



**A Taxonomic Study of the Genus *Campylotropis* Bunge
(Leguminosae-Papilionoideae) in Thailand**

Jiratthi Sathaphorn

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

Prince of Songkla University

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I hereby certify that this work has not been accepted in substance for any degree, and is not being currently submitted in candidature for any degree.

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ชื่อวิทยานิพนธ์	การศึกษานุกรมวิธานของพืชสกุล <i>Campylotropis</i> Bunge (Leguminosae-Papilionoideae) ในประเทศไทย
ผู้เขียน	นายจิรรัฐ สัตถาพร
สาขาวิชา	พฤกษศาสตร์
ปีการศึกษา	2561

บทคัดย่อ

การศึกษานุกรมวิธานของพืชสกุล *Campylotropis* Bunge (Leguminosae-Papilionoideae) ในประเทศไทย โดยศึกษาจากลักษณะทางสัณฐานวิทยาของตัวอย่างที่เก็บได้จากการเก็บรวบรวมในภาคสนามทุกเขตพรรณพฤกษชาติของประเทศไทย ตั้งแต่ เดือนพฤศจิกายน 2559 ถึง มกราคม 2561 รวมทั้งตัวอย่างพรรณไม้แห้งในพิพิธภัณฑ์พืชทั้งในและต่างประเทศ พบพืชสกุลนี้จำนวน 7 ชนิด และ 1 ชนิดย่อย ได้แก่ *C. bonii* Schindl., *C. capillipes* (Franch.) Schindl. subsp. *prainii* (Collett & Hemsl.) Iokawa & H. Ohashi, *C. decora* (Kurz) Schindl., *C. harmsii* Schindl., *C. parviflora* (Kurz) Schindl., *C. pinetorum* (Kurz) Schindl. และ *C. sulcata* Schindl. โดยมีการคืนสภาพทางอนุกรมวิธานของชนิด *C. parviflora* จากฟอร์ม *C. cytisoides* f. *parviflora* นอกจากนี้มีการจัดทำรูปวิธานในการจำแนกชนิด คำบรรยายลักษณะสัณฐานวิทยา ข้อมูลทางนิเวศวิทยา การกระจายพันธุ์ ภาพวาดลายเส้น และรูปถ่ายของพืชสกุลนี้ในประเทศไทย การศึกษาลักษณะทางสัณฐานวิทยาของเรณูและชีววิทยาระดับโมเลกุลเพื่อศึกษาวงศ์วานวิวัฒนาการ โดยใช้ยีนในคลอโรพลาสต์ *trnL-trnF* intergenic spacer และ *trnL* intron ถูกนำมารวมกับข้อมูลทางสัณฐานวิทยาเพื่อใช้ในการจำกัดขอบเขตในระดับสกุลและชนิด ผลการศึกษาพบว่าข้อมูลที่ได้จากการศึกษาลักษณะสัณฐานวิทยาเป็นหลักฐานที่เหมาะสมที่สุดในการใช้ในการระบุชนิดของพืชสกุลนี้ในประเทศไทย ในขณะที่หลักฐานทางเรณูวิทยาและชีววิทยาระดับโมเลกุลสามารถนำไปสนับสนุนในการจัดกลุ่มของบางชนิดในสกุลนี้ และใช้จัดจำแนกระหว่างสกุลใกล้เคียงได้

Thesis title	A Taxonomic Study of the Genus <i>Campylotropis</i> Bunge (Leguminosae-Papilionoideae) in Thailand
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ABSTRACT

A taxonomic study of the genus *Campylotropis* Bunge (Leguminosae-Papilionoideae) in Thailand based on morphological features of fresh specimens in all floristic regions in Thailand from November 2016 to January 2018 including herbarium specimens in Thailand and other countries is provided. Seven species and one subspecies are recognised for Thailand, namely *C. bonii* Schindl., *C. capillipes* (Franch.) Schindl. subsp. *prainii* (Collett & Hemsl.) Iokawa & H. Ohashi, *C. decora* (Kurz) Schindl., *C. harmsii* Schindl., *C. parviflora* (Kurz) Schindl., *C. pinetorum* (Kurz) Schindl. and *C. sulcata* Schindl. Taxonomic change for *C. parviflora* is reinstated from *C. cytisoides* f. *parviflora* in this study. A key to species, morphological descriptions, ecological data, distributions, illustrations and photographs are also presented. The studies on pollen morphology and phylogenetic relationship using *trnL-trnF* intergenic spacer and *trnL* intron are included with morphological characters to circumscribe the generic and species delimitations. The results reveal that the evidence of morphology is the most suitable evidence for species delimitation of *Campylotropis* in Thailand and evidences from palynology and phylogenetic relationship can be satisfactory applied to group some related *Campylotropis* species and related genera.

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CHAPTER 1

GENERAL INTRODUCTION

Leguminosae (Fabaceae) is the third largest family in the world in terms of species number after Orchidaceae and Asteraceae, respectively, with approximately 770 genera and 19500 species (Lewis *et al.*, 2005, 2013; Legume Phylogeny Working Group, 2013, 2017; Simpson, 2010; Balslev & Chantaranothai, 2018). Legumes are cosmopolitan in distribution, representing important ecological constituents in almost biomes across the world and occur in even the most extreme habitats (Schrire *et al.*, 2005) including a large number of economically important species. The current phylogeny composes of six subfamilies: Caesalpinoideae, Cercidoideae, Detarioideae, Dialioideae, Duparquestioideae, and Papilionoideae (Legume Phylogeny Working Group, 2017).

Subfamily Papilionoideae is the largest subfamily and most advanced group in Leguminosae (Schrire, 1984) comprising about 503 genera and 14000 species (Legume Phylogeny Working Group, 2017; Balslev & Chantaranothai, 2018). The explicit characters to define the subfamily are papilionate flower composing standard, wing, and keel (Legume Phylogeny Working Group, 2017). Recently, the subfamily Papilionoideae can be morphologically divided into 22 tribes including Abreae, Aeschynomeneae, Amorphaeae, Cicereae, Crotalariaeae, Dalbergieae, Desmodieae, Euchrestaeae, Fabeae, Galegeae, Genisteae, Hedyreae, Indigofereae, Loteae, Millettieae, Phaseoleae, Psoraleae, Robinieae, Sesbanieae, Sophoreae, Thermopsidaeae, and Trifolieae (Huang *et al.*, 2010).

Tribe Desmodieae is one highly advanced of several tribes in Papilionoideae comprising 27 genera with mainly tropical distribution (Ohashi *et al.*, 1981), distinguished from other tribes by having jointed indehiscent fruits and 1–3-foliolate leaves. The tribe shows high levels of specialisation and diversity with good correlation in a notable range of features to give a rather precise stepwise progression through

series, section, subgenus, genus, and generic group (Schubert, 1963, 1971; Ohashi, 1973). Recently, two subtribes are recognised based on phylogenetic reconstructions (Bailey *et al.*, 1997; Doyle *et al.*, 2000; Kajita *et al.*, 2001; Lavin *et al.*, 2001) which are Desmodiinae and Lespedezinae.

Genus *Campylotropis* Bunge belongs to subtribe Lespedezinae in tribe Desmodieae comprising about 37 species greatly distributed in temperate Asia to tropical Asia (Iokawa and Ohashi, 2002a, 2008; Lewis *et al.*, 2005; Huang *et al.*, 2010). The genus was firstly described by Bunge (1835) based on Chinese species, *C. macrocarpa* (Bunge) Rehder, which used to be accommodated under related genus, *Lespedeza* Michx. The apparent character to distinguish *Campylotropis* from *Lespedeza* is the presence of single flower per bract while two flowers are subtended in *Lespedeza* (Ohashi *et al.*, 1981). All species of the genus *Campylotropis* are shrub or shrublet with 3-foliolate leaves, without stipel, 1-flowered bracts, soon caducous bracteole, pinkish-white to creamy-white or purple to blue corolla, shallowly falcate, and incurved keel which is a symbolic of the name '*Campylotropis*' by deriving from two Greek words, '*campylo*' meaning curved and '*tropis*' meaning keel (Lewis *et al.*, 2005), 1-ovuled ovaries, and 1-seeded indehiscent pods (Ohashi *et al.*, 1981; Iokawa & Ohshi, 2002a).

As far as known, Thailand is known of having high biodiversity of Papilionoideae about 129 genera and 600 species (Balslev & Chantaranothai, 2018); however, many tribes are taxonomically needed to be revised and updated checklist due to recent taxonomic problems, new discoveries, molecular phylogeny or other evidences. Especially in tribe Desmodieae, although many particular revisions or checklists of some genera have been conducted continuously (Tokeaw & Chanratanothai, 2013; Saisorn & Chantaranothai, 2015, 2018; Saisorn *et al.*, 2016; Leeratiwong *et al.*, 2017), taxonomy or species lists of Demodoid legume are still far to be completed. Currently, one of the problems left in the classification of tribe Desmodieae in Thailand is lacking information of subtribe Lespedezinae which has only one genus found in Thailand, *Campylotropis*.

The completed taxonomic treatment of the genus *Campylotropis* in Thailand is necessary to be revised. Three evidences including morphological data, palynological data, and molecular phylogeny are to concern in this study to avoid biases from the single evidence and to obtain information as much as possible for further interpretations. Problems of doubtful or unknown species, synonymy, and misidentification of species are also necessary to be improved. Therefore, the purpose of this study is to conduct taxonomic treatment on the genus *Campylotropis* in Thailand based on herbarium specimens and recent collections from field surveys. Valid scientific names, complete information on the morphology, palynology, molecular phylogeny of the genus, distribution, and ecology of this genus in Thailand will be provided and the result of this study can be contributed to the advancement of the Flora of Thailand account.

Objectives

1. To provide a complete account and taxonomic treatment of the genus *Campylotropis* in Thailand
2. To clarify the species circumscription of the genus *Campylotropis* in Thailand by using morphological, palynological, and molecular evidences

Scopes of study

The scope of this study included taxa of *Campylotropis* found in Thailand based on morphological characters with ecological data and distribution. Palynology and molecular studies using cpDNA are included to increase concrete information and to evaluate the phylogenetic reconstruction within the genus and related genera.

Expected outcomes

The completed revision and information of morphology, palynology, and molecular studies are useful to solve taxonomic problems of the genus *Campylotropis* in Thailand including species boundary, synonymy, and misidentification. The result of this project will be also contributed to the Flora of Thailand project.

CHAPTER 2

TAXONOMY

2.1. Introduction

A taxonomic study of the genus *Campylotropis* has been conducted by Iokawa and Ohashi (2002a, 2002b, 2002c) with few species recorded for Thailand. A preliminary study of the genus in Thailand showed that the taxonomic treatment and species circumscriptions of some species should be reinvestigated thoroughly to limit species boundaries and variations within Thai taxa. This chapter aims to provide a taxonomic treatment of the genus *Campylotropis* in Thailand based on evidence from qualitatively and quantitatively morphological investigations with naked eyes and microscopes. Morphological description, taxonomic treatment, key to species, ecological data, illustrations, and photographs are provided.

2.2. Literature reviews

2.2.1. Classification within the tribe Desmodieae

Desmodieae has been firstly proposed by Hutchinson (1964) generally characterised by having 1–3 foliolate leaves, with or without stipel; terminal or axillary raceme or pseudoraceme inflorescences; upper lobes often jointed or sometime bifid in calyx, transversely jointed or only 1 articulate, or 2-valved fruit, and well-developed radicular lobed and mostly with rim membrane seeds (Ohashi *et al.*, 1981). The classification within tribe Desmodieae has been later defined by Ohashi *et al.* (1981) comprising of 27 genera and ca 540 species in three subtribes: Brynae, Desmodiinae, and Lespedezinae. Based on the molecular studies, subtribe Brynae was later removed to another tribe (Bailey *et al.*, 1997; Doyle *et al.*, 2000; Lavin *et al.*, 2001) together with genera *Phylacium* Benn. and *Neocollettia* Hemsl. which were formerly placed in

subtribe Lespedezinae (Kajita *et al.*, 2001). Two subtribes remain in Desmodieae which are Desmodiinae and Lespedezinae. The subtribe Desmodiinae is latest characterised by the presence of stipel, hooked hairs on fruit, without inflexed auriculated standard, and 1-many-ovuled ovary. This subtribe has been assorted based on molecular study of Lewis *et al.* (2005) comprising *Phyllodium* and *Desmodium* groups with 27 genera. The subtribe Lespedezinae is defined by the absence of hooked hairs, 1-ovuled ovary and usually recognisable by inflexed auricles on standard (Ohashi *et al.*, 1981) consisting of *Campylotropis*, *Lespedeza*, and *Kummerowia* Schindl. Tribe Desmodieae in Thailand accommodates about 18 genera (Niyomdham, 1994; Ohashi *et al.*, 1981; Balslev & Chantaranothai, 2018) in two subtribes. Concerning of subtribe Lespedezinae, *Campylotropis* is the only one genus in the subtribe found in Thailand.

2.2.2. The history of taxonomic study of the genus *Campylotropis*

The genus *Campylotropis* was established by Bunge (1835) who divided from the genus *Lespedeza* using the distinct character which has one flower per bract subtended. There is the only one species in the first publication of the genus describing, *C. chinensis* Bunge. Subsequently, the concept of the genus has been continuously changed. Miquel (1855) firstly adopted the *Campylotropis* as generic status with 3 species, *C. cytisoides* Benth. and *C. macrostyla* Lind. including the new species, *C. virgata* Miq. On the other hands, subsequent taxonomic treatments accommodated *Campylotropis* as subgenera or section under the genus *Lespedeza* (Bentham, 1865; Maximowicz, 1873; Baker, 1876; Taubert, 1894).

Later, Schindler (1912a, 1912b, 1926, 1928) raised these subgenera or section *Campylotropis* under *Lespedeza* back to separated genus *Campylotropis* in monographical study with total 47 species: *C. alata* Schindl., *C. argentea* Schindl., *C. balfouriana* (Diels) Schindl., *C. bodinieri* Schindl., *C. bonatiana* (Pamp.) Schindl., *C. bonii* Schindl., *C. capillipes* (French.) Schindl., *C. chinensis*, *C. cytisoides* (Jung.) Miq., *C. decora* (Kurz) Schindl., *C. delavayi* (Franch.) Schindl., *C. diversifolia* (Hemsl.) Schindl., *C. drummondii* Schindl., *C. eriocarpa* (Maxim.) Schindl., *C. esquirolii* Schindl., *C. falconeri* (Prain) Schindl., *C. fulva* Schindl., *C. giraldii* Schindl., *C. glauca* Schindl., *C. grandifolia* Schindl., *C. griffithii* Schindl., *C. harmsii*, Schindl.,

C. henryi Schindl., *C. hirtella* (Franch.) Schindl., *C. latifolia* (Dunn) Schindl., *C. macrostyla* (D. Don) Schindl., *C. meeboldii* (Schindl.) Schindl., *C. muehleana* Schindl., *C. neglecta* Schindl., *C. paniculata* Schindl., *C. parvifolia* (Kurz) Schindl., *C. pinetorum* (Kurz) Schindl., *C. polyantha* (French.) Schindl., *C. prainii* (Coll. & Hemsl.) Schindl., *C. rockii* Schindl., *C. sargentiana* Schindl., *C. sericophylla* (Collett & Hemsl.) Schindl., *C. sessifolia* Schindl., *C. souliei* Schindl., *C. speciosa* Schindl., *C. splendens* Schindl., *C. stenocarpa* (Klotzsch) Schindl., *C. sulcata* Schindl., *C. thomsonii* (Benth.) Schindl., *C. trigonoclada* (Franch.) Schindl., *C. willsonii* Schindl., and *C. yunnanensis* (French.) Schindl.

Iokawa and Ohashi (2002a, 2002b, 2002c) revised the whole genus *Campylotropis* with total 37 species including new species: *C. alba* Iokawa & Ohashi, *C. alopochroa* Ohashi, *C. argentea*, *C. bonii*, *C. brevifolia*, *C. burmanica* Ohashi, *C. capillipes*, *C. cytisoides*, *C. decora*, *C. delavyi*, *C. diversifolia*, *C. falconeri*, *C. fulva*, *C. grandifolia*, *C. griffithii*, *C. harmsii*, *C. henryi*, *C. hirtella*, *C. howellii*, *C. latifolia*, *C. luhitensis* Ohashi, *C. macrocarpa*, *C. macrostyla*, *C. pauciflora*, *C. pinetorum*, *C. polyantha*, *C. sargentiana*, *C. speciosa*, *C. stenocarpa*, *C. sulcata*, *C. tenuiramea*, *C. teretiracemosa*, *C. thomsonii*, *C. trigonoclada*, *C. wenshanica*, *C. wilsonii*, and *C. yunnanensis*.

Due to the centre distribution of the genus is in China (Fu, 1987; Iokawa & Ohashi, 2002, 2008; Ohashi, 2005), a large number of new species were mainly found in China especially in the south (Ricker, 1946; Ohashi, 1974a, 1974b, 1974c, 1976; Chen, 1988; Fu, 1995), for example, *C. brevifolia* Ricker, *C. filipes* Ricker, *C. gracilis* Ricker, *C. hersi* Ricker, *C. huberi* Ricker, *C. longepedunculata* Ricker, *C. mortalana* Ricker, *C. nepalensis* Ricker, *C. purpurascens* Ricker, *C. reticulate* Ricker, *C. smithi* Ricker, *C. wangi* Ricker, *C. burmanica* Ohashi, *C. kingdonii* Ohashi, *C. alopochloa* Ohashi, *C. luhitensis* Ohashi, *C. pauciflora* C.J. Chen, *C. teretiracemosa* C.J. Chen, *C. yajiangensis* P.Y. Fu, *C. wenshanica* P.Y. Fu, *C. tenuiramea* P.Y. Fu, and *C. tomentosioetiolata* P.Y. Fu. However, these new taxa were treated to be synonym by subsequent taxonomic treatments (Fu, 1995; Iokawa & Ohashi, 2002a, 2002b, 2002c, 2004). Iokawa and Ohashi (2008) published an updated checklist of the genus in China comprising 32 species: *C. alba*, *C. alopochroa*, *C. argentea*, *C. bonii*, *C. brevifolia*, *C.*

capillipes, *C. cytisoides*, *C. decora*, *C. delavayi*, *C. diversifolia*, *C. fulva*, *C. grandifolia*, *C. harmsii*, *C. henryi*, *C. hirtella*, *C. howellii*, *C. latifolia*, *C. luhitensis*, *C. macrocarpa*, *C. pauciflora*, *C. pinetorum*, *C. polyantha*, *C. sargentiana*, *C. speciosa*, *C. sulcata*, *C. tenuiramea*, *C. teretiracemosa*, *C. thomsonii*, *C. trigonoclada*, *C. wenshanica*, *C. wilsonii*, and *C. yunnanensis*. This latest account was also adopted to Huang *et al.* (2010) in Flora of China Volume 10 with short descriptions of each taxon.

2.2.3. Previous studies of the genus *Campylotropis* in Thailand and adjacent countries

The first information of *Campylotropis* species in Thailand was published by Craib (1928) that all species were formerly accommodated in genus *Lespedeza* with seven species, namely *L. bonii* Gagnap. var. *augusticapa* (Schindl.) Craib (= *C. bonii*), *L. decora* Kurz (= *C. decora*), *L. harmsii* Craib (= *C. harmsii*), *L. henryi* Schindl. (= *C. decora*), *L. parviflora* Kurz (= *C. parviflora*), *L. pinetorum* Kurz (= *C. pinetorum*), and *L. sulcata* Craib (= *C. sulcata*). Later, the first and the latest version of Thai Plant Names, Tem Smitinand (Pooma & Suddee, 2001, 2014) listed only 2 *Campylotropis* species, namely *C. parviflora* and *C. pinetorum*. Additionally, *Lespedeza decora* (= *C. decora*) and *L. harmsii* (Schindl.) Craib (= *C. harmsii*) were reported from the study of vegetation of Doi Chiang Dao in Chiang Mai province (Smitinand, 1966). According to previous studies above, account of Thai *Campylotropis* is uncertain in total number of species and synonyms with genus *Lespedeza*. The constant taxonomic account of Thai *Campylotropis* is still needed to be clarified the number and taxonomic status of the genus in Thailand.

2.2.4. Phytogeography in Thailand

Thailand is located in Southeast Asia between the latitudes 5–21° N and longitudes 97–106° E, estimated 513115 square kilometers (Santisuk, 2007). The country borders to neighbouring countries with Myanmar in the West and North-West, Laos in the North-East, Cambodia in the South-East, and Malaysia in the South. The elevations of terrains vary diversely from sea level (0 m) to high mountains (2565 m) and the most of conspicuous terrain features of Thailand contain several high mountains

covering most of north and extending along western border with Myanmar down into Malay Peninsular (Maxwell, 2004). In biodiversity aspects, the country is located in overlapping zone of Sino-Himalayan and Malesian floristic regions (Smitinand, 1989) and both the Indo-Burmese and Sundaland biodiversity hotspots (Myers *et al.*, 2000). According to Smitinand (1958), floristic regions of Thailand are divided into 7 regions (Table 2.1 & Fig. 2.1) which are northern, north-eastern, western, central, south-eastern, south-western, and peninsular regions. This framework is also commonly used by many Thai botanists for studying taxonomic treatments and Flora of Thailand project.

Table 2.1 The characteristic of floristic regions in Thailand and types of forests by Smitinand (1958).

Thai floristic regions	Floristic elements	Types of forests
Northern (N)	Indo-Burmese	Dry deciduous, dry hill evergreen forest and montane temperate forest (on high elevation)
North-Eastern (NE)	Indo-Chinese	Dry deciduous to mixed deciduous forest, dry evergreen forest and scattered savannahs
Eastern (E)	Indo-Chinese	Dry dipterocarp forest, savannahs
Central (C)	Mainly under cultivation	Scattered evergreen forest, mangrove
South-Eastern (SE)	Cochin Chinese and Malayan	Tropical rain forest, savannahs, mangrove and tidal forest
South-Western (SW)	Tanasserim or lower Burmese	Bamboo forest, mixed deciduous and dry dipterocarp forest
Peninsular (PEN)	Malayan and Burmese (the northern part)	Tropical rain forest, peat swamp and mangrove

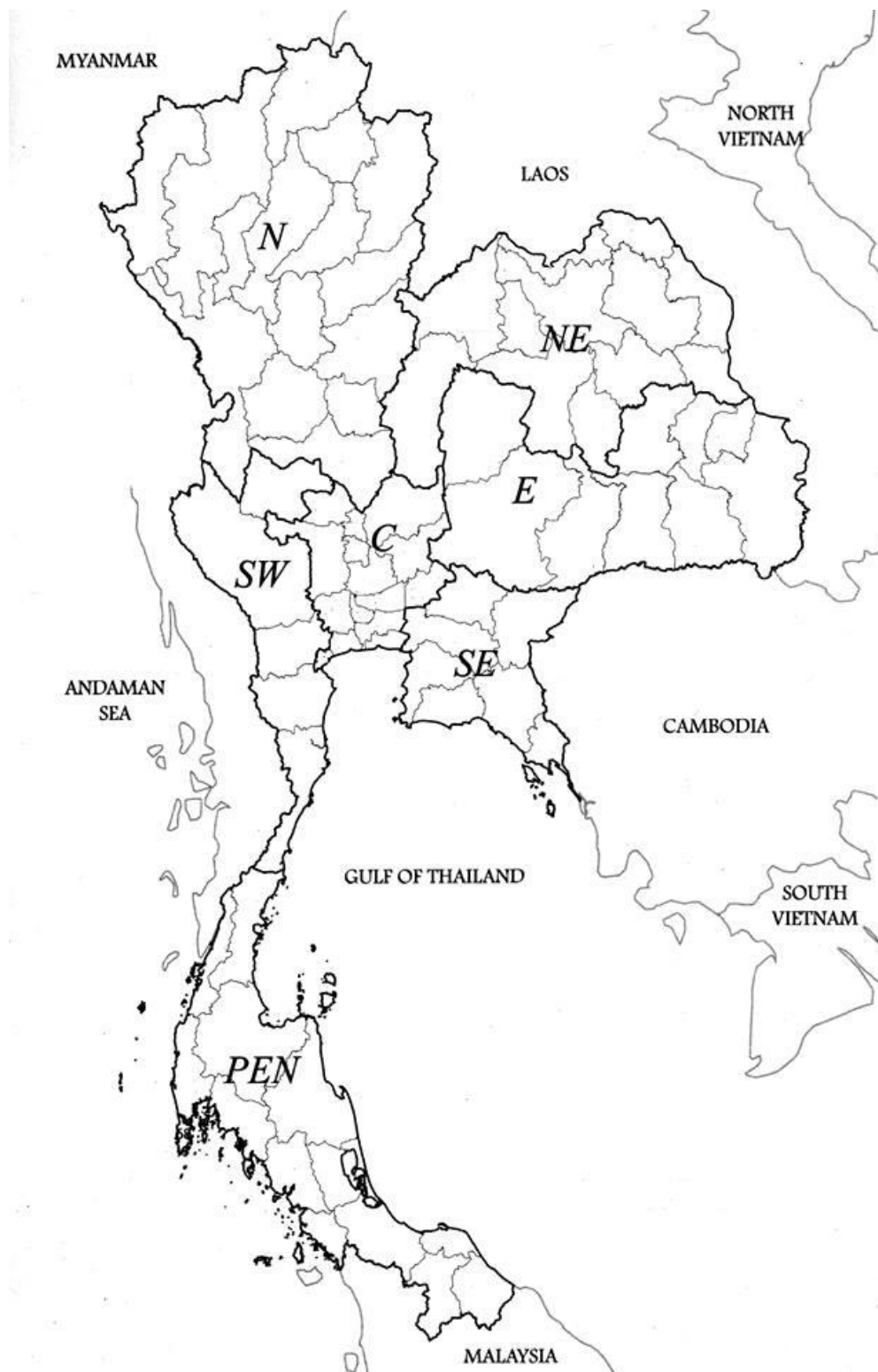


Figure 2.1 Floristic regions in Thailand (Smitinand, 1958).

2.3. Methodology

2.3.1. Literature reviews

Literature, floras, journals and publications including the original publications that accorded to the genus *Campylotropis* and its allies were reviewed emphasizing in Thailand and neighbouring countries which are China, Korea, Japan, Myanma, Laos, Vietnam, Cambodia, Malaysia, and Indonesia. The herbarium specimens were investigated both the herbaria in Thailand and selected herbaria in other countries as shown in the Table 2.2 to use as the guidance for field surveys and further study. Cited specimens that have been seen are indicated with ! while *n.v.* (*non vide*) indicates unseen specimens.

2.3.2. Field surveys

Field surveys were carried out from November 2016 to January 2018 based on previous herbarium collections and possible places where habitats are appropriate in all seven Thai floristic regions. Methods on field survey and collecting plant specimens followed the process of Bridson and Forman (1999). The specimens were collected by branching with flowers and/or fruits approximately 1–2 feet and some flowers and/or fruits were preserved in 70% alcohol for further study. Some characters that may be changed in colour or easily broken were recorded before collecting. The localities of plants were marked by GPS and condition of habits were also recorded. Both vegetative and reproductive parts were photographed by Nikon D5300 with AF-P DX NIKKOR 18–55mm f/3.5–5.6G VR.

2.3.3. Laboratory study

All specimens of *Campylotropis* collected from Thailand were morphologically investigated by recording both qualitative and quantitative data. The whole collected plants were observed, measured both vegetative and reproductive parts: stems (young twigs and mature stems), leaves (petioles, stipules, foliolate leaves, and petiolules), inflorescences (peduncles, axis, bracts, and bracteoles), flowers (pedicels, calyx,

corolla, androecium, and gynoecium), and fruits. Line drawings were made with free-hand and some small characters were drawn by an Olympus SZX12 stereo microscope with attached Olympus SZX-DA Drawing tube and Nikon OPTIPHOT-2 with attached Nikon Drawing tube. The key to species, full descriptions, and line drawings were provided. Ecological data and their distributions were also noted from recent study including retrieved from labels of herbarium specimens. All specimens collected from field surveys throughout Thailand were dried and deposited at Prince of Songkla University Herbarium (PSU), the Forest Herbarium, Department of National Park, Wildlife and Plant Conservation (BKF), and others.

Table 2.2 List of herbaria for investigation on the genus *Campylotropis* in Thailand

Countries	Herbaria list (herbarium acronyms follow Thiers, 2018)
Thailand	Kasin Suvathabhandhu Herbarium, Chulalongkorn university, Bangkok (BCU) Bangkok Herbarium, Botanical section, Department of Agriculture, Bangkok (BK) Forest Herbarium, National park, Wildlife and Plant Conservation Department, Bangkok (BKF) Chiang Mai University Herbarium, Faculty of Pharmaceutical Science, Chiang Mai (CMU) Chiang Mai University Herbarium, Faculty of Science, Chiang Mai (CMUB) Khon Kaen University Herbarium, Khon Kaen (KKU) Prince of Songkla University Herbarium, Songkhla (PSU) The Queen Sirikit Botanical Garden Herbarium, Chiang Mai (QBG)
Denmark	Aarhus University Herbarium (AAU) University of Copenhagen Herbarium (C)
France	Muséum National d'Histoire Naturelle Herbarium (P)
The Netherlands	The National herbarium of the Netherlands, Leiden (L) University of Utrecht Herbarium (U) Herbarium Vadense, Wageningen University (WAG)
The United Kingdoms	Herbarium of Natural History Museum, London (BM) Herbarium of Royal Botanic Gardens, Edinburgh (E) Herbarium of Royal Botanic Gardens, Kew, London (K)
United States of America	The United States National Herbarium (US) New York Botanical Garden Herbarium (NY)

2.4. Results and discussions

The investigations on morphology of the fresh and herbarium specimens of the genus *Campylotropis* in Thailand including adjacent countries illustrate both morphological features and taxonomic treatments in following titles.

MORPHOLOGY

Hairs

Hair is a notable character to distinguish *Campylotropis* species from Thailand. Two main types of hairs can be grouped into two types based on their number of cells which are uniseriate type and multiseriate type. Uniseriate type comprises unicellular hairs which can be distinguished by their directions, straightness, and length into five categories for easily usages following terminology of Harris and Harris (1994). Multiseriate type is glandular hairs which are basically composed of three parts: stalk, bulbous part, and elongated neck. These several types of hairs are generally found in both vegetative and reproductive parts depending of each taxon (Fig. 2.2). Based on terminology of these hairs, details are shown in following descriptions.

Uniseriate type

Appressed hairs	short straight hairs that pressed close or flat against leaves surfaces (Fig. 2.2A)
Patent hairs	short straight hairs that spread in upright position (Fig. 2.2B)
Pilose hairs	straight hairs that are long and soft in upright position (Fig. 2.2C)
Velutinous hairs	velvety; short, soft hairs, soft spreading hairs (Fig. 2.2 D)
Sericeous hairs	straight hairs that are silky, long, soft, slender, some what appressed hairs (Fig. 2.2E)

Multiseriate type

Glandular hairs	hairs that bear glands in side (Fig. 2.2F)
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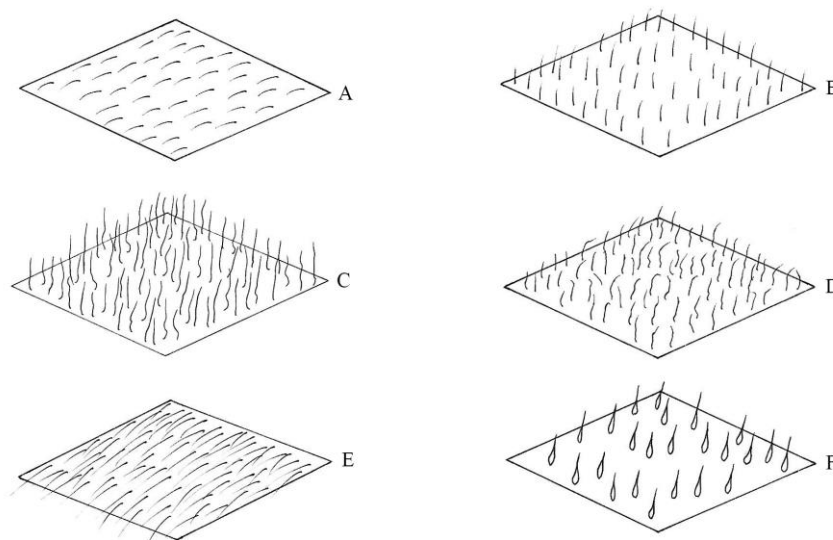


Figure 2.2 Drawing types of hairs of *Campylotropis* in Thailand. A: appressed hairs, B: patent hairs, C: pilose hairs, D: velutinous hairs, E: sericeous hairs, F: glandular hairs.

Habitats

Most species of Thai *Campylotropis* are naturally specialised growing in limestone habitat in fully exposed to sunlight at high altitude and few species preferred under shaded on moist soil. *C. bonii*, *C. capillipes* subsp. *prainii*, *C. decora*, *C. harmsii*, and *C. sulcata* are recognised as limestone-specific species that can be only found in limestone vegetations. *C. parviflora* and *C. pinetorum* can generally found on moist soil and granite bedrock under slightly or fully shaded areas from canopy (Fig. 2.3).

Stems and branches

All plant habits of Thai *Campylotropis* exhibit perennial small shrub to shrublet (Fig. 2.4). The shape of stem of Thai *Campylotropis* can be divided into three main types in cross-section view which are terete, polygonal and sulcate stem (Figs. 2.5–2.6). Terete stems can be found in *C. bonii*, *C. capillipes* subsp. *prainii*, and *C. harmsii*. Polygonal stem is found in *C. decora*, *C. parviflora*, and *C. pinetorum* while *C. sulcata*

exhibits sulcate stem. The type of hair on stems is usually appressed hairs and more compact in young twigs except *C. pinetorum* that is covered with dense velutinous hairs (Fig. 2.6). Branching of *Campylotropis* species are generally much lateral branched, except *C. harmsii* apparently poses zigzag branched. In comparison with related genera, *Lespedeza* is subshrubs, shrubs, or perennial herbs while *Kummerowia* is annual herb (Iokawa & Ohashi, 2002a; Huang *et al.*, 2010; Jabbrou *et al.*, 2018).

Leaves

The leaves of Thai *Campylotropis* are pinnately 3-foliolate leaves with distinct petioles and rachises. Terminal leaflets are equal or slightly larger than the other two lateral leaflets while the shape of leaflets are similar to each other and slightly various within the plants. The results from morphological investigations are shown in Table 2.3. Two types of leaves texture have been found in this study, charactaceous and subcoriaceous. The type of hairs on leaves surface is very taxonomically great value to identify a species which are mostly glabrous on adaxial surface and shortly appressed hairy on lower surface. From the result (Table 2.3 & Figs. 2.7–2.8), all hairs covered on leaf surfaces is uniseriate hair which can be recognised into four types as appressed hairs, pilose hairs, velutinous hairs, and sericeous hairs. These hairs may physiologically play an important role to prevent water loss and overloaded light absorbing (Wuenschel, 1970; Ehleringer *et al.*, 1976; Ripley *et al.*, 1999). Interestingly, the stipel of the genus has been recognised as absence or early caducous (Fu, 1987) or sometimes present (Hutchinson, 1964; Iokawa & Ohashi, 2002a); however, all species found in Thailand are exstipellate even in early stage of development. In *C. harmsii*, according to Iokawa and Ohashi (2002a), showed dimorphism of having petiole and sessile, nevertheless, in this study, *C. harmsii* exhibits a uniform of petiole.



Figure 2.3 Habitats of Thai *Campylotropis*. A-B: Exposed limestone vegetation in northern part of Thailand, C: exposed limestone vegetation in southern part of Thailand, D: exposed moist soil in evergreen forest vegetation, E: partly shaded in pine forest, F: shaded in evergreen forest.



Figure 2.4 Habits of Thai *Campylotropis*. A-B: shrub, C: shrublet.

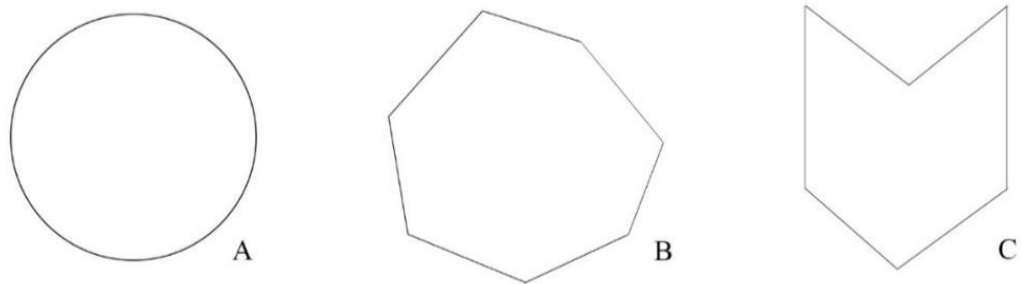


Figure 2.5 Diagrams of outlines from stem cross-section. A: terete stem, B: polygonal stem, C: sulcate stem.

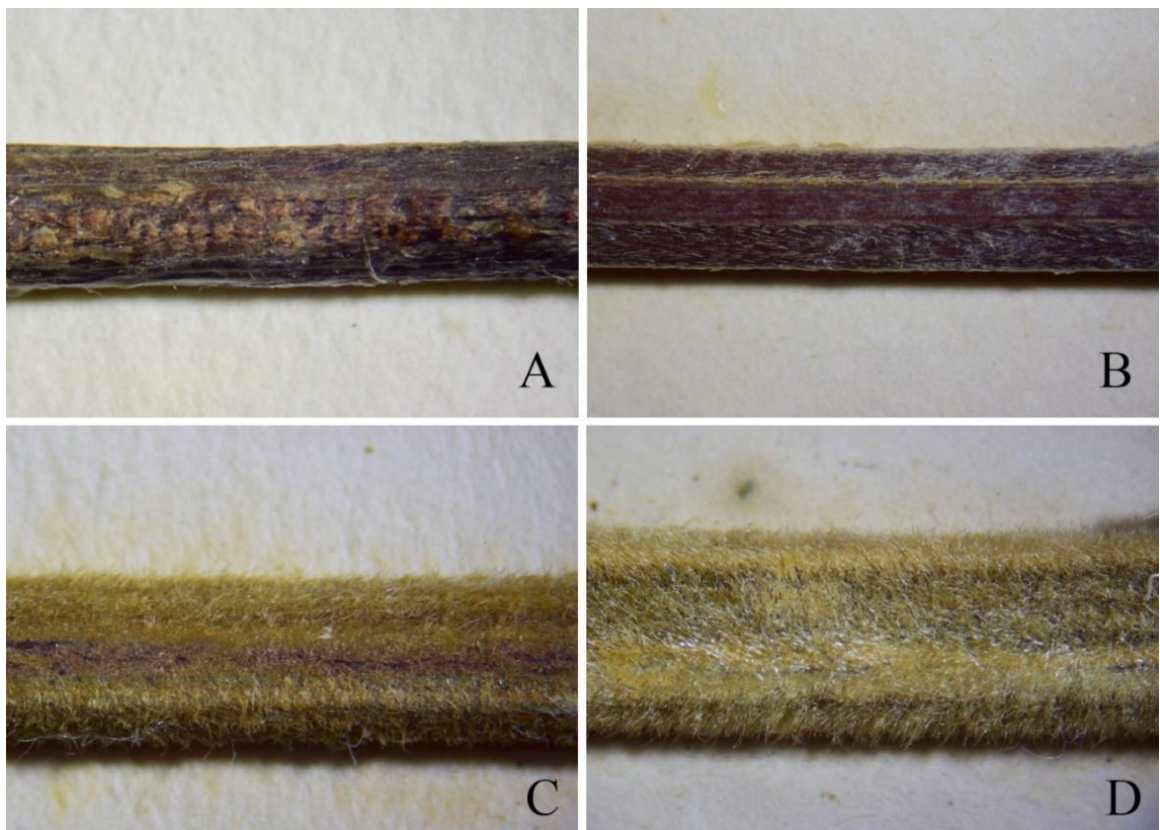


Figure 2.6 Outlines of stems. A: terete stem, B: polygonal stem. Types of hairs on stems: A, B: appressed hairs, C: patent hairs, D: velutinous hairs.

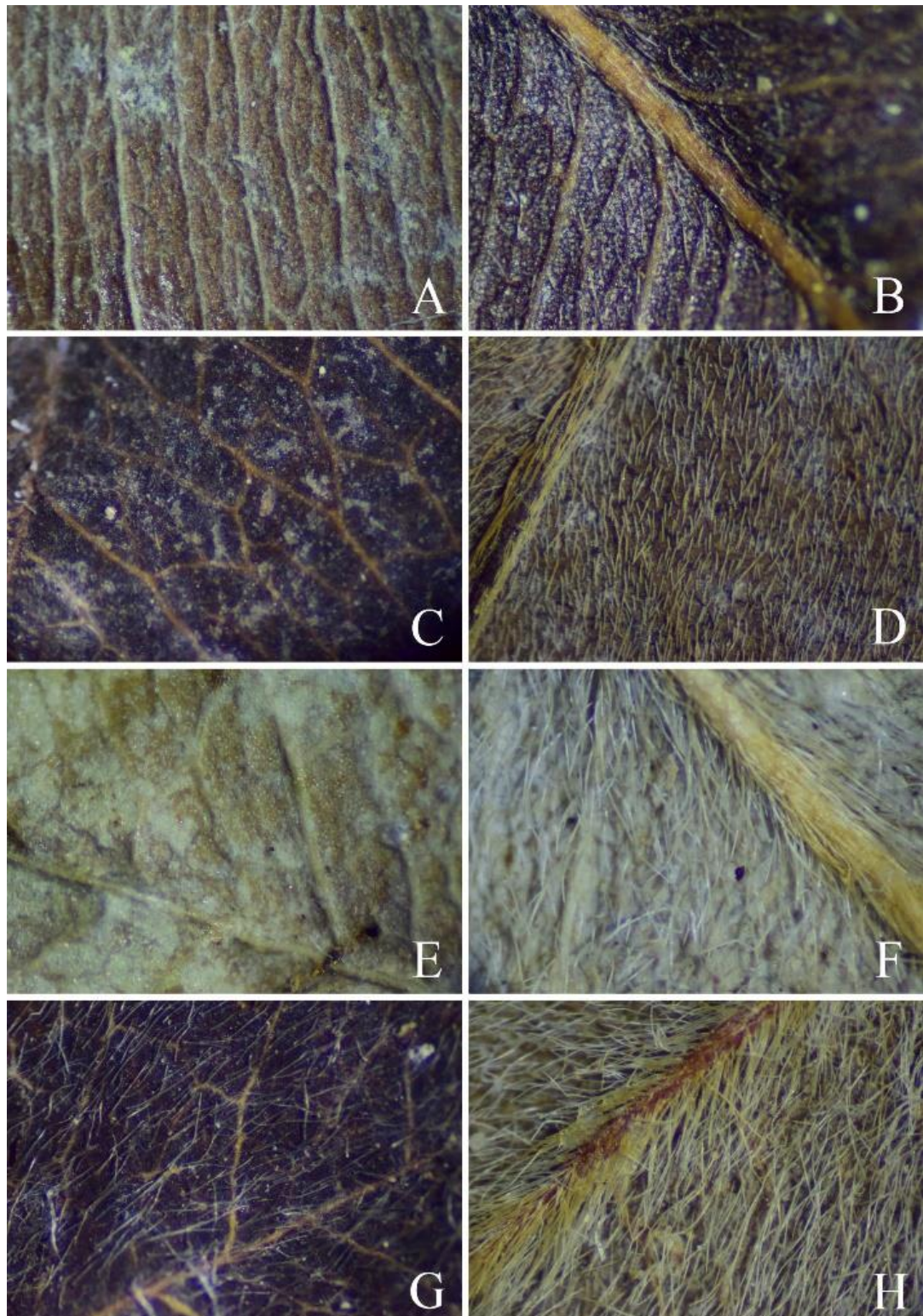


Figure 2.7 Hairs on leaves. A, C, E, G represented upper surface of leaves, B, D, F, H represented lower surface of leaves. A-B: *C. bonii*, C-D: *C. capillipes* subsp. *prainii*, E-F: *C. decora*, G-H: *C. harmsii*.

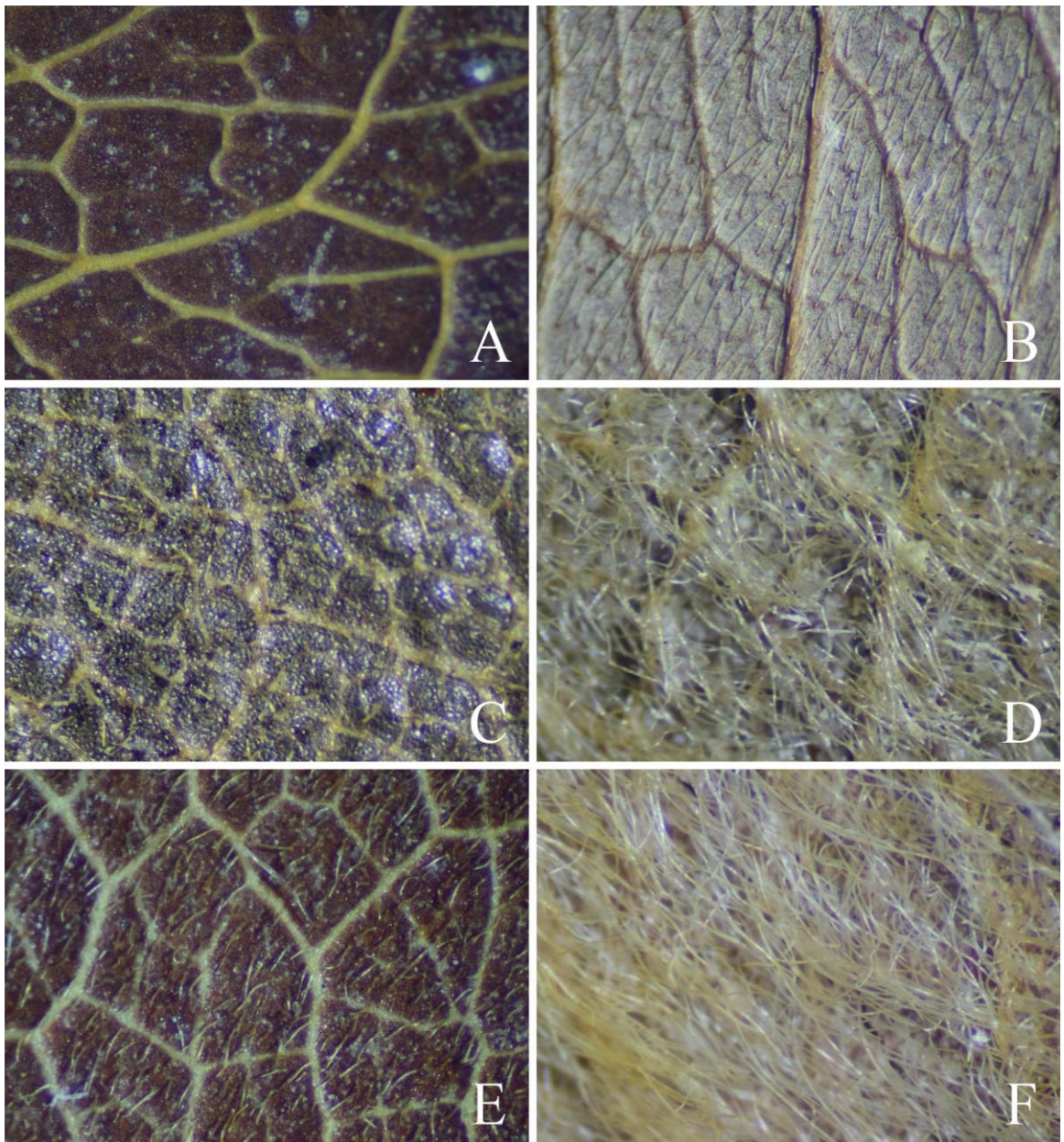


Figure 2.8 Hairs on leaves (continued). A, C, E represented upper surface of leaves, B, D, F represented lower surface of leaves. A-B: *C. parviflora*, C-D: *C. pinetorum*, E-F: *C. sulcata*.

Inflorescences

Inflorescences of *Campylotropis* species are basically regarded as a reduced form of pseudoraceme which is very similar to those racemes. These racemes are generally produced at axillary nodes with foliolate leaves while terminal inflorescences are considered as panicles which are surrounded by axillary racemes subtended by reduced leaves. Inflorescences of *C. bonii*, *C. capillipes* subsp. *prainii*, *C. harmsii*, and *C. pinetorum* pose an axillary raceme while the rests reveal both terminal and axillary (Table 2.4 & Figs. 2.9A–2.9B). These two types of inflorescences of Thai *Campylotropis* exhibit both axillary raceme and terminal panicle likewise the previous (Iokawa & Ohashi, 2002a; Huang & Ohashi, 2010). Phyllomes occurring in the *Campylotropis* inflorescences that born at base pedicels and base of calyx are regarded as bract and bracteole, respectively, following Nemoto and Ohashi (1996). The flowers are papilionaceous form with one-flowered on bracts subtended. The inflorescences including peduncles, inflorescence axes, and pedicels are commonly covered with many types of hairs which are taxonomically useful to separate species (Table 2.4). Comparing to its related genus, *Lespedeza*'s inflorescence structure exhibits a pseudoraceme which its lateral branches of inflorescence are reduced and formed two flowers per bract subtended (Nemoto & Ohashi, 1996).

Glandular hairs are frequently found in many *Campylotropis* species throughout inflorescences including pedicels and calyx. This hair on inflorescences might play an important role against small phytiphagous insect to harm flower and fruit setting (Jaime *et al.*, 2013). Glandular hairs are not only being as protector from pests but also cover the plant to avoid of cold penetration damaging internal plant cells (Bosabalidis & Sawidis, 2014) because many Thai species can be found in high altitudes with low temperature. Five species of Thai *Campylotropis* collected from high elevation suitably relate with bearing glandular hairs through inflorescences except the other two species, *C. bonii* and *C. capillipes* subsp. *prainii*, may generate other mechanisms to prevent plant damages instead.

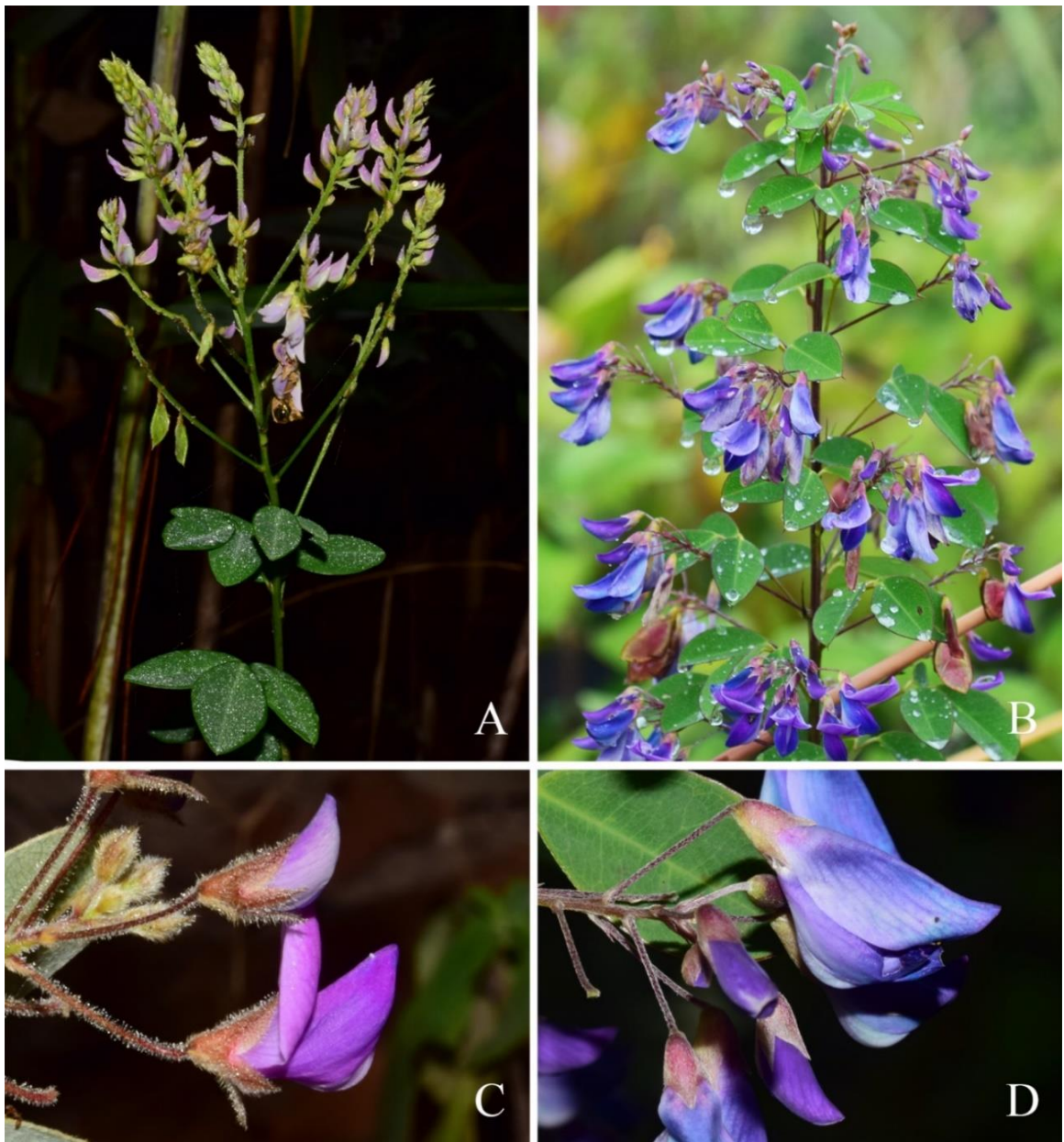


Figure 2.9 Inflorescences types and calyx. A: terminal panicle, B: axillary raceme, C: calyx tube shorter than lobes, D: calyx tube longer than lobes.

Calyx

The calyx of Thai *Campylotropis* is campanulate with 4 lobes. The length of calyx tubes ranges from 1 mm (*C. parviflora*) to 3.5 mm (*C. decora*). Dorsal lobes are usually triangular in shape which are wider than other lobes, sometimes they can be recognised as slightly 2-lobed from dividing of the tip. The length is from 1.2 mm (*C. capillipes* subsp. *prainii*) to 4.8 mm (*C. decora*) and the width is from 0.5 mm (*C. parviflora*) to 4 mm (*C. harmsii*). Lateral lobes are usually triangular in shape which are equal to the other side. The size ranges from 1 mm (*C. capillipes* subsp. *prainii*) to 5 mm (*C. decora*) by 0.3 mm (*C. parviflora*) to 2.2 mm (*C. decora*). The lowest lobes are usually triangular in shape which are the longest lobes. The length ranges from 1.5 mm (*C. bonii* and *C. parviflora*) to 5 mm (*C. decora* and *C. harmsii*). The width is from 0.5 mm (*C. capillipes* subsp. *prainii* and *C. parviflora*) to 1.8 (*C. decora*). There are two main groups of calyx based on their length which are calyx tube longer or equal to calyx lobes and calyx tube shorter than calyx lobes. *C. bonii*, *C. capillipes* subsp. *prainii*, *C. parviflora*, and *C. pinetorum* are grouped in the former group while three species, *C. decora*, *C. harmsii*, and *C. sulcata* are shown to be in the latter group. Most species reveal calyx lobes as triangular in outline and not overlapped to each other except *C. decora* shows ovate-triangular and overlapped lobes (Table 2.5 & Figs. 2.9C–2.9D & 2.10). Based on their colour, *C. bonii* and *C. parviflora* exhibit greenish tone of calyx; however, others show reddish to purplish tone. These length of calyx tube and calyx lobes including their colours can be taxonomically used to distinguish some *Campylotropis* species in Thailand.

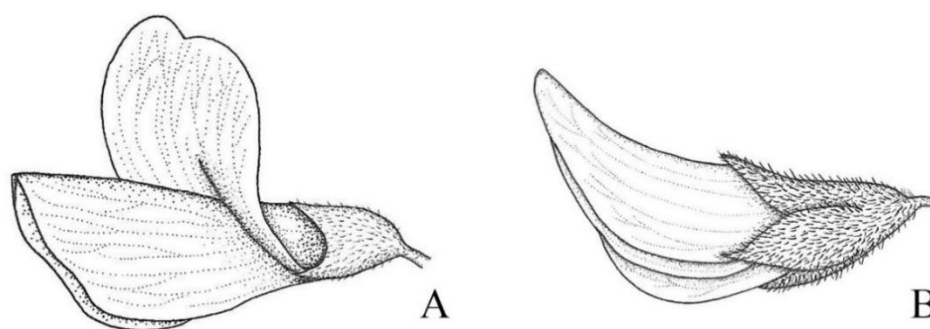


Figure 2.10 Two types of calyx. A: not overlapping calyx lobes and calyx tube longer than calyx lobes, B: overlapping calyx lobes and calyx tube shorter than calyx lobes.

Corolla

Two groups of corolla of Thai *Campylotropis* are classified depending on their colours which are light to dark violet or dark blue group and pinkish white to creamy white group (Figs. 2.11A–2.11D). *C. parviflora* and *C. pinetorum* belong to the latter group while others are accommodated in the former group. The measurement on corolla shape and size including standards, wings, and keels are shown in Table 2.6. The shapes of standards are elliptic, elliptic-ovate, elliptic oblong, obovate-oblong, or obovate. The length ranges from 5.5 mm (*C. parviflora*) to 14 mm (*C. decora*) and the width ranges from 2.5 mm (*C. parviflora*) to 10 mm (*C. decora*). Claws present in all taxa ranging from 1 mm to 2 mm in length. Auricles can be found in *C. capillipes* subsp. *prainii*, *C. decora*, and *C. harmsii* which have the length from 0.1 mm to 0.3 mm. The shapes of wings are oblong, oblong-obovate, or spatulate. The length of wing is from 5 mm (*C. parviflora*) to 12 mm (*C. decora*) and the width is from 2 mm (*C. parviflora*) to 5.5 mm (*C. capillipes* subsp. *prainii* and *C. harmsii*). Claws and auricles display in all taxa which have the length from 1.5 mm to 3.5 mm and 0.4 mm to 1 mm, respectively. The shapes of keels are generally boat-shaped. The length of keel ranges from 5.5 mm (*C. parviflora*) to 13 mm (*C. decora*) and the width is from 1.4 mm (*C. parviflora*) to 3.8 mm (*C. decora*). Claws and auricles appear in all taxa which their lengths range from 1 mm to 3.8 mm and 0.2 mm to 1 mm, respectively. In comparison, keels of *Campylotropis* differ from those of *Lespedeza* and *Kummerowia* by having acute apex of keel (Bentham, 1865; Iokawa & Ohashi, 2002a; Huang *et al.*, 2010).

Androecium

The androecium of the genus is diadelphous with one vexillary (9+1). Filaments fuse into staminal tube and separate at the top about 1/4 of their length. Lengths of stamens vary from 6 mm (*C. parviflora*) to 16 mm (*C. decora*). The anthers are uniform with oblong or ovate-oblong in shape and yellow in colour. The size of anthers ranges from 0.2 mm (*C. harmsii*) to 0.6 mm (*C. capillipes* subsp. *prainii* and *C. decora*) by 0.1

mm (*C. harmsii* and *C. pinetorum*) to 0.4 mm (*C. capillipes* subsp. *prainii* and *C. parviflora*) (Table 2.7).

Gynoeciums

The length of pistils of Thai *Campylotropis* ranges from 6 mm (*C. parviflora*) to 17 mm (*C. decora*). The ovary of the genus is superior with 1 locule and 1 ovule and marginal placentation. Ovary shape is oblong with or without hairs. The style is filiform ranging from 4 mm (*C. parviflora*) to 14 mm (*C. decora*). The stigma is capitate surrounded by minute hairs (Table 2.8).

Fruits and seeds

All species of Thai *Campylotropis* produce indehiscent pods with 1 article and 1 seed. The shapes of pods usually oblong in outline with laterally flattened. The length of fruit is from 4 mm (*C. sulcata*) to 20 mm (*C. harmsii*) by 2 mm (*C. sulcata*) to 7 mm (*C. capillipes* subsp. *prainii*) (Table 2.9). Reddish reticulated venations are usually found on surface of pods (Figs. 2.11E-2.11F). All species *Campylotropis* in Thailand exhibit hair structures on their fruits especially appressed hairs or mixed with glandular hairs except *C. capillipes* subsp. *prainii* that are rarely with hairs. The single seed of their pods of Thai *Campylotropis* is reniform in shape and the length ranges from 1.2 mm (*C. sulcata*) to 8 mm (*C. bonii* and *C. harmsii*) by 0.5 mm (*C. sulcata*) to 3.5 mm (*C. bonii* and *C. harmsii*). All seed characters of *Campylotropis* in Thailand are quite similar to each other except the size (Table 2.10).



Figure 2.11 Colour of corolla and fruits. A: creamy white, B: pinkish white to pink, C: purple, D: dark blue, E: young fruits, F: mature fruits.

Table 2.3 Shapes, types of hairs, and texture on leaves of *Campylotropis* in Thailand.

Taxa	Shape	Upper surface	Lower surface	Leaf texture
1. <i>C. bonii</i>	Obcordate-obdeltoid	Glabrous	Appressed hairy	Subcoriaceous
2. <i>C. capillipes</i> subsp. <i>prainii</i>	Obovate-oblong or obcordate	Glabrous	Appressed hairy	Chartaceous
3. <i>C. decora</i>	Obovate or Obovate-oblong	Glabrous	Appressed hairy	Subcoriaceous
4. <i>C. harmsii</i>	Transversely elliptic	Pilose hairy	Ailose hairy	Chartaceous
5. <i>C. parviflora</i>	Narrowly ovate to elliptic	Glabrous	Appressed hairy	Subcoriaceous
6. <i>C. pinetorum</i>	Narrowly elliptic	Appressed hairy	Velutinous hairy	Subcoriaceous
7. <i>C. sulcata</i>	Elliptic-oblong or obovate- elliptic	Appressed hairy	Sericeous hairy	Subcoriaceous

Table 2.4 Types and hairs on inflorescences of *Campylotropis* in Thailand.

Taxa	Types of Inflorescence	Types of hairs
1. <i>C. bonii</i>	Receme	Appressed hairy
2. <i>C. capillipes</i> subsp. <i>prainii</i>	Receme	Appressed hairy
3. <i>C. decora</i>	Raceme and panicle	Patent hairy and glandular hairy
4. <i>C. harmsii</i>	Receme	Patent hairy and glandular hairy
5. <i>C. parviflora</i>	Raceme and panicle	Patent hairy and glandular hairy
6. <i>C. pinetorum</i>	Receme	Velutinous hairy and glandular hairy
7. <i>C. sulcata</i>	Raceme and panicle	Patent hairy and glandular hairy

Table 2.5 Characters of calyx of *Campylotropis* in Thailand.

Taxa	Length of calyx tubes (mm)	Size and shape of calyx lobes			colour
		Dorsal lobes (mm)	Lateral lobes (mm)	Lowest lobes (mm)	
1. <i>C. bonii</i>	1.8–2	Triangular 1.5–2 × 1–1.5	Narrowly triangular 1.3–1.5 × 0.7–0.8	Triangular to narrowly triangular 1.5–1.8 × 0.6–1	Green
2. <i>C. capillipes</i> subsp. <i>prainii</i>	2–2.5	Triangular 1.2–2.5 × 1–2.5	Triangular 1–2 × 0.5–1.2	Narrowly triangular 1.5–2.2 × 0.5–1.2	Reddish-brown to red
3. <i>C. decora</i>	2.5–3.5	Ovate-triangular 4–4.8 × 2–3.5 Overlapped on lateral lobes	Ovate-triangular 4–5 × 2–2.2	Triangular 3.5–5 × 1.5–1.8	Reddish-brown
4. <i>C. harmsii</i>	2–3	Triangular 3–3.5 × 3–4	Triangular 4–4.2 × 1.2–1.5	Narrow triangular 4.5–5 × 1–1.2	Reddish-brown
5. <i>C. parviflora</i>	1–2	Narrowly triangular to setaceous 1.5–2 × 0.5–0.6	Narrowly triangular to setaceous 1.5–1.8 × 0.3–0.4	narrowly triangular to setaceous 1.5–2 × 0.5–0.6	Green
6. <i>C. pinetorum</i>	2–2.5	Triangular 2.5–3 × 1.8–2	Triangular 2.5–3 × 1–1.1	Narrowly triangular 2.8–3 × 0.7–1	Reddish-brown
7. <i>C. sulcata</i>	1.5–1.8	Triangular 2.2–3 × 1.8–2	Triangular 2–2.2 × 0.8–1	Triangular 2.2–3 × 0.7–1	Reddish-brown

Table 2.6 Characters of corolla of *Campylotropis* in Thailand.

Characters	<i>C. bonii</i>	<i>C. capillipes</i> subsp. <i>prainii</i>	<i>C. decora</i>	<i>C. harmsii</i>	<i>C. parviflora</i>	<i>C. pinetorum</i>	<i>C. sulcata</i>
1. Standards							
1.1. Shape	Elliptic-ovate	Obovate-oblong	Obovate	Elliptic-oblong	Elliptic-oblong	Obovate-oblong	Elliptic
1.2. Size (mm)	7.5–9 × 5–7	10–11 × 7–8	9.2–14 × 8–10	10–11 × 7–7.5	5.5–6 × 2.5–3	7.5–8 × 6–7	8.5–11 × 5–6.5
1.3. Claw length (mm)	1.5–2	1.7–2	1–2	1.2–2	1–1.2	1.5–2	0.8–1
1.4. Auricle length (mm)	-	0.3–0.5	0.1–0.3	0.2–0.3	-	-	-
2. Wings							
2.1. Shape	Oblong	Oblong to oblong-obovate	Oblong	Oblong	Oblong	Spathulate	Oblong
2.2. Size (mm)	8–8.5 × 2.5–3	9.5–10 × 4.5–5.5	9–12 × 4–5	10–11 × 5–5.5	5–6 × 2–2.2	5.3–5.5 × 2.5–3.2	8–9.5 × 3–4
2.3. Claw length (mm)	1.5–2.5	2.5–3.5	2.4–3	2–2.5	1.4–1.5	2.5–2.7	1.5–2
2.4. Auricle length (mm)	0.5–0.6	0.5–1	0.4–1	0.5–1	0.5–0.6	0.8–1	0.5–1
3. Keels							
3.1. Shape	Boat-shaped	Boat-shaped	Boat-shaped	Boat-shaped	Boat-shaped	Boat-shaped	Boat-shaped
3.2. Size (mm)	7.5–8 × 2.5–3	9.5–10 × 2.5–3	9–13 × 3–3.8	9–10 × 2.8–3	5.5–6 × 1.4–1.5	6–6.5 × 2.5–3	9.5–11 × 2.5–3
3.3. Claw length (mm)	1.5–2.5	2.5–3.5	2.4–3.8	2.5–3.5	1–1.2	2.8–3	1.5–2.5
3.4. Auricle length (mm)	0.2–0.3	0.4–0.5	0.3–0.7	0.3–0.5	0.3–0.5	0.3–0.5	0.5–1
4. Colour	Light to dark purple	Dark blue to purple	Light purple	Pinkish-purple	Pinkish-white to creamy white	Pinkish-white to creamy white	Light to dark purple

Table 2.7 Characters of androecium of *Campylotropis* in Thailand.

Taxa	Length of stamens (mm)	Length of staminal tubes (mm)	Length of free parts (mm)	Anthers	
				Shape	Size (mm)
1. <i>C. bonii</i>	7–9	6–7	2–2.5	Oblong	0.3–0.4 × 0.2–0.3
2. <i>C. capillipes</i> subsp. <i>prainii</i>	9.5–11.5	5.5–9	1.5–2.5	Ovate-oblong	0.4–0.6 × 0.3–0.4
3. <i>C. decora</i>	10–16	7.5–12	1.5–4	Oblong	0.5–0.6 × 0.2–0.3
4. <i>C. harmsii</i>	9.5–13	7–11	2–3	Oblong	0.2–0.5 × 0.1–0.3
5. <i>C. parviflora</i>	6–7	4.5–5	2–3	Oblong	0.4–0.5 × 0.3–0.4
6. <i>C. pinetorum</i>	8–8.5	4–6	2–2.5	Oblong	0.3–0.4 × 0.1–0.2
7. <i>C. sulcata</i>	8–10	6–8	2.5–3	Ovate-oblong	0.3–0.4 × 0.2–0.3

Table 2.8 Characters of gynoecium of *Campylotropis* in Thailand.

Taxa	Length of pistils (mm)	Length of style (mm)	Types of hairs
1. <i>C. bonii</i>	9–9.5	6–6.5	Appressed hairy
2. <i>C. capillipes</i> subsp. <i>prainii</i>	10.5–13	5.5–8	Glabrous or appressed hairy
3. <i>C. decora</i>	11–17	7.4–14	Patent hairy
4. <i>C. harmsii</i>	11–14	7–10	Velutinous hairy
5. <i>C. parviflora</i>	6–7	4–5	Patent hairy
6. <i>C. pinetorum</i>	8.5–9	6.5–7	Patent hairy
7. <i>C. sulcata</i>	8–12	6.5–9.5	Patent hairy

Table 2.9 Characters of fruits of *Campylotropis* in Thailand.

Taxa	Shape	Size (mm)	Types of hairs
1. <i>C. bonii</i>	Obliquely oblong	11–15 × 4–5	Sparsely appressed hairy
2. <i>C. capillipes</i> subsp. <i>prainii</i>	Obliquely elliptic to Oblong	10–14 × 3–7	Glabrous or appressed hairy
3. <i>C. decora</i>	Obliquely ovate	5–8.5 × 4–5	Patent hairy and glandular hairy
4. <i>C. harmsii</i>	Ovate-oblong	8–20 × 2.3–6	Pilose hairs
5. <i>C. parviflora</i>	Obliquely obovate	6.5–9 × 4–5	Patent hairy
6. <i>C. pinetorum</i>	Obliquely ovate	5–6 × 2.5–3	Densely patent hairy
7. <i>C. sulcata</i>	Obliquely ovate	4–7 × 2–4	Densely patent hairy

Table 2.10 Characters of seeds of *Campylotropis* in Thailand.

Taxa	Shape	Size of seeds (mm)
1. <i>C. bonii</i>	Reniform or oblong	6–8 × 3–3.5
2. <i>C. capillipes</i> subsp. <i>prainii</i>	Reniform or obliquely elliptic	1.8–2 × 0.7–1.2
3. <i>C. decora</i>	Reniform	1.5–4.6 × 1–3
4. <i>C. harmsii</i>	Reniform	4.5–8 × 3–3.5
5. <i>C. parviflora</i>	Reniform	2–4.5 × 1.5–2.3
6. <i>C. pinetorum</i>	Reniform or oblong	2.6–2.8 × 1.3–1.5
7. <i>C. sulcata</i>	Reniform	1.2–1.5 × 0.5–1

TAXONOMIC TREATMENT

In this study, approximately 380 specimens of Thai *Campylotropis* were examined including fresh and herbaria materials. Seven species and one subspecies are recognised (Table 2.11). The taxonomic treatment based on morphological features, key to species, morphological descriptions of the genus and species, distribution, ecology, and examined specimens of each species are provided.

Table 2.11 List of the genus *Campylotropis* in Thailand and distribution.

Taxa	Thai Floristic regions						
	N	NE	E	SE	C	SW	PEN
1. <i>Campylotropis bonii</i> Schindl.							×
2. <i>Campylotropis capillipes</i> subsp. <i>prainii</i> (Collett & Hemsl.) Iokawa & H. Ohashi	×						
3. <i>Campylotropis decora</i> (Kurz) Schindl.	×						
4. <i>Campylotropis harmsii</i> Schindl.	×						
5. <i>Campylotropis parviflora</i> (Kurz) Schindl.	×	×	×			×	
6. <i>Campylotropis pinetorum</i> (Kurz) Schindl.	×	×					
7. <i>Campylotropis sulcata</i> Schindl.	×		×				

Thai Floristic Regions: N = Northern, NE = North-eastern, E = Eastern, SE = South-eastern, C = Central, SW = South-western, PEN = Peninsular.

CAMPYLOTROPIS

Bunge, Uchen. Zap. Imp. Kazansk. Univ. 4: 157. 1835; Miq., Fl. Ned. Ind. 1: 229. 1855; Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 11: 338, 424. 1912; Rehder, Man. Cult. Trees & Shrubs 1: 517. 1927; Hutch., Gen. Fl. Pl. 1: 488. 1964; H. Ohashi, J. Jap. Bot. 49(2): 40. 1974; H. Ohashi *et al.* in Polhill & P.H. Raven, Advances Legume Syst. 1: 300. 1981; Thuân in Thuân *et al.*, Fl. Cambodge, Laos & Vietnam 23: 143. 1987; P.Y. Fu, Bull. Bot. Res., Harbin 7(4): 22. 1987; P.Y. Fu, Fl. Reipubl. Popularis Sin. 41: 92. 1995; Iokawa & H. Ohashi, J. Jap. Bot. 77: 191. 2002; X.F. Gao, in Inst. Bot. Kunming. Acad. Sin., Fl. Yunnan. 10: 550. 2006; P. Huang *et al.* in Z.Y. Wu *et al.*, Fl. China 10: 292. 2010. Type species: *C. chinensis* Bunge (= *C. macrocarpa* (Bunge) Rehder).—*Phlebosprium* Jungh., Reisen Durch Java: 346. 1847; Hassk., Flora 30: 508. 1847. Type species: *P. cytisoides* Jungh.—*Phlebosporium* Benth. & Hook.f., Gen. Pl. 1: 524. 1865. Type species: *P. cytisoides* Benth.—*Lespedeza* sect. *Campylotropis* (Bunge) Benth., Hook's J. Bot. Kew Gard. Misc. 4: 48. 1852; Taub. in Engl. & Prant, Nat. Pflanzenfam. 3(3): 332. 1894; Nakai, *Lespedeza* of Japan & Korea: 3. 1927. Type species: *L. cytisoides* Benth.—*Lespedeza* subgen. *Campylotropis* (Bunge) Maxim, Trudy Imp. S.-Peterburgsk. Bot. Sada 2: 345, 347. 1873. Type species: *L. cytisoides* Benth.—*Lespedeza* Michx. subgen. *Oxyramphis* (Wall. ex Meisn.) Baker in Hook.f., Fl. Brit. India 2: 143. 1879.—*Oxyramphis* Wall., Numer. List: No. 5348. 1831, *nom. nud.* Type species: *O. macrostyla* (D. Don) Wall. ex Meisn.

Shrubs 1–4 m tall. *Stems* erect or ascending, much branched, terete, polygonal, or sulcate, hairy. *Leaves* pinnately 3-foliolate, alternate, subcoriaceous to chartaceous; petioles hairy; stipules triangular or triangular-lanceolate or triangular-linear, striate, persistent, outside hairy, inside glabrous; stipels absent. *Inflorescences* axillary raceme or terminal panicle with reduced subtending leaves; peduncles hairy. *Flowers* papilionaceous, 1-flowered per subtending bract, fragile; bracts present at base of pedicels, mostly narrowly triangular, persistent or caducous, outside hairy, inside glabrous; bracteoles occurring at base of calyx, triangular, ovate-triangular or setaceous, persistent or caducous, outside hairy, inside glabrous. *Calyx* of 4 sepals, campanulate, outside hairy, inside glabrous; dorsal 1-lobed, entire or 2-toothed at apex; lateral 2-

lobed, slightly shorter than dorsal one; lowest 1-lobed, longest. *Corolla* 5 petals, light to dark violet, dark blue or pinkish-white to creamy-white, glabrous; standard variable in shape, mostly broadly obovate or elliptic, clawed, auricle present or absent; wings mostly oblong, clawed, auricle 1; keel boat-shaped, narrowly oblong, falcate, clawed, auricle 1, ventral sutures joined. *Stamens* 10, diadelphous (9+1), base connate into staminal tubes about 3/4 of its length; anthers uniform, ovate-oblong or oblong, yellow. *Pistils* 1-carpellate; ovary superior, oblong, glabrous to hairy, 1-locular, 1-ovuled; styles filiform, incurved at right angle about 1/4 of its length; stigmas terminal, capitate. *Pod* a legume, 1-articulated, indehiscent, laterally flattened, apex acuminate or rounded and mucronate, obvious reticulate veins, hairy; fruiting stalks elongate. *Seed* 1, reniform, obliquely elliptic or oblong, brown, reddish-brown or blackish brown; hilum with annulus aril.

KEY TO THE SPECIES

1. Corolla pinkish-white to creamy-white; standard with green blotches on both sides; wings less than or equal to 6 mm long
 2. Lower surface of leaflets with velutinous hairs; upper surface of leaflets with black spots; pods less than or equal to 6 mm long **6. C. pinetorum**
 2. Lower surface of leaflets with appressed hairy; upper surface of leaflets without black spots; pods more than 6 mm long **5. C. parviflora**
1. Corolla dark blue or light to dark violet; standard without green blotches on both sides; wings more than 6 mm long
 3. Upper surface of leaflets pilose; stems with shortly zigzag lateral branches **4. C. harmsii**
 3. Upper surface of leaflets glabrous; stems without shortly zigzag lateral branches
 4. Peduncle with appressed hairs; pods glabrous or with appressed hairs
 5. Standard with white and yellow blotches, 7.5–9 mm long and without auricles; peduncle sparsely with appressed hairs; wings less than or equal to 8.5 mm long **1. C. bonii**
 5. Standard without white and yellow blotches, 10–11 mm long and with auricles;

peduncle densely shortly appressed hairy; wings more than 8.5 mm long

2. C. capillipes

4. Peduncle with patent hairs and glandular hairy; pods with patent hairy
 6. Calyx lobes more than 3 mm long, overlapping, dorsal lobe ovate-triangular;
 lower surface of leaflets with appressed hairs; pedicels more than 2 mm long

3. C. decora

6. Calyx lobes less than or equal to 3 mm long, not overlapping, dorsal lobe
 triangular; lower surface of leaflets with sericeous hairs; pedicels less than or
 equal to 2 mm long

7. C. sulcata

1. **Campylotropis bonii** Schindl. in Engl., Bot. Jahrb. Syst. 54 (1): 64. 1916; Thuân in Thuân *et al.*, Fl. Cambodge, Laos & Vietnam 23: 143. 1987; Iokawa & H. Ohashi, J. Jap. Bot. 77(4): 201. 2002.— *Lespedeza bonii* (Schindl.) Gagnep. in Lecomte & Gagnep., Fl. Indo-Chine 2: 520. 1920. Type: Vietnam, Tuan-Du, *Bon 4320* (holotype **P** 00758118!, isotypes **P** 00758120!, **P** 00758119!).— *Campylotropis bonii* var. *anguticarpa* Schindl. in Fedde Repert. Nov. Regni Veg. 22: 271. 1926; Craib, Fl. Siam. 1(3): 432. 1928. Type: Thailand, Phangnga, small island near Panyi island, *Herb. Hort. Singapore no. 4079* (holotype **BM!**, isotype **K!**). Figs. 2.12A & 2.13–2.14.

Shrub 1–3 m tall. *Stems* erect or ascending, terete, dark brown, glabrous or sparsely covered with appressed hairs. *Leaves*: petioles 8–17 mm long, glabrous or sparsely appressed-hairy; rachis 2–5 mm long; stipules triangular or triangular-lanceolate, 2–3 by 0.8–1 mm, outside appressed-hairy; leaflets obcordate-obdeltoid, subcoriaceous; terminal leaflets 1.2–2.5 by 0.9–2 cm, lateral leaflets 1–2 by 0.5–1.5 cm, apex emarginate, base cuneate, margins entire; upper surface green, glabrous; lower surface light green, appressed-hairy; lateral veins 9–12 pairs; petiolules 2.5–4 mm long, densely appressed-hairy. *Inflorescences* axillary raceme, 2.5–3.5 cm long, laxly flowered; peduncles 8–10 mm long, sparsely appressed-hairy; bracts triangular, 0.5–1 by 0.2–0.5 mm, glabrous; bracteoles triangular, 0.7–1 by 0.3–0.5 mm, glabrous; pedicels 7–11 mm long, sparsely appressed-hairy. *Calyx* green, appressed-hairy; tube 1.8–2 mm long; dorsal lobe triangular, 1.5–2 by 1–1.5 mm; lateral lobes narrowly

triangular, 1.3–1.5 by 0.7–0.8 mm; lowest lobe triangular to narrowly triangular, 1.5–1.8 by 0.6–1 mm. *Corolla* light to dark purple with white and yellow blotches at base; standard elliptic-ovate, 7.5–9 by 5–7 mm, apex acute, claw 1.5–2 mm long, auricles absent; wings oblong, 8–8.5 by 2.5–3 mm, slightly upward, apex rounded, claw 1.5–2.5 mm long, auricle 0.5–0.6 mm long; keel 7.5–8 by 2.5–3 mm, claw 1.5–2.5 mm long, auricle 0.2–0.3 mm long. *Stamens* 7–9 mm long, staminal tubes 6–7 mm long, free part of filaments 2–2.5 mm long; anthers oblong, 0.3–0.4 by 0.2–0.3 mm. *Pistils* 9–9.5 mm long; styles 6–6.5 mm long, appressed-hairy at base. *Pods* obliquely oblong, 11–15 by 4–5 mm, brown, apex rounded and mucronate, sparsely appressed-hairy; fruiting stalks 8–10 mm long. *Seeds* reniform or oblong, 6–8 by 3–3.5 mm, brown.

Thailand.— PENINSULAR: Krabi [Sra Morakot Wildlife Sanctuary, 10 Apr. 2003, *Middleton et al.* 2100 (**BKF**); Tham Suea Temple, 5 Jan. 2006, *Gardner & Sidisunthron* ST2161 (**QBG, L**), *ibid.*, 18 Apr. 2007, *Gardner* ST2895 (**BKF, QBG**), *ibid.*, 24 Oct. 1991, *Larsen et al.* 42555 (**BKF, P**), *ibids.*, 8 May 2002, *Pooma et al.* 3609 (**BKF**), *ibids.*, 10 May 2017, *Sattaphorn & Leeratiwong* 80 (**PSU**), *ibids.*, 22 Aug. 2017, *Sattaphorn & Leeratiwong* 81 (**PSU**); Phangnga [Khao Ping Gun, 25 Oct. 1974, *S.N.* (**BK**); Small Island near Panyi Island, 17 Dec. 1928, *Herb. Hort. Singapore* no. 4079 (**BM, K**); Phuket [28 Feb. 1994, *Schmidt s.n.* (**P**)].

Distribution.— Vietnam.

Ecology.— Fissures on limestone outcrops, alt. 150–330 m. Flowering: April to October. Fruiting: April to October.

Vernacular.— Lueat Nai Tai (เลือดในไต).

Note.— *Campylotropis bonii* is characterised by having a light to dark purple corolla with white and yellow blotches on the standard, sparsely appressed hairs on the peduncle, and distinctly obcordate-obdeltoid leaflets.

2. **Campylotropis capillipes** (Franch.) Schindl. in Fedde, *Repert. Spec. Nov. Regni Veg.* 11: 341. 1912; *Hand.-Mazz.*, *Symb. Sin.* 7: 573. 1933; C.Y. Wu *et al.*, *Index Fl. Yunnan.* 1: 573. 1984; P.Y. Fu, *Bull. Bot. Res.*, Harbin 7(4): 28. 1987; P.Y. Fu, *Fl.*

Reipubl. Popularis Sin. 41: 98. 1995.— *Lespedeza capillipes* Franch., Pl. Delavay. 165. 1890; Iokawa & H. Ohashi, J. Jap. Bot. 77(4): 206. 2002; X.F. Gao, Inst. Bot. Kunming. Acad. Sin., Fl. Yunnan. 10: 557. 2006; P. Huang *et al.* in Y.Z. Wu *et al.*, Fl. China 10: 294. 2010. Type: China, Yunnan, monte Hee-chan-men, *Delavay 2733* (lectotype **K** 03089370! selected by Iokawa & Ohashi (2008), isolectotypes **K** 000894863!, **P** 00758122!).

subsp. **prainii** (Collett & Hemsl.) Iokawa & H. Ohashi, J. Jap. Bot. 77(4): 209. 2002; Iokawa & H. Ohashi, J. Jap. Bot. 83(1): 41. 2008; P. Huang *et al.* in Y.Z. Wu *et al.*, Fl. China 10: 295. 2010.— *Lespedeza prainii* Collett & Hemsl., J. Linn. Soc., Bot. 28: 46. 1890; H. Lév., Cat. Pl. Yun-Nan: 158. 1916.— *Campylotropis prainii* (Collett & Hemsl.) Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 11: 341. 1912; C.Y. Wu *et al.*, Index Fl. Yunnan. 1: 576. 1984; P.Y. Fu, Bull. Bot. Res., Harbin 7(4): 28. 1987; P.Y. Fu, Fl. Reipubl. Popularis Sin. 41: 98. 1995. Type: Myanmar, Shan, *Collett 951* (holotype **K** 000894915!). Figs. 2.12A & 2.15–2.16.

Shrub 1–3 m tall. *Stems* erect, terete, blackish-brown, densely appressed-hairy. *Leaves*: petioles 5–33 mm, densely appressed-hairy; rachis 1–3 mm long; stipules triangular-lanceolate or setaceous, 4–10 by 1–2 mm, outside appressed-hairy; leaflets obovate-oblong or obcordate, chartaceous; terminal leaflets 0.8–2.8 by 0.5–1.5 cm, lateral leaflets 0.5–2.2 by 0.5–2 cm, apex retuse or rounded and mucronate, base cuneate or rounded, margins entire; upper surface dark green, glabrous; lower surface light green, densely appressed-hairy; lateral veins 7–12 pairs; petiolules 1–2 mm long, densely appressed-hairy. *Inflorescences* axillary raceme, 2.5–6 cm long, densely flowered, flowers usually pendulous; peduncles 1–2.6 cm long, appressed-hairy; bracts triangular, 3–7 by 1–2 mm, appressed-hairy; bracteoles triangular, 1–2.5 by 1–2 mm, glabrous; pedicels 3–10 mm long, densely appressed-hairy. *Calyx* reddish-brown to red, appressed-hairy; tube 2–2.5 mm long; dorsal lobe triangular, 1.2–2.5 by 1–2.5 mm, with or without 2 teeth; lateral lobes triangular 1–2 by 0.5–1.2 mm; lowest lobe narrowly triangular, 1.5–2.2 by 0.5–1.2 mm. *Corolla* dark blue to purple; standard obovate-oblong, 10–11 by 7–8 mm, apex obtuse or emarginate, claw 1.7–2 mm long, auricles 0.3–0.5 mm long, reflexed; wings oblong to oblong-obovate, 9.5–10 by 4.5–5.5 mm,

apex rounded, claw 2.5–3.5 mm long, auricle 0.5–1 mm long; keel 9.5–10 by 2.5–3 mm, claw 2.5–3.5 mm long, auricle 0.4–0.5 mm long. *Stamens* 9.5–11.5 mm long, staminal tubes 5.5–9 mm long, free part of filaments 1.5–2.5 mm long; anthers ovate-oblong, 0.4–0.6 by 0.3–0.4 mm. *Pistils* 10.5–13 mm long; styles 5.5–8 mm long, glabrous or appressed-hairy. *Pods* obliquely elliptic to oblong, 10–14 by 3–7 mm, greenish-red to brownish-red, apex rounded and mucronate, glabrous or appressed-hairy; fruiting stalks 5–11 mm long. *Seeds* reniform or obliquely elliptic, 1.5–2 by 0.7–1.2 mm, reddish-brown.

Thailand.— NORTHERN: Chiang Mai [Ban Sa Ngin Nhua, 27 Nov. 2014, *Pongamornkul* 4453 (**QBG**), *ibid.*, 27 Jan. 2016, *Pongamornkul* 5639 (**QBG**); Doi Chiang Dao, 12 Nov. 1963, *Adisai* 648 (**BK**), *ibid.*, 4 Nov. 1963, *Bunchuai* 1305 (**K, L**), *ibid.*, 7 Dec. 1965, *Hannipman* 3278 (**C, L**), *ibid.*, 8 Feb. 1983, *Koyama et al. T-33268* (**BKF**), *ibid.*, 11 Nov. 1995, *Maxwell 95-1174* (**BKF, CMUB, L**), *ibid.*, 30 Jan. 1996, *Maxwell 96-136* (**BKF, CMUB**), *ibid.*, 27 Sept. 1971, *Murata et al. T-15201* (**BKF, P**), *ibid.*, 28 Nov. 2005, *Norsaengsri* 276 (**QBG**), *ibid.*, 23 Oct. 1992, *Pooma* 690 (**BKF, CMUB**), *ibid.*, 11 Nov. 2016, *Satthaphorn* 76 (**PSU**), *ibid.*, 12 Nov. 2016, *Satthaphorn* 77 (**PSU**), *ibid.*, 27 Oct. 2017, *Satthaphorn* 82 (**PSU**), *ibid.*, 28 Oct. 2017, *Satthaphorn* 83 (**PSU**), *ibid.*, 15 Jan. 2018, *Satthaphorn & Leeratiwong* 90 (**PSU**); *ibid.*, 18 Dec. 2003, *Sawai* 492 (**KKU**), *ibid.*, 19 Dec. 2003, *Sawai* 481 (**KKU**), *ibid.*, 27 Oct. 1979, *Shimizu et al. T-21037* (**BKF**), *ibid.*, 27 Oct. 1979, *Shimizu et al. T-21090* (**BKF**), *ibid.*, Dec. 1959, *Smitinand & Abbe* 6244 (**K**), *ibid.*, 3 Dec. 1961, *Smitinand & Anderson* 7347 (**BK, K**), *ibid.*, 10 Nov. 1962, *Smitinand* 7762 (**BKF**), *ibid.*, 21 Nov. 1999, *Suksathan* 2170 (**QBG**), *ibid.*, 9 Nov. 1997, *Triboun* 649 (**BK**); Doi Nom, 2 Nov. 1963, *Phusomeseang* 47 (**K, L**); Hui Nam Dang National Park, 17 Jan. 2002, *Chayamarit et al. 3131* (**BKF**); Uttaradit [Phu Soi Dao National Park, 8 Feb. 2010, *Norsaengsri* 6484 (**QBG**)].

Distribution.— Myanmar, China.

Ecology.— On exposed rugged limestone, lower montane pine oak forest, alt. 1300–2100 m. Flowering: September to November. Fruiting: October to February.

Vernacular.— Thua Khao Dok Khram (ถั่วเขาดอกคราม).

Note.— *Campylotropis capillipes* subsp. *prainii* is different from the typical one by the leaflets being glabrous on the upper surface (vs. appressed hairs) and raceme short, 1.5–3 cm long (vs. long, 2–8 cm) and calyx lobes are distinctly shorter than calyx tube (vs. calyx lobes as long as calyx tube). The species is similar to *C. bonii* in having appressed hairs on the peduncle and purple corolla, but the former species is easily separated by having dense appressed hairs (vs. sparsely appressed hairs) on the peduncle and the absence of white and yellow blotches on the standard.

3. ***Campylotropis decora*** (Kurz) Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 11: 428. 1912; Iokawa & H. Ohashi, J. Jap. Bot. 77(4): 213. 2002; Iokawa & H. Ohashi, J. Jap. Bot. 83(1): 44. 2008; P. Huang *et al.* in Y.Z. Wu *et al.*, Fl. China 10: 295. 2010.— *Lespedeza decora* Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 42: 231. 1873; Forest Fl. Burma 1: 381. 1877; Collett & Hemsl., J. Linn. Soc., Bot. 28: 45. 1890; Prain in King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 66: 377. 1897; Craib, Fl. Siam. 1(3): 433. 1928. Type: Myanmar, Martaban, *Kurz 1665* (holotype **CAL** 0000012094!).— *Lespedeza sericophylla* Collett & Hemsl., J. Linn. Soc., Bot. 28: 45. 1890; Prain in King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 66: 374. 1897.— *Campylotropis sericophylla* (Collett & Hemsl.) Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 11: 428. 1912. Type: Myanmar, Shan hills, Toungyi, *Collett 13* (holotype **K** 000894914!).— *Campylotropis sessilifolia* Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 11: 427. 1912. Type: Myanmar, South Shan hills, Toungyi, *Robertson 54* (holotype **K** 000894917!).— *Lespedeza henryi sensu* Gagnep. in Lecomte & Gagnep., Fl. Indo-Chine 2: 520. 1920; Craib, Fl. Siam. 1(3): 433. 1928, *non* Schindl. 1912.— *Campylotropis henryi sensu* Thuân in Thuân *et al.*, Fl. Cambodge, Laos & Vietnam 23: 144. 1987, *non* Schindler, 1912. Figs. 2.12B & 2.17–2.18.

Shrub 0.8–2 m tall. *Stems* erect, polygonal, greenish-brown to blackish-brown, densely appressed-hairy. *Leaves*: petioles 0.2–3.5 cm long, sulcate with adaxial wings, appressed-hairy, angled; rachis 1–13 mm long; stipules triangular, 4–7 by 0.5–1.2 mm, outside appressed-hairy, persistent; leaflet obovate or obovate-oblong, subcoriaceous; terminal leaflets 0.6–6.2 by 0.4–3 cm, lateral leaflets 0.5–5.7 by 0.4–3 cm, apex

emarginate, rounded or truncate and mucronate, base rounded or slightly cordate, margins entire; upper surface green, glabrous; lower surface, light green, densely appressed-hairy; lateral veins 7–12 pairs; petiolules 1–3 mm long, densely appressed-hairy. *Inflorescences* axillary raceme or terminal panicle, 2–10 cm long, densely flowered; peduncle 0.2–3 cm long, patent-hairy and densely glandular-hairy; bract triangular 1–4.5 by 0.5–1.2 mm, patent-hairy; bracteoles narrowly triangular, 1–3 by 0.1–0.5 mm, patent-hairy; pedicels 3–11 mm long, patent-hairy and densely glandular-hairy. *Calyx* reddish-brown, patent-hairy and glandular-hairy; tube 2.5–3.5 mm long; dorsal lobe ovate-triangular, 4–4.8 by 2–3.5 mm, bifid or not; lateral lobes ovate-triangular, 4–5 by 2–2.2 mm long, overlapping other lobes; lowest lobe triangular, 3.5–5 by 1.5–1.8 mm. *Corolla* light purple; standard obovate, 9.2–14 by 8–10 mm, apex acute or obtuse, claw 1–2 mm long, auricle 0.1–0.3 mm long; wings oblong, 9–12 by 4–5 mm long, claw 2.4–3 mm long, auricle 0.4–1 mm long, apex rounded; keel boat-shaped, 9–13 by 3–3.8 mm, apex acute, claw 2.4–3.8 mm long, auricle 0.3–0.7 mm long. *Stamens* 10–16 mm long, staminal tubes 7.5–12 mm long, free part of filaments 1.5–4 mm long; anthers oblong, 0.5–0.6 by 0.2–0.3 mm. *Pistils* 11–17 mm long; style 7.4–14 mm long, glabrous. *Pods* obliquely ovate, 5–10 by 4–5 mm, dark brown, apex acuminate, densely patent-hairy and glandular-hairy; fruiting stalks up to 14 mm long. *Seeds* reniform, 1.5–4.6 by 1–3 mm, blackish-brown.

Thailand.— NORTHERN: Mae Hong Son [Doi Pha Daeng, 26 Dec. 2012, *Norsaengsri 10025 (QBG)*; Huai San, 5 Feb. 2014, *Norsaengsri 10815 (QBG)*]; Chiang Mai [Doi Chiang Dao, 26 Mar. 1991, *Banziger 918 (CMU, L)*, *ibid.*, 29 Feb. 1940, *Garret 1158 (E, K, L, P)*, *ibid.*, 28 Nov. 1913, *Kerr 2862 (K)*, *ibid.*, 3 Mar. 1979, *Koyama et al. s.n. (BKF)*, *ibid.*, 28 Jan. 1996, *Maxwell 96-116 (BKF, CMUB, L)*, *ibid.*, 21 Dec. 1931, *Put 4484 (E, K)*, *ibid.*, 14 Jan. 2018, *Sathaphorn & Leeratiwong 89 (PSU)*, *ibid.*, 15 Jan. 2018, *Sathaphorn & Leeratiwong 91 (PSU)*, *ibid.*, 27 Oct. 1979, *Shimizu et al. T-21090 (BKF)*, *ibid.*, 17 Feb. 1958, *Smitinand 4252 (L)*, *ibid.*, 6 Dec. 1959, *Smitinand 6243 (BKF)*, *ibid.*, 16 Feb. 1958, *Sørensen et al. 1243 (C)*]; Chiang Rai [Doi Tung, 2 April 2011, *Bult 1161 (BKF, CMUB)*, *ibid.*, 21 Apr. 2008, *Maxwell 08-95 (CMUB, QBG, L)*, *ibid.*, 14 Feb. 2012, *Norsaengsri & Tathana 8966 (QBG)*, *ibid.*, 28 Mar. 2012, *Norsaengsri & Tathana 9268 (QBG)*, *ibid.*, 17 Feb. 1992, *Pooma*

649 (**BKF, CMUB**); Mae Sai, 16 Feb. 1993, *Banziger 1079 (CMUB, L)*]; Tak [Doi Hua Mot, 22 Dec. 1993, *Herb. trip. 778 (BCU)*, *ibid.*, 14 Dec. 2003, *Mattapha 508 (KKU)*, *ibid.*, 14 Jan. 2004, *Mattapha 573 (KKU)*, *ibid.*, 11 Feb. 1987, *Paisooksantivatana y2049-87 (BK)*, *ibid.*, 23 Jan. 2017, *Satthaphorn 78 (PSU)*]; Keng Sroi, 20 Nov. 1920, *Kerr 4635 (BK, K)*].

Distribution.— Myanmar, China, Laos.

Ecology.— In open, or on partly shaded rugged limestone, or deciduous forest, alt. 800–2250 m. Flowering: December to March. Fruiting: January to April.

Vernacular.— Thua Khao Hin Pun (ถั่วขาหินปูน).

Note.— *Campylotropis decora* is distinguished by having densely patent hairs mixed with glandular hairs throughout the peduncle and ovate-triangular overlapping calyx lobes which are distinctly longer than the calyx tube. From a field survey, specimens at Doi Chiang Dao, Chiang Mai province, have thicker leaflets than other collections.

4. ***Campylotropis harmsii*** Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 11: 342. 1912; P.Y. Fu, Bull. Bot. Res., Harbin 7(4): 28. 1987; P.Y. Fu, Fl. Reipubl. Popularis Sin. 41: 97. 1995; Iokawa & H. Ohashi, J. Jap. Bot. 77(5): 255. 2002; X. F. Gao, Inst. Bot. Kunming. Acad. Sin., Fl. Yunnan. 10: 556. 2006; Iokawa & H. Ohashi, J. Jap. Bot. 83(1): 44. 2008; P. Huang *et al.* in Z.Y. Wu *et al.*, Fl. China 10: 296. 2010.— *Lespedeza harmsii* (Schindl.) H. Lév., Cat. Pl. Yun-Nan: 158. 1916; Craib, Fl. Siam. 1(3): 433. 1928. Type: China, Yunnan, Szemao, *Henry 9803D* (lectotype **K** 000894861! designated by Iokawa & Ohashi (2008); isolectotype **E** 00025802!). Figs. 2.12B & 2.19–2.20.

Shrub 0.5–4 m tall. *Stems* terete, shortly zigzag lateral branches, blackish-brown, patent-hairy. *Leaves*: petioles 4–14 mm long, densely appressed-hairy; rachis 1–9 mm long; stipules ovate-triangular, 4–7 by 1–2 mm, outside appressed-hairy; leaflets transversely elliptic, chartaceous; terminal leaflets 0.8–3.5 by 0.5–2 cm, lateral leaflets 0.6–2.8 by 0.4–1.5 cm, apex acute and mucronate, base cuneate, margins entire;

upper surface dark green, pilose; lower surface light green, densely pilose, midrib and lateral vein 5–8 pairs; petiolules 1.2–1.7 mm long, densely appressed-hairy. *Inflorescences* axillary raceme, 2–8 cm long, laxly flowered; peduncles 3–9 mm long, densely patent-hairy and sparsely glandular-hairy; bracts ovate triangular, 1–2.2 mm by 0.3–1 mm, patent-hairy; bracteoles ovate-triangular, 1–1.2 mm by 0.2–0.3 mm, appressed-hairy; pedicels 4–13 mm long, densely patent-hairy. *Calyx* reddish-brown, densely patent-hairy; tube 2–3 mm long; dorsal lobe triangular, 3–3.5 by 3–4 mm; lateral lobes triangular, 4–4.2 by 1.2–1.5 mm; lowest lobe narrow triangular, 4.5–5 by 1–1.2 mm. *Corolla* pinkish-purple to white; standard elliptic-oblong, 10–11 by 7–7.5 mm, apex acute, claw 1.2–2 mm long, auricle 0.2–0.3 mm long, inflexed; wings oblong, 10–11 by 5–5.5 mm, apex rounded, slightly upward, claw 2–2.5 mm long, auricle 0.5–1 mm long; keel 9–10 by 2.8–3 mm, claw 2.5–3.5 mm long, auricle 0.3–0.5 mm long. *Stamens* 9.5–13 mm long, staminal tubes 7–11 mm long, free part of filaments 2–3 mm long; anthers oblong, 0.2–0.5 by 0.1–0.3 mm. *Pistils* 11–14 mm long; styles 7–10 mm long, pilose. *Pods* ovate-oblong, 8–20 by 2.3–6 mm, brown, densely pilose, apex acuminate; fruiting stalks 7–13 mm. *Seeds* reniform, 4.5–8 by 3–3.5 mm, brown.

Thailand.— NORTHERN: Chiang Mai [Doi Chiang Dao, 4 Dec. 2012, Chamchamroon *et al.* V.C. 1685 (BKF), *ibid.*, 7 Jan. 1975, Geesink *et al.* 8137 (BKF, C, K, L, P), *ibid.*, 6 Nov. 1922, Kerr 6592 (BK, K), *ibid.*, 1 Dec. 1984, Koyama *et al.* T-39775, *ibid.*, 28 Nov. 2005, Norsaengsri 274 (QBG), *ibid.*, 30 Nov. 2005, Norsaengsri 277 (QBG), *ibid.*, 19 Dec. 2014, Saisorn 347 (KKU), *ibid.*, 14 Jan. 2018, Sathaphorn & Leeratiwong 88 (PSU), *ibid.*, 30 Nov. 2005, Sawai 985 (KKU)]; Nan [Doi Phu Ka, 27 Feb. 1921, Kerr 4960 (BK, K)].

Distribution.— China.

Ecology.— In open, limestone ridge, evergreen forest, alt. 1200–2250 m. Flowering: December to January. Fruiting: December to January.

Vernacular.— Thua Khao Bai Khon (ถั่วขาวใบขน).

Note.— *Campylotropis harmsii* is different from other Thai *Campylotropis* species by having shortly zigzag lateral branches and pilose hairs on both surfaces of leaflets.

5. **Campylotropis parviflora** (Kurz) Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 11: 342. 1912; C.Y. Wu *et al.*, Index Fl. Yunnan. 1: 575. 1984; P.Y. Fu, Bull. Bot. Res., Harbin 7(4): 50. 1987; Thuân in Thuân *et al.*, Fl. Cambodge, Laos & Vietnam 23: 146. 1987; P.Y. Fu, Fl. Reipubl. Popularis Sin. 41: 123. 1995; X.F. Gao, Inst. Bot. Kunming. Acad. Sin., Fl. Yunnan. 10: 558. 2006.— *Lespedeza parviflora* Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 42: 231. 1873; Forest Fl. Burma 1: 380. 1877; Collett & Hemsl., J. Linn. Soc., Bot. 28: 45. 1891; Prain in King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 66: 377. 1897; H. Lév., Cat. Pl. Yun-Nan: 158. 1916; Gagnep. in Lecomte & Gagnep., Fl. Indo-Chine 2: 522. 1920; Craib, Fl. Siam. 1(3): 433. 1928.— *Campylotropis cytisoides* Miq. f. *parviflora* (Kurz) Iokawa & H. Ohashi, J. Jap. Bot. 77(4): 212. 2002; Iokawa & H. Ohashi, J. Jap. Bot. 83(1): 44. 2008, **syn. nov.** Type: Myanmar, Martaban, *Mason 34* (holotype CAL 0000012096!). Figs. 2.12C & 2.21–2.22.

Shrub or shrublet 0.3–2 m tall. *Stems* erect, polygonal, brown to dark brown, appressed-hairy. *Leaves*: petioles 0.4–5.5 cm long, sparsely appressed-hairy; rachis 1–10 mm long; stipules triangular-linear, 5–10 by 0.5–1 mm, outside appressed-hairy; leaflets narrowly ovate to elliptic, subcoriaceous; terminal leaflets 1.3–5 by 0.5–1.6 cm, lateral leaflets 0.9–3.8 by 0.3–1.6 cm, apex acute or rounded and mucronate, base rounded or cuneate, margins entire; upper surface dark green, glabrous or slightly appressed-hairy mainly on midrib; lower surface pale green to grey, shortly appressed-hairy; lateral veins 7–12 pairs; petiolules 1.5–2 mm long, densely appressed-hairy. *Inflorescences* axillary raceme or terminal panicle, 8.5–11 cm long, densely flowered; peduncles 5.2–6 cm long, densely patent-hairy and sparsely glandular-hairy; bracts triangular, 1–1.2 by 0.2–0.3 mm, appressed-hairy, reddish-brown, usually caducous; bracteoles setaceous, 0.5–1 mm long, densely appressed-hairy; pedicels 1.5–4 mm long, appressed-hairy and sparsely glandular-hairy. *Calyx* green, densely appressed-hairy; tube 1–2 mm long; dorsal lobe narrowly triangular to setaceous, 1.5–2 by 0.5–0.6 mm, with or without 2 teeth; lateral lobes narrowly triangular to setaceous 1.5–1.8 by 0.3–0.4 mm; lowest lobe narrowly triangular to setaceous, 1.5–2 by 0.5–0.6 mm. *Corolla* pinkish-white to creamy-white with green blotches on both surface of standard; standard elliptic-oblong, 5.5–6 by 2.5–3 mm, apex acute, claw 1–1.2 mm long, auricle absent; wings oblong, 5–6 by 2–2.2 mm, apex rounded, slightly upward, claw 1.4–1.5

mm, auricle 0.5–0.6 mm long; keel 5.5–6 by 1.4–1.5 mm, claw 1–1.2 mm long, auricle 0.3–0.5 mm long. *Stamens* 6–7 mm long, staminal tubes 4.5–5 mm long, free part of filaments 2–3 mm long; anthers oblong, 0.4–0.5 by 0.3–0.4 mm. *Pistils* 6–7 mm long; styles 4–5 mm long, appressed-hairy at base. *Pods* obliquely obovate, 6.5–9 by 4–5 mm, dark brown, arranging mainly one side of rachis, apex acuminate, patent-hairy; fruiting stalks 3–5 mm. *Seeds* reniform, 2–4.5 by 1.5–2.5 mm, brown.

Thailand.— NORTHERN: Mae Hong Son [Ban Huai Hee, 1 May 2014, *Norsaengsri 11116 (QBG)*; Doi Pui, 16 Dec. 2007, *Tanaka et al. HN8480 (QBG)*; Kiew Lom, 12 Dec. 2007, *Tanaka et al. HN8196 (QBG)*; Mae Sariang, 8 Jul. 1968, *Larsen et al. 2237 (K)*; Mountain pass between Pai and Pang Mapha along road no. 1095, 13 Dec. 1998, *Konta et al. 4470 (BKF)*; Muang Sroi Waterfall, 17 Jan. 1983, *Koyama et al. T-32675 (QBG)*, *ibid.*, 8 Feb. 2013, *Norsaengsri 10245 (QBG)*]; Chiang Mai [12 Nov. 1911, *Kerr 1587B (E, P)*; Ban Au Tam, 21 Jan. 2015, *Pongkamornkul 4552 (QBG)*; Ban Gong Por Nue, 26 Jan. 2016, *Pongkamornkul 5590 (QBG)*, 27 Jan. 2016, *Pongkamornkul 5649 (QBG)*; Ban Huay Bon, 13 Jan. 1988, *Paisooksantivatana et al. y 2217-88 (BK)*; Ban Mae Sa Ngim, 17 Nov. 2015, *Pongkamornkul 5155 (QBG)*; Ban Pak Tang Muzer, 28 Mar. 2015, *Pongkamornkul 4628 (QBG)*; Ban Pong Khrai, 9 Feb. 2006, *Glamwaewwong 2253 (QBG)*; Doi Ang Khang, 30 Jan. 1999, *Larsen & Larsen KL47264 (AAU)*; Doi Chiang Dao, 20 Nov. 1990, *Banziger 768 (CMU)*, *ibid.*, 27 Feb. 2003, *Chamchumroon & Sup V.C.1944 (BKF)*, *ibid.*, 19 Jan. 1991, *Maxwell 91-80 (CMU, L)*, *ibid.*, 27 Jan. 1996, *Maxwell 96-111 (BKF, CMUB)*, *ibid.*, 29 Dec. 1955, *Pleunchit 1046 (BKF)*, *ibid.*, 19 Dec. 1931, *Put 4398 (BCU, K)*, *ibid.*, 14 Jan. 2018, *Satthaphorn & Leeratiwong 86 (PSU)*, *ibid.*, 15 Jan. 2018, *Satthaphorn & Leeratiwong 92 (PSU)*; Doi Inthanon National Park, 11 Jan. 1994, *Fukuoka & Koyama T-62083 (BKF)*, *ibid.*, 3 Jan. 1975, *Geesink et al. 8049 (K, L)*, *ibid.*, 6 Feb. 1998, *Konta & Phengklai 4033 (BKF)*, *ibid.*, 17 Dec. 1998, *Konta et al. 4651 (BKF)*, *ibid.*, 3 Jan. 1975, *Koyama et al. T-39663 (BKF)*, *ibid.*, Nov. 1968, *Phengklai & Smitinand 6047 (BKF)*, *ibid.*, 26 Jul. 1988, *Phengklai et al. 6981 (BKF)*, *ibid.*, 17 Dec. 1965, *Takawa et al. T2463 (BKF, P)*, *ibid.*, 15 Apr. 1970, *Worawoat 93 (BKF)*; Doi Pha Hom Pok, 25 Feb. 1958, *Sørensen et al. 1630 (C)*; Doi Pui, 8 Jan. 1969, *Nooteboom 636 (BKF, K, L)*, *ibid.*, 11 Jan. 1979, *Paisooksantiwatana 94-79 (BK, CMUB)*, *ibid.*, 2 Mar. 1974,

Sadakorn 314 (BK), *ibid.*, 13 Jan. 2018, *Satthaphorn & Leeratiwong 85 (PSU)*; Doi Sutep, 5 Mar. 1966, *Chermsirivathana 457 (BK)*, *ibid.*, 10 Feb. 1926, *Collins 1223 (BK, K, US)*, *ibid.*, 1 Jan. 1905, *Hosseus 202 (C, E, K, L, P)*, *ibid.*, 25 Jan. 1910, *Kerr 951 (K, L, P)*, *ibid.*, 12 Nov. 1911, *Kerr 1507 (K)*, *ibid.*, 22 Dec. 1920, *Kerr s.n. (BK, P)*, *ibid.*, 26 Dec. 1987, *Maxwell 87-1643 (CMU, L)*, *ibid.*, 10 Mar. 1988, *Maxwell 88-321 (BKF, CMU, L)*, *ibid.*, 10 Jan. 1969, *Nooteboom 710 (L)*, *ibid.*, *Schultze & Pattanavibul 053/037-05 (WAG)*, *ibid.*, 5 Mar. 1966, *Sukku 70 (BKF)*, *ibid.*, 8 Feb. 1958, *Sørensen et al. 876 (C, E)*, *ibid.*, 15 Apr. 1958, *Sørensen et al. 2762 (C, L)*, *ibid.*, 16 Apr. 1958, *Sørensen et al. 2775 (C)*, *ibid.*, 19 Jan. 1967, *Umpai 349 (BK)*; Doi Kio Lom, 18 Jan. 2002, *Chayamarit et al. 3140 (BKF)*; Doi Sahng Liang, 16 Dec. 1997, *Maxwell 97-1494 (BKF, CMUB)*; Huay Mae Mae, 24 Jan. 1996, *Na Nakorn et al. 5657 (QBG)*; Khun Wang Highland, 11 Jan. 1986, *Paisooksirivathana y1746-86 (BK)*; Mae Cheam, 7 Dec. 1998, *Maxwell 98-1438 (CMUB, L)*; Mae Dad Noi, 25 Jan. 2010, *Norsaengsri & Intamusik 6345 (QBG)*; Mae Rim, 19 Dec. 2000, *Glamwaewwong 25 (QBG)*, *ibid.*, 18 Dec. 2001, *Glamwaewwong 121 (QBG)*, *ibid.*, 8 Jan. 1983, *Koyama et al. T-32097 (BKF)*, *ibid.*, 9 Jan. 1990, *Maxwell 90-47 (CMU, E)*, *ibid.*, 18 Jan. 1994, *Na Nakorn et al. 406 (QBG)*, *ibid.*, 21 Dec. 1995, *Na Nakorn et al. 5511 (QBG)*, *ibid.*, 20 Jan. 1996, *Na Nakorn et al. 5559 (QBG)*, *ibid.*, Jan. 1992, *Phengkklai et al. 9007 (BKF)*, *ibid.*, 21 Dec. 1978, *Pradit & Munpanid 539 (AAU)*, *ibid.*, 22 Mar. 2017, *Satthaphorn 79 (PSU)*; *ibid.*, 26 Nov. 1951, *Smitinand 150 (BKF, P)*, *ibid.*, 1 Jan. 1998, *Srisanga & Puff 6 (QBG)*, *ibid.*, 19 Jan. 2015, *Sudjit et al. 3 (QBG)*; Mae Sae, 27 Jan. 1977, *S.N. (BKF)*; Mae Sanam, 26 Dec. 1978, *Niyomdham et al. 143 (BKF, K, L)*; Mae Soi Valley, 4 Jan. 1991, *Maxwell 91-22 (CMU, L)*; Mae Taeng, 3 Dec. 1977, *Santisuk 1448 (C, K)*; Mae Taman Reforest Unit, 28 Nov. 1984, *Koyama et al. T-39663 (BKF)*; Mae Wang, 18 Dec. 1998, *Konta et al. 4715 (BKF)*, *ibid.*, 20 Feb. 2004, *Maxwell 04-91 (CMUB, L)*; Mae Ya Mae Kang, 29 Dec. 1913, *Garret 103 (BK, C, E, K, L, P)*; Mai Muang Nao Arboretum, 25 Dec. 2001, *Sankamethawee 384 (BKF, CMUB, L)*; Om Koi, 30 Nov. 2013, *Pongkamornkul 3791 (QBG)*, *ibid.*, 12 Jan. 1988, *Santisuk 6664 (BKF)*; Pake Same Village, 28 Dec. 2000, *Pongkamornkul 587 (QBG)*; Pha Dok Siao Waterfall, 25 Dec. 2015, *Pisuttimarn 413-1 (KKU)*; Chiang Rai [Doi Luang National Park, 28 Oct. 1997, *Maxwell 97-1252 (CMUB, L)*; Khun Jae National

Park, 1 Jan. 1998, *Maxwell* 98-12 (**BKF, CMUB, L**); Khun Korn Waterfall, 12 Jan. 1997, *KK* 26 (**BCU**); Mae Fah Luang, 1 Feb. 2006, *Maxwell* 06-95 (**CMUB, L**); Mae Tameo Village, 2 Mar. 1989, *Bragg* 63 (**CMU**); Lumphun [Doi Khun Tan National Park, 27 Dec. 1993, *Maxwell* 93-1564 (**CMUB, L**)]; Lampang [Jae Sawn National Park, 3 Dec. 1995, *Maxwell* 95-1256 (**BKF, CMUB, L**)]; Tak [Mae Ra Mard, 24 Dec. 2002, *Niyomdham & Puudjaa* 7062 (**BKF**); Thung Yai Naresuan East Wildlife Sanctuary, 22 Dec. 2011, *Watthana & La-onsri* 4095 (**BKF**)]; NORTH-EASTERN: Phetchabun [Nam Nao National Park, 25 Dec. 1982, *Koyama et al.* T-31666 (**BKF**), *ibid.*, *Sawai* 446 (**KKU**)]; Loei [Na Haew, Nhu Tong Kao, 25 Apr. 1994, *BGO staff s.n.* (**QBG**); Phu Kradueng, 21 Mar. 1958, *Sørensen et al.* 2383 (**C, BKF**); Phu Suan Sai, 10 Dec. 1996, *BGO Staff* 74 (**QBG**); Phu Ruea National Park, 5 Dec. 2004, *Sawai & Rob* 832 (**KKU**)]; EASTERN: Chaiyaphum [Between Nam Phrom and Tunkamang, 13 Dec. 1971, *Beusekom et al.* 4208 (**BKF, C, K, L, P**); Khonsarn, Dec. 1994, *Wangwasit* 64 (**BK**), *ibid.*, Dec. 1994, *Wangwasit* 65 (**BK**); Phu Khiao, 8 Nov. 1984, *Murata et al.* T-50138 (**BKF**)]; SOUTH-WESTERN: Kanchanaburi [Ban Piloc, 19 Feb. 1967, *Chermsirivathana* 640 (**BK**), *ibid.*, 10 Dec. 1969, *Chermsirivathana* 1687 (**BK**); Huay Ban Kau, 11 Nov. 1971, *Beusekom et al.* 3670 (**BKF, K, L**)].

Distribution.— Myanmar, China, Laos, Vietnam.

Ecology.— In open, partly shaded areas in dry evergreen forest, alt. 600–1800 m. Flowering: November to March. Fruiting: November to March.

Vernacular.— Lueat Nai (เลื้อยไน), Hing Men (หิ้งมัน).

Note.— In this study, *Campylotropis cytisoides* f. *parviflora* is reinstated to species level, *C. parviflora*. The taxon *C. cytisoides* f. *parviflora* was established by Iokawa and Ohashi (2002a) apart from the typical forma by the density of glandular hairs, the length of leaflets, the texture of leaflets and the length of inflorescences. From specimen investigations, both holotypic specimens have been found having more different characters. *Campylotropis cytisoides* f. *parviflora* also differs from the typical forma by having pinkish-white to creamy-white corolla (vs. purplish-blue), 1–2 mm long calyx tube (vs. 2–3 mm), 5.5–6 mm long standard (vs. 7.5–9 mm), and sparsely short appressed-hairy on lower surface of leaflets (vs. densely long appressed-hairy).

Because of having many different characters, therefore, the taxon is raised, *C. cytisoides* f. *parviflora* to be *C. parviflora*.

6. **Campylotropis pinetorum** (Kurz) Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 11: 429. 1912; Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 20: 285. 1924; Thuân in Thuân *et al.*, Fl. Cambodge, Laos & Vietnam 23: 147. 1987; Iokawa & H. Ohashi, J. Jap. Bot. 77(5): 277. 2002; X.F. Gao, Inst. Bot. Kunming. Acad. Sin., Fl. Yunnan. 10: 555. 2006; P. Huang *et al.* in Z.Y. Wu *et al.*, Fl. China 10: 298. 2010.— *Lespedeza pinetorum* Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 42: 230. 1873; Forest Fl. Burma 1: 381. 1877; Prain in King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 66: 375. 1897; Gagnep. in Lecomte & Gagnep., Fl. Indo-Chine 2: 524. 1920; Craib, Fl. Siam. 1(3): 433. 1928. Type: Myanmar, Martaban, *Kurz 1637* (holotype CAL 0000012101!). Figs. 2.12D & 2.23–2.24.

Shrub 0.4–1.5 m tall. *Stems* erect, polygonal, brown, densely yellowish-velutinous. *Leaves*: petioles 1.8–2.8 cm long, velutinous; rachis 3–6 mm long or indistinct; stipules triangular, 7–9 by 2.5–4 mm, outside velutinous, persistent; leaflets narrowly elliptic, subcoriaceous; terminal leaflets 5.5–9 by 1.4–4.6 cm, lateral leaflets 4.8–7.7 by 1.3–3.3 cm, apex acute, base cuneate, margins entire; upper surface light green, finely appressed-hairy, especially on veins; lower surface pale green, densely ascending velutinous, mature leaflets with scattered black spots; lateral veins 7–12 pairs; petiolules 1.5–2 mm long, velutinous. *Inflorescences* axillary raceme, 3–6 cm long, densely flowered; peduncles 0.5–1.5 cm long, velutinous and sparsely glandular-hairy; bracts triangular, 5–8 by 2–3 mm, patent-hairy; bracteoles setaceous, ca 1 mm long, patent-hairy, early caducous; pedicels 1.5–2 mm long, patent-hairy. *Calyx* reddish-brown, patent-hairy; tube 2–2.5 mm long; dorsal lobes triangular, 2.5–3 by 1.8–2 mm, with or without 2 long teeth, lateral lobes triangular, 2.5–3 by 1–1.1 mm, lowest lobe narrowly triangular, 2.8–3 by 0.7–1 mm. *Corolla* pinkish-white to creamy-white; standard obovate-oblong, 7.5–8 by 6–7 mm, apex rounded, claw 1.5–2 mm long, auricle absent; wings spathulate, 5.3–5.5 by 2.5–3.2 mm, apex rounded, claw 2.5–2.7 mm long, auricle 0.8–1 mm long; keel 6–6.5 by 2.5–3 mm, claw 2.8–3 mm long, auricle 0.3–0.5

mm long. *Stamens* 8–8.5 mm long, staminal tubes 4–6 mm long, free part of filaments 2–2.5 mm long; anthers oblong, 0.3–0.4 by 0.1–0.2 mm. *Pistils* 8.5–9 mm long; styles 6.5–7 mm long, densely patent-hairy. *Pods* obliquely ovate, 5–6 by 2.5–3 mm, brown, apex rounded and mucronate, densely patent-hairy; fruiting stalks 2–3 mm long. *Seeds* reniform or oblong, swollen, 2.6–2.8 by 1.3–1.5 mm, reddish-brown.

Thailand.—NORTHERN: Chiang Mai [Doi Ang Khang, 2 Feb. 2007, *Srisanga et al.* 2956 (**CMUB, QBG**); Doi Inthanon National Park, 14 Feb. 2001, *Chayamarit et al.* 2397 (**BKF**), *ibid.*, 12 Feb. 1998, *Konta et al.* 4245 (**BKF**), *ibid.*, 18 Feb. 1998, *Konta et al.* 4371 (**BKF**), *ibid.*, 20 Dec. 1998, *Konta et al.* 4915 (**BKF**), *ibid.*, 31 Dec. 1989, *Maxwell* 89-1614 (**CMU, L**), *ibid.*, 18 Feb. 1998, *Niyondham* 5322 (**BKF**), *ibid.*, 11 Feb. 1998, *Phengkklai et al.* 11002 (**BKF**), *ibid.*, 16 Mar. 2004, *Pornpongrungrueng* 459 (**KKU**), *ibid.*, 13 Jan. 2018, *Satthaphorn & Leeratiwong* 84 (**PSU**), *ibid.*, 7 Jan. 1998, *Srisanga et al.* 94 (**AAU, BKF, QBG**); Doi Mon Chong, 1 Jan. 1997, *BGO Staff* 8346 (**QBG**); Doi Pui, Mar. 1997, *Chayamarit & Phathanacharoen* 701 (**BKF**), *ibid.*, Mar. 1997, *Chayamarit & Phathanacharoen* 669 (**BKF**), *ibid.*, 8 Feb. 1979, *Pradit* 681 (**C**), *ibid.*, 24 Feb. 1975, *Sadakorn* 513 (**BK**), *ibid.*, 5 Feb. 2015, *Srisanga et al.* 3870 (**QBG**); Doi Sutep, *Cockerell s.n.* (**US**), *ibid.*, 8 Jan. 1911, *Kerr* 1645 (**BK, C, K, L, P**), *ibid.*, 23 Jan. 1988, *Maxwell* 88-67 (**AAU, BKF, CMU, L**), *ibid.*, 10 Jan. 1969, *Nooteboom* 711 (**BKF, C, K, L**), *ibid.*, 9 Feb. 1958, *Sørensen et al.* 891 (**C, BKF**), *ibid.*, 8 Jan. 1959, *Sørensen et al.* 6589 (**C, E**), *ibid.*, 19 Jan. 1967, *Umpai* 361 (**BK**); Kawng Sang, 22 Jan. 1964, *Hansen et al.* 10877 (**C, K, L**); Chiang Rai [Doi Chang, 17 Feb 1968, *Hansen & Smitinand* 12620 (**AAU, BKF, C, E, K, L, P**)]; Phayao [Doi Luang National Park, 10 Feb. 2016, *Muangyen* 702 (**QBG**)]; Nan [Khun Sathan National Park, 27 Jan. 2013, *Norsaeangsri* 10110 (**QBG**)]; Uttaradit [Phu Miang-Phu Thong Wildlife Sanctuary, 27 Jan. 2011, *Rom Klao Botanical Garden* 0159/2554 (**QBG**); Phu Soi Dao National Park, 8 Feb. 2010, *Norsaeangsri* 6482 (**QBG**)]; Phitsanulok [Phu Soi Dao National Park, 9 Feb. 2000, *Suksathan* 2313 (**QBG**)]; Kamphaeng Phet [Mae Wong National Park, 3 Jan. 1999, *Bult* 207 (**BKF, QBG**)]; NORTH-EASTERN: Loei [Phu Kradueng National Park, 10 Jan. 1960, *Abbe & Smitinand* 9427 (**BKF**), *ibid.*, 10 Feb. 1931, *Kerr* 20063 (**K, L**); Phu Luang Wildlife

Sanctuary, 27 Nov. 1987, *Dee 995* (BKF); Phu Ruea National Park, 16 Jan. 1967, *Smitinand 10153* (BKF), *ibid.*, 13 Dec. 1966, *Umpai 333* (BK)].

Distribution.— Myanmar, Laos, Vietnam.

Ecology.— In open, grassy areas, hill evergreen forest, lower montane forest, alt. 1000–2250 m. Flowering: November to March. Fruiting: January to March.

Vernacular.— Thua Khao (ถั่วเขา), Thua Doi (ถั่วดอย), Thua Pa (ถั่วป่า), Ka Sam Peak (กาสามปีก).

Note.— *Campylotropis pinetorum* resembles *C. parviflora* in having pinkish-white to creamy-white corolla. However, the former has black spots on the upper leaf surface, velutinous hairs on the lower leaf surface and pods less than or equal to 6 mm long, while the latter has no black spots on the upper leaf surface, appressed hairs on the lower leaf surface and pods more than 6 mm long.

7. ***Campylotropis sulcata*** Schindl. in Engl., Bot. Jahrb. Syst. 54 (1): 65. 1916; C.Y. Wu *et al.*, Index Fl. Yunnan. 1: 576. 1984; P.Y. Fu, Bull. Bot. Res., Harbin 7(4): 51. 1987; P.Y. Fu, Fl. Reipubl. Popularis Sin. 41: 126. 1995; Iokawa & H. Ohashi, J. Jap. Bot. 77(6): 326. 2002; X.F. Gao, Inst. Bot. Kunming. Acad. Sin., Fl. Yunnan. 10: 554. 2006; Iokawa & H. Ohashi, J. Jap. Bot. 83(1): 54. 2008; P. Huang *et al.* in Z.Y. Wu *et al.*, Fl. China 10: 300. 2010.— *Lespedeza sulcata* (Schindl.) Craib. Fl. Siam. 1(3): 434. 1928. Type: China, Yunnan, *Bon s.n.* (holotype P 03089818!).— *Campylotropis rockii* Schindl. in Fedde, Repert. Spec. Nov. Regni Veg. 22: 270. 1926; C.Y. Wu *et al.*, Index Fl. Yunnan. 1: 576. 1984; P.Y. Fu, Bull. Bot. Res., Harbin 7(4): 29. 1987; P.Y. Fu, Fl. Reipubl. Popularis Sin. 41: 100. 1995; X.F. Gao, Inst. Bot. Kunming. Acad. Sin., Fl. Yunnan. 10: 553. 2006. Type: China, Yunnan, Simao, Ganlanba as west of Mekong, Salween water divide, upper Kan-lan-chai, *Rock 7059* (holotype US, *n.v.*).— *Campylotropis purpurascens* Ricker in Rehder *et al.*, J. Wash. Acad. Sci. 36: 39. 1946. Type: China, Yunnan, Hila, Shunning, *Yü 17571* (holotype A, *n.v.*; isotypes E 00025717!, US 00288564!). Figs. 2.12D & 2.25–2.26.

Shrub 1–2 m tall. *Stems* erect, sulcate, dark brown, densely patent-hairy. *Leaves*: petioles 0.4–2.9 cm long, sulcate, densely sericeous; rachis 1–6 mm long; stipules triangular-linear, 8–10 by 0.6–1 mm, outside appressed-hairy, persistent; leaflets elliptic-oblong or obovate-elliptic, subcoriaceous; terminal leaflets 2–6.5 by 0.4–2.8 cm, lateral leaflets 1.5–4.5 by 0.3–2.3 cm, apex acute or retuse and mucronate, base cuneate, margins entire; upper surface dark green, appressed-hairy; lower surface light green, densely sericeous, midrib adaxially sunken, 7–12 pairs; petiolules 1–3 mm long, densely sericeous. *Inflorescences* axillary raceme or terminal panicle, 2.5–16 cm long, densely flowered; peduncles 1.2–2 cm long, densely patent-hairy and sparsely glandular-hairy; bracts triangular, 3.5–4.5 by 0.4–0.5 mm, appressed-hairy, reddish-brown usually caducous before anthesis; bracteoles triangular, 0.5–1 by 0.2–0.3 mm, appressed-hairy; pedicels 1–2 mm long, densely patent-hairy, young flowers subsessile. *Calyx* reddish-brown, appressed-hairy; tube 1.5–1.8 mm long; dorsal lobe triangular, 2.2–3 by 1.8–2 mm, with or without 2 teeth; lateral lobes triangular, 2–2.2 by 0.8–1 mm, lowest lobe triangular 2.2–3 by 0.7–1 mm. *Corolla* light to dark purple; standard elliptic, 8.5–11 by 5–6.5 mm, apex acute, claw 0.8–1 mm long, auricle absent; wings oblong, 8–9.5 by 3–4 mm, slightly falcate, apex rounded, claw 1.5–2 mm long, auricle 0.5–1 mm long; keel 9.5–11 by 2.5–3 mm, claw 1.5–2.5 mm long, auricle 0.5–1 mm long. *Stamens* 8–10 mm long, staminal tubes 6–8 mm long, free part of filaments 2.5–3 mm long, upward; anthers ovate-oblong, 0.3–0.4 by 0.2–0.3 mm. *Pistils* 8–12 mm long; styles 6.5–9.5 mm long, densely patent-hairy. *Pods* obliquely ovate, 4–7 by 2–4 mm, dark brown, apex acuminate, densely short patent-hairy, calyx and style persistent; fruiting stalks 1–5 mm long. *Seeds* reniform, 1.2–1.5 by 0.5–1 mm, blackish-brown.

Thailand.— NORTHERN: Mae Hong Son [Doi Laem Rang, 27 Dec. 2012, *Norsaengsri 10061 (QBG)*; Nong Khao Klang (Karen) Village, 29 Oct. 2007, *Maxwell 07-680 (QBG)*]; Chiang Mai [Doi Chiang Dao, 12 Nov. 2011, *Clark 235 (QBG)*, *ibid.*, 2 Nov. 1922, *Kerr 6509 (BK, E, K)*, *ibid.*, 4 Nov. 1995, *Maxwell 95-1067 (BKF, CMUB, L)*, *ibid.*, 27 Jan. 1996, *Maxwell 96-101 (BKF, CMUB, L)*, *ibid.*, 19 Dec. 2015, *Pisuttimarn 410-1 (KKU)*, *ibid.*, 17 Oct. 1994, *Pooma 873 (BKF, CMUB)*, *ibid.*, 11 Nov 2016, *Satthaphorn 75 (PSU)*, *ibid.*, 14 Jan. 2018, *Satthaphorn & Leeratiwong 87 (PSU)*, *ibid.*, 17 Dec. 2003, *Sawai 508 (KKU)*, *ibid.*, 11 Dec. 1987, *Smitinand s.n.*

(**BKF**), *ibid.*, 7 Nov. 1997, *Triboun 698* (**BK**); Chiang Rai [Khun Jae National Park, 23 Nov. 1997, *Maxwell 97-1416* (**BKF, CMUB, L**), *ibid.*, 1 Jan. 1998, *Maxwell 98-4* (**BKF, CMUB, L**)]; Phitsanulok [Phu Hin Rong Kla National Park, 1 Oct. 1990, *Chantaranonthai et al. 90/515* (**KKU**), *ibid.*, 9 Oct. 1987, *Sridith 53* (**BCU**), *ibid.*, 30 Oct. 1987, *Sridith 76* (**BCU**), *ibid.*, 29 Oct. 2001, *Watthana & Suksathan 1543* (**AAU, CMUB, QBG**)]; EASTERN: Chaiyaphum [Phu Khiao, 8 Nov. 1984, *Murata et al. T-41784* (**BKF**)].

Distribution.— China.

Ecology.— In open, rugged limestone, mixed deciduous forest, scrub forest, alt. 850–2000 m. Flowering and fruiting: October to January. Fruiting: October to January.

Vernacular.— Thua Doi Khon Yao (ถั่วคอกขนยาว).

Note.— *Campylotropis sulcata* is distinct in having sulcate stem, patent hairs on the peduncle and light to dark purple petals. Its vegetative characters may resemble *C. decora* in some aspects: obovate-elliptic leaflets and the peduncle with patent hairs, however it differs from the latter in having sericeous hairs on the lower surface of leaflets (vs. appressed hairs), without glandular hairs on the peduncle (vs. with patent hairs mixed with glandular hairs), bracts which are more than 2 mm long (vs. less than or equal to 2 mm long), and standard without auricles.

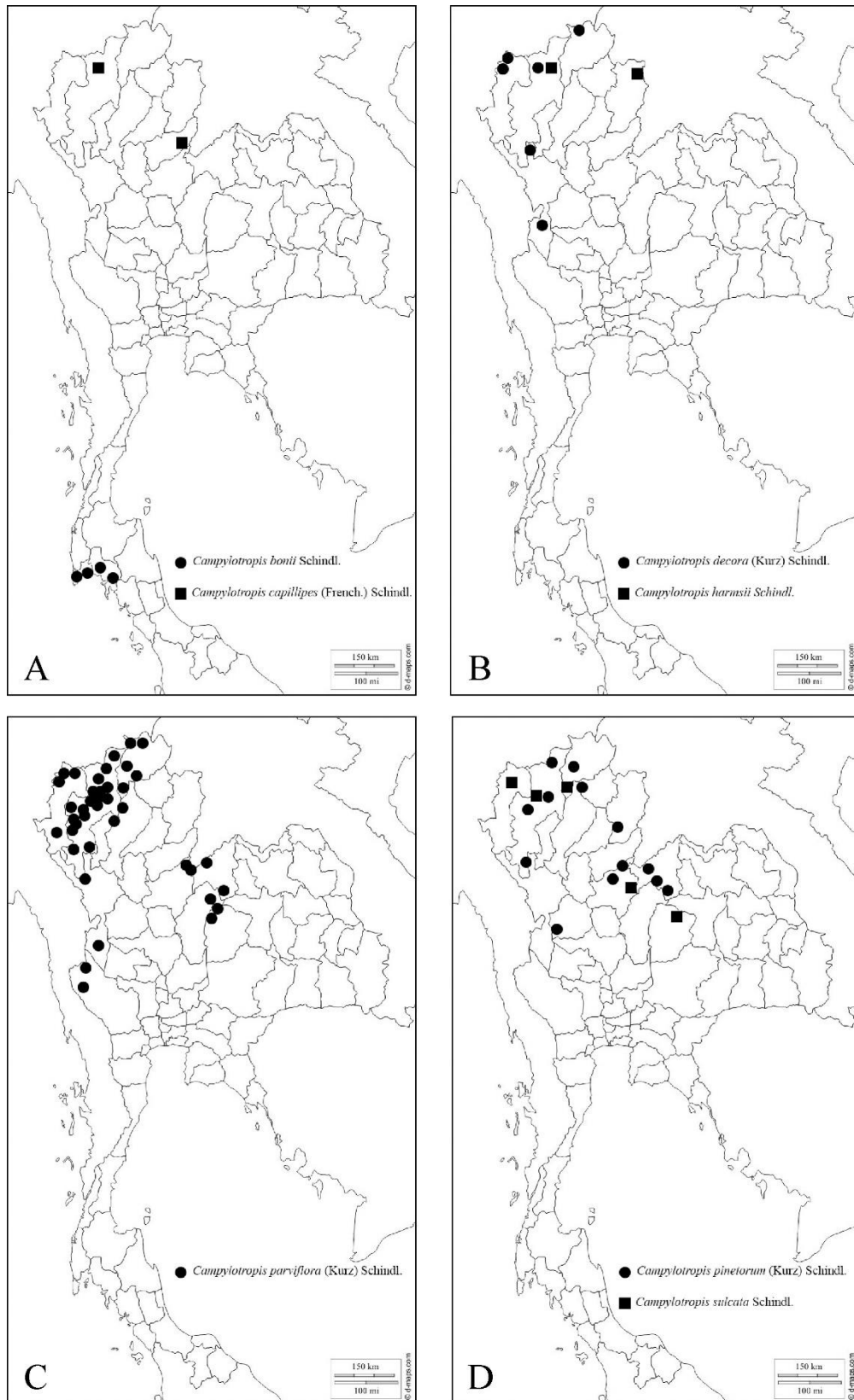


Figure 2.12 Distribution maps of *Campyloptropis* in Thailand.

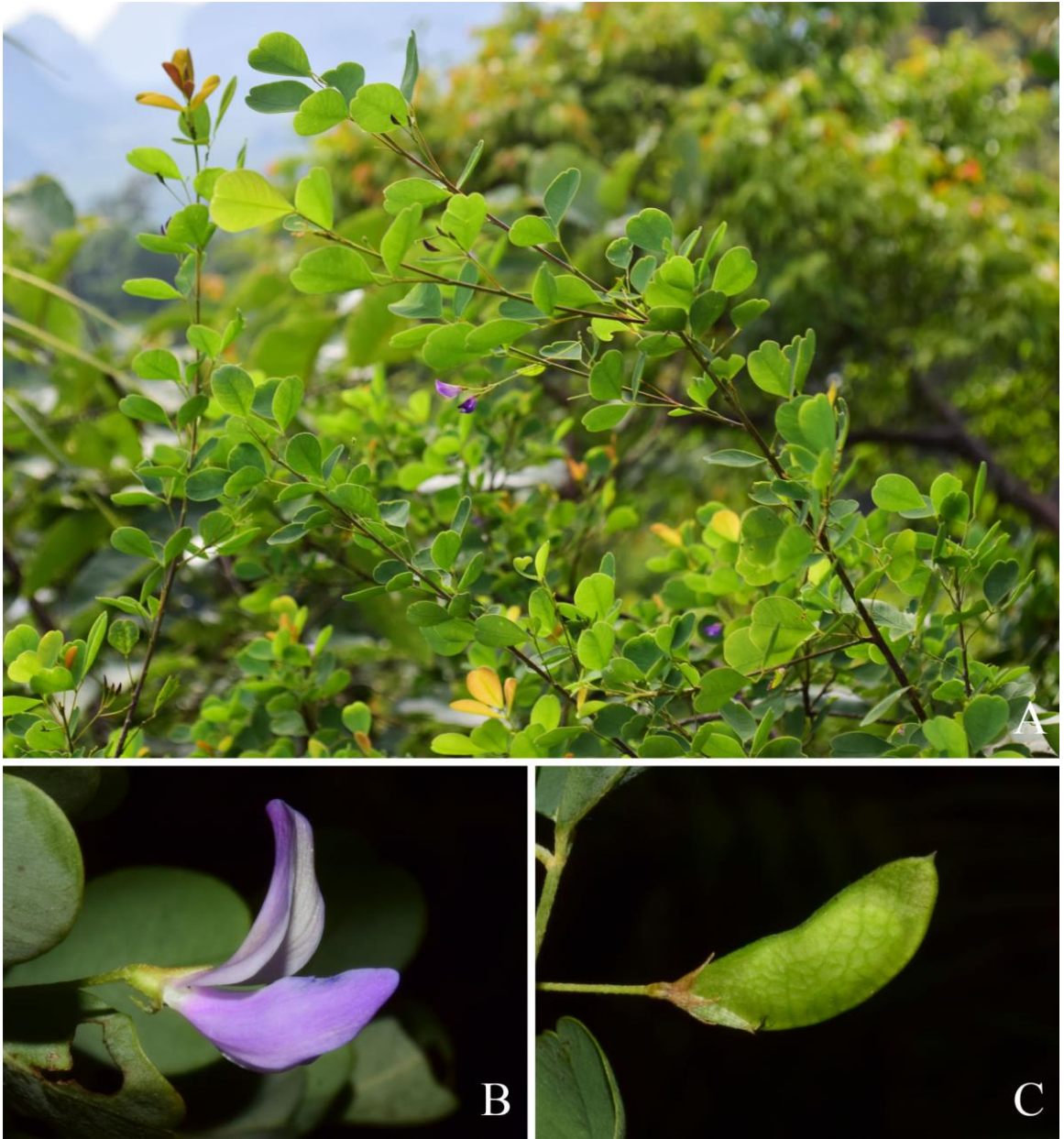


Figure 2.13 *Campylotropis bonii*. A: habit, B: flower, C: fruit.

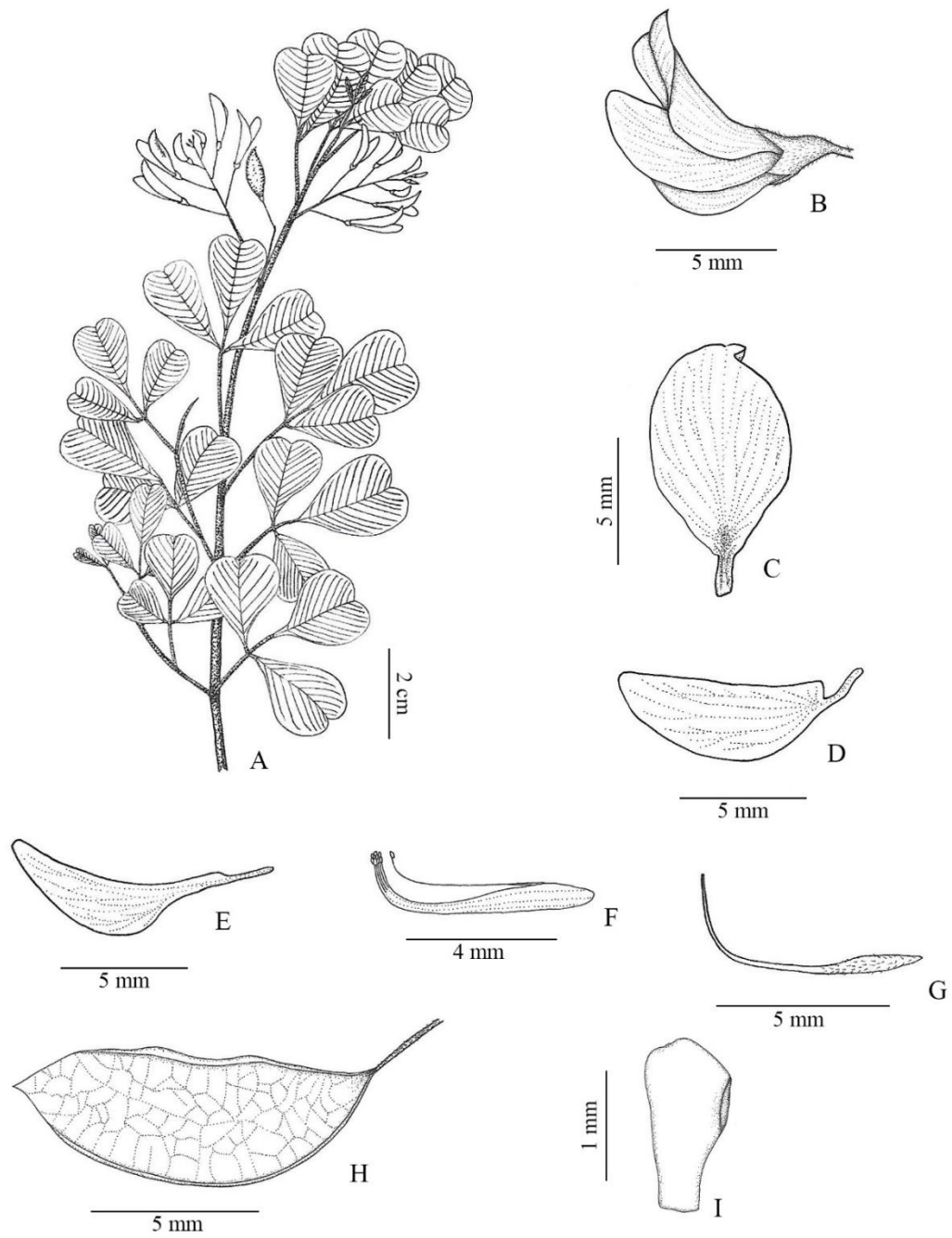


Figure 2.14 Drawing of *Campylotropis bonii*. A: flowering branch, B: flower, C: standard, D: wing, E: keel, F: stamen, G: pistil, H: pod, I: seed. All from *Sattaphorn & Leeratiwong 80* (PSU).



Figure 2.15 *Campylotropis capillipes* subsp. *prainii*. A: habit, B: flowers, C: fruits.

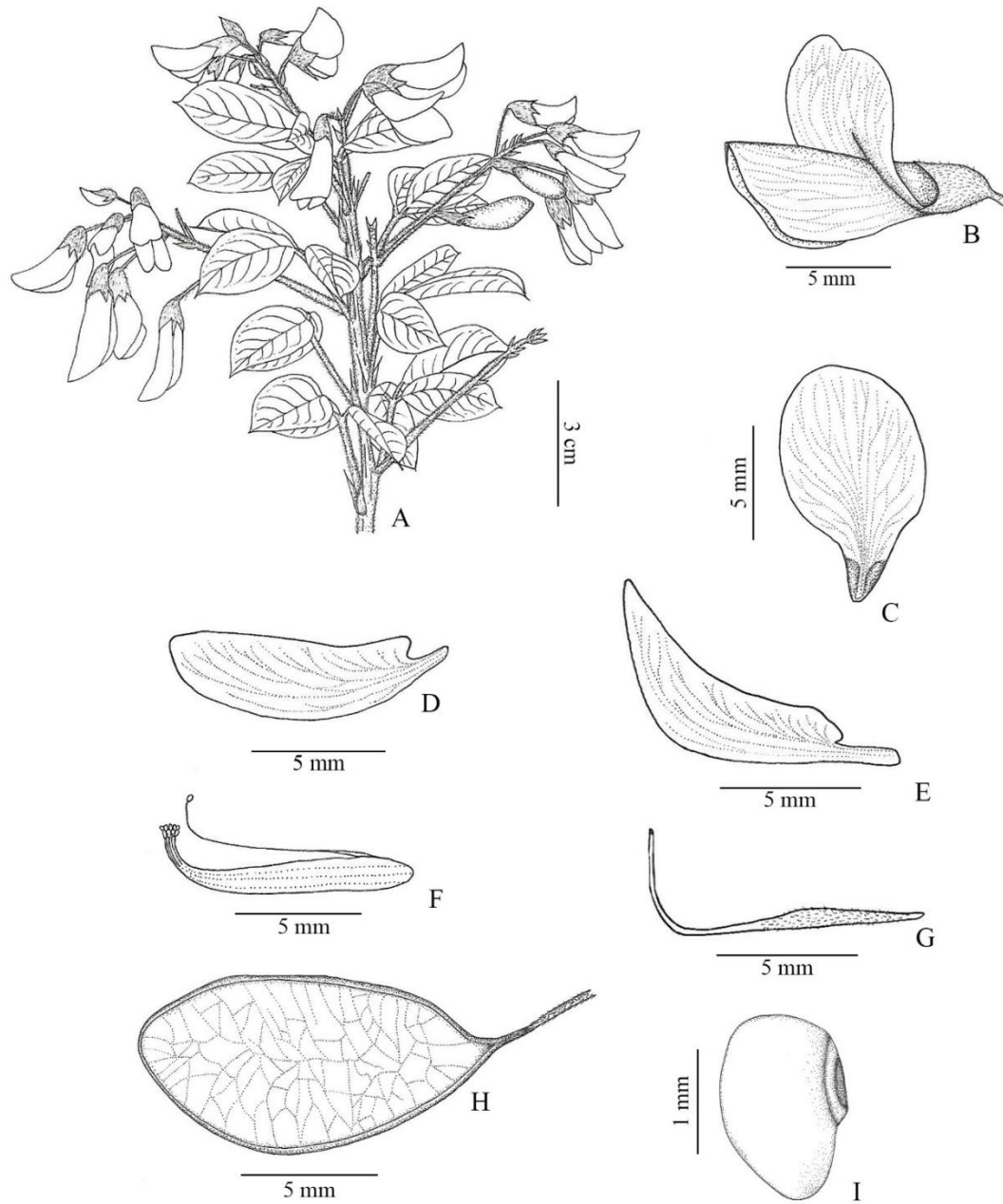


Figure 2.16 Drawing of *Campylotropis capillipes* subsp. *prainii*. A: flowering branch, B: flower, C: standard, D: wing, E: keel, F: stamen, G: pistil, H: pod, I: seed. All from *Sattthaphorn 82* (PSU).



Figure 2.17 *Campylotropis decora*. A: habit, B: flowers, C: fruits.

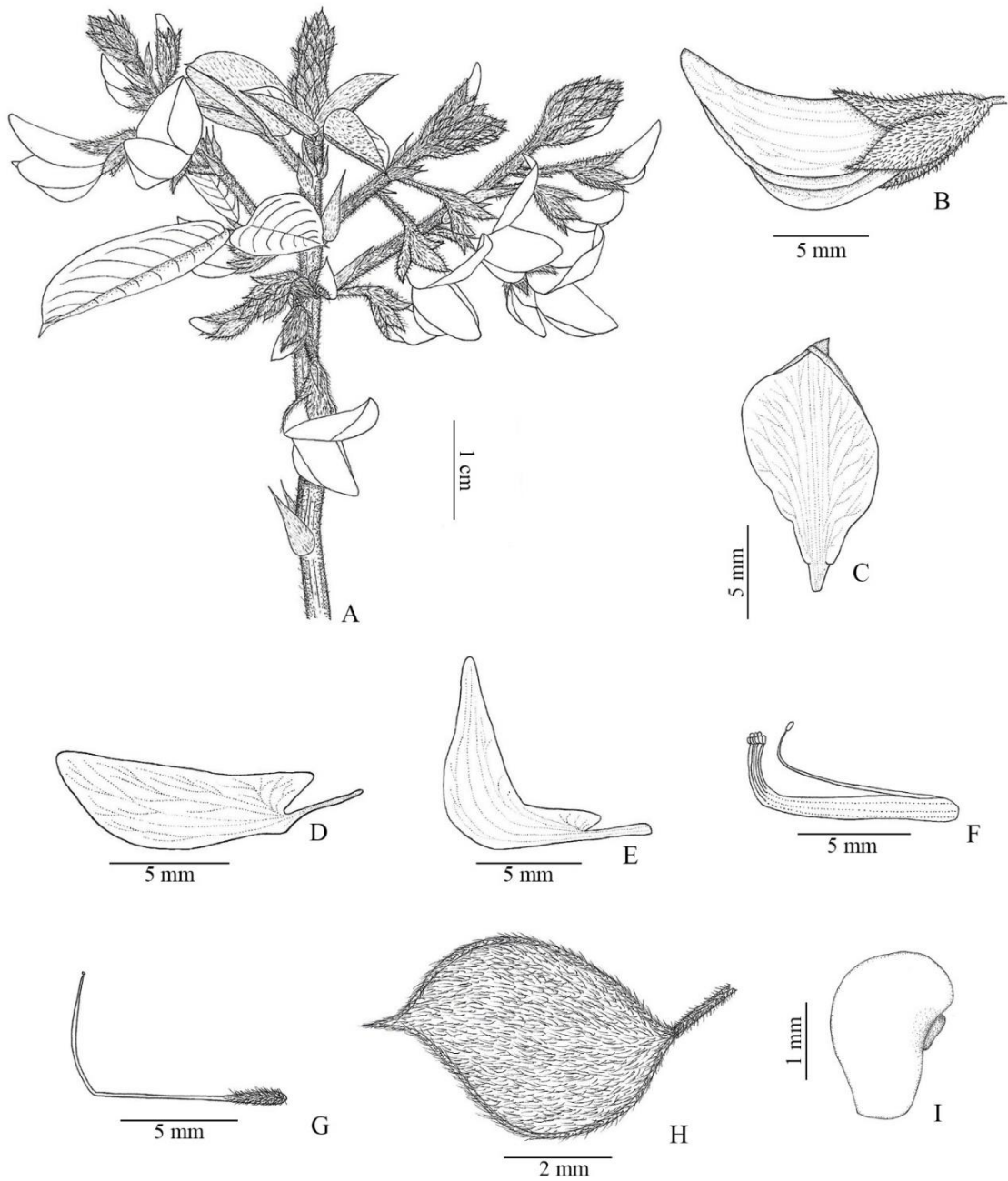


Figure 2.18 Drawing of *Campylotropis decora*. A: flowering branch, B: flower, C: standard, D: wing, E: keel, F: stamen, G: pistil, H: pod, I: seed. A-G from *Sattaphorn & Leeratiwong 91* (PSU) and G-H from *Sattaphorn 78* (PSU).



Figure 2.19 *Campylotropis harmsii*. A: habit, B: flowers, C: fruits.

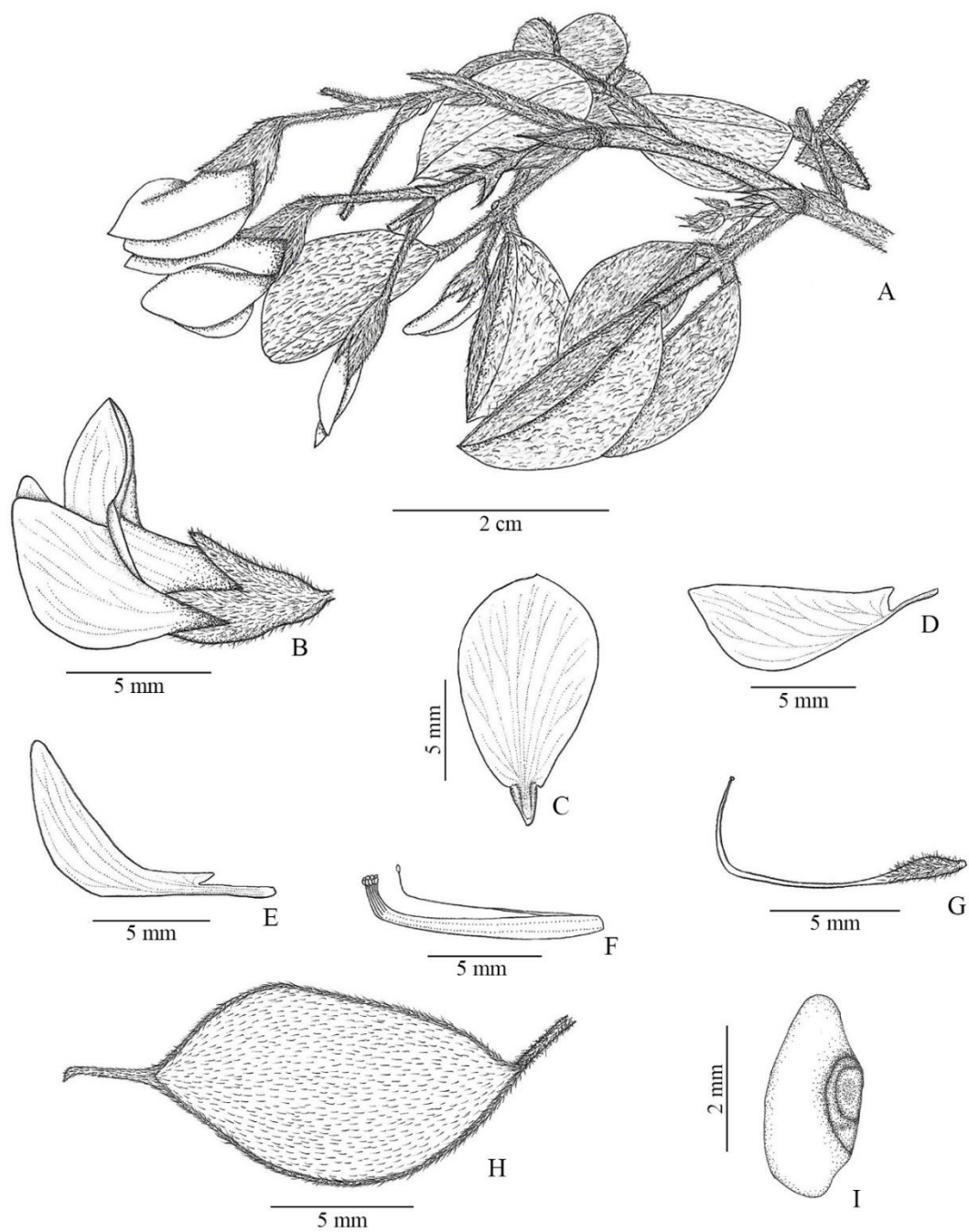


Figure 2.20 Drawing of *Campylotropis harmsii*. A: flowering branch, B: flower, C: standard, D: wing, E: keel, F: stamen, G: pistil, H: pod, I: seed. All from Sattaphorn & Leeratiwong 88 (PSU).



Figure 2.21 *Campylotropis parviflora*. A: habit, B: flowers, C: fruits.

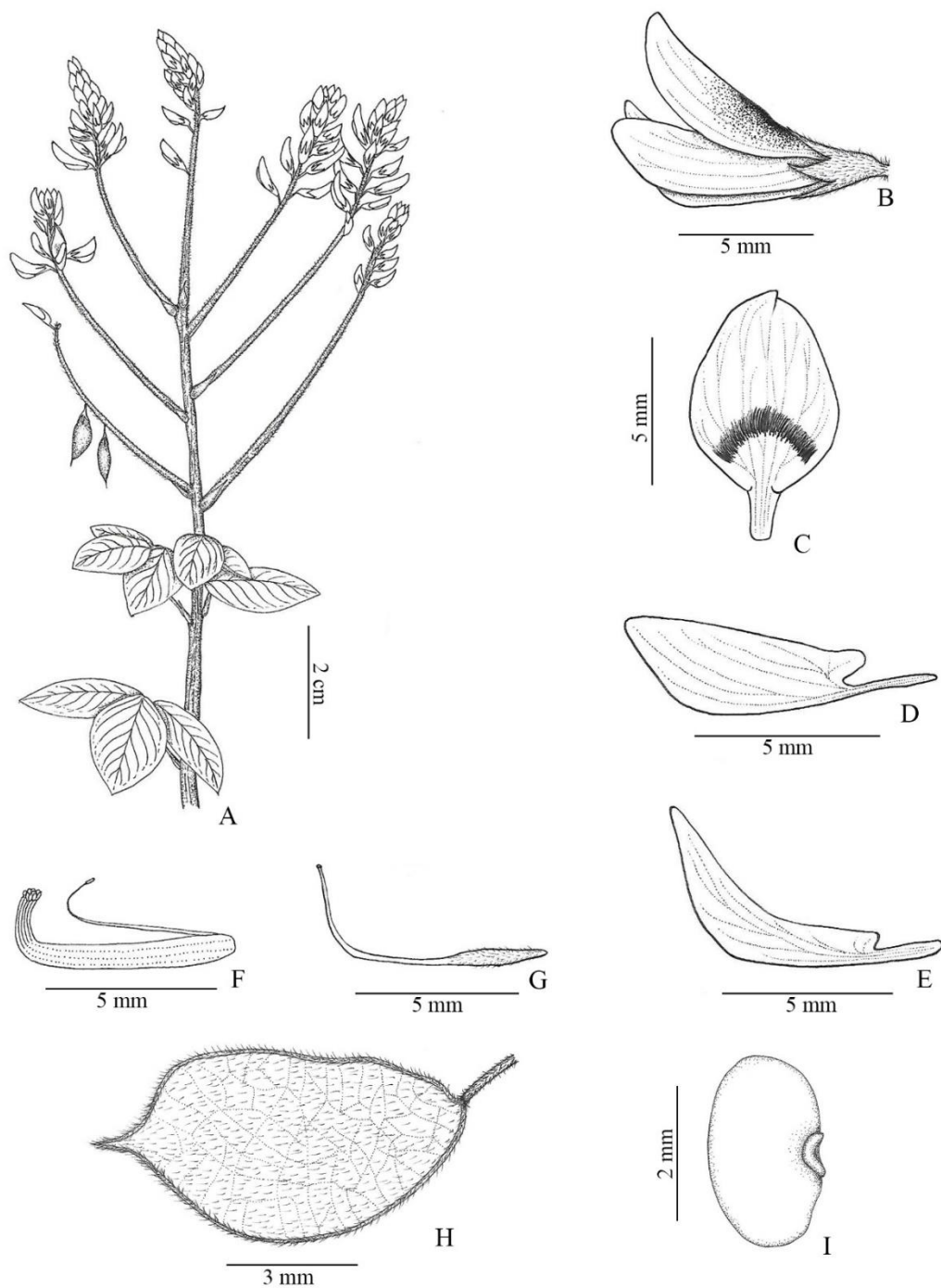


Figure 2.22 Drawing of *Campylotropis parviflora*. A: flowering branch, B: flower, C: standard, D: wing, E: keel, F: stamen, G: pistil, H: pod, I: seed. All from Sattaphorn & Leeratiwong 85 (PSU).



Figure 2.23 *Campylotropis pinetorum*. A: habit, B: flowers, C: fruits.

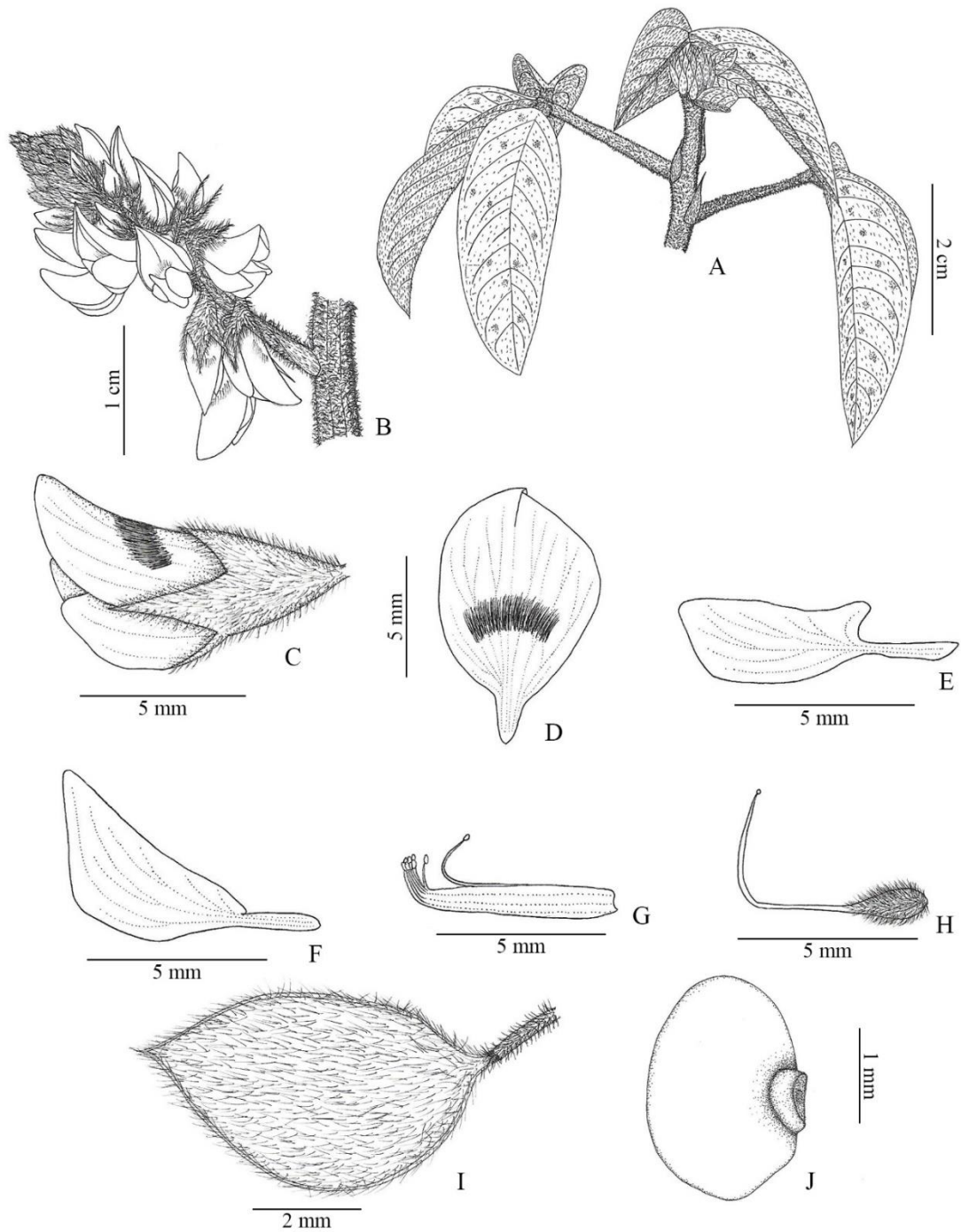


Figure 2.24 Drawing of *Campylotropis pinetorum*. A: leaves branch, B: flowering branch, C: flower, D: standard, E: wing, F: keel, G: stamen, H: pistil, I: pod, J: seed. All from Sathaphorn & Leeratiwong 84 (PSU).



Figure 2.25 *Campylotropis sulcata*. A: habit, B: flowers, C: fruits.

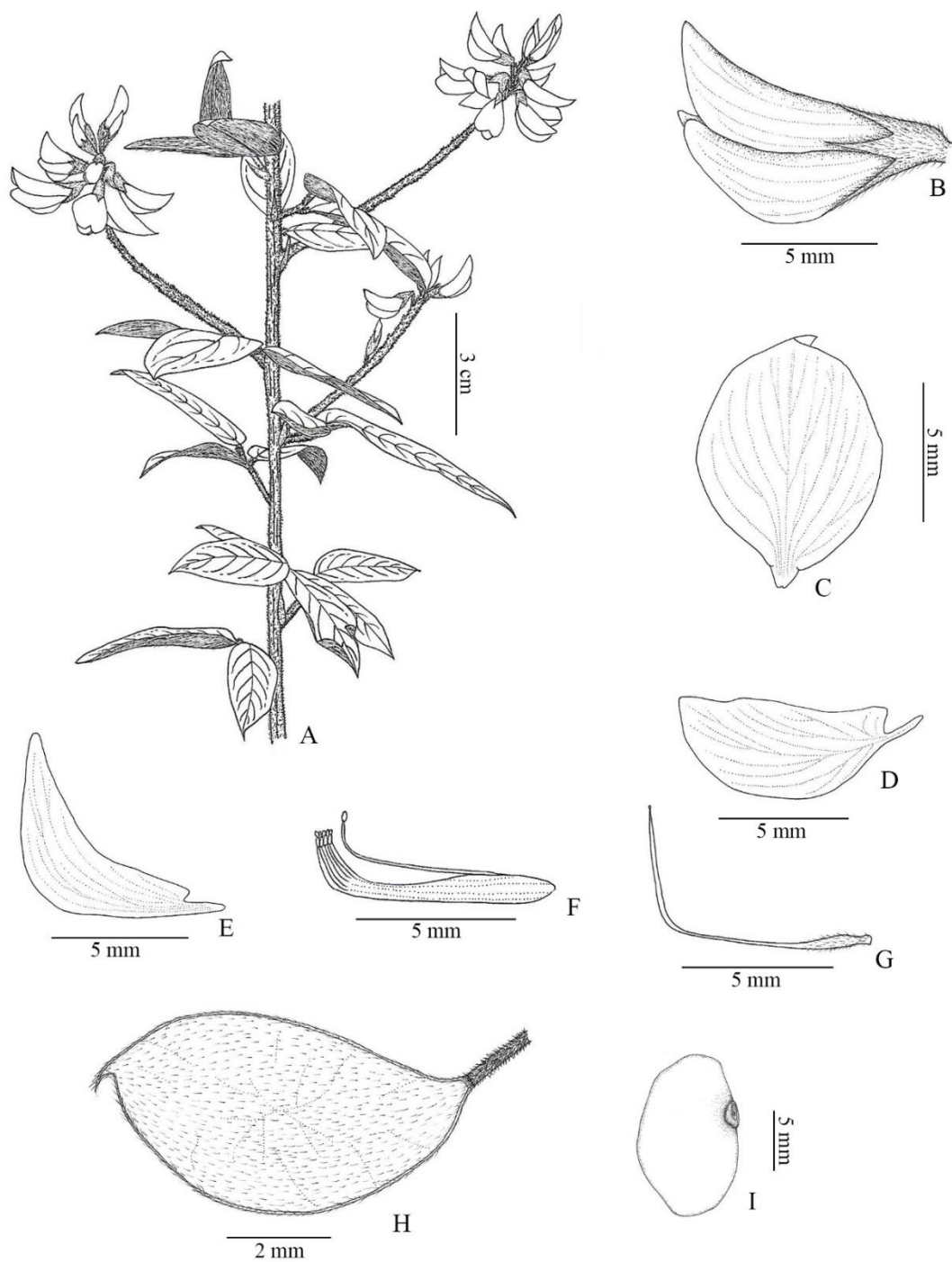


Figure 2.26 Drawing of *Campylotropis sulcata*. A: flowering branch, B: flower, C: standard, D: wing, E: keel, F: stamen, G: pistil, H: pod, I: seed. All from *Sattaphorn 75* (PSU).

Diversity and distribution of the genus *Campylotropis* in Thailand

Seven species and one subspecies of the genus *Campylotropis* in Thailand are enumerated from taxonomic treatment based on morphological evidence including their distributions in Thailand (Table 2.11). *C. parviflora* demonstrates the widest populations spreading in 4 floristic regions. *C. capillipes* subsp. *prainii*, *C. decora*, and *C. harmsii* establish restrictively only in northern Thailand on limestone vegetations. The species found only in the peninsular is *C. bonii*. The species richness from the northern Thailand shows the highest number due to optimal conditions for most *Campylotropis* species especially limestone vegetation that continuously coincided from southern China (Iwatsuki, 1972) where is the centre of distribution of the genus (Fu, 1987; Iokawa & Ohashi, 2002a, 2008; Ohashi, 2005). Considering of the limestone preference species in total 7 species, 5 species are generally recognised as limestone-specific species: *C. bonii*, *C. capillipes* subsp. *prainii*, *C. decora*, *C. harmsii*, and *C. sulcata*. Other 2 species are non-limestone-specific species, *C. pinetorum* and *C. parviflora* that can be found in moist soil in pine-oak forest. The observations during field surveys suggest that most Thai *Campylotropis* should be treated as vulnerable plant of Thailand: *C. capillipes*, *C. decora*, *C. harmsii*, and *C. sulcata*, due to growing in specific habitats especially limestones in only some locations and *C. bonii* should be recognised as a rare species because few populations are only found in southern Thailand.

The altitudinal distribution and adaptation

The members of *Campylotropis* in Thailand distribute altitudinally between 150 and 2250 m above sea level (Table 2.12). Most species, *C. capillipes* subsp. *prainii*, *C. decora*, *C. harmsii*, *C. pinetorum*, and *C. sulcata*, establish restrictively in montane temperate vegetation at high altitude near the top of mountain exposed to sunlight and wind. These species may have mechanisms to exhibit the thicker leaves and glandular hairs to protect the plant from strongly direct sunlight, wind and freezing condition. *C. parviflora* can be found at wide range of elevation from 600 to 1800 m in evergreen forest exhibiting thinner leaves because the species usually occurs in fully shade and

lower altitude. *C. bonii* was found in limestone outcrop by the sea between 150 and 330 m high. Because this species is also exposed to sunlight and wind directly, the species may pose thicker leaves to avoid strong sunlight and salt spray damaging internal cells.

Improvement of taxonomic problems

Previous taxonomic treatments and uncertain checklists cause insufficient information of the genus *Campylotropis* for Thailand in both taxonomic and ecological aspects. Most taxonomic data are based on the study in some particular countries which is not totally useful for Thai taxa. This study provides many solutions for taxonomic problems in following paragraphs.

Comparing to the first *Campylotropis* recorded as *Lespedeza* in Thailand (Craib, 1928), six species are similar and one species is newly added in present treatment. Following by Thai plant name checklist by Pooma and Suddee (2001, 2014), five more species are recently recorded in this study. New localities for *C. capillipes* subsp. *prainii*, *C. decora*, *C. harmsii*, *C. parviflora*, *C. pinetorum*, and *C. sulcata* are also recorded in this study (Table 2.12).

Iokawa and Ohashi (2002a, 2002b) has not seen holotypes of *C. parviflora*, *C. decora*, and *C. pinetorum* mentioned to be kept at K, K, and E herbaria, respectively. In fact, this study shows that these three holotypes are kept at CAL herbarium and already done investigation in this study. From the investigation of CAL specimens, taxonomic change for *C. parviflora* is proposed. Previously, *C. cytisoides* f. *parviflora* was established by Iokawa and Ohashi (2002a); however, in this study, the examination on both holotype specimens of *C. parviflora* (Myanmar) and *C. cytisoides* (Indonesia) confirms that *C. parviflora* is clearly separated from *C. cytisoides* as species level by many vegetative and reproductive characters. Hence, *C. parviflora* is reinstated to species level and *C. cytisoides* f. *parviflora* is treated as under *C. parviflora* in this taxonomic treatment.

Many *Campylotropis* specimens kept in Thai herbaria are usually identified as unknown genera or species. The causation of this problem may lack the effective key to species for Thai *Campylotropis* taxa and information of the genus which are not well-known from Thai plant checklists. However, the author is already done providing the correct species name on determination slips on *Campylotropis* specimens in Thai herbaria.

These taxonomic improvements can solve taxonomic problems for the genus in Thailand providing species account for Thailand, morphological description, and effective key to species to clearly separate species including ecological data. The result of this study provides base knowledges for further study and also contributes to the Flora of Thailand for Leguminosae project.

Phytogeography

A large number of *Campylotropis* taxa have been recorded from many Asian countries comprising of Pakistan, India, Bhutan, Nepal, Mongolia, Myannar, China, Laos, Vietnam, Taiwan, Korea, Japan, and Indonesia (Gagnepain, 1920; Hooker, 1879; Huang *et al.*, 2010; Iokawa & Ohashi, 2002a, 2002b, 2002c; Thuân *et al.*, 1978). The number of species of *Campylotropis* recorded in Thailand are compared to other Asian countries and four species are recognised to accommodate the same species with Thai taxa (Table 2.13). Myanmar shows the highest value of Sørensen's similarity index following by Laos, Vietnam, and China, respectively, with nine countries shown without shared taxa with Thailand. Number of taxa recorded from Myanmar is similar to Thai taxa while a large number of Chinese taxa show much more species than Thai taxa effecting low value of the index.

Campylotropis species recorded in Thailand greatly distribute in Sino-Himalayan (Line in Fig. 2.27) and some part of Indo-China (Dashed line in Fig. 2.27). *C. capillipes* subsp. *prainii*, *C. decora*, *C. harmsii*, *C. parviflora*, and *C. sulcata*, spread throughout southern China to Thailand as a southmost limited of these six species.

Corresponding to natural distribution, northern Thailand has wide areas of mountain ranges which are continuously jointed to upper Myanmar, Laos, south-western China, and eastern Himalayas ranges. Northern mountains in Thailand are considered as continental highlands extending southward of Shan Hill, Myanmar thus flora seems to be similar to those Sino-Himalayan mountains (Iwastuki, 1972). Only *C. bonii* is distributed extending from Vietnam to southern Thailand where is recognised as Indo-China region. From the field survey, this species can be found at near the exposed at the top of limestone outcrop of Tham Suea Temple where can be only accessed by stairway. This occasional discovery leads to hypothesise that the species may also occur in many tops of limestone outcrop where are not possible to access the top in southern Thailand and continue to Vietnam. So this disjunct distribution may be interpreted in terms of unreachable area.

Utilizations

The genus has been mainly used in several medicinal purposes especially biochemical extracts that play an important role in antibacterial activities. Many publications revealed that the extraction of *Campylotropis hirtella* contains tyrosinase inhibitor and isoflavones effecting to bacteria activities (Ma *et al.*, 2017; Tan *et al.*, 2016; Xie *et al.*, 2016). Ethnobotany of some locals in northern Thailand believes that boiled root of *C. parviflora* is very helpful of blood circulation. Not only usage for medicinal purposes but also usage for fodder, the whole plant of *C. macrostyla* is used for feeding crop animals in India (Mathur & Joshi, 2013).

Table 2.12 Distributions and forest types of *Campylotropis* in Thailand. Asterisks indicate new localities recorded.

Taxa	Distribution in Thailand	Forest types	Altitudes (m)
<i>C. bonii</i>	PENINSULAR: Krabi, Phangnga, Phuket	Scattered on the limestone outcrop	150–330
<i>C. capillipes</i> subsp. <i>prainii</i>	NORTHERN: Chiang Mai, Uttaradit*	On exposed rugged limestone, lower montane pine oak forest	1300–2150
<i>C. decora</i>	NORTHERN: Mae Hong Son*, Chiang Mai, Chiang Rai*, Tak*	In open, partly shaded in limestone rugged, deciduous forest	800–2150
<i>C. harmsii</i>	NORTHERN: Chiang Mai, Nan*	In open, limestone ridge, evergreen forest	1200–2150
<i>C. parviflora</i>	NORTHERN: Mae Hong Son*, Chiang Mai, Chiang Rai*, Lumphun*, Tak* NORTH-EASTERN: Phetchabun, Loei EASTERN: Chaiyaphum* SOUTH-WESTERN: Kanchanaburi	In open, partly shaded areas on limestone mountain, dry evergreen forest	600–1800
<i>C. pinetorum</i>	NORTHERN: Chiang Mai, Chiang Rai*, Nan*, Uttaradit*, Phitsanulok*, Kamphaeng Phet* NORTH-EASTERN: Loei	In open, grassy areas, hill evergreen forest, lower montane forest	1000–2250
<i>C. sulcata</i>	NORTHERN: Mae Hong Son*, Chiang Mai, Chiang Rai*, Phitsanulok* EASTERN: Chaiyaphum*	In open, rugged limestone, mixed deciduous forest, scrub forest	850–2000

Table 2.13 Recording of *Campylotropis* species in neighbouring countries, number of shared taxa with Sørensen's similarity Index.

Countries	Number of taxa recorded	Number of taxa shared with Thailand	Sørensen's Similarity Index (%)
Pakistan (Iokawa & Ohashi, 2002a)	3	0	0
India (Hooker, 1879; Iokawa & Ohashi, 2002a)	7	0	0
Bhutan (Iokawa & Ohashi, 2002a)	2	0	0
Nepal (Iokawa & Ohashi, 2002a)	4	0	0
Mongolia (Iokawa & Ohashi, 2002a)	1	0	0
Myanmar (Thuân <i>et al.</i> , 1978; Iokawa & Ohashi, 2002a)	7	4	57.14
China (Iokawa & Ohashi, 2002; Huang <i>et al.</i> , 2010)	32	5	25.64
Laos (Gagnepain, 1920; Thuân <i>et al.</i> , 1978; Iokawa & Ohashi, 2002a)	3	3	54.55
Vietnam (Gagnepain, 1920; Thuân <i>et al.</i> , 1978; Iokawa & Ohashi, 2002a)	3	2	40
Taiwan (Iokawa & Ohashi, 2002a)	1	0	0
Korea (Iokawa & Ohashi, 2002a)	1	0	0
Japan (Iokawa & Ohashi, 2002a)	1	0	0
Indonesia (Iokawa & Ohashi, 2002a)	1	0	0

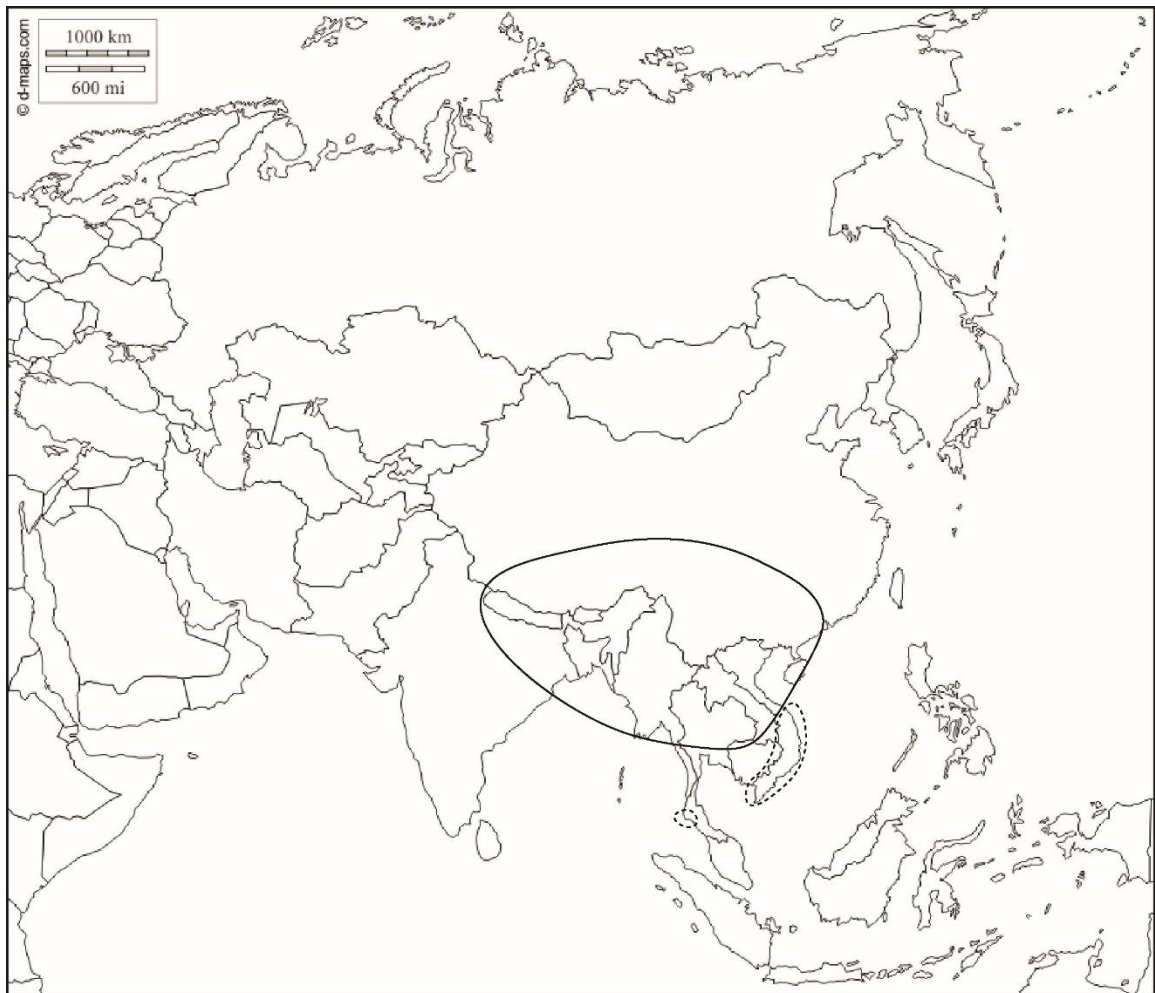


Figure 2.27 Phytogeography of *Campylotropis* species in Thailand. Line indicates Sino-Himalayan region and dashed line shows Indo-China region.

CHAPTER 3

PALYNOLOGY

3.1. Introduction

The studying of pollen morphology is one of taxonomic tools used for species delimitation. Pollen grains have a variety of size, shape, symmetry, aperture and exine sculpturing (Erdman, 1954). In Leguminosae, this palynological evidence is widely used to test the position of species or genera (Guinet, 1981), nevertheless great palynological data usually fall into previous subfamilies Caesalpinoideae and Mimosoideae except Papilionoideae (Ferguson & Skvarla, 1981). To be completed the information of palynological study within family, studying of pollen grains within subfamily Papilionoideae is further needed especially in tribe Desmodieae that has not much studies in the past. Previously, palynological studies on the genus *Campylotropis* were barely known because few palynological information of the genus were conducted in only some particular regions (Perveen & Qaiser, 1998; Iokawa & Ohashi, 2002a; Xu *et al.*, 2011). This study aims to firstly provide palynological data as one of those evidences to delimit species boundaries of the genus *Campylotropis* in Thailand. The description, key to species based on pollen morphology, and taxonomical trends are provided in recent study.

3.2. Literature reviews

3.2.1. General pollen morphology of subfamily Papilionoideae and tribe Desmodieae

Pollen morphologies in the subfamily Papilionoideae are considerably various. The great significant values to classify the pollen are apertures and wall stratifications while shape, size, and the sculpturing of the tectum are considered as secondary

characters to significantly classify tribes and within genera. Generally, the sizes of the pollens are usually not greater than 50 μm and shapes vary from prolate or spheroidal to oblate and triangular flattened in some specialised pollen types (Ferguson & Skvarla, 1981; Guinet, 1981). Pollen morphology of tribe Desmodieae is shown to be a natural tribe with a fairly high degree of specialisation. Common features of pollen morphology in tribe Desmodieae are tricolporate apertures without an aperture membrane, thick endexine, the loss of or very thin foot layer; however, shapes, sizes, tectum types, and wall stratifications are diverse (Ferguson & Skvarla, 1981; Ohashi *et al.*, 1971, 1981; Saisorn & Chantaranothai, 2015).

3.2.3. Previous studies on pollen morphology of the genus *Campylotropis*

Few pollen morphologies of *Campylotropis* were reported from studying of particular palynoflora in some countries and regions (Perveen & Qaiser, 1998; Xu *et al.*, 2011). The pollen grains are generally tricolporate with smooth colpi margin. The pollen shapes vary in prolate, subprolate or prolate spheroidal with triangular or semitriangular in polar view, elliptic in equatorial view, and reticulate ornamentation. Only studying of Iokawa and Ohashi (2002a), report on some *Campylotropis* pollen morphology is emphasised, of which, three taxa are similar with Thai taxa which are *C. decora*, *C. parviflora* (= *C. cytisoides* f. *parviflora*), and *C. sulcata*.

3.2. Materials and Methods

The pollen grains of all Thai *Campylotropis* species were collected from natural habitats shown in Table 3.1. Pollen with anther samples were treated using the acetolysis method following Erdtman (1954). For examination with light microscopy (LM), pollen grains were mounted in glycerine jelly and observed with the Olympus BX43 with Single-Grain technique (Zetter, 1989). Measurements of the length of polar and equatorial axes with the standard deviation (SD), exine thickness including outline, shape and ornamentation recorded were taken from at least 20 grains for each sample. For LM study, pollen grains were acetolysed and mixed with glycerine before mounting on slides (Erdtman, 1954). The pollen size, outline, exine thickness, and apertural

condition were investigated. For examination with SEM, pollen grains were directly taped onto a specimen stub with Single-Grain technique (Zetter, 1989). Pollen grains on stub were coated with Gold (Au) using SPI-MODULE™ Sputter Coater, SPI 11425. Observations of SEM were conducted with FEI Quanta 400 and photographed the outline, apertures, and ornamentation.

Table 3.1 Selected specimens for palynological investigations.

Samples	Taxa	Localities	Voucher specimens
1	<i>C. bonii</i>	Tham Suea temple, Krabi	<i>Sathaphorn & Leeratiwong 80 (PSU)</i>
2	<i>C. bonii</i>	Tham Suea temple, Krabi	<i>Sathaphorn & Leeratiwong 81 (PSU)</i>
3	<i>C. capillipes</i> subsp. <i>prainii</i>	Doi Chiang Dao, Chiang Mai	<i>Sathaphorn 76 (PSU)</i>
4	<i>C. capillipes</i> subsp. <i>prainii</i>	Doi Chiang Dao, Chiang Mai	<i>Sathaphorn 82 (PSU)</i>
5	<i>C. capillipes</i> subsp. <i>prainii</i>	Doi Chiang Dao, Chiang Mai	<i>Sathaphorn & Leeratiwong 90 (PSU)</i>
6	<i>C. decora</i>	Doi Hua Mod, Tak	<i>Sathaphorn 78 (PSU)</i>
7	<i>C. decora</i>	Doi Chiang Dao, Chiang Mai	<i>Sathaphorn & Leeratiwong 91 (PSU)</i>
8	<i>C. harmsii</i>	Doi Chiang Dao, Chiang Mai	<i>Sathaphorn & Leeratiwong 88 (PSU)</i>
9	<i>C. parviflora</i>	Mae rim, Chiang Mai	<i>Sathaphorn 79 (PSU)</i>
10	<i>C. parviflora</i>	Doi Inthanon, Chiang Mai	<i>Sathaphorn & Leeratiwong 85 (PSU)</i>
11	<i>C. parviflora</i>	Doi Chiang Dao, Chiang Mai	<i>Sathaphorn & Leeratiwong 92 (PSU)</i>
12	<i>C. pinetorum</i>	Doi Inthanon, Chiang Mai	<i>Sathaphorn & Leeratiwong 84 (PSU)</i>
13	<i>C. sulcata</i>	Doi Chiang Dao, Chiang Mai	<i>Sathaphorn 75 (PSU)</i>

GLOSSARY OF PALYNOLOGY

Technical terms and meaning follow Hesse *et al.* (2009).

Convex	Curved or swelling out
Exine	Outer layer of the pollen wall which is usually resistant to acetolysis
Foveolate	Roundish lumen more than 1 μm in diameter; distance between two adjacent lumina larger than their diameter
Heterobrochate reticulate	Reticulate pollen wall with lumina of different sizes
Lumen (Lumina)	General term for the space enclosed by muri
Microreticulate	Network like pattern formed by exine elements (muri), where the lumina are smaller than 1 μm
Monad	Dispersal unit consisting of a single pollen grain
Muri	Exine elements forming the meshes in a reticulum
Ornamentation	General term, applied in palynology to surface features
Perforate	Pollen wall with holes less than 1 μm in diameter
Prolate	Pollen grain with a polar axis longer than the equatorial diameter
Protrusion	The state of being protruded
Reticulate	Network like pattern formed by exine elements (muri), where the lumina are wider than 1 μm
Tricolporate	Pollen grain with three colpi

3.3. Results

The results from palynological investigations of Thai *Campylotropis* are shown in Table 3.2 and Figs. 3.1–3.4. Pollen grains of *Campylotropis* in Thailand are monad, isopolar, radially symmetric, and tricolporate aperture. All species are prolate in shape. The length of polar axis ranges from 19.75 μm (*C. bonii*) to 40 μm (*C. harmsii*) and the length equatorial axis is from 17.5 μm (*C. bonii*) to 37 μm (*C. decora*) with exine thickness ranging from 0.75 μm (*C. pinetorum* and *C. sulcata*) to 1.84 μm (*C. decora*). The protrusion structure at aperture margin can be found in *C. harmsii*, *C. parviflora*, and *C. pinetorum* (Figs. 3.2–3.3). The ornamentations are various in types which are microreticulation, microreticulation with perforation, and heterobronchate reticulation with perforation. All species show outline of polar view as convex-triangular except triangular in *C. pinetorum* (Fig. 3.3). Key to species based on pollen morphology and descriptions of each species are provided.

Key to species of *Campylotropis* in Thailand based on pollen morphology

1. Aperture of pollen grains with protrusion
 2. Pollen grains with only microreticulate ornamentation; outline of polar view triangular
 - 6. *C. pinetorum***
 2. Pollen grains with microreticulate or heterobronchate ornamentation mixed with perforation; outline of polar view convex triangular
 3. Ornamentation heterobronchate and perforate; equatorial axis 23.5–37 μm long
 - 4. *C. harmsii***
 3. Ornamentation microreticulate and perforate; equatorial axis 20–23.75 μm long
 - 5. *C. parviflora***
1. Aperture of pollen grains without protrusion
 4. Ornamentation heterobronchate reticulate and perforate
 - 7. *C. sulcata***
 4. Ornamentation microreticulate and perforate
 5. Lumina ≥ 0.5 μm in diameters
 - 2. *C. capillipes* subsp. *prainii***
 5. Lumina < 0.5 μm in diameters
 - 1. *C. bonii* & 3. *C. decora***

3.3.1. *Campylotropis bonii*

Pollen grains 19.75–24.5 μm (average $22.46 \pm 0.47 \mu\text{m}$) in polar axis, 17.5 – 21.25 μm (average $19.48 \pm 0.37 \mu\text{m}$) in equatorial axis, pollen shape prolate with P/E 1.153. Outline of polar view convex triangular. Ornamentation microreticulate and perforate. Exine thickness 1.05 – 1.84 μm (Table 3.2 & Figs. 3.1A–3.1D).

3.3.2. *Campylotropis capillipes* subsp. *prainii*

Pollen grains 25–30 μm (average $27.65 \pm 0.65 \mu\text{m}$) in polar axis, 22.5–26.25 μm (average $24.09 \pm 0.48 \mu\text{m}$) in equatorial axis, pollen shape prolate with P/E 1.148. Outline of polar view convex triangular. Ornamentation microreticulate and perforate. Exine thickness 0.85–1.31 μm (Table 3.2 & Figs. 3.1E–3.1H).

3.3.3. *Campylotropis decora*

Pollen grains 21.25–32.5 μm (average $26.5 \pm 1.35 \mu\text{m}$) in polar axis, 18.5–27.5 μm (average $23.16 \pm 1.04 \mu\text{m}$) in equatorial axis, pollen shape prolate with P/E 1.144. Outline of polar view convex triangular. Ornamentation microreticulate and perforate. Exine thickness 1.12–1.84 μm (Table 3.2 & Figs. 3.2A–3.2D).

3.3.4. *Campylotropis harmsii*

Pollen grains 25.5–40 μm (average $32.05 \pm 1.38 \mu\text{m}$) in polar axis, 23.5–37 μm (average $27.93 \pm 1.34 \mu\text{m}$) in equatorial axis, pollen shape prolate with P/E 1.148. Aperture with protrusion. Outline of polar view convex triangular. Ornamentation heterobronchate reticulate and perforate. Exine thickness 0.99–1.24 μm (Table 3.2 & Figs. 3.2E–3.2H).

3.3.5. *Campylotropis parviflora*

Pollen grains 25.25–30 μm (average $27.93 \pm 0.57 \mu\text{m}$) in polar axis, 20–23.75 μm (average $22.01 \pm 0.42 \mu\text{m}$) in equatorial axis, pollen shape prolate with P/E 1.27. Aperture with protrusion. Outline of polar view convex triangular. Ornamentation

microreticulate and perforate. Exine thickness 0.85–1.27 μm (Table 3.2 & Figs. 3.3A–3.3D).

3.3.6. *Campylotropis pinetorum*

Pollen grains 23.75–29.5 μm (average $26.33 \pm 0.65 \mu\text{m}$) in polar axis, 19.5–25 μm (average $22.4 \pm 0.59 \mu\text{m}$) in equatorial axis, pollen shape prolate with P/E 1.17. Aperture with protrusion. Outline of polar view triangular. Ornamentation microreticulate. Exine thickness 0.75–1.30 μm (Table 3.2 & Figs. 3.3E–3.3H).

3.3.7. *Campylotropis sulcata*

Pollen grains 22.5–28.5 μm (average $24.96 \pm 0.62 \mu\text{m}$) in polar axis, 19.5–24.5 μm (average $21.4 \pm 0.57 \mu\text{m}$) in equatorial axis, pollen shape prolate with P/E 1.16. Outline of polar view convex triangular. Ornamentation heterobronchate reticulate and perforate Exine thickness 0.75–1.46 μm (Table 3.2 & Figs. 3.4A–3.4D).

3.4. Discussion

3.4.1. Pollen morphology of the genus *Campylotropis* in Thailand

Pollen grains from all *Campylotropis* species in Thailand share common features which are monad in type, prolate in shape, and tricolporate with smooth colpi at margins. Several features of pollen morphology can be fundamentally clustered for easily identifying at species level: size, protrusion at aperture margin, outline of polar view, and detail of exine sculpturing. From the numerical investigation, size of pollen grains can be classified based on average values of length of P-axis and E-axis into 3 groups which are small, medium, and large. The smallest pollen grains in this study is *C. bonii* (22.46 x 19.48 μm) while the biggest is the pollen grain of *C. harmsii* (32.05 x 27.93 μm). Pollen grains of *C. capillipes* subsp. *prainii* (27.65 x 24.09 μm), *C. decora* (26.5 x 23.16 μm), *C. parviflora* (27.93 x 22.01 μm), *C. pinetorum* (26.34 x 22.4 μm), and *C. sulcata* (24.96 x 21.4 μm) are grouped as a medium size. However, the variation

of P-axis and E-axis values are recognised as plasticity within the same species (Table 3.2). The presence of protrusion at colpi are only shown in pollen grains of *C. harmsii*, *C. parviflora*, and *C. pinetorum*. Types of ornamentation can be divided into 3 groups based on Hesse *et al.* (2009)'s criteria which are microreticulation (*C. pinetorum*), microreticulation with perforation (*C. bonii*, *C. capillipes* subsp. *prainii*, *C. decora*, and *C. parviflora*), and heterobronchate reticulation with perforation (*C. harmsii* and *C. sulcata*). Thus, these differences can be regarded to distinguish some *Campylotropis* species in Thailand.

Comparing to previous palynological study of the genus *Campylotropis* by Iokawa and Ohashi (2002a), three taxa are similar to the present study, *C. decora*, *C. parviflora* (= *C. cytisoides* f. *parviflora*), and *C. sulcata*. In this study, pollen grains of *C. decora* and *C. parviflora* show slightly larger in length of P-axis comparing to former study while *C. sulcata* reveals slightly smaller size than the previous one. However, the information of *C. bonii*, *C. capillipes* subsp. *prainii*, *C. harmsii*, and typical *C. pinetorum* are firstly recorded here. Type of exine sculpturing of *C. parviflora* and *C. capillipes* subsp. *prainii* in previous study have been noted as homobronchate and heterobronchate reticulations, while, in this study, the ornamentations of both species are microreticulation mixed with perforation. Anyhow, these variations in size and exine ornamentation may depend on the environment factors which are resource availability (Stephenson *et al.*, 1994; Lau *et al.*, 1995; Delph *et al.*, 1997) and hydration (Matamorov-Vidal *et al.*, 2016).

However, the study of pollen morphology in Thai *Campylotropis* provides information that may not be useful for every taxon to identify at species level due to overlapping characters between taxa. However, inclusion of palynological data to taxonomic study displays the more reliable values according to use macromorphology themselves (Guinet, 1981). Even then, this the first palynological data of the genus indicated intensive studies should be more conducted in more taxa and large scale of study site for further systematic implications.

3.4.2. Comparison of pollen grains of the genus *Campylotropis* and related genera

Pollen grains from all *Campylotropis* species in Thailand share common features in the genus which are monad in type, prolate in shape, and tricolporate with smooth colpi margins. These characters are also similar to the pollen morphology of the related genera, *Lespedeza*, and *Kummerowia* (Ferguson & Skvarla, 1981; Ohashi *et al.*, 1981; Iokawa & Ohashi, 2002a; Xu *et al.*, 2011) which may indicate the closer relationship within subtribe Lespedezinae. Pollen investigation of Xu *et al.* (2011) reveals that the apparent character to distinguish the genus *Campylotropis* apart from *Lespedeza* are absence of foveolate type and the detail of the depth of lamina which are shallow laminar while deeper in *Lespedeza*. Furthermore, the pollen character used to divide *Campylotropis* from *Kummerowia* is the absence of funiform structure on exine surface while presence in *Kummerowia*. These differences of exine sculpturing are considered as an important taxonomic tool with high value and stability (Walker & Doyle, 1975). The pollen morphologies of these three genera correlately support evidences from morphology and molecular study to separate at intergeneric level (Iokawa & Ohashi, 2002a; Nemoto *et al.*, 2010; Han *et al.*, 2010).

Table 3.2 Investigation on pollen grains of *Campylotropis* in Thailand.

Taxa	Polar axis (µm)	Equatorial axis (µm)	P/E	Outline of polar view	Outline of equatorial view	Aperture	Ornamentation (Hesse <i>et al.</i> , 2009)	Exine Thickness (µm)
	(min) average (max)	(min) average (max)						
<i>C. bonii</i>	(19.75) 22.46±0.47 (24.5)	(17.5) 19.48±0.37 (21.25)	1.153402	Convex triangular	elliptic	tricolporate	microreticulate, perforate	1.05–1.84
<i>C. capillipes</i> subsp. <i>prainii</i>	(25) 27.65±0.65 (30)	(22.5) 24.09±0.48 (26.25)	1.147894	Convex triangular	elliptic	tricolporate	microreticulate, perforate	0.85–1.31
<i>C. decora</i>	(21.25) 26.5±1.35 (32.5)	(18.5) 23.16±1.04 (27.5)	1.144091	Convex triangular	elliptic	tricolporate	microreticulate, perforate	1.12–1.84
<i>C. harmsii</i>	(25.5) 32.05±1.38 (40)	(23.5) 27.93±1.34 (37)	1.147717	Convex triangular	elliptic	tricolporate with protrusion	heterobronchate reticulate, perforate	0.99–1.24
<i>C. parviflora</i>	(25.25) 27.93±0.57 (30)	(20) 22.01±0.42 (23.75)	1.268597	Convex triangular	elliptic	tricolporate with protrusion	microreticulate, perforate	0.85–1.27
<i>C. pinetorum</i>	(23.75) 26.34±0.65 (29.5)	(19.5) 22.4±0.59 (25)	1.175781	triangular	elliptic	tricolporate with protrusion	microreticulate	0.75–1.30
<i>C. sulcata</i>	(22.5) 24.96±0.62 (28.5)	(19.5) 21.4±0.57 (24.5)	1.166472	Convex triangular	elliptic	tricolporate	heterobronchate reticulate, perforate	0.75–1.46

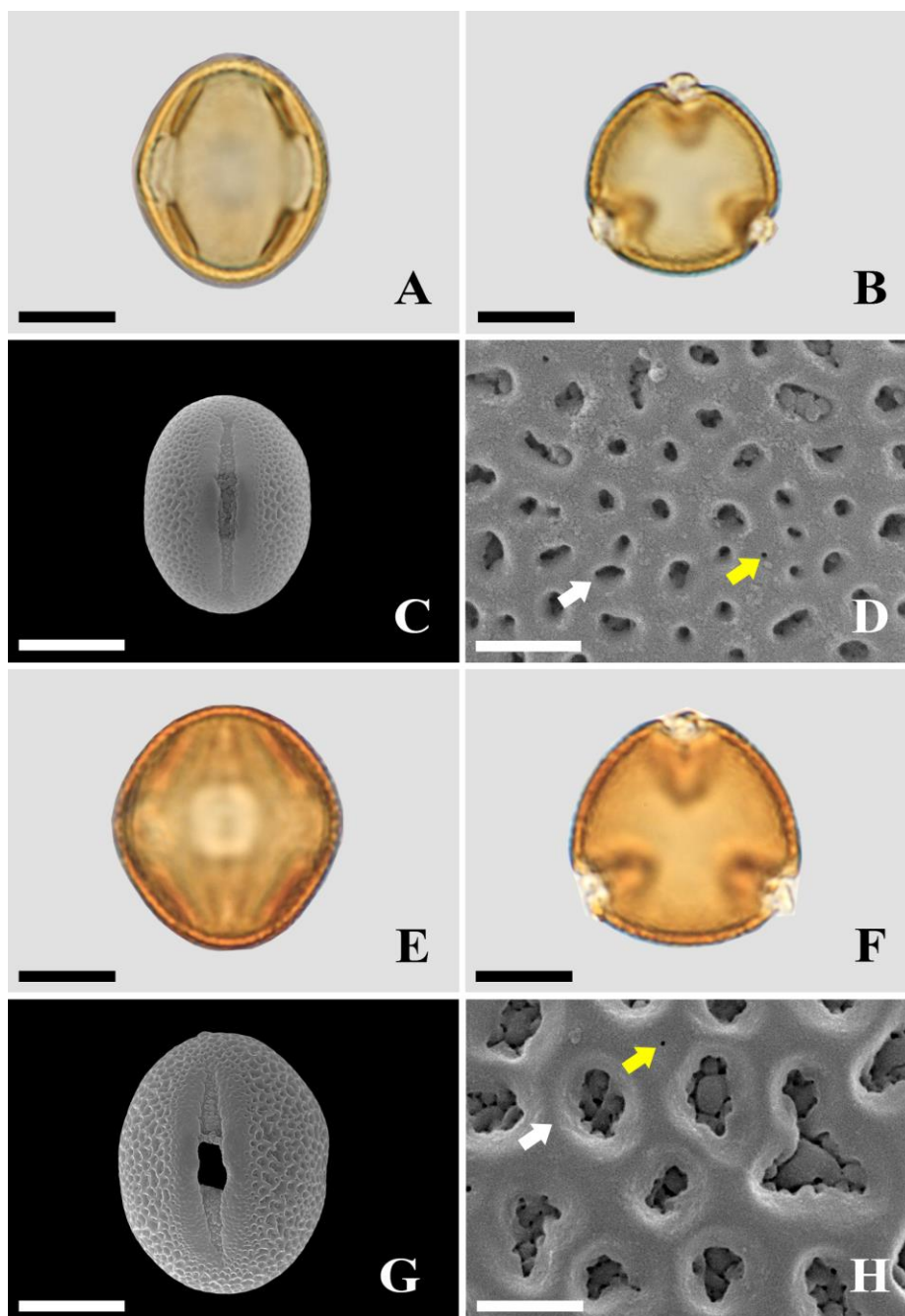


Figure 3.1 Palynological study of Thai *Campylotropis*. A-D: *C. bonii*; E-H: *C. capillipes* subsp. *prainii*. A, E: equatorial view (scale bars 10 μm); B, F: polar view (scale bars 10 μm); C, G: SEM overview of grains (scale bars 10 μm); D, H: SEM showing the detail of ornamentations (scale bars 1 μm). White arrows show microreticulate ornamentation. Yellow arrows show perforation.

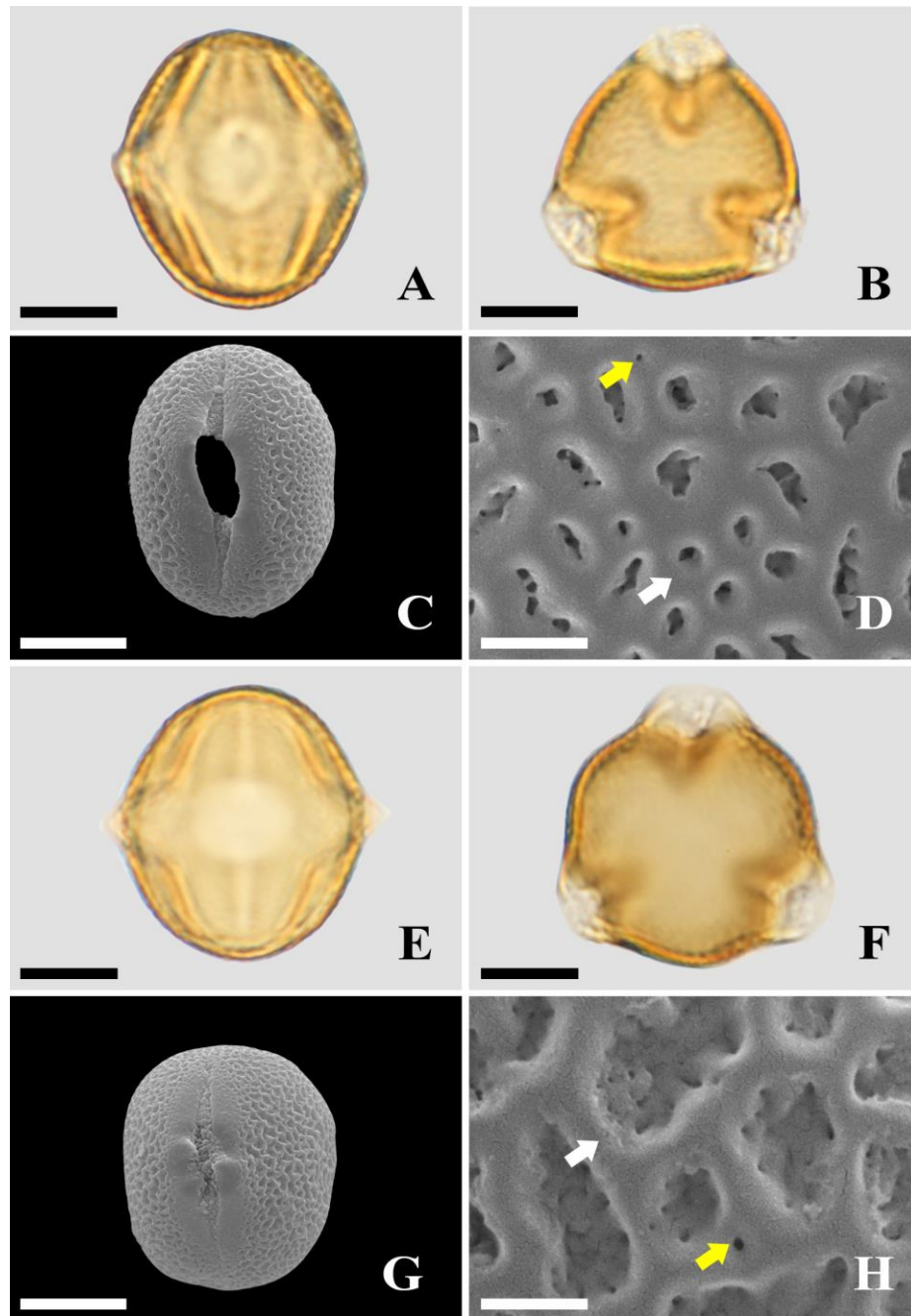


Figure 3.2 Palynological study of Thai *Campylotropis* (continued). A-D: *C. decora*; E-H: *C. harmsii*. A, E: equatorial view (scale bars 10 μm); B, F: polar view (scale bars 10 μm); C, G: SEM overview of grains (scale bars 10 μm); D, H: SEM showing the detail of ornamentations (scale bars 1 μm). White arrows show microreticulation in *C. decora* and heterobronchate reticulation in *C. harmsii*, respectively. Yellow arrows show perforation.

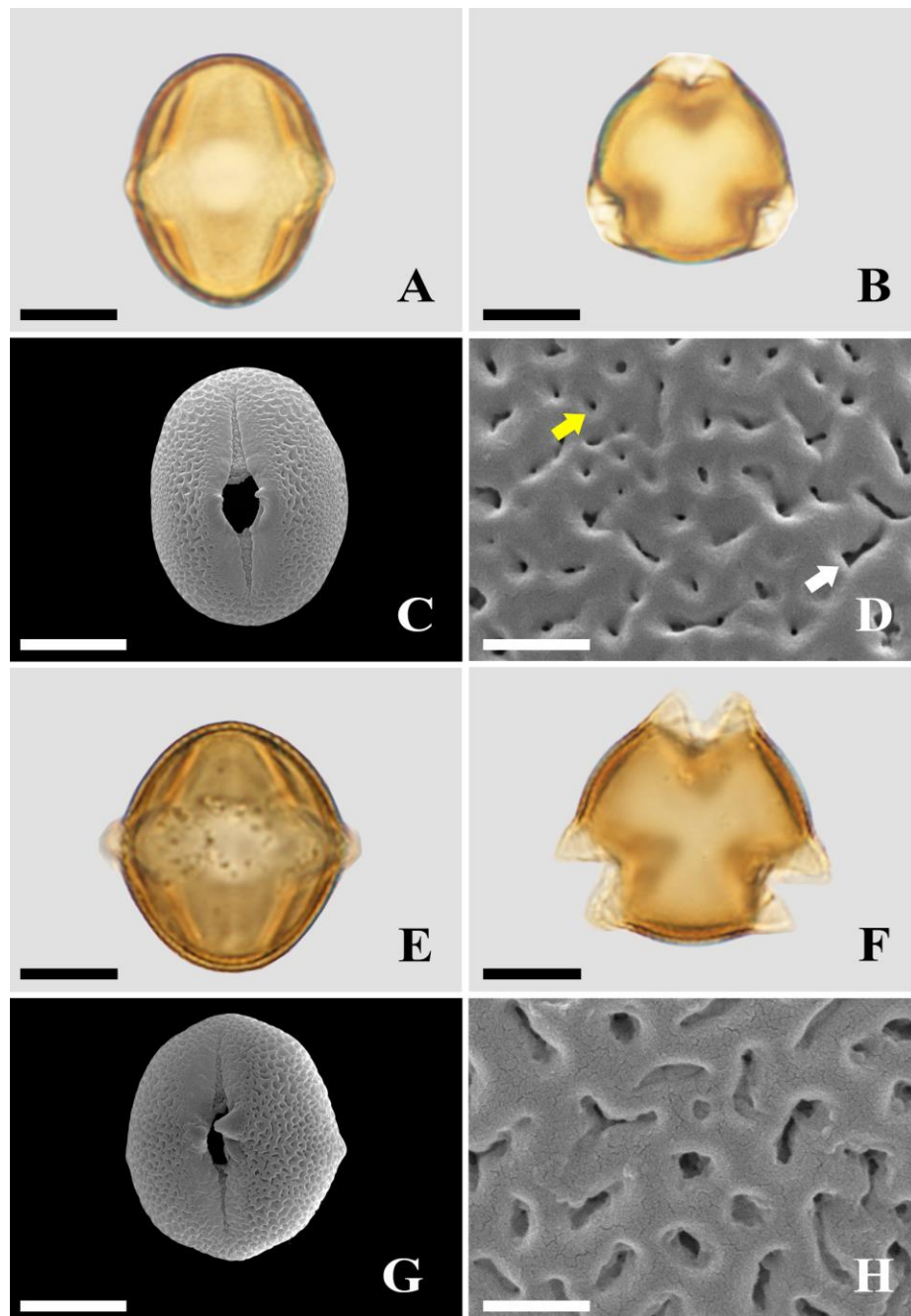


Figure 3.3 Palynological study of Thai *Campylotropis* (continued). A-D: *C. parviflora*; E-H: *C. pinetorum*. A, E: equatorial view (scale bars 10 µm); B, F: polar view (scale bars 10 µm); C, G: SEM overview of grains (scale bars 10 µm); D, H: SEM showing the detail of ornamentations (scale bars 1 µm). White arrow shows microreticulation. Yellow arrow shows perforation.

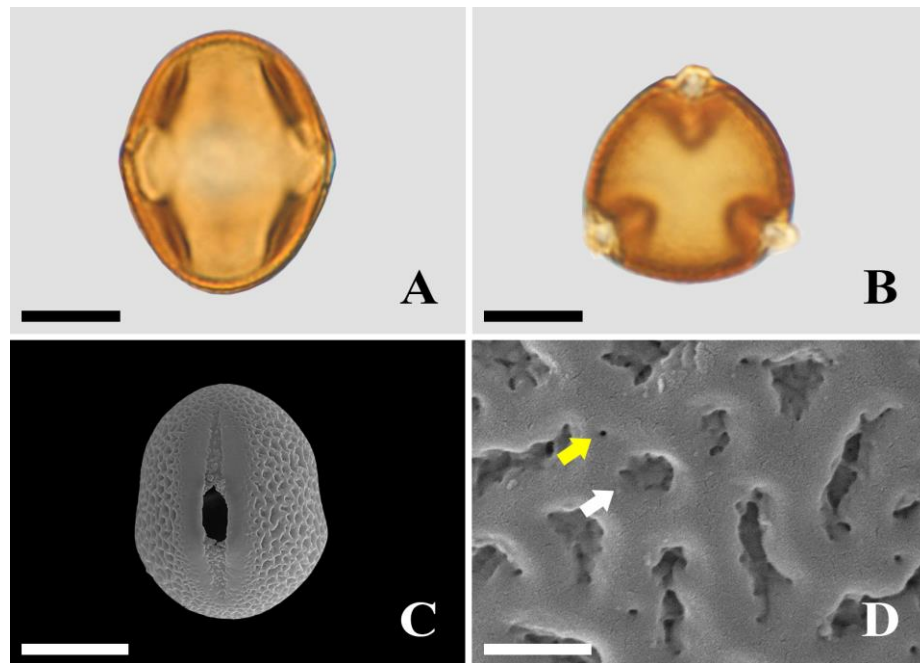


Figure 3.4 Palynological study of Thai *Campylotropis* (continued). A-D: *C. sulcata*. A: equatorial view (scale bars 10 μm); B: polar view (scale bars 10 μm); C: SEM overview of grains (scale bars 10 μm); D: SEM showing the detail of ornamentations (scale bars 1 μm). White arrow shows heterobronchate reticulation. Yellow arrow shows perforation.

CHAPTER 4

MOLECULAR STUDY

4.1. Introduction

Molecular data have had an intimate impact on the field in plant systematics to elucidate the forces governing evolutionary changes for several decades (Guat *et al.*, 1997). One of the most effective tools to investigate relationships among angiosperms and other plants is chloroplast DNA (cpDNA). More than two decades, chloroplast genes have served as useful tools for the reconstruction of plant phylogenies (Xu *et al.*, 2012). They contain non-coding regions which display the highest frequency of mutations (Palmer *et al.*, 1988; Clegg *et al.*, 1991). These regions are widely used as genetic markers that reflect the evolutionary process and phylogenetic relationship between group or taxa (Taberlet *et al.*, 1991; Soltis & Kuzoff, 1995; Nemoto *et al.*, 1995).

Previous studies on phylogenetic relationships among family Leguminosae, non-coding chloroplast regions are widely used to solve many problematic issues within family and lower taxa (Wojciechowski *et al.*, 2004; Delgado-Salinas *et al.*, 2006; Stefanović *et al.*, 2009; Legume Phylogeny Working group, 2013, 2017). Concerning of studying of tribe Desmodieae and lower taxa, supertree of Desmodieae has been constructed based on cpDNA data which is strongly supported monophyletic relationship with other tribes (Lewis *et al.*, 2005). Interestingly, several studies indicated that *trnL-trnF* regions in chloroplast can be widely used for phylogenetic reconstruction from the single gene or both of them ranging from higher to lower taxonomic levels in Leguminosae variable from family to species (Bruneau *et al.*, 2001; D'yachenko *et al.*, 2015; Duan *et al.*, 2016; Stefanović *et al.*, 2009; Nemoto *et al.*, 2010; Cubas *et al.*, 2002; Pardo *et al.*, 2004; Sinou *et al.*, 2009; Amirahmadi *et al.*, 2010; Han *et al.*, 2010).

Due to lacking information of *Campylotropis* phylogenetic tree in Thailand and confirming the position of the genus from phylogenetic relationship comparing to other related genera, *Lespedeza* and *Kummerowia*. This study aims to provide the first phylogenetic relationship among the species of *Campylotropis* in Thailand and related taxa based on two combined cpDNA regions which are *trnL-trnF* intergenic spacer and *trnL* intron.

4.2. Previous molecular studies of the genus *Campylotropis* and related genera

Few molecular studies of the genus *Campylotropis* were mainly reported as representative taxa for supporting the phylogenetic status of other related genera, *Lespedeza* and *Kummerowia*. Formerly, subtribe Lespedezinae in tribe Desmodieae was morphologically proposed by Ohashi *et al.* (1981) accommodated 5 genera, namely *Campylotropis*, *Kummerowia*, *Lespedeza*, *Neocollettia* and *Phylacium*. When molecular phylogeny was included in classification of family Leguminosae, the status of some genera have been phylogenetically changed. *Phylacium* and *Neocollettia* have been moved to tribe Phaseoleae (Nemoto *et al.*, 1995; Doyle *et al.*, 2000) and the rest remained in the Lespedezinae. To study the phylogenetic relationship of the whole subfamily Papilionoideae based on chloroplast genomes, some representatives from subtribe Lespedezinae was included in previous studies. The result shows that subtribe Lespedezinae and tribe Desmodieae are monophyletic group (Kajita *et al.*, 2001; Stefanović *et al.*, 2009). The phylogenetic status of the genus *Campylotropis* is recently placed in subtribe Lespedezinae that also comprises with members of *Lespedeza* and *Kummerowia*. *Campylotropis* has been recognised as sister to *Lespedeza* with nested *Kummerowia* based on chloroplast sequences while nuclear gene caused paraphyly (Han *et al.*, 2010; Nemoto *et al.*, 2010; Xu *et al.*, 2012; Jabbour *et al.*, 2018).

4.3. Materials and Methods

4.3.1. Material sampling and total DNA extraction

Seven *Campylotropis* species in Thailand were collected including representative species of *Lespedeza*, *Kummerowia*, and the outgroup *Dendrolobium* obtained from Genbank (Table 4.1). Fresh leaves of Thai *Campylotropis* were collected from natural habitats and kept in silica gel at -20°C . Total genomic DNA was isolated using the DNeasy Plant mini kit (Qiagen, Hilden, Germany) following the manufacturer's instruction. Isolated DNA was stored at -20°C .

Table 4.1 Samples information obtained from GenBank in this study.

Species	Voucher specimens	Accession numbers	
		<i>trnL-trnF</i> intergenic spacer	<i>trnL</i> intron
<i>Dendrolobium dispernum</i> (Hayata) Schindl. (Nemoto <i>et al.</i> , 2010)	<i>Y. Iokawa 5393</i> (TUS)	AB538924	AB538884
<i>Kummerowia stipulacea</i> (Maxim.) Makino (Nemoto <i>et al.</i> , 2010)	<i>Y. Iokawa 5240</i> (TUS)	AB538926	AB538886
<i>K. striata</i> (Thunb.) Schindl. (Nemoto <i>et al.</i> , 2010)	<i>Y. Iokawa 5239</i> (TUS)	AB538927	AB538887
<i>Lespedeza bicolor</i> Turcz. (Nemoto <i>et al.</i> , 2010)	<i>T. Nemoto 8621</i> (TUS)	AB538928	AB538888
<i>L. buergeri</i> Miq. (Nemoto <i>et al.</i> , 2010)	<i>T. Nemoto 8608</i> (TUS)	AB538929	AB538889
<i>L. angustifolia</i> (Pursh) Elliott (Nemoto <i>et al.</i> , 2010)	<i>A. F. Clewell & R. K. Godfrey 2067</i> (TUS)	AB538940	AB538900
<i>L. capitata</i> Michx. (Nemoto <i>et al.</i> , 2010)	<i>T. Nemoto 5867</i> (TUS)	AB538941	AB538901
<i>Campylotropis bonii</i> Schindl.	<i>Sathaphorn & Leeratiwong 81</i> (PSU)	MH671359	MH671366
<i>C. capillipes</i> (Franch.) Schindl. subsp. <i>prainii</i> Iokawa & Ohashi	<i>Sathaphorn & Leeratiwong 90</i> (PSU)	MH671360	MH671367
<i>C. decora</i> (Kurz) Schindl.	<i>Sathaphorn & Leeratiwong 91</i> (PSU)	MH671361	MH671368
<i>C. harmsii</i> Schindl.	<i>Sathaphorn & Leeratiwong 88</i> (PSU)	MH671362	MH671369
<i>C. parviflora</i> (Kurz) Schindl.	<i>Sathaphorn & Leeratiwong 92</i> (PSU)	MH671363	MH671370
<i>C. pinetorum</i> (Kurz) Schindl.	<i>Sathaphorn & Leeratiwong 84</i> (PSU)	MH671364	MH671371
<i>C. sulcata</i> Schindl.	<i>Sathaphorn 75</i> (PSU)	MH671365	MH671372

4.3.2. Chloroplast markers

The region between *trnT* (UGU) and *trnF* (GAA) is located in transfer RNA sequences of chloroplast. Within this region, three non-coding regions are *trnT-trnL* intergenic spacer, *trnL* intron, and *trnL-trnF* intergenic spacer (Fig. 4.1). The result of the discovery demonstrates that the sequencing of intergenic spacers can be used to investigate the phylogenetic relationship between closely related species while *trnL* intron is probably less variable suitable for evolutionary studies at higher taxonomic levels (Kuhnel *et al.*, 1990; Taberlet *et al.*, 1991).

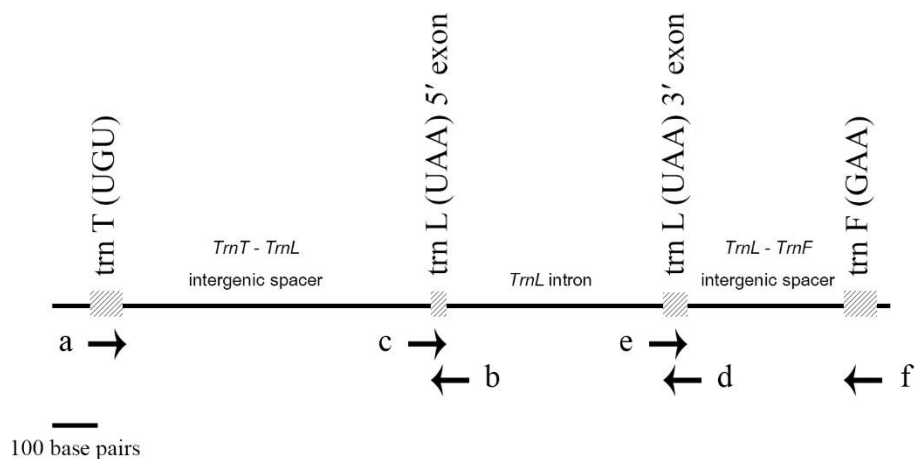


Figure 4.1 Sequence of *trnT-trnF* region and a-f indicated positions of primers based on Taberlet *et al.* (1991).

4.3.2. Amplification of chloroplast markers

Double-stranded DNA copies of two chloroplast markers, *trnL-trnF* intergenic spacer and *trnL* intron were amplified with universal primers (Taberlet *et al.*, 1991) (Table 4.2). The PCR mixture following manufacturer's instruction (One PCRTM, GeneDirex) were carried out in 50 μ l mixture, which contained 25 μ l OnePCRTM (containing *Taq* DNA polymerase, PCR Buffer, dNTP, gel loading dyes, and fluorescence dye), 1 μ l forward primer, 1 μ l reverse primer, 1 μ l DNA template, and

22 µl ddH₂O. All markers were amplified following the manufacturer's protocol on AllInOneCycler™ thermocycler (Bioneer, South Korea). The conditions for PCR were 2 min at 94°C for initial denaturation, followed by 30 cycles of 30 s at 94°C, 60 s at proper temperatures for each primer pair (58.5°C for *trnL-trnF* intergenic spacer and 60.5°C for *trnL* intron) (Table 4.2) for annealing, 2 min at 72°C for extension. After 30 cycle amplification, the final products were incubated at 72°C to complete the reaction. Sequencing reactions and analyses were performed with the MacroGen sequencing service (MacroGen, Korea).

Table 4.2 Sequences of the primers used for PCR amplification and sequencing.

Primers	Sequences (5'–3')	Direction	Amplified regions	Annealing temperature	References
e	GGTTCAAGTCCTCTATCCC	Forward	<i>trn L-trnF</i> intergenic spacer	58.5°C	Taberlet <i>et al.</i> , 1991
f	ATTGAACTGGTGACACGAG	Reverse	<i>trn L-trnF</i> intergenic spacer	58.5°C	Taberlet <i>et al.</i> , 1991
c	CGAAATCGGTAGACGCTACG	Forward	<i>trnL</i> intron	60.5°C	Taberlet <i>et al.</i> , 1991
d	GGGGATAGAGGGACTTGAAC	Reverse	<i>trnL</i> intron	60.5°C	Taberlet <i>et al.</i> , 1991

4.3.3. Sequence alignment and phylogenetic analyses

Sequences of the coding region *trnL-trnF* intergenic spacer and *trnL* intron of *Campylotropis*, *Lespedeza*, and *Kummerowia* were aligned using from PhyDE-1 version 0.9971 (Müller *et al.*, 2010). Phylogenetic analyses based on the maximum parsimony criterion were performed using PAUP* version 4.0b10 (Swofford, 2002) for two combined data sets. The probability values (P) greater than 0.05 were used to identify data sets. Insertions and deletions were treated as missing data. All characters were equally weighted and unordered (Fitch, 1971). All data sets were analysed by the heuristic search method with tree bisection-reconnection (TBR) branch swapping. Maximum Likelihood (ML) was analyzed using RAxML version 8.2.4 (Stamatakis, 2014) under the general time-reversible (GTR) nucleotide substitution model

supporting values for branches on the ML tree with 1000 bootstrap replicates in CIPRES Science Gateway (Miller *et al.*, 2010). Bootstrap percentages (BP) are described as high (85–100%), moderate (75–84%), low (50–74%), or no (<50%) support. Bayesian (BS) analysis was performed using MrBayes v.3.2.6. (Ronquist & Huelsenbeck, 2003) in the CIPRES Science Gateway v.3.3 (Miller *et al.*, 2010). Two runs using the Metropolis-coupled MCMC (Markov Chain Monte Carlo) algorithm, each with four random-initiated chains (one ‘cold’ and three ‘heated’) (Huelsenbeck *et al.*, 2001), involved 10 million generations and these were sampled every 1000 generations. The trees were summarised into a majority-rule consensus tree including the posterior probabilities (PP) as branch support estimates. Only more than PP values P 0.96 were considered as a strong support (Erixon *et al.*, 2003). Both Maximum Likelihood tree and Bayesian tree were edited using FigTree v.1.3.1. (Rambaut, 2009).

4.4. Results

A combined data matrix of two chloroplast regions, *trnL-trnF* intergenic spacer and *trnL* intron, composes of 881 characters after alignment. Individual sequences varied from 297 to 349 bp for *trnL-trnF* intergenic spacer region and from 531 to 532 bp for *trnL* intron. All sequences are deposited in Genbank (Table 4.1). From these three analyses of phylogenetic relationship, the parsimonious tree (Fig. 4.2) is congruent with Maximum Likelihood (Fig. 4.3), and Bayesian (Fig. 4.4) trees which trends to similar in relationship of generic and species. Maximum parsimony phylogram of combined data is preferred because of showing high supported and easily to discuss with previous parsimonious trees. One of most 194 parsimonious trees (tree length = 195, consistency index (CI) = 0.918, retention index (RI) = 0.802) from Maximum parsimony (MP) analysis is shown in Fig. 4.2 with bootstrap percentages. The tree shows the monophyletic relationship within subtribe Lespedezinae which was divided into two main sister clades (Clades A & B), *Lespedeza* with *Kummerowia* clade and *Campylotropis* clade. Clade A consists of genus *Lespedeza* in subclades A and B and nested *Kummerowia* in subclade C with 82% bootstrap support. Subclade A consists of representative Asian *Lespedeza* species while species in subclade B are American

species. Clade B contributes the genus *Campylotropis* in Thailand comprised subclades D and E with 93% bootstrap support. Subclade D consists of *C. bonii* and *C. parviflora* with 60% bootstrap support. Subclade E comprises 5 Thai *Campylotropis* species, *C. capillipes* subsp. *prainii*, *C. decora*, *C. harmsii*, *C. pinetorum*, and *C. sulcata* with 77% bootstrap support.

4.5. Discussion

4.5.1. DNA extraction

All flesh specimens kept in silica gel were sampled in procedure with 3 replications. Most *Campylotropis* leaves collected in Thailand contain lot of fibers and polysaccharide that may quantitatively affect nucleic acid isolation (Asif *et al.*, 2000; Japelaghi *et al.*, 2011). From the preliminary study, fresh specimens should be proceeded in extraction method after collecting from the field trips because several specimens that had been kept more than a year before taking out to proceed affecting to final yield values obtained from spectrophotometre.

4.5.2. Phylogenetic relationship within subtribe Lespedezinae

The results from Maximum parsimony, Maximum likelihood, and Bayesians analyses demonstrate that phylogenetic relationship of *Campylotropis*, *Kummerowia*, and *Lespedeza*, within subtribe Lespedezinae, is monophyly. *Campylotropis* clade is similarly shown to be a sister group to two *Lespedeza* clades and *Kummerowia* in all analyses which *Lespedeza* clades show closer position to *Kummerowia* clade than *Campylotropis* clade. This position of the genus *Campylotropis* can be used to confirm several previous studies (Nemoto *et al.*, 1995; Stefanović *et al.*, 2009; Han *et al.*, 2010; Nemoto *et al.*, 2010; Xu *et al.*, 2012; Jabbour *et al.*, 2018). However, these three phylogenetic trees using ITS causes paraphyletic relationship in subtribe (not shown) and also supports by the result from Han *et al.* (2010).

According to sister relationship of *Kummerowia* and *Lespedeza* within Clade A, the results suggest that the genus *Kummerowia* should be treated under the genus *Lespedeza* rather than a distinct genus. Comparing to those *Campylotropis* clades (Clade A with subclades D & E), these two sister subclades are grouped within the same genus. This proposal can be morphologically implied based on the presence of nectary glands which show in *Lespedeza* and *Kummerowia* but not in *Campylotropis*. Furthermore, the inflorescence types in *Lespedeza* and *Kummerowia* are diagnosed as pseudoraceme while in *Campylotropis* exhibits a reduced form of pseudoraceme that resembles to those simple racemes (Nemoto *et al.*, 1996). Consequently, the number of taxa represented in this study is slightly diminutive to recircumscribe the phylogenetic relationship within subtribe Lespedezinae. In further study, more taxa of these three genera should be added phylogenetic trees to be absolutely certain that *Kummerowia* will be accommodated under the genus *Lespedeza*.

4.5.2. Phylogenetic reconstruction of *Campylotropis* in Thailand

From the phylogenetic relationship of *Campylotropis* of these three analyses, separation of subclades D (*C. bonii* and *C. parviflora*) and E (*C. capillipes* subsp. *prainii*, *C. decora*, *C. harmsii*, *C. pinetorum*, and *C. sulcata*) are morphologically supported by the colour of calyx which are green and red, respectively (Sattaphorn *et al.*, 2018). Members in subclade D can be roughly recognised as “lower altitude group” widely established in wide ranges in lower elevation. Subclade E or “higher altitude group” usually found at the summits occasionally in lower altitudes. However, the creamy to pinkish white corolla groups of *C. parviflora* and *C. pinetorum* are separated in different subclades in all analyses. This phenomenon exhibits evidence of homoplasy within Thai *Campylotropis* species. This phylogenetic reconstruction of the genus *Campylotropis* in Thailand is the first partition to study the relationship of the whole genus. However, the recent results may be difficult to create several groups referred to other evidences. To complete the phylogenetic relationship of the genus, all species are still needed to be included into phylogram for further grouping and discussions.

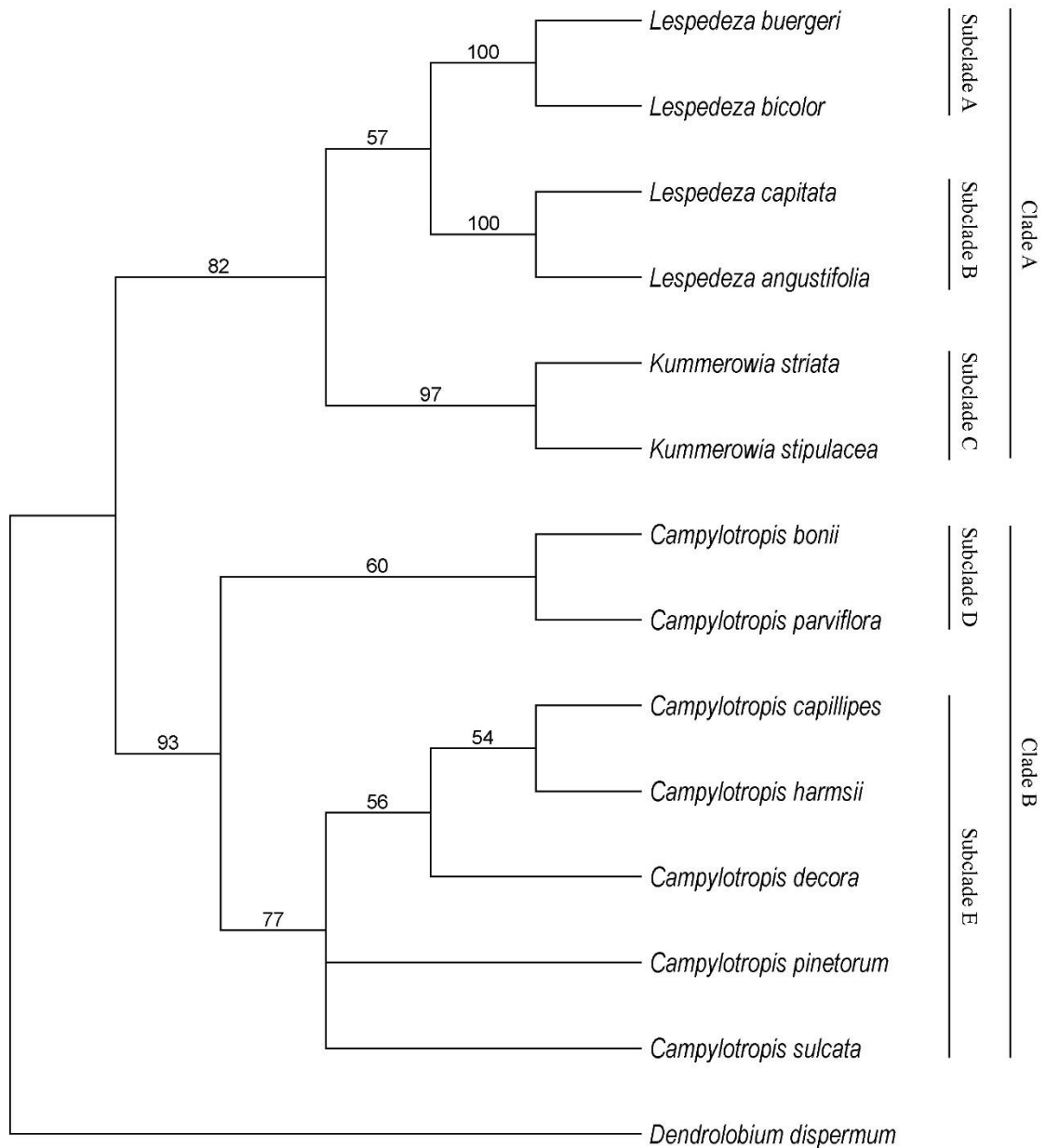


Figure 4.2 One of 194 most parsimonious trees from Maximum Parsimony (MP) analysis of combined *trnL-trnF* intergenic spacer and *trnL* intron datasets (1000 random addition replicates, tree-bisection-reconnection (TBR) branch swapping). Bootstrap (BS) values indicate above branches and the numbers of clade indicate at right.

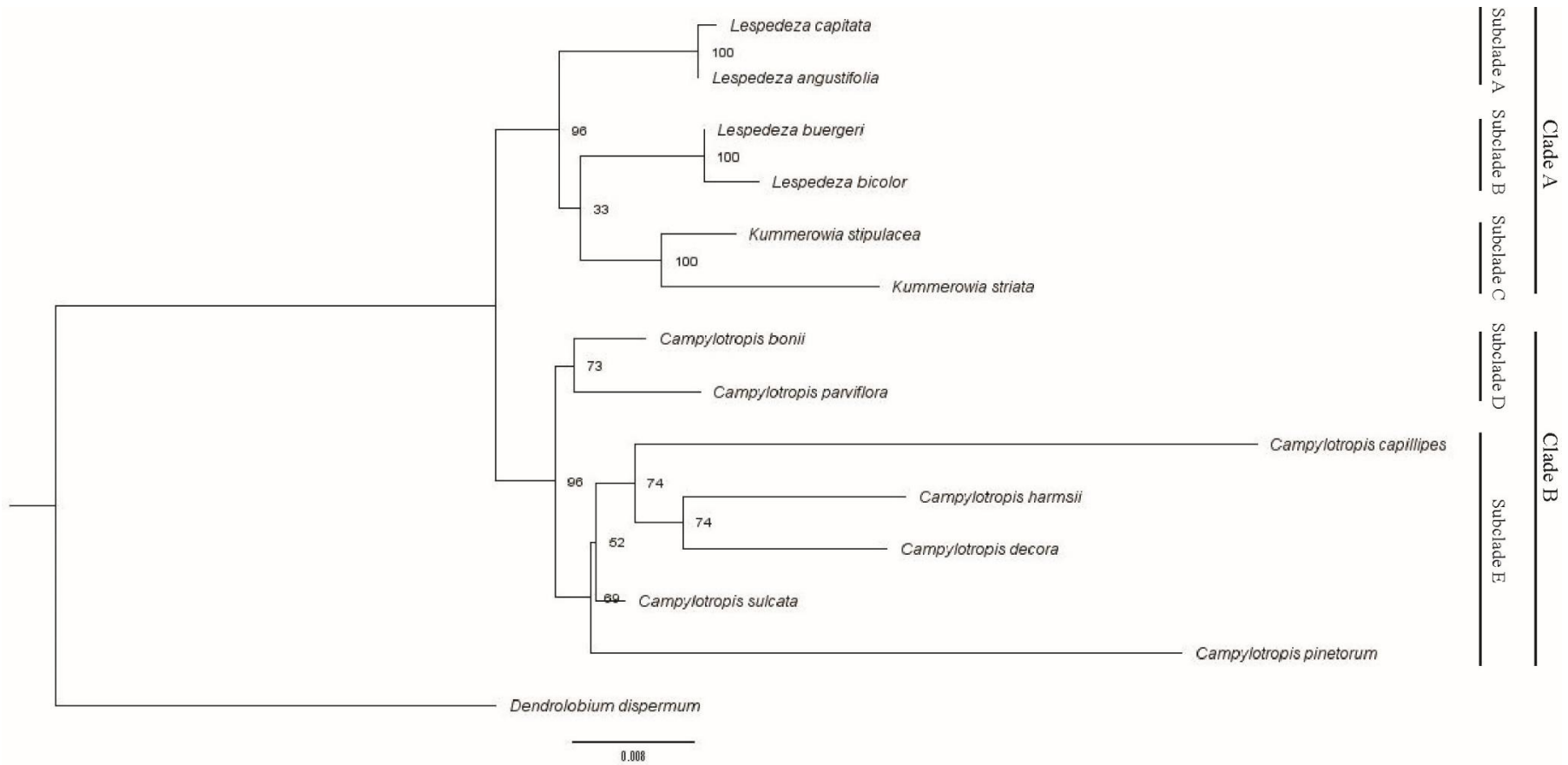


Figure 4.3 The strict consensus tree derived from Maximum Likelihood (ML) analysis of combined *trnL-trnF* intergenic spacer and *trnL* intron datasets. Bootstraps percentages are shown on branches. Nucleotide substitution rates indicated below the tree.

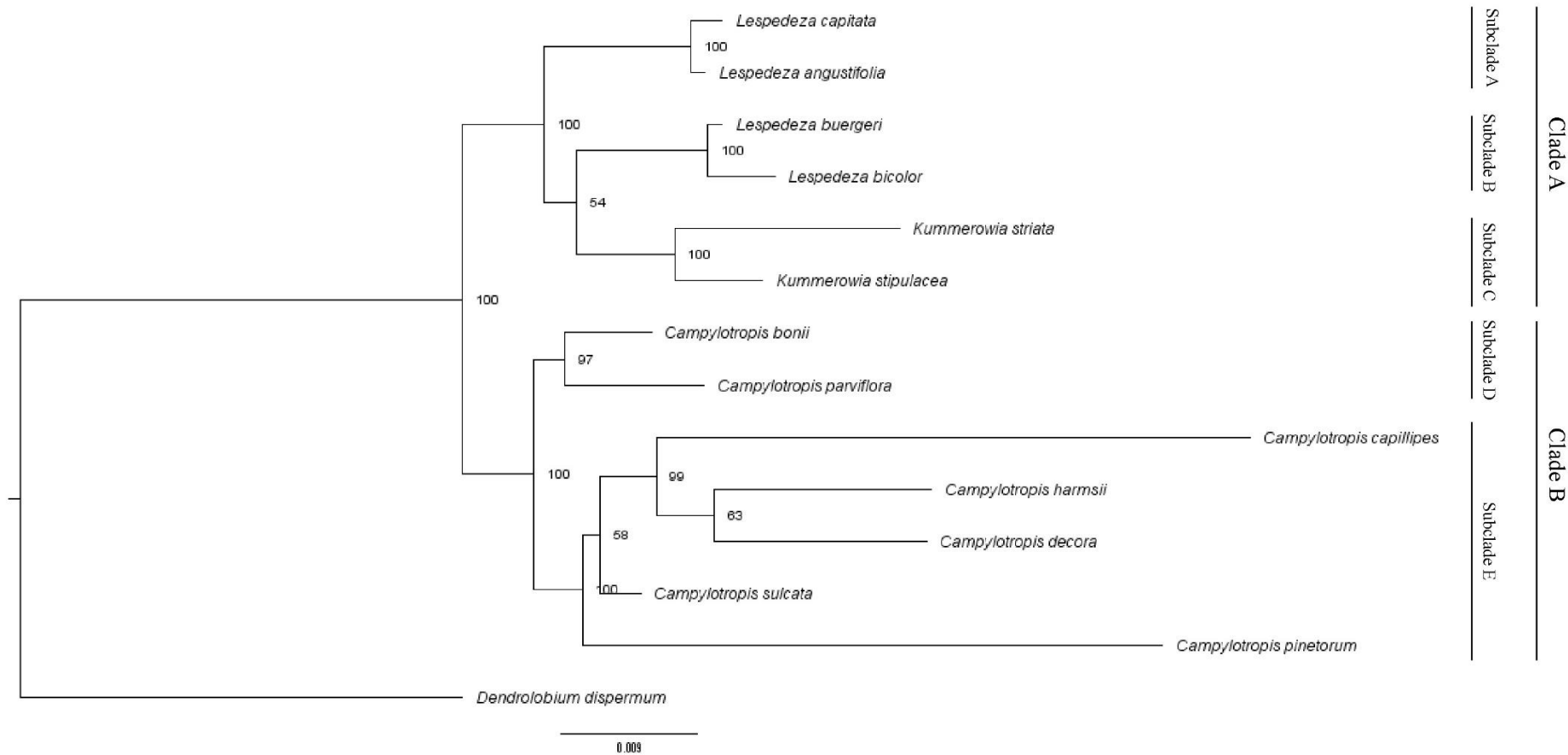


Figure 4.4 The strict consensus Bayesian analysis (BS) of combined *trnL-trnF* intergenic spacer and *trnL* intron datasets. Numbers above branches indicate posterior probabilities (PP) value.

CHAPTER 5

SUMMARY

5.1. Diversity of the genus *Campylotropis* in Thailand

The completed revision of *Campylotropis* is provided in this study. Seven species and one subspecies are recognised for Thailand, namely *C. bonii* Schindl., *C. capillipes* (Franch.) Schindl. subsp. *prainii* (Collett & Hemsl.) Iokawa & H. Ohashi, *C. decora* (Kurz) Schindl., *C. harmsii* Schindl., *C. parviflora* (Kurz) Schindl., *C. pinetorum* (Kurz) Schindl., and *C. sulcata* Schindl. Based on phytogeography of Thailand, *Campylotropis* species establish in 5 Thai floristic regions which are northern, north-eastern, eastern, south-western, and peninsular Thailand. Six species can be found in northern, 2 species in north-eastern, 2 species in eastern, 1 species in south-western, and 1 species in peninsular Thailand.

5.2. Species circumscription of the genus *Campylotropis* in Thailand

The investigations on morphology of both qualitative and quantitative of Thai *Campylotropis* can be concluded that the greatest taxonomic value for separating species are types of hairs on stems, leaves, and inflorescences because these characters are significantly different to other species. Other good characters are recognised as lower taxonomic value using to group some species; for instance, the colour of calyx and collora, the length of pedicels, and the shape of leaflets. The varieties of morphological characters have been investigated in this work. Most of them are contributed quantitatively on the leaves and floral features.

Studying on pollen morphology of 13 samples of 7 Thai *Campylotropis* species by using light microscope and scanning electron microscope, pollen morphology of *Campylotropis* in Thailand can be characterised by monad, isopolar, radially

symmetric, and tricolporate aperture. Size, shape, and ornamentation are the most informative characters to group some species and generic delimitation. However, some Thai *Campylotropis* species are difficult to distinguish based on pollen morphology, although slight differences are observed.

The molecular analysis of the genus *Campylotropis*, two related genera and an outgroup is conducted on combined data of *trnL-trnF* intergenic spacer and *trnL* intron of chloroplast DNA. The phylogenetic analysis supports the monophyly of the current circumscribed *Campylotropis* species and two related genera. Moreover, interpretation of two clades from *Campylotropis* in Thailand is in agreement with the colour of calyx with strongly supported while homoplasy in colour of corolla is observed.

From all results, these three evidences can be concluded that morphology is the most suitable evidence to clearly recognised the members of the genus *Campylotropis* in Thailand. Evidences from palynological and molecular studies are still needed to confirm the differences between species and to decrease biases for the investigation on morphology that depends on the vision of conductor. These two evidences can also be used to group some species. In studying taxonomy of this genus in wider area and more taxa, these two evidences may be useful to solve the problems of the complexity from morphological characters.

5.4. Future study

This study presented in this thesis provides the understanding of the morphology, palynology, and molecular information including some aspects in evolution of the genus *Campylotropis* in Thailand. Although these morphological, palynological, and molecular studies of this genus have been covered and strongly supported in this thesis but these evidences at species level of some species from other countries are still problematic. To complete taxonomy of the genus *Campylotropis* in monography scale, adding more taxa sampling is required for further investigation in morphology, palynology, and molecular studies. Other techniques should be also

included in further studies, such as cytological or population genetic studies to possibly clarify the taxonomic relationship or complexity of the genus and provide an improved delimitation of some variable taxa. In addition, chemical compounds in members of the genus in Thailand have never been studied; however, from the literature review, some species from outside Thailand contain chemical compounds used for various purposes. To adopt this study to Thai taxa, the chemotaxonomy of these plant might generate a new tool to improve the classification and provide essential information on plant biochemical compound that may be able to be commercially or medically important for human in the future.

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- Calsberg Foundation for the Flora of Thailand
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