REVISION OF *CODONOBOEA* SECT. *BOEOPSIS* AND SECT. *SALICINI* (GESNERIACEAE) IN PENINSULAR MALAYSIA

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REVISION OF *CODONOBOEA* SECT. *BOEOPSIS* AND SECT. *SALICINI* (GESNERIACEAE) IN PENINSULAR MALAYSIA

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ABSTRACT

Peninsular Malaysia is the centre of diversity of the genus *Codonoboea* Ridl. with 74 species recorded. In this study, species from sect. *Boeopsis* (11 spp.) and sect. *Salicini* (4 spp.) are studied. There are four objectives in this study, namely to provide detailed descriptions of species and a key to species of both sect. *Boeopsis* and sect. *Salicini*. Secondly, to produce distribution maps and assess conservation status of the species. Then thirdly, to determine whether all species with pollen flowers in *Codonoboea* are monophyletic using morphology and molecular phylogenetic data. And fourth and lastly, to determine the trend of evolution of the pollen flower from the nectar flower in *Codonoboea*.

In this study, 15 species, including a new species, *Codonoboea oreophila*, are recognised. A key to all species is prepared for species identification. Detailed species description, nomenclature, geographical distribution, habitat and ecology of the species are provided, as well as a full list of specimens examined.

Both sections were grouped due to the short corolla tube and other characters, i.e. rosette habit in sect. *Boeopsis* and narrow leaves in sect. *Salicini.* There are seven corolla shapes among the species. Informative morphological characters, such as corolla shape and colour, stamens and anther shape, are found to be useful for species identification.

Molecular phylogenetic study based on *trnL-F* intron spacer and Internal Transcribed Spacer (ITS) markers was carried out using two *Boea* and four *Microchirita* species as outgroup and 38 samples of *Codonoboea* (14 from species in this study) as ingroup. The data are analysed using Bayesian Inference and Maximum Parsimony methods.

Fourteen of the 15 species are endemic in Peninsular Malaysia. Most species are found on the east coast of Peninsular Malaysia, which is determined as the centre of species diversity. Five species fall within threatened categories when conservation status for all species was assessed.

To answer the trend of pollen and nectar flower evolution in *Codonoboea*, morphological characters were mapped on molecular phylogenetic trees. The result showed conclusively that both *Boeopsis* and *Salicini* sections are not monophyletic and morphological characters of *Codonoboea* are very plastic. The evolution of corolla shapes could be due to adaptation to pollinator, which is *Trigona* bees.

ABSTRAK

Semenanjung Malaysia adalah pusat kepelbagaian genus *Codonoboea* Ridl. dengan 74 spesies telah direkodkan. Dalam kajian ini, spesies dari seksyen *Boeopsis* (11 spp.) dan seksyen *Salicini* (4 spp.) telah dikaji. Terdapat empat objektif dalam kajian ini, iaitu menjalankan kajian taksonomi terperinci terhadap spesies kedua-dua seksyen. Kedua, untuk menghasilkan peta taburan dan menilai status pemuliharaan spesies. Seterusnya, untuk menentukan sama ada semua bunga debunga di *Codonoboea* adalah monofiletik berdasarkan data morfologi dan data filogenetik molekul. Akhir sekali, untuk menentukan sama ada arah evolusi bunga debunga dari bunga madu di *Codonoboea*.

Dalam kajian ini, 15 spesies, termasuk spesies yang baru, *Codonoboea oreophila* dikaji. Satu kekunci kepada semua spesies disediakan untuk mengenal pasti spesies. Huraian terperinci spesies, tatanama, taburan geografi, habitat dan ekologi spesies disediakan, serta senarai penuh spesimen yang telah diperiksa juga disediakan.

Spesies-spesies digolongkan dalam kedua-dua seksyen berdasarkan cirri-ciri tiub korola yang pendek dan juga ciri-ciri lain, seperti tabiat roset dalam seksyen *Boeopsis* dan daun yang tirus dalam seksyen *Salicini*. Terdapat tujuh bentuk korola di kalangan spesies kajian. Ciri morfologi seperti bentuk dan warna korola serta bentuk stamen dan anter didapati berguna untuk mengenal pasti spesies.

Kajian filogenetik molekul berdasarkan '*trnL-F* intron spacer' dan 'Internal Transcribed Spacer' (ITS) telah dijalankan dengan menggunakan dua spesies *Boea* dan empat *Microchirita* sebagai '*out-group'* dan 38 (14 sampel dari spesies dalam kajian ini) sampel *Codonoboea* sebagai '*in-group*'. Data yang dianalisis menggunakan '*Bayesian Inference'* dan kaedah '*Maximum Parsimony'*.

Empat belas daripada 15 spesies adalah endemik di Semenanjung Malaysia. Pantai timur Semenanjung Malaysia merupakan pusat kepelbagaian spesies di mana kebanyakan spesies terdapat di kawasan tersebut. Lima spesies termasuk dalam kategori terancam apabila status pemuliharaan ke semua spesies telah dinilai.

Untuk mengetahui trend evolusi bunga debunga dan bunga madu dalam *Codonoboea*, ciri-ciri morfologi telah dipetakan atas pokok filogenetik molekul. Hasil kajian menunjukkan secara yakin bahawa kedua-dua seksyen *Boeopsis* dan *Salicini* bukan monofiletik dan morfologi *Codonoboea* sangat plastik. Evolusi bentuk korola mungkin disebabkan oleh adaptasi kepada pendebunga, iaitu lebah *Trigona*.

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Symbol and Abbreviation	**Word**
%	percent
^{o}C	degree Celsius
>	greater than
<	lesser than
alt.	altitude
AOO	area of occupancy
BI	Bayesian inference
BKF	Herbarium, Royal Forest Department, Bangkok, Thailand
Bkt.	*Bukit*, hill
BM	Herbarium, Natural History Museum, London, UK
bp	base pair
BS	Bootstrap
C	Centre
c.	circa, about
CI	Consistency Index
cm	centimeter
cpDNA	chloroplast DNA
CTAB	hexadecyltrimethylammonium bromide
DNA	deoxyribonucleic acid
E	Herbarium, Royal Botanic Garden, Edinburgh, UK
e.g.	*exempli gratia*, for example
EOO	extent of occurrence
et al.	*et alii*, and others
etc.	*et cetera*, and the rest
f.	*filius*, the son
fig.	figure
FR	Forest Reserve
G.	*Gunung*, mountain
HI	Homoplasy Index
i.e.	*id est*, that is
ITS	internal transcribed spacer
IUCN	International Union for Conservation of Nature
K	Herbarium, Royal Botanic Garden, Kew, UK
KBG	Kepong Botanical Garden
KEP	Herbarium, Forest Research Institute Malaysia, Selangor, Malaysia
KLU	Herbarium, University Malaya, Kuala Lumpur, Malaysia
L	Herbarium, Nederland National Herbarium, Leiden University Branch, the Nederlands
MCMC	Markov Chain Monte Carlo
Min	minute
µl	microlitre
m	meter

mm	millimeter
mM	micromole
MP	Maximum parsimony; most parsimonious
n.a.	not available
NE	North East
no.	number
NP	National Park
nrDNA	nuclear ribosomal DNA
P.	*Pulau*, island
PCR	polymerase chain reaction
pers. comm.	personal communication
PP	Posterior probability
RBGE	Royal Botanic Garden Edinburgh, UK
RC	Rescaled consistency index
rDNA	ribosomal deoxyribonucleic acid
RI	Retention index
S	South
SAN	Herbarium, Sabah Forestry Department, Sabah, Malaysia
SAR	Herbarium, Sarawak Forestry Department, Sarawak, Malaysia
s.l.	*sensu lato*, in the wider sense
s.n.	*sensu numero*, without number
s.s.	*sensu stricto*, in the narrow sense
sec	second
SEM	scanning electron microscopy
Sg.	*Sungai*, river
SING	Herbarium, Singapore Botanic Garden, Singapore
SP	State Park
sp.	species, singular
spp.	species, plural
SW	south west
TBR	tree bisection-reconnection
TPA	Totally Protected Area
UKMB	Herbarium, Universiti Kebangsaan Malaysia, Bangi, Malaysia
var.	variety

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 General introduction

Gesneriaceae Rich. & Juss. *ex* DC., the African violet family, is a diverse family with 139 genera and *c*. 2900 species worldwide (Mabberley, 2008). The family is widely distributed mostly in the sub- and tropical forest in the Old and New World (Weber, 2004). Elevation of the species distributions ranges from sea level to high alpine areas in the Himalayas (Brummitt, 2007).

Following descriptions in Weber (2004) and Brummitt (2007), habits of Gesneriaceae are herb, shrub, climber, epiphyte and rarely tree. The leaves are usually oppositely arranged, but sometimes in whorls, near-distichous or spiral-alternate. Stipule is lacking in the species. Inflorescence of Gesneriaceae is specialised by pair-flowered cymes, or reduced to a single flower. The flowers are usually showy, 5- (rarely 4-) merous; the corollas are zygomorphic to rarely actinomorphic; the fertile stamens are usually 2 or 4 and rarely 5 (in actinomorphic flower). The ovary is single locular and consists of 2 fused carpels with lateral, T-shaped placentation; stigma ranges from capitate, bilabiate to bifid. While the fruits are berry or capsule with numerous seeds.

The family is subdivided into three subfamilies, namely Coronantheroideae, Gesnerioideae and Didymocarpoideae (Brummitt, 2007). Coronantheroideae is mostly distributed in Australasia region, while Gesnerioideae and Didymocarpoideae in New World and Old World. The genus *Codonoboea* Ridl. belongs to subfamily Didymocarpoideae, together with *Aeschynanthus*, *Didymocarpus* and *Ridleyandra* etc (Brummitt, 2007). The group is mainly found in paleotropical region of the world, including mainland Asia, Malesia, The Pacific, Africa (nine genera) and as far as Europe (three genera).

Codonoboea is distributed from Thailand, Sumatra, Peninsular Malaysia, Borneo, the Philippines, Sulawesi and New Guinea. Peninsular Malaysia, with 74 species is the place with highest number of species (Kiew & Lim, 2011). It is the largest herbaceous plant genus dwelling at the forest floor in the Peninsular Malaysia forest.

Codonoboea is a very diverse herbaceous genus. In Peninsular Malaysia, habits of the genus range from creeping, rosette to erect herb; the leaf arrangement is either alternate or opposite. To facilitate the classification, species in Peninsular Malaysia are classified into 10 sections established by various authors (Weber & Burtt, 1998).

The most common flower type of the *Codonoboea* is nectar flowers, which is characterized by long, funnel-shaped corolla tube, well-developed nectary that provides nectar as reward to the pollinator. Often, nectar guides at the base of the corolla tube are present. On the other hand, plant with pollen flower in *Codonoboea* is represented by species from section *Boeopsis* and *Salicini*. Key characters to tell pollen flower apart from nectar flower is the relatively short corolla tube, larger and more showy anthers, much reduced nectary and the absent or faint nectar guides. Reward for the pollinator is the pollen.

1.2 Problem statements

What is the current number of species in section *Boeopsis* and *Salicini*? Any new species to be described? Are there any up-to-date complete taxonomical study of all species in both sections? What is the conservation status and distribution range of all the species? Evolution of flower type in *Codonoboea* is unknown. Which flower type is the more plesiomorphic and which is the derived one? Does the flower type evolve once or several times in the history of *Codonoboea*?

1.3 Objectives

The objectives of this study are:

(a) Provide detailed description of species as well as a taxonomic key to species.

(b) Produce distribution map and assess conservation status of the species.

(c) Determine whether all speices with pollen flowers in *Codonoboea* are monophyletic.

(d) Determine whether molecular data can shed light on evolution of pollen flower in *Codonoboea*.

2.0 LITERATURE REVIEW

2.1 Taxonomy

2.1.1 Genus *Codonoboea*

Codonoboea species were first included in *Didymocarpus* (Clarke, 1883; Ridley, 1905, 1908b, 1923). The taxonomic history of *Didymocarpus* Wall. was summarised by Burtt (1998). *Codonoboea* Ridl. was described as a genus by Ridley (1923), but later redefined as a section within *Didymocarpus* (Kiew, 1990).

Weber & Burtt (1983, 1998) redefined *Didymocarpus* as a genus with orthotropic fruits that split on both sides. The establishment of *Didymocarpus* excluded species with plagiotropic fruits that split only adaxially, which were transferred to *Henckelia* Sprengl. by Weber & Burtt (1998) and Burtt (1998), who made new combinations. Therefore, majority of *Didymocarpus* species in Ridley (1923) were transferred to *Henckelia*.

Evidence from molecular phylogenetic data (Moeller *et al.* 2009), showed conclusively that the Malesian and Indian-Sri Lanka *Henckelia sensu* Weber & Burtt is not monophyletic and Weber *et al.* (2011) redefined *Henckelia* which is now confined to taxa from Sri Lanka, S and NE India, Nepal, Bhutan, Southern China, Northern Vietnam, Northern Laos and Northern Thailand. To accommodate the Peninsular Malaysia species, Kiew & Lim (2011) made combination for the 74 Peninsular Malaysian species.

2.1.2 Sections in *Codonoboea*

To deal with such a large genus with about 180 species (Weber 2004; Mabberley 2008), several authors have tried to group the species into sections (Bentham 1876; Ridley 1896, 1905, 1923; Kiew 1990, 1995; Weber & Burtt 1998). Among them, nine sections have been recognised in Peninsular Malaysia (Weber & Burtt, 1998) (Table 2.1).

Kiew & Lim (2011) did not assign any sections when Malesian *Henckelia* species were transferred to *Codonoboea*.

Table 2.1. Sections in *Codonoboea* (from Weber & Burtt, 1998).

Section	Publication	Salient characters
Boeopsis	Ridley. 1907. J. Roy. As. Soc. Str. Br. 49: 22; Kiew. 1992. Gard. Bull. Sing. 44: 39.	Small campanulate corolla, leaves arranged in a rosette
Codonoboea	Kiew. 1990. Blumea 35: 167.	Epiphyllous flowers
Didymanthus	Clarke. 1883. Monogr. Phan.5 (1): 87, tab. 10.	Erect stem, opposite and well-spaced leaves
Glossadenia	Weber & Burtt. 1998. Beitr. Biol. Pflanzen 70: 335	Unilateral and ventral nectary
Heteroboea	Bentham. 1876. Genera Plantarum 2: 1022.	Alternate leaves, winged petiole
Pectinati	Ridley. 1923. Flora of Malay Peninsula 2: 508.	Serrate to deeply toothed lamina
Reptantes	Ridley. 1905. J. Str. Br. Roy as soc 44: 29.	Creeping stem, opposite and well-spaced leaves
Salicini	Ridley. 1896. J. Linn. Soc. Bot. 32: 514; Kiew. 1992. Gard. Bull. Sing. 44: 41.	Small campanulate corolla, narrow lamina
Venusti	Kiew. 1995. Malayan Nature Journal 48: 203.	Foliaceous, conspicuous bracts

2.1.2.1 Taxonomic history of section *Boeopsis*

Ridley first described section *Boeopsis* in 1907 and defined the section as '…small species with short corolla tube and two short stamens with thick sigmoid filaments and subglobose or elliptic anthers…'. He transferred several species from section *Acaules* such as *C. heterophylla* and *C. puncticulata* into the section. This section is a natural group characterized by both in reproductive (small corolla flowers) and vegetative (rosette plant with crowded leaves) characters.

In Flora of Malay Peninsula, Ridley (1923) defined section *Boeopsis* as plants with '…leaves crowded in a tuft at the top of a woody root stock, peduncle slender, flowers usually small…'. However, he expanded the concept of section by including *C.*

grandifolia (Ridl.) Kiew, *C. longipes* (C.B.Clarke) Kiew, *C. primulina* (Ridl.) Kiew, *C. pumila* and *C. soldanella* (Ridl.) C.L.Lim. With the addition of these species, the section became an unnatural group, for instance, *C. grandifolia*, *C. longipes* and *C. primulina* have long tubular corollas and furthermore, *C. longipes* and *C. primulina* have yellowish corollas in contrast with purplish in other species in the section.

In compiling a list of sections, Burtt (1954) lectotypified *Codonoboea longipes* as lectotype for section *Boeopsis* based on Ridley's flora account in 1923. The diagnostic characters given were '…leaves crowded in a tuft at the top of a woody root stock; peduncles slender; flower usually small…'. Kiew (1992) pointed out that it was an error because Burtt did not realise that Ridley (1907) did not include *C. longipes* in the original publication.

In 1992, Kiew proposed to resurrect section *Boeopsis* following its original definition in Ridley (1907) with the diagnostic characters of the section as the small rosette habit, purple campanulate flowers and a short capsule. *Codonoboea puncticulata* was chosen as lectotype to the section. Therefore, *C. longipes*, *C. primulina* and *C. grandifolia* were excluded from the section. Also, Kiew (1992) included Ridley's concept *Paraboea* by adding species formerly from *Paraboea* section *Campanulati*, i.e. *C. floribunda* (M.R.Hend.) C.L.Lim and *C. rubiginosa* (Ridl.) C.L.Lim.

In addition, Kiew (1992) included *C. anthonyi* (Kiew) C.L.Lim, *C. codonion* (Kiew) C.L.Lim, *C. leiophylla* (Kiew) C.L.Lim, *C. yongii* (Kiew) C.L.Lim and a new species from Kelantan. List of species in section *Boeopsis* is shown in Table 2.2.

2.1.2.2 Taxonomic history of section *Salicini*

Section *Salicini* was first described by Ridley (1896). He defined the section as '…small, short flowered species with willow leaves crowded at top of a short woody stem…'. Three species were listed under the section, namely *C. salicina* (Ridl.) C.L.Lim, *C. pectinata* (Oliv.) Kiew and an unknown sterile species. Ridley (1905) later described the unknown species as *C. densifolia* (Ridl.) C.L.Lim. In the same paper, Ridley added *C. serratifolia* (Ridl.) Kiew to section *Salicini*.

Instead of retaining *C. salicina* in section *Salicini*, Ridley (1923) transferred the species to *Paraboea* section *Campanulati*, which became a mixture (see section 2.1.2.1). Meanwhile, the other species, i.e., *C. densifolia*, *C. pectinata* and *C. serratifolia* from section *Salicini* were transferred to section *Pectinati*. However, Ridley (1923) re-defined section *Pectinati* to include species with distinctly deeply serrate or pectinate leaf margins and white tubular flowers. Therefore, Kiew (1987) excluded *C. densifolia*, which has entire leaf margin, from the section *Pectinati*.

Burtt (1971) resurrected sect. *Salicini* and selected *C. salicina* as lectotype. Also, he excluded *Didymocarpus cordatus* A.DC. and *C. grandifolia* (formally in *Paraboea* section *Campanulati*) from section *Salicini*. However, only *C. densifolia* and *C. salicina* conform to the original description of section *Salicini*. *Codonoboea holttumii* (M.R.Hend.) C.L.Lim with yellow flowers was excluded because flower colour of species in section *Salicini* is pink, purple or bluish-purple (Kiew, 1992).

Kiew (1987, 1992) suggested that section *Salicini* be restricted to the original sense, for species with willow-shaped leaves and small campanulate flowers. Therefore, four species, namely *C. densifolia*, *C. salicina*, *C. salicinoides* (Kiew) C.L.Lim and *C. tiumanica* (Ridl.) C.L.Lim were included in section *Salicini*. List of species in section *Salicini* is shown in Table 2.2.

Table 2.2. List of species, current name, basionym and protologue of Peninsular Malaysian species in sect. *Boeopsis* and sect. *Salicini*.

Current name	Basionym	Protologue
Section *Boeopsis*		
C. anthonyi (Kiew) C.L.Lim	*D. anthonyi* Kiew	Gard. Bull. Singapore 44: 24 (1992)
C. codonion (Kiew) C.L.Lim	*D. codonion* Kiew	Gard. Bull. Singapore 42: 49 (1989)
C. floribunda (M.R. Hend.) C.L.Lim	*P. floribunda* M.R.Hend.	Gard. Bull. Straits Settl. 7: 117 (1933)
C. heterophylla (Ridl.) C.L.Lim	*D. heterophyllus* Ridl.	Trans. Linn. Soc. London, Bot. (ser. 2) 3: 329 (1893)
C. leiophylla (Kiew) C.L.Lim	*D. leiophyllus* Kiew	Gard. Bull. Singapore 44: 28 (1992)
C. oreophylla Kiew *ex*. C.L.Lim		Blumea (in press)
C. pumila (Ridl.) C.L.Lim	*D. pumilus* Ridl.	J. Straits Br. Roy. Asiat. Soc. 44: 56 (1905)
C. puncticulata (Ridl.) C.L.Lim	*D. puncticulatus* Ridl.	J. Linn. Soc. 32: 510 (1896)
C. rubiginosa (Ridl.) C.L.Lim	*P. rubiginosa* Ridl.	J. Linn. Soc. 38: 319 (1908)
C. soldanella (Ridl.) C.L.Lim	*D. soldanellus* Ridl.	J. Straits Branch Roy. Asiat. Soc. 61: 33 (1912)
C. yongii (Kiew) C.L.Lim	*D. yongii* Kiew	Gard. Bull. Singapore 42: 62 (1989)
Section *Salicini*		
C. densifolia (Ridl.) C.L.Lim	*D. densifolius* Ridl.	J. Straits Branch Roy. Asiat. Soc. 44: 51 (1905)
C. salicinoides (Kiew) C.L.Lim	*D. salicinoides* Kiew	Gard. Bull. Singapore 44: 35 (1992)
C. salicina (Ridl.) C.L.Lim	*D. salicinus* Ridl.	Trans. Linn. Soc. London, Bot. (ser. 2) 3: 329 (1893)
C. tiumanica (Ridl.) C.L.Lim	*P. tiumanica* Burkill *ex* Ridl.	Fl. Mal. Penins. 2 : 530 (1923)

Note: *C. = Codonoboea, D. = Didymocarpus, P. = Paraboea*.

3.0 MORPHOLOGY

3.1 Introduction

Important characters that distinguish *Codonoboea* from the other Didymocarpoid genera in Peninsular Malaysia are the number of stamens and fruit characters (Weber *et al.*, 2011, Kiew & Lim, 2011). When *Codonoboea* was resurrected, these characters were used in the key to differentiate *Codonoboea* from other morphologically similar genera.

Morphological characters were also used in defining sections in *Codonoboea* (Kiew, 1987, 1990, 1992, 1995; Ridley 1896, 1905, 1907, 1923, Weber & Burtt, 1998) as shown in Table 2.1. Various parts are used to define the sections, such as leaf margin (section *Pectinati*, Ridley, 1923; Kiew, 1987), creeping habit (sect. *Reptantes*, Ridley 1905, 1923), presence of unilateral, ventral nectary (sect. *Glossadenia*, Weber & Burtt, 1998).

In the key to identify species (part 4.3.2), morphological characters that are easily observed on herbarium sheets are used. The present morphological study was mostly based on both herbarium and living materials.

3.2 Materials and Methods

The morphological study is based on specimens from herbarium materials, living materials, spirit collections and photographs as mentioned in Chapter 4. However, flowers are often not preserved well in the herbarium materials, thus living plants are important.

Quantitative and qualitative characters of both the vegetative and reproductive parts of each species were obtained from species descriptions (part 4.2.4). Measurements of morphological characters as well as qualitative descriptions of the specimens were made from live plants, herbarium specimens, spirit specimens and photographs.

The data of each specimen were tabulated in both Delta and BRAHMS softwares (part 4.2.4.).

3.3 Results:

3.3.1 Habit and stem

Stems of all the species studied are woody and often stout, which concur with the findings in Kiew (2009) that all *Codonoboea* species are long-lived and continuously growing. When the stems grow, leaves are produced continuously from the stem apex. Therefore, the old stems are often seen with many knobbly leaf scars.

The characteristics of stems determine the habit of the plant. Species from sect. *Boeopsis* are rosette plants on the forest floor or on earth banks. The rosette form is easily observed when the plant is young. However, as the plant grows, the lower part of the stem is often decumbent while the upper part remains erect, holding a tuft of leaves above ground level.

Codonoboea anthonyi is a robust erect herb with a stem to 40 cm tall. *Codonoboea codonion*, *C. floribunda* and *C. salicinoides* are less robust but can grow up to 30 cm tall. *Codonoboea heterophylla*, *C. soldanella* and *C. yongii* are always rosette herbs that grow up to 10 cm tall, with a very short and compact stem.

Codonoboea oreophila and *C. pumila* are usually rosette plants but occasionally produce long side branches that more or less creep on the ground. The same habit is seen in *C. puncticulata*, where the majority of specimens are rosette plants while some individuals have a creeping habit (discussed in part 4.3.2). Stems of the rheophytic species, such as *C. densifolia*, *C. salicina* and *C. tiumanica*, are wiry and pliable. Stems of these species are long, those of *C. densifolia* and *C. salicina* reaching 34–42 cm long.

3.3.2 Leaves

3.3.2.1 Arrangement

All the species have opposite leaves that are often decussate on the lower part of the stem. Due to compactness of leaves at the stem apex, leaf arrangement for some species is difficult to observe. However, leaf arrangement can be seen from the leaf scars on stem and the leaves on the lower part of the stem.

3.3.2.2 Petioles

In rosette species, young leaves at the top of the rosette are almost sessile while those that are older, lower leaves gradually become longer. For species growing on vertical earth bank, the petiole length in a pair of leaf are often very different, e.g. *Codonoboea tiumanica*, where petiole length of the leaf hanging down can be two to three times longer than the upper leaf.

Angle between petiole and the main axis of the stem determines the vertical position of the leaves. Most species with rosette leaves have leaves almost lying on the ground and the petioles are almost perpendicular to the stem. More robust species with erect stems, such as, *C. anthonyi*, *C. codonion* and *C. salicinoides*, have leaves are held about 45–60° to the stem while leaves on the lower part are almost perpendicular to the stem.

Shape of the cross-section of the petiole is often grooved above, except for *C. rubiginosa*, *C. tiumanica* and *C. yongii* where the petioles are terete. Petioles and midribs of *C. salicinoides* are distinct in the transverse ribs that are conspicuous when dry.

3.3.2.3 Lamina shape and size (length-width ratio)

Lamina shape is an important character to differentiate some closely similar species, such as *Codonoboea oreophila* and *C. pumila*, and is used in the key to identify species (part 3.3.1.).

Codonoboea pumila, *C. puncticulata* and *C. yongii* have obovate to oblanceolate laminas, with the smallest length-width ratio, which is less than 2.9 (Table 3.1). The most common lamina shape is obovate (occasionally oblanceolate), e.g. in *C. codonion*, *C. floribunda*, *C. heterophylla*, *C. oreophila*, *C. puncticulata*, *C. soldanella* and *C. yongii*. Average lamina length-width ratio for these species is between 2 to 3, with exceptional cases in *C. codonion* and *C. heterophylla* where there is a larger ratio in some individuals (Plate 1C, Plate 2C). On the other hand, oblanceolate laminas are common in *C. anthonyi*, *C. leiophylla*, *C. rubiginosa* and *C. salicinoides* (lamina length-width ratio around 3–4).

For the rheophytic species, the leaves are narrowly lanceolate, e.g. *C. densifolia* and *C. salicina* (lamina length-width ratio > 3.8). Another rheophytic species, *C. tiumanica*, has wider range of shape (lanceolate to elliptic) and ratios of 1.7–6.9.

As a long-lived herb, the plant flowers at very young stage and continuously produces flowers and fruits throughout its lifespan. Therefore, in herbarium specimens, various sizes of lamina are found. However, the ratio of length to width is very consistent (Table 3.1).

Table 3.1. Lamina length to width ratio of *Codonoboea* species.

Species	Width (cm)	Length (cm)	Ratio
C. anthonyi	(3.4–)3.8–4.3(–4.6)	11.6–13.9(–19.1)	(2.7–)3.3–4.4
C. codonion	(4–)5.4–5.5(–6.6)	(7.3–)10.2–18.3(–20.6)	(2–)2.4–3.7(–4.7)
C. densifolia	(0.6–)0.8–1.2(–1.9)	(4–)6–9(–15.6)	(4.3–)5.7–12(–15.6)
C. floribunda	(4–)5.4–5.7(–6.6)	(11.3–)13.2–15.2	2.5–2.8(–3)
C. heterophylla	2.5–3.4(–4.5)	(4.5–)10.2–15.9	(1.9–)2.3–3.6(–3.8)
C. leiophylla	(1.6–)2.6–3.2(–4)	7.9–8.6(–11.4)	2.4–4(–5.2)
C. oreophila	1.6–2.2(–3.1)	3–4.8(–6)	(1.5–)2–2.8(–3.4)
C. pumila	(1.6–)2–2.3(–3.6)	(3.3–)4.1–4.5(–5.6)	1.5–2(–2.8)
C. puncticulata	(1.7–)2.1–4.1(–6.1)	(4.6–)7.2–8.6(–12.4)	1.5–2.9
C. rubiginosa	1.5–2.4(–2.9)	(3.7–)5.2–6.8(–11.1)	(2.4–)3–3.8
C. salicina	(0.7–)1.1–1.4(–2.3)	(5.6–)8.3–11.8(–16.1)	(3.8–)4.5–10(–12)
C. salicinoides	(1.8–)2.1–3.2(–3.6)	(7.8–)11–15.3	(2.9–)3.4–5.6
C. soldanella	*c.* 2.5	*c.* 7.5	3
C. tiumanica	(1–)2–2.4(–3.1)	(2.3–)5.4–6.5(–8.1)	(1.7–)2.6–3.5(–6.9)
C. yongii	(4.2–)4.8–5.1	(8.1–)10.1–13.3	(1.6–)2.4–2.7
C. oreophila	1.6–2.2(–3.1)	3–4.8(–6)	(1.5–)2–2.8(–3.4)

3.3.2.4 Lamina base, margin and apex

In terms of lamina base, almost half (8 species) of the species have a rounded to cordate base while the remaining seven species have a cuneate base. Species with rounded to cordate leaves are *C. floribunda*, *C. heterophylla*, *C. oreophila*, *C. pumila*, *C. puncticulata*, *C. rubiginosa*, *C. soldanella* and *C. yongii*. Among them, only *C. puncticulata* occasionally has peltate base.

The most common type of lamina margin is crenate to crenulate, as seen in *C. codonion*, *C. floribunda*, *C. heterophylla*, *C. oreophila* and *C. puncticulata*, while the margins of *C. rubiginosa*, *C. salicina*, *C. salicinoides* and *C. tiumanica* are serrate to serrulate.

Codonoboea yongii is the only species with a denticulate margin. The margins of *C. anthonyi* and *C. leiophylla* are entire in the lower half but are distantly shallowly serrate towards the apex. Only *C. pumila* and *C. densifolia* have a completely entire margin.

In lamina apex, only *C. oreophila* and *C. soldanella* always have a rounded apex while the rest have acute apices with occasionally rounded apices in *C. pumila*, *C. puncticulata*, *C. rubiginosa* and *C. yongii*.

3.3.2.5 Lamina indumentum

All species in this study are at least hairy on the midrib and lower surface of the veins. Species can be grouped into those that are hairy on the upper surface of the lamina or are glabrous. Among the 15 species, only *C. oreophila*, *C. pumila*, *C. rubiginosa*, *C. tiumanica* and *C. yongii* and are always hairy above. The rest are strictly glabrous above. This is a consistent character except for *C. puncticulata*, where a few specimens have a glabrous lamina.

The trichome type is unbranched, uniseriate. Only *C. rubiginosa* and *C. yongii* have 1–2-celled trichomes, while the rest have 3–4(–5) cells, with those of *C. puncticulata* and *C. tiumanica* reaching 7 cells.

Codonoboea oreophila, *C. pumila* and *C. rubiginosa* are densely hairy above. Trichomes of *C. oreophila* and *C. rubiginosa* are erect but are appressed near the margin. *Codonoboea pumila* is unique in its dense, neatly arranged hairs with the tips pointing away from the lateral veins and towards the leaf margin. These dense and silvery hairs resemble those of *Loxocarpus* species.

Both *C. tiumanica* and *C. puncticulata* have scattered hairs on the upper surface of lamina but are glabrous underneath. Hairs in *C. tiumanica* are consistently present while in *C. puncticulata*, the majority of plants are hairy, but several glabrous individuals were encountered in Jengai FR, Terengganu. The lamina of *C. yongii* is covered with very minute and erect hairs, to 0.2 mm long, giving the lamina a glabrescent appearance. The other species are completely glabrous above.

3.3.3 Inflorescences

3.3.3.1 Inflorescence type

All the inflorescences are axillary and in the form of pair-flowered cymes. In a cyme unit the terminal flower is associated with a frontal flower, giving the pair-flower arrangement. This concurs with Weber (2004) that this inflorescence type is found in all Gesneriaceae.

3.3.3.2 Number of flower and inflorescence branching

The number of flowers per inflorescence depends on branching pattern and series of flower number reduction as was proposed by Weber (1978, 1982, 2004). In this study, species like *C. leiophylla*, *C. puncticulata* and *C. tiumanica* have inflorescences that strictly have a single flower (terminal flower, Fig. 3.1A) and the lateral and frontal flowers do not develop. *Codonoboea oreophila* has often a single flower but occasionally two.

On the other hand, *C. pumila* and *C. densifolia* often have inflorescences with two flowers (a terminal and front flower, Fig. 3.1B). Occasionally, in *C. pumila*, the front flower does not develop, resulting in a single flower. In *C. densifolia*, sometimes one or both of the lateral flowers develop and produce an inflorescence with three or four flowers.

Codonoboea anthonyi, *C. heterophylla*, *C. salicina* and *C. soldanella* always have three to four flowers (Fig. 3.1C). The number of flowers in *C. anthonyi* is very consistent with 4 flowers while in *C. heterophylla* and *C. salicina*, one or both of the lateral flowers often do not develop.

The rest of the species have a wider range of flower number (Fig. 3.1D, 3.1E). As demonstrated in Weber (1978, 2004) the lateral flower can be further branched and produce another unit of pair-flowered cyme. However, the number of flowers produced by the lateral branch is variable depending on the branching and number of flower developed. This occurs in *C. floribunda*, *C. salicinoides* and *C. yongii* where there are usually 3–4 flowers but the number can range from 2–8 (in *C. floribunda* and *C. salicinoides*) and 5–12 (in *C. yongii*). *Codonoboea codonion* and *C. rubiginosa* have a wider range of flower number, ranging from 2–22 flowers.

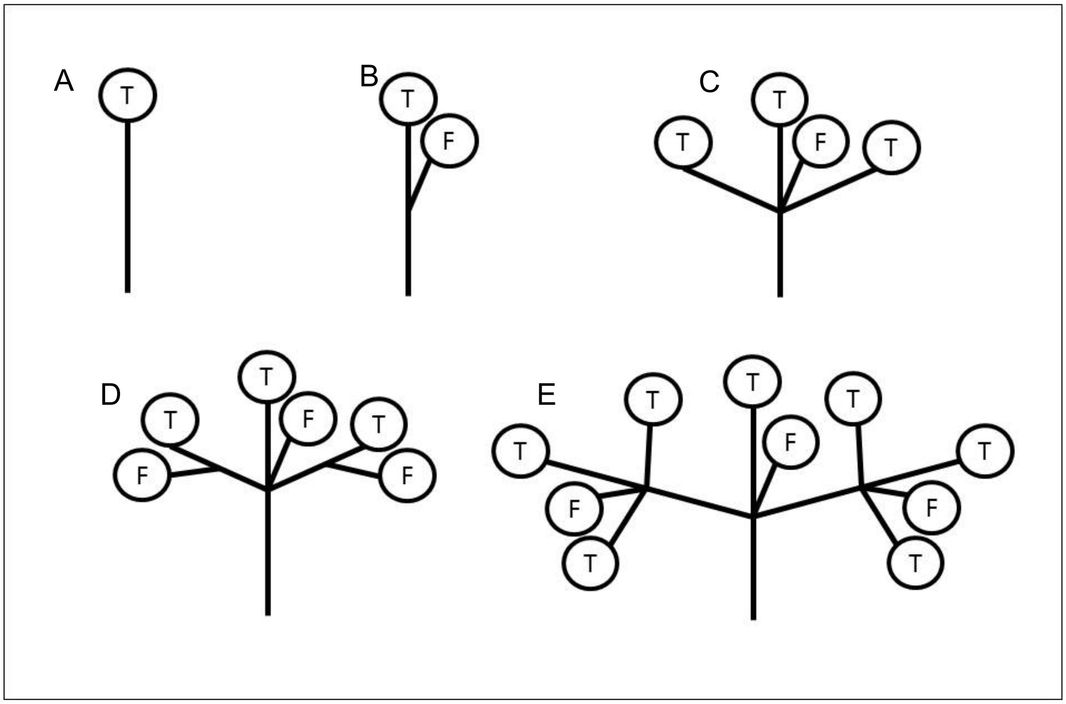


Figure 3.1. Pair-flowered inflorescence diagram. A. inflorescence with solitary flower, B. inflorescence with terminal flower and frontal flower developed, C. inflorescence with both lateral flowers developed, D & E. inflorescence with lateral branch further develop into pair-flowed cyme unit. T= terminal flower, F= frontal flower.

3.3.3.3 Bracts

Bracts of those species are always in opposite or subopposite pairs, located on the peduncle near or directly subtending the flowers. Most species have small, ligulate or linear and inconspicuous bracts. *Codonoboea codonion* and *C. floribunda* are the only two species with more obvious, foliose and distinctly 3-veined bracts. Their bracts are often greenish in life while for the rest, they are concolourous with the peduncles.

Bracts of *C. floribunda* are exceptionally larger, measuring at least 1.4 mm wide while the bracts of other species are less than 1.2 mm wide.

3.3.4 Flowers

3.3.4.1 Calyx

Calyces of species are mostly small, linear to narrowly triangular and smaller than 2.9 × 0.9 mm. Like the bracts, the calyces are always concolourous with the pedicels and peduncles. Furthermore, they often tightly clasp the base of the corolla tube. The only exception is *C. floribunda* where the calyx is at least 2.6–4.3 × 1 mm. In addition, it is always perpendicular to the pedicel rather than held close to corolla.

3.3.4.2 Corolla size and shape

The two sections in this study were characterised by having a short, campanulate corolla tube (Ridley, 1896, 1907; Kiew, 1992), with ratio of corolla length to width ranging from 0.25 to 1.25. In contrast, the ratio for *Codonoboea* species in other sections with long and tubular corollas is greater than 2.

Seven types of corolla shape can be recognised in these two sections, namely campanulate, small campanulate, pouched, *C. puncticulata*-type, *C. densifolia*-type, *C. tiumanica*-type and small tubular type (Fig. 3.2).

3.3.4.2.1 Campanulate type

Campanulate type of corollas is seen in *C. anthonyi* (Plate 1B), *C. floribunda* (Plate 2B) and *C. leiophylla* (Plate 2E) where the corollas broadly widen from the base to the corolla tube to the tip of the lower and lateral corolla lobes. The upper two corolla lobes are reflexed. Tips of the corolla lobes are rounded (Fig. 3.2A1). The lower part of the corolla tube is longer than the upper and straight when seen in side view (Fig. 3.2A2), sometimes shallowly gibbous below as in *C. leiophylla*.

In general, the campanulate corollas are larger compared with other flower types, measuring 15.2–19.6 mm across the lobes and 11.9–14.8 mm long. The corolla tube is almost as long (4–6.4 mm) as wide (6 mm).

3.3.4.2.2 Small campanulate type

The small campanulate corolla type (Fig. 3.2B2) is found in *C. codonion* (Plate 1D), *C. heterophylla*, *C. salicina* (Plate 6E) and *C. salicinoides* (Plate 7B), where the corolla tube widens broadly right from the base. The upper corolla lobes are reflexed and are often darker in colour than the other corolla lobes and the corolla tube. The distinct difference from the other flower types is the pointed apex of the corolla lobes (Fig. 3.2B1).

Difference in size separates the two campanulate types: corollas of the small campanulate type measure only 7–8.8 mm across and 3.9–7.2 mm long, while those of the campanulate type are larger. The corolla tubes are almost the identical in length and width, measuring 3.1–3.3 mm long and 3.1–4.5 mm across.

3.3.4.2.3 Pouched type

This corolla shape is very similar to that described for *Streptocarpus tanala* Humbert and *S. thompsonii* R.Br. (Harrison *et al.*, 1999). The corolla tube is more or less rounded in cross section. The basal part of the corolla tube points downwards, followed by a small bend, making the corolla mouth face forward (Fig. 3.2C1). The bent part of the corolla tube is gibbous on the ventral side. The apices of the corolla lobes are rounded and only the upper two are slightly reflexed, while the others are spreading. Species with pouched flowers are *C. pumila* (Plate 4E), *C. rubiginosa* (Plate 6C) and *C. yongii*.

3.3.4.2.4 *Codonoboea densifolia*-type

Among all the species, *C. densifolia* (Plate 1F) is the only species with this corolla type. The corolla shape is broad tubular with a unique abrupt hump dorsally about half way along its length (Fig. 3.2D2). Ventrally, the corolla tube is narrow at the base and abruptly widens at about a quarter of its length. The corolla tube is rounded at base in cross section to half of the length where it abruptly changes to oval (Fig. 3.2D1). The corolla lobes range from not to slightly reflexed, and have rounded apices (Fig. 3.2D1). The corolla tube is tubular, with the length to width ratio 1.8–1.9.

3.3.4.2.5 *Codonoboea puncticulata*-type

This corolla type is found only in *C. puncticulata* (Plate 5C). The corolla has a short-tube, to 5.6 mm long with the base of the upper corolla lobes abruptly reflexed and forming a thick rim at their base (Fig. 3.2E2). From side view, the base of the upper corolla lobes is the most protuding part. The lateral lobes and lower corolla tube dilate widely from the base and lobes, almost forming a flat-faced flower (Fig. 3.2E1).

The corolla tube measures *c*. 4–5.6 mm long, 4–4.8 mm wide, the corolla mouth is somewhat triangular in front view (Fig. 3.2E1). The apices of the corolla lobes are rounded and only the upper two are reflexed, while the others are spreading.

3.3.4.2.6 *Codonoboea tiumanica*-type

This type of corolla is only seen in *C. tiumanica* (Plate 7D–E). The corolla tube base is short and narrow (to 0.7 × 0.3 mm) and widens abruptly to a ventricose tube (Fig. 3.2F2). The upper part of the corolla tube is indented with two concave surfaces on both sides and a deeper concave indention at the central part near the corolla tube mouth. The corolla tube is 6.3–6.8 mm long, *c*. 7.6 mm wide, with all the corolla lobes reflexed. All the corolla lobes are isomorphic, reflexed and the apices with shallow 1–3 irregular lobes (Fig. 3.2F1).

3.3.4.2.7 Small tubular type

This corolla type is only found in *Codonoboea oreophila* (Plate 4B–C). The corolla is trumpet-shaped, as long as 19 mm long (Fig. 3.2G2), *c*. 10 mm wide at mouth (Fig. 3.2G1). The corolla tube is *c*. 10 mm long, *c*. 4 mm wide, narrower at base (*c*. 2 mm wide). The corolla lobes are rounded, only the upper pair reflexed, lateral and lower lobes spreading from corolla tube. (Fig. 3.2G1).

3.3.4.3 Filament position and shape

All species of *Codonoboea* have two epipetalous stamens. All species in this study have filaments positioned at the lower ventral surface in the corolla tube. The attachment of the filament is *c*. 1–2 mm from the corolla base, except in *C. anthonyi* and *C. oreophila*. In *C. anthonyi*, the filament is attached close (to 0.7 mm) to the corolla base and in *C. oreophila*, the filament is about 4.1 mm from the base.

In terms of shape, filaments of the majority of species are short and straight and point toward the style. The filaments of *C. pumila* bends slightly halfway.

Particular modifications of filaments are observed in *C. puncticulata* and *C. tiumanica*. In *C. puncticulata*, the filaments grow parallel to the style but bend upwards at a right angle near the apex, towards the style. The filaments of *C. tiumanica* are strongly recurved, exposing the basal part of the anther towards the corolla mouth (Fig. 3.3A).

3.3.4.3.1 Anther shape

In *Codonoboea* species, the pair of anthers joined at the apex by connective tissue. Between the anther pair, powdery pollen is accumulated after dehiscence. Mechanical force is required to open the base of the anther pair to release the pollen after dehiscence.

The majority of the species in this study have reniform anthers (Fig. 3.3C) except for *C. anthonyi*, *C. densifolia*, *C. floribunda* and *C. leiophylla* that have subcordate anthers (Fig. 3.3B).

3.3.4.4 Pistil

Pistils of all the species except *C. oreophila* protrude about 1–4 mm from the corolla tube, exposing the stigma. Therefore, the pistil length is relative to the corolla tube length, which ranges from 5.8 to 8.1 mm long. Pistil of *C. oreophila* is the same length as the corolla tube without protruding beyond corolla tube.

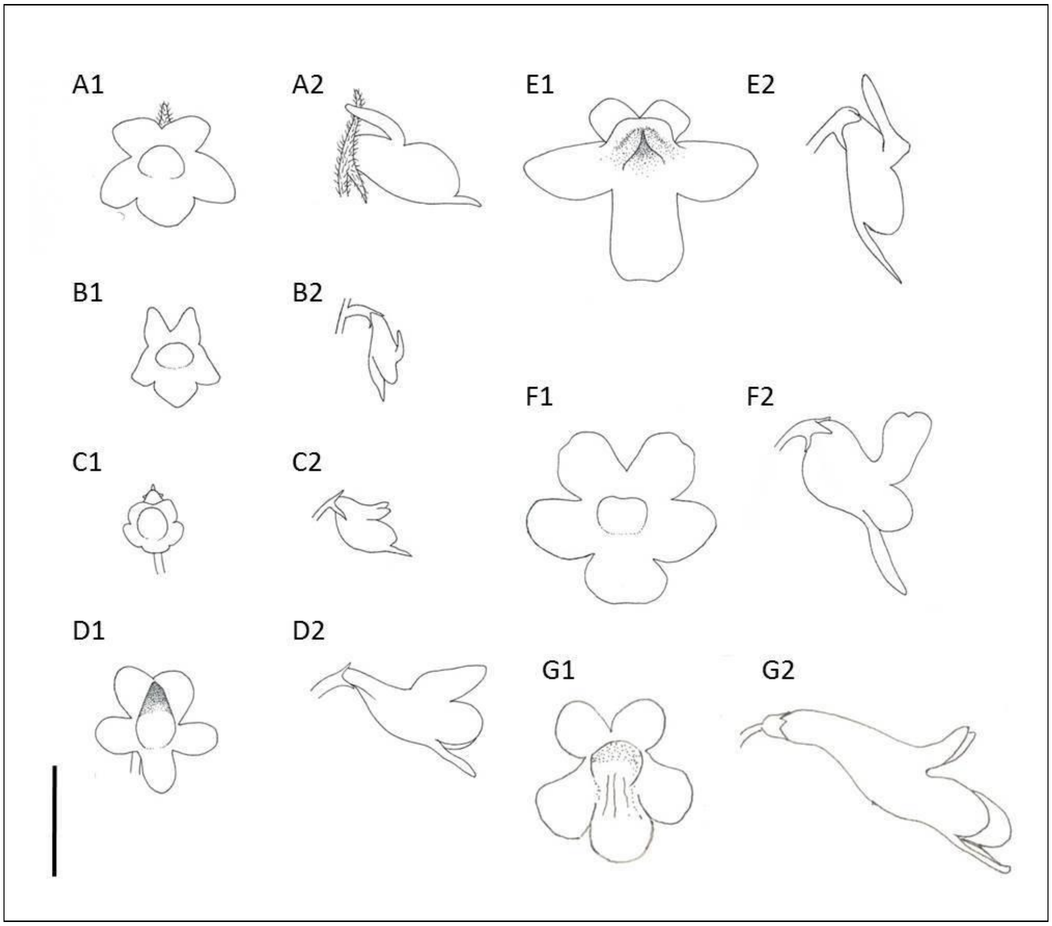


Figure 3.2. Front (1) and side (2) views of different flower types. A. campanulate type, B. small campanulate type, C. pouched type, D. *Codonoboea densifolia* type, E. *C. puncticulata* type, F. *C. tiumanica* type and G. small tubular type — Scale bar = 1 cm.

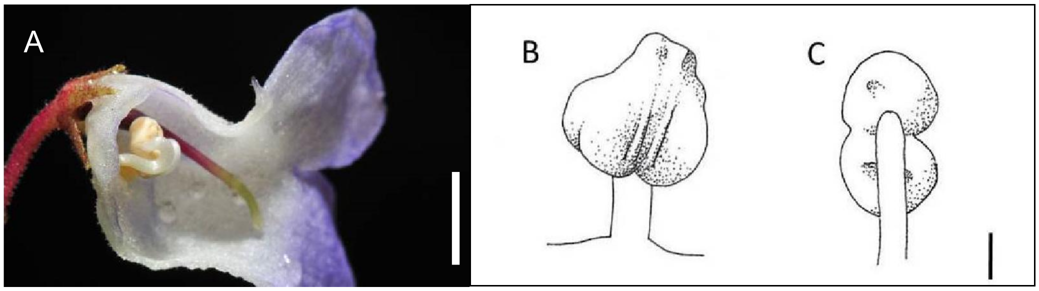


Figure 3.3. A. recurved filament of *Codonoboea tiumanica*, arrow showing the indented concave surface, B. subcordate anther shape (*C. densifolia*), C. reniform anther shape (*C. codonion*) — Scale bars: A = 5 mm, B–C = 1 mm.

3.3.4.5 Nectary

Kiew (1992) performed SEM on nectaries of several species of *Codonoboea*. Sections *Didymanthus* and *Heteroboea* have cylindrical nectaries. *Loxocarpus*, sect. *Boeopsis* and sect. *Salicini* have very reduced nectaries or the nectary is absent.

Nectaries of species in this study, if present, surrounding the base of the pistil. They are often short and are hidden at the base of corolla. To examine the nectary, corolla and calyx have to be removed completely.

Among the species, *C. anthonyi*, *C. densifolia* and *C. salicina* have no nectaries while the other species have a nectary ranging from 0.1 mm to 1 mm tall. *Codonoboea salicinoides* has a very reduced nectary, which is very thin and almost translucent. *Codonoboea oreophila* has well-developed nectary to 1 mm tall. Although the nectary of *C. tiumanica* is as tall as 1 mm, it is membranous and nearly translucent. For the rest, the nectaries are thicker and at least 0.3 mm tall. All the nectaries are shallow to deeply lobed.

3.3.5 Fruits

Fruit is one of the important characters for generic delimitation of several closely similar genera, called the "*Codonoboea* group" in Kiew & Lim (2011), all have capsules that are cylindrical, plagiotropic and split adaxially.

Among the species, some grouping according to size and shape of fruit can be observed. Fruits of *C. codonion*, *C. heterophylla*, *C. salicina*, *C. salicinoides*, *C. soldanella* and *C. yongii* are slender and small, measuring less than 2.1 cm long and 1.4 mm thick (Table 3.2).

In contrast, *C. anthonyi*, *C. densifolia*, *C. leiophylla*, *C. pumila*, *C. puncticulata*, *C. rubiginosa* and *C. tiumanica* have larger fruits, often measuring more than 2.1 cm long and 1.4 mm thick. The narrowly oblong fruit of *C. floribunda* is even longer than 2.1 cm but thinner than 1.4 mm.

When the fruit matures, it splits adaxially, and become a narrow gutter-shaped capsule. For majority of the species, width of the split capsule is less than 1.5 mm. However, *C. densifolia* and *C. tiumanica* are distinct in their capsules, which open wide to become narrowly boat-shaped and to 4 mm wide.

Table 3.2. Summary of thickness and length of capsules.

Species	Length (cm)	Thickness (mm)
C. anthonyi	(1.9–)2.5– 2.8(–3.6)	(1.2–)1.4– 1.7(–1.9)
C. codonion	(1.2–)1.3–1.7(–2.1)	0.7–1.2
C. densifolia	(1.6–)2.1– 2.6(–2.9)	1–1.5(–2.3
C. floribunda	2.1–2.9	1.2–1.4
C. heterophylla	1.1–2.1	0.7–1.2
C. leiophylla	2.3–2.9(–3.9)	(1.2–)1.8– 2.1
C. oreophila	(2.5–)3–3.5	1
C. pumila	(1.6–)2.3–2.9	(1–)1.4–1.5(–1.8)
C. puncticulata	(1.5–)2.3–3.1	(1.4–)1.7–2.3
C. rubiginosa	(1.3–)2–2.1	(1.1–)1.6–2
C. salicina	1.2–1.5(– 2.1)	(0.7–)1–1.2(–1.4)
C. salicinoides	(0.9–)1.1–1.9(–2.1)	(0.6–)0.9–1.1(–1.4)
C. soldanella	1.7 cm	*c.* 1.4
C. tiumanica	2.1–2.4(–2.7)	(1–)1.4–1.9(–2.5)
C. yongii	1.2–1.5(– 2.1)	(0.7–)1–1.2(–1.4)

3.3.6 Seeds

Seeds of the species in this study are minute (less than 0.3 × 0.4 mm in size), ovoid to ellipsoid. A fertile capsule produces a large quantity of seeds.

3.3.7. Indumentum of inflorescences and flowers

3.3.7.1. Peduncles, pedicels, bracts and calyces

Indumentum types include unicellular to multicellular, glandular or eglandular of various density and lengths. However, no distinct patterns or groupings were observed.

Usually, peduncles, pedicels, bracts and calyces share the same indumentum type. However, in some species, some differences are found in certain parts. For instance, *Codonoboea codonion* and *C. densifolia* have glabrous bracts while the remaining parts are hairy. Also, in *C. salicina*, a mixture of long and short hairs occurs only on peduncle, while only fine and short hairs are found on pedicel, bracts and calyx.

Presence of glandular hairs only occurs in two species, i.e. *C. anthonyi* and *C. densifolia*. *Codonoboea anthonyi* has mixture of long eglandular hair and sessile hairs with 4-celled head while *C. densifolia* has mixture of long glandular and eglandular hairs.

Codonoboea floribunda has 5–7-celled eglandular hairs to 2.2 mm long, while hair lengths of the other species are shorter than 1 mm long. The only species with very few scattered hairs is *C. salicinoides*, where the peduncle, pedicel, bract and calyx are glabrescent.

3.3.7.2 Corollas

Corollas have specific hair types, which are different from those on peduncle to calyx. All species have glabrous inner surfaces in the corolla tube while the outer surfaces of corolla tube and corolla lobes have different hair types.

Among the species, only *C. anthonyi* and *C. rubiginosa* have completely glabrous corollas. Corolla of *C. floribunda* is almost glabrous because the hairs are very scattered, short and fine. *Codonoboea leiophylla*, *C. oreophila*, *C. pumila*, *C.*

puncticulata and *C. yongii* have sparse, eglandular hair outside while *C. densifolia* is densely hairy outside.

The small campanulate flower type of *C. codonion*, *C. heterophylla*, *C. salicina* and *C. salicinoides* have sessile glandular hairs on outer and inner surfaces of the corollas, including the corolla lobes. However, on the other surfaces of the corollas, *C. salicina* and *C. salicinoides* only have sessile glandular hairs while *C. codonion* and *C. heterophylla* have a mixture of both sessile and sparse eglandular hairs on the outside of corolla tube and lobes.

3.3.7.3 Pistil

All species in the study are hairy on both the ovary and style, except for *C. densifolia*, where the style is glabrous. Ovarian and stylar indumentum of all species are different in terms of trichome type and density (Table 3.3).

Species with very sparse hairs that appear almost glabrous throughout are *C. anthonyi*, *C. salicina* and *C. salicinoides*. *Codonoboea densifolia* has a totally glabrous style but the ovary is covered with dense, long glandular hairs.

Codonoboea floribunda, *C. heterophylla*, *C. leiophylla*, *C. oreophila*, *C. pumila*, *C. puncticulata*, *C. salicina*, *C. salicinoides* and *C. tiumanica* have the same indumentum type on both the ovary and style, but it is denser on the ovaries. In the other species, the indumentum on the ovary is different from that on the style.

Those species with glandular hairs are *C. anthonyi*, *C. codonion*, *C. densifolia*, *C. floribunda*, *C. pumila*, *C. rubiginosa*, *C. salicina*, *C. salicinoides* and *C. yongii.* Among them, *C. densifolia* only has long-stalked hairs on the ovary and a glabrous style. *Codonoboea yongii* has long-stalked hairs on the ovary and short-stalked glandular hairs on the style. *Codonoboea pumila* has only short-stalked hairs. *Codonoboea yongii* has long-stalked glandular hairs on ovary and short-stalked ones on style. Sessile glandular hairs are found in *C. anthonyi*, *C. codonion*, *C. floribunda*, *C. rubiginosa*, *C. salicina* and *C. salicinoides*.

Table 3.3. Summary of ovary and style indumentum.

Species	Ovary	Style
C. anthonyi	mixture of dense eglandular hairs and sessile glandular hairs	extremely sparse mixture eglandular hairs and sessile glandular hairs
C. codonion	sessile glandular hairs	very fine, sparse eglandular hairs
C. densifolia	dense straight, long-stalked glandular hairs	glabrous
C. floribunda	dense mixture of short pointed eglandular hairs and scattered sessile glandular hairs	sparse mixture of short pointed eglandular hairs and scattered sessile glandular hairs
C. heterophylla	dense short eglandular, appressed hairs, pointing towards stigma	sparse short eglandular, appressed hairs, pointing towards stigma
C. leiophylla	denser eglandular hairs	sparse eglandular hairs
C. oreophila	dense eglandular hairs	eglandular hairs
C. pumila	dense short-stalked glandular hairs	sparse short-stalked glandular hairs
C. puncticulata	dense eglandular hairs	sparse eglandular hairs
C. rubiginosa	dense short, sessile glandular hairs	sparse short, sessile glandular hairs
C. salicina	very fine sessile glandular hairs, appearing glabrous	extremely sparse fine sessile glandular hairs, appearing glabrous
C. salicinoides	sessile glandular hairs, appearing glabrous	extremely sparse fine sessile glandular hairs, appearing glabrous
C. tiumanica	dense short eglandular hairs	spare short eglandular hairs
C. yongii	mixture of dense long eglandular and long-stalked glandular hairs	mixture of long dense eglandular hairs and short-stalked glandular hairs

3.3.8. Colour of the floral parts

3.3.8.1 Corolla tubes and lobes

Kiew (1992) recorded that colour range of species in sections *Boeopsis* and *Salicini* falls within purple to pink . From field observations and herbarium label records, colour range of the species is within those reported, but there are differences in brightness.

Each species exhibits different floral coloration and pattern. Often, the corolla tube is different in colour between the outer and inner surfaces. Also, the upper reflexed corolla lobes are darker or have a different colour from the other lobes. The colour gives a strong contrast compared with the lighter coloured corolla tube and the three other corolla lobes. Those from campanulate and small campanulate corollas have darker and reflexed upper corolla lobes.

Other species have either upper corolla lobes concolor with the other lobes (*C. densifolia*, *C. oreophila*, *C. puncticulata* and *C. tiumanica*) or concolor with the corolla tube (pouched type).

3.3.8.2 Stamens

Stamens of most of the species are white. However, the filament base and point of attachment to the corolla tube in *C. densifolia*, *C. puncticulata* and *C. tiumanica* are distinctly bright yellow. For these three species, in contrast, the anthers are white to very pale yellowish. Non-white including dull yellow anthers were observed in *C. codonion*, *C. heterophylla* and *C. salicinoides*; yellow in *C. yongii* and dark pinkish in *C. salicina*.

3.3.8.3 Pistil

Pistil coloration for all species is unique to each species, therefore, cannot be classed into groups. In general, ovaries are much darker, turning lighter towards the style and are mostly white at the protruding stigma.

Codonoboea oreophila has pinkish purple pistil throughout. Pistil colours of *C. heterophylla*, *C. salicina* and *C. salicinoides* are more or less similar in colour range to that of the corolla. For example, *C. codonion*, *C. salicina* and *C. salicinoides* with pinkish or pale lilac corollas have pinkish pistils while *C. heterophylla* (lilac corolla) has a pale purple pistil. Among these species, the styles are similar in colour to the ovaries but slightly lighter.

Ovary colour of *Codonoboea anthonyi* (purplish-red), *C. densifolia* (pale yellowish), *C. floribunda* (dark orange to maroon), *C. leiophylla* (dark crimson to purple), *C. rubiginosa* (yellowish brown), *C. puncticulata* (dark purplish brown) and *C. tiumanica* (dark purplish maroon) are different from their styles. *Codonoboea anthonyi* has pale greenish style while *C. floribunda*, *C. leiophylla*, *C. puncticulata*, *C. rubiginosa* and *C. tiumanica* have pale yellowish green styles. *Codonoboea densifolia* has a white to translucent style. *Codonoboea pumila*, on the other hand, has a dark purplish ovary and slightly lighter purple style.

Stigmas are mostly uniform in colour because the majority of them are white. Exceptional cases are yellowish green in *C. floribunda*, *C. puncticulata* and *C. rubiginosa* and pale green in *C. salicinoides.*

3.3.9 Position of stamens and pistil

Basically, there are two positions, i.e. up-down position and left-right position (enantiostylous). The up-down position occurs in flowers with campanulate, small campanulate, pouched type and *C. puncticulata* type, where the filaments are short, with the anthers positioned near the base of the corolla mouth while the pistil is positioned on top of the stamens with style protruding from the corolla tube (Fig. 3.1B).

The enantiostyly type is observed only in the *C. densifolia*, *C. oreophila* and *C. tiumanica* types of corolla. Like those in the up-down position, the style is asserted above the base of stamens. However, the whole pistil either points to the left or right towards the corolla mouth. The stamens are positioned towards the opposite side of the pistil. From the front view, both parts are opposite of each other (Plate 1F).

3.4 Discussion and conclusion

3.4.1 Taxonomically informative characters

After comparing and examining all the morphological characters, characters listed in Table 3.4 are found to be informative and consistent. These characters are widely used in the key to species in part 4.3.2.

Table 3.4. List of taxonomically informative characters.

Plant part	Character
Lamina	Shape
	Base, margin and apex
	Indumentum of upper surface
Inflorescence	Peduncle length
	Number of flowers per inflorescence
Flower	Corolla shape
	Corolla colour
	Corolla indumentum
	Stamen and anther shape
	Pistil indumentum
Fruit	Capsule width

In previous taxonomic studies, Ridley (1923) and Kiew (1987, 1990, 1992, 1995) used mostly lamina characters, i.e. shape, base, margin, apex and indumentum to distinguish species within the sections. In this study, these characters are found to be useful for species identification as is shown in the key (part 3.3.2). Peduncle length and number of flower per inflorescence are useful characters used by Kiew (1992).

New informative characters are mostly those of flower and fruit. The fruit width is a new distinct character which could only be determined in *C. puncticulata* and *C. tiumanica*. Flower characters are hard to observe in herbarium sheets, thus are less user-friendly for identification. New informative characters like corolla shape, colour, stamens and anther shape are useful to identify the species, even in the field or in images of living plants. The corolla shape also indicates the grouping of the species, which is supported by molecular phylogenetic analyses (Chapter 5). For instant, those species with the small campanulate flower type group together.

As listed in Table 3.3, indumentum on pistil is very specific for each species. However, this requires careful examination under the microscope.

3.4.2 Observation of insect visits

Occurrence of flower visitors was observed in the field. The potential pollinators were captured and the species determined by staff from Entomology Programme, FRIM.

Observations of pollination in *Codonoboea* species are rare (Kiew, 1992, 2009). In the field observation in Endau-Rompin SP, observations were conducted from 0900 to 1600 hr. on *C. densifolia*, an enantiostylous species with white corolla tube with contrasting pale purplish blue concolor corolla lobes. *Trigona* bees started visiting the flowers around 1000 hr and the activity peaked between 1030 to 1130 hr.

Floral morphology in angiosperms evolves to attract pollinators and therefore promote pollen dispersal and cross-pollination. Thus, flowers of many plants species have evolved to suit different groups of animal pollinators, resulting in the recognition of distinct pollination syndromes (Faegri & van der Pijl, 1966).

The evolutionary drive of the flower is suggested to be driven by adaptation to pollinator (Faegri and van der Pijl, 1966). The only recorded flower visitors are bumble bees (*Bombus* species, Family: Apidae, Subfamily: Bombinae) on both *Codonoboea hispida* (Ridl.) Kiew and *C. robinsonii* (Ridl.) Kiew (Kiew, 1992, 2009).

3.4.2.1 Inflorescence as visual signal

In general, species in this study are rosette plants with relatively long peduncles that fully expose the flowers, like *C. pumila*, *C. puncticulata*, *C. rubiginosa* and *C. yongii*. The long peduncles increase the visibility of the flowers and therefore help to attract the pollinators.

In contrast, in the caulescent species, like *C. anthonyi*, *C. salicina* and *C. salicinoides* the peduncles are relatively shorter and bear the flowers closer to the leaves. This is classified as a frondose inflorescence by Weber (2004). Some of the inflorescences may even be covered by the leaves. In contrast, these species often flower gregariously. For example, *C. salicina*, one plant with five to six inflorescences was seen flowering simultaneously in the field. This also occurs in other caulescent species, such as *C. robinsonii* and *C. platypus*. It was reported that a single plant of *C. quinquevulnera*, a caulescent species with a single-flowered inflorescence, was seen bearing 20 to 30 flowers at the same time (Kiew, 1989).

3.4.2.2 Floral traits to produce visual signal

Weber (1989) and Kiew (1992) drew attention to flower evolution from nectar to pollen flowers within *Codonoboea*. Weber (2004) suggested five types of pollination syndromes in Gesneriaceae, namely nectar flowers, deceptive nectar flowers, pollen flowers, partially and fully deceptive pollen flowers and perfume flowers.

All species in the study except *C. oreophila* fit best with the description of partially and fully deceptive pollen flowers. This concurs with Weber (2004) where *C. puncticulata* is listed as one of the example species of partially and fully deceptive pollen flowers. With its tubular corolla shape, presence of nectar guide and well developed nectary, *Codonoboea oreophila*, fits the characteristics of the nectar flower. However, pollination activity of *C. oreophila* was not observed to identify the potential pollinator.

To attract the hymenopterous insects, flowers often have UV reflective blue/ purplish colour in contrast with UV absorptive stamen or anther parts. This strong colour contrast creates an “ultraviolet bull’s-eye” (Silberglied, 1979). Reflexed upper corolla lobes with darker colour in both campanulate and small campanulate flowers increase contrast in the flowers and may help to attract the pollinator. The lighter coloured pistils protrude right below the darker upper corolla lobes. This colour contrast may attract insect to the upper part of the corolla and the protruding pistil is perfect to land on. Observation of insect visits (part 4.4.2) confirms this. Furthermore, hairs on the pistils provide the holding base for the pollinator to crawl upside-down towards the anthers for their pollen reward.

Observation on the enantiostylous flower type as observed in *C. densifolia* (part 3.4.2) shows a different type of coloration adaption to attract insects. *Codonoboea densifolia* has a short tubular corolla tube and concolor corolla lobes. The attachment point of the stamens on corolla tube is yellowish. *Trigona drescherii* was observed to land on the corolla tube and crawl towards the anthers. When the insect exited, a dust of pollen was seen on the body. The style of *C. densifolia*, without serving the function for the insect landing, is glabrous (Table 3.3).

4.0 TAXONOMY

4.1 Introduction

Taxonomy of the small flowered *Codonoboea* species in this study follow the 15 species listed in Kiew (1992), under sect. *Boeopsis* (11 species) and sect. *Salicini* (4 species). All 15 species were described by various authors (Ridley, 1893, 1896, 1905, 1908a, 1912, 1923; Henderson, 1933; Kiew, 1989, 1992). However, most species descriptions, especially those by Ridley were brief, incomplete and often left out important diagnostic characters. Therefore, an updated and complete species description and a key to all the 15 species are important. In that study, species identification keys for both sections were constructed separately.

A listing of nomenclature and typifications of all *Henckelia* species was provided by Vitek *et al.* (2000) and for *Codonoboea* species in Peninsular Malaysia by Kiew & Lim (2011).

4.2 Materials and Methods

4.2.1 Precursory literature and type specimen review

All precursory papers and protologues listed in Vitek *et al.* (2000) and Kiew & Lim (2011), as well as important papers on nomenclature and taxonomy revision of Gesneriaceae were sourced.

Type specimens were examined and compared with the original description to confirm that the correct name is applied to the taxa.

4.2.2 Field collections

From information on herbarium specimen labels, localities of the species in Peninsular Malaysia were listed and, where possible, revisited.

Material collected included herbarium specimens, spirit collections of reproductive parts, materials in silica-gel for molecular phylogenetic analysis. Spirit collections were fixed in Copenhagen Mixture (3.5 parts methyl alcohol, 5.5 parts water and 0.5 parts glycerol).

Standard collecting methods and materials followed Bridson & Forman (1992). Location of specimens collected (latitude and longitude) and altitude were recorded using Global Positioning System (GPS). Field characters, such as morphological and habitat notes, were recorded. Colour photographs were taken to record the habitat, flower colour etc. Living plants were collected and transplanted in the Kepong Botanical Garden (KBG), FRIM. The living plants provided the opportunity to examine the reproductive parts of the plants if the specimens were sterile in the field.

4.2.3 Specimen management

Specimens loaned from other herbaria E, K, KEP, KLU, L, SAR and SING were sorted, identified and annotated to the correct species. To manage data from the large number of herbarium specimens, the Botanical Research and Herbarium Management System (BRAHMS) (Copyright© 1985–2013 Department of Plant Sciences, University of Oxford) was used. In this system, data from specimens, such as collector, date of collection, locality, field description etc. are databased and specimen labels generated.

4.2.4 Species description

Quantitative and qualitative characters of the specimens were observed and recorded following guideline by Vogel & Veldkamp (1987). For detailed flower description, specimens in spirit as well as live plants in the field or nursery were examined.

For each specimen, measurements and descriptions were tabulated into a matrix table. Data in the matrix table enabled immediate comparison and compilation of the measurements and descriptions.

Detailed species descriptions were made by referring to the matrix table, field observations, photographs and living plants in Kepong Botanical Garden. Qualitative characters of specimens were described following botanical terminology in Harris and Harris (1997). Format of species descriptions was based on guideline given in Guide to Preparing Manuscripts for The Flora of Peninsular Malaysia (Kiew *et al.*, 2006).

4.2.5 Key to identify species

A user-friendly key was constructed based on easily visible and consistent characters of the species. Vegetative characters were given priority wherever possible so that even sterile specimens can be identified. The use of microscopic characters or characters required dissection were avoided altogether in the key construction.

4.3 Results

Dimensions and descriptions of vegetative and reproductive parts were measured from the herbarium specimens and live specimens. The data were tabulated into a matrix table. Characters that distinguish the species were evaluated. From this data, detailed species descriptions were produced and the key constructed.

4.3.1 Key to identify species

1. Laminas hairy above, hairs at least 1 mm long…… 2
   Laminas glabrous or very shortly hairy with hairs to 0.2 mm long above (in *C. yongii*)……6

2. Lamina thickly leathery. Fruit narrowly cylindrical, < 2 mm wide when open. Montane species (> 950 m altitude)…… 3
   Lamina papery, membranous or leathery. Fruit broad, boat-shaped, to 4 mm wide when open. Lowland to hill species (< 930 m altitude)……. 5

3. Hairs on lamina erect. Flowers > 5 per inflorescence….. **10. C. rubiginosa**
   Hairs on lamina appressed, flowers 1–2 per inflorescence…… 4

4. Laminas oblanceolate to oblong, margin crenulate…… **7. C. oreophila**
   Laminas broadly ovate to broadly obovate, hairs appressed above throughout, margin entire…… **8. C. pumila**

5. Lamina leathery, base rounded to cordate, margin crenulate…… **9.C. puncticulata** (in part)
   Lamina membranous, base attenuate to broadly cuneate, margin serrate at upper half…… **14. C. tiumanica**

6. Lamina margin entire at least basal half ……7
   Lamina margin crenulate or serrate throughout…… 9

7. Lamina length at least 4.5 times longer than wide…… **3. C. densifolia**
   Lamina length < 4 times longer than wide …… 8

8. Flower single, corolla lobes oval ……**6. C. leiophylla**
   Flowers (3–)4, corolla lobes bluntly triangular …… **1. C. anthonyi**

9. Peduncle, pedicel and calyx long hairy, hairs to 2.2 mm long. Bracts foliose, at least 1.4 mm wide. Calyx at least 2.5 mm long, erect …… **4. C. floribunda**
   Peduncle, pedicel and calyx short hairy, hairs to 1 mm long. Bracts linear, ligulate or small triangular, < 1.3 mm wide. Calyx < 2.5 mm, held close to corolla, …… 10

10. Lamina base cuneate…… 11
    Lamina base rounded or cordate……13

11. Petiole and midrib drying with transverse ribs…… **12. C. salicinoides**
    Petiole and midrib drying without transverse ribs…… 12

12. Lamina oblong-oblanceolate, to 2.3 cm wide. Bracts 0.1–0.3 mm wide…… **11. C. salicina**
    Lamina obovate to oblanceolate, broader than 4 cm. Bracts 3-veined, (0.8–)1.1–1.3 mm wide……**2. C. codonion**

13. Flower single. Fruit broadly boat-shaped, to 4 mm wide when open …… **9.C. puncticulata** (in part)
    Flowers 2 or more. Fruit narrowly cylindrical, < 2 mm wide when open …… 14

14. Veins white and much paler than lamina above, margin denticulate. Peduncle at least 13 cm long …… **15. C. yongii**
    Veins more or less concolor with lamina, margin crenate. Peduncle to 5.1 cm long…… 15

15. Lamina apex broadly acute……**5. C. heterophylla**
    Lamina apex rounded……**13. C. soldanella**

4.3.2 Species description

1. ***Codonoboea anthonyi*** (Kiew) C.L.Lim — **Fig. 4.1, Plate 1A–B**

(S. Anthonysamy, herbarium assistant in the Biology Department, Universiti Putra [Pertanian] Malaysia)

Gard. Bull. Sing. 62 (2011) 256. **Basionym:** *Didymocarpus anthonyi* Kiew, Gard. Bull. Sing. 44 (1992) 24. **Homotypic Synonym:** *Henckelia anthonyi* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 339. **Type:** Peninsular Malaysia, Terengganu, Ulu Besut, *Kiew RK 2700*, 7 May 1988 (holotype KEP; isotypes K, SING).

Robust, erect to semi erect **herb**. **Indumentum** of stem apex and petiole long, matted, dark brown hairs. **Stems** to 40 cm tall, (3.2–)4.3–4.6(–6.3) mm thick, unbranched, woody, dark reddish brown to yellowish brown, with swollen leaf scars. Flowering at *c*. 9 cm tall. **Leaves** decussate, tufted, slightly more crowded at top; petioles (12.7–)15.3–17.4(–23) mm long, (1.2–)1.5–2(–3.2) mm wide, in life brownish green, succulent, widely grooved above, when dry dark greenish brown; laminas oblanceolate, 11.6–13.9(–19.1) × (3.4–)3.8–4.3(–4.6) cm, in life glossy green to yellowish green above with pale yellowish green midrib, often with greyish green patch along midrib, pale greyish green to glaucous beneath, drying greenish, greyish brown to dark brown above, pale yellowish to brown, sometimes orange-brown beneath, leathery, glabrous except midrib, lateral veins and margin beneath with shortly appressed hairs; base sharply cuneate, tapering, sometimes oblique, margin entire in lower half, upper half finely distantly serrate, with a tuft of hairs in the notch, teeth *c*. 3–4 per cm, apex narrowly acute; midrib slightly grooved or flat above, prominent beneath, lateral veins 11–13(–18) pairs, obscure above, slightly prominent beneath, brown to dark, darker then lamina, upper veins arching upward towards apex, intercostal veins reticulate, obscure above, often inconspicuous near midrib, becoming obvious towards margin beneath. **Inflorescences** *c*. 3–10 per plant, each (3–)4-flowered. Indumentum of peduncle, pedicel, bracts and calyx sparse, with appressed, 1–4-celled eglandular hairs with sessile *glandular* hairs; corolla *glabrous*. Peduncle (4.3–)5.7–6.6(–9.5) cm long, erect with flowers held above leaves, dark purplish-maroon. Bract pair ligulate, narrowly triangular, (2.9–)4.5–5.1 × 1–1.2 mm, in life yellowish green. Pedicels slender, 11.1–16.3 mm long, concolor with peduncle. **Flowers** nodding. Calyx almost divided to base, purplish maroon, lobes narrow acute, apex acute, 2.5–3.4 × 0.6–1 mm, lower lobes slightly longer; corolla broadly campanulate, *c*. 15.2 mm across, *c*. 11.9 mm long, corolla tube *c*. 6.4 mm long, 7–8 mm wide, white, upper surface of corolla tube and upper corolla lobes pale to dark purple, corolla lobes anisomorphic, lobes *bluntly triangular*, apex narrowly rounded, upper lobes *c*. 5 × 5.1 mm, reflexed, lateral lobes *c*. 4 × 4.9 mm, slightly reflexed, lower lobe *c*. 3.6 × 4.8 mm, dilating from base, projecting 5.5–10 mm beyond upper; stamens positioned below pistil, filaments flattened, to 0.9 mm thick, straight, *c*. 1 mm long, 0.7 mm wide at base, white, joined to corolla tube *c*. 0.7 mm from base, anthers subcordates, 2.1–3 × 2 mm, *c*. 0.9 mm thick, white, connivent at apex; nectary absent; pistil to *c*. 8 mm long, protruding *c*. 2.5–3 mm from corolla mouth, ovary ellipsoid, *c*. 2–3 × 0.9 mm, in life ovary purplish red, style pale green to white, stigma dull yellowish green, pistil with a mixture of eglandular hairs and sessile glandular hairs, denser on ovary, style 6 mm long, stigma rounded, *c*. 0.2 × 0.5 mm, glistening, apex papillose. **Fruits** narrowly ovoid, slightly curved upwards, (1.9–)2.5– 2.8(–3.6) cm long, (1.2–)1.4– 1.7(–1.9) mm thick, purplish maroon, minutely sparse hairy to subglabrous. **Seeds** ovoid, *c*. 0.25 × 0.14 mm.

Distribution. Endemic in Peninsular Malaysia, Terengganu and Kelantan.

Ecology. Primary lowland forest to 200 m altitude. Locally common on vertical earth banks or hill slopes by river.

Additional specimen examined: TERENGGANU, Pelagat FR: *Kiew, R. RK 2700* (KEP), *Lim, C.L. FRI 64994* (KEP, SAN, SING, L, K, A), *Sam, Y.Y. FRI 46648* (KEP), *Sam, Y.Y. FRI 47022* (KEP); Ulu Besut FR: *Anthonysamy, S. SA 675* (KEP, SING); Kelantan, Relai FR: *Kiew, B.H. KBH 4* (KEP).

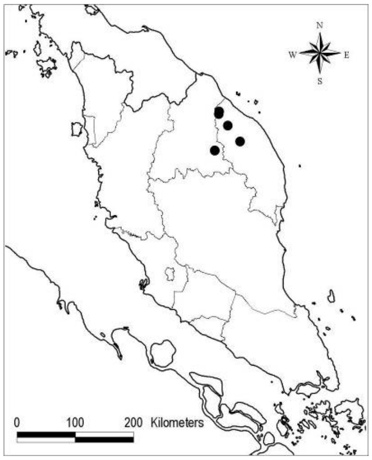


Figure 4.1. Distribution map of *Codonoboea anthonyi* in Peninsular Malaysia.

2. *Codonoboea codonion* (Kiew) C.L.Lim — **Fig. 4.2, Plate 1C–D**

(Greek, *codonion* = small bell; referring to the small bell-shaped flower)

Gard. Bull. Sing. 62 (2011) 257. **Basionym:** *Didymocarpus codonion* Kiew, Gard. Bull. Sing. 42 (1989) 49. **Homotypic Synonym:** *Henckelia codonion* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 342. **Type:** Peninsular Malaysia, Pahang, Kuala Kenyam, *Kiew B.H. RK 1204*, 30 September 1982 (holotype KEP; isotype SING).

Erect **herb**. **Indumentum** of stem apex and petiole of long, multicellular, ferruginous, appressed hairs, hairs to 1.3 mm long. **Stems** erect, to *c.* 15.3 cm tall, (2.3–)3.1–4.3(–6.8) mm thick, unbranched, woody, dark reddish brown, knobbly with swollen leaf scars. Flowering at *c.* 2.6 cm tall. **Leaves** decussate, tufted at top of stem; petioles 3.2–13.5(–28.4) mm long, 1.2–1.7(–1.9) mm wide, in life dark brownish red, widely grooved above, when dry dark reddish brown; laminas obovate to oblanceolate, (7.3–)10.2–18.3(–20.6) × (4–)5.4–5.5(–6.6) cm, in life often *bullate*, in life pale green above, often with two greyish band along margins, pale yellowish brown beneath, drying dark reddish to greenish brown above, paler beneath, papery, glabrous except midrib and lateral veins beneath with appressed hairs; base narrowly cuneate, margin broadly crenate, teeth 3–4 per cm, apex broadly acute; veins flat above, prominent beneath, lateral veins 9–15 pairs, intercostal reticulate, more conspicuous beneath. **Inflorescences** *c.* 5– 10(–>30) per plant, each (2–)4–9(–22)-flowered. Indumentum of peduncle, pedicel and calyx long, straight, appressed, eglandular hairs to 0.6 mm, 2–4-cell, bracts *glabrous*; corolla tube and lobes outside with a mixture of minute, scattered, sessile glandular and sparse long eglandular hairs, 5–6-celled, frontal surface of corolla lobes with short scattered, sessile glandular hairs, denser at margin. Peduncle 3–5.8(–12.3) cm long, erect with flowers held slightly above leaves, pale maroon. Bract pair *foliose*, lanceolate, (3–)4.9–5.6 × (0.8–)1.1–1.3 mm, *3-veined*, pale maroon to yellowish green, glabrous, apex rounded. Pedicels slender, 1.6–2.2 mm long, concolor with peduncle. **Flowers** nodding. Calyx maroon purple, lobes lanceolate, apex acute, (1.4–)1.7–1.8(–2.5) × 0.5 mm; corolla small campanulate, *c*. 8–8.8 mm across, *c*. 3.9–4.3 mm long, corolla tube *c*. 3.3 mm long, 3.1–3.3 mm wide, white to pale lilac or pale pinkish, slightly darker on upper corolla lobes, corolla lobes anisomorphic, lobes triangular, apex pointed, upper lobes *c*. 3.9 × 3.7 mm, reflexed, lateral lobes *c*. 3.9 × 3.7 mm, reflexed, lower lobe *c*. 3.2 × 3.1 mm, lower lobe dilating from base, lower lobe projecting *c*. 2 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments straight, *c*. 1.2 mm long, 0.3 mm wide at base, white, joined to corolla tube *c*. 1 mm from base, anthers reniform, 1.2 × 1.7 mm, 0.8 mm thick, *bright yellow*, connivent at apex; nectary 0.3 mm tall, shallow lobed, upper part split, dull yellow; pistil to *c*. 5.8 mm long, protruding *c*. 2.5 mm from corolla mouth, ovary narrow ovoid, *c*. 1.8 × 0.7 mm, in life ovary orange to pinkish, style pinkish, stigma white, ovary with sessile glandular hairs, style with very fine, sparse eglandular hairs, style 3.8 mm long, stigma slightly capitate, *c*. 0.3 × 0.5 mm, glistening, apex densely papillose. **Fruits** narrowly cylindrical, (1.2–)1.3–1.7(–2.1) cm long, 0.7–1.2 mm thick, drying dark reddish brown, glabrous. **Seeds** ovoid, *c*. 0.25 × 0.15 mm.

Distribution. Endemic in Peninsular Malaysia, Pahang and Terengganu.

Ecology. Lowland to hill forest, 15–550 m altitude, on forest floor, slopes, on ridge tops and stream banks.

Additional specimen examined: PAHANG, G. Aais FR: *Sam, Y.Y. FRI 49054* (KEP), *FRI 49084* (KEP); Taman Negara, Kem Tengah: *Lim, C.L. FRI 64892* (KEP); Taman Negara, Kuala Keniyam: *Mohd Shah MS 2678* (SING), *Balgooy, M.M.J. van 2549* (L), *Kiew, R. RK 1457* (L); Taman Negara, Sg. Anak Melantai: *RK 2419* (KEP); Taman Negara, Ulu Sat, Kuala Kelapah: *Mohd. Shah MS 1749* (KEP, SING); Taman Negara, Ulu Sg. Sepia, Kuala Aur: *MS 1892* (KEP, SING), *MS 1929* (KEP, SING); Taman Negara, Ulu Sg. Tembeling: *Mohd Shah MS 1516* (KEP, SING); TERENGGANU, Bkt. Bandi FR: *Sam, Y.Y. FRI 47181* (KEP); Chemerong FR: *Lim, C.L. FRI 64963* (KEP); G. Padang: *Moysey, L. 33387* (SING), Jengai FR: *Anonymous s.n. (0105938)* (SING), *s.n. (0105940)* (SING), *s.n. (0105942)* (SING), *s.n.* (SING), *s.n.* (SING), *s.n. (0105943)* (SING), Jerangau FR: *Lim, C.L. FRI 65040* (KEP, SAN, SING), *FRI 65112* (KEP, SAN), *Anonymous s.n. (0105939)* (SING), Taman Negara, Batu Biwa: *Kiew, R. RK 2301* (SING), Tasik Kenyir: *Lim, C.L. FRI 52983* (KEP), *Julius, A. FRI 56111* (KEP, SAN, SING, L), Ulu Telemong FR: *Kiew, R. RK 5344* (KEP), *Chew, M.Y. FRI 51821* (A, KEP, SING).

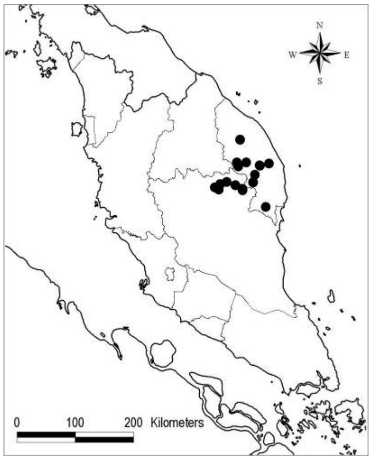


Figure 4.2. Distribution map of *Codonoboea codonion* in Peninsular Malaysia.

3. ***Codonoboea densifolia*** (Ridl.) C.L.Lim — **Fig. 4.3, Plate 1E–F**

(Latin, *densi* = dense, *folia* = leaves; having dense leaves)

Gard. Bull. Sing. 62 (2011) 259. **Basionym:** *Didymocarpus densifolius* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 51, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 761, Fl. Malay Pen. 2 (1923) 521. **Homotypic Synonyms:** *Paraboea densifolia* (Ridl.) M.R.Hend., Gard. Bull. Straits Settlem. 5 (1930) 79. – *Henckelia densifolia* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 343. **Type:** Peninsular Malaysia, Johor, G. Janing [Janeng], *Lake & Kelsall s.n.*, 20 October 1892 (holotype SING). **Heterotypic synonyms:** *Paraboea caerulea* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 66, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 772, Fl. Malay Pen. 2 (1923) 529; *non Didymocarpus caeruleus* (R.Br.) Koord. – *Didymocarpus azureus* B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44. **Type:** Peninsular Malaysia, Terengganu, Bundi, *Rostado s.n.*, February 1904 (holotype SING).

Rheophyte, erect to semi-erect **herb**. **Indumentum** of stem apex, petiole and young leaves beneath with appressed hairs, 3–4-celled, to 1.5 mm long, silvery, denser at stem apex. **Stems** to *c*. 42 cm long, (1.5–)2.4–3.6(–5.8) mm thick, often unbranched, sometimes 2–6-branched, woody, pale yellowish brown, knobbly with swollen leaf scars. Flowering at *c*. 4 cm tall. **Leaves** decussate, tufted at top of stem; petioles 4.9–8.7(–12.8) mm long, 0.5–1(–1.4) mm wide, tapering towards leaves, dark reddish brown; laminas oblong-oblanceolate, (4–)6–9(–15.6) × (0.6–)0.8–1.2(–1.9) cm, in life dark green above, whitish green, tinge pinkish to purplish beneath, drying dark greenish to reddish brown above, yellowish to reddish brown beneath, leathery, glabrous except midrib and lateral veins beneath with long silvery appressed hairs; base narrowly cuneate, decurrent, margin entire, thickened, sometimes slightly wavy in life, apex narrowly acute; midrib slightly raised to flat above, prominent beneath, lateral veins (7–)14–24(–40) pairs, obscure above, distinctly darker beneath, intercostal inconspicuous on both surfaces. **Inflorescences** *c*. 1–7 per plant, each (1–)2(–4)-flowered. Indumentum of peduncle, pedicel, basal part of calyx and corolla outside with a mixture of erect, long-stalked *glandular* and eglandular hairs to 0.3 mm long, bracts *glabrous*; corolla hairy outside, glabrous inside. Peduncle (2.8–)4.9–7.3(–9.1) cm long, erect with flowers held slightly above leaves, purplish maroon, drying yellowish brown. Bract pair, ligulate, (2.1–)2.6–3.9(–5.7) × 0.5–0.6(–0.8) mm, apex narrowly rounded, yellowish brown. Pedicels slender, (3.9–)7.3–8.3 mm long, concolor with peduncle. **Flowers** held horizontally. Calyx almost divided to base, purplish brown, lobes oblong, apex retuse, blunt, (1.5–)2.2–2.7 × 0.4–0.7 mm; corolla broad tubular with an abrupt hump dorsally, to *c*. 10.4–12.6 mm long, 8–9 mm wide, corolla tube *c*. 7.9–9.1 mm long, 4.3–4.7 mm wide, white to very pale bluish, corolla lobes pale purplish blue, *concolor*, inner surface darker, corolla lobes anisomorphic, lobes oval, apex rounded, upper lobes 3.4–4.5 × 3–4.1 mm, *non-reflexed*, lateral lobes 2.5–3.3 × 3.3 mm, lower lobe 2.6–3.6 × 2.4–3.3 mm, lateral and lower lobes dilating from base, lower lobe projecting *c*. 1 mm beyond upper part of corolla tube*; stamens enantiostylous*, *locate at opposite side to the pistil*, filaments white, dark yellow at base, flattened, straight, *c*. 1.2 mm long, 0.3 mm wide at base, joined to corolla tube *c*. 2.7–3.7 mm from base, anthers subcordate, 1.8–2 × 1.5–1.6 mm, 0.5–0.6 mm thick, white, connivent at apex; without nectary; pistil to *c*. 8.1 mm long, *contained within and not projecting beyond corolla tube*, ovary narrow ovoid, *c*. 2.7–2.9 × 0.6–0.7 mm, in life ovary pale yellowish, style white to translucent, stigma white, ovary with straight, dense long-stalked glandular hairs, style glabrous, style to 4.8 mm long, stigma *capitate*, *globular*, *c*. 0.7 × 0.7 mm, glistening, apex long papillose. **Fruits** narrowly cylindrical, (1.6–)2.1– 2.6(–2.9) cm long, 1–1.5(–2.3) mm thick, yellowish brown, dense short hairy. **Seeds** ovoid, minute, *c*. 0.15 × 0.06 mm.

Distribution. Endemic in Peninsular Malaysia, Pahang (P. Tioman) and Johor (Panti FR & Endau-Rompin SP)

Ecology. Lowland to hill dipterocarp forest 60–750 m altitude, locally common on vertical earth bank and rocky stream bank.

Additional specimen examined: JOHOR, Endau-Rompin SP, G. Janing: *Kiew, R. RK 1785* (KEP), *Kiew, B.H. RK 1650* (KEP), *RK 1646* (KEP), *Kiew, R. RK 1853* (SING), Endau-Rompin SP, G. Janing Barat: *RK 1783* (SING), Labis FR: *Saw, L.G. FRI 34348* (KEP, L, SING), Panti FR, G. Panti: *Corner, E.J.H. 30654* (SING), *32540* (SING), Panti FR, Sg. Pelepah: *31431* (SING), *32489* (L, SING), Panti FR, Sg. Segun: *30870* (L, SING), Panti FR, Waterfalls: *Maxwell, J.F. 82-118* (SING), PAHANG, Endau-Rompin SP, Ulu Kinchin: *Kiew, B.H. KBH 86-41* (KEP), Endau-Rompin SP, Ulu Sg. Anak Endau: *Sam, Y.Y. FRI 44460* (KEP, KEP, SAN), Endau-Rompin, SP, Sg. Keriong: *Turner, I.M. 96-105* (SING), P. Tioman, G. Kajang: *Mohd Nur 18917* (SING), *Henderson, M.R. 21657* (SING), *Nor Ezzawanis, A.T. FRI 54426* (KEP).

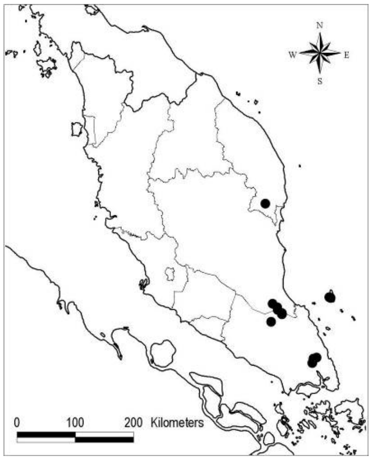
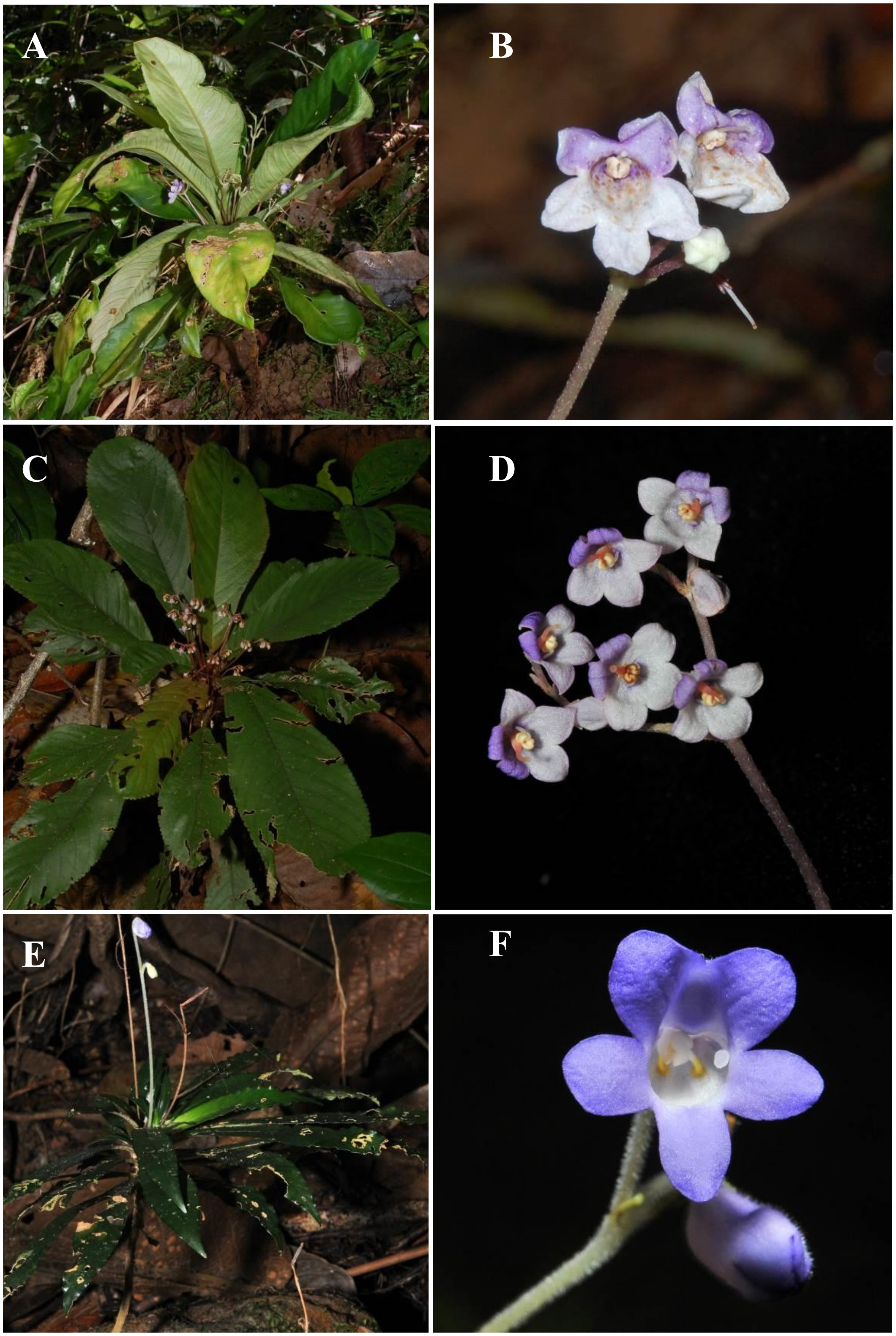


Figure 4.3. Distribution map of *Codonoboea densifolia* in Peninsular Malaysia.

Plate 1



Codonoboea anthonyi. A, habit; B, flowers. *Codonoboea codonion*. C, habit; D, flowers. *Codonoboea densifolia*, E, habit; F, flowers.

4. ***Codonoboea floribunda*** (M.R.Hend.) C.L.Lim — **Fig. 4.4, Plate 2A–B**

(Latin, *flori-* = flower, *-bunda* = abundant; having abundant flowers)

Gard. Bull. Sing. 62 (2011) 261. **Basionym:** *Paraboea floribunda* M.R.Hend., Gard. Bull. Sing. 7 (1933) 117. **Homotypic Synonyms:** *Didymocarpus floribundus* (M.R.Hend.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44. – *Henckelia floribunda* (M.R.Hend.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 345. **Type:** Peninsular Malaysia, Terengganu, Kemaman, Bkt. Kajang, Sg. Nipah, *Corner 26022*, June 1932 (holotype K).

Erect **herb**. **Indumentum** of stem apex and petioles long multicellular, ferruginous, erect to semi erect hairs. **Stems** erect, to *c*. 14 cm tall, (2.3–)3.1–4(–5.8) mm thick, unbranched, woody, dark reddish brown, knobbly with swollen leaf scars. Flowering at *c*. 10 cm tall. **Leaves** decussate, tufted at top of stem, all leaves held *c*. 30^o–60^o at top of stem, elsewhere more or less horizontally from stem; petioles 14.2– 26.4(–49.4) mm long, 1.2–1.7(–1.9) mm wide, in life dark maroon, widely grooved above, when dry yellowish brown; laminas oblanceolate, (11.3–)13.2–15.2 × (4–)5.4–5.7(–6.6) cm, in life pale glossy green above, pale whitish green beneath with tinge purple base, drying reddish to greenish brown above, paler beneath, papery, glabrous except both side of midrib and lateral veins beneath with long hairs; base cuneate, often minutely cordate, margin broadly serrate to crenate, teeth 3–4 per cm, apex broadly acute; veins slightly sunken above when young, midrib slightly raised to flat above, prominent beneath, lateral veins 9–13 pairs, intercostal reticulate, more conspicuous beneath, often with parallel veins joining perpendicularly between two adjacent lateral veins. **Inflorescences** *c*. 2–5(–10) per plant, each 2–5(–7–8)-flowered. Indumentum of peduncle, pedicel, bracts and calyx *long*, *straight*, *erect, eglandular hairs to 2.2 mm*, 5–

6(–7)-cell, shorter on calyx; corolla with scattered eglandular hair, shorter than 0.5 mm to almost glabrous outside, glabrous inside. Peduncle 4.1–5.8(–7.8) cm long, erect with flowers held slightly above leaves, dark purplish maroon. Bract pair, *foliose*, (3–)4.7–6.8(–7.9) × (1.4–)2.5–2.9 mm, green, *3-veined*, margin appressed hairy, apex rounded. Pedicels slender, (4.1–)5.8–7.8 mm long, concolor with peduncle. **Flowers** held horizontally. Calyx *erect*, maroon purple, lobes lanceolate, apex acute, 2.6–4.3 × 1 mm; corolla broadly campanulate, lower corolla tube curve up, *c*. 19.6 mm across, *c*. 12.9 mm long, corolla tube *c*. 4 mm long, 6.2 mm wide, purplish, darker on upper corolla lobes, corolla lobes anisomorphic, lobes oval, apex rounded, upper lobes *c*. 5.3 × 5.2 mm, reflexed, lateral lobes *c*. 4.9 × 5.6 mm, reflexed, lower lobe *c*. 4.3 × 6.2 mm, lower lobe dilating from base, lower lobe projecting *c*. 5.5 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments straight, *c*. 1.3 mm long, 0.4 mm wide at base, white, joined to corolla tube *c*. 1.1 mm from base, anthers subcordate, 1.6 × 1.8 mm, 0.7 mm thick, white, with dull yellow line, connivent at apex; nectary 0.5 mm tall, shallowly lobed; pistil to *c*. 6.7 mm long, protruding *c*. 2.5 mm from corolla mouth, ovary narrow ovoid, *c*. 2.5 × 0.9 mm, in life ovary dark orange to maroon, style yellowish green, stigma white, pistil with a mixture of short point eglandular hairs and scattered sessile glandular hairs, denser on ovary, style 3.9 mm long, stigma slightly capitate, rounded, *c*. 0.5 × 0.5 mm, glistening, apex densely papillose. **Fruits** narrowly cylindrical, drying 4-angular, 2.1–2.9 cm long, 1.2–1.4 mm thick, drying dark reddish brown, glabrous. **Seeds** ovoid *c*. 0.35 × 0.2 mm.

Distribution. Endemic in Peninsular Malaysia, Terengganu.

Ecology. Lowland to upper hill dipterocarp forest, 81–152 m altitude, on forest floor and stream banks.

Additional specimen examined: TERENGGANU, Bkt. Kajang: *Kiew, R. RK 2686* (SING), *RK 2687* (SING), *RK 2676* (SING), *Corner, E.J.H. SFN 30714* (SING), Sg. Nipah: *Kiew, R. RK 2653* (KEP), Sg. Nipah FR: *Sam, Y.Y. FRI 47190* (KEP), *FRI 47223* (KEP), *Kiew, R. RK 5327* (KEP), *Lim, C.L. FRI 64971* (KEP, SAN, SING, L, K, E), *FRI 65153* (KEP), *Sam, Y.Y. FRI 47199* (KEP), Sri Bangun: *Sinclair, J. SFN 39863* (SING), Ulu Bendong: *Corner, E.J.H. SFN 30110* (L, SING). Exsitu: Forest Research Institute Malaysia: *Sam, Y.Y. FRI 47227* (KEP), *FRI 47207* (KEP).

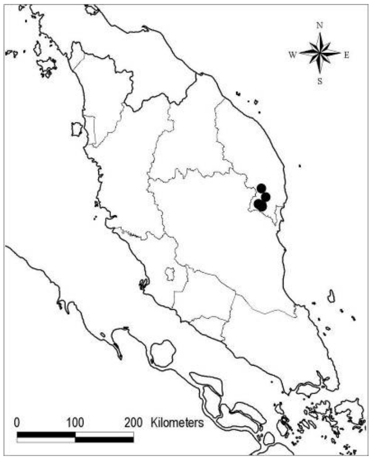


Figure 4.4. Distribution map of *Codonoboea floribunda* in Peninsular Malaysia.

5. ***Codonoboea heterophylla*** (Ridl.) C.L.Lim — **Fig. 4.5, Plate 2C**

(Greek, *hetero-* = different, *phylla-* = leaf; having different kind of leaves)

Gard. Bull. Sing. 62 (2011) 262. **Basionym:** *Didymocarpus heterophyllus* Ridl., Trans. Linn. Soc, ser. 2, Bot. 3 (1893) 329, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 55, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 763, Fl. Malay Pen. 2 (1923) 522; Kiew, Gard. Bull. Sing. 42 (1989) 53. **Homotypic Synonym:** *Henckelia heterophylla* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 346. **Type:** Peninsular Malaysia, Pahang, Sg. Tahan, *Ridley 2170*, 1891 (holotype SING).

Rosette **herb**. **Indumentum** of stem apex and petioles long, multicellular, appressed hairs, to 1.3 mm long. **Stems**, to *c*. 10 cm tall, (1.5–)2.1–2.8 mm thick, unbranched, woody, dark yellowish brown, knobbly. Flowering at *c*. 5 cm tall. **Leaves** decussate, more or less appressed to ground; petioles 13.5–29.7 mm long, 0.9–1.2 mm wide, in life dark brownish red, grooved above, when dry dark greenish to reddish brown; laminas obovate to oblanceolate, (4.5–)10.2–15.9 × 2.5–3.4(–4.5) cm, in life dull dark green above, yellowish brown to orange-brown beneath, drying dark reddish to greenish brown above, yellowish to greenish brown beneath, papery, glabrous except midrib and lateral veins beneath with appressed hairs; base rounded, cordate, margin crenate, teeth 3–4 per cm, apex broadly acute; veins in life sunken above, bullate, drying flat above, prominent beneath, lateral veins 9–15 pairs, intercostal vein reticulate, obscure above, more conspicuous beneath. **Inflorescences** *c*. 1–6(8–12) per plant, each 3–4-flowered. Indumentum of peduncle, pedicel, bracts and calyx a mixture of long erect and appressed eglandular hairs, to 0.8 mm long, 3–6-celled and short hairs; corolla tube and lobe outside with a mixture of minute, scattered, sessile glandular hairs and sparse short eglandular hairs, 5–6-celled, frontal surface of corolla lobes with sessile glandular hairs, denser at margin. Peduncle 3.2–5.1 cm long, erect with flowers held slightly above leaves, pinkish purple. Bract pair, ligulate *c*. 4.1 × 0.8 mm, pale purplish maroon, sparse hairy, 3-veined, apex rounded. Pedicels slender, (1.6–)3.2–4.6 mm long, concolor with peduncle. **Flowers** nodding. Calyx pale brownish maroon, lobes lanceolate, apex acute, 1.1–1.2 × 0.4 mm; corolla campanulate, *c*. 8 mm across, *c*. 4.3 mm long, corolla tube *c*. 3.3 mm long, *c*. 3.1 mm wide, pinkish purple, corolla lobes anisomorphic, apex pointed, upper lobes *c*. 3.1 × 2.5 mm, lilac, reflexed, lateral lobes *c*. 2.5 × 3.0 mm, lower lobe *c*. 3.3 × 2.9 mm, lateral and lower lobes dilating from base, lower lobe projecting *c*. 3 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments straight, *c*. 1.2 mm long, 0.3 mm wide at base, white, joined to corolla tube *c*. 1 mm from base, anthers reniform, 1 × 1.8 mm, 0.8 mm thick, bright yellow, connivent at apex; nectary 0.3 mm tall, shallowly lobed, upper part split; pistil to *c*. 5.8 mm long, projecting *c*. 2 mm beyond upper corolla tube, ovary pale purple, style pale purple, stigma white, pistil short eglandular, appressed hairs, pointing towards stigma, denser on ovary, ovary narrow ovoid, *c*. 1.8 × 0.7 mm, style 3.8 mm long, stigma slightly capitate, *c*. 0.3 × 0.5 mm, glistening, apex densely papillose. **Fruits** narrowly cylindrical, 1.1–2.1 cm long, 0.7–1.2 mm thick, drying dark reddish brown, glabrous. **Seeds** ovoid, *c*. 0.3 × 0.2 mm.

Distribution. Endemic in Peninsular Malaysia, Johor and Pahang.

Ecology. Lowland to hill forest, 60–720 m altitude, on earth banks by river or hill slopes.

Additional specimen examined: JOHOR, Bkt. Pengantin, Sg. Juasseh, Labis: *Mohd Shah MS 2238* (SING), Endau-Rompin SP, G. Janing: *Kiew, R. RK 1812* (KEP), *Lake s.n.* (SING), Endau-Rompin SP, Sg. Jasin: *Kiew, R. RK 1691* (KEP, SING), Endau-Rompin SP, Upeh Guling: *Chua, L.S.L. FRI 33035* (KEP, SAN, SAR, K, L, SING, BKF); PAHANG, Endau-Rompin SP, G. Keriong: *Davison, G.W.H. GD 7* (KEP, SAN), *GD 13* (KEP), Endau-Rompin SP, Ulu Kinchin: *Kiew, B.H. KBH 86-9* (KEP), Endau-Rompin SP, Ulu Sg. Anak Endau: *Sam, Y.Y. FRI 44452* (KEP), *FRI 44457* (KEP); PAHANG, Taman Negara, G. Pondok Dua: *Lim, C.L. FRI 64870* (KEP), Taman Negara, Kuala Teku: *Kiew, R. RK 2423* (KEP), *Mohd. Shah MS 1379* (KEP, SING), *Seimund, E. 548* (SING), *462* (SING), *Holttum, R.E. SFN 20098* (SING), *Kiah, S. SFN 31739* (SING), Taman Negara, Sg. Tahan, Sg. Puteh: *FRI 64890* (KEP).

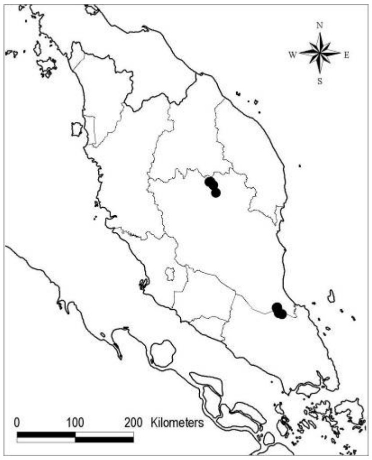


Figure 4.5. Distribution map of *Codonoboea heterophylla* in Peninsular Malaysia

6. ***Codonoboea leiophylla*** (Kiew) C.L.Lim — **Fig. 4.6, Plate 2D–E**

(Greek, *leio-* = smooth, *phylla* = leaf; having smooth leaves)

Gard. Bull. Sing. 62 (2011) 264. **Basionym:** *Didymocarpus leiophyllus* Kiew, Gard. Bull. Sing. 44 (1992) 28. **Homotypic Synonym:** *Henckelia leiophylla* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 348. **Type:** Peninsular Malaysia, Terengganu, Ulu Setiu [Setui], *Kiew RK 2265*, 28 April 1986 (holotype KEP; isotype SING).

Erect to semi erect **herb**. **Indumentum** of stem apex and petioles short, appressed, dark brown hairs. **Stems** to *c*. 19 cm tall, (1.5–)2.5–3.6(–5.2) mm thick, unbranched, woody, dark brown to yellowish brown, smooth with swollen leaf scars. Flowering at *c*. 2 cm tall. **Leaves** decussate, tufted at top of stem, all leaves held more or less horizontally from stem; petioles (5.4–)9.3–13.3(–15.6) mm long, 1–1.4 mm wide, in life brownish green, succulent, widely grooved above, when dry dark brown to yellowish brown; laminas oblanceolate, 7.9–8.6(–11.4) × (1.6–)2.6–3.2(–4) cm, in life glossy green above, pale greyish green to glaucous beneath, drying greenish, yellowish to greyish brown above, pale yellowish brown to orange-brown beneath, leathery, glabrous except midrib, lateral veins and margin beneath with shortly appressed hairs; base narrowly cuneate, tapering, sometimes oblique, margin entire, sometimes shallowly serrate towards apex, apex broadly acute, sometimes short acuminate or rounded; midrib slightly raised or flat above, prominent beneath, lateral veins 8–12 pairs, obscure above, slightly prominent beneath, sometimes paler than lamina above, darker then lamina beneath, upper veins arching upward towards apex, intercostal veins faint on both surface. **Inflorescences** *c*. 3–28 per plant, each 1-flowered. Indumentum of peduncle, pedicel, bracts and calyx with sparse, appressed, 2–3-celled, curved, eglandular hairs; corolla with short erect, eglandular hairs outside, glabrous inside. Peduncle 3–5.9 cm long, erect with flowers held above leaves, dark pinkish maroon. Bract pair linear, (1–)1.5–2.1(–2.8) × 0.3–0.5 mm, in life pale maroon. Pedicels slender, 6.4–12.2 mm long, concolor with peduncle. **Flowers** nodding. Calyx almost divided to base, purplish brown, lobes narrow acute, apex acute, (1.8–)2–2.6(–3.2) × 0.5–0.6 mm, lower lobes slightly longer; corolla broadly campanulate, *c.* 17.8 mm across, *c.* 14.8 mm long, corolla tube *c.* 5.1 mm long, *c.* 6.7 mm wide, lower part of tube more or less gibbose, pale lilac to white, upper corolla lobes slightly darker, corolla lobes anisomorphic, lobes oval, apex narrowly rounded, upper lobes *c.* 5.9 × 4.2 mm, reflexed, lateral lobes *c.* 5.4 × 5.8 mm, lower lobe *c.* 4.9 × 5.7 mm, lateral and lower lobes dilating from base, lower lobe projecting 10 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments flattened, straight, *c.* 1.7 mm long, 0.7 mm wide at base, white, joined to corolla tube *c.* 1.1 mm from base, anthers subcordate, 2.1 × 1.5 mm, 0.8 mm thick, white, connivent at apex; nectary 0.5 mm tall, deeply lobed; pistil to *c.* 6.9 mm long, protruding *c.* 2 mm from corolla mouth, ovary narrow ovoid, *c.* 2.7 × 0.9 mm, in life ovary dark crimson to purple, style yellowish green, stigma white, pistil with eglandular hairs, denser on ovary, sparse on style, dull pale yellow, style *c.* 4.4 mm long, pale green to white, stigma rounded, slightly discoid, *c.* 0.4 × 0.5–1 mm, glistening, apex papillose. **Fruits** narrowly cylindrical, slightly curved upwards, 2.3–2.9(–3.9) cm long, (1.2–)1.8– 2.1 mm thick, purplish maroon, minutely sparse hairy. **Seeds** ellipsoid, *c.* 0.4 × 0.16 mm.

Distribution. Endemic in Peninsular Malaysia, Terengganu and Kelantan.

Ecology. Lowland, locally common on vertical earth banks, hill slopes by river, to 100 m altitude.

Additional specimen examined: TERENGGANU, G. Lawit: *Kiew, R. RK 2272* (SING), G. Tebu FR: *Lim, C.L. FRI 64998* (KEP, SAN, SING), Ulu Setiu FR: *Anthonysamy, S. SA 670* (KEP), *SA 662* (KEP, SING), *Kiew, R. RK 2265* (KEP, SING), *Sam, Y.Y. FRI 44386* (KEP, KEP, L, SAN, SAR), *FRI 46650* (KEP, SAN), *Mohd Shah MS 3509* (SING), *Anthony, S. SA 718* (SING), *Lim, C.L. FRI 64951* (KEP), *FRI 64991* (KEP); KELANTAN, Relai FR (Kuala Aring FR): *Kiew, B.H. KBH 1* (KEP).

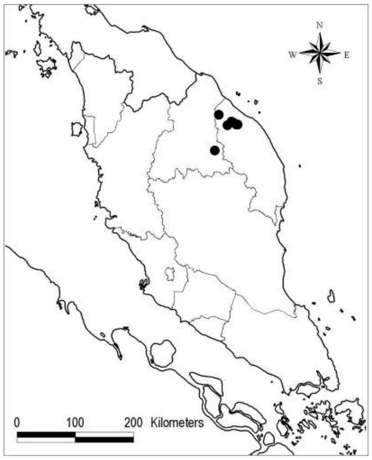
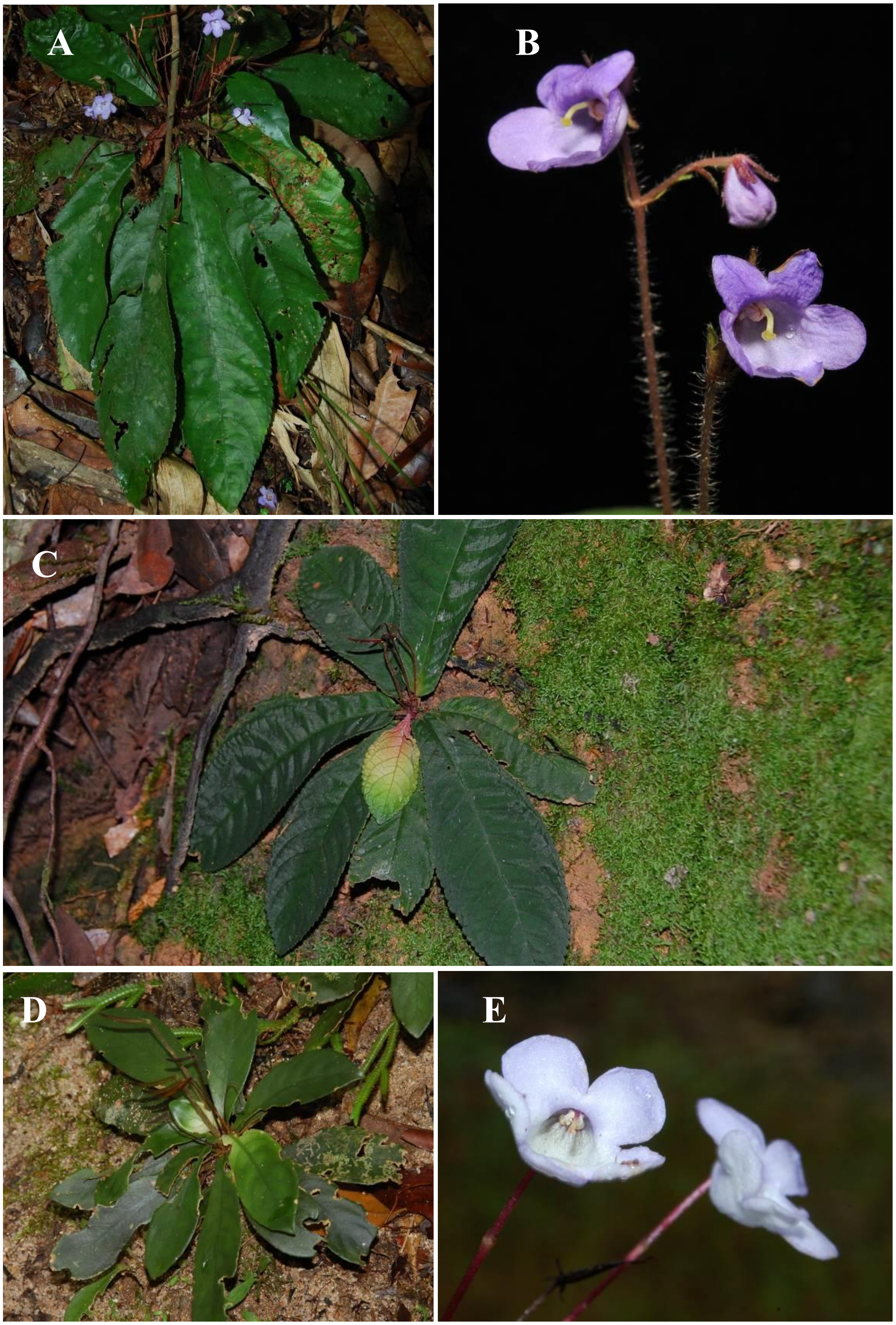


Figure 4.6. Distribution map of *Codonoboea leiophylla* in Peninsular Malaysia.

Plate 2



Codonoboea floribunda. A, habit; B, flowers. *Codonoboea heterophylla*. C, habit. *Codonoboea leiophylla*, D, habit; E, flowers.

7. ***Codonoboea oreophila*** Kiew *ex* C.L.Lim — **Fig. 4.7, Plate 3, 4A–C**

(Greek, *oreo-* = mountain, *-philos* = love; from its habitat, because it is only found in montane forest)

in Lim, Kiew & Haron, Blumea 2013. **Type:** *Lim et al. FRI 56646*, Peninsular Malaysia, Kelantan, G. Stong SP, G. Stong, 1231 m altitude, 5°20'25" N, 101°56'57" E, 26 July 2008 (holo KEP, iso E, K, L, SING).

Rosette **herb**. **Indumentum** of uniseriate, multicellular (about 2--3(--5)-celled), very fine, translucent, eglandular hairs on young stem, petioles and upper lamina surface, more or less appressed near margin, on lower lamina surface more erect and longer on veins beneath; fine, dark purplish maroon on peduncle, pedicel and calyx; very fine, to 0.3 mm long on corolla outside, corolla lobes short ciliate. **Stem** branched, (2--3)6.5--9(--11) cm long, 1.4--3.8(--7) mm thick, woody, base of stem often creeping, sometimes producing an elongated semi-woody side branch to 8.2 cm long, 1.7 mm thick, pale green in life. Flowering at *c*. 2.5 cm tall. Upper internodes crowded, lower internodes 5--9 mm long, sometimes to 2.5--3.5(--4.6) cm in the elongated side branch. **Leaves** decussate; sessile in young leaves, petioles to (0.5--)1.5--2.4(--3.2) cm long, succulent, broadly grooved above in mature leaves; lamina oblanceolate to oblong, 3--4.8(--6) × 1.6--2.2(--3.1) cm, in life dark green above, brownish to greyish green beneath, drying greyish to greenish brown above, paler beneath, succulent in life, drying thickly leathery; base rounded to broadly cuneate, sometimes cordate, often unequal, margin crenulate, teeth *c*. 6--8 per cm, teeth towards the apex often slightly overlapping the one behind, apex broadly obtuse to rounded; midrib grooved above, prominent beneath, lateral veins to 9--12 pairs, lower pairs almost parallel, upper pairs sharply arching to apex, obscure above, prominent beneath, intercostal veins inconspicuous.

Inflorescences 1(–2) per axil, 1-flowered. Peduncle slender, (4.4--)5.8--6.6(--9) cm long, erect, with flower held above leaves, dark purplish-maroon, apex bent and pointing downwards in bud, upon flowering becoming horizontal. Bract pairs opposite or subopposite, ligulate, *c.* 0.8--1.7 × 0.3 mm. Pedicel slender, (0.8--)1.2--1.5 cm long, concolourous with peduncle. **Flowers** held horizontally; calyx dark purplish maroon, free to base, lobes broadly oblong, apex acute, 1.5--2.4 × 0.8 mm, lower lobes slightly longer; corolla trumpet-shaped, to 19 mm long, *c.* 10 mm wide at mouth, pale lilac, darker on lower and lateral corolla lobes, with streaks of darker purple outside, tube white inside with 2 light yellowish nectar guides near mouth, tube to 10 mm long, 4 mm wide, narrower at base (*c.* 2 mm wide), corolla lobes 5, apex rounded, upper lobes *c.* 4 by 3 mm, reflexed, lateral lobes *c.* 5 × 6 mm, lower lobe *c.* 5 × 5 mm, lateral and lower lobes spreading from base; stamens with filaments white, filiform, *c.* 3 mm long, 0.2 mm wide at base, joined to corolla tube *c.* 4.1 mm from base, slightly bent at base, straight above, anthers white, reniform, *c.* 0.5 by 1.5 mm, connivent at apex; staminodes 2, to 0.7 mm long, often curled; nectary annular, *c.* 1 mm tall, lower side slightly taller, shallowly lobed; pistil to 12.5 mm long, not projecting beyond the corolla tube, ovary and style pinkish purple, stigma purple, pistil with short eglandular hairs, denser on the ovary, ovary ovoid, *c.* 4.5 by 1.3 mm, style 7.3 mm long, stigma discoid, *c.* 0.4 by 0.4 mm, in life glistening, apex dense papillose. **Fruits** narrowly cylindrical, slightly quadrangular in cross section, splitting on dorsal side, (2.5--)3--3.5 cm long, 1 mm thick, dark purplish maroon, style persistent to 0.5--0.7 mm long. **Seeds** ovoid, *c.* 0.3 by 0.2 mm.

Distribution. Endemic in Peninsular Malaysia, Kelantan, known only from G. Stong SP.

Ecology. Mossy ground and mossy base of trees, and on earth banks on ridges in upper montane forest above 1000 m altitude.

Notes. Altitude recorded at *Mohd Nur SFN 12229* is 2600 ft (792 m). Site collection visit to G. Stong revealed that the species is only confined to area above 1000 m. Kiew (1992) proposed the species as *Didymocarpus oreophilus* Kiew but without a valid description. When it was published in Lim *et al.* (2013), the name retained thus "ex" was added in the author citation.

Additional specimen examined: Kelantan, G. Stong SP, G. Stong, *Mohd Nur & Foxworthy SFN 12229* (SING), *Symington*, *FMS 37716* (SING)*, Kiew*, *RK 2734* (KEP); ridge to G. Tera: *Chew FRI 53568* (K, KEP, SING); near Saji Swamp: *Yao FRI 55850* (KEP).

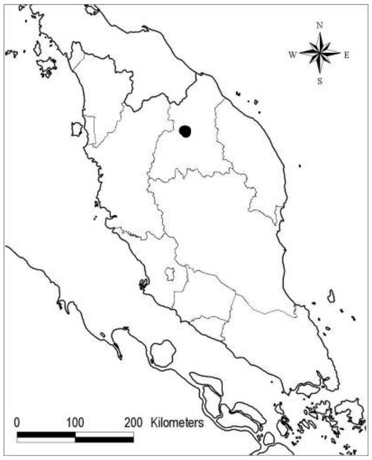


Figure 4.7. Distribution map of *Codonoboea oreophila* in Peninsular Malaysia.

Plate 3

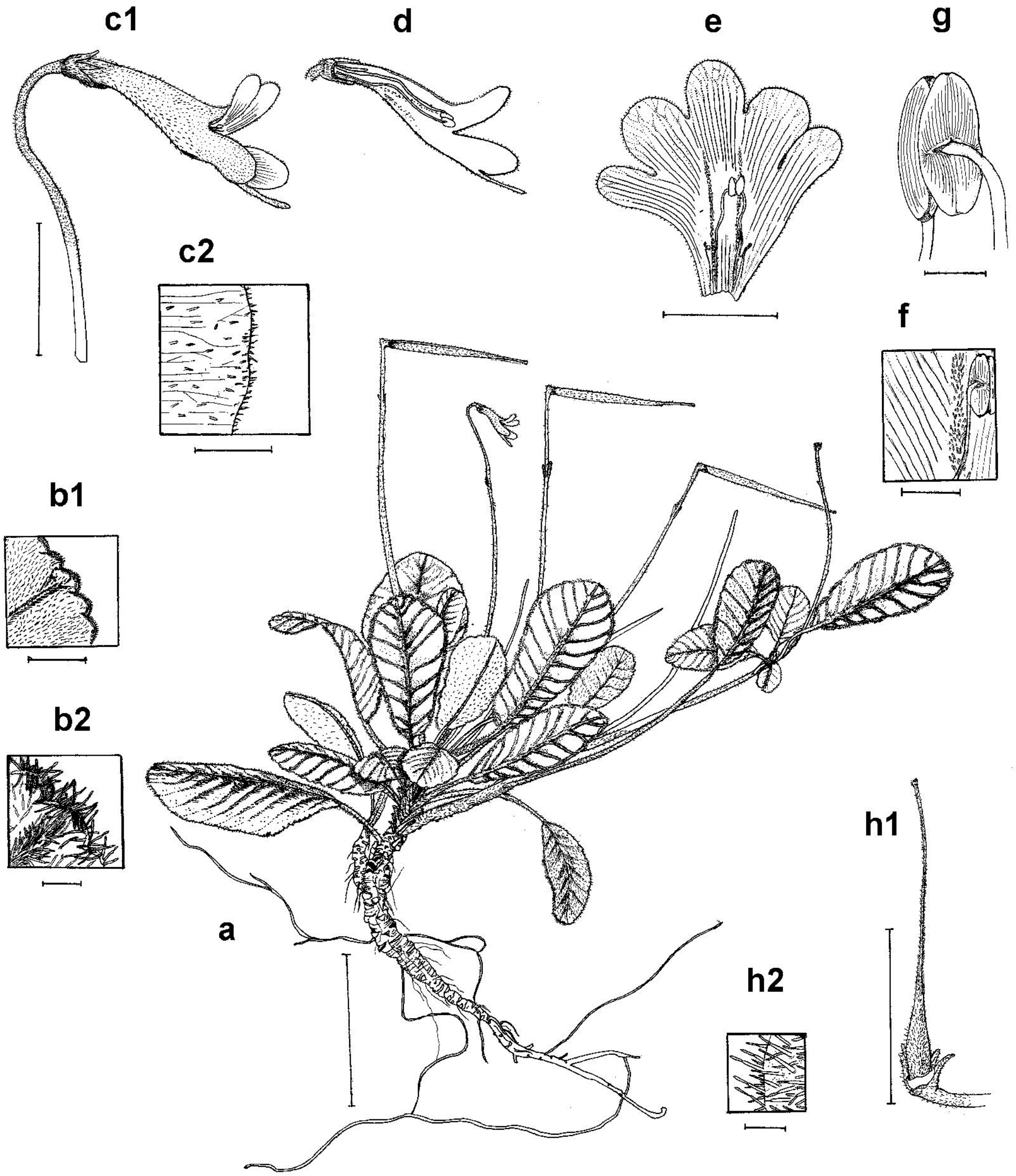


Illustration of *Codonoboea oreophila* Kiew *ex*. C.L.Lim. **a**, habit; **b1**, lamina margin indumentum beneath, **b2**, close up of lamina margin indumentum beneath; **c1**, side view of flower, **c2**, indumentums of corolla lobe outside; **d**, side view of flower with part of corolla tube and pistil removed; **e**, corolla inside, showing nectar guide, stamens and staminoids; **f**, close-up of nectary guide below stamen; **g**, side view of anthers; **h1**, pistil with part of calyx removed, to reveal nectary at base, **h2**, close up of pistil indumentum (all from *Lim et al. FRI 56646*). — Scale bars: a = 4 cm, b1 = 5 mm, b2 = 1 mm, c1 = 1 cm, c2 = 1 mm, d = 1 cm, e = 1 cm, f = 0.25 mm, g = 1 mm, h1 = 5 mm, h2 = 0.5 mm.

8. *Codonoboea pumila* (Ridl.) C.L.Lim — Fig. 4.8, Plate 4D–E

(Latin, *pumilus* = dwarfish, small; referring to the plant size)

Gard. Bull. Sing. 62 (2011) 268. **Basionym:** *Didymocarpus pumilus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 56, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 763, Fl. Malay Pen. 2 (1923) 523; Henderson, Malay. Wild Flowers Dicot. (1959) 349. **Homotypic Synonym:** *Henckelia nana* A.Weber, Beitr. Biol. Pflanzen 70 (1998) 350. **Type** (lecto Kiew & Lim 2011)**:** Peninsular Malaysia, Pahang, G. Semangkok [Semangko Pass], *Burn-Murdoch s.n.*, February 1904 (lectotype SING).

Rosette, sometimes prostate **herb**. **Indumentum** of stem apex, petiole, lamina above, veins beneath long, multicellular, silvery, appressed hairs, 3–4-celled, to 2 mm long, hairs on lamina above neatly appressed, with hair tips pointing away from the lateral veins and towards the leaf margin. **Stems** erect, to *c.* 11 cm long, often grow horizontally into mossy ground layer, (0.8–)1.2–1.9(–3) mm thick, branched, woody, greyish brown, slightly knobbly with swollen leaf scars. Flowering at *c.* 2 cm tall. **Leaves** decussate, tufted at top of stem, all leaves held horizontally from stem, often appressed to ground; petioles (1–)1.4–2.2(–2.9) cm long, 0.9–1.1(–1.4) mm wide, in life brownish green, widely grooved above, when dry yellowish brown; laminas broadly ovate to broadly obovate, (3.3–)4.1–4.5(–5.6) × (1.6–)2–2.3(–3.6) cm, in life dull dark green above, dark maroon purple beneath, drying dull greyish brown above, yellowish brown beneath, thick leathery, hairs neatly appressed towards margin above; base broad cuneate, margin *entire*, *recurved*, apex broadly acute to rounded; veins slightly sunken above, prominent beneath, lateral veins 5–7 pairs, intercostal inconspicuous. **Inflorescences** *c.* 1–6(–11) per plant, each (1–)2-flowered. Indumentum of peduncle, pedicel, bracts and calyx, erect, dense, to 0.2 mm long, 2(–3)-celled eglandular hairs;

corolla outside with scattered, short, erect eglandular hairs, 1–2-celled, glabrous inside. Peduncle (3.7–)4.4–5.4(–6.3) cm long, erect with flowers held above leaves, dark purplish maroon. Bract pair ligulate, (0.8–)2.5–2.8 × 0.5–1.1 mm, dull green, margin hairy, apex pointed. Pedicels slender, (1.4–)4.3–8.3 mm long, concolor with peduncle. **Flowers** nodding. Calyx almost divided to base, maroon purple, lobes narrow triangular, apex acute, 1.1–1.7 × 0.7 mm; corolla pouch-shape, *c.* 7.4 mm across, *c.* 7 mm long, corolla tube *c.* 4.2 mm long, 3.5 mm wide, mauve to dark purplish, darker at corolla tube and lobes outside, pale on corolla lobes inside, corolla lobes *concolor*, anisomorphic, lobes oval, apex rounded, upper lobes *c.* 1.8 × 2.2 mm, *non-reflexed*, lateral lobes *c.* 2.3 × 3 mm, lower lobe *c.* 2.8 × 3.6 mm, lateral and lower lobes dilating from base, lower lobe projecting *c.* 2 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments curve out half way and bend towards mouth, *c.* 1.7 mm long, 0.2 mm wide at base, white, joined to corolla tube *c.* 2 mm from base, anthers reniform, 0.9 × 1.6 mm, 0.6 mm thick, white, connivent at apex; nectary 0.6 mm tall, shallowly lobed; pistil to *c.* 6.7 mm long, protruding *c.* 2 mm from corolla mouth, ovary ovoid, *c.* 2 × 0.8 mm, style 4.7 mm long, in life ovary dark purple, style purple, stigma white, pistil with *short-stalked glandular hairs*, denser on ovary, stigma slightly capitate, *c.* 0.2 × 0.4 mm, glistening, apex densely papillose. **Fruits** narrowly cylindrical, (1.6–)2.3–2.9 cm long, (1–)1.4–1.5(–1.8) mm thick, dark purplish maroon, drying yellowish brown, short hairy. **Seeds** ovoid, *c.* 0.37 × 0.21 mm.

Distribution. Endemic in Peninsular Malaysia, Pahang, Fraser's Hill and Semangkok FR

Ecology. Lower to upper montane forest, 950–1280 m altitude, on mossy forest floor and earth banks.

Additional specimen examined: PAHANG, Fraser's Hill: *Banka, R. RB 5* (KEP), *Kiew, R. RK 3437* (KEP), *Saw, L.G. FRI 44928* (KEP), Fraser's Hill, Gap: *Curtis, C. 3782* (SING), Fraser's Hill, Methodist Bungalow: *Mohd. Shah MS 633* (L), Fraser's Hill, Pine Tree Hill: *Perumal, B. FRI 41508* (KEP), *Purseglove, J.W. P 4192* (L), *Yao, T.L. FRI 55963* (KEP, SING, SAN, K, L), *Lim, C.L. FRI 64901* (KEP, SAN, SING, L), Semangkok FR: *Ridley, H.N. 12082* (SING).

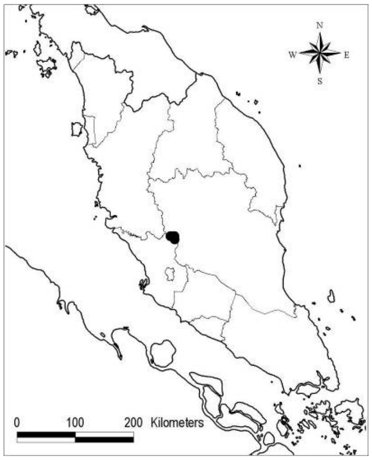
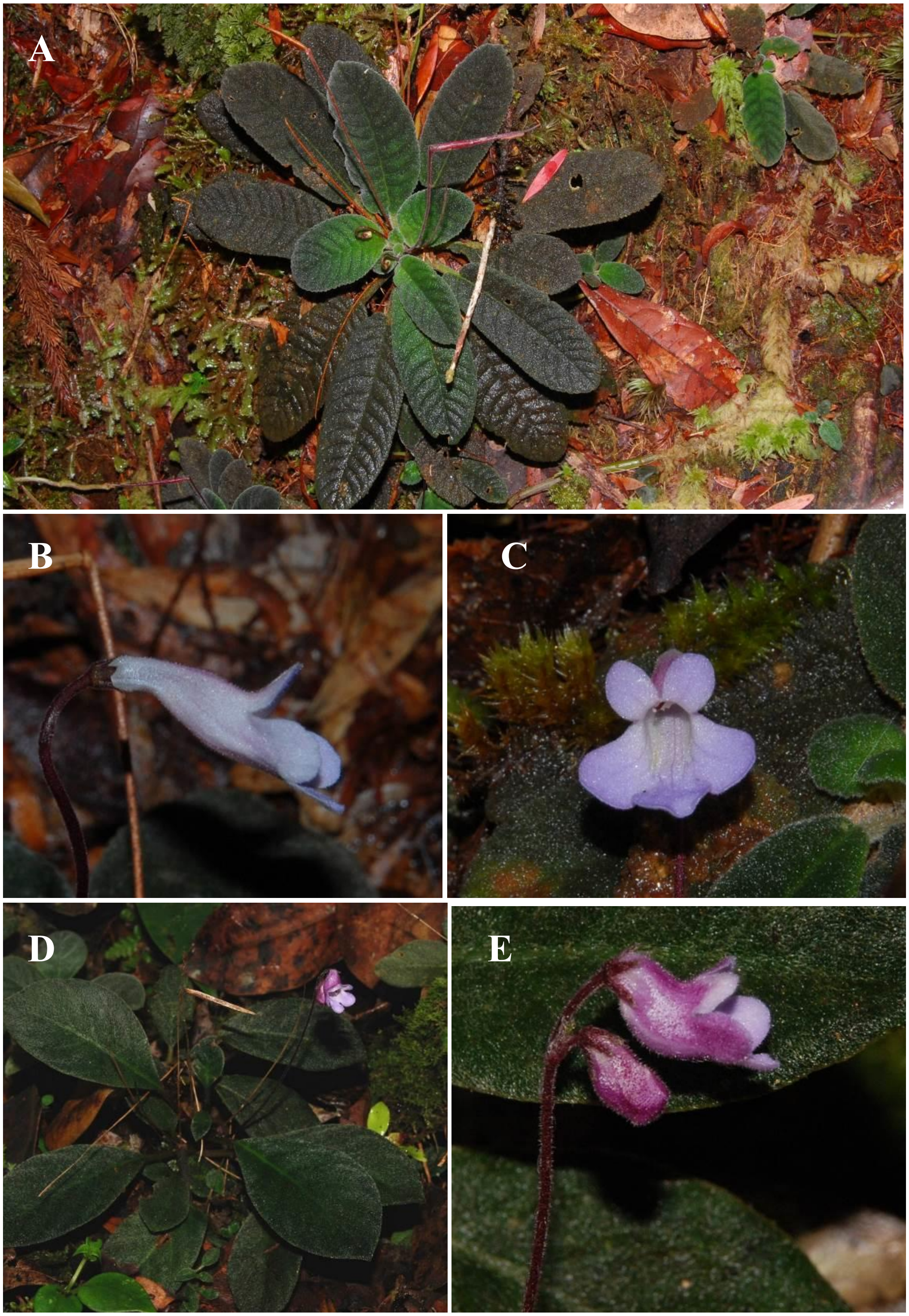


Figure. 4.8. Distribution map of *Codonoboea pumila* in Peninsular Malaysia.

Plate 4



Codonoboea oreophila. A, habit; B, lateral view of flower; C, frontal view of flower. *Codonoboea pumila*. D, habit; E, flowers.

9. *Codonoboea puncticulata* (Ridl.) C.L.Lim — **Fig. 4.9, Plate 5A–C**

(Latin, *puncticulate* = marked with minute dots; referring to the dotted leaf surfaces)

Gard. Bull. Sing. 62 (2011) 268. **Basionym:** *Didymocarpus puncticulatus* Ridl., J. Linn. Soc. 32 (1896) 510, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 55, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 763, Fl. Malay Pen. 2 (1923) 522; Kiew, Malay Nat. J. 41 (1987) 220. **Homotypic Synonym:** *Henckelia puncticulata* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 353. **Type:** Peninsular Malaysia, Johor, G. Panti, *Ridley s.n.*, December 1892 (holotype SING; photo K). **Heterotypic synonym:** *Didymocarpus perditus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 54, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 763, Fl. Malay Pen. 2 (1923) 522. **Type:** Singapore, Selitar, *Ridley s.n.*, 3 Nov 1889 (holotype SING).

Rosette, rarely decumbent **herb**. **Indumentum** of stem apex, petiole, lamina above, veins beneath with long, sericeous, semi erect, hairs, 4–6(–7)-celled. **Stems** to *c*. 22 cm long, (1.6–)2.4–3.6(–6.7) mm thick, rarely branched, woody, greyish brown, stout, densely knobbly with swollen leaf scars. Flowering at *c*. 2 cm tall. **Leaves** decussate, tufted at top of stem, all leaves held horizontally from stem, appressed to ground; petioles (1.1–)2.1–5.6(–10.9) cm long, (1.1–)1.3–1.8(–2.2) mm wide, in life reddish brown, grooved above, when dry greyish to yellowish brown; laminas oblanceolate to obovate, (4.6–)7.2–8.6(–12.4) × (1.7–)2.1–4.1(–6.1) in life dull greyish green to pale green above, often with greyish patch at around midrib above, purplish maroon to pale greyish green beneath, drying dark greenish brown above, reddish greenish to greyish brown beneath, *often minutely punctuate above*, papery to leathery, hairs semi erect to appressed above, dense to scattered, rarely glabrous; base broadly rounded, often cordate, occasionally peltate, oblique, margin crenulate, teeth (3–)4–5(–6) per cm, apex rounded to broadly acute; midrib flat to slightly sunken above, prominent beneath, lateral veins (7–)10–13(–19) pairs, intercostal distinctly reticulate, often faint above, conspicuous beneath. **Inflorescences** *c.* (2–)5–9(–11) per plant, each1-flowered. Peduncle, pedicels, bracts and calyx with dense, erect hairs, 0.2 mm long, 2-cell, lower cell to about 90 % of total length; corolla outside with short, eglandular hairs, margin ciliate, glabrous inside. Peduncle (3.5–)5.9–8.6(–9.8) cm long, erect with flowers held much higher above leaves, dark maroon. Bract pair, subopposite, ligulate, 0.6–0.9(–1.3) × 0.3–0.5 mm, green, apex blunt. Pedicels to (3.8–)4.3–7.8(–11.6) mm long, concolor with peduncle. **Flowers** held horizontally. Calyx almost divided to base, dark maroon purple, lobes triangular, apex pointed, (0.9–)1.2–1.7 × 0.5 mm; corolla almost flat-faced, *c.* 14.8–16.7 mm across, *c.* 4–5.6 mm long, corolla tube *c.* 4–5.6 mm long, 4–4.8 mm wide, pale purple, darker near side lobes at mouth, bright yellow below stamen, base of reflexed upper lobes rim of white, corolla lobes anisomorphic, lobes oblong-oval, apex rounded, upper lobes *c.* 6.1 × 5.1 mm, strongly reflexed, lateral lobes *c.* 7.3 × 5.4 mm, lower lobe *c.* 7.5 × 4.9 mm, lateral and lower lobes dilating broadly from base, lower lobe projecting *c.* 2 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments, *c.* 2.5 mm long, 0.5 mm wide at base, kneed, straight to about 1.6 mm, bend abruptly upward, white, joined to corolla tube *c.* 1.6 mm from base, anthers reniform, 1.5 × 1.9 mm, 0.7 mm thick, white, connivent at apex; nectary 0.5 mm tall, white, with uneven shallow lobes; pistil to *c.* 8.2 mm long, protruding *c.* 4 mm from corolla mouth, ovary ovoid, *c.* 2.5 × 0.8 mm, in life ovary dark purplish brown, style yellowish green, stigma darker yellowish green, pistil with dense eglandular hairs, silvery, denser on ovary, sparse on style, style *c.* 5.7 mm long, stigma capitate, discoid, *c.* 0.3 × 0.6 mm, glistening, apex non-papillose, almost glabrous with small pimples. **Fruits** narrowly ovoid, (1.5–)2.3–3.1 cm long, (1.4–)1.7–2.3 mm thick, when fully open, *broad boat-shape*, to 4 mm broad, dark purplish maroon, drying reddish brown, dense short hairy. **Seeds** ovoid, *c.* 0.3 × 0.4 mm.

Distribution. Singapore and Peninsular Malaysia, Johor, Pahang and Terengganu.

Ecology. Lowland to hill forest, 20–924 m altitude, on various habitats, from shaded earth bank, river banks, rock surface in forest floor, river or by waterfall.

Notes. This is a variable species, the typical type is the rosette form with a woody rootstock. However, some populations in Bkt. Bauk and Sg. Paka FR, Terengganu showing the decumbent habit where the main stems are branched, producing long and slender lateral branches that creep on ground. The decumbent lateral shoots often produce roots at lower nodes. In the case of some decumbent populations in *C. puncticulata*, there has been discussion whether to raise it to a subspecies rank (Tam, S.M. *pers. comm.*). In a field study in Sg. Paka FR, revealed that both decumbent and rosette forms are sympatric and can be found on the natural habitat. Furthermore the flowers produced are the same and molecular phylogenetic results (Chapter 5) confirm that they are the same. The decumbent form could be the ecotype form of the common rosette form.

Additional specimen examined: JOHOR, Endau-Rompin SP, Sg. Gerugul: *Kiew, B.H. KBH 86-8* (KEP), Kota Tinggi: *Mohd Shah MS 2077* (L, SING), Kota Tinggi-Jemaluang Road: *Sinclair, J. 40302* (SING), Mawai: *Teruya, Z. 1099* (SING), Mersing: *Keng, H. K 2082* (L), Panti FR, G. Panti: *Lim, C.L. FRI 65661* (KEP), Panti FR: *Suppiah, T. KEP 98991* (KEP), Panti FR, Cpt. 48: *Sam, Y.Y. FRI 50142* (E, KEP, KEP, SAN, SING, WU), Panti FR, G. Panti: *Weber, A. UPM 3430* (KEP), *Ng, F.SP FRI 1747* (KEP), *Holttum, R.E. 18096* (SING), *15048* (SING), *s.n.* (SING), *Banka, R. RB 3* (SING), *Kiew, R. RK 2400* (SING), *Ahmad, S. AS 6* (L, SING), *Stone, B.C. 4798* (L), *Kuswata, K. 429* (L), Panti FR, G. Panti Barat: *Symington, C.F. FMS 35769* (KEP), *Maxwell, J.F. 77-177* (L), Panti FR, Sg. Pelepak kiri: *Kloss, C.B. s.n.* (SING), Panti FR, Waterfalls: *Banka, R. RB 11* (KEP), *Mohd Shah MS 2412* (SING), *MS 443* (SING, K, E), *Teruya, Z. 878* (SING), *Maxwell, J.F. 80-115* (L); PAHANG, Endau-Rompin SP, Sg. Taku: *Rahimatsah, A. UPM 5603* (KEP), Endau-Rompin SP, Ulu Sg. Anak Endau: *Sam, Y.Y. FRI 44453* (KEP), *FRI 44463* (KEP); TERENGGANU, Bkt. Bauk FR: *Anthonysamy, S. SA 601* (KEP), *Weber, A. UPM 3420* (KEP), *Davison, G.W.H. GD 6* (KEP, SING), *Kochummen, K.M. FRI 2592* (KEP), *Sam, Y.Y. FRI 44397* (KEP, SAN, SAR), *FRI 47170* (KEP), *Saw, L.G. FRI 44888* (KEP, SING), *Sam, Y.Y. FRI 44398* (KEP, SAN), Chemerong FR: *Lim, C.L. FRI 64962* (KEP), Dungun: *Anthony, S. SA 594* (SING), Jengai FR: *Sam, Y.Y. FRI 47154* (KEP, SAN), *Anonymous s.n.* (SING), *s.n.* (SING), *s.n. (0105992)* (SING), Pasir Raja FR: *s.n. (0105989)* (SING), Rasau Kerteh FR: *Sam, Y.Y. FRI 47172* (KEP), *Saw, L.G. FRI 44992* (SING), *Lim, C.L. FRI 64989* (KEP, SAN), Rasau Kerteh VJR: *Chan, Y.C. FRI 16853* (SING), Rasau-Kerteh-Ulu Chukai FR: *FRI 16853* (KEP), *Kochummen, K.M. KEP 94938* (KEP), Sg. Nipah: *Corner, E.J.H. s.n.* (SING), Sg. Nipah FR: *Kiew, R. RK 2675* (KEP, SING), *Sam, Y.Y. FRI 47195* (KEP), *Markandan, M. FRI 42698* (KEP), *Lim, C.L. FRI 64972* (KEP, SAN), Sg. Paka FR: *FRI 64970* (KEP), Sri Bangun: *Sinclair, J. 39883* (SING), Ulu Berang, Sg. Tersat: *Moysey, L. 33610* (SING), Ulu Dungun: *Yong, G.C. RK 3136* (KEP, SING).

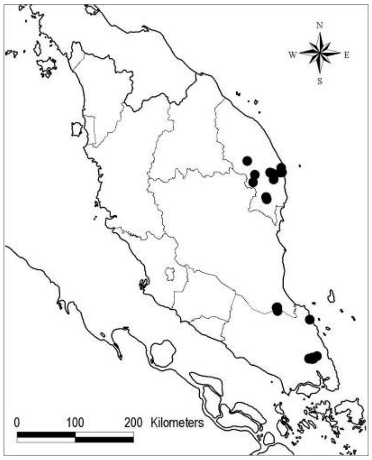
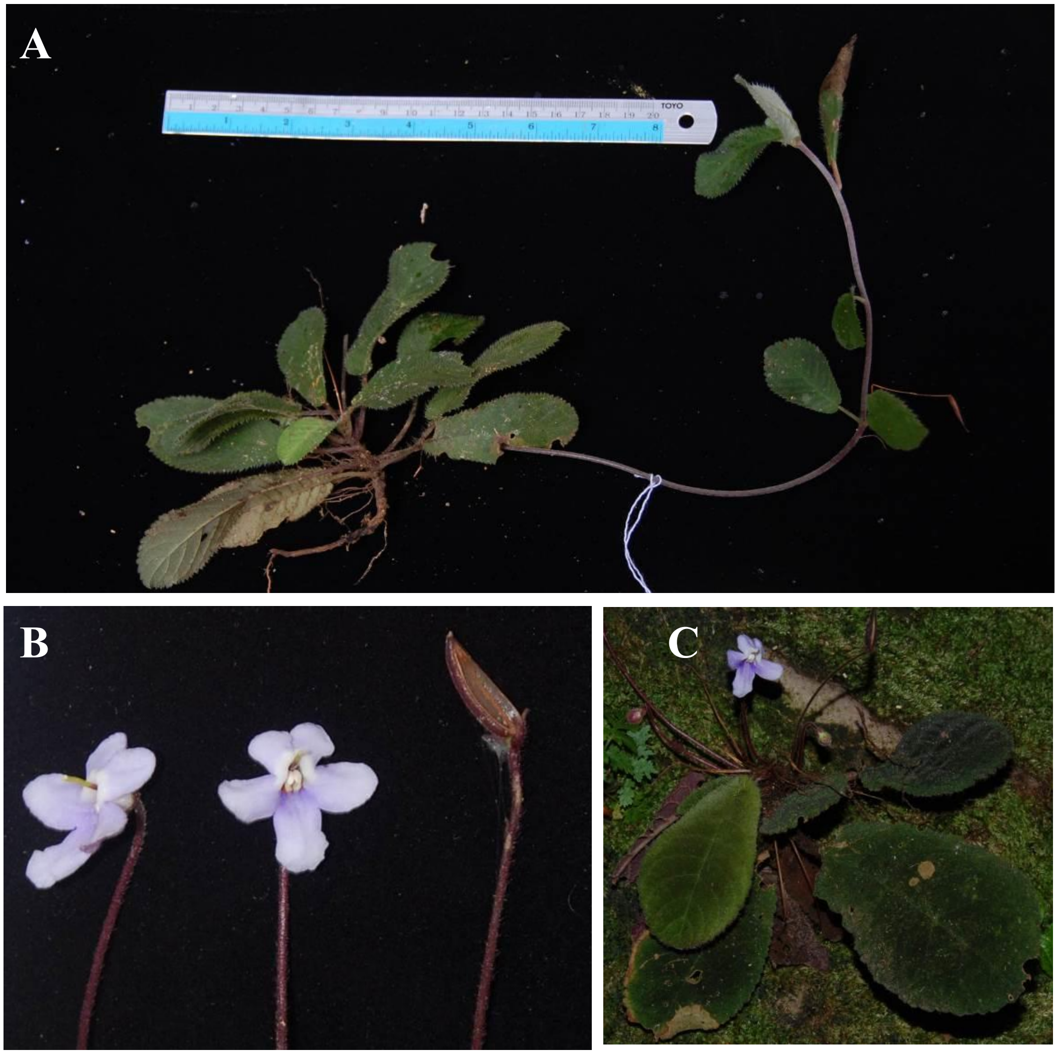


Figure 4.9. Distribution map of *Codonoboea puncticulata* in Peninsular Malaysia.

Plate 5



Codonoboea puncticulata. A, decumbent habit; B, flowers and fruit; C, rosette habit.

10. *Codonoboea rubiginosa* (Ridl.) C.L.Lim — **Fig. 4.10, Plate 6A–C**

(Latin, *rubiginosus* = brown-red, rusty colour; referring to the dried leaf colour)

Gard. Bull. Sing. 62 (2011) 271. **Basionym:** *Paraboea rubiginosa* Ridl., J. Linn. Soc. 38 (1908) 319, Fl. Malay Pen. 2 (1923) 530. **Homotypic Synonyms:** *Didymocarpus rubiginosus* (Ridl.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44; Kiew, Gard. Bull. Sing. 42 (1989) 59. – *Henckelia rubiginosa* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 355. **Type** (lecto Kiew, 1989)**:** Peninsular Malaysia, Pahang, G. Tahan, *Wray & Robinson 5390*, 3 June 1905 (lectotype K; isolectotype SING).

Rosette **herb**. **Indumentum** of stem apex, petiole, lamina above, veins beneath with short, matted, ferruginous, erect, velvety, (1–)2-celled, to 0.3 mm long. **Stems** to *c*. 18.7 cm long, 4–4.9(5.4–7) mm thick, unbranched, woody, reddish brown, densely knobbly with swollen leaf scars. Flowering at *c*. 2 cm tall. Internodes crowded above, often much longer on young shoot, to 11.2 mm long on flushed young stem. **Leaves** decussate, tufted at top of stem, all leaves held horizontally from stem, appressed to ground; petioles 1.5–1.7(–19.5) mm long, 1.5–1.7(–2.4) mm wide, in life reddish brown, terete, when dry dark reddish brown; laminas oblong to oblanceolate, (3.7–)5.2–6.8(–11.1) × 1.5–2.4(–2.9) cm, in life dull yellowish, orange to brownish green above, yellowish brown with tinge maroon beneath, drying dark reddish brown above, reddish brown beneath, thick leathery, hairs dense, erect above; base broadly acute, rounded to cordate, margin strongly *recurved*, sharply serrate, teeth to 10 per cm, apex broadly acute to rounded; veins sunken above, prominent beneath, lateral veins 11–13(–17) pairs, almost parallel, slightly bend near margin, intercostal inconspicuous. **Inflorescences** *c*. 2–5(–7) per plant, each (2–)8–12(–22)-flowered. Peduncle, pedicels, bracts and calyx with dense, erect, eglandular hairs, to 0.2 mm long, 2–4-celled; corolla *glabrous*. Peduncle 9.8–15.9 cm long, erect with flowers held much higher above leaves, dark maroon. Bract pair narrow triangular, (2.4–)4.2–4.5 × 1.1 mm, dark maroon, apex blunt. Pedicels to 4.5 mm long, concolor with peduncle. **Flowers** nodding. Calyx almost divided to base, maroon purple, lobes narrow triangular, apex blunt, 1–1.5 × 0.5 mm; corolla pouch-shape, *c*. 4.8 mm across, *c*. 7 mm long, corolla tube *c*. 5.3 mm long, 4 mm wide, white with tinge pinkish purple on outside of corolla, corolla lobes *concolor*, anisomorphic, lobes oval, apex rounded, upper lobes *c*. 1.4 × 2 mm, *slightly reflexed*, lateral lobes *c*. 1.6 × 2.7 mm, lower lobe *c*. 2.9 × 2.6 mm, lateral and lower lobes dilating from base, lower lobe projecting *c*. 2 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments straight, *c*. 1.6 mm long, 0.2 mm wide at base, white, joined to corolla tube *c*. 2.1 mm from base, anthers reniform, 0.8 × 1.6 mm, 0.5 mm thick, white, connivent at apex; nectary 0.6 mm tall, 3-lobed, upper part split with a small lobe between the split; pistil to *c*. 6.7 mm long, protruding *c*. 2 mm from corolla mouth, ovary ellipsoid, *c*. 3.3 × 0.9 mm, in life ovary yellowish brown, style yellowish green, stigma darker yellowish green, pistil with short, sessile glandular hairs, *c*. < 0.1mm long, denser on ovary, sparse on style, style 3.4 mm long, stigma slightly pointed, *c*. 0.2 × 0.4 mm, glistening, apex papillose. **Fruits** narrowly cylindrical, (1.3–)2–2.1 cm long, (1.1–)1.6–2 mm thick, dark purplish maroon, drying reddish brown, short hairy. **Seeds** ellipsoid, *c*. 0.4 × 0.15 mm.

Distribution. Endemic in Peninsular Malaysia, Pahang, Taman Negara, G. Tangga Lima Belas.

Ecology. Upper montane forest, 1524–1646 m altitude, on exposed granite outcrops (Plate 5A), totally exposed to semi-shaded mossy side.

Notes. Lower parts of stems often grow deep into crevices or mossy layer on exposed rocks.

Additional specimen examined: PAHANG, Taman Negara, G. Tahan: *Mohd Haniff SFN 7865* (SING), *Kloss, C.B. 12187* (SING), *Holttum, R.E. SFN 20784* (SING), *Ridley, H.N. 16043* (SING), Taman Negara, G. Tahan, Wray's Camp: *Kiew, R. RK 2467* (KEP), Taman Negara, G. Tangga Lima Belas: *Lim, C.L. FRI 64849* (KEP, SAN, SING), *Chew, M.Y. FRI 60219* (K, KEP, SING), Taman Negara, G. Tuan Sket: *Mohd Shah MS 1477* (SING), Taman Negara, Padang: *Kiew, R. RK 2446* (SING).

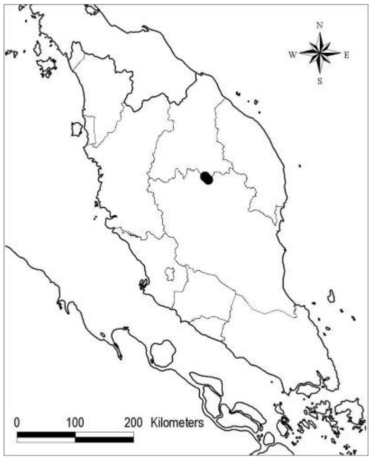


Figure 4.10. Distribution map of *Codonoboea rubiginosa* in Peninsular Malaysia.

11. ***Codonoboea salicina*** (Ridl.) C.L.Lim — **Fig. 4.11, Plate 6D–E**

(Latin, *salicinus* = resembling *Salix*; referring to narrow leaves)

Gard. Bull. Sing. 62 (2011) 271. **Basionym:** *Didymocarpus salicinus* Ridl., Trans. Linn. Soc. Ser. 2, Bot. 3 (1893) 329, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 52, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 761; Kiew, Gard. Bull. Sing. 42 (1989) 60. **Homotypic Synonyms:** *Paraboea salicina* (Ridl.) Ridl., Fl. Malay Pen. 2 (1923) 530. – *Henckelia salicina* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 355. **Type** (lecto Kiew, 1989)**:** Peninsular Malaysia, Pahang, Sg. Tahan, *Ridley 2166*, August 1891 (lectotype K; isolectotypes BM, SING). **Heterotypic synonyms:** *Didymocarpus filicifolius* Ridl., J. Fed. Malay States Mus. 6 (1916) 116; Kiew, Gard. Bull. Sing. 42 (1989) 60. – *Paraboea filicifolia* (Ridl.) Ridl., Fl. Malay Pen. 2 (1923) 530. **Type** (lecto Kiew, 1989)**:** Peninsular Malaysia, Pahang, G. Tahan, Padang, *Ridley 16059*, July 1911 (lectotype K; isolectotypes BM, SING).

Rheophyte, erect to semi erect **herb**. **Indumentum** of stem apex and petiole short, appressed, dark reddish brown hairs. **Stems** wiry, to *c*. 34 cm long, (1.9–)2.1–3.8(–5.2) mm thick, *2–5-branched*, woody, dark reddish brown, knobbly with swollen leaf scars. Flowering at *c*. 10 cm tall. **Leaves** decussate, tufted at top of stem, all leaves held *c*. 30^{o}–60^{o} at top of stem, elsewhere more or less horizontally from stem; petioles (4.9–)6.8–9.6(–15.1) mm long, 0.5–1 mm wide, in life dark reddish green, widely grooved above, when dry dark reddish brown; laminas oblong-oblanceolate, (5.6–)8.3–11.8(–16.1) × (0.7–)1.1–1.4(–2.3) cm, in life glossy green above, pale yellowish green beneath, drying reddish brown above, paler beneath, thin papery, glabrous except midrib, lateral veins and margin beneath with short appressed hairy; base narrowly cuneate, decurrent, margin serrulate, sometimes double serrate, teeth 5–11 per cm, apex narrowly acute; veins slightly sunken above in life, midrib slightly sunken above, prominent beneath, lateral veins 13–18 pairs, often with intermediate veins not reaching margin in between, prominent beneath, looping near margin, forming intramarginal loop, intercostal reticulate, conspicuous beneath. **Inflorescences** *c*. 2–40 per plant, each (2–)3–4-flowered. Indumentum of peduncle with a mixture of lax long appressed and denser short erect eglandular hairs, pedicel, bracts and calyx with very short, fine eglandular hairs; corolla tube outside, both surfaces of corolla lobes with sessile or very short stalked glandular hairs, 1–2-celled, corolla tube glabrous inside. Peduncle (1.2–)1.9–3.6 cm long, erect with flowers held slightly above leaves, dark reddish brown. Bract pair linear, (0.7–)1.1–2.1(–3.6) × 0.1–0.3 mm, brownish green. Pedicels slender, 1.5–3.1 mm long, concolor with peduncle. **Flowers** nodding. Calyx almost divided to base, purplish brown, lobes very narrow acute, apex acute, 0.9–1 × 0.3 mm; corolla small campanulate, *c*. 7 mm across, *c*. 6 mm long, corolla tube *c*. 3.3 mm long, 3.7 mm wide, pale pinkish, upper corolla lobes and corolla tube outside darker, corolla lobes anisomorphic, lobes triangular, apex acute, upper lobes *c*. 2.3 × 2.1 mm, reflexed, lateral lobes *c*. 2.7 × 2.6 mm, lower lobe *c*. 2.7 × 3.4 mm, lateral and lower lobes dilating from base, lower lobe projecting *c*. 2.5 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments white, flattened, straight, *c*. 1.2 mm long, 0.3 mm wide at base, joined to corolla tube *c*. 1.1 mm from base, anthers reniform, 0.8 × 1.4 mm, 0.5 mm thick, constricted at middle part, *dark pinkish*, connivent at apex; nectary absent; pistil to *c*. 6.4 mm long, protruding *c*. 2 mm from corolla mouth, ovary narrow ovoid, *c*. 2.2 × 0.7 mm, in life ovary and style pinkish, stigma white, ovary with very fine sessile glandular hairs, appearing glabrous, style with very fine eglandular hairs, style 3.9 mm long, stigma slightly capitate, globular, *c*. 0.3 × 0.4 mm, glistening, apex papillose. **Fruits** narrowly cylindrical, 1.2–1.5(– 2.1) cm long, (0.7–)1–1.2(–1.4) mm thick, reddish brown, glabrous. **Seeds** ovoid, *c*. 0.3 × 0.2 mm.

Distribution. Endemic in Peninsular Malaysia, Pahang, Taman Negara, Sg. Teku, Sg. Tahan, Lata Luis.

Ecology. Lowland to upper hill dipterocarp forest, 150–1300 m altitude, locally common on vertical earth banks, rocky stream banks.

Additional specimen examined: PAHANG, Taman Negara, G. Pondok Dua: *Lim, C.L. FRI 64857* (KEP, SAN), Taman Negara, G. Tahan: *Wong, Y.K. W 10* (KEP), *Wray, L. 5544* (SING), Taman Negara, Kem Kubang: *Lim, C.L. FRI 64816* (KEP), Taman Negara, Kem Teku: *FRI 64875* (KEP), Taman Negara, Kuala Teku: *FRI 56375* (E, KEP, KEP), *Mohd Haniff 8087* (SING), *Kiah, S. SFN 31705* (SING), *Seimund, E. 583* (SING), *588* (SING), *Ridley, H.N. 16271* (SING), Taman Negara, Lata Luis: *Chua, L.S.L. FRI 41535* (KEP), Taman Negara, Merapoh: *Kiew, R. RK 4049* (E, KEP), Taman Negara, Merapoh (kem kubang): *RK 4118* (KEP, SING), Taman Negara, Sg. Tahan: *Ng, F.SP FRI 1425* (KEP, SING), *Ridley, H.N. 2166* (SING), *Holttum, R.E. SFN 20055* (SING), *Mat s.n.* (SING), *Corner, E.J.H. s.n.* (L), Taman Negara, Sg. Tahan, Lata Berkoh: *Kiew, R. RK 1223* (KEP), *RK 1222* (KEP), *RK 1220* (SING), *RK 1221* (SING), Taman Negara, Sg. Tahan, Sg. Melantai: *RK 2409* (SING).

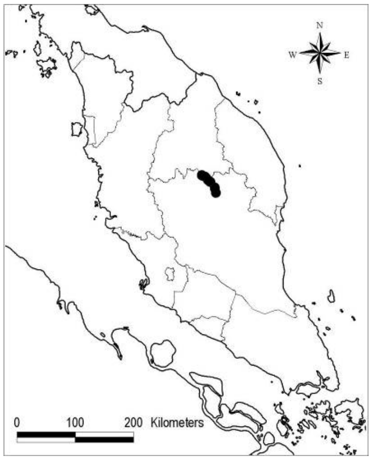
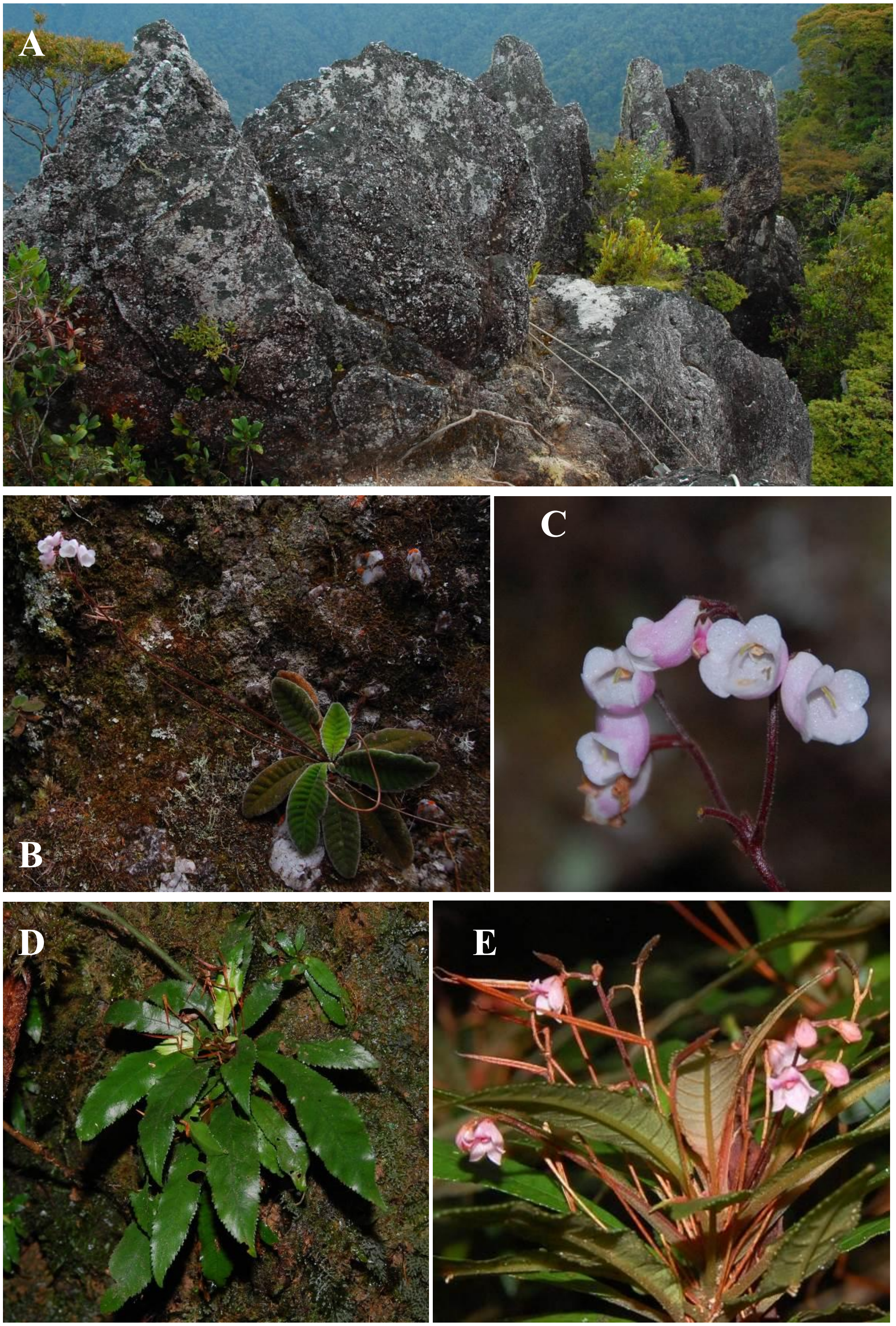


Figure 4.11. Distribution map of *Codonoboea salicina* Peninsular Malaysia

Plate 6



Codonoboea rubiginosa. A, habitat of the quartz outcrop; B, habit; C, flowers. *Codonoboea salicina*. D, habit; E, flowers.

12. ***Codonoboea salicinoides*** (Kiew) C.L.Lim — **Fig. 4.12, Plate 7A–B**

(Latin, *salicinoides* = resembling *C. salicina*)

Gard. Bull. Sing. 62 (2011) 271. **Basionym:** *Didymocarpus salicinoides* Kiew, Gard. Bull. Sing. 44 (1992) 35. **Homotypic Synonyms:** *Henckelia salicinoides* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 355. – *Paraboea salicina* (Ridl.) Ridl. var. *major* Ridl., Fl. Malay Pen. 5 (1925) 325. **Type** (lecto Kiew, 1993)**:** Peninsular Malaysia, Kelantan, Kuala Aring, *Yapp 193* (lectotype K; isolectotype CGE).

Erect **herb**. **Indumentum** of stem apex and petiole short, appressed, tomentose, ferruginous hairs. **Stems** to *c*. 44 cm long, (2.2–)2.8–3.5(–5.5) mm thick, unbranched, woody, dark greenish brown, smooth with swollen leaf scars. Flowering at *c*. 5 cm tall. **Leaves** decussate, tufted at top of stem, all leaves held *c*. 30^{o}–60^{o} at top of stem, elsewhere more or less horizontally from stem; petioles (3.4–)8–17.9(–24.8) mm long, 0.8–1.2(–1.7) mm wide, drying with *horizontal ridged*, in life dark maroon brown, widely grooved above, when dry dark greenish to reddish brown; laminas narrow oblanceolate, (7.8–)11–15.3 × (1.8–)2.1–3.2(–3.6) cm, in life dull green above, pale whitish green beneath, drying reddish to yellowish brown above, paler beneath, papery, glabrous except midrib, lateral veins and margin beneath with short appressed hairy; base sharply cuneate, decurrent, often oblique, margin serrate, teeth 4–6(–8) per cm, apex acute to narrowly acuminate; veins slightly sunken above in life, midrib prominent beneath, drying with *horizontal ridges*, lateral veins 9–13(–17) pairs, prominent beneath, sharply arching near margin, intercostal reticulate, conspicuous beneath. **Inflorescences** *c*. 7–15(–45) per plant, each (2–)3–4(–7)-flowered. Indumentum of peduncle, pedicel, bracts and calyx very scattered, appressed, eglandular hairs, almost glabrescent; corolla tube outside, both surfaces of corolla lobes with sessile or very short stalked glandular hairs, 1–2-celled, corolla tube glabrous inside. Peduncle (2.3–)3.6–4.9(–5.7) cm long, erect with flowers held slightly above leaves, pale maroon green, drying dark maroon brown. Bract pair, narrowly linear, 1.2–1.5(–2.3) × 0.2 mm, pale green to pinkish. Pedicels slender, (1.1–)2.5–3.4 mm long, concolor with peduncle. **Flowers** nodding. Calyx almost divided to base, purplish brown, lobes very narrow acute, apex acute, 0.7 × 0.3 mm; corolla small campanulate, *c.* 7 mm across, *c.* 7.2 mm long, corolla tube *c.* 3.1 mm long, 4.5 mm wide, pale lilac, upper corolla lobes and corolla tube above darker, corolla lobes anisomorphic, lobes triangular, apex acute, upper lobes *c.* 2.2 × 1.9 mm, reflexed, lateral lobes *c.* 2.1 × 2.9 mm, lower lobe *c.* 2.1 × 2.7 mm, lateral and lower lobes dilating from base, lower lobe projecting *c.* 4.5 mm beyond upper part of corolla tube; stamens positioned below pistil, filaments white, flattened, straight, *c.* 0.9 mm long, 0.2 mm wide at base, joined to corolla tube *c.* 1.9 mm from base, anthers reniform, 0.7 × 1.3 mm, 0.5 mm thick, constricted at middle part, *dull yellow*, connivent at apex; nectary to 0.1 mm tall, *faint*, *membranous, translucent*; pistil *c.* 6.1 mm long, protruding *c.* 2 mm from corolla mouth, ovary narrow ovoid, *c.* 1.9 × 0.7 mm, in life ovary pale pinkish, style white, stigma pale green, ovary with sessile glandular hairs, appearing glabrous, sparse on style, style *c.* 3.9 mm long, stigma slightly capitate, globular, *c.* 0.3 × 0.3 mm, glistening, apex dense papillose. **Fruits** narrowly cylindrical, (0.9–)1.1–1.9(–2.1) cm long, (0.6–)0.9–1.1(–1.4) mm thick, reddish brown, glabrous. **Seeds** minute, ovoid, *c.* 0.15 × 0.1 mm..

Distribution. Endemic in Peninsular Malaysia, Johor, Pahang and Terengganu.

Ecology. Lowland, 20–213 m altitude, locally common on vertical earth banks, rocky stream banks or forest floor.

Additional specimen examined: JOHOR, Kluang FR: *Sanusi, T. S 188* (KEP, K, L, A, US, AAU, SING); PAHANG, Tekam FR: *Rafidah, A.R. FRI 51719* (KEP), Bkt. Cheras: *Anthonysamy, S. SA 571* (KEP, SING); TERENGGANU, Bkt. Kajang: *Anthonysamy, S. SA 584* (KEP), Bkt. Bauk FR: *SA 596* (KEP), Dungun: *SA 595* (KEP), Bkt. Bauk FR: *Davison, G. GD 8* (KEP), *Kochummen, K.M. FRI 2587* (KEP), *Saw, L.G. FRI 44890* (KEP, SING), Bkt. Bandi FR: *FRI 44997* (KEP), Sg. Nipah FR: *Sam, Y.Y. FRI 47238* (KEP), Bkt. Bauk FR: *Davison, G. GD 7* (SING), Bkt. Kajang: *Corner, E.J.H. SFN 30198* (A, K, L, LAE, SING), Ulu Bendong: *SFN 30027* (L, SING), Sg. Nipah: *Kiew, R. RK 2654* (L, SING), Bkt. Bauk FR: *Lim, C.L. FRI 64954* (KEP), Sg. Nipah FR: *FRI 64973* (KEP, SAN), Bkt. Bauk FR: *FRI 64978* (KEP, SAN, SING, L, K, A, SAR, CNS), Sg. Nipah FR: *Rafidah, A.R. FRI 51635* (BKF, KEP, L, SAR, SING), Bkt. Bauk FR: *Jutta, M. FRI 59549* (KEP, SAN, SAR, SING), exsitu: Forest Research Institute Malaysia: *Sam, Y.Y. FRI 47070* (KEP), *FRI 47221* (KEP), *FRI 47222* (KEP).

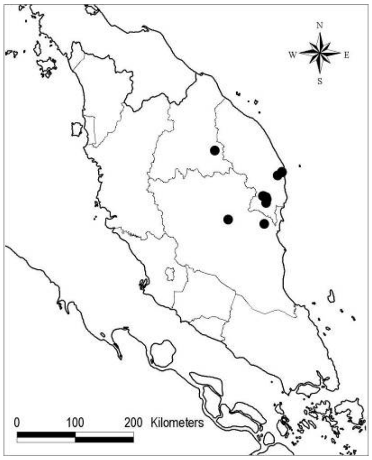


Figure 4.12. Distribution map of *Codonoboea salicinoides* in Peninsular Malaysia.

13. ***Codonoboea soldanella*** (Ridl.) C.L.Lim — **Fig. 4.13**

(resembles snowbell (*Soldanella* L., Primulaceae)

Gard. Bull. Sing. 62 (2011) 272. **Basionym:** *Didymocarpus soldanellus* Ridl., J. Straits Branch Roy. Asiat. Soc. 61 (1912) 33, Fl. Malay Pen. 2 (1923) 523. **Homotypic Synonym:** *Henckelia soldanella* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 356. **Type:** Peninsular Malaysia, Perak, G. Korbu [Kerbau], *Haniff s.n.*, July 1910, cult. B. G. Sing (holotype SING).

Rosette **herb**. **Leaves** tufted at top of stem; petioles *c*. 5.8 mm long, *c*. 1.2 mm wide; laminas oblanceolate to oblong, *c*. 7.5 × 2.5 cm, in life dark green above, paler beneath, bullate; base rounded, cordate, subpeltate, oblique, margin double crenate, teeth *c*. 4 per cm, apex rounded; lateral veins 10–11 pairs, intercostal vein reticulate, obscure above, conspicuous beneath. **Inflorescences** *c*.3-flowered. Indumentum of peduncle, pedicel reddish pubescent, minutely pubescent on corolla. Peduncle *c*. 5 cm long, erect with flowers held slightly above leaves, reddish. **Flowers** nodding, Calyx almost divided to base, linear, dull red pubescent, *c*. 2.5 mm long; corolla broadly campanulate, oblique, *c*. 9.5 mm long, *c*. 6.4 mm across, violet, corolla lobes ovate triangular, lower lip longer; filaments violet in life, short, sinuate, anthers yellow-white, reniform; ovary and style cylindric, pubescent, stigma capitate. **Fruits** narrowly cylindric. *c*. 1.7 cm long, *c*. 1.4 mm thick.

Distribution. Narrowly endemic to Peninsular Malaysia, Perak, G. Korbu. Only collected once.

Ecology. Unknown.

Note. This specimen is poorly collected, and only represented by the incomplete type species. The type specimen only consists of a single scrap of a piece of leaf and a fruit. Floral descriptions of the species are based on Ridley (1912, 1923).

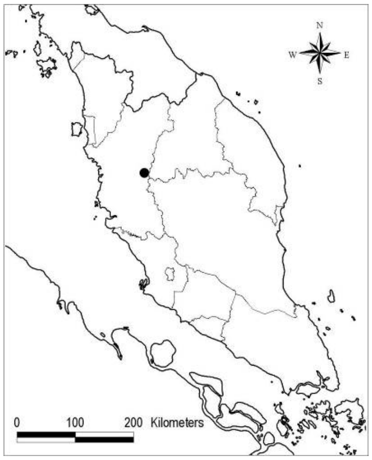


Figure 4.13. Distribution map of *Codonoboea soldanella* in Peninsular Malaysia.

14. ***Codonoboea tiumanica*** (Ridl.) C.L.Lim — **Fig. 4.14, Plate 7C–F**

(of Tioman Island, Pahang)

Gard. Bull. Sing. 62 (2011) 272. **Basionym:** *Paraboea tiumanica* Burkill ex Ridl., Fl. Malay Pen. 2 (1923) 530. **Homotypic Synonyms:** *Didymocarpus tiumanicus* (Ridl.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44. – *Henckelia tiumanica* (Burkill ex Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 357. **Type** (lecto Kiew & Lim 2011)**:** Peninsular Malaysia, P. Tioman [Tiuman], W of Juara Bay, *Burkill 1142*, 29 June 1915 (lectotype K; isolectotype SING).

Rosette **herb**. **Indumentum** of stem apex, petiole and lamina long, erect, to 3 mm long, silvery, (3–)–7-celled hairs. **Stems** to 16.5 cm tall, (1.6–)2.1–3.5(–3.9) mm thick, occasionally branched, woody, often bluntly ridged especially below leaf scars. Flowering at *c*. 4 cm tall. **Leaves** decussate, always crowded at top of stem, all leaves held horizontally from stem; petioles sessile at first, to (0.5–)2.2–3.4(–9.1) cm long, 1–1.3 mm wide, in life light grey-yellowish green, succulent, terete, when dry pale greyish brown, flat; laminas lanceolate to elliptic, rarely ovate, sometimes oblique, (2.3–)5.4–6.5(–8.1) × (1–)2–2.4(–3.1) cm, in life green to dark green above with band of light yellowish green at midrib, greyish green to glaucous beneath, drying greyish green to dark greyish brown above, light yellowish to greyish brown beneath, drying membranous, indumentum of long hairs on margin, dense to sparse on lamina above, often glabrous beneath; base attenuate to broadly cuneate, margin entire at lower half, serrate towards apex, teeth *c*. 5–6 per cm, apex attenuate to broadly acute to rounded; midrib slightly raised or flat above, slightly prominent beneath, lateral veins (5–)6–8 pairs, obscure above, very fine beneath, slightly darker then lamina, intercostal veins inconspicuous. **Inflorescences** *c*. 1–10(–28) per plant, each 1-flowered. Indumentum of peduncle, pedicel, calyx erect, sparse, a mixture of erect, long and short, eglandular hairs, hairs 2–4-celled, bracts with semi-erect, longer eglandular hairs; corolla with very short, sparse, eglandular hairs outside, glabrous inside. Peduncle slender, (3.4–)4–5(–5.6) cm long, erect with flower held above leaves, dark purplish-maroon. Bract pairs, opposite, ligulate, *c*. 1.3–2.4 × (0.2–)0.3(–0.4) mm, when fresh yellowish green above, dark maroon base. Pedicel slender, 0.6–0.7(–0.9) cm long, concolor to peduncle. **Flowers** held horizontally. Calyx light brownish green, free to base, lobes oblong, apex acute, 2.1–2.4 × 0.7–0.9 mm, lower lobes slightly longer; corolla shortly ventricose, 18–19 mm across, *c*. 9 mm long, corolla tube white, corolla lobes pale lilac, inner surface darker, tube 6.3–6.8 mm long, *c*. 7.6 mm at widest point, abruptly narrow at base (*c*. 3 mm wide), corolla lobes 5, *isomorphic*, lobes rounded, apex often with 1–3 shallowly lobes, upper lobes *c*. 6–6.2 × 6.1–6.5 mm, lateral lobes *c*. 6.4–7.2 × 6.9–7.8 mm, lower lobe *c*. 6.8 × 7.8 mm; stamens *enantiostyly*, *locate at opposite side to the pistil*, filaments white, dark yellow at base, *recurved*, *c*. 3.2 mm long, attached *c*. 1.9 mm from lower corolla base, anthers white, reniform, 2.3 × 0.8 mm, 1 mm thick, connivent; nectary encircling base of ovary, *faint*, *membranous, translucent*, deeply lobed, c. 1 mm tall; pistil, *c*. 7.5 mm long, *contained within and not projecting beyond corolla tube*, ovary 2.4 × 0.8 mm, in life dark purplish maroon at base, turning light green and pale yellow in portion protruding out of corolla tube, stigma white, pistil with short eglandular hairs, *c*. < 0.1 mm long, denser on ovary, sparse on style, stigma small capitate, *c*. 0.5 mm diameter. **Fruits** broadly ovoid, 2.1–2.4(–2.7) cm long, (1–)1.4–1.9(–2.5) mm thick, *c*. 0.9 mm wide, maroon, dense short hairy, when fully open, *broad boat-shape*, to *c*. 2–4 mm wide. **Seeds** ovoid, 0.4 × 0.25 mm.

Distribution. Endemic in Peninsular Malaysia, Johor (P. Pemanggil and P. Tinggi) and Pahang (P. Tioman).

Ecology. On earth banks and rock crevices by river, from *c.* 10–1050 m altitude at G. Kajang, P. Tioman.

Notes. When growing on vertical rocks, lower leaves have longer petioles compared to the upper ones.

Additional specimen examined: JOHOR, P. Pemanggil: *Mohd Noor MN 72* (SING), P. Tinggi: *Anonymous PT 96-283* (SING), *PT 96-619* (SING), *Lim, C.L. FRI 64949* (KEP), *FRI 65002* (KEP); PAHANG, P. Tioman: *Kadim, T. K 583* (SING), *Mohd Nur SFN 18581* (SING), *Kiew, R. RK 5210* (SING), P. Tioman, Bkt. Rokem: *Weber, A. UPM 3436* (KEP), P. Tioman, G. Kajang: *Henderson, M.R. SFN 21669* (SING), *SFN 21665* (SING), P. Tioman, Juara Bay: *Burkill, I.H. 1027* (SING).

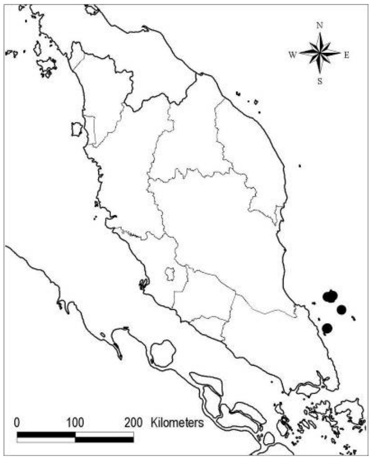
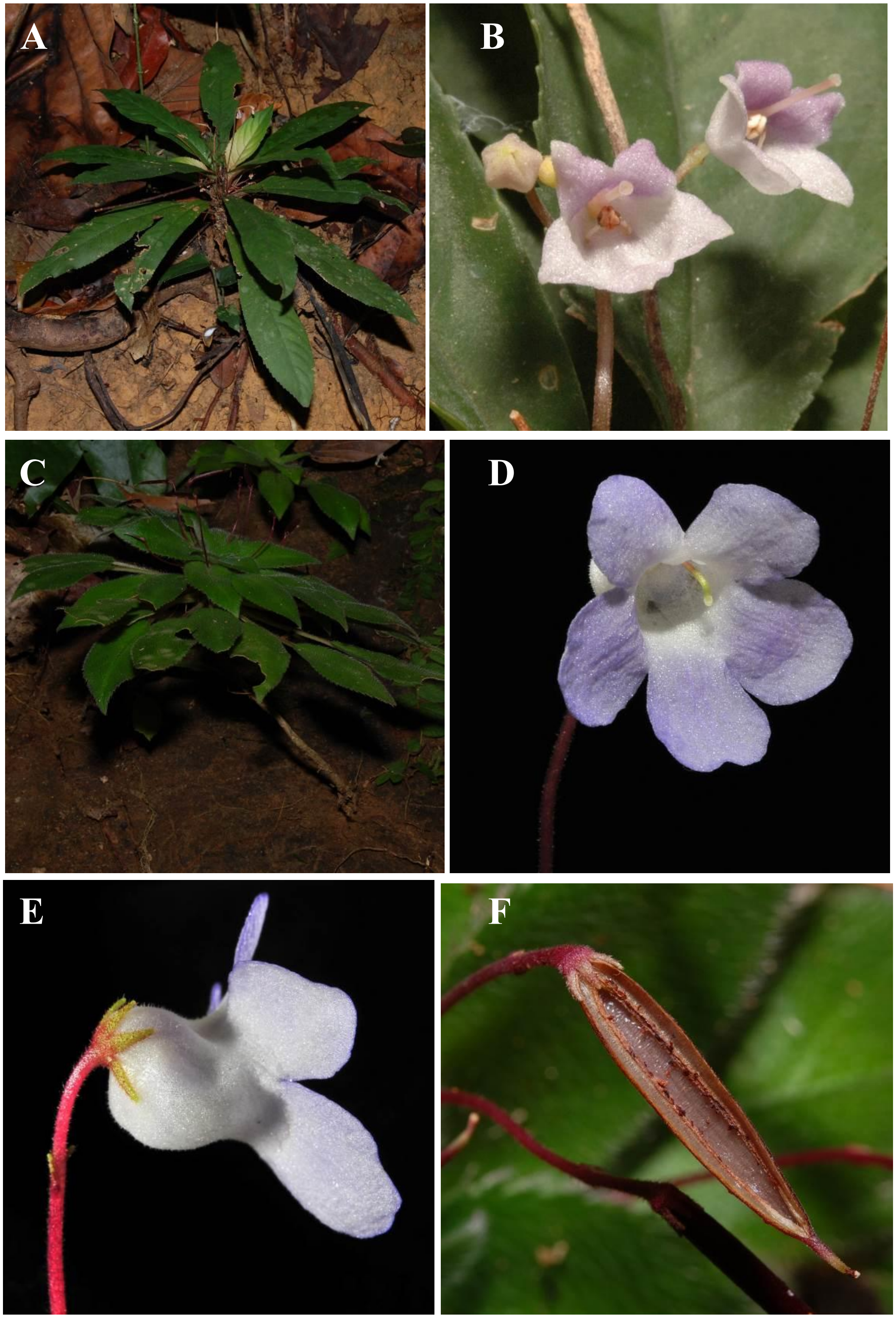


Figure 4.14. Distribution map of *Codonoboea tiumanica* in Peninsular Malaysia.

Plate 7



Codonoboea salicinoides. A, habit; B, flowers. *Codonoboea tiumanica*. C, habit; D–E, flower; F, fruit.

15. ***Codonoboea yongii*** (Kiew) C.L.Lim — **Fig. 4.15**

(G.C. Yong, the naturalist who discovered the plants)

Gard. Bull. Sing. 62 (2011) 273. **Basionym:** *Didymocarpus yongii* Kiew, Gard. Bull. Sing. 42 (1989) 62. **Homotypic Synonym:** *Henckelia yongii* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 359. **Type:** Peninsular Malaysia, Pahang, Sg. Teku, *Kiew RK 2481*, 29 March 1987 (holotype KEP; isotypes K, L, SING).

Rosette **herb**. **Indumentum** of stem apex, petiole and both surfaces of lamina short, erect, eglandular, hairs, to *c*. 0.5 mm long, hairs on laminas to 0.2 mm long. **Stems** wiry, to *c*. 4 cm long, 2.9–4.8 mm thick, unbranched, woody, dark reddish brown, knobbly with swollen leaf scars. Flowering at *c*. 3 cm tall. Internodes crowded above, 2.7–5.3 mm long below. **Leaves** decussate, tufted at top of stem, all leaves held horizontally from stem, appressed to ground; petioles 3.4–7.8(–17.3) mm long, 1.2–1.4(–2.7) mm wide, terete, tapering, when dry dark reddish brown; laminas obovate to lanceolate, (8.1–)10.1–13.3 × (4.2–)4.8–5.1 cm, in life light or dark green above with white veins, often purplish beneath, drying dark reddish brown to ferruginous above, dark reddish brown beneath, leathery, minutely hairy, longer at midrib and lateral veins beneath and leaf margin with appressed hairs; base cordate, oblique, margin *denticulate*, teeth 5–6 per cm, apex broadly acute or rounded; veins slightly raised above prominent beneath, *in life white and much paler than lamina above*, lateral veins 7–8 pairs widely spaced, forming intramarginal veins, *c*. 4–5 mm away from margin, often with intermediate veins not reaching margin in between, intercostal inconspicuous above, reticulate beneath. **Inflorescences** *c*. 2–5 per plant, each 3–4(–12)-flowered. Indumentum of peduncle, pedicels, bracts, calyx and corolla outside minute, eglandular hairs, to 0.15 mm long, 1(–2)-celled, corolla glabrous inside. Peduncle (13–)16.5–17 cm long, erect with flowers held above leaves, dark reddish brown, sparse hairy. Bract pairs, opposite, narrowly ligulate, 1.8–2.5 × 1 mm. Pedicels slender, to 1–2.5(–3.7) mm long, concolor with peduncle. **Flowers** nodding. Calyx purplish brown, free to base, lobes very narrow acute, apex acute, 1–1.5 × 0.3 mm; corolla campanulate, minutely hairy outside, corolla tube white to pale lilac outside, corolla lobes rosy-lilac, *concolor*, tube *c*. 3.3 mm long, 3.7 mm wide, corolla lobes 5, *isomorphic*, lobes oval, apex rounded; filaments straight, *c*. 1.5 mm long, anthers *yellow*, reniform, connivent at apex; nectary to *c*. 1 mm tall; ovary cylindrical, *c*. 1 mm long, style *c*. 2 mm long, curve upwards, colour in life unknown, ovary with a mixture of dense long eglandular and long-stalked glandular hairs, style with a mixture of long dense eglandular hairs and short-stalked glandular hairs, stigma slightly discoid, white. **Fruits** narrowly cylindrical, 1.2–1.5(– 2.1) cm long, (0.7–)1–1.2(–1.4) mm thick, reddish brown, glabrous. **Seeds** ovoid, *c*. 0.3 × 0.2 mm.

Vernacular name. Kale-leaved *Codonoboea*.

Distribution. Endemic in Peninsular Malaysia, Pahang, Taman Negara, Sg. Teku.

Ecology. Lowland forest, *c*. 75 m altitude, edge of overhanging rocks or cliffs with leaf litter and earth.

Note. Most of the floral measurements and description adapted from Kiew (1989) because no mature flower available on the specimen. Only some buds are available from *RK 2481* (L), therefore, measurements of floral parts are not taken.

Additional specimen examined: PAHANG, Taman Negara, Kuala Tahan: *Mohd Haniff 8301* (SING), Taman Negara, Kuala Teku: *Kiew, R. RK 2481* (KEP, L), *Wong, Y.K. W 27* (KEP).

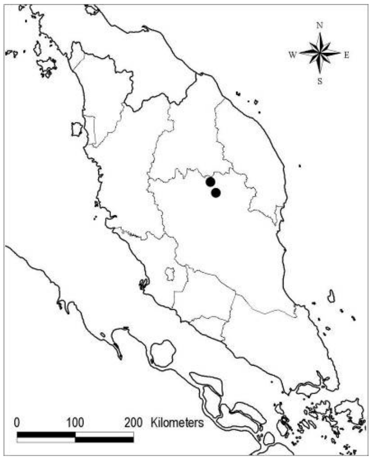


Figure 4.15. Distribution map of *Codonoboea yongii* in Peninsular Malaysia.

3.4. Discussion and Conclusion

3.4.1. Species identification and closely similar species

The diagnostic characters for each species are, in fact, consistent, very obvious and without the need to dissect of the flowers. Among the species, in this study, most of the species with hairy laminas (*Codonoboea oreophila*, *C. pumila*, *C. puncticulata*, *C. rubiginosa* and *C. tiumanica*) can be easily identified based on several outstanding and unique features presence in each species (see key).

However, among the species with glabrous laminas, there has been some confusion. For example, many species, such as *C. codonion*, *C. floribunda* and *C. salicinoides* have been misidentified as *C. heterophylla*. In the plant checklist of Bkt. Bauk, Tam (1999) listed *C. heterophylla* (*Kochummen, K.M. FRI 2587* (KEP)) but the species should be *C. salicinoides*.

The confusion is due to the similarity of the leaf characters, where the habits are rosette and the laminas are usually oblong, oblanceolate or oblong-obovate. The important diagnostic characters to differentiate these species are the presence of transverse ribs on midrib and petioles of *C. salicinoides*; the peduncles and pedicels with long hairs, presence of large bracts and calyx of *C. floribunda*. Furthermore, the cuneate lamina base of *C. codonion* distinguishes it from the rounded one in *C. heterophylla*.

Other than being confused with *C. heterophylla*, *C. salicinoides*, as the name suggests, is similar to *C. salicina* in leaf characters. The difference between these two species has been listed by Kiew (1992). However, as more specimens were examined, the overlaps in lamina width and petiole length measurements as well as number of flowers increased but both species are distinctly different in that *C. salicina* has a branched stem while *C. salicinoides* has unbranched stem. Furthermore, the unique transverse ribs on petiole and midrib differentiate *C. salicinoides* from all other species.

Due to limited characters available from the only specimen available, the type, lamina size and shape of *C. soldanella* is closest to *C. heterophylla*. Nonetheless, *C. soldanella* can be distinguished from *C. heterophylla* by its rounded lamina apex compared to the broadly acute apex in *C. heterophylla.* Kiew (1992) pointed out that fruit length of both species are distinct. However, after specimen examination, fruit length of *C. heterophylla* ranges from 1.1 to 2.1 cm, which overlaps with that of 1.7 cm in *C. soldanella*.

Herbarium specimens of *C. anthonyi* and *C. leiophylla* are often confused because of their entire leaf margins and smooth lamina surfaces. Furthermore, leaf sizes of both species often overlaps. The difference between the species is the inflorescence where *C. anthonyi* always has 4 flowers while *C. leiophylla* is single-flowered.

5.0 MOLECULAR PHYLOGENETIC STUDY

5.1 Introduction

Phylogenetic studies have become a new tool in taxonomic studies, especially to discern systematic affiliations among organisms by analysing nucleic acid data (Judd *et al.*, 2002). Molecular data are more accurate because they reflect changes at the gene level, the gene regions evolve often neutrally, compared to morphological data, which are more subject to convergent evolution (Downie and Palmer, 1992).

Phylogenies are widely used in many families and genera, such as *Callicarpa* (Lamiaceae) (Bramley, 2009), *Hoya* (Apocynaceae) (Wanntorp, 2009), *Macaranga* and *Mallotus* (Euphorbiaceae) (van Welzen *et al.*, 2009) and Hymenophyllaceae (Ebihara *et al.*, 2006).

In Gesneriaceae, many phylogenetic studies have been carried out to solve taxonomic problems. Palee *et al.* (2006) demonstrated that *Didymocarpus s.l.* forms a strongly supported monophyletic clade. Also, the origin of the genus is apparently the Malay Peninsula, with of yellow/ white corolla colour being plesiomorphic characters. The tribe *Epithemateae* in Gesneriaceae has been shown to form a strongly supported monophyletic clade (Mayer *et al.*, 2003). Examples of the application of phylogenetic approaches in taxonomic studies can be seen in other genera in Gesneriaceae, such as *Aeschynanthus* (Denduangboripant *et al.*, 2001), *Cyrtandra* in the Pacific Ocean (Cronk *et al.*, 2005), *Saintpaulia* (Moeller and Cronk, 1997a, 1997b) and *Streptocarpus* (Moeller and Cronk, 2001).

A preliminary study of subfamily Didymocarpoideae (to which *Codonoboea* belongs) was studied by Moeller *et al.* (2009, 2011) and Weber *et al.* (2011). The latter is the most recent and comprehensive study where species of *Codonoboea* were included. However, no species of either sect. *Boeopsis* and sect. *Salicini* were included.

In the phylogenetic analyses above, usually either chloroplast DNA (cpDNA) or nuclear ribosomal DNA (nrDNA) or both were included. Using a single region may be insufficient to resolve some taxonomic problems, also to address issues of hybridization (e.g. Hughes *et al.*, 2005). For instance, Moeller and Cronk (1997b) reported that the ITS region alone was unable to resolve relationships among species of the *Saintpaulia ionantha* complex. This has since been addressed by sinking the more than 20 species into six (Darbyshire, 2006). The latest publication by Weber *et al.* (2011) included both gene regions, nrDNA (internal transcribed spacer, ITS) and cpDNA (*trnL-F* intron and spacer region) for analysis.

5.2 Materials and Methods

5.2.1 Taxon sampling

5.2.1.1 Ingroup taxa

Twenty seven taxa (Appendix A) of *Codonoboea* from Peninsular Malaysia and three species of *Codonoboea* from Borneo, the Philippines and Sumatra were sampled. These included nine taxa from sect. *Boeopsis* and three from sect. *Salicini*, listed in Kiew (1992). Voucher specimens are deposited in KEP and E.

Although new combination for *Codonoboea* species outside Peninsular Malaysia is still on-going, *Codonoboea* is used as genus of the species in the phylogenetic trees to avoid confusion with *Henckelia s.s.*

5.2.1.2 Selection of outgroup

From a preliminary phylogenetic tree of 162 taxa of didymocarpoid Gesneriaceae, species from *Microchirita* (*M. caliginosa*, *M. involucrata*, *M. viola* and *M.* sp. nov.) and *Boea* (*Boea hygrometrica* and *B. philippensis*) were selected as outgroup taxa for the study of *Codonoboea* samples (Appendix A).

5.2.2 DNA materials

Leaf samples were collected during field trips or from living plants cultivated at the Kepong Botanical Garden (KBG) nursery. Fresh, healthy, young and clean leaves were taken, torn into small pieces and placed in a tea bag before they were dried rapidly directly in a zip-lock bag full of silica gel.

5.2.3 Methods

The phylogenetic studies were carried out in collaboration with staffs of the Royal Botanic Garden Edinburgh (E), because of their leading role in the molecular and taxonomic studies of Old World Gesneriaceae.

5.2.3.1 DNA extraction

Total genomic DNA was extracted from the dried leaves using a standard 2% hexadecyltrimethylammonium bromide (CTAB) protocol (Doyle and Doyle, 1987), or by using the DNeasy® Plant Mini Kit (QIAgen Ltd., Dorking, Surrey, UK) according to the protocols provided by the manufacturer.

5.2.3.1.1 Gel electrophoresis of genomic DNA

The quantity and quality of the DNA was determined by agarose gel electrophoresis. The process separates DNA molecules according to their molecular weights.

Agarose gels of 1 % were prepared by mixing agarose and TBE buffer. SYBR® Safe DNA gel stain (Invitrogen, Carlsbad, California, US) was added as DNA stain to enable visualization of the DNA. TBE and agarose was heated in a microwave until the agarose was totally dissolved. The solution was left to cool down before pouring it into a gel tray. A suitable gel comb of the appropriate size and tooth number was placed in the tray and the gel was left to set. Next, the comb was removed and the agarose gel placed in the electrophoresis tank containing 1 × TBE buffer.

For each DNA sample, 2 µl of gel loading dye was added and mixed with 5 µl of genomic DNA solution. Then, the mixture was loaded into the gel well. Five µl of Fermentas 1kb plus DNA ladder was loaded for comparing the molecular weight of the PCR products. Electrophoresis was carried out in BioRad tanks (Munich, Germany) at 100 V and 300 mA.

After electrophoresis, the gel was removed from gel electrophoresis tank and placed into a UV trans-illuminator. The UV image of the gel was captured with the software GeneSnap 4.00-Gene Genius Bio Imaging System (Syngene, Frederick, Maryland, USA).

5.2.3.2 PCR amplification and sequencing

Two regions, namely the chloroplast *trnL-F* intron-spacer region, and the nuclear ITS1-5.8S-ITS2 region, were amplified from the extracted DNA. Amplification of the *trnL-F* region was performed by using primers "C" and "F" (Taberlet *et al.*, 1991) following Moeller *et al.* (2009). When the primer pair "C" and "F" could not produce a clean sequence, alternative primers such as primer "A" or "D" were used, which bind at upstream or internal sites respectively (Taberlet *et al.*, 1991). For the ITS region, "angiosperm-specific" primers "AB101" and "AB102" (Sun *et al.*, 1994) were used. Primers and their sequences used in the PCR amplification are listed in Table 5.1.

Table 5.1. Primers and their sequences used in the PCR amplification.

DNA region	Primer name	Sequence
ITS1-5.8S-ITS2	Forward: "AB101"	ACG AAT TCA TGG TCC GGT GAA GTG TTC G
	Reverse: "AB102"	TAG AAT TCC CCG GTT CGC TCG CCG TTA C
trnL-F intron-spacer	Forward: "C"	CGA AAT CGG TAG ACG CTA CG
	Reverse: "F"	ATT TGA ACT GGT GAC ACG AG
	Forward (external): "A"	CAT TAC AAA TGC GAT GCT CT
	Reverse (internal): "D"	GGT TCA AGT CCC TGA TCC C

5.2.3.2.1 Primer preparation

The primers were diluted to a stock solution of 100 μM by adding the appropriate amount of distilled water following guidelines of the supplier. For the working solution, a further dilution to 10 μM was carried out by adding 180 μl distilled water to 20 μl of primer stock solution.

5.2.3.2.2 PCR amplification

Before PCR, a 50 μl reaction mixture for each sample was prepared following the recipe in Moeller *et al.* (2009). Reagents and their volumes contained in the 50 μl mixture are shown in Table 5.2.

Table 5.2. Reagents and the volume contain of 50 μl reaction mixture.

Reagent	Volume/ μl
10×NH_4 reaction buffer (Bioline, UK)	5.00
dNTPs (2 mM)	5.00
$MgCl_2$ (50 mM)	2.50
forward primer (10 μM)	1.50
reverse primer (10 μM)	1.50
dH_2O	32.25
Biotaq polymerase (Bioline, UK)	1.25
template DNA	1.00

Additionally to the DNA samples, a negative control was added to each set of reactions. The negative control was prepared by adding sterile distilled water instead of genomic DNA.

The PCR temperature profiles for both gene regions were as in Mayer *et al.* (2003), Moeller *et al.* (2009) and Moeller & Cronk (1997a), respectively (Table 5.3–5.4). PCR reactions were carried out in a BioRad Tetrad® 2 cycler (BioRad, Hercules, CA, US).

Table 5.3. The thermocycle profile for *trnL-F* region.

Process	Temperature (°C)	Time	Time of repetition
Initial denaturation	94	4 min	1
Denaturation	94	45 sec	
Primer annealing	55	3 min	30 ×
Primer extension	72	3 min	
Final extension	72	10 min	1

Table 5.4. The thermocycle profile for ITS region.

Process	Temperature (°C)	Time	Time of repetition
Initial denaturation	94	3 min	1
Denaturation	94	1 min	
Primer annealing	55	1 min	30 ×
Primer extension	72	1.5 min	
Final extension	72	5 min	1

5.2.3.2.3 Resolution of PCR products

After PCR, each sample was run on a 1 % agarose gel to check for PCR amplification success. For each reaction a volume of 5 µl was mixed with 2 µl of gel loading dye. The mixture was loaded into the gel wells. A Fermatas 1kb plus DNA ladder was added in one of the wells as a size marker. Then, electrophoresis was carried out and the gel was visualised and documented under UV light as above for genomic DNA.

5.2.3.2.4 Purification of PCR products

Amplified products were purified using ExoSAP-IT® (Amersham-Pharmacia Biotech. Inc., Piscataway, NJ, USA). The process was performed by adding 2 µl of ExoSAP-IT® to 5 µl of PCR product. The mixtures were then run on a BioRad Tetrad® 2 cycler following the thermocycle profile shown in Table 5.5.

Table 5.5. The thermocycle profile for ExoSAP-IT® purification process.

Process	Temperature (°C)	Time (min)	Time of repetition
Digest excessive primers and by-products	37	30	1
Denaturation	80	15	1

5.2.3.2.5 Sequencing PCR

The purified PCR products were sequenced in the forward and reverse directions for sequence conformation using the Sanger dideoxy chain-termination method in 10µl reactions (Table 5.6) and PCR profile (Table 5.7), then analysed on an ABI 310 sequencer.

Table 5.6. Sanger sequencing reaction mix (1/8 reactions).

Reagent	Volume/ µl
Bigdye mix (Life Technologies, UK)	1.00
primer (10µM)	0.32
5x sequencing buffer	2.00
dH2O	4.00
template DNA	2.68

Table 5.7. The thermocycle profile for cycle sequencing.

Process	Temperature (°C)	Time	Time of repetition
Denaturation	95	30 sec	
Primer annealing	50	20 sec	25 ×
Primer extension	60	4 min	

5.2.3.3 Sequence alignment and phylogenetic analysis

5.2.3.3.1 Sequence alignment

Sequence contigs of both forward and reverse reactions were assembled, examined and edited in Sequencher 4.5 (Gene Codes Corp, Ann Arbor, USA). Low quality 5' and 3' ends were trimmed off manually. Ambiguous bases were resolved by comparing sequence fragments of forward, reverse or additional fragments sequenced from upstream or internal primers. The final sequence contigs were exported for further analysis.

Alignment of all DNA sequences was carried out with CLUSTAL W2 in BioEdit version 7.0.0. The data alignment was then optimised manually in MacClade 4.08 (Maddison and Maddison, 2003).

5.2.3.3.2 Phylogenetic analysis

For this study, the data matrices were analysed in two sets:

1) a matrix including the *trnL-F* region with 162 samples (32 sequences were new, while the rest extracted from GenBank as published by Moeller *et al.* (2009) and Weber *et al.*, (2011). Among the 162 samples, 11 were outgroups, six coronantheroids, 23 gesnerioids, 19 epithematoids, 101 didymocarpoids and two unassigned taxa. The reason for the large analysis was to test the phylogenetic position and monophyly of *Codonoboea* species.
2) a reduced matrix that consisted of 42 samples, i.e. 33 samples of *Codonoboea*, three *Codonoboea* and six outgroup samples (from *Microchirita* and *Boea*). The reduced data matrix was re-aligned and the ITS region added to better resolve the relationships among the taxa. The reduced matrix was analysed as follows:
    i) *trnL-F* region only that included 22 *Codonoboea* samples, with four outgroup samples from *Microchirita* and two from *Boea*.
    ii) ITS region only that included 33 *Codonoboea* samples and the same outgroups as the analysis of the *trnL-F* region.
    iii) a complete combined *trnL-F* & ITS matrix (22 samples) that excluded those samples without *trnL-F* data.
    iv) a combined *trnL-F* & ITS matrix (36 samples) that included those samples without *trnL-F* data.
    v) a combined *trnL-F* & ITS and gap matrix (36 samples) that included those samples without *trnL-F* data.

The datasets were obtained directly from the aligned sequences while the gap matrices were generated automatically with GapCoder with manual optimisation. GapCoder generates additional characters based on the simple gapcoding rules of Simmons and Ochoterena (2000).

The sequence matrices were analysed by Maximum Parsimony (MP) in PAUP*4.0b10 (Swofford, 2002) on unordered and equally weighted characters, and by Bayesian inference (BI; Yang and Rannala, 1997) using MrBayes version 3.1.2 (Huelsenbeck and Ronquist, 2001, 2007).

Descriptive tree statistics, such as consistency index (CI), retention index (RI) and rescaled consistency index (RC), were also calculated using PAUP*4.0b10. Statistical branch support analyses were performed twofold, as 10,000 replicates of heuristic Bootstrap and Jacknife resampling (BS; Felsenstein, 1985), with TBR (tree bisection-reconnection) swapping on and MulTrees off (Spangler and Olmstead, 1999) in PAUP*4.0b10.

5.3 Results and discussion

5.3.1 DNA extraction

Genomic DNA was successfully extracted from all leaf samples. High quality DNA shows a discrete band at approximately 15–20 kbp. Although the brightness of the bands was faint, they were sufficient templates for the PCR amplification process.

5.3.2 Amplification of targeted genes

5.3.2.1 ITS region

All samples were successfully amplified with the primer pair "AB101" x "AB102". These primers are "angiosperm-specific" and would exclude the possibility of amplifying any fungal rDNA that may be present on or in the leaf samples. The length of the ITS region was approximately 670–840 bp.

5.3.2.1 *TrnL-F* region

All the samples were successfully amplified with the primer pair "C" × "F" for the *trnL-F* region, yielding PCR products of approximately 1000–1100 bp.

Despite easier to amplify with the primer pair "C" × "F", some sequences of these PCR products were very "noisy". The eletropherograms showed multiple peaks underneath and on top of each other, meaning that there were several products amplified from the template. However, the failed sequences were rather random and did not show any trend that was taxonomy related. The difficulty to amplify clean sequences also occurred in other *Codonoboea* and *Microchirita* (A. Forrest, pers. comm.). This may be due to the primers not being entirely specific to the *trnL-F* region, and pseudogenes were present. Another reason could be that the *trnL-F* region is included in the inverted repeat and thus have more than one copy in the genome, that when amplified, both show signals in the eletropherograms.

The problem was partly solved by using alternative primers, “A” or “D”, that have annealing site upstream or internally of the trn*L-F* region respectively. In the first trouble-shooting, primer “A” and “F” were used to PCR followed by sequencing PCR with primer “C” and “F”. This combination successfully sequenced eight samples (Table 5.6). Samples that further failed were sequenced with primer “C” and “D” to at least amplify the intron region of the gene. The sequences of the same sample where assembled to form a single contig.

5.3.3 Phylogenetic analysis

5.3.3.1 Phylogenetic analysis using the *trnL-F* region with 162 taxa

The aligned data matrix had 1384 characters, of which 137 ambiguous characters had to be eliminated, at the beginning and end of the matrix. The remaining 1247 characters were used for analysis, of which 647 were constant, 193 variable, but parsimony uninformative and 407 (32.6%) were parsimony informative.

The maximum parsimony analysis retrieved 574 most parsimonious trees of 1594 steps length and a CI of 0.59, and RI of 0.85 (Fig. 5.1, 5.2). In the strict consensus phylogenetic trees (Fig. 5.2), it is shown conclusively that *Henckelia sensu* Weber & Burtt (1998) is not a monophyletic genus. This result agreed with finding in Moeller *et al.* (2009, 2011) and Weber *et al.* (2011). Compared with previous studies, more *Codonoboea* samples had been included in the present study. The phylogenetic tree showed conclusively that *Codonoboea* formed a well supported monophyletic clade (BS 86 %, JN 76 %). The clade fell on a polytomy with the clades of *Microchirita* (BS 87 %, JN 84 %) and *Henckelia sensu* Weber *et al.* (2011) (BS 88 %, JN 88 %). All samples from both sect. *Boeopsis* and sect. *Salicini* fell into the *Codonoboea* clade.

Species from *Loxocarpus* show conclusively that they are different from *Codonoboea*. Even though being scattered into various places in the *Boea*-clade in the

MP analysis, one Bayesian analysis of the data shows the genus as monophyletic (Yao, T.L., pers. comm.), though neither in Moeller *et al.* (2009, 2011) nor Weber *et al.* (2011) on more samples.

From the phylogenetic tree, species from *Microchirita* as well as *Boea philippensis* and *B. hygrometrica* were selected as outgroups for the analysis with smaller data sets focusing on *Codonoboea*.

Figure 5.1. A single representative phylogram of 574 most parsimonious trees of 1594 steps, based on *trnL-F* sequences of 162 samples.

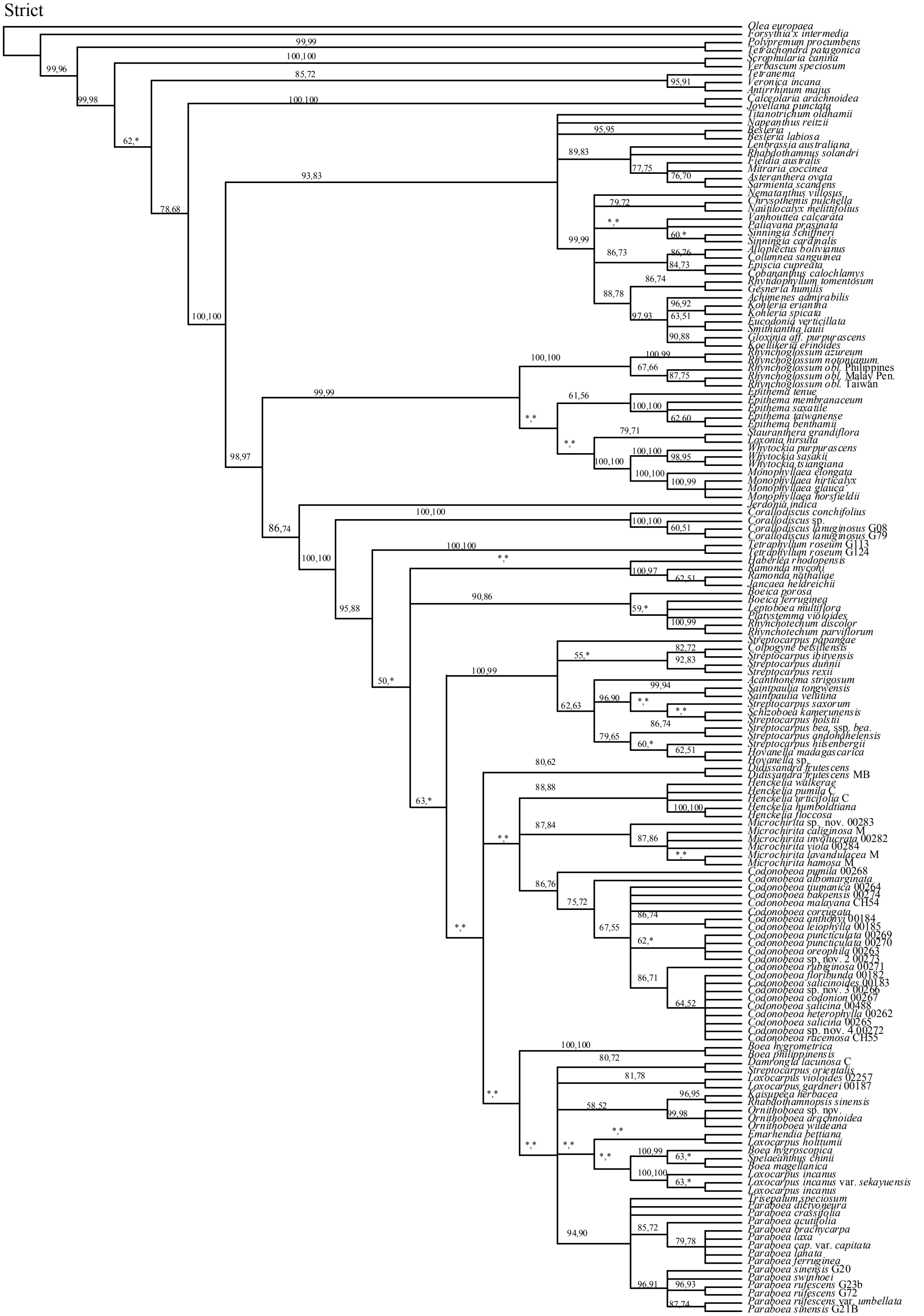


Figure 5.2. Strict MP consensus tree of 574 most parsimonious trees of 1594 steps based on *trnL-F* sequences of 162 samples (CI = 0.59, RI = 0.85, RC = 0.50). Bootstrap and Jackknife values (BS, JK) are given above branches. * indicates branches with <50% support.

Figure 5.3. MP 50% majority rule consensus tree of 574 most parsimonious trees based on *trnL-F* sequences of 162 samples.

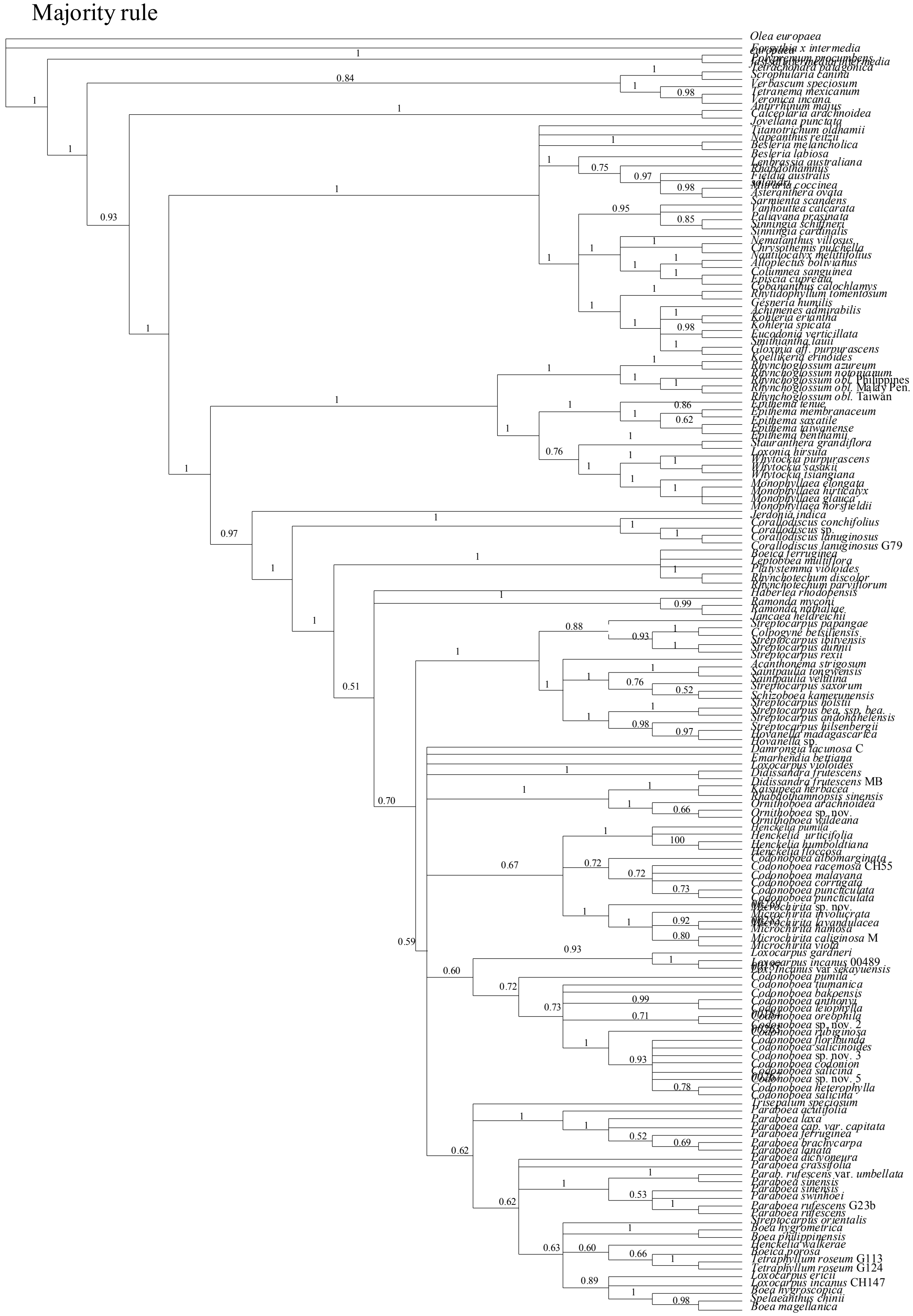


Figure 5.4. BI tree based on *trnL-F* sequences of 162 samples. Posterior probability values are given above branches.

5.3.3.2 Phylogenetic analysis of the reduced data sets

5.3.3.2.1 Phylogenetic analysis of the *trnL-F* region

The data matrix had 876 characters, of which 753 were constant, 76 variable but parsimony uninformative and 47 (5.4%) parsimony informative.

Only a single most parsimonious tree resulted from the MP analysis, with an almost fully resolved topology. The tree showed clearly that the *Codonobea* samples (22 samples) are monophyletic, distinctly different from the outgroup taxa, with 88% Bootstrap and 78 % Jackknife support (Fig. 5.5). The phylogram (Fig. 5.5) showed that the *Codonoboea* clade differed from the outgroup samples by 46 changes. Among the ingroup samples, *Codonoboea corrugata* (36 changes) and *C. albomarginata* (30 changes) showed relatively long branches. This may be due to the relatively poor *trnL-F* sequences obtained as explained in part 5.3.2.1, which caused some ambiguous base callings and consequently difficulties in the alignment.

The BI tree (Fig. 5.6) was similarly resolved and had a different topology compared to the MP trees, though these concerned areas with low branch support.

Despite being able to show the generic delimitation, the MP *trnL-F* analysis failed to support intraspecific relationships. Many species relationships had weak or no branch support. This may be due to the low percentage of parsimony informative (5.4%) sites in the data matrix. Such difficulties in inferring intraspecific taxonomic relationships were encountered in other studies, such as on Polygalaceae (Persson, 2001), or *Lysimachia* (Myrsinaceae) (Hao *et al.* 2004).

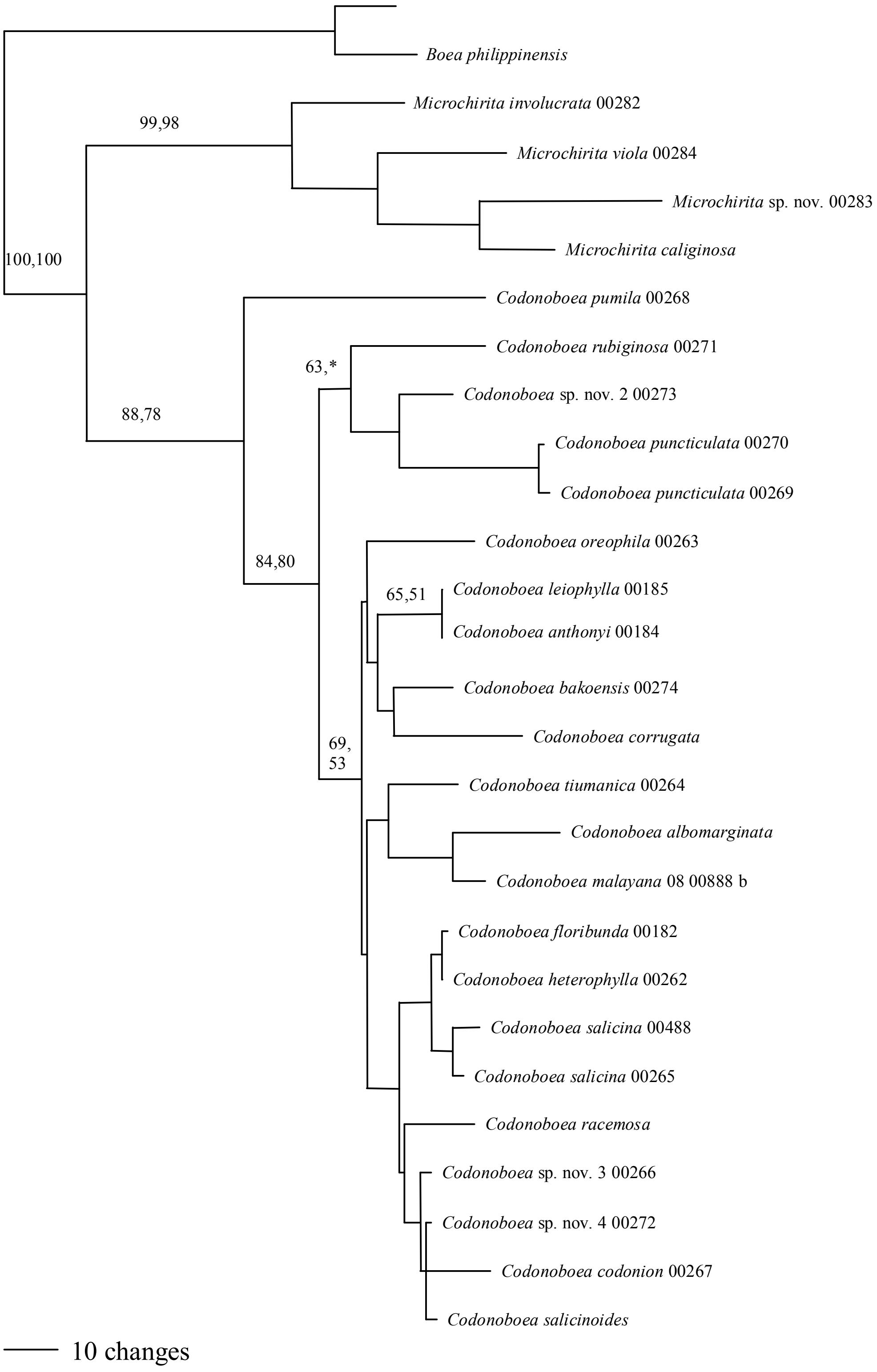


Figure 5.5. Phylogram of the single most parsimonious tree of 143 steps, based on *trnL-F* sequences of 22 *Codonoboea* and six outgroup samples. CI = 0.9301, RI = 0.9296. Bootstrap and Jackknife values (BS, JK) are given above branches.

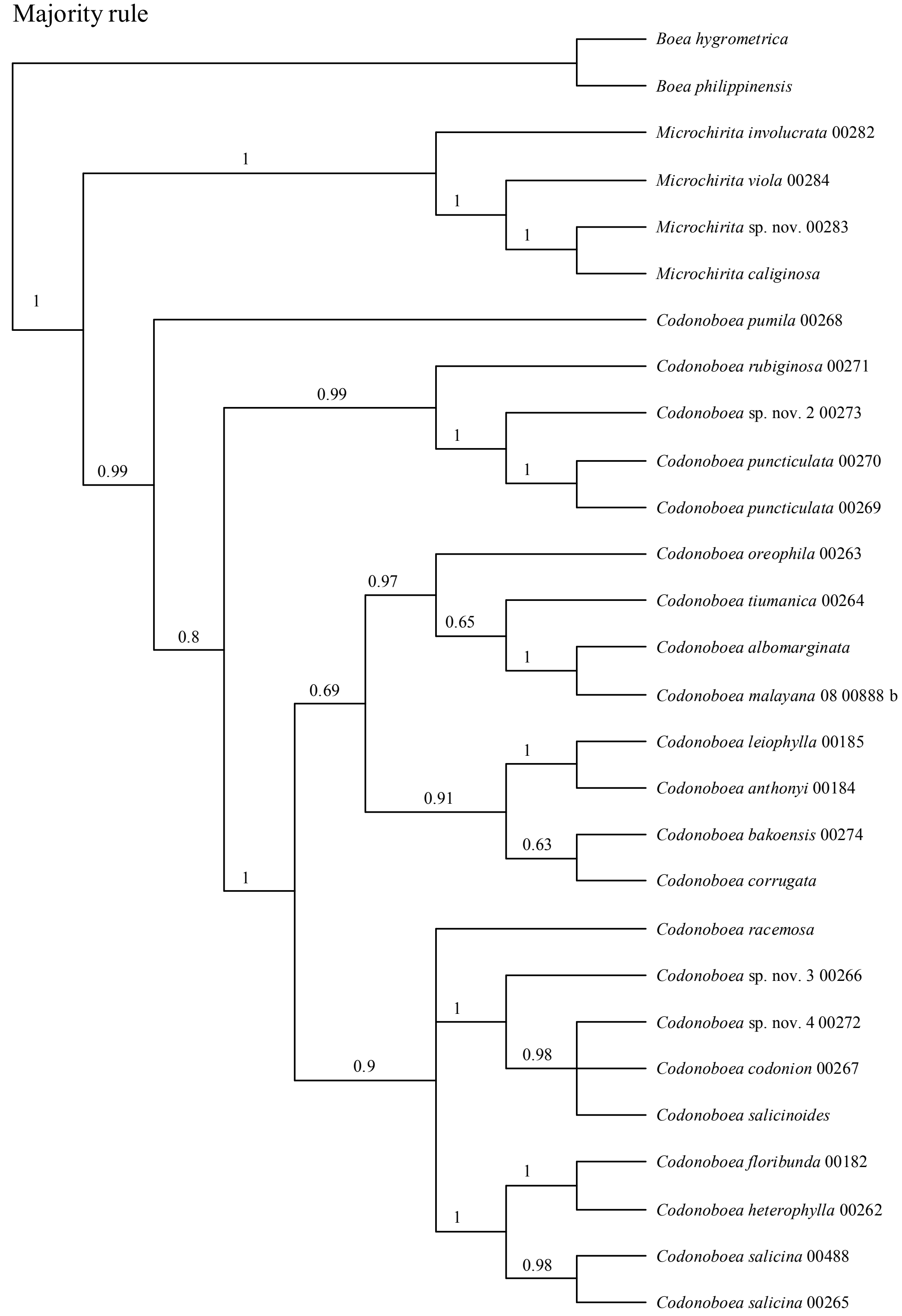


Figure 5.6. BI tree based on *trnL-F* sequences of 22 samples. Posterior probability values are given above branches.

5.3.3.3 Phylogenetic analysis using the ITS region on *Codonoboea*

The data matrix of the ITS region had 682 characters. Among these 398 were constant, 73 variable but parsimony uninformative and 211 (30.9%) parsimony informative.

The MP analysis resulted in three most parsimonious trees of 595 steps length and a CI of 0.56. The phylogram in Fig. 5.10 shows that the terminal branch lengths of the taxa varied greatly in length. This may suggest that the ITS region of the species evolved at different rates of evolution. The average number of steps per character (595/682=0.87) suggested a relatively low level of base substitution saturation, but the relatively low CI indicates local homoplasies in the matrix.

The consensus trees in Fig. 5.8 and 5.9, show a lower resolution than the trn*L-F* tree, and included three hard and two soft polytomies. The presence of the latter indicates topology conflicts among the three most parsimony trees found, perhaps a consequence of the locally accelerated rates of evolution.

The backbone of the strict consensus tree (Fig. 5.8) was not well-resolved, compared to the majority rule tree (Fig. 5.9), and included one polytomy with nine lineages (Fig. 5.8).

Comparing both, the *trnL-F* tree (Fig. 5.5) and the ITS majority rule tree (Fig. 5.9), several consistencies were observed. The first was the clade formed by *C. leiophylla* and *C. anthonyi*, while the second was a large clade consisting of a number of species from *Codonoboea racemosa* to *C. salicina* (Fig. 5.9). A further consistency was the location of *C. pumila* as sister to the rest of the samples in both trees. On the other hand, some taxa, such as *C. rubiginosa*, *C. oreophila*, *C. albomarginata* and *C. malayana* were located in different places on both trees.

In general, the positions of the taxa and the backbone topology of the BI tree (Fig. 5.10) are very similar to the majority rule tree generated by MP (Fig. 5.9).

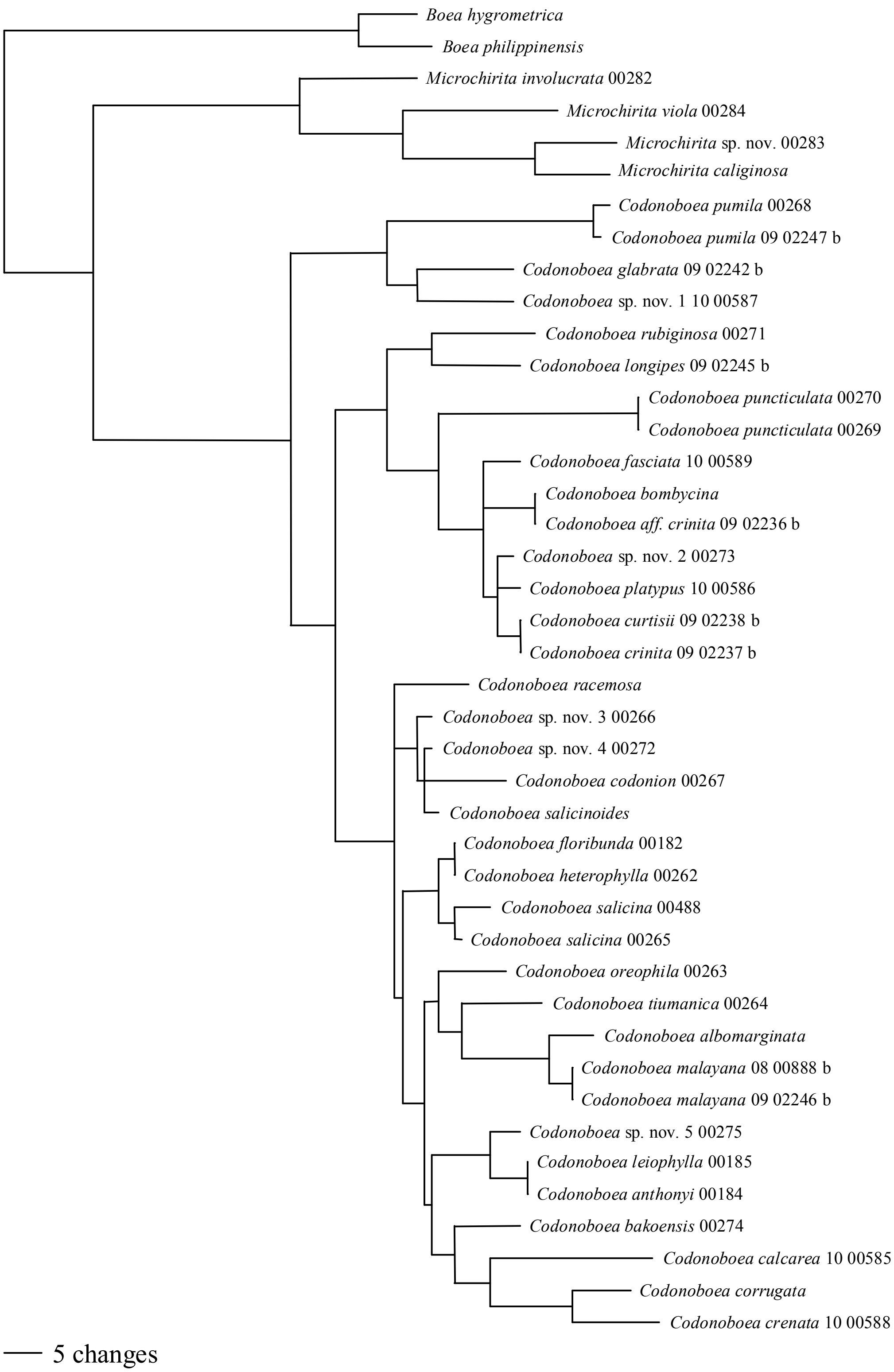


Figure 5.7. A single representative phylogram of 3 most parsimonious trees of 595 steps, based on ITS sequence of 36 ingroup and six outgroup samples.

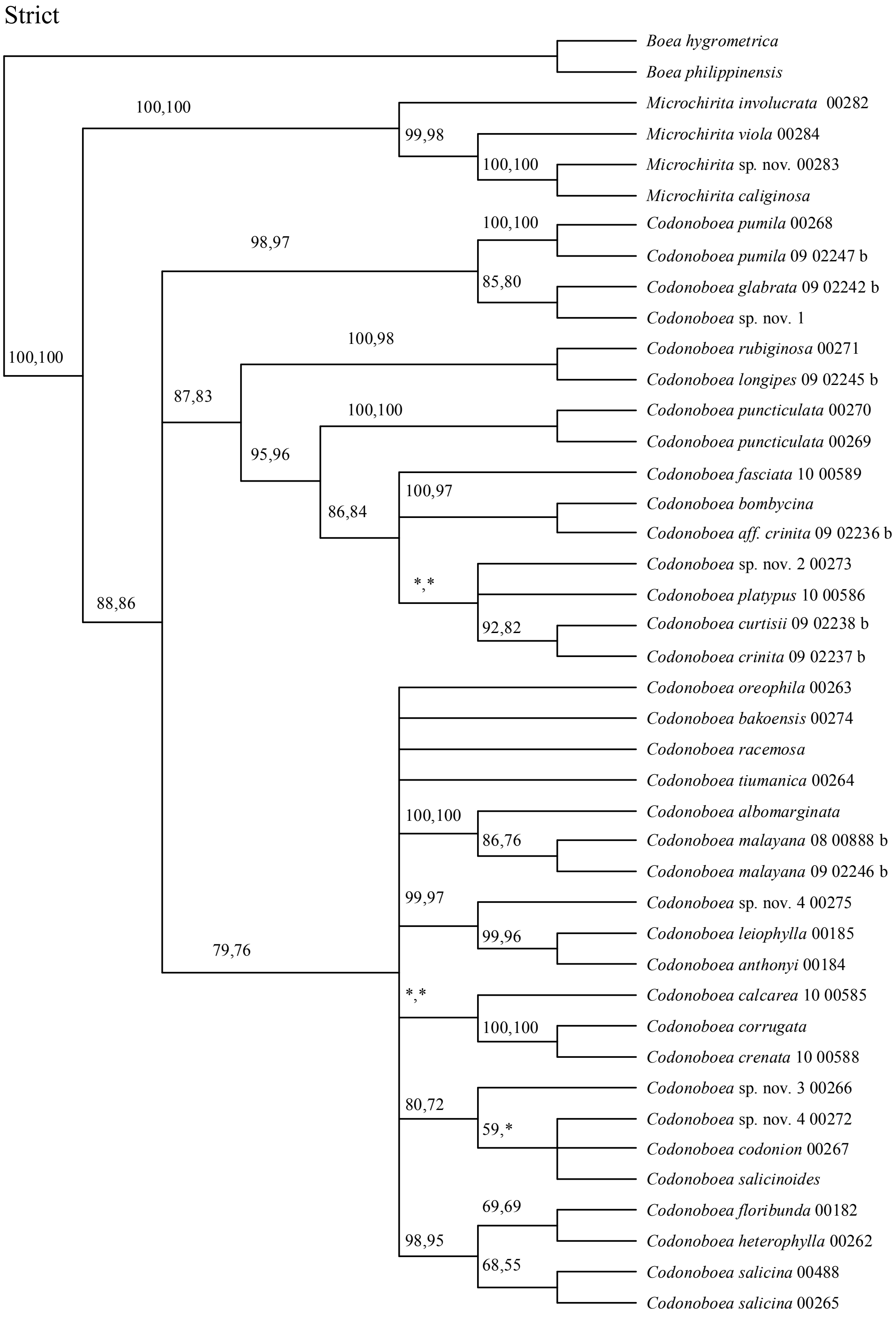


Figure 5.8. Strict MP consensus tree of 3 most parsimonious trees of 595 steps based on ITS sequences of 36 samples (CI = 0.65, RI = 0.78, RC = 0.50). Bootstrap and Jackknife values (BS, JK) are given above branches. * indicates branches with <50% support.

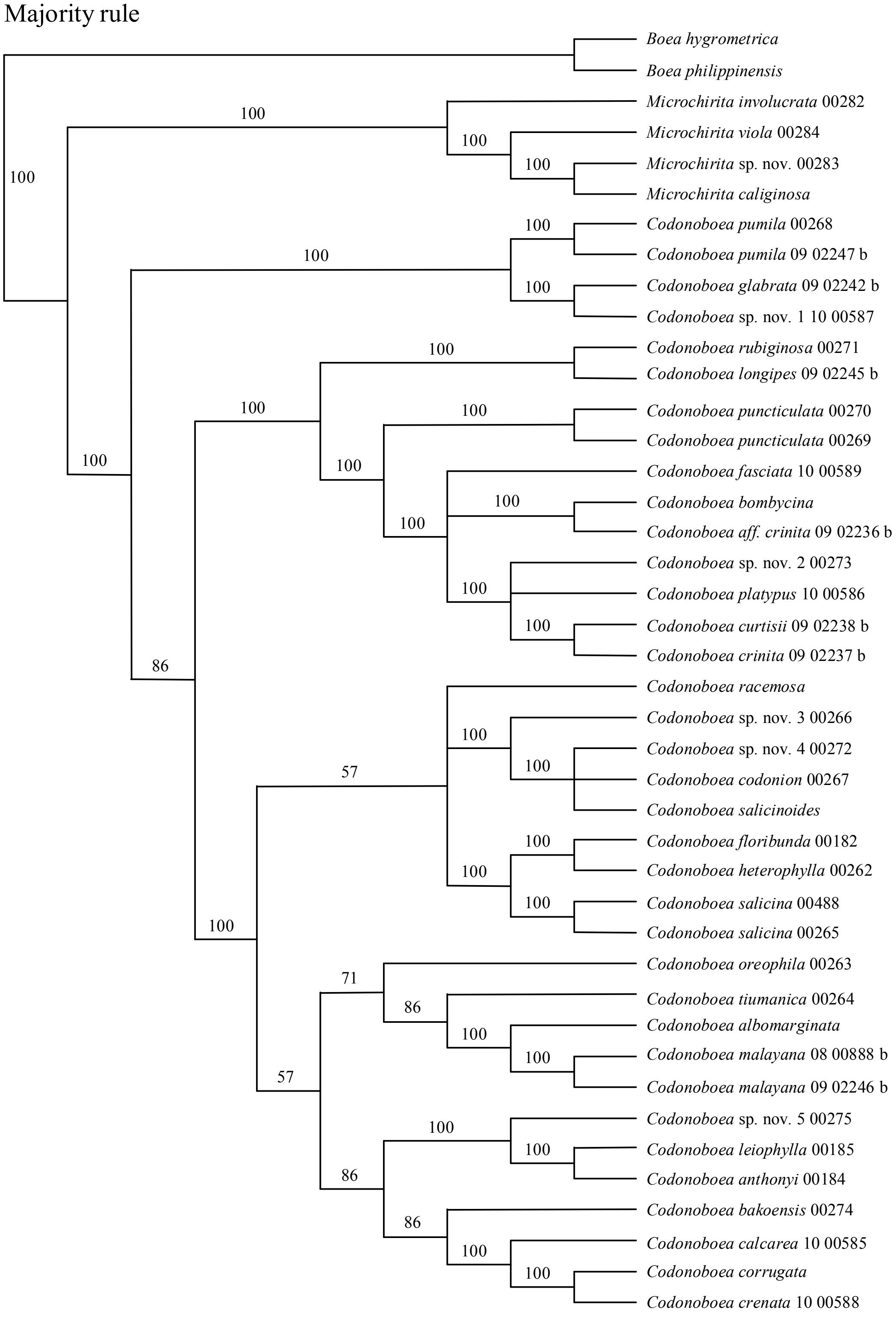


Figure 5.9. MP 50% majority rule consensus tree of 595 steps based on ITS sequences of 36 samples.

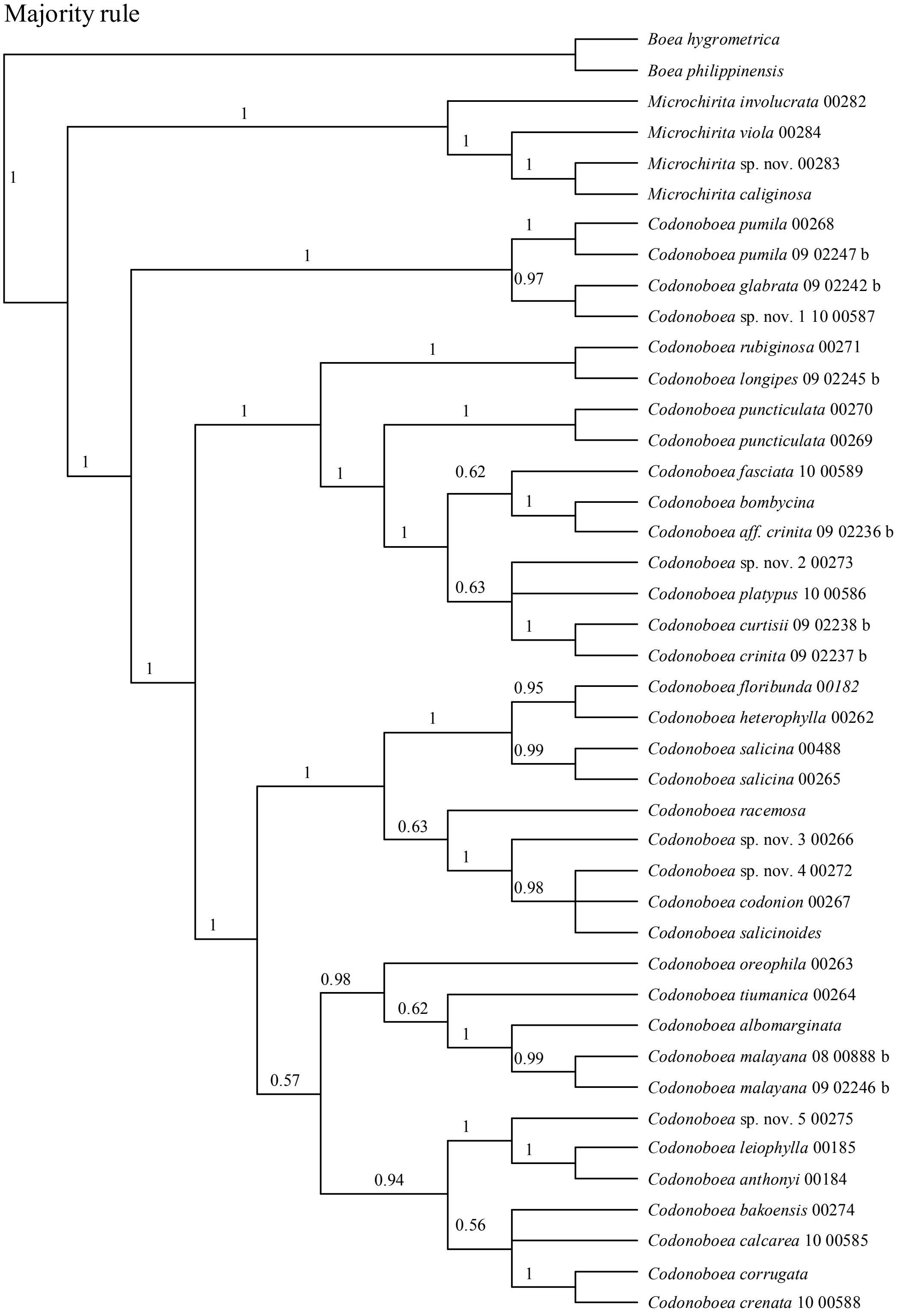


Figure 5.10. BI tree based on ITS sequences of 36 samples. Posterior probability values are given above branches.

5.3.3.4 Phylogenetic analysis of combined ITS and *trnL-F* genes, excluding taxa with missing *trnL-F* sequences on *Codonoboea*

The combined data matrix had 1558 characters, of which 1179 were constant, 150 variable but parsimony uninformative and 229 (14.7 %) parsimony informative.

One most parsimonious tree was obtained after maximum parsimony analysis with a length of 647 steps and a CI of 0.72 and RI of 0.75 (Fig. 5.11). Compared with the trees based on ITS and *trnL-F* separately, the combined tree (Fig. 5.12). showed a more similar topology to the latter, however, with a better supported backbone and supported relationships.

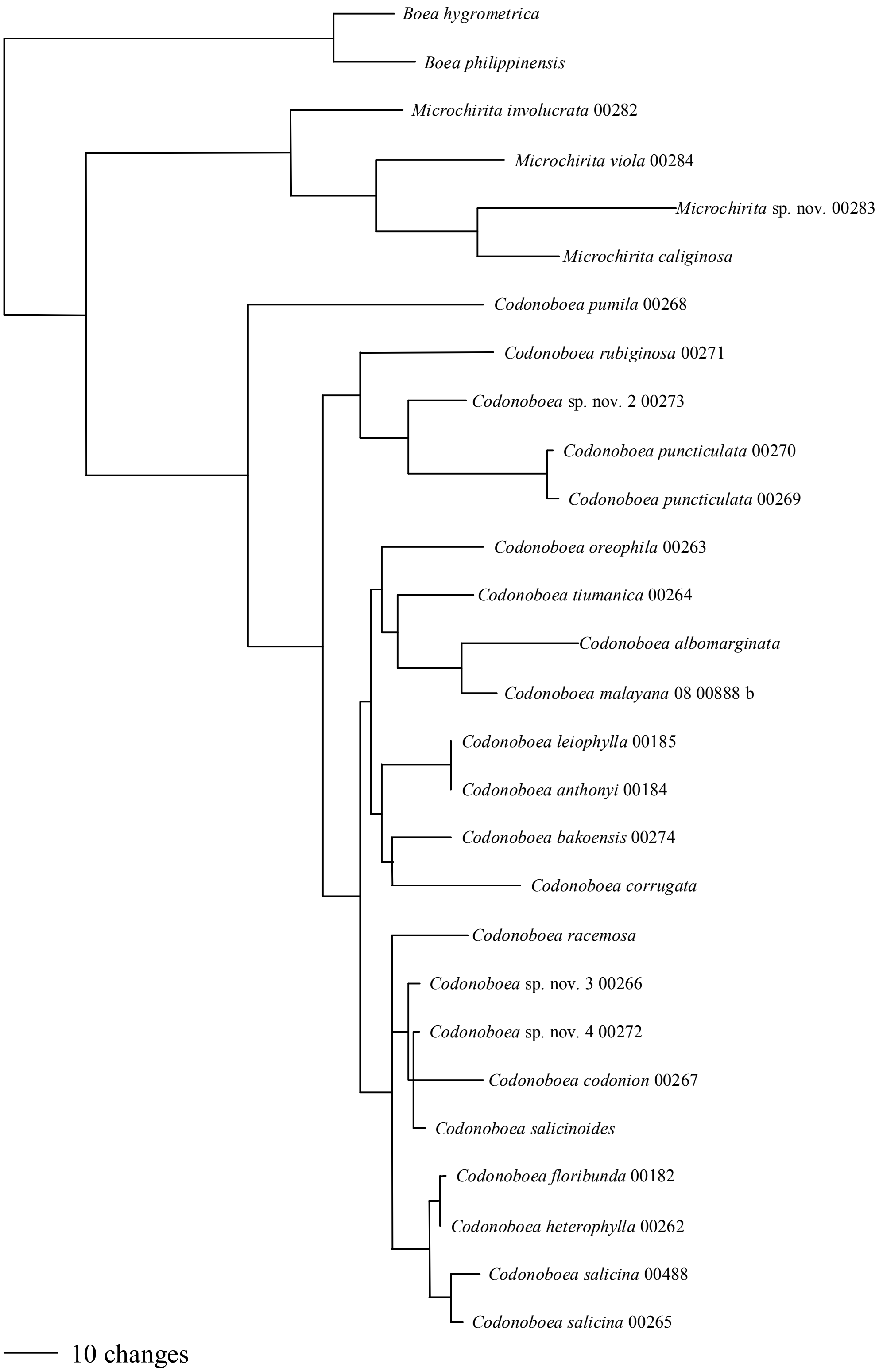


Figure 5.11. Phylogram of one of three most parsimonious trees of 647 steps, based on combined ITS and *trnL-F* sequences (excluding taxa with missing *trnL-F* data) of 22 ingroup and six outgroup samples.

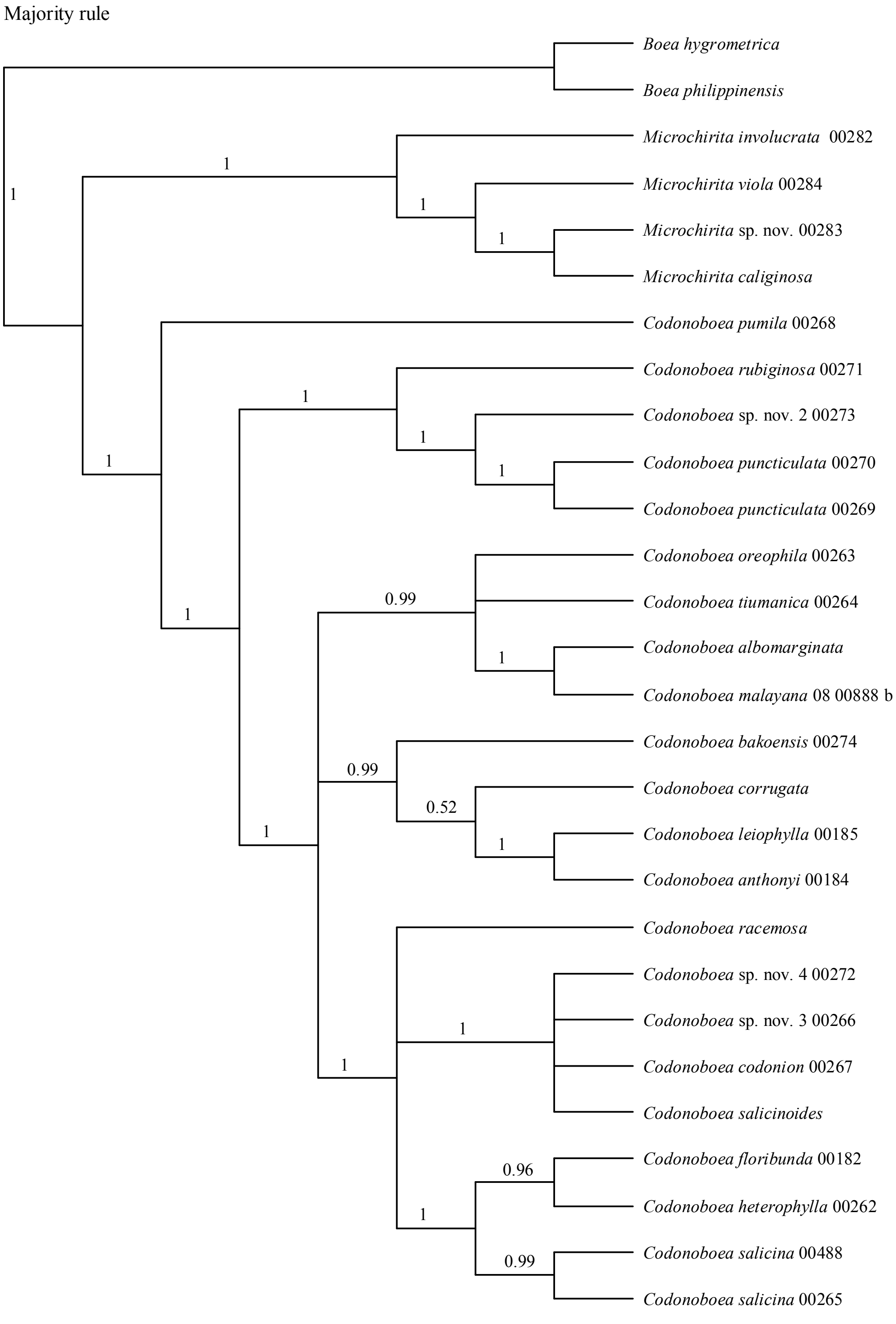


Figure 5.12. BI tree based on combined ITS and *trnL-F* sequences (excluding taxa with missing *trnL-F* data) of 36 samples. Posterior probability values are given above branches.

5.3.3.5 Phylogenetic analysis of combined ITS and *trnL-F* genes, including taxa with missing *trnL-F* sequences on *Codonoboea*

Sequences of 14 taxa with missing *trnL-F* sequences were added to the data set under part 5.3.3.4. In this data matrix, 1558 characters were used for analysis, of which 1151 were constant, 149 variable but parsimony uninformative and 258 (16.6 %) parsimony informative.

Three most parsimonious trees were recovered in the parsimony analysis, with a length of 747 steps, and a CI of 0.69, and RI of 0.79 (Fig. 5.13). Like the trees generated in part 5.3.3.4, the topology of the majority rule consensus tree (Fig. 5.15) did not differ greatly from that based on ITS alone (Fig. 5.9), except for the collapse of part of the backbone. The general topology of the BI tree (Fig. 5.16) was nearly identical to the one generated by MP (Fig. 5.15), except for some near terminal polytomies.

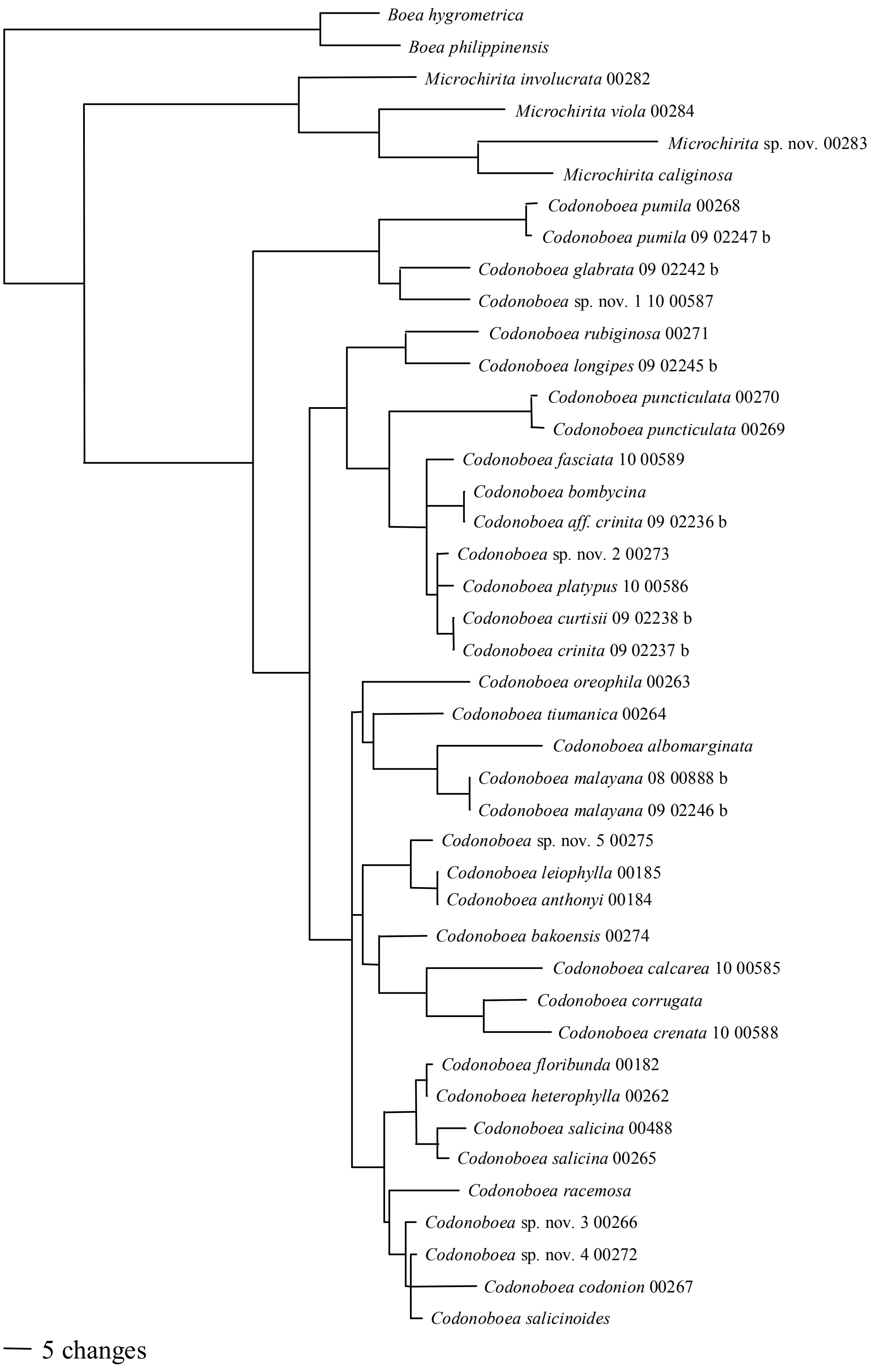


Figure 5.13. A single representative phylogram of 3 most parsimonious trees of 747 steps, based on combined ITS and *trnL-F* sequences (including taxa with missing *trnL-F* data) of 36 ingroup and six outgroup samples

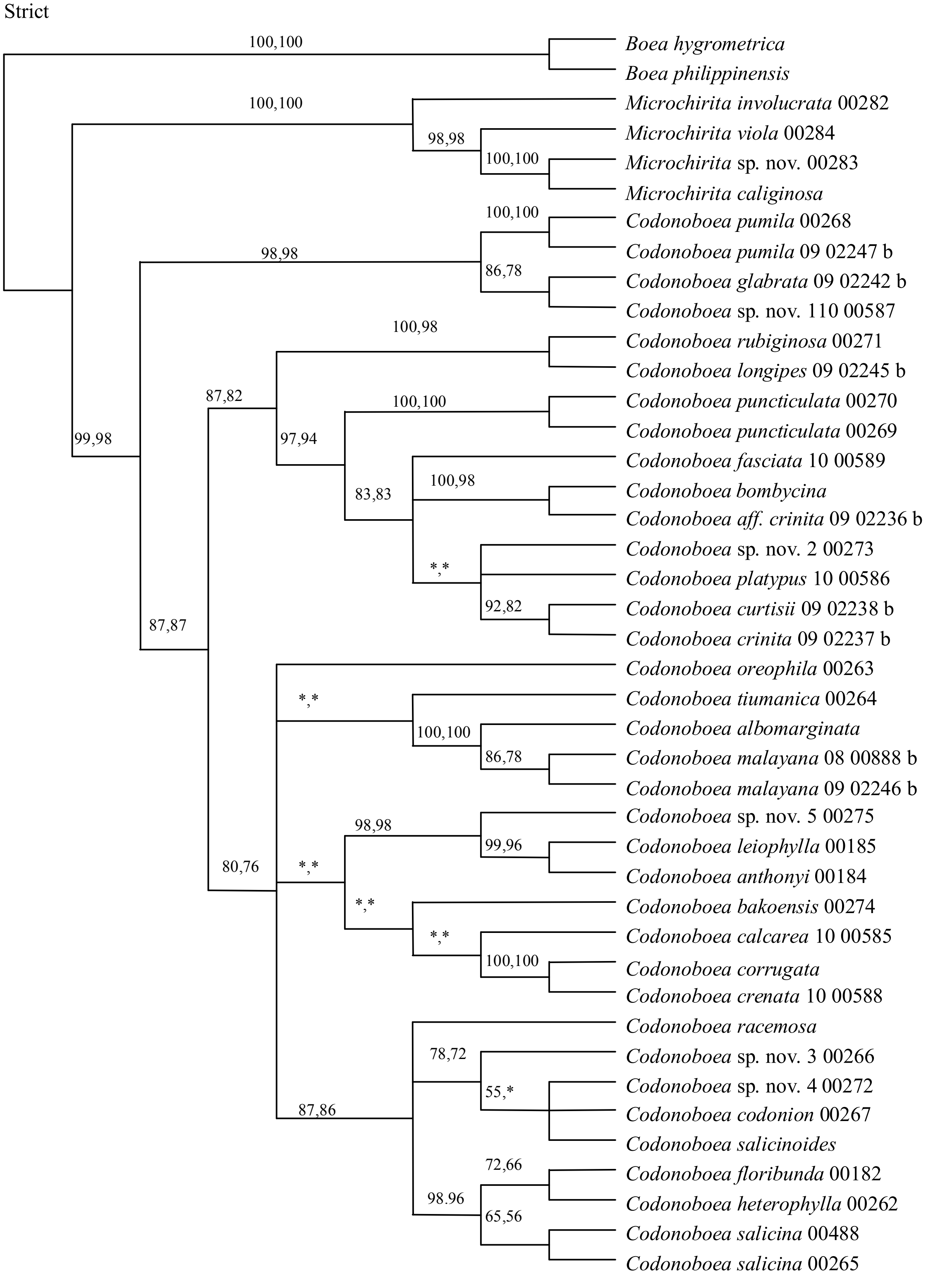


Figure 5.14. Strict MP consensus tree of 3 most parsimonious trees of 747 steps based on combined ITS and *trnL-F* sequences (including taxa with missing *trnL-F* data) of 36 samples. (CI = 0.69, RI = 0.79, RC = 0.55). Bootstrap and Jackknife values (BS, JK) are given above branches. * indicates branches with <50% support.

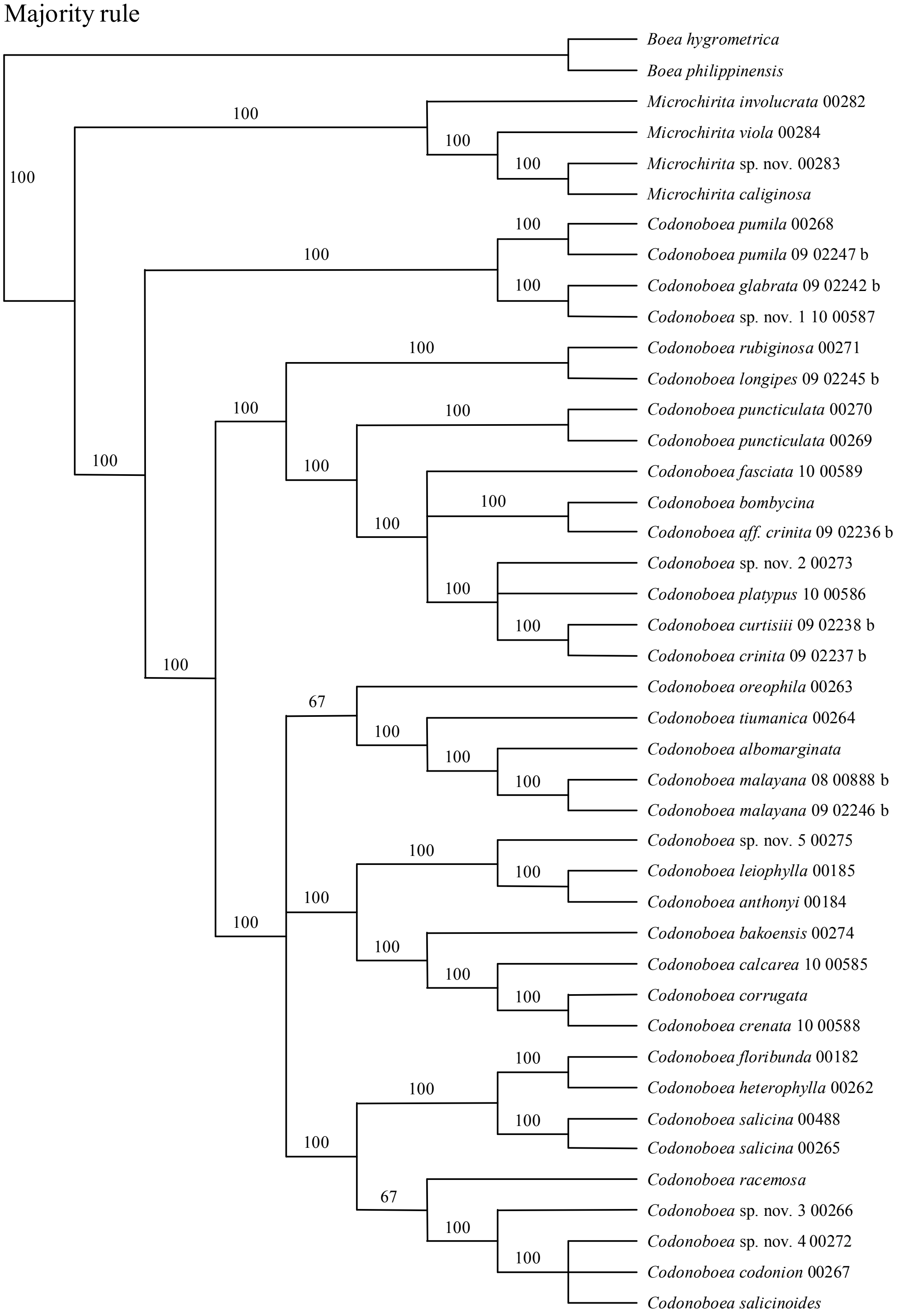


Figure 5.15. MP 50% majority rule consensus tree of 3 most parsimonious trees of 747 steps based on combined ITS and *trnL-F* sequences (including taxa with missing *trnL-F* data) of 36 samples.

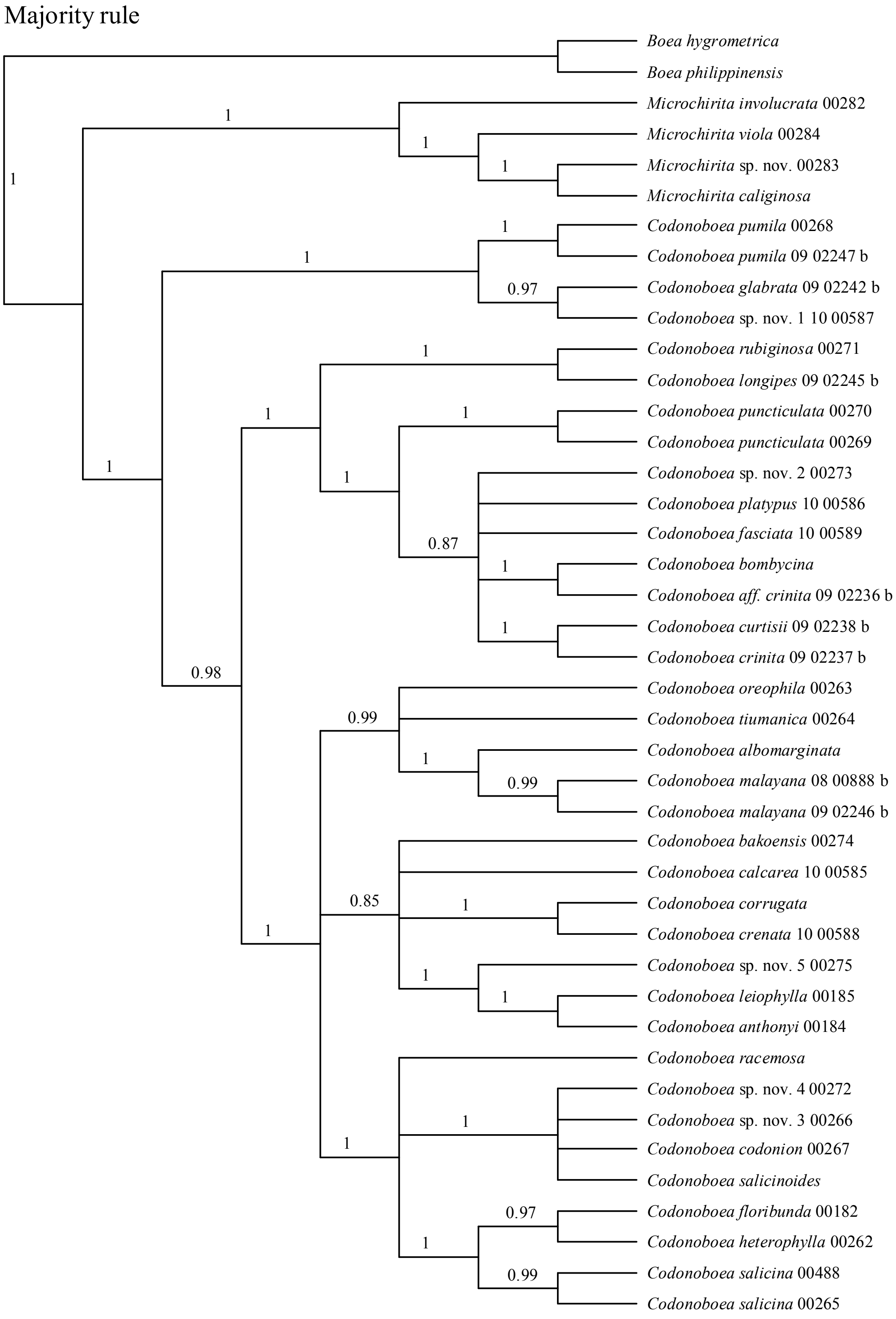


Figure 5.16. BI tree based on combined ITS and *trnL-F* sequences (including taxa with missing *trnL-F* data) of 36 samples. Posterior probability values are given above branches.

5.3.3.6 Phylogenetic analysis on *Codonoboea* of combined ITS, *trnL-F* genes and gap matrix, including taxa with missing *trnL-F* sequences

The data matrix had 1584 characters, of which 1151 were constant, 149 variable but parsimony uninformative and 284 (17.9 %) parsimony informative.

This data matrix was the most complete among the analyses. The additional gap matrix of 26 characters increased the percentage of parsimony informative sites from 16.6 % to 17.9 %. The maximum parsimony analysis retrieved two most parsimonious trees of 782 steps and a CI of 0.70 and RI of 0.80 (Fig. 5.17). The added gap character matrix did not affect the fundamental topology of the phylogenetic tree.

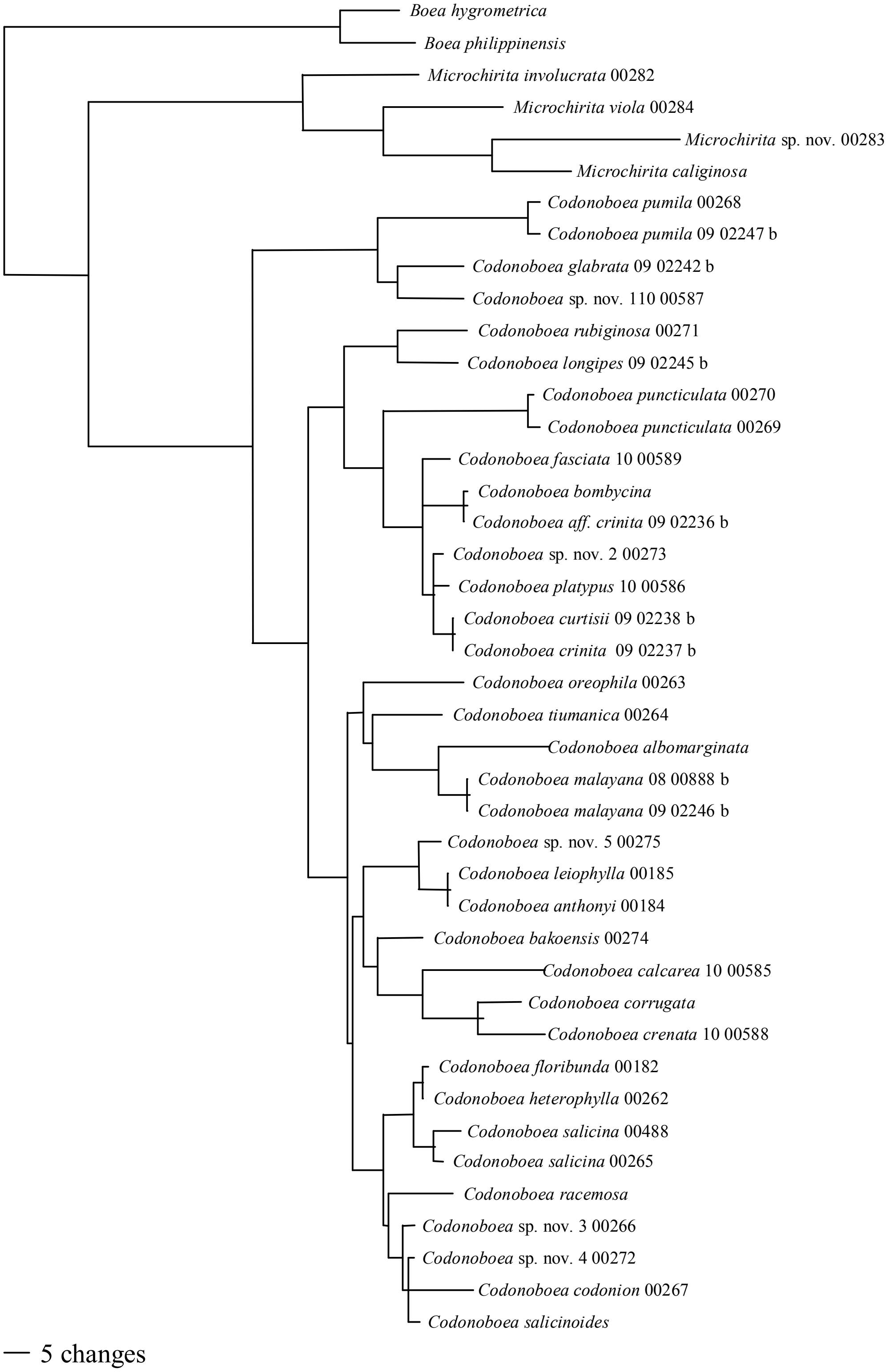


Figure 5.17. A single representative phylogram of 2 most parsimonious trees of 782 steps, based on combined ITS and *trnL-F* sequences plus gap matrix data (including taxa with missing *trnL-F* data) of 36 samples.

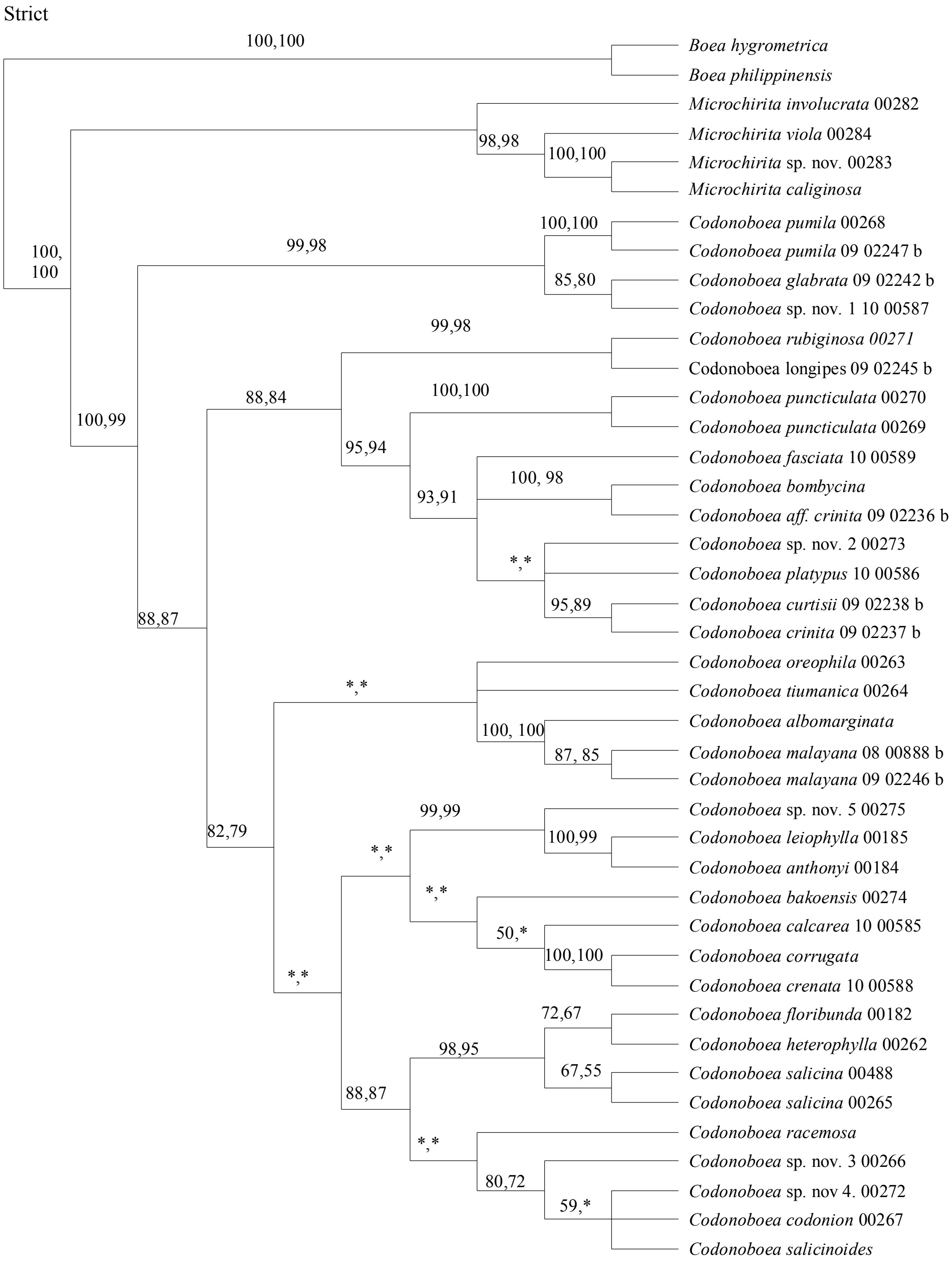


Figure 5.18. Strict MP consensus tree of 2 most parsimonious trees of 782 steps based on combined ITS and *trnL-F* sequences plus gap matrix data (including taxa with missing *trnL-F* data) of 36 samples (CI = 0.70, RI = 0.80, RC = 0.55). Bootstrap and Jackknife values (BS, JK) are given above branches. * indicates branches with <50% support.

Majority rule

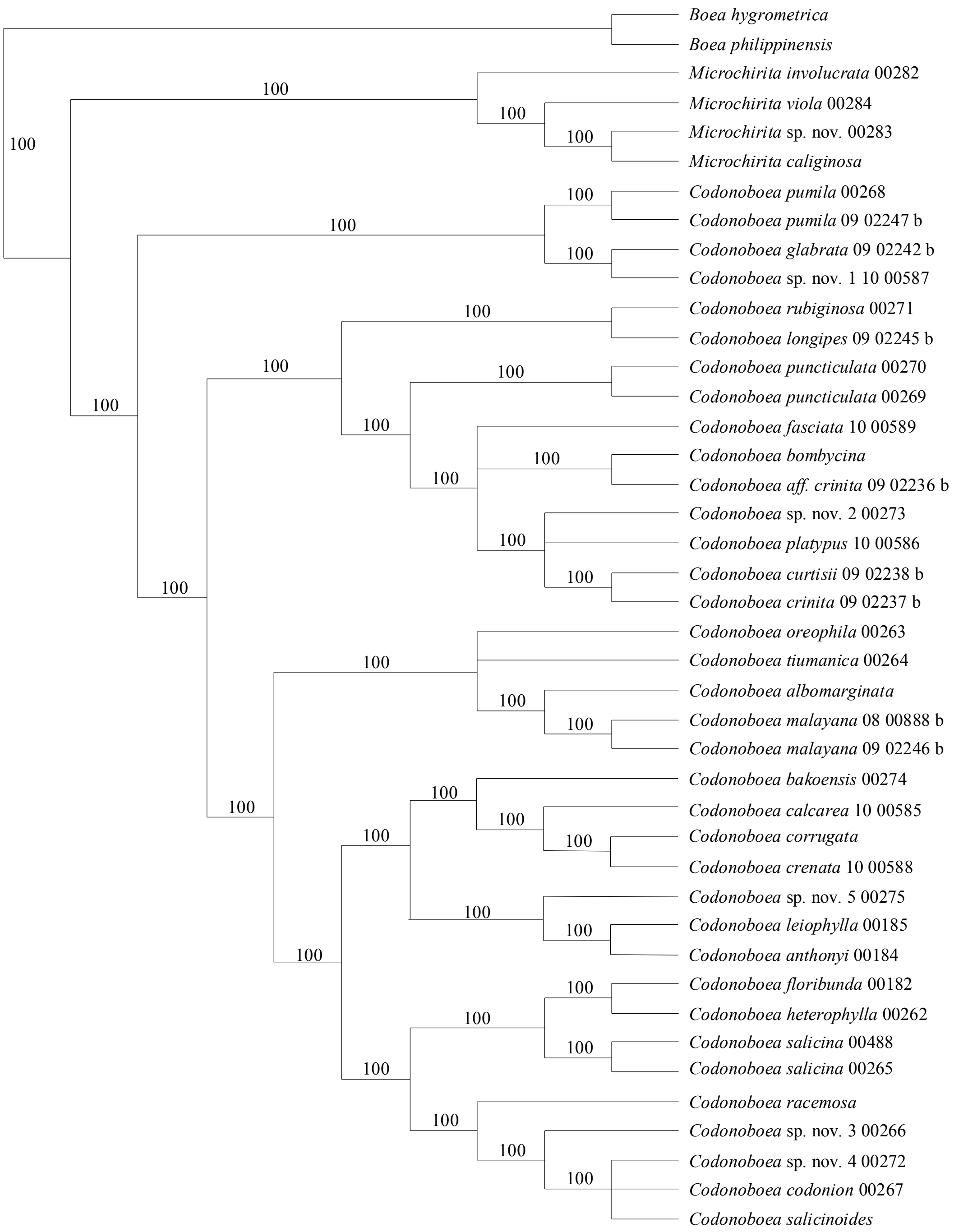


Figure 5.19. MP 50% majority rule consensus tree of 2 most parsimonious trees of 782 steps based on combined ITS and *trnL-F* sequences plus gap matrix data (including taxa with missing *trnL-F* data) of 36 samples.

Majority rule

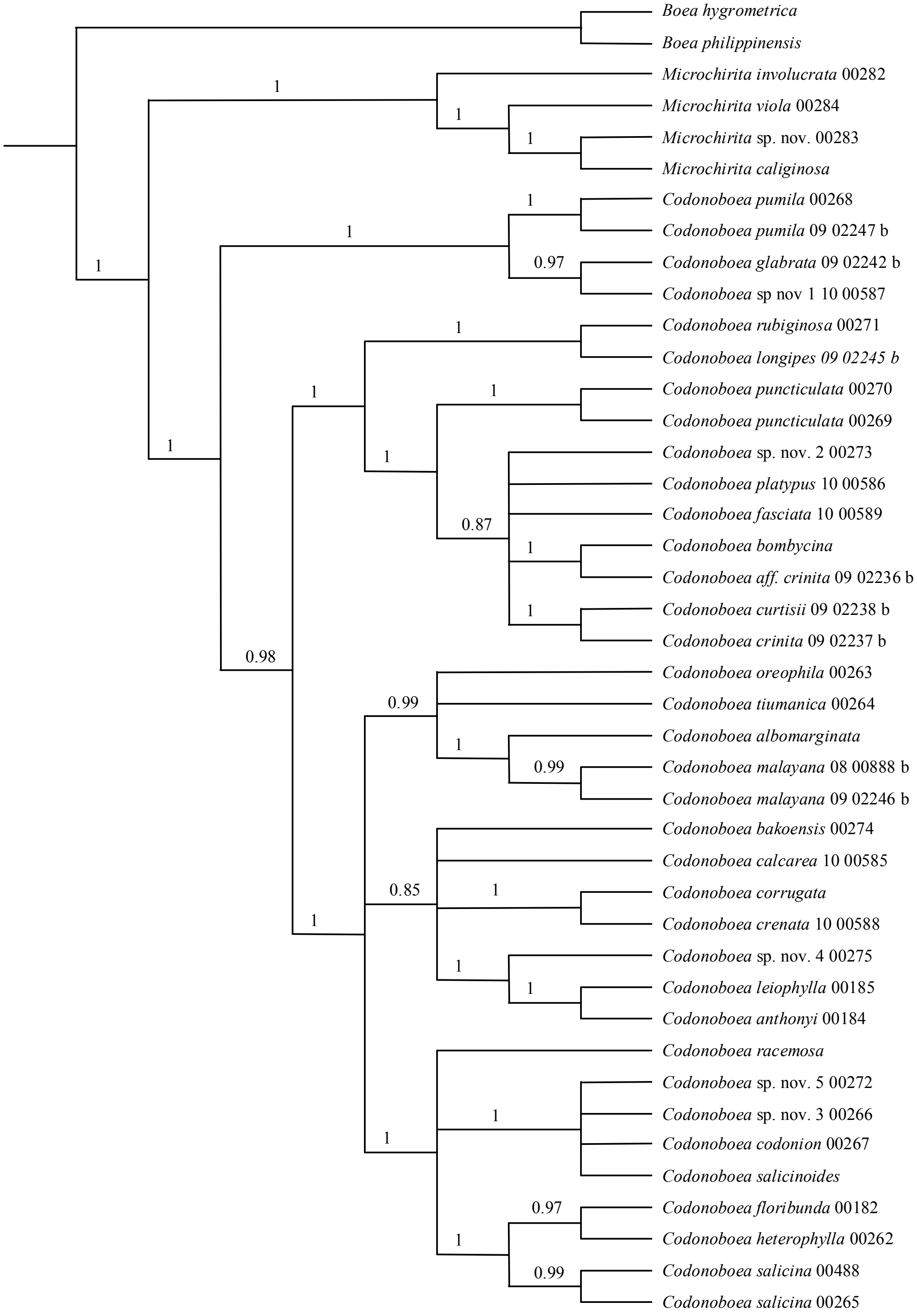


Figure 5.20. BI tree based on combined ITS and *trnL-F* sequences plus gap matrix data (including taxa with missing *trnL-F* data) of 36 samples. Posterior probability values are given above branches.

6.0 GEOGRAPHICAL DISTRIBUTION AND CONSERVATION STATUS ASSESSMENT

6.1 Introduction

Species of *Codonoboea* section *Boeopsis* and *Salicini* grow in deep shade in primary forest, or on exposed quartz outcrops (*C. rubiginosa*), steep earth banks in forest or within splash zones by streams (*C. densifolia*, *C. salicina* and *C. tiumanica*). According to Kiew (2009), there are no weedy species in Gesneriaceae that would benefit from habitat disturbance. Therefore, assessing species conservation status and identifying conservation hotspots are important to prevent species extinctions.

The conservation status of a taxon indicates the likelihood that a species will survive in the future. It takes into account criteria, such as threat, species distribution and population fluctuations for the assessment.

Before a conservation assessment can be conducted, the geographical distribution of a particular species needs to be compiled. This requires up-to-date information. Kiew (1992) plotted the distribution of species of sect. *Boeopsis*. To date, many new locality records require an update.

Conservation status assessments of *Codonoboea* species were conducted by Kiew (1991) following contemporary IUCN criteria. In the assessment, *Codonoboea primulina* (Ridl.) Kiew was listed as rare, vulnerable and *C. pumila* as endangered.
Following the establishment of standard guidelines and methodology (IUCN, 1994) the conservation status of 195 species of Gesneriaceae in Peninsular Malaysia were again assessed (Kiew, 2001). The results showed that 0.5 % of the species were Extinct (EX) and the rest belonged to the threatened category. Of these, 78 % were Critically Endangered (CE), 14.3 % were Endangered (EN) and 7.7 % were Vulnerable (VU) categories.

There are nine Red List categories in IUCN ver. 3.1, namely Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). In Malaysia, an additional category, Rare (RA) has been included. This category caters for a taxon that is not exposed to any known direct or plausible threat and does not qualify under the five IUCN threatened categories. This caterogy caters for species that are rare and occur in two or less sites or has an EOO (extent of occurrence) 100 km^2 or less or an AOO (area of occurrence) of 10 km^2 or less (Chua, 2012).

6.2 Methodology

Assessing the conservation status of the 15 taxa from both sections *Boeopsis* and *Salicini* was carried out following the Malaysia Plant Red List, Guidelines for Contributors (Chua & Saw, 2006). Gathering of baseline information was done prior to the assessment. The information required includes:

- Taxonomic information
- Distribution, mapping of the extent of occurrence (EOO) and area of occupancy (AOO)
- Population decline and threats
- The Red List category and criteria
- Current conservation measures for the taxon
- Legal protection status
- Utilisation

The conservation status of each species was then assessed based on the IUCN Red List Categories & Criteria, Version 3.1, 2001 (hppt://www.iucn.org/) including the rationales for assessment. The assessments were then discussed and approved by national assessors.

6.3 Results and discussions

6.3.1 Geographical distribution and endemism

From data retrieved from herbarium sheets, literature records and site observations, distribution maps of each species were plotted (Fig. 4.1–4.15).

Among the 15 species of *Codonoboea* included in this study, only *C. puncticulata* is found to occur outside Peninsular Malaysia. This makes the rate of endemism (93.3 %) similar to the 94 % reported by Kiew (2001).

Codonoboea puncticulata (Table, 6.1, Fig. 4.9) is most widespread in Terengganu, Pahang and Johor with an extent of occurrence of 11,835 km^2. *Codonoboea anthonyi*, *C. codonion*, *C. densifolia*, *C. heterophylla* and *C. salicinoides* are also widespread and also found in more than one state in Peninsular Malaysia.

Five species (36 %), namely *Codonoboea pumila*, *C. rubiginosa*, *C. salicina*, *C. soldanella* and *C. yongii* are narrowly endemic and are at present known from to a single locality. This figure is lower than that 69 % by Kiew (2001) for all *Codonoboea*. *Codonoboea yongii* is the most narrowly distributed and is confined to a few overhanging rocks along Sg. Teku, Pahang (Kiew, 1992). Although it was collected from Kuala Tahan in 1992, no specimen of this species has been collected from that locality since, even though Sg. Tahan has been well botanised.

Narrow endemism of these species may be the result of ineffective seed dispersal mechanisms. All *Codonoboea* species have long, narrow, gutter-shaped capsules that split only above and have tiny seeds, which are therefore, are unlikely to be dispersed by animals. The herbaceous species growing on forest floor cannot rely on wind for dispersal. Burtt (1976) and Kiew (2009) proposed that these species could be dispersed by rain splash. Hence, distance of dispersal is limited to a few metres from the mother plant.

Geographical barriers, such as mountains and rivers, often limit the distribution of species. For instance, *C. rubiginosa,* a lithophyte, is confined to exposed quartz outcrops on G. Tahan. The dense forests with high canopy surrounding these outcrops limit the ability of this species to disperse widely.

Combining all the distribution maps into a single map (Fig. 6.1), shows most species are found to the east of the Main Range of Peninsular Malaysia from Kelantan to SW Pahang. The overall distribution pattern is similar to the one plotted by Kiew (1992) but with greatly increased sampling of each species. This distribution pattern is characteristic of species of the Riau Pocket *sensu* Ashton (1992). The pattern was pointed out by Wong (1998) where *Codonoboea* sect. *Boeopsis* was given as one of the examples of Riau Pocket taxa.

Only two species, *Codonoboea*. *pumila* of Fraser's Hill, Pahang (Fig. 4.8) and *C. soldanella* of G. Korbu, Perak. (Fig. 4.12) are found on ridge of the Main Range of Peninsular Malaysia. Both species are narrow endemics in montane forest.

In terms of altitudinal distribution, only *Codonoboea pumila* (Fraser's Hill), *C. oreophila* (G. Stong and G. Tera), *C. rubiginosa* (G. Tahan) and *C. soldanella* (G. Korbu) are confined to altitudes above 1000 m.

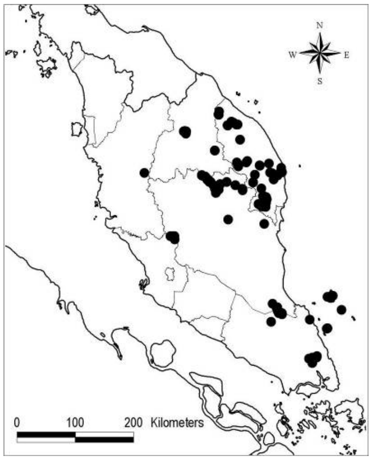


Figure 6.1. Combined distribution maps of all species in sect. *Boeopsis* and sect. *Salicini* in Peninsular Malaysia.

6.3.2 Disjunct distribution of a single species

Codonoboea densifolia (Fig. 4.3), *C. heterophylla* (Fig. 4.5) and *C. puncticulata* (Fig. 4.9) exhibit disjunct geographical distributions. *Codonoboea puncticulata*, for example, has one population centred in the southern part of Terengganu and the other on the east coast of Johor. Reason for this disjunction could be the specific soil type of the natural habitats. *Codonoboea puncticulata* is often found on sandstone in Johor and Terengganu. This disjunctive distribution is also observed in *Livistona endauensis* J.Dransf. & K.M.Wong (Palmae), which is also restricted to sandstone (Weiner & Corlett, 1987). Both *C. puncticulata* and *L. endauensis* are sympatric in Terengganu (Rasau-Kerteh-Ulu Chukai FR and Bkt. Bauk FR) and Johor (Endau-Rompin SP).

6.3.3 Conservation status

The conservation status of each species in this study is listed in Table 6.2 and summarised in Table 6.3. All except *C. puncticulata* are endemic to Peninsular Malaysia, therefore, the status equal to global status.

For all the species assessed, none fall into the Extinct (EX) or Critically Endangered (CR) categories. Under the threatened categories (5 species, 33.3 %), three are EN and two VU, while nine (60.0 %) are not threatened (3 RA, 2 NT, 4 LC) and one (6.7 %) is Data Deficient (DD) (Table 6.3).

Codonoboea soldanella is categorised as Data Deficient (DD) because it is only known from the type specimen and had not been collected since 1910. A thorough search of the type locality, G. Korbu, Perak, is required before it can be assessed.

Table 6.1. Area of Occupancy (AOO), Extent of Occurrence (EOO), number of collections, number of locality and the occurance within Protected Areas for *Codonoboea* species. n.a.= not available.

Species	No. Collection	No. Locality	EOO (sq. km)	AOO (sq. km)	Within TPA
C. anthonyi	6	4	593	16	No
C. codonion	27	17	6229	68	Yes
C. densifolia	20	12	7294	48	Yes
C. floribunda	16	6	197	24	No
C. heterophylla	19	9	970	36	Yes
C. leiophylla	13	8	1037	32	No
C oreophila	6	3	10	10	Yes
C. pumila	16	1	18	16	No
C. puncticulata	62	21	11835	84	Yes
C. rubiginosa	10	1	16	16	Yes
C. salicina	25	1	129	36	Yes
C. salicinoides	23	6	9166	36	No
C. soldanella	1	1	n.a.	4	Yes
C. tiumanica	13	5	24	20	Yes
C. yongii	3	1	n.a.	8	Yes

Table 6.2. List of *Codonoboea* species and their conservation status.

Species	Conservation status	Rationale
C. anthonyi	EN B2ab(i, iii)	Quality of the forest habitats is declining.
C. codonion	LC	There are many populations in Taman Negara.
C. densifolia	LC	It occurs in Endau-Rompin State Park, which is totally protected.
C. floribunda	EN B2ab(i, iii)	Quality of the forest habitats is declining.
C. heterophylla	LC	It is locally common and restricted to national and state parks.
C. leiophylla	EN B2ab(i, iii)	Quality of the forest habitats is declining.
C oreophila	RA	It is narrowly endemic to G. Stong State Park.
C. pumila	VU B2ab(iii)	It is endemic in Fraser's Hill. The area fall under Environmentally Sensitive Area as defined under National Physical Plan 2010. Correspondingly, Fraser’s Hill is also under Central Forest Spine.
C. puncticulata	NT	It is widespread and occurs in many forest reserves and in the Endau-Rompin State Park.
C. rubiginosa	RA	Changes in the local climate may alter the cloud cover and affect its niche.
C. salicina	LC	It is locally common in Taman Negara National Park.
C. salicinoides	VU A4c, B1ab(iii)	Quality of its occupied habitats, in particular Kelantan and Terengganu, has declined. The population in Kelantan is known from one specimen collected in 1899. Populations occur in a Virgin Jungle Reserve.
C. soldanella	DD	This very rare endemic species is known from only the type collection and its locality, altitude and habitat are unknown.
C. tiumanica	NT	Much of the island is under wildlife reserve which is totally protected. It also occurs in adjacent isolated islands and at altitudes below 1000 m.
C. yongii	RA	It is narrowly endemic to Taman Negera.

Table 6.3. Summary of conservation status assessment of *Codonoboea* species in this study.

	Category	No. Taxa (%)	Summary
Extinct	EX	0	0
Threatened	CR	0	5 (33.3)
	EN	3 (20.0)	
	VU	2 (13.3)	
Not threatened	RA	3 (20.0)	9 (60.0)
	NT	2 (13.3)	
	LC	4 (26.7)	
Data deficient	DD	1 (6.7)	1 (6.7)

6.3.4 Threats faced by species

From the criteria given in the Red List Guidelines, the most relevant criteria for this study group are B: "geographical distribution", followed by criterion A: "population reduction".

The main reasons for species to be classified into threatened categories are:

1) Restricted distribution and small EOO. Many *Codonoboea* species are known from less than five localities, e.g. *C. pumila* (3 localities).

2) Degradation of habitat and change of environment. Destruction to the pristine environment includes logging activities, conversion of land use status to plantation and human settlements.

The greatest threat to *Codonoboea* species is the deterioration or destruction of its natural habitat. These species are adapted to undisturbed habitats on forest floor and are particularly vulnerable to the opening of canopy and exposure to extreme heat and light.

Due to restricted distributions, quality change of natural habitat is the major threat to most species. For instance, logging activities in forest reserves like Jengai FR and Sg. Nipah FR in SW Terengganu affect the survival of*Codonoboea codonion*, *C. floribunda*, *C. puncticulata* and *C. salicinoides* found there.

Species occurring in highland areas face a possible threat from human recreational activities, such as clearing of forest paths. For instance, several populations of *C. pumila* in Fraser's Hill are easily accessible by forest trails. The populations were destroyed by tourist activity and the problem persisted until 1970s (Kiew, R., pers. comm.). As for *Codonoboea rubiginosa* in G. Tahan, it is found on exposed quartz outcrops, which is the main access trail for ascending G. Tahan.

6.3.5 Legislation protection of the species

Codonoboea codonion, *C. heterophylla*, *C. rubiginosa*, *C. salicina* and *C. yongii* are found in Taman Negara. The status of the National Park has been protected by the Federal National Parks Act 1980 (Act 226) (Pakhriazad *et al.*, 2009). This area has been gazetted as a Totally Protected Area (TPA) since 1938. Therefore the chance of long-term survival of the species within this area is high.

Other totally protected areas where species are located are Endau-Rompin SP (both Johor National Parks Corporation Enactment of 1989 and National Forestry Act 1984), G. Stong SP (National Forestry Act 1984) and P. Tioman (Wildlife Protection Act 1972). These acts provide a legal framework for the long-term protection of the species. In Endau-Rompin SP, *C. densifolia*, *C. heterophylla* and *C. puncticulata* are found while *C. densifolia* and *C. tiumanica* are found on P. Tioman.

Five species (33.3 %), i.e. *Codonoboea anthonyi C. floribunda, C. leiophylla*, *C. pumila* and *C. salicinoides*, are not found within TPAs. Therefore, these species are listed in threatened categories in the IUCN Red List, as any change of their natural habitat could threaten the future survival of the species.

6.3.6 Recommendations for conservation

6.3.6.1 Gazettement of species distribution hotspots

The southern part of Terengganu is identified as a species hotspot. Areas under state land and forest reserves, which are not totally protected, need to be gazetted as totally protected areas to help conserve the gene pool of the species.

6.3.6.2 Long-term monitoring of highly vulnerable species

Although found in TPAs, some species, such as *C. rubiginosa* with an extremely narrow distribution, require close monitoring of its populations.

6.3.6.3 More active species search for possible new population

For the DD species (*C. soldanella*), more detailed search at the type site and around surrounding areas with similar micro-habitat is required to discover possible new locality sites as suggested in Chua (2010).

6.3.6.4 *Ex-situ* conservation

Germplasm collection of the threatened species should be established in the nursery of research institutes such as Kepong Botanic Garden (KBG) of FRIM. This will enable the conservation of the genetic resources of species. However, *ex-situ* conservation should only be a last resort because there might be limited genetic resource exchange to preserve the variability of the genes.

7.0 GENERAL DISCUSSION AND CONCLUSIONS

7.1 Monophyly of genus *Codonoboea*

The Phylogenetic trees of 162 samples (Fig. 5.1, 5.2, 5.3, 5.4) show conclusively that *Codonoboea* species from Peninsular Malaysia together with *Codonoboea bakoensis*, *C. corrugata* and *C. racemosa*, form a strongly supported monophyletic clade. The clade is sister to *Henckelia* and *Microchirita*. . In Weber *et al.* (2011), *Codonoboea* was only represented by *C. albomarginata* and *C. corrugata* from this clade. This study, both samples were included, together with a larger sample from *Codonoboea*.

Codonoboea is distinguished by the slender plagiotropic fruits that split only on the dorsal side and the two fertile stamens (Kiew & Lim, 2011). All samples within the *Codonoboea* clade share the same fruit type and stamen number. Therefore, more taxonomic combination are required to cater for the non-Peninsular Malaysia *Codonoboea* species, like *C. bakoensis* (Borneo), *C. corrugata* (Philippines), *C. racemosa* (Sumatera) etc.

7.2 Polyphyly of sect. *Boeopsis* and sect. *Salicini*

Section *Heteroboea* is well-supported with all the species forming a clade together with the undescribed *Codonoboea* sp. nov. 2 (Fig. 7.1). Species of this section are caulescent, with solitary, tubular flowers, and spirally arranged leaves. Section *Didymanthus*, characterised by opposite leaves and woody erect stems, are split into two different clades. Species in this study from both sect. *Boeopsis* and sect. *Salicini* are also not monophyletic (Fig. 5.1–5.20). Species of both sections scatter in different clades in the tree. *Codonoboea codonion*, *C. floribunda* and *C. heterophylla* (sect. *Boeopsis*) are found in the same clade together with *C. salicina* and *C. salicinoides*.

Codonoboea pumila together with *C. glabrata* and *C. oreophila* fall in a clade on a basal most branch.

The backbone of the tree is not well-supported, therefore, more samples and data are required to resolve the relationship among the clades. It shows that *Codonoboea* is a very diverse genus. Until more samples are included in the molecular phylogenetic study, the sectional delimitation in *Codonoboea* is still unresolved.

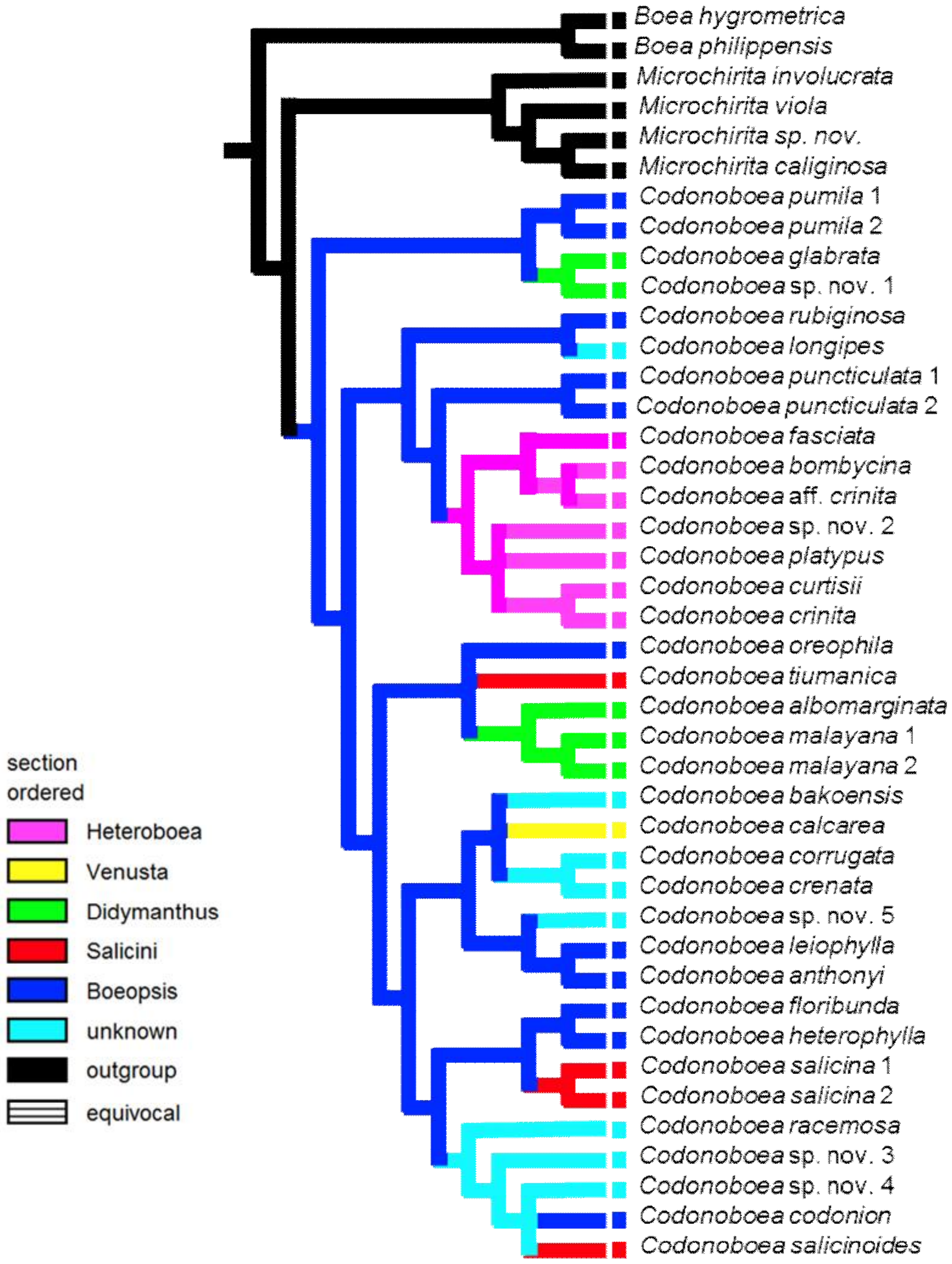


Figure 7.1. Mapping of *Codonoboea* sections on phylogenetic tree of combined ITS, *trnL-F* genes and gap matrix, including taxa with missing *trnL-F* sequences.

7.3 Usefulness of characters defining sect. *Boeopsis* and sect. *Salicini*

Other than possessing a small flower, Kiew (1992) defined sect. *Boeopsis* as rosette plants while sect. *Salicini* is characterised by willow-shaped leaves. With the help of character mapping onto phylogenetic tree, the validity of the characters can be compared.

In sect. *Boeopsis*, not all species are rosette plants. For example, *C. anthonyi*, *C. codonion*, *C. floribunda* and *C. tiumanica* are species with a distinct stem. Habit of the plants is very plastic (Fig. 7.2) and changes according to habitat adaptation. Although *C. oreophila* and *C. puncticulata* are predominantly rosette plants, creeping individuals are observed in the same habitat, especially those growing on hill slopes.

In terms of lamina shape, Fig. 7.3 demonstrates also that not all species in sect. *Salicini* have narrow leaves. Willow-shaped leaves are found among the rheophytic species that usually anchor themselves on river banks or rocks in the stream. *Codonoboea tiumanica* from sect. *Salicini* has broader lamina and usually grows slightly above the flood zone of the river. This makes evolutionary sense, since broad leaves are more susceptible to the water current. *Codonoboea* sp. nov. 2, a species of sect. *Heteroboea*, and grows in rocky streams, thus having evolved narrow leaves.

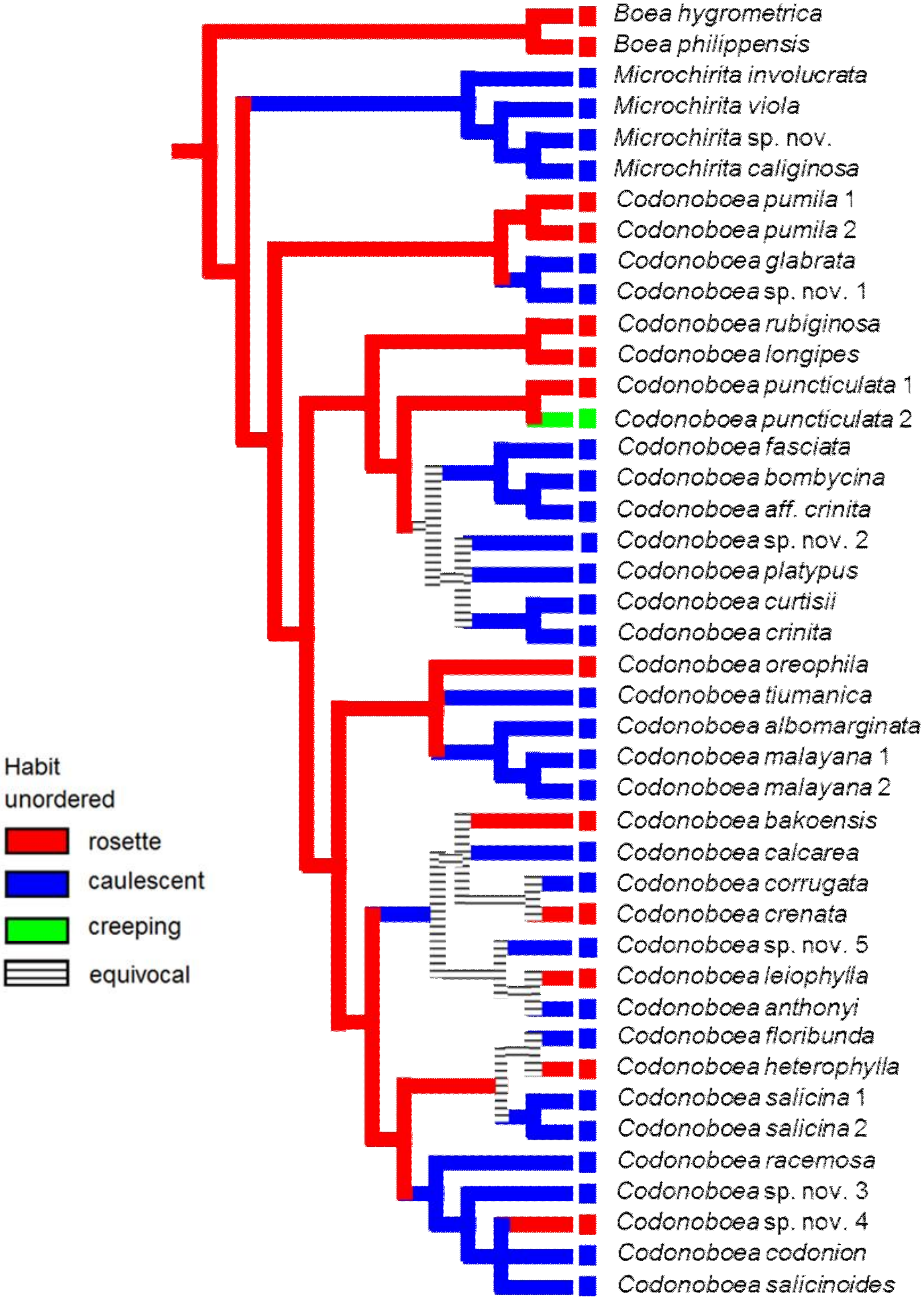


Figure 7.2. Mapping of habit on phylogenetic tree of combined ITS, *trnL-F* genes and gap matrix, including taxa with missing *trnL-F* sequences.

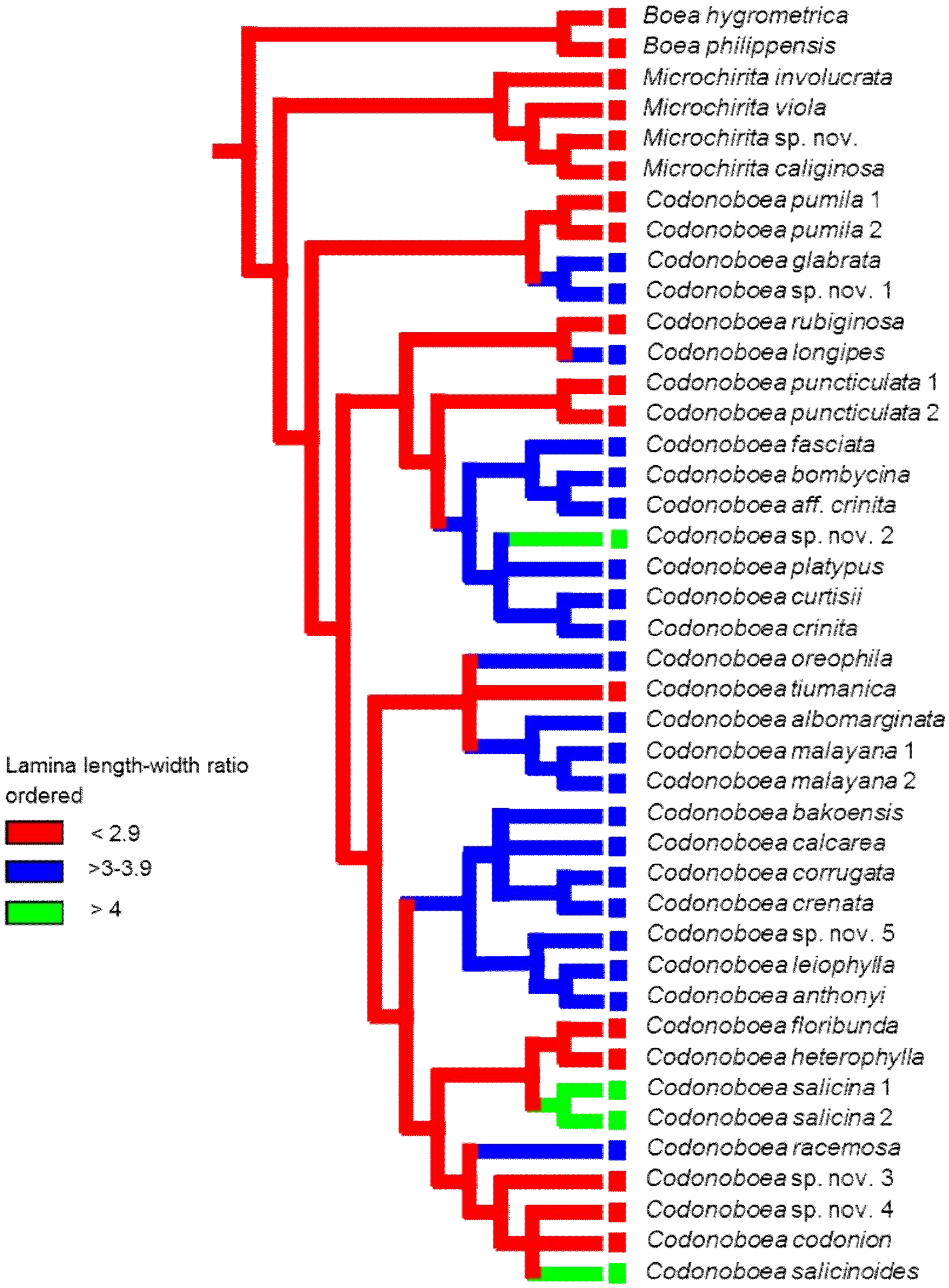


Figure 7.3. Mapping of lamina length-width ratio on phylogenetic tree of combined ITS, *trnL-F* genes and gap matrix, including taxa with missing *trnL-F* sequences.

7.4 Evolution of flowers in *Codonoboea*

To answer the trend of pollen and nectar flower evolution in *Codonoboea*, floral morphological characters were mapped on molecular phylogenetic trees to reveal the evolution of corolla types and the direction of change (Fig. 7.4).

Codonoboea is a very diverse genus, within the 32 spp. sampled in the molecular phylogenetic study, 10 corolla types are found. These corolla types represent both pollen and nectar flowers, where pollen flowers are represented by the campanulate type, the small campanulate type, the *C. puncticulata* type, the *C. tiumanica* type and the pouch type. On the other hand, nectar flowers are of the tubular type, the small tubular type, the narrow tubular type and the *Codonoboea calcarea*-type.

Based on the data available (32 spp. out of estimated 125 spp.), only preliminary trend can be drawn. In *Codonoboea*, the mapping (Fig. 7.4) shows that the tubular type is the plesiomorphic character state. There is a trend of increasing corolla size through time with reversal to pouch type at *C. rubiginosa*.

In the small campanulate clade, there is seemingly an occasion of reversal to tubular type on *C. racemosa* and reversal to campanulate type on *C. floribunda*. However, the branch leading to thoese species are equivocal. Therefore, occurance on *C. racemosa* could be plesiomorphism to the tubular corolla type, while *C. floribunda* could have parallel evolution with the *C. anthonyi* clade with campanulate flower.

Figure 7.5 gives a better picture of the trend of corolla tube shape evolution where corolla types are grouped according length-width ratio of the corolla tube. Pollen flowers tend to have a low length-width ratio (0.5–1.3), i.e. a short tube in relation to the corolla tube opening and *vice versa*. Obviously, tubular flowers (nectar flower) is the most plesiomorphic character, sharing the same corolla type with the outgroup: *Microchirita*. The result contrasts with floral evolution trend in *Streptocarpus* and *Saintpaulia* where *Streptocarpus tanala* Humbert, with pouch flower is the plesiomorphic state (Hughes *et al*, 2006).

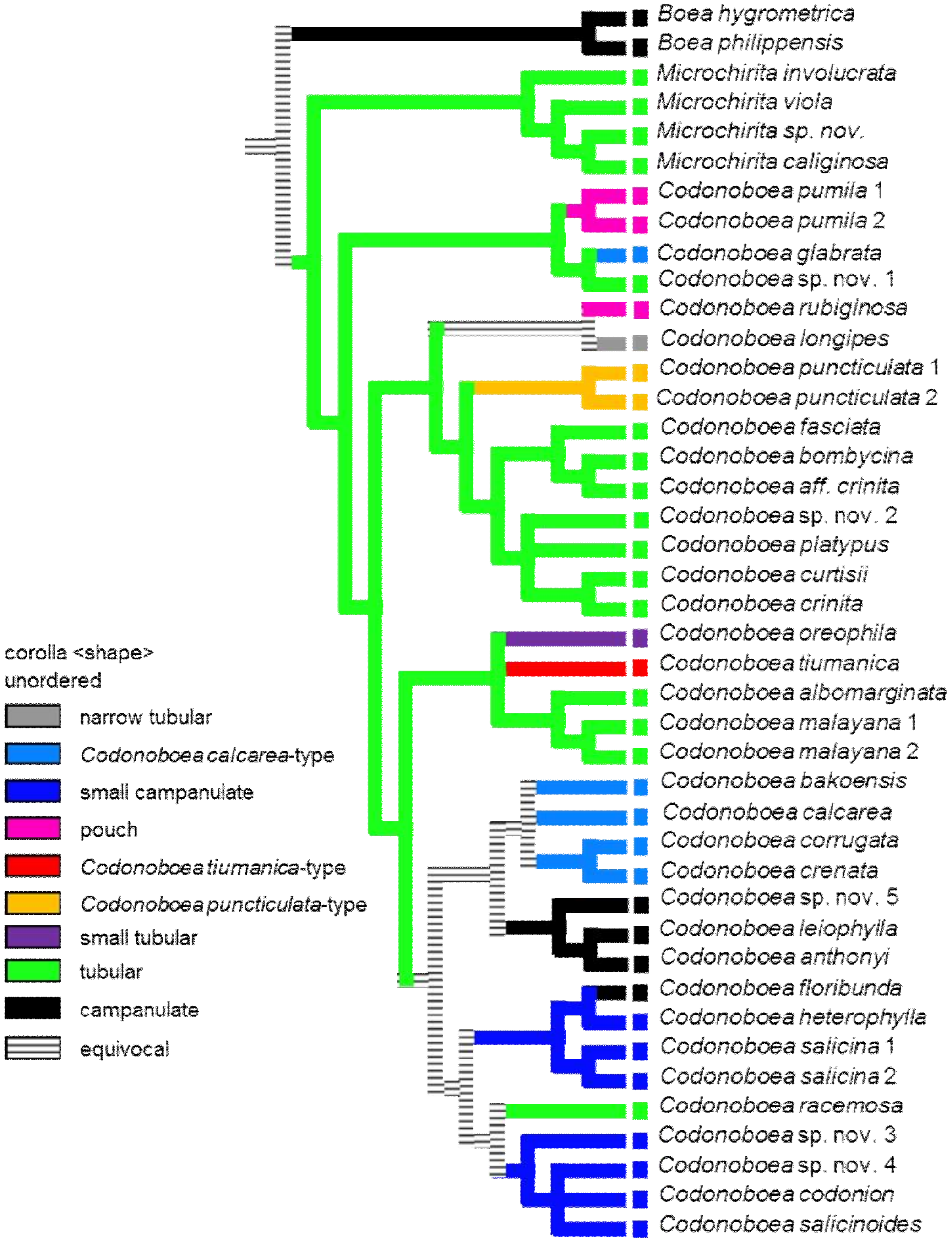


Figure 7.4. Mapping of corolla type on phylogenetic tree of combined ITS, *trnL-F* genes and gap matrix, including taxa with missing *trnL-F* sequences.

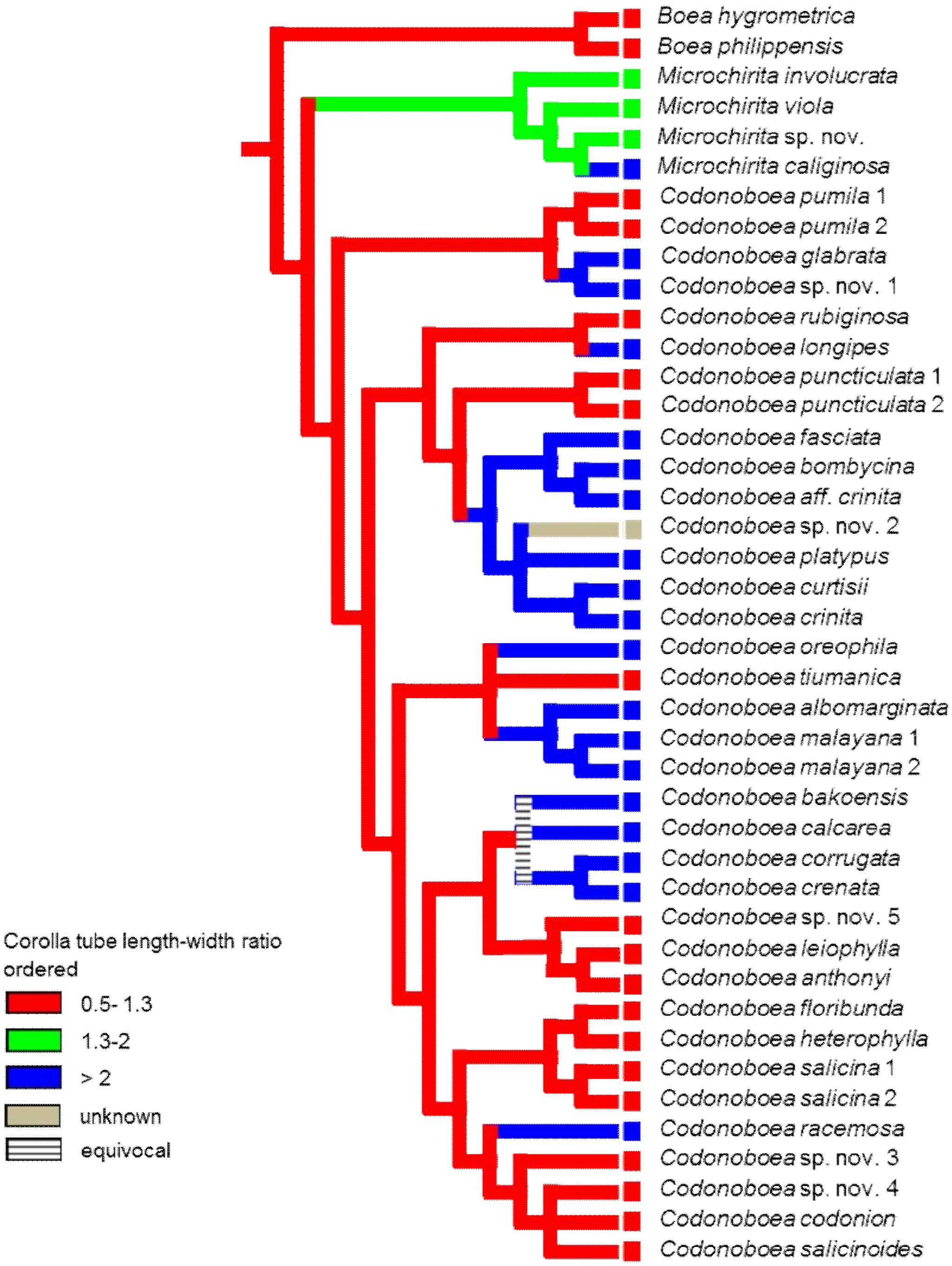


Figure 7.5. Mapping of corolla tubes length-width ratio on phylogenetic tree of combined ITS, *trnL-F* genes and gap matrix, including taxa with missing *trnL-F* sequences.

7.5 Conclusions

This study is the first detailed taxonomy study of species listed in both sect. *Boeopsis* and sect. *Salicini* by Kiew (1992). Fifteen species are described and a key provided using mostly vegetative characters given to aid species identification. Flowering material of *C. oreophila* was collected for the first time during this study that resulted in the confirmation of its new species status.

Concurring with the results of Moeller *et al.* (2009, 2011), *Codonoboea* is confirmed to be a distinct monophyletic genus, with a distribution in Thailand, Sumatra, Peninsular Malaysia, Borneo, the Philippines, Sulawesi and New Guinea. Characters that distinguish it from the closely similar genera, such as *Didymocarpus*, *Ridleyandra*, are the presence of two stamens and plagiotropic fruits that split only on the dorsal side.

Peninsular Malaysia is the centre of species diversity of the genus and shows high a endemism here; for example, 14 of the 15 species is sect. *Boeopsis* and sect. *Salicini* are endemic in Peninsular Malaysia (except for *C. puncticulata* that is also found in Singapore). Other than *C. pumila* (Fraser's Hill, Pahang) and *C. soldanella* (G. Korbu, Perak), most species are found on the east coast of Peninsular Malaysia. Within Peninsular Malaysia, the southern part of Terengganu is identified as a species hotspot where six species are to be found.

When the conservation status of all 15 species is assessed, six species fall within threatened categories. Areas under state land and forest reserves, especially in south Terengganu, which are not totally protected, need to be gazetted as totally protected areas to help conserve the gene pool of the species.

Morphological study of the 15 species shows that the characters are very diverse. There are actually seven types of corolla shapes among the species. Some morphological characters are found to be informative for species identification, such as corolla shape and colour, stamen and anther shape.

By utilising the molecular phylogenetic technique, questions on the monophyly of pollen flowers as well as evolutionary trends on flower types in *Codonoboea* are answered. Concurring with the morphological findings, molecular phylogenetic results confirm that species from both sections, *Boeopsis* and *Salicini*, are polyphyletic. However, more samples from other sections are required to give a better idea of sectional classification of the genus.

A tubular flower is the plesiomorphic state in *Codonoboea* from which other corolla types have evolved, several more than once independently. This convergent evolution of the corolla type is likely driven by adaptation to pollinators, such as the bee *Trigona* sp.

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Appendix A

List of additional samples included in the molecular phylogenetic analysis.

Voucher number	Species	Deposit in	Origin
Gu 01-6184	*Boea hygrometrica*	KUN	China, unknown locality
S.Scott 02-142	*Boea philippensis*	E	Indonesia, Sulawesi
Weber 840805-1/12	*Codonoboea albomarginata*	WU	Peninsular Malaysia, Perak, Bkt. Larut
FRI 64994	*Codonoboea anthonyi*	KEP	Peninsular Malaysia, Terengganu, Lata Tembakah
FRI 57977	*Codonoboea bakoensis*	KEP	Borneo, Sarawak, Bako NP
FRI 56039	*Codonoboea bombycina*	KEP	Peninsular Malaysia, Pahang, Cameron Highlands, Robinson Waterfalls
FRI 53627	*Codonoboea calcarea*	KEP	Peninsular Malaysia, Kelantan, G. Stong
FRI 65040	*Codonoboea codonion*	KEP	Peninsular Malaysia, Terengganu, Jerangau FR
RBGE-PNHE 1998 na	*Codonoboea corrugata*	E	Philippines, Palawan
FRI 65403	*Codonoboea crinita*	KEP	Peninsular Malaysia, Perak, Maxwell Hill
RK 5436	*Codonoboea crinita*	KEP	Peninsular Malaysia, Pahang, Fraser’s Hill
FRI 65452	*Codonoboea crenata*	KEP	Borneo, Sabah, Bkt. Leila
RK 5433	*Codonoboea curtisii*	KEP	Peninsular Malaysia, Pahang, Fraser’s Hill
FRI 52894	*Codonoboea fasciata*	KEP	Peninsular Malaysia, Pahang, Taman Negara, Kuala Teku
FRI 64971	*Codonoboea floribunda*	KEP	Peninsular Malaysia, Terengganu, Sg. Nipah FR, Jeram Tanduk
FRI 65656	*Codonoboea glabrata*	KEP	Peninsular Malaysia, Johor, G. Panti
FRI 64892	*Codonoboea heterophylla*	KEP	Peninsular Malaysia, Pahang, Taman Negara, Anak Sg. Melantai
FRI 64991	*Codonoboea leiophylla*	KEP	Peninsular Malaysia, Terengganu, Ulu Setiu FR
FRI 56552	*Codonoboea longipes*	KEP	Peninsular Malaysia, Johor, G. Ledang
FRI 57513	*Codonoboea malayana*	KEP	Peninsular Malaysia, Pahang, Fraser’s Hill
FRI 56646	*Codonoboea oreophila*	KEP	Peninsular Malaysia, Kelantan, G. Stong
FRI 65096	*Codonoboea platypus*	KEP	Peninsular Malaysia, Terengganu, Jerangau FR
FRI 55963	*Codonoboea pumila*	KEP	Peninsular Malaysia, Pahang, Fraser’s Hill
RK 5435	*Codonoboea pumila*	KEP	Peninsular Malaysia, Pahang, Fraser’s Hill
FRI 64970	*Codonoboea puncticulata*	KEP	Peninsular Malaysia, Terengganu, Sg. Paka FR
FRI 64962	*Codonoboea puncticulata*	KEP	Peninsular Malaysia, Terengganu, Chemerong FR
SMTSU-110/110	*Codonoboea racemosa*	E	Indonesia, Sumatra
FRI 64849	*Codonoboea rubiginosa*	KEP	Peninsular Malaysia, Pahang, G. Tahan
FRI 64875	*Codonoboea salicina*	KEP	Peninsular Malaysia, Pahang, Taman Negara, Kuala Teku
FRI 64816	*Codonoboea salicina*	KEP	Peninsular Malaysia, Pahang, Taman Negara, Kem Kubang
FRI 64978	*Codonoboea salicinoides*	KEP	Peninsular Malaysia, Terengganu Bkt. Bauk,
FRI 65002	*Codonoboea tiumanica*	KEP	Peninsular Malaysia, Johor, P. Tinggi
FRI 56644	*Codonoboea* sp. nov. 1	KEP	Peninsular Malaysia, Kelantan, G. Stong
2008-1201	*Codonoboea* sp. nov. 2 (Chukai)	KBG	Peninsular Malaysia, Terengganu, Rasau-Kerteh-Ulu Chukai FR

Voucher number	**Species**	**Deposit in**	**Origin**
FRI 65123	*Codonoboea* sp. nov. 3 (Sg. Lembing)	KEP	Peninsular Malaysia, Pahang, Kuantan, Sg. Lembing
FRI 47221	*Codonoboea* sp. nov. 4 (Sg. Nipah) 00272	KEP	Peninsular Malaysia, Terengganu, Sg. Nipah FR
FRI 58126	*Codonoboea* sp. nov. 5 (Tembat)	KEP	Peninsular Malaysia, Terengganu, Tembat FR
Cult. HBV GS-96-02	*Microchirita caliginosa*	WU	Peninsular Malaysia
FRI 64447	*Microchirita involucrata*	KEP	Peninsular Malaysia, Kelantan, G. Reng
FRI 64388	*Microchirita viola*	KEP	Peninsular Malaysia, Kedah, P. Langkawi
FRI 64441	*Microchirita* sp. nov.	KEP	Peninsular Malaysia, Kelantan, Gua Setir

Appendix B

Data matrix of character state score.

No.	Character	Character states	Score
1	Geographic region	China	1
		Palawan, the Philippines	2
		West Coast Peninsular Malaysia	3
		East Coast Peninsular Malaysia	4
		Borneo	5
		Sumatera, Indonesia	6
2	Section	*Heteroboea*	1
		Venusta	2
		Didymanthus	3
		Salicini	4
		Boeopsis	5
		unknown	6
		outgroup	7
3	Habit	rosette	1
		erect	2
		creeping	3
4	Leaves arrangement	opposite	1
		spiral/ alternate	2
5	Lamina length-width ratio	< 2.9	1
		3–3.9	2
		> 4	3
6	Lamina margin	entire	1
		dentate	2
		serrate	3
		serrulate	4
		crenate	5
		crenulate	6
7	Lamina indumentum above	hairy	1
		glabrous	2
8	Number of flower per inflorescence	1	1
		2	2
		3–4	3
		> 5	4
9	Presence of glandular hair on peduncle & pedicel	yes	1
		no	2

No.	Character	Character states	Score
10	Corolla type	narrow tubular	1
		Codonoboea crenata-type	2
		small campanulate	3
		pouch-type	4
		campanulate2	5
		small tubular type	6
		Codonoboea tiumanica-type	7
		Codonoboea puncticulata-type	8
		tubular type	9
		Codonoboea densifolia-type	10
11	Corolla tube length-width ratio	0.5–1.2	1
		1.3–2	2
		> 2.1	3
12	Corolla bilabiate	yes	1
		no	2
13	Presence of glandular hair on corolla	yes	1
		no	2
14	Corolla lobe apex shape	rounded	1
		pointed	2
15	Upper pairs of corolla lobes reflexed?	yes	1
		no	2
16	Upper pairs of corolla lobe concolor with other lobes	yes	1
		no	2
17	Filament shape	stout, short, straight	1
		slender, straight	2
		curved inwards	3
		kneed	4
18	Anther shape	reniform	1
		subcordate	2
19	Presence of nectar guides	yes	1
		no	2
20	Nectary	absent	1
		< 0.7 mm tall	2
		> 1 mm tall	3
21	Presence of glandular hair on pistil	yes	1
		no	2
22	Stigma shape	bi-lobed	1
		discoid	2
		globular	3

Appendix B

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
B. hygrometrica	1	7	1	1	1	6	1	1	2	5	1	2	1	1	1	1	1	1	2	1	2	2
B. philippensis	1	7	1	1	2	4	1	4	1	5	1	2	2	2	1	1	1	1	2	2	1	2
M. involucrata	3	7	2	1	1	4	1	4	1	9	2	1	1	1	2	1	2	1	1	3	2	1
M. viola	3	7	2	1	1	3	1	4	1	9	2	1	1	1	2	1	2	1	1	3	2	1
M. caliginosa	4	7	2	1	1	4	1	4	1	9	3	1	1	1	2	1	2	1	1	3	1	1
M. sp. nov.	4	7	2	1	1	4	1	4	1	9	2	1	1	1	2	1	2	1	1	3	-	1
C. albomarginata	3	3	2	1	2	1	1	3	2	9	3	1	1	1	2	1	2	1	1	3	1	2
C. anthonyi	4	5	2	1	2	1	2	3	2	5	1	2	2	1	1	2	1	2	2	1	1	3
C. bakoensis	5	6	1	1	2	1	1	3	2	2	3	1	1	1	1	1	2	1	1	2	1	2
C. bombycina	3	1	2	2	2	4	1	1	1	9	3	1	1	1	2	1	2	1	1	3	1	2
C. calcarea	4	2	2	1	2	3	1	3	2	2	3	1	1	1	1	1	2	1	1	3	-	2
C. codonion	4	5	2	1	1	5	2	4	2	3	1	2	2	2	1	2	1	1	2	2	1	3
C. corrugata	2	6	2	1	2	3	1	3	2	2	3	1	1	1	-	-	2	1	1	3	-	2
C. crenata	5	6	1	1	2	3	1	4	2	2	3	1	1	1	1	1	2	1	1	3	2	2
C. crinita 1	3	1	2	2	2	4	1	1	1	9	3	1	1	1	2	1	2	1	1	3	1	2
C. crinita 2	3	1	2	2	2	4	1	1	1	9	3	1	1	1	2	1	2	1	1	3	1	2
C. curtisii	3	1	2	2	2	4	1	1	1	9	3	1	1	1	2	1	2	1	1	3	1	2
C. densifolia	3	4	1	1	3	1	2	2	1	10	2	2	1	1	1	2	1	2	1	1	1	2
C. fasciata	3	1	2	2	2	4	1	1	1	9	3	1	1	1	2	1	2	1	1	3	1	2
C. floribunda	4	5	1	1	1	5	2	4	2	5	1	2	2	1	1	2	1	2	2	2	1	3
C. heterophylla	4	5	1	1	1	5	2	4	2	3	1	2	2	2	1	2	1	1	2	2	2	3
C. glabrata	4	3	2	1	2	1	2	3	1	2	3	1	1	1	1	1	2	1	1	3	1	2
C. leiophylla	4	5	1	1	2	1	2	1	2	5	1	2	2	1	1	1	1	2	2	2	2	3
C. longipes	3	6	1	1	2	2	2	4	1	1	3	1	1	1	1	1	2	1	1	3	2	2
C. malayana 1	3	3	2	1	2	1	1	1	1	9	3	1	1	1	2	1	2	1	1	3	1	2

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
C. malayana 2	3	3	2	1	2	1	1	1	1	9	3	1	1	1	2	1	2	1	1	3	1	2
C. oreophila	3	5	1	1	2	6	1	1	2	9	3	1	2	1	1	2	2	1	1	3	2	2
C. platypus	4	1	2	2	2	4	1	1	1	9	3	1	1	1	2	1	2	1	1	3	1	2
C. pumila 1	4	5	1	1	1	1	1	2	2	4	1	2	2	1	1	1	1	1	2	2	1	3
C. pumila 2	3	5	1	1	1	1	1	2	2	4	1	2	2	1	1	1	1	1	2	2	1	3
C. puncticulata 1	3	5	1	1	1	6	1	1	2	8	1	2	2	1	1	2	4	1	2	2	2	3
C. puncticulata 2	4	5	3	1	1	6	1	1	2	8	1	2	2	1	1	2	4	1	2	2	2	3
C. racemosa	4	6	1	1	2	5	2	3	2	9	3	2	2	1	-	-	2	1	-	3	-	2
C. rubiginosa	6	5	1	1	1	4	1	4	2	4	1	2	2	1	1	1	1	1	2	2	1	3
C. salicina 1	4	4	1	1	3	4	2	3	2	3	1	2	1	2	1	2	1	1	2	1	1	3
C. salicina 2	4	4	1	1	3	4	2	3	2	3	1	2	1	2	1	2	1	1	2	1	2	3
C. salicinoides	4	4	2	1	3	4	2	4	2	3	1	2	1	2	1	2	1	1	2	2	1	3
C. soldanella	4	5	1	1	2	5	-	3	-	4	1	2	-	-	-	-	-	-	-	-	-	-
C. tiumanica	3	4	2	1	1	4	1	1	2	7	1	2	2	1	1	1	3	1	2	3	2	3
C. yongii	4	5	1	1	1	2	1	4	2	4	1	2	2	1	1		2	1	2	3	1	3
C. sp. nov. 1	3	3	2	1	2	4	1	3	1	9	3	1	1	1	2	1	2	1	1	3	1	2
C. sp. nov. 2	4	1	1	2	3	3	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. sp. nov. 3	4	6	2	1	1	5	2	4	2	3	1	2	1	2	1	2	1	1	2	2	2	3
C. sp. nov. 4	4	6	2	1	1	5	2	3	2	3	1	2	-	2	1	2	1	1	2	2	2	3
C. sp. nov. 5	4	6	2	1	2	1	2	3	2	5	1	2	2	1	1	1	2	2	2	2	2	3

* *B.* = *Boea*; *C.* = *Codonoboea*; *M.* = *Microchirita*

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RESEARCH ARTICLE

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Codonoboea oreophila (*Gesneriaceae*), a new species from Peninsular Malaysia

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Key words

Codonoboea
Gesneriaceae
new species
Peninsular Malaysia

Abstract A new species of *Codonoboea* from Gunung Stong, Kelantan, Peninsular Malaysia, is described and illustrated.

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INTRODUCTION

A species of *Gesneriaceae* has been collected in Gunung Stong State Park by various collectors since 1924. It is found in montane forest on the highest peak, Gunung Stong (N5°20'19", E101°56'28"; alt. 1 434 m) and on other nearby peaks, such as Gunung Tera at 1 176 m. Kiew (1992) pointed out that it was a new species in *Didymocarpus* sect. *Boeopsis* (Ridley 1923) and suggested '*oreophila*' as the species epithet. However, in the absence of flowers, the species was not formally described. In July 2008, flowering plants were collected and several unique characters of the flowers confirmed its status as a species new to science and that it is different from the other species in the section *Boeopsis* by its long corolla tube and the presence of pale yellow nectar guides.

All species in *Didymocarpus* section *Boeopsis* have now been transferred to *Codonoboea* (Kiew & Lim 2011). Among *Codonoboea* species, *C. oreophila* Kiew ex C.L.Lim most resembles *C. pumila* (Ridl.) C.L.Lim and *C. rubiginosa* (Ridl.) C.L.Lim. All three have a rosette of thick succulent leaves that are densely silky hairy above, with leaf size ranging from 3–6 by 1.6–3 cm. However, it is distinct from these two species by having oblanceolate leaves sometimes with a cordate and unequal base, narrower bracts (to 0.3 mm wide), single flowers and a longer corolla with two nectar guides (Table 1) and is here described as a new species.

Codonoboea oreophila Kiew ex C.L.Lim, *sp. nov*. — Fig. 1

Diagnosis: *Codonoboea pumila* simillima, habitu foliorum indumento, sed inflorescentiis unifloris (1–)2-floris in *C. pumila*, 2–12-floris in *C. rubiginosa*) corollis longioribus angustioribusque c. 15.5–18.8 mm longis (usque ad 7 mm in *C. nana* et *C. rubiginosa*) differt. — Typus: *Lim et al. FRI 56646* (holo KEP; iso E, K, L, SING), Peninsular Malaysia, Kelantan, Gunung Stong State Park, Gunung Stong, 1 231 m alt., N5°20'25", E101°56'57", 26 July 2008.

Etymology. From its habitat, because it is only found in montane forest.

Rosette herb. *Indumentum* of uniseriate, multicellular (about 2–3(–5)-celled), very fine, translucent, eglandular hairs on young stem, petioles and upper lamina surface, more or less appressed near margin, on lower lamina surface more erect and longer on veins beneath; fine, dark purplish maroon on peduncle, pedicel and calyx; very fine, to 0.3 mm long on corolla outside, corolla lobes short ciliate. *Stem* branched, (2–3–)6.5–9(–11) cm long, 1.4–3.8(–7) mm thick, woody, base of stem often creeping, sometimes producing an elongated semi-woody side branch to 8.2 cm long, 1.7 mm thick, pale green in life. Flowering at c. 2.5 cm tall. Upper internodes crowded, lower internodes 5–9 mm long, sometimes to 2.5–3.5(–4.6) cm in the elongated side branch. *Leaves* decussate; sessile in young leaves, petioles to (0.5–)1.5–2.4(–3.2) cm long, succulent, broadly grooved above in mature leaves; lamina oblanceolate to oblong, 3–4.8(–6) by 1.6–2.2(–3.1) cm, in life dark green above, brownish to greyish green beneath, drying greyish to greenish brown above, paler beneath, succulent in life, drying thickly leathery; base rounded to broadly cuneate, sometimes cordate, often unequal, margin crenulate, teeth c. 6–8 per cm, teeth towards the apex often slightly overlapping the one behind, apex broadly obtuse to rounded; midrib grooved above, prominent beneath, lateral veins to 9–12 pairs, lower pairs almost parallel, upper pairs sharply arching to apex, obscure above, prominent beneath, intercostal veins inconspicuous. *Inflorescences* 1(–2) per axil, 1-flowered. Peduncle slender, (4.4–)5.8–6.6(–9) cm long, erect, with flower held above leaves, dark purplish maroon, apex bent and pointing downwards in bud, upon flowering becoming horizontal. Bract pairs opposite or subopposite, ligulate, c. 0.8–1.7 by 0.3 mm. Pedicel slender, (0.8–)1.2–1.5 cm long, concolourous with peduncle. *Flowers* held horizontally; calyx dark purplish maroon, free to base, lobes broadly oblong, apex acute, 1.5–2.4 by 0.8 mm, lower lobes slightly longer; corolla trumpet-shaped, to 19 mm long, c. 10 mm wide at mouth, pale lilac, darker on lower and lateral corolla lobes, with streaks of darker purple outside, tube white inside with 2 light yellowish nectar guides near mouth, tube to 10 mm long, 4 mm wide, narrower at base (c. 2 mm wide), corolla lobes 5, apex rounded, upper lobes c. 4 by 3 mm, reflexed, lateral lobes c. 5 by 6 mm, lower lobe c. 5 by 5 mm, lateral and lower lobes spreading from base; stamens with filaments white, filiform, c. 3 mm long, 0.2 mm wide at base, joined to corolla tube c. 4.1 mm from base, slightly bent at base, straight above, anthers white, reniform, c. 0.5 by 1.5 mm, connivent at apex; staminodes 2, to 0.7 mm long, often curled; nectary annular, c. 1 mm tall, lower side slightly taller, shallowly lobed; pistil to 12.5 mm long, not projecting beyond the corolla tube, ovary and style pinkish purple, stigma purple,

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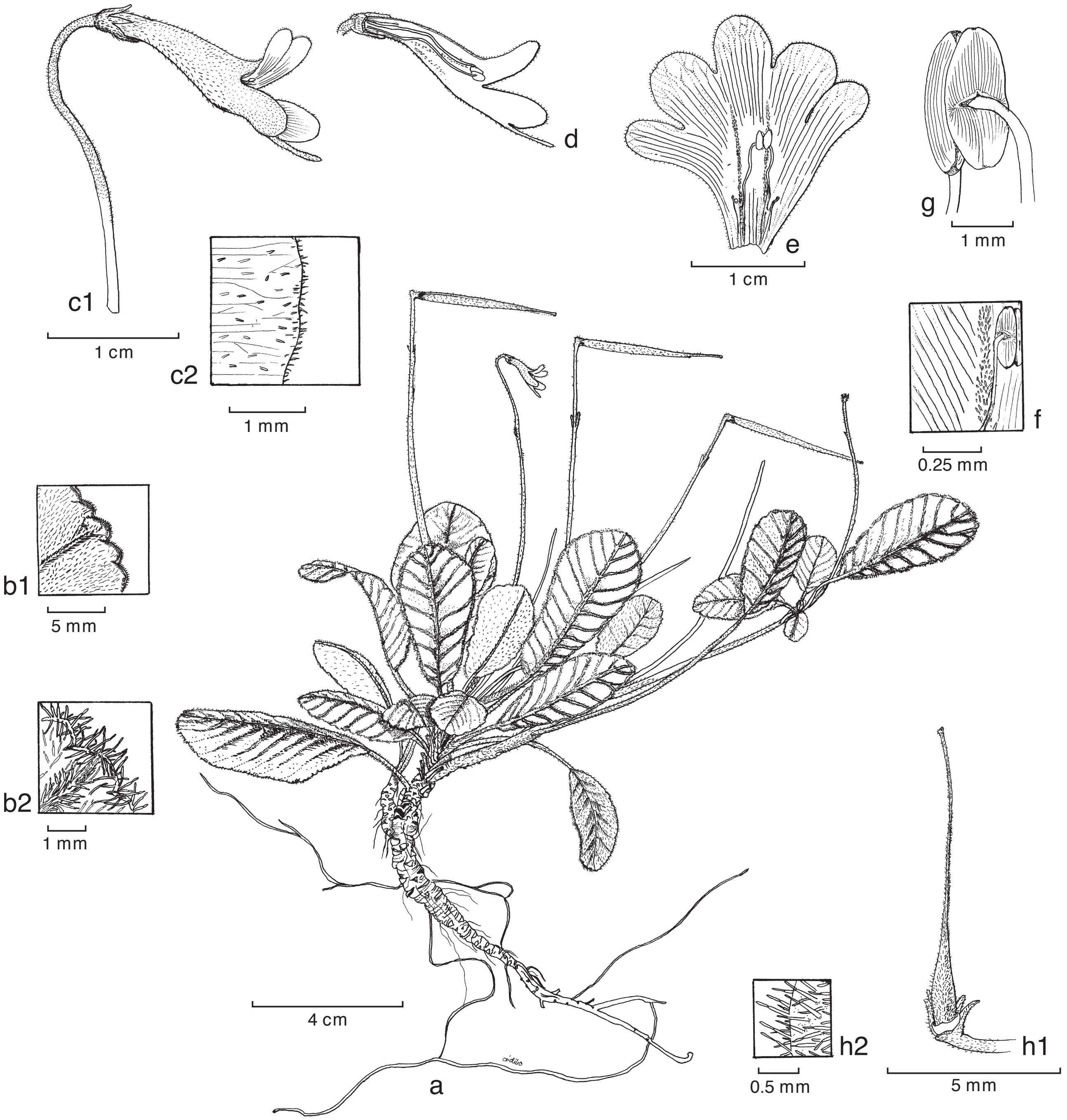

Fig. 1 *Codonoboea oreophila* Kiew ex. C.L.Lim. a. Habit; b1. lamina margin indumentum beneath; b2. close up of lamina margin indumentum beneath; c1. side view of flower; c2. indumentums of corolla lobe outside; d. side view of flower with part of corolla tube and pistil removed; e. corolla inside, showing nectar guide, stamens and staminoids; f. close-up of nectary guide below stamen; g. side view of anthers; h1. pistil with part of calyx removed, to reveal nectary at base; h2. close up of pistil indumentum (all *Lim et al. FRI 56646*, KEP).

Table 1 Diagnostic differences between *Codonoboea pumila*, *C. oreophila* and *C. rubiginosa*.

Character	*C. pumila*	*C. oreophila*	*C. rubiginosa*
Petiole length (mm)	(1–1.2)1.4–2.2(2.8–2.9)	(0.5–)1.5–2.4(–3.2)	1.5–1.7(9.9–19.5)
Lamina shape	broad ovate to broad obovate	oblanceolate to oblong	oblong to obovate
Lamina length (cm)	(3.3–3.9)4.1–4.5(–5.6)	3–4.8(–6)	(3.7–4.9)5.2–6.8(7.4–11.1)
Lamina width (cm)	(1.6–1.9)2–2.3(–3.6)	1.6–2.2(2.6–3.1)	1.5–2.4(–2.9)
Lamina base	broad attenuate	rounded to broadly cuneate, sometimes cordate, unequal	base broadly acute, rounded to cordate
Indumentum of upper leaf surface	appressed	appressed	erect
No. flowers per inflorescence	(1–)2	1	(2–6)8–12(–22)
Bract length (mm)	(0.8–1.6)2.5–2.8	0.8–1.7	(2.4–2.7)4.2–4.5
Bract width (mm)	0.5–1.1	0.3	1.1
Corolla length (mm)	c. 7	19–21	c. 7
Presence of nectar guides	–	+	–

pistil with short eglandular hairs, denser on the ovary, ovary ovoid, c. 4.5 by 1.3 mm, style 7.3 mm long, stigma discoid, c. 0.4 by 0.4 mm, in life glistening, apex dense papillose. *Fruits* narrowly cylindrical, slightly quadrangular in cross section, splitting on dorsal side, (2.5–)3–3.5 cm long, 1 mm thick, dark purplish maroon, style persistent to 0.5–0.7 mm long. *Seeds* ovoid, c. 0.3 by 0.2 mm.

Distribution — Endemic in Peninsular Malaysia, known only from Gunung Stong State Park, Kelantan.

Habitat — Mossy ground and mossy base of trees, and on earth banks on ridges in upper montane forest above 1 000 m altitude.

Other specimens examined. KELANTAN, Gunung Stong State Park – Gunung Stong, *Mohd Nur & Foxworthy SFN 12229* (SING), *Symington, FMS 37716* (SING), *Kiew, RK 2734* (KEP); ridge to Gunung Tera: *Chew FRI 53568* (K, KEP, SING); near Saji Swamp: *Yao FRI 55850* (KEP).

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Names and new combinations for Peninsular Malaysian species of *Codonoboea* Ridl. (Gesneriaceae)

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ABSTRACT. Five species are reinstated in *Codonoboea* Ridl. and new combinations are made for 74 species that occur in Peninsular Malaysia that were formerly included in *Henckelia* Spreng. *Codonoboea albina* (Ridl.) Kiew is reinstated at specific rank and var. *winkleri* (Ridl.) Kiew as a variety of *C. malayana* (Ridl.) Kiew. Lectotypes are designated where appropriate.

Keywords. *Codonoboea*, Gesneriaceae, nomenclature, Peninsular Malaysia, synonymy, taxonomy, typification

Introduction

Codonoboea Ridl. in its current wider sense is the largest genus of dicotyledonous herbs in Peninsular Malaysia with 79 named species. This compares with other large herb genera such as the 45 species in *Argostemma* Wall., Rubiaceae, 45 in *Sonerila* Roxb., Melastomataceae (Turner 1997) and 52 species in *Begonia* L., Begoniaceae (Kiew 2005). Botanical exploration of poorly known areas continues to discover new *Codonoboea* species, such as the two new species from Gunung Stong, Kelantan (Kiew 2009) and several others that await description. *Codonoboea* is confined to primary forest where it is ubiquitous from the lowlands to the highlands occurring on granite, sandstone and quartz derived soils or rocks but it is noticeably absent from limestone and aquatic habitats. It is diverse in regard to habit (although there are no climbing or epiphytic species), leaf and flower morphology. Its centre of diversity is Peninsular Malaysia, but species are also found in S Thailand, Sumatra, Singapore, Borneo, Palawan (the Philippines), Sulawesi and New Guinea (Weber & Burtt 1998).

Ridley (1923) in his *Flora of the Malay Peninsula* first described *Codonoboea* as a genus and included three species that in his opinion did not fit into any of the other genera. However, *Codonoboea* was ill-defined and not clearly distinct from the closest genus, *Paraboea* Ridl. Indeed the two diagnostic characters, namely peduncles adnate to the petiole (epiphyllous) and corolla lobes very short and tooth-like were present in only two of the three species. Burtt (1971) later transferred some *Paraboea* species to *Didymocarpus* Wall.

In 1990, Kiew reduced *Codonoboea* to a section within *Didymocarpus* and re-defined it to include four similar species with epiphyllous inflorescences. However, *Didymocarpus* itself underwent re-definition (Weber & Burtt 1983, 1998) that resulted in the exclusion of species with plagiotropic fruits that split on the adaxial side as opposed to the orthotropic ones of *Didymocarpus s. str*. that split both abaxially as well as adaxially. Based on morphological similarity, the excluded Peninsular Malaysian species together with *Loxocarpus* R.Br. species were placed in *Henckelia* Spreng., a small genus of 15 species from S India and Sri Lanka, a decision that resulted in 180 new combinations (Weber & Burtt 1998, Vitek et al. 2000).

Recent molecular analyses (Moeller et al. 2009) now show conclusively that the Indian and Sri Lankan *Henckelia* species are distinct from the Peninsular Malaysian species and among the Peninsular Malaysian species, *Loxocarpus* species are also distinct from both *Henckelia* and other morphologically similar genera. These non-*Henckelia* and non-*Loxocarpus* species are now accommodated in the genus *Codonoboea* that is the remaining validly published name for this group of species and the generic circumscription is enlarged to accommodate them. For the 79 Peninsular Malaysian species, this necessitates making new combinations for 74 of the species and these are provided below.

Materials and methods

In working toward the family Gesneriaceae account for the on-going Flora of Peninsular Malaysia project, the Peninsular Malaysian taxa have been re-examined through extensive fieldwork, examination of herbarium specimens including types, and the literature. New combinations in *Codonoboea* are made for accepted names together with references (including recent literature), synonyms and types. Lectotypes are designated where appropriate. Notes are provided where an explanation is needed. The species are arranged alphabetically. In due course, the new taxa will be published and, for all species, distribution in Peninsular Malaysia will be mapped and a conservation status for each taxon will be assessed and a key for identification provided.

In Peninsular Malaysia, *Codonoboea* belongs to a group of genera that includes the seven in the key below, which provides the characters that distinguish between them.

Key to the *Codonoboea* group of genera in Peninsular Malaysia

Fertile stamens 4.
    Capsules very slender, becoming ribbed and scarcely splitting ...... ***Didissandra****
    Capsules thick, smooth and hard, splitting completely on the adaxial side .... ***Ridleyandra***
Fertile stamens 2.
    Capsules orthotropic, splitting adaxially and abaxially.
        Stigma distinctly bilobed. (Always on limestone.)
            Rosette herbs, inflorescences scapiform, calyx tubular .... ***Damrongia***
            Caulescent herbs, inflorescences often epiphyllous, calyx divided to base .... ***Microchirita***
        Stigma peltate or rounded (not bilobed). (Never on limestone.) .... ***Didymocarpus***
    Capsules plagiotropic, splitting only adaxially.
        Capsules slender, cylindric, 1–5 cm long .... ***Codonoboea***
        Capsules short and distinctly thicker at base, 0.4–0.9 cm long ....

.... ***Loxocarpus***

*in Borneo, some *Didissandra* species have 2 fertile stamens.

Codonoboea **Ridl.**
Fl. Malay Pen. 2 (1923) 533. LECTOTYPE: *Codonoboea leucocodon* (Ridl.) Ridl. (Ivanina (1967) Gesneriaceae, the Carpological Review). **Synonyms**: *Didymocarpus pro parte* Ridl. *ibid* 506. – *Didymocarpus* sect. *Codonoboea* (Ridl.) Kiew, Blumea 35 (1990) 171. – *Paraboea pro parte* Ridl. *ibid* 527. – *Henckelia* Spreng. *pro parte* Weber & Burtt, Beitr. Biol. Pflanzen 70 (1998) 316–325; Weber *in* Kubitzki, Fam. Gen. Vasc. Pl. 7 (2004) 146.

Perennial herbs with continuous growth. ***Stems*** usually woody, erect and either caulescent with an unbranched or branched stem to c. 50 cm tall or short and forming a rosette, or creeping. ***Leaves*** usually opposite, sometimes alternate to spiral, sessile or petiolate. ***Inflorescences*** axillary, with 1 or several per axil, sometimes epiphyllous; pedunculate pair-flowered cymes with 3–4 flowers or reduced to a single flower or branched, paniculate and many-flowered; bracteoles usually small, sometimes absent or large and conspicuous. ***Flowers*** 5-merous, with a small calyx divided almost to base; corolla tubular with 5 lobes, the lower 3 lobes often longer, large and trumpet-shaped to narrowly tubular to campanulate to short-tubed and flat-faced; tube often pale purple, cream-coloured or white with concolourous lobes or with lobes deeply coloured and contrasting, less commonly red or yellow; frequently with a pair of yellow or orange-brown nectar guides, rarely with additional stripes or spots; stamens 2, filaments long or short with the anthers positioned in the mouth of the corolla, anthers coherent, connectives often with a tooth-like appendage; nectary forming a deep or shallow ring, sometimes with a lobed rim or short on the adaxial side or it does not surround the ovary base and is tongue-like or is lacking; ovary cylindric, tapering into the style, stigma either peltate or rounded (but never bilobed or lamellate). ***Capsules*** plagiotropic, splitting adaxially, long, cylindric, 1–5 cm long, usually slender, rarely curved and slightly thicker towards the base.

1. ***Codonoboea alba*** (Ridl.) C.L.Lim, ***comb. nov.***
   Basionym: *Didymocarpus albus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 41, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 754, Fl. Malay Pen. 2 (1923) 517. **Synonym**: *Henckelia alba* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 338. TYPE: *Curtis 3299*, Peninsular Malaysia, Perak, Gunung Bujang Melaka [Bujong Malacca], Aug 1898 (lectotype SING, here designated, isolectotype K).

   Codonoboea alba var. ***major*** (Ridl.) C.L.Lim, ***comb. nov.***
   Basionym: *Didymocarpus albus* var. *major* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 41, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. (1908) 754, Fl. Malay Pen. 2 (1923) 517. TYPE: *Wray 3905*, Peninsular Malaysia, Perak, Gunung Bubu, Mar 1890 (holotype SING).

   Note: Vitek et al. (2000) listed this taxon as ‘var. uncertain’. Examination of the type specimen shows that it belongs to *C. alba* but that the differences in habit and internodes length justify its status as a variety. Wray's collection number was erroneously cited as 3209 in Ridley (1908).

2. ***Codonoboea albina*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus albinus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 37, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 751, Fl. Malay Pen. 2 (1923) 512; Henderson, Malay. Wild Flowers Dicot. (1959) 346; Stone, Fed. Mus. J. 26 (1981) 99. TYPE: *Wray* (*King's Coll. 8070*), Peninsular Malaysia, Perak, Gunung Batu Putih, Aug 1886 (holotype SING).

Note: Weber & Burtt (1998), followed by Vitek et al. (2000), were in error in considering this species as synonymous with *Codonoboea hispida* (Ridl.) Kiew because it is clearly distinct in its longer petiole and larger lamina with a distinctly serrulate margin, its paniculate inflorescence with about 7 flowers and its smaller flower with purple spots. It is therefore reinstated here as a distinct species.

3. ***Codonoboea albomarginata*** (Hemsl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus albomarginatus* Hemsl., J. Bot. 25 (1887) 204; Ridley, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 39, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 752, Fl. Malay Pen. 2 (1923) 515; Henderson, Malay. Wild Flowers Dicot. (1959) 347. **Synonym**: *Henckelia albomarginata* (Hemsl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 338. TYPE: *Wray 65*, Peninsular Malaysia, Perak, Waterfall Hill, Jan 1884 (lectotype K, here designated, isotype SING).

4. ***Codonoboea alternans*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus alternans* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 37, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 751, Fl. Malay Pen. 2 (1923) 513. **Synonym**: *Henckelia alternans* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 338. TYPE: *Curtis 3133*, Peninsular Malaysia, Perak, Gunung Bujang Melaka [Bujong Malacca], Dec 1895 (lectotype SING, here designated, isolectotype K).

Note: Among the syntypes, this specimen is selected because it is deposited in more than one herbarium.

5. ***Codonoboea anthonyi*** (Kiew) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus anthonyi* Kiew, Gard. Bull. Sing. 44 (1992) 24. **Synonym**: *Henckelia anthonyi* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 339. TYPE: *Kiew RK 2700*, Peninsular Malaysia, Terengganu, Ulu Besut (holotype KEP, isotypes K, SING).

6. ***Codonoboea ascendens*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus ascendens* Ridl., J. Linn. Soc. 32 (1896) 512, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 45, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 756, Fl. Malay Pen. 2 (1923) 517. **Synonym**: *Henckelia ascendens* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 339. TYPE: *Haviland s.n.*, Peninsular Malaysia, Perak, Tapah [Tapa], 1894 (lectotype SING, here designated; isolectotype BM).

7. ***Codonoboea atrosanguinea*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus atrosanguineus* Ridl., Trans. Linn. Soc, ser. 2, Bot. 3 (1893) 328, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 47, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 758, Fl. Malay Pen. 2 (1923) 518; Kiew, Gard. Bull. Sing. 42 (1989) 49. **Synonym**: *Henckelia atrosanguinea* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 340. TYPE (lecto Kiew, 1989): *Ridley s.n.*, Peninsular Malaysia, Pahang, Sungai Tahan (lectotype SING).

8. ***Codonoboea bombycina*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus bombycinus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 48, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 759, Fl. Malay Pen. 2 (1923) 518. **Synonym**: *Henckelia bombycina* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 340. TYPE: *King's Coll. 10587*, Peninsular Malaysia, Perak, Ulu Bubong, Jul 1886 (lectotype SING, here designated).

9. ***Codonoboea breviflora*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didissandra breviflora* Ridl., Bull. Misc. Inform. Kew 1926 (1926) 474. **Synonyms**: *Didymocarpus breviflorus* (Ridl.) A.Weber & Kiew, Gard. Bull. Sing. 41 (1988) 7, fig. 4d–f & 5a–b. – *Henckelia breviflora* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 340. TYPE: *Hume 8437*, Peninsular Malaysia, Selangor, Ulu Gombak, 23 Sep 1921 (holotype SING).

10. ***Codonoboea caelestis*** Ridl.
Bull. Misc. Inform. Kew 1929 (1929) 259. **Synonyms**: *Didymocarpus caelestis* (Ridl.) Kiew, Blumea 35 (1990) 175. *Henckelia caelestis* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 341. TYPE (lecto Kiew, 1990): *Henderson 19683*, Peninsular Malaysia, Kelantan, Sungai Keteh at Gua Ninik (lectotype K, isolectotypes CGE, SING).

11. ***Codonoboea calcarea*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus calcareus* Ridl., Bull. Misc. Inform. Kew 1929 (1929) 258; Kiew, Malay. Nat. J. 48 (1995) 204. **Synonym**: *Henckelia calcarea* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 341. TYPE (lecto Kiew, 1995): *Nur & Foxworthy SFN 12192*, Peninsular Malaysia, Kelantan, Gunung Stong [Gunong Sitong], 6 Mar 1924 (lectotype K; isolectotype SING).

12. ***Codonoboea castaneifolia*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus castaneifolius* Ridl., J. Straits Branch Roy. Asiat. Soc. 86 (1922) 302, Fl. Malay Pen. 2 (1923) 514; Kiew, Malay. Nat. J. 48 (1995) 205. **Synonym**: *Henckelia castaneifolia* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 341. TYPE: *Yapp 438*, Peninsular Malaysia, Perak, Gunung Inas (lectotype K, here designated; isolectotype CBE).

13. ***Codonoboea codonion*** (Kiew) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus codonion* Kiew, Gard. Bull. Sing. 42 (1989) 49. **Synonym**: *Henckelia codonion* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 342. TYPE: *Kiew B.H. RK 1204*, Peninsular Malaysia, Pahang, Kuala Kenyam, 30 Sep 1982 (holotype KEP, isotype SING).

14. ***Codonoboea corneri*** (Kiew) Kiew, ***comb. nov.***
Basionym: *Didymocarpus corneri* Kiew, Blumea 35 (1990) 172, figs. 2 & 4. **Synonym**: *Henckelia corneri* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 342. TYPE: *Kiew RK 2655*, Peninsular Malaysia, Terengganu, W of Chukai [Chukei], close to Sungai Nipah [Sg. Nipa], 5 May 1988 (holotype L, isotypes K, KEP, SING).

15. ***Codonoboea craspedodroma*** **(**Kiew) Kiew, ***comb. nov.***
Basionym: *Didymocarpus craspedodromus* Kiew, Malayan Nat. J. 41 (1987) 213. **Synonym**: *Henckelia craspedodroma* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 342. TYPE: *Kiew RK 1757*, Peninsular Malaysia, Johor, Sungai Jasin (holotype KEP).

16. ***Codonoboea crinita*** (Jack) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus crinitus* Jack, Malayan Misc. 1, 2 (1820) 1, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 49, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 759, Fl. Malay Pen. 2 (1923) 519, fig. 124; Henderson, Malay. Wild Flowers Dicot. (1959) 348, fig. 325. **Synonym**: *Henckelia crinita* (Jack) Spreng., Syst. veg., ed. 16; 4, 2 (1827) 13. TYPE: *Jack s.n.*, Peninsular Malaysia, Pulau Pinang [Penang] (holotype E).

Codonoboea crinita var. ***elongata*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus crinitus* Jack var. *elongatus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 50, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 760, Fl. Malay Pen. 2 (1923) 520. TYPE: *Curtis 3781*, Peninsular Malaysia, Perak, Tapah (specimen not located).

Note: Codonoboea crinita is one of the most variable species in Peninsular Malaysia and a detailed study is required to understand the variation within this species and whether sub-specific taxa can be recognised.

17. ***Codonoboea crocea*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus croceus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 44, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 756, Fl. Malay Pen. 2 (1923) 516. **Synonym**: *Henckelia crocea* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 343. TYPE: *Ridley 9776*, Peninsular Malaysia, Perak, Gunung Keledang, on banks, Aug 1890 (lectotype SING, here designated).

Note: The type is selected because it includes both flowering and fruiting material and is the earlier collection by Ridley himself.

18. ***Codonoboea curtisii*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus crinitus* var. *curtisii* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 49, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 759. **Synonyms**: *Didymocarpus curtisii* (Ridl.) Ridl., Fl. Malay Pen. 2 (1923) 520. – *Henckelia curtisii* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 343. TYPE: *Curtis s.n.*, Peninsular Malaysia, Selangor, above the Gap, Gunung Semangkok

[Gunong Semangko Pass], May 1902 (lectotype SING, here designated).

Note: Vitek et al. (2000) draw attention to the citation of the basionym by Ridley (1923) as ‘J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74: 759 (1908)’ as erroneous.

19. ***Codonoboea davisonii*** (Kiew) Kiew, ***comb. nov.***
Basionym: *Didymocarpus davisonii* Kiew, Malayan Nat. J. 43 (1990) 242. **Synonym**: *Henckelia davisonii* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 343. TYPE: *Kiew RK 2834*, Peninsular Malaysia, Pahang, Gunung Lesong, 31 Oct 1989 (holotype KEP, isotype SING).

20. ***Codonoboea dawnii*** **(**Kiew) Kiew, ***comb. nov.***
Basionym: *Didymocarpus dawnii* Kiew, Malayan Nat. J. 48 (1995) 201. **Synonym**: *Henckelia dawnii* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 343. TYPE: *Davison D 6*, Peninsular Malaysia, Perak, N of E-W Highway, 3 Mar 1995 (holotype KEP).

21. ***Codonoboea densifolia*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus densifolius* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 51, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 761, Fl. Malay Pen. 2 (1923) 521. **Synonyms**: *Paraboea densifolia* (Ridl.) M.R.Hend., Gard. Bull. Straits Settlem. 5 (1930) 79. – *Henckelia densifolia* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 343. TYPE: *Lake & Kelsall s.n.*, Peninsular Malaysia, Johor, Gunung Janing [Janeng] (holotype SING).
Heterotypic synonyms: *Paraboea caerulea* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 66, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 772, Fl. Malay Pen. 2 (1923) 529; *non Didymocarpus caeruleus* (R.Br.) Koord. – *Didymocarpus azureus* B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44. TYPE: *Rostado s.n*., Peninsular Malaysia, Terengganu, Bundi, 1904 (holotype SING).

Note: Ridley (1905) cited Kelsall as the collector in the protologue of *Didymocarpus densifolius*, but the specimen records Lake & Kelsall as the collectors.

22. ***Codonoboea doryphylla*** (B.L.Burtt) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus doryphyllus* B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 23 (1960) 99. **Synonyms**: *Didymocarpus lanceolatus* Ridl., J. Fed. Malay States Mus. 4 (1909) 50, Fl. Malay Pen. 2 (1923) 520, *nom. illeg. non* C.B.Clarke (1883). – *Henckelia doryphylla* (B.L.Burtt) A.Weber, Beitr. Biol. Pflanzen 70 (1998). TYPE: *Robinson & Kloss s.n.*, Peninsular Malaysia, way to Gunung Irau (?).

Note: A search in BM, CBE, E, K and SING failed to locate the type specimen, which was known from a single collection; nor are there other specimens annotated by Ridley. The status of this species at species level is dubious for Ridley (1923) himself drew attention to its close similarity to *C. fasciata*.

23. ***Codonoboea ericiflora*** (Ridl.) Ridl.
Fl. Malay Pen. 2 (1923) 533. **Basionym**: *Didymocarpus ericiflorus* Ridl., J. Fed. Malay States Mus. 6 (1915) 166; Kiew, Gard. Bull. Sing. 42 (1989) 51, Blumea 35 (1990) 173. **Synonym**: *Henckelia ericiflora* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 344. TYPE (lecto Kiew, 1989): *Ridley 16283*, Peninsular Malaysia, Pahang, Gunung Tahan, Wray's camp, Jul 1911 (lectotype K, isolectotype SING).

24. ***Codonoboea falcata*** (Kiew) Kiew, ***comb. nov.***
Basionym: *Didymocarpus falcatus* Kiew, Malayan Nat. J. 41 (1987) 218, fig. 3. **Synonym**: *Henckelia falcata* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 344. TYPE: *Kiew RK 1726*, Peninsular Malaysia, Johor, Gunung Janing Barat (holotype KEP).

25. ***Codonoboea fasciata*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus fasciatus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 50, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 760, Fl. Malay Pen. 2 (1923) 520; Kiew, Gard. Bull. Sing. 42 (1989) 52. **Synonym**: *Henckelia fasciata* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 344. TYPE (lecto Kiew, 1989): *Ridley 2169*, Peninsular Malaysia, Pahang, Sungai Tahan, 1891 (lectotype K, isolectotype SING).

26. ***Codonoboea flava*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus flavus* Ridl., J. Linn. Soc. 32 (1896) 507, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 34, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 749, Fl. Malay Pen. 2 (1923) 510; Henderson, Malay. Wild Flowers Dicot. (1959) 346. **Synonym**: *Henckelia flava* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70: 344 (1998). TYPE: *Ridley 2914*, Peninsular Malaysia, Perak Hills, 1891 (holotype BM).
Heterotypic synonyms: *Staurogyne serrulata* C.B.Clarke, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist.74 (1908) 642; Ridley, Fl. Malay Pen. 2 (1923) 563. SYNTYPES: *Wray 1599*, Peninsular Malaysia, Perak, Ulu Batang Padang (CAL); *Scortechini s.n.*, *sine loc*. (CAL).
Didymocarpus flavus Ridl. var. *purpurascens* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 34, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 749, ***syn. nov.*** TYPE: *Ridley 11901*, Peninsular Malaysia, Perak, Bukit Kapayung, Sungai Siput, Feb 1904 (lectotype K, here designated, isolectotype SING).

Notes: 1. *Staurogyne serrulata* was synonymised by Burtt, Notes Roy. Bot. Gard. Edinburgh 36 (1978) 151. We have not seen the Calcutta specimens so are in no position to choose a lectotype.
2. Ridley (1905) distinguished *Didymocarpus flavus* var. *purpurescens* by its purplish stem and broad leaves but examination of the type shows that its leaves are no broader (3.25–4.25 × 2.5–5 cm) than those of the typical variety (7.5–12.5 × 3.5–5 cm). In species of *Codonoboea*, the presence or absence of purple coloration of the stem and leaves often varies between populations of the same species so is not a good taxonomic character. For these reasons and the fact that it does not differ in other characters, this variety is reduced to synonymy.

27. ***Codonoboea flavescens*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus flavescens* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 35, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 749, Fl. Malay Pen. 2 (1923) 511. **Synonym**: *Henckelia flavescens* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 344. TYPE: *Ridley 7585*, Peninsular Malaysia, Selangor, Kuala Kubu (holotype SING).

28. ***Codonoboea flavobrunnea*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus flavobrunneus* Ridl., Trans. Linn. Soc, ser. 2, Bot. 3 (1893) 329, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 39, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 753, Fl. Malay Pen. 2 (1923) 515; Kiew, Gard. Bull. Sing. 42 (1989) 52. **Synonyms**: *Henckelia flavobrunnea* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 344. TYPE (lecto Kiew, 1989): *Ridley 2163*, Peninsular Malaysia, Pahang, Tahan Valley, Jul 1891 (lectotype K, isolectotypes BM, SING). **Heterotypic synonym**: *Didymocarpus flavobrunneus* Ridl. var. *montanus* Ridl., J. Fed. Mal. States Mus. 6 (1915) 167, Fl. Malay Pen. 2 (1923) 515; Kiew, Gard. Bull. Sing. 42 (1989) 52. TYPE (lecto Kiew, 1989): *Ridley 16284*, Peninsular Malaysia, Pahang, Gunung Tahan, Wray's Camp, Jul 1911 (lectotype K, isolectotype SING).

29. ***Codonoboea floribunda*** (M.R.Hend.) C.L.Lim, ***comb. nov.***
Basionym: *Paraboea floribunda* M.R.Hend., Gard. Bull. Sing. 7 (1933) 117. **Synonyms**: *Didymocarpus floribundus* (M.R.Hend.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44. – *Henckelia floribunda* (M.R.Hend.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 345. TYPE: *Corner 26022*, Peninsular Malaysia, Terengganu, Kemaman, Bukit Kajang, Sungai Nipah, Jun 1932 (holotype K).

30. ***Codonoboea geitleri*** (A.Weber) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus geitleri* A.Weber, Pl. Syst. Evol. 165 (1989) 95. **Synonym**: *Henckelia geitleri* (A.Weber) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 345. TYPE: *Weber & Anthonysamy 860824–3/1*, Peninsular Malaysia, Pahang, Kuantan, Sungai Pandan, 24 Aug 1986 (holotype WU, isotypes WU, KEP).

31. ***Codonoboea glabrata*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus glabratus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 38, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 751, Fl. Malay Pen. 2 (1923) 513. **Synonym**: *Henckelia glabrata* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 345. TYPE: *King's Coll. 209*, Peninsular Malaysia, Johor, Gunung Panti, Jun 1880 (lectotype SING, here designated; isolectotype K).

Note: The Singapore sheet is chosen as the lectotype because the K sheet is a portion of the Singapore one.

32. ***Codonoboea grandifolia*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Paraboea grandifolia* (Ridl.) Ridl., Fl. Malay Pen. 2 (1923) 531. **Synonyms**: *Didymocarpus grandifolius* Ridl., J. Linn. Soc. Bot. 38 (1908) 318 *non* *Didymocarpus grandifolius* (A.Dietr.) F.G.Dietr. (1834). – *Didymocarpus*

tahanicus B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 46; Kiew, Malay. Nat. J. 48 (1995) 205, Gard. Bull. Sing. 42 (1989). – *Henckelia tahanica* (B.L.Burtt) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 357. TYPE: *Wray & Robinson 5369*, Peninsular Malaysia, Pahang, Gunung Tahan (holotype BM *fide* Burtt (1971), isotype SING).

33. *Codonoboea heterophylla* (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus heterophyllus* Ridl., Trans. Linn. Soc, ser. 2, Bot. 3 (1893) 329, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 55, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 763, Fl. Malay Pen. 2 (1923) 522; Kiew, Gard. Bull. Sing. 42 (1989) 53. **Synonym**: *Henckelia heterophylla* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 346. TYPE: *Ridley 2170*, Peninsular Malaysia, Pahang, Sungai Tahan, 1891 (holotype SING).

34. *Codonoboea hirsuta* (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus hirsutus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 48, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 758, Fl. Malay Pen. 2 (1923) 520. **Synonym**: *Henckelia hirsuta* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 346. TYPE: *King's Coll. 715*, Peninsular Malaysia, Perak, Gopeng [Goping], Sep 1880 (lectotype SING, here designated).

Note: King's Coll. 715 is selected as the lectotype because of confusion with the numbering of *King's Coll. 2529* in Ridley (1905) and *2829* in Vitek et al. (2000), which has not been relocated to verify the correct number.

35. *Codonoboea hirta* (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus hirtus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 36, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 750, Fl. Malay Pen. 2 (1923) 512. **Synonyms**: *Henckelia hirta* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 346. – *Paraboea campanulata* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 65, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 771, Fl. Malay Pen. 2 (1923) 529. – *Didymocarpus campanulatus* (Ridl.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44, ***syn. nov.*** TYPE: *Curtis s.n.*, Peninsular Malaysia, Selangor, above the Gap, on the road to Simpang Mines, May 1902 (holotype SING).
Heterotypic synonym: *Chirita uniflora* Ridl., J. Straits Branch Roy. Asiat. Soc. 61 (1912) 34, Fl. Malay Pen. 2 (1923) 525. TYPE: *Ridley s.n.*, Peninsular Malaysia, Selangor, Simpang Mines Track, Apr 1911 (holotype K).

Notes: 1. Ridley (1905) originally described *Didymocarpus hirtus* from material without flowers but later (Ridley 1923) described the corolla as 'nearly 1 in. long', compared with *P. campanulata* that he described with corollas 'half an inch long'. Apart from corolla length, specimens of these two taxa share the same habit, leaf arrangement and morphology. Weber & Burtt (1998) are correct in suggesting that 'this is probably no more than an abnormal specimen of *Henckelia* with a very short corolla'. It is here reduced to synonymy.
2. Wood (1974) referred *Chirita uniflora* to *Didymocarpus* and Vitek et al. (2000)

based on Ridley's description suggested that it belonged to *Henckelia hirta.* Based on examination of the type, Rafidah (2010) confirmed that *Chirita uniflora* is a synonym of *Codonoboea hirta*.

36. ***Codonoboea hispida*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus hispidus* Ridl., J. Linn. Soc. 32 (1896) 507, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 750, Fl. Malay Pen. 2 (1923) 511; Henderson, Malay. Wild Flowers Dicot. (1959) 347. **Synonyms**: *Didymocarpus hispidulus* Ridl. (in error), J. Straits Branch Roy. Asiat. Soc. 44 (1905) 35. – *Henckelia hispida* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 346. TYPE: *Curtis 2037*, Peninsular Malaysia, Perak, Taiping [Thaiping] Hills, Gunung Hijau, Sep 1889 (holotype SING).
Heterotypic synonyms: *Didymocarpus hispidus* Ridl. var. *selangorensis* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 36 J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 750, Fl. Malay Pen. 2 (1923) 512; Stone, Fed. Mus. J. 26 (1981) 99, ***syn. nov.*** TYPE: *Curtis 3752*, Peninsular Malaysia, Selangor, Gunung Semangkok [Gunong Semangko], (holotype SING).
Didymocarpus albinellus Ridl., J. Fed. Malay States Mus. 4 (1909) 51, Fl. Malay Pen. 2 (1923) 512; Henderson, Malay. Wild Flowers Dicot. (1959) 346. TYPE: *Ridley 13679*, Peninsular Malaysia, Pahang, Gunung Beremban [Berumban], Nov 1908 (lectotype SING, here designated, isolectotype K).
Staurogyne macrantha C.B.Clarke, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 642; Ridley, Fl. Malay Pen. 2 (1923) 563. TYPE: *King's Coll. 2417*, Peninsular Malaysia, Perak, Larut (holotype CAL *n.v.*).

Notes: 1. *Didymocarpus hispidus* var. *selangorensis* is no more than a white-flowered form of the typical one that has purple stipes on the lower lobes. It is therefore here reduced to synonomy.
2. Weber & Burtt (1998) were correct in treating *Didymocarpus albinellus* as a synonym. It just represents smaller-leaved plants, perhaps the result of growing in more exposed conditions.
3. *Staurogyne macrantha* was synonymised by Burtt, Notes Roy. Bot. Gard. Edinburgh 36 (1978) 151.

37. ***Codonoboea holttumii*** (M.R.Hend.) C.L.Lim, ***comb. nov.***
Basionym: *Paraboea holttumii* M.R.Hend., Gard. Bull. Sing. 4 (1927) 54. **Synonyms**: *Didymocarpus holttumii* (M.R.Hend.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44. – *Henckelia holttumii* (M.R.Hend.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 346. TYPE: *Holttum 10685*, Peninsular Malaysia, Johor, Gunung Belumut, 25 May 1923 (lectotype SING, here designated).

Note: The SING specimen is selected because Henderson was carrying out research there. In addition, the specimen at K has not been relocated.

38. ***Codonoboea inaequalis*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus inaequalis* Ridl., J. Linn. Soc. 32 (1896) 506, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 41 J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist.

74 (1908) 753. **Synonym**: *Henckelia inaequalis* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 347. TYPE: *Curtis 2568*, Peninsular Malaysia, Kedah, Pulau Langkawi, Gunung Machinchang [Chinchang], Sep 1890 (holotype SING).

39. ***Codonoboea kelantanensis*** (Kiew) Kiew, ***comb. nov.***
Basionym: *Henckelia kelantanensis* Kiew, Gard. Bull. Sing. 61 (2009) 73. TYPE: *Chew et al. FRI 53518*, Peninsular Malaysia, Kelantan, Stong Tengah Forest Reserve, path to Camp Cobra, 8 Feb 2007 (holotype KEP, isotypes E, L).

40. ***Codonoboea johorica*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didissandra johorica* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 22, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 739, Fl. Malay Pen. 2 (1923) 502. **Synonym**: *Henckelia johorica* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 355. TYPE: *Ridley 4175*, Peninsular Malaysia, Johor, Gunung Panti (lectotype SING, here designated; isolectotype K).

Notes: Ridley was carrying out research in Singapore when he described this species. Therefore, the SING specimen is selected as lectotype.

41. ***Codonoboea lancifolia*** (M.R.Hend.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus lancifolius* M.R.Hend., Gard. Bull. Straits Settlem. 4 (1927) 52. **Synonym**: *Henckelia lancifolia* (M.R.Hend.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 348. TYPE: *Burkill & Haniff 16946*, Peninsular Malaysia, Pahang, gorge of the Sungai Tras near Raub, 12 Nov 1924 (holotype SING).

42. ***Codonoboea leiophylla*** (Kiew) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus leiophyllus* Kiew, Gard. Bull. Sing. 44 (1992) 28.
Synonym: *Henckelia leiophylla* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 348. TYPE: *Kiew RK 2265*, Peninsular Malaysia, Terengganu, Ulu Setiu [Setui] (holotype KEP, isotype SING).

43. ***Codonoboea leucantha*** **(**Kiew) Kiew, ***comb. nov.***
Basionym: *Didymocarpus leucanthus* Kiew, Gard. Bull. Sing. 44 (1992) 31.
Synonym: *Henckelia leucantha* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 348. TYPE: *Kiew RK 2767*, Peninsular Malaysia, Selangor, Ulu Ampang (holotype KEP, isotype SING).

44. ***Codonoboea leucocodon*** (Ridl.) Ridl.
Fl. Malay. Pen. 2 (1923) 533. **Basionym**: *Paraboea leucocodon* Ridl., J. Fed. Malay States Mus. 6 (1915) 167. **Synonyms**: *Didymocarpus leucocodon* (Ridl.) Kiew, Gard. Bull. Sing. 42 (1989) 53, Blumea 35 (1990) 175. – *Henckelia leucocodon* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 348. TYPE (lecto Kiew, 1989): *Ridley 16041*, Peninsular Malaysia, Pahang, Gunung Tahan, Jul 1911 (lectotype K, isolectotype SING).

45. ***Codonoboea lilacina*** (Ridl.) Ridl.
Fl. Malay Pen. 2 (1923) 534. **Basionym**: *Didymocarpus lilacinus* Ridl., Trans.

Linn. Soc, ser. 2, Bot. 3 (1893) 330, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 56, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 764; Kiew, Blumea 35 (1990) 174, Gard. Bull. Sing. 42 (1989) 54. **Synonym**: *Henckelia lilacina* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 348. TYPE (lecto Kiew, 1989): *Ridley 2165*, Peninsular Malaysia, Pahang, Tahan Valley, Jul 1911 (lectotype K, isolectotype SING).

46. *Codonoboea longipes* (C.B.Clarke) Kiew, ***comb. nov.***
Basionym: *Didymocarpus longipes* C.B.Clarke *in* A.DC. & C.DC., Monogr. Phan. 5, 1 (1883) 86; Ridley, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 40, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 753, Fl. Malay Pen. 2 (1923) 521. **Synonym**: *Henckelia longipes* (C.B.Clarke) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 349. TYPE: *Maingay 2723*, Peninsular Malaysia, Johor [Malacca in error], Gunung Ledang [Mt. Ophir], Aug 1867–68 (lectotype K, here designated, isolectotype L).

Notes: Among the syntypes, *Maingay 2723* is selected because it is a flowering specimen and the sheet includes a description of the dissected flower. Early collectors approached Gunung Ledang from Malacca town but in fact Gunung Ledang lies within the state of Johor.

47. *Codonoboea malayana* (Hook.f.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus malayanus* Hook.f., Gard. Chron. 20 (1896) 123 & fig. 24, Bot. Mag. (1897) *t.* 7526; Ridley, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 38, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 752, Fl. Malay Pen. 2 (1923) 514; Henderson, Malay. Wild Flowers Dicot. (1959) 347, fig. 324. **Synonym**: *Henckelia malayana* (Hook.f.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 349. TYPE: *Curtis s.n.*, Peninsular Malaysia, Pulau Pinang [Penang] (holotype K).
Heterotypic synonym: *Didymocarpus malayanus* Hook.f. var. *fasciatus* Ridl., Fl. Malay Pen. 2 (1923) 514, ***syn. nov.*** TYPE: *Robinson s.n.*, Peninsular Malaysia, Perak, Gunung Korbu [Kerbau], 16 Mar 1913 (lectotype K, here designated).

Notes: Among the three specimens in the type folder at K, *Robinson s.n.* is selected because it is annotated as var. *fasciata* in Ridley's hand and its leaves are conspicuously fasciate even in the dried state. However, whether the leaves have the broad pale grey band along the midrib varies between and within populations so cannot be used as a taxonomic character. In addition, the plate of *Didymocarpus malayanus* in Botanical Magazine shows the leaves to be clearly fasciate. *Codonoboea malayana* is a widespread and variable species so the distinction between a 'round-leaved form' of var. *fasciatus* versus the typical variety with leaves 'ovate blunt or rounded, … sometimes lanceolate acute' does not support it as a distinct taxon. For these reasons this variety is reduced to synonymy.

Codonoboea malayana (Hook.f.) Kiew var. ***winkleri*** (Ridl.) Kiew, ***comb. & stat. nov.***
Basionym: *Didymocarpus winkleri* Ridl., J. Straits Branch Roy. Asiat. Soc. 50 (1908) 123, Fl. Malay Pen. 2 (1923) 515; Lim et al., Malay Nat. J. 61 (2009)

178, fig. 3. TYPE: *Winkler 1791*, Peninsular Malaysia, Negeri Sembilan, Gunung Angsi, 2 Apr 1908 (lectotype SING, here designated, isolectotype BM).

Notes: Weber & Burtt (1998) followed by Vitek et al. (2000) reduced *Didymocarpus winkleri* to synonomy with *D. malayanus* without giving any reason for their decision. Apart from its pure white flowers, var. *winkleri* is distinct from var. *malayana* in its erect habit and floriferous inflorescences with about 10 flowers.

48. ***Codonoboea marginata*** (C.B.Clarke) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus marginatus* C.B.Clarke *in* A.DC & C. DC, Monogr. Phan. 5, 1 (1883) 96, Fl. Malay Pen. 2 (1923) 516. **Synonym**: *Henckelia marginata* (C.B.Clarke) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 349. TYPE: *Lobb 184*, Peninsular Malaysia, 'Malacca' (lectotype 'Luzon' K, here designated; isolectotype 'Malacca' K).
Heterotypic synonym: *Didymocarpus ophirensis* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 43, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 755. TYPE: *Ridley 3185*, Peninsular Malaysia, Johor [Malacca] lower part of Gunung Ledang [Mount Ophir] (holotype SING).

Notes: 1. There are two sheets of *Lobb 184*, one annotated 'Malacca', the other 'Luzon', which is crossed out and replaced by 'Malacca'. No doubt both were collected in the Malacca area, probably from Gunung Ledang (Mt. Ophir), which is actually in Johor. This 'Luzon'specimen is selected as the lectotype because it has both flowers and fruits (the other specimen has only fruits).
2. It is likely that when Ridley was working on his Flora at Kew, he had the opportunity to examine the Lobb specimens of *Didymocarpus marginatus* because in Ridley (1923) he treated his *D. ophirensis* as a synonym.

49. ***Codonoboea miniata*** (Kiew) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus miniatus* Kiew, Novon 5 (1995) 40. **Synonym**: *Henckelia miniatus* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 350. TYPE: *Kiew RK 3792*, Peninsular Malaysia, Terengganu, Bukit Bauk (holotype KEP, isotypes L, SING).

50. ***Codonoboea modesta*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus modestus* Ridl., J. Fed. Malay States Mus. 6 (1915) 53, Fl. Malay Pen. 2 (1923) 513. **Synonym**: *Henckelia modesta* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 350. TYPE: *Dyak Coll. s.n.*, Peninsular Malaysia, Gunung Korbu [Gunong Kerbau], 1913 (holotype K).

51. ***Codonoboea nitida*** (Kiew & A.Weber) Kiew, ***comb. nov.***
Basionym: *Didymocarpus nitidus* Kiew & A.Weber, Gard. Bull. Sing. 41 (1988) 4, fig. 3 & 4a–c. **Synonym**: *Henckelia nitida* (Kiew & A.Weber) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 351. TYPE: *Weber & Anthonysamy 840711–1/1*, Peninsular Malaysia, Selangor, Gunung Bunga Buah, E of summit, Jul 1984 (holotype WU, isotypes E, K, KEP, KLU, L, WU).

52. ***Codonoboea nivea*** Kiew
Malayan Nat. J. 41 (1987) 210. **Synonyms**: *Didymocarpus niveus* (Kiew) Kiew, Blumea 35 (1990) 174. – *Henckelia nivea* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 351. TYPE: *Kiew B.H. KBH 86–33*, Peninsular Malaysia, Pahang, Ulu Kinchin, Sungai Damong Kechil (holotype KEP, isotypes K, L, SING).

53. ***Codonoboea parviflora*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus parviflorus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 33, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 748, Fl. Malay Pen. 2 (1923) 510. **Synonym**: *Henckelia parviflora* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 352. TYPE: *Ridley 11970*, Peninsular Malaysia, Negeri Sembilan, Gunung Angsi, 1914 (lectotype SING, here designated; isolectotype K).

54. ***Codonoboea pauziana*** (Kiew) Kiew, ***comb. nov.***
Basionym: *Henckelia pauziana* Kiew, Gard. Bull. Sing. 61, 1 (2009) 74, fig. 1. TYPE: *Chew et al. FRI 53513*, Peninsular Malaysia, Kelantan, Stong Tengah Forest Reserve, Batu Hampar to Cobra Camp, 8 Feb 2007 (holotype KEP [flower], isotypes KEP [fruits], K, L, SAN, SING).

55. ***Codonoboea pectinata*** (Oliv.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus pectinatus* C.B.Clarke ex Oliv. in Hook., Icon. Pl. 23 (1892) *t*. 2246; Ridley, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 53, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1909) 762, Fl. Malay Pen. 2 (1923) 521. **Synonym**: *Henckelia pectinata* (Oliv.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 352. TYPE: *King's Coll. 10711*, Peninsular Malaysia, Perak, Aug 1886 (lectotype K, here designated, isolectotype SING).

Notes: The type collection is recorded from limestone rocks. Unfortunately, the locality of this Perak plant is not recorded, so it is not possible to confirm whether this is correct. So far in Peninsular Malaysia no *Codonoboea* species is recorded from limestone and in Selangor *C. pectinata* grows on granite rocks. The Kew specimen is selected as the lectotype because the sheet includes a description of the species and a rough flower dissection.

56. ***Codonoboea platypus*** (C.B.Clarke) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus platypus* C.B.Clarke, in A.DC. & C.DC., Monogr. Phan. 5, 1 (1883) 94; Ridley, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 46, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 757, Fl. Malay Pen. 2 (1923) 517; Henderson, Malay. Wild Flowers Dicot. (1959) 348; Kiew, Malay Nat. J. 41 (1987) 220. **Synonym**: *Henckelia platypus* (C.B.Clarke) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 352. TYPE: *Griffith 3825*, Peninsular Malaysia, Melaka [Malacca] (lectotype K, here designated).

Notes: Griffith 3825 is chosen as the lectotype because among the syntypes it is the only specimen with both flowers and fruits and which shows both the upper and lower leaf surfaces.

57. ***Codonoboea polyanthoides*** (Kiew) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus polyanthoides* Kiew, Gard. Bull. Sing. 42 (1989) 56. **Synonym**: *Henckelia polyanthoides* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 352. TYPE: *Kiew RK 2480*, Peninsular Malaysia, Pahang, Sungai Teku, 29 Mar 1987 (holotype KEP).

58. ***Codonoboea primulina*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus primulinus* Ridl., J. Fed. Malay States Mus. 10 (1922) 250, Fl. Malay Pen. 2 (1923) 522; Kiew, Malay. Naturalist 37, 2 (1983) 6, fig. **Synonym**: *Henckelia primulina* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 352. TYPE: *Ridley s.n.*, Peninsular Malaysia, Selangor, Klang Gates, Bukit Lompat Bayan, 2 Jan 1921 (lectotype SING, here designated; isotype K).

59. ***Codonoboea pulchella*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus pulchellus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 44, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 755, Fl. Malay Pen. 2 (1923) 516. **Synonym**: *Henckelia pulchella* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 353. TYPE: *Machado H.B.S. 11629*, Peninsular Malaysia, Pahang, Kuala [Kwala] Lipis, May 1913 (lectotype SING, here designated; isotype K).

60. ***Codonoboea pumila*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus pumilus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 56, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 763, Fl. Malay Pen. 2 (1923) 523; Henderson, Malay. Wild Flowers Dicot. (1959) 349. **Synonym**: *Henckelia nana* A.Weber, Beitr. Biol. Pflanzen 70 (1998) 350. TYPE: *Burn-Murdoch s.n.*, Peninsular Malaysia, Pahang, Gunung Semangkok [Semangko Pass], Feb 1904 (lectotype SING, here designated).

Note: Weber in Weber & Burtt (1998) re-named this species *Henckelia nana* because another species was already named *H. pumila*. Since ‘pumila’ has not been used in *Codonoboea*, the original specific name is retained for this species.

61. ***Codonoboea puncticulata*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus puncticulatus* Ridl., J. Linn. Soc. 32 (1896) 510, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 55, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 763, Fl. Malay Pen. 2 (1923) 522; Kiew, Malay Nat. J. 41 (1987) 220. **Synonym**: *Henckelia puncticulata* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 353. TYPE: *Ridley s.n.*, Peninsular Malaysia, Johor, Gunung Panti, Dec 1892 (holotype SING, photo K).
Heterotypic synonym: *Didymocarpus perditus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 54, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 763, Fl. Malay Pen. 2 (1923) 522. TYPE: *Ridley s.n.*, Singapore, Selitar, 3 Nov 1889 (holotype SING).

Notes: Didymocarpus perditus was described from Singapore where Ridley (1905) discovered two plants in 1889. However, by 1905 he described the locality as destroyed by cultivation and thought the species probably extinct. Kiew (1987) showed that it is conspecific with *Codonoboea puncticulata* from Peninsular Malaysia. It has never been collected again from Singapore so is certainly extinct there.

62. ***Codonoboea pyroliflora*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus pyroliflorus* Ridl., Trans. Linn. Soc, sen 2, Bot. 3 (1893) 330; Kiew, Gard. Bull. Sing. 42 (1989) 57. **Synonyms**: *Paraboea pyroliflora* (Ridl.) Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 67, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 772, Fl. Malay Pen. 2 (1923) 529. – *Henckelia pyroliflora* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 353. TYPE (lecto Kiew 1989): *Ridley 2164*, Peninsular Malaysia, Pahang, Sungai Tahan, Jul 1891 (lectotype K, isolectotypes BM, SING).

63. ***Codonoboea quinquevulnera*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus quinquevulnerus* Ridl., Trans. Linn. Soc, ser 2, Bot. 3 (1893) 328, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 47, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 758, Fl. Malay Pen. 2 (1923) 518; Kiew, Gard. Bull. Sing. 42 (1989) 58. **Synonym**: *Henckelia quinquevulnera* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 353. TYPE (lecto Kiew, 1989): *Ridley 2153*, Peninsular Malaysia, Pahang, Sungai Tahan, Aug 1891 (lectotype K, isolectotype SING).

64. ***Codonoboea ramosa*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus ramosus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 34, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 749, Fl. Malay Pen. 2 (1923) 511. **Synonym**: *Henckelia ramosa* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 353. TYPE: *Wray 868*, Peninsular Malaysia, Perak, Gunung Batu Putih (holotype SING).

65. ***Codonoboea reptans*** (Jack) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus reptans* Jack, Malayan Misc. 1, 5 (1820) 3; Ridley, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 42, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 754, Fl. Malay Pen. 2 (1923) 515; Henderson, Malay. Wild Flowers Dicot. (1959) 346, fig. 323. **Synonym**: *Henckelia reptans* (Jack) Spreng., Syst. veg. ed. 16; 4, 2 (1827) 14. TYPE: *Wallich 1830*, Peninsular Malaysia, Pulau Pinang [Penang], 1830 (neotype K).

Notes: Codonoboea reptans is a very variable species with wide ecological amplitude from the lowlands to mountains. The neotype is selected because it was also collected from the type locality in Pulau Pinang.

Only var. *monticola* is distinct from other subspecific taxa of *C. reptans* by its much narrower leaves. Whether var. *modesta* and var. *violascens* are distinct from the typical variety needs more field observations of variation between and within populations.

Codonoboea reptans var. ***modesta*** **(**Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus reptans* var. *modestus* Ridl., Fl. Malay Pen. 2 (1923) 516. **Synonym**: *Didymocarpus modestus* Ridl., J. Straits Branch Roy. Asiat. Soc.

82 (1920) 186, *nom. illeg*., non *D. modestus* Redl. (1915). TYPE: *Ridley s.n.*, Peninsular Malaysia, Selangor, Ulu Gombak (lectotype K, here designated).

Note: Ridley's specimen is selected as lectotype because it includes a brief description and drawing of the flower.

Codonoboea reptans var. ***monticola*** **(**Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus reptans* var. *monticolus* Ridl., J. Linn. Soc. 32 (1896) 511, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 42, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 755, Fl. Malay Pen. 2 (1923) 516. **Synonym**: *Henckelia reptans* var. *monticola* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 354. TYPE: *Ridley 2913*, Peninsular Malaysia, Perak, Larut Hills, 1892 (lectotype BM, here designated).

Note: Among the specimens that Ridley cited, this specimen is selected as the lectotype because Ridley (1905) singled out the Larut Hills population as typical of this variety.

Codonoboea reptans var. ***violascens*** **(**Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus reptans* var. *violascens* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 43, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 755, Fl. Malay Pen. 2 (1923) 516. TYPE: *Ridley 7583*, Peninsular Malaysia, Selangor, Rawang, May 1891 (lectotype SING, here designated; isotype K).

66. ***Codonoboea ridleyana*** (B.L.Burtt) Kiew, ***comb. nov.***
Basionym: *Didymocarpus ridleyanus* B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 23 (1960) 99; Kiew, Gard. Bull. Sing. 42 (1989) 59. **Synonyms**: *Didymocarpus grandiflorus* Ridl., J. Fed. Malay States Mus. 6 (1915) 167, Fl. Malay Pen. 2 (1923) 523, *non Didymocarpus grandiflorus* (Wall.) A.Dietr. ex Steud. – *Henckelia ridleyana* A.Weber, Beitr. Biol. Pflanzen 70 (1998) 354. TYPE: *Ridley s.n.*, Peninsular Malaysia, Pahang, Gunung Tahan, in forest by the stream below Wray's camp, Jul 1911 (holotype K).

Notes. 1. For reasons that are not at all clear, Weber considered *Didymocarpus ridleyanus* B.L.Burtt as an illegitimate name and on transferring this species to *Henckelia* recorded it as *H. ridleyana* A.Weber *nom. nov*. However, *Didymocarpus grandiflorus* (Wall.) A.Dietr. ex Steud. is a legitimate name based on *Chirita grandiflora* Wall. Correctly, Weber's combination should have been *Henckelia ridleyana* (B.L.Burtt) A.Weber.
2. Although reported to be in K (Kiew 1989, Vitek et al. 2000), no specimens of this species could be located in the collection in a recent (2010) search. Nor are there any at SING.

67. ***Codonoboea robinsonii*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus robinsonii* Ridl., J. Linn. Soc, Bot. 38 (1908) 318, Fl. Malay Pen. 2 (1923) 513; Kiew, Gard. Bull. Sing. 42 (1989) 59. **Synonym**: *Henckelia robinsonii* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 354. TYPE

(lecto Kiew, 1989): *Wray & Robinson 5470*, Peninsular Malaysia, Pahang, Gunung Tahan, 5 Jul 1905 (lectotype K, isolectotypes BM, SING).

68. ***Codonoboea rubiginosa*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Paraboea rubiginosa* Ridl., J. Linn. Soc. 38 (1908) 319, Fl. Malay Pen. 2 (1923) 530. **Synonyms**: *Didymocarpus rubiginosus* (Ridl.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44; Kiew, Gard. Bull. Sing. 42 (1989) 59. – *Henckelia rubiginosa* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 355. TYPE (lecto Kiew, 1989): *Wray & Robinson 5390*, Peninsular Malaysia, Pahang, Gunung Tahan, 3 Jun 1905 (lectotype K, isolectotype SING).

69. ***Codonoboea rugosa*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus rugosus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 45, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 756, Fl. Malay Pen. 2 (1923) 517. **Synonym**: *Henckelia rugosa* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 355. TYPE: *Gimlette s.n.*, Peninsular Malaysia, Kelantan, Kuala [Kwala] Lebir (holotype SING).
Heterotypic synonym: *Didymocarpus lithophilus* Kiew, (Gard. Bull. Sing. 42 (1989) 54, *nomen*), Gard. Bull. Sing. 44 (1992) 38. TYPE: *Ridley 2152*, Peninsular Malaysia, Pahang, Sungai Tahan, Aug 1891 (holotype K, isotype SING).

70. ***Codonoboea salicina*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus salicinus* Ridl., Trans. Linn. Soc. ser 2, Bot., 3 (1893) 329, J. Straits Branch Roy. Asiat. Soc. 44 (1905) 52, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 761; Kiew, Gard. Bull. Sing. 42 (1989) 60. **Synonyms**: *Paraboea salicina* (Ridl.) Ridl., Fl. Malay Pen. 2 (1923) 530. – *Henckelia salicina* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 355. TYPE (lecto Kiew, 1989): *Ridley 2166*, Peninsular Malaysia, Pahang, Sungai Tahan, Aug 1891 (lectotype K, isolectotypes BM, SING).
Heterotypic synonyms: *Didymocarpus filicifolius* Ridl., J. Fed. Malay States Mus. 6 (1916) 116, Fl. Malay Pen. 2 (1923) 530; Kiew, Gard. Bull. Sing. 42 (1989) 60. – *Paraboea filicifolia* (Ridl.) Ridl., Fl. Malay Pen. 2 (1923) 530. TYPE (lecto Kiew, 1989): *Ridley 16059*, Peninsular Malaysia, Pahang, Gunung Tahan, Padang, Jul 1911 (lectotype K, isolectotypes BM, SING).

71. ***Codonoboea salicinoides*** (Kiew) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus salicinoides* Kiew, Gard. Bull. Sing. 44 (1992) 35. **Synonyms**: *Henckelia salicinoides* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 355. – *Paraboea salicina* (Ridl.) Ridl. var. *major* Ridl., Fl. Malay Pen. 5 (1925) 325. TYPE (lecto Kiew, 1993): *Yapp 193*, Peninsular Malaysia, Kelantan, Kuala Aring (lectotype K, isolectotype CGE).

72. ***Codonoboea serratifolia*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus serratifolius* Ridl., J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1909) 761, Fl. Malay Pen. 2 (1923) 521. **Synonyms**: *Didymocarpus serratus* Ridl., J. Straits Branch Roy. Asiat, Soc. 44 (1905) 52, *nom. illeg.*, non *D. serratus* R.Br. (1839). – *Henckelia serratifolia* (Ridl.) A.Weber, Beitr. Biol.

Pflanzen 70 (1998) 356. TYPE: *Ridley 11922*, Peninsular Malaysia, Perak, Larut Hills, below the Tea Gardens, Feb 1904 (lectotype SING, here designated; isolectotype K).

73. ***Codonoboea soldanella*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus soldanellus* Ridl., J. Straits Branch Roy. Asiat. Soc. 61 (1912) 33, Fl. Malay Pen. 2 (1923) 523. **Synonym**: *Henckelia soldanella* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 356. TYPE: *Haniff s.n.*, Peninsular Malaysia, Perak, Gunung Korbu [Kerbau], Jul 1910. cult. B. G. Sing. (holotype SING).

74. ***Codonoboea stolonifera*** (Kiew) Kiew, ***comb. nov.***
Basionym: *Didymocarpus stoloniferus* Kiew, Gard. Bull. Sing. 44 (1992) 36. **Synonym**: *Henckelia stolonifera* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 357. TYPE: *Kiew RK 1638*, Peninsular Malaysia, Pahang, Gunung Ulu Kali, 25 Mar 1985 (holotype KEP, isotype SING).

75. ***Codonoboea tiumanica*** (Ridl.) C.L.Lim, ***comb. nov.***
Basionym: *Paraboea tiumanica* Burkill ex Ridl., Fl. Malay Pen. 2 (1923) 530. **Synonyms**: *Didymocarpus tiumanicus* (Ridl.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44. – *Henckelia tiumanica* (Burkill ex Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 357. TYPE: *Burkill 1142*, Peninsular Malaysia, Pulau Tioman [Tiuman], West of Juara Bay, 29 Jun 1915 (lectotype K, here designated; isolectotype SING).

76. ***Codonoboea urticoides*** (A.Weber) Kiew, ***comb. nov.***
Basionym: *Didymocarpus urticifolius* Ridl., Fl. Malay Pen. 2 (1923) 511, non *D. urticifolius* (D.Don) Wonisch (1909). **Synonym**: *Henckelia urticoides* A.Weber, Beitr. Biol. Pflanzen 70 (1998) 358. SYNTYPES: *Ridley 14277*, Peninsular Malaysia, Perak, Temengor [Temengoh], Jul 1909 (?K); *Curtis 1328*, Taiping [Thaiping] Hills, Gunung Hijau, Dec 1887 (?K).

Notes: Its smaller stature and two-flowered inflorescences with larger flowers place this species in *Codonoboea* rather than *Didymocarpus*. Neither Weber (1998) nor Vitek et al. (2000) typified this species, although Vitek et al. cited both syntypes as being at K. However, a search there and at SING could not locate either of the syntypes nor any other specimens annotated as this species. Therefore it is not possible either to lectotypify or neotypify this species.

77. ***Codonoboea venusta*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus venustus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 51, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 760, Fl. Malay Pen. 2 (1923) 514; Kiew, Malay. Nat. J. 48 (1995) 206. **Synonym**: *Henckelia venusta* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 358. TYPE (lecto Kiew, 1995): *Curtis 3751*, Selangor, Gunung Semangkok, May 1902 (lectotype K, isolectotype SING).
Heterotypic synonyms: *Paraboea pubiflora* Ridl., J. Fed. Malay States Mus. 4

(1909) 51. – *Didymocarpus pubiflorus* (Ridl.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31 (1971) 44. TYPE: *Robinson & Kloss s.n.*, Peninsular Malaysia, Pahang, Cameron Plateau, Nov 1908 (holotype BM *fide* Kiew (1995), isotype SING).

Note: Didymocarpus pubiflorus was reduced to synonomy by Kiew (1995).

78. ***Codonoboea viscida*** (Ridl.) Kiew, ***comb. nov.***
Basionym: *Didymocarpus viscidus* Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 36, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 750, Fl. Malay Pen. 2 (1923) 512. **Synonym**: *Henckelia viscida* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 359. TYPE: *Ridley 9781*, Peninsular Malaysia, Perak, Gunung Keledang, Sep 1898 (holotype SING).

79. ***Codonoboea yongii*** (Kiew) C.L.Lim, ***comb. nov.***
Basionym: *Didymocarpus yongii* Kiew, Gard. Bull. Sing. 42 (1989) 62. **Synonym**: *Henckelia yongii* (Kiew) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 359. TYPE: *Kiew RK 2481*, Peninsular Malaysia, Pahang, Sungai Teku, 29 Mar 1987 (holotype KEP, isotypes K, L, SING).

Name of uncertain status

Paraboea scortechinii Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 65, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74 (1908) 772, Fl. Malay Pen. 2 (1923) 529. **Synonyms**: *Didymocarpus scortechinii* (Ridl.) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 31(1971) 44. – *Henckelia scortechinii* (Ridl.) A.Weber, Beitr. Biol. Pflanzen 70 (1998) 356. TYPE: *Scortechini s.n.*, Peninsular Malaysia, Perak (?).

Notes: In the original description, Ridley (1905) noted that the species was known from 'a single incomplete specimen' that had no number or locality. It was presumably without fruits because no description of them was provided. He noted that it was allied to *P. cordifolia*, which unfortunately is an error because there is no species of this name. Among the species he described under *Paraboea*, from the description *P. scortechinii* is most similar to *P. cordata* (A.DC.) Ridl. so it is likely that he intended *P. cordata* when he wrote *P. cordifolia*. In 1923, Ridley again recorded it as 'very little known' and no further specimens were cited.

Burtt (1971) transferred all the short-flowered species in Ridley's *Paraboea* sect. *Campanulatae* that included *P. scortechinii* to *Didymocarpus* stating 'although it has not been possible to confirm the botanical validity of every species, it seems desirable to provide names in *Didymocarpus* if they are not already available'. He did not cite a type so it is not clear whether he had seen any specimens of this species.

However, since then *Didymocarpus* has been redefined (Weber & Burtt 1983) to include species with fruits that split along both sutures (among other characters) while those that split only on the upper side were included in *Henckelia*. *Didymocarpus cordatus* A.DC. remained in *Didymocarpus*. Weber

& Burtt (1998) transferred *D. scortechinii* to *Henckelia* without comment. Vitek et al. (2000) did not locate the type nor did our search, nor have specimens subsequently been collected that have been identified as this species.

From the description, *P. scortechinii* is in fact more similar to *D. cordatus* in leaf shape, in its branched panicles and half-inch long flowers, than it is to the other short-flowered campanulate species transferred first to *Didymocarpus* and then to *Henckelia* and now to *Codonoboea*. However, without the fruit the affinity of this species to either *Didymocarpus* or *Codonoboea* cannot be resolved. Its half-inch long campanulate flower excludes it from belonging to *Paraboea* as now redefined by Burtt (1984). Species of *Paraboea* in Peninsular Malaysia are restricted to limestone but without locality data the habitat of this species remains unknown. For all these reasons *Paraboea scortechinii* is listed here as a dubious name.

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