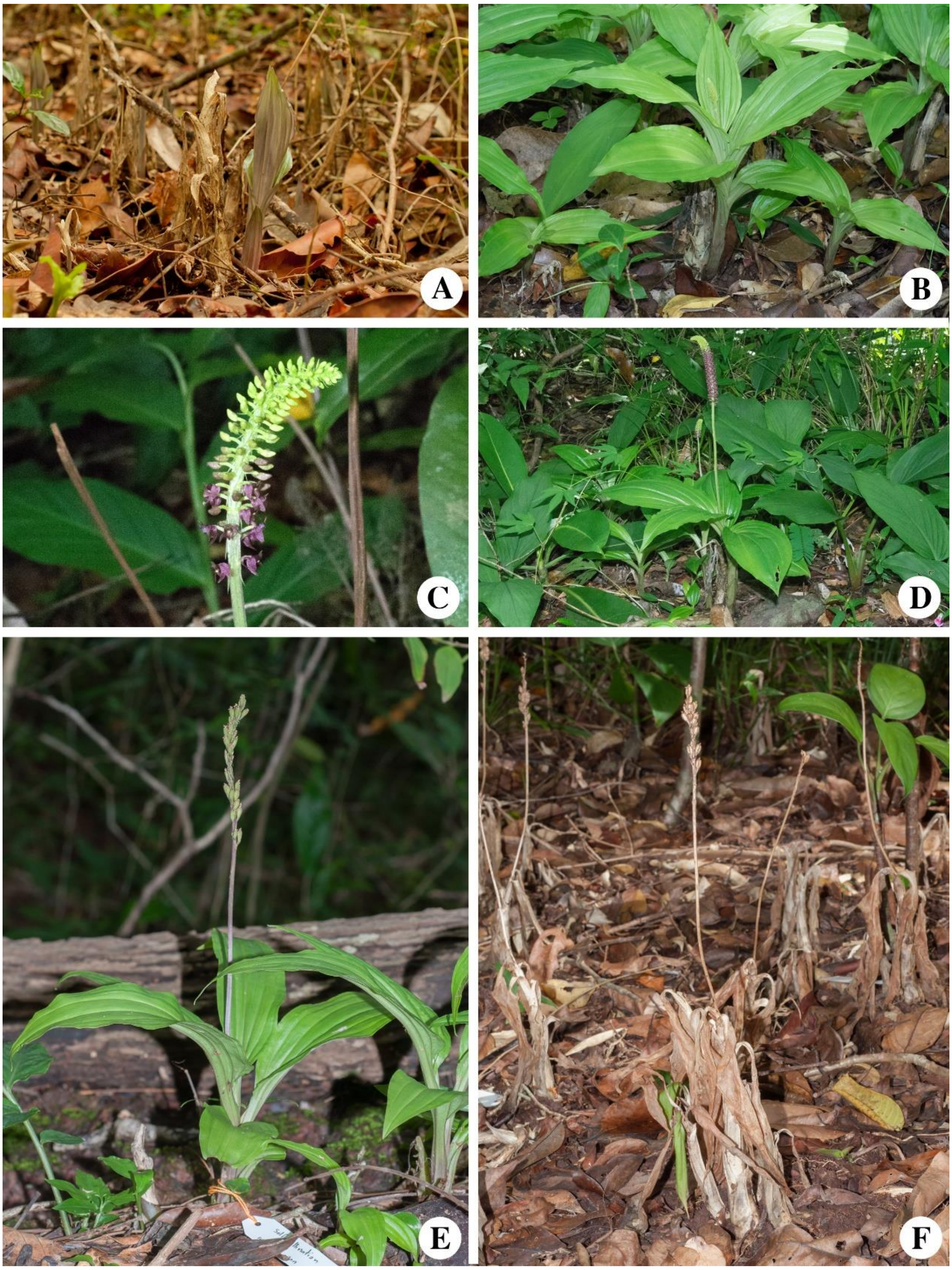

Figure 5.18 Phenology of *D. ophrydis*. **A:** New pseudobulbs were produced in early April. **B:** Leaves and inflorescences were developed in the following months. **C–D:** Flowers in the flowering period. **E:** Fruits were set and developing. **F:** Mature fruits dehisced and plants entered the dormancy stage.

Figure 5.19 Nectar of *D. ophrydis*. **A–B:** Nectar of *D. ophrydis* was produced on labellum margin and labellum cavity (arrow).

D. ophrydis flowers were anthesis from late afternoon and fully open in early morning of the next day. Nectar was produced on labellum margin and labellum cavity which could persist for 24–48 hours (Fig. 5.19A–B). The amount of nectar (collected from 150 flowers) was only 0.5–1 µl and nectar concentration was less than 0.5% brix.

The result from labellum anatomy showed that the parenchyma cells were contained a lot of anthocyanin (Fig. 5.20A–D) and chloroplast (Fig. 5.20E) so that the labellum colour was purple. Moreover, the needle-shaped crystals of calcium oxalate or raphides were found in parenchyma cells (Fig. 5.20F) and encircled the openings (Fig. 5.20G). Moreover, the densely cytoplasm of subepidermal cells had not rather difference (Fig. 5.20H).

Neutral red staining showed pink-orange colour in labellum margin and epidermis of labellum cavity (Fig. 5.21A–C). The results could be indicated that the osmophores may be located on adaxial epidermis on labellum margins and labellum cavity. The surface was rugose (Fig. 5.21D–E). The nectary of *D. ophrydis* located on the adaxial surface of labellum margin and labellum cavity (Fig. 5.21F) which consisted of openings in epidermis (Fig. 5.21G–H).

Sudan red staining on cuticle of epidermis of the labellum of *D. ophrydis* (Fig. 5.22A–E) and it also stained a great number of oil droplets in parenchyma cells of the whole labellum (Fig. 5.22F–H). The results indicated that the labellum of *D. ophrydis* could produce some lipids as the main nectar components or some fragrance.

The pollination strategies of *D. ophrydis* revealed that *D. ophrydis* produced nectar as reward to pollinators. The main nectar components may be lipids. The nectary was in the epidermis which consisted of opening in epidermis and subepidermal cells. The needle-shaped crystals of calcium oxalate or raphides were found in parenchyma cells and encircled the openings. The osmophores of *D. ophrydis* may be presented on adaxial epidermis of labellum whose surface was rugose.

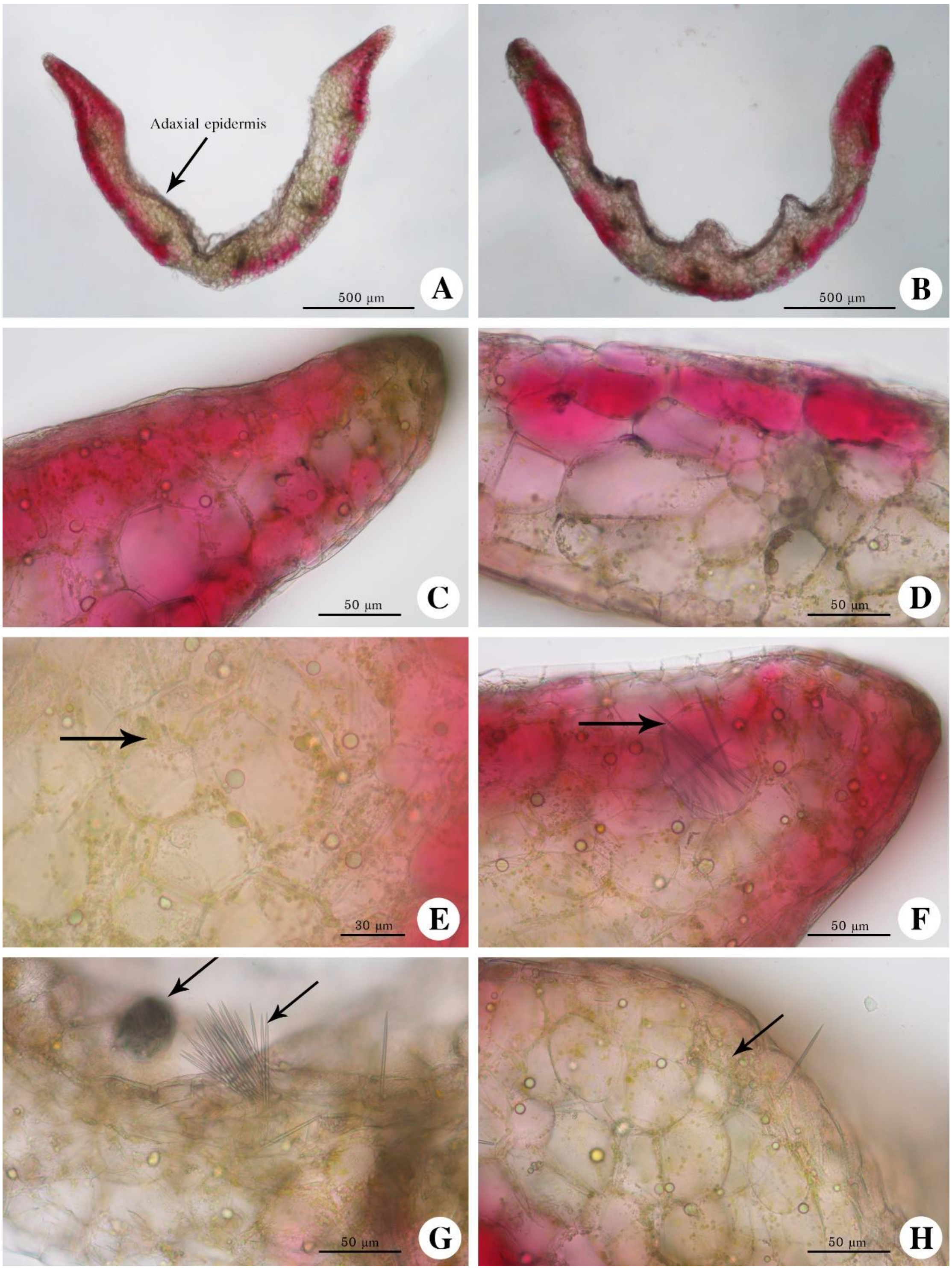

Figure 5.20 Labellum anatomy of *D. ophrydis* in distilled water. **A–B:** Cross-sections of labellum. **C–D:** Anthocyanin in parenchyma cells. **E:** Chloroplast in parenchyma cells. **F:** Raphides in parenchyma cell. **G:** Raphides encircled on opening. **H:** Cytoplasm in subepidermal cells.

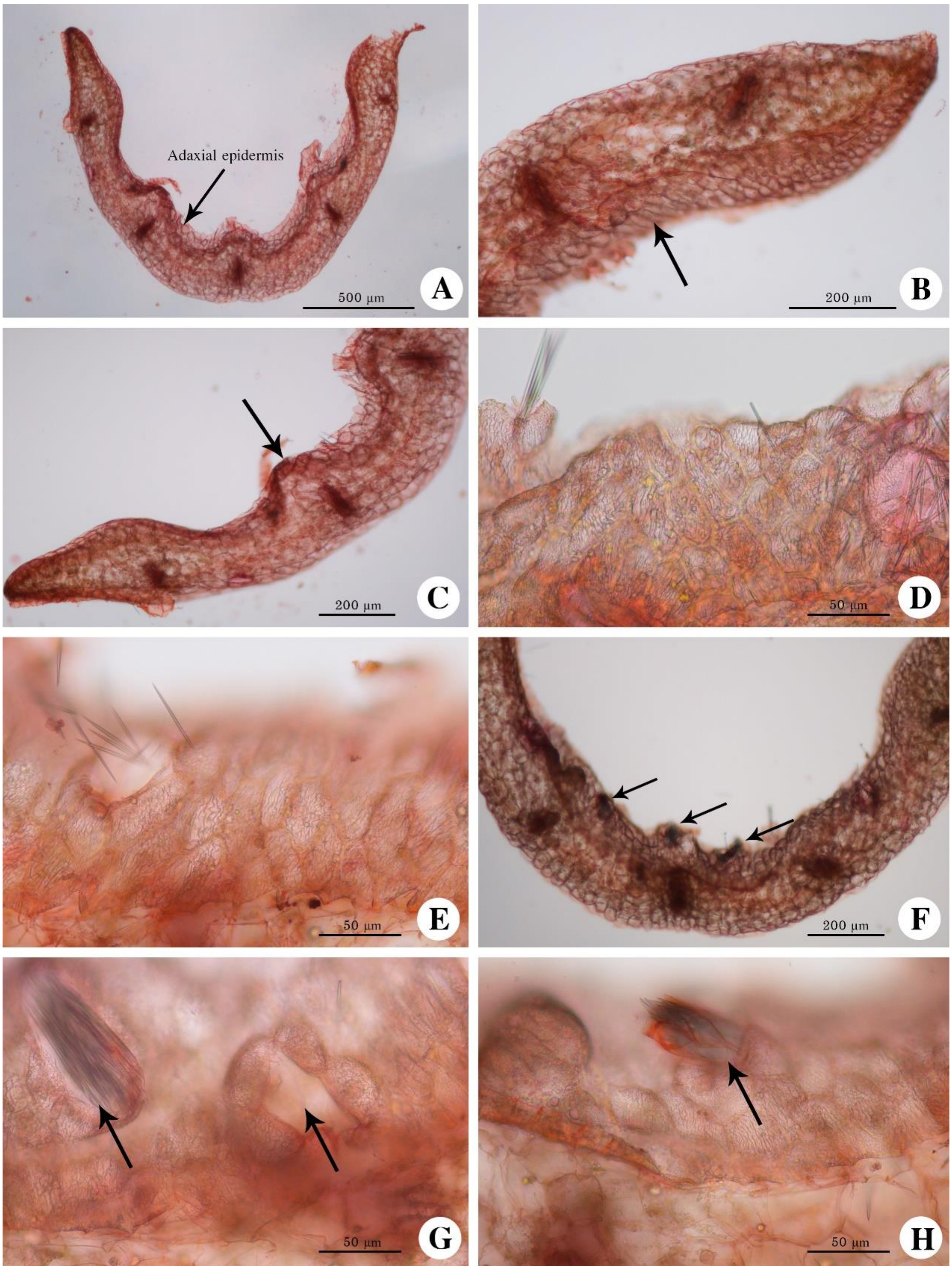

Figure 5.21 Labellum anatomy of *D. ophrydis* stained with Neutral red. **A:** Cross-sections of labellum. **B–C:** Osmophores may located on adaxial epidermis in labellum cavity. **D–E:** Rugose surface of epidermal cells in labellum cavity. **F:** The nectary consisted of a few opening in epidermis. **G–H:** The opening were encircled by raphides.

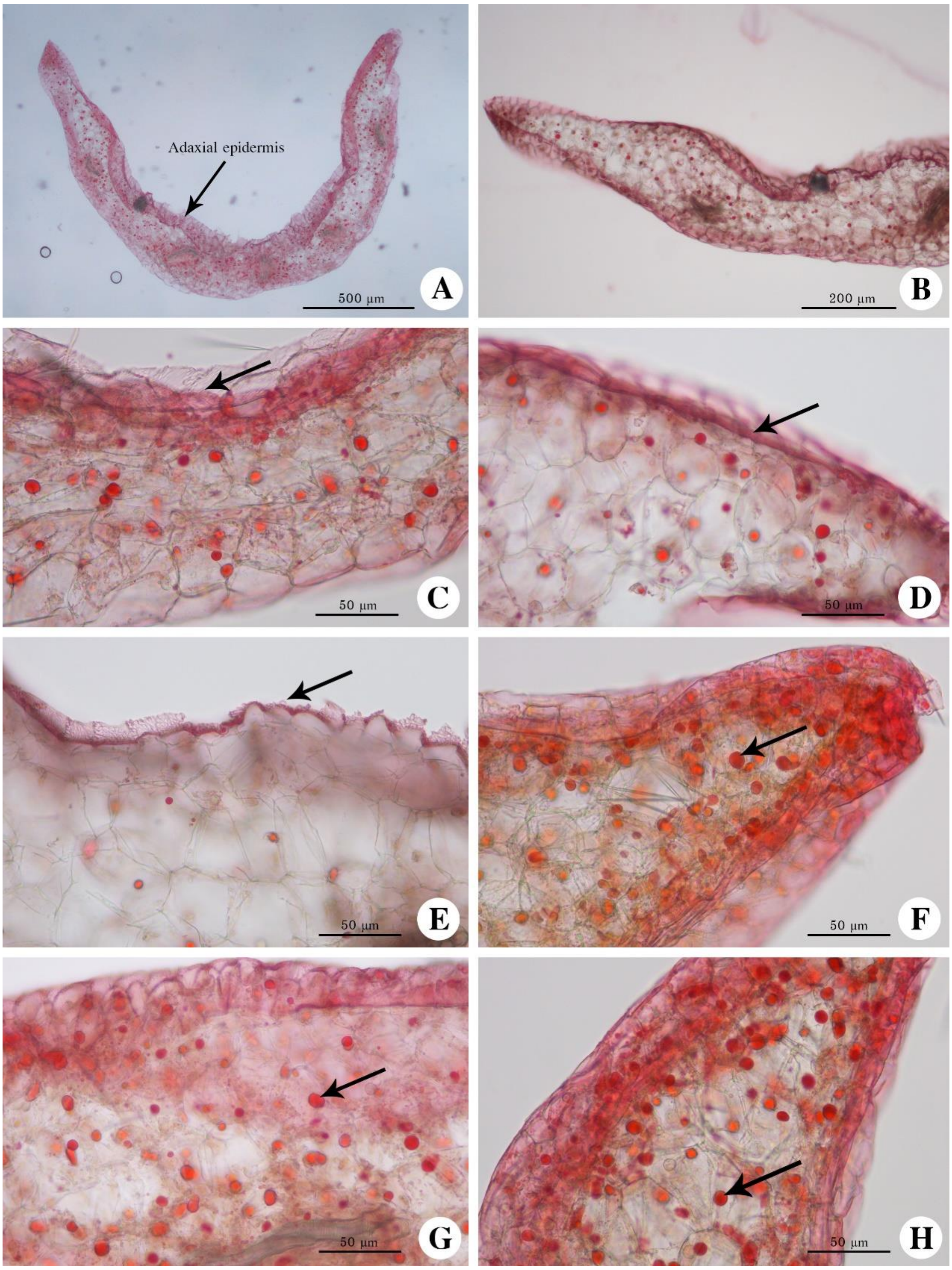

Figure 5.22 Labellum anatomy of *D. ophrydis* stained with Sudan red. **A–B:** Cross-sections of labellum showing stained cuticle and epidermis. **C–E:** Cuticle of epidermis stained to red (arrow). **F–H:** Oil droplets stained to red (arrow).

5.2.2 Breeding system and natural fruit sets

The summary of the experiment was showed in Tabel 5.4. The natural fruit set from open pollinations showed high variation rate (1.5–76%), with mean of 20.7% and 23.2% in the first and second seasons (Table 5.4 and Fig. 5.23A–D). Also, high rate fruit set was observed from unmanipulated flowers; it is suggested that *D. ophrydis* is autonomous self-pollination (Fig 5.24A–D). Comparable levels of fruit set were seen from hand self-pollination (Fig 5.26A–D) and hand cross-pollination (Fig 5.27A–D) showing higher percentage of fruit set. Thus, *D. ophrydis* is self-compatible. However, the much lower percentage of fruit set in unbagged emasculation in both seasons suggested that low pollinator visit flowers to carry pollinia from another flowers to deposit on emasculated flowers (Fig 5.25A–B). Moreover, the much lower percentage of fruit set in bagged emasculation in the first season, suggested that agamospermy may not be present in *D. ophrydis* (Fig 5.25C–D).

When compared the number of fruit setting and fruit dehiscence, the results showed that the number of fruit dehiscence was lower than fruit setting because some fruits were destroyed by some insects and larvae (Table 5.4).

Table 5.4 Fruit set of *D. ophrydis* from all experiments in two seasons.

Year	**2015**			**2016**			
Treatment	No. flowers	No. fruit sets	% fruit sets	No. flowers	No. fruit sets	% fruit sets	No. fruit dehiscence
(A) Open pollination	5,613	1,165	20.7%	7,357	1,708	23.2%	1,494
(B) Hand pollination							
- (B1) Unmanipulated flowers	310	29	9.4%	991	160	16.1%	139
- (B2) Unbagged emasculation	62	0	0	277	1	0.4%	1
- (B3) Bagged emasculation	89	3	3.3%	187	0	0	-
- (B4) Hand self-pollination	97	36	**37.1%**	343	187	**54.5%**	114
- (B5) Hand cross-pollination	100	51	**51%**	445	373	**83.8%**	360

Figure 5.23 Open pollination of *D. ophrydis*. **A–B:** Low percentage of natural fruit set. **C–D:** High percentage of natural fruit set.

Figure 5.24 Unmanipulated flowers of *D. ophrydis*. **A:** Low percentage of fruit set. **B–D:** High percentage of fruit set.

Figure 5.25 Unbagged emasculation and bagged emasculation of *D. ophrydis*. **A:** No fruit set in most plants of unbagged emasculation. **B:** Only fruit set of unbagged emasculation in the second season. **C:** A few fruit set of bagged emasculation in the first season. **D:** No fruit set in most plants of bagged emasculation in both seasons.

Figure 5.26 Hand self-pollination of *D. ophrydis*. **A–D:** High percentage of fruit set in most plants.

Figure 5.27 Hand cross-pollination of *D. ophrydis*. **A–D:** High percentage of fruit set in most plants.

5.2.3 Pollinators and pollination mechanism

Flowers of *D. ophrydis* were rarely visited by diurnal insects, e.g. Diptera (Mosquitoes and Midges), Hymenoptera (Stingless bees), and Hemiptera (Plant bugs), which search and feed nectar on from labellum margin and labellum cavity. The observations showed visits to flowers of *D. ophrydis* were fairly rare, only one or two times in all seasons. Insects visited only on cloudy or sunny days, but not rainy day as rainfall restrict the insects foraging activity. Plant bug may act as pollinators of *D. ophrydis* because they did succeed in removing pollinia (Table 5.5).

During visits, all insects landed and walked directly on inflorescences (Fig. 5.28A–C). They tried to feed nectar by insertion proboscis in labellum cavity. While accessing nectar in labellum cavity, pollinia attached on proboscis (Fig. 5.28D).

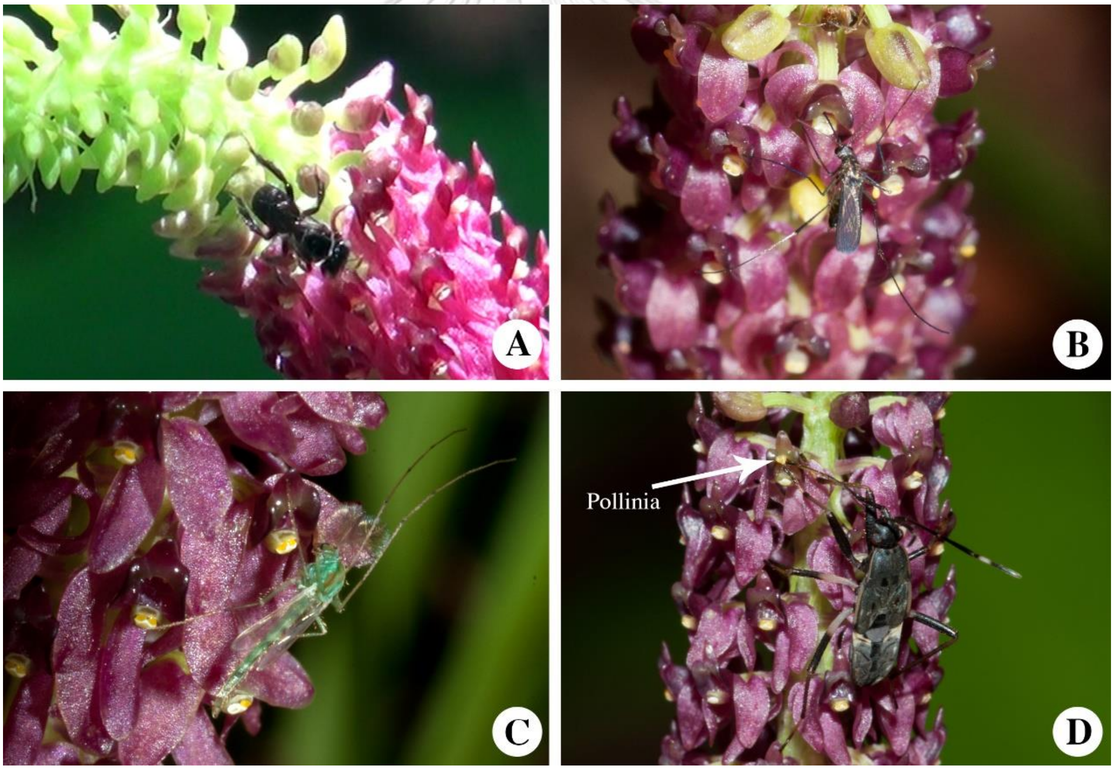

Figure 5.28 Pollinators and visitors of *D. ophrydis*. **A:** Stingless bee was feeding nectar. **B:** Mosquito was inserting proboscis in labellum cavity. **C:** Midges was feeding nectar. **D:** Pollinia attached on proboscis of beetles.

Surprisingly, it also found that this orchid is capable of self-pollinating, in particular autonomous self-pollination resulting from rain-assisted autogamy. The pollination mechanism were assisted by viscous drops forming on stigma and water adhesion. The mechanism can be explained as following: after rainfall, the viscous drop is forming on stigma (Fig. 5.29A). Then, a swollen viscous drop is enlarged till it reaches pollinia (Fig. 5.29B). When the viscous drop shrinks through evaporation, and pollinia are pulled out onto the stigma (Fig. 5.29C). Then, pollinia are enlarged on stigma and enters a fertilization process (Fig. 5.29D). Time spent in this process can last from 10 minutes to one hour. In contary, if flowers are open in the dry weather and no rain drop acumulates on stigma surface, the viscous drop will not form, so that pollinia can not move onto the stigma surface. Accordingly, the pollination mechanism of *D. ophrydis* will depend on rain.

Figure 5.29 Rain-assisted self-pollination of *D. ophrydis*. **A:** A viscous drop is formed on stigma. **B:** Pollinia are attached to and pulled out by a viscous drop. **C:** Pollinia are deposited onto the stigma after a viscous drop evaporated. **D:** Pollinia enters a fertilization process.

Table 5.5 Insects and number of visits to flowers of *D. ophrydis.*

Insect species	**Number of visits**	**Frequency of carrying or removing pollinia**
Stingless bees (Family Apidae)	2	0
Mosquitoes (Family Culicidae)	1	0
Midges (Family Chironomidae)	1	0
Plant bugs (Family Miridae)	1	1

CHAPTER VI
DISCUSSION

6.1 Taxonomic revision

6.1.1 *Crepidium* and *Dienia* in Thailand

In the present study, the species account of *Crepidium* is more than the previous report of Seidenfaden (1978; 1997) by 6 species (Table 6.1) while that of *Dienia* is the same, i.e. one species. It found that four species are new records to Thailand, two species are from new combinations and one species is the new species to science. Furthermore, two species, namely *C. godefroyi* and *C. ovalisepalum*, are not found in Thailand, both were misidentified by Seidenfaden (1978).

Table 6.1 Comparison of *Crepidium* and *Dienia* account in Thailand between previous studies by Seidenfaden (1978; 1997) and the present study.

No.	Taxa	Seidenfaden (1978, 1997)	Present study	Notes
Crepidium Blume				
1.	*C. acuminatum*	✓	✓	
2.	*C. aschistum*	✓	✓	
3.	*C. bahanense*	–	✓	New record
4.	*C. bancanum*	✓	✓	
5.	*C. biauritum*	✓	✓	
6.	*C. calophyllum*	✓	✓	
7.	*C. chamaeorchis*	*Malaxis chamaeorchis*	✓	New combination
8.	*C. concavum*	✓	✓	
9.	*C. falcifolium*	*C. godefroyi*	✓	New species (Misidentified as *C. godefroyi*)
10.	*C. josephianum*	–	✓	New records
11.	*C. khasianum*	✓	✓	

No.	Taxa	Seidenfaden (1978, 1997)	Present study	Notes
12.	*C. klimkoanum*	–	✓	Margońska (2005b)
13.	*C. luniferum*	✓	✓	
14.	*C. mackinnonii*	✓	✓	
15.	*C. macrochilum*	✓	✓	
16.	*C. maximowiczianum*	–	✓	New record
17.	*C. merapiense*	✓	✓	
18.	*C. micranthum*	–	✓	New record
19.	*C. octodentatum*	✓	✓	
20.	*C. orbiculare*	✓	✓	
21.	*C. perakense*	✓	✓	
22.	*C. polyodon*	✓	✓	
23.	*C. prasinum*	✓	✓	
24.	*C. purpureum*	✓	✓	
25.	*C. szemaoense*	*C. ovalisepalum*	✓	New combination (Misidentified as *C. ovalisepalum*)
Dienia Lindl.				
1.	*D. ophrydis*	✓	✓	

Notes: ✓= present, – = absent.

6.1.1.1 New combinations

Two new combinations namely, *C. chamaeorchis* (Schltr.) Nuammee, Seelanan, Suddee & H. A. Pedersen and *C. szemaoense* (Tang & F. T. Wang) Nuammee, Seelanan, Suddee & H. A. Pedersen were made based on the following reasons:

1. *Glossochilopsis chamaeorchis* (Schltr.) Szlach. (basionym: *Microstylis chamaeorchis* Schltr.) is the type species of *Glossochilopsis* Szlach. However, the only feature that consistently separates *G. chamaeorchis* (and *Seidenfia* Szlach.) from all species of *Crepidium* Blume s.s. is the labellum not being provided with auricle and it remains to be demonstrated that *G. chamaeorchis* and *Seidenfia* are not nested in *Crepidium*. Based on this background and in agreement with Pridgeon *et al.* (2005) in treating *Glossochilopsis* and *Seidenfia* as synonyms of *Crepidium*, therefore, the new combination, *C. chamaeorchis*, is provided.

2. In Flora of China, Chen and Wood (2009a) placed *Malaxis szemaoensis* as the synonym of *Crepidium ovalisepalum* (J. J. Sm.) Szlach., a species originally described as *Microstylis ovalisepala* J. J. Sm. from Sumatra (Smith, 1928). Only the type specimen of *Microstylis ovalisepala* is known from Sumatra [West Sumatra, Gunung Kuriman, 1000 m, 24 June 1918, *Bünnemeijer 3315* (holotype **L!)**] when publishing the new combination, *Malaxis ovalisepala* (J. J. Sm.) Seidenf., Seidenfaden (1978) also referred two collections from Doi Chiang Dao, Chiang Mai province, Thailand to this species.

Based on the comparison of the type specimens of *Microstylis ovalisepala*, and *Malaxis szemaoensis*, and the descriptions in Smith (1928), Tang and Wang (1951) and Chen and Wood (2009a), it was clear that both were two distinct species that mainly differ in vegetative characters. *Microstylis ovalisepala* is characterized by a creeping rhizome and an elongated ascending stem bearing c. 10 foliage leaves, whereas *Malaxis szemaoensis* has a short pseudobulbous stem bearing 2–4 leaves. These differences mean that *Microstylis ovalisepala* probably shows the same annual stem/rhizome dynamics, i.e. a creeping rhizome and an elongated ascending stem, never produces pseudobulbs, whereas *Malaxis szemaoensis* matches the majority of *Crepidium* species in producing a new pseudobulb annually through sympodial growth. Based on this background, the new combination, *Crepidium szemaoense*, is erected. As a result, *C. ovalisepalum* is not found in Thailand.

6.1.1.2 New records

There are four new records for Thailand as follows:

1. *C. bahanense* (Hand.-Mazz.) S. C. Chen & J. J. Wood is found in sandy soil along streams and shallow moist depressions in open grassland. This species distributed in China and it is occurred as a small population in only one areas at Phu Ruea National Park, Loei province.

2. *C. josephianum* (Rchb. f.) Marg. is found on humus-rich soil in hill evergreen forest. This species distributed in India and it is occurred as a very small population, less than 10 plants, at Phu Luang Wildlife Sanctuary, Loei province which is at risk to extinct from natural habitat.

3. *C. maximowiczianum* (King & Pantl.) Szlach. is found in humus-rich soil in shaded areas in pine forest. This species distributed in India and it is occurred a small population in only one areas at Doi Ang Khang, Chiang Mai province.

4. *C. micranthum* (Hook. f.) Szlach. is found in humus-rich soil in shaded areas along streams in evergreen forest. This species distributed in Peninsular Malaysia and it is occurred as a large population in Khao Luang National Park, Nakhon Si Thammarat province and Khao Phanombenja, Krabi province.

The new record of *Crepidium* suggested that some elements from adjacent floristic regions, such as species of Indo-Himalaya, Sino-Indochina, China and Peninsular Malaysia floristic regions could possibly distribute to Thailand.

6.1.1.3 New species

During field exploration, the specimens collected from a limestone hill in Nakhon Sri Thammarat province, peninsular Thailand, were initially identified as *Malaxis godefroyi* (Rchb. f.) Kuntze [=*Crepidium godefroyi* (Rchb. f.) Szlach] based on the key provided by Seidenfaden (1978). However, they were more similar to *C. khasianum* (Hook. f.) Szlach. than to *C. godefroyi*. Further study of morphological characters and examination of the type specimen of *C. godefroyi* [basionym:

Microstylis godefroyi Rchb. f.] and *C. khasianum* as well as relevant literature have convinced the author that these specimens in reality represent a distinct species new to science, which is later named and described as *C. falcifolium* Nuammee, Seelanan & H. A. Pedersen.

Previously, Seidenfaden treated the Thai specimens, *Smitinand & Sleumer 1160*, as *Malaxis godefroyi* (Rchb. f.) Kuntze (Seidenfaden, 1969; 1978) and later (implicitly) as *Crepidium godefroyi* (Rchb. f.) Szlach. (Seidenfaden, 1997). This species, *C. godefroyi*, was originally described as *Microstylis godefroyi* Rchb. f. (Reichenbach 1878, p.37), based upon the type collection from Cambodia [Mont de Pursat, 16 June 1875, *Godefroy 414* (holotype **C! W!** photo seen, isotype **P!** photo seen, **RBGE!** photo seen)]. In comparison with the type, *Smitinand & Sleumer 1160* is very distinct from *C. godefroyi*. Instead, *Smitinand & Sleumer 1160* closely matches *C. falcifolium*. *C. godefroyi* is characterized by a pyriform pseudobulb bearing 2–3 ligulate to narrowly elliptic leaves and by a labellum that is not constricted at the middle and is distally bilobed with acute to obtuse lobes. In contrast, *Smitinand & Sleumer 1160* matches the type specimen of *C. falcifolium* in having a (fusiform-)terete pseudobulb bearing 5–7 distinctly falcate to narrowly lanceolate leaves and a labellum that is constricted at the middle (by means of locally revolute margins) and is distally bilobed with rounded lobes. Accordingly, *Smitinand & Sleumer 1160* is redetermined as *C. falcifolium*. Consequently, *C. godefroyi* is not found in Thailand.

6.1.1.4 Putative natural hybrid

Crepidium acuminatum (D. Don) Szlach. × **polyodon** (Hook. f.) Szlach.

Crepidium acuminatum and *C. polyodon* (Szlachetko, 1995), based on *Microstylis polyodon* Hook. f., differ in a number of floral characters, i.e. *C. acuminatum* has larger flowers, fewer teeth in the distal part of the labellum and narrower and differently shaped labellum auricles (Table 6.2 and Fig 6.1). Both flower in the rainy season, but the pollination biology is only known for *C. acuminatum* which is cross-pollination orchid and self-incompatibility breeding system. However, these is no report on pollination biology for *C. polyodon*.

In a mixed population of these two species at Huai Yang Waterfall National Park in Prachuap Khiri Khan province (SW Thailand), the specimens (*Nuammee 439* **BCU**) appeared largely intermediary (Table 6.2; Fig. 6.1B and E). Particularly, it had intermediate auricle shape and an intermediate number of teeth in the distal part of the labellum and flower diameter and auricle width were within the lower part of the range recorded for *C. acuminatum*. Referring to the general trend of orchid hybrids to be morphologically intermediary between their parental taxa (Nilsson, 1985; Aagaard *et al.*, 2005; Hedrén *et al.*, 2012), the plant vouchered as *Nuammee 439* is hypothesized to be a natural hybrid between *C. acuminatum* and *C. polyodon*. However, the comparative molecular data would be needed to test this hypothesis (Rieseberg and Carney, 1998).

Table 6.2 Comparison of *Crepidium acuminatum* (D. Don) Szlach., *C. polyodon* (Hook. f.) Szlach. and a putative natural hybrid. All data were scored from materials collected in Thailand.

Character	***C. acuminatum*[1]**	**Putative hybrid[2]**	***C. polyodon*[3]**
Width of lip (mm)	4.0–9.5	5.5–6.0	2.5–4.0
No. teeth on distal part of labellum	2	4–5	12–16
Shape of lip auricles	Obliquely triangular to oblong-ovate	Obliquely triangular-oblong	Falcately linear-triangular
Width of lip auricles (mm)	1.5–4.0	2.5	1.0–2.0

1) Specimens examined: *van Beusekom & Phengklai 1282* (**L**); *Garrett 404* (**K**); *Geesink et al. 5896* (**L**); *Kerr 100* (**K,** 4 specimens), *437* (**K**), *445* (**K**), *872* (**K**); *Koyama T-61151* (**BKF**); *Maxwell 88-976* (**L**); *Nuammee 377* (**BCU**), *398* (**BCU**), *449* (**BCU**), *438* (**BCU**); *Palee 233* (**BKF**); *Seidenfaden & Smitinand GT 2595* (**C**).

2) Specimen examined: *Nuammee 439* (**BCU**).

3) Specimens examined: *Geesink & Santisuk 5159* (**C**, **L**); *Kerr 457* (**K,** 2 specimens); *Nuammee 437* (**BCU**, 2 specimens).

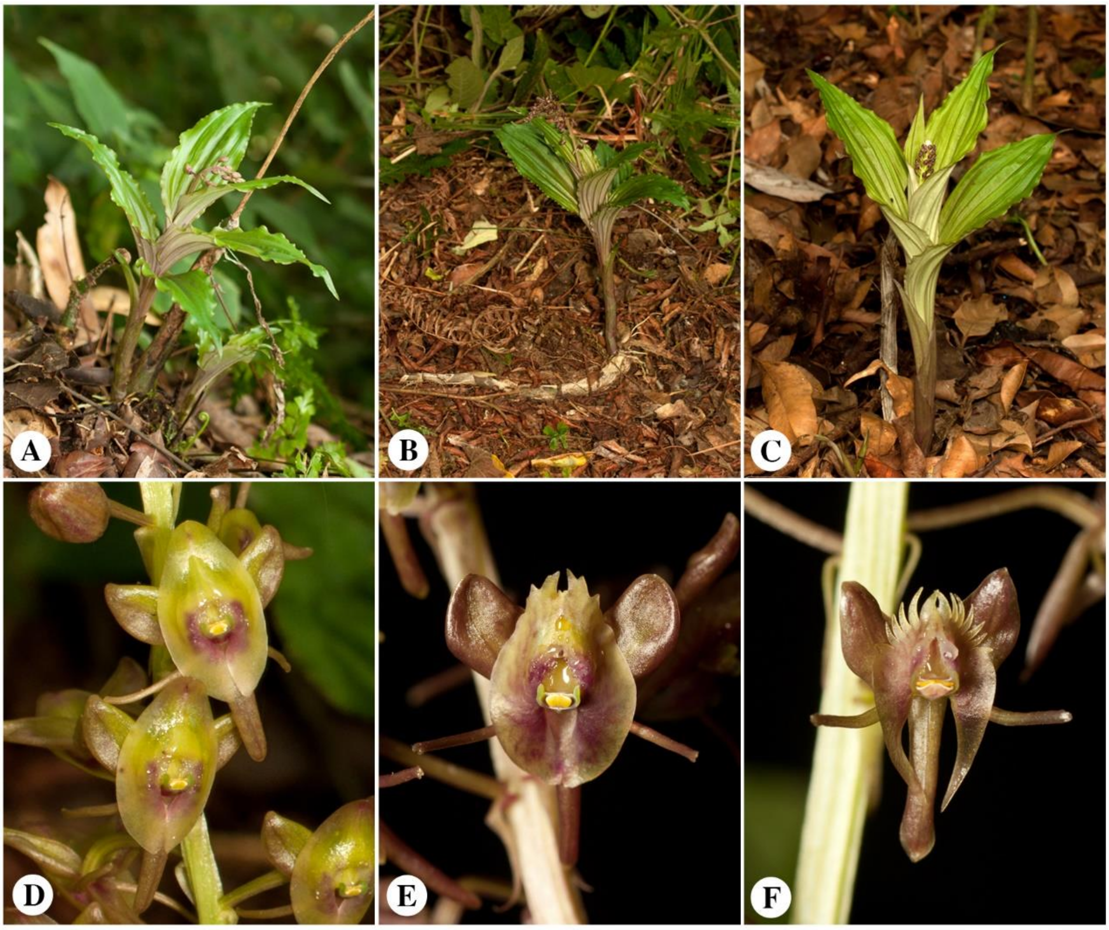

Figure 6.1 Comparison of *Crepidium acuminatum* (D. Don) Szlach., *C. polyodon* (Hook. f.) Szlach. and a putative natural hybrid. **A:** Plant habit of *C. acuminatum.* **B:** Plant habit of putative natural hybrid. **C:** Plant habit of *C. polyodon.* **D:** Flower of *C. acuminatum.* **E:** Flower of putative natural hybrid. **F:** Flower of *C. polyodon.*

6.1.2 Distribution, biogeography, ecological habitat and conservation assessment

Crepidium and *Dienia* are the genus of terrestrial orchids which usually grow in humus-rich soil in the shaded areas or along streams, less often on mossy rocks and on the lower part of tree trunks in evergreen forest, tropical rain forest, hill evergreen forest, pine forest and seasonal evergreen forest, and sometimes occurs in sandy soil or shallow moist depressions in open grassland and mixed deciduous forest on limestone hills. The altitude of Thai *Crepidium* and *Dienia* are ranging from near sea level to 2,200 m. According to phytogeography of Thailand, the country has been classified into seven floristic regions, namely northern, north-eastern, eastern, central, south-eastern, south-western and peninsular (Smitinand, 1958). The distribution of Thai *Crepidium* and *Dienia* were listed in Table 6.3.

Most of *Crepidium* species are rare species whereas *D. ophrydis* is a common species which widely distributed in all floristic regions of Thailand. Interestingly, eighteen species of *Crepidium* are occurred in only one floristic regions. Seven species are found only in the northern, i.e. *C. khasianum*, *C. klimkoanum*, *C. mackinnonii*, *C. maximowiczianum*, *C. orbiculare*, *C. purpureum*, *C. szemaoense*. Eight species are found only in the peninsular Thailand, i.e. *C. aschistum*, *C. bancanum*, *C. falcifolium*, *C. luniferum*, *C. merapiense*, *C. micranthum*, *C. perakense*, *C. prasinum*. Two species are found in only the northeastern, i.e. *C. bahanense* and *C. josephianum*. Moreover, *C. concavum* is the species found in only southwestern of Thailand. However, other species are often found in two to four floristic regions and *C. acuminatum* are the most widely distributed among *Crepidium* species in Thailand. Although *C. polyodon* are found in four floristic regions, they are growing in small populations in each floristic region.

The specimens studied by Seidenfaden (1978), (Margońska, 2005b) and the present study were mostly collected from the northern and peninsular Thailand, with a few specimens collected from the other floristic regions. It is possibly deu to the lack of preferred ecological habitats for *Crepidium* and *Dienia* species in the central, eastern, northeastern and southeastern parts of Thailand. Both *Crepidium* and *Dienia* species usually grow in the forests, especially in various national parks and wildlife sanctuaries at high elevation. Accordingly, it is less likely to be found both in the central, eastern, northeastern and southeastern parts of Thailand that are low elevation and have been urbanized and cleared for agriculture, e.g. rice field (Fig. 6.2).

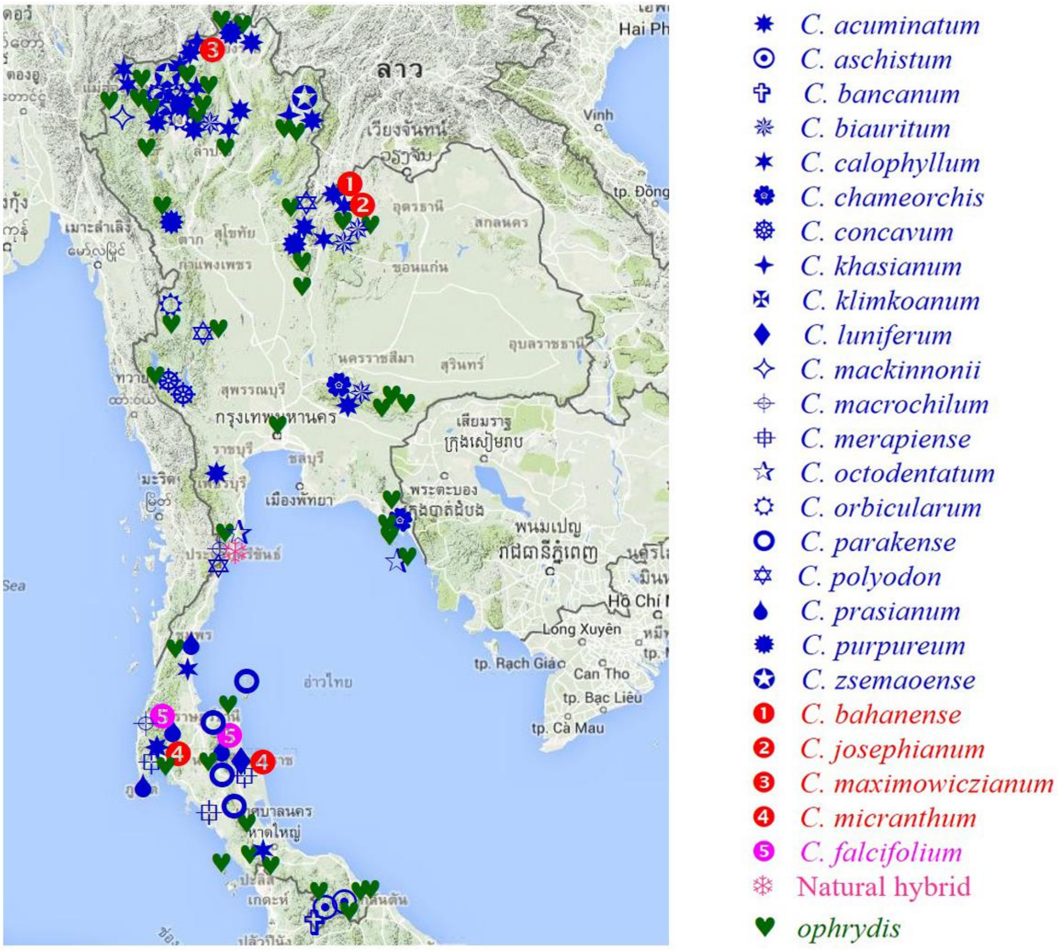

Figure 6.2 Distribution map of *Crepidium* and *Dienia* in Thailand.

Table 6.3 Distribution of *Crepidium* and *Dienia* in Thailand.

No.	**Species**	**Thailand floristic region**							**Altitude**
		N	**NE**	**E**	**C**	**SE**	**SW**	**P**	**(m)**
Crepidium Blume									
1.	*C. acuminatum*	✓	✓	–	–	–	✓	✓	660–1,800
2.	*C. aschistum*	–	–	–	–	–	–	✓	c. 1,000
3.	*C. bahanense*	–	✓	–	–	–	–	–	c. 1,200
4.	*C. bancanum*	–	–	–	–	–	–	✓	c. 800
5.	*C. biauritum*	✓	✓	✓	–	–	–	–	660–2,200
6.	*C. calophyllum*	✓	✓	–	–	–	–	✓	550–1,500
7.	*C. chamaeorchis*	–	–	✓	–	✓	–	–	1,200–1,400
8.	*C. concavum*	–	–	–	–	–	✓	–	400–500
9.	*C. falcifolium*	–	–	–	–	–	–	✓	200–250
10.	*C. josephianum*	–	✓	–	–	–	–	–	c. 1,400
11.	*C. khasianum*	✓	–	–	–	–	–	–	1,700–1,900
12.	*C. klimkoanum*	✓	–	–	–	–	–	–	800–1,200
13.	*C. luniferum*	–	–	–	–	–	–	✓	900–1,200
14.	*C. mackinnonii*	✓	–	–	–	–	–	–	800–1,200
15.	*C. macrochilum*	–	–	–	–	–	✓	✓	400–1,000
16.	*C. maximowiczianum*	✓	–	–	–	–	–	–	c. 1,700
17.	*C. merapiense*	–	–	–	–	–	–	✓	200–300
18.	*C. micranthum*	–	–	–	–	–	–	✓	800–1,200
19.	*C. octodentatum*	–	–	✓	–	✓	✓	–	50–1,000
20.	*C. orbiculare*	✓	–	–	–	–	–	–	1,000–1,800
21.	*C. perakense*	–	–	–	–	–	–	✓	200–800
22.	*C. polyodon*	✓	✓	–	–	–	✓	✓	200–1,000
23.	*C. prasinum*	–	–	–	–	–	–	✓	200–300
24.	*C. purpureum*	✓	–	–	–	–	–	–	550–1,500
25.	*C. szemaoense*	✓	–	–	–	–	–	–	900–2,150
Dienia Lindl.									
1.	*D. ophrydis*	✓	✓	✓	✓	✓	✓	✓	0–2,000

Notes: N = Northern, NE = Northeastern, E = Eastern, C = Central, SE = Southeastern, SW = Southwestern, P = Peninsular, ✓= present, – = absent.

According to van Welzen *et al.* (2011), Thailand is situated on the borders or at the cross-roads between four major biogeographical regions: the Himalayas in the northwest, China in the north, Indochina in the east, and Sundaland in the south. Therefore, the species diversity is influenced by Indo-Burmese, Sino-Himalayan, Indo-Chinese, and Malesian elements (Takhtajan, 1986). Regarding to *Crepidium*'s distribution, Thailand is likely to be the meeting point of Asian species (Table 6.4).

D. ophrydis is the only species that widely distributed from northern India to northern Australia while three species of *Crepidum,* i.e. *C. acuminatum*, *C. calophyllum* and *C. purpureum* have rather wide distribution from northern India to Indonesia.

Five species are members of the Sino-Himalaya elements, i.e. *C. biauritum, C. khasianum, C. josephianum, C. mackinnonii* and *C. maximowiczianum*. In addition, four species namely, *C. khasianum*, *C. josephianum*, *C. mackinnonii* and *C. maximowiczianum* have distributed from Napal and NE India downwards to northern and northeastern Thailand at high elevation. However, there is no previous report about the distribution of these four species in Myanmar. This study indicates that Thialand may be the easternmost station of these four species. *C. biauritum* has distributed from NE India, Myanmar and restricted distribution in Laos.

Nine *Crepidium* species in Thailand are Indo-Chinese and Indo-Burmese species which are distribute in many floristic regions of Thailand except the central floristic region, i.e. *C. bahanense, C. concavum, C. falcifolium, C. klimkoanum, C. macrochilum, C. octodentatum, C. polyodon, C. orbiculare* and *C. szemaoense.*

Eight species are Malesian species, i.e. *C. aschistum*, *C. bancanum*, *C. chamaeorchis*, *C. luniferum*, *C. merapiense*, *C. micranthum*, *C. perakense* and *C. prasinum.* The *Crepidium* species in Thailand that distributed from Melasian element are restricted only in Chumphon or Surat Thani provinces, especially, the creeping rhizome species, e.g. *C. micranthum*, *C. perakense* and *C. aschistum*. Because the stem and leaves of these species occurs all year round, they are not enter the dormancy stage. Thus, the creeping rhizome species grows in only habitats with high humidity and rainfall. However, *C. chamaeorchis* is the only Malesian species that distributed further to highest latitude as it is found in Khao Yai National Park. It may be due to it has rather thick leaves and ability to produce pseudobulb which can survive in dry season.

In addition, four endemic species are found in Thailand, i.e. *C. aschistum*, the endemic species of peninsular Thailand, grows in humus-rich soil along stream in evergreen forest at c. 1000 m alt. and *C. falcifolium*, also the endemic species of peninsular Thailand, grows in humus-rich soil in mixed deciduous forest on limestone hills at 200–250 m alt. Presently, less than 50 mature individuals from the natural habitat were observed, this two species should be evaluated as a critically endangered species (IUCN, 2012). Both *C. klimkoanum* and *C. macrochilum* are another endemic species of Thailand with large populations.

6.1.3 Typification

The lectotype for *C. josephianum* was selected from a drawing by W. Fitch based on from a plant sent by Gammie from Sikkim (India) and flowering in Royal Botanic Garden, Kew [see in the library of **K**; reproduction in Bot. Mag. 103: t. 6325. 1877] (Nuammee *et al.*, 2016). However, the type specimens of *C. acuminatum* (*Wallich s.n.*), *C. calophyllum* (*Reichenbach s.n.*), *C. merapiense* (*Schlechter 15943*) and *C. purpureum* (*Macrae s.n.*) are not found. According to International Code of Nomenclature (ICN), the lectotypification or neotypification should be futher designated.

Table 6.4 List of species of *Crepidium* and *Dienia* based on the biogeographical distribution.

No.	**Taxa**	**Biogeographical regions**			
		Sino-Himalaya elements	**Indo-Burmese elements**	**Indo-Chinese elements**	**Malesian elements**
1.	*C. acuminatum*	✓	✓	✓	✓
2.	*C. aschistum*	–	–	–	✓
3.	*C. bahanense*	–	✓	✓	–
4.	*C. bancanum*	–	–	–	✓
5.	*C. biauritum*	✓	–	–	–
6.	*C. calophyllum*	✓	✓	✓	✓
7.	*C. chamaeorchis*	–	–	–	✓
8.	*C. concavum*	–	✓	✓	–
9.	*C. falcifolium*	–	✓	✓	–
10.	*C. josephianum*	✓	–	–	–
11.	*C. khasianum*	✓	–	–	–
12.	*C. klimkoanum*	–	✓	✓	–
13.	*C. luniferum*	–	–	–	✓
14.	*C. mackinnonii*	✓	–	–	–
15.	*C. macrochilum*		✓	✓	–
16.	*C. maximowiczianum*	✓	–	–	–
17.	*C. merapiense*	–	–	–	✓
18.	*C. micranthum*	–	–	–	✓
19.	*C. octodentatum*	–	✓	✓	–
20.	*C. orbiculare*	–	✓	✓	–
21.	*C. perakense*	–	–	–	✓
22.	*C. polyodon*	–	✓	–	–
23.	*C. prasinum*	–	–	–	✓
24.	*C. purpureum*	✓	✓	✓	✓
25.	*C. szemaoense*	–	✓	✓	–
26.	*D. ophrydis*	✓	✓	✓	✓

Notes: ✓= present, – = absent.

6.2 Pollination biology

6.2.1 Plant phenology and floral features

Both *C. acuminatum* and *D. ophrydis* emerge in the rain season which produce the new pseudobulbs in April and flower from May to June. However, the flowering period may extend to July depending on climate in each year. Mature friuts are dehisce in the winter season like other terrstrial orchids. Orchid seeds are widely dispersed by wind because of their small size and low weight (Brzosko *et al.*, 2017). After that plants enters the dormancy stage in summer season, having mature pseudobulbs as a sourse of energy and nutrients for the next season. Other orchid genera such as some species of *Dendrobium*, *Liparis, Calanthe* and *Habenaria* enter the dormancy stage similar to *Crepidium* and *Dienia*.

Flowers of *C. acuminatum* and *D. ophrydis* are usually anthesis from late afternon to fully open in early morning of the next day and produce and secrete nectar on labellum. Most insects visiting flowers of these two species are diurnal insects, large quantity of nectar is produced in the morning to attract insects. Nevertheless, the amount of nectar and nectar concentration are varied and many factors may influence the amount of nectar and nectar concentration, e.g. age of flowers, time of flower anthesis, temperature and humidity. Although both of *C. acuminatum* and *D. ophrydis* produces nectar, the amount of nectar in *D. ophrydis* is less than *C. acuminatum* bacause the flowers of *D. ophrydis* is much smaller than those of *C. acuminatum.*

In generally, the secretory cells of nectary in flowering plants may be epidermal cells, trichomes, or nectariferous parenchyma cells where nectar is transported into specialized intercellular spaces and outside through stomata (Fahn, 1979). In this study, the nectary of *C. acuminatum* and *D. ophrydis* consists of a single-layered epidermis and subepidermal cells which are several layers of large parenchyma cells. The opening occur in epidermis at area flanking labellum cavity and inside of labellum cavity that frequently encircled by rephides. Nectar of *C. acuminatum* and *D. ophrydis* may secrete from parenchyma cells and is transported to outside through opening. However, the details of secretory cells shoud be futher studied by histology, SEM and TEM.

The main nectar components of *C. acuminatum* may be sucrose while *D. ophrydis* may be lipids. Lipid droplets are also found in the cytoplasm and in the nectary cells of other orchids (Figueiredo and Pais, 1992; Stpiczyńska, 1997; Stpiczyńska and Matusiewicz, 2001; Stpiczyńska *et al.*, 2003; 2005).

Osmophores, a fragrance gland, are found in many orchid species that produces floral fragrance to attract their pollinators (Stpiczyńska, 2001; Wiemer *et al.*, 2009; Pansarin *et al.*, 2014). The osmophores of *C. acuminatum* and *D. ophrydis* may be presented on adaxial epidermis of labellum which is short cone-shaped cells with rugose surface in *C. acuminatum* but in *D. ophrydis* shorter cone-shaped cell. Osmophores of *Malaxis rzedowskiana* produce a pleasant floral fragrance that having kaurene, ß-ionone and *a*-ionone as the main components (Kite and Salazar, 2008) whereas those of *Liparis viridiflora* flowers produced the strange fragrance consisting of (E,E)-α-farnescene (Kaiser, 1993). Osmophores in *C. acuminatum* and *D. ophrydis* may produce some weak floral fragrance though it may not be detectable by author sense. Thus, chemical ecological study about floral fragrance in these two orchids are needed to reveal information about chemical components and it possible roles.

Hoshimoto (1993) reported that raphides were also found on the labellum of some species in Malaxidinae, i.e. *C. acuminatum*, *C. bancanoides*, *C. khasianum,* and on labellum and inner tissue of *D. ophrydis*. He noticed that the raphides are placed in the areas near the column that may function as a protecting apparatus against herbivores, or may be used to trace area for insects that carry out pollinia. Moreover, Kowalkowska and Margońska (2009) suggested that the glistening bundle of raphides may enhance pollinators to visit the flowers.

6.2.2 Breeding system, natural fruit sets and seed viability

The pollination study of *C. acuminatum* revealed that this species is a cross-pollination orchid and has self-incompatibility breeding system. This species is completely relied on pollinators for pollination success. Generally, the production of fruits per inflorescence is used to determine the reproductive success of Orchidaceae (Montalvo and Ackerman, 1987; Ackerman, 1989; Zimmerman and Aide, 1989; Ackerman and Montalvo, 1990; Neiland and Wilcock, 1998; Oh *et al.*, 2001; Pansarin *et al.*, 2008a). The fruit set of cross-pollination orchids, as in the case of *C. acuminatum*, is low as a consequence of deficient pollen transfer between plants where the scarcity of efficient pollinators seems to be a limiting factor (Li *et al.*, 2008; Pansarin *et al.*, 2008a; Suetsugu and Tanaka, 2013). Moreover, self-incompatibility in plants as one of the most important means in preventing inbreeding seems to be the limiting factor to limit natural fruit set in orchids (Aragón and Ackerman, 2001; Borba *et al.*, 2001; Oh *et al.*, 2001; Hietz *et al.*, 2006; Pinheiro *et al.*, 2015). However, other factors, e.g. pests, inflorescence size, habitat, plant density, population size and climate variation can exert a strong influence on the reproductive success of orchid species (Neiland and Wilcock, 1998; Kindlmann and Balounová, 2001; Tremblay *et al.*, 2005).

The natural fruit set of *C. acuminatum* was very low in all three seasons when compared to hand cross-pollinations, it may be due to self-incompatibility, pollinator limitation, coupling with other environmental factors. Furthermore, the occurrence of a high percentage of potentially viable seeds from hand cross-pollinations and open-pollination but low percentage in hand self-pollination shows that *C. acuminatum* is strict self-incompatibility. The machanisms of self-incompatibility involve interruptions in many process, e.g. pollen germination, pollen tube growth, ovule fertilization and embryo development (Gibbs, 1988; Silva and Goring, 2001).

The pollination study of *D. ophrydis* revealed that this species is autonomous self-pollination orchid assited by rain and has self-compatibility breeding system. The natural fruit sets showed the differences of fruit set percentages among individual inflorescences, from low to high percentages which depended on the correlation of flowering period and rain period as well as position of flowers (Pansarin *et al.*, 2008b). The high natural fruit set is common in autonomous self-pollination orchids (Peter and Johnson, 2009a; Fan *et al.*, 2012; Suetsugu, 2015).

The production of fruits per inflorescence has been used to determine the reproductive success of Orchidaceae (Montalvo and Ackerman, 1987; Ackerman, 1989; Zimmerman and Aide, 1989; Ackerman and Montalvo, 1990; Neiland and Wilcock, 1998; Oh *et al.*, 2001; Pansarin *et al.*, 2008a; Suetsugu, 2015), accordingly, *D. ophrydis* is one of high reproductive success orchid species. The presenec of some fruits from bagged emasculation in the first season may not be from agamospermy or apomixis which only reported in a few orchid species (Naumova, 1993; Richards, 2003; Whitton *et al.*, 2008; Campacci *et al.*, 2017).

6.2.3 Pollinators and pollination process

The insects visit to flowers of *C. acuminatim* and *D. ophrydis* are diurnal insects. High frequent visits are Diptera [hoverflies (cf. *Meliscaeva cinctella* and cf. *Baccha elongata*), fungus gnats, mosquitoes and midges] while low frequent visits in are Hymenoptera (honey bees, ants), Orthoperta (crickets) and Hemiptera (plant bugs). Previous pollination study in tribe Malaxideae reported that insects visiting to flowers were Ditera. For example, *Malaxis paludosa* was pollinated by male fungus gnat, *Phronia digitata* Hackman (Diptera, Mycetophilidae) by mean of the pollinia attached at the ventral–anterior part of the thorax behind the mouthparts and by mosquitoes (*Aedes* sp.) though the pollinating process being unknown (Reeves and Reeves, 1984) while *Liparis reflexa* was pollinated by unidentified dipteran in family Sarcophagidae (Wallace, 1974). It appears that Diptera and Hymenoptera are major pollinators in tribe Malaxideae.

The four species of insects, i.e. hoverfly (cf. *Meliscaeva citella*), honey bee, fungus gnat and cricket can carry pollinia of *C. acuminatim* whreas only species of plant bugs carry pollinia of *D. ophrydis*. Hoverflies and honey bees are general pollinator in flowering plants (Kearns and Inouye, 1997; Klecka *et al.*, 2018) whereas crickets are also the new pollinator of orchids which have just been reported by Micheneau *et al.* (2010) and Pedersen *et al.* (2018). Nevertheless, if pollinia attach on their legs, it will be failed in pollination. Because the flowers of *C. acuminatim* and *D. ophrydis* are non-resupinate flowers, pollinia attachment on proboscis, prodive the suitable position to withdraw or deposit pollinia on stigma for pollination success.

Although *D. ophrydis* is a nectariferous orchid, however the observations suggested that insect visitation as the amount of nectar secreted was very low and devoid of sugar, it may not play any role in attracting pollinator. It has been suggested that pollinators will learn to avoid non-rewarding plants (Li *et al.*, 2011), if so, *D. ophrydis* might be shifting its pollination mode from entomophily to self-pollination.

Furthermore, the rain assisted self-pollination are also found in other orchids in tribe Malaxideae, e.g. *Liparis loeselii* (Catling, 1980), *Cyrtopodium polyphyllum* (Pansarin *et al.*, 2008b), *Acampe rigida* (Fan *et al.*, 2012). Each species is different from another in the detail of mechanism. These three differ from *D. ophrydis* in having resupinate flowers, however, all rely on viscous drop in stigma to withdraw pollinia/pollinium from anther. In addition, the autonomous self-pollination assisted by rain thus seen to be an important strategy that guarantees fruit set when pollinator's visits are scarce (Garay, 1960; Catling, 1980; Pansarin *et al.*, 2008b; Fan *et al.*, 2012).

CHAPTER VII

CONCLUSION

7.1 Taxonomic revision and Pollination biology

Twenty five species of *Crepidium* and only one species of *Dienia*, *D. ophrydis* (J. Koenig) Ormerod & Seidenf., are distributed in Thailand. Among these four species of *Crepidium* are new records for Thailand namely, *C. bahanense* (Hand.-Mazz.) S. C. Chen & J. J. Wood, *C. josephianum* (Rchb. f.) Marg., *C. maximowiczianum* (King & Pantl.) Szlach. and *C. micranthum* (Hook. f.) Szlach. as well as *C. falcifolium* Nuammee, Seelanan & H. A. Pedersen is a new orchid species for Thailand. Furthermore, the two new combinations are made and substantiated, i.e. *C. chamaeorchis* (Schltr.) Nuammee, Seelanan, Suddee & H. A. Pedersen and *C. szemaoense* (Tang & F. T. Wang) Nuammee, Seelanan, Suddee & H. A. Pedersen. In addition, a putative natural hybrid between *C. acuminatum* (D. Don) Szlach. × *C. polyodon* (Hook. f.) Szlach. is firstly hypothesized and reported in Thailand.

Two species namely, *C. godefroyi* and *C. ovalisepalum* were recorded from Thailand by Seidenfaden (1978; 1997). In fact, they were misidentified and are not found in Thailand.

Crepidium and *Dienia* species are found in northern, northeastern, eastern, southeastern, southwestern and peninsular parts of Thailand. The habitat included evergreen forest, tropical rain forest, hill evergreen forest, pine forest and seasonal evergreen forest, mixed deciduous forest and open grassland from near sea level to 2,200 m. Moreover, *Crepidium* species in Thailand are mainly elements from Indo-Burmese, Indo-Chinese and Malesian floristic regions with a few are from Sino-Himalaya floristic regions.

The pollination biology of *C. acuminatum* (D. Don) Szlach showed nectar were produced on labellum base and cavity. The amount of nectar is 1–6.5 µl (with mean of 2.5 µl) and nectar concentration is 4–17% brix (with mean of 11.5% brix) as well as the main nectar composition may be sucrose. The nectary is produced from epidermis and two or three layers of subepidermal cells. The secretory epidermis has few opening and encircled by raphides. Controlled hand-pollination suggested that *C.*

acuminatum is likely cross-pollinated orchids and relies on pollinators for pollination success. Most of insects visited to flowers are diurnal insects which there are four species may act as pollinators. While accessing nectar in labellum cavity, pollinia may be attached on their proboscis, at which the probable position is for higher chance for pollination success.

In contrary, the pollination biology of *D. ophrydis* showed nectar were produced on labellum margin and cavity. The amount of nectar is only 0.5–1 µl and nectar concentration is less than 0.5% brix. The nectary is produced from epidermis and subepidermal cells. The secretory epidermis has few opening and encircled by raphides. The main nectar composition may be lipids and some small insects visited to flowers during daytimes. Controlled hand-pollination suggested that *D. ophrydis* has self-compatible breeding system In addition, it also has an autonomous self-pollination assisted by rain. The pollination mechanism of the latter involve viscous drops on stigma and water adhesion.

In conclusion, the disrecovery of new records, new species and newly acquired knowledge of species distributions within Thailand suggested the Thai orchid flora is still incompletely known. It is an important role to work continuously on taxonomic revision for the completion of the Thai orchid Flora. Although, orchid species are very similar floral morphology, but they can have different pollination biology that found in *C. acuminatum* and *D. ophrydis*.

7.2 Future work and recommendation

1. More intensive field work on the northeast and lower-peninsular parts of Thailand should be carried out.

2. The mechanism of self-incompatibility in *C. acuminatum* should be investigated further, e.g. pollen tube germination in gynostemium.

3. Nectar composition should be analyzed to ascertain its role(s) in pollination.

REFERENCES

Aagaard, S. M. D., Såstad, S. M., Greilhuber, J. and Moen, A. 2005. A secondary hybrid zone between diploid *Dactylorhiza incarnata* ssp. *cruenta* and allotetraploid *D. lapponica* (Orchidaceae). *Heredity* 94: 488–496.

Ackerman, J. D. 1989. Limitations to sexual reproduction in *Encyclia krugii* (Orchidaceae). *Systematic Botany* 14: 101–109.

Ackerman, J. D. and Montalvo, A. M. 1990. Short- and long-term limitations to fruit production in a tropical orchid. *Ecology* 71: 263–272.

Ames, O. 1938. Resupination as a diagnostic character in the Orchidaceae with special reference to *Malaxis monophyllos*. *Botanical Museum Leaflets, Harvard University* 6(8): 145–183.

APG IV. 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* 181: 1–20.

Aragón, S. and Ackerman, J. D. 2001. Density effects on the reproductive success and herbivory of *Malaxis massonii*. *Lindleyana* 16(1): 3–12.

Arditti, J. 1992. *Fundamentals of Orchid Biology*. New York: Wiley.

Argue, C. L. 2012. *The Pollination Biology of North American Orchids*, Vol. 2: North of Florida and Mexico. New York: Springer.

Ascensao, L., Francisco, A., Cotrim, H. and Pais, M. S. 2005. Comparative structure of the labellum in *Ophrys fusca* and *O. lutea* (Orchidaceae). *American Journal of Botany* 92(7): 1059–1067.

Averyanov, L. V. 2013. The orchids of Vietnam. Illustrated survey. Part 4. Subfamily Epidendroideae (tribes – Arethuseae and Malaxideae). *Turczaninowia* 16(1): 5–163.

Banziger, H., Sun, H. and Luo, Y.-B. 2005. Pollination of a slippery lady slipper orchid in south-west China: *Cypripedium guttatum* (Orchidaceae). *Botanical Journal of the Linnean Society* 148: 251–264.

Barretto, G., Cribb, P. J. and Gale, S. W. 2011. *The wild orchids of Hong Kong*. Hong Kong: Natural History Publications (Borneo).

Beaman, T. E., Wood, J. J., Beaman, R. S. and Beaman, J. H. 2001. *Orchids of*

Sarawak. Kota Kinabalu: Natural History Publications (Borneo) in association with The Royal Botanic Gardens, Kew. xvi.

Bentham, G. 1881. Notes on Orchideae. *Journal of the Linnean Society, Botany* 18(110): 281–367.

Bentham, G. and Hooker, J. D. 1883. *Genera plantarum 3*. London: Lovell Reeve & Co.

Blume, C. L. 1825a. *Tabellen en Platen voor de favanshe orchideën*. Batavia: Ter Lands Drukkerii.

Blume, C. L. 1825b. Orchideen. In *Bijdragen tot de Flora van Nederlandsch India*. Batavia: Ter Lands Drukkerij.

Borba, E. L., Semir, J. O. and Shepherd, G. J. 2001. Self-incompatibility, Inbreeding Depression and Crossing Potential in Five Brazilian *Pleurothallis* (Orchidaceae) Species. *Annals of Botany* 88: 89–99.

Borror, D. J., Triplehorn C. A. and Johnson, N. F. 1989. *An introduction to the study of insects*, 6th ed. Philadelphia: Saunders College Publishing, Pennsylvania.

Bridson, D. and Forman, L. 1998. *The Herbarium Handbook*, 3rd ed. England: Royal Botanic Garden, Kew, Whitstable Litho Printers Ltd.

Brown, R. 1810. *Prodromus Florae Novae Hollandiae et Insula Van-Diemen*. London: J. Johnson and Co.

Brzosko, E., Ostrowiecka, B., Kotowicz, J., Bolesta, M., Gromotowicz, A., Gromotowicz, M., Orzechowska, A., Orzołek, J. and Wojdalska, M. 2017. Seed dispersal in six species of terrestrial orchids in Biebrza National Park (NE Poland). *Acta Societatis Botanicorum Poloniae* 86(3): 1–14.

Buakhlai, A., Seelanan, T. and Thaithong, O. 2005. *Diversity of Orchids at Khao Khaew Area in Khao Yai National Park.* Master's Thesis, Department of Botany, Faculty of Science, Chulalongkorn University,

Buanaka, K., Juntawong, N., Nanakorn, W., Paisooksantivatana, Y., Sabhasri, D., Inthagool, N. and Pingsopha, B. 2009. Diversity of terrestrial orchids at pine camping area in Phu Soi Dao National Park, Uttaradit province. *Proceedings of 47th Kasetsart University Annual Conference: Plants*: 131–138.

Cameron, K. M. 1998. Foliar architecture of vanilloid orchids: insights into the evolution of reticulate leaf venation in monocotyledons. *Botanical Journal of the*

Linnean Society 128(45–70).

Cameron, K. M. 2005. Leave it to the leaves: A molecular phylogenetic study of Malaxideae (Epidendroideae, Orchidaceae). *American Journal of Botany* 92(6): 1025–1032.

Campacci, T. V. S., Castanho, C. T., Oliveira, R. L. F., Suzuki, R. M., Catharino, E. L. M. and Koehler, S. 2017. Effects of pollen origin on apomixis in *Zygopetalum mackayi* orchids. *Flora* 226: 96–103.

Catling, P. M. 1980. Rain-assisted autogamy in *Liparis loeselii* (Linnaeus) L. C. Rich. (Orchidaceae). *Bulletin of the Torrey Botanical Club* 107: 525–529.

Catling, P. M. 1984. Distribution and pollination biology of Canadian Orchids. In K. W. Tan (Ed.), *Proceedings of the 11th World Orchid Conference* (pp. 121–135). Miami: The American Orchid Society.

Chantanaorrapint, S. and Thaithong, O. 2005. *Preliminary Study of Orchidaceae at Huai Yang Waterfall National Park, Prachaup Khiri Khan Province, Thailand*. In H. Nair and J. Arditti (eds.), Processdings of the 17th World Orchid Conference “Sustaining Orchids for the Future” 2002, pp. 146–149. Shah Alam: Natural History Publications (Borneo).

Chase, M. W., Cameron, K. M., Freudenstein, J. V., Pridgeon, A. M., Salazar, G., van den Berg, C. and Schuiteman, A. 2015. An updated classification of Orchidaceae. *Botanical Journal of the Linnean Society* 177: 151–174.

Chen, X. Q. and Wood, J. J. 2009a. 78. *Crepidium* Blume. In Z. Y. Wu, P. H. Raven and D. Hong (Eds.), *Flora of China* (Vol. 25: Orchidaceae, pp. 229–234). Beijing: Science Press & St. Louis: Missouri Botanical Garden Press.

Chen, X. Q. and Wood, J. J. 2009b. 79. *Dienia* Lindley. In Z. Y. Wu, P. H. Raven and D. Hong (Eds.), *Flora of China* (Vol. 25: Orchidaceae, pp. 234-235). Beijing: Science Press & St. Louis: Missouri Botanical Garden Press.

Cheng, J., Shi, J., Shangguan, F.-Z., Dafni, A., Deng, Z.-H. and Luo, Y.-B. 2009. The pollination of a self-incompatible, food-mimic orchid, *Coelogyne fimbriata* (Orchidaceae), by female *Vespula* wasps. *Annals of Botany* 104: 565–571.

Chimyam, S. 1999. *Potential Streamflow of Reserved Forest at Phuhinrongkla National Park, Changwat Phitsanulok - Loei.* Master’s Thesis, Department of

Conservation, Faculty of Forestry, Kasetsart University,

Clements, M. A. and Jones, D. L. 1996. *Crepidium myosotis*, a new species of Orchidaceae from Papua New Guinea. *Lasianthera* 1: 32–45.

Comber, J. B. 2001. *Orchids of Sumatra*. England: The Royal Botanic Gardens, Kew.

Cozzolino, S. and Widmer, A. 2005. Orchid diversity: an evolutionary consequence of deception? *TRENDS. In Ecology and Evolution* 20: 487–494.

Damapong, S. 2007. *A Taxonomic study of Orchidaceae at Doi Phahom Pok, Doi Phahom Pok National Park, Chiang Mai Province.* Master’s Thesis, Department of Biology, Faculty of Science, Naresuan University,

Darwin, C. 1862. *On the various contrivances by which British and foreign orchids are fertilized by insects and on the good effects of intercrossing*, 1st ed. London: John Murray.

Dressler, R. L. 1981. *The Orchids: Natural History and Classification*. Cambridge: Harvard University Press.

Dressler, R. L. 1993. *Phylogeny and Classification of the Orchid Family*. Oregon: Dioscorides Press.

Dressler, R. L. 2005. How many orchid species? *Selbyana* 26: 155–158.

du Petit-Thouars, L.-M. A. A. 1809. Extrait de trois Memoires lus a la premiere classe de líInstitut, sur líhistoire des plantes orchidees des iles australes d’Afrique. *Nouv. Bull. Sci. Soc. Philom. Paris* 1: 314–319.

du Petit-Thouars, L.-M. A. A. 1822. *Histoire particulière des plantes Orchidées recueillies sur les trois îles australes d'Afrique, de France, de Bourbon et de Madagascar*. L'auteur. Paris.

Duangdee, K. 2015. *Orchid Diversity along trails to the plateau, Phu Kradueng National Park, Loei Province.* Master’s Thesis, Department of Botany, Faculty of Science, Chulalongkorn University,

Fahn, A. 1979. Ultrastructure of nectaries in relation to nectar secretion. *American Journal of Botany* 66: 977–985.

Fan, X.-L., Barrett, S. C. H., Lin, H., Chen, L.-L., Zhou, X. and Gao, J.-Y. 2012. Rain pollination provides reproductive assurance in a deceptive orchid. *Annals of Botany* 110(5): 953–958.

Figueiredo, A. C. S. and Pais, M. S. 1992. Ultrastructural aspects of the nectary spur of *Limodorum abortivum* (L.) Sw. (Orchidaceae). *Annals of Botany* 70: 325–331.

Fryxell, P. A. 1957. Mode of reproduction of higher plants. *Botanical Review* 23: 135–233.

Fupunya, A. and Suwanthada, C. 2008. *Liparis* and *Malaxis* in some forest areas of Khun Mae Kwuang National Reserved Forest. *Agricultural Sci. J.* 39(3) (Suppl): 145–148.

Garay, L. A. 1960. On the origin of Orchidaceae. *Botanical Museum Leaflets, Harvard University* 19: 57–95.

Gaskett, A. C. 2011. Orchid pollination by sexual deception: pollinator perspectives. *Biological review* 86: 33–75.

Gibbs, P. E. 1988. Self-incompatibility mechanisms in flowering plants: some complications and clarifications. *Lagascalia* 15: 17–28.

Gomiz, N. E., Torretta, J. P. and Aliscioni, S. S. 2013. Comparative anatomy of elaiophores and oil secretion in the genus *Gomesa* (Orchidaceae). *Turkish Journal of Botany* 37: 859–871.

Govaerts, R. 2011. World checklist of Orchidaceae [Online]. Available from: http://apps.kew.org/wcsp/. Retrieved 22 January 2014.

Grant, B. 1895. *The orchids of Burma*. Rangoon: Hanthawaddy Press.

Hedrén, M., Nordström, S., Pedersen, H. Æ. and Ståhlberg, D. 2012. Systematics and conservation genetics of *Dactylorhiza majalis* ssp. *elatior* (Orchidaceae) on Gotland. *Nordic Journal of Botany* 30: 257–272.

Hietz, P., Winkler, M., Cruz-Paredes, L. and Jiménez-Aguilar, A. 2006. Breeding Systems, Fruit Set, and Flowering Phenology of Epiphytic Bromeliads and Orchids in a Mexican Humid Montane Forest. *Selbyana* 27(2): 156–164.

Holttum, R. E. 1964. *Flora of Malaya*, 3rd ed. Singapore: Singapore Botanic Gardens.

Hooker, J. D. 1890. *Flora of British India*, Vol. 5. England: L. Reeve & Co., Kent.

Hoshimoto, T. 1993. Novelties of the Genus *Malaxis* to Japan. *Annals of the Tsukuba Botanical Garden* 5(2): 1–8.

Humaña, A. M., Cisternas, M. A. and Valdivia, C. E. 2008. Breeding system and pollination of selected orchids of the genus *Chloraea* (Orchidaceae) from central

Chile. *Flora* 203: 469–473.

Ibrahim, H., Leong, P. K. F., Yam, T. W. and Lua, H. K. 2011. The rediscovery of the orchid *Dienia ophrydis* (J. Koenig) Seidenf. (Orchidaceae) in Singapore. *Nature in Singapore* 4: 329–337.

IUCN. 2012. IUCN red list categories and criteria version 3.1. Ed. 2. Gland, Switzerland and Cambridge, UK: IUCN.

Jersáková, J., Johnson, S. D. and Kindlmann, P. 2006. Mechanisms and evolution of deceptive pollination in orchids. *Biological Reviews* 81: 219–235.

Johnson, S. D. 1996. Bird pollination in South African species of *Satyrium* (Orchidaceae). *Plant Systematics and Evolution* 203: 91–98.

Jones, D. L. and Clements, M. A. 1997. *Crepidium flavovirens*, a New Species of Orchidaceae from Australia. *Novon* 7(4): 376–378.

Jussieu, A. L. 1789. *Gernera plantarum*. Paris: Herissant.

Kaiser, R. 1993. *The scent of orchids: olfactory and chemical investigations*. Basel: Roche.

Kearns, C. A. and Inouye, D. W. 1997. Pollinators, Flowering Plants, and Conservation Biology. *Biosience* 47(5): 297–307.

Kindlmann, P. and Balounová, Z. 2001. Irregular flowering patterns in terrestrial orchids: theories vs empirical data. *Web Ecology* 2: 75–82.

King, G. and Pantling, R. 1898. *The orchid of Sikkim Himalaya*, Vol. 8. Calcutta: Annals of the royal Botanical Garden.

Kite, G. C. and Salazar, G. A. 2008. Chemical composition of the inflorescence odor of *Malaxis rzedowskiana* (Orchidaceae). *Revista Mexicana de Biodiversidad* 79: 153–157.

Klecka, J., Hadrava, J., Biella, P. and Akter, A. 2018. Flower visitation by hoverflies (Diptera: Syrphidae) in a temperate plant-pollinator network. *Peer J Preprints*: 21–46.

Ko Kut. 2017. [Online]. Available from: http://climate.tmd.go.th/data/province/. Retrieved 25 January 2017.

Kowalkowska, A. and Margońska, H. B. 2009. Diversity of labellar micromorphological structures in selected species of Malaxidinae (Orchidaceae). *Acta Societatis*

Botanicorum Poloniae 78(2): 141–150.

Kraenzlin, F. 1900. Flora of Koh Chang: Orchidaceae and Apostasiaceae. In J. Schmidt (Ed.), *Das Pflanzereich* (Vol. Heft 45).

Li, P., Huang, B. Q., Pemberton, R. W., Luo, Y. B. and Cheng, J. 2011. Floral display influences male and female reproductive success of the deceptive orchid *Phaius delavayi*. *Plant Systematics and Evolution* 296: 21–27.

Li, P., Luo, Y., Bernhardt, P., Kou, Y. and Perner, H. 2008. Pollination of *Cypripedium plectrochilum* (Orchidaceae) by *Lasioglossum* spp. (Halictidae): the roles of generalist attractants versus restrictive floral architecture. *Plant Biology* 10: 220–230.

Limkittikul, K., Kidyoo, M., Khunwasi, C., Nuammee, A. and Bhodhibundit, P. 2016. Additional report of species diversity and conservational status of orchids in Huai Yang Waterfall National Park, Prachuap Khiri Khan Province. *Thai Journal of Botany* 8(2): 231–254.

Lindley, J. 1824. *Consisting of coloured figures of exotic plants cultivated in British gardens; with their history and mode of treatment 10*. London: The Botanical Register.

Lindley, J. 1826. *Orchidearum Sceletos*. London.

Lindley, J. 1830. *The Genera and Species of Orchidaceous Plants 1*. London: Ridgeways.

Linnaeus, C. 1753. *Species Plantarum*. Stockhlom: Impensis Laurentii Salvii.

Liu, K.-W., Liu, Z.-J., Huang, L.-Q., Li, L. Q., Chen, L.-J. and Tang, G.-D. 2006. Pollination: Self-fertilization strategy in an orchid. *Nature* 44: 945.

Makerd, W. 2011. *Taxonomic study of Orchidaceae at Mae Wong National Park, Nakhon Sawan and Kamphaeng Phet.* Master's Thesis, Department of Biology, Faculty of Science, Naresuan University,

Margońska, H. B. 2002. A new species of *Crepidium* (Orchidaceae, Malaxidinae) from Sabah, Borneo. *Annales Botanici Fennici* 39: 63–66.

Margońska, H. B. 2005a. Contributions to the taxonomic revision of the genus *Crepidium* (Orchidaceae-Malaxidinae): The new subsection *Maximowiczianae* (Section *Hololobus*). *Edinburgh Journal of Botany* 62(3): 165–179.

Margońska, H. B. 2005b. *Crepidium klimkoanum* – a new orchid species (Orchidaceae, Malaxidinae), from Thailand. *Candollea* 60: 372–377.

Margońska, H. B. 2005c. Short Communication: A new combination and a new subsection in *Crepidium* (Orchidaceae). *Edinburgh Journal of Botany* 62(3): 193–194.

Margońska, H. B. 2006. *Seidenforchis* – A new genus of Malaxidinae (Orchidaceae) from Thailand. *Acta Societatis Botanicorum Poloniae* 75(4): 301–307.

Margońska, H. B. 2014. New *Crepidium* species (Orchidaceae, Malaxidinae) from the Island of Negros, Philippines. *Phytotaxa* 172: 51–54.

Margońska, H. B. and Kowalkowska, A. 2008. Taxonomic revision of *Dienia* (Malaxidinae, Orchidaceae). *Annales Botanici Fennici* 45: 97–104.

Margońska, H. B. and Szlachetko, D. L. 2001a. Notes on the genus *Crepidium* (Orchidaceae, Malaxidinae). *Polish Botanical Journal* 46(1): 43–45.

Margońska, H. B. and Szlachetko, D. L. 2001b. A new *Crepidium* species (Orchidaceae, Malaxidinae) from Sarawak, Borneo. *Polish Botanical Journal* 46(1): 67–69.

Margońska, H. B. and Szlachetko, D. L. 2010. Two new combinations and a new subsection in *Crepidium* Blume emend. Szlach. (Orchidaceae, Malaxidinae). *Annalen des Naturhistorischen Museums in Wien, Serie B* 111: 175–180.

Margońska, H. B., Szlachetko, D. L. and Kubala, T. 1999. Ein neue Art der Gattung *Crepidium* (Orchidaceae, Malaxidinae) aus Papua Neuguinea. *Die Orchidee* 50(5): 510–512.

Micheneau, C., Fournel, J., Warren, B. H., Hugel, S., Gauvin-Bialecki, A., Pailler, T., Strasberg, D. and Chase, M. W. 2010. Orthoptera, a new order of pollinator. *Annals of Botany* 105: 355–364.

Micheneau, C., Johnson, S. D. and Fay, M. F. 2009. Orchid pollination: from Darwin to the present day. *Botanical Journal of the Linnean Society* 161: 1–19.

Michener, C. D. 2007. *The Bees of the World*, 2nd ed. Baltimore: The Johns Hopkins University Press.

Millar, A. 1978. *Orchids of Papua New Guinea: An introduction*. Canberra, Australia: Australian National University Press.

Montalvo, A. M. and Ackerman, J. D. 1987. Limitations to fruit production in *Ionopsis* *utricularioides* (Orchidaceae). *Biotropica* 19: 24–31.

Naumova, T. N. 1993. *Apomixis in Angiosperms: Nucellar and Integumentary Embryony*. Boca Raton: CRC Press.

Neiland, M. R. M. and Wilcock, C. C. 1998. Fruit set, nectar reward, and rarity in the Orchidaceae. *American Journal of Botany* 85(12): 1657–1671.

Nilsson, L. A. 1985. Characteristics and distribution of intermediates between *Platanthera bifolia* and *P. chlorantha* (Orchidaceae) in the Nordic countries. *Nordic Journal of Botany* 5: 407–419.

Nilsson, L. A., Jonsson, L., Ralison, L. and Randrianjohany, E. 1987. Angraecoid orchids and hawkmoths in Central Madagascar: Specialized pollination systems and generalist foragers. *Biotropica* 19: 310–318.

Nuammee, A., Seelanan, T., Suddee, S. and Pedersen, H. A. 2016. Notes on *Crepidium* (Orchidaceae): two new combinations, a putative natural hybrid and four species newly recorded for Thailand. *Thai Forest Bulletin (Botany)* 44(1): 35–44.

Office of National Park; Department of National Parks Wlidlife and Plant Conservation. 2017. Phu Hin Rong Kla National Park [Online]. Available from: http://park.dnp.go.th/visitor/nationparkshow.php?PTA_CODE=1048. Retrieved 31 October 2017.

Oh, G. S., Chung, M. Y., Chung, S. G. and Chung, M. G. 2001. Contrasting breeding systems: *Liparis kumokiri* and *L. makinoana* (Orchidaceae). *Annales Botanici Fennici* 38: 281–284.

Oldroyd, H. 1970. *Handbooks for the Identification of British Insects*, Vol. IX, part 1. Diptera. Introduction and key to families. London: The Society and Sold at its Rooms.

Pansarin, E. R. and Amaral, M. C. E. 2008. Reproductive biology and pollination mechanisms of *Epidendrum secundum* (Orchidaceae). Floral variation: a consequence of natural hybridization? *Plant Biology* 10: 211–219.

Pansarin, E. R. and Amaral, M. C. E. 2009. Reproductive biology and pollination of southeastern Brazilian *Stanhopea* Frost ex Hook. (Orchidaceae). *Flora* 204: 238–249.

Pansarin, L. M., Pansarin, E. R. and Sazima, M. 2008a. Reproductive biology of

Cyrtopodium polyphyllum (Orchidaceae): a Cyrtopodiinae pollinated by deceit. *Plant Biology* 10: 650–659.

Pansarin, L. M., Pansarin, E. R. and Sazima, M. 2008b. Facultative autogamy in *Cyrtopodium polyphyllum* (Orchidaceae) through a rain-assisted pollination mechanism. *Australian Journal of Botany* 56: 363–367.

Pansarin, L. M., Pansarin, E. R. and Sazima, M. 2014. Osmophore structure and phylogeny of *Cirrhaea* (Orchidaceae, Stanhopeinae). *Botanical Journal of the Linnean Society* 176: 369–383.

Pearce, N. R. and Cribb, P. J. 2002. *Flora of Bhutan*, Vol. 3. Edinburgh: Royal Botanic Garden Edinburgh and Royal Government of Bhutan.

Pedersen, H. Æ., Srimuang, K., Bänziger, H. and Watthana, S. 2018. Pollination-system diversity in *Epipactis* (Orchidaceae): new insights from studies of *E. flava* in Thailand. *Plant Systematics and Evolution* 304: 895–909.

Pedersen, H. Æ., Watthana, S., Kocyan, A. and Srimuang, K. 2012. Pollination biology of *Luisia curtisii* (Orchidaceae): indications of a deceptive system operated by beetles. *Plant Systematics Evolution* 299: 177–185.

Pedersen, H. Æ., Watthana, S. and Srimuang, K. 2013. Orchids in the torrent: on the circumscription, conservation and rheophytic habit of *Epipactis flava*. *Botanical Journal of the Linnean Society* 172: 358–370.

Peter, C. I. and Johnson, S. D. 2009a. Autonomous self-pollination and pseudo-fruit set in South African species of *Eulophia* (Orchidaceae). *South African Journal of Botany* 75: 791–797.

Phu Hin Rong Kla National Park. 2017. Statistics on temperature, rainfall and forest fires.

Pinheiro, F., Cafasso, D., Cozzolino, S. and Scopece, G. 2015. Transitions between self-compatibility and self-incompatibility and the evolution of reproductive isolation in the large and diverse tropical genus *Dendrobium* (Orchidaceae). *Annals of Botany* 116: 457–467.

Pridgeon, A. M. 1987. The velamen and exodermis of orchid roots. In J. Arditti (Ed.), *Orchid biology: reviews and perspectives* (Vol. 4, pp. 139–192). Ithaca, New York: Cornell University Press.

Pridgeon, A. M., Cribb, P. J., Chase, M. W. and Rasmussen, F. N. 1999. *Genera Orchidacearum*, Vol. 1: Apostasioideae and Cypripedioideae. New York: Oxford University Press.

Pridgeon, A. M., Cribb, P. J., Chase, M. W. and Rasmussen, F. N. 2001. *Genera Orchidacearum*, Vol. 2: Orchidoideae (Part 1). New York: Oxford University Press.

Pridgeon, A. M., Cribb, P. J., Chase, M. W. and Rasmussen, F. N. 2003. *Genera Orchidacearum*, Vol. 3: Orchidoideae (Part 2), Vanilloideae. New York: Oxford University Press.

Pridgeon, A. M., Cribb, P. J., Chase, M. W. and Rasmussen, F. N. 2005. *Genera Orchidacearum*, Vol. 4: Epidendroideae (Part 1). New York: Oxford University Press.

Pridgeon, A. M., Cribb, P. J., Chase, M. W. and Rasmussen, F. N. 2009. *Genera Orchidacearum*, Vol. 5: Epidendroideae (Part 2). New York: Oxford University Press.

Pridgeon, A. M., Cribb, P. J., Chase, M. W. and Rasmussen, F. N. 2014. *Genera Orchidacearum*, Vol. 6: Epidendroideae (Part 3). New York: Oxford University Press.

Reeves, L. M. and Reeves, T. 1984. Life history and reproduction of *Malaxis paladosa* in Minnesota. *American Orchid Society Bulletin* 53: 1280–1291.

Reichenbach, H. G. 1878. *Otia botanica Hamburgensia : Fasciculus primus*. Hamburgi: Typis T. T. Meissneri.

Richard, L. C. 1817. *De Orchideis Europaeis Annotations*. Berlin, Paris.

Richards, A. J. 1997. *Plant breeding systems*. London: Garland Science.

Richards, A. J. 2003. Apomixis in flowering plants: an overview. *Philosophical Transactions of the Royal Society B* 358: 1085–1093.

Ridley, H. N. 1888. A revision of the genera *Microstylis* and *Malaxis*. *Botanical Journal of the Linnean Society* 24: 308–351.

Rieseberg, L. H. and Carney, S. E. 1998. Plant hybridization. *New Phytologist* 140: 599–624.

Rojchana-umpawam, P., Chantanaorrapint, A., Somchai, S. and Chantanaorrapint, S.

2016. Species Diversity of Orchids in Ton Nga Chang Wildlife Sanctuary, Songkhla province. *Thai Journal of Botany* 8(1): 45–63.

Schlechter, R. 1926. Das System der Orchidaceen. In *Notizblatt des Botanischen Gartens und Museums zu Berlin-Dahlem, Bd. 9, Nr. 88*. Berlin-Dahlem: Botanischer Garten und Botanisches Museum.

Seidenfaden, G. 1969. Contributions to the orchids Flora of Thailand. *Botanisk Tidsskrift* 65(1): 100–162.

Seidenfaden, G. 1970. Contributions to the orchids Flora of Thailand. *Botanisk Tidsskrift* 65(2): 313–370.

Seidenfaden, G. 1978. Orchid genera in Thailand 7. *Dansk Botanisk Arkiv* 33: 1–95.

Seidenfaden, G. 1997. *Contribitions to the orchid genera of Thailand 13*. Fredensborg, Denmark: Olsen & Olsen.

Seidenfaden, G. and Smitinand, T. 1959a. *The Orchids of Thailand: A Preliminary List. Part I*. Bangkok: The Siam Society.

Seidenfaden, G. and Smitinand, T. 1959b. *The Orchids of Thailand: A Preliminary List. Part II (1)*. Bangkok: The Siam Society.

Seidenfaden, G. and Smitinand, T. 1960. *The Orchids of Thailand: A Preliminary List. Part II (2)*. Bangkok: The Siam Society.

Seidenfaden, G. and Smitinand, T. 1961. *The Orchids of Thailand: A Preliminary List. Part III*. Bangkok: The Siam Society.

Seidenfaden, G. and Smitinand, T. 1963. *The Orchids of Thailand: A Preliminary List. Part IV (1)*. Bangkok: The Siam Society.

Seidenfaden, G. and Smitinand, T. 1965. *The Orchids of Thailand: A Preliminary List. Part IV (2)*. Bangkok: The Siam Society.

Seidenfaden, G. and Wood, J. J. 1992. *The Orchids of Peninsular Malaysia and Singapore: a revision of R.E. Holttum: Orchids of Malaya*. Fredensborg, Denmark: Olsen & Olsen.

Shi, J., Luo, Y.-B., Bernhardt, P., Ran, J.-C., Liu, Z.-J. and Zhou, Q. 2009. Pollination by deceit in *Paphiopedilum barbigerum* (Orchidaceae): a staminode exploits the innate colour preferences of hoverflies (Syrphidae). *Plant Biology* 11: 17–28.

Silva, N. F. and Goring, D. R. 2001. Mechanisms of self-incompatibility in flowering plants. *Cellular and Molecular Life Sciences* 58: 1988–2007.

Simpson, M. G. 2010. *Plant systematics*, 2nd ed. Burlington, USA: Academic Press (Elsevier).

Singh, S. K., Murugesan, M. and Mao, A. A. 2016. A new species of *Crepidium* (Orchidaceae) from Meghalaya, North-east India. *Keanean Journal of Science* 5: 9–12.

Smith, J. J. 1905. Die Orchideen von Java. In *Flora Buiten-zorg 6* (pp. 1–673). Leiden.

Smith, J. J. 1928. Additions to the orchid flora of Selebes. *Bulletin du Jardin botanique de Buitenzorg, ser. 3* 10: 1–24.

Smitinand, T. 1958. The genus *Dipterocarpus* Gaertn. f. in Thailand. *Thai Forest Bulletin (Botany)* 4: 1–26.

Stern, W. L. 2014. *Anatomy of the Monocotyledons*, Vol. 5: Orchidaceae. New York: Oxford University Press.

Stern, W. L., Curry, K. J. and Whitten, W. M. 1986. Staining fragrance glands in orchid flower. *Bulletin of the Torrey Botanical Club* 113(3): 288–297.

Stoutamire, W. P. 1974. Relationships of the purple-fringed orchids *Platanthera psycodes* and *P. grandiflora*. *Brittonia* 26: 42–58.

Stpiczyńska, M. 1997. The structure of the nectary of *Platanthera bifolia* L. (Orchidaceae). *Acta Societatis Botanicorum Poloniae* 66: 5–11.

Stpiczyńska, M. 2001. Osmophores of the fragrant orchid *Gymnadenia conopsea* L. (Orchidaceae). *Acta Societatis Botanicorum Poloniae* 70(2): 91–96.

Stpiczyńska, M., Davies, K. L. and Gregg, A. 2003. Nectary structure and nectar secretion in *Maxillaria coccinea* (Jacq.) L. O. Williams ex Hodge (Orchidaceae). *Annals of Botany* 93: 87–95.

Stpiczyńska, M., Davies, K. L. and Gregg, A. 2005. Comparative Account of Nectary Structure in *Hexisea imbricata* (Lindl.) Rchb. f. (Orchidaceae). *Annals of Botany* 95: 749–756.

Stpiczyńska, M. and Matusiewicz, J. 2001. Anatomy and ultrastructure of the spur nectary of *Gymnadenia conopsea* L. (Orchidaceae). *Acta Societatis Botanicorum Poloniae* 70: 267–272.

Suetsugu, K. 2015. Autonomous self-pollination in the nectarless orchid *Pogonia minor*. *Plant Species Biology* 30(1): 37–41.

Suetsugu, K. and Tanaka, K. 2013. Pollination of *Sedirea japonica* (Orchidaceae) by *Bombus diversus diversus* (Hymenoptera: Apidae). *European Journal of Entomology* 110: 545–548.

Swartz, O. 1778. *Nova Genera et Species Plantarum seu Prodromus*. Orchidaceae. Holmiae: Upsala & Abo. pp. 118–126.

Swartz, O. 1800. Afhandling om Orkidernes slaegter och deras systematiska indelning. Konl. *Vetenskaps Academiens Nya Handling-as* 21: 115–254.

Szlachetko, D. L. 1995. Systema Orchidalium. *Fragmenta Floristica et Geobotanica Polonica, Suppl. 3*: 123–133.

Szlachetko, D. L. and Margońska, H. B. 1998a. New species and new combinations in the genus *Crepidium* (Orchidaceae) from Australasia. *Adansonia* 20(2): 341–349.

Szlachetko, D. L. and Margońska, H. B. 1998b. Notes on the genus *Crepidium* (Orchidaceae, Malaxidinae), with descriptions of new species from Northern Sumatra. *Fragmenta Floristica et Geobotanica Polonica* 43: 184.

Szlachetko, D. L. and Margońska, H. B. 1998c. Three new species of the genus *Crepidium* (Orchidaceae) from South-east Asia. *Fragmenta Floristica et Geobotanica Polonica* 43(1): 7–12.

Szlachetko, D. L. and Margońska, H. B. 2000a. A new species of *Crepidium* (Orchidaceae, Malaxidinae) from New Guinea. *Adansonia* 22(2): 265–267.

Szlachetko, D. L. and Margońska, H. B. 2000b. New *Crepidium* (Orchidaceae, Malaxidinae) from Solomon Islands and Bismark Archipelago. *Annales Botanici Fennici* 37: 303–307.

Szlachetko, D. L. and Margońska, H. B. 2002. Gynostemia Orchidalium, Vol. 2: Orchidaceae (Epidendroideae). *Acta Botanica Fennica* 173: 1–197.

Szlachetko, D. L., Margońska, H. B. and Rutkowski, P. 1999. *Dienia seidenfadeniana*, a new orchid species from Australia. *Adansonia ser. 3* 21(2): 221–223.

Takhtajan, A. 1986. *Floristic regions of the world*. Berkeley: University of California Press.

Tang, T. and Wang, F. T. 1951. Contributions to the Knowledge of Eastern Asiatic Orchdaceae II. *Acta Phytotaxonomica Sinica* 1: 23–102.

Teixeira, S. P., Borba, E. L. and Äosemir, J. 2004. Lip anatomy and its implications for the pollination mechanisms of *Bulbophyllum* species (Orchidaceae). *Annals of Botany* 93: 499–505.

Thaithong, O. 1999. *Orchids of Thailand*. Bangkok: Office of Environmental Policy and Planing.

Tippayasri, P. and Ngernsaengsaruay, C. 2008. Some Terrestrial Orchid Species in Phu Hin Rong Kla National Park, Phitsanulok Province. *Proceedings of 46th Kasetsart University Annual Conference: Plants*. 74–81.

Tremblay, R. L., Ackerman, J. D., Zimmerman, J. K. and Calvo, R. N. 2005. Variation in sexual reproduction in orchids and its evolutionary consequences: a spasmodic journey to diversification. *Biological Journal of the Linnean Society* 84: 1–54.

van Welzen, P. C., Parnell, J. A. N., Boyce, P. C., Bygrave, P., Byrne, C., Chayamarit, K., Chantaranothai, P., Couch, C., Curtis, T., Dransfield, S., Esser, H.-J., Jebb, M. H. P., Kirkup, D. W., Larsen, K., Larsen, S. S., Macklin, J., Maderm, A., Meade, C., Middleton, D. J., Moat, J., Muasya, A. M., Nielsen, I. C., Pattharahirantricin, N., Prajaksood, A., Pendry, C. A., Pooma, R., Simpson, D. A., Staples, G. W., Suddee, S., Sungkaew, S., Teerawatananon, A., Trias-Blasi, A., Wilkin, P. and Raes, N. 2011. The Current and Future Status of Floristic Provinces in Thailand. In Y. Trisurat, R. P. Shrestha and R. Alkemade (Eds.), *Land Use Climate Change and Biodiversity Modeling: Perspectives and Applications*. U.S.A: Information Science Reference (an imprint of IGI Global), Hershey.

Wallace, B. J. 1974. The pollination of *Liparis reflexa* (R. Br.) Lindley. *Orchadian* 4: 67–73.

Whitton, J., Sears, C. J., Baack, E. J. and Otto, S. P. 2008. The dynamic nature of apomixes in the angiosperms. *International Journal of Plant Sciences* 169: 169–182.

Wiemer, A. P., Moré, M., Benitez-Vieyra, S., Cocucci, A. A., Raguso, R. A. and Sérsic,

A. N. 2009. A simple floral fragrance and unusual osmophore structure in *Cyclopogon elatus* (Orchidaceae). *Plant Biology* 11: 506–514.

Zimmerman, J. K. and Aide, T. M. 1989. Patterns of fruit production in a neotropical orchid: pollinator vs. resource limitation. *American Journal of Botany* 76: 67–73.

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