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Systematics of the Thai Hypericaceae Juss. and Kielmeyeroideae (Clusiaceae Lindl.)

Thesis submitted for the Degree of Doctor of Philosophy

2009

Caroline Byrne

Supervisor: Professor John A.N. Parnell

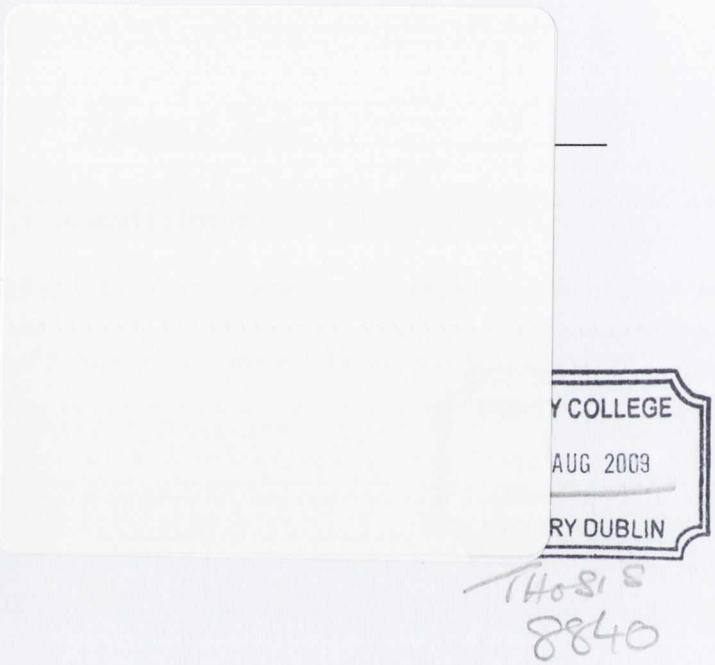
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Abstract

The Clusiaceae (Subfamily Kielmeyeroideae) and Hypericaceae families are fully revised for Thailand. 33 species are recognised in six genera, these are: *Calophyllum* Linnaeus, *Kayea* Wallich, *Mammea* Linnaeus and *Mesua* Linnaeus in Clusiaceae (Subfamily Kielmeyeroideae) and *Cratoxylum* Blume and *Hypericum* Linnaeus in Hypericaceae respectively. Descriptions, full synonyms relevant to the Thai taxa, distribution maps, line drawings, ecology, phenology, vernacular names and specimens examined are given. One name change is made: *Cratoxylum cochinchinense* (Lour.) Blume is changed to *Cratoxylum chinense* (Retz.) Merr and all species previously in the genus *Mesua* have been moved to the genus *Kayea*, except *Mesua ferrea* Linnaeus.

The leaf morphology of the genus *Calophyllum* was examined using Scanning Electron Microscopy to see if the leaf surfaces of the species differed. It was found that there was no significant difference in the leaf surfaces of the different species of Thai *Calophyllum* and that variation occurred within and between species.

30 accessions representing two of the four genera of Thai Clusiaceae and the two genera of Thai Hypericaceae were selected for a molecular study to investigate the relationships between the genera in the Thai Clusiaceae and Hypericaceae. Two chloroplast gene regions were used to investigate the similarities and differences between the two families, namely the genes: *rpL*16 and *rps*16.

Two taxa were found to be endemic to Thailand (one species in the Clusiaceae and one species in the Hypericaceae respectively). The distribution for the two families in Thailand was found to vary with the Thai Clusiaceae being found mainly in Central and Peninsular Thailand whilst the Thai Hypericaceae were found mainly in the North and the North-East of Thailand.

A computer-based key was also produced for the two families in Thailand. The CD-ROM contains a dichotomous key and a multiple access key, as well as a glossary accompanied with illustrations, and species descriptions accompanied with photographs or line drawings. The computer-based key is the first of its kind for the Flora of Thailand project and it is hoped that keys of this kind will be published more frequently

in the future for the Flora of Thailand project as they are easy to edit and update and less expensive to do so also.

Overall the project has provided a comprehensive revision of the Thai Clusiaceae (Subfamily Kielmeyeroideae) and Hypericaceae and has contributed to the ongoing Flora of Thailand project.

Acknowledgements

I would like to give my sincerest thank you to my supervisor, Professor John Parnell for his excellent guidance and support throughout my study. His enthusiasm for taxonomy has without a doubt been contagious.

I would also like to express my sincerest thanks to the staff at the School of Botany, Trinity College who have helped me in various ways. I would especially like to thank Dr. Trevor Hodkinson for his help with the lab work. In the herbarium I would like to thank Mrs Marcella Campbell for help with specimens and for our wonderful conversations. I would also like to thank Atchara Teerawatananon, Dr. Saravut Sungkaew, Ruth Bone and Caoimhe Muldoon for their help and valuable suggestions on molecular work and Anna Trias Blasi for her great company during fieldwork. I would also like to express my sincerest thanks to Caroline Nienhuis, Evelyn Gallagher, Dr. Chloe Galley and Sarah Eftonga for their helpful suggestions and support.

I would also like to sincerely thank Dr. Mats Gustafsson who gave me so much guidance and support with all of my molecular work and helped me with invaluable suggestions when there seemed to be no solutions. I will be forever indebted.

Many thanks to Elaine Cullen and Nicole Tilley for their beautiful line drawings without which the project would be unfinished. The staff, directors and keepers of the herbaria mentioned in the taxonomic treatment chapter are thanked for making specimens available on loan for this study, or providing research facilities during visits. Dr. Noeleen Smyth is also thanked for her help in sourcing plant material and for her helpful suggestions.

In Thailand, I am deeply indebted to Dr. Kongkanda Chayamarit (Forest Herbarium (BKF)), Professor Pranom Chantaranothai (Khon Kaen University), and all of the staff and students at the various institutes and Botanic Gardens who were so hospitable and helpful during fieldwork in Thailand.

A huge thanks to my parents and sisters and David Butler and Daniel Hazelden. Their support and help during this project was immeasurable and I will forever be indebted to them.

Finally I would like to offer my sincerest thank you to the Irish Research Council for Science, Engineering and Technology (IRCSET) for their generous research grant for the project.

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Chapter 1

General Introduction and Aims

1.1 Introduction

This chapter introduces the Clusiaceae Lindl. and Hypericaceae Juss. families. The taxonomic histories of the two families are discussed, an introduction to the sister groups of the two families is given, as well as an introduction to the morphology of the Clusiaceae and the Hypericaceae. The Flora of Thailand Project is introduced and the two families are also discussed in the context of Thailand and SE Asia.

1.2 Taxonomic History of the Clusiaceae Lindl. and Hypericaceae Juss.

Both the Clusiaceae and Hypericaceae families are dealt with together in this section as their status as two separate families has varied and in previous literature they have been dealt with as one family under the name Guttiferae or Clusiaceae.

The Guttiferae (nom. alt.: Clusiaceae Lindl., Nat. Syst. Bot., ed. 2: 74. 1836) and Hypericaceae ('Hyperica') were first described by Antoine Laurent de Jussieu in 1789 in *Genera Plantarum*. He noted that the two families were similar, differing only in a few ways, namely the different fruits, the number of locules and the presence of perisperm (nutritive tissue derived from the nucleus and surrounding the embryo of a seed (Harris et al., 2001)). That is, the Guttiferae have baccate or drupaceous fruit and most of the Hypericaceae have capsular fruit (*Vismia* Vand. and *Hypericum* L. spp. can have baccate fruit). The Guttiferae are unilocular and the Hypericaceae are multilocular. The Guttiferae have a straight plumule without perisperm and the Hypericaceae have a straight plumule with or without perisperm. De Jussieu recognised 14 genera in the Clusiaceae (*Cambogia* L., *Clusia* L., *Garcinia* L., *Tovomita* Aublet, *Quapoya* Aublet, *Grias* L., *Moronobea* Aublet, *Macoubea* Aublet, *Mammea* L., *Macanea* Juss., *Singana* Aublet, *Mesua* L., *Rheedia* L. and *Calophyllum* L.) and three genera in the Hypericaceae (*Ascryum* L., *Brathys* L.f. and *Hypericum* L.). The type genus of the Clusiaceae is *Clusia* L. and the type genus of the Hypericaceae is *Hypericum* L.

However it was Planchon and Triana who laid the foundation of our knowledge of the families in 1860 when they described them in *Annales des Sciences Naturelles* (1860,

1861, 1862). In their classification, they divided the family into five tribes, and 33 genera based on embryo type and stigma shape. Six genera were placed into '*genera dubia*' due to uncertainties regarding morphological characters. See Table 1.1 for a summary of the classification.

Table 1.1 Summary of the classification of the Clusiaceae by Planchon and Triana (1860).

Tribe	Subtribe	Genus	Authority	Section
I Clusieae	Euclusieae	*Clusia*	L.	
		Oxystemon	Planch. & Triana	
		Cochlanthera	Chois.	
		Polythecandra	Planch. & Triana	
		Arrudea	Camb.	
		Clusiella	Planch. & Triana	
		Androstylium	Miq.	
		Quapoya	Aubl.	3 Sections : *Euquapoya, Hemiquapoya,*
				Renggeria
		Rengifa	Poepp.	
		Balboa	Planch. & Triana	
		Oedematopus	Planch. & Triana	
		Havetiopsis	Planch. & Triana	3 Sections: *Euhavetiopsis, Havetiella,*
				Oligospora
		Pilosperma	Planch. & Triana	
		Havetia	H.B. & K.	
	Tovomiteae	*Chrysochlamys*	Poepp. & Endl.	2 Sections: *Adelphia, Heterandra*
		Tovomita	Aubl.	
		Tovomitopsis	Planch. & Triana	
II Moronobeae		*Moronobea*	Aubl.	
		Chrysopia	Thou.	
		Montrouziera	Pancher	
		Pentadesma	Don	
		Symphonia	L.f.	
		Platonia	Mart.	
III Garcinieae		*Ochrocarpos*	Thou.	
		Garcinia	L.	6 Sections: *Mangostana, Peltostigma,*
				Cambogia, Trachycarpus, Comarostigma,

Table 1.1 continued.

Tribe	Subtribe	Genus	Authority	Section
				Hebradendron
IV Calophylleae		*Discostigma*	Hassk.	2 Sections: *Eudiscostigma, Ternophyllum*
		Xanthochymus	Roxb.	
		Rheedia	L.	2 Sections: *Eurheedia, Verticillaria*
		Calophyllum	L.	
		Kayea	Wall.	
		Mesua	L.	
		Mammea	L.	
V Quiineae		*Quiina*	Aubl.	
Genera dubia		*Macoubea*	Aubl.	
		Singana	Aubl.	
		Macanea	Juss.	
		Soala	Blanco	
		Gynotroches	Blume	
		Marila	Swartz	

Later important treatments were those of Bentham and Hooker (1862), Vesque (1893), who was the last monographer of the group and Engler and Prantl (1895).

Bentham and Hooker recognised five tribes in the Guttiferae and three tribes in the Hypericaceae. In the Guttiferae, the five tribes were distinguished from each other based on embryo type and stigma shape. Tribe *Clusieae* was categorised as having a thick fleshy embryo and minute/small scale-like cotyledons and it included the following genera: *Clusia* L., *Renggeria* Meisn., *Rengifa* Poepp. & Endl., *Havetia* H.B. & K., *Pilosperma* Planch. & Triana, *Havetiopsis* Planch. & Triana, *Clusiella* Planch. & Triana, *Balboa* Planch. & Triana, *Chrysochlamys* Poepp. & Endl. and *Tovomita* Aubl. Tribe *Moronobeae* was characterised and distinguished by the absence of cotyledons and an elongated style with an apex with five splits and it contained the following genera: *Symphonia* L. f., *Montrouzeria* Benth. & Hook. f., *Moronobea* Aubl., *Platonia* Raf. and *Pentadesma* Sabine. Tribe *Garcinieae* has no cotyledons, or if present, very small. This tribe included *Garcinia* L., *Xanthochymus* Roxb., *Rheedia* L. and *Ochrocarpos* Thou. Tribe *Calophylleae* was characterised by thick fleshy cotyledons,

fused or separated and with a short radicle and included *Calophyllum* L., *Kayea* Wall., *Mesua* L. and *Mammea* L. and Tribe *Quiineae* had thick distinct cotyledons with a short radicle and included the genus *Quiina* Aubl.

In the Hypericaceae, the three tribes were distinguished based on the presence/absence of wings on the seeds and the presence/absence of hairs on the inside of the petals. Tribe *Hypericeae* with *Ascryum* L. and *Hypericum* L., was described as having a septicidal capsule, seeds not winged, hairless petals and cotyledons with short radicles. Tribe *Cratoxyleae* with *Eliea* Cambess. and *Cratoxylum* Blume was described as having a septicidal capsule, winged seeds, hairless petals and cotyledons with long radicles and Tribe *Vismieae* had fleshy indehiscent fruit, wingless seeds and petals with hairs often present on the inside. This tribe contained the genera *Endodesmia* Benth., *Vismia* Vand., *Psorospermum* Spach and *Haronga* Thou.

Vesque (1893) was the last monographer of the family. In his classification, Vesque divided the Guttiferae into four subfamilies, namely *Calophylleae, Garcinieae, Clusieae* and *Moronobeae*, based on extensive anatomical observations, particularly those based on the shape and type of stomata present. In his monograph, Vesque sunk the genera *Ochrocarpos* Thou. and *Calysaccion* Wight and placed all of the taxa in the genus *Mammea* L.. He also reduced the genus *Xanthochymus* Roxb. to a subgenus of *Garcinia* L. and omitted the genera *Renggeria* Meisn. and *Havetiopsis* Planch. & Triana. He reduced *Cambogia* L. to a section in the subgenus *Eugarcinia* in the genus *Garcinia* L. The following table summarises Vesque's classification of the Guttiferae:

Table 1.2 Classification of the Clusiaceae by Vesque (1893).

Subfamily	Genus	Authority	Subgenus	Section
Calophylleae	*Calophyllum*	L.		4 Sections: *Inophyllum, Microphyllum,*
				Apetalum, Hypodermata
	Kayea	Wall.		
	Mesua	L.		
	Mammea	L.		

Table 1.2 continued.

Subfamily	Genus	Authority	Subgenus	Section
	Poeciloneuron	Beddome		
Garcinieae	*Garcinia*	L.	*Rheediopsis*	2 Sections: *Teracentrum, Rheediopsis*
			Xanthochymus	1 Section: *Xanthochymus*
			Eugarcinia	29 Sections: *Discostogma,*
				Mucestigma, Echinostogma,
				Plinothostigma, Pachyphyllum,
				Conocentrum, Mangostana,
				Gynegonia, Kiras, Tagmanthera,
				Simonsanthera, Cambogia, Tetradium,
				Cladogynos, Olostigma, Anisostigma,
				Mungotia, Didymodenia, Rhinostigma,
				Tetraclinia, Oxycarpus, Hebradendon,
				Peltostigma, Gamodesmis, Depastigma,
				Stemmandra, Sphaerocentrum,
				Comarostigma, Dicrananthera,
	Rheedia	L.		3 Sections: *Eurheedia, Ruscoides,*
				Verticillaria
Clusieae	*Clusia*	L.	*Thysanoclusia*	5 Sections: *Anandrogyne, Criuva,*
				Stauroclusia, Phloianthera, Euclusia
			Cordyloclusia	2 Sections: *Cordylandra, Retinostemon*
			Omphaloclusia	1 Section: *Gomphanthera*
			Polythecandra	1 Section: *Polythecandra*
	Cochlanthera	Chois.		
	Rengifa	Poepp. & Endl.		
	Havetia	H.B. & K.		
	Oedematopus	Planch. & Triana		
	Pilosperma	Planch. & Triana		
	Balboa	Planch. & Triana		
	Clusiella	Planch. & Triana		
	Astrotheca	Miers ex		
		Planch. & Triana		
	Chrysochlamys	Poepp. & Endl.		
	Tovomitopsis	Planch. & Triana		

Table 1.2 continued.

Subfamily	Genus	Authority	Subgenus	Section
	Tovomita	Aubl.		
Moronobeae	*Symphonia*	L.f.		
	Montrouziera	Benth. & Hook. f.		
	Moronobea	Aubl.		
	Platonia	Raf.		
	Pentadesma	Sabine		

Vesque's classification of the family is similar to that of both Planchon and Triana and Bentham and Hooker. All authors had the four main groups, namely *Clusieae*, *Moronobeae*, *Garcinieae* and *Calophylleae*. Planchon and Triana and Bentham and Hooker also included the tribe *Quiineae*, which Vesque omitted, and Planchon and Triana and Bentham and Hooker classified the above groups as tribes, whereas Vesque referred to them as subfamilies. In total 33 genera were included by Planchon and Triana. Bentham and Hooker reduced this to 24 genera and Vesque also included 24 genera, although different to the 24 genera included by Bentham and Hooker (see above section for the differences between the classifications).

In 1895, Engler and Prantl described the Guttiferae in *Die Natürlichen Pflanzenfamilien*. In their work, they included *Renggeria* Meisn. and *Havetiopsis* Planch. & Triana, previously omitted by Vesque and also included three more genera in Tribe *Clusioideae* in Section *Garcinieae* namely, *Clusianthemum* Vieill., *Tripetalum* K. Schum. and *Pentaphalangium* Warb. They classified the family into six subfamilies. See Table 1.3 for a summary of their classification.

Table 1.3 Classification of the Clusiaceae including Hypericaceae by Engler and Prantl (1895).

Subfamily	Section	Genus	Authority
Kielmeyeroideae	*Kielmeyereae*	*Mahurea*	Aubl.
		Kielmeyera	Mart.

Table 1.3 continued.

Subfamily	Section	Genus	Authority
		Marila	Sw.
	Caraipeae	*Caraipa*	Aubl.
		Haploclathra	Benth.
Hypericoideae	*Hypericeae*	*Ascryum*	L.
		Hypericum	L.
	Cratoxyleae	*Cratoxylum*	Blume
		Eliea	Cambess.
	Vismieae	*Vismia*	Vand.
		Psorospermum	Spach
		Haronga	Thou.
Endodesmioideae		*Endodesmia*	Benth.
Calophylloideae		*Mesua*	L.
		Mammea	L.
		Ochrocarpos	Thou.
		Calophyllum	L.
		Poeciloneuron	Bedd.
		Kayea	Wall.
Clusioideae	*Clusieae*	*Clusia*	L.
		Clusiella	Planch. & Triana
		Rengifa	Poepp. & Endl.
		Oedematopus	Planch. & Triana
		Havetiopsis	Planch. & Triana
		Havetia	H.B. & K.
		Pilosperma	Planch. & Triana
		Renggeria	Meisn.
		Tovomita	Aubl.
		Tovomitopsis	Planch. & Triana
		Chrysochlamys	Poepp. & Endl.
		Balboa	Planch. & Triana
	Garcinieae	*Clusianthemeum*	Vieill.
		Tripetalum	K. Schum.
		Pentaphalangium	Warb.
Moronboideae		*Pentadesma*	Sabine
		Platonia	Raf.
		Moronobea	Aubl.

Table 1.4 below summarises the above revisions of the families, showing which author used what name and also if the Hypericaceae were included as a subfamily within the Guttiferae or if the Clusiaceae and Hypericaceae families were revised separately. The two families, when revised separately were separated based on the differences in the fruits, the number of locules and the presence or absence of perisperm. See page 1 for more information regarding the differences between the Clusiaceae and Hypericaceae

Table 1.4 Summary of the Taxonomic History of the Clusiaceae and Hypericaceae from 1789-1895.

		Guttiferae incl. Hypericaceae	Clusiaceae	Hypericaceae
de Jussieu	**1789**		+	+
Planchon & Triana	**1860**		+	
Bentham & Hooker	**1862**		+	+
Vesque	**1893**		+	
Engler & Prantl	**1895**	+		

1.3 Historical Name Changes in the Clusiaceae

Within the Clusiaceae, there is a taxonomic problem regarding the status of the genera *Kayea* and *Mesua*. *Mesua*, a monotypic genus was first described by Linnaeus in 1753. In his *Species Plantarum*, he described the species *Mesua ferrea*. *Kayea* was introduced in 1832 when Wallich described *Kayea floribunda* in *Plantae Asiaticae Rariores*. The two genera were distinguished by their ovary type and stigma shape. *Mesua* has a two-celled ovary and peltate stigma and *Kayea* has a one-celled ovary with a single seed and a 4-fid stigma (Bentham and Hooker, 1862). However, in 1969, Kostermans observed that one and two-celled fruits could have one or two seeds on an individual tree of *Mesua ferrea* and also that *Kayea* species had been observed with two-seeded fruits. For this reason, in 1969, Kostermans sunk the genus *Kayea* and transferred all taxa into the genus *Mesua* (Table 1.5 gives a summary of important botanical works from SE Asia and the genus in which taxa were placed by different authors). Many authors have followed this classification until 1993, when Stevens (1993) recognised *Kayea* and *Mesua* as two separate genera based on their growth pattern, morphology and anatomy. This has since been followed, with Turner (2000), Notis (2004) and Zakaria (2007) recognising that it had been inappropriate to transfer *Kayea* species to *Mesua* and

therefore leaving all described *Kayea* species in *Kayea*. Zakaria (2007) used chloroplast DNA sequence data and showed that *Mesua* appeared to be polyphyletic as *Mesua ferrea* did not form a cluster with the rest of the *Mesua* taxa. Despite the history of the two genera being closely related, *Mesua* is the sister to *Calophyllum* and *Kayea* is more closely related to *Poeciloneuron*, an endemic genus of the Western Ghats (Notis, 2004). Notis's findings were based on three gene regions (*rbc*L, *mat*K, ITS) and morphological characters; *Kayea* and *Poeciloneuron* both have narrow stigmas, and *Mesua* and *Calophyllum* have broad stigma lobes (Notis, 2004).

Table 1.5 The placement of taxa in the genera *Mesua* or *Kayea* or in both in previous SE Asian Botanical Works. *Mesua ferrea* is separated from *Mesua* spp. as this species has always remained under this name and has never been moved to *Kayea*. +/- indicates the presence or absence of the species or genus in each botanical work respectively.

		Mesua ferrea	*Mesua spp.*	*Kayea spp.*
Wight	**1834**	+	-	-
Thwaites	**1858**	+	+	+
Miquel	**1859**	+	-	-
Hooker	**1874**	+	+	+
Kurz	**1877**	+	-	+
Gamble	**1881**	+	-	+
King	**1890**	+	-	+
Prain	**1903**	+	-	-
Brandis	**1907**	+	-	+
Pitard	**1910**	+	-	+
Gamble	**1915**	+	-	-
Haines	**1921**	+	-	-
Ridley	**1922**	+	+	+
Craib	**1925**	+	-	+
Backer	**1963**	+	-	-
Whitmore	**1973**	+	+	-
Saldanha	**1976**	+	+	-
Dassanayake	**1980**	+	+	-
Grierson	**1984**	+	+	-
Hô	**1991**	+	+	-
Xi-wen	**2007**	+	-	-

From Table 1.5, it can be seen that the status of *Mesua* and *Kayea* has varied over the years. Some authors (*e.g.* Thwaites, Hooker, Gamble, Brandis, Ridley, Craib) have included the two genera in their botanical works, whilst others have placed all taxa into the genus *Mesua* (*e.g.* Saldanha, Dassanayake, Grierson). However, based on recent evidence, the genera *Mesua* and *Kayea* will be treated as two separate taxa in this treatment.

In the past, another taxonomic problem was that of the genera *Mammea* and *Ochrocarpos*. *Mammea* was first described by Linnaeus in 1753 in his *Species Plantarum* in which he described two species, namely *Mammea americana* L. and *Mammea asiatica* L. *Ochrocarpos* was later described in 1806 by Thouars in *Genera Nova Madagascariensis*. These genera were dealt with separately by Choisy (1824) and Planchon and Triana (1860-1862). In 1867 Bentham and Hooker transferred the Old World *Mammea,* as recognised by Planchon and Triana to *Ochrocarpos*. This shift was based on inferences made about the cotyledons and the characters of the style. However the differences in the characters of the style were not recognised by all authors and de Wilde (1956) concluded that the characters were too weak to be of taxonomic value. Staner (1934) also kept *Mammea* and *Ochrocarpos* separate but agreed that *Ochrocarpos* was probably a subgenus of *Mammea*. Kostermans (1956) came to the conclusion that the Old World species of *Ochrocarpos* should be referred to *Mammea*. In 1961 Kostermans completed the monograph of the Asiatic and Pacific species of *Mammea*, in which he also included the genus *Ochrocarpos*. Stevens (1974) also included *Ochrocarpos* in the genus *Mammea* and stated that nowadays these genera are considered to be congeneric. Table 1.6 shows which genus the corresponding authors used.

Table 1.6 Summary of some of SE Asian botanical works which included the genera *Ochrocarpos* or *Mammea* or both.

		Ochrocarpos	*Mammea*
Hooker	**1874**	+	-
Kurz	**1877**	+	-
Gamble	**1881**	+	-
Prain	**1903**	+	-
Brandis	**1907**	+	-
Pitard	**1910**	+	-
Gamble	**1915**	+	-
Haines	**1921**	+	-
Ridley	**1922**	+	-
Craib	**1925**	+	-
Staner	**1934**	+	+
deWilde	**1956**	-	+
Kostermans	**1956, 1961**	-	+
Backer	**1963**	-	+
Whitmore	**1973**	-	+
Stevens	**1974**	-	+
Xi-wen	**2007**	-	+

Table 1.6 shows a transition from the genus *Ochrocarpos* to the genus *Mammea*. From the late 1950's to present, *Mammea* is the accepted name for all taxa which were previously placed in the genus *Ochrocarpos*.

1.4 Phylogenetic Relationship of the Clusiaceae and Hypericaceae

The Clusiaceae and Hypericaceae families belong to the order Malpighiales (Stevens, 2007; Davis et al., 2004; Chase et al., 1993). This order is poorly understood and relationships within the Malpighiales are not really resolved (Tokuoka et al., 2006; Stevens, 2006, Davis et al., 2004; APG II, 2003). The order consists of 700 genera and over 16,000 species in 30 families (Tokuoka et al., 2006).

Studies looking at the relationships within the order have been carried out and papers have been published over the last six years showing varied results regarding these relationships. Mostly the studies have been based on phylogenetic analyses, using plastid (*atp*B and *rbc*L) and nuclear (18S) gene regions (Tokuoka et al., 2006; Stevens,

2006; Davis et al. 2005; Davis et al., 2004; APG II, 2003; Savolainen et al., 2000a, 2000b; Soltis et al., 2000) and in combination (Savolainen at al., 2000a, 2000b; Soltis et al., 2000).

Nevertheless the positions of the Clusiaceae and Hypericaceae families are still not settled, but results from these studies have shown that the Podostemaceae Rich. ex C. Agardh and Bonnetiaceae Beauvis are the two closest families to the Clusiaceae and Hypericaceae. In a paper by Davis et al. (2005), the bootstrap support for the Hypericaceae-Podostemaceae-Bonnetiaceae-Clusiaceae clade was 100%. In a recent paper by Tokuoka & Tobe (2006), both the Hypericaceae-Podostemaceae and Clusiaceae-Hypericaceae-Podostemaceae clades were strongly supported with BS 100% and Davis & Chase (2004) also had a strongly supported clade (BS 100%) for Bonnetiaceae-Clusiaceae-Hypericaceae.

The Podostemaceae is an aquatic family of angiosperms that occur on rocks in waterfalls and rapids (Kato, 2004). They appear quite different to the other families in this order in terms of habit. Koi (2005) suggested that saltational evolution might have occurred to give rise to the Podostemaceae, as there is a lack of intermediate species between this family and the Clusiaceae and Hypericaceae (the two closest related families). Morphological analyses have shown that both the Podostemaceae and Hypericaceae families have similarities such as cells with secretory products and also both have papillate stigmas and the pollen is sometimes tricolpate (Stevens, 2007; Stevens, 2006). However, tricolpate pollen is widespread in the angiosperms.

The Bonnetiaceae shares some morphological characteristics with both the Clusiaceae and Hypericaceae; all three families have similar exotegmic seeds and antepetalous staminal fascicles or phalanges (Stevens, 2007).

A characteristic common to all four families is the presence of distinctive xanthones (Stevens, 2007; Kubitzki et al., 1978).

1.5 The Clusiaceae (or Guttiferae) including Hypericaceae, or the Clusiaceae and the Hypericaceae as two separate families?

In the 19th century, the Clusiaceae and Hypericaceae were dealt with as two separate families by de Jussieu (1789) and Bentham and Hooker (1862). However, more recent the Hypericaceae have been placed within the Clusiaceae (Guttiferae) as a subfamily as it was thought that the Hypericaceae did not warrant family rank (Robson, 1974). Most recently phylogenetic trees using plastid (*atp*B and *rbc*L) and nuclear (18S) gene regions have shown that they are not as closely related and in order for the Clusiaceae and Hypericaceae to be included in the same family, the Podostemaceae would have to be included, in order to make the family monophyletic. For this reason, the Hypericaceae should retain family rank (Stevens, 2006; Soltis et al., 2000):

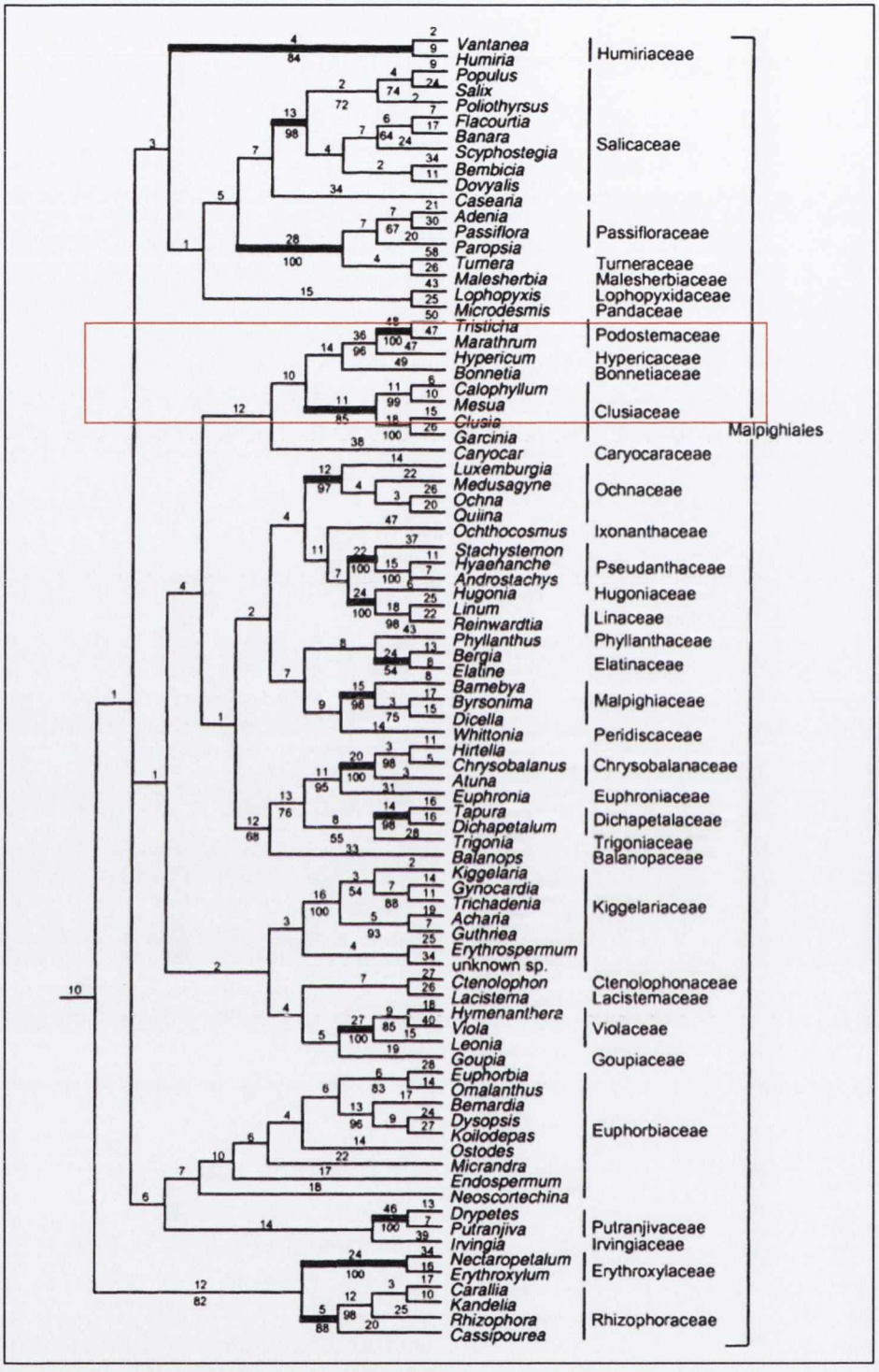


Figure 1.1 Bootstrap consensus tree adapted from Chase et al. (2000) showing the relationships between the Clusiaceae and Hypericaceae. Branch length (numbers above branch) and bootstrap support (numbers below branch) are indicated on the tree. The broader branches indicate clades which are supported with bootstrap support greater than 80%.

From Figure 1.1 we can see that the Clusiaceae and Hypericaceae form a clade with the Bonnetiaceae and Podostemaceae. We can see that the two families are treated separately in this study and in many other previous studies (Tokuoka et al., 2006; Stevens, 2006; Davis et al., 2005; Daviset al., 2004; APG II, 2003; Savolainen et al., 2000a, 2000b; Soltis et al., 2000). Based on previous molecular work and differing morphological characters, the two families will be dealt with separately unless otherwise stated.

Stevens (2007) separated the Guttiferae into 2 separate families. He recognised 27 genera and 1,050 species in the Clusiaceae (or Guttiferae) and 9 genera and 560 species in the Hypericaceae.

1.6 The Clusiaceae (or Guttiferae)

This family, as recognised by Stevens, has a Pantropical distribution and its members are woody. Many different dyes, timbers, gums and resins are derived from members of this family (Stevens, 2007). It consists of evergreen trees or shrubs with canals or glands present in all parts of the plant (Stevens, 2007). They are usually hairless and sometimes have uni/multicellular hairs present. The leaves are usually opposite, alternate or whorled. The inflorescences are axillary or terminal, and sometimes comprise single flowers. The sepals and petals are usually free (Gustafsson, 2000), with two to five sepals and four to five petals (Stevens, 2007). The stamen number varies quite a lot from four stamens to an infinite number of stamens aggregated into fascicles. The ovary is superior, and has two to many ovules. The fruits are berries, drupes or capsules and the size of the seeds varies immensely. The seeds have wings or an aril or neither.

Stevens considers two subfamilies: *Kielmeyeroideae* Engler (1888) and *Clusioideae* Engler (1888). The *Kielmeyeroideae* subfamily contains two tribes, namely Tribe *Calophylleae* Choisy (1824) with 12 genera and Tribe *Endodesmieae* Engler (1925) with two genera. The *Kielmeyeroideae* subfamily is characterised by spiral leaves with pellucid dots, moderate-sized cotyledons and perfect flowers. The *Clusioideae* subfamily contains three tribes, namely Tribe *Clusieae* Choisy (1824) with five genera,

Tribe *Garcinieae* Choisy (1824) with two genera and Tribe *Symphonieae* Choisy (1824) with seven genera. The subfamily has leaves with canals and minute cotyledons.

The Clusiaceae are found mainly in moist, tropical, lowland or lower montane forests (Stevens, 2007). The majority of genera are found in primary forests, some growing in peat swamp forests (*Calophyllum pisiferum* Planchon & Triana, *Calophyllum rupicolum* Ridl., *Calophyllum sclerophyllum* Vesque, *Calophyllum teysmannii* Miq.), and some growing in black-water floodplains (*Caraipa* Aublet, *Haploclathra* spp. Bentham) (Stevens, 2007). The Tribe *Clusieae* and the genus *Clusiella* Planch. & Triana almost exclusively contain epiphytic or lianescent taxa and CAM (Crassulacean acid metabolism) is known to occur in *Clusia* L. (Stevens, 2007; Lüttge 2002, 1999).

It is the *Kielmeyeroideae* subfamily which is of most interest to me as it is here that Tribe *Calophylleae* is found in which the four genera of Clusiaceae that occur in Thailand are located (*Calophyllum* L., *Mesua* L., *Kayea* Wall. and *Mammea* L.). These four genera (*Calophyllum* L., *Mesua* L., *Kayea* Wall. and *Mammea* L.) will be discussed in the context of Thailand under the section on The Flora of Thailand Project. The genus *Garcinia* is also found in Thailand but this genus will not be dealt with here as it is currently under revision in Thailand by C. Ngoensangsrauay.

1.7 The Hypericaceae

This family has a worldwide distribution. Members of the Hypericaceae are evergreen or deciduous herbs, shrubs or trees with glands or canals present in most parts of the plant. They usually have uni/multicellular hairs. The leaves are opposite, alternate or whorled. The inflorescences are terminal or cymose and the flowers are single and perfect. The sepals and petals are free, with four to five (sometimes two) sepals and four to five (sometimes three) petals present. The stamens are free, connate or fasciculate and the number of stamens ranges from nine to hundreds. There is no nectary present. The ovary is superior and can have a single ovule or many ovules. The fruit is a capsule or baccate (berry-like), sometimes a drupe. The fruit may be winged or not.

The Hypericaceae is divided into three Tribes: Tribe *Vismieae* Choisy (1821) with two genera, Tribe *Hypericeae* Choisy (1821) with five genera and Tribe *Cratoxyleae*

Bentham (1862) with two genera. Some members of this family are more or less aquatic (Stevens, 2007).

The genus *Hypericum* L. is found in temperate regions and high montane areas in tropical regions. In Africa, the genus *Harungana* Lam. is found in open, dry vegetation and *Vismia* Vand. and some species of *Harungana* Lam. grow well in secondary habitats (Stevens, 2007). The species *Harungana madagascariensis* Poir. is sometimes lianescent also (Stevens, 2007)

It is the genera *Hypericum* L. and *Cratoxylum* Blume that are of interest to me as these two genera are found in Thailand. These genera will be discussed in the context of Thailand in more detail under the section on the Flora of Thailand Project.

1.8 Background information to Thailand

Thailand is bordered on the west by Myanmar (Burma), on the east by Lao PDR and Cambodia, and in the south by peninsular Malaysia and the Andaman and China Seas. It covers an area of approximately 515,000km^2, extending approximately 1,620km from north to south and approximately 775km from east to west (Royal Thai Embassy, 2008). This makes Thailand only slightly smaller than the largest EU country – France. The country has a diverse array of habitats and was once completely covered in forest.

The population of Thailand is approximately 62 million (Ministry of Foreign Affairs, Kingdom of Thailand, 2007) and it has a population density which is one of the highest in South-East Asia. Over the last three decades, rapid economic growth and development has occurred, involving many of Thailand's natural resources *e.g.* timber, minerals and fisheries (Arbhabhirama, 1987). Because of this, Thailand has experienced one of the fastest rates of deforestation in the world and this is having significant environmental impacts (Santisuk et al., 1991). Forest cover has declined from 50% of the total land area in the 1950's to 25% in 2000 (Middleton, 2003). Despite the rapid developments occurring, Thailand's flora still remains relatively poorly studied and undocumented (Pooma et al., 2005).

The Thai government began to recognise this problem and the need for conservation in 1973, when it adopted a policy to actively protect the remaining forest. At present,

there are 115 National Parks and Wildlife Sanctuaries. They consist of 6.72 million hectares of land or 8% of the total land area (Napompethet al., 1998). To date, according to the IUCN, the list of threatened plants in Thailand consists of 29 critically endangered species, 21 endangered species and 36 vulnerable species (IUCN, 2008). However, the number of species actually present in these categories could be much higher because of the gross under-collection in the country (see Chapter 5), so there is an urgency to 'protect, and manage the available forest biodiversity for future sustainable utilisation' (Boontawee et al., 1995).

1.9 The Flora of Thailand Project and the Clusiaceae and Hypericaceae

The Flora of Thailand Project is a collaborative effort involving a number of American, European and Asian institutions. The project was initiated in 1963 by K. Larsen (Aarhus), in collaboration with J.E. Vidal (Paris), B.L. Burtt (Edinburgh), L.L. Forman (Kew), C. Phengklai (Bangkok), B. Hansen (Copenhagen), T. Smitinand (Bangkok), C.G.G.J. van Steenis (Leiden) and C.F. van Beusekon (Leiden) and was formally launched in 1967 (Middleton, 2003, BKF, 2006). At present the editorial board consists of representatives from worldwide herbaria including H.J. Esser (Munich), K. Larsen (Aarhus), S. Hul (Paris), M. Kato, D.J. Middleton (Edinburgh), M. Newman (Edinburgh), I. Nielsen (Aarhus), J. Parnell (Dublin), H. Pedersen (Copenhagen), C. Phengklai (Bangkok), T. Santisuk (Bangkok), D.A. Simpson (Kew) and P.C. van Welzen (Leiden) (BKF, 2006). The project aims to produce a complete treatment of the entire vascular flora for Thailand.

The first volume was published in 1970 and other volumes have been published since. As a result of the project, accounts of approximately 3,917 species in 154 families have been completed, with the total number of vascular plants estimated to be in the region of 10,250 species in 304 families (Middleton, 2003). Thus, accounts of approximately 35% of Thailand's flora have been completed so far. It is hoped that the Flora could be completed within 30 years (Parnell, 2000) rather than the previously estimated 100 years (Santisuk et al., 1991).

To date, the Flora of Thailand has been published as books and as PDF files. However, the flora has yet to be published electronically in the form of a database with interactive identification keys, images and distribution maps. This has been noted by Middleton

(2003) who said that the project would benefit from a web accessible format; changes will need to be made to the Flora especially for an undercollected region like Thailand and this medium allows for updates and changes to be made in a much easier and cheaper way than do printed media. Therefore, one of the principal aims of this project is to produce a web accessible multi-access key which will be the first of its kind for Thailand.

The Clusiaceae and Hypericaceae are two families in Thailand which have yet to be revised for the project. Therefore one of the aims of this project is to complete a taxonomic treatment for these families in Thailand.

The Thai Clusiaceae and Hypericaceae

In his revision, Sangkaew (1999) reported 17 species of *Calophyllum* (Clusiaceae) in Thailand. They were as follows: *Calophyllum calaba* L., *Calophyllum canum* Hook. f., *Calophyllum depressinervosum* M.R. Henderson & Wyatt-Smith, *Calophyllum dryobalanoides* Pierre, *Calophyllum inophyllum* L., *Calophyllum macrocarpum* Hook. f., *Calophyllum molle* King, *Calophyllum pisiferum* Planchon & Triana, *Calophyllum polyanthum* Wall. ex Choisy, *Calophyllum rupicolum* Ridley, *Calophyllum sclerophyllum* Vesque, *Calophyllum soulattri* Burm. f., *Calophyllum symingtonianum* M.R. Henderson & Wyatt-Smith, *Calophyllum tetrapterum* Miquel, *Calophyllum teysmannii* Miq., *Calophyllum thorelii* Pierre and *Calophyllum touranense* Gagnepain ex P.F. Stevens.

Smitinand (2001) reported 29 taxa occurring in Thailand in the Clusiaceae and Hypericaceae together under Guttiferae. He included all of the 17 *Calophyllum* species recorded by Sangkaew (1999), six species in the genus *Cratoxylum* (Hypericaceae), namely *Cratoxylum arborescens* (Vahl) Blume, *Cratoxylum cochinchinense* (Lour.) Blume, *Cratoxylum formosum* (Jack) Dyer, *Cratoxylum formosum* (Jack) Dyer subsp. *pruniflorum* (Kurz) Gogelein, *Cratoxylum maingayi*, *Cratoxylum sumatranum* (Jack) Blume subsp. *neriifolium* Gogelein, and one species in the genus *Hypericum* (Hypericaceae), namely *Hypericum hookerianum* Wight & Arnott. Two species were recorded in the genus *Mammea* (Clusiaceae): *Mammea harmandii* Kostermans and *Mammea siamensis* Kostermans and three species were reported in the genus *Mesua*

(Clusiaceae) namely *Mesua ferrea* L., *Mesua ferruginea* (Pierre) Kostermans and *Mesua nervosa* Planchon & Triana.

The following is a brief description of the four genera and 21 species of Clusiaceae and the two genera and 12 species of Hypericaceae that I have recognised in Thailand respectively:

The Thai Clusiaceae

Calophyllum L. – approximately 186 species, 14 of which occur in Thailand. The 14 species include: *Calophyllum calaba* L., *Calophyllum dryobalanoides* L., *Calophyllum inophyllum* L. *Calophyllum macrocarpum* Hook. f., *Calophyllum pisiferum* Planchon & Triana, *Calophyllum polyanthum* Wallich, *Calophyllum rupicolum* Ridley, *Calophyllum sclerophyllum* Vesque, *Calophyllum soulattri* Burmann f., *Calophyllum symingtonianum* M.R. Henderson & Wyatt-Smith, *Calophyllum tetrapterum* Miquel, *Calophyllum teysmannii* Zoll. ex Planch. & Triana, *Calophyllum thorelii* Pierre and *Calophyllum touranense* Gagnep. ex P.F. Stevens. The distribution is worldwide in tropical areas including Africa, North and South America, Tropical and Temperate Asia, Australasia and the Pacific. They are restricted to areas that are humid and in lowland or montane rainforests but can grow in drier, open areas (Stevens, 1980). Some of the main characteristic features of this genus include fissured bark with exudate, leaves with distinct venation, terminal or axillary inflorescences, four to eight tepals and drupaceous fruits. *Calophyllum inophyllum* L. is one species in this genus that is of economic importance as it is used in many countries for different purposes. In Java, the seed oil and latex is used to dye batik cloth. The timber is strong and durable and used as a general-purpose timber for masts, bridgework, boat building and cabinet making. The oils produced from the fruits are used to treat ulcers, rheumatism and skin diseases such as eczema, and a decoction of the bark and latex is used both internally and externally as a remedy for many infections and also for skin and eye diseases and rheumatism. In local medicine, the flowers, leaves and seeds are also used. Although this tree grows slowly, it is also used for reforestation and afforestation projects and at shorelines to protect the coast (ICRAF, 2008). A more comprehensive description of this genus is given in the Taxonomic Treatment in Chapter 3.

Kayea Wall. – approximately 75 species occur in tropical Asia namely Borneo, Burma, Cambodia, Ceylon (Sri Lanka), India, Laos, Malaysia, Nepal, Singapore, Sri Lanka, Sumatra, Thailand and Vietnam. Three species occur in Thailand, namely *Kayea elegans* Pierre, *Kayea ferruginea* Pierre and *Kayea kunstleri* King. This genus comprises trees with opposite, hairless and coriaceous leaves. The inflorescences are large with solitary flowers and there are four sepals and petals present. The fruit is an indehiscent fleshy fruit with one to four seeds. Chapter 3 provides a full description of this genus.

Mammea L. – approximately 75 species, occurring throughout the tropics in Africa, Central America, Madagascar and Tropical Asia. There are three species found in Thailand, namely *Mammea brevipes* (Craib) Kostermans, *Mammea harmandii* (Pierre) Kostermans and *Mammea siamensis* T. Anderson. Madagascar is thought to be the centre of origin for this genus (Stevens, 2007). The species are all trees with clear or coloured resinous sap and are found in areas of low to medium altitude. The leaves are simple and opposite and some have black glandular dots present. The inflorescences are quite often cauliflorous and the fruit is fleshy and coriaceous when dry. For a full taxonomic description of this genus, see Chapter 3.

Mesua L. –one species in Tropical Asia, namely *Mesua ferrea* L. It has long been cultivated in the area. It is found growing naturally at low altitudes. This genus comprises trees with a sticky exudate which dries black. The leaves are opposite, often with dots on the upper surface. The inflorescences are solitary, axillary or terminal and there are four or five sepals and petals present. The fruits of this genus are quite variable and can be drupes, berries or capsules. *Mesua ferrea* L is often used in folk medicine for a variety of skin disorders. It is found naturally growing and it is also cultivated throughout Asia and has many other uses also: the seed is used in meal for poultry as it is a good source of protein and energy, it is used for firewood, the timber is used in heavy construction and furniture making, the flowers are used for dyeing fabrics, to stuff pillows and in cosmetic products and an oil called nahor is extracted from the seeds and is used to treat dandruff and rheumatism (ICRAF, 2008). See Chapter 3 for a full description of this genus and the Thai species.

The Thai Hypericaceae

Cratoxylum Blume – eight species in three sections (Whitmore, 1963) found in northeastern India and southern China to western Malesia at low altitudes or in low montane areas. Six species occur in Thailand. These species include *Cratoxylum arborescens* Blume, *Cratoxylum chinense* (Retz.) Merr., *Cratoxylum formosum* (Jack) Dyer subsp. *formosum*, *Cratoxylum formosum* (Jack) Dyer subsp. *pruniflorum* (Kurz) Gogelein, *Cratoxylum maingayi* Dyer and *Cratoxylum neriifolium* Kurz. Species vary from deciduous to evergreen trees or shrubs that are usually hairless and exude a yellow resinous sap. The leaves are papyraceous and usually have pellucid dots present. The inflorescences are terminal panicles or short terminal cymes or sometimes axillary cymes. There are five sepals and petals present and the corolla is usually pink or white in colour. The genus *Cratoxylum* is used as a source of timber (Heywood, 1993). The wood is used for joinery and for light construction and furniture making (MTC, 2002). For a full description of this genus and the species that occur in Thailand, see Chapter 3.

Hypericum L. – approximately 420 species found worldwide but mainly in temperate regions of Africa, North America, Asia, Europe and the former Soviet Union. In Thailand six species occur mainly in the Northern Floristic Region. These are *Hypericum henryi* H. Lév. & Vaniot. subsp. *hancockii* N. Robson, *Hypericum hookerianum* Wight & Arnott, *Hypericum japonicum* Thunberg, *Hypericum napaulense* Choisy, *Hypericum patulum* Thunberg and *Hypericum siamense* N. Robson. This genus consists of trees or herbs that show a lot of morphological variation. The leaves are opposite and can be sessile or subsessile. There are four to five sepals and petals present and the flowers are usually yellow and showy. The petals are sometimes spotted with black glands. *Hypericum* species are cultivated as ornamentals as they have showy flowers. In the British Isles, there are over 80 varieties available as garden plants (Lord et al., 2004). Many members of this genus also yield compounds important to the pharmaceutical industry such as flavonoids, tannins, phenol-carbonic acids and xanthones (Frohne et al., 2005) and *Hypericum perforatum* L. is known for its' medicinal properties, as it is used as an herbal remedy to help mild depression (Frohne et al., 2005). A comprehensive description of this genus is provided in the Taxonomic Treatment chapter (Chapter 3).

1.10 History of Botanical works relevant to the Clusiaceae and Hypericaceae in South East Asia and surrounding regions

The first account of the Clusiaceae and Hypericaceae in South East Asia and surrounding regions was in 1834, when Robert Wight described the two families in his *Prodromus Florae Peninsulae Indiae Orientalis*. In his work, he recognised four genera and 12 species in the Guttiferae (*Garcinia, Xanthochymus, Mesua, Calophyllum*) and one genus and four species in the Hypericaceae (*Hypericum*). The work was based on Wight's collections mainly from the virgin forests of south India and also on collections made by local collectors. He described several new species from both families in this publication. Later, in 1940, he published *Illustrations of Indian Botany*, in which he provided illustrations of the orders of Indian plants described in his Prodromus. He also described several new species from both families in this publication.

In 1858, Thwaites published the genera and species of Guttiferae (*Garcinia, Terpnophyllum, Xanthochymus, Mesua, Kayea, Calophyllum*) and Hypericaceae (*Hypericum*) in Ceylon (Sri Lanka) in his *Enumeration Plantarum Zeylaniae*. He recognised 18 species in the Clusiaceae and one species in the Hypericaceae respectively.

In 1859, Miquel published the genera and species from the Clusiaceae and Hypericaceae found in the Dutch Indies. He recorded six genera and 22 species in the Clusiaceae and four genera and 17 species in the Hypericaceae. *Garcinia, Stalagmites, Discostigma, Mesua, Calophyllum* and *Calysaccion* were recorded for the Clusiaceae and *Brathys, Norysca, Cratoxylum* and *Tridesmis* were recorded for the Hypericaceae. New species were described in this treatment too. His work was based entirely on herbarium specimens collected by other collectors, as he never visited the Tropics himself (van Steenis, 1974). He studied plants from all areas in the East Indies, especially those from Surinam and Indonesia.

In 1863, Bentham, recorded the species found in Australia. *Calophyllum* (with one species) and *Hypericum* (with two species) were recorded for the Guttiferae and Hypericaceae, respectively.

In 1874, Hooker recorded the species found in the British Indian Empire (India, Pakistan, Bangladesh). He recorded six genera and 61 species in the Guttiferae, namely *Garcinia, Ochrocarpos, Calophyllum, Kayea, Mesua* and *Poeciloneuron* and three genera and 26 species in the Hypericaceae; *Ascryum, Hypericum* and *Cratoxylum.* Hooker's *Flora of British India* remains one of the greatest floristic achievements of the East Asian Region and is still widely used today both in South East Asia and also in neighbouring regions. He described several new species in this work from both families.

In 1877, Kurz, in his *Forest Flora of British Burma*, recorded five genera and 24 species in the Guttiferae and one genus and five species in the Hypericaceae. *Garcinia, Ochrocarpos, Calophyllum, Kayea* and *Mesua* were recorded for the Guttiferae and *Cratoxylum* was recorded for the Hypericaceae. He recorded a new species in the genus *Ochrocarpos* in his Flora.

In 1881, the Guttiferae and Hypericaceae were recorded by Gamble in *A Manual of Indian Timbers*. He divided the Guttiferae into two tribes: Tribe *Garcinieae* and Tribe *Calophylleae*. He included two genera and 38 species in Tribe *Garcinieae*: *Garcinia* and *Ochrocarpos* and four genera and 10 species in Tribe *Calophylleae*: *Calophyllum, Kayea, Mesua* and *Poeciloneuron*. He recorded two genera (*Hypericum*, *Cratoxylum*) and three species in the Hypericaceae.

King, in 1890 recorded the species of the Malay Peninsula. He recorded four genera and 61 species in the Guttiferae (*Calophyllum, Garcinia, Kayea*, *Mesua*) and one genus and four species in the Hypericaceae (*Cratoxylum*). He recorded two new species of *Kayea* and several new species of *Garcinia* and *Calophyllum.*

Next Prain, in *Bengal Plants* (1903) recorded four genera and seven species in the Guttiferae and two genera and two species in the Hypericaceae, namely *Ochrocarpos, Mesua, Calophyllum* and *Garcinia* in the Guttiferae and *Hypericum* and *Cratoxylum* in the Hypericaceae respectively.

Brandis recorded the taxa in India in his *Indian Trees* in 1907. Six genera and 45 species were recorded for the Guttiferae: *Garcinia, Ochrocarpos, Calophyllum, Poeciloneuron, Mesua* and *Kayea* and two genera and nine species for the Hypericaceae: *Cratoxylum* and *Hypericum*.

The next major floristic work of the region was *Flore Générale de L'Indo-Chine* in which Pitard and Gagnepain recorded the genera and species occurring throughout Indo-China. Five genera and 41 species were recorded for the Guttiferae (*Ochrocarpos, Garcinia, Calophyllum, Kayea, Mesua*) and two genera and eight species for the Hypericaceae (*Hypericum, Cratoxylum*). Pitard described several new species of Guttiferae in this work. The accounts were based mainly on limited material collected by French botanists during the French colonial period.

In 1915, the species found in Madras were recorded in Gamble's *Flora of the Presidency of Madras*. Five genera and 20 species were recorded in the Guttiferae and two genera and six species in the Hypericaceae. The genera for the Guttiferae and Hypericaceae were *Garcinia, Ochrocarpos, Calophyllum, Mesua* and *Poeciloneuron* and *Hypericum* and *Cratoxylum* respectively.

The Botany of Bihar and Orissa was published in 1921 by Haines. He recorded four genera and five species in the Guttiferae (*Garcinia, Ochrocarpos, Calophyllum, Mesua*) and one genus and three species in the Hypericaceae (*Hypericum*).

In Ridley's *Flora of the Malay Peninsula* (1922), there were five genera and 73 species recorded in the Guttiferae (*Garcinia, Ochrocarpos, Calophyllum, Kayea* and *Mesua*) and two genera and six species recorded in the Hypericaceae (*Hypericum* and *Cratoxylum*). Again several new species were described here.

In 1925, Craib listed the species of each family found in Thailand in his *Florae Siamensis Enumeratio*. He listed five genera and 35 species in the Guttiferae (*Garcinia, Ochrocarpos, Calophyllum, Kayea* and *Mesua*) and two genera and nine species in the Hypericaceae (*Hypericum* and *Cratoxylum*) and described two new varieties, one in the genus *Ochrocarpos* and one in the genus *Hypericum*.

In 1943, the Supplement to the *Flore Générale de L'Indo-Chine* was published and Gagnepain recorded four new species in the Clusiaceae and one new species in the Hypericaceae.

In 1963, Backer and Bakhuizen published the *Flora of Java*, with four genera and 17 species in the Clusiaceae and two genera and six species in the Hypericaceae, namely *Mesua, Mammea, Garcinia* and *Calophyllum* in the Clusiaceae and *Hypericum* and *Cratoxylum* in the Hypericaceae.

Ten years later, Whitmore published the *Tree Flora of Malaya*. He recorded four genera and 87 species in the Guttiferae: *Garcinia, Mammea, Calophyllum* and *Mesua*.

Robson, in 1974 described the Hypericaceae for the Malesian Flora in *Flora Malesiana*. He recorded two genera and 21 species: *Hypericum* and *Cratoxylum*. In his treatment, Robson treated the Hypericaceae as a subfamily of the Guttiferae.

In 1974 also, Smith and Darwin wrote an account of the Guttiferae of the Pacific Islands in the Fijian region. They recorded three genera and 16 species: *Calophyllum, Mammea* and *Garcinia*. New species were recorded too.

In 1976 the *Flora of the Hassan District in India* was published. *Hypericum, Garcinia, Calophyllum* and *Mesua* were all recorded under the name of Clusiaceae. Eight species were recorded.

In 1980, the *Flora of Ceylon* was published. Kostermans recorded the 25 species of Clusiaceae found in the region. The genera found included *Garcinia, Calophyllum, Mesua* and *Clusia*.

In 1994, the *Flora of Bhutan* was published. Three genera and eight species were recorded for the Guttiferae (*Mesua, Garcinia* and *Calophyllum*) and one genus and 17 species for the Hypericaceae (*Hypericum*).

Câycò Vietnam was published in 1994. Hô Pham-hoang recorded six genera and 63 species under the name of Guttiferae: *Ochrocarpos, Calophyllum, Garcinia, Mesua,*

Hypericum and *Cratoxylum*. No detail of types or specimens was given in this treatment.

In 1999, the Hypericaceae of Ceylon were published in Volume XIII of the *Flora of Ceylon*. Three species in the genus *Hypericum* were recorded.

In 2007, the *Flora of China* was published. Eight genera and 95 species were recorded and described under Clusiaceae (Guttiferae): *Calophyllum, Mammea, Garcinia, Cratoxylum, Mesua, Hypericum, Lianthus* and *Triadenum.*

1.11 Aims of the project

This study aims to provide a taxonomic revision of the Clusiaceae and Hypericaceae of Thailand.

Detailed aims of this study are:

- To provide information on the general morphology of the two families. See Chapter 2 for a full discussion.
- To resolve the identity of Thai taxa within the two families. This will be discussed in the Taxonomic Treatment chapter (Chapter 3).
- To construct species level descriptions and distribution maps, which will be used to produce an account for these groups for the Flora of Thailand. These will be presented in Chapter 3-Taxonomic Treatment.
- To construct Phylogenetic trees for key members of the Clusiaceae and Hypericaceae families of Thailand. This will be dealt with in Chapter 4-Phylogenetic Analysis.
- To discuss and comment on the phytogeographical distribution and ecology of the Thai taxa in Thailand and surrounding regions. See Chapter 5 for a full discussion.
- To construct an innovative computer-based key to the Thai Clusiaceae and Hypericaceae families, which will be the first of its kind for the region. This key will be presented in CD-ROM format. A history of online databases, their importance, and an introduction to the key will be presented in Chapter 6-Computer-based Key.

- To expand the existing herbarium collections.

Chapter 2

General Morphology

2.1 Introduction

The general morphological characters described here are those used to describe the Thai Clusiaceae and Hypericaceae. The information presented is derived from examined herbarium specimens from Thailand and from various sources cited throughout the chapter. The characters discussed here form the basis for the taxonomic chapter (Chapter 3). Terms used, some of which are specific to the two families of study are explained and where appropriate illustrations are provided to aid explanation.

The Thai Clusiaceae will be dealt with first, followed by the Thai Hypericaceae.

2.2 Thai Clusiaceae – General Morphology

Habit

The Thai Clusiaceae are evergreen. They are generally shrubs (*e.g. Calophyllum rupicolum* Ridley, *Calophyllum pisiferum* Planchon & Triana) or trees. The bole is usually cylindrical and ranges from buttressed (*e.g. Calophyllum* L.) to fluted (*e.g. Mesua ferrea* L.) to straight (*e.g. Mammea* L., *Kayea* Wall.) at the base. The canopy is large and emergent and the size varies significantly from shrubs up to 5m high (*e.g. Calophyllum pisiferum* Planchon & Triana) to large trees up to 45m high (*e.g. Calophyllum sclerophyllum* Vesque). The initial growth of the taxa is monopodial (Stevens, 2007). The branches develop from the axils of the uppermost pairs of leaves and the terminal bud grows out (Stevens, 2007).

Branching

Mammea taxa have stout or unbranched stems and large leaves (Stevens, 2007), whilst the other genera have branched stems and moderate to large leaves.

Bark

The bark surfaces can be broadly categorised as smooth, scaly, rough or fissured. The bark of immature species of *Calophyllum* is usually smooth with diamond-shaped or boat-shaped fissures that gradually change to longitudinal fissures in mature trees (Sangkaew, 1999). The bark in *Mammea, Kayea* and *Mesua* species is usually smooth

to slightly scaly and sometimes irregularly fissured. All Thai genera exude a sap, which varies in colour from the colour of clear honey (*e.g. Calophyllum, Mammea*) to creamy white (*e.g. Calophyllum, Kayea, Mesua ferrea*) to pink-brown (*e.g. Mesua ferrea*). The wood is quite durable and the inner bark is pink or red or rarely brown (*e.g. Mesua ferrea*) in colour. The outer bark varies from grey (*e.g. Calophyllum, Kayea, Mammea*) to brown (*e.g. Calophyllum, Kayea, Mammea*) to red (*e.g. Mesua ferrea*).

Indumentum

The Thai Clusiaceae are generally hairless, although some species of *Calophyllum* have small multicellular hairs on the dorsal side of the outer pair of tepals (*e.g. C. macrocarpum* Hook, f., *C. pisiferum* Planchon & Triana, *C. polyanthum* Wall., *C. sclerophyllum* Vesque, *C. soulattri* Burmann, f., *C. thorelii* Pierre, *C. touranense* Gagnep. ex P.F. Stevens).

Leaves

The leaves are simple, petiolate, opposite and entire. The leaves have slender secondary veins which usually have resin-cavities in between (*e.g. Calophyllum, Kayea, Mesua*). Some have intersecondary (*e.g. Kayea, Mammea*) and tertiary (*e.g. Kayea, Mammea*) venation also. *Calophyllum* taxa usually have an intramarginal vein but this is sometimes embedded in marginal thickening (Stevens, 2007). Figure 2.1 shows the different types of venation found in the Thai Clusiaceae and a definition of each type.

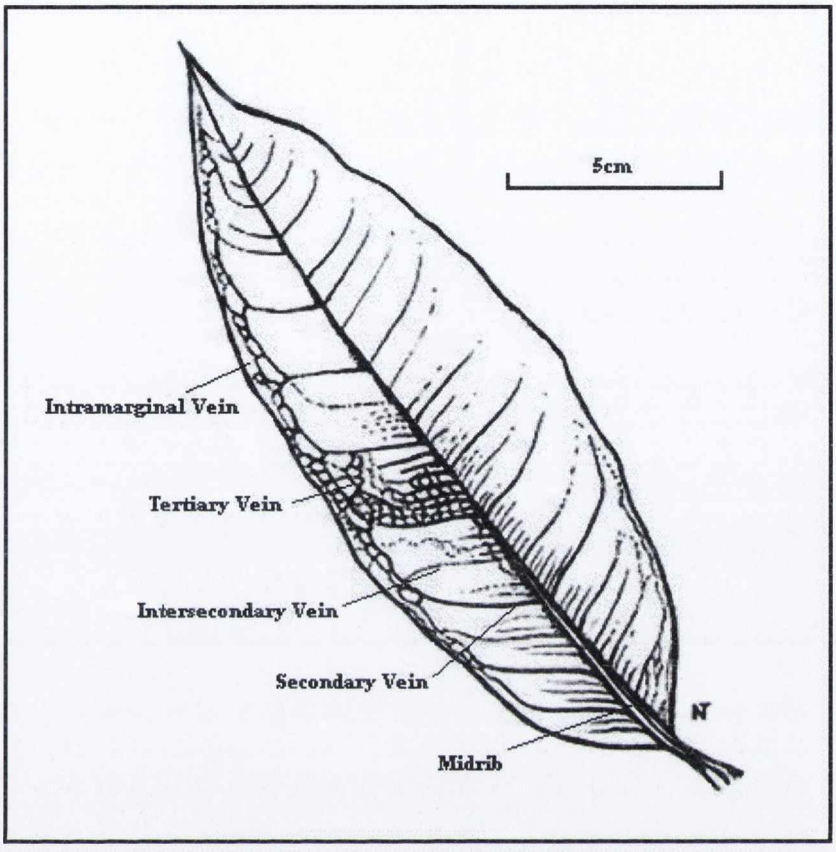


Figure 2.1 Illustration showing leaf venation (leaf from the genus *Kayea*): midrib, secondary, intersecondary, tertiary and intramarginal veins present. (Illustration by Nicole Tilley).

Midrib: the central vein of the leaf. (Harris et al., 2001)

Secondary Veins: veins which are smaller in size than the midrib and which arise from the midrib (Chantaranothai, 1989).

Intersecondary Veins: veins which arise from the midrib and are of moderate size between the secondary and tertiary veins. They generally originate from the midrib and have a course parallel or nearly so to the secondary vein. They sometimes join with a secondary vein (Chantaranothai, 1989).

Tertiary Veins: finer than secondary veins and intersecondary veins and generally apparently run at right angles to the secondary veins (Chantaranothai, 1989).

Intramarginal Veins: defined as the first pair of secondary veins encountered when moving apically from the base of the lamina. They closely parallel the leaf margin and often fuse with secondary veins (Chantaranothai, 1989).

The leaves are coriaceous. *Kayea* taxa are only slightly coriaceous, with some being quite delicate and almost papyraceous. Some are occasionally glaucous (*e.g. Kayea, Mammea, Mesua ferrea*). Figure 2.2 shows an example of the different leaves found in the Thai Clusiaceae.

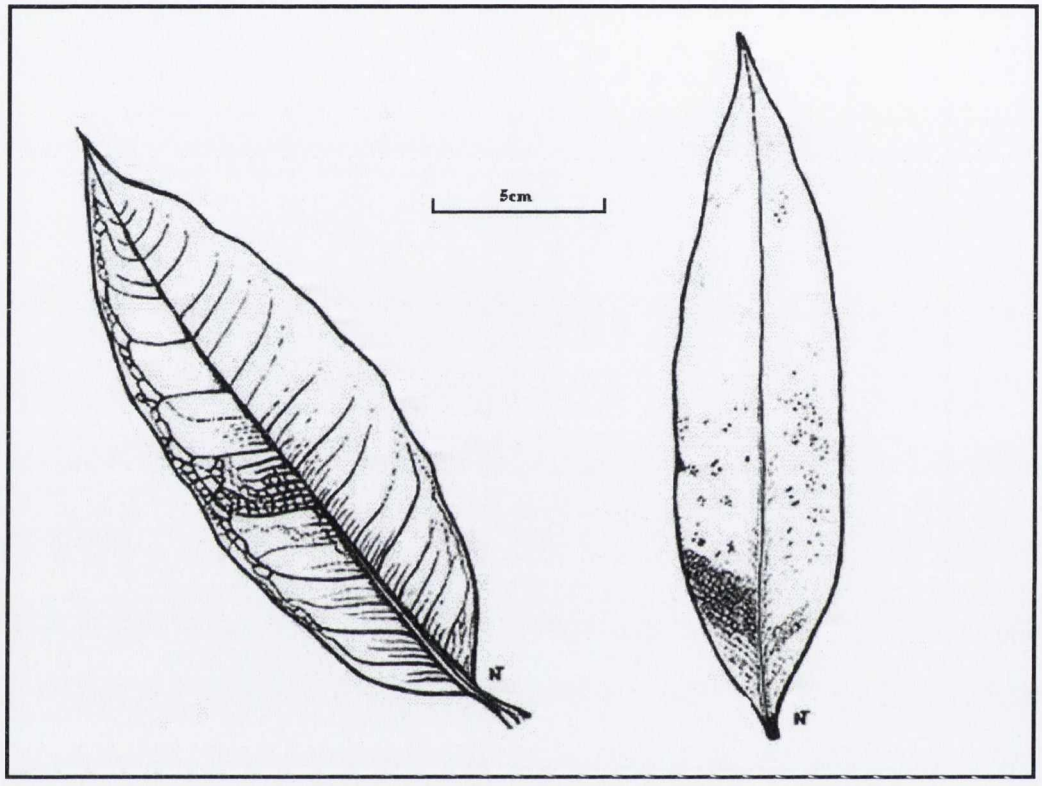


Figure 2.2 Examples of leaves found in the Thai Clusiaceae including *Kayea*, *Mesua*, *Calophyllum* and *Mammea* respectively. (Illustrations by Nicole Tilley).

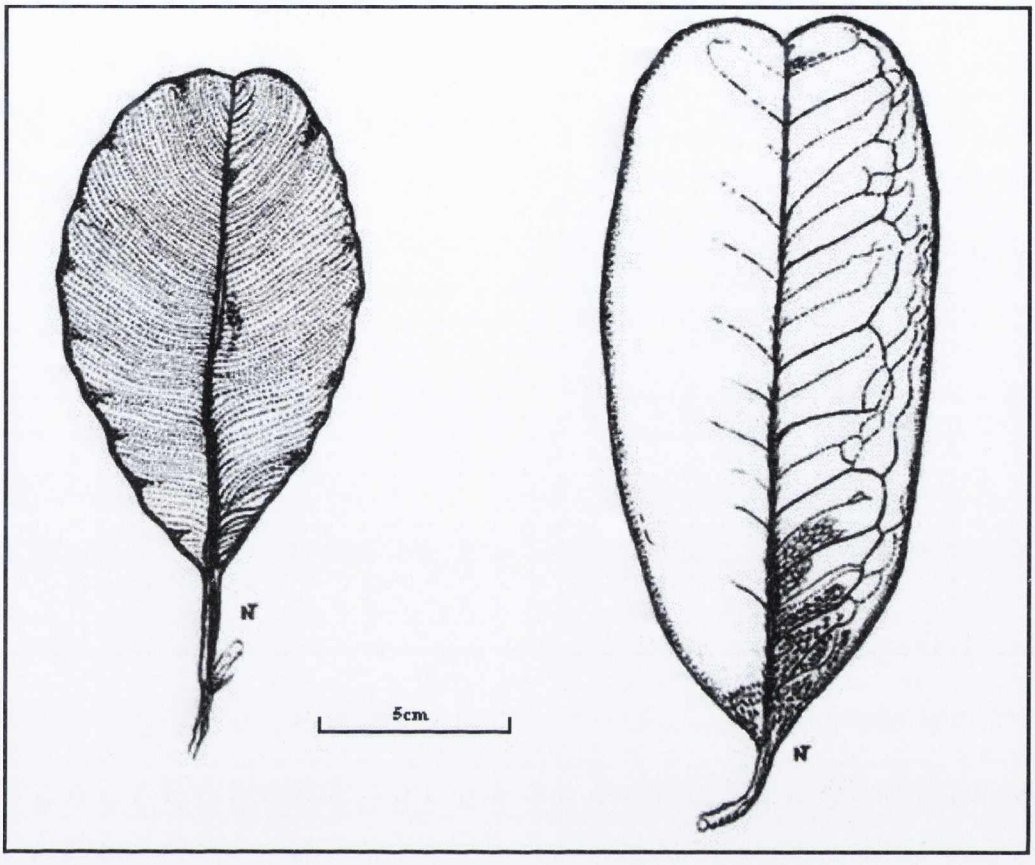


Figure 2.2 continued.

Leaf size is variable: *Calophyllum* and *Mammea* taxa exhibit large leaves up to 30cm long, whilst those of *Kayea* and *Mesua ferrea* are usually less than 15cm long. Leaf size can sometimes vary greatly within a single specimen. Maximum petiole length, lamina length and width were measured for all specimens. Figure 2.3 shows two leaves (from the genera *Kayea* and *Mammea* respectively) with letters corresponding to the length of the petiole and the length and width of the lamina measurements taken respectively.

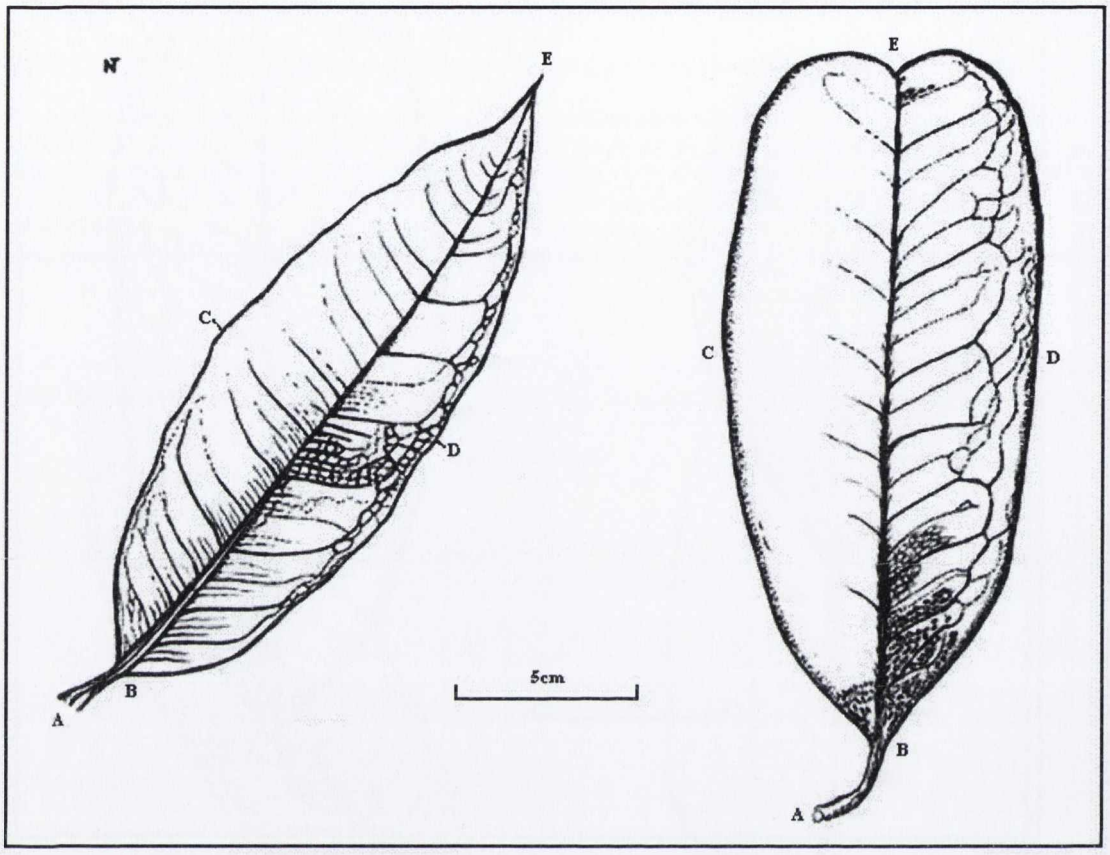


Figure 2.3 Lamina measurements. Distance A-B: Petiole length (mm) (the length from the base of the petiole to the base of the lamina). Distance B-E: Lamina length (cm) (measured along the axis of the midrib). Distance C-D: Lamina width (cm) (the point at the greatest width, measured at right-angles to the axis). (Illustrations by Nicole Tilley).

The leaf shapes are very variable and include the following shapes (definitions from Harris et al., 2001):

Elliptic: in the shape of an ellipse, or a narrow oval; broadest at the middle and narrower at the two equal ends.

Lanceolate: lance-shaped; much longer than wide; with the widest point below the middle.

Oblanceolate: inversely lanceolate, with the attachment at the narrower end.

Oblong: two to four times longer than broad with nearly parallel sides.

Obovate: inversely ovate with the attachment at the narrower end.

Oval: broadly elliptic, the width over one-half the length.

Ovate: egg-shaped in outline and attached at the broad end.

Rotund: round or rounded in outline.

The only leaf shape found in all genera is elliptic leaves. Figure 2.4 shows the various leaf shapes associated with the Thai Clusiaceae.

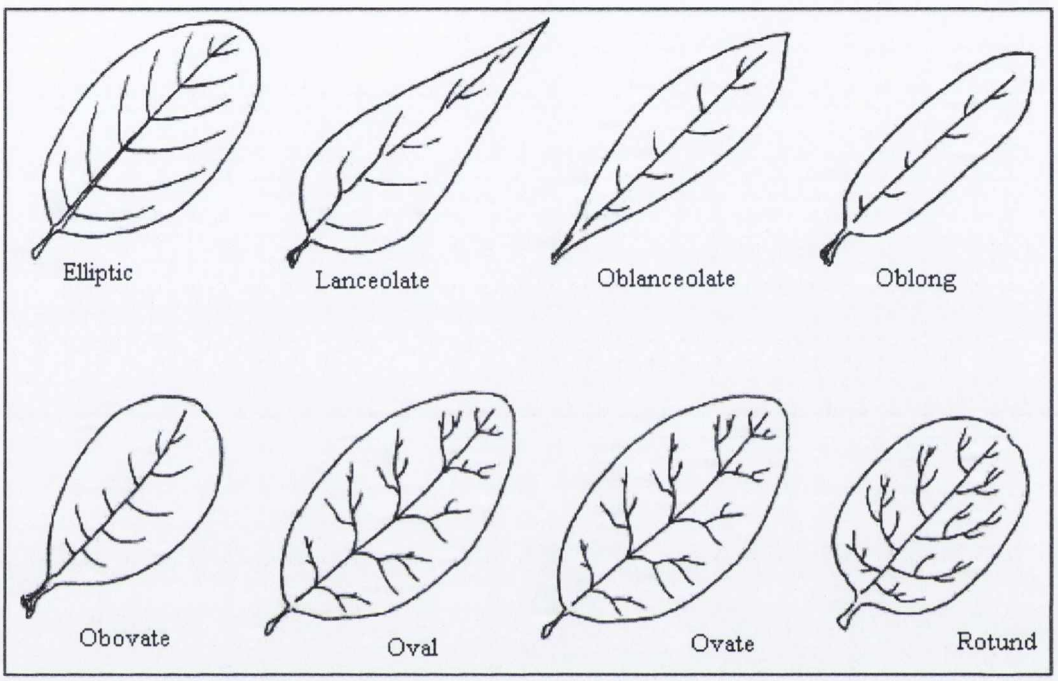


Figure 2.4 Leaf shapes found in the Clusiaceae (Illustrations adapted from Harris et al., 2001).

The leaf apices and bases vary considerably. Apex shapes include (definitions from Harris et al., 2001):

Acute: tapering to a pointed apex with more or less straight sides.

Acuminate: gradually tapering to a sharp point and forming concave sides along the tip.

Cuspidate: tipped with a short, sharp, abrupt point (cusp).

Obtuse: blunt or rounded at the apex; with the sides coming together at an angle greater than 90 degrees.

Retuse: with a shallow notch in a round or blunt apex.

Rounded: with a rounded apex.

Figure 2.5 shows the various leaf apex shapes associated with the Thai Clusiaceae.

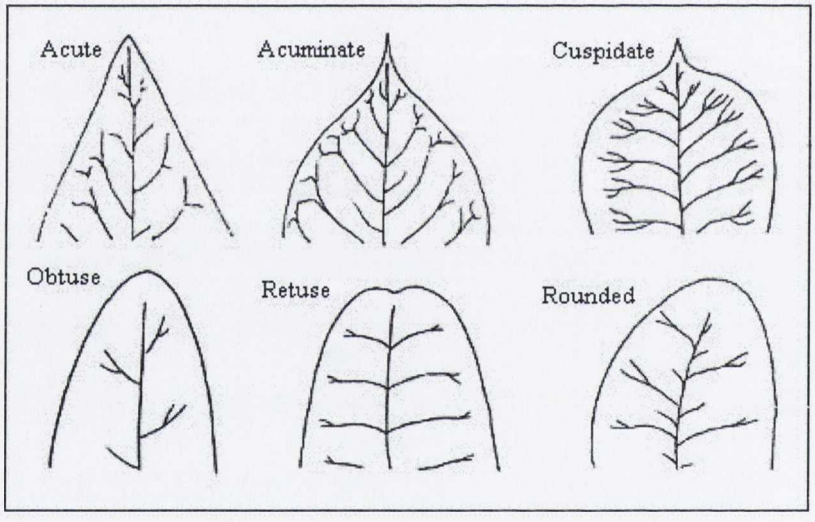


Figure 2.5 Leaf apex shapes found in the Clusiaceae (Illustrations adapted from Harris et al., 2001).

Base shapes include (definitions from Harris et al., 2001):

Acute: tapering to a pointed base with more or less straight sides.

Aequilateral: equal-sided, as opposed to oblique.

Amplexicaul: clasping the stem, as the base or stipules of some leaves.

Attenuate: tapering gradually to a narrow tip or base.

Cordate: heart-shaped, with the notch at the base.

Cuneate: wedge-shaped, triangular and tapering to a point at the base.

Obtuse: blunt or rounded at the base; with the sides coming together at an angle greater than 90 degrees.

Rounded: with a rounded base.

Figure 2.6 shows the various leaf base shapes associated with the Thai Clusiaceae.

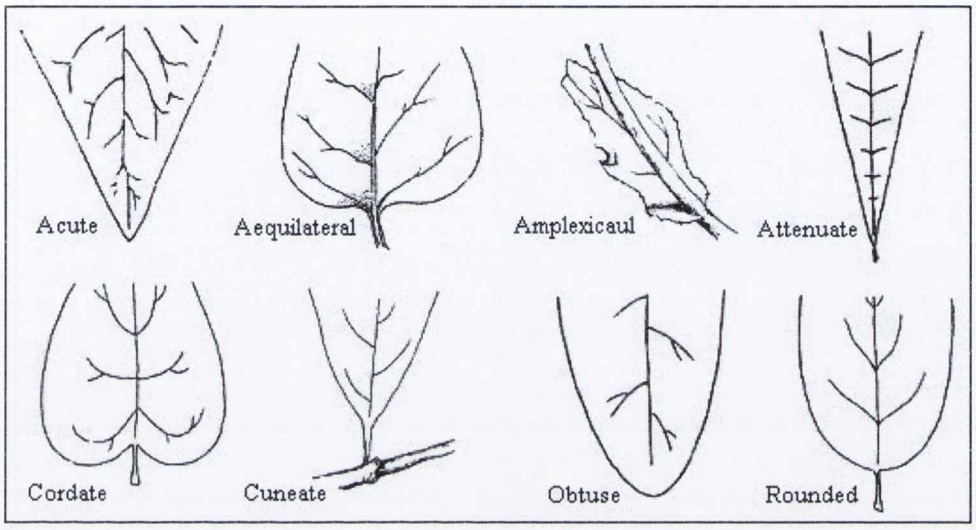


Figure 2.6 Leaf base shapes found in the Clusiaceae (Illustrations adapted from Harris et al., 2001).

The midrib is normally strongly to moderately raised on the lower surface especially in *Calophyllum* taxa and usually only slightly raised or not at all on the upper surface.

Inflorescences and Flowers

The inflorescences occur in the axils of leaves or terminally. They are usually racemes (an unbranched, elongated inflorescence with pedicellate flowers maturing from the bottom upwards), panicles (a branched, racemose inflorescence with flowers maturing from the bottom upwards) or modified cymes (a flat-topped or round-topped determinate inflorescence, paniculate, in which the terminal flower blooms first) and a terminal flower is usually present (definitions from Harris et al., 2001). Some species of *Mammea* have clusters of flowers in the axils of fallen leaves. They can have numerous flowers (*e.g. Calophyllum*), a few large flowers (*e.g. Mammea, Mesua*) or (seldom) solitary flowers (*e.g. Kayea, Mammea, Mesua ferrea*). Figure 2.7 shows the main types of inflorescences that occur in the Clusiaceae.

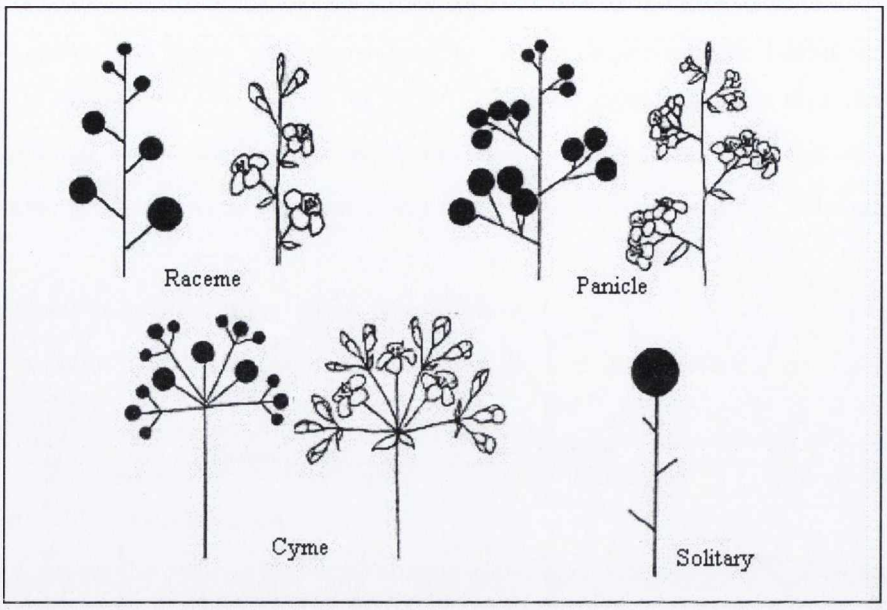


Figure 2.7 Inflorescence types found in the Clusiaceae (Illustrations adapted from Harris et al., 2001).

The sepals and petals can be difficult to distinguish. They have four sepals that are decussate in aestivation or two sepals that are valvate or connate in aestivation (Stevens, 2007). The petal number is four and these have decussate aestivation. Petal numbers in *Mammea* increase by the division of the innermost petals (Stevens, 2007). *Mammea* taxa can have between two to six petals. The tepal number in the genus *Calophyllum* ranges from four to eight. Most are hairless except for the dorsal side of the outermost tepals in some species of *Calophyllum* (*e.g. C. macrocarpum, C. pisiferum, C. polyanthum, C. sclerophyllum, C. soulattri, C. thorelii, C. touranense*). Both the sepals and petals vary in shape and colour. They can be elliptic, rotund or oval (see above for definitions) in shape and are white, pink or pale yellow in colour. Figure 2.8 shows an example of a flower from each Thai genus of Clusiaceae.

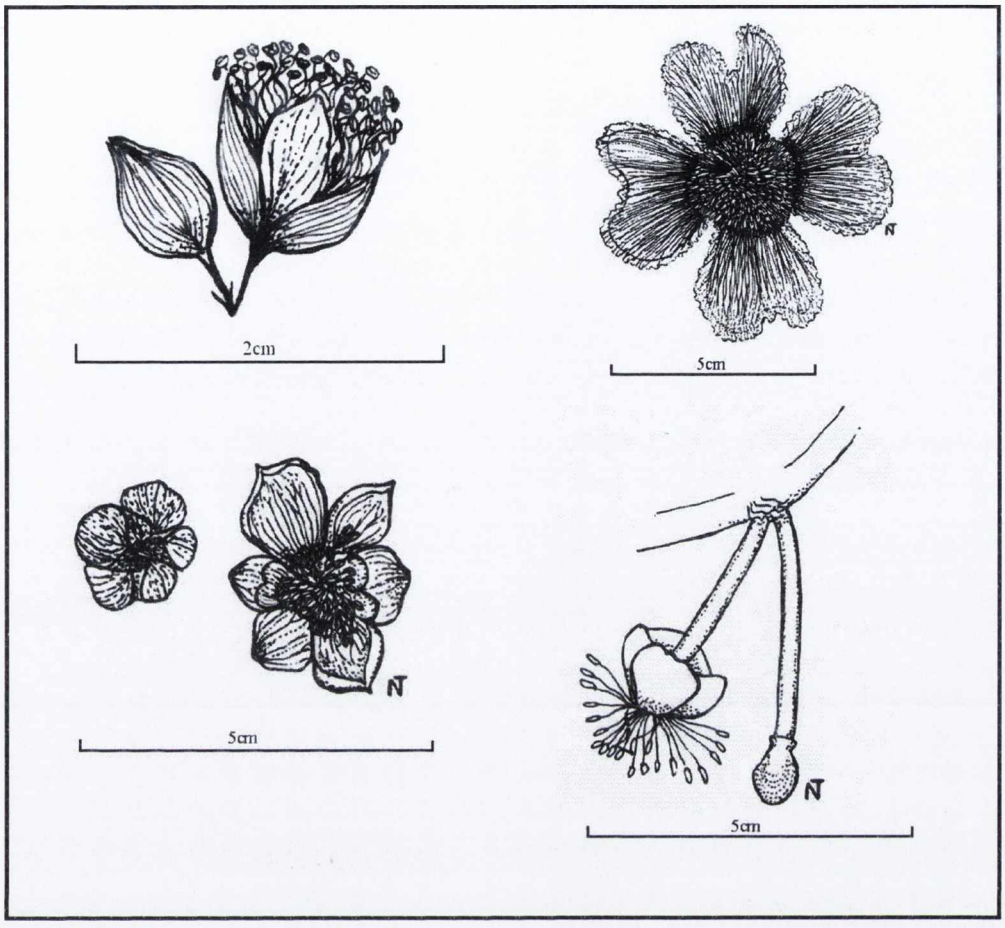


Figure 2.8 Examples of flowers found in the Thai Clusiaceae including *Kayea, Mesua, Calophyllum* and *Mammea* respectively. (Illustrations by Nicole Tilley).

Stamens

They have numerous free stamens (*e.g. Calophyllum, Kayea, Mammea*) or stamens that are arranged in fascicles (*e.g. Kayea*) or basally connate (*e.g. Calophyllum, Mammea, Mesua ferrea*). There are prominent apical anther glands in *Mammea* and *Mesua ferrea*. Dehiscence is vertical in all genera.

Ovary

The ovary is superior and can be one (*e.g. Calophyllum, Kayea*) or two (*e.g. Mammea, Mesua*) –celled, with one (*e.g. Calophyllum*) to four (*e.g. Kayea, Mammea, Mesua*) ovules. When the number of ovules is equal to the number of perianth segments, they are opposite the sepals (Stevens, 2007). They have slender, long styles, which are either peltate (*e.g. Calophyllum, Mammea, Mesua*) or 4-fid (*e.g. Kayea*). *Calophyllum* has several vascular bundles in the style (Stevens, 2007). Placentation is basically axile and

the placentae meet in the middle in *Mammea* and *Mesua* taxa, but not always in *Calophyllum* and *Kayea* taxa (Stevens, 2007).

Fruit

They have capsules that dehisce septicidally or indehiscent fleshy berries or drupes with one to four seeds. *Calophyllum* and *Mammea* have one-seeded fruits and *Mesua* and *Kayea* can have one to four-seeded fruits. Woody testae occur in *Calophyllum* and *Mammea*. Some have a persistent enlarged calyx which encloses the fruit (*e.g. Kayea*, *Mesua ferrea*). The shapes of the fruits vary but are most commonly ovoid, globose or ellipsoid.

Seeds

The seeds are small and usually less than 4mm long. According to Stevens (2007), they have a testa with an epidermis as well as a low lignified exotegmen. They have large well-developed cotyledons (*e.g. Calophyllum*) or reduced cotyledons that have been replaced in function by swollen hypocotyls (Heywood, 1993). Endosperm is absent.

Dispersal Mechanisms

Taxa with small dry seeds are usually winged and can be dispersed by wind. *Calophyllum inophyllum* have heavy seeds and are probably water dispersed. The fruits of *Calophyllum inophyllum* are also eaten by bats and birds and thus dispersed (Stevens, 2007). *Mammea* taxa have large fleshy fruits that attract mammals which probably eat the fruit and disperse the seeds (Stevens, 2007).

Pollination

Entomophily is probably the most obvious way which pollination occurs as they have numerous showy flowers. Nectar-secreting glands are sometimes absent (Rendle, 1925), but other pollinator rewards include pollen and resin, the latter rarely seen outside this family (Gustafsson et al., 2002; Bittrich et al., 1997).

2.3 Thai Hypericaceae – General Morphology

Habit

The Thai Hypericaceae are evergreen or deciduous herbs, shrubs or trees. The annual herbs are found in the genus *Hypericum* L. The Thai *Hypericum* taxa spread by horizontal runners which then become erect or ascending and can grow up to 3m high. In drier regions, *Hypericum* taxa can sprout from lignotubers after times of stress (*e.g.* fire, drought) and species that occur in swamp areas sometimes have swollen roots with air spaces to allow for respiration (Stevens, 2007; Hagemann, 1989). The Thai *Cratoxylum* taxa are usually trees but sometimes shrubs (*e.g. C. chinense* (Retz.) Merr., *C. maingayi* Dyer) and can grow up to 45m high (*e.g. C. arborescens* Blume). The bole is straight and without buttresses.

Branching

The stems are usually terete and in *Hypericum* taxa, fissures can appear on older stems and the cork layer may flake off in long strips. The stem colour varies from green-red when young to brown-black when mature. The branches of *Cratoxylum* taxa tend to be smooth and delicate, with some larger branches having long stout spines.

Bark

The bark surfaces of *Cratoxylum* taxa vary from deeply fissured (*e.g. C. neriifolium* Kurz, *C. chinense* (Retz.) Merr.) to roughly cracked and flaking (*e.g. C. arborescens* Blume, *C. formosum* (Jack) Dyer, *C. maingayi* Dyer, *C. neriifolium* Kurz). The bark of some *Cratoxylum* taxa (*e.g. C. formosum* (Jack) Dyer) have short sharp projections. The exudate is a yellow resinous sticky sap that dries a deep blood red colour, or occasionally white. The inner bark is brown (*e.g. C. maingayi*), reddish-brown (*e.g. C. arborescens*) or white (*e.g. C. chinense*) and the outer bark is brown (*e.g. C. arborescens, C. chinense*) or black (*e.g. C. neriifolium*).

Glands

Glands or canals are present in most parts of the plant especially in the genus *Hypericum* (see Figure 2.9). These are spherical or elongate schizogenous (formed by the splitting or separation of tissue) glands and canals (Cicarelli et al., 2001a).

Indumentum

The Thai genera are all hairless except for *C. formosum* (Jack) Dyer subsp. *pruniflorum* (Kurz) Gogelein which has small orange or brown hairs present on the stems and underside of leaves.

Leaves

The leaves are simple, sessile, subsessile or petiolate, opposite, whorled or alternate and entire. They have well-developed midribs and can have secondary, intersecondary and tertiary veins. The venation can be faint or apparent and is variable from leaf to leaf. Figure 2.9 illustrates the various leaf and venation types found in the Thai Hypericaceae (see Figure 2.1 above for venation names and definitions).

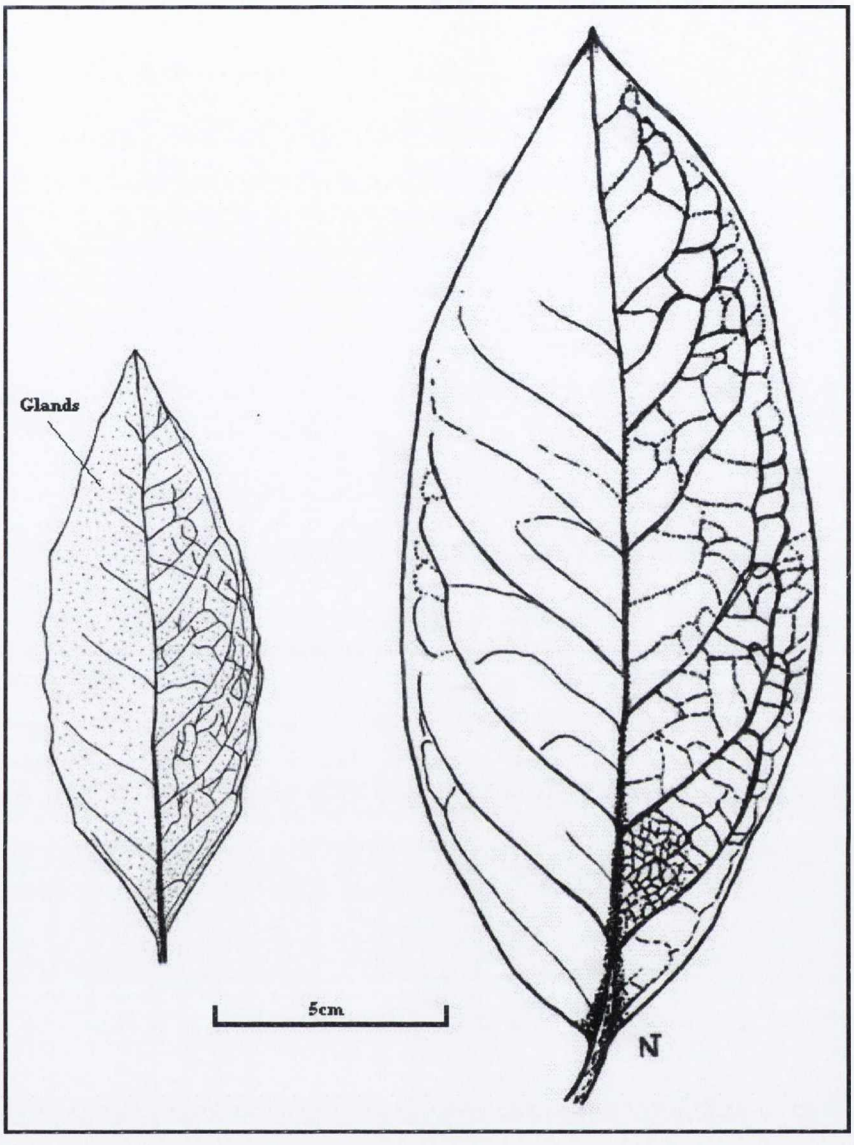


Figure 2.9 Leaf venation types in the Thai Hypericaceae (*Hypericum* and *Cratoxylum* respectively) showing prominent glands present on the *Hypericum* leaf. (Illustrations by Nicole Tilley).

The leaves are usually papyraceous and sometimes quite delicate. In *Hypericum* taxa, the underside is sometimes glaucous. In general, the leaves are moderate or sometimes small. Leaves are shorter than 16cm and no wider than 6cm. The length of the petiole (if present) varies from 0.2-1cm long. Maximum petiole length, lamina length and width were measured for all specimens. Figure 2.3 (page 34) shows the various lamina measurements that were taken.

The leaf shape is variable. They include: elliptic, lanceolate, oblanceolate, oblong, obovate, oval, ovate and rotund (see Clusiaceae Leaves section above for definitions). Elliptic leaves are found in both genera of Thai Hypericaceae. Figure 2.10 shows the various leaf shapes associated with the Thai Hypericaceae.

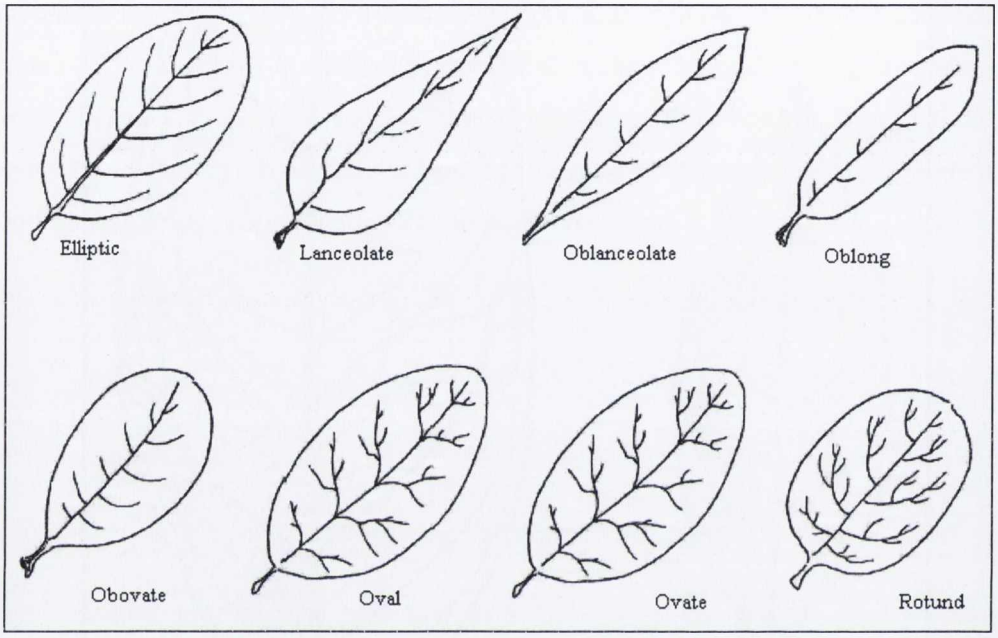


Figure 2.10 Leaf shapes found in the Hypericaceae. (Illustrations adapted from Harris et al., 2001).

The leaf apices and bases vary also. Figures 2.11 and 2.12 show the shape of leaf apices and bases respectively associated with this family. Apex shapes include: acute, acuminate, cuspidate, obtuse, rounded and base shapes include: acute, amplexicaul, attenuate, cordate, cuneate, and rounded (see Clusiaceae Leaves section above for definitions).

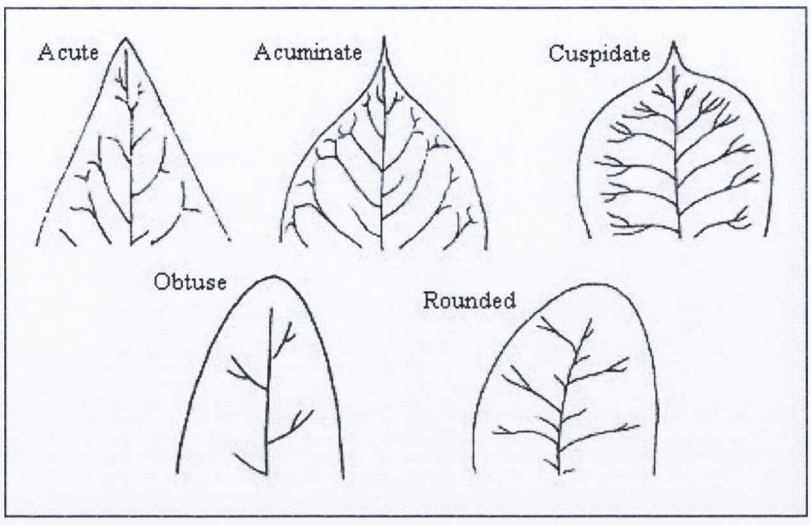


Figure 2.11 Leaf apex shapes found in the Hypericaceae. (Illustrations adapted from Harris et al., 2001).

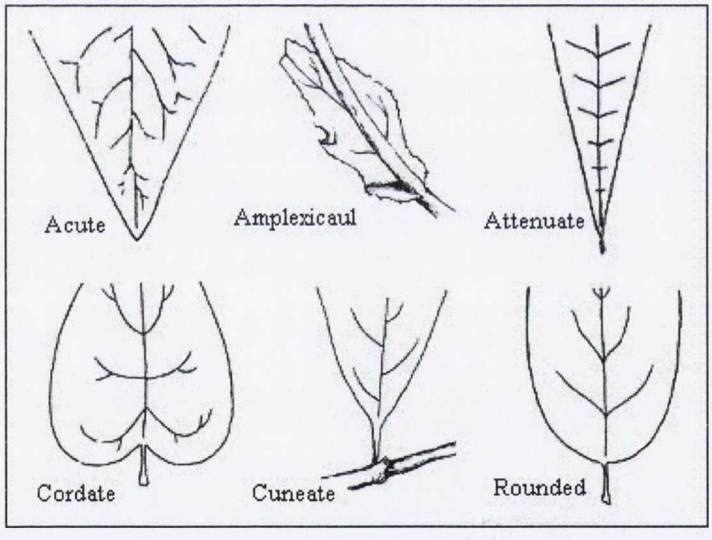


Figure 2.12 Leaf base shapes found in the Hypericaceae. (Illustrations adapted from Harris et al., 2001).

Inflorescences and Flowers

The inflorescences in the Hypericaceae are usually umbellate, paniculate, corymbose or cymose. They can be axillary or terminal and always have a terminal flower. The flowers can be in groups of three's (*e.g. Cratoxylum, Hypericum*), or there can be as many as 30 flowers in a terminal inflorescence (*e.g. Hypericum*) or occasionally the

flowers can be solitary (*e.g. Hypericum*). Figure 2.13 shows the main types of inflorescences that occur in the Hypericaceae. They include umbels (a flat-topped or convex inflorescence with the pedicels arising more or less from a common point, like the straits of an umbrella), panicles (a branched, racemose inflorescence with flowers maturing from the bottom upwards), corymbs (a raceme or panicle in which the flowers that arise from lower down on the axis have longer stalks than those that arise higher up, so that all the flowers are brought to about the same levels and the inflorescence has a flat top) and cymes (a flat-topped or round-topped determinate inflorescence, paniculate, in which the terminal flower blooms first) (definitions from Harris et al., 2001).

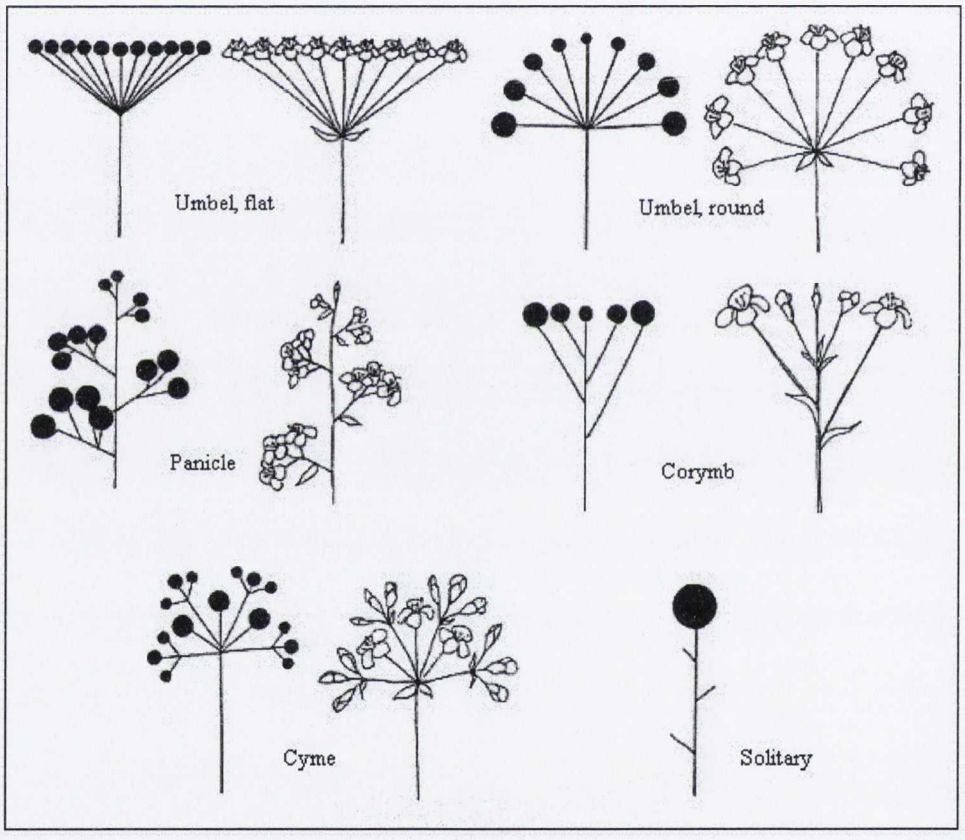


Figure 2.13 Inflorescence types found in the Hypericaceae (Illustrations adapted from Harris et al., 2001).

There are normally a lot of flowers present and some *Cratoxylum* taxa have flowers borne in clusters on old leafless twigs. The sepals and petals are always present and free. The Thai taxa have five sepals and five petals. The five sepals are quincuncial in

aestivation and contorted. The sepals are persistent, imbricate and coriaceous. Some have serrated edges due to the presence of gland-tipped teeth (*e.g. Hypericum*). The five petals are contorted. These are sometimes dotted with black glands (*e.g. Hypericum*) and are caducous to subpersistent. Both the sepals and petals vary in colour. The sepals are usually green and the petals are yellow (*e.g. Hypericum*), pink, red or white (*e.g. Cratoxylum*) in colour. Figure 2.14 shows an example of a flower from each Thai genus of Hypericaceae.

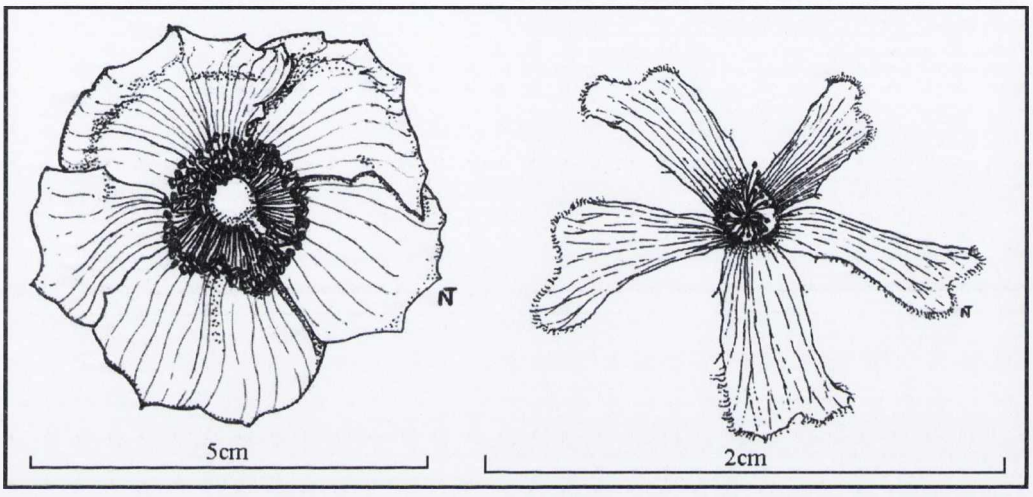


Figure 2.14 Examples of flowers found in the Thai Hypericaceae including *Hypericum* and *Cratoxylum* respectively. (Illustrations by Nicole Tilley).

Stamens

The Thai Hypericaceae have numerous stamens. They are fasciculate, usually in three to five antepetalous fascicles. Dehiscence is longitudinal. The filaments are long and slender and the anthers are oblong or round. They are shorter than the petals and are usually the same colour as the petals with brown dots occasionally present on the connective (*e.g. Cratoxylum*).

Ovary

The ovary is superior and one to three-celled. It can have from four to an infinite number of ovules. There are two to five long, free styles. Placentation is basically axile in *Cratoxylum* and it varies from axile to parietal in *Hypericum* (Stevens, 2007). The stigmas are more or less punctate and the surface of the stigma is occasionally papillate or more often smooth (Shivanna et al., 1989).

Fruit

The fruits are capsular and dehisce loculicidally or septicidally (Hutchinson, 1973) or are sometimes many-seeded berries (*e.g. Hypericum*). They can have persistent calyces (*e.g. Cratoxylum*).

Seeds

The seeds are usually winged. They have an erect white embryo with thin free cotyledons (Heywood, 1993). The seed coat consists of a testa with a thin-walled epidermis that often contains tannins (Stevens, 2007). The endosperm usually persists as a thin layer around the embryo (Stevens, 2007).

Dispersal Mechanisms

Taxa with small winged seeds are wind dispersed and animals disperse those with fleshy berries or drupes.

2.4 Scanning Electron Microscopy Analysis of the Leaf Surfaces of the *Calophyllum* taxa

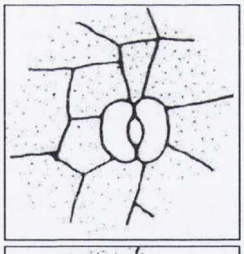
Scanning electron microscopy was carried out on the leaf surfaces of 75 specimens from the genus *Calophyllum*. A representative for each Thai species was included in the analysis (except *Calophyllum symintonianum* M.R. Henderson & Wyatt-Smith). Where possible, replicates of each species were included. The analysis was performed in order to see if the leaf surfaces varied significantly between species. This was done because this genus can be difficult to identify to species level with complete confidence.

Two images of each leaf surface were taken at X50k and X300k. A third image at 1.2k was also taken if stomata were present in order to see them more clearly.

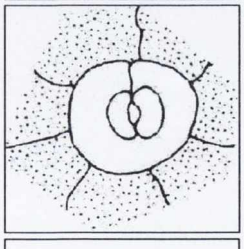
An analysis of the leaf surfaces was carried out and various characters were scored in the form of presence or absence. Table 2.1 shows the characters used in the analysis. See Appendix 1 for the completed matrix and the scores received by each species represented in the analysis.

Table 2.1 Characters used in scanning electron microscopy leaf analysis.

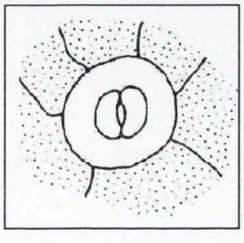
	Character	1	0
1	Upper surface Stomata	Present (1)	Absent (0)
2	Lower surface Stomata	Present (1)	Absent (0)
3	Upper surface Anomocytic Stomata[1]	Present (1)	Absent (0)
4	Lower surface Anomocytic Stomata	Present (1)	Absent (0)
5	Upper surface Desmocytic Stomata[2]	Present (1)	Absent (0)
6	Lower surface Desmocytic Stomata	Present (1)	Absent (0)
7	Upper surface Pericytic Stomata[3]	Present (1)	Absent (0)
8	Lower surface Pericytic Stomata	Present (1)	Absent (0)
9	Upper Surface Wax	Present (1)	Absent (0)
10	Lower Surface Wax	Present (1)	Absent (0)
11	Upper Surface Veins	Present (1)	Absent (0)
12	Lower Surface Veins	Present (1)	Absent (0)
13	Upper Surface Veins	Prominent (1)	Faint (0)



1 Anomocytic Stomata (Illustrations adapted from Stace, 1989)



2 Desmocytic Stomata (Illustrations adapted from Stace, 1989)



3 Pericytic Stomata (Illustrations adapted from Stace, 1989)

Table 2.1 continued

	Character	1	0
14	Lower Surface Veins	Prominent (1)	Faint (0)
15	Upper Surface Composition	Rough (1)	Smooth (0)
16	Lower Surface Composition	Rough (1)	Smooth (0)
17	Upper Surface: Dotted[4]	Present (1)	Absent (0)
18	Lower Surface: Dotted	Present (1)	Absent (0)
19	Upper Surface: Aciculated[5]	Present (1)	Absent (0)
20	Lower Surface: Aciculated	Present (1)	Absent (0)
21	Upper Surface: Lacunose[6]	Present (1)	Absent (0)
22	Lower Surface: Lacunose	Present (1)	Absent (0)
23	Upper Surface: Pitted[7]	Present (1)	Absent (0)
24	Lower Surface: Pitted	Present (1)	Absent (0)

2.5 Methods

Winclada Methods

On completion of character scoring, the data were imported into WinClada version 1.00.08. WinClada (Nixon, 2002) is a computer software package that allows the user to input data and to produce cladograms (phylogenetic trees) and map character changes onto it.

On opening WinClada, the dataset was opened as a Winc file. The data were analysed using the following parameters:

The Analyze tab was selected. Ratchet (Island Hopper) was then chosen and the parameters used were as follows: 200# of iterations/rep

1# Trees to hold/iteration

1# Characters to sample

x1 Stemname for Files

[4] Dotted – minute impressions
[5] Aciculated – fine irregular streaks
[6] Lacunose – numerous large deep excavations
[7] Pitted – numerous small shallow depressions or excavations (Definitions from Lindley, 1848)

Under Optional Settings, amb.poly = (default), 10 Random Constraint Level and 0 Random Seed No. were selected and under Multi Ratchet Settings, No. of sequential ratchet runs was set to 10 and No. of simultaneous threads was set to 1.

When the Island Hop analysis was complete, a consensus tree was chosen. This was done as follows:

The Trees tab was selected and under Trees, Consensus Comprise>Consensus (Strict) was chosen.

The Nodes tab was then selected and under Nodes, Calculate frequency of nodes was chosen. The UNselected trees only option was ticked and this produced the resulting consensus tree shown in Appendix 2.

SPSS and DataDesk Methods

Another analysis of the leaf surfaces was carried out using SPSS 14.0 (SPSS Inc., 2005) and DataDesk 6.1 (Velleman, 1992) to investigate if any patterns of similarity between species emerged using these statistical techniques. Non-metric multidimensional scaling was carried out as this statistical technique allows the pattern of proximities (*i.e.* similarities or differences) to be visually represented as clusters and dimensions and thus easy to interpret.

The data from Appendix 1 were imported into SPSS and an individual analysis was carried out on each group of species replicates and the average figure obtained for each species was used in the final analysis. The parameters set for the analysis were as follows:

Analyze > Scale > Multidimensional Scaling (PROXSCAL)

The proximities were created from the data

Model: Interval with a minimum and maximum of 3 dimensions

Restrictions: No restrictions

Options: Initial Configuration > Multiple Random Starts: 500

Iteration Criteria: Stress Convergence: 0.0005

Minimum Stress: 0.0005

Maximum Iterations: 1000

Measure: Binary > Lance & Williams

The results were then imported into DataDesk where a three-dimensional plot was drawn (Figure 2.15).

2.6 Results and Conclusions

WinClada Results

The tree produced by WinClada was of no significant value (See Appendix 2 for the tree produced by WinClada). Replicates of the same species did not cluster together and no pattern emerged highlighting groups of species that may have similar leaf surfaces. It showed that the characters are variable within a species and among species. The results are not phylogenetically informative due to variation within a species.

SPSS and Datadesk Results

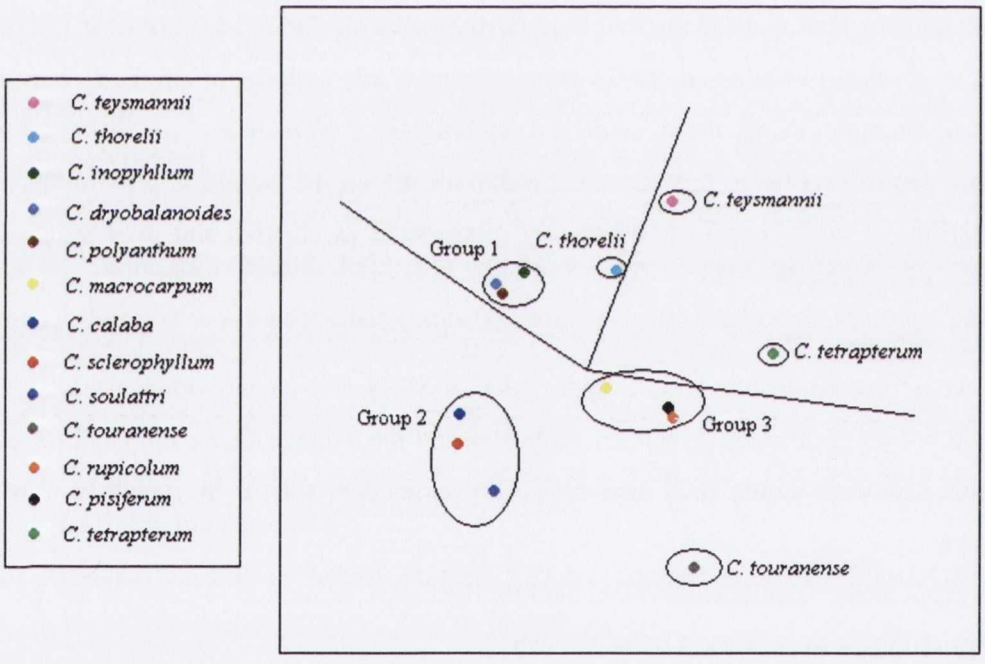


Figure 2.15 Three-dimensional plot of NMS of *Calophyllum* leaf surface characters showing the groups of Thai *Calophyllum* species that are most similar to one another. (Stress-1: 0.08929).

I have divided Figure 2.15 into groups. The groups consist of species that cluster closely together. From the above figure, it can be seen that there are three groups: Group 1 consists of *C. inophyllum*, *C. dryobalanoides* and *C. polyanthum*, Group 2

consists of *C. calaba*, *C. sclerophyllum* and *C. soulattri* and Group 3 consists of *C. macrocarpum*, *C. pisiferum* and *C. rupicolum*. Four species do not cluster with any other species or groups, namely *C. thorelii*, *C. teysmannii*, *C. tetrapterum* and *C. touranense*. The clustering of species is based on the similarities between the leaf surfaces.

It can be seen that the species which cluster together are more similar to each other based on the characters of the leaf surfaces (see Table 2.1 above). *Calophyllum touranense* appears to differ the most in terms of leaf surface as this species does not cluster with any of the groups and is most distantly placed in the plot compared to the other species' points. *Calophyllum tetrapterum* and *C. teysmannii* are found in the same plane but do not cluster close to each other. The species in Group 1 (*C. inophyllum*, *C. dryobalanoides* and *C. polyanthum*) appear to be the most similar as the points are positioned close to one another. *Calophyllum pisiferum* and *C. rupicolum* in Group 3 are very similar as the points slightly overlap indicating a high degree of similarity between the species based on the leaf characters.

Figure 2.15 shows there are some species of Thai *Calophyllum* that are more similar to one another based on the leaf surface characters (*e.g. Calophyllum pisiferum* and *Calophyllum rupicolum*).

However, the above figure is based on an average value obtained for each species and the variability within a species is not taken into account. Because of the variability within a species, the above result is only an approximate indication of similarity between species.

2.7 General Conclusions

Clusiaceae

The bark exudate is an important character in the Clusiaceae as well as the presence of the multicellular hairs only found in the genus *Calophyllum*. The sepal and petal number can help identify a member of this family to genus level, as can the number of cells and ovules in the ovary. Some characters are more obvious in living plants and should be recorded in the field to make the information available for other botanists. These characters include the sepal and petal colour, the arrangement of flowers in

inflorescences, the bark colour and texture and detailed general information on the ecological habitat.

Hypericaceae

The habit is an important character to identify between genera in this family. The bole is an important identification character for *Cratoxylum* as many taxa have short, sharp, pointed projections present along the bole which help one to recognise this genus in the field. The presence of glands or canals is useful to aid identification as these are usually present on the leaves and can be easily seen in the light. In the field, characters such as sepal and petal colour, the texture and presence/absence of the projections on the bole of *Cratoxylum* taxa should be recorded. Also the leaf colour can aid in identifying taxa as some are green and some are red. This character is useful in the field too. Ecological habitat is quite an important tool for identifying the *Hypericum* taxa as members of this genus usually grow in exposed, rocky places at high altitudes. Therefore a detailed description of ecological habitat should be recorded for all taxa.

Chapter 3

Taxonomic Treatment

3.1 Introduction

This chapter aims to provide a taxonomic revision of the Thai Clusiaceae and Hypericaceae.

3.2 Materials and Methods

This study was undertaken at the Herbarium in the Botany Department at Trinity College Dublin, Ireland. Approximately 2,345 specimens were examined from herbaria worldwide including (Abbreviations taken from Holmgren, et al., 1998 [continuously updated]:

Arnold Arboretum, Harvard University, Massachusetts, USA (**A**); Herbarium Jutlandicum, Botanical Institute, University of Aarhus, Denmark (**AAU**); Herbarium, Plant and Soil Science Department, University of Aberdeen, Scotland, UK (**ABD**); Botanischer Garten und Botanisches Museum Berlin-Dahlem, Zentraleinrichtung der Freien Universitat Berlin, Berlin, Germany (**B**); Bangkok Herbarium, Botany and Weed Science Division, Department of Agriculture, Bangkok, Thailand (**BK**); Forest Herbarium, National Park and Wildlife and Plant Conservation Department, Bangkok, Thailand (**BKF**); Herbarium, The Natural History Museum, London, UK (**BM**); Herbarium, Botanical Museum and Library, University of Copenhagen, Denmark (**C**); Herbarium, Faculty of Pharmacy, Chiang Mai University (**CMU**); Herbarium, Royal Botanic Garden Edinburgh, Scotland, UK (**E**); Herbarium, Conservatoire et Jardin botaniques de la Ville de Genève (**G**); Herbarium, Royal Botanic Gardens, Kew, London, UK (**K**); Faculty of Science. Khon Kaen University, Thailand (**KKU**); Nationaal Herbarium Nederland, Leiden University, Netherlands (**L**); William and Lynda Steere Herbarium, New York Botanical Garden, New York, USA (**NY**); Herbier, Departement de Systematique et Evolution, Museum National d'Histoire Naturelle, Paris (**P**); Herbarium, Biology Department, Prince of Songkhla University (**PSU**); Herbarium, Queen Sirikit Botanic Garden (**QBG**); Herbarium, Singapore Botanic Gardens, Singapore (**SING**); the Herbarium, Department of Botany, Trinity College Dublin (**TCD**); Nationaal Herbarium Nederland, Utrecht University branch (**U**); Museum of Evolution, Botany Section (Fytoteket), Uppsala University, Sweden (**UPS**).

Plant Identification and Determination Methods

As two entities are never exactly the same, it is critical to determine the characteristics or boundaries for the taxon in question. When considering the possible taxa, one must evaluate the diagnostic characterisation of each taxon. This is a listing of all the features of a taxon that distinguish it from all other taxa (Simpson, 2006).

In order to identify each herbarium specimen to species level, the following methods were adopted:

1. Written descriptions

   Each herbarium specimen was compared with written descriptions of the possible known taxa. This method allows for the range of variation of the unknown plant specimen to be taken into account. This method is time-consuming as it involves reading all of the available written descriptions in floras and monographs in the distribution range for the families in question.

2. Specimen Comparison

   The label on each herbarium specimen was covered and that specimen was then placed under a taxon name based on the characters associated with that taxon name and the corresponding matching characters associated with each individual specimen. This is a very useful method of identification, as many features of a plant (*e.g.* colour, surface textures) are often not adequately described in descriptions or visible from photographs or illustrations (Simpson, 2006). When the possible taxa names were applied to the specimens, these were then verified with the available descriptions in the floras and monographs.

3. Image Comparison

   Any available images of verified type specimens were viewed and specimens that I had already placed under a taxon name were then compared to the photograph or illustration of the verified type specimen.

Descriptions

All descriptions given are based on observations made from herbarium material (See Character List below) and living plants observed while in the field (Table 3.1 below). Dimensions used are based on herbarium specimens and living plants measured in the field. For dry specimens, flowers were softened in water before measurements were taken. Vernacular names and geographical information were taken from specimens and literature. Ecological information was taken from specimens, from field observations and from literature. See Character List (page 57) for a full list of measurements taken from each herbarium specimen and Table 3.1 for a full list of measurements taken from living material in the field respectively.

Distribution maps are provided. These were done using Arc-GIS 9, Version 9.1. Maps show the distribution of all species in Thailand. The co-ordinates of localities used have been taken from label data, and in the cases where only Changwat (province) names have been provided, a co-ordinate point is mapped in that Changwat to show the presence of the specimen.

All specimens cited after each description have been seen. These specimens are arranged by floristic region, then by province number and finally by collector number.

The majority of floras and publications in SE Asia have been cited and synonyms found in these works have been verified and cited.

All types that have been seen are indicated by (!) after the herbarium abbreviation. Where a new lectotype has been chosen, this is indicated after the designated specimen.

All abbreviations used regarding book or periodical titles and author citations follow 'The International Plant Names Index' (2008). Any abbreviations not found on the website were abbreviated according to abbreviations most commonly found in botanical literature.

Character List

References

Type:

Description

Habit Size, shape, texture, colour (inner and outer bark), latex present/absent. ***Branchlets*** size, shape, texture, colour, scars present/absent. ***Leaves*** petioled/not petioled, length petiole, blade-colour, texture, raised etc., colour of leaf, texture of leaf, shape of leaf, size, base shape, apex shape, venation detail: secondary, intersecondary, tertiary and intramarginal veins, curling of leaf edges. ***Inflorescence*** shape, pedicel length, shape of branch, number of flowers present. ***Calyx*** number present, colour, shape, size, texture, any markings, persistent/caducous. ***Corolla*** number present, colour, shape, size, texture, any markings, persistent/caducous. ***Stamens*** number per fascicle, shape, size, colour, distinguish between filament and anther. ***Ovary*** shape, size, colour, texture, style description-stigma. ***Fruit*** shape, size, texture, colour, type (i.e. capsule that splits, fleshy etc.), persistent style/stigma. ***Seeds*** number, shape, size, colour, texture.

Distribution: Thailand and worldwide.
Phenology:
Ecology:
Altitude:
Uses:
Local name:
Observations: Any additional pieces of information not mentioned under uses

THAILAND
Distribution in Thailand – Location by floristic region, changwat and area (if known), collector name, number and herbarium.

Fieldwork took place over a ten-week period from February to May 2007. During field work eight Thai National Parks, two Wildlife Sanctuaries, three Botanical Gardens and various other areas (*e.g.* arboreta, waterfalls, dams) were visited. Fieldwork was carried out in all floristic regions of Thailand except the Eastern floristic region and where possible collections were made from all of these regions. All species found were studied in their natural habitats and taxonomic and ecological information was gathered. See Table 3.1 for a full list of information gathered for each specimen. In total, 28 specimens were collected. New collections were made for the following two Changwat: Chachoengsao (Clusiaceae) and Trat (Clusiaceae). Table 3.2 provides a list of the provinces and locations visited during the ten-week field trip to Thailand.

Table 3.1 Taxonomic and ecological information gathered for each specimen during fieldwork

Measurements taken in field
Habit and Branchlets
Height
Diameter at breast height (DBH)
Buttressed or not
Bark colour, texture, thickness
Wood hardness, colour
Fissures present/absent
Scars present/absent
Exudate colour, consistency
Internode length
Thorns/spines/sharp projections present/absent
Leaves
Deciduous/evergreen
Texture
Colour
Coriaceous or not
Size
Hairy or not
Canals or glands present/absent
Shape
Petiolate or sessile (length if petiolate)
Venation detail

Table 3.1 continued.

Inflorescence
Shape
Pedicel length
No. of flowers present
Inflorescenc type
Flowers
Persistent/Caducous
Scent
Corolla colour, texture, shape, size
Calyx colour, texture, shape, size
Canals or glands present/absent
Phenology
Pollinators present/absent
Stamens
No. per fascicle
Anther shape, size, colour
Anther and filament distinguishable or not
Ovary
Shape
Size
Colour
Texture
Stigma shape, size, colour
Fruit & Seeds
Number
Colour
Texture
Size
Shape
Seed-coat colour, texture
Aril colour, texture
Dispersal
Local name
Uses
Habitat
Additional Observations

Table 3.2 List of the provinces and areas visited in Thailand for collecting.

Province	Place Visited	Approximate Longitude & Latitude	
Northern			
Chiang Mai	QBG Botanic Gardens		
	Doi Inthanon National Park	18.35N	98.29E
North-Eastern			
Loei	Phu Rua National Park	17.29N	101.20E
Khon Kaen	Ubon Rattana Dam	16.45N	101.37E
	Phu Taga National Park	16.41N	102.37E
South-Western			
Kanchanaburi	Erawan National Park	15.06N	99.02E
	Thong Pha Phum National Park	15.03N	98.07E
	Sai Yok Noi Falls National Park	15.08N	99.01E
Central			
Nakhon Nayok	Khao Yai National Park	14.15N	101.22E
South-Eastern			
Sa Kaeo	Khao Chakan Arboretum	13.55N	102.10E
Chon Buri	Ang Ruenai Wildlife Sanctuary	12.35N	101.51E
Chanthaburi	Khao Soi Dao Wildlife Sanctuary	13.20N	102.30E
Trat	Namtok Klong Kaeo National Park	12.37N	102.34E
Peninsular			
Trang	Thung Khai Botanic Gardens		
	Khao Chong Botanic Gardens		
	Soi Yung Waterfall	7.33N	99.24E
	Ton Tae Waterfall	7.35N	99.90E

The Clusiaceae will be described first, followed by the Hypericaceae.

Taxonomic Account

3.3 Clusiaceae Lindl. Results

Evergreen trees or shrubs with canals or glands present in all parts of the plant; usually hairless; uni/multicellular hairs sometimes present. ***Leaves*** opposite, alternate or whorled. ***Inflorescences*** axillary or terminal, sometimes comprise single flowers. ***Calyx*** sepals 2-5, free. ***Corolla*** petals 4-5, free. ***Stamens*** 4-∞, free or aggregated into fascicles. ***Ovary*** superior, 2-∞ ovules. ***Fruits*** berries, drupes or capsules, size varies immensely. ***Seeds*** +/- winged, +/- aril.

Pantropical distribution.

Two subfamilies: *Kielmeyeroideae* Engler (1888) and *Clusioideae* Engler (1888).

The *Kielmeyeroideae* subfamily is characterised by spiral leaves with pellucid dots, moderate-sized cotyledons and perfect flowers. The *Clusioideae* subfamily has leaves with canals and minute cotyledons.

Key to Thai Genera:

1. Ovary 1-celled.....**2**
   Ovary 2 (-many) celled.....**3**

2. Stigma 4-fid; ovary 1-celled; ovules 4(-8).....**1. *Kayea***
   Stigma peltate; ovary 1-celled; ovule 1. .....**2. *Calophyllum***

3. Sepals 2; ovary 2 (-many) celled .....**3. *Mammea***
   Sepals 4-5; ovary 2-celled .....**4. *Mesua***

Kayea Wall. Pl. As. Rar. 3:5. 1832; Wight, Ill. Ind. Bot. 129. 1840; Thwaites, Enum. Pl. Zeyl. 51-58. 1858; Planchon & Triana, Ann. Sci. Nat. ser. 4, 15: 296. 1861; Bentham & Hooker, Gen. Pl. 1: 176. 1862; T. Anderson in Hook, f. Fl. Brit. Ind. 2: 276. 1874; Kurz, Forest Fl. Burma 1: 96. 1877; Engler & Prantl, Nat. Pflanzenfamilien 3(6): 222. 1895; Brandis, Indian Trees 56. 1907; Pitard, Fl. Indo-Chine 1(4): 325. 1910; Ridl., Fl. Malay. Penin. 1:188. 1922.

Type: *Kayea floribunda* Wallich 4840 (Isotype: BM!).

Trees; hairless. ***Leaves*** opposite; coriaceous; lanceolate; veins distant, not prominent. ***Inflorescences*** solitary and large, or in terminal or axillary panicles and small. ***Calyx*** sepals 4; imbricate. ***Corolla*** petals 4; imbricate; white or pink. ***Stamens*** numerous; filaments basally connate or free; anthers small; dehiscence vertical. ***Ovary*** 1-celled; ovules 4 (rarely 8); style slender; stigmas narrow, 4-fid. ***Fruit*** fleshy; indehiscent; 1-4 seeded; enclosed in enlarged calyx (in majority of species). ***Seeds*** thick; testa thin; woody.

Distribution: (Tropical Asia) Borneo, Burma, Cambodia, Ceylon, India, Indonesia, Malacca, Malaysia, Philippines, Thailand.

Key to species:

1. Inflorescence not solitary, axillary or terminal; usually paniculate; fruit globose.....**1. *K. ferruginea***
   Inflorescence solitary, axillary or terminal; fruit not globose.....**2**

2. Fruit ovoid to ellipsoid; <5cm long; with persistent calyx; leaf apex acute to sometimes cuspidate.....**2. *K. kunstleri***
   Fruit ellipsoid; >7cm long; with/without persistent calyx; leaf apex cuspidate.....**3. *K. elegans***

1. *Kayea ferruginea* Pierre, Fl. Cochinch, t.99. 1889; Ridl., J. Roy Asiat. Soc. S. Br. 54, 21 1897; Pitard in Lecomte, Fl. Indo-Chine 1(4): 326. 1910; Ridl., Fl. Malay. Penin. 1:189-190. 1922; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 276. 1943.

Type: Vietnam, *Pierre 1050* (Lectotype: K! (Lectotype designated here); Isolectotypes: GH!, K!, NY!, P!); *Pierre 4564* (Syntype: P!).

Synonyms

-*Mesua ferruginea* (Pierre) Kosterm., in Reinwardtia 6: 427. 1969; Whitmore, Tree Flora of Malaya 2: 162-236. 1973; Keng, Tree Flora of Malaya 3: 275-296. 1978; Turner, Gard. Bull. Singapore 47: 264. 1995. Type: Vietnam, *Pierre 1050* (Lectotype: K! (Lectotype designated here); Isolectotypes: GH!, K!, NY!, P!).

Description

Habit tree or shrub 8-12m tall; dbh 25cm; bark grey-brown; smooth to scaly; inner bark pink to red. ***Branchlets*** green/grey/brown/black in colour; smooth to slightly flaking; scars present; round. ***Leaves*** petioled, 0.7-1.1cm long; colour varies from bronze to green/yellow; midrib very pronounced on lower surface, very depressed in channel on upper surface; lamina varies from coriaceous to smooth, with a slight shine to glaucous and dull; elliptic to lanceolate; 5-14.7 x 2.1-4.6cm; base cuneate; apex acute, some acuminate; secondary, intersecondary, tertiary and intramarginal veins visible; all very faint and fine; approximately 16 secondary veins on each side; distance between secondary veins approximately 10-14mm; tertiary veins dense. ***Inflorescence*** paniculate; pedicel up to 3cm long; forming a rounded ball of small spheres; approximately 15 clustered together at terminal point; cluster approximately 1.5cm long; usually 3-5 flowers clustered in leaf-axils. ***Calyx*** sepals 4; persistent; in 2 pairs; opposite. ***Corolla*** petals 4; acute; oblong; imbricate; 4-lobed; white. ***Stamens*** in fascicles; numerous; anthers orange/yellow; round; anther size, 0.5 x 0.5mm; filament approximately 2mm long. ***Ovary*** long single style protruding. ***Fruit*** globose, with acute tip; petioled, 3mm long; rough texture; brown; 3-3.5 x 2.5-3.5cm; enlarged calyx surrounding the fruits; 1-seeded.

Distribution: Thailand: Surat Thani, Narathiwat; **Worldwide:** Cambodia, Malaya, Singapore.

Phenology: Flowering: March-June.

Ecology: Common along Rivers/Streams.

Altitude: Near Sea Level.

Local Name: Paong sar (Gagnepain, 1943)/Na-kho-pa-he (*C. Niyomdham 778*).

IUCN Regional (Thailand) Status: Data Deficient (DD).

THAILAND

Peninsular Region: 65. *Surat Thani Province:* Bang Yai River Street, Surat, *Sakol 1018* (BK); Ban Duara, *D. Bourke 2501* (BK, K); **76. *Narathiwat Province:*** Tak Bai, *C. Niyomdham 778* (BKF, P); Tak Bai, Bang Khoontang, *C. Niyomdham 810* (BKF, K, P).



Map 3.1 Distribution of *Kayea ferruginea* in Thailand.

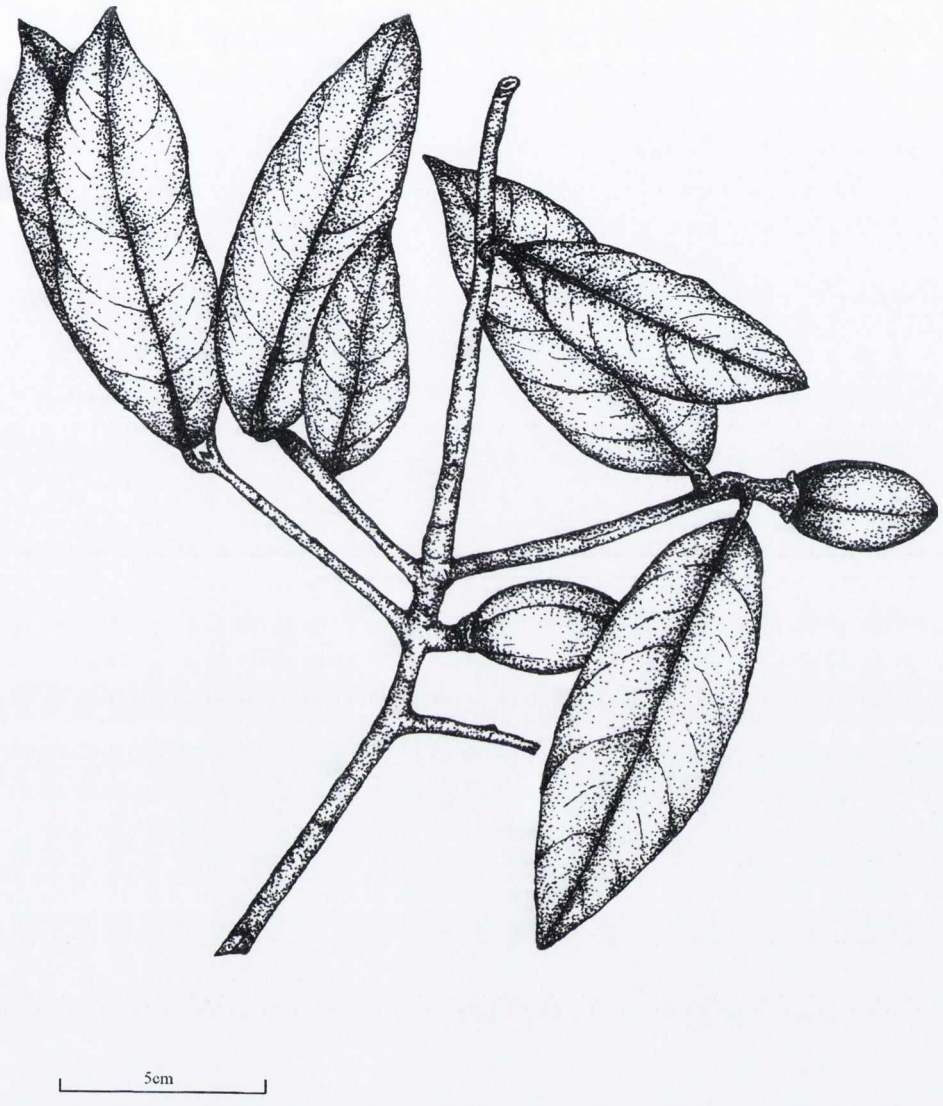


Figure 3.1 Line drawing of *Kayea ferruginea* (leaves and fruit). (Illustration by Elaine Cullen).

2. *Kayea kunstleri* King, in J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59(2): 182 & 620. 1890; Ridl., Fl. Malay. Penin. 1: 190-191. 1922.

Type: Larut, Perak, Malaysia, *Dr. King's Collector 6850* (Lectotype: K! (Lectotype designated here); Isolectotypes: BM!, BO, GH!); *Dr. King's Collector 3301* (Syntype: BO).

Synonyms

-*Kayea curtisii* King, in Ann. Bot. Gard. Calcutta 5: 144, t.174B. 1896. Type: *Curtis 748 & 805* (Lectotype: K! (Lectotype designated here); Isolectotype: BO).

-*Kayea rivulorum* Ridl., in J. Straits Branch Roy. Asiat. Soc. 54: 22. 1910. Syntypes: *Goodenough 1976* (SING!); Selangor, Malaysia, *Ridley 7349* (Isosyntypes: GH!, SING!).

-*Mesua kunstleri* (King) Kosterm., in Reinwardtia 6: 427. 1969; Whitmore, Tree Flora of Malaya 2: 228. 1973. Type: Larut, Perak, Malaysia, *Dr. King's Collector 6850* (Lectotype: K! (Lectotype designated here); Isolectotypes: BM!, BO, GH!).

Description

Habit shrub to small tree, 0.5 to 8m tall, dbh 10-30cm; inner bark pink; outer bark brown; sap whitish-cream. ***Branchlets*** brown/red to light brown in colour; thin; striate; scars present. ***Leaves*** petioled, 0.4-1.6cm long; surface dull green to brown to orange/yellow in colour, some dots/glands present; varying from coriaceous to thin and delicate; some glaucous; midrib pale cream to green on upper surface and light brown to tan on lower surface; not very obvious on either surfaces, slightly more prominent on lower surface; elliptic to oblanceolate, 6.7-11.6 x 1.4-3.6cm; base cuneate to acute; apex acute, some cuspidate, few acuminate; venation extremely faint on some leaves, varying from leaf to leaf, veins appear to fade on older leaves, arising at different points on either side of the midrib. ***Inflorescence*** solitary, axillary or terminal; pedicel length 1.5-3cm long, smooth; bud smooth. ***Calyx*** sepals 4; outer 2 smaller, round-oval, green; inner 2 larger, elliptic; white, persistent. ***Corolla*** petals 4; oblong-acuminate; caducous;

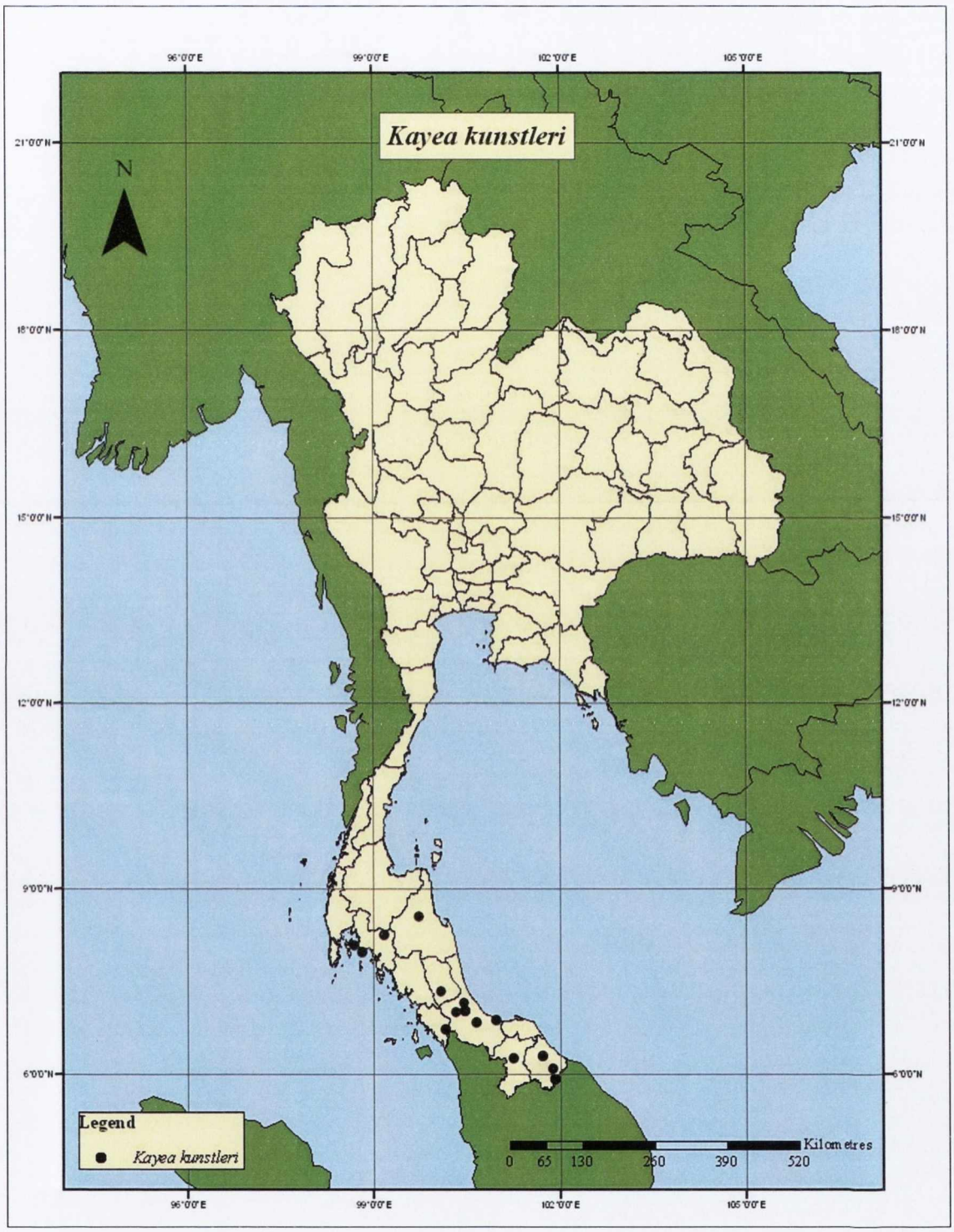
flowers white; up to 1cm long. ***Stamens*** numerous; in fascicles; anthers round to almost oblong; anther & filament 1.5-2cm long; anther yellow; filament cream. ***Ovary*** yellow; 1 style. ***Fruit*** fruiting calyx yellow-greenish; persistent; fruits green outside; cream inside; ovoid to ellipsoid; wood-like texture with scales; 3.5-4.5cm long; dehiscent capsule with 4 valves.

Distribution: Thailand: Krabi, Nakhon Si Thammarat, Phattalung, Satun, Songkhla, Yala, Narathiwat; **Worldwide:** Malaya, Singapore.
Phenology: Flowering: March-June. Fruiting: July-September.
Ecology: Evergreen Forest; Open Disturbed Growth.
Altitude: 50 - 600m.
Local name: Nakaboot (*Maxwell 84-179*).
IUCN Global Status: Least Concern (LC).
IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Peninsular Region: 68. *Krabi Province:* *A.F.G. Kerr 18842* (BK, BM, C, K, L, P); **69. *Nakhon Si Thammarat Province:*** Khao Luang, near Khiri Wong Village, *C.F. van Beusekom & C. Phengkhlai 778* (BKF); **70. *Phattalung Province:*** 10km East of Na Thawi, *K. Larsen, S.S. Larsen, A.S. Barfod, W. Nanakorn, W. Ueachirakan & P. Sirirugsa 41691* (AAU); **72. *Satun Province:*** Thale Ban National Park, *D.J. Middleton, T. Boonthavikoon, S.J. Davies, C. Hemrat & M.F. Newman 391* (A, BKF); **73. *Songkhla Province:*** Ko Hong Hill, Haad Yai, *Chirayupin 2* (BK); Ko Hong Hill, Haad Yai, *Sritungnant 11* (PSU); Ko Hong Hill, Haad Yai, *Cheuntai 18* (PSU); Haad Yai, *Pradit 190* (BK); Ko Hong Hill, Haad Yai, *J.R. Cannon JRC 243* (PSU); PSU, behind Biology Building, *Congdon & Hamilton 249* (PSU); Kuan Meed, south of Haad Yai, *Congdon & Hamilton 403* (PSU); Sadao, S. Sutheesoen 1683 (BK); Utapao, *A.F.G. Kerr 3684* (BM, K); PSU Campus, *S. Sutheesoen 3692* (BK); Ban Tepa, *A.F.G. Kerr 14742* (BK, BM, C, K, L, P); Prakawp, *A.F.G. Kerr 15846* (BK, BM, K, L); Khao Kho Hong, Hat Yai, *K. Larsen, S.S. Larsen, A.S Barfod, W. Nanakorn, W. Ueachirakan & P. Srirugsa 40956* (AAU); Khao Mot Daeng, Ko Hong, Hat Yai, *K. Larsen, S.S. Larsen, C. Niyomdham, W. Ueachirakan & P. Sirirugsa 42186* (AAU, BKF, P, PSU); Koh Hong, *K. Larsen, S.S. Larsen, S.S Renner, C. Niyomdham, W. Ueachirakan & P. Sirirugsa 42652* (AAU, P); Ko Hong Hill, Haad Yai, *J.F. Maxwell 84-179* (PSU); Ko

Hong Hill, Haad Yai, *J.F. Maxwell 85-1186* (PSU); Yaw Island, Muang District, *J.F. Maxwell 86-624* (BKF, L, PSU); **75. *Yala Province:*** Banang Station, *A.F.G. Kerr 7376* (BK, BM, K); **76. *Narathiwat Province:*** Waeng, *S. Phusomsaeng 440* (L); Kao Re Chan, Toh Moh, *M.C. Lakshnakara 728* (BK, BM, C, K, L, P); Kao Cha Bor, Toh Moh, *M.C. Lakshnakara 816* (BM, C, K, L, P); Waeng, *S. Phusomsaeng, B. Sangkhachand & B. Nimanong 1027* (BKF); Nikhomwang, *Prayad 1296* (BK); Nikhomwang, *Prayad 1331*(BK); Sungei Padi, Chatwarin Falls, *K. Larsen & S.S. Larsen 32998* (AAU, BKF, K, L, P); Waeng, *S. Phusomsaeng 41118* (K); **Unknown Locations:** Ban Tu Gor, Tan Yong Mas, *M.C. Lakshnakara 843* (BM, C, K, L, P); *P. Srirugsa s.n.* (PSU).



Map 3.2 Distribution of *Kayea kunstleri* in Thailand.



Figure 3.2 Line drawing of *Kayea kunstleri* (leaves and fruit). (Illustration by Elaine Cullen).

3. *Kayea elegans* King, in J. Asiat. Soc. Beng., Pt. 2, Nat. Hist. 59(2): 183. 1890; Vesque, in DC. Monogr. Phan. 8: 622. 1893.

Type: Larut, Perak, Malaysia, *Dr. King's Collector, 7346* (Lectotype: K! (Lectotype designated here); Isolectotypes: BM!, BO, GH!).

Synonyms

-*Kayea caudata* King, in J. Asiat. Soc. Beng., Pt. 2, Nat. Hist. 59(2): 183; 1890; Vesque, in DC., Monogr. Phan.7: 621. 1893. Type: Malaya (Perak), *King 7937* (Holotype: K!).

-*Mesua elegans* (King) Kosterm., in Reinwardtia 6: 427. 1969; Whitmore, Tree Flora of Malaya 2: 162-236. 1973; Turner, Gard. Bull. Singapore 47: 264. 1995. Type: Larut, Perak, Malaysia, *Dr. King's Collector, 7346* (Lectotype: K! (Lectotype designated here); Isolectotypes: BM!, BO, GH!).

Description

Habit hairless tree 12-18m tall; bark and inner wood red. ***Branchlets*** drooping; slender; thin; terete; yellow/brown/grey in colour; scarring present. ***Leaves*** petioled, 0.4-0.7cm long; upper and lower surface glaucous, some slightly coriaceous; rigid; midrib pale yellow and depressed on upper surface; yellow-tan and slightly prominent on lower surface (almost depressed); oblong to elliptic to lanceolate in shape; 5.6-9.9 x 1.6-2.6cm; base cuneate, some acute; apex cuspidate, apex length 1.3-2 cm long; veins visible, no intramarginal veins present, very faint on upper surface, veins not arising at same point on opposite side of midrib; some leaves undulate. ***Inflorescence*** solitary, axillary or terminal; pedicel up to 10cm long with several ovate-acute bracts at its base; 10mm in diameter. ***Calyx*** sepals 4; equal; coriaceous. ***Corolla*** petals 4; oblong, acute, smaller than sepals. ***Ovary*** ovoid; attenuate. ***Fruit*** ochrish grey; endocarp thin; 7.5-8.2 x 2-7-3.8cm; ellipsoid and tapering into a stout beak; smooth surface with ridges at 4 corners. ***Seeds*** 3-6; black; shape varying from oblong to round to almost square; covered in a thin paper-like layer inside fruit.

Distribution: Thailand: Ranong; **Worldwide:** Malaya, Singapore.

Phenology: Flowering: approximately March. Fruiting: approximately April.

Ecology: Evergreen Forest.

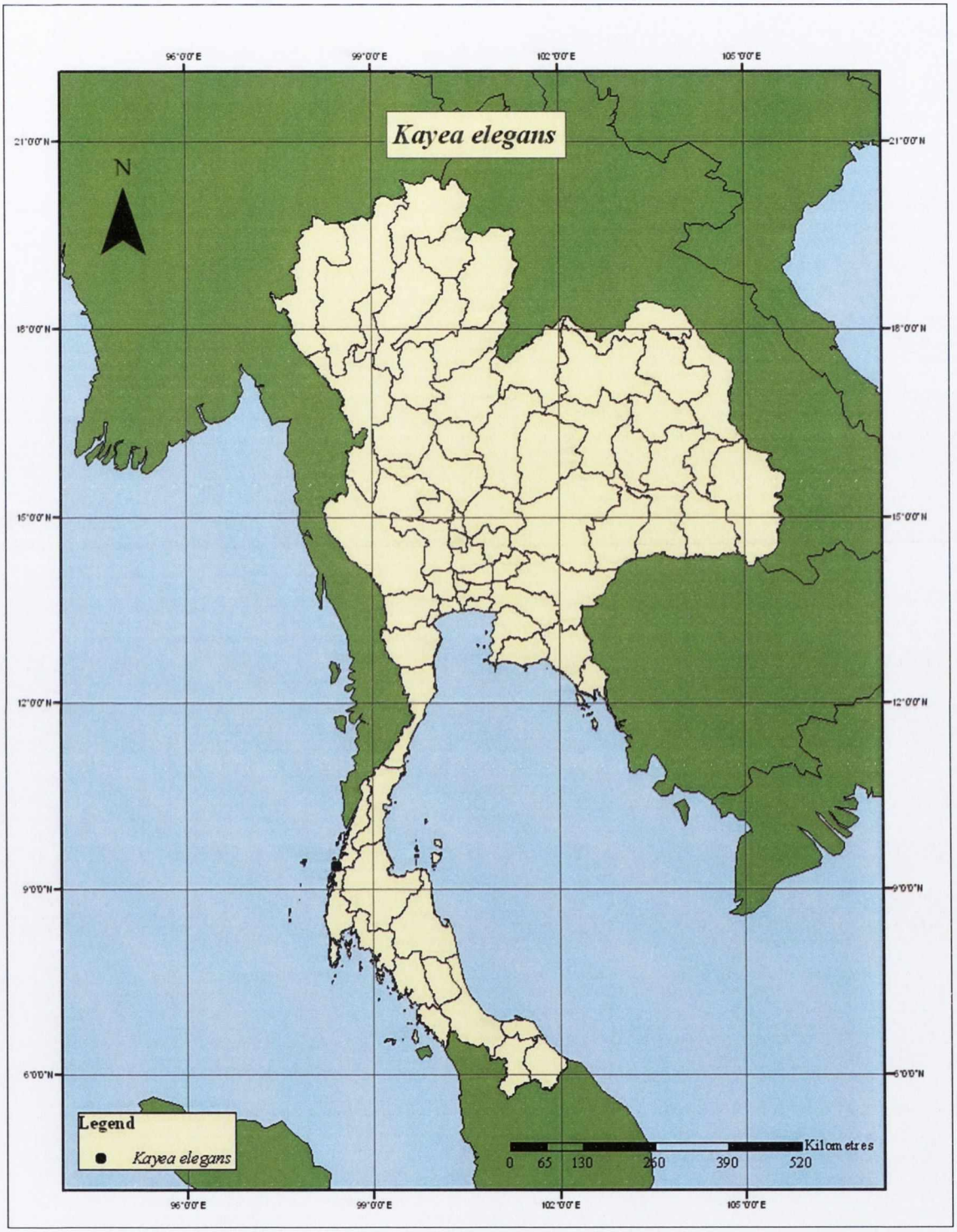
Altitude: 450 - 600m.

IUCN Global Status: Least Concern (LC).

IUCN Regional (Thailand) Status: Critically Endangered (CR).

THAILAND

Peninsular Region: 64. *Ranong Province:* Khlong Kom Puang, *R. Geesink & T. Santisuk 4950* (AAU, BKF, L, P).



Map 3.3 Distribution of *Kayea elegans* in Thailand.



Figure 3.3 Line drawing of *Kayea elegans* (leaves and fruit). (Illustration by Elaine Cullen).

***Calophyllum* L.** Sp. Pl. 513. 1753; L., Gen. Pl. ed. 5. 229. 1754; Lam., Encycl. 1: 552. 1785; Juss., Gen. Pl. 286. 1791; Willd., Sitzungsber. Ges. Naturf. Freunde Berlin 5: 78. 1811; Choisy, Mem. Soc. Hist. Nat. Paris 1: 228. 1823; Choisy, in DC. Prodr. 1: 562. 1824; Endl., Gen. Pl. 1028. 1840; Choisy, Descr. Guttif. Inde, 41. 1849; Miq., Fl. Ned. Ind. 1(2): 509. 1859; Planchon & Triana, Ann. Sci. Nat. Bot. 4(15): 241. 1862; T. Anderson, in Hook. f., Fl. Brit. India 1: 271. 1874; Vesque, Epharmosis 2: 6. 1889; King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59: 172. 1890; Vesque, in DC. Monogr. Phan. 8: 529. 1893; Trimen, Handb. Fl. Ceylon 1: 98. 1893; Engler, in Engler & Prantl, Nat. Pflanzenfamilien 3(6): 220. 1895; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 316. 1910; Ridl., Fl. Malay. Penin. 1: 181. 1922; Engler, in Engler & Prantl, Nat. Pflanzenfamilien 2(21): 192. 1925; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 268. 1943; Perrier de la Bathie, in Humbert, Fl. Madagasc. 136: 3. 1951; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 285. 1956; Maheshwari, Bull. Bot. Surv. India 2: 139. 1960; Backer & Bakh. f., Fl. Java 1: 384. 1963; A.C. Smith & S.P. Darwin, J. Arnold Arbor. 55: 216. 1974; P.F. Stevens, Austral. J. Bot. 22: 349. 1974; P.F. Stevens, J. Arnold Arbor. 61: 167. 1980.

Type: *Calophyllum inophyllum* L. Habitat in India. *Herb. Hermann* 2: 82 No. 201 (Lectotype: BM!).

Synonyms

-*Ponna* Rheede ex. Boehm., Ludw. Def. Gen. Pl. 239. 1760. *Nomen superfluum.*

-*Augia* Lour., Fl. Cochinch. 337. 1790, *pro minore parte.*

-*Balsamaria* Lour., Fl. Cochinch. 2: 469. 1790.

-*Apoterium* Blume, Bijdr. Fl. Ned. Ind. 1(5): 218. 1825.

-*Calaba* Mill., Gard. Dict. Abr., 4.1754; Druce in Rep. Bot. Exch. Cl. Brit. Isles, 3: 430. 1913.

Trees with fissured bark usually yellow-brown to grey-brown in colour. 2 different types of exudate: clear and honey-coloured exudate and an opaque white exudate.

Leaves simple, petiolate, opposite, coriaceous; close, fine parallel veins from midrib towards margin, some having distinct intramarginal veins, veins are usually distinct; the midrib is depressed on upper surface. ***Inflorescences*** terminal or axillary. ***Floral parts*** tepals 4 or 8; flowers are similar among species; white in colour; bracts and bracteoles ovate and caducous. ***Stamens*** 30-600; usually hairless; basifixed; vertically dehiscent; filaments are slender and joined at base into 4-6 bundles. ***Ovary*** 1-celled; 1 ovule; hairless; stigma peltate; superior. ***Fruit*** drupe; ovoid to globose; varying in colour from yellow/green to orange/brown to black.

Distribution: Africa, Asia Temperate (East Asia), Asia Tropical (Indian Subcontinent, Malesia, Indonesia), Australasia, North America (Mexico), South America.

Key to species:

1. Bark exudate the colour of clear honey..... **2**
   Bark exudate milky white/yellow..... **3**

2. Outer pair of tepals dorsally pubescent..... **5**
   Outer pair of tepals dorsally hairless..... **9**

3. Youngest twigs hairless..... ***1. C. rupicolum***
   Youngest twigs pubescent..... **4**

4. Youngest twigs and base of inflorescences orange pubescent; flowers in axillary racemes; leaves ovate or elliptic..... **2. *C. pisiferum***
   Youngest twigs and base of inflorescences red-brown pubescent; flowers axillary, paniculate or in cymes; leaves oblong-ovate to elliptic-ovate..... **3. *C. soulattri***

5. Tepals more than 8; outer pair of tepals equalling the next pair in shape and size..... **4. *C. touranense***
   Tepals 8 or fewer; outer pair of tepals not equal to the next pair in shape and size..... **6**

6. Leaf apex acuminate to acute; branchlets 4-angled..... **5. *C. macrocarpum***
   Leaf apex acuminate, retuse, or cuspidate; branchlets terete..... **7**

7. Branchlets terete or flattened; leaf apex acuminate to acute..... **6. *C. polyanthum***
   Branchlets terete; leaf apex cuspidate to retuse..... **8**

8. Stamens less than 200; inflorescences terminal and from upper leaf axils; fruit spherical to ellipsoid, drying light green to purple..... **7. *C. thorelii***
   Stamens more than 200; inflorescences axillary racemes; fruit ovoid to rotund, drying reddish-brown to almost black..... **8. *C. sclerophyllum***

9. Leaves slightly coriaceous; fruit ellipsoid to obovoid; stamens less than 70.....**9. *C. symingtonianum***

Leaves coriaceous; fruit ellipsoid, globose, obovoid or subglobose; stamens usually more than (65-) 70..... **10**

10. Tepals 4 (-6).....**10. *C. calaba***

Tepals 8.....**11**

11. Leaf apex retuse to round.....**11. *C. inophyllum***

Leaf apex acute to acuminate.....**12**

12. Stamens 35-90; tepals (4-) 8; intramarginal veins absent.....**12. *C. tetrapterum***

Stamens 65-220; tepals 8; intramarginal veins present.....**13**

13. Tree without buttresses; inflorescences terminal and from upper leaf axils, usually covered with brown pubescence; fruit ovoid, apex acute to acuminate.....**13. *C. dryobalanoides***

Tree with/without buttresses, if present, small; inflorescences in racemes, usually hairless but occasionally covered with brown pubescence; fruit ellipsoid to subglobose, apex acute to round.....**14. *C. teysmannii***

1. *Calophyllum rupicolum* Ridl., in Trans. Linn. Soc. London, Bot. 3(9): 278. 1893; Ridl., Fl. Malay. Penin. 1: 182. 1922; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 346. 1956; T.C. Whitmore, Tree Flora of Malaya 2: 168. 1973; P.F. Stevens, J. Arnold Arbor. 61: 515. 1980.

Type: Malaya, Pahang, *Ridley 2636* (Holotype: SING!; Isotypes: BM!, K!).

Synonyms

-*Calophyllum rupicolum* Ridl. variety; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 347, pl. 27. 1956 *pro parte*.

-*Calophyllum rupicolum* Ridl. var. *elatum* T.C. Whitmore, Gard. Bull. Singapore 26: 270. 1973, *pro parte*; T.C. Whitmore, Tree Flora of Malaya 2: 168. 1973, *pro parte*.

Description

Habit tree 10-35m tall; dbh 30cm; without buttresses; bark greyish-brown, rough, small fissures present; outer bark thin; inner bark pink; exudate milky-yellow (opaque-whitish), sticky. ***Branchlets*** terete to quadrangular; smooth; striations present on some specimens; hairless; brown to red/brown in colour; scars absent. ***Leaves*** petioled, 0.4-0.9cm long; midrib varies from light yellow/green to red/brown in colour on both surfaces; midrib prominent on both surfaces; midrib fades and disappears near apex (approximately 10-20cm from apex) on some specimens; approximately half of leaves glaucous and other half coriaceous, shiny; 5.2-15 x 2.2-3.6cm; shape varies from elliptic to elliptic-lanceolate to obovate-oval; base narrowly tapering; apex varies from bluntly acute to rounded to slightly cuspidate; secondary veins present on both surfaces; on upper surface some leaves show fading of venation at/near edges of leaves. ***Inflorescence*** axillary; pedicels 0.3-0.8cm long, slender, hairless. ***Floral parts*** tepals 4; the outer pair ovate and the inner pair oblong-elliptic. ***Stamens*** anther 0.4-1mm long; approximately 50 stamens per flower. ***Ovary*** style 2-2.7mm long. ***Fruit*** ovoid-globose; 8mm diameter; pale-yellow to green in colour, wrinkled.

Distribution: Thailand: Narathiwat; **Worldwide:** Northeast Malaya to Sumatra.

Phenology: Flowering: October-November. Fruiting: December-April.

Ecology: Peat Swamp Forest, Evergreen Forest.

Altitude: Near Sea Level - 270m.

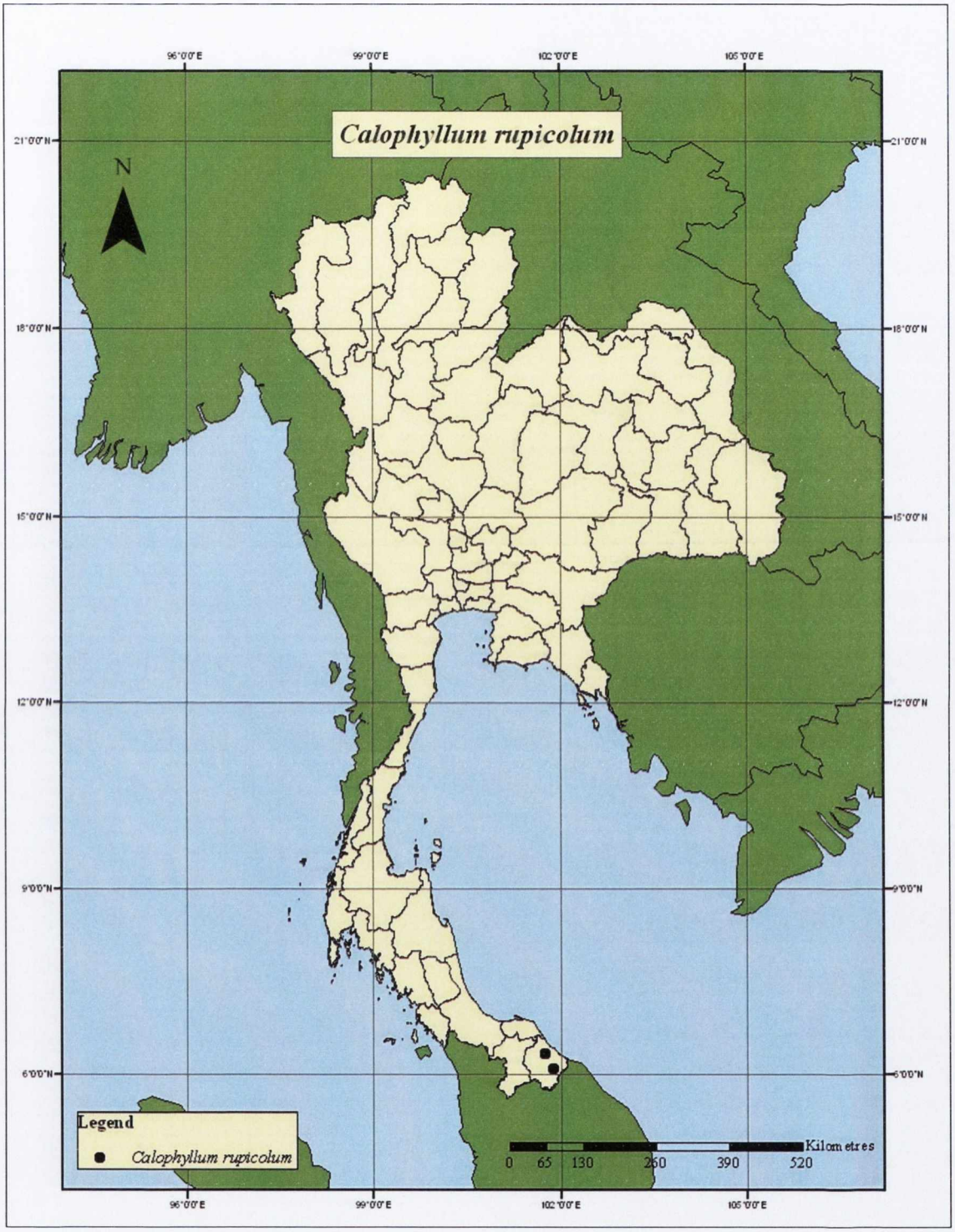
Local name: Tanghon nam (Sangkaew, 1999)/Tang hon bai lek (*C. Niyomdham & D. Sriboonma 1623*).

IUCN Regional (Thailand) Status: Critically Endangered (CR).

Note on synonymy: The above two synonyms were not validly published in accordance with the Principles of the International Code of Botanical Nomenclature.

THAILAND

Peninsular Region: 76. *Narathiwat Province:* Waeng, *B. Sangkhachand et al 1067* (BKF, L); Paa Waai, Su Ngi Paadee, *C. Niyomdham & D. Sriboonma 1623* (BKF); **Unknown Locations:** Unknown collector *57479* (L).



Map 3.4 Distribution of *Calophyllum rupicolum* in Thailand.

2. *Calophyllum pisiferum* Planchon & Triana, in Ann. Sci. Nat., Bot. 4(15): 294. 1862; Ridl., Fl. Malay. Penin. 1: 184. 1922; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 345. 1956; T.C. Whitmore, Tree Flora of Malaya 2; 172. 1973; P.F. Stevens, J. Arnold Arbor. 61: 518. fig. 32, k, l. 1980.

Type: Malaya, Malacca, *Gaudichaud 86* (Lectotype: G!; Isolectotype: P!).

Synonyms

-*Calophyllum retusum* Wall. ex Choisy var. *cochinchinense* Pitard, in Lecomte, Fl. Indo-Chine 1(4): 321. 1910; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1: 275. 1943; Pham & Nguyen, Cay-Co Mien Nam Viet-Nam, 179. 1960; Pham, Cay-Co Mien Nam Viet-Nam. 2(2): 303. 1970. Type: Cochinchine (Vietnam), *Thorel 1395* (Lectotype: P!; Isolectotype: B, K!).

-*Calophyllum retusum* Wall. ex Choisy var. *cambodgense* Pitard, in Lecomte, Fl. Indo-Chine 1(4): 321. 1910; Gagnep., in Humbert, Suppl. Fl Indo-Chine 1:275. 1943; Pham, Cay-Co Mien Nam Viet-Nam. 2(2): 303. 1970. Type: Cambodia, *Hahn 86* (Holotype: P!).

-*Calophyllum sangkae* Craib, Kew Bull. 1925: 18. 1925; Craib, Fl. Siam. 1:122. 1931. Type: Thailand, Surin, *Kerr 8283* (Holotype: K!; Isotypes: ABD!, BM!, BK!, P!).

-*Calophyllum motleyi* Ridl., Kew Bull. 1938:122. 1938. Type: Dutch SE Borneo, *Motley 865* (Holotype: K!).

-*Calophyllum retusum* auct., non Wall. ex Choisy; T. Anderson, in Hook. f., Fl. Brit. India 1:272. 1874, *pro parte*; Pierre, Fl. Forest. Cochinch. 1: pl. 102. 1865; Vesque, Epharmosis 2: t. 25. 1889; King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist.. 50: 176. 1890, *pro majore parte*.

Description

Habit shrub up to 5m tall or tree up to 35m tall; dbh 60cm; bole straight; no buttresses; fissured, outer bark brown-yellow to grey-brown; inner bark dark red; exudate clear to slightly opaque. ***Branchlets*** slightly flattened to rectangular; covered in minute orange pubescence; internode 1-2.5cm long. ***Leaves*** petioled, 0.3-0.7cm long; concave above and convex below; elliptic or ovate in shape; coriaceous, smooth, orange/yellow to brown, 3.5-10.8 x 1-3.3cm; base round to cuneate; apex acute to round; midrib depressed on upper surface and pronounced on lower surface; venation distinct on both surfaces; not arising at same points of midrib and some splitting again *i.e.* intersecondary veins; 7-13 veins per 0.5cm. ***Inflorescence*** axillary racemes; covered with brown pubescence; 7-15 flowers per inflorescence; pedicels 0.5-1.5cm long. ***Floral parts*** tepals 4, the outer pair ovate, 4-5 x 2-3mm, dorsally brown pubescence; inner pair elliptic to obovate-elliptic, 5-7 x 3-5mm, slightly dorsally pubescent to hairless. ***Stamens*** in fascicles, approximately 30-70 stamens per flower; filaments 3-3.5mm long; anther 0.4-0.6mm long; anther oblong-elliptic in shape. ***Ovary*** 1.5-3mm long; style 4-5mm long. ***Fruit*** oval to ellipsoid with an acute apex; 0.9-1.3 x 0.7-1cm; orange when ripe; rough ridges on the surface.

Distribution: Thailand: Surin, Prachin Buri, Chanthaburi, Trat, Narathiwat; **Worldwide:** Indochina, Malaysia and Indonesia.

Phenology: Fruiting: October-January. Fruiting: November-April.

Ecology: Evergreen Forest, Peat Swamp Forest, by water, in rocky areas.

Altitude: Near Sea Level – 1,700m.

Uses: Branches are used for constructing houses and boat poles (Sangkaew, 1999).

Local name: Katangham nam (*A.F.G. Kerr 9435*)/Ka thang han bai lek (*C. Leeratiwong 2002-32*)/Pa-ong (Sangkaew, 1999).

IUCN Global Status: Least Concern (LC).

IUCN Regional (Thailand) Status: Near Threatened (NT).

THAILAND

Eastern Region: 30. *Surin Province:* Sangka, *A.F.G. Kerr 8283* (ABD, BK, BM, P); **South-Eastern Region: 57. *Prachin Buri Province:*** Huay Kasian, *Sakol 109* (BK); **61.**

Chanthaburi Province: East of Makam, *Th. Sorensen, K. Larsen & B. Hansen 464* (C); **62. *Trat Province:*** Ko Kut S.W., *Ch. Charoenphol, K. Larsen & E. Warncke 5097* (AAU, BKF, P); Ko Kut S.W., *Ch. Charoenphol, K. Larsen & E. Warncke 5106* (AAU, BKF, C, K); Kow Kut, *T. Smitinand 5722* (BKF); Ampo Kao Saming, *A.F.G. Kerr 9435* (BK, BM, C, K, L, P); Kao Kuap (or Panom Tom), *A.F.G. Kerr 17774* (A, BK, BM, C, K, L, P); Waterfall, Kudi Island, *C. Leeratiwong 2002-32* (PSU); **Peninsular Region: 76. *Narathiwat Province:*** Paa Wai, Su Ngai Paadee, *C. Niyomdham & W. Ueachirakan 1916* (AAU, BKF, C, K, L, P); Paa Wai, Su Ngai Paadee, *C. Niyomdham & W. Ueachirakan 1935* (AAU, BKF, E, K, L, P); Su Ngai Paadee, *C. Niyomdham 1952* (AAU, BKF, K, L).



Map 3.5 Distribution of *Calophyllum pisiferum* in Thailand.

3. *Calophyllum soulattri* Burman f., in Fl. Ind. 121. 1768; F. Mueller, J. Roy. Soc. New S. Wales 24: 174. 1890; F. Mueller, Bot. Centralbl. 44(1): 29. 1891; Merr., Interpr. Herb. Amboin. 371. 1917; Merr., Philipp. J. Sci. 19: 366. 1921; Merr., Enum. Philip. Fl. Pl. 3: 81. 1923; Holthius, Blumea 5: 214. 1942; Heyne, Nutt. Pl. Ind.-Ned. ed. 3. 1: 1085. 1950; Sastri et al., Wealth India 2: 20. 1950 *pro parte*; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 319. 1956; Maheshwari, Bull. Bot. Surv. India 2: 142. 1960; Backer & Bakh. f., Fl. Java 1: 386. 1963; T.C. Whitmore, Guide Forests Brit. Solomon Is. 77. 1966; I.H. Burkill, Dict. Econ. Prod. Malay Penin. 2(1): 416. 1966; T.C. Whitmore, Gard. Bull. Singapore 22: 15. 1967; Meijer, Bot. News Bull. Forest Dept., Sabah 7:16. 1967; Pham, Cay-Co Mien Nam Viet-Nam. 2(2): 300. fig. 1970; Foreman, Check List Vasc. Pl. Bougainville, 42. 1971; T.C. Whitmore, Tree Flora of Malaya 2; 192. 1973; Hartley et al., Lloydia 36: 276. 1973; P.F. Stevens, Austral. J. Bot. 22: 399. 1974; P.F. Stevens, J. Arnold Arbor. 57: 175. 1976; H. Keng, Gard. Bull. Singapore 28: 245. 1976; Corner, Gard. Bull. Singapore Suppl. 1:105. 1978; Perry, Med. Pl. E. SE. Asia, 174. 1980; P.F. Stevens, J. Arnold Arbor. 61: 277. 1980.

Type: Java, *Burman s.n.* (Holotype: G!).

Synonyms

-*Calophyllum suriga* Buch.-Ham ex Roxb., Hort. Bengal. 93. 1814; Fl. Ind. 2(2): 608. 1832; G. Don, Gen. Syst. 1: 623. 1831, *nomen*; Wight, Illus. Ind. Bot. 1: 129. 1840; Planchon & Triana, Ann. Sci. Nat., Bot. 4(15): 292. 1862; T. Anderson, in Hook. f., Fl. Brit. India 1: 276. 1874; Vesque, in DC. Monogr. Phan. 8: 609. 1893, *nomen superfluum*.

-*Apoterium sulatri* Blume, Bijdr. Fl. Ned. Ind. 5: 218. 1825. Type specimen not found.

-*Calophyllum tetrapetalum* Roxb. ex G. Don, Gen. Hist. 1: 622. 1831; Roxb., Hort. Bengal. 93. 1814, *nomen*; Carey, in Roxb., Fl. Ind. 2(2): 608. 1832; Wight, Illus. Ind. Bot. 129. 1840. *Calophyllum hirtellum* Miq., Pl. Jungh. 291. 1854; Miq., Fl. Ned. Ind., Eerste Bijv. 1(2): 511. 1859. Type: Java, *Junghuhn s.n.* (Holotype: L!; Isotypes: P!, U!).

-*Calophyllum cymosum* Miq., Fl. Ned. Ind., Eerste Bijv. 1(3): 497. 1861; F. Mueller, in Walp., Ann. Syst. Bot. 7: 357. 1868. Type: Sumatra, *Teysmann, HB 653* (Lectotype: U!; Isolectotypes: BO, K!, L, MEL).

-*Calophyllum diepenhorstii* Miq., Fl. Ned. Ind., Eerste Bijv.1(3): 497. 1861; F. Mueller, in Walp., Ann. Syst. Bot. 7: 357. 1868; Vesque, in DC. Monogr. Phan. 8:605. 1893. *Calophyllum spectabile* Willd. var. *diepenhorstii* (Miq.) Boerl., Cat. Pl. Phan. Hort. Bot. Bogor. 2: 81. 1901. Type: Sumatra, *Diepenhorst HB 2236* (Holotype: U!; Isotypes: BO, L!, MEL).

-*Calophyllum wallichianum* auct. non Planchon & Triana; Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 45:119. 1876; Theobald, Burma 2: 637. 1883; Maheshwari, Bull. Bot. Surv. India 2: 146. 1960. Type specimen not found.

-*Calophyllum lanceolatum* Warb., Bot. Jahrb. Syst. 13: 381. 1891, non Blume, 1825. Type specimen not found.

-*Calophyllum warburgii* Engler & Prantl, Nat. Pflanzenfamilien 3(6): 221. 1893; Lauterb., Nova Guinea Bot. 8: 843. 1912; Lauterb., Bot. Jahrb. Syst. 58: 13. 1922; A.C. Smith, J. Arnold Arbor. 22: 345. 1941, *pro majore parte*. Type: Kei Inseln, *Warburg 20048* (Lectotype: US! (Lectotype designated here); Isolectotypes: A, LAE).

-*Calophyllum kiong* K. Schum. & Lauterb., Fl. Deutsch. Sudsee, 450. 1901; Lauterb., Bot. Jahrb. Syst. 58:11. 1922. O. Schwarz, Repert. Spec. Nov. Regni Veg. 24: 89. 1927. Type specimen not found.

-*Calophyllum hibbardii* Elmer, Leafl. Philipp. Bot. 2: 503. 1908. Type: Philippine Islands, *Elmer 9837* (Lectotype: L! (Lectotype designated here); Isolectotypes: A, BM!, BO, E!, F, FI, G, K!, LY, MO, NY!, US, W).

-*Calophyllum treubii* Koord., in Koorders–Schum., Syst. Verz. 3:87. 1914; Koorders–Schum., Suppl. Fl. N. O. Celebes, 2: pl. 88. 1922. *nomen*.

-*Calophyllum oblongum* Koord., ex Koorders–Schum., Syst Verz. 3:87. 1914; Koorders –Schum., Suppl. Fl. N. O. Celebes, 2: pl. 89. 1922. *nomen.*

-*Calophyllum minahassae* Koord., in Koorders-Schum., Syst. Verz. 3:87. 1914. *nomen.*

-*Calophyllum wigmannii* Koord., in Koorders–Schum., Syst. Verz. 3: 87, 88. 1914. *nomen.*

-*Calophyllum lancifolium* Elmer, Leafl. Philipp. Bot. 7: 2683. 1915; Merr., Enum. Philipp. Fl. Pl. 3: 80. 1923. Type: Philippine Islands, *Elmer 13266* (Lectotype: A; Isolectotypes: BM!, BO, E!, F, FI, G, GH!, K!, L!, MO, NY!, U!, UC, US, W).

-*Calophyllum zschokkei* Elmer, Leafl. Philipp. Bot. 7: 2686. 1915; Merr., Enum. Philipp. Fl. Pl. 3: 81. 1923. Type; Philippine Islands, *Elmer 12129* (Lectotype: GH; Isolectotypes: A, BM!, BO, E!, F, FI, G, K!, L!, MO, NY!, P!, W).

-*Calophyllum versteegii* Lauterb., Bot. Jahrb. Syst. 58:12. 1922. Type: South New Guinea, *Versteeg 1748* (Lectotype: K! (Lectotype designated here); Isolectotypes: BO, L!, U!).

-*Calophyllum cholobtaches* Lauterb., Bot. Jahrb. Syst. 59:20. 1924. Type: Palau Inseln, *Ledermann 14251* (Lectotype: WRSL).

-*Calophyllum solomonense* A.C. Smith, J. Arnold Arbor. 22:346. 1941; T.C. Whitmore, Guide Forests Brit. Solomon Is. 78. 1966, *pro parte*; T.C. Whitmore, Gard. Bull. Singapore 22: 9. 1967, *pro parte*; P.F. Stevens, Austral. J. Bot. 22: 398. 1974, *pro parte*. Type: Solomon Is., *Kajewski 2469* (Holotype: A; Isotypes: BM!, BO, BRI, G, L!, P!, SING!).

-*Calophyllum inophyllum* auct. non L., Holthius, Blumea 5 : 214. 1942.

-*Calophyllum paludosum* C.T. White, J. Arnold Arbor. 31:98. 1950; T.C. Whitmore, Guide Forests Brit. Solomon Is. 77. 1966; T.C. Whitmore, Gard. Bull. Singapore 22: 14.

1967. Type: Solomon Is. *BSIP 192* coll. *Walker & White* (Holotype: BRI; Isotypes: A, CANB, K!, LAE, MEL).

Description

Habit large tree 10-20m tall; dbh up to 30cm; bole straight; with/without buttresses, if present, small; bark shallowly fissured, almost smooth; outer bark light brown; heartwood dark brown; exudate white. ***Branchlets*** flattened; with reddish-brown pubescence; internode 3-10cm long. ***Leaves*** petioled, 1.1-2.3cm long; oblong-ovate to elliptic-ovate; coriaceous, yellow-brown, 6-30 x 3-7.5cm; base cuneate to slightly acute; apex acute to acuminate; midrib wider and more apparent on lower surface, depressed in channel on upper surface about ½ of lamina length, dark green above and pale green underneath, immature leaves with light brown midribs; venation very obvious; arising at same point from both sides of the midrib; some sparse hairs noticeable on petioles of leaves, almost hairless. ***Inflorescence*** axillary, paniculate or in cymes; 11-29 flowers per inflorescence; covered with brown pubescence; pedicels 1-3cm long. ***Floral parts*** tepals 4, the outer pair oval to suborbicular, 3-4.5 x 4.5-5mm, hairless or slightly pubescent at margin; inner ones obovate, 5-6.5 x 5-6mm, hairless or slightly pubescent at margin; tepals, filaments and style white. ***Stamens*** in fascicles, 59-97 stamens per flower; filament 3-5mm long; anther 1-2.6mm long; anther white or yellow in colour. ***Ovary*** 2-2.5mm long; style 3-5mm long. ***Fruit*** ovoid to spherical; 0.8-1 x 0.7-1cm; round at apex; purple to black in colour; petioled, 2-2.9cm long.

Distribution: Thailand: Kanchanaburi, Chumphon, Krabi, Nakhon Si Thammarat, Phattalung, Trang, Satun, Songkhla; **Worldwide:** Cambodia, Vietnam, from Malaysia to Australia.

Phenology: Flowering: March-October. Fruiting: all year.

Ecology: Primary Evergreen Forest, by water, peat swamp area, found on granitic bedrock.

Altitude: 50 – 500m.

Uses: Used for masts and spars and in house construction (Stevens 1980).

Local name: Tang hon loko (*A.F.G. Kerr 19035*)/Tang hon bai yai (Sangkaew, 1999).

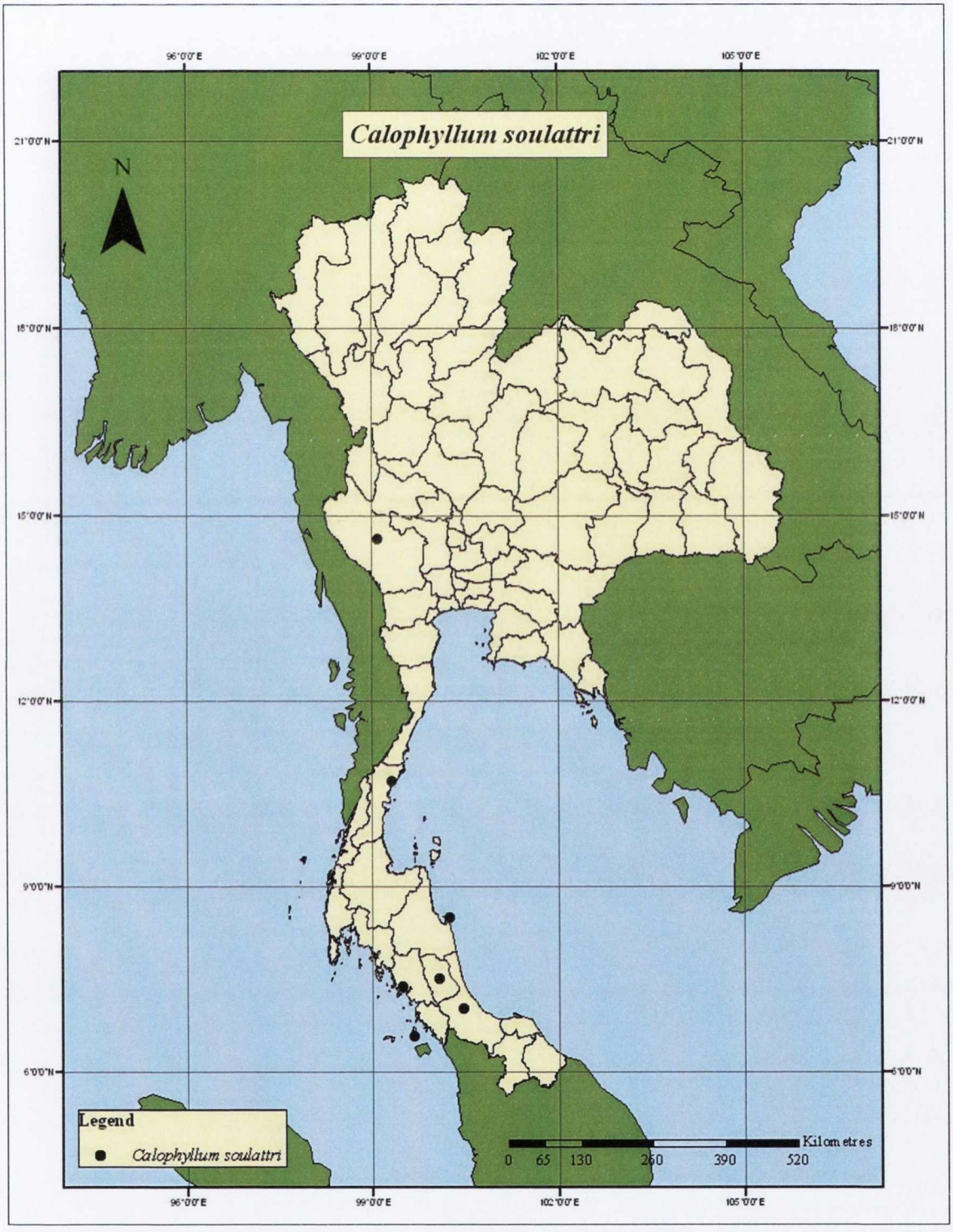
IUCN Global Status: Least Concern (LC).

IUCN Regional (Thailand) Status: Least Concern (LC).

Outlying specimen: Kanchanaburi Province: Thung Phra Rusee, *T. Smitinand 255* (BKF).

THAILAND

South-Western Region: 37. *Kanchanaburi Province:* Thung Phra Rusee, *T. Smitinand 255* (BKF); **Peninsular Region: 63. *Chumphon Province:*** Bang Son, *Put 1562* (BK, BM, K); Tongtapai Sara, *S. Sutheesoen 2204* (BKF); **68. *Krabi Province:*** Kow Pra-Bahng Krahm Wildlife Sanctuary, *J.F. Maxwell s.n.* (CMU); **69. *Nakhon Si Thammarat Province:*** Prom Lake Falls, Khao Luang NP, Prom Kiri District, *J.F. Maxwell 87-194* (A, BKF, L, P, PSU); **70. *Phattalung Province:*** Tamote Falls NP, Tamote, *J.F. Maxwell 86-546* (A, AAU, BKF, L, PSU); **71. *Trang Province:*** Bangsak, *A.F.G. Kerr 19035* (A, BK, BM, K, L, P); **72. *Satun Province:*** Tarutao Island, Talo-Oo-Dang, *G. Congdon 1261* (A, AAU, PSU); **73. *Songkhla Province:*** Dton Nga Chang Reserve, Haad Yai, *P. Sirirugsa 442* (PSU); Dton Nga Chang Reserve, Haad Yai, *J.F. Maxwell 85-766* (A, AAU, BKF, L, PSU).



Map 3.6 Distribution of *Calophyllum soulattri* in Thailand.

4. *Calophyllum touranense* Gagnep. ex P.F. Stevens, in J. Arnold Arbor. 61(2): 226. 1980.

Type: Indochina (Vietnam) *J. & M.S. Clemens 4162* (Holotype A; Isotypes: K!, NY!, P!).

Synonyms

-*Calophyllum touranense* Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1: 271. 1943; Pham & Nguyen, Cay-Co Mien Nam Viet-Nam, 179. bang 62bis C. 1960; Pham, Cay-Co Mien Nam Viet-Nam, 2(2): 302. fig. 1970. *Nomen invalidum.*

Description

Habit tree 7-25m tall; dbh 100cm; bark whitish-grey; outer bark brownish-yellow, deeply fissured, slash marked red; exudate: the colour of clear honey. ***Branchlets*** terete; flaking, rough to smooth to pubescent; colour varies from grey-brown to red-brown; scars present. ***Leaves*** petioled, 0.9-1.9cm long; midrib quite inconspicuous on both surfaces but more prominent on lower surface; midrib wider at base and gradually narrowing towards apex; on lower surface midrib almost rectangular and raised approximately 0.1-0.3mm above leaf; colour varies from light tan to brown on lower surface and brown to red on upper surface; coriaceous, some slightly glaucous; leaf colour varies from brown to red to olivaceous; hairless; 5.4-16 x 2.5-5.5cm; shape varies: lanceolate, elliptic, ovate to oval; base aequilateral to cuneate; apex acute to acuminate; secondary veins present and slightly prominent on both surfaces; intramarginal veins present. ***Inflorescence*** terminal, from upper leaf axils and from adjacent foliate axils; pedicels 0.3-0.6cm long. ***Floral parts*** tepals (8)9-13; outer pair suborbicular; dorsally pubescent; the next pair suborbicular, the inner pair elliptic. ***Stamens*** approximately 400; filaments up to 4mm long; anthers oblong. ***Ovary*** approximately (1.5-3)1.5mm long; style (3-5)3mm long. ***Fruit*** spherical to globose, round at apex; wrinkled with longitudinal striations; 2.5-4 x 1.5-2.2cm; purple/red to black when dry; greenish brown when ripe.

Distribution: Thailand: Phetchabun, Nakhon Phanom, Nakhon Ratchasima; **Worldwide:** Vietnam.

Phenology: Flowering: January-March (October). Fruiting: February-June and September-October.

Ecology: Evergreen forest, Montane Forest, rocky or stony ground.

Altitude: 650 - 1,500m.

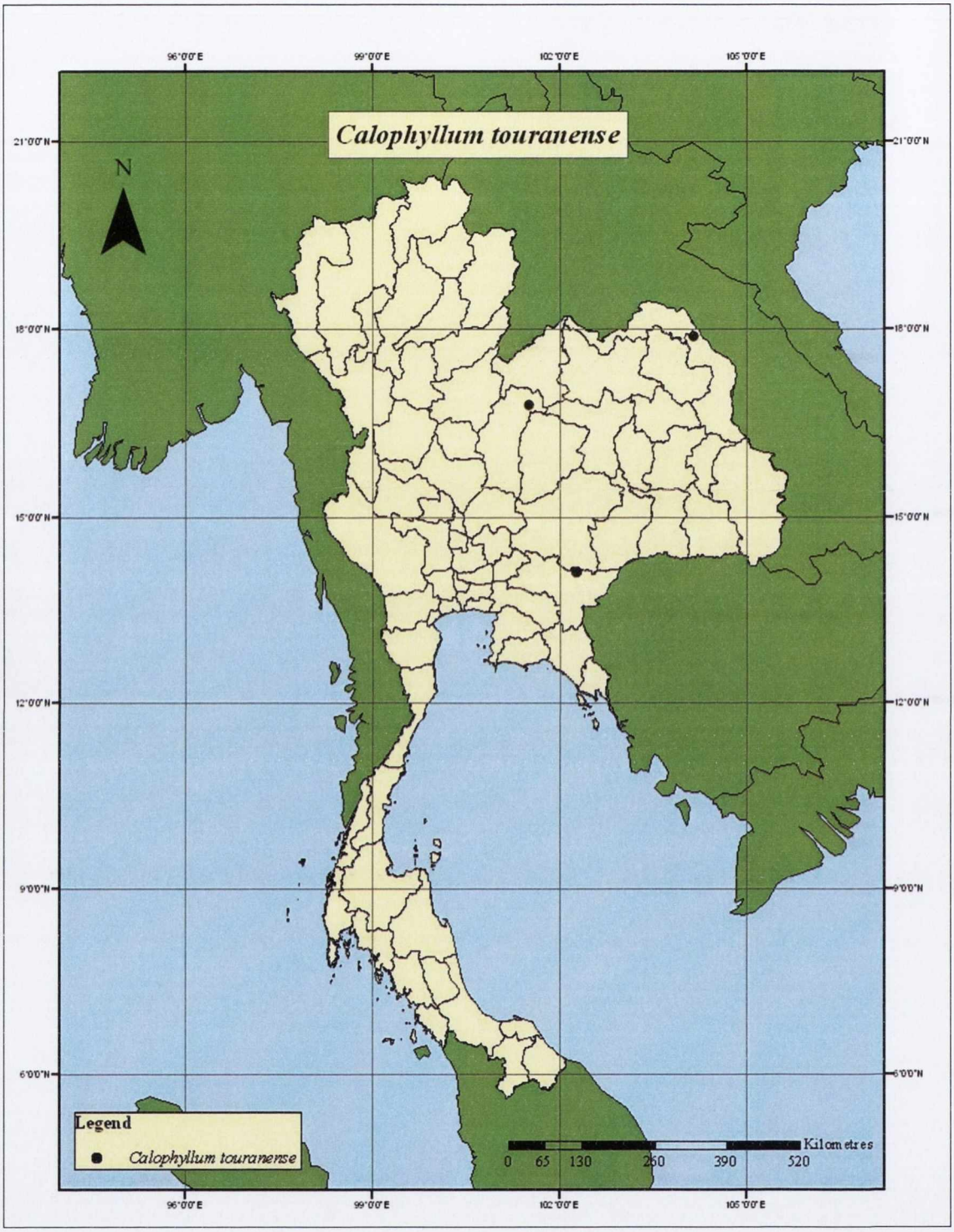
Uses: Used in house construction (Sangkaew, 1999).

Local name: Tanghon khao (Sangkaew, 1999).

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

North-Eastern Region: 16. ***Phetchabun Province:*** Tung Salaeng Luang, *R. Pooma 728* (BKF); **22.** ***Nakhon Phanom Province:*** Phu Lankha, *T.P. 1951* (BKF); **Eastern Region: 28.** ***Nakhon Ratchasima Province:*** Khao Yai NP, Khao Kieo, *C.F. van Beusekom & C. Charoenphol 1724* (A, BKF, C, K, L, P); Khao Yai NP, Khao Laem, *C.F. van Beusekom & C. Charoenphol 1765* (BKF, L); Khao Yai NP, *T. Smitinand & R.G. Robbins 7913* (BKF); Khao Rom, Khao Yai, *N. Fukuoka & M. Ito T-34637* (BKF); Khao Yai NP; *T. Santisuk s.n.* (BKF). **Unknown Locations:** *C.P. 1957* (BKF); *E. Poilane 277/9* (BKF); *T. Santisuk, s.n.* (BKF).



Map 3.7 Distribution of *Calophyllum touranense* in Thailand.

5. *Calophyllum macrocarpum* Hook. f., in Fl. Brit. Ind. 1: 273. 1874; King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59: 179. 1890; Vesque, in DC. Monogr. Phan. 8: 603. 1893; Ridl., J. Straits Branch Roy. Asiat. Soc. 33:48. 1900; Ridl., Fl. Malay. Penin. 1: 187. 1922; M.R. Henderson, Gard. Bull. Straits Settlm. 4:224. 1928; M. R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15:317. 1956; Kochummen, Malayan Forest Rec. 2(17): 218. 1965; I.H. Burkill, Dict. Econ. Prod. Malay Penin. 2(1): 416. 1966; Meijer, Bot. Bull. Herb. Forest Dept., Sabah 7:16. 1967; T.C. Whitmore, Tree Flora of Malaya 2: 187. 1973; H. Keng, Gard. Bull. Singapore 28: 244. 1976; Corner, Gard. Bull. Singapore Suppl. 1: 104. 1978; P.F. Stevens, J. Arnold Arbor. 61: 452. fig. 28, g, h. 1980.

Type: Malaya, Malacca, *Maingay 1728* (Lectotype: K!).

Description

Habit tree 25-35m tall, dbh up to 110cm; bole straight; usually without buttresses; bark deeply fissured, boat-shaped, outer bark yellow-brown to dark-brown to black in colour, some areas of bark emitting a reddish hue; inner bark brown to black; exudate: the colour of clear honey. ***Branchlets*** flattened, 4-angled; slightly brown pubescence at node; internode 0.5-4cm long. ***Leaves*** petioled, 1.5-3.2cm long; elliptic to oblanceolate to lanceolate; concave above and convex below; coriaceous, very smooth, light green to khaki green in colour, 8-16.5 x 3-4.6cm; base cuneate to acute; apex acuminate to rarely acute; midrib on upper surface depressed in channel approximately ½ of lamina length, very pronounced on lower surface; venation pronounced on both surfaces, arising at same point on both sides of midrib, approximately 0.5mm apart, 5-10 veins per 0.5cm. ***Inflorescence*** axillary; 5-15 flowers per inflorescence; covered with red-brown pubescence; pedicels 0.7-3.3cm long. ***Floral parts*** tepals 8 (rarely 10), the outer pair ovate to suborbicular, 6-7 x 5-6mm, dorsally densely pubescent; inner ones ovate to elliptic to oblong-elliptic, 7-17.5 x 3-8mm, dorsally pubescent; the next 2 with the same shape and size, oblong-elliptic, 6-13 x 2-3mm, dorsally slightly pubescent. ***Stamens*** in fascicles, 160-200 per flower; filament 3-6mm long; anther 1-1.3mm long. ***Ovary*** 2-3mm long; style 3-5mm long, stigma peltate. ***Fruit*** ellipsoid; 6.5-15 x 4.5-8cm; acute at

apex; yellow-green when ripe, drying dark brown and wrinkled with longitudinal striations.

Distribution: Thailand: Nakhon Si Thammarat, Trang, Narathiwat; **Worldwide:** Malaya to Borneo excluding Java.

Phenology: Flowering: May-July. Fruiting: August-June.

Ecology: Evergreen Rainforest.

Altitude: 100 - 220m.

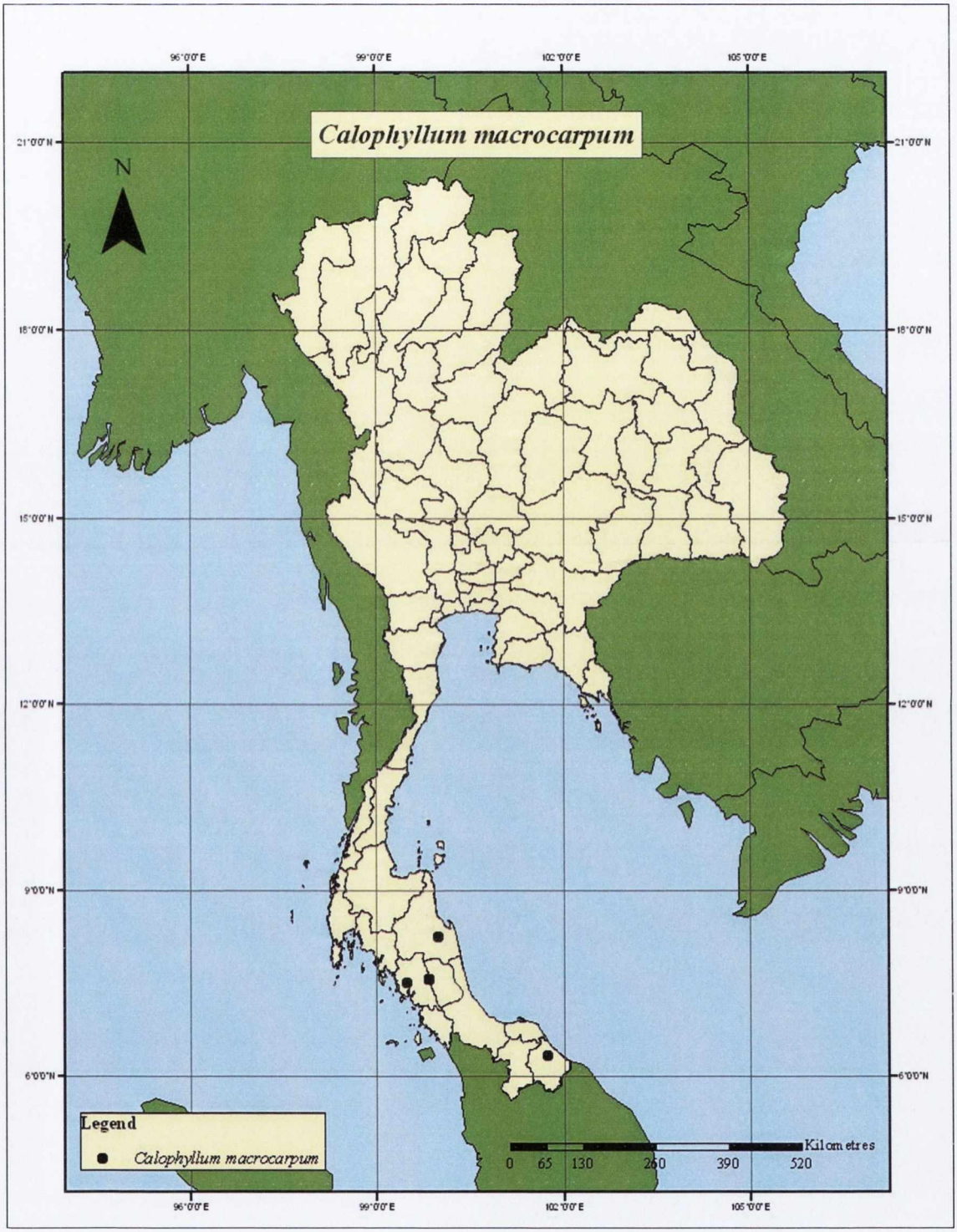
Uses: The wood is used in construction and furniture making (Sangkaew, 1999).

Local name: Chuad (*S. Phusomsaeng & T. Smitinand 240*)/Tanghon (Sangkaew, 1999).

IUCN Regional (Thailand) Status: Data Deficient (DD).

THAILAND

Peninsular Region: 69. *Nakhon Si Thammarat Province:* Krung Ching Waterfall, *C. Niyomdham et al 2250* (BKF); **71. *Trang Province:*** Khao Chong *S. Phusomsaeng & T. Smitinand 240* (BK, K, L, P); *S. Phusomsaeng et al 1617* (BKF, L); **76. *Narathiwat Province:*** Khao Saam Sip, *C. Niyomdham 4792* (BKF).



Map 3.8 Distribution of *Calophyllum macrocarpum* in Thailand.

6. *Calophyllum polyanthum* Wall., Numer. List [Wallich], n. 4844. 1821; Choisy, Descr. Guttif. Inde, 43. 1829; Choisy, Mém. Soc. Phys. Genève 12: 423. 1851; Planchon & Triana, Ann. Sci. Nat., Bot. 4(15): 278. 1862; Bedd., Fl. Sylv. S. India 3:22. 1871; T. Anderson, in Hook. f., Fl. Brit. India 1: 274. 1874; Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 43: 88. 1874; Kurz, Forest Fl. Burma 1: 95. 1877; Gamble, List Trees Darjeeling Dist. 7. 1878; Theobald, Burma 2:636. 1883; Vesque, Epharmosis 2:t. 6. 1889; Vesque, in DC. Monogr. Phan. 8: 555. 1893; Prain, Bengal Pl. 1:246. 1903; Brandis, Indian Trees, 54. 1907; A.M. & J.M. Cowan, Trees N. Bengal, 17. 1929; Craib, Fl. Siam. 1:121. 1931; Kanjilal et al., Fl. Assam 1:114. 1934; Sastri et al., Wealth India 2: 19. 1950; Maheshwari, Bull. Bot. Surv. India 2: 144. 1960; Dutt et al., Indian Forester 100: 65. 1974; P.F. Stevens, J. Arnold Arbor. 61:220. 1980; L. Xiwen, L. Jie & P.F. Stevens, Fl. China 13: 38-40. 2007.

Type: India, Assam, *Wallich 4844* (Holotype: G; Isotype: BM!, FI, G, GH!, K!, P!).

Synonyms

-*Calophyllum smilesianum* Craib, Kew Bull. 1924: 85. 1924; Craib, Fl. Siam. 1: 122. 1931; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1:270. 1943. Type: Thailand, *Kerr 5792* (Holotype: K!; Isotype: BM!, E!, P!).

-*Calophyllum smilesianum* Craib, *var. lutea* Craib, Kew Bull. 1924: 86. 1924; Craib, Fl. Siam. 1: 122. 1931; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1: 271. 1943. Type: Thailand, *Kerr 5180* (Holotype: K!; Isotypes: ABD!, BK!, BM!).

-*Calophyllum williamsianum* Craib, Kew Bull. 1924: 86. 1924; Craib, Fl. Siam.1: 122. 1931; Gagnep., in Humbert, Suppl. Fl. Indo-Chine Suppl. 1: 270. 1943. Type: Thailand, *Kerr 5038* (Holotype: K!; Isotypes: E!, P!).

Description

Habit tree 6-40m tall; dbh 150-400cm; bole straight; no buttresses; bark slightly fissured; outer bark brown-grey/yellow; exudate: the colour of clear honey. ***Branchlets*** flattened, sometimes terete; brown, slightly pubescent. ***Leaves*** petioled, 1.2-2.5cm long; slightly pubescent to hairless, round to obovate-oblong, yellow to dark brown in colour, 3-19 x 1.8-6.5cm; base attenuate to cuneate; apex acuminate to acute; midrib pronounced on lower surface and subtle on upper surface; depressed in channel on upper surface about 2/3 of the lamina length; brown/black in colour on upper surface and orange/yellow on lower surface; lateral veins distinct on both surfaces; radiating at same points from both sides of the midrib and fading near the edges of the leaves; very fine. ***Inflorescence*** terminal and from upper leaf axils; covered in brown pubescence; pedicels 1-1.8cm long. ***Floral parts*** tepals 8, the outer pair oval to suborbicular, 3-4 x 3-3.5mm, dorsally grey-brown pubescent; inner ones ovate, 5-8 x 4.5-5.5mm, dorsally slightly pubescent and densely so towards base; the next 2 with the same shape and size; ovate, 6-6.5 x 5-5.5mm, slightly pubescent along margin towards base, yellowish-white in colour. ***Stamens*** in fascicles, approximately 200-277 per flower; filament 2.5-4.5mm long; anther 1-1.7mm long; anther oblong, orange/brown in colour and centre of anther darker in colour; basally connate. ***Ovary*** 2-2.2mm long; style 3.5-4mm long; stigma peltate. ***Fruit*** ovoid to globose; 3-4 x 2-3cm; acute to round at apex; green or black when ripe; smooth or flaking at surface. ***Seeds*** 35 x 30mm.

Distribution: Thailand: Mae Hong Son, Chiang Mai, Nan, Phitsanulok, Phetchabun, Loei, Chumphon, Trang; **Worldwide:** India to Southwestern China, Cambodia and Indonesia.

Phenology: Flowering: January-July. Fruiting: May-February.

Ecology: Evergreen Forest and Lower Montane Forest.

Altitude: 60 – 1,950m.

Uses: Wood is used in construction and furniture making (Sangkaew, 1999).

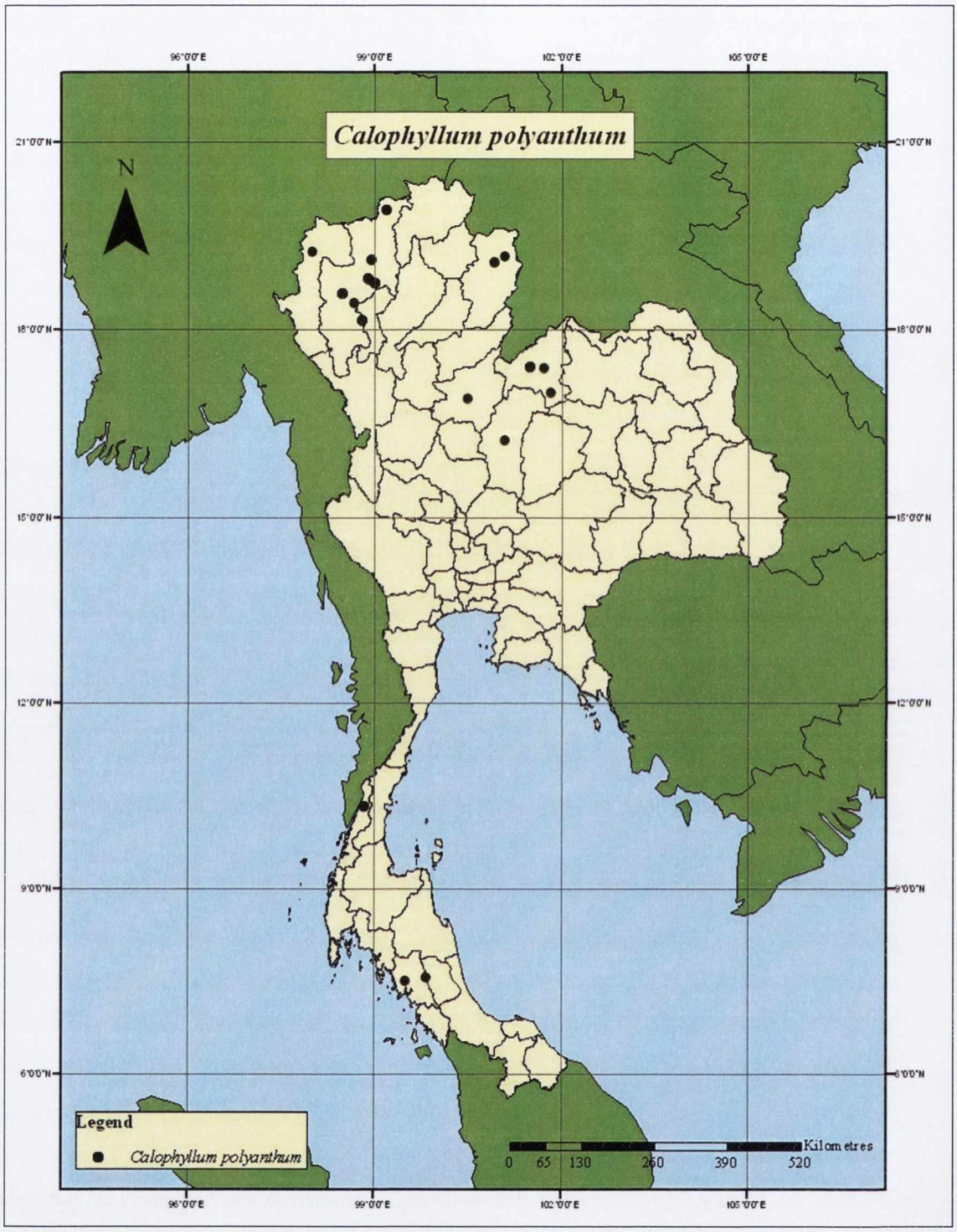
Local name: Pa-ong (*A.F.G. Kerr 8752*)/Kho-mai-do (Sangkaew, 1999)/Saa-chum-mun (Sangkaew, 1999)/Ma haen doi (Sangkaew, 1999).

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 1. ***Mae Hong Son Province:*** North Mae Hong Son, en route to Doi Chiang, *T. Santisuk 1148* (A, BKF); **2.** ***Chiang Mai Province:*** Doi Ka, *K. Winit 1375* (BK, BKF, K); Mae Taeng, *T. Santisuk 1491* (A, C, K, L, P); Doi Pa Kao, *A.F.G. Kerr 2608* (BM, E, K); Me Chem, *A.F.G. Kerr 2691* (K); Mae Sanga Watershed Management Unit, Mae Cham District, *D. Sookchaloem, T. Sangnin & S. Sillapasuwan 3340* (BKF); Doi Nang Ka, *Put 3765* (BK, BM, K, L); Eastern side of Doi Inthanon, *F. Konta & C. Phengkhlai 4003* (BKF); Chom Thong District, Doi Hua Sua, *F. Konta, C. Phengkhlai & S. Khao-iam 4673* (BKF); Doi Tiu, *A.F.G. Kerr 5038* (ABD, BM, E, K, P); Doi Pahom Poh, Muang Fang, *A.F.G. Kerr 5180* (ABD, BK, BM, K); Doi Inthanon, Mae Cham, *T. Santisuk 6821* (BKF); Doi Inthanon NP, *C. Phengkhlai et al 7049* (BKF, C, P); Doi Inthanon NP, *C. Phengkhlai et al 7089* (BKF); Doi Inthanon NP, *C. Phengkhlai et al 7105* (BKF); Inthanon NP, *C. Phengkhlai et al 7155* (AAU, C, K, P); Doi Inthanon NP, *T. Smitinand, M.E.D. Poore & R.G. Robbins 7708* (BKF); Doi Inthanon NP, *T. Smitinand, M.E.D. Poore & R.G. Robbins 7787* (BKF); Doi Inthanon, Khum Mae Wang, *C. Phengkhlai, F. Konta & S. Khao-iam 10881* (BKF); Doi Inthanon, Doi Hua-Suea, *C. Phengkhlai, F. Konta & S. Khao-iam 11297* (BKF); Mae Taeng, Doi Hua Chang, *T. Smitinand 90-38* (E, K, P); Doi Sutep-Pui, *J.F. Maxwell 04-175* (CMU); Doi Inthanon NP, *M. Kanzaki & C. Kwanchai C654* (CMU); Doi Sutep NP, near Chang Kian Village, *S. Gardner & S. Kopachan s245b1* (BM, CMU); Forest station to the top, Doi Chiang, Mae Taeng District, *T. Shimizu, H. Toyokuni, H. Koyoma, T. Yahara & T. Santisuk T-20574* (A, AAU, BKF, L); West side of Doi Inthanon NP, *N. Fukuoka T-62568* (BKF); **5.** ***Nan Province:*** Doi Phu Kha, Pua, *P. Srisanga, S. Watthana & W. Laongsri 816* (QBG); Doi Phu Kha, Pua, *R. Pooma, A. Mauric & M. Greijmans 1446*, (A, BKF, CMU); Doi Phu Kha, Pua, *P. Srisanga 1725* (QBG); Doi Phu Kha, Pua, *P. Srisanga 2021* (QBG); Doi Phu Kha, Pua, *T. Santisuk s.n.* (BKF); **12.** ***Phitsanulok Province:*** Foothill of Phu Mieng Mountain, *K. Larsen 938* (AAU); **North-Eastern Region: 16.** ***Phetchabun Province:*** Loon Salaeng Haeng, *C. Phengkhlai s.n.* (BKF); **17.** ***Loei Province:*** Phu Kradung, *D. Bunpheng 706* (BKF); Kao Keo Kang, *A.F.G. Kerr 5792* (ABD, BM, E, K, P); Kao Krading, *A.F.G. Kerr 8752* (ABD, BK, BM, E, K, P, TCD); Phu Kradung NP, *T. Smitinand 11780* (BKF); **Peninsular Region: 63.** ***Chumphon Province:*** Kao Tong, *A.F.G. Kerr 11523* (A, BK, C, K, L, P); **71.** ***Trang***

Province: Khao Chong Botanical Garden, *T. Smitinand et al 5* (BKF); Chawng, *T. Smitinand 4106* (BKF).



Map 3.9 Distribution of *Calophyllum polyanthum* in Thailand.

7. *Calophyllum thorelii* Pierre, in Fl. Forest. Cochinch. 1: t.103. 1885; Vesque, in DC. Monogr. Phan. 8: 601. 1893; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 322. 1910; Craib, Fl. Siam. 1:122. 1931; Gagnep., in Humbert, Fl. Suppl. Indo-Chine 1:269. 1943; P.F. Stevens, J. Arnold Arbor. 61:218. 1980.

Type: Cochinchine (Vietnam), *Pierre 34* (Lectotype: P!; Isolectotypes: A!,BM!, K!).

Synonyms

-*Calophyllum thorelii* Pierre var. *oxycarpum* Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1:270. 1943. *Nomen invalidum.*

Description

Habit tree up to 30m tall; dbh up to 35cm; outer bark brownish-yellow, deeply fissured, slash mark pink to reddish-brown; exudate: the colour of clear honey. ***Branchlets*** terete; smooth; light to dark red-brown in colour; longitudinal ridges present; scars present. ***Leaves*** petioled, 2.2-3cm long; midrib depressed on upper surface and very prominent on lower surface; midrib glaucous on upper surface and yellow-tan on lower surface; leaf colour varies from green to light dull brown on upper surface and from yellow to tan on lower surface; strongly coriaceous; 8.1-15 x 2.9-4.8cm; elliptic to oblanceolate, few oblong; base cuneate to gradually tapering; apex cuspidate, few acute; secondary and intramarginal veins present, prominent on both surfaces, 0.8mm apart, arising from same points on opposite sides of the midrib; all leaf edges curling when dry. ***Inflorescence*** terminal and from upper leaf axils. ***Floral Parts*** tepals 8; outer pair ovate to oval; dorsally pubescent; the next pair ovate to obovate-oblong and the next 2 pairs same shape and size: obovate to elliptic-oblong. ***Stamens*** 124-178 per flower. ***Fruit*** spherical to ellipsoid; light green to purple; 1.8-2.8 x 1.2-2cm; inside fruit stringy fibres present.

Distribution: Thailand: Lampang, Nakhon Sawan, Nakhon Ratchasima, Chon Buri, Chanthaburi, Trat; **Worldwide:** Vietnam.

Phenology: Flowering: October-January. Fruiting: December-May.

Ecology: Rocky Deciduous Forest, Evergreen Forest, Bamboo Jungle.

Altitude: 30 - 400m.

Uses: Wood is used for construction and the fruits are edible. The flowers are very fragrant (Sangkaew, 1999).

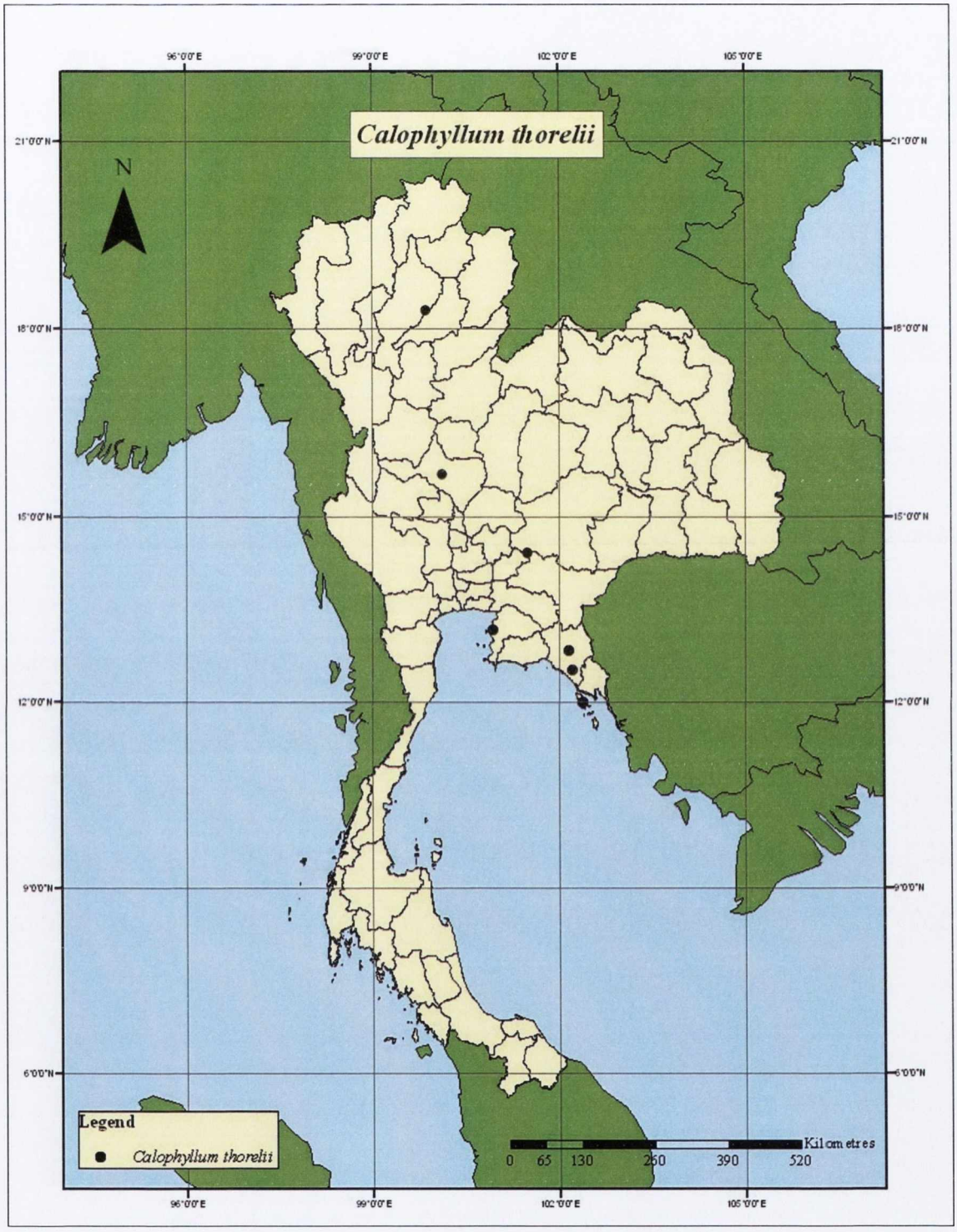
Local name: Kanghan (Sangkaew, 1999)/Kathanghan (Sangkaew, 1999).

IUCN Regional (Thailand) Status: Near Threatened (NT).

Note on species limits: *C. thorelii* is very similar to *C. sclerophyllum* differing only in a few ways, namely, the leaf texture, the inner bark colour and the inflorescence type. The leaves are glaucous in *C. thorelii* and coriaceous in *C. sclerophyllum*, the inner bark is brown in *C. thorelii* and orange in *C. sclerophyllum* and the inflorescence is terminal in *C. thorelii* and a raceme in *C. sclerophyllum*.

THAILAND

Northern Region: 7. *Lampang Province:* Mt. Salor, *Winit 1492* (BK); **15. *Nakhon Sawan Province:*** Nakawn Tai, *A.F.G. Kerr 5816* (BK); **Eastern Region: 28. *Nakhon Ratchasima:*** Kao Lam, Kanat, *A.F.G. Kerr 9978* (BK); Kao Lam, Kanat, *A.F.G. Kerr 9979* (BK); **South-Eastern Region: 59. *Chon Buri Province:*** Nong Ta-River, Sriracha Forest, *D.J. Collins 1127* (C, K, L); Pra Chedi Mountains, Sriracha District, *J.F.Maxwell 75-210* (AAU, BK, L); **61. *Chanthaburi Province:*** At Chanthaburi River on path leading to Prachadu Hill, *D.J. Collins 563* (ABD, BM, K); Lem Sing, *A.F.G. Kerr 9368* (BK, C, K, L, P); Kao Sabap, Chanthabun, *A.F.G. Kerr 9556* (A, BK, C, K, L, P); **62. *Trat Province:*** Koh Chang Island, Aw Ong Kang, *R. Geesink, T. Hattink & C. Phengkhlai 6579* (AAU, BKF, C, K, L, P); Koh Chang, *J.F Maxwell 74-404* (AAU, BK). **Unknown Locations:** *R. Geesink, C. Hattink & C. Phengkhlai 6800* (BKF); *Winit 1751* (BK).



Map 3.10 Distribution of *Calophyllum thorelii* in Thailand.

8. *Calophyllum sclerophyllum* Vesque, in Epharmosis 2: t. 33. 1889; Vesque, in DC. Monogr. Phan. 8:587. 1893; Merr., Bibliogr. Enum. Born. Pl. 394. 1921; Masamune, Enum. Phan. Born. 476. 1942; Heyne, Nutt. Pl. Ned.-Ind., ed. 3. 1:1085. 1950; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15:324. 1956; J. Anderson, Gard. Bull. Singapore 20: 154. 1963; Pukol & Ashton, Checkl. Brunei Trees, 93. 1964; Ashton, Oxford Forest Mem. 25: pl. 32. 1964; Smythies, Common Sarawak Trees, 64: pl. 22. 1965; Kochummen, Malayan Forest Rec. 2(17): 214. 1965; T.C. Whitmore, Tree Flora of Malaya 2: 191. 1973; J. Anderson, Trees Peat Swamp Sarawak, 88. 1973; Corner, Gard. Bull. Singapore Suppl. 1: 105. 1978; P.F. Stevens, J. Arnold Arbor. 61:447. 1980.

Type: Sarawak, *Beccari PB 2705* (Holotype: O; Isotypes: FI!, K!, M).

Synonyms

-*Calophyllum rhizophorum* Boerl. & Koord., in Koord.–Schum., Syst. Verz. 2: 40. 1911; J. Anderson, Trees Peat Swamp Sarawak, fig. 26C. 1973. Type: Sumatra, *Koorders 10333* (Holotype: BO).

-*Calophyllum subluridum* Wyatt-Smith, Malayan Forest Rec. 17: 113. 1952. *Nomen nudum.*

-*Calophyllum teysmannii* Miq. var. *inophylloide* (King) P.F. Stevens, *sensu.* C. Phengkhlai & C. Niyomdham, Flora in Peat Swamp Areas of Narathiwat, 196. fig. 108. 1991.

Description

Habit tree 20-45m tall; dbh up to 300cm; bark shallowly fissured, scaly; outer bark pale green to light brown in colour; inner bark fissured, soft, pink to red or dark orange in colour; exudate: the colour of clear honey. ***Branchlets*** sturdy; thick; terete; dark brown to black in colour; pubescent, waxy or hairless; striations present; scars present. ***Leaves*** petioled, 1.9-2.8cm long; midrib prominent on both surfaces; fades towards apex on upper surface approximately 2/3 of lamina length; midrib dark brown to black on lower

surface and light tan to dark brown on upper surface; 6.2-16.7 x 3.1-7.9cm; lamina thickly coriaceous; obovate, oval or rotund; base cuneate to slightly attenuate; apex blunt or mainly retuse; both secondary veins and intramarginal veins present and very prominent on both surfaces; (intersecondary veins present on 1 leaf only but very prominent and only occur on 1 side of the midrib and only on the lower surface). ***Inflorescence*** axillary racemes; pedicels up to 3cm long; 9-11 flowers per inflorescence. ***Floral parts*** tepals 8; the outer pair orbicular to suborbicular, dorsally brown pubescent; the next pair orbicular to suborbicular, the next two pairs obovate. ***Stamens*** 200-360 per flower; anther 1.3-1.8mm long. ***Ovary*** style 4.5-6.5mm long. ***Fruit*** ovoid to rotund with acute or round apex; 2.4 x 1.6cm; drying dull reddish brown to almost black; surface very finely wrinkled.

Distribution: Thailand: Narathiwat; **Worldwide:** Malay Peninsula to Borneo excluding Java.

Phenology: Flowering: July-August. Fruiting: (April) August-December.

Ecology: Peat Swamp Forest.

Altitude: Near Sea Level.

Uses: A good timber species used in general construction (Sangkaew, 1999).

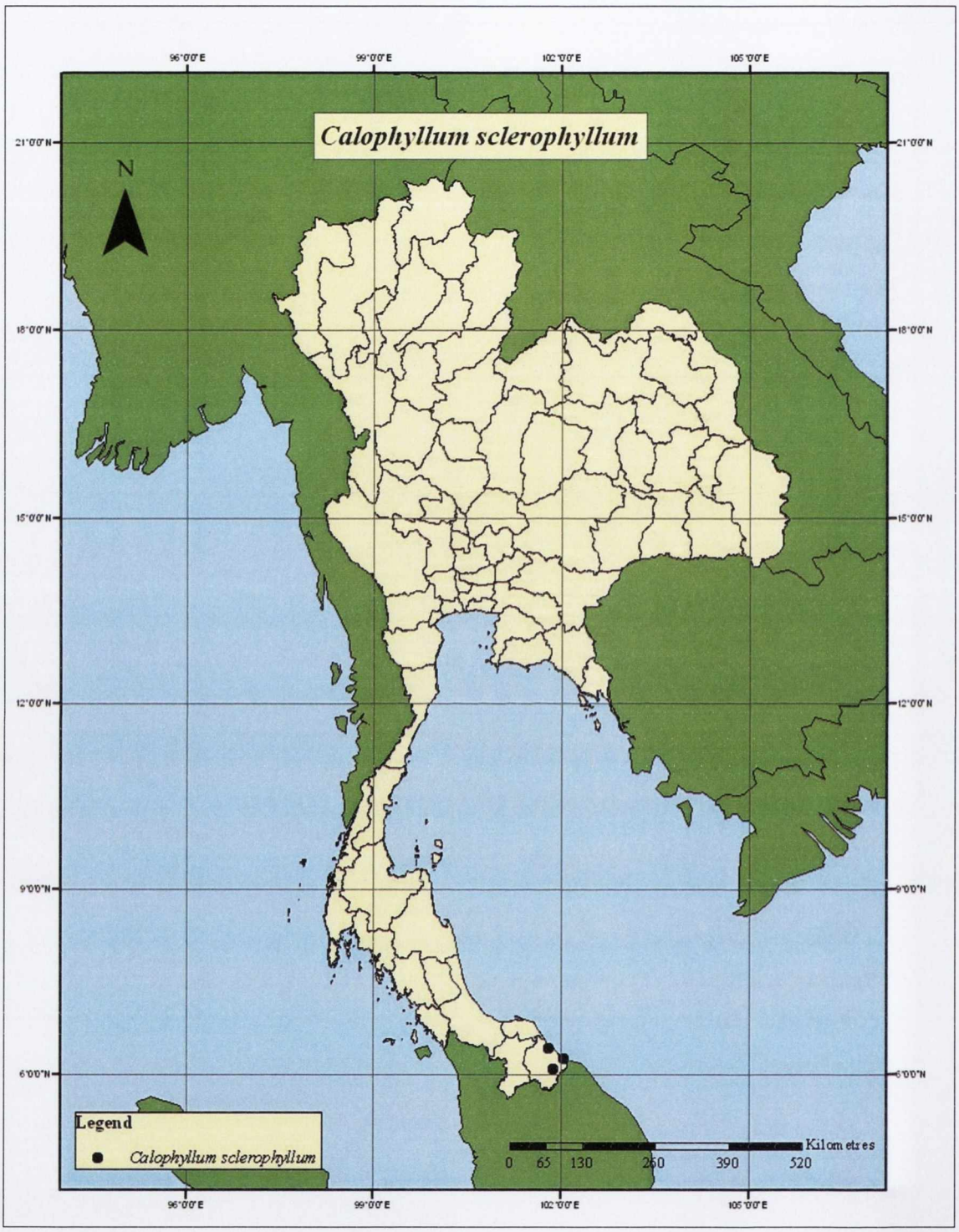
Local name: Ya-Kang (Sangkaew, 1999)/Kra thing phru (Sangkaew, 1999).

IUCN Regional (Thailand) Status: Critically Endangered (CR).

Note on species limits: see *C. thorelii* above.

THAILAND

Peninsular Region: 76. *Narathiwat Province:* Bang Kuntang, Tak Bai, *C. Niyomdham 654* (BKF); Paa Ye, Su Ngai Paadee, *C. Niyomdham & W. Ueachirakan 1815* (BKF); Ban Nara, *T. Smitinand 11960* (BKF).



Map 3.11 Distribution of *Calophyllum sclerophyllum* in Thailand.

9. *Calophyllum symingtonianum* M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 338. pl. 18. 1956; Kochummen, Malayan Forest Rec. 2(17): 222. 1965; T.C. Whitmore, Tree Flora of Malaya 2: 192. 1973; P.F. Stevens, J. Arnold Arbor. 61: 229. 1980.

Type: Malaya, Pahang, *SFN 32633* coll. *Nur* (Holotype: SING; Isotypes: A, K!, KEP, L!, MO, P!, UC, US).

Description

Habit tree up to 40m tall; up to dbh 300cm; without buttresses; bark grey to yellow-brown; rough; fissured; inner bark pink; outer bark greyish-brown to yellowish-brown; exudate: the colour of clear honey, sticky. ***Branchlets*** terete; hairless; dark brown to greyish; smooth; thin. ***Leaves*** petioled, 1-1.3cm long; midrib light green to brown on upper surface and pale green to yellow on lower surface; quite discrete on both surfaces, slightly more prominent on lower surface; surface smooth, slightly coriaceous; green to red/brown in colour; 6.3-9.4 x 2.4-3cm; elliptic to lanceolate in shape; base tapering to acute; apex acuminate; secondary veins present; arising from same points on both sides of the midrib. ***Inflorescence*** terminal and from upper leaf axils; some with pale brown pubescence. ***Floral parts*** tepals 8; outer pair of tepals dorsally hairless or (occasionally) dorsally slightly pubescent towards base. ***Stamens*** 46-70 per flower. ***Fruit*** ellipsoid to slightly obovoid; apex acute to round; 2.5cm long; dull reddish brown to dark purple when dry; hairless and wrinkled.

Distribution: Thailand: Trang, Songkhla, Yala (Locations taken from Sangkaew, 1999); **Worldwide:** Malaya.
Phenology: Flowering: Fruiting: February-April.
Ecology: Evergreen forest.
Altitude: 460m.
Uses: Hard wood used to build houses (Sangkaew, 1999).
Local name: Tang hon (Sangkaew, 1999).
IUCN Regional (Thailand) Status: Data Deficient (DD).

THAILAND

Unknown Location: No collector name or number (BKF).



Map 3.12 Distribution of *Calophyllum symingtonianum* in Thailand.

10. *Calophyllum calaba* L., in Sp. Pl. 732. 1753; P.F. Stevens, J. Arnold Arbor. 61: 256. 1980; P.F. Stevens, in Jarvis et al., Regnum Veg. 127: 28. 1993.

Type: Ceylon (Sri Lanka), *Hermann* 3: 3, No. 202 (Lectotype: BM!).

Synonyms

-*Calophyllum saigonense* Pierre, Fl. Forest. Cochinch. 1: t. 105. 1885; Vesque, in DC. Monogr. Phan. 8: 602. 1893; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 318. 1910; Craib, in Schmidt, Bot. Tidsskr. 32: 328. 1915; Craib, Fl. Siam. 1: 121. 1931; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1: 274. 1943; Pham & Nguyen, Cay-Co Mien Nam Viet-Nam, 179. 1960; Pham, Cay-Co Mien Nam Viet-Nam. 2(2): 303. 1970; H. Keng, Gard. Bull. Singapore 28: 245. 1976. Type: Cochinchine, Beucar, *Pierre 3649* (Lectotype P!; Isolectotype: E!, K!, P!).

-*Calophyllum curtisii* Ridl., J. Asiatic Soc. Bengal Pt. 2, Nat. Hist. 59: 176. 1890; Curtis, J. Straits Branch Roy. Asiatic Soc. 25: 78. 1894; Ridl., Fl. Malay. Penin. 1: 185. 1922; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 321. 1956; Kochummen, Malayan Forest Rec. 2(17): 221. 1965; T.C. Whitmore, Tree Flora of Malaya 2: 177. 1973; Corner, Gard. Bull. Singapore Suppl. 1: 104. 1978. Type: Malaya, Penang, *Curtis 523* (Lectotype: K! (Lectotype designated here); Isolectotypes: BM!, BO).

Description

Habit tree up to 30m tall; dbh 20cm; bole straight; without buttresses; bark deeply fissured, outer bark yellow to grey-yellow in colour; inner bark red-pink; exudate the colour of clear honey, sticky. ***Branchlets*** flattened to terete; some smooth-waxy, some showing tiny minute hairs on stems; tomentose; internode 1-3cm long. ***Leaves*** petioled, 0.3-1.9cm long; midrib depressed on upper surface and pronounced on lower surface, orange/brown on lower surface and red/light tan on upper surface, midrib wide on lower surface, approximately 2mm wide and narrowing towards apex to approximately 1mm wide; upper and lower surface smooth, coriaceous, green/orange/yellow/brown in colour; young leaves reddish pubescence; concave above and convex below, 3.5-11.2 x

0.9-4.4cm; base cuneate to attenuate to slightly acute; apex acute to round, sometimes cuspidate; venation very obvious on both surfaces, secondary veins present; dense, arising at same points on both sides of the midrib, approximately 0.5mm apart; intramarginal vein inconspicuous but present. ***Inflorescence*** axillary; covered in brown pubescence; 3-15 flowers per inflorescence; pedicels 0.3-2.8cm long. ***Floral parts*** tepals 4, sometimes 6; the outer pair elliptic-obovate to ovate; 3-5 x 2-3mm, dorsally brown pubescent; inner one elliptic-oblong, 4.5-7 x 1.5-3mm, dorsally pubescent. ***Stamens*** in fascicles, approximately 20-95 per flower; filament 2-6mm long; anther 1-1.2mm long; anther orange in colour. ***Ovary*** 1.5-2mm long; style 2-4mm long. ***Fruit*** ellipsoid to ovoid; 0.5-1 x 0.5-0.8cm; round at apex; yellow-green to pale brown when ripe.

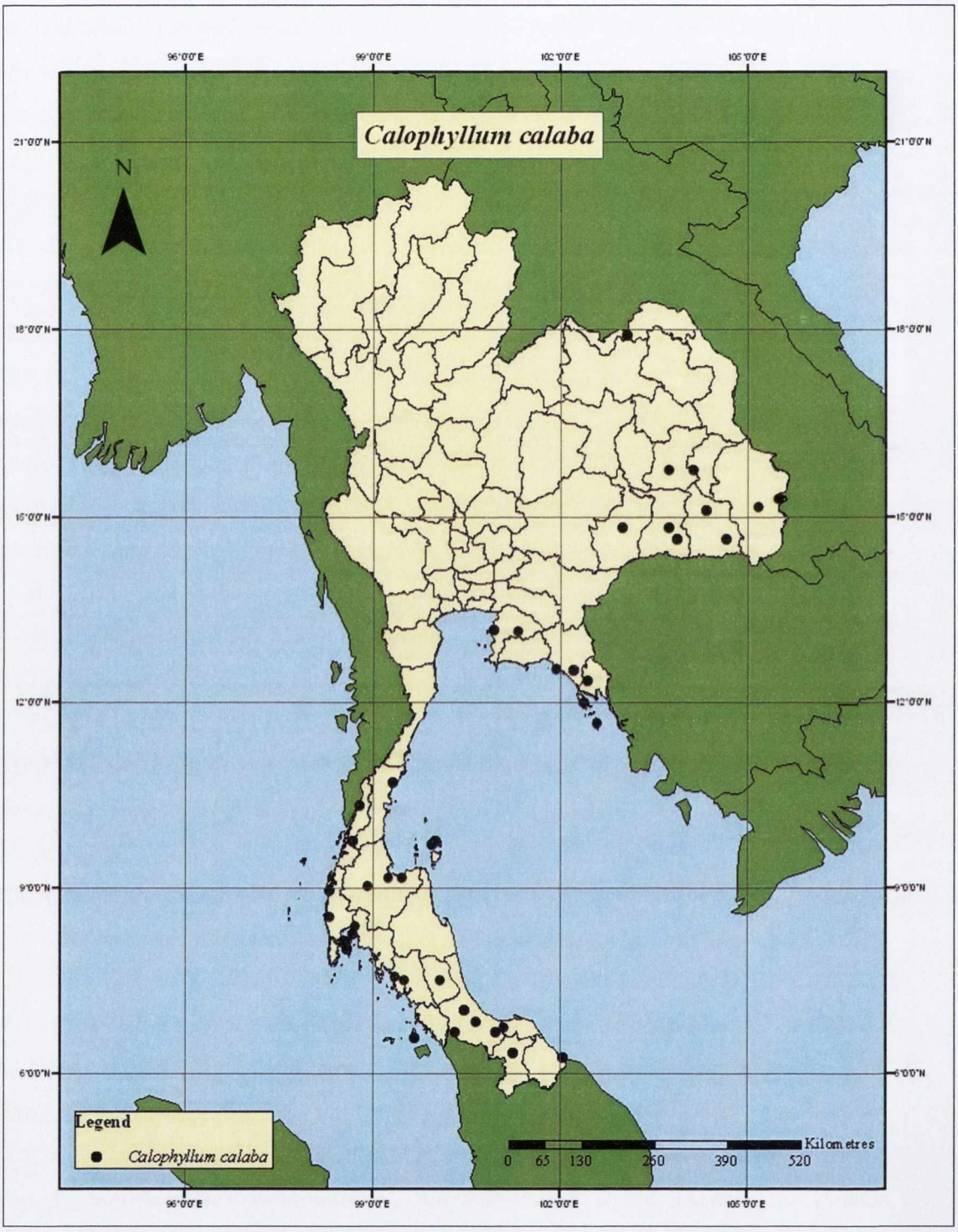
Distribution: Thailand: Nong Khai, Buri Ram, Surin, Roi Et, Yasothan, Si Sa Ket, Ubon Ratchathani, Chon Buri, Chanthaburi, Trat, Chumphon, Ranong, Surat Thani, Phangnga, Phuket, Krabi, Phattalung, Trang, Satun, Songkhla, Pattani, Yala, Narathiwat; **Worldwide:** Indonesia, Malaysia, South Asia and Himalaya and Vietnam.
Phenology: Flowering: August-December. Fruiting: October-April.
Ecology: Savannah, Evergreen Forest, Secondary Forest.
Altitude: Near Sea Level – 650m.
Uses: This wood is used in house construction. The fruits are edible (Sangkaew, 1999).
Local name: Pha uung (Sangkaew, 1999)/Pa-ong (Sangkaew, 1999)/Pa-ung (Sangkaew, 1999)/Phanghan klet raet (Sangkaew, 1999).
IUCN Regional (Thailand) Status: Least Concern (LC).
Note: In the West Indies there is a species referred to as *Calophyllum calaba* Jacq. This is not the same species that occurs in Asia, Indonesia and Malaysia. The West Indian species referred to as *Calophyllum calaba* Jacq. should be called *Calophyllum jacquinii* Faw. & Rendle based on priority of publication as *Calophyllum calaba* L. was published in 1753 and *Calophyllum calaba* Jacq. was published in 1768 (Fawcett et al., 1910).

THAILAND

North-Eastern Region: 20. *Nong Khai Province*: Chaiyaburi, *A.F.G. Kerr 8526* (ABD, BK, BM, E, K, TCD); **Eastern Region: 29. *Buri Ram Province:*** *C. Phengkhlai et al 3331* (A, BKF, PSU); **30. *Surin Province:*** *C. Phengkhlai et al 3624* (A, BKF,

PSU); Sangka, *A.F.G. Kerr 8271* (ABD, BK, BM, C, K, P, TCD); **31. *Roi Et Province*:** *Wanarale 62* (BK, K); T. Banna, Suwanapoom, *S. Sutheesoen 5342* (BK); T. Banna, Suwanapoom, *S. Sutheesoen 5358* (BK); **32. *Yasothan Province:*** *T. Smitinand s.n.* (BKF); **34. *Si Sa Ket Province:*** Kantaralak District, *P. Sangkhachand 201* (BK); *C. Phengkhlai 900* (C, K, L, P); Pha-ung, *C. Phengkhlai 38105* (E); Kantaralak District, Lalie Sub-District, *J.F. Maxwell 72-205* (AAU); Chong Bat Lak, Kantaralak, *J.F. Maxwell 76-205* (AAU, BK, L); Kantaralak District, Dongkrak Range, Chong Bat Lak, *J.F. Maxwell 76-592* (AAU, BK, L); **35. *Ubon Ratchathani Province:*** Lam Don Hoi, *T. Smitinand & J. Turbang 10504* (BKF); Khong Chiam Falls, *T. Smitinand 90-267* (BKF); **South-Eastern Region: 59. *Chon Buri Province:*** Kong Yai Boo, *D.J. Collins 645* (K); Sriracha, Nah Prow, *D.J. Collins 804* (ABD, BM, K); Hoop Ban, Sriracha Forest, *D.J. Collins 1661* (BM, K); Sriracha Forest, *D.J. Collins 1779* (BK, K); **61. *Chanthaburi Province:*** Ban Chao Lao, *K. Chayamarit 281* (BKF); Kao Sabap, *A.F.G. Kerr 17993* (A, BK, BM, C, K, L, P); **62. *Trat Province:*** Kao Saming, *Put 566* (BK, K, L); Koh Chang, Klong Son, *J. Schmidt 668* (C, K); Koh Kut, Aow Salad, *C. Phengkhlai et al 13582* (BKF); **Peninsular Region: 63. *Chumphon Province:*** Bang Son, *A.F.G. Kerr 11318* (A, BK, C, K, L, P); **64. *Ranong Province:*** Ban Naka, *T. Santisuk 797* (A, BKF); Khlong Naka, *R. Geesink, P. Hiepko & C. Phengkhlai 7561* (AAU, BKF, C, K, L, P); Ban Lam Lieng, *A.F.G. Kerr 11733* (A, BK, BM, C, K, L, P); *A.F.G. Kerr s.n.* (BK); **65. *Surat Thani Province:*** Kao Tam Nong, Na Sarn, *Sakol 1070* (BK); Kaw Pa-ngan, *Put 1155* (BK, BM, K); Kaw Pa-ngan, *Put 1156* (BK, BM, K, L); Chaiya, G. Seidenfaden 2576 (C); Kaw Tao, *A.F.G. Kerr 16065* (A, BK, BM, C, K, L, P); Than Khanon, *Pierre s.n.* (BKF); **66. *Phangnga Province:*** Ko Kho Khao, *B. Sangkhachand 1185* (BKF, K, L); Between Thai huiang & Thung Maphrao, *T. Smitinand 4157* (BKF); Kaw Yao Yai, *A.F.G. Kerr 17291* (A, BK, BM, C, K, L, P); Lamlieng to La-un, *A.F.G. Kerr 18419* (K, L); **67. *Phuket Province:*** Tha-chai/-chat, *C. Phengkhlai & T. Smitinand 6105* (AAU, BKF, L, P); **68. *Krabi Province:*** Ao Luk, *A.F.G. Kerr 18567* (L); **70. *Phattalung Province:*** *W. Siwanna s.n.* (BKF); **71. *Trang Province:*** Had Vhao Mai NP, Si Kao District, *A. Mauric 15* (BKF); *M.E. Poilane 23626* (BKF); **72. *Satun Province:*** Tarutao, Son Bay, *G. Congdon 400* (A, AAU, PSU); Ky Island, Tarutao, *G. Congdon 493* (A, AAU); Tarutao Island, *G. Congdon 1260* (A); Kanchanadit, *A.F.G. Kerr 13653* (BK, BM, K); **73. *Songkhla Province:*** Kobe Island, Satingpra District, *P. Srirugsa 835* (A, BKF, PSU); Klong Hoy Kong, Haad Yai District, *J.F. Maxwell 85-65* (A, BKF, PSU); Ko Hong Hill/Prince of Songkhla University Campus, *J.F. Maxwell 85-1181* (A,

AAU, BKF, L, PSU); Ko Hong Hill/Haad Yai, *J.F. Maxwell 86-261* (A, BKF, L, PSU); **74. *Pattani Province:*** *T. Santisuk s.n.* (BKF); **75. *Yala Province:*** *Put 3668* (BK, BM, C, K, L); *Put 3670* (A, BK, BM, C, K, L, P); **76. *Narathiwat Province:*** Kok Mai Rue, Tak Bai, *C. Niyomdham et al 1136* (A, AAU, BKF, C, K, L, P); Kok Mai Rue, Tak Bai, *C. Niyomdham et al 1225* (A, BKF, C, K, L, P); **Unknown Locations:** No collector *177* (BKF); *J.R. Conran 291* (PSU); *Hewitt, 2063* (BM, K).



Map 3.13 Distribution of *Calophyllum calaba* in Thailand.

11. ***Calophyllum inophyllum*** L., Sp. Pl. 513. 1753; Burmann f., Fl. Ind, 120. 1768; G. Forster, Fl. Ins. Austral. 41. 1768; Choisy, in DC. Prodr. 1:562. 1824; Blume, Bijdr. Fl. Ned. Ind. 5: 217. 1825; Blanco, Fl. Filip. 612. 1837; Wight, Icon. Pl. Ind. Orient. pl. 77. 1839; Thwaites, Enum. Pl. Zeyl. 51. 1858; Miq., Fl. Indiae Batavae 1(2): 510. 1859; Planchon & Triana, Ann. Sci. Nat. Bot. 4(15): 282. 1862; Bentham, Fl. Austral. 1: 183. 1863; T. Anderson, in Hook, f., Fl. Brit. India 1: 273. 1874; F. Mueller, Descr. Notes Papuan Pl. 36. 1875; Hillebr., Fl. Hawaiian Isl. 40. 1888; Vesque, Epharmosis 2: t.1. 1889, Vesque, in DC. Monogr. Phan. 8: 544. 1893; Drake, in Grandid., Hist. Phys. Madagascar 35: pl. 355. 1894; Brandis, Indian Trees, 54. fig. 43. 1907; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 324. 1910; Heckel, Ann. Mus. Hist. Nat. Marseille, 2(10): 262, pl. 25. 1912; Koord-Schum., Syst. Verz. 1:4. 1912; Merr., Enum. Philipp. Fl. Pl. 3:79. 1923; Craib, Fl. Siam. 1: 120. 1931; Kanehira, Fl. Micron. 234, fig. 106 1933; Merr., Trans. Amer. Philos. Soc. 24(2): 269. 1935; Kanehira, Formosan Trees. Rev. ed. 473. fig. 433. 1936; Sastri et al., Wealth India 2; 18. 1950; Heyne, Nutt. Pl. Ned.-Ind. ed. 3 1: 1083. 1950; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 314. pl. 1C. 1956; N. Robson, in Exell & Wild, Fl. Zambes. 1: 394. t.76. 1961; Hui.–L. Li, Woody Fl. Taiwan, 601. fig. 235. 1963; Baker & Bakh. f., Fl. Java 1: 386. 1965; T.C. Whitmore, Guide Forests Brit. Solomon Is. 77. 1966; T.C. Whitmore, Tree Flora of Malaya 2: 186. 1973; P.F. Stevens, Austral. J. Bot. 22: 374. 1974; A.C. Smith & Darwin, J. Arnold Arbor. 55: 223. figs. 6-8. 1974; P.F. Stevens, J. Arnold Arbor. 57: 170. 1976; Bamps et al., in Polhill, Fl. Trop. E. Africa, Guttiferae: 3. 1978; Perry, Med. Pl. E. & SE. Asia, 173. 1980; P.F. Stevens, J. Arnold Arbor. 61: 324. 1980; L. Xiwen, L. Jie & P.F. Stevens, Fl. China 13: 38-40. 2007.

Type: Ceylon, *Hermann* 2: 82, No. 201 (Lectotype: BM!).

Synonyms

-*Balsamaria inophyllum* Lour., Fl. Cochinch. 2: 470. 1790. Type: *Unknown collector s.n.* (Holotype: BM!).

-*Calophyllum ovatifolium* Norona, Verh. Batav. Genootsch. Kunsten 5(4): 13. 1790.

-*Calophyllum bintagor* Roxb., Hortus Bengal. 41. 1814; G. Don, Gen. Syst. 1: 622. 1831; Roxb., Fl. Ind. 2: 607. 1832. Type: based on *Rumphius, Herb. Amboin.* 2: t.71. 1741.

-*Calophyllum blumei* Wight, Illus. Ind. Bot. 1: 128. 1840; Walp., Rep. Bot. Syst. 1: 397. 1842. Type specimen not found.

-*Calophyllum wakamatsui* Kanehira, Bot. Mag. (Tokyo) 48: 401. 1934; Kanehira, J. Dept. Agric. Kyushu Imp. Univ. 4: 371. 1935. Type: Palau, *Kanehira 2343* (Isotype: NY!).

-*Calophyllum inophyllum* Linnaeus var. *takamaka* Fosberg, Kew Bull. 29: 255. 1974. Type: Aldabra Atoll, *Fosberg 49272* (Holotype: US; Isotype: GH!, K!, NY!).

Description

Habit tree 7-30m tall; dbh 11-12cm; bole +/- straight; without buttresses; bark slightly fissured, rough, outer bark grey to brown; exudate: the colour of clear honey. ***Branchlets*** striate; slightly brown pubescence or hairless; internode 2-3cm long; yellow-greenish sap in centre of branchlets. ***Leaves*** petioled, 1.5-3cm long; elliptic-obovate, sometimes oblong, obtuse, rounded or emarginate; coriaceous, rarely glaucous, dark green on upper surface and dull green on lower surface, concave above and convex below, 8-15 x 4-8cm; base cuneate to attenuate; apex retuse to round, rarely acute; midrib depressed on upper surface in channel about ¾ of lamina length, underside raised; lateral veins dense and distinct on both surfaces; 6-8 veins per 0.5cm. ***Inflorescence*** axillary panicles 5-10cm long; pubescent or hairless; up to 12 flowers per inflorescence; pedicels 0.6-4cm long. ***Floral parts*** tepals 8; reflexed when flower is fully open; the outer pair oval to suborbicular; hairless; imbricate; the next pair elliptic and the 2 inner pairs elliptic to obovate; ***Stamens*** in fascicles but not distinct fascicles, 40-250 stamens per flower; filament 4-5mm long, white to yellow-green in colour; anther 1-1.5mm long; anther bright yellow/orange in colour. ***Ovary*** subglobose; 1.5 – 3.5mm long, style 5-7mm long, style with flat stigma,

almost white, 8-9mm long; 1 ovule; red in colour. ***Fruit*** globose; 2.5-3.2 x 3cm; round at apex.

Distribution: Thailand: Chiang Mai, Phayao, Phrae, Mukdahan, Kanchanaburi, Saraburi, Krung Thep Maha Nakhon (Bangkok), Chon Buri, Rayong, Trat, Chumphon, Surat Thani, Phangnga, Phuket, Phattalung, Satun, Songkhla; **Worldwide:** Widespread from East Africa to Australia.

Phenology: Flowering: October-December. Fruiting: all year.

Ecology: Evergreen & Deciduous Forests, marshy grounds, sandy rocky shorelines.

Altitude: Near Sea Level – 300m.

Uses: This species is used for various purposes due to its' high durability. The wood is used in underwater construction and for furniture making. The seed oil is used in soap making and as medicine to treat conditions such as rheumatism and skin infections. The plant also has many other medicinal uses due the presence of saponins and hydrocyanic acid (Sangkaew, 1999; Stevens, 1980).

Local name: Kra thing (Sangkaew, 1999)/Saaraphee thale (Sangkaew, 1999)/Thing (Sangkaew, 1999).

IUCN Global Status: Least Concern (LC).

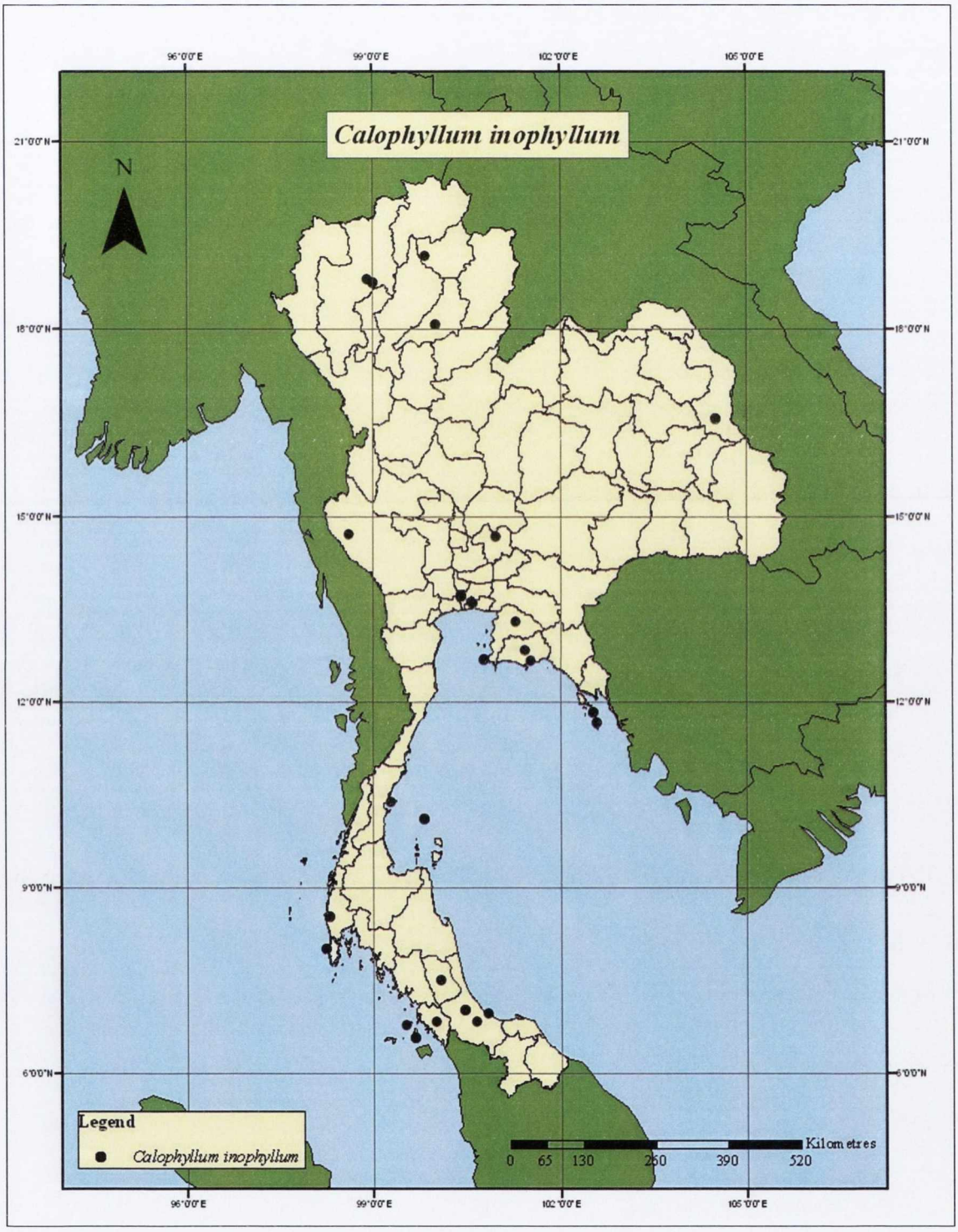
IUCN Regional (Thailand) Status: Least Concern (LC).

Notes: Visited by bees.

THAILAND

Northern Region: 2. *Chiang Mai Province:* *A.F.G. Kerr 3265* (ABD, BM, E, K); **4. *Phayao Province:*** Kwan Phayao, *BGO Staff 1108* (QBG); **8. *Phrae Province:*** *L.V.P. 268* (BKF, K); **North-Eastern Region: 23. *Mukdahan Province:*** *M.C. Lakshnakara 946* (ABD, BK, BM, K, TCD); **South-Western Region: 37. *Kanchanaburi Province:*** Wangka, *B.S. 390* (BK); **Central Region: 47. *Saraburi Province:*** Pukae, 14km from North of Saraburi, in direction of Lopburi, *J. Lambinon 87/08* (AAU); **52. *Krung Thep Maha Nakhon Province:*** Beside the library, Kasetsart University, Bang Khen, *B. Watdahnahsahp 16* (A, L, PSU); *A. Marcan 849* (ABD, BM); *A. Marcan 984* (BM); Paknam, *A. Marcan 987* (BM); *A.F.G. Kerr 4344* (ABD, BM, K, TCD); Kasetsart University Campus, Bang Khen, *J.F. Maxwell 75-430* (AAU, BK); Paknam, *A.F.G. Kerr s.n.* (BM); Royal Palace, *T. Smitinand s.n.* (BKF); **South-Eastern Region: 59. *Chon Buri Province:*** *Apiom, Sompit & Pannarai 9* (KKU): Pataya seaside, *T. Chotmaiwee 28* (BK): Koh Kram Island, Pattaya, East Coast, *D.J. Collins 942* (ABD, K, TCD); Kasetsart University, Sriracha Campus, *J.F. Maxwell 04-827* (CMU); **60.**

Rayong Province: Chak Phong Klaeng, *K. Kertsawang 319* (QBG); Phae Arboretum, Phae District, *T. Shimizu, H. Toyokuni, H. Koyama, T. Yahara & D. Phanichapol T-23297* (L); **62. *Trat Province:*** Ko Kut SW, *C. Charoenphol, K. Larsen & E. Warncke 5111* (AAU, E); **Peninsular Region: 63. *Chumphon Province:*** Had Sai Ree, *Vachanapong 64* (BK); Saek Island, Parlenam, *Jaram 167* (BM); **65. *Surat Thani Province:*** Kaw Tao, *A.F.G. Kerr 11217* (ABD, BK, BM, K); **66. *Phangnga Province:*** North of Thung Maphrao, *K. Larsen, S.S. Larsen, I. Nielsen & T. Santisuk 31115* (AAU, K, L, P); **67. *Phuket Province:*** *A. Ubolchalaket 111* (P); **70. *Phattalung Province:*** *L.V.P. 772* (BKF, K); **72. *Satun Province:*** Tarutao, near, Malaeca Creek, *G. Congdon 115* (A, PSU); West side of Pulau Adang, *G. Congdon 115A* (P); Tarutao NP, Ow Son, *G. Congdon 147* (A, AAU, PSU); Langu, Ko Pulon Mai Phai, *C. Phengkhlai et al 14760* (BKF); Tarutao Island, *C. Chermsirivathana & Kasem 1453* (BK); **73. *Songkhla Province:*** Ko Hong Hill, Haad Yai, *S. Songsiri 17* (PSU); PSU Campus, Haad Yai, *Congdon & Hamilton 489* (A, PSU); Koh-Kham Island, Chana, *P. Sirirugsa PS425* (PSU); **Unknown Locations:** Koh Kahdat, *J. Schmidt 546* (C).



Map 3.14 Distribution of *Calophyllum inophyllum* in Thailand.

12. *Calophyllum tetrapterum* Miq., Pl. Jungh. 291. 1854; P.F Stevens, J. Arnold Arbor. 61: 505. 1980.

Type: Sumatra, *Junghuhn s.n.* (Holotype: U!; Isotype: BO!, L!).

Synonyms

-*Calophyllum bancanum* Miq., Fl. Ned. Ind., Eerste Bijv. 1(3): 499. 1861; Kurz, Nat. Tijdschr. Nederl.-Indie 27: 192. 1864; F. Mueller, in Walp. Ann. Syst. Bot. 7: 357. 1868; Scheffer, Nat. Tijdschr. Nederl-Indie 31:354. 1870, 32: 405. 1873. Type: Bangka, *Teysmann, HB 3214* (Holotype: U!; Isotype: BO, K!, L!).

-*Calophyllum gracile* Miq., Fl. Ned. Ind., Eerste Bijv 1(3): 498. 1861; F. Mueller, in Walp. Ann. Syst. Bot. 7: 357. 1868. *Calophyllum pulcherrimum* Wall ex. Choisy var. *gracile* (Miq.) Boerl., Cat. Hort. Bogor. 2:82. 1901. Type: Sumatra, *Teysmann, HB 649* (Holotype: U!; Isotype: BO, K!, L!, MEL).

-*Calophyllum floribundum* Hook. f., Fl. Brit. India 1: 272. 1874; King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59: 175. 1890; Ridl., Fl. Malay. Penin. 1:184. 1922; M.R. Henderson, Gard. Bull. Straits Settlem. 4:224. 1928; M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 332. pl.16. 1956; Smythies, Common Sarawak Trees 61. 1965; Kochummen, Malayan Forest Rec. 2(17): 215. 1965; I.H. Burkill, Dict. Econ. Prod. Malay Penin. Ed. 2. 1: 412. 1966; T.C. Whitmore, Tree Flora of Malaya 2: 180. 1973; Corner, Gard. Bull. Singapore, Suppl. 1: 104. 1878. Type: Malaya, Malacca, *Maingay 1660* (Lectotype: K!).

-*Calophyllum prainianum* King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59: 175. 1890; Vesque, in DC Monogr. Phan. 8: 550. 1893; Ridl., Fl. Malay. Penin. 1:183. 1922. Syntypes: Malaya, Perak, Larut, *Dr. King's Collector* [*Kunstler*] 5366 (BM!, FI, G, K!, P!, UC), [*Kunstler*] 7243 (BM!, FI, K!, L!, P!).

-*Calophyllum venustum* King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59: 180. 1890; Vesque, in DC. Monogr. Phan. 8: 549. 1893; Ridl., Fl. Malay. Penin. 1:186. 1922.

Type: Malaya, Perak, Larut, *Dr. King's Collector* [*Kunstler*] *7763* (Lectotype: L! (Lectotype designated here); Isolectotypes: FI, G, K!).

-*Calophyllum foetidum* Ridl., Journ. As. Soc. Straits 54: 18. 1910; Fl. Malay. Penin. 1:186. 1922. Type: Singapore, *Ridley 11958* (Lectotype: SING!; Isolectotypes: BM!, K!).

-*Calophyllum lanceola* Ridl., Journ. As. Soc. Straits 82:170. 1920; Ridl., Fl. Malay. Penin. 1:82. 1922. Type: Malaya, *Ridley 5751* (Holotype: SING!).

-*Calophyllum rupicolum* Ridl. var. *elatum* T.C. Whitmore, Gard. Bull. Singapore 26: 270. 1970; T.C Whitmore, Tree Flora of Malaya 2: 169. 1973. Type: Malaya, Kelantan, *FRI 2538* coll. *Kochummen* (Holotype: KEP, Isotypes: K!, L!, SING!).

-*Calophyllum pulcherrimum* auct., non Wall. ex Choisy; T. Anderson, in Hook. f., Fl. Brit. India 1: 271. 1874; Pierre, Fl. Forest. Cochinch. 1: pl. 104A. 1885, *pro parte*; Vesque, Epharmosis 2: t. 21. 1889; Vesque, in DC. Monogr. Phan. 8: 570. 1893, *pro parte*; Curtis, Journ. As. Soc. Straits 25: 78. 1894; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 321. 1910; Ridl., Fl. Malay. Penin. 1:182. 1922, *pro parte*; I.H. Burkill & M.R. Henderson, Gard. Bull. Straits Settlem. 3: 347. 1925; Craib, Fl. Siam. 1: 121. 1931; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1: 274. 1943; Pham & Nguyen, Cay-Co Mien Nam Viet-Nam, 179. 1960; Pham, Cay-Co Mien Nam Viet-Nam. 2(2): 301. fig. 1970. Type specimen not found.

-*Calophyllum dryobalanoides* auct., non Pierre; Craib, Fl. Siam. 1:120. 1931; Gagnep., in Humbert, Suppl. Fl. Indo-Chine, 1: 274. 1943, *pro parte*.

-*Calophyllum globuliferum* Ridl., Bull. Misc. Inform. Kew 1938: 121. 1938. Type specimen not found.

Description

Habit medium to large tree up to 25m tall; dbh 30cm; bole straight; with or without small buttresses; bark coarsely but shallowly fissured or smooth; outer bark grey-brown

to dark grey-black; exudate: the colour of clear honey; inner bark soft, pink. ***Branchlets*** terete to flattened; slender; hairless; internode 1-3cm long; brown/red/grey in colour. ***Leaves*** petioled, 0.5-1.5cm long; obovate to elliptic; concave above and convex below; coriaceous, lower surface slightly glaucous, red-brown in colour, some leaves green/yellow, 3.5-13.2 x 1.4-4cm; base cuneate to attenuate; apex acute to acuminate; midrib not very pronounced on either surface; depressed in channel about ½ of lamina length on upper surface, underside raised; secondary veins present and prominent on both surfaces, arising roughly from the same place on both sides of the midrib; spacing of veins varies from leaf to leaf; dense on all leaves; approximately 6-17 veins per 0.5cm; intramarginal veins absent. ***Inflorescence*** axillary; 3-11 flowers per inflorescence; covered with brown pubescence; pedicels 0.5-2.5cm long. ***Floral parts*** tepals (4)-8, sometimes 5, 6, 7 or 8, the outer pair ovate, oval to suborbicular, 3-5 x 3-4mm, hairless to slightly pubescent along margin and apex; inner pair obovate or ligulate, 4-8 x 3-5mm, hairless, the next 2 with same shape and size, obovate to spathulate, 5-7 x 2-3mm, or the innermost ones oblong-oblanceolate, 5-6 x 1-1.5mm, hairless. ***Stamens*** in fascicles, 36-86 stamens per flower; filament 2-5mm long; anther 1-1.3mm long; anther oblong or elliptic-oblong. ***Ovary*** 1-2mm long; style 2-4.5mm long. ***Fruit*** ovoid-globose; 0.6-1 x 0.5-0.8cm; acute to round at apex; dark green when ripe.

Distribution: Thailand: Trat, Chumphon, Ranong, Surat Thani, Krabi, Trang, Satun, Songkhla, Narathiwat; **Worldwide:** Cambodia, Vietnam, Malaysia and Indonesia excluding Java.

Phenology: Flowering: all year. Fruiting: January-May (October).

Ecology: Evergreen Forest, Tropical Rainforest, water areas, peat areas, savannah.

Altitude: Near Sea Level – 700m.

Uses: Young leaves are edible as vegetation (Sangkaew, 1999).

Local name: Tang hon (Sangkaew, 1999).

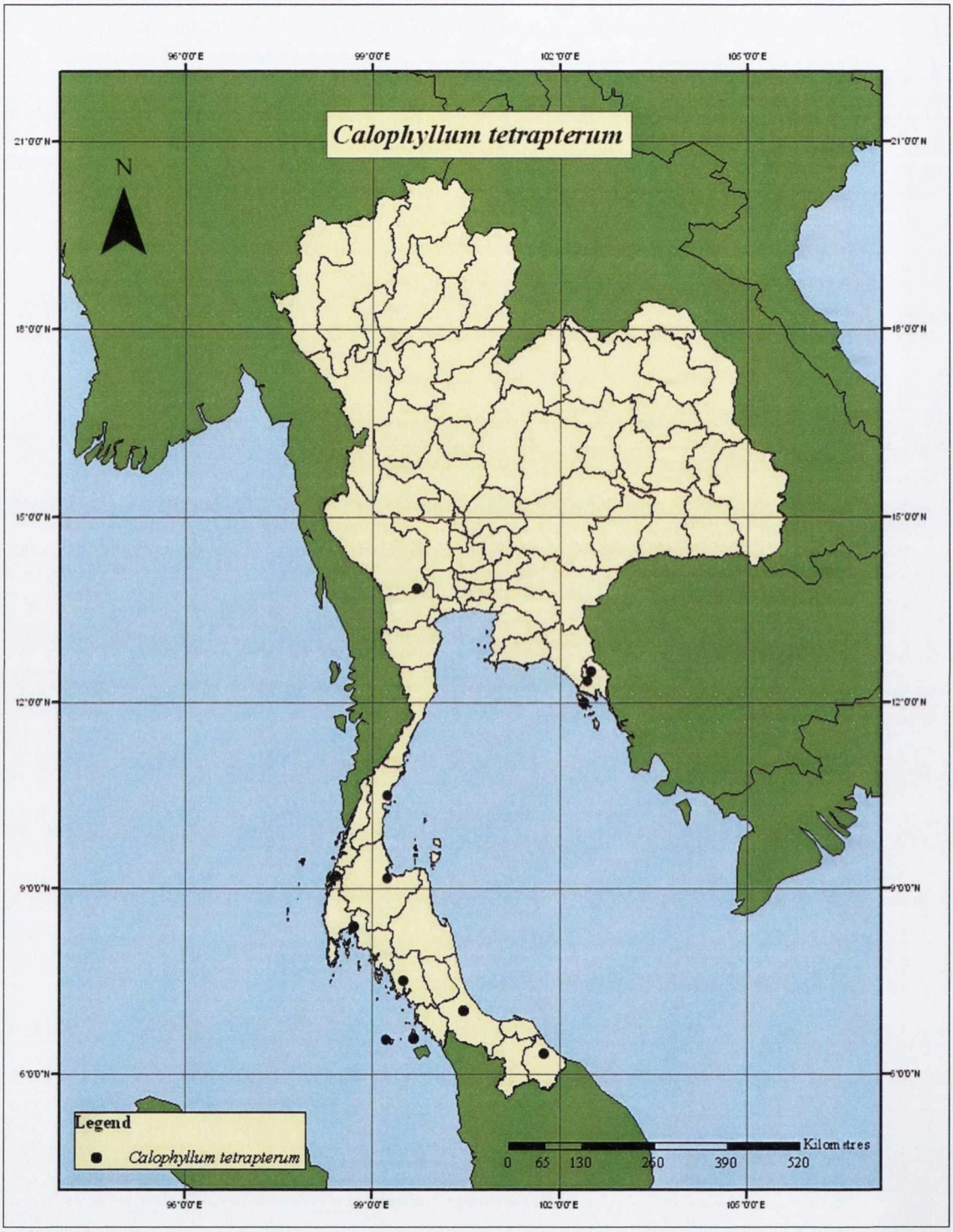
IUCN Global Status: Least Concern (LC).

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

South-Eastern Region: 62. *Trat Province:* Koh Chong, Jungle at Klong Munse, *J. Schmidt 528* (C, K); Kao Saming, *Put 567* (BK, K, L); Koh Chong, Klong Majum, *J.*

Schmidt 603a (C, K); Klawng Non Si, Koh Chang, *A.F.G. Kerr 9175* (A, BK, C, E, K, L, P); **Peninsular Region: 63. *Chumphon Province:*** Kao Kaeom, Sawee, *S. Sutheesoen 2227* (BK); **64. *Ranong Province:*** Khuraburi, Koh Phra Thong, *C. Phengkhlai et al 13729* (BKF); **65. *Surat Thani Province:*** Kao Kuap (or Panom Tom), *A.F.G. Kerr 17772* (BK, BM, K, L); **68. *Krabi Province:*** Kow Pra-Bahng Krahm Wildlife Sanctuary, *J.F. Maxwell 655* (CMU); Ao Luk, *A.F.G. Kerr 18567* (A, BK, BM, C, K, P); Kow Pra-Bahng Krahm Wildlife Sanctuary, *J.F. Maxwell 06-201* (CMU); **71. *Trang Province:*** Khao Chong, *S. Phusomsaeng & T. Smitinand 240* (AAU); Klawng Mayom Salak Kawk, Kaw Chang, *A.F.G Kerr 6930* (BKF, K); **72. *Satun Province:*** Rawi Island, *G. Congdon 631* (A); Tarutao NP at waterfall above Choe-lae Village east side of Adang, *G. Congdon 951* (AAU, PSU); Tarutao, *A.F.G. Kerr 14213* (BK, BM, C, K, L, P); **73. *Songkhla Province:*** Dton Nga Chang Reserve, Haad Yai, *P. Srirugsa 592* (PSU); Dton Nga Chang Reserve, Haad Yai, *P. Srirugsa 737* (PSU); Klong Hoy Kong, Haad Yai, *J.F. Maxwell 85-65* (P); Dton Nga Chang Reserve, Haad Yai, *J.F. Maxwell 85-417* (A, AAU, BKF, E, L, PSU); ***76. Narathiwat Province:*** Waeng, *P. Nitrasirirak 206* (BKF); Bala-Hala, Waeng, *P. Puudjaa 573* (BKF); Waeng, *B. Sangkhachand, S. Phusomsaeng & B. Nimanong 1067* (C); **Unknown Locations:** Hui Tonpong, *C. Punyabukkana 874* (ABD, BKF, K); Near Bukit Kallang, off Sime Road, *J.F. Maxwell 82-89* (BKF).



Map 3.15 Distribution of *Calophyllum tetrapterum* in Thailand.

13. *Calophyllum dryobalanoides* Pierre, in Fl. Forest. Cochinch. 1: t.106. 1885; Vesque, in DC. Monogr. Phan. 8:601. 1893; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 319. 1910; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1: 274. 1943, *pro minore parte*; Pham & Nguyen, Cay-Co Mien Nam Viet-Nam, 179. 1960; Pham, Cay-Co Mien Nam Viet-Nam, 2(2): 302. 1970; P.F. Stevens, J. Arnold Arbor. 61:232. 1980.

Type: Cochinchine (Vietnam) *Pierre 83* (Lectotype: P!; Isolectotypes: A, BM!, K!, L!, P!, SING!).

Description

Habit tree 0-30m tall; dbh 20cm; without buttresses; bole straight; bark fissured, outer bark brown-yellow or grey-yellow; exudate: the colour of clear honey. ***Branchlets*** quadrangular; slender; some with slightly brown pubescence, or waxy or hairless; internode 1-2.5cm long. ***Leaves*** petioled, 0.6-1.5cm long; lanceolate to elliptic-entire; coriaceous, very smooth, dark green above, paler green underneath, 4-8.9 x 1.5-3.5cm; base cuneate to slightly acute; apex acuminate; midrib not obvious on either surface, more pronounced on lower surface; yellow in colour; venation very pronounced; distance between veins 0.2-0.8mm; veins evenly spaced and meeting at the same points on opposite sides of the midrib; intramarginal veins present. ***Inflorescence*** terminal and from upper leaf axils; 7-37 flowers per inflorescence; covered with brown pubescence; pedicels 0.6-1cm long. ***Floral parts*** tepals 8, the outer pair oval to suborbicular; 3.5-5 x 3-4mm; dorsally slightly brown pubescence on outer side near base or hairless; inner one obovate to suborbicular, 4-6 x 5-6mm, hairless; the next two the same shape and size, elliptic-obovate, 4-5 x 3.5-4mm, hairless; white in colour. ***Stamens*** in fascicles, 140-170 stamens per flower; filament 2-3mm long; anther 0.6-1mm long; anther orange/yellow in colour. ***Ovary*** 1.5-2mm long; style 1.5-3mm long. ***Fruit*** ovoid; 1-1.5 x 0.7-1cm; apex acute to acuminate; green.

Distribution: Thailand: Phetchaburi, Trat. **Worldwide:** Cambodia, Vietnam.
Phenology: Flowering: September-December. Fruiting: January-March (August).
Ecology: Evergreen Forest, Secondary Forest, near water.
Altitude: 50 - 1,200m.

Uses: Wood is used in construction. Fragrant oil emitted from the flower is used in hair dressing (Sangkaew, 1999).

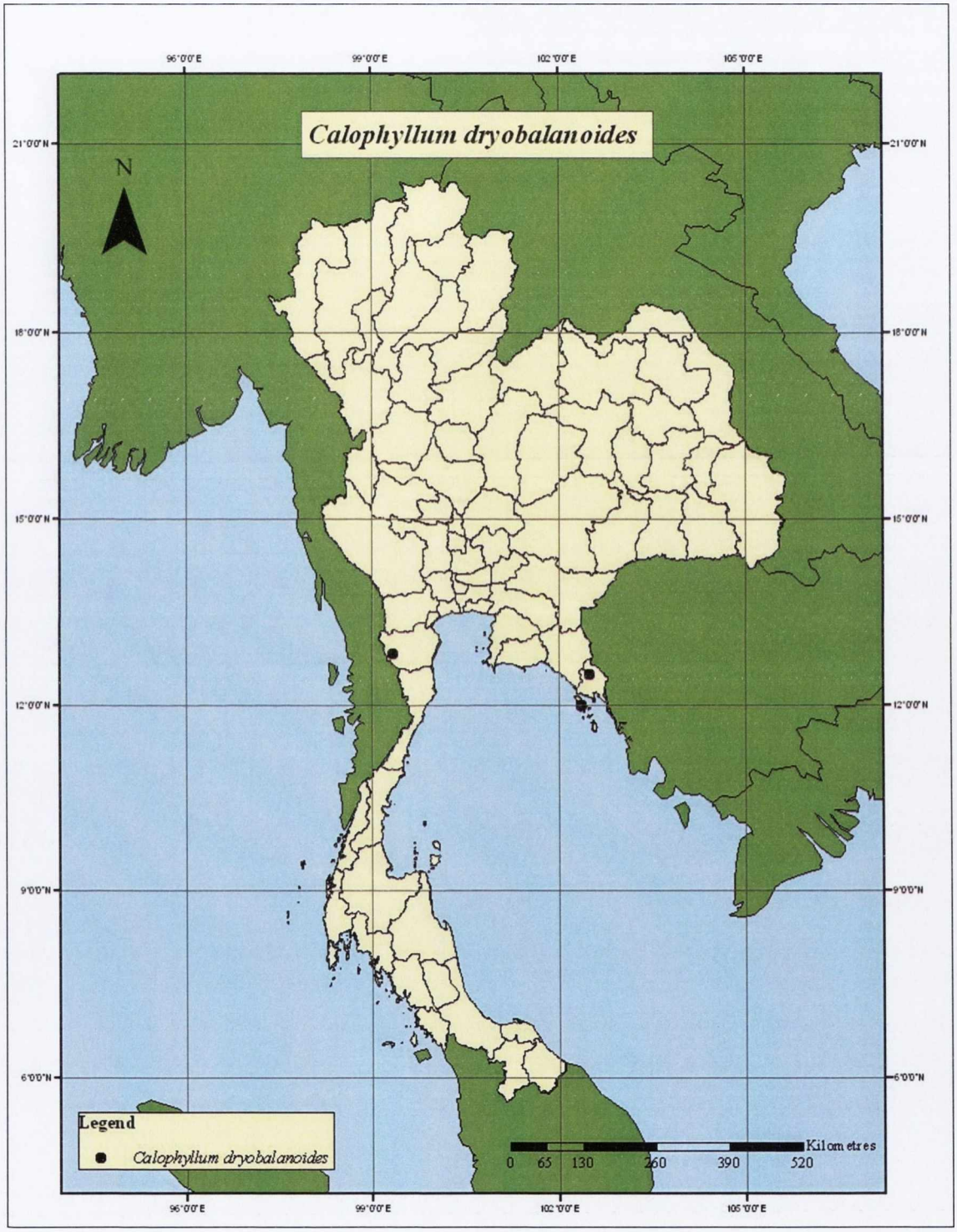
Local name: Pha-ong (Sangkaew, 1999).

IUCN Regional (Thailand) Status: Data Deficient (DD).

Note on species limits: *C. dryobalanoides* and *C. teysmannii* are similar species differing only in the tepal colour, the leaf colour, the leaf apex shape and the inflorescence type. *C. dryobalanoides* has white tepals, yellow leaves, acuminate-shaped leaf apices and an axillary or terminal inflorescence. *C. teysmannii* has yellow tepals, brown or red leaves, acute-shaped leaf apices and raceme inflorescences.

THAILAND

South-Western Region: 39. *Phetchaburi Province:* Amphoe Kaeng Krachan, Kaeng Krachan NP, on road from Ban Krang Camp to Khao Phanoen Thung Ranger Substation, *D.J. Middleton, S. Suddee, J. Davies & C. Hemrat 999* (A); **South-Eastern Region: 62. *Trat Province:*** Kaw Chang, Klawng Mayom Salak Kawk, *A.F.G. Kerr 6390* (ABD, BM); Kaw Chang, Klawng Non Si, *A.F.G. Kerr 9175* (BM); Baw Rai, *A.F.G. Kerr 9462* (BK, K, L).



Map 3.16 Distribution of *Calophyllum dryobalanoides* in Thailand.

14. *Calophyllum teysmannii* Zoll. ex Planch. & Triana, Ann. Sci. Nat., Bot. 4(15): 275. 1861; Miq., Fl. Ned. Ind., Eerste Bijv. 1(3): 499. 1861; P.F. Stevens, J. Arnold Arbor. 61: 431. 1980.

Type: Indonesia, Sumatra, *Teysmann, HB 650* (Holotype: U!; Isotypes: BO, L!, P!).

Synonyms

-*Calophyllum intramarginale* M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 342. pl. 22. 1956. Type: Malaya, *SFN 31900* coll. *Moysey & Kiah* (Holotype: SING!; Isotypes: A, K!, KEP).

-*Calophyllum inophylloide* King var. *singapurense* M.R. Henderson & Wyatt-Smith, Gard. Bull. Singapore 15: 316. pl 9. 1956; Kochummen, Malayan Forest Rec. 2(17): 215. 1965; Smythies, Common Sarawak Trees, 61. 1965; T.C. Whitmore, Gard. Bull. Singapore 26: 270. 1973; T.C. Whitmore, Tree Flora of Malaya 2: 186. 1973; Corner, Gard. Bull. Singapore Suppl. 1: 104. 1978. Type: Singapore, *SFN 32518* coll. *Corner* (Holotype: SING!; Isotypes: K!, KEP).

Description

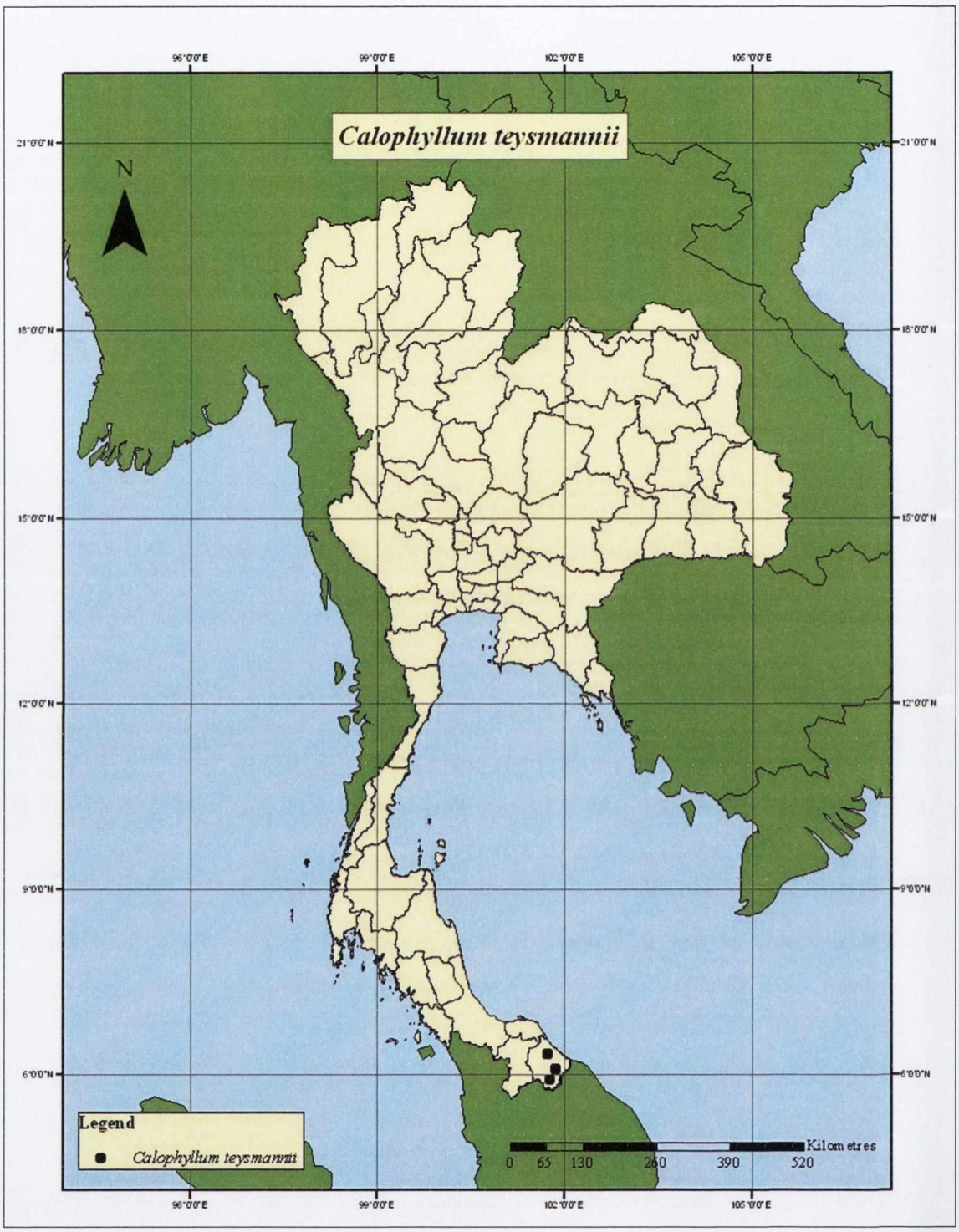
Habit tree 5-35m tall; dbh 95cm; bole straight; small buttresses sometimes present, if present up to 70cm tall; shallowly fissured and scaly, outer bark greyish-brown to dark brown; inner bark orange-brown to black; exudate: the colour of clear honey. ***Branchlets*** flattened; slender; with brown or black pubescence, waxy or hairless; internode 0.5-3.5cm long. ***Leaves*** petioled, 3-12mm long; leaves on flowering branches elliptic-oblong or obovate; other leaves oblong-lanceolate to obovate; concave above and convex below; coriaceous, red-brown to khaki green, 3.5-9 x 1.5-4.5cm; base acute to cuneate; apex acute to retuse; midrib depressed in channel on upper surface about 1/3 of lamina length; underside raised; lateral veins on both surfaces distinct but sometimes obscured; 6-10 veins per 0.5cm; intramarginal veins present. ***Inflorescence*** racemes, 3-11 flowers per inflorescence; usually hairless but sometimes covered with brown pubescence; pedicels 0.5-4.3cm long. ***Floral parts*** tepals 8, the outer pair oval to

suborbicular, the next pair elliptic and the inner ones obovate, 4-5 x 4-4.5mm, hairless or slightly pubescent at margin; inner one ovate to suborbicular, 5-8 x 5.5-7mm, hairless or slightly pubescent at margin; white to pale yellow in colour, green in bud. ***Stamens*** in fascicles, 65-212 stamens per flower; filament 3-4.5mm long; anther 1-1.5mm long; filaments white; anthers yellow. ***Ovary*** 1-2.5mm long; style 2-5mm long; style white, stigma peltate. ***Fruit*** ellipsoid to subglobose; 2-2.5 x 1.8-2cm; apex acute to round; yellow-green to pale brown when ripe, striate to smooth.

Distribution: Thailand: Narathiwat; **Worldwide:** Cambodia, Indonesia, Malaysia.
Phenology: Flowering: April-August (October). Fruiting: (April) July-August.
Ecology: Peat Swamp Forest.
Altitude: Near Sea Level – 250m.
Local name: Tang honbai neep (Sangkaew, 1999).
IUCN Regional (Thailand) Status: Critically Endangered (CR).
Note on species limits: see *C. dryobalanoides* above.

THAILAND

Peninsular Region: ***76. Narathiwat Province:*** Paa Ye, Su Ngai Paadee, *C. Niyomdham & W. Ueachirakan 1815* (AAU, C, E, K, L, P); Pha Khluai, Sukirin, *C. Niyomdham & P. Puudjaa 4717* (BKF); Kao Nakarat, Sukirin, *C. Niyomdham 4836* (BKF); Pru Kok Kaa Laa, *C. Niyomdham et al 5127* (AAU, BKF); To Daeng, *C. Niyomdham s.n.* (BKF);
Unknown Locations: Seletar Reservoir, Mandai Road, *M. Shah & A. Shukor MS 2398* (C).



Map 3.17 Distribution of *Calophyllum teysmannii* in Thailand.

Mammea L. Sp. Pl. 1:512. 1753; Jussieu, Gen. Pl. 257. 1789; Bentham & Hooker, Gen. Pl. 1: 176. 1862; Engler, in Engler & Prantl, Nat. Pflanzenfamilien 3(6): 219. 1895; Kosterm., Pengum. Lemb. Pusat Penjel. Kehut 72:15. 1961; Backer & Bakh. f., Fl. Java 1: 384. 1963; Whitmore, Tree Flora of Malaya 2: 226. 1973; P.F. Stevens, Aust. J. Bot., 22: 413-423. 1974.

Type: *Mammea americana* L. Lectotype: Herb. Linn. No. 675.1 (LINN!).

Synonyms

-*Ochrocarpos* Thou. Hist. Veg. Isles Austr. Afr. ed. 2 t. 26, cum anal. 1805; Thou., Gen. Nov. Madag. 15. 1806; Engler, in Engler & Prantl, Nat. Pflanzenfamilien 3(6): 220. 1895. Type: *Ochrocarpos madagascariensis* Choisy, Madagascar. *Du Petit-Thouars, L.M.A. s.n.* (Holotype: P!)

-*Calysaccion* Wight, Ill. Ind. Bot. 1:130. 1840. Type: *Calysaccion longifolium* Wight. Possible Types: *Wight 144* (NY!) or India, *J.E. Stocks s.n.* (NY!)

Trees with clear or coloured resinous sap. ***Leaves*** simple, opposite, entire, often coriaceous and persistent, stipules absent, some with black glandular dots. ***Inflorescences*** terminal or axillary, some often cauliflorous, solitary or cymose; bisexual or unisexual, sometimes in clusters in axils of fallen leaves. ***Calyx*** sepals 2; entirely closed and fused and later splitting into 2 sepals when in flower; reflexed during flowering, persistent. ***Corolla*** petals 4-6, free or nearly entirely connate, usually white. ***Stamens*** numerous; free or basally connate; dehiscence vertical. ***Ovary*** 2 (-many) celled; ovules 4; style short or not present; if present, stigma peltate; superior. ***Fruit*** fleshy; coriaceous when dry; caducous sepals. ***Seeds*** 1 – 4, embryo with 2 fused cotyledons.

Distribution: Borneo, Burma, China, Flores, Java, North America, Philippines, Samoa, South America, Thailand.

Key to species:

1. Emarginate leaves absent.....**1. *M. harmandii***
   Emarginate leaves present (at least some).....**2**
2. Leaves obovate or elliptic; 11-29.5cm long; pedicels up to 0.5cm long.....**2. *M. brevipes***
   Leaves obovate, oblanceolate or oblong; 7.5-25cm long; pedicels longer than 0.5cm.....**3. *M. siamensis***

1. *Mammea harmandii* (Pierre) Kosterm., Addit. Notes Mimos.; the Genera *Mammea* L. and *Ochrocarpos* Thou. 13. 1956; Kosterm., Commun. Forest Res. Inst. Bogor 72: 22. 1961.

Type: Laos, *Harmand 1072* (Holotype: P!; Isotype: P!).

Synonyms

-*Ochrocarpos harmandii* Pierre, Fl. Cochinch. 3: t.93. 1883; Vesque, in DC. Monogr. Phan. 8:528. 1874; Engler & Prantl, Nachtr. 3(6): 247. 1897; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 295. 1910; Petelot, Pl. medic. Cambodge, Laos, Vietnam (Recherches agron. C.L.V. 14) 1: 59. 1952. Type: Laos, *Harmand 1072* (Holotype: P!; Isotype: P!).

-*Calysaccion harmandii* Pierre, in Bull. Soc. Linn. Paris 2: 1226. 1896-1897. Type: Laos, *Harmand 1072* (Holotype: P!; Isotype: P!).

Description

Habit tree 6-10m tall, dbh 25-30cm; bark reddish-brown with yellow sticky latex, inner bark dark red to pale flesh-like in colour. ***Branchlets*** terete with longitudinal ridges, smooth. ***Leaves*** petioled, 1-1.7cm long; midrib raised on lower surface; green-brown on upper surface and light green-brown on lower surface; coriaceous; obovate, lanceolate, elliptic; 13.1-17 x 4.4-5.6cm; base cuneate; apex mostly cuspidate, few round or acute; netted veining visible, obscure, no intramarginal veins present; undulate. ***Inflorescence*** clusters of flowers borne on the branches; flowers arising on branches at the points where small branches are connected to larger branches, arising from separate points but close together on the branches. ***Calyx*** sepals 2; elliptic; persistent. ***Corolla*** petals 2; elliptic; longitudinal veins present on petals. ***Stamens*** oblong, anther and filament 3mm long. ***Ovary*** globose; stigma peltate; style up to 4mm long. ***Fruit*** vertically dehiscing; petiole up to 1-2.2cm long; rough; ellipsoid; acute tip; 2.3-2.5 x 1.0-1.4cm; yellow.

Distribution: Thailand: Chiang Rai, Nakhon Ratchasima, Saraburi.
Phenology: Flowering: February-May. Fruiting: July-October.
Ecology: Evergreen Forest, Deciduous Forest.

Altitude: 150 – 650m.

IUCN Regional (Thailand) Status: Data Deficient (DD).

Note on species limits: *M. harmandii* and *M. brevipes* are two similar species. The number of petals present in *M. harmandii* is 2 and 4-6 in *M. brevipes*. The outer bark colour also differs: red in *M. harmandii* and grey in *M. brevipes*.

THAILAND

Northern Region: 3. *Chiang Rai Province:* Doi Tung, near Temple, *T. Santisuk s.n.* (BKF); **Eastern Region: 28. *Nakhon Ratchasima Province:*** Sakaerat, *C.F. van Beusekom, R. Geesink & C. Wid 3291* (BKF, C, K, L, P); Khao Phrik, Sikiew District, *J.F. Maxwell 76-307* (L); **Central Region: 47. *Saraburi Province:*** Sahm Lahn Forest, Muang District, *J.F. Maxwell 75-174* (AAU, BK, L); Sahm Lahn Forest, Muang District, *J.F. Maxwell 76-434* (AAU, BK, L).



Map 3.18 Distribution of *Mammea harmandii* in Thailand.

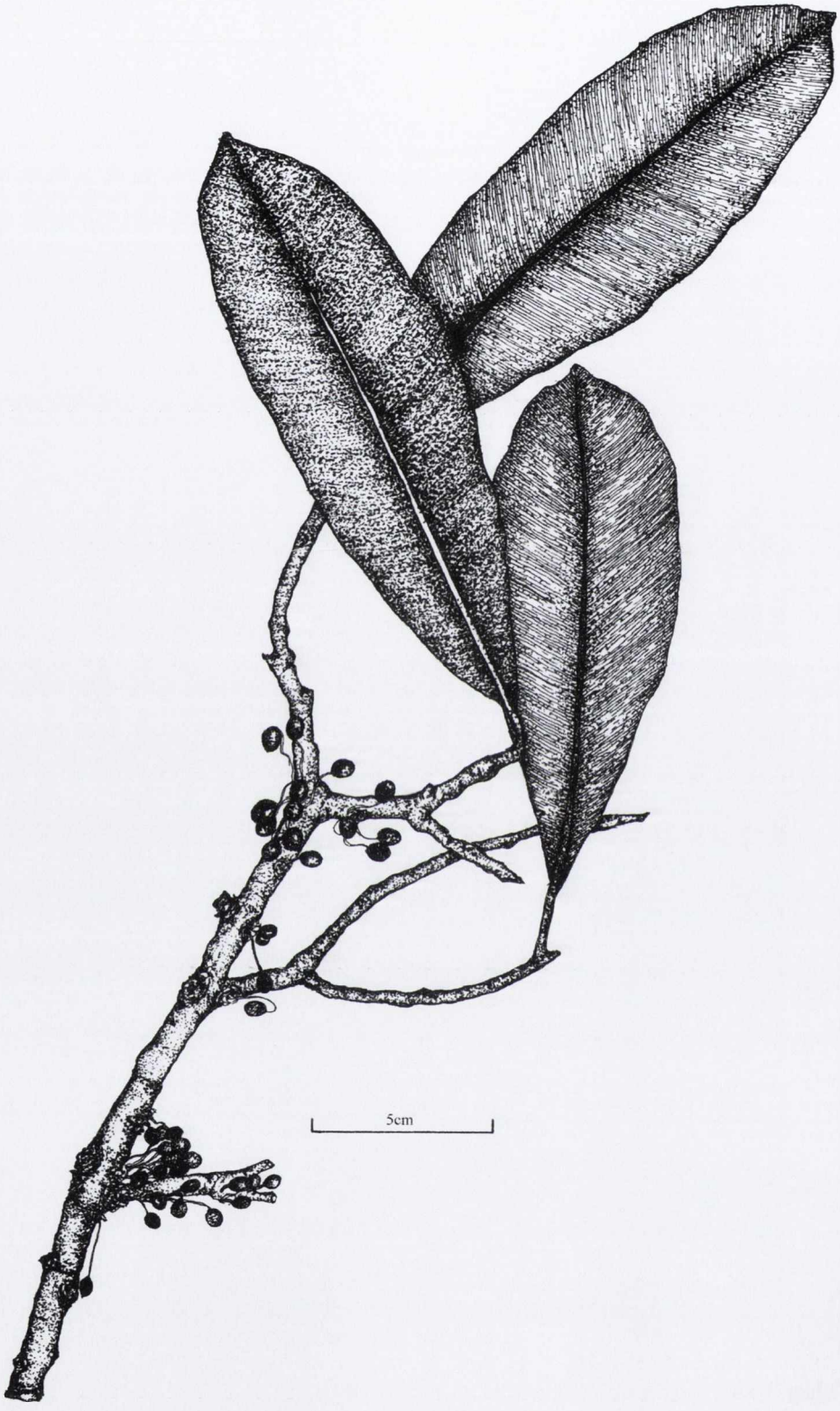


Figure 3.4 Line drawing of *Mammea harmandii* (leaves and fruit). (Illustration by Elaine Cullen).

2. *Mammea brevipes* (Craib) Kosterm., in Pengum. Lemb. Pusat Penjel. Kehut 72: 13. 1961; Whitmore, Tree Flora of Malaya 2: 226. 1973.

Type: Phetchabun, Thailand, *Kerr 5706* (Holotype: K!; Isotype: BM!).

Synonyms

-*Ochrocarpos siamensis* (non Anderson) Ridley, Fl. Malay Penin. 1:180. 1922. Type: Robinson 6304 (Holotype: K!).

-*Ochrocarpos harmandii* Pierre var. *brevipes* Craib, Fl. Siam.1(1): 119. 1925. Type: Phetchabun, Thailand, *Kerr 5706* (Holotype: K!; Isotype: BM!).

Description

Habit tree 8-12m tall; bark varies from smooth to rough; dark brown to grey. ***Branchlets*** terete. ***Leaves*** petioled, 0.6-2cm long; midrib raised on lower surface, dark brown-green on upper surface and yellow on lower surface; coriaceous, some glaucous; khaki green to dark green on upper surface; pale yellow on lower surface; elliptic to obovate; 11-29.5 x 5-11cm; base cuneate or almost acute; apex rounded or cuspidate, if cuspidate, tips 3-4mm long, some emarginate; secondary, intersecondary, tertiary and intramarginal veins visible, secondary veins 7-10mm apart, 10-15 secondary veins per side; leaf edges slightly curling downwards especially near the leaf base. ***Inflorescence*** many flowers found clustered together; shortly petioled; pedicels terete, up to 0.5cm long; borne on inconspicuous irregularly rounded protuberances 3-5mm wide; each subtended by 4-8 closely imbricate bracts. ***Calyx*** sepals 2; persistent; papyraceous, elliptic, 7-9 x 5-7mm; obtuse or slightly acute at apex with 15-18 parallel nerves. ***Corolla*** petals 4-6, obovate to round, 10-17 x 4-8mm. ***Stamens*** in fascicles; approximately 200; anthers oblong, 1-3mm long; free or weakly connate at the base; anthers oblong, 1.5-2mm long. ***Ovary*** ellipsoid; 2-2.5mm in diameter; style terete, approximately 2mm long; stigma peltate; 2-lobed, approximately 2mm in diameter. ***Fruit*** oval to elliptic, with short petiole up to 3mm long; hard, wood-like; purple/red in colour; 2-2.7 x 1-1.3cm. ***Seeds*** the seed is embedded in pulp, when fresh.

Distribution: Thailand: Phetchabun; Worldwide:

Phenology: Flowering: March.

Ecology: Evergreen Forest, on limestone.

Altitude: 400 – 500m.

IUCN Regional (Thailand) Status: Critically Endangered (CR).

Note on species limits: see *M. harmandii* above.

THAILAND

North-Eastern Region: 16. *Phetchabun Province*: Muang, *A.F.G. Kerr 5706* (ABD, BM, K); Chondaen, *A.F.G. Kerr 20392* (ABD, BK, BM, E, K).



Map 3.19 Distribution of *Mammea brevipes* in Thailand.

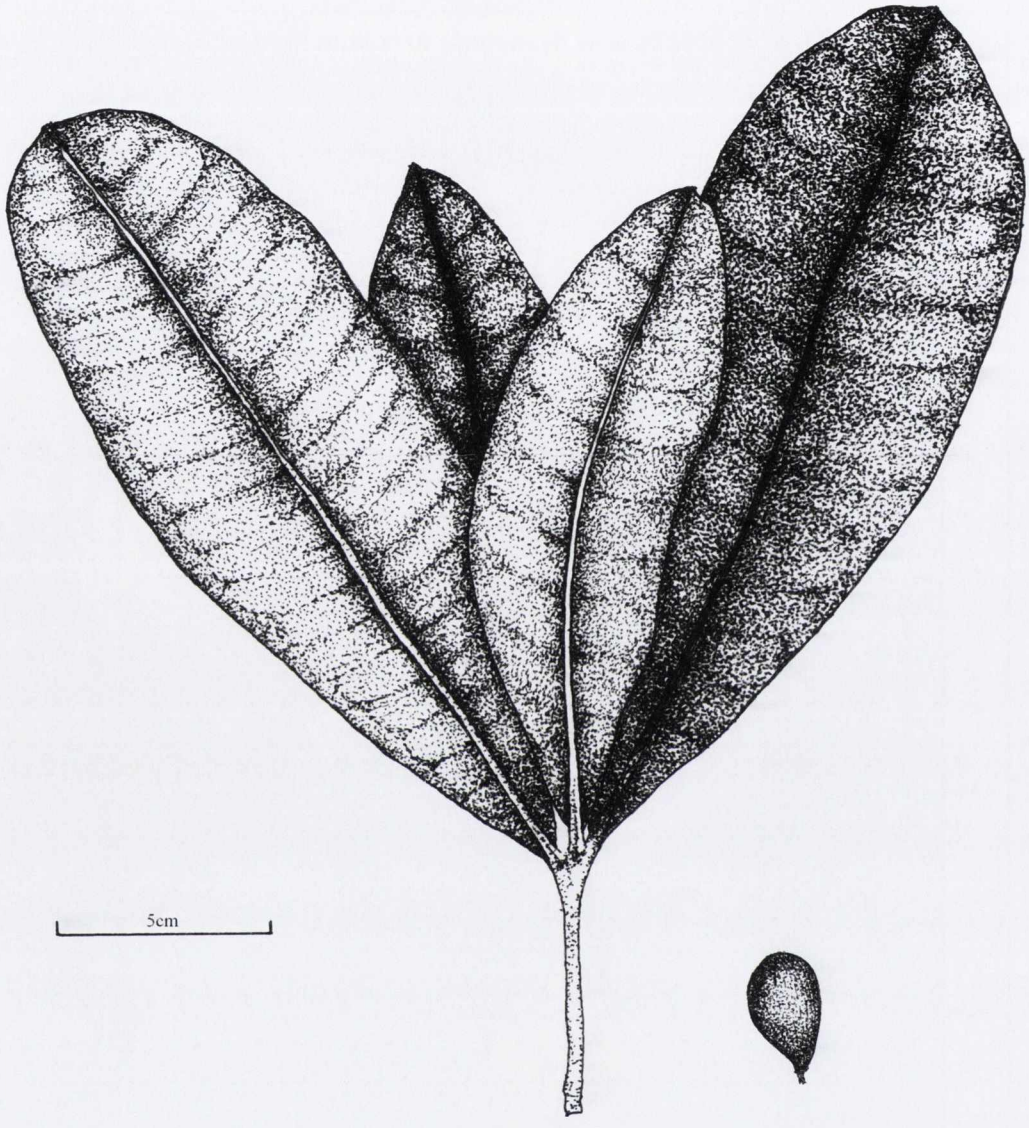


Figure 3.5 Line drawing of *Mammea brevipes* (leaves and fruit). (Illustration by Elaine Cullen).

3. *Mammea siamensis* (Miq.) T. Anderson, in J. Linn. Soc. 9: 261. 1867; Hook. f., Fl. Brit. Ind. 1: 271. 1874; Vesque, in DC. Monogr. Phan. 8:527. 1893; Kosterm., Pengum. Lemb. Pusat Penjel. Kehut 72: 26. 1961; Whitmore, Tree Flora of Malaya 2: 226. 1973.

Type: Thailand, Bangkok, *Teijsman s.n.* (Holotype: BO). (BO Cannot find specimen).

Synonyms

-*Calysaccion siamensis* Miq., Mus. Bot. 1: 209. 1863-64. Type: Thailand, Bangkok, *Teysmann, HB 5953* (Lectotype: U!; Isolectotype: L!).

-*Ochrocarpos siamensis* (Miq.) T. Anderson, in Hook, f. Fl. Brit. Ind. 1: 270-271. 1874; Kurz, Forest Fl. Burma 1: 94. 1877; Gamble, Man. Ind. Timb. 56. 1881; Pierre, Fl. Cochinch. t. 94-96. 1885; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 293-294. 1910; Ridl., Fl. Malay. Penin. 1: 180. 1922; Craib, Fl. Siam. 1(1):119. 1925; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 254. 1943. Type: Thailand, Bangkok, *Teijsman s.n.* (Holotype: BO). (BO Cannot find specimen).

Description

Habit evergreen tree to 20m tall; dbh 10-30cm; with dark green, spreading crown and short trunk; bark thick, roughly cracked and flaking, sometimes smooth or slightly fissured; inner bark red with pale yellow latex; outer bark dark grey. ***Branchlets*** smooth; yellowish in colour. ***Leaves*** shortly petioled, 0.5-1.5cm long; midrib dark green above and green underneath; young leaves purple, mature leaves dark-green above, yellow-green underneath; coriaceous; oblanceolate, obovate or oblong, 7.5-25 x 2.5-7cm; base narrowly cuneate; apex blunt to slightly cuspidate, some emarginate; side veins numerous on both surfaces. ***Inflorescence*** clustered on old woody twigs behind leaves; pedicels light green to yellow, up to 2cm long. Male and female flowers on separate trees; flowers approximately 1.2-2.5cm long, white or pale yellow in colour. ***Calyx*** sepals 2; elliptic; light green; 2-7mm long. ***Corolla*** petals 4, oblong; 6-8mm long. ***Stamens*** between 60-90 stamens per flower; filaments white, free; anthers yellow, 1-2mm long. ***Ovary*** style and ovary light green and turning darker green; single short style with 2-lobed stigma. ***Fruit*** oval to ellipsoid with short blunt tip; up to 4 x

2.5cm but usually smaller; 2-valved; rind with sparse white latex; juicy and dull yellow inside; orange on outside. ***Seeds*** single seed with thin yellow coating (aril).

Distribution: Thailand: Chiang Mai, Lampang, Phetchabun, Nakhon Ratchasima, Phetchaburi, Krung Thep Maha Nakhon (Bangkok), Chon Buri, Chumphon, Songkhla; **Worldwide:** Laos, Malaysia (Penang).

Phenology: Flowering: February-June. Fruiting: June.

Ecology: Dry, Mixed Evergreen Forest, Deciduous Forest, on Granite Bedrock.

Altitude: 50 – 460m.

Uses: The flowers contain aromatic oil and the plant is widely cultivated. The pollen is used by Thai people as a cosmetic. The flowers are used to make necklaces (Kostermans, 1961).

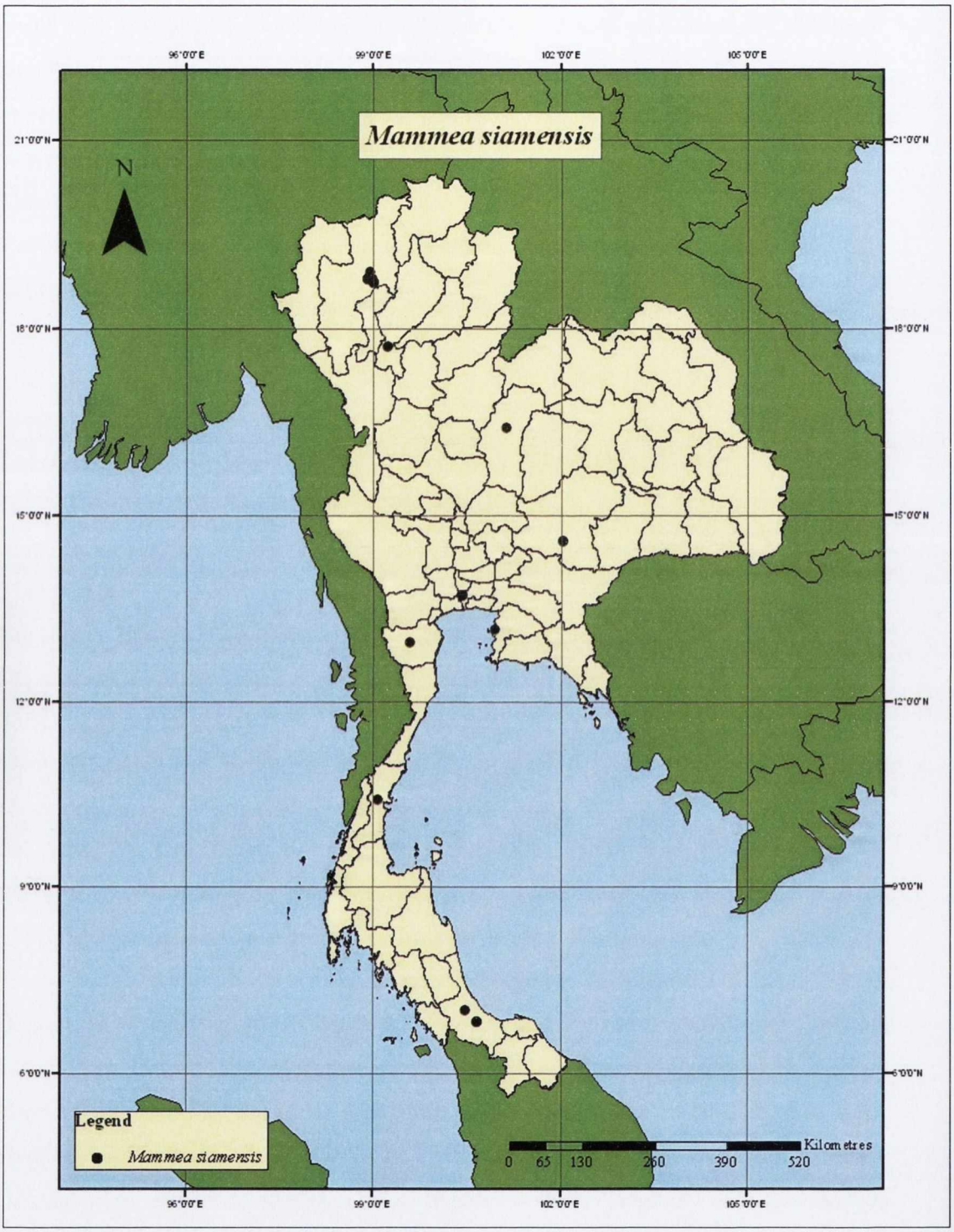
Local name: Sarapee (*P. Palee 30*)/Sa ra pi (*M.C. Lakshnakara 854*).

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 2. *Chiang Mai Province*: Chiang Mai University, Biology Department, *P. Palee 30* (A, CMU, E, P); Suan Gaew, Mae Rim, *C. Glamwaewong 156* (QBG); Lower slopes, *A.F.G. Kerr 548* (BM, K, P); Doi Sutep, Ban Salienue, Hawt, *Kasin 806* (BK); Doi Sutep, *Th. Sorensen, K. Larsen & B. Hansen 5810* (C); Doi Sutep, *Th. Sorensen, K. Larsen & B. Hansen 5829* (C);Muang Tun, *A.F.G. Kerr 6193* (ABD, BK, BM, K); Doi Sutep. Between the Agricultural Station and TV-7 Station, *J.F. Maxwell 88-739* (AAU, L); East side, 76/1 Soi 5, Sutep Road, *J.F. Maxwell, 92-70* (A, CMU, E, P); Huay Kaew Arboretum, Amphur Muang, *C. Phengkhlai s.n.* (BKF); Doi Sutep. *A.F.G. Kerr s.n.* (BM); **7. *Lampang Province:*** Jaehmwittya School, Jaeham District, *M. Panatkool 464* (CMU); **16. *Phetchabun Province:*** Ban Wang Saphung, Wang Pong District, *Th. Wongprasert 012-31* (BKF); **Eastern Region: 28. *Nakhon Ratchasima Province:*** Sakaerat. Pak Thong Chai District, Reforestation Station, *D.D. Soejarto, T, Santisuk, K. Taylor & N. Nantasan 6022* (A, L); Khao Phrik, Sikiew District, *J.F Maxwell 76-307* (BK); **South-Western Region: 39. *Phetchaburi Province:*** *A. Marcan 1176* (ABD, BM); Kao Wong, *Sakol 459* (BK); **Central Region: 52. *Krung Thep Maha Nakhon Province:*** *R. Zimmermann 105* (BM, L); Krungthep, M.*C. Lakshnakara 305* (ABD, BK, K); *M.C. Lakshnakara 854* (BK, BM); *A. Marcan 1707* (ABD, BM); *No collector 5953* (L); Phloenchit 11561 (BKF); **South-Eastern**

Region: 59. *Chon Buri Province*: Naprow, Near Sriracha, *D.J. Collins 789* (ABD, BK, E, K); **Peninsular Region: 63. *Chumphon Province:*** *No collector 4360* (K); **73. *Songkhla Province:*** Maa Bee Yah Village, Foothills of Klong Rhang Hill, Nah Mawn District, *J.F. Maxwell 86-70* (A, L, PSU); PSU, Haad Yai District, *J.F. Maxwell 86-343* (A, BKF, PSU).



Map 3.20 Distribution of *Mammea siamensis* in Thailand

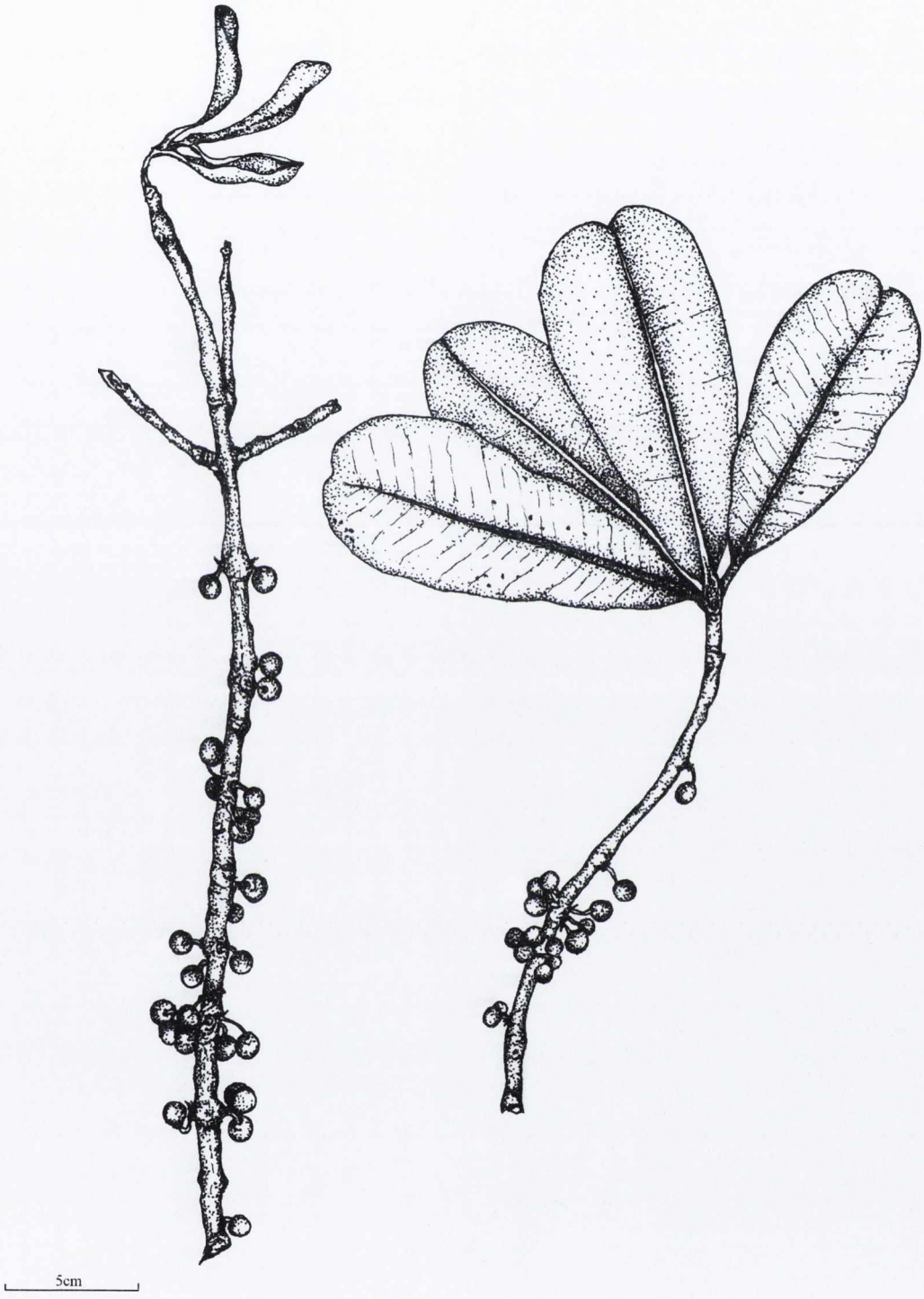


Figure 3.6 Line drawing of *Mammea siamensis* (fruiting stem). v(Illustration by Elaine Cullen).

Mesua L. Sp. Pl. 2: 515. 1753; Jussieu, Gen. Pl. 258. 1789; Wight, Prodr. Fl. Ind. Orient. 102. 1834; Miquel, Fl. Ned. Ind. 509. 1859; Planchon & Triana, Ann. Sci. Nat., Bot. 4(15): 298. 1861; Bentham & Hooker, Gen. Pl. 1: 176. 1862; T. Anderson, in Hook, f., Fl. Brit. Ind. 2: 276. 1874; Kurz, Forest Fl. Burma 1: 96. 1877; King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59(2): 184 - 185. 1890; Engler & Prantl, Nat. Pflanzenfamilien 3(6): 218-219. 1895; Prain, Bengal Pl. 245. 1903; Pitard, in Lecomte, Fl. Indo-Chine 1(4): 328. 1910; Gamble, Fl. Madras 76. 1915; Haines, Bot. Bihar Orissa 2:55. 1921; Ridl., Fl. Malay. Penin. 1:191. 1922; Whitmore, Tree Flora of Malaya 2: 227-228. 1973; Dassanayake, Rev. Handb. Fl. Ceylon 1:107, 1980; Gamble, Man. Ind. Tim. (ed. 2a) 59. 1992; L. Xiwen, L. Jie & P.F. Stevens, Fl. China 13: 38. 2007.

Type: *Mesua ferrea* L. Habitat in India. Herb. Hermann 1: 38 No. 203 (Lectotype: BM!).

Trees; inner bark usually with sticky exudate drying black. ***Leaves*** opposite; coriaceous; often with dots; numerous slender veins. ***Inflorescences*** solitary, axillary or terminal. ***Calyx*** sepals 4-5; imbricate. ***Corolla*** petals 4-5; imbricate. ***Stamens*** numerous; filaments basally connate. ***Ovary*** superior; 2-celled; ovules 4; style long; stigma peltate, broad stigma lobes. ***Fruit*** fleshy or woody; drupe, berry or capsule; 1-4 seeded. ***Seeds*** testa fragile; absent aril.

Distribution: Tropical Asia.

Mesua ferrea L., in Sp. Pl. 1: 515. 1753; Burmann, Fl. Ind. 121. 1768; Choisy, in DC. Prodr. 1:562. 1824; Wight, Prodr. Fl. Ind. Orient. 102. 1834; Wight, Icon. t. 118. 1839; Graham, Cat. Pl. Bombay 26. 1839; Thwaites, Enum. Pl. Zeyl. 5. 1858; Miq., Fl. Ind. Bat. 1:509. 1860; Planchon & Triana, Ann. Sci. Nat., Bot. 4(15): 299. 1861; Dalzell & Gibson, Bombay Fl. 31. 1861; Beddome, Fl. Sylv. S. India t. 64. 1871; T. Anderson, in Hook, f., Fl. Brit. Ind. 2: 277. 1874; Kurz, Forest Fl. Burma 1: 97. 1877; Gamble, Man. Ind. Timb. 27. 1881; Pierre, Fl. Cochinch. 7:t. 97. 1885; Watt, Dict. Econ. Prod. India 5: 236. 1891; Vesque, in DC. Monogr. Phan. 8:630. 1893; Talbot, Trees Bombay Pres.16. 1894; Woodrow, J. Bombay Nat. Hist. Soc. 1: 81. 1901; Prain, Bengal Pl. 246. 1903; Brandis, Indian Trees 55. 1907; Gamble, Fl. Madras 1: 77. 1915; Haines, Bot. Bihar Orissa 2:55. 1921; Ridl., Fl. Malay. Penin. 1:192. 1922; Kirtikar & Basu, Indian Med. Pl. 2(1): 274. 1933; Kamjilal, Fl. Assam 1: 111. 1934; Mooney, Suppl. Bot. Bihar Orissa 27. 1950; Bor, Man. Ind. For. Bot. 201. 1953; Kitamura, Fauna Fl. Nepal Himalaya 1:179. 1955; MacMillan, Trop. Pl. & Gard. 5: 87. 1956; Sastri, B.N., Wealth of India 6: 349. 1962; Maheshwari, Bull. Bot. Surv. India 5: 337. 1963; Whitmore, Tree Flora of Malaya 2: 227-228. 1973; Dassanayake, Rev. Handb. Fl. Ceylon 1:107, 1980; Gamble, Man. Ind. Tim. (ed. 2a) 59. 1992; Xiwen, L. Jie, L. & P.F.Stevens, Fl. China 13: 38. 2007.

Type: India, *Hermann* 1: 38, No. 203 (Holotype: BM!).

Synonyms

-*Nagassarium* Rumph., Herb. Amboin. 7:3, t. 2. 1750. Type: India, *Hermann* 1: 38, No. 203 (Holotype: BM!).

-*Calophyllum nagassarium* Burm., Fl. Ind. 121, 1768. Type: [Amboina and Java], *Herb. Burmann.* (Holotype: G).

-*Mesua speciosa* Choisy, in DC. Prodr. 1:562. 1824. Type: India, *Hermann* 1: 38, No. 203 (Holotype: BM!).

-*Mesua nagassarium* (Burm. f.) Kosterm., Ceylon J. Sci., Biol. Sci. 12:71, 1976; Dassanayake, Rev. Handb. Fl. Ceylon 1:107, 1980; P.F. Stevens, J. Arnold Arbor. 61:682, 1980. Type: [Amboina and Java], *Herb. Burmann.* (Holotype: G).

Description

Habit tree up to 30m tall, dbh 95cm; bole straight, cylindrical, often fluted at base; bark ash-grey turning dark-dull brown, scaly, irregularly fissured; inner bark brownish-red to pink or red; exuding an aromatic clear resin; sapwood creamy white to pinkish-brown; heartwood dark red, hard, tough and heavy. ***Branchlets*** young twigs slender, grey and terete; end bud inconspicuous. ***Leaves*** petioled, 0.4-1.2cm long; green above and below, young leaves pink; midrib faint and depressed on both surfaces; slightly more pronounced on lower surface; lower surface glaucous; coriaceous or delicate; elliptic, oblong or lanceolate, 1-15 x 1-18cm; base acute or obtuse; apex acute; side veins very fine, almost invisible, secondary, intersecondary, tertiary and intramarginal veins faint especially on young leaves, numerous, rather patent, invisible on the white waxy lower surface; margin entire. ***Inflorescence*** solitary; axillary; on short peduncles, 0.8-2.3cm long; slender, diameter 4-10cm; sweet scented. ***Calyx*** sepals 4; imbricate; in 2 rows; small outer pair and larger inner pair; light green; persistent; densely velvety puberulous outside; orbicular, imbricate, fleshy, 12-15mm long. ***Corolla*** petals 4; white; cuneate, obovate or obcordate, curled and erose at the margins, brown/purple striations present; caducous; 16-40mm long. ***Stamens*** numerous; anthers orange-golden-yellow; 4-10mm long; anthers large, linear. ***Ovary*** up to 5mm; ovoid; 2-locular; style 1-1.1cm long; stigma peltate. ***Fruit*** ovoid to ellipsoid with conical point; striate; sepals enlarged up to 4cm long, calyx persistent; dark orange or purple/brown; pericarp tough; ovoid with pointed tip; 2.5-3.5cm. ***Seeds*** 1-4; woody; smooth, glossy brown, oily; up to 2.4cm.

Distribution: Thailand: Mae Hong Son, Chiang Mai, Phayao, Sukhothai, Krung Thep Maha Nakhon (Bangkok), Chanthaburi, Ranong, Phuket, Krabi, Nakhon Si Thammarat, Trang, Yala, Narathiwat; **Worldwide:** Burma, Cambodia, Laos, Vietnam, India, Malacca, Malaysia, Sri Lanka (Ceylon), Tropical Nepal.

Phenology: Flowering: February-May. Fruiting: May-October.

Ecology: Evergreen Forest, Deciduous Forest, Near Sea, on limestone.

Altitude: 10 – 1,050m.

Uses: The wood from this species is one of the strongest woods found in Asia and is used for construction work, for railway sleepers and in boat building. The seed oil is used for soap making and the flowers and flower buds are used in cosmetics and perfumery. In India the leaves and flowers are also used as hair decorations and the fruits are sometimes eaten (Maheshwari, 1963).

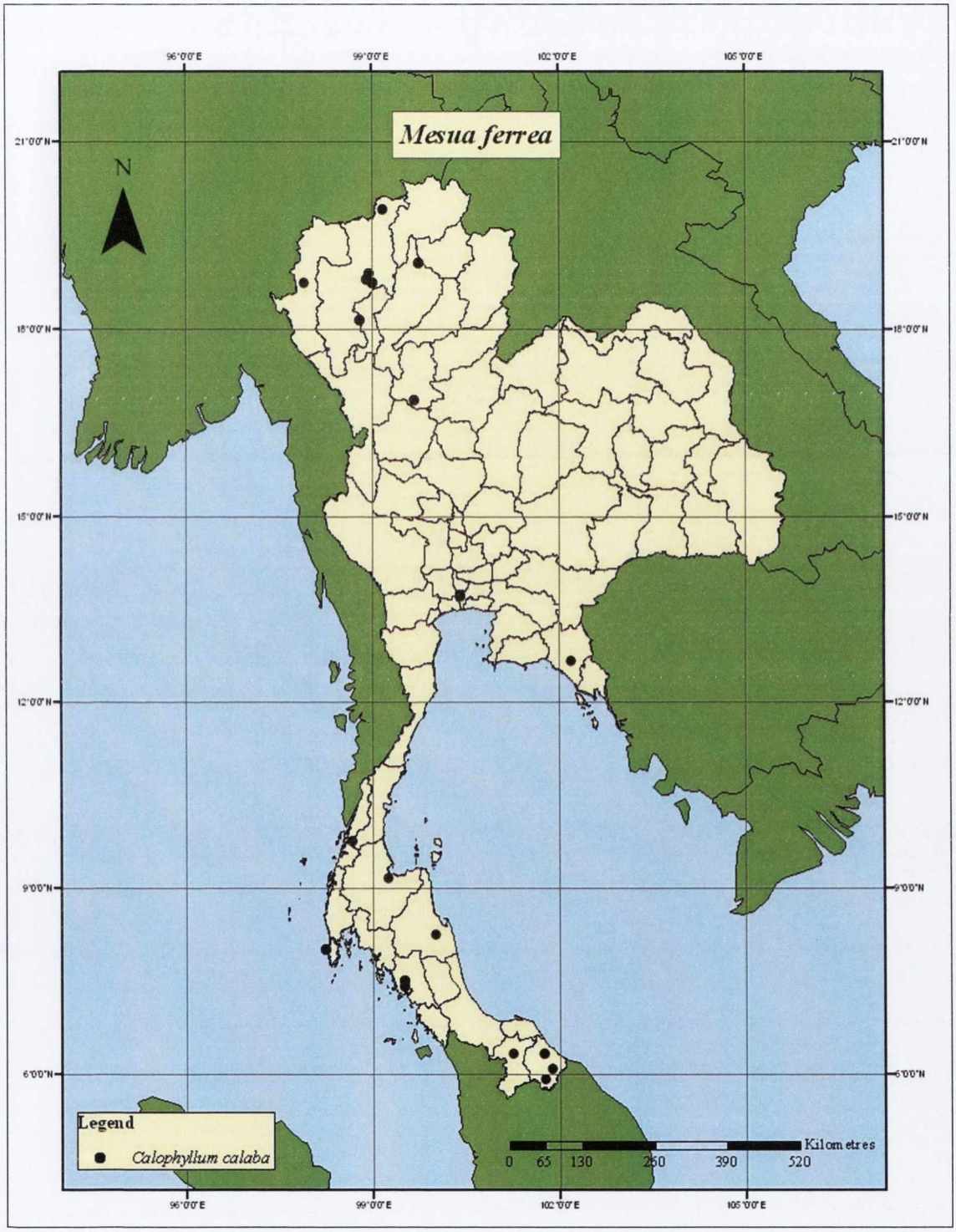
Local name: Mai Bun nak (*P. Vanpruk 720*)/Bun Nak (*A.F.G. Kerr 5916*).

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 1. *Mae Hong Son Province:* Pang Mu, *T. Smitinand 4597* (BKF); **2. *Chiang Mai Province:*** CMU, in front of Humanities Faculty, Muang District, *S. Intien 15* (A, CMU); CMU, in front of Humanities Faculty, Muang District, *G. Tumersnis 32* (CMU); Huai Pu, QBG, Mae Rim, *S. Watthana 86* (QBG); Huai Kew Arboretum, *W. Sankamethawee 122* (CMU); Doi Suthep, *W. Pongamornkul 131* (QBG); Amphoe Muang, B*run, Bjornland, Schumacher 159* (C); Maesa Botanic Garden, *R. Pooma 291* (BKF); Huai Kew Arboretum, *R. Pooma 632* (BKF); Botanic Garden, Mae Rim, *BGO Staff 710* (QBG); Huai Kew Arboretum, *BGO Staff 3366* (BKF, QBG); Chiang Dao Watershed Station, *R. Geesink, D. Phanichapol & T. Santisuk 5687* (AAU, BKF, C, E, K); Doi Sutep, *A.F.G. Kerr 1211* (BM, K, TCD); Doi Sutep, East side, Kohntatahn Falls Area, *J.F. Maxwell 89-631* (E); Chaibragen, Sidongyen Subdistrict, Lahn Village, *J.F. Maxwell 91-472* (A, E, P); Doi Sutep Pui NP, Park HQ, Muang, *S. Kopachon s162b1* (BM, CMU); Danta Bua, *A.F.G. Kerr s.n.* (BM); *A.F.G. Kerr s.n.* (BM); Doi Sutep, *H. Dixen s.n.* (AAU); **4. *Phayao Province:*** Doi Luang NP, east side of Jahn Bah Tawng, Muang District, *J.F. Maxwell 97-451* (A, CMU); Doi Luang NP, east side of Jahn Bah Tawng, Muang District, *J.F. Maxwell 97-844* (A, BKF, CMU); **11. *Sukhothai Province:*** Mt. Kao Luang, *A.F.G. Kerr 5916* (AAU, ABD, BK, BM, K); **Central Region: 52. *Krung Thep Maha Nakhon Province:*** Phrayathai, *P. Agooroo 22* (BKF); *R. Zimmermann 110* (BM, K, L, P); *A. Marcan 581* (BM, K); *A. Marcan 1998* (BM, K); *A.F.G. Kerr s.n.* (BM); **South-Eastern Region: 61. *Chanthaburi Province***: Cultivated in arboretum, Makhan District, *T. Santisuk et al., s.n.*; **Peninsular Region: 64. *Ranong Province:*** Khao Pawta Luang Keow, *R. Geesink, T. Hattink & C. Charoenphol 7434* (BKF, K); Hard Hin Dam, *K. Larsen & S.S. Larsen 33352* (AAU, K, P); **67. *Phuket Province:*** Muang Mai, *A.F.G. Kerr 17400* (ABD, BK, BM, C, E, K, TCD); **68. *Krabi Province:*** *P. Vanpruk 720* (BKF, K); **69. *Nakhon Si Thammarat Province:*** *S.*

Thaworm 50 (BKF); **71. *Trang Province:*** Chawng, *S. Boongird 62* (A); Khao Chong, *S. Phusomsaeng 171* (C, E, K, P); Khao Chong, *C. Bunnab 376* (BKF, L); Khao Chong, *P. Sangkhachand 1863* (BK); Chawng, *T. Smitinand 4117* (BKF); Kantang, *A.F.G. Kerr 17484* (E); Kantang, *A.F.G. Kerr 17485* (ABD, BK, BM, C, K, TCD); **75. *Yala Province:*** Bangland, Taanto, *C. Niyomdham 5126* (BKF); **76. *Narathiwat Province:*** Nikom Vang, *Prayad 417* (BK); Khao E-dang, Sukhirin, *P. Puudjaa 498* (BKF); Waeng, *B. Sangkhachand 1317* (BKF, L); Sungei Padi, Chatwarin Falls, *K. Larsen & S.S. Larsen 32998* (L).



Map 3.21 Distribution of *Mesua ferrea* in Thailand.



Figure 3.7 Line drawing of *Mesua ferrea* (flowers, fruit and leaves). (Illustration by Elaine Cullen).

3.4 Hypericaceae Juss. Results

Evergreen or deciduous herbs, shrubs or trees with glands or canals present in most parts of the plant, uni/multicellular hairs usually present. ***Leaves*** opposite, alternate or whorled. ***Inflorescences*** terminal or cymose; flowers single, perfect. ***Calyx*** sepals (2)4-5, free. ***Corolla*** petals (3)4-5, free. ***Stamens*** 9-∞, free, connate or fasciculate, nectary absent. ***Ovary*** superior, 1-∞ ovules. ***Fruit*** capsule or baccate (berry-like), sometimes drupe, +/- wings.

Worldwide distribution. The genus *Hypericum* L. is found in temperate regions and high montane areas in tropical regions.

Three Tribes: Tribe *Vismieae* Choisy (1821), Tribe *Hypericeae* Choisy (1821) and Tribe *Cratoxyleae* Bentham (1862). Some members of this family are more or less aquatic (Stevens, unpublished).

Key to Thai Genera:

1. Herbs with horizontal runners; flowers usually yellow.....**1. *Hypericum***
   Deciduous to evergreen trees or shrubs; flowers pink or white.....**2. *Cratoxylum***

Hypericum L. Sp. Pl. 2: 783. 1753; Linnaeus, Gen. Pl. 5: 341. 1754; Jussieu, Gen. Pl. 257. 1789; Wight, Prodr. Fl. Ind. Orient. 99. 1834; Dyer, in Hook, f., Fl. Brit. India 1: 253. 1874; Gamble, Man. Ind. Timb. 48. 1881; Engler, in Engler & Prantl, Nat. Pflanzenfamilien 3(6): 215. 1895; Prain, Bengal Pl. 243. 1903; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 284. 1910; Craib, Bull. Misc. Inform. Kew 66. 1913; Gamble, Fl. Madras 69. 1915; Haines, Bot. Bihar Orissa 2:51 1921; Ridl., Fl. Malay. Penin. 1:151. 1922; Craib, Fl. Siam. 1(1):110. 1925; R. Keller, in Engler & Prantl, Nat. Pflanzenfamilien 2(25):175.1925 pro parte excl. Sect IV Elodea; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 248. 1943; Backer & Bakh. f., Fl. Java 1: 382. 1963; N. Robson, J. Roy. Hort. Soc. 95(2): 482. 1970; N. Robson, in Fl. Males., Ser. 1, Spermat. 8: 4-6. 1974; N. Robson, Bull. Brit. Mus. (Nat. Hist.), Bot. 12(4): 163-325. 1985; N. Robson, Taxon 39(1): 134-135. 1990; N. Robson, Syst. Biodivers. 4(1): 19-98. 2005; L. Xiwen & N. Robson, Fl. China 13: 2-35. 2007.

Type: *Hypericum perforatum* L. 'Habitat in Europae pratis'. Herb. Linn. No. 943.34 (Lectotype: LINN!).

Exhibits a wide range of habit forms from herbs to trees up to 12m high; trees only occur amongst the primitive species of the genus; herbs are more common and spread by means of horizontal runners before becoming erect or ascending; the stems eventually become terete, the stem colour varies from green to red when young and brown to black when older; fissures appear when older and the stems can turn a grey colour and the cork layers flake off in strips. ***Leaves*** sessile or subsessile; opposite; entire; venation present, some with parallel venation; two types of glands present: blackish-red cells containing a wax and schizogenous intercellular spaces lined by cells which secrete an oil, the former are called dark glands and the latter are pale glands. ***Inflorescences*** solitary, in three's, cymose or umbellate. ***Calyx*** sepals (4)-5; basally connected; shape is very variable; sepal margins entire; sepals bear the same glands as the leaves. ***Corolla*** petals (4)-5; usually yellow or sometimes white; they spread out or become reflexed; aestivation always contorted; dotted with black glands. ***Stamens*** numerous; basally connate; distinct; sometimes in five free antepetalous fascicles; anthers dehisce introrsely by longitudinal slits; usually same colour as the petals; usually shorter than the petals; stamen length varies within fascicles and the longest stamens are found on the outside of the fascicle ring. ***Ovary*** superior; unilocular cell;

styles 2-5; stigmas distinct; persistent; varies in size and shape from narrowly elliptic to ovoid to globose. ***Fruit*** a woody or coriaceous septicidal capsule. ***Seeds*** small, globose to ovoid or ellipsoid; the number of seeds is sometimes very large (over 1000); winged seeds are found on species with dehiscent fruit.

Distribution: Africa, Asia Temperate, Asia Tropical, Europe, Former Soviet Union, North America.

Key to Species:

1. Herbs with flowers under 2.5cm across.....**2**
   Shrubs up to 3m tall, with flowers 5 - 8cm across.....**3**

2. Sepals with glands; stems terete; ovary 3-celled.....**1. *H. napaulense***
   Sepals entire, with/without glands; stems quadrangular; ovary 1-celled.....**2. *H. japonicum***

3. Sepals 4; petals 4; leaves oblong or ovate-oblong to elliptic with clear intramarginal vein.....**3. *H. siamense***
   Sepals 5; petals 5; leaves oblong, ovate-oblong, elliptic, lanceolate or oblanceolate without intramarginal vein.....**4**

4. Sepals entire or denticulate; ovate, oblong or elliptic; stems spreading, 2-lined .....**4. *H. patulum***
   Sepals entire; stems arching or erect.....**5**

5. Leaves variable: lanceolate, oblanceolate, elliptic, oblong, obtuse; sepals with obvious longitudinal striations, +/- equal, imbricate; stems arching, young branches compressed; stamens 60-80.....**5. *H. hookerianum***
   Leaves narrowly lanceolate to elliptic; sepals without obvious striations, not equal, not imbricate; stems erect, young branches thin; stamens 40-60.....**6. *H. henryi* subsp. *hancockii***

1. *Hypericum napaulense* Choisy, Prodr. (D.C.) 1: 552. 1824; Dyer, in Hook. f., Fl. Brit. India 1: 253. 1874; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 284. 1910; Craib, Fl. Siam. 1(1):111. 1925; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 251. 1943; Li Xiwen & Li Yan-hui, in Li Hsiwen, Fl. Reipubl. Popularis Sin. 50(2): 1-112. 1990; L. Xiwen & N. Robson, Fl. China 13: 2-35. 2007.

Type: Nepal, Gossain Than, *Wallich s.n.* (Holotype: G!; Isotypes: BM!, K!).

Synonyms

-*Hypericum pallens* D.Don, Prodr. Fl. Nepal. 219. (Jan-Feb) 1825. Type: West Himalaya, *Wallich 4814* (Holotype: K!).

-*Hypericum setosum* Wall., Numer. List. [Wallich] n. 4814. 1828, *nomen nudum.*

-*Hypericum wightianum* Wall., Numer. List. [Wallich] n. 4818. 1828; Wight, Prodr. Fl. Ind. Orient. 99. 1834; Gamble, Fl. Madras 69. 1915. Type: Madras, *Wallich 4818* (Lectotype:K! (Lectotype designated here); Isolectotype: BM!).

Description

Habit shrub or perennial herb up to 1m tall; hairless; decumbent. ***Branchlets*** terete; slender; striations present; light golden-brown to dark red-brown. ***Leaves*** sessile; midrib depressed on upper surface and pronounced on lower surface; light green to tan on upper surface and dark brown/black on lower surface; hairless, delicate, smooth; 0.7-2.5 x 0.4-1.5cm; elliptic to oblanceolate; base cuneate to slightly tapering; apex shape varies from slightly acute to rounded to subacuminate; parallelodromous veins faint; round (black) dots present on upper surface of (some) most leaves. ***Inflorescence*** pedicel up to 5cm long; solitary or corymbose cyme with up to 17 flowers; thin and delicate; spine-like hairs present on all stalks of inflorescences. ***Calyx*** sepals 5; persistent; oblanceolate; apex slightly pointed to round; some with gland-tipped teeth; 0.5-0.6 x 0.1-0.2cm; bracts with black glandular hairs. ***Corolla*** petals 5; caducous; twice as big as calyx; yellow/cream in colour; longitudinal lines present on petals; elliptic to oblanceolate; 6-13mm long; tip slightly pointed. ***Stamens*** in 3 fascicles.

Ovary 3-locular; styles 0.9-1.3mm. ***Fruit*** capsule; ovoid to elliptic; 3-celled; green. ***Seeds*** 0.5-0.6mm long.

Distribution: Thailand: Chiang Mai; **Worldwide:** Burma, Himalaya, Laos, Temperate Nepal, Tibet, Yunnan (South China).

Phenology: Flowering: May-August and October-December.

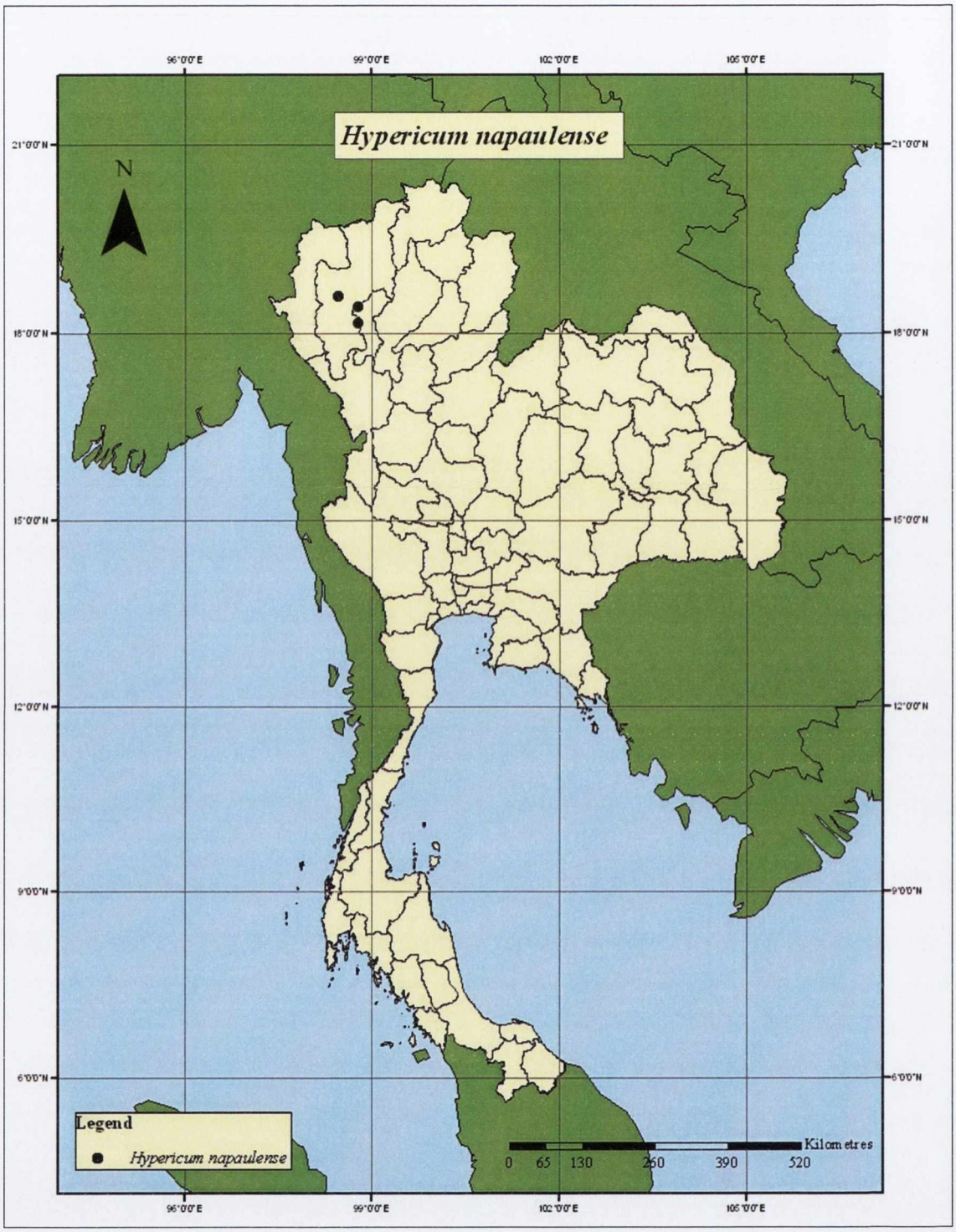
Ecology: Marsh Areas, On Limestone.

Altitude: 1,400 – 2,500m.

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 2. *Chiang Mai Province:* Summit of Iloi Angka, *H. Garrett 421* (ABD, BM, E, K, L, P, TCD); Doi Chang Dao, *R. Pooma 703* (BKF); Doi Pa Kao, *A.F.G. Kerr 5392* (ABD, BK, BM, K); Doi Inthanon, *T. Smitinand, M.E.D. Poore & R.G. Robbins 7643* (BKF); Doi Chang Dao, *T. Santisuk s.n.* (BKF).



Map 3.22 Distribution of *Hypericum napaulense* in Thailand.



Figure 3.8 Line drawing of *Hypericum napaulense* (flowering stem). (Illustration by Elaine Cullen).

2. *Hypericum japonicum* Thunb. ex Murray, Syst. Veg., ed. 14: 702. (May-June) 1784; Thunb., Fl. Jap. 295. (August) 1784; Choisy, Prodr. Monogr. Hyperic. 48. 1821; Blume, Bijdr. Fl. Ned. Ind. 1: 143. 1825; D. Don, Prodr. Fl. Nepal. 219. 1825; Wight, Prodr. Fl. Ind. Orient. 99. 1834; Choisy, in Syst. Verz. (Zollinger) 151. 1854; Miquel, Ann. Mus. Bot. Lugduno-Batavi 2: 259. 1866; Dyer, in Hook. f., Fl. Brit. India 1: 263. 1874; Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist.43: 84. 1874; Trimen, Fl. Ceylon 1: 93. 1893; Engler, in Engler & Prantl, Nat. Pflanzenfamilien 3(6): 215. 1895; Bailey, Queensl. Fl. 1: 101. 1899; Prain, Bengal Pl. 243. 1903; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 284. 1910; Koord.-Schum., Syst. Verz. 187. 1911-1914; Gamble, Fl. Madras 69. 1915; Haines, Bot. Bihar Orissa. 2:51 1921; Ridl., Fl. Malay. Penin. 1: 151. 1922; Lauterb., Bot. Jahrb. Syst. 5: 58. 1922; Craib, Fl. Siam. 1(1):111. 1925; Ridl., Kew Bull. 59. 1926; Henderson, Gard. Bull. Straits Settlem. 4: 222. 1928; Corner, Wayside Trees of Malaya 324. 1940; Y. Kimura, Bot. Mag. (Tokyo) 54: 87. 1940; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 248. 1943; Backer & Bakh. f., Fl. Java 1: 382. 1963; Ohwi, Fl. Jap. 631. 1965; N. Robson, in Fl. Males., Ser. 1, Spermat. 8: 4-6. 1974; N. Robson, Taxon 39(1): 134-135. 1990; L. Xiwen & N. Robson, Fl. China 13: 2-35. 2007.

Type: Japan, Honshu, *Thunberg s.n.* (Holotype: UPS!; Isotype: BM!).

Synonyms

-*Hypericum chinense* Osbeck, Dagb. Ostind. Resa 244. 1757, *nom. rejic. prop.* Type: China, *Osbeck s.n.* (Holotype: S!) (See note at end of description re: rejection of name).

-*Hypericum pusillum* Choisy, Prod. Hyp. 50. 1821. Type specimen not found.

-*Brathys nepalensis* Blume, Mus. Bot. 2:19. 1852. Type: Japan, Honshu, *Thunberg s.n.* (Holotype: UPS!; Isotype: BM!).

-*Brathys laxa* Blume, Mus. Bot. 2: 19. 1852. Type: Japan, *Pierot 252* (Lectotype: L!); Japan, *Keiske, I. s.n.* (Syntype: L!).

-*Brathys japonica* Blume, Mus. Bot. 2: 19. 1852. Type: Japan, *Siebold s.n.* (Holotype:L!).

-*Hypericum calycatum* Jacquem. ex Dyer, in Hook. f., Fl. Brit. India 1: 256. 1874. Type: Japan, Honshu, *Thunberg s.n.* (Holotype: UPS!; Isotype: BM!).

-*Hypericum thunbergii* Franch. & Sav., Enum. Pl. Jap. 2: 300. 1878. Type specimen not found.

-*Sarothra japonica* (Thunb.) Y. Kimura, Nakai & Honda, Nova Fl. Jap. 10: 235. 1951. Type: Japan, Honshu, *Thunberg s.n.* (Holotype: UPS!, Isotype: BM!).

-*Sarothra laxa* (Blume) Y. Kimura, Nakai & Honda, Nova Fl. Jap. 10: 241. 1951. Type: Japan, *Pierot 252* (Lectotype: L!); Japan, *Keiske, I. s.n.* (Syntype: L!).

Description

Habit annual or perennial herb, with erect or decumbent branched stems, 15-45cm long; stems green, approximately 3mm wide at base; hairless. ***Branchlets*** slender; stems quadrangular. ***Leaves*** sessile; papyraceous, sometimes glaucous beneath; midrib green above and light green below; decussate, ovate to lanceolate, some auricled, 6-10 x 2-6mm; base cordate-amplexicaul; apex rounded or obtuse; side veins present, 1-8 veins present each side. ***Inflorescence*** pedicels up to 1cm long; flowers terminal, mostly elongated inflorescences, sometimes solitary, sometimes 1-30 flowered; 6-10mm across; axes green. ***Calyx*** sepals 5; entire, light green; elliptic, 2-6mm long; free; persistent; oblong-lanceolate; subequal to unequal; apex acute to rounded; 3-5 longitudinal veins present. ***Corolla*** petals, 5; orange-yellow; oblanceolate, obovate or elliptic, 2-5 x 1-1.5mm long; persistent. ***Stamens*** approximately 3mm long; persistent; 7-25 stamens per fascicle; anthers yellow; filaments light orange. ***Ovary*** ovoid to subglobose; stigma, style and ovary light green; styles 3. ***Fruit*** 3-5mm long; 3-valved; globose; red. ***Seeds*** many; approximately 0.5mm long; brown or yellow; cylindrical; longitudinally ribbed.

Distribution: Thailand: Mae Hong Son, Chiang Mai, Chiang Rai, Nan, Tak, Loei, Sakhon Nakhon, Chaiyaphum, Chanthaburi, Surat Thani; **Worldwide:** Australia, China, Japan, Java, Madagascar, Nepal, New Zealand, Philippines, Singapore.

Phenology: Flowering: April-June (October). Fruiting: April-June (November).

Ecology: Deciduous Forest, Bamboo Forest, Wet Grassland, Bog, Savannah,

Altitude: 50 – 2,500m.

Local name: Bua thong (*W. Pongamornkul 161*).

IUCN Regional (Thailand) Status: Least Concern (LC).

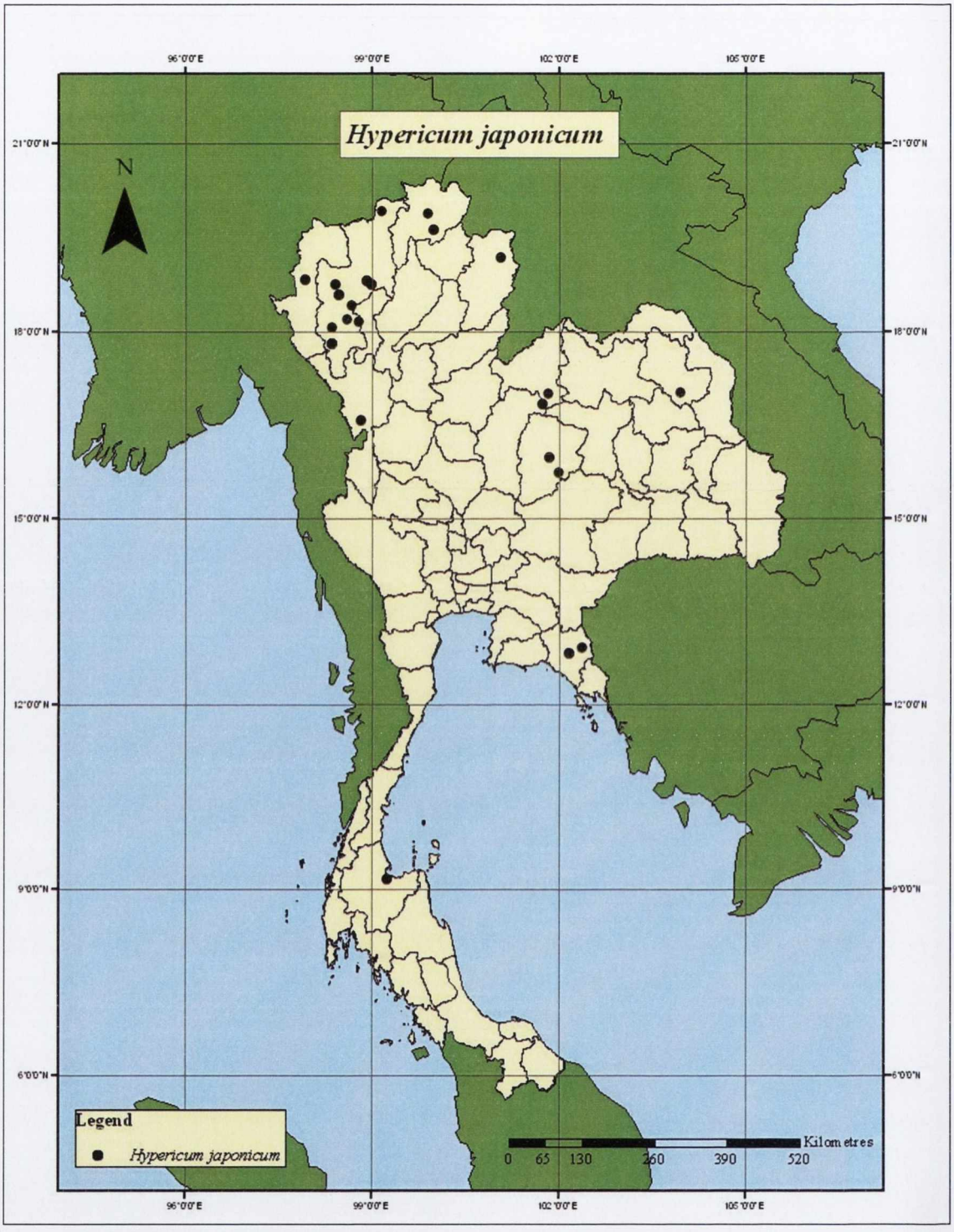
Outlying specimen: Surat Thani: Tung Luang, *A.F.G. Kerr 12512* (ABD, BM, K).

Note on synonymy: *Hypericum chinense* Osbeck has never been used since it was published. Merrill pointed out its priority over *H. japonicum* Thunb. ex. Murray but thought the name *H. chinense* L. applied to the same species. *H. chinense* L. is a cultivated shrub and this name has been used almost exclusively in botanical and horticultural literature until 1985, when Robson (1985) pointed out the above synonymy. Since then *H. chinense* L. has been replaced by *H. monogynum* L. (synonym of *H. chinense* L.) and *H. japonicum* Thunb. ex. Murray has been conserved, as to replace it with the name *H. chinense* Osbeck would cause a '*nomun confusum*'. See Robson, 1990 for more information regarding the name

THAILAND

Northern Region: 1. *Mae Hong Son Province:* Khun Yuam, *K. Larsen & S.S. Larsen 34138* (AAU, K, P); **2. *Chiang Mai Province:*** Doi Inthanon, *No collector 28* (K); Mai Muang Nao Arboretum, *W. Sankamethawee 157* (A); Chiang Dao, *W. Pongamornkul 161* (QBG); Muang Fang, *J. Sadakorm, 227* (BK); Doi Sutep, *C. Chermsirivathana & T. Bomkind 434* (BK); Doi Sutep, *No collector 485* (P); Doi Inthanon, *C. Chermsirivathana & T. Bomkind 730* (BK); Doi Inthanon, *R. Pooma 1070* (BKF); Ob Luang tableland, along road from Bo Luang to Om Koi, *C.F. van Beusekom & C. Phengkhlai 1188* (AAU, BKF, C, E, K, L, P); Doi Sutep, *H.J. Deignan 1526* (A); West of Fang, *Th. Sorensen, K. Larsen & B. Hansen 1663* (C);10km south of Bo Luang along the Om Koi trail, *K. Larsen, T. Santisuk & E. Warncke 1942* (AAU, BKF, C, E, L, P); Doi Sutep, *Th. Sorensen, K. Larsen & B. Hansen 2701* (C); Mae Sanam, *C. Phengkhlai, M. Tamura, C. Niyomdham & B. Sangkhachand 4155* (BKF); Om Koi, *C. Phengkhlai, M. Tamura, C. Niyomdham & B. Sangkhachand 4167* (BKF); Doi Sutep, *C.C. Hosseus 4855* (BM, K); Bo Luang, *R. Geesink, D. Phanichapol & T. Santisuk 5833* (C, E, L, P); Bo Luang, *R. Geesink, D. Phanichapol & T. Santisuk 5867* (BKF, C, E, K, L, P); Chom Thong, *J.E. Vidal, Y. Vidal & C. Niyomdham 6198* (P); Ban Tha Ma Kiang, Phrao, *W. Nanakorn et al 9204* (QBG); Om Koi, *B. Hansen, G. Seidenfaden & T. Smitinand*

10843 (C, K, L); Near Bo Luang at 37km, *B. Hansen, G. Seidenfaden & T. Smitinand 11017* (C); Doi Sutep, east side, above Kohntatahn Falls, Muang, *J.F. Maxwell 88-408* (L); Ban Bah Bae, Mae Dtang District, *J.F. Maxwell 90-1244* (A); Ban Tah Nah Giang, Sahn Sai Subdistrict, Prow Valley, Prow, *J.F. Maxwell 92-403* (A, E, P); Summit of Doi Poa Lohn, Mae Seuk Subdistrict, Mae Jam District, *J.F. Maxwell 97-38* (A, BKF); Doi Inthanon, *S. Tsugaru T-61735* (A, AAU, BKF); Amper Sann Pa Tong, *Y. Paiseeksantivatana, Y 1742-86* (BK); **3. *Chiang Rai Province:*** Chiang Kien, *A.F.G. Kerr 2486* (BM, E, K, TCD); Chiang Kien, *A.F.G. Kerr 2486A* (BM); Ban Dai, Sidawnmoon subdistrict, group 3, Chiang Saen, *J.F. Maxwell 89-312* (L); **5. *Nan Province:*** Doi Phu Kha NP, Pua, *P. Srisanga 1119* (QBG); Doi Phu Kha NP, Pua, *P. Srisanga 1399* (QBG); **10. *Tak Province:*** Huey Khek, Lom Sak *B. Hansen, G. Seidenfaden & T. Smitinand 11236* (BKF, C); **North-Eastern Region: 17. *Loei Province:*** Phu Kradung, *K. Juntabendlham, 149* (BK); Phu Kradung, *C. Chermsirivathana & T. Bomkind 1885* (BK); Phu Kradung, *C. Chermsirivathana & T. Bomkind 1889* (BK); Phu Kradung, *E. Hennipman 3704* (BKF, C, L); Phu Kradung, *Ch. Charoenphol, K. Larsen & E. Warncke 4808* (AAU); **21. *Sakhon Nakhon Province:*** Phu Phan NP, c. 100km west of Park HQ, *P. Chantaranothai & J. Parnell 90/799* (TCD); **Eastern Region: 27. *Chaiyaphum Province:*** Thung Kra Mang, Phu Khieo, *K. Larsen, S.S. Larsen, I. Nielsen & T. Santisuk 31604* (AAU, K, L, P); **South-Eastern Region: 61. *Chanthaburi Province:*** Pong Nam Ron, *T. Smitinand 3286* (BKF, K, L, P); Kao Ploi Wen, *A.F.G. Kerr 18049* (K, TCD); **Peninsular Region: 65. *Surat Thani:*** Tung Luang, *A.F.G. Kerr 12512* (ABD, BM, K); **Unknown Locations:** No collector *49* (KKU).



Map 3.23 Distribution of *Hypericum japonicum* in Thailand.



Figure 3.9 Line drawing of *Hypericum japonicum*. (Illustration by Elaine Cullen).

3. *Hypericum siamense* N. Robson, in Bull. Brit. Mus. (Nat. Hist.), Bot., 12 (4): 240 1985; Li Xiwen & Li Yan-hui, in Li Hsiwen, Fl. Reipubl. Popularis Sin. 50(2): 1-112. 1990; L. Xiwen & N. Robson, Fl. China 13: 2-35. 2007.

Type: Doi Chiang Dao, *A.F.G. Kerr s.n.* (Holotype:BM!; Isotype: ABD!).

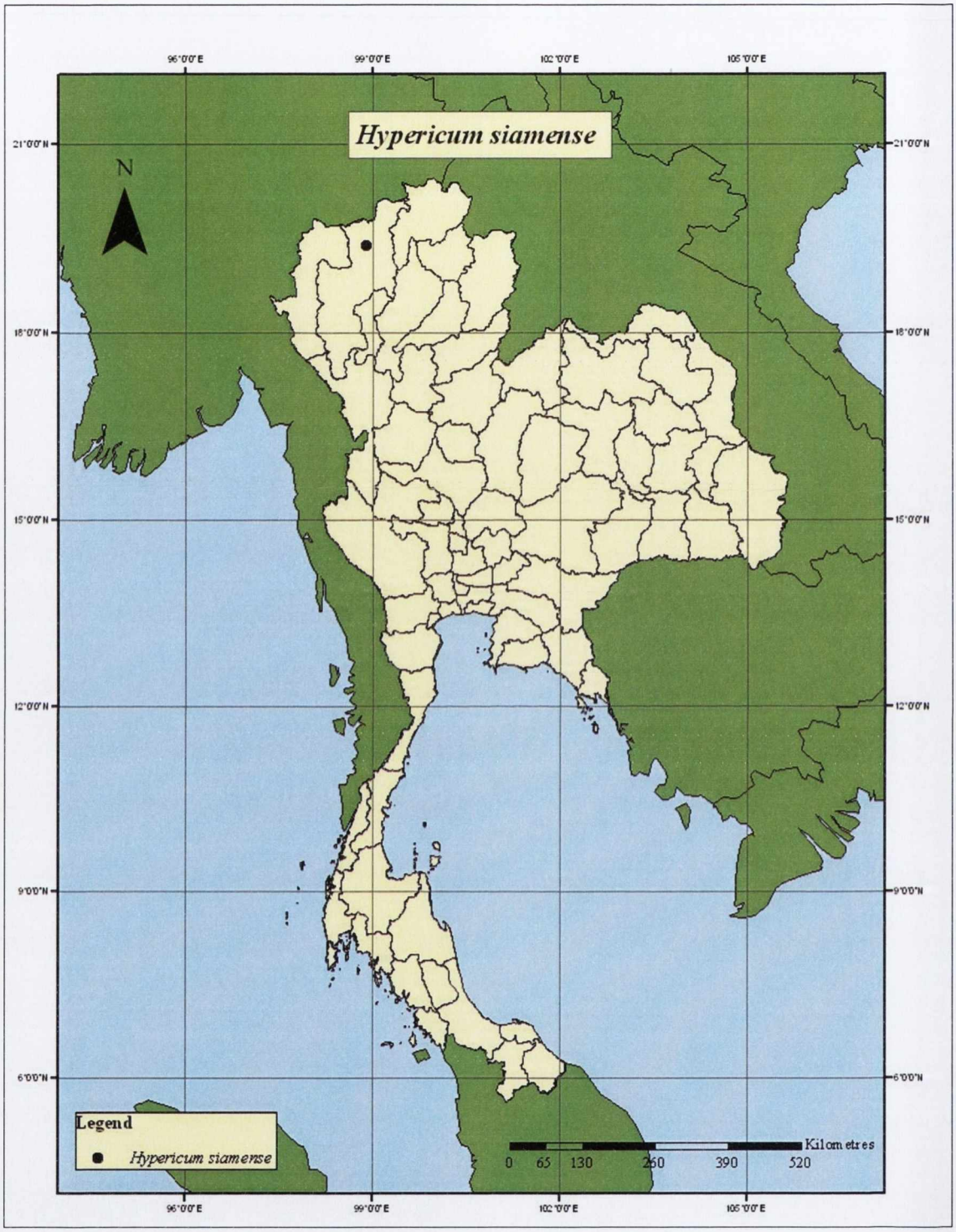
Description

Habit bushy shrub, 0.7-3m tall; perennial herb. ***Branchlets*** terete; brown to red; rigid; scars present, rough; internode 0.5-2cm long. ***Leaves*** subsessile to sessile; midrib depressed in upper surface and pronounced on lower surface, midrib narrowing towards apex but still visible, brown/red on both surfaces; delicate leaves; some glaucous; 2.3-3.6 x 0.6-1.8cm; shape varies from lanceolate to elliptic to oblong or ovate-oblong; base varies from cuneate to tapering; apex acute or acuminate; secondary veins and intramarginal veins visible; intersecondary veins and tertiary veins faint; few black round glands present. ***Inflorescence*** pedicels up to 1cm long; solitary and axillary, or 1-5 flowered and corymbiform. ***Calyx*** sepals 4; free; imbricate or reflexed to spreading; unequal; 0.8-1.2 x 0.3-0.6cm; triangular to ovate; longitudinal striations present. ***Corolla*** petals 4; yellow, some tinged red on dorsal side, large; longitudinal striations present; 2-2.4 x 1.2-1.7cm; obovate. ***Stamens*** many, in fascicles, approximately 45-50 stamens per fascicle; anthers oblong; 10-11mm long; yellow to orange in colour. ***Ovary*** ovoid; styles 2.5-6mm long. ***Fruit*** ovoid. ***Seeds*** orange-brown; approximately 1mm long.

Distribution: Thailand: Chiang Mai.
Phenology: Flowering: July-January.
Ecology: Limestone Ridge, Exposed Cliff Edge.
Altitude: 1,800 - 2,200m.
Local name: Bua thong (*W. Pongamornkul 392*).
IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 2. *Chiang Mai Province:* Chiang Dao, *A.F.G. Kerr 11* (K); Doi Chiang Dao, *W. Pongamornkul 171* (QBG); Doi Chiang Dao, *W. Pongamornkul 392* (QBG); Doi Chang Dao, *T. Smitinand & H. Sleumer 1055* (L); Doi Chiang Dao, *P. Suksathan 1117* (QBG); Doi Chiang Dao, *P. Suksathan 2842* (QBG); Doi Chiang Dao, *P. Suksathan 2845* (QBG); Doi Chiang Dao, *BGO Staff 2895* (QBG); Doi Chiang Dao, *BGO Staff 2919* (QBG); Payap, Doi Chang Dao, *E. Hennipman 3277* (L); Doi Chiang Dao, *T. Smitinand, M.E.D. Poore & R.G. Robbins 7789* (BKF, E); Doi Chiang Dao, *G. Murata, K. Iwatsuki & C. Phengkhlai* 15211 (AAU, K); Doi Chang Dao, *T. Smitinand, J.A.R. Anderson 25915* (K); Doi Chang Dao, *T. Smitinand & M.E.D. Poore 30328* (L); Below the summit of Doi Chiang Dao, *T. Shimizu, H. Koyama & A. Nalampoon T-10109* (BKF); Doi Chiang Dao, *G. Murata, K. Iwatsuki & C. Phengkhlai T-15262* (BKF, K, P): Higher elevation of Doi Chiang Dao, *G. Murata, K. Iwatsuki & C. Phengkhlai T-15280* (BKF); Doi Chiang Dao, *A.F.G. Kerr s.n.* (ABD, BM).



Map 3.24 Distribution of *Hypericum siamense* in Thailand.

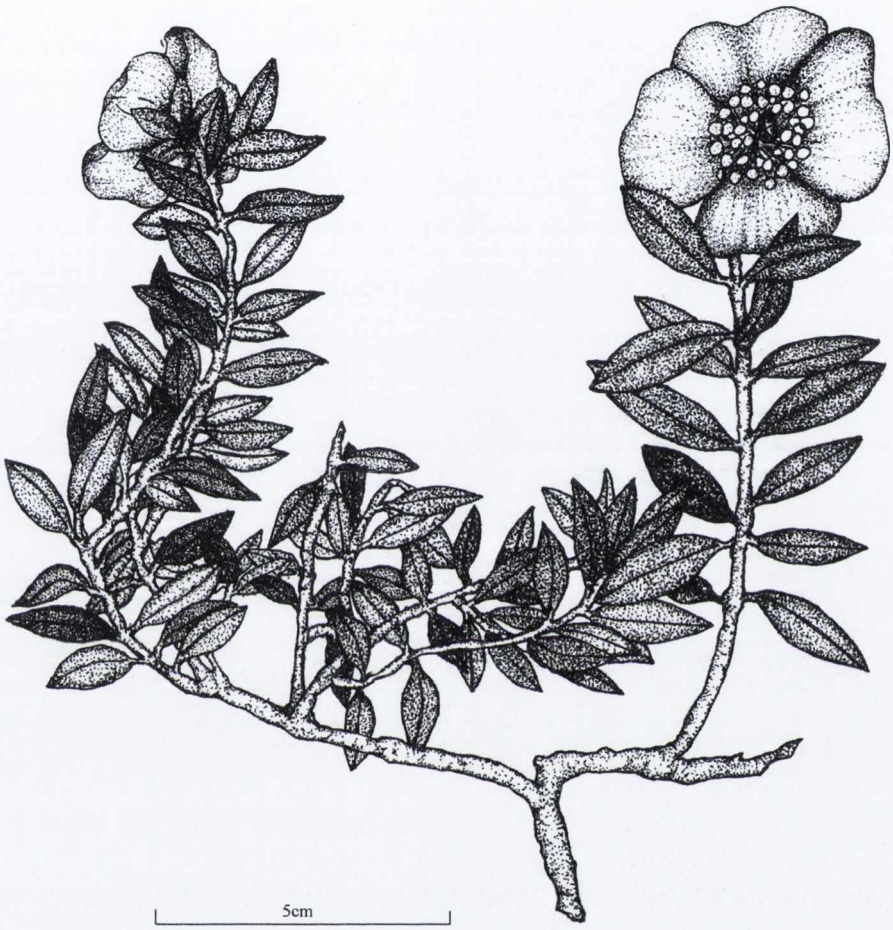


Figure 3.10 Line drawing of *Hypericum siamense* (flowering stem). (Illustration by Elaine Cullen).

4. *Hypericum patulum* Thunb. ex Murray, Syst. Veg., ed. 14: 700. (May-Jun) 1784; Thunb., Fl. Jap. t. 17, 295. (Aug) 1784; Curtis, Bot. Mag. 50: t. 5693. 1823; Choisy, in DC. Prod. 1:545. 1824; Dyer, in Hook. f. Fl. Brit. India 1: 254. 1874; Gamble, Man. Ind. Timb. 48. 1881; Gamble, in Humbert, Suppl. Fl. Indo-Chine 1(3): 248. 1943; Zollinger, Syst. Verz. 1-2: 151. 1854; Maxim., in Bull. Acad. Imp. Sci. Saint-Pétersbourg 27: 429. 1882; Hemsley, in J. Linn. Soc., Bot. 23:73. 1886; Kuntze, Rev. Gen. Bot. 1: 60. 1891; Koehne, Deut. Dendrol. 415. 1893; R. Keller, in Bull. Herb. Boissier 5: 638. 1897; Diels, in Bot. Jahrb. Syst. 29: 476. 1900; H. Lév., in Bull. Soc. Bot. France 53: 499. 1906; R. Keller, in Engler & Prantl, Nat. Pflanzenfamilien 2(21): 176. 1925; Rehder, in J. Arnold Arbor. 15: 100. 1934; Y. Kimura, in Bot. Mag. (Tokyo) 54: 88. 1940; Lauener, in Notes Roy. Bot. Gard. Edinburgh 27: 4. 1966; N. Robson, in J. Roy. Hort. Soc. 95: 491. 1970; N. Robson, in Bull. Brit. Mus. (Nat. Hist.), Bot., 12(4): 261 1985; L. Xiwen & N. Robson, Fl. China 13: 2-35. 2007.

Type: Japan, *Thunberg s.n.* (Holotype: UPS!).

Ic: Y. Kimura, in Nakai & Honda, Nov. Fl. Jap. 10; 100, f. 41. 1951.

Synonyms

-*Norysca patula* (Thunb.)Voigt, Hort. Suburb. Calcutt. 90. 1845. Type: Japan, *Thunberg s.n.* (Holotype: UPS!).

-*Norysca urala* K.Koch, Hort. Dendrol. 3:66. 1853. Blume, Mus. Bot. 2: 23. 1856; Y. Kimura, in Nakai & Honda, Nov. Fl. Jap. 10: 99, f. 41. 1951. Type: Narainhetty, Nepal, *Hamilton, s.n.* (Lectotype: BM!).

-*Eremanthe patula* K. Koch, Hort. Dendrol. 65. 1853. Type: Japan, *Thunberg s.n.* (Holotype: UPS!).

-*Hypericum nepalense* Hort. ex K. Koch, Dendrologie 1: 497. 1869. Type: Narainhetty, Nepal, *Hamilton, s.n.* (Lectotype: BM!).

-*Hypericum uralum* sensu Hance, in J. Bot. 16: 104. 1878, non *H. uralum* Buch.-Ham. ex D. Don, in Bot. Mag. 50:t. 2375. 1823. Type: Narainhetty, Nepal, *Hamilton, s.n.* (Lectotype: BM!).

-*Hypericum argyi* H. Lév. & Vaniot, Bull. Soc. Bot. France 54: 591. 1908; H. Lév., Fl. Kouy-Tcheou. 198: 1914; H. Lév., Mem. Real. Acad. Ci. Barcelona 3(12): 553. 1916. Type: China, *d'Argy s.n.* (Holotype: E!).

-*Komana patula* (Thunb.)Y. Kimura ex Honda, Nom. Pl. Japonic. 509. 1939; Y. Kimura ex Hisauti, Kikasyokubutsu, 179. 1950; cf. Y. Kimura, Nakai & Honda, Nova Fl. Jap. 10: 97, 99. 1951. Type specimen not found.

Description

Habit shrub up to 3m tall; with spreading branches, greyish-brown. ***Branchlets*** terete, becoming 2-lined; thick; rough; dark brown to red-orange; scarring present. ***Leaves*** sessile to petioled, if petioled, up to 0.5-2mm long; midrib visible and prominent on upper surface, black in colour on both surfaces; smooth, delicate; 1.5-6.0 x 0.5-3.0 cm; lanceolate to oblanceolate or ovate, oblong or elliptic; base cuneate; apex acuminate to obtuse; colour of leaves varies from light brown to dark red; leaves in whorls at top of branch and sparse along stems; venation not very apparent; without intramarginal veins; leaf edges undulate. ***Inflorescence*** pedicels 0.2-0.7cm long; 1-15 flowered. ***Calyx*** sepals 5; free, imbricate, unequal or subequal; entire to sometimes denticulate; sometimes red; ovate to elliptic or oblong; 5-10 x 3.5-7mm. ***Corolla*** petals 5; oblong to obovate; golden yellow; longitudinal striations present; 1.2-1.8 x 1-1.4cm. ***Stamens*** in fascicles; 50-70 stamens per fascicle; longest stamens 7-12mm; anthers bright yellow. ***Ovary*** ovoid; styles 4-5.5mm. ***Fruit*** ovoid. ***Seeds*** dark brown.

Distribution: Thailand: Chiang Mai; **Worldwide:** Burma, China, Himalaya, Japan, New Zealand, Sumatra, Vietnam.
Phenology: Flowering: May-September. Fruiting: July-October.
Ecology: Open Ridges.
Altitude: 1,900 - 2,520m.
IUCN Regional (Thailand) Status: Data Deficient (DD).

THAILAND

Northern Region: 2. *Chiang Mai Province:* Doi Chiang Dao, *T. Smitinand & H. Sleumer et al 1055* (BKF); Doi Chiang Dao, *T. Koyama, C. Phengkhlai, C. Niyomdham, M. Tamura, H. Okada & P.J. O' Connor 15639* (AAU, BKF); The swampy place and its' vicinity of the summit, Doi Inthanon, *S. Tsugaru T-61869* (A, AAU, BKF); Doi Chiang Dao, *A.F.G. Kerr s.n.* (BK).



Map 3.25 Distribution of *Hypericum patulum* in Thailand.



Figure 3.11 Line drawing of *Hypericum patulum*. (Illustration by Elaine Cullen).

5. *Hypericum hookerianum* Wight & Arn., Prodr. Fl. Ind. Orient. 1: 99. 1834; Dyer, in Hook. f., Fl. Brit. India 1: 254. 1874; Gamble, Fl. Madras 69. 1915; R. Keller, in Engler & Prant, Nat. Pflanzenfamilien 2(21): 176. 1925; Y. Kimura, in Hara, Fl. E. Himalaya 210. 1966; Mathew, in Rec. Bot. Surv. India 20: 45. 1969; N. Robson, in J. Roy. Hort. Soc. 95: 490. 1970; N. Robson, in Hara & Williams, Enum. Fl. Pl. Nepal 2: 61. 1979; N. Robson, in Bull. Brit. Mus. (Nat. Hist.), Bot. 12 (4): 255. 1985; L. Xiwen & N. Robson, Fl. China 13: 2-35. 2007.

Type: India *Wight 332* (Holotype: K!; Isotype: E!).

Synonyms

-*Norysca hookeriana* Wight, Ill. Ind. Bot. 1: 113. 1840; Blume, Mus. Bot. 2: 22. 1856; Y. Kimura, in Nakai & Honda, Nov. Fl. Jap. 10: 98. 1951. Type: India *Wight 332* (Holotype: K!; Isotype: E!).

-*Hypericum oblongifolium* Hook., Bot. Mag. 82: t. 4949. 1856. India *Wight 332* (Holotype: K!; Isotype: E!).

-*Hypericum garrettii* Craib, in Bull. Misc. Inform. Kew 66. 1913; Craib, Fl. Siam. 1(1):110. 1925; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 248. 1943. Type: Thailand, Chiang Mai, Doi Inthanon, *Garrett, 67* (Lectotype: K! (Lectotype designated here); Isolectotypes: BM!, E!).

Description

Habit shrub 1-3m tall. ***Branchlets*** terete; arching; stems brown; smooth; slender; scars present; young branches compressed. ***Leaves*** sessile-subsessile; midrib depressed on both surfaces; on upper surface midrib colour very variable: red, yellow/white, dark red; on lower surface midrib colour red or brown; leaves delicate, papyraceous, hairless; colour varies from vibrant green to red to dull red/black; 3.3-6.3 x 1.3-2.4cm; shape variable: lanceolate, oblanceolate, elliptic, oblong, obtuse; base cuneate; apex cuneate, bluntly acute, acuminate; secondary, intersecondary and tertiary veins visible, no intramarginal veins; few pellucid dots present. ***Inflorescence*** pedicels 0.3-1.6cm;

terminal; 1-5 (10) flowered, from apical node. ***Calyx*** sepals 5; ovate to obovate; +/- imbricate; green; red/brown longitudinal veins present; oblong, elliptic to obovate-spathulate, rounded; entire; 3.5-9 x 2-6.5mm. ***Corolla*** petals 5; bright yellow to golden yellow; longitudinal veins present; entire; 9-18 x 5-12mm; caducous; obovate; as long as sepals. ***Stamens*** numerous; in 5 fascicles with 60-80 stamens; yellow; anthers oblong; 4-6(8)mm long; approximately ¼ - ½ as long as petals; anthers bright yellow to orange-yellow. ***Ovary*** 3-7 x 4-6mm long; styles 5; longer than anthers; ovoid to globose. ***Fruit*** green; ovoid. ***Seeds*** dark brown to red; approximately 0.5mm long; elliptic.

Distribution: Thailand: Mae Hong Son, Chiang Mai; **Worldwide:** Bhutan, Burma, China, Himalaya, India, Nepal, Vietnam.

Phenology: Flowering: April-July. Fruiting: September-October.

Ecology: Primary Evergreen Forest, Marshy Ground, Open Savannah, Swamp.

Altitude: 1,850 - 2,595m.

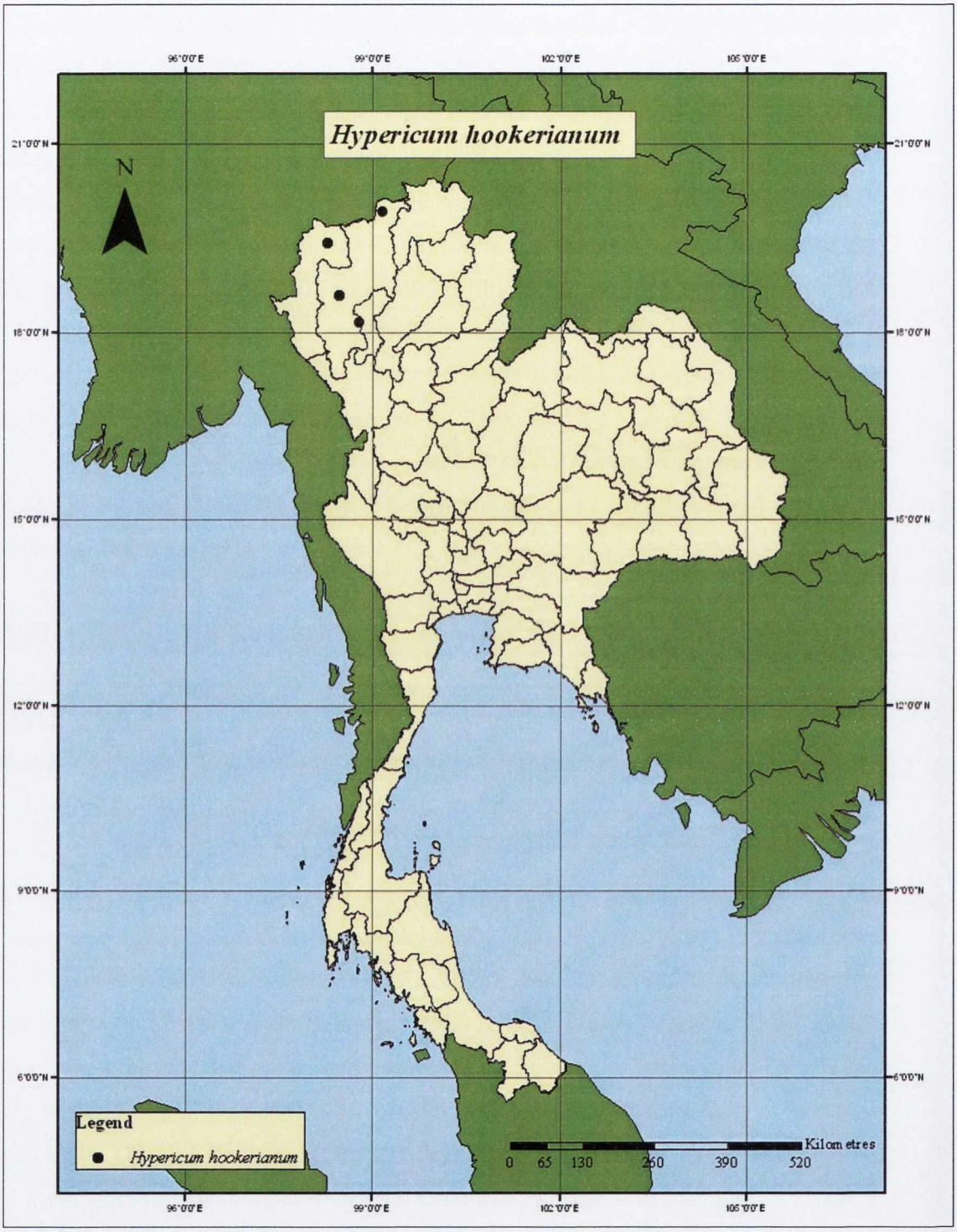
Local name: Bua thong (*BGO Staff 7117*).

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 1. *Mae Hong Son Province:* Doi Chong, *B. Hansen & T. Smitinand 12674* (AAU, BKF, E, K, L, P); **2. *Chiang Mai Province:*** Doi Inthanon NP, *BGO Staff 24* (QBG); Doi Angka, Pa Ngem N Peak, *H.B.G. Garrett 67* (BM, E, K); Inthanon NP, *A.F.G. Kerr 67* (E); Pa Ngem N Rocks, Doi Angka, *H.B.G. Garrett 70* (BM); Kew Mae Pan, *S. Mattapha 394* (KKU); Doi Inthanon NP, *W.N. 548* (BKF); Doi Pha Hom Phok, *C. Phengkhlai & B. Sangkhachand 973* (BKF); Doi Inthanon NP, *R. Pooma 1072* (BKF);Doi Pha Hom Pok, *P. Suksathan 1488* (QBG): Western flank of Doi Inthanon, Mae Pau, *C.F. van Beusekom & C. Phengkhlai 2397* (AAU, BKF, C, E, P); Inthanon NP, *M. Balick & W. Nanakorn 3410* (AAU); Doi Inthanon, Chom Thong *W. Nanakorn et al 4396* (QBG); Mae Chaem District: Top area of Doi Inthanon in Doi Inthanon NP, *F. Konta, C. Phengkhlai & S. Khao-lam 4880* (BKF); Kew Mae Pan, Doi Inthanon, *C. Niyomdham 5244* (BKF); Doi Inthanon, *A.F.G. Kerr 5312* (ABD, BK, BM, K, TCD); Doi Inthanon, *C. Phengkhlai & T. Smitinand 6072* (BKF); Doi Inthanon NP, *BGO Staff 7117* (QBG); Doi Chiang Dao, *T. Smitinand & J.A.R. Anderson 7303* (BKF); Inthanon NP, *C. Phengkhlai et al 7416* (K); Doi Inthanon NP, *C. Phengkhlai et al. 7484* (BKF);

Doi Inthanon NP, *T. Smitinand, M.E.D. Poore & R.G. Robbins 7645* (BKF); Kew Mae Pan, Doi Inthanon, *BGO Staff 7928* (QBG); Doi Inthanon, *R. Geesink, P. Hiepko & C. Phengkhlai 7998* (K, L); Kew Mae Pan, Doi Inthanon, *C. Phengkhlai, F. Konta & S. Khao-iem 11394* (BKF); Doi Chiang Dao, *T. Smitinand & M.E.D. Poore 30238* (AAU); Doi Inthanon, *K. Larsen, S.S. Larsen, T. Norgoard, K. Pharsen, P. Puudjaa & W. Ueachirakan 44980* (AAU); Doi Inthanon NP, forest trail at 42km along summit road, *P. Chnataranothai, J. Parnell, D. Simpson & R. Pooma 90-626* (K); Doi Doi Inthanon NP, forest trail at 42km along summit road, *P. Chantaranothai, J. Parnell, D. Simpson & R. Pooma 90-686* (K); Doi Inthanon NP, Summit of Doi Inthanon, *J.F. Maxwell 91-776* (AAU, E, P); Higher elevation of Doi Inthanon, Payap District, *M. Tagawa, K. Iwatsuki & N. Fukuoka T-2856* (BKF); Near Pagoda, the west side of the main route, Doi Inthanon, *H. Koyama T-61088* (BKF); Kew Mae Pan, Doi Inthanon, *BGO Staff s.n.* (QBG); **Unknown Locations:** *N.K.B. Robson s.n.* (AAU, BKF).



Map 3.26 Distribution of *Hypericum hookerianum* in Thailand.



Figure 3.12 Line drawing of *Hypericum hookerianum* (flowering stem). (Illustration by Elaine Cullen).

6. *Hypericum henryi* H. Lév. & Vaniot subsp. ***hancockii*** N. Robson, in Bull. Brit. Mus. (Nat. Hist.), Bot., 12(4): 261 1985; L. Xiwen & N. Robson, Fl. China 13: 2-35. 2007.

Type: China, Yunnan, *Hancock Kew 116* (Holotype: K!; Isotype: K!).

Synonyms

-*Hypericum garrettii* var. *ovatum* Craib, Fl. Siam. 1(1):111. 1925. Type: Thailand, Chiang Mai, *Kerr 5188* (Holotype: K!; Isotypes: ABD!, BM!, E!, BK!).

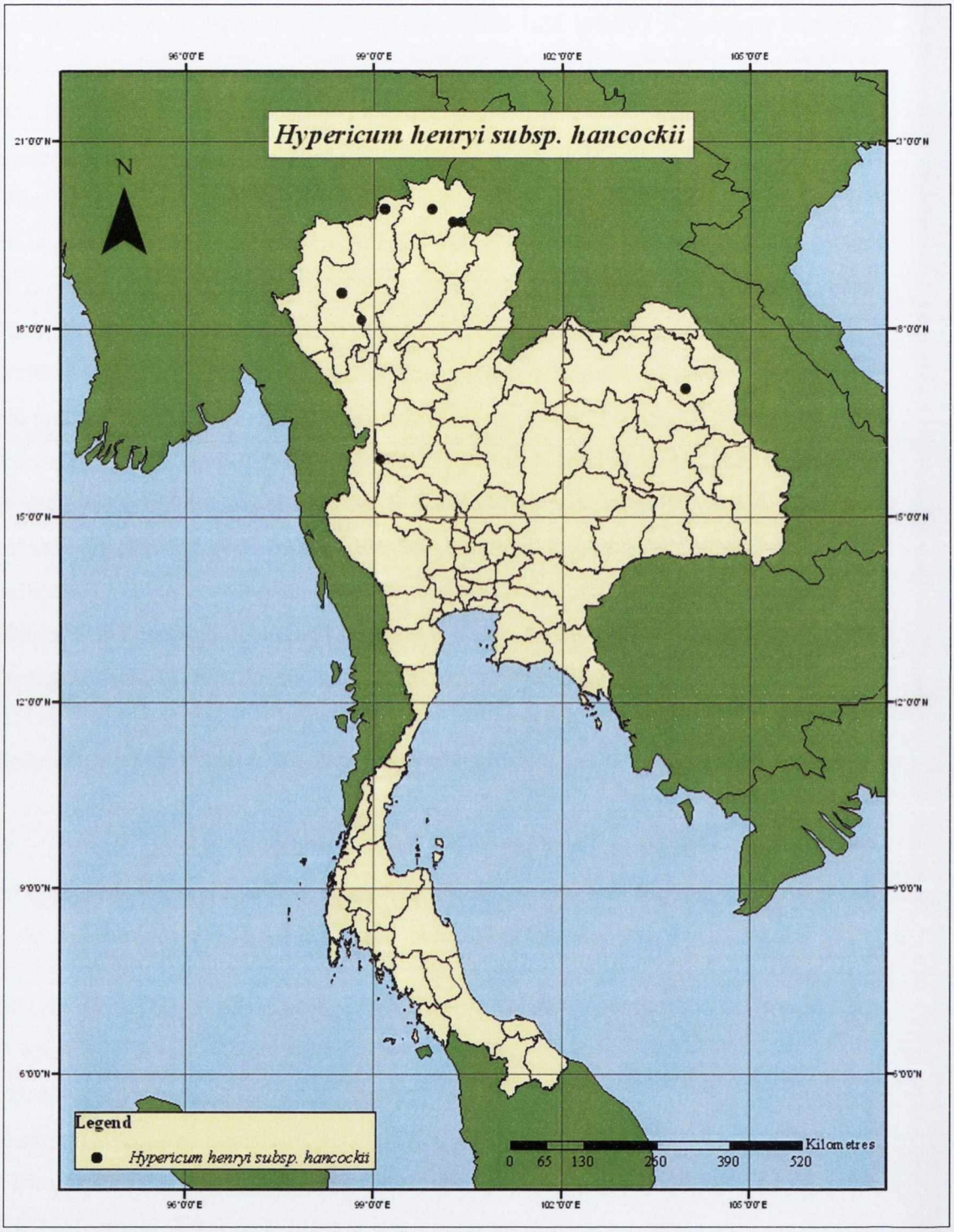
Description

Habit shrub up to 3m tall. ***Branchlets*** terete; erect; slender; smooth; new branches thin; red-brown in colour; internodes 1-2cm. ***Leaves*** sessile; midrib depressed on upper surface and pronounced on lower surface, red/brown in colour, hairless, midrib fades slightly towards apex, but still visible; leaf colour varies from green to golden yellow to red/brown; some leaves 2-toned; leaves delicate and hairless; 1.5-4.3 x 0.4-2cm; lanceolate to elliptic; base cuneate to rounded; apex varies from acute to cuspidate to obtuse; sometimes glaucous; secondary veins visible, intersecondary and tertiary veins faint, secondary veins not arising from same point on opposite sides of midrib; some leaves trinerved; black glands present. ***Inflorescence*** pedicels 0.3-1.5cm long; flattened; branches terete; panicle; 3 flowers per corymb. ***Calyx*** sepals 5; obovate to ovate or elliptic; orange; 6 x 4mm; unequal. ***Corolla*** petals 5; petals twice as long as sepals; ovate; 8-25 x 6-15mm; yellow. ***Stamens*** in fascicles with 40-60 stamens present; anthers round; yellow; longest 5-13mm, usually half as long as petals. ***Ovary*** styles 4, protruding; style 4-6mm long; ovoid. ***Seeds*** brown.

Distribution: Thailand: Chiang Mai, Chiang Rai, Nakhon Sawan, Sakhon Nakhon.
Worldwide: Burma, China, New Zealand, Sumatra, Vietnam.
Phenology: Flowering: All year. Fruiting: July-November.
Ecology: Evergreen Forest, Mountain, Exposed/Open Ridges.
Altitude: 280 - 2,560m.
IUCN Regional (Thailand) Status: Least Concern (LC).
Outlying specimen: Sakhon Nakhon Province: An Gop, Phu Phan NP, *P. Chantaranothai, J. Parnell, D. Middleton & D. Simpson 973* (TCD).

THAILAND

Northern Region: 2. *Chiang Mai Province:* Doi Inthanon, trail to the summit, Jam Thong District, *C.M. Byrne 9* (TCD); Kew Mae Pan Nature Trail, Doi Inthanon, *C.M. Byrne 10* (TCD); Kew Mae Pan Nature Trail, Doi Inthanon, *C.M. Byrne 11* (TCD); Huay Mae, Klang Pat, Pha Mon, *K. Suvarmasuddhi 318* (BKF); Doi Pha Hom Phok, *C. Phengkhlai 973* (C, E); Doi Angka, Pa Ngem, *K. Winit 1350* (ABD, BKF, K); Doi Pahom Poh, Muang Fang, *A.F.G. Kerr 5188* (ABD, BM, E, K, TCD); Doi Angka, Pa Ngem N Peak, *A.F.G. Kerr 6300* (ABD, BM, K); Higher elevation of Doi Inthanon, *H. Koyama, H. Terao & Th. Wongprasert T-32090* (BKF); Doi Pha Hom Phok, Fang District, *H. Koyama, H. Terao & Th. Wongprasert T-33411* (BKF); Doi Pha Hom Phok, Fang District, *H. Koyama, H. Terao & Th. Wongprasert T-33438* (BKF); **3. *Chiang Rai Province:*** Doi Pa Hom Pok, *B. Lojtnant & C. Niyomdham 166* (AAU); Doi Pa Hom Pok, NW of Phan, *K. Iwatsuki, N. Fukuoka & A. Chintayungkun 9690* (AAU, BKF, E, K, L); Doi Dtung, NW side of Pah Hoong, *J.F Maxwell 06-1006* (CMU); **15. *Nakhon Sawan Province:*** Klong Lan, Mo Ko Choo Mountain, *M. Van de Bult 209* (BKF, CMU); **North-Eastern Region: 21. *Sakhon Nakhon Province:*** An Gop, Phu Phan NP, *P. Chantaranothai, J. Parnell, D. Middleton & D. Simpson 973* (TCD); **Unknown Locations:** *Sander & Sons.*



Map 3.27 Distribution of *Hypericum henryi* subsp. *hancockii* in Thailand.

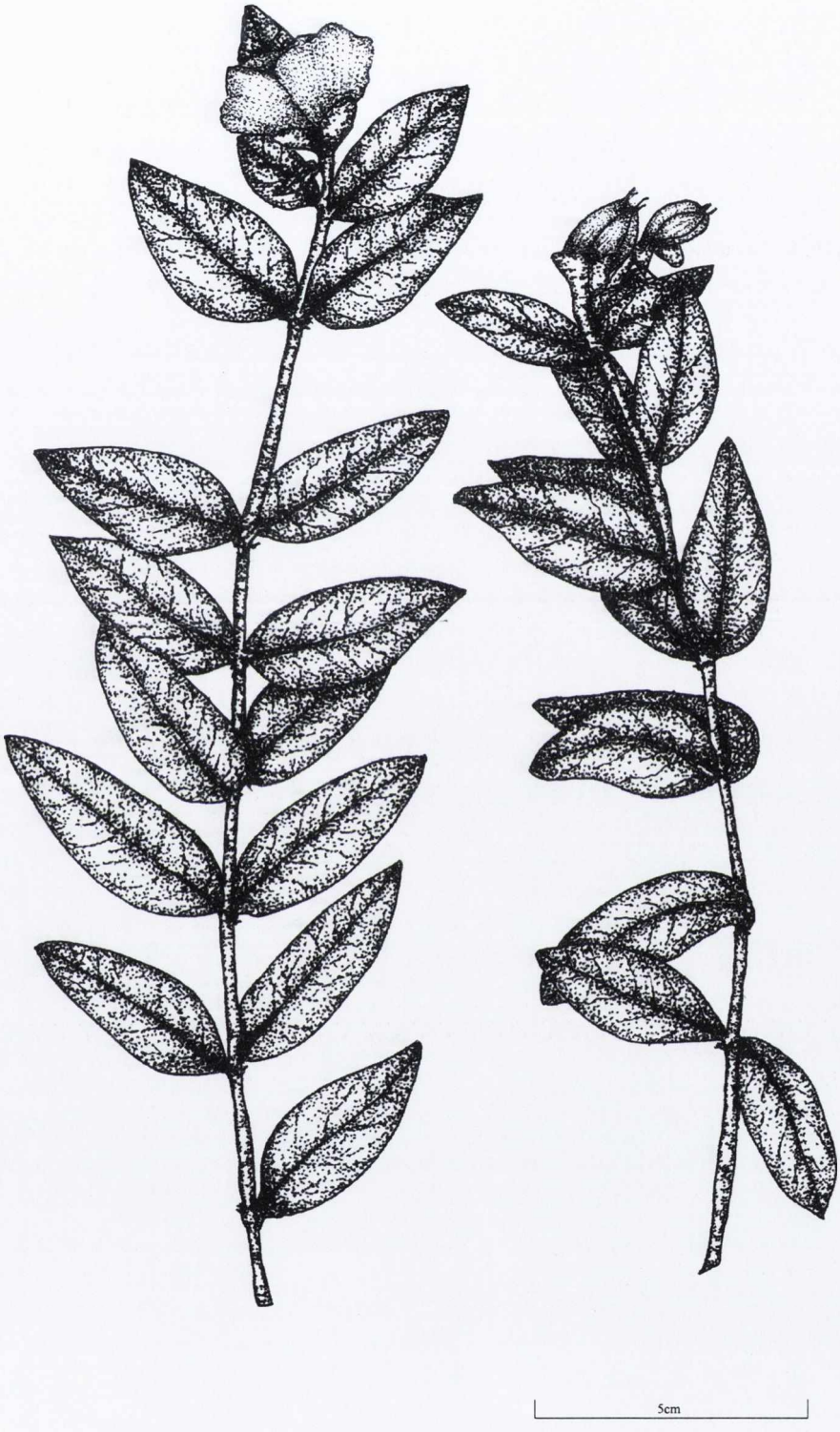


Figure 3.13 Line drawing of *Hypericum henryi* subsp. *hancockii* (flower, fruit and leaves). (Illustration by Elaine Cullen).

***Cratoxylum* Blume** Verh. Batav. Genootsch. Kunsten 9: 172, 174. 1823; Blume, Mus. Bot. 2: 17. 1852; Miquel, Fl. Ned. Ind. 515. 1859; Dyer, in Hook. f., Fl. Brit. India 1: 257. 1874; Kurz, Forest Fl. Burma 1: 83. 1877; Gamble, Man. Ind. Timb. 48. 1881; King, J. Asiat Soc. Bengal, Pt. 2, Nat. Hist. 59(2): 145. 1890; Engler, in Engler & Prantl, Nat. Pflanzenfamilien 3(6): 215. 1895; Prain, Bengal Pl. 245. 1903; Brandis, Indian Trees, 47. 1907; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 287. 1910; Gamble, Fl. Madras 70. 1915; Ridl., Fl. Malay. Penin. 1: 152. 1922; Craib, Fl. Siam. 1(1):111. 1925; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 251. 1943; Backer & Bakh., f. Fl. Java (Spermatoph.) 1: 383. 1963; Gogelein, Blumea 15(2): 454. 1967; Baas, Blumea 18(2): 369. 1970; N. Robson, in Fl. Males., Ser. 1, Spermat. 8: 4-6. 1974; Corner, Wayside Trees of Malaya 1: 325. 1988.

Type: *Hornschuchia hypericina* Blume, Salak, Gunung, Java, Indonesia. *Blume, C.L. s.n.* (Isotype: L!).

Synonyms

-Hornschuchia Blume, Cat. Gew. Buitenzorg 15. 1823. Type: *Hornschuchia hypericina* Blume, Salak, Gunung, Java, Indonesia. *Blume, C.L. s.n.* (Isotype: L!).

Deciduous to evergreen trees or shrubs; all hairless except *C. formosum subsp. pruniflorum*; exudes a yellow resinous sap which changes to black when dry. ***Leaves*** opposite; sessile to petiolate; entire; papyraceous; pellucid dots usually present; eucamptodromous venation; base attenuate to subcordate; apex rounded to cuspidate. ***Inflorescences*** terminal panicles, short terminal or axillary cymes. ***Calyx*** sepals 5; persistent, coriaceous, usually accrescent. ***Corolla*** petals 5; caducous to subpersistent; obovate; exceeding sepals; pink or white in colour. ***Stamens*** 3 or 5 fascicles; adelphous; persistent; dorsifixed; slender; sometimes with a brown dot on the connective. ***Ovary*** 3-celled; ovoid to ellipsoid; styles free; ovules 4-∞. ***Seeds*** oblong and winged all round or partly winged; embryo erect.

Distribution: Borneo, Burma, Cambodia, India, Indonesia, Laos, Malaysia, South and Southwest China, Philippines, Vietnam.

Key to species:

1. Flowers in small clusters on old leafless twigs.....2
   Flowers on leafy twigs.....3

2. Flowers white; leaves obovate, elliptic, lanceolate, oblanceolate or round; fruits 4-6mm diameter; seeds 6-8 per loculus.....**1. *C. formosum***
   Flowers dark red; leaves obovate, elliptic or oblong; fruits 2-4mm diameter; seeds 5-6 per loculus.....**2. *C. maingayi***

3. Evergreen tree up to 45m high; flowers in terminal pyramidal panicles; leaves obovate, oblanceolate, oblong or elliptic.....**3. *C. arborescens***
   Deciduous tree or shrub up to 30m high; flowers in short terminal panicles or cymes; leaves oblong, elliptic or lanceolate.....4

4. Leaves sessile to subsessile; inflorescence in terminal cymes.....**4. *C. neriifolium***
   Leaves petioled; inflorescence in short terminal panicles.....**5. *C. chinense***

1. *Cratoxylum formosum* (Jack) Dyer in Hook, f. Fl. Brit. Ind. 1: 258. 1874; Gogelein, Blumea 15: 467. 1967; N. Robson, in Fl. Males., Ser. 1, Spermat. 8: 4-6. 1974; L. Xiwen, L. Jie & P.F. Stevens, Fl. China 13: 36-38. 2007.

Synonyms

-*Cratoxylum formosum* (Jack) Dyer in Hook, f. Fl. Brit. Ind. 1: 258. 1874; Kurz, Forest Fl. Burma 1: 83. 1877; King, in J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59(2): 145. 1890; Koord. & Val., Bijdr. Boomsoort. Java 5: 137. 1900; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 287. 1910; Ridl., Fl. Malay. Penin. 1:152. 1922; Craib, Fl. Siam. 1(1):111. 1925; Corner, Gard. Bull. Straits Settlem. 10: 23, 28. 1939; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 251. 1943; Backer & Bakh. f., Fl. Java (Spermatoph.) 1: 383. 1963; Meijer, Bot. News Bull. Forest Dept., Sabah 7: 64. 1967; Gogelein, Blumea 15: 467. 1967; Corner, Wayside Trees of Malaya 1: 325. 1988; P.H. Hô, Ill. Fl. Vietnam 1(1): 578, f. 1602. 1991; Thin, Sida 17(4): 742. 1997. Type: Sumatra, *Jack s.n.* (Holotype: CAL!).

Description

Habit small tree to 8m tall; dbh 10cm; bark thick, scaly and flaking; inner bark with watery sap. ***Branchlets*** larger branches armed with long stout thorns; stem spiny; brown in colour; interpetiolar scars interrupted. ***Leaves*** petioled, 0.2-0.8cm long; light green, some yellow/green or brown/red in colour; midrib faint on upper surface, on lower surface obvious, narrowing towards apex; leaf shape variable; oval, elliptic, lanceolate, round, oblanceolate, obovate, 3.2-10.4 x 1.3-4cm; base cuneate, few being acute; apex variable: acute, round, obtuse, acuminate or cuspidate; netted veining present on both surfaces, obvious on some leaves and faint on others, secondary, intersecondary, tertiary and intramarginal veins present; veins do not arise from same points on both sides of the midrib, 7-12 pairs of very clear side veins which are joined in loops near margins. ***Inflorescence*** in clusters of flowered cymes of 1-6 on old leafless twigs; pedicels 0.3-1(1.5) cm long. ***Calyx*** sepals 5; persistent; oblong to elliptic; green-grey in colour; 5-7 x 2-3mm. ***Corolla*** petals, 5; obovate to oblong; persistent?; flowers white. ***Stamens*** anthers round; fused into 3 slender fascicles; 20-30 stamens; slightly shorter than the 3 free pale green styles. ***Ovary*** 2-4.5mm long; styles 3, 2-8mm long, green; hairless. ***Fruit*** oval, oblong, obovate with pointed tip;

purple/deep red in colour; 4-6mm; petioled, 6-11mm long; petiole is hairy; covered by persistent sepals at base. ***Seeds*** 6-8 per loculus; obovate, oblong or oblanceolate; 6-7.5 x 2-4mm.

All parts hairless.....subsp. *formosum*
Young twigs, pedicels, calyx and leaves pubescent.....subsp. *pruniflorum*

subsp. *formosum*

Type: Sumatra, *Jack s.n.* (Holotype: CAL!).

Synonyms

-*Elodea formosa* Jack, Malay. Misc. 2(7): 24. 1822. Type: Sumatra, *Jack s.n.* (Holotype: CAL!).

-*Hypericum biflorum* (*non* Lamarck) Choisy, in DC. Prod. 1:546. 1824. Type: Holotype: FI!.

-*Tridesmis jackii* Spach, Ann. Sci. Nat., Bot. 2(5): 352. 1836. Type: Sumatra, *Jack s.n.* (Holotype: CAL!).

-*Tridesmis formosa* Korth., Verh. Nat. Gesch. Bot. 179, t. 37. 1836. Type: Sumatra, *Jack s.n.* (Holotype: CAL!).

-*Tridesmis ochnoides* Spach, Hist. Veg. Phan. 5:359. 1836; Ann. Sci. Nat. Bot. 2(5): 351, t. 4a. 1836; Blume, Mus. Bot. 2:18. 1852. Type: Holotype: FI!.

-*Hypericum aegiptium* Blanco, Fl. Filip. 615. 1837. Type: Palawan, Taytay, *Merrill s.n.* (Illustrative specimen: Merrill, No. 632) US!.

-*Cratoxylum pentadelphum* Turcz., Bull. Soc. Naturalistes Moscou 36: 580. 1863. Type: Java, *Horsfield s.n.* (Lectotype: BM! (Lectotype designated here); Isolectotypes: CGE, KW).

-*Cratoxylum formosum* (Jack) Dyer in Hook, f. Fl. Brit. Ind. 1: 258. 1874; Kurz, Forest Fl. Burma 1: 83. 1877; King, in J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59(2): 145. 1890; Koord. & Val., Bijdr. Boomsoort. Java 5: 137. 1900; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 287. 1910; Ridl., Fl. Malay. Penin. 1:152. 1922; Craib, Fl. Siam. 1(1):111. 1925; Corner, Gard. Bull. Straits Settlem. 10: 23, 28. 1939; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 251. 1943; Backer & Bakh. f., Fl. Java (Spermatoph.) 1: 383. 1963; Meijer, Bot. News Bull. Forest Dept., Sabah 7: 64. 1967; Gogelein, Blumea

15: 467. 1967; Corner, Wayside Trees of Malaya 1: 325. 1988; P.H. Hô, Ill. Fl. Vietnam 1(1): 578, f. 1602. 1991; Thin, Sida 17(4): 742. 1997. Type: Sumatra, *Jack s.n.* (Holotype: CAL!).

All parts hairless; connective without glands.

Distribution: Thailand: Chiang Mai, Sukhothai, Kalasin, Maha Sarakham, Khon Kaen, Chaiyaphum, Roi Et, Si Sa Ket, Ubon Ratchathani, Kanchanaburi, Prachuap Khiri Khan, Saraburi, Nakhon Nayok, Sa Kaeo, Chon Buri, Rayong, Chanthaburi, Trat, Chumphon, Surat Thani, Phangnga, Krabi, Trang, Satun; Songkhla, Narathiwat; **Worldwide:** Cambodia, Indonesia, Laos, Malaysia, Philippines, Vietnam.

Phenology: Flowering: March-June. Fruiting: April-October.

Ecology: Evergreen forests, Deciduous forests, Beach, Scrub Area.

Altitude: 20 – 900m.

Uses: The wood is used in construction (Pitard, 1910).

Local name: Tao (*A.F.G. Kerr 14431*)/Teo (*A.F.G. Kerr 9748*)/Tang-som (*B. Sangkhachand 355*)/Tiu Khaao (*BGO Staff 3*).

IUCN Global Status: Least Concern (LC).

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 2. *Chiang Mai province:* Doi Sutep, *H.B.G. Garrett 32* (K); **11. *Sukhothai Province:*** *Pradit 899* (BK); **North-Eastern Region: 24. *Kalasin Province:*** Kalasin Morning Market, A. Muang Kalasin, *M. Widmer 30* (BKF); **25. *Maha Sarakham Province:*** Pa Khok Dang Khaeng, Maha Sarakham University, *BGO Staff 3* (QBG); **26. *Khon Kaen Province:*** Nam Pong, *P. Chantaranothai et al s.n.*; **Eastern Region: 27. *Chaiyaphum Province:*** Pa-Hin-Ngam Forest Park, *S. Suddee 26* (BKF); East Chaiyaphum, *C. Chaloenphol 85* (L); Pak Pang via Chaiyaphum, *A.F.G. Kerr 19970* (AAU, ABD, BK, BM, C, E, K); **31. *Roi Et Province:*** Kasetwisai, Ban Nam Om, *Y. Paisooksantivatana & S. Sutheesoem 1027-82* (BK); **34. *Si Sa Ket Province:*** Kantaralak District, *P. Songkhachand 203* (BK); Kantaralak District, *P. Songkhachand 208* (BK); Kantaralak District, *P. Songkhachand 214* (BK); Kantaralak District, *P. Songkhachand 245* (BK); **35. *Ubon Ratchathani Province:*** Nam Tok Sae, NE, *S. Phusomsaeng 33* (BKF, C, E, K, L, P); Wormchumsak, Ubol, *Chirayupin 187* (BK);

Dong Phahuan, *C. Niyomdham 4598* (AAU); **South-Western Region: 37. *Kanchanaburi Province:*** Dongyai, *C. Phengkhlai, B. Sangkhachand & B. Nimanong 2928* (C, E, K, L); Between Kritee & Meung Chah, *R. Geesink & C. Phengkhlai 6169* (C, E, K, L, P); **40. *Prachuap Khiri Khan Province:*** Klawng Lah Met, *K. Winit 628* (ABD, BK, BKF); Klawng Lah Met, *K. Winit 19056* (ABD, K); Huay Yang Forest Reserve, *V. Lamkay 40-112* (KKU); *M. Godefroy-Lebeuf s.n.* (K); **Central Region: 47. *Saraburi Province:*** Sahm Lahn, *J.F. Maxwell 74-219* (AAU, BK, BKF); Sahm Lahn Forest, Muang District, *J.F. Maxwell 74-590* (AAU, BK, L); **50. *Nakhon Nayok Province:*** Pakphli District, *W. Somprasong & P. Sangkhachand 53* (BK); Kao Silar, *S. Sutheesoen 3242* (BK); **South-Eastern Region: 56. *Sa Kaeo Province:*** Aran Pratet, *Put 2020* (AAU, ABD, BK, BM, E, K); **59. *Chon Buri Province:*** Sriracha Forest, 16 miles inland from sea, *D.J. Collins 159* (AAU, BK. E, K); Sriracha Forest, *D.J. Collins 578* (K);Sriracha Forest, Kong Yai Boo, *D.J. Collins 723* (ABD, E, K, TCD); Sriracha Forest, *A.F.G. Kerr 4033* (ABD, BM, K, TCD); Chantalen Falls, *C. Chermsirivathana & P. Sangkhachand 1969* (BK); Koh Khram, Sattahip, *C. Phengkhlai et al 11930* (BKF); Ang Chong Nam, Bahn Bund District, *J.F. Maxwell 76-129* (BK, P); **60. *Rayong Province:*** Chank Phong, Klaeng, *K. Kertsawang 252* (QBG); **61. *Chanthaburi Province:*** Lem Sing, *A. Marcan 1339* (ABD, BM); Makam, *G. Smitinand 5751* (AAU, BKF, L); Plain of Makam, *Th. Sorensen, K. Larsen & B. Hansen 7232* (C); **62.*Trat Province:*** Leam Koh, *B. Sangkhachand 355* (BKF, L); Koh Chang Noi, *J. Schmidt 696* (C, K); Ampo Kao Saming to Klung, *A.F.G Kerr 17923* (AAU, ABD, BK, BM, C, K, L); **Peninsular Region: 63. *Chumphon Province:*** Phon *Th. Sorensen, K. Larsen & B. Hansen 2142* (C, K); **65. *Surat Thani Province:*** Nah Muang Falls, Koh Samui, *Chirayupin 152* (BK); Kaw Samui, A.F.G. *Kerr 12539* (ABD, BK, BM, E, K); Ban Na San, *A.F.G. Kerr 13324* (AAU, ABD, BK, E, K); **66. *Phangnga Province:*** Kao Nanghong, *S. Sutheesoen* 2563 (BK); **68. *Krabi Province:*** Sakeo, *A.F.G. Kerr 9748* (AAU, ABD, BK, BM, C, E, K, L); **71. *Trang Province:*** Angtong Falls, Sigow District, *Taworn 78* (PSU); Amphoe Nayong, Khao Chong NP. Trail from Botanic Gardens HQ to Ton Yai, *D.J. Middleton, T. Boonthavikoon, S.J. Davies, C. Hemrat & M.F. Newman 345* (A, E, TCD); Khao Chong, *C. Bunnab 415* (BKF); Khao Chong, *S. Phusomsaeng et al 1594* (BKF); Khao Chong, *P. Sangkhachand 1798* (BKF); Khao Chong, *P. Sangkhachand 1913* (BKF); Khao Chong, *C. Chermsirivathana 2203* (BK); Trang Forest near Chung Waterfalls, *D.J. Collins 2357* (AAU, BM, K, P); Chawng, *T. Smitinand 2960* (BKF, L); Kaw Libong, *A.F.G. Kerr 19056* (AAU, ABD, BK, BM, E,

K); Khao Chong, *K. Larsen & S.S. Larsen 33255* (AAU, C, K, P); Khao Chong, *J.F. Maxwell 75-831* (BK, L); **72. *Satun Province:*** Klawng Ton, *A.F.G. Kerr 14431* (AAU, ABD, BK, BM, K); **73. *Songkhla Province:*** Near Suanisan Restaurant, Haad Yai, *R. Pollawat 6* (PSU); Haad Yai. Kuan Meed, *G. Congdon 404* (AAU, BKF); Haad Yai. Ko Hong Hill, summit ridge, *J.F. Maxwell 85-348* (A, BKF, E, L, PSU); Ko Hong Hill, summit ridge, *J.F. Maxwell 85-946* (A, AAU, L, PSU); **76. *Narathiwat Province:*** Bacho, *B. Sangkhachand 65* (C); **Unknown Locations:** *L. Pierre 146* (E); Tapraya, Prajinburg, *S & J 2093* (BK); *J. Dyer 13324* (AAU, BM, E).



Map 3.28 Distribution of *Cratoxylum formosum* subsp. *formosum* in Thailand.

subsp. *pruniflorum* (Kurz) Gogelein, Blumea 15: 469. 1967.

Type: Burma, *Wallich 7276* (Lectotype: BM! (Lectotype designated here); Isolectotypes: CAL!, K!, L!).

Synonyms

-*Hypericum prunifolium* Wall., Numer. List. [Wallich] n. 7276. 1828. Type: Burma, *Wallich 7276* (Lectotype: BM! (Lectotype designated here); Isolectotypes: CAL!, K!, L!).

-*Tridesmis pruniflora* Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat Hist. 41(2): 293. 1872. Type: Burma, *Wallich 7276* (Lectotype: BM! (Lectotype designated here); Isolectotypes: CAL!, K!, L!).

-*Cratoxylum* (errore) '*prunifolium*' Dyer in Hook. f., Fl. Brit. India 1: 257. 1874; Brandis, Indian Trees, 47. 1907; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 287. 1910; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 251. 1943. Type: Burma, *Wallich 7276* (Lectotype: BM! (Lectotype designated here); Isolectotypes: CAL!, K!, L!).

-*Cratoxylum pruniflorum* Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat Hist. 43(2): 84. 1874; Kurz, Forest Fl. Burma 1:84. 1877; Craib, Fl. Siam. 1(1): 113. 1925. Type: Burma, *Wallich 7276* (Lectotype: BM! (Lectotype designated here); Isolectotypes: CAL!, K!, L!).

-*Cratoxylum dasyphyllum* Handel-Mazzetti, Sinensia 2: 4. 1931. Type: China, *Ching 7980* (Holotype: L!; Isotype: NY!, W).

Young twigs, pedicels, calyx and leaves pubescent; connective with glands.

Distribution: Thailand: Mae Hong Son, Chiang Mai, Chiang Rai, Lamphun, Lampang, Phrae, Tak, Phitsanulok, Nakhon Sawan, Loei, Chaiyaphum, Buri Ram, Surin, Si Sa Ket, Kanchanaburi, Saraburi, Nakhon Nayok, Chon Buri, Chanthaburi, Krabi; **Worldwide:** Indochina.

Phenology: Flowering: March-May. Fruiting: April-November.

Ecology: Evergreen forests, Deciduous forests, Rocky Dipterocarp Savannah, on Limestone.

Altitude: 20 – 950m.

Uses: The bark is used as a medicine to treat diarrhoea in domestic animals and the young leaves are used as a substitute for tea. (Xiwen et al., 2007).

Local name: Teaw (*BGO Staff 27*)/Ra-vein (*B. Sangkhachand 640*)/Tiu Khon (*BGO Staff 6*)/Tiu Daeng (*S. Watthana 98*)/Tui (*BGO Staff 8184*)/Sah gwe jo (*J.F. Maxwell 95-428*)/Sih weh jo (*J.F. Maxwell 98-604*).

IUCN Regional (Thailand) Status: Least Concern (LC).

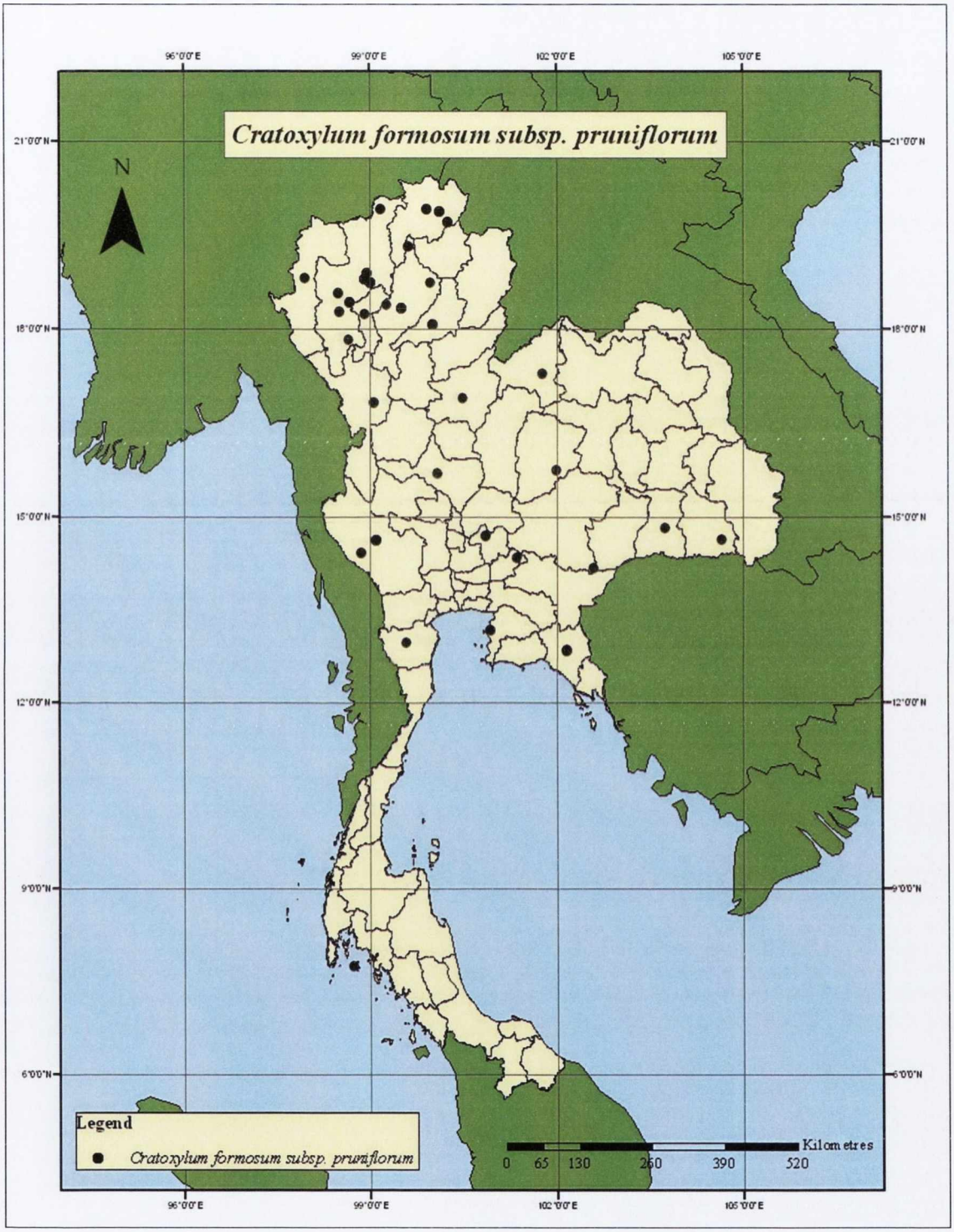
Note on species limits: *C. formosum* subsp. *formosum* and *C. formosum* subsp. *pruniflorum* are almost identical. The only difference between these two subspecies is the presence of hairs on the young twigs, pedicels, calyx and leaves in *C. formosum* subsp. *pruniflorum*.

THAILAND

Northern Region: 1. *Mae Hong Son Province:* Khun Youm, *B. Nimanong, S. Phusomsaeng & C. Phengkhlai 1787* (PSU); Di Bao-hae, Mae Sariang, *S. Sutheesoen 2379* (BK); **2. *Chiang Mai Province:*** Botanic Garden, Mae Rim, *BGO Staff 6* (QBG); Botanic Garden, Mae Rim, *Morakot 8* (QBG); Botanic Garden, Mae Rim, *S. Watthana 98* (QBG); Mae Sanam Arboretum, *W. Sankamethawee 110* (CMU); Doi Sutep, *Soradetch 426* (BKF); Jawn Tong. Fang. Pong Namron, *S. Phengnaren 579* (BKF, L); Botanic Garden, Mae Rim, *BGO Staff 587* (QBG); Doi Sutep, *A.F.G. Kerr 611* (BM, K, P, TCD); Doi Pha Dam, between Hang Dong & Bo Luang, *K. Larsen, T. Santisuk & E. Warncke 2152* (AAU, BKF, E, L, P); Doi Sutep, *Th. Sorensen, K. Larsen & B. Hansen 2910* (C): Mae Saa Mai, *BGO Staff 6216* (QBG); Doi Inthanon NP, *BGO Staff 6389* (QBG); Doi Inthanon NP, *C. Phengkhlai et al 6551* (C, K); Doi Sutep, east side, Huay Gayo Falls Area, *J.F. Maxwell 87-604* (BKF, L); Muang District, Doi Sutep, east side, East side of Kohntatahn Falls Area, *J.F. Maxwell 88-430* (AAU, BKF, L); Jawn Tong, *J.F. Maxwell 91-661* (A, AAU, E, P); Nuang, Mae Soi Valley, Mae Soi Subdistrict, *J.F. Maxwell 90-255* (E); Jawn Tong, Mae Soi Valley, Mae Soi Subdistrict, *J.F. Maxwell 90-525* (L); Muang District, East side of the Central University Library, Chiang Mai University, *J.F. Maxwell 92-213* (A, CMU, E); Mae Pah Boo (Karen Village), *J.F. Maxwell 95-428* (A, CMU); Doi Lahn, *J.F. Maxwell 96-1204* (A, BKF, CMU); Doi Bah

Gluay, *J.F. Maxwell 97-434* (A, BKF, CMU); Jahm Luan Subdistrict, Huay Yah Dtai (Karen) Village, slopes along Mae Jon River, *J.F. Maxwell 98-649* (A, CMU, L); Doi Sutep-Pui NP, *J.F. Maxwell 00-148* (A, CMU); Doi Inthanon NP, *M. Hara C533* (CMU); Mae Ya Waterfall, Doi Inthanon, *M. Hara E98* (CMU); Tad Noi, Somthong, *C. Taengsuwan s.n.* (BKF); **3. *Chiang Rai Province:*** Kuhn Jae (Chaae) NP, *J.F. Maxwell 98-397* (BKF, CMU); Doi Luang NP, *J.F. Maxwell 98-604* (A, BKF, CMU); **6. *Lamphun Province:*** Me Tun, *K. Winit 315* (BM, K); Ban Pha Mon (Chom Thong), *J.E. Vidal, Y. Vidal & C. Niyomdham 6205* (BKF, E, K, L, P); Doi Kuhn Dahn NP, *J.F. Maxwell 94-579* (A, CMU); **7. *Lampang Province:*** Forest at Jaehamwitthaya School, *M. Panatkool 257* (A, CMU); Forest at Jaehamwitthaya School, *M. Panatkool 309* (A, CMU); Forest at Jaehamwitthaya School, *M. Panatkool 481* (A, CMU); Me Kang, *K. Winit 1403* (ABD, BK, BKF, K); Muang Ngao, *Put 4013* (ABD, ABD, BK, BM, E, K); Ngao, Pra-to-pha, *C. Phengkhlai & N. Fukuoka 10127* (BKF); Huay Tak, *N. Tharawattananon 40372* (BKF); Doi Luang NP, *J.F. Maxwell 97-386* (A, CMU); **8. *Phrae Province:*** Hui Mae Sai, Padaeng District, *R. Sukket 3* (BKF); Wang Mon, *L.V.P. 285* (BKF, K); **10. *Tak Province:*** Larn Sarng, *R. Geesink, D. Phanichapol & T. Santisuk 5596* (C); Lansang NP, *G. Murata, N. Fukuoka & C. Phengkhlai T-16683* (BKF, P); **12. *Phitsanulok Province:*** Tung Salaeng Luang, *K. Larsen, T. Smitinand & E. Warncke 468* (AAU, BKF); **15. *Nakhon Sawan Province:*** Klong Lon, 2km from Tr. In. Southerly direction, *M. van de Bult 79* (BKF, CMU); **North-Eastern Region: 17. *Loei Province:*** Namtok Taad Hueang, Nahaew, *BGO Staff 27* (QBG); Nahaew, *BGO Staff 120* (QBG); Si Tang, Wang Sapung District, *T. Smitinand 1216* (BKF); Nahaew, *BGO Staff 3976* (QBG); HQ-Phu Son, Phu Ruea NP, *BGO Staff 8184* (QBG); **Eastern Region: 27. *Chaiyaphum Province:*** *Ch. Chaloenphol 85* (BK); Nam Phrom, *C.F. van Beusekom, R. Geesink, C. Phengkhlai & B. Wongwan 4100* (C); **29. *Buri Ram Province:*** Lam Nong Rong, *S. Suksakorn 892* (K); **30. *Surin Province:*** *C. Phengkhlai et al 3590* (PSU); **34. *Si Sa Ket Province:*** Kantaralak District, *P. Sangkhachand 296* (BK); **South-Western Region: 37. *Kanchanaburi Province:*** Saneh Rawng Village, Sangklaburi, *K. Kansuntisukmongkol 186* (A, CMU); Tung Yai Naresuan West Wildlife, Thong Pap Poom, *M. van de Bult 885* (CMU);Near Kin Sayok about 120km north west of Kanburi, *A. Kostermans* 1090 (A, C, L); Dongyai, *C. Phengkhlai, B. Sangkhachand, B. Nimanong & T. Smitinand 2928* (AAU); Ban Kao, *K. Larsen 8297* (C); *A.F.G. Kerr 10604* (ABD, BK, BM, E, K, TCD); Muang Cha Area, Sahng Kra District, *J.F. Maxwell 73-208* (BK); **39. *Phetchaburi Province:*** Phetchabun, *B.*

Sangkhachand 3112 (C, L); **Central Region: 47. *Saraburi Province:*** Sahm Lahn Forest, Muang District, J.*F. Maxwell 74-528* (AAU, BK); Sahm Lahn Forest, Muang District, *J.F. Maxwell 75-108* (BK, L); **50. *Nakhon Nayok Province:*** Muang District, *P. Charoenchai & S. Poompuang 246* (CMU); **South-Eastern Region: 59. *Chon Buri Province:*** Sriracha, *A.F.G. Kerr 4034* (ABD, BM, K); Kaw Kieo, Sriracha District, *J.F. Maxwell 75-102* (BK, L); Pra Chedi mountain, Kaw Kieo, Sriracha, *J.F. Maxwell 75-419* (BK, L); **61. *Chanthaburi Province:*** *B. Sangkhachand 640* (L); Soi Dao, *K. Larsen 10015* (C); Khao Phra Bat, N. of Chanthaburi. *K. Larsen, S.S. Larsen, I. Nielsen & T. Santisuk 32141* (AAU, E, K, P); **Peninsular Region: 68. *Krabi Province:*** Kow Pra-Bahng Krahm Wildlife Sanctuary, *J.F. Maxwell 06-240* (CMU); **Unknown Locations:** *Vanpruk 479* (P); Truck Lek, *A. Marcan 737* (BM); Muan Jawn, *A.F.G. Kerr s.n.* (P); *A.F.G. Kerr s.n.* (BM); *A.F.G. Kerr s.n.* (BM).



Map 3.29 Distribution of *Cratoxylum formosum* subsp. *pruniflorum* in Thailand.



Figure 3.14 Line Drawing of *Cratoxylum formosum* subsp. *formosum* (flowering stem). (Illustration by Elaine Cullen).

2. *Cratoxylum maingayi* Dyer in Hook. f., Fl. Brit. India 1: 258. 1874; King, in J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59(2): 145. 1890; Gagnep., in Notul. Syst. (Paris) 1: 19. 1909; Ridl., Fl. Malay. Penin. 1:152. 1922; Gogelein, Blumea 15(2): 470. 1967; N. Robson, in Fl. Males., Ser. 1, Spermat. 8: 4-6. 1974; Corner, Wayside Trees of Malaya 1: 325. 1988; Phengklai C. & Niyomdham C., Flora in peat swamp areas of Narathiwat. 1991.

Type: Malaya, Penang, *Maingay 145* (Holotype: BM!; Isotypes: CAL, CGE, K!, L!).

Synonyms

-*Cratoxylum harmandii* Pierre, Fl. Forest. Cochinch. 1: t. 53. 1882; Gagnep., Notul. Syst. (Paris) 1: 18. 1909. Type: Vietnam, *Harmand, F.J. 3235* (Holotype: L!; Isotype: P!).

-*Cratoxylum formosum* var. *thorelii* Pierre *ex* Gagnep., Notul. Syst. (Paris) 1; 19. 1909. Type: New Caledonia, *Godefroy, F.F. 295* (Holotype: L!, Isotypes: K!, P!).

-*Cratoxylum cochinchinense* var. *calcareum* Ridl., Kew Bull. 115. 1938. Type: Borneo, *Haviland, G.D. 1463* (Lectotype: L! (Lectotype designated here); Isolectotype: K!, SING!).

-*Cratoxylum acuminatum* Merr., Papers Mich. Acad. Sc. 23: 185. 1938. Type: Sumatra, *Rahmat Si Boeea 7687* (Lectotype: L! (Lectotype designated here); Isolectotypes: A!, MICH!, SING!).

-*Cratoxylum subglaucum* Merr., Papers Mich. Acad. Sc. 23: 186. 1938. Type: Sumatra, *Rahmat Si Boeea 7907* (Lectotype: L! (Lectotype designated here); Isolectotypes: A!, MICH!, SING!).

-*Cratoxylum parvifolium* Merr., J. Arnold Arbor. 19: 56. 1938. Type: Vietnam, *Clemens, J. & Clemens, M.S. 3454* (Lectotype: L! (Lectotype designated here); Isolectotypes: A!, BM!, MICH!, P!, U!, US!, W).

-*Cratoxylum thorelii* Pierre *ex* Gagnep., Suppl. Fl. Indo-Chine 1: 252. 1943. Type: Indo-China, *Thorel 2065* (Holotype: P!).

Description

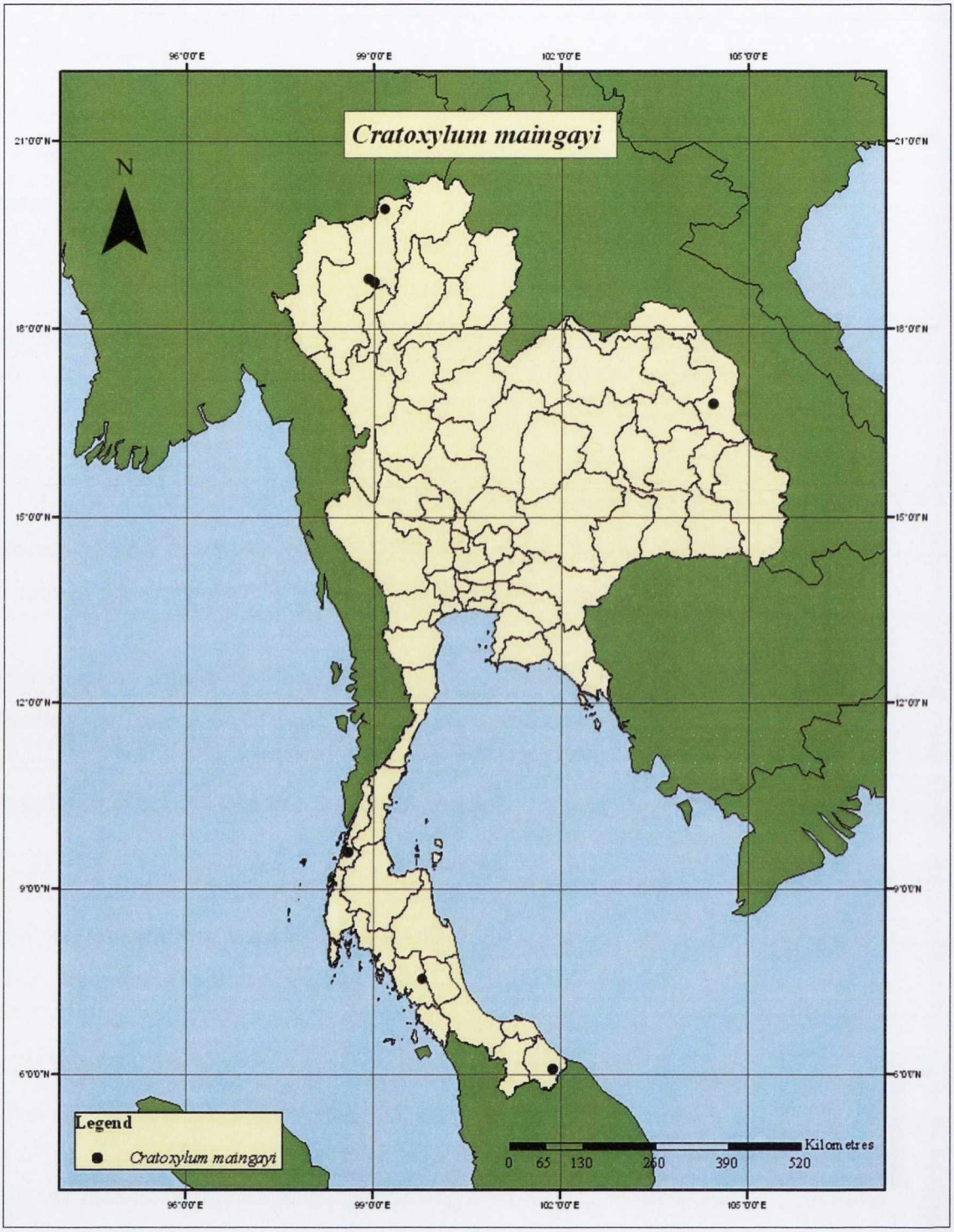
Habit deciduous shrub or tree up to 20m high; bark composed of many, thin flaking layers; brown in colour; inner bark brown, with yellow exudate. ***Leaves*** petioled, 0.5-1cm long; midrib dark green above and greyish-pale to light green beneath; coriaceous; obovate to elliptic to oblong; 2-9 x 1-4.5cm; base round to cuneate; apex acute to round; secondary veins present, raised on both surfaces. ***Inflorescence*** pedicels light green, 0.2-0.6cm long; axillary cymes of 2-4 flowers on leafless twigs; flowers pink-white. ***Calyx*** sepals 5, oblong; 2.5-5 x 1-3mm; light green. ***Corolla*** petals 5, elliptic; 6-12 x 2-5mm; dark red; lateral veins present; styles as long as petals. ***Stamens*** anthers cream; filaments white; numerous. ***Ovary*** 2-3mm long. ***Fruit*** capsule; oblong to acute; 2-4mm diameter. ***Seeds*** winged; 5-6; oblong to ovate-oblong.

Distribution: Thailand: Chiang Mai, Nakhon Phanom, Ranong, Trang, Narathiwat; **Worldwide:** Indochina, Malaya, Penang, Sarawak, Singapore, Sumatra.
Phenology: Flowering: May-June. Fruiting: November-December.
Ecology: Lowland Forest, Peat Swamp Forest.
Altitude: Near Sea Level – 850m.
Local name: Taeo (*B. Sangkhachand 1139*)/Sah gwee jo (*J.F. Maxwell 95-426*).
IUCN Global Status: Least Concern (LC).
IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 2. *Chiang Mai Province:* Maesa Botanic Garden, *R. Pooma 207* (CMU); Muang Fang, *J.F. Maxwell 90-255* (A, CMU, E, P); Doi Suthep-Pui NP, SW side off road to Sisangwen Falls, Hang Dong District, *J.F. Maxwell 92-666* (CMU, P); Mae Pah Boo (Karen Village), *J.F. Maxwell 95-426* (A, CMU); **North-Eastern Region: 22. *Nakhon Phanom Province:*** Phu Phan NP, *H. Koyama, H. Terao & T. Wongprasert T-31004* (A, BKF); **Peninsular Region: 64. *Ranong Province:*** Kapoe, *B. Sangkhachand 1139* (BKF, K, L); **71. *Trang Province:*** Khao Chong, *C. Boonnab 92*

(BKF); **76. *Narathiwat Province:*** Pa Wai, Su Hgai Padee, *C. Niyomdham et al 928* (A, AAU, BKF, C, K, L).



Map 3.30 Distribution of *Cratoxylum maingayi* in Thailand.



Figure 3.15 Line drawing of *Cratoxylum maingayi* (flowering stem). (Illustration by Elaine Cullen).

3. *Cratoxylum arborescens* Blume, Mus. Bot. 2:17. 1852; Dyer, in Hook. f., Fl. Brit. India 1: 258. 1874; Kurz, Forest Fl. Burma 1: 83. 1877; King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59(2): 146. 1890; Ridl., Fl. Malay. Penin. 1:152. 1922; Engler, in Engler & Prantl, Nat. Pflanzenfamilien 2(21): 184. 1925; Corner, Gard. Bull. Straits Settlem. 10: 22, 31. 1939; Meijer, Bot. News Bull. Forest Dept., Sabah 7: 64. 1967; Gogelein, Blumea 15(2): 471. 1967; N. Robson, in Fl. Males., Ser. 1, Spermat. 8: 4-6. 1974; Corner, Wayside Trees of Malaya 1: 325. 1988; Phengkhlai C. & Niyomdham C., Flora in peat swamp areas of Narathiwat. 1991.

Type: Malaya, *König 1778* (Holotype: C!).

Synonyms

-*Hypericum arborescens* Vahl, Symb. Bot. (Vahl) 2: 86, t. 43. 1791. *Vismia arborescens* Choisy, Prodr. Monogr. Hyperic. 36. 1821. Type: Malaya, *König 1778* (Holotype: C!).

-*Hypericum coccineum* Wall., Numer. List. [Wallich] n. 4823. 1828. *Nomen nudum.*

-*Cratoxylum blancoi* Blume, Mus. Bot. 2:17. 1852. Type: Luzon, Antipolo, *Ramos s.n.* (Illustrative specimen: Merrill, No. 851) US!.

-*Ancistrolobus glaucescens* Turcz., Bull. Soc. Imp. Naturalistes Moscou 31(1): 383. 1858. Type: *Lobb 419* (Lectotype: BM! (Lectotype designated here); Isolectotype: L!).

Description

Habit evergreen tree to 45m tall; bark scaly, reddish/brown, red hue quite apparent; hairless. ***Branchlets*** young shoots with continuous interpetiolar scars. ***Leaves*** petioled, 0.5-1.0cm long; red to green in colour; coriaceous; obovate-oblong to obovate-oblanceolate or elliptic, 5-16 x 2-6cm; base cuneate to attenuate; apex acute to cuspidate, numerous faint secondary veins present. ***Inflorescence*** a many-flowered terminal pyramidal panicle; pedicels 0.2-0.4cm long, slender, flowers usually borne on leafy twigs; homostylous. ***Calyx*** sepals 5; concave, obovate to oblong; 3.5-6 x 2-

4.5mm. ***Corolla*** petals 5; obdeltoid; deep red or pink or very rarely orange or white; 4.5-7 x 2-5mm; usually caducous. ***Stamens*** 4-5mm long; between 30-40 stamens present per fascicle; green-yellow in colour; obovate. ***Ovary*** 1.5-2mm long, pistil 3-5mm. ***Fruit*** round to oblong; 7-9 x 4mm. ***Seeds*** 10-18 per loculus; narrowly oblong; approximately 5 x 0.8mm.

Distribution: Thailand: Narathiwat; **Worldwide:** Borneo, Burma, Java, Singapore, Sumatra.

Phenology: Flowering: May-September.

Ecology: Evergreen Forest, Peat Swamp Forest.

Altitude: Near Sea Level - 460m.

Uses: Valued as a timber (Ridley, 1922).

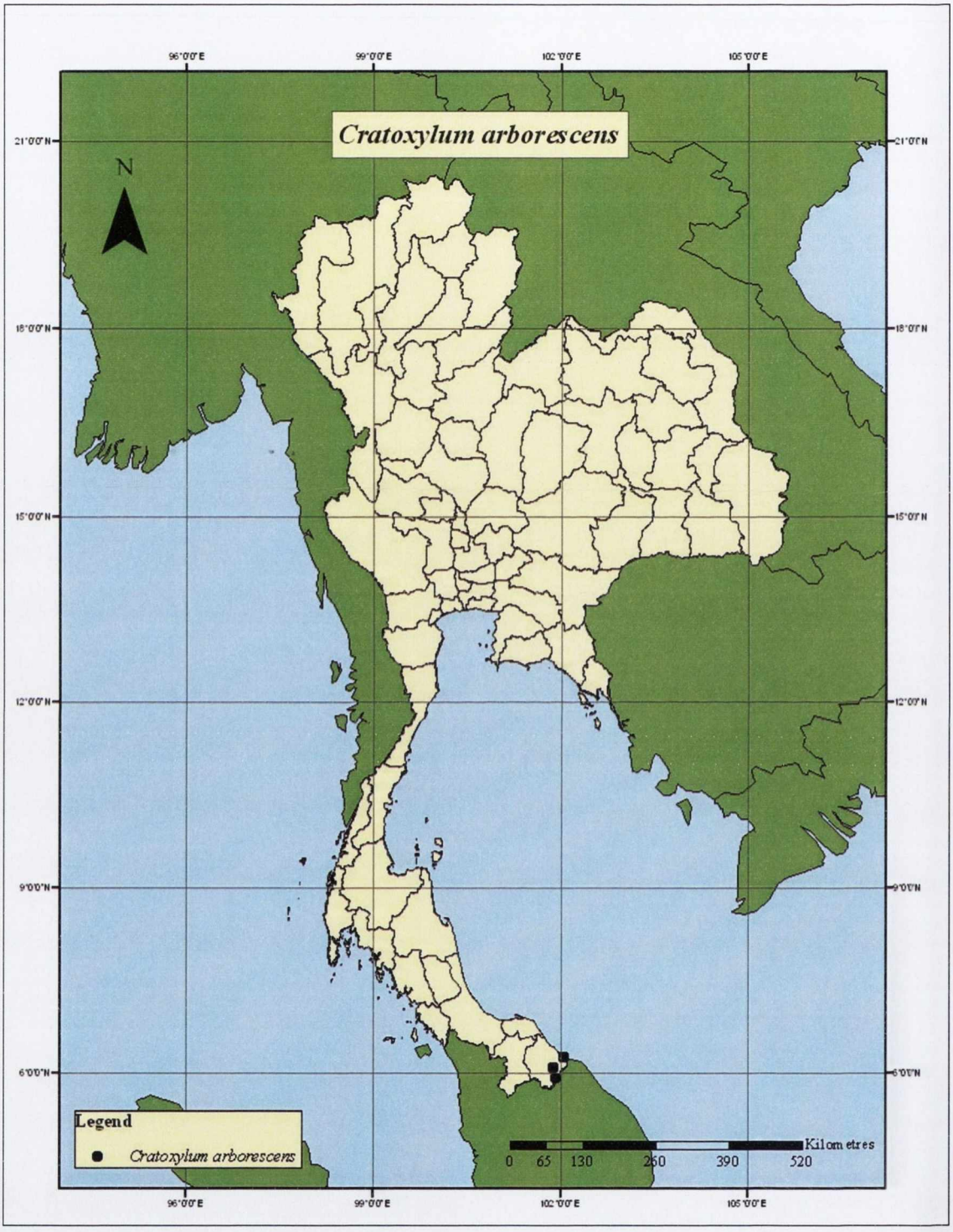
Local name: Ngong ngung (*C. Niyomdham 23*)/Gawng ngahng (*J.F. Maxwell 87-532*).

IUCN Global Status: Least Concern (LC).

IUCN Regional (Thailand) Status: Critically Endangered (CR).

THAILAND

Peninsular Region: 76. ***Narathiwat Province:*** Tak Bai, *C. Niyomdham 23* (AAU, K); Toh Moh, Ban Bajo, *M.C. Lakshnakara 758* (BK, BM, K); Tak Bai, *C. Niyomdham 829* (A, AAU, BKF, K); Tak Bai, Ku Chum, *C. Niyomdham & D. Sriboonma 1601* (AAU, BKF, E, K, L, P); Ben Yuan Yahng, Sungei Padi, *J.F. Maxwell 87-532* (A, BKF, L, PSU).



Map 3.31 Distribution of *Cratoxylum arborescens* in Thailand.



Figure 3.16 Line drawing of *Cratoxylum arborescens* (flowering stem). (Illustration by Elaine Cullen).

4. *Cratoxylum neriifolium* Kurz, in J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 41(2): 293. 1872; Dyer, in Hook. f., Fl. Brit. India 1: 257. 1874; Kurz, Forest Fl. Burma 1: 85. 1877; Gamble, Man. Ind. Timb. 48. 1881; Prain, Bengal Pl. 244. 1903; Brandis, Indian Trees, 47. 1907; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 291. 1910; Craib, Fl. Siam. 1(1):112. 1925; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 254. 1943.

Type: Burma, *Wallich 4824* (Lectotype: BM! (Lectotype designated here), Isolectotype: CAL!, K!).

Synonyms

-*Hypericum neriifolium* Wall., Numer. List. [Wallich] n. 4824. 1828, *nomen nudum.*

-*Cratoxylum sumatranum* Blume subsp. *neriifolium* (Kurz) Gogelein, Blumea 15(2): 463. 1967. Type: Burma, *Wallich 4824* (Lectotype: BM! (Lectotype designated here), Isolectotype: CAL!, K!).

Description

Habit deciduous tree 7-20m tall; dbh 40cm; bark thick, roughly cracked and flaking, black, fissured, very rough. ***Branchlets*** terete to flattened; smooth; colour varies from black to black-red to green; scars absent. ***Leaves*** sessile; midrib depressed on upper surface and pronounced on lower surface; on upper surface depression of midrib very obvious; light yellow to red/brown on upper surface; yellow to dark red on lower surface; coriaceous and tough; some leaves glaucous; 5.7-10.3 x 1.5-3.1cm; shape varies from lanceolate to elliptic to oblong; base rounded to slightly cordate; apex acute to rounded to acuminate; secondary, intersecondary and intramarginal veins present; all visible. ***Inflorescence*** in short terminal panicles; flowers in groups of 3; flowering branch flattened, then spreading into many-branched terete delicate pedicels; length of pedicel variable. ***Calyx*** sepals 5; persistent; obovate; 6 x 3mm; greenish-brown in colour. ***Corolla*** petals 5; twice as long as sepals; bright scarlet. ***Stamens*** filaments free. ***Ovary*** 1.5-3mm long. ***Fruit*** a capsule covered by persistent sepals, 8-9 x 4-5mm. ***Seeds*** 6-8 per cell.

Distribution: Thailand: Chiang Mai, Chiang Rai, Lampang, Phrae, Phitsanulok, Udon Thani, Nakhon Ratchasima, Kanchanaburi, Trang; **Worldwide:** Burma, Cambodia, India, Laos.

Phenology: Flowering: April-August. Fruiting: (August) September-March.

Ecology: Deciduous forests, Evergreen forests, on Limestone.

Altitude: 150 - 800m.

Uses: Used in construction, and for wooden utensils (*e.g.* handles of chisels and hammers) (Kurz, 1877).

Local name: Tao (*A.F.G. Kerr 8619*)/Ki chiu (*A.F.G. Kerr 4776*)/Tio dam (*K. Winit 1794*).

IUCN Regional (Thailand) Status: Least Concern (LC).

THAILAND

Northern Region: 2. *Chiang Mai Province:* Muang Payao, *Put 3970* (AAU, ABD, BM, E, K); **3. *Chiang Rai Province:*** Payao, *Prayad 441* (BK); Huey Dong, at Tew Dam, *K. Winit 1794* (ABD, BK, BKF, K, TCD); Muan Payao, *Put 3970* (AAU, ABD, BK, BM, E); **7. *Lampang Province:*** Mae Huud, Ngao, *C. Sabhasi 2* (BKF); Che Hom, *A.F.G. Kerr 4776* (AAU, ABD, BK, BM, K); **8. *Phrae Province:*** Pai Ton, *L.V.P. 270* (BKF, K); Sui Kamin, *Somkid 469* (BKF); Song Mae Yom NP, Daw Boon Subdistrict, *J.F. Maxwell 91-872* (AAU, CMU, E, P); **12. *Phitsanulok Province:*** In strip of cut out forest near rivulet (Ran Ti River), *A. Kostermans 274* (A, K, L); **North-Eastern Region: 19. *Udon Thani Province:*** Nawng Bua, *A.F.G. Kerr 8619* (ABD, BK, BM, C, E, K, P, TCD); **Eastern Region: 28. *Nakhon Ratchasima Province:*** Pak Thong Chai, *S. Phengnaren 529* (BKF); **South-Western Region: 37. *Kanchanaburi Province:*** Kwae Noi Basin, *No Collector 143* (L); Tham Phe, *C. Phengkhlai 322* (L); Brangkasi, about 100km south of Wangka, *G. den Hoed & A. Kostermans 474* (BK, K, L); South of Ka Tha Lai in Pan Puang River Valley, about 40km south east of Wangka, *A. Kostermans 869* (A, BK, K, L); Tapoh, *Danish Expedition 8991* (A, C, E); Taeng Yai Naresuan Wildlife Reserve, Lai Wa Subdistrict, Ban Saneh Pawng (Karen Village), *J.F. Maxwell 93-929* (A, CMU); **Peninsular Region: 71. *Trang Province:*** Near Medicinal Plant Exp. Plot, Trang Hort. Exp. Station, Amper Sikao, Y. Paisooksantivatana & P. Sangkhachand Y2133-87 (BK); **Unknown Locations:** *Somkid 103* (BKF); Kao Pa-sha, Nong, Chag, Li-thai thani, *S. Sutheesoen 3008* (BK).



Map 3.32 Distribution of *Cratoxylum neriifolium* in Thailand.



Figure 3.17 Line drawing of *Cratoxylum neriifolium* (flowering stem). (Illustration by Elaine Cullen).

5. *Cratoxylum chinense* (Retz.) Merr., Philip., J. Sci., C 4: 292. 1909.

Type: China, *Collector unknown s.n.* (LD!).

Synonyms

-*Hypericum chinense* Retz., Observ. Bot. (Retzius) 5: 27. 1789. Type: China, *Bladh s.n.* (Lectotype: LD!).

-*Hypericum cochinchinense* Lour., Fl. Cochinch.. 2:472. 1790. Type: Hue, Vietnam, *Squires 303*. Type specimen not found.

-*Hypericum petiolatum* (*non* L.) Lour., Fl. Cochinch. 2:479. 1790. Type: *Squires 333* (Holotype: E!)

-*Hypericum biflorum* Lam., Encycl. (Lamarck) 4(1): 170. 1797; Hook & Arnott, Bot. Beechey Voy. 173. 1833. Type: China, *Bladh s.n.* (Lectotype: LD!).

-*Vismia cochinchinensis* Spreng., Syst. Veg. (ed. 16) [Sprengel] 3: 350. 1826. Type: Hue, Vietnam, *Squires 303*. Type specimen not found.

-*Hypericum pulchellum* Wall., Numer. List. [Wallich] n. 4821. 1828. Type: Singapore, *Wallich 4821* (Lectotype: BM! (Lectotype designated here); Isolectotypes: CGE!, K!).

-*Hypericum carneum* Wall., Numer. List. [Wallich] n. 4820. 1828. Type: China, *Wallich 4820* (Lectotype: BM! (Lectotype designated here); Isolectotypes: CGE!, KW).

-*Hypericum horridum* Wall., Numer. List. [Wallich] n. 4822. 1828. Type: *Wallich, 4822* (Holotype: BM!).

-*Elodea pulchella* Hort. Chels. ex Loud., Hort. Brit. Suppl. 1: 587. 1832. Type: Singapore, *Wallich 4821* (Lectotype: BM! (Lectotype designated here); Isolectotype: CGE!, K!).

-*Ancistrolobus ligustrinus* Spach, Ann. Sci. Nat., Bot. 2(5):352, t. 6. 1836. Type: China, *Bladh s.n.* (Lectotype: LD!).

-*Ancistrolobus sp.* Wight, Ill. 1: 3. 1840. Type: *Griffith, 1104* (Holotype: CGE!).

-*Cratoxylum polyanthum* Korth., Verh. Nat. Gesch. Ned. Bezitt., Bot. 175, t. 36. 1842; Korth., Flora, 31:579. 1848; Miquel, Fl. Ned. Ind. 1(2): 515. 1859; Dyer, in Hook. f., Fl. Brit. India 1: 257. 1874; Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 43(2): 85. 1874; Kurz, Forest Fl. Burma 1: 83. 1877; King, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 59(2): 145. 1890; Brandis, Indian Trees, 47. 1907; Gagnep., in Lecomte, Fl. Indo-Chine 1(4): 287. 1910; Ridl., Fl. Malay. Penin. 1: 152. 1922; Craib, Fl. Siam. 1(1):112. 1925; Gagnep., in Humbert, Suppl. Fl. Indo-Chine 1(3): 253. 1943. Type: Borneo, *Korthals s.n.* (Lectotype: L!; Isolectotypes: BM!, NY!, L!).

-*Elodea chinensis* Hance, London J. Bot. 7: 472. 1848. Type: China, *Bladh s.n.* (Lectotype: LD!).

-*Cratoxylum cochinchinense* (Lour.) Blume, Mus. Bot. 2:17. 1852; Corner, Gard. Bull. Straits Settlem. 10: 26-27, 34. 1939; Smythies, Comm. Sarawak Trees. 69. 1965; Gogelein, Blumea 15(2): 463. 1967; N. Robson, in Fl. Males., Ser. 1, Spermat. 8: 4-6. 1974; Corner, Wayside Trees of Malaya 1: 325. 1988; P.H. Hô, Ill. Fl. Vietnam 1(1): 579, f. 1604 1991; Thin, Sida 17(4): 742. 1997; S. Gardner, P. Sidisunthorn & V. Anunsarnsunthorn, A field guide to forest trees of northern Thailand 48. 2000; L. Xiwen, L. Jie & P.F. Stevens, Fl. China 13: 36-38. 2007. Type: Hue, Vietnam, *Squires 303*. Type specimen not found.

-*Cratoxylum ligustrinum* Blume, Mus. Bot. 2: 16. 1852; Merr., Trans. Amer. Philos. Soc. 24, 2: 268. 1935; Corner, Gard. Bull. Straits Settlem. 10: 34. 1939; Meijer, Bot. News Bull. Forest Dept., Sabah 7: 64. 1967; Corner, Wayside Trees of Malaya 1: 325. 1988. Type: China, *Bladh s.n.* (Lectotype: LD!).

-*Cratoxylum petiolatum* Blume, Mus. Bot. 2:17. 1852. Type: *Squires 333* (Holotype: E!)

-*Cratoxylum myrtifolium* Blume, Mus. Bot. 2: 17. 1852. Type: Borneo, *Müller s.n.* (Syntype: L!).

-*Cratoxylum wightii* Blume, Mus. Bot. 2: 18. 1852. Type: *Griffith, 1104* (Holotype: CGE!).

-*Elodea sp.* Griff., Notul. 4: 569. 1854. Type: *Griffith, 1104* (Holotype: CGE!).

-*Ancistrolobus brevipes* Turcz., Bull. Soc. Imp. Naturalistes Moscou. 31(1): 383. 1858. Type: Singapore, *Lobb 485* (Lectotype: BM! (Lectotype designated here); Isolectotypes: KW, W).

-*Cratoxylum lanceolatum* Miq., Fl. Ind. Bat. Suppl. 1: 500. 1861. Type: Indonesia, Sumatra, *Teysmann, HB 3813* (Holotype: U!; Isotype: K!, L!).

-*Cratoxylum polyanthum* var. *wightii* Dyer, in Hook, f., Fl. Brit. India 1: 25. 1874; Corner, Gard. Bull. Straits Settlem. 10: 21-36. 1939. Type: *Griffith, 1104* (Holotype: CGE!).

-*Cratoxylum polyanthum* var. *genuinum* Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 43(2): 85. 1874. Type specimen not found.

-*Cratoxylum polyanthum* var. *macrocarpum* Boerl., Cat. Hort. Bog. 62. 1901. Type: *Boerlage s.n.* (Lectotype: L! (Lectotype designated here); Isolectotype: K!).

-*Cratoxylum hypoleuca* Elm., Leafl. Philip. Bot. 5: 1787. 1913. Type: Philippines, *Elmer 12913* (Lectotype: K! (Lectotype designated here) Isolectotypes: BM!, E!, L!, U!, US!, W).

Description

Habit tree or shrub 2-30m tall; dbh 35cm; bark deeply fissured, yellow at cambium; resin reddish-brown; sapwood white; heartwood brown, hard. ***Branchlets*** terete;

smooth; light brown to dark brown; slender; delicate; scars present. ***Leaves*** petioled, 0.2-0.5cm long; midrib faint on both surfaces, a little more pronounced on lower surface but faint, narrowing approximately 1/2 mm towards apex; very faint on upper surface, colour of midrib varies from light green to red/brown; leaves smooth and delicate to papyraceous to coriaceous and shiny; colour of leaves varies from dark tan/red to light yellow/green, some glaucous; 2.9-12.1 x 1.0-4.7cm; oblong to elliptic; base cuneate to attenuate; apex round, acuminate or acute; secondary, intersecondary, tertiary and intramarginal veining visible on both surfaces, especially obvious on lower surface, veins do not arise at same points on either side of midrib; black dots present on upper surface, density of black dots varying with each leaf. ***Inflorescence*** flowering stems flattened; 2 flowers at each pair of leaves or some in terminal cymes, 1-5 flowered; pedicels 0.1-0.2cm long. ***Calyx*** sepals 5; persistent; oval, obovate, obtuse; dull green to dark purple; 5-7 x 2-5mm. ***Corolla*** petals 5; red, crimson, pink or orange; longitudinal veins present on petals; 5-10 x 2.5-5mm. ***Stamens*** round; yellow; 4-8mm long; sometimes congested; between 45-55 stamens present per fascicle. ***Ovary*** 2-3mm long; style 1-3mm long. ***Seeds*** (5)6-8 per loculus; oblanceolate, elliptic or oblong; 6-8 x 2-3mm.

Distribution: Thailand: Chiang Mai, Chiang Rai, Lamphun, Phrae, Sukhothai, Phitsanulok, Loei, Sakon Nakhon, Nakhon Phanom, Khon Kaen, Nakhon Ratchasima, Surin, Ubon Ratchathani, Uthai Thani, Kanchanaburi, Ratchaburi, Phetchaburi, Prachuap Khiri Khan, Saraburi, Nakhon Nayok, Sa Kaeo, Prachin Buri, Chon Buri, Rayong, Chanthaburi, Trat, Chumphon, Ranong, Surat Thani, Phangnga, Phuket, Krabi, Nakhon Si Thammarat, Phattalung, Trang, Satun, Songkhla, Pattani, Yala, Narathiwat; **Worldwide:** Borneo, Burma, Indochina, Malaya, Philippines, Sumatra.

Phenology: Flowering: March-June. Fruiting: August.

Ecology: Evergreen, Deciduous Forest, Tropical Rainforest, Savannah, Scrub.

Altitude: Near Sea Level – 1,100m.

Local name: Teo (*W.R.S. Ladell 204*)/Taew (*Bunnak 418*)/Tiu kliang (*BGO Staff 63*)/Tarat Ki Tai (*B. Sangkhachand, 179A*)/Seu gwae joh (*J.F. Maxwell 01-514*).

IUCN Global Status: Least Concern (LC).

IUCN Regional (Thailand) Status: Least Concern (LC).

Note on synonymy: The name *Cratoxylum chinense* (Retz.) Merr., Philip., J. Sci., C 4: 292. 1909 is the valid name for this species as the species was moved from the genus

Hypericum to the genus *Cratoxylum*. *Hypericum chinense* Retz. was published in 1789. This species was previously referred to as *Cratoxylum cochinchinense* (Lour.) Blume, Mus. Bot. 2:17. 1852. However *Cratoxylum cochinchinense* is invalid based on priority of publication as the species was previously referred to as *Hypericum cochinchinense* Lour. and this species was published in 1790, one year after the valid publication of *Hypericum chinense*.

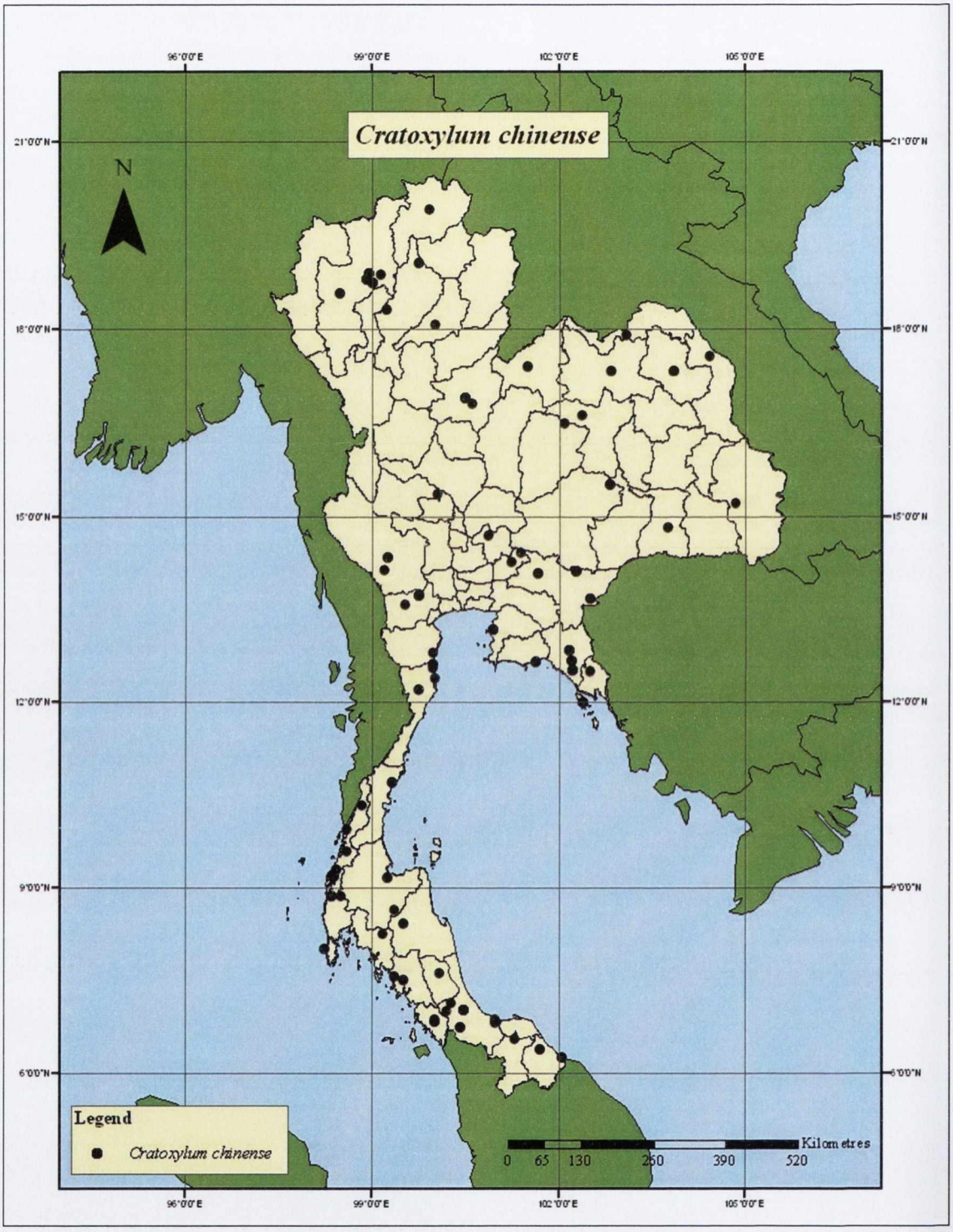
THAILAND

Northern Region: 2. *Chiang Mai Province:* Botanic Garden, Mae Rim, *Sucheera 6* (QBG); Botanic Garden, Mae Rim, *S. Watthana & S. Siriphum 22* (QBG); Botanic Garden, Mae Rim, *BGO Staff 63* (QBG); Botanic Garden, Mae Rim, *S. Watthana 96* (QBG); Huai Paan, *Serm 115* (QBG); Botanic Garden, Mae Rim, *R. Pooma 207* (BKF); San Pan See, QBG, Mae Rim, *C. Glamwaewong 241* (QBG); Botanic Garden, Mae Rim, *BGO Staff 600* (QBG); Me Ta, *K. Winit 714* (ABD, BKF, K); Doi Sutep, *A.F.G. Kerr 1080* (BM, C, K, L, TCD); Doi Sutep to Ban Neh, *J.F. Rock 1553* (A, K);); *No collector 1938* (BK); Doi Sutep, *Th. Sorensen, K. Larsen & B. Hansen 2682* (BKF, C, K); Doi Sutep, *Th. Sorensen, K. Larsen & B. Hansen 3369* (C, K); Botanic Garden, Mae Rim, *BGO Staff 6109* (QBG); Inthanon NP, *C. Phengkhlai et al 6746* (BKF, E, K); *J.F. Maxwell 01-514* (A, CMU); Doi Lahn, *J.F. Maxwell 03-130* (A, CMU); Doi Sutep, *J.F. Maxwell 88-544* (L); Mae Kahn (Karen Village), Doi Luang NP, east side, Mae Dtawn Nai Village Area, *J.F. Maxwell 97-679* (CMU, BKF), Along Mae Klang River, *N. Fukuoka T-62376* (PSU); Ban Mae-Hoi, Chom Thong, *B. Cholsuk s.n.* (BKF); **3. *Chiang Rai Province:*** Payapri Village (Akha), *S. Gardner & P. Sidisunthorn 2093* (A, CMU); Above Payapri Lao Mae Village, *J.F. Maxwell 05-646* (CMU); Doi Giah, *J.F. Maxwell 06-295* (CMU); **6. *Lamphun Province:*** Doi Kahn Dahn NP, trail from Mah Meun Station to Psh Dtoop Falls, Mae Tah, *J.F. Maxwell 94-572* (A, CMU); **8. *Phrae Province:*** Hui Kamin, RHS of Hui, *Somkid 467* (BKF); **11. *Sukhothai Province:*** Soke Pra Ruang Waterfall, *J.F. Maxwell 72-280* (AAU, BK); **12. *Phitsanulok Province:*** Nong Hin, *S. Phusomsaeng 218* (C, L); Tung Salaeng Luang, *K. Larsen, T. Smitinand & E. Warncke 465* (AAU, BKF, L, P); Thong Nang Tow, *Prayad 561* (BK); Kong Sophe Waterfall, *P. Sangkhachand 585* (BK); Thung Salaeng Luang, *G. Murata, N. Fukuoka & C. Phengkhlai T-16507* (BKF, L, P); Tung Salaeng Luang National Park, ca. 80km east of Phitsanulok, *G. Murata, N. Fukuoka & C. Phengkhlai T-17058* (C, K, L, P); **North-Eastern Region: 17. *Loei Province:*** Si Tan Forest, Wang Sapung, *Din 204*

(ABD, BK, BKF, K); Chung Pae, *B. Khantchai 1045* (BKF, K, L); **21. *Sakon Nakhon Province:*** *M.C. Lakshnakara 1003* (AAU, ABD, BK, BM, E, K); **22. *Nakhon Phanom Province:*** Tha-Utan, Nakornbhanom, *Pradit 422* (BK); Tha-Utan, Nakornbhanom, *Pradit 447* (BK); **26. *Khon Kaen Province:*** Kanchanapisaele Temple, Phu Wieng District, *C. Kantachote 168* (KKU); **Eastern Region: 28. *Nakhon Ratchasima Province:*** Kao Yai NP, *G. Murata, N. Fukuoka & C. Phengkhlai T-16272* (BKF, L, P); Between Kao Yai NP & Pok Chong, *G. Murata, N. Fukuoka & C. Phengkhlai T-16507* (BKF, K, L); **30. *Surin Province:*** Rattana, *Sakol 286* (BK); Vao Yai, *Uarem? 408* (BK); Between Loong & Kong Bung Pru Villages, *J.F. Maxwell 03-329* (CMU); **33. *Ubon Ratchathani Province:*** UR Gene Conservation Station, Ban Bahai Village, Huay Yang Subdistrict, Khong Chiam, *M. Greijmans 183* (CMU); **South-Western Region: 36. *Uthai Thani Province:*** Nong/Prue Forest, Ban Rai, *Bunnak 957* (BKF); **37. *Kanchanaburi Province:*** Saneh Pawng Village, Sangklaburi District, *K. Kansuntisukmongkol 83* (CMU); Near Neeckey, near Wangka, *Kwae Noi River Basin Exp. 274* (BK); Huai Aek, *B. Sangkhachand 1598* (BKF, C, K, L, P); Sadong, Salag Prah Wildlife Sanctuary, *C.F. van Beusekom, R. Geesink, C. Phengkhlai & B. Wongwan 4037* (BKF, C, K, L, P); **38. *Ratchaburi Province:*** Hua Hin-Pak Ta Wan, *W.R.S. Ladell 204* (ABD, K); Nawng Ke, *D.J. Collins 1571* (AAU, ABD, BK, K); **39. *Phetchaburi Province:*** Ang Num Yen, *Vachanapong 320* (BK); T. Nong Ya Pong, *Sakol 545* (BK); Huai Saai, Cha-am, *P. Puudjaa 935/1* (BKF); **40. *Prachuap Khiri Khan Province:*** Pranburi, *S. Phengnaren 141* (BKF); Hua Hin, *A. Marcan 344* (BM, K); Sam Roi Yat, *D.D. Soejarto, T. Smitinand, T. Santisuk & K. Taylor 5785* (BKF, L); Nawng Kang, *A.F.G. Kerr 10911* (AAU, ABD, BK, K); **Central Region: 47. *Saraburi Province:*** Pukae, Muang District, *Dee 81* (BKF); Forestry Station, Pukae, *O. Thananan 2496* (BKF); Sahm Lahn, *J.F. Maxwell 73-697* (AAU, BK); **50. *Nakhon Nayok Province:*** Khao Yai NP, Muang District, along the road to Hayo Sawat Falls near Lahm Dakawng Camping site at 43km, *J. Aramwith 7* (A, CMU); Pakphli District, *Parinya, Winai & Prayad 36* (BK); Pakhli District, *W. Somprasong & P. Sangkhachand 49* (BK); Pakphli District, *Parinya, Winai & Prayad 60* (BK); Khao Yai NP, Muang District, *A. Boonkongchart 69* (A, BKF, CMU); Khao Yai NP, Muang District, *P. Charoenchai & S. Poompuang 269* (CMU); Khlong Sai Area, *P. Charoenchai 450* (CMU); Khlong Sai Area, *P. Charoenchai 527* (BKF, CMU); Tu Rean Forest, *D. Bunpheng s.n.* (L); **South-Eastern Region: 56. *Sa Kaeo Province:*** Aran Pratet, *Put 2023* (AAU, ABD, BK, K): Muang, *F. Srisanit s.n.* (BKF); **57. *Prachin Buri Province:*** *C. Phengkhlai et al 3711*

(A, BKF, PSU); **59. *Chon Buri Province:*** Khao Nang Nom, Panusnikom, *Vachance 60* (BK); Sriracha, *D.J. Collins 126* (BM, K); Sriracha, *D.J. Collins 199* (BM, C, E, K, L, TCD); Low hill, back of Sriracha, *D.J. Collins 1300* (AAU, ABD, K); Kao Chalak, near Sriracha, *D.J Collins 1453* (ABD, K); Khao Khieo Opened Zoo, *C. Phengkhlai et al 12888* (BKF); Kasetsart University at Ao Udom, west side of Kow Hill, *J.F. Maxwell 03-236* (CMU);Khao Kieo, Sriracha District, J.*F. Maxwell 75-131* (BK); Khao Kieo, Sriracha District, *J.F. Maxwell 75-420* (BK); **60. *Rayong Province:*** Chak Phong, Klaeng, *K. Kertsawang 293* (QBG); **61. *Chanthaburi Province:*** Kao Sra-Bap, Pliew Waterfall, *Vachanapong 100* (BK); *B.S. 170* (BKF); Ma Kuam, *M.C. Lakshnakara 482* (AAU, ABD, BK, E, K); Outside entrance to river on the way to the lighthouse, *D.J. Collins 556* (K); Kao Sabap, Chanthabun, *Put 890* (AAU, ABD, BK, BM, C, E, K, L, P); Lem Ling, *A. Marcan 1347* (ABD); Pliew Falls, *J.F. Maxwell 71-245* (AAU, BK, L); **62. *Trat Province:*** *B. Sangkhachand, 179A* (L); Kaw Chang, Khlawng Son, *Bunnak 418* (A, BKF); Makham, *B. Sangkhachand 629* (C, E, K, L, P); Koh Chong Khlong, *J. Schmidt 735* West slopes of Kao Sabap, *G. Seidenfaden 2683* (C); Near Ban Saphan Hin, ca. 60km SE from Trat, *G. Murata, N. Fukuoka & C. Phengkhlai T-17628* (BKF); **Peninsular Region: 63. *Chumphon Province:*** Pathiu, *Jaray 29* (BK); Tha Sae, *Jaray 87* (BK); Bang Son, *Put 1469* (AAU, ABD, BK, C, E, K, L); **64. *Ranong Province:*** Kapoe, *B. Sangkhachand 1139* (C); **65. *Surat Thani Province:*** *D. Prapat 47* (BKF, C, L); Kao Tapet, *Sakol 1026* (BK); Koh Prob, *Sakol 1387* (BK); Pha Phet, *T. Smitinand 5592* (BKF); **66. *Phangnga Province:*** Thung Chalee, Nang Yo, *C. Niyomdham et al 356* (BKF, C, K, L, P); Low hill along road S. of Takua Pa, *C.F. van Beusekom & C. Phengkhlai 732* (AAU, BKF, C, E, K, L, P); Kopah, *Hariff 2948* (BM, K); **67. *Phuket Province:*** On way from Ton Sai Wildlife Reserve to Pa Klok, *C. Niyomdham et al 217* (BKF, C); Foothills of Khao Phra Mountain, *N.K.B. Robson 30761* (AAU, E, K, P); Khao Phra Mountain, *K. Larsen, S.S. Larsen, I. Nielsen & T. Santisuk 30764* (AAU, E, K, P); **68. *Krabi Province:*** Nai Chong, Amphoe Muang, *C. Chermsirivathana & Kasem 1327* (BK); Ko Pra-Bahng Krahm Wildlife Sanctuary, *J.F. Maxwell 06-590* (CMU); **69. *Nakhon Si Thammarat Province:*** Chawang, *Sanan 767* (AAU, BKF, L); Chong Khao Thung, Song District, *T. Shimizu, F. Konta, T. Smitinand & B. Sangkhachand T-28951* (BKF); **70. *Phattalung Province:*** Khaeun-Kha-Nuun, *C. Purintavasagul 223* (PSU); **71. *Trang Province:*** *L.V.P. 602* (K); Chum Het, *A.F.G. Kerr 15212* (ABD, BK, K): Si Kao, *A.F.G. Kerr 19017* (AAU, ABD, BK, K); Near Med Plant Exp. Plot, Trang Hort. Exp. Sta., Amper Sikao, *Y. Paisooksantivatana & P. Sangkhachand Y-2135-87* (BK);

72. *Satun Province:* Kuan Kalong, *No collector 365* (BKF); Khuan Kalong, *S. Phengnaren 496* (BKF, K, L, P); **73. *Songkhla Province:*** *Udomsak 16* (PSU); Ton Nga Chang Wildlife Sanctuary, 20km west of Haad Yai, *Students 22* (PSU); Haad Yai Municipal Park, Haad Yai, Wat Kawn Chong, Haad Yai, *Congdon & Hamilton 22* (A, PSU); Bahn Dtoon, Muang District, *Suwit 32* (PSU); Park, Haad Yai, *Students 36* (PSU); PSU Campus, *Peechate 37* (PSU); Tumbol Kho Sa Ba, Thae-Pa, *K.K. et al 54* (PSU); Haad Yai, *Pradit 202* (BK); Kuan Meed, *Congdon & Hamilton 404* (PSU); Ko Hong Hill, Haad Yai, P. *Srirugsa 404* (PSU); Khlong Hae, Haad Yai, *Vachanapong 654* (BK); Ratapoom, *S. Sutheesoen 1733* (BK); Tepa, *A.F.G. Kerr 14709* (ABD, BK, BM); Kampengpet, *Kiah 24350* (ABD); Ko Hong Hill, Haad Yai, *K. Larsen, S.S. Larsen, I. Nielsen & T. Santisuk 40938* (PSU); Ton Nga Chond Wildlife Sanctuary, *K. Larsen, S.S. Larsen, I. Nielsen & T. Santisuk 41030* (AAU, BKF, P, PSU); Khao Choom Sak, Haad Yai, *K. Larsen, S.S. Larsen, S.S. Renner, C. Niyomdham, W. Ueachirakan & P. Srirugsa 42818* (AAU, P); Ko Hong Hill, Haad Yai *J.F. Maxwell 85-537* (A, AAU, BKF, E, L, P, PSU);. Klong Hoy Kong, Haad Yai, *J.F. Maxwell 85-934* (AAU, BKF, L, PSU); Near Boripath Waterfall, *P. Srirugsa PS21* (PSU); Tung Lung, *Vitchu V9* (PSU); **74. *Pattani Province:*** Banang Station, *A.F.G. Kerr 7316* (AAU, ABD, BK, BM, E, K); *A.F.G. Kerr 7745* (AAU, ABD, BK, BM, E, K); **75. *Yala Province:*** Muang, *N. Saephu 8* (PSU); **76. *Narathiwat Province:*** Yi-ngo, *B. Sangkhachand 155* (C, L, P); Tak Bai, *C. Niyomdham 692* (BKF, C); **Unknown Locations:** *Vanpruk 298* (BKF, K); *R.W. Squires 333* (E); *Sanan 767* (AAU); *M. le Thorel 1062* (E); *Haniff 2948* (BM); *Sorensen, Larsen & Hansen 3015* (C); *L. Pierre 3236* (E); *Bitsenuloke, G.W. Groff 6146* (K); *L. Vanpruk s.n.* (BKF, K); *M. Godefroy-Lebeuf s.n.* (K).



Map 3.33 Distribution of *Cratoxylum chinense* in Thailand.



Figure 3.18 Line drawing of *Cratoxylum chinense* (flowering stem). (Illustration by Elaine Cullen).

Chapter 4

Phylogenetic Relationships of the Thai Clusiaceae and Hypericaceae

4.1 Introduction

One of the aims of systematics is to develop classifications that reflect evolutionary history. These classifications are usually based on several criteria: morphological anatomical, chemical, distributional, and more recently molecular DNA data (Singh, 1999). Taxonomy is sometimes considered a controversial area of biology as the definition of a member of a particular rank such as family, genus, species is subjective and often two experts working on the same group will disagree about their taxonomy. Phylogenetics, on the other hand is arguably less controversial as it is primarily concerned with evolutionary relationships of organisms, and the assignment of a group to a taxonomic rank is of secondary importance. However these two areas of biology are closely linked as the aim of a classification is to reflect evolutionary history so phylogenetics plays an important role in developing a scientific basis of systematics but it does not solve all of the problems within systematics (Nei et al., 2000).

The field of molecular systematics has developed rapidly in recent years. Extensive improvements in molecular techniques have led many molecular biologists to investigate relationships within the angiosperms (e.g. Taberlet et al., 1991, Kita et al., 1995; Bayer et al., 1998; Potgieter, 1999; Savolainen et al., 2000a, 2000b; Soltis et al., 2000; APG II, 2003; Davis et al., 2005; Tokuoka et al., 2006) and these studies have provided new insights into various aspects of classification of the angiosperms. These investigations have been based mainly on DNA amplified by the Polymerase-Chain-Reaction (PCR). The PCR makes DNA amplification and sequencing accessible and thus has led to many changes in the field of plant systematics. A major advantage of PCR is the ability to isolate and amplify specific sequences of DNA without using recombinant DNA technology. It allows us to examine sequence variation on specific areas of a genome (Jordan et al., 1996) and also to study the same region in many species of a particular group (Judd et al., 2002). In some studies, combinations of plastid and nuclear genes have been used as they have led to better resolution and higher confidence for the groupings found (Savolainen at al., 2000a, 2000b; Soltis et al., 2000).

Relationships within Order Malpighiales

The order Malpighiales consists of 30 families with 700 genera and 16,000 species (Tokuoka et al., 2006). The order is considered to be monophyletic on the basis of molecular data (Tokuoka et al., 2006). Relationships within this order are poorly understood. Over the last decade, studies have been carried out to try to resolve relationships within the order. These studies were based on phylogenetic analyses, using plastid (*atp*B and *rbc*L) and nuclear (18S) DNA genes (Savolainen et al., 2000a, 2000b; Soltis et al., 2000; APG II, 2003; Davis et al., 2004; Davis et al., 2005; Stevens, 2006; Tokuoka et al., 2006) and in combination.

The positions of the Clusiaceae and Hypericaceae families within the Malpighiales are still not fully resolved but results from recent studies have shown that the Podostemaceae and Bonnetiaceae are the two closest related families to the Clusiaceae and Hypericaceae (see Figure 4.1; Chase et al., 2000). In a paper by Davis et al. (2005), the bootstrap support for the Hypericaceae-Podostemaceae-Bonnetiaceae-Clusiaceae clade was 100%. In a recent paper by Tokuoka et al. (2006), both the Hypericaceae-Podostemaceae and Clusiaceae-Hypericaceae-Podostemaceae clades were strongly supported with BS 100% and Davis & Chase (2004) also found a relatively strongly supported clade (BS 88%) for Bonnetiaceae-Clusiaceae-Hypericaceae. The Podostemaceae and Ochnaceae were found to be the sister group to the Bonnetiaceae-Clusiaceae-Hypericaceae clade (BS 97%).

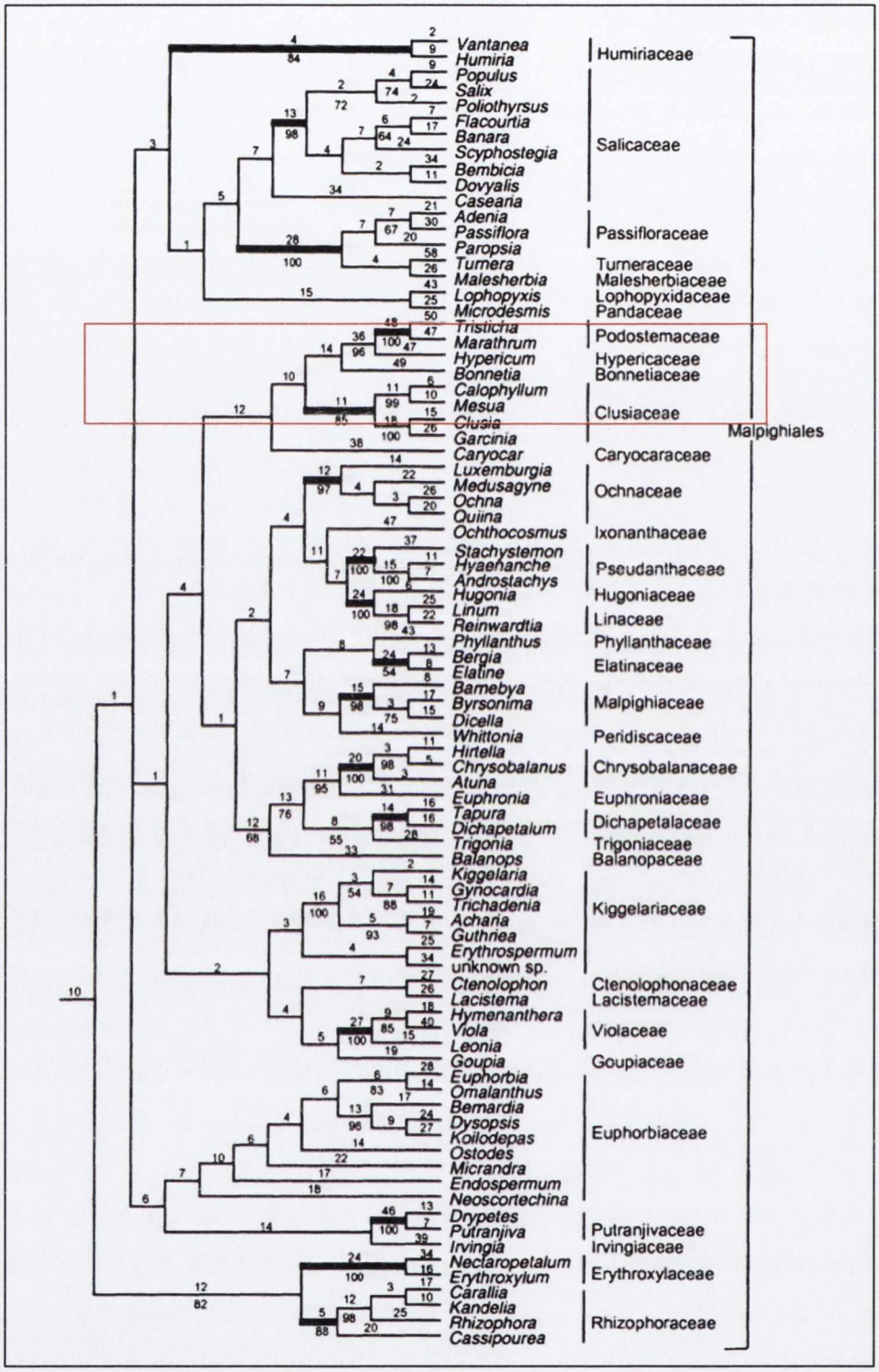


Figure 4.1 Phylogenetic tree adapted from Chase et al. (2000). Branch length (numbers above branch) and bootstrap support (numbers below branch) are indicated on the tree. The broader branches indicate clades which are supported with bootstrap support greater than 80%.

Podostemaceae and Hypericaceae both have cells that contain secretory products and also both families have pollen that is usually tricolpate and stigmas that are papillate (Stevens, 2007, 2006). The Bonnetiaceae was shown to share some morphological characteristics with the Clusiaceae and Hypericaceae families also, namely the presence of staminal fascicles or phalanges and all three families have similar exotegmic seeds (Stevens, 2007). Characteristics common to all four families include the presence of distinctive xanthones and all four families have tenuinucellate ovules (Kubitzki et al., 1978; APG II, 2003; Stevens, 2007).

The Clusiaceae and Hypericaceae families are dealt with in this thesis as two separate families and both families are considered to be monophyletic. However, Gustafsson (2002) noted that it is difficult to point to a single uncontradicted morphological synapomorphy for each of the separate families. For example, resin-containing ducts and glands are present in both families but the homologies of these structures are uncertain (Gustafsson, 2002). Because of this, the two families have sometimes been placed together as one family under the name Guttiferae (*e.g.* Engler and Prantl, 1925) or as the Clusiaceae including the Hypericaceae (*e.g.* Gustafsson, 2002).

4.2 Aims of the study

The original aims of this molecular study were to undertake a phylogenetic study of all Thai Clusiaceae and Hypericaceae at the species level and more specifically, to investigate the relationship between *Kayea* and *Mesua* (in Clusiaceae) to see how closely related these two genera are. However, due to amplification and sequencing problems, it was not possible to carry out a study at the specific level as the fresh DNA samples and the herbarium samples would not amplify, even when using target regions such as *trnL-F*, *matK* and *atpB-rbcL* which are known to be reliable for amplification success over a wide range of species. When amplification was successful for some of the above gene regions, the sequencing was unsuccessful. For this reason, sequencing was eventually completed for a small number of samples (30 in total, see Appendix 3 for more information) using the *rps*16 and *rpL*16 gene regions respectively and the analyses were carried out at the family and generic levels.

The aims of the molecular study at the family and generic levels were to resolve the relationships between genera in the Thai Clusiaceae and Hypericaceae and to investigate their monophyly.

4.3 Materials and Methods

Target DNA Regions and Primer Trials

Two target chloroplast DNA gene regions were chosen for the analysis, namely *rps*16 and *rpL*16. These were chosen based on previous studies carried out which showed that the developed primers for each of these gene regions are reliable for amplification success over a wide range of species (see Jordan et al., 1996; Oxelman et al., 1997).

The *rps*16 gene codes for a chloroplast ribosomal protein. The *rps*16 exons are separated by a group II intron (Oxelman et al., 1997). The *rpL*16 gene also codes for a chloroplast ribosomal protein that is found in the large single-copy region of the chloroplast genome. It consists of two exons that are separated by a long intron (Jordan et al., 1996). See Table 4.1 for more information on the above gene regions.

Table 4.1 Chloroplast gene regions and universal primer combinations used for PCR amplification. (F: forward primer, R: reverse primer).

Target Region	Primer Base Sequence (F-forward; R-reverse)	Reference
***rps*16**	**16F:** 5'-GTGGTAGAAAGCAACGTGCGACTT-3'	Oxelman et al.,
	2R: 5'- TCGGGATCGAACATCAATTGCAAC-3'	1997
***rpL*16**	**F71:** 5'-GCTATGCTTAGTGTGTGACTCGTTG-3'	Jordan et al.,
	R1161: 5'-CGTACCCATATTTTTCCACCACGAC-3'	1996

30 specimens were used in this study: *Malpighia glabra* L., was used as an outgroup for the two gene regions. The remaining 29 specimens were representative of two of the four genera of Thai Clusiaceae, the two genera of Thai Hypericaceae, the Podostemaceae and two South American genera of the Clusiaceae. Ideally the Bonnetiaceae should have been included in the analysis as this family is closely related to the Clusiaceae and Hypericaceae (see 4.1 above for information regarding the two families). However, due to unsuccessful amplification and sequencing, it was not

possible to include a representative from this family. Information regarding the names and samples used are provided in Appendix 3.

Extraction of Total Genomic DNA using CTAB

Approximately 0.2g fresh weight leaf material was stored in silica gel immediately after collecting. This prevents the degradation of the DNA by removing the moisture from the tissue and thus ensuring the quality and yield of DNA is to a high standard. The protocol for the isolation and extraction of total genomic DNA from silica gel dried leaf material was a modified version of the CTAB method developed by Doyle and Doyle (1987) and given in Hodkinson et al. (2007). This method was used, as it is an efficient and reliable method to produce high molecular weight DNA. It minimises the degradation of DNA due to DNases and it also minimises the co-isolation of contaminants, which can inhibit the action of restriction endonuncleases and reduce the efficiency of the PCR (Hodkinson, 2008).

Protocol for the Extraction of Total Genomic DNA

Extraction buffer (2XCTAB[4] 10ml) was added to a 30ml re-useable capped centrifuge tube and preheated to 65°C in a water bath. Mortars and pestles were also preheated to 65°C. The silica gel dried leaf material was weighed (0.03-0.12g) and cut into small pieces. The cut leaf material was ground into a paste in the pre-heated mortar, using a small amount of the extraction buffer.

The remaining buffer was then added to the paste and the material was further ground to form a slurry. This was poured back into the centrifuge tubes and incubated at 65°C for 10 minutes. 5ml of CI[5] was added to each tube, the lids were replaced and the solutions were mixed on a shaker in a horizontal position for approximately 30 minutes. The tubes were then centrifuged at 4,000rpm (c. 3,500g) for 10 minutes. The upper aqueous phase containing the DNA was then removed using a transfer pipette and placed in a fresh 50ml centrifuge tube.

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[4] *2XCTAB Buffer*
100mM Tris-HCL pH 8.0
1.4M NaCL
20mM EDTA
2% CTAB (hexadecyltrimethylammonium bromide, w/v)

[5] *CI* - 24:1 chloroform:isoamyl alcohol

Approximately equal volume (4ml) of ice-cold isopropanol was added to the aqueous layer to precipitate the DNA. The samples were then stored at -20°C for 1-2 weeks to further precipitate the DNA.

Purification of Total Genomic DNA

Purification of the extracted samples was carried out using alcohol (ethanol) precipitation. This was done to remove impurities from the precipitate and in order to transfer the DNA to a suitable storage buffer for freezing and for PCR.

Protocol for Purification of Total Genomic DNA

The samples were centrifuged at 2,000rpm (c. 1,800g) for 10 minutes to pellet the DNA. The supernatant was poured off and 1.5ml of wash buffer[6] was added and the solution was gently mixed. The samples were centrifuged at 2,000rpm (c. 1,800g) for 5 minutes to further pellet the DNA. The supernatant was again poured off and the tubes were gently placed upside down on a paper towel for 5 minutes to allow the excess wash buffer to drain away. The tubes were then turned the right way up and placed in a fume hood for 20 minutes to ensure that all traces of ethanol were removed via evaporation. The pellet was re-suspended in 0.5ml TE[7] Buffer. This was transferred to a labelled 1.5ml micro-centrifuge tube using a transfer pipette and the samples were stored at -20°C until further cleaning.

Further Purification of Total Genomic DNA

Further purification of samples using the JETquick Spin Column Technique was carried out to ensure successful amplification of samples using the PCR. This was done following the protocol of the manufacturer GENOMED GmbH. The manufacturer provided the following information regarding the provided constituents of the kit: Binding solution (H1) contained concentrated guanidine hydrochloride and isopropanol. Wash buffer (H2) contained ethanol, NaCl, EDTA and Tris-HCL and TE-buffer contained 10mM Tris-HCL (pH 8) and 0.1 mM EDTA.

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[6] *Wash Buffer* - 70% ethanol

[7] *TE Buffer*
Tris (10mM) HCl & 0.1mM EDTA (Ethlene-diaminetetra-acetic acid disodium salt at pH8)

Protocol for the Further Purification of Total Genomic DNA

400µl binding solution (H1) and 100µl DNA sample were added to labelled spin columns (in 2ml receiver tubes). The tubes were centrifuged at 12,000rpm (c. 10,000g) for 1 minute. The flow through was discarded and the spin columns were re-inserted into the empty receiver. 500µl of wash buffer (H2) was added to the centre of the spin columns. The samples were centrifuged again at 12,000rpm (c. 10,000g) for 1 minute and the flow through was discarded once again. The samples were centrifuged at maximum speed (13,000rpm (c. 10,000g)) for 1 minute to ensure the remaining wash buffer was removed and the spin columns were placed into new 1.5ml microfuge tubes and 50µl of warm TE buffer was added to each sample to dissolve the DNA. The samples were then centrifuged at 12,000rpm (c. 10,000g) for 2 minutes. The spin columns were discarded and the samples were placed in the freezer until required.

Protocol for Assessing Quantity and Quality of Total Genomic DNA

A rough assessment of the quantity and quality of the total DNA sample was determined using electrophoresis. The electrophoresis was carried out on an agarose gel containing ethidium bromide stain which binds to the DNA and fluoresces in the presence of UV light. A 1.2% agarose gel in 1XTBE[8] buffer was prepared in a Duran bottle. Approximately 80ml of the gel solution was melted and 2µl of ethidium bromide ($10ngml^{-1}$) was added and the solution was mixed by gentle swirling. The gel was then poured into a casting boat and allowed to set for 25 minutes. The combs were removed by gently pulling them out vertically and the tape was also removed. The gel was then placed in a buffer tank filled with 1XTBE so that the gel was covered by a few millimetres of solution.

6µl of clean DNA was mixed with 2µl loading dye (4g sucrose, 25mg bromophenol blue (200-400bp), H_2O to 10ml) and these were then loaded onto the gel along with a 1kb ladder. The tank was connected to the power supply and run at 155V for approximately 30 minutes.

The gel was then removed from the tank and placed in a UV light box in order to view the degree of fluorescence and hence the amount of DNA present. A digital image was

[8] *TBE Buffer*
Tris, boric acid & EDTA x 10 (Ethlene-diaminetetra-acetic acid disodium salt at pH8)

then taken using the Scientific Imaging System from Digital Science (Kodak ID 2.0.2) gel photography software.

Trials were then carried out using each of the primers in order to find conditions to optimise the amplification success of the regions. Temperature and length of time for each process was examined and presented here are the optimum temperatures and time lengths for each of the primers used.

A master mix was made up according to Table 4.2 or amplification of each gene region.

Table 4.2 Master mix components with volume and concentrations for PCR amplification of chloroplast regions.

Component	Volume per Sample	Concentration/Amount
Sterile ultra-pure H_2O	36.75µl	-
X10 Buffer (Promega)[9]	5µl	
Forward primer (100ngµl^{-1})	0.5µl	50ng
Reverse Primer (100ngµl^{-1})	0.5µl	50ng
dNTP's	1µl	0.2mM
$MgCl_2$	4µl	2.5mM
Taq (Promega) (5 units µl^{-1})	0.25µl	1.5 units
Total	50µl	

48µl master mix and 2µl DNA were mixed together and spun down on a microcentrifuge. The samples were then loaded onto the thermocycler (Applied Biosystems 9700). The thermocycler (Applied Biosystems 9700) was set to the following conditions for *rpL*16 and *rps*16 respectively (Table 4.3).

[9] *X10 Buffer (Promega)*

500mM KCl, 100mM Tris-HCl (pH 9.0 at 25°C) and 1.0% Triton® X-100.

Table 4.3 Conditions of amplification for *rpL*16 and *rps*16 gene regions.

Process	Temperature	Time	Number of Cycles
Premelt	95°C	5 minutes	
Denature	95°C	30 seconds	
Anneal	52°C-54°C	30 seconds	30
Extension	72°C	30 seconds	
Final Extension	72°C	7 minutes	
Soak	4°C	∞	

Cycle Sequencing of Chloroplast Genes

The amplified regions of cpDNA were sequenced using the *Taq* Dye-Deoxy/Terminator cycle sequencing kits (V.31: Applied Biosystems. Foster City, California, USA). Cycle sequencing utilises dideoxynucleotide chain termination (Hillis et al., 1996).

Cycle Sequencing Protocol

The amplified gene regions were cleaned as outlined above using the Spin Column Cleaning technique. These samples were then prepared for Cycle Sequencing. 1µl Applied Biosystems Taq Dye-deoxy / terminator cycle sequencing mix V.3.1 (PINK Mix) was added to fresh 0.2ml flat-topped tubes. Two master mixes containing sequencing buffer and sterile water were prepared according to Table 4.4 and the forward and reverse primers were then added to the separate master mixes. 6µl of the master mix was added to each tube containing PINK mix and 3µl of the amplified PCR product was added to each tube bringing the total volume up to 10µl.

Table 4.4 Master mix components, volumes and concentrations for each sample for amplification of target DNA regions before sequencing.

Component	Volume
PINK Mix	1µl
Sterile ultra-pure H_20	3.1µl
Sequencing Buffer (200mM Tris HCl pH 9, 5mM $MgCl_2$)	1.5µl
Primer (Forward/Reverse; 5ng/µl)	1.4µl
Total	7µl

The samples were then vortexed and centrifuged and loaded onto the thermocycler (Applied Biosystems 9700) which was set to the following conditions:

Table 4.5 Conditions for amplification of forward and reverse sequences of target DNA regions before sequencing.

Temperature	Time	Number of Cycles
96°C	10 seconds	
50°C	5 seconds	28
60°C	4 minutes	

Sample Purification prior to automated DNA Sequencing

Before sequencing each sample was further purified. This was done by mixing 50µl ethanol (EtOH: 100%) with 2µl sodium acetate (NaOAc: 3M) for each sample. 52µl of this mixture was added to each cycle sequencing sample and mixed. The samples were then left at room temperature for 10 minutes. After 10 minutes, the samples were transferred to ice for 30-60 minutes (60 minutes preferably). After this incubation period, the samples were centrifuged at 13,000rpm (c. 10,000g) for 25 minutes. The supernatant was discarded and 300µl EtOH (70%) was then added to each sample and they were again centrifuged at 13,000rpm for 15 minutes. The supernatant was again discarded and the process was repeated once again. The drained tubes were then placed between two layers of tissue and allowed to dry overnight to ensure all alcohol had evaporated. The product was then stored in the freezer at –20°C until further required.

Preparation for Automated Sequencing

The samples were prepared for sequencing by adding 10µl of Hi-Di Formamide, a preparation reagent, into each tube. The contents of the tubes were mixed on a vortex and heated on a heat block to 95°C for 5 minutes. The samples were then placed on ice for 3 minutes. The contents of the tubes were then transferred to a 96-well plate and spun down to ensure the contents were at the bottom of the tubes. The septa were then inserted into the tubes (for the autosampler of the 3130*xl* Genetic Analyser).

Samples were loaded onto an ABI Prism 3130*xl* Genetic Analyser (Applied Biosystems) with a 36cm capillary and POP7 polymer. The sequence data were automatically saved and compiled using Sequence Analysis Version 5.3.1 (Applied Biosystems)

Sequence Assembly, Alignment and DNA Analysis

The electropherograms from the automated sequencing were edited and assembled using Autoassembler version 2.1 software (Applied Biosystems). These sequences were then imported into PAUP version 4.0b 10 (PPC) (Swofford, 2001) and aligned using Se-Al v2.0 a11 (Rambaut, 2002) and finally aligned by eye, following the guidelines in Kelchner (2000) for non-coding plastid DNA.

Phylogenetic Analysis

Parsimony analysis was performed using PAUP version 4.0b 10 (PPC) (Swofford, 2001). Heuristic searches with 1,000 replicates were employed. Starting trees were obtained using random stepwise addition (1,000 replicates), holding 1 tree at each step during stepwise addition for branch-swapping. The branch-swapping algorithm used was tree-bisection-reconnection (TBR); no more than 100 trees of score (length) greater than or equal to 20 were saved in each replicate. All characters were unordered and had equal weight. Gaps were treated as missing data. If a gap of more than one bp was a direct duplication it was only saved as a single character and the rest of the gaps were deleted from the analysis.

Relative clade support was assessed by performing bootstrap analyses (Felsenstein, 1985) of 1,000 replicates with random addition sequence and TBR branch swapping. Only branch support values above 50% were displayed. The consistency index (CI)

(Kluge et al., 1969), retention index (RI) (Farris, 1989) and rescaled consistency index (RC) (Farris, 1989) were also calculated using PAUP to estimate the amount of homoplasy in the data.

The resulting trees were rooted using the outgroup *Malpighia glabra*.

4.4 Results

*rps*16 Gene Region

The aligned *rps*16 matrix was 1,637 bp long. 771 characters were excluded and of the remaining 866 characters, 646 were constant, 135 were variable but parsimony-uninformative and 85 were parsimony informative.

The tree search using maximum parsimony found two equally most parsimonious trees, each consisting of 269 steps, with a CI of 0.89 and a RI of 0.78 respectively. Bootstrap (BS) percentages (≥50% BS) are described as low (50-74%), moderate (75-84%) and high (85-100%). One of the two equally most parsimonious trees is shown as a cladogram with bootstrap values and branch lengths in Figure 4.2 and the strict consensus information is shown in Figure 4.2.

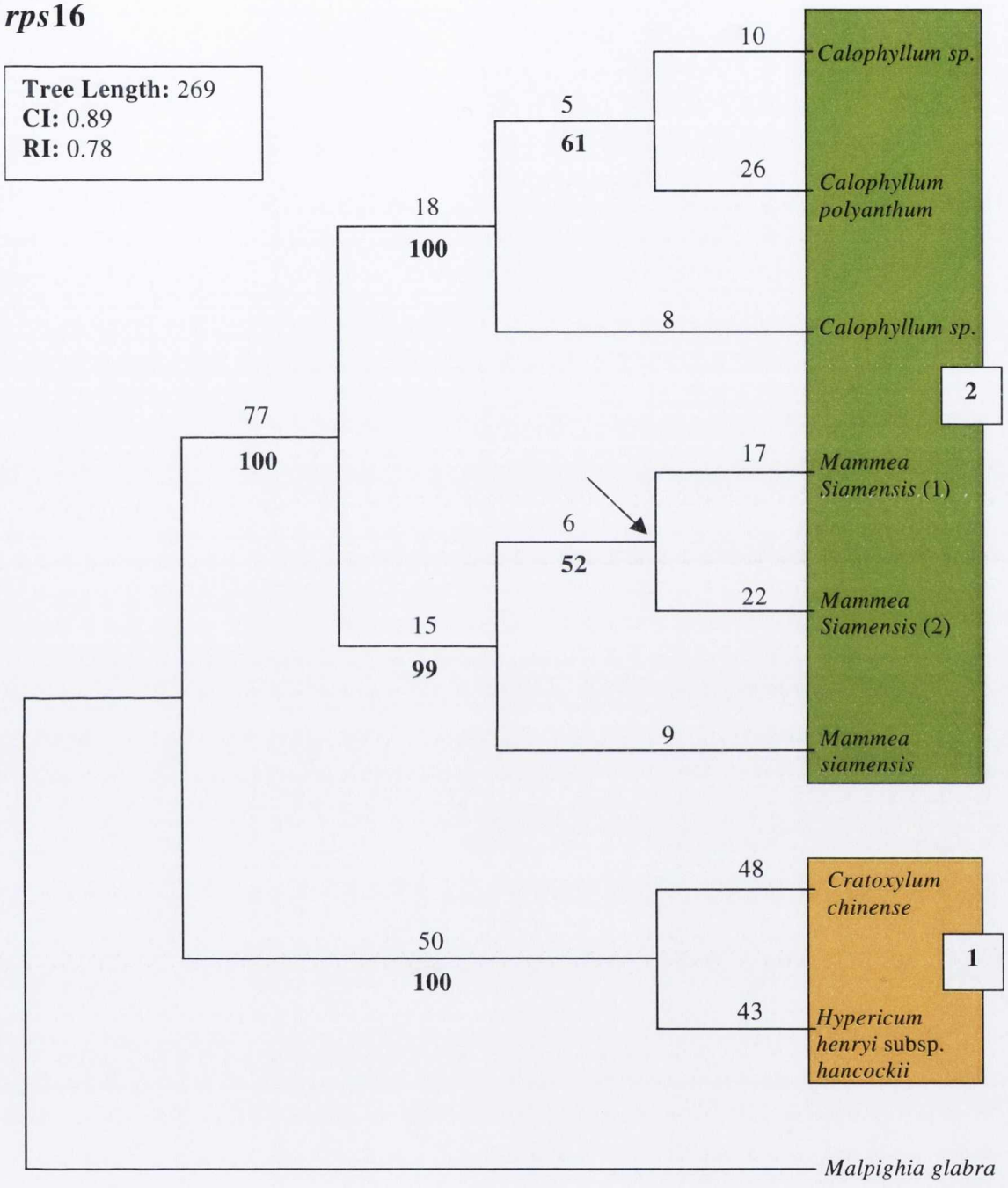


Figure 4.2 One of the two equally most parsimonious trees shown as a cladogram obtained for the *rps*16 sequence data. Branch length (numbers above branch) and bootstrap support (numbers below branch) are indicated on the tree. The arrowhead represents the node not supported by the strict consensus. Group 1: Thai Hypericaceae and Group 2: Thai Clusiaceae.

Group 1 represents the Thai Hypericaceae. This family is monophyletic with 100%BS support. Group 2 represents the Thai Clusiaceae. This family is also monophyletic with 100%BS support. Within the family, there are two resolved groups, namely the *Calophyllum* clade and the *Mammea* clade. These two clades are also monophyletic with high bootstrap support of 100% and 99% respectively. These two clades are sister in this tree (100%BS). *Mammea siamensis* (1) and *Mammea siamensis* (2) are grouped together with a low bootstrap value of 52% and this is not supported in the strict consensus.

*rpL*16 Gene Region

The aligned *rpL*16 matrix was 2,093bp long. 517 characters were excluded and of the remaining 1,576 characters, 1,110 were constant, 230 were variable but parsimony-uninformative and 236 were parsimony informative.

The tree search using maximum parsimony found 12 equally most parsimonious trees, each consisting of 622 steps. CI and RI were 0.86 and 0.88 respectively. One of the 12 equally most parsimonious trees is shown as a cladogram with bootstrap values and branch lengths in Figure 4.3 and the strict consensus information is also shown in Figure 4.3.

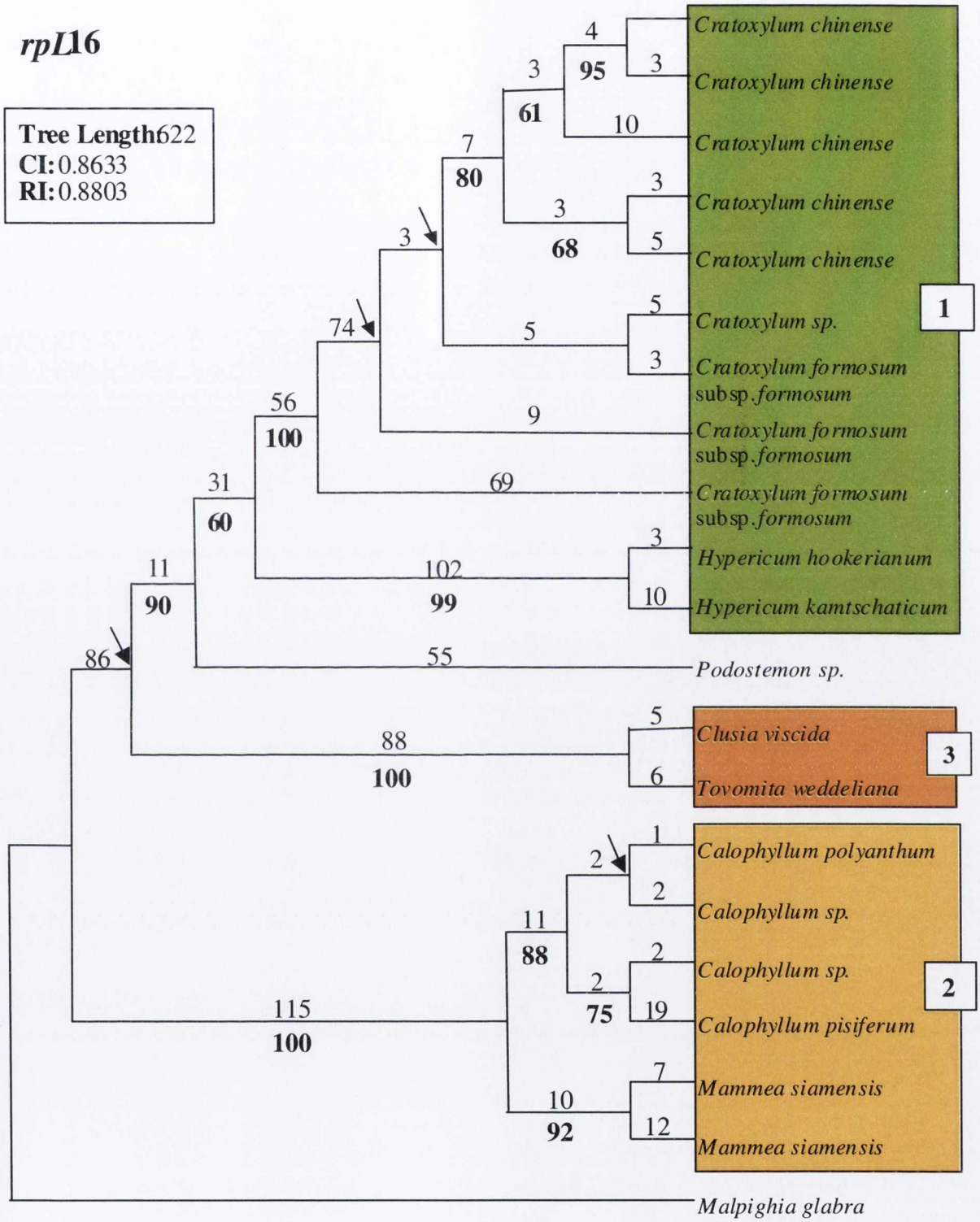


Figure 4.3 One of the 12 equally most parsimonious trees shown as a cladogram obtained for the *rpL*16 sequence data. Branch length (numbers above branch) and bootstrap support (numbers below branch) are indicated on the tree. The arrowheads

represent the nodes not supported by the strict consensus. Group 1: Thai Hypericaceae, Group 2: Thai Clusiaceae, Group 3: South American Clusiaceae.

Figure 4.3 shows three well-defined groups: Thai Hypericaceae, Thai Clusiaceae and South American Clusiaceae. However, the tree provides little information as to how the three groups are related to each other.

Group 1 represents the Thai Hypericaceae. This family is monophyletic and has low bootstrap support of 60%. Within the Thai Hypericaceae, there are two resolved monophyletic clades, namely the *Hypericum* clade and the *Cratoxylum* clade with 99% and 100% bootstrap support respectively. The Podostemaceae is sister to the Hypericaceae (90%BS). The strict consensus also supports this.

Group 2 represents the Thai Clusiaceae. Within the family, there are two resolved clades, namely the *Mammea* clade and the *Calophyllum* clade. These two clades are monophyletic and both clades have high bootstrap support of 92% and 88% respectively. There is strong support for the sister relationship between the *Calophyllum* clade and the *Mammea* clade (100%BS).

Group 3 represents the South American Clusiaceae, namely, *Clusia* and *Tovomita*. This clade is strongly supported with bootstrapping (100%BS).

The above cladogram shows that the Clusiaceae are not grouping together but there is no evidence against the monophyly of this family as the branches collapse in the strict consensus. Therefore, it is unclear as to which of the groups is most closely related to Group 1 and the Podostemaceae.

Combined *rps*16 and *rpL*16 Gene Regions

A combined analysis of the two plastid DNA regions was carried out as combined analyses have often yielded more accurate trees than partitioned analyses (Bouchenak-Khelladi et al., 2008). This 'total evidence' approach was promoted in 1989 by Kluge who noted that all independent characters available for the set of species sampled should be combined as different data may interact positively to resolve a phylogenetic tree (Hillis, 1987; Kluge, 1989; Bouchenak-Khelladi et al., 2008). The two datasets were combined in this analysis as the results from the individual analyses of the two gene regions showed similar groupings and no major incongruences were found between the results from the two single gene region analyses. Plastid DNA is inherited as a single chromosome and the two gene regions sequenced here are 'linked' and should have the same phylogenetic history.

The aligned combined matrix was 3,730bp long. 1,288 characters were excluded and of the remaining 2,442 characters, 1,756 were constant, 364 were variable but parsimony-uninformative and 322 were parsimony informative.

The tree search using maximum parsimony found 200 equally most parsimonious trees, each consisting of 911 steps, with a CI of 0.85 and an RI of 0.84 respectively. One of the 200 equally most parsimonious trees is shown as a cladogram with bootstrap values and branch lengths in Figure 4.4. The strict consensus information is also shown in Figure 4.4.

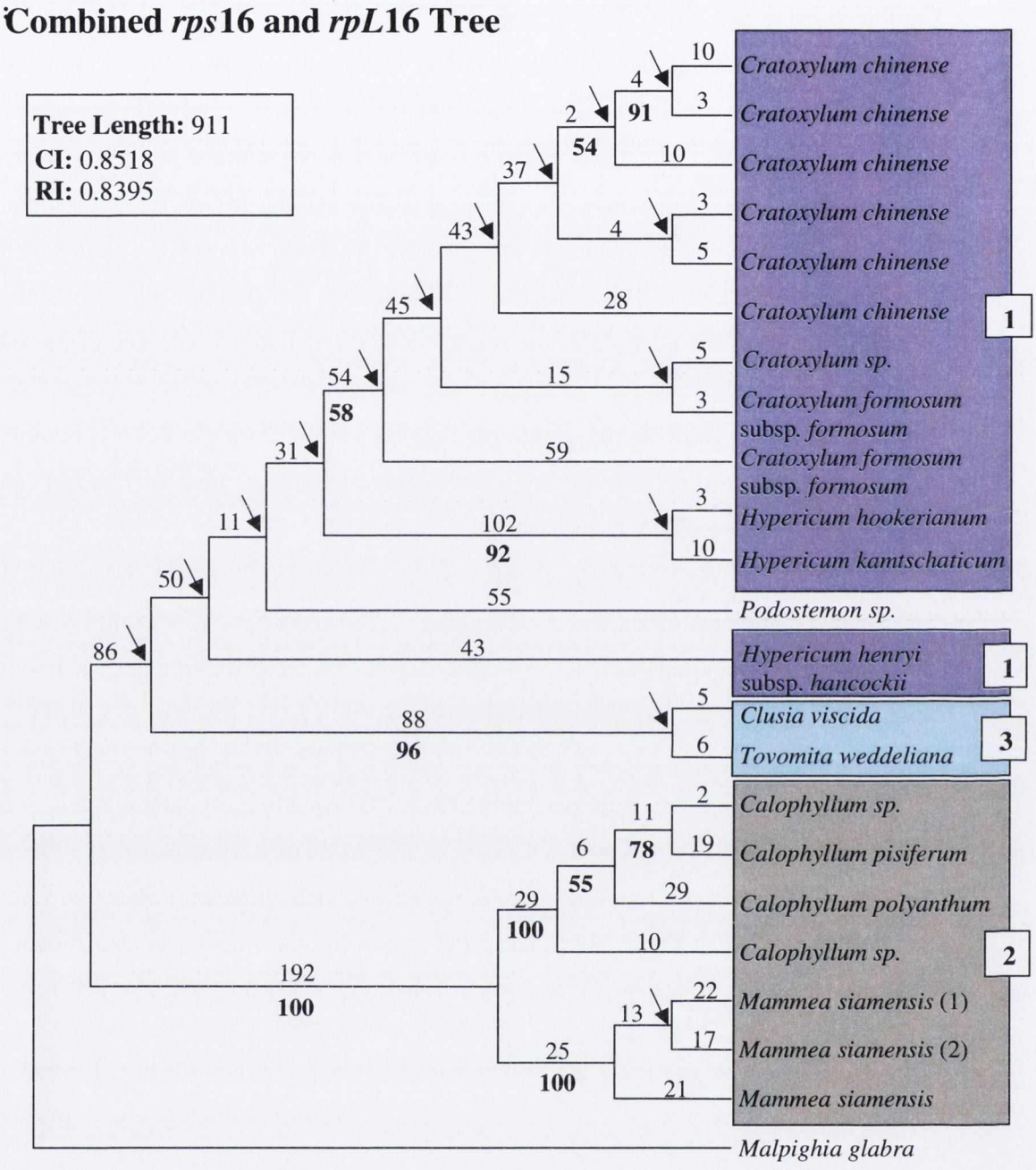


Figure 4.4 One of the 200 equally most parsimonious trees shown as a cladogram obtained for the combined *rps*16 and *rpL*16 sequence data. Branch length (numbers above branch) and bootstrap support (numbers below branch) are indicated on the tree. Arrowheads represent nodes not supported by the strict consensus. Group 1: Thai Hypericaceae, Group 2: Thai Clusiaceae, Group 3: South American Clusiaceae.

Group 1 represents the Thai Hypericaceae. Within this group there are representatives of the two Thai genera of Hypericaceae: *Hypericum* and *Cratoxylum*. *Hypericum henryi* subsp. *hancockii* is not grouped with the other Hypericaceae taxa, but there is no evidence against this species grouping with the remainder of the Hypericaceae. The Podostemaceae is embedded within the Hypericaceae. The strict consensus does not support this, as the whole spine of the clade collapses in the strict consensus.

Group 2 represents the Thai Clusiaceae. Within this group, there are two resolved clades: the *Calophyllum* clade and the *Mammea* clade. Bootstrapping supports both monophyletic clades with 100%BS support for both clades. *Mammea siamensis* (1) and *Mammea siamensis* (2) are grouped together. However, bootstrapping and the strict consensus does not support this.

Group 3 represents the *Clusia* and *Tovomita* clade. This clade is strongly supported with high bootstrapping (96%BS).

The collapsing of the majority of branches in the strict consensus of the combined analysis could be due to the amount of missing data included in the dataset. This would account for the low bootstrap percentages and the lack of support from the strict consensus (Bouchenak-Khelladi, 2008).

4.5 Discussion and Conclusion

The discussion will be based on the combined results of all analyses (see Table 4.6 for a summary of the findings from the three analyses) but mainly on the *rpL*16 analysis, as the results from all three trees are more or less congruent, with only soft congruence present.

Table 4.6 Overall summary of information available from the *rps*16, *rpL*16 and combined analyses. (BS: Bootstrap, SC: Strict Consensus).

	***rps*16**		***rpL*16**		**Combined**	
	BS	**SC**	**BS**	**SC**	**BS**	**SC**
Group 1: Hypericaceae + Podostemaceae	N/A	N/A	90	+	-	-
Family 1: Thai Hypericaceae	100	+	60	+	-	-
Family 2: Thai Clusiaceae	100	+	100	+	100	+
Genus 1: *Cratoxylum*	N/A	N/A	100	+	-	-
Genus 2: *Hypericum*	N/A	N/A	99	+	-	-
Genus 3: *Calophyllum*	100	+	88	+	100	+
Genus 4: *Mammea*	99	+	92	+	100	+

N/A = not included in the analysis or information not available

\+ present in the BS or SC

\- absent in the BS or SC

The above results show that both the Thai Hypericaceae and Thai Clusiaceae are monophyletic. The South American Clusiaceae are also monophyletic (*rpL*16 only) but there is no support for or against their inclusion in Clusiaceae.

Cratoxylum and *Hypericum*

These two genera are monophyletic in the above study. Bootstrapping and the strict consensus support this. The two genera are sister to one another. This finding would be expected as the two genera are found in the same family but in different Tribes (Stevens, 2007). Within the Hypericaceae, there are three tribes, namely Vismieae, Hypericeae and Cratoxyleae. *Hypericum* is found in Hypericeae and *Cratoxylum* occurs in Cratoxyleae. The monophyly of the two genera is also supported morphologically as the two genera have different habits: *Cratoxylum* are generally woody plants or trees and *Hypericum* are herbs or shrubs, the flowers are generally homostylous or heterostylous in *Cratoxylum* and always homostylous in *Hypericum*, the flowers are

generally red, purple, pink or white in *Cratoxylum* and yellow in *Hypericum* and the fruit is a more or less loculicidal capsule in *Cratoxylum* and a septicidal capsule in *Hypericum*. The two genera also differ in their distribution both worldwide and within Thailand. Worldwide, *Hypericum* is found in temperate regions and in montane tropical areas at high altitudes, whereas *Cratoxylum* is only found in the Palaeotropics from India to Malesia at low to moderate altitudes (Stevens, 2007). Within Thailand, *Hypericum* is found mainly in the North of the country in the cooler temperate-like climate. In fact, only *H. japonicum* occurs outside the North and Northeastern floristic regions. *Cratoxylum* occurs throughout the whole of Thailand and is found in a wide range of habitats. The monophyly of the two genera is supported by morphological, biogeographical and now molecular data.

Cratoxylum

From the above results, it can be seen that within the genus *Cratoxylum*, there are some differences between the branch lengths both between and within species. For example, *Cratoxylum chinense* has five representatives in the *rpL*16 tree. Two of the five representatives have a branch length of 3, two more have a branch length of 5 and one branch was not scored. This shows that even though these are the same species, there is slight variation within the species. This was reflected in the alignment of the sequences as some of the sequences were more difficult to align than others and not all of the *Cratoxylum chinense* representatives aligned well together. The same is true for *Cratoxylum formosum* subsp. *formosum*. This species has three representatives in the above analyses. The branch length numbers differ quite substantially within this species. For example from the *rpL*16 tree, it can be seen that one branch length for this species is 69 and the other is 9. This is quite a large difference. Again these differences and variation were found during sequence alignment. This variation is also seen morphologically as both *Cratoxylum chinense* and *Cratoxylum formosum* subsp. *formosum* exhibit varied habits depending on the habitat and altitude at which they are found (*e.g.* both species can vary from bushy shrubs (NE Thailand) to trees (PEN Thailand).

Hypericum

From Figure 4.3 (above), it can be seen that there are two species from the *Hypericum* genus represented in the analysis. The branch lengths are slightly different and this may

be due to the different distributions of the two species as only *Hypericum hookerianum* is found within Thailand.

Calophyllum and *Mammea*

These two genera are monophyletic and this is supported in all three analyses (see Table 4.6 above). Again these two genera are morphologically distinct from one another and their distribution ranges in Thailand only slightly overlap. Members of *Mammea* are hairless trees, with leaves with distant secondary veins. They rarely have resin canals present on the leaves and can have two to six petals. They occur in every floristic region in Thailand, but mainly in Central and Peninsular Thailand. The genus, *Calophyllum* consists of shrubs or trees. They are hairless or sometimes have multicellular hairs present on the dorsal side of the tepals. The leaves have closely parallel secondary veins that alternate with canals and they have four to eight tepals. This genus also occurs in every floristic region in Thailand, but many species are confined to specific habitat types such as Peat Swamp Forests (*C. pisiferum, C. rupicolum, C. sclerophyllum, C. teysmannii*).

Calophyllum

Overall, the four representatives of this genus are quite similar. This is reflected in the small differences between branch lengths. However, from Figure 4.3, it can be seen that the clade containing *Calophyllum* sp. and *Calophyllum pisiferum* has quite a big difference in the branch lengths. *Calophyllum pisiferum* has a branch length of 19 and *Calophyllum* sp. has a branch length of 2 respectively. This would reflect quite a large difference between these two species. However, between the two *Calophyllum* clades, there is very little difference as the length of both branches is 2.

The results from the analyses have shown the Clusiaceae and Hypericaceae should remain as two separate families. Within the families, there is high support for the monophyly of all genera. The relationships between the Thai and South American genera of Clusiaceae and the Thai Hypericaceae are still unresolved.

Overall the study has yielded some interesting preliminary results. This is the first study that has used the *rps*16 gene region to sequence members of the Clusiaceae and Hypericaceae and previously, only one sequence (*Hypericum kamtschaticum*) existed

for the *rpL*16 gene region for the Hypericaceae and none existed for the Clusiaceae. This study is also the first study to sequence *Calophyllum polyanthum* and *Calophyllum pisiferum* (Clusiaceae).

4.6 Further work to be carried out

Many problems occurred during the DNA extraction and sequencing process. For this reason, it was not possible to carry out research at the species level for the Thai Clusiaceae and Hypericaceae. Silica-dried fresh leaf samples, as well as herbarium leaf material were used for sequencing but unfortunately only 30 samples were successful and no herbarium samples were successfully sequenced.

This preliminary study has highlighted the need for more fieldwork to be carried out in Thailand and if possible for fresh leaf samples of all species to be collected and sequenced.

Due to the above mentioned difficulties regarding DNA extractions, a different extraction method may be adopted in the future in order to obtain DNA from the Thai Clusiaceae and Hypericaceae. The primary and secondary compounds in plants vary from one taxon to another and for this reason, different isolation buffers have been proposed that are optimal for specific taxa (Hodkinson et al., 2007). However few of these buffers have been reviewed or published. Some have been widely published and are universally used (*e.g.* CTAB) but these universal detergents are not always the best for the plant families in question (Hodkinson et al., 2007).

Obtaining good quality DNA can be problematic especially when plant material that is rich in polyphenolics, tannins, polysaccharides, gums and resins is used (Thomson, 2002). Polyvinylpyrrolidone (PVP) is often used to decrease the effect of polyphenols and tannins (Porebski et al., 1997; Karakousis et al., 2003). PVP may be used for future extractions from these plant families as both families contain gums, resins and tannins (Stevens, 2007). The commonly used methods for extracting total DNA from plants usually vary in the detergents used to solubilise the cellular membranes and the means of separating the DNA from proteins and other cellular components (Hodkinson et al., 2007). As mentioned above, CTAB is one of the most commonly used detergents. However Sodium dodecyl sulphate (SDS) is often used as a substitute for CTAB and for

future DNA extractions, SDS may be used instead of CTAB in order to investigate if higher quality DNA can be obtained.

Another area of the DNA extraction process that may be modified in the future is the purification of the DNA. One of the best methods for DNA purification is to use equilibrium gradient centrifugation using caesium chloride, long periods of ultracentrifugation and large amounts of ethidium bromide (Sambrook et al., 1998; Ausubel et al., 2002; Hodkinson et al., 2007). However this method is quite expensive, time-consuming and toxic so therefore most laboratories do not employ this technique. A less expensive method would be to purify the DNA extracts with phenol extraction and ethanol precipitation (Powell et al., 2002). This can yield higher quantities of pure DNA (Hodkinson et al., 2007). This method will therefore be considered in the future for purifying DNA.

Another area of this study that may be modified for future investigations of the Thai Clusiaceae and Hypericaceae is the gene regions that are used. The data from the *rps*16 and *rpL*16 gene regions have proven valuable for studying relationships between the two families. These gene regions are highly variable and thus highly informative but this makes the sequences difficult to align. A less variable gene region should be employed for further investigations at higher taxonomic levels. Once major monophyletic groups (families, tribes, subtribal levels) have been stabilised, then non-coding DNA regions such as those used in this study can be applied to investigate relationships of lower taxonomic rank such as subtribes and genera.

Chapter 5

Phytogeography and Ecology of Clusiaceae Lindl. and Hypericaceae Juss. of Thailand

5.1 Introduction

Phytogeography is the study of the geographic distribution of plants. It deals with all aspects of plant distribution from factors affecting the distribution, such as the geological history of a region to the presence and absence of natural barriers (*e.g.* deserts, mountains, oceans etc.), to the distribution of individual species ranges (Allaby, 2004).

Over the past few years, the history of plate tectonics and other areas of Biogeography have become an area of increasing interest to Biologists and three symposia based on the Indo-Australian tropics took place, resulting in two significant publications: *Biogeography and Geological Evolution of the Malay Archipelago* edited by R. Hall & J.D. Holloway (1998) and *Faunal and Floral Migrations and Evolution in SE Asia and Australia* edited by I. Metcalfe, J.M.B. Smith, M. Morwood & I. Davidson (2001). These publications have become an excellent, indispensable source to anyone studying the origin of the Southeast Asian Biogeography, 'an area that combines biological richness with extreme geological complexity' (Holloway, 2003), as both references provide information about the tectonic history and other important information regarding SE Asia and the origin of its flora.

To date, very little research has been carried out on plant distribution patterns in Thailand. This was highlighted in the paper by Parnell et al. (2003) in which many gaps in collecting activity for Thailand were highlighted and the restricted quality of data available from herbarium collections was also noted. For these reasons, it is difficult to interpret even simple biogeographic patterns for Thailand.

In this chapter, the aim is to provide brief information about the habitats, ecology and distribution patterns for the Clusiaceae and Hypericaceae in SE Asia, with particular emphasis on Thai taxa.

5.2 Biogeographical History of SE Asia

In order to comment on the floristic make-up of Thailand and surrounding countries, it is important to have an understanding of the tectonic history of SE Asia. This region is an area of enormous complexity and the tectonic history of the area is not really fully understood (see Figure 5.1 for an overview of the time-scale of the period in question).

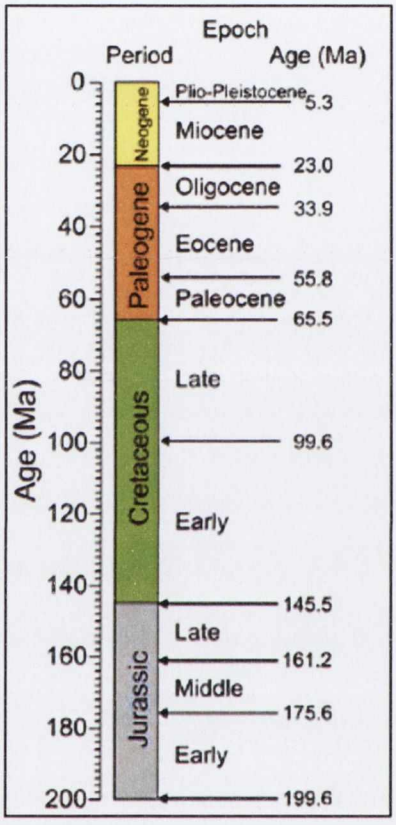


Figure 5.1 Simplified Jurassic-Cretaceous-Cenozoic (200-0Ma) time-scale based on Gradstein et al., 2005. (Illustration adapted from Ali et al., 2008).

SE Asia is made up of two landmasses, namely the supercontinents, Gondwanaland and Laurasia (Humphries et al., 1986). It is a very active region and has only achieved its' current state quite recently. Approximately 180Ma ago Gondwanaland and Laurasia separated when the central Atlantic Ocean opened between Africa and North America. Gondwanaland began to move and split and there are several major events which have shaped and influenced the present day fauna and flora of SE Asia.

Between 170 and 120Ma ago India separated from Antarctica-Australia and Africa and South America (Figure 5.2).

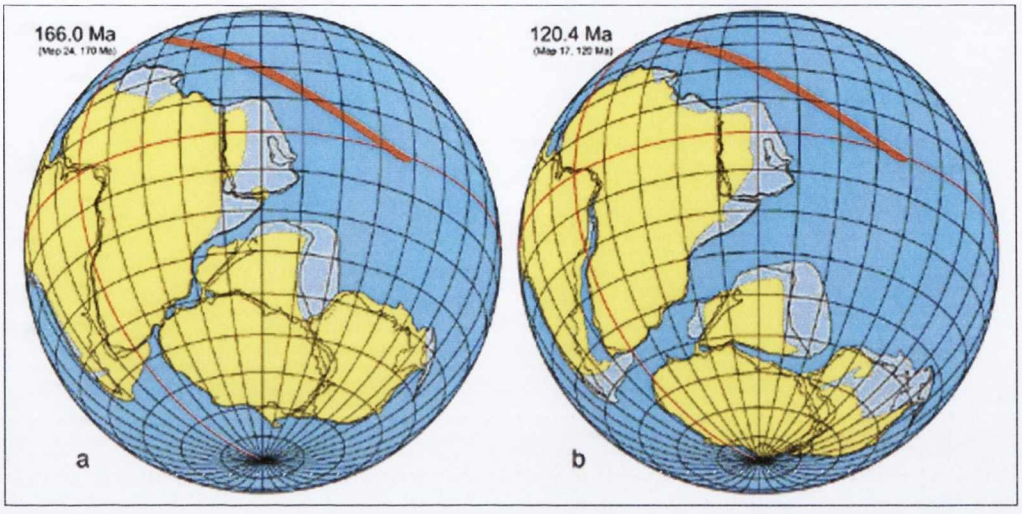


Figure 5.2 Break-up and dispersal of Gondwana at (a) 166.0Ma and (b) 120.4Ma. (Illustration adapted from Ali et al., 2008).

This separation took place just at the end of the late Jurassic and at the beginning of the early Cretaceous (Ali et al., 2008, Metcalfe et al., 2001). Approximately 50Ma ago an ocean ridge formed between Australia and Antarctica (Hall et al., 1998). This separated Australia/New Guinea (consisting of New Guinea, part of Eastern Indonesia and some of the Southwest Pacific Islands) from Antarctica. Between 120 and 73Ma, India's northward advance took place at a rate of approximately 6.6cm per year. This increased to 21.1cm per year between 73 and 57Ma. In the Late Paleocene (57Ma), the northward advance slowed down and the '57Ma event' occurred in which India collided with an intra-oceanic arc located sub-equatorially which is thought to have been part of western Indonesia (see Figure 5.3) (Ali et al., 2008).

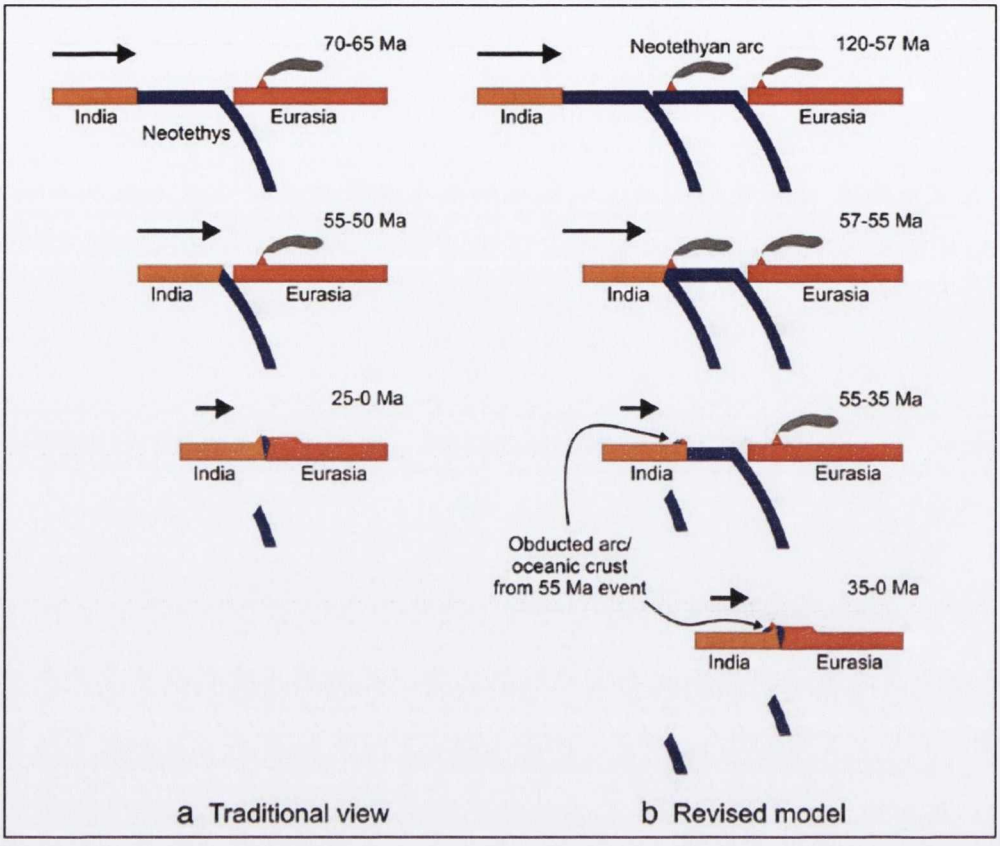


Figure 5.3 Traditional (a) and revised (b) models describing the Late Cretaceous-Cenozoic passage of India towards the Tibet part of Asia (approximately S-N profile). Model (a) shows a simple Tethyan Ocean plate configuration with two continents and one ocean. Model (b) shows Neotethys with two oceanic plates separated by north-dipping subduction zone. These tectonic movements would have increased India's biological connectivity with the other continents, principally East and SE Asia. (Illustration adapted from Ali et al., 2008).

Approximately 35Ma India collided with the Tibet part of Asia (Ali et al., 2008). India then moved westward along Southeast Asia where it first collided with Sumatra and then Burma, until it finally made a hard impact 22-23Ma with the Lhasa block. However, it is believed that biological exchange between India and Asia initially began after the '57Ma event'. It is thought that India may have maintained some physical connections with either Gondwanaland or other landmasses during the Cretaceous Period and that it was not completely isolated until its initial collision with Eurasia (Ali et al., 2008). This collision had important implications for the present-day biogeography of the region. It is thought that India brought new Gondwanan elements

to a Lauraceous SE Asia (Friis et al., 2003, Hall et al., 1998). The collision between India and Eurasia would have caused major changes in climate and habitats, which would have led to changes in land area and drainage systems. Large volumes of sediment would have moved south from Central Asia into the Sunda shelf and thus driven dispersal from Gondwana via India into SE Asia (Hall et al., 1998). A collision between Asia and Australia/New Guinea then occurred between 15-5Ma ago during the middle Miocene to Pliocene. This convergence brought two separate floras into direct contact and helped to give rise to the present-day distribution of the flora. During the Quaternary (the last 2Ma) important climatic changes occurred which resulted in a drier climate and lower sea level (Whitmore, 1981). Sea levels would have been approximately 180m lower than present and the islands of the Sunda shelf (Java, Borneo, Sumatra and Palawan) and the Sahul shelf (New Guinea and the Northern Moluccas) would have been exposed and joined to mainland Asia and Australia respectively (Cumings et al., 2008), allowing for the movement of plants and thus the movement of vegetation belts (Heywood et al., 1995). This recent geological period had dryer cooler conditions and would allow for the reintegration of plants previously segregated due to submergence of land or fluctuations in temperature and climatic conditions which are characteristic of previous periods (*e.g.* Mid Miocene-16 Ma).

Due to the environmental and geological fluctuations, SE Asia is one of the most floristically diverse and rich regions in the world (Morley, 2000).

5.3 Biogeographical History of Thailand

As with all of SE Asia, the tectonic history is not fully understood. Thailand is no exception to this. Thailand consists of two continental blocks, namely the western block that is part of the Sibumasu (Shan-Thai) block (The Sibumasu block consists of Sumatra, Malaysia, West Thailand (including the southern peninsula), East Burma, Northwest Laos and Southwest Yunnan) (Qinglai et al., 2004) and the eastern block which forms part of the Indochina block (Hall et al., 1998). The Sibumasu block is bound to the east by the Uttaradit-Nan to Raub-Bentong suture and to the west by the Shan boundary (Ridder-Numan, 1998). It consists of a piece of land 4,000km long and is thought to have been derived in relation to the major neighbouring terranes which are the Indochina terrane to the immediate east, the South China terrane south of the Tsingling suture, the North China terrane and the Australian continent (Metcalfe et al.,

2001, Hall et al., 1998). This collision between the eastern and western blocks is thought to have taken place sometime during the Triassic (252-205Ma) (Metcalfe et al., 2001, Ridder-Numan, 1998).

The southern peninsula of Thailand consists of two phytogeographical transitions (Hughes et al., 2003). That is the area 400-500km south of the Isthmus of Kra (this is the part of the peninsula that is only 45km wide (Hughes et al., 2003)) near the Thai-Malay border where there are perhumid evergreen rainforests and wet seasonal evergreen rainforests and the second phytogeographical transitional zone in Peninsular Thailand is the area just north of the Isthmus where there are wet seasonal evergreen rainforests and mixed moist deciduous forests. The Isthmus of Kra is known to be an area that can act as a barrier amongst flora and fauna or as a transitional zone where some species move either north or south (Hughes et al., 2003). It is thought that there are differences in the numbers of species of certain genera found in Northern and Southern Thailand because it is thought that the Thai-Malay peninsula may have been inundated with water for two periods during the Mid-Miocene and the early Pliocene which would have affected faunal and floral migratory routes (Hughes et al., 2003). It is estimated that the sea levels could have been approximately 150m higher than present during the middle Miocene and this would have flooded the Isthmus from approximately 24 to 13Ma. Again during the early Pliocene, it is thought to have been flooded from 5.5 to 4.5 Ma when sea levels rose 140m higher than today (Outlaw et al., 2008, Hughes et al., 2003). At present, it was found that if sea levels rose by 100m, two areas in the peninsula would flood (Woodruff, 2003a) and there would be two straits opened, one of which would be 30-100km wide and the other would be 40-50km wide. These two straits would submerge 80% of Southern Thailand and create several prominent islands. It is thought that forest habitat would only remain on the western hills and on the Nakhon Si Thammarat range (Hughes et al., 2003). This scenario could have been the case during the two previous inundations. The above sea level fluctuations in Thailand would have played an important role in the distributional patterns of the flora and fauna.

The peninsular region of Thailand is an important area as it is the meeting point of the Indo-Burmese and Sundaland floristic regions (see above) and the area is home to two of the worlds' six most threatened and diverse hotspots (Myers et al., 2000). This

region of Thailand is also important as approximately 500 genera of plants have their northernmost or southernmost distributional boundaries along the peninsula, near or at the Isthmus of Kra.

5.4 Geography of Thailand

Thailand is bordered on the west by Burma, on the east by Lao PDR and Cambodia and in the south by Peninsular Malaysia and the Andaman and China Seas. It covers an area of approximately 515,000km^2 and was once almost completely covered in forest (Xianpu et al., 1995).

Thailand consists of major plains and mountain ranges including:

The Central Plain of the Chao Phraya River

This area has the highest concentration of agriculture in Thailand. The basin covers 30% of the land area of Thailand and is home to 40% of the country's population (UNESCO, 2006).

The Korat Plateau

This is in Northeast Thailand and is drained by the Mekong River, which forms the border between Thailand and Cambodia. It is surrounded by the Phetchabun Range from Khao Yai National Park north to the Phu Luang and Phu Phan ranges in Sakhon Nakhon and the Dangrek Range from the Thai-Lao-Cambodia border to Khao Yai National Park. Khao Yai National Park is where the ranges meet (van Liere et al., 2005). This plateau was once covered in dense forest, but at present, forest only remains on the hills (Xianpu et al., 1995).

The Northern Highlands

This range extends from North Laos and Burma to c. 18°N (Xianpu et al., 1995). It includes Loei province north of Phu Luang and Chiang Rai (van Liere et al., 2005). It is a very mountainous area with a steep and rugged topography.

The Tenasserim Hills

These run from the Northern Highlands to the Isthmus of Kra along the western border with Burma (Xianpu et al., 1995). Many protected areas overlap in this region as it has

both dry evergreen forest and semi-evergreen rainforests. The protected areas account for 11,530km^2 of the land area and include Sai Yok National Park, Kaeng Krachan and Khlong Saeng (Wikramanayake, 2002).

Peninsular Thailand

This area extends to the Malaysian border. This region has karst limestone towers, which have some rare herbs and low-growing plants (Santisuk et al., 1991).

5.5 Climate

Thailand's climate is monsoonal. The climate becomes progressively wetter and uniformly hot in the south of the country. The north of Thailand is seasonally cooler and drier, especially in the northeast. Rainfall varies, depending on regions, and Thailand experiences occasional typhoons from the South China Sea. In the Central Plains and Northern Highlands, rainfall is approximately 1,500mm per year, in the Korat plateau, the annual rainfall is around 1,000mm and the Southeast and Peninsular Thailand receive from 2,000mm to 4,000mm annual rainfall respectively. In the north of Thailand, inland areas are also relatively dry. The temperature varies depending on the region of Thailand. There is a much more noticeable seasonal difference in temperature north of the Thai peninsula. The mean monthly temperature in the cool months is 25°C (December-January) and approximately 30°C in the hottest months, namely April and May (Davis et al., 1995).

5.6 Vegetation

The vegetation found throughout Thailand is dependent on altitude, rainfall and the underlying geology (Heywood et al., 1995). The following is a summary of the forest types which occur in Thailand that are of particular relevance to this project (Santisuk, 1991):

There are two broad forest types in Thailand, namely a) Evergreen Forests and b) Deciduous Forests.

a) Evergreen Forests

1. Malayan Mixed Dipterocarp Forest

This occurs in climates which lack a regular dry season. This forest consists of tall, lowland forest with a distinct discontinuous emergent stratum above the main canopy, composed mainly of dipterocarps and rich in tree species. The tree species richness is mainly due to the presence of large genera with many species.

2. Wet Seasonal Evergreen Forest

This forest type is found in areas with less than three months dry season and more than 2,000mm rainfall per year. It is tall, lowland forest only found in Indo-Burma. Again it has a distinct discontinuous emergent stratum above the main canopy. The families found here are usually dipterocarps mixed with Bombacaceae, Sterculiaceae and Leguminosae. Many endemic species occur in these species rich forests.

In Thailand two geographical types occur. They differ in species composition, soil types and geographical distribution:

Peninsular Wet Seasonal Evergreen Forest

This forest type is found on clay rich soils derived mainly from granite. It is found from Chumphon southwards and also in other areas such as Khao Soi Dao.

Southeastern Wet Seasonal Evergreen Forest

This forest type occurs on yellow sandy leached soils derived from sandstone. They are found in Southeast Thailand and a modified form is found in Peninsular Thailand in Tarutao. It has an emergent canopy.

3. Dry Evergreen Forest

This is similar to the Wet Seasonal Evergreen Forest but it is poorer in species composition and the trees are generally shorter in stature, less than 40m tall. Dipterocarps are dominant here. This type is found in areas where there are more than three months and less than five months of rainfall per year and where the mean annual rainfall exceeds 1,500mm. This forest is occasionally subjected to fire and when this happens, the understorey is temporarily replaced by bamboo.

4. Montane Forests

These forests are of low to moderate stature, with an even canopy which usually lacks emergents. The composition varies but most contain Fagaceae, Lauraceae and Theaceae. It occurs above 800m and is moderately rich in tree species.
In Thailand two altitudinal types are recognised:

Upper Montane Forest

This forest is shorter in stature and has a poor tree flora. It is abundant in epiphytes and ferns, many of which are regional endemics. This is confined to higher peaks above 1,800m.

Lower Montane Forest

These trees are generally taller in stature than those of the Upper Montane Forests and rich in tree species but poor in epiphyte species. This forest is found from 800-1,800m above sea level. The dominant species of this forest type is *Pinus kesiya* Royle *ex* Gordon.

5. Limestone Forest

This forest type suffers extreme stress as it lacks soil and is subjected to extreme water stress. Some are deciduous, depending on how dry the area is and also how seasonal the climate is. This is home to a distinctive flora due to the calcium rich conditions. There is high endemism in ground herbs and palms and also woody broad-leaved genera. These karst limestone forests occur in southern Thailand and also in the north and west where limestone mountains are found (Heywood et al., 1995).

6. Peat Swamp Forest

This forest type accumulates peat on flat lowlands due to the lack of a dry season and the everwet equatorial climate. It is only found in Peninsular Thailand and has a distinctive evergreen forest of moderate stature but with few endemics.

b) Deciduous Forests

In Thailand, these forest types have spread due to man, through fire. This has been at the expense of the evergreen forest types. They occur in lowland areas up to 1,200m

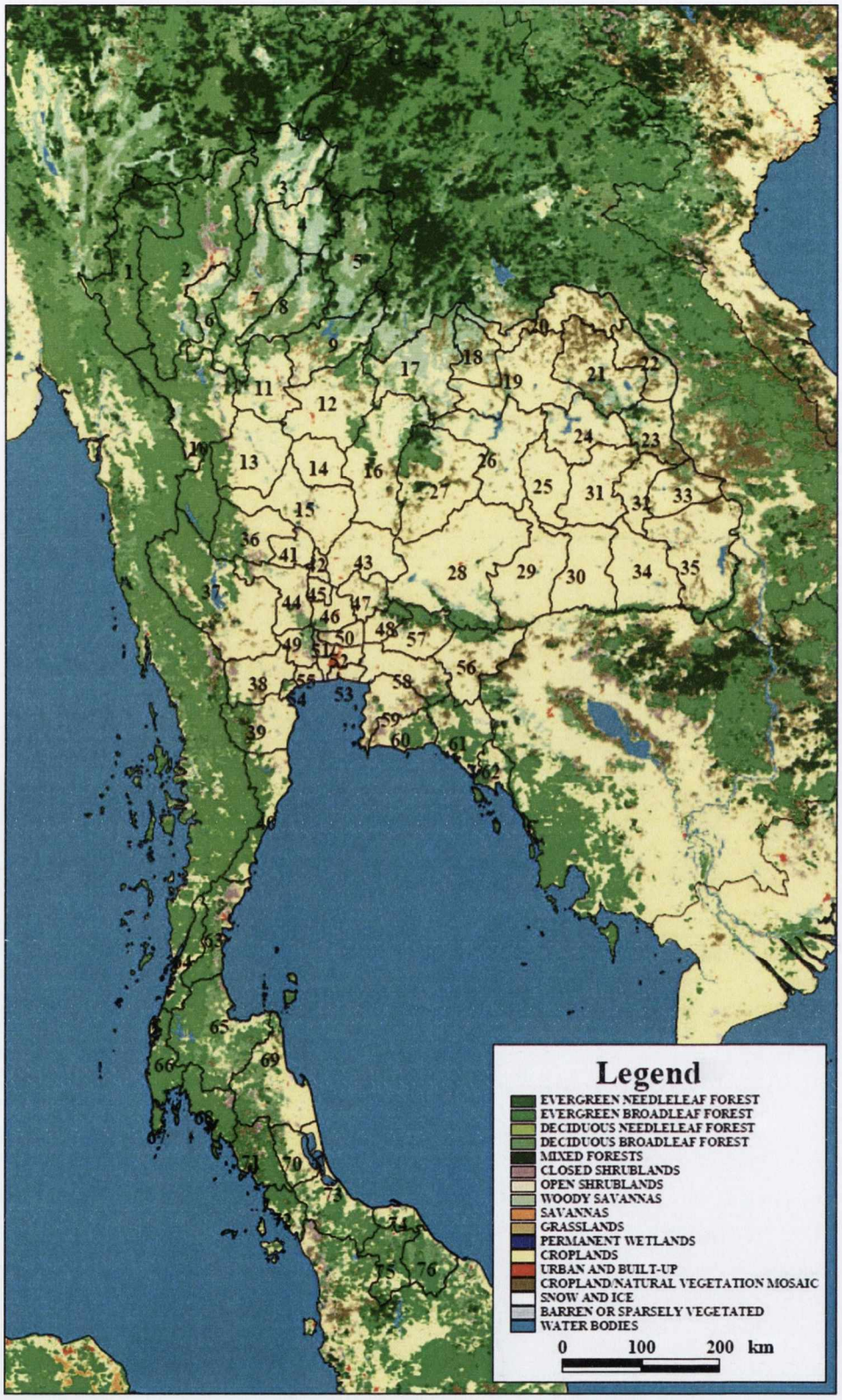
and where there is at least three months of drought and less than 1,500mm rainfall per annum.

1. Mixed Deciduous Forests

Forests with low to moderate species richness. Verbenaceae and Leguminosae are abundant canopy trees and the understorey consists of bamboo or juveniles. It occurs on clay rich soils north of the peninsula. The stature varies from tall trees up to 40m high in valley sites to trees only 5m high on rocky ridges. The species richness also declines in these rocky ridge areas.

2. Dry Dipterocarp Forests

Similar to the Mixed Deciduous Forest but poorer in species. The canopy consists of fire resistant Dipterocarpaceae and *Pinus merkusii* Jungh. & de Vriese which is sometimes the dominant species. The understorey is made up of juveniles and tall grasses. It is found on acidic, infertile, sandy and lateritic soils. The soils are dry and shallow here (van Liere, 2005).

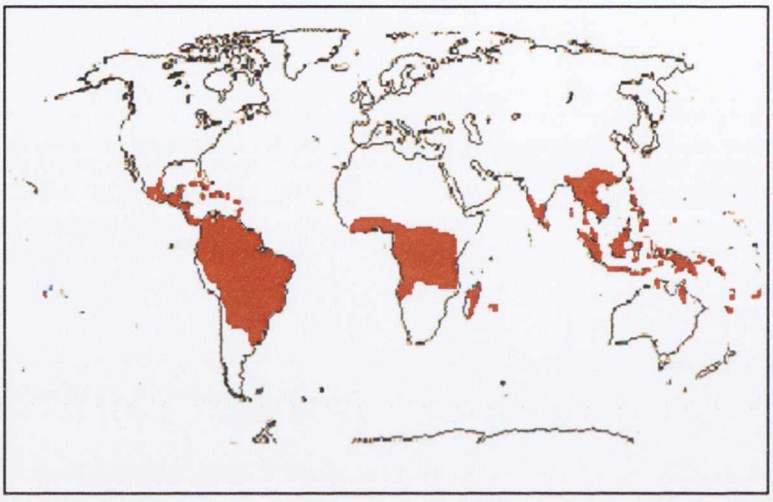


Map 5.1 Map of Vegetation types in Thailand and Changwat boundaries (taken from Parnell et al., 2003).

The above map, taken from Parnell et al. (2003) shows the vegetation types and Changwat boundaries in Thailand. The vegetation types described on this map fit loosely with those described above. That is, the vegetation descriptions are not classified into the same categories as those of Parnell et al. (2003) but both the descriptions and the map cover the main types of forests occurring in Thailand.

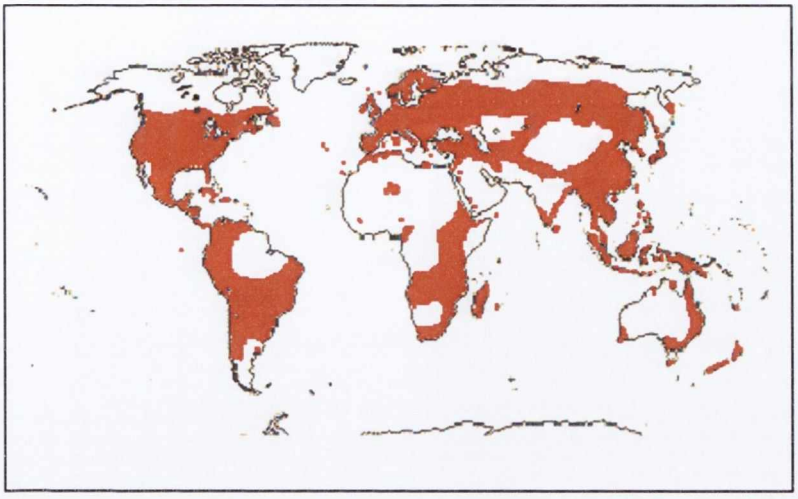
5.7 Worldwide Distribution of Clusiaceae and Hypericaceae

The Clusiaceae is a Pantropical family with genera occurring in America (North America: Florida and Hawaii; South America: Bolivia, Brasil, Colombia, Costa Rica, Ecuador, Panama, Peru, Puerto Rico and Venezuela) (Notis, 2004), Africa (Tropical Africa, Angola, Cameroon, Congo, Gabon, Madagascar, Tanzania, Uganda, Zambia,) (Hutchinson et al., 1958), Asia (Burma, India, Indochina, Indonesia, Malaysia and the Philippines) and Australia. It is thought that China is the link between the Clusiaceae of Asia and America (Hiu-Lin, 1952). Most genera are restricted to either the Old World or the New World with few occurring in both. For example the genus *Calophyllum* has numerous species, which occur in tropical Asia and Australia, and fewer in tropical America (Rendle, 1925). *Calophyllum inophyllum* is an example of a species with a wide distribution as it occurs both in the neotropics and the paleotropics (Notis, 2004). The genus *Mammea* also occurs in North America, Asia and Africa with its centre of diversity believed to be in Madagascar. The *Mammea* species found in Africa and Central Asia have been called the 'phenetically primitive' species of this genus (Stevens, 2007). Map 5.2 shows the worldwide distribution of Clusiaceae.



Map 5.2 Worldwide distribution of the Clusiaceae family. (Map adapted from Stevens, 2006).

The Hypericaceae has a worldwide distribution, with the genus *Hypericum* found predominantly in temperate areas. Again, members of this family are widely distributed throughout America (Found in all of North America (http://wisplants.uwsp.edu)), Africa (West Tropical Africa, Mountains of East Africa from Ethiopia to Zimbabwe, Cameroon, Sudan to Angola, The Cape, Gabon, Congo, Uganda, Madagascar, The Mascarene Islands) (Hutchinson et al., 1958), Europe, Asia, Australia and New Zealand. Some species have a wide distribution range *e.g. Hypericum japonicum* from Japan to Australia and New Zealand, and *Hypericum humifusum* from Europe to South Africa and India. The genus *Triadenum* occurs in East and Northeast Asia and Northeast America. It is clear that this family has a worldwide distribution but the floristic similarity between Southeast Asia and North America, for example, is primarily at the generic and not specific level (Hui-Lin, 1952). Map 5.3 shows the worldwide distribution of Hypericaceae.



Map 5.3 Worldwide distribution of the Hypericaceae family. (Map adapted from Stevens, 2006).

5.8 SE Asian Distribution of Clusiaceae and Hypericaceae

Many of the genera occurring in Thailand are found in surrounding SE Asian countries. However, little data are available for some countries in SE Asia and systematic study in Indochina is not very well developed. Even within Thailand which has amongst the best developed strategies for conservation and systematic study in the region, there is still room for improvement especially a need for more collecting trips to increase the number and diversity of herbarium collections.

The following table shows the Thai Clusiaceae and Hypericaceae and their occurrence in Southeast Asia and surrounding regions, namely the eastern floristic region (Africa, South Asia & Himalaya, Burma and South China) and the western floristic region (Laos, Cambodia, Vietnam, Malaysia, Indonesia, Philippines and Australia).

Table 5.1 Distribution of Clusiaceae and Hypericaceae in South East Asia and surrounding regions. (**AF**: Africa, **SA**: South Asia & Himalaya, **BU**: Burma, **SC**: South China, **TH**: Thailand, **LA**: Laos, **CA**: Cambodia, **VN**: Vietnam, **ML**: Malaysia, **IN**: Indonesia, **PHI**: Philippines, **AU**: Australia) (Thunberg, 1784; Wight, 1834; Blanco, 1837; Miquel, 1859; Bentham, 1863; Thwaites, 1858; Hooker, 1874; Gamble, 1881; Trimen, 1893; Brandis, 1907; Pitard 1910; Gamble, 1915; Merrill, 1917; Haines, 1921; Ridley, 1922; Craib, 1925; Gagnepain, 1943; Anderson, 1963; Backer et al., 1963;

Adams, 1972; Gandhi, 1976; Kostermans, 1976; Dassanayake, 1980; Grierson et al., 1984; Hô, 1991; Phengkhlai et al., 1991; Xi-Wen et al., 2007).

Taxa	AF	SA	BU	SC	TH	LA	CA	VN	ML	IN	PHI	AU
Calophyllum inophyllum	x	x	x	x	x	x	x	x	x	x	x	x
Calophyllum pisiferum			x	x	x	x	x	x	x	x		
Calophyllum soulattri		x			x		x	x	x	x	x	x
Calophyllum calaba		x			x			x	x	x		
Calophyllum tetrapterum					x		x	x	x	x		
Calophyllum teysmannii					x		x		x	x		
Calophyllum dryobalanoides					x		x	x				
Calophyllum macrocarpum					x				x	x		
Calophyllum rupicolum					x				x			
Calophyllum sclerophyllum					x				x	x		
Calophyllum symingtonianum					x				x			
Calophyllum thorelii					x			x				
Calophyllum touranense					x			x				
Calophyllum polyanthum		x		x	x					x		
Clusia major (cultivated)					x							
Kayea elegans					x				x	x		
Kayea ferruginea					x		x		x			
Kayea kunstleri					x				x			
Mammea siamensis					x	x			x			
Mammea brevipes					x				x			
Mammea harmandii					x							
Mesua ferrea		x	x		x	x	x	x	x	x		
Cratoxylum chinense		x	x	x	x	x		x	x	x	x	
Cratoxylum formosum subsp. *formosum*			x	x	x	x	x	x	x	x	x	
Cratoxylum maingayi			x	x	x	x	x	x	x	x		
Cratoxylum neriifolium			x		x	x	x			x		
Cratoxylum formosum subsp. *pruniflorum*			x	x	x	x	x	x				
Cratoxylum arborescens			x	x	x				x	x		
Hypericum japonicum	x	x		x	x	x			x	x	x	x
Hypericum patulum		x	x	x	x			x		x		
Hypericum henryi subsp. *hancockii*			x	x	x			x		x		
Hypericum nepaulense		x	x	x	x	x						
Hypericum hookerianum			x	x	x					x		
Hypericum siamense					x							

From the above table, it can be seen that in general there are a lot of easterly patterns and few westerly patterns for the Clusiaceae family and that the occurrence of the Hypericaceae family in both the eastern (Africa, South Asia & Himalaya, Burma and South China) and western floristic regions (Laos, Cambodia, Vietnam, Malaysia, Indonesia, Philippines and Australia) is almost equal in both directions.

Clusiaceae

The majority of the species appear to occur mainly in the eastern regions with only few species occurring in the western regions and with only the species *Calophyllum inophyllum* occurring in all regions. Of the 14 species of *Calophyllum* occurring in Thailand, five occur in the western regions and all 14 occur in the eastern regions. None of the *Kayea* taxa are found in the west and all three *Kayea* species are found in the eastern areas. The species of *Mammea* found in Thailand are not very widespread in any area except for the species *Mammea brevipes* and *Mammea siamensis* which occur in Thailand, Malaysia and Laos (*M. siamensis*). No members of this genus are found in the western regions. *Mesua ferrea* grows naturally and is cultivated in Thailand and the surrounding countries. It is recorded from most countries to the east and west of Thailand except South China. Its eastern limit appears to be Indonesia as it is not recorded from The Philippines or Australia and its' western limit seems to be South Asia and Himalaya as there are no records for this species in Africa.

Hypericaceae

Six species of *Cratoxylum* are found in Thailand and all of these occur in both the eastern and western regions. This would suggest that this genus has quite a wide distribution range in SE Asia. Of the six species of *Hypericum* occurring, five species occur in the eastern region and five species are found in the western region also. *Hypericum japonicum, H. patulum, H. henryi* subsp. *hancockii* and *H. nepaulense* are found in the eastern and western floristic regions, so this suggests a wide distribution range for these species.

From the above table, it appears that the centre of distribution for most of the species in the two families are in the east and they have dispersed and speciated as they have spread in a westerly direction. However, for the genus *Cratoxylum*, this may not be the

case as both the eastern and western regions have equal numbers of species occurring there. Perhaps the centre of distribution for this genus is in Thailand from where they have spread to surrounding countries; or the centre of distribution could lie either in the eastern region or in the western region and only a few species have moved to distant places and so achieved a wider distribution range.

Statistical analysis of Table 5.1 using Ward's Method to infer species distribution patterns

Ward's Method was used on the above dataset in order to see if there were any patterns of distribution emerging. The statistical techniques were performed using SPSS 14.0. Ward's Method was used as this hierarchical cluster method is designed to optimise the minimum variance within clusters. It differs from other methods as it uses an analysis of variance approach to evaluate the distance between clusters (Abler, 1987)

Non-metric multidimensional scaling was carried out as well as the hierarchical cluster analysis. Non-metric multidimensional scaling yielded similar results to those presented below for the hierarchical cluster analysis using Ward's Method but are not presented here because of the similarity in the results. The results presented here are the dendrograms produced from the hierarchical cluster analysis using Ward's Method as these show the results in a clear medium that is easy to see and interpret.

The parameters set for the analysis were as follows:
Analyze > Classify > Hierarchical Cluster
Statistics: Agglomeration Schedule
Plots: Dendrogram
Cluster Method: Ward's Method
Measure: Binary > Squared Euclidean distance
See Figures 5.4-5.7 for the resulting dendrograms for the Clusiaceae and the Hypericaceae respectively using Ward's Method.

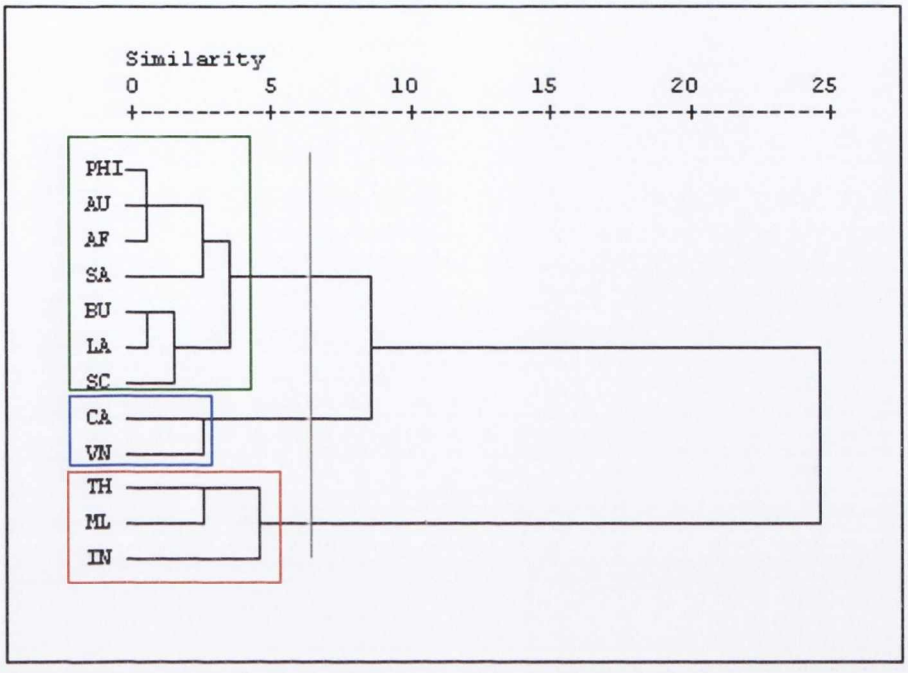


Figure 5.4 Dendrogram showing areas in SE Asia and the surrounding regions. Regions are grouped together based on similarity of species of Thai Clusiaceae found in each region. (**AF**: Africa, **SA**: South Asia & Himalaya, **BU**: Burma, **SC**: South China, **TH**: Thailand, **LA**: Laos, **CA**: Cambodia, **VN**: Vietnam, **ML**: Malaysia, **IN**: Indonesia, **PHI**: Philippines, **AU**: Australia).

Figure 5.4 shows the dendrogram produced for the distribution of the Clusiaceae in SE Asia and surrounding regions. In this case I have split the dendrogram into three groups. The cut-off point is subjective and there are various ways in which the dendrogram could be divided.

Group 1 (Thailand, Malaysia & Indonesia): Group 1 shows the Clusiaceae of Thailand are most similar to those of Malaysia and Indonesia in terms of species composition. Thailand and Malaysia share many of the same species, as do Thailand and Indonesia, and Malaysia and Indonesia.

Group 2 (Cambodia & Vietnam): Group 2 shows that Cambodia and Vietnam share similar species of Clusiaceae.

Group 3 (Philippines, Australia, Africa, South Asia & Himalaya, Burma, Laos & South China): Group 3 shows that these countries share similar species of Clusiaceae.

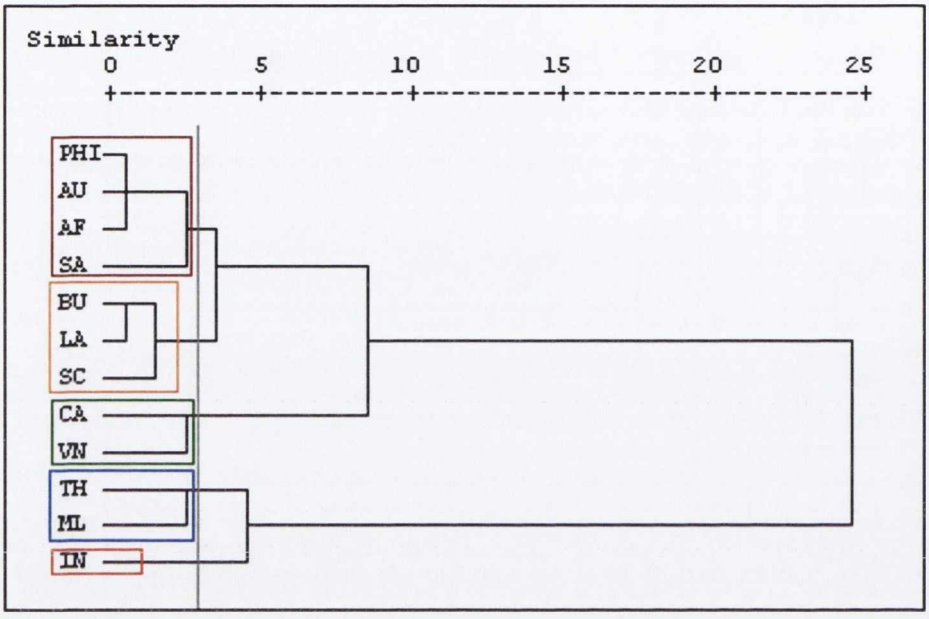


Figure 5.5 Dendrogram showing areas in SE Asia and the surrounding regions. Regions are grouped together based on similarity of species of Thai Clusiaceae found in each region. (**AF**: Africa, **SA**: South Asia & Himalaya, **BU**: Burma, **SC**: South China, **TH**: Thailand, **LA**: Laos, **CA**: Cambodia, **VN**: Vietnam, **ML**: Malaysia, **IN**: Indonesia, **PHI**: Philippines, **AU**: Australia).

Figure 5.5 shows the dendrogram produced for the distribution of the Clusiaceae in SE Asia and surrounding regions. In this case I have split the dendrogram into five groups. The cut-off point is subjective and there are various ways in which the dendrogram could be divided.

Group 1 (Indonesia): Group 1 shows Indonesia in a group of its own. It is closely related to Group 2.

Group 2 (Thailand & Malaysia): Group 2 shows the Clusiaceae of Thailand are most similar to those of Malaysia. Thailand and Malaysia share many of the same species.

Group 3 (Cambodia & Vietnam): Group 3 shows that Cambodia and Vietnam share similar species of Clusiaceae.

Group 4 (Burma, Laos & South China): This grouping shows these three countries that are situated close to one another have similar Clusiaceae species.

Group 5 (Philippines, Australia, Africa & South Asia & Himalaya): This group shows that the Philippines, Australia, Africa and South Asia & Himalaya share similar species of the Thai Clusiaceae.

Figure 5.4 shows that Thailand clusters with Malaysia and Indonesia and Figure 5.5 shows Thailand is most similar to Malaysia in terms of species composition, with Indonesia being closely related to Thailand but less so than Malaysia. Based on this, it appears that the species of Clusiaceae in Thailand may have migrated from Indonesia through Malaysia and north into Thailand and then from Thailand north and west to the surrounding regions. Those species that are found in the Philippines and Australia could have dispersed from Indonesia, whilst those found in Africa and South Asia and Himalaya are perhaps hardier species that dispersed further west or were maybe brought there by humans or may have established there and persisted since the landmasses were joined together.

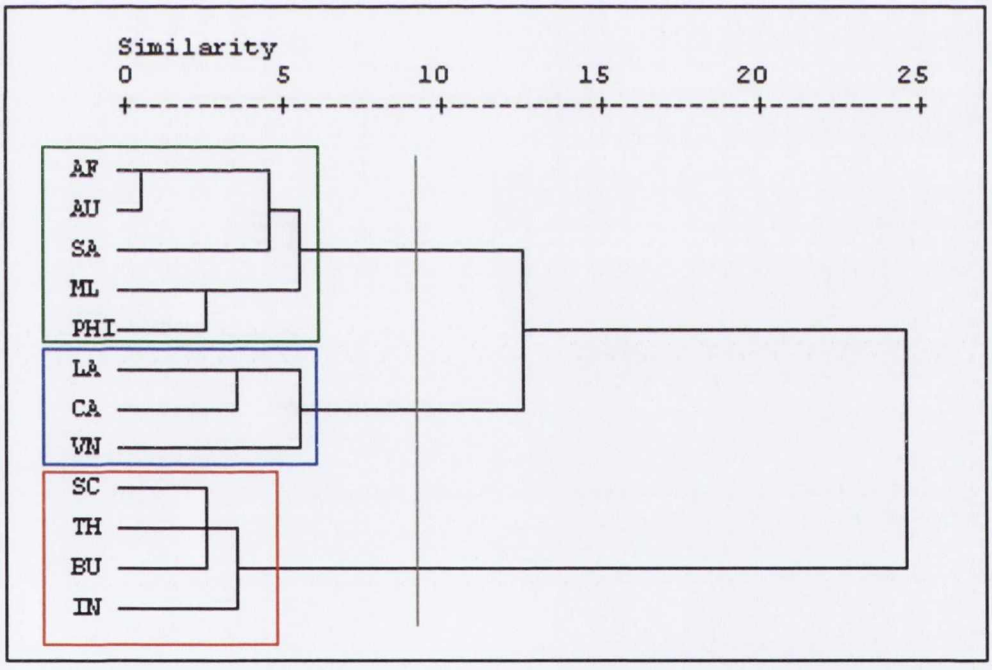


Figure 5.6 Dendrogram showing areas in SE Asia and the surrounding regions. Regions are grouped together based on similarity of species of Thai Hypericaceae found in each region. (**AF**: Africa, **SA**: South Asia & Himalaya, **BU**: Burma, **SC**: South

China, **TH**: Thailand, **LA**: Laos, **CA**: Cambodia, **VN**: Vietnam, **ML**: Malaysia, **IN**: Indonesia, **PHI**: Philippines, **AU**: Australia).

Figure 5.6 shows the dendrogram produced for the distribution of the Hypericaceae in SE Asia and surrounding regions. In this case I have split the dendrogram into three groups. The cut-off point is subjective and there are various ways in which the dendrogram could be divided.

Group 1 (South China, Thailand, Burma & Indonesia): Group 1 shows that South China, Burma and Indonesia are the regions that are most similar to Thailand in terms of species composition.

Group 2 (Laos, Cambodia and Vietnam): Group 2 shows that the three countries found to the east of Thailand all share similar species of Hypericaceae.

Group 3 (Africa, Australia, South Asia & Himalaya, Malaysia & Philippines): This group shows that Africa, Australia, South Asia and Himalaya, Malaysia and the Philippines house similar species of the Thai Hypericaceae.

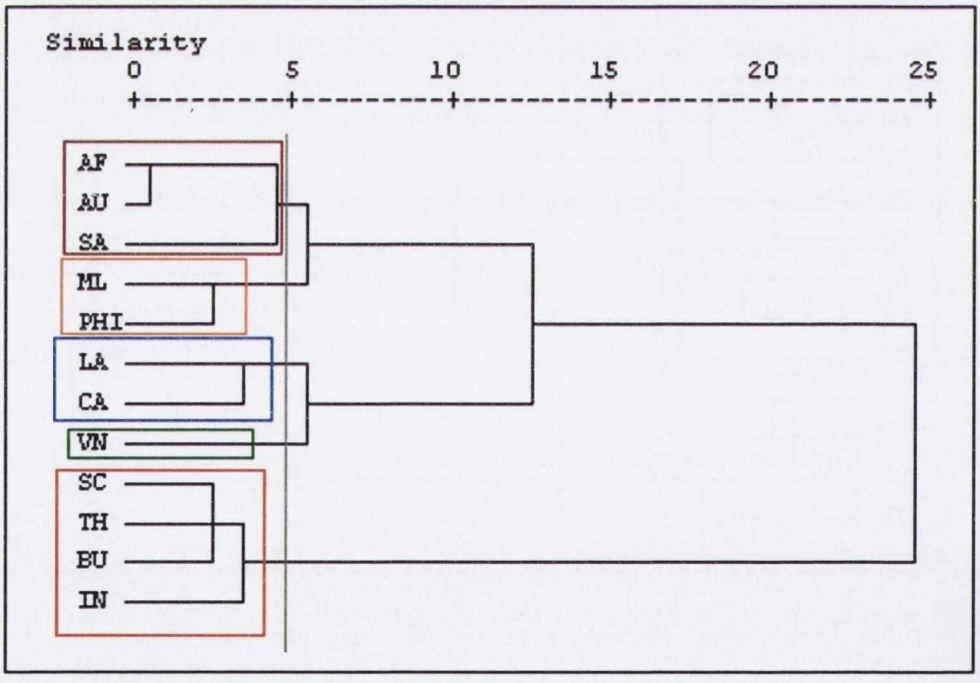


Figure 5.7 Dendrogram showing areas in SE Asia and the surrounding regions. Regions are grouped together based on similarity of species of Thai Hypericaceae found

in each region. (**AF**: Africa, **SA**: South Asia & Himalaya, **BU**: Burma, **SC**: South China, **TH**: Thailand, **LA**: Laos, **CA**: Cambodia, **VN**: Vietnam, **ML**: Malaysia, **IN**: Indonesia, **PHI**: Philippines, **AU**: Australia).

Figure 5.7 shows the dendrogram produced for the distribution of the Hypericaceae in SE Asia and surrounding regions. In this case I have split the dendrogram into five groups. The cut-off point is subjective and there are various ways in which the dendrogram could be divided.

Group 1 (South China, Thailand, Burma & Indonesia): Group 1 (shows the same results as Figure 5.6) shows that South China, Burma and Indonesia are the two regions that are most similar to Thailand in terms of species composition of the Thai Hypericaceae.
Group 2 (Vietnam): Group 2 shows Vietnam as a separate group. Vietnam is found to the east of Thailand.
Group 3 (Laos & Cambodia): Group 3 shows that Laos and Cambodia share similar species of Hypericaceae.
Cluster 4 (Malaysia & Philippines): Malaysia and the Philippines have similar species of Thai Hypericaceae.
Cluster 5 (Africa, Australia & South Asia & Himalaya): This group shows that Africa, Australia and South Asia and Himalaya share similar taxa of Thai Hypericaceae.

From the above dendrograms, it can be seen that the Thai Clusiaceae and Hypericaceae have similar patterns of distribution for some genera. Both dendrograms show Indonesia grouping with Thailand; therefore indicating similar species composition. This similar species composition seems to be based on the genus *Cratoxylum* rather than the Hypericaceae family as a whole.

A clear difference between the two families is the relationship between the Thai Hypericaceae and the region to the north of Thailand (South China). The genus *Hypericum* (Hypericaceae) has high species diversity in Northern Thailand. The species diversity decreases in the south of Thailand with only *H. japonicum* found outside the North and North-Eastern floristic regions of Thailand. Many of the same species of *Hypericum* occur in Southern China and Northern Thailand. The Thai Clusiaceae have the opposite pattern of distribution in Thailand. This family is more

species diverse in the south of Thailand and the numbers of species occurring gradually decrease in the north of Thailand. The Thai Clusiaceae share few of the same species with South China. Only the more hardy species of Clusiaceae that grow in various habitat types are found in the north of Thailand. These different patterns of distribution for the two families would be expected as the Hypericaceae are generally found in temperate and montane regions of the world (*e.g.* North Thailand, South China), whilst the Clusiaceae generally occur in tropical regions (*e.g.* South Thailand).

Other factors that may contribute to the different patterns of distribution for the two families in Thailand include the underlying geology and altitude. For example, much of the north and west of Thailand has limestone mountains. As limestone mountains are rich in calcium, only few genera and species can grow here. Some Hypericaceae taxa favour these calcium-rich conditions (*e.g. Hypericum siamense*, *Cratoxylum neriifolium*). Another example is in the south of Thailand where peat swamp forests are found. Again only certain taxa can grow in these everwet conditions. Some members of *Calophyllum* (Clusiaceae) favour these conditions (*e.g. Calophyllum pisiferum*, *Calophyllum teysmannii*). Altitude may also be another contributing factor to the different distribution patterns for the two familes. Some taxa only grow at high altitudes (*e.g. Hypericum napaulense* (above 1,400m above sea level) (Hypericaceae)), whilst some taxa are only found at sea level (*Calophyllum sclerophyllum*, *Kayea ferruginea* (Clusiaceae)) or low altitudes (*Calophyllum rupicolum*, *Calophyllum teysmannii*, *Calophyllum inophyllum*: up to 400m above sea level (Clusiaceae)). As the highest mountain range in Thailand is found in Northern Thailand (Chiang Mai), this may be a causative factor as to why the genus *Hypericum* is mainly concentrated in this region of Thailand as this genus grows mainly at high altitudes.

5.9 Distribution of Clusiaceae and Hypericaceae in Thailand (including habitat and ecology information)

a) Clusiaceae

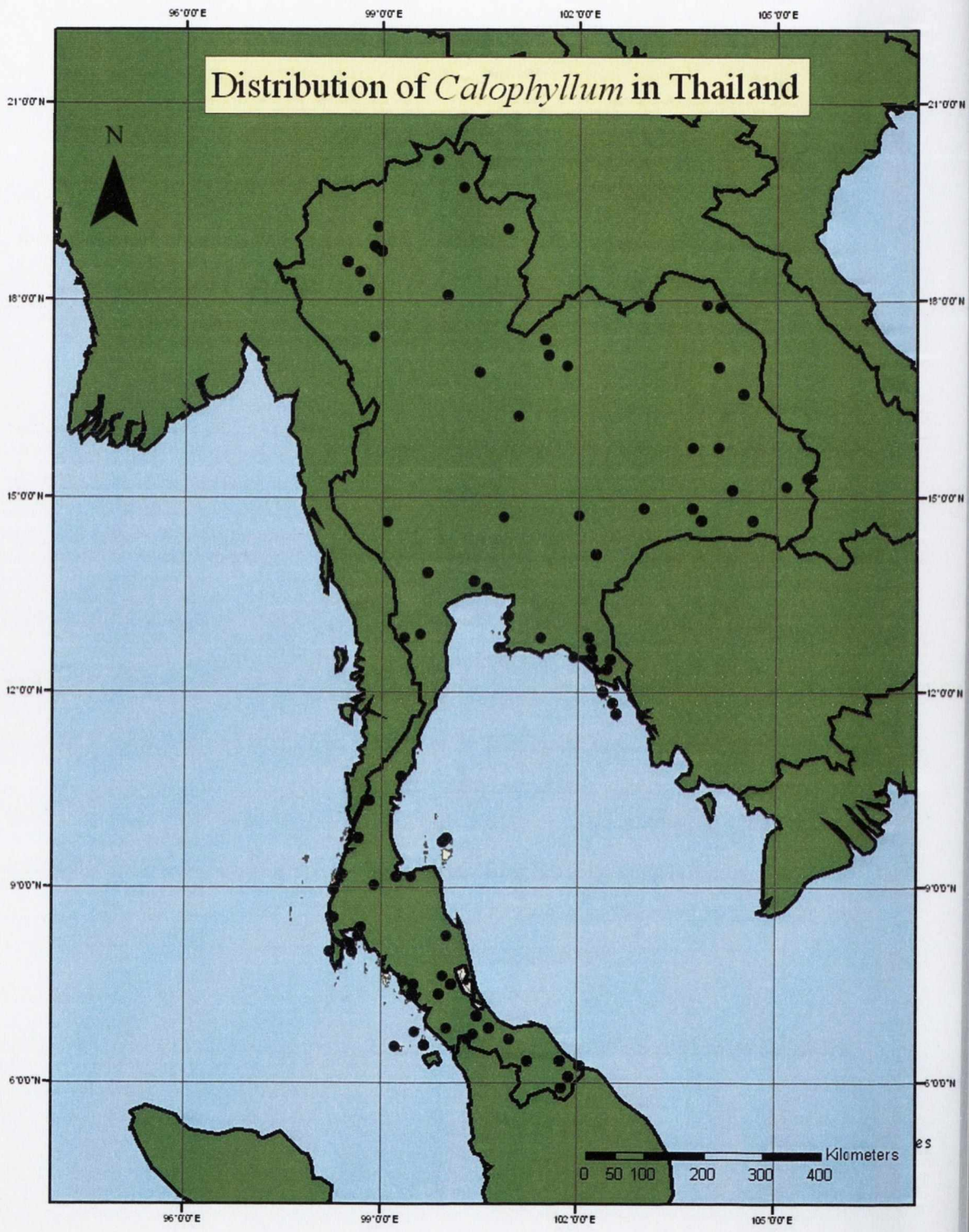
Clusiaceae in Thailand are found in a wide range of habitats including tropical, evergreen and deciduous forests, peat swamps, and seashores, by roadsides, along rivers and along paths in forests.

Members of this family are found at a wide range of altitudes from sea level to 1,950m above sea level.

(All locations are taken from examined herbarium specimens)

Calophyllum

This genus occurs throughout Thailand and is found in various habitats including tropical rainforests (*C. calaba*), evergreen forests (*C. pisiferum, C. macrocarpum, C. rupicolum, C. polyanthum, C. soulattri, C. thorelii, C. tetrapterum, C. touranense*), peat swamp forests (*C. pisiferum, C. rupicolum, C. sclerophyllum, C. teysmannii*), by the sea (*C. inophyllum*) and in hill evergreen forests (*C. touranense, C. polyanthum*). Members of this genus occur on a variety of substrates including sandy soil, granitic bedrock, limestone bedrock and peat. Some members of this genus are confined to Peninsular Thailand only (*C. rupicolum, C. sclerophyllum, C. symingtonianum, C. teysmannii, C. macrocarpum*). Some species occur in North, Northeastern and Peninsular Thailand (*C. calaba, C. inophyllum*). *C. polyanthum* is found mainly in Chiang Mai province in Northern Thailand, and also in the Northeast in Loei, Phetchabun and Phitsanulok and *C. touranense* is found in the Northeast and Eastern floristic regions only.



Map 5.4 Distribution of *Calophyllum* in Thailand.

Kayea

The genus, *Kayea* occurs in evergreen forests (*K. kunstleri, K. elegans,*) and along rivers (*K. kunstleri, K. ferruginea*). It occurs mainly on limestone (*K. kunstleri*). All species are confined to Peninsular Thailand.



Map 5.5 Distribution of *Kayea* in Thailand.

Mammea

In Thailand few herbarium collections exist for this genus. Members of this genus occur in hill evergreen forests (*M. harmandii*), mixed evergreen forests (*M. brevipes, M. siamensis*) and deciduous forests (*M. siamensis*). Both *M. harmandii* and *M. siamensis* are also cultivated in Thailand. They are found in limestone areas (*M. harmandii*) and on granite bedrock and sandstone (*M. siamensis*). *Mammea siamensis* is probably the most widespread species in Thailand with records of the species occurring in every floristic region in the following provinces: Chiang Mai (N), Phetchabun (NE), Nakhon Ratchasima (E), Phetchaburi (SW), Bangkok (C), Chon Buri (SE) and Songkhla (PEN). *Mammea brevipes* has records from one single changwat in Phecthaburi in the Southwest. *Mammea harmandii* is found in Central Thailand in Saraburi and the neighbouring province of Nakhon Ratchasima in the Eastern floristic region. One record also exists for this species in Chiang Rai province in Northern Thailand, but with no detailed locality given.



Map 5.6 Distribution of *Mammea* in Thailand.

Mesua

Mesua ferrea is widespread throughout Thailand. This tree is regularly cultivated in Thailand as it has big showy flowers. It also occurs naturally and is found in evergreen forests, deciduous forests and tropical rainforests.



Map 5.6 Distribution of *Mammea* in Thailand.

Mesua

Mesua ferrea is widespread throughout Thailand. This tree is regularly cultivated in Thailand as it has big showy flowers. It also occurs naturally and is found in evergreen forests, deciduous forests and tropical rainforests.



Map 5.7 Distribution of *Mesua* in Thailand (excluding cultivated specimens).

b) Hypericaceae

The Hypericaceae occur in many habitats throughout Thailand including deciduous and evergreen forests, rice fields, open scrub forest, along roadsides, swamp margins, in tropical seasonal rainforests and on exposed ridges.

Members of this family occur at a wide range of altitudes from sea level to 2,600m above sea level. The genus *Hypericum* is found at altitudes above 1,000m in Thailand.

Cratoxylum

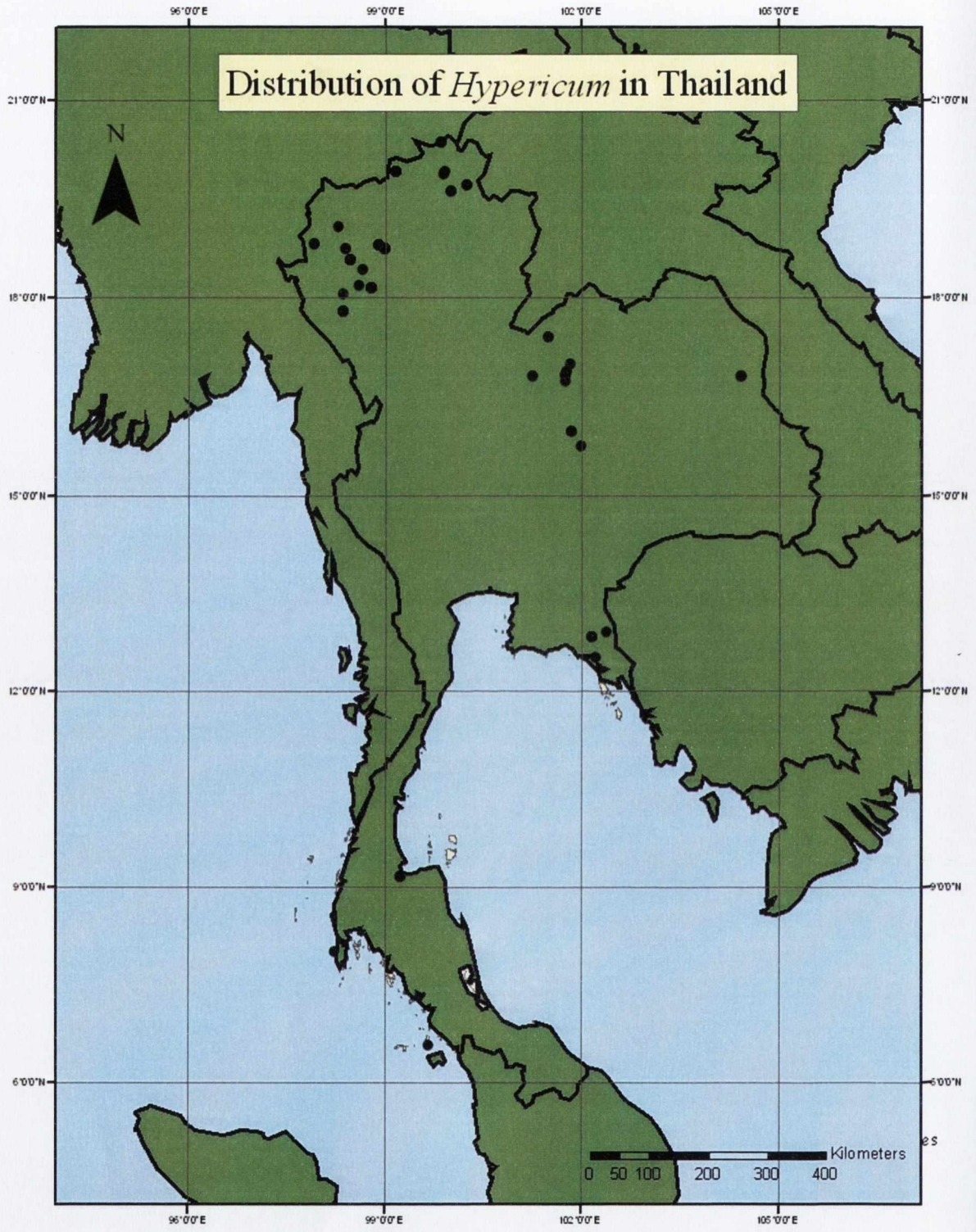
This genus is widespread throughout Thailand; it occurs in every floristic region and is found in a wide range of ecological habitats. Many species are found occurring in several areas of Thailand, *e.g. C. chinense*. This species is found in deciduous and evergreen forests, tropical rainforests, and savannahs, along swamp margins and at roadsides throughout every floristic region in Thailand. Another common species is *C. formosum* subsp. *formosum*, which is found in deciduous monsoon forests, evergreen forests, dry dipterocarp and bamboo forests in every floristic region also. Some species are adapted only to specific habitats. *Cratoxylum arborescens* is only found in Peninsular Thailand in peat swamp forests. Again this genus is found on a variety of substrates including limestone (*C. formosum* subsp. *formosum*), granite bedrock (*C. arborescens, C. formosum* subsp. *formosum*) and peat (*C. arborescens, C. maingayi*).



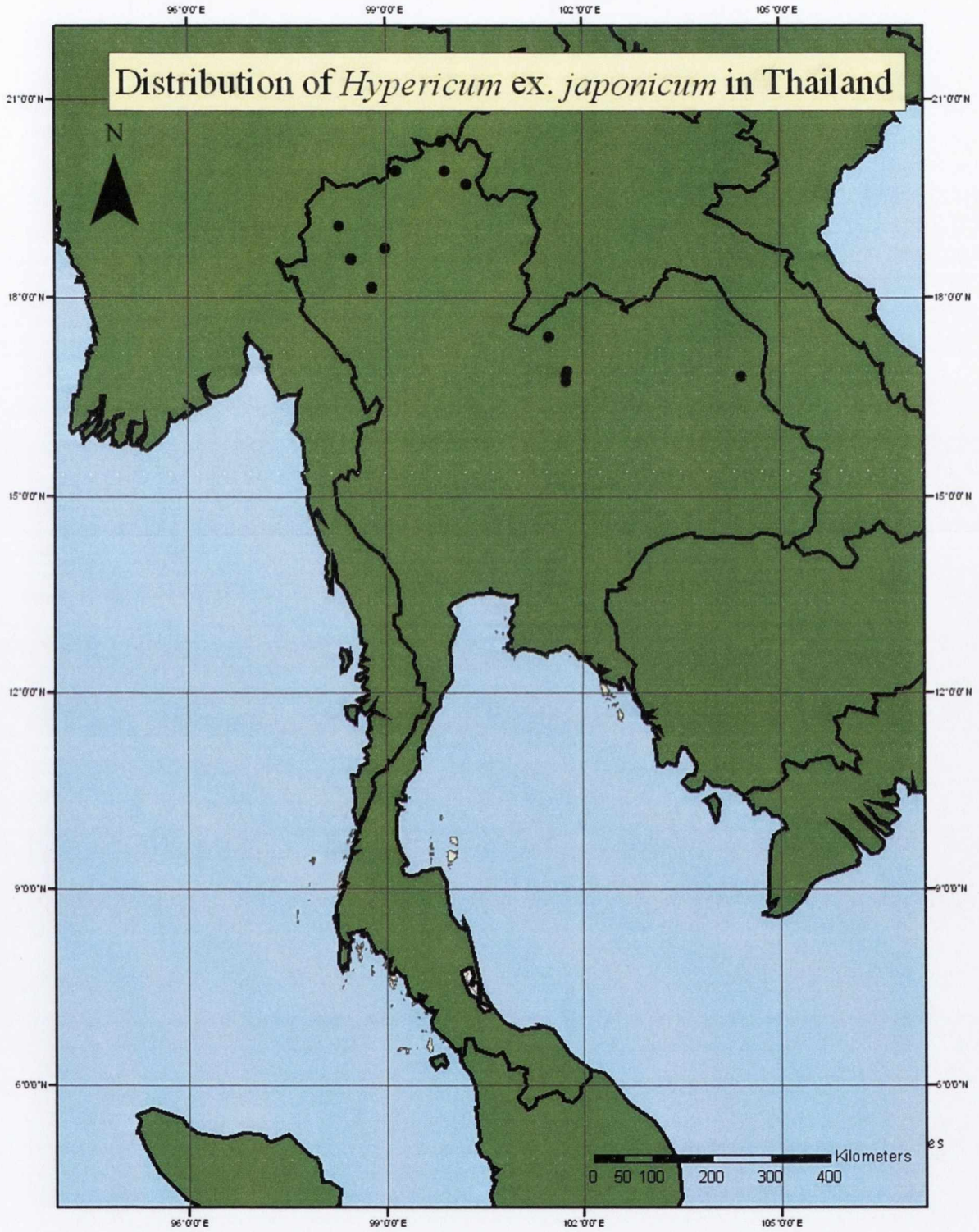
Map 5.8 Distribution of *Cratoxylum* in Thailand.

Hypericum

Members of this genus are usually found at higher altitudes above 1,000m on exposed rocky ridges (*H. siamense, H. patulum, H. henryi* subsp. *hancockii*), in fen or bog areas (*H. japonicum, H. napaulense, H. hookerianum*), in deciduous forests (*H. japonicum*), in evergreen forests (*H. hookerianum*) and in rice fields (*H. japonicum*). They occur on limestone and granite bedrock, with *H. japonicum* occurring mainly in moist or marshy areas. Members of this genus are found mainly in Northern Thailand in the provinces of Chiang Mai and Chiang Rai, with few records existing for the Northeast and Southeast. In fact, only *H. japonicum* occurs outside the North and Northeastern floristic regions of Thailand with records for this species in the following provinces: Mae Hong Son (N), Chiang Mai (N), Chiang Rai (N), Tak (N), Chanthaburi (SE), Surat Thani (PEN), Loei (NE), Udon Thani (NE), Sakon Nakhon (NE) and Chaiyaphum (E).



Map 5.9 Distribution of *Hypericum* in Thailand



Map 5.10 Distribution of the genus *Hypericum* excluding *Hypericum japonicum* in Thailand.

Clusiaceae

From the herbarium collections, it appears that the majority of the species from the genus *Calophyllum* are concentrated primarily in Peninsular Thailand, with the exception of two species (*C. polyanthum, C. touranense*), which are confined to the North and Northeast of Thailand. For this reason, it seems apparent that this genus has entered Thailand both from Indochina and Malaysia or its centre of distribution is in Thailand and taxa have moved from Thailand to the surrounding regions. Peninsular Malaysia shares many of the same species with Thailand including *C. macrocarpum, C. rupicolum, C. soulattri, C. tetrapterum* (Zakaria et al., 2007) and *Calophyllum* is widespread throughout Indochina.

The genus *Kayea* is also confined to the south of Thailand. All species occur south of the Isthmus of Kra. This suggests that this genus almost certainly entered Thailand from a south-easterly direction from Malaysia and Indonesia and this would also be supported by the fact that *Kayea* is not widespread throughout Indochina and only the species *K. ferruginea* occurs naturally in Indochina while the remaining species (*K. elegans, K. kunstleri*) are found in Malaysia and Indonesia. This suggests that the genus has its centre of distribution in the southeast and it has dispersed and speciated as it spread in a westerly direction and that Thailand is at the western limit for this genus.

Only one record for *Mammea* exists in Indochina (Laos) (Newman et al., 2007) but again this is most likely due to the poor collecting activity and lack of conservation strategies. Malaysia shares two of the same species of *Mammea* with Thailand, namely *M. brevipes* and *M. siamensis*. Both of these species occur in various areas of Thailand but perhaps they entered Thailand again from the south but this is hard to comment on, as there are no records for this genus in any other country in SE Asia.

Hypericaceae

The Hypericaceae family occurs throughout Thailand with the genus *Hypericum* being concentrated primarily in Northern Thailand. For this reason, northern taxa probably entered SE Asia, in particular Thailand from India, Himalaya, South China and Burma. The genus *Hypericum* is found in Northern Thailand primarily in Chiang Mai province, with only few species occurring outside this province and only *H. japonicum* occurring outside the North and Northeastern floristic regions and its' southernmost boundary is at

Satun (Changwat No. 72). It is probably confined to this area due to more favourable climatic conditions as Northern Thailand has a cooler climate than the warmer south. It is possible but unlikely that the high density of records for this genus in Chiang Mai is due to the relatively high number of plant collections for this province. 20% of all collections in Thailand come from this single Changwat (Parnell et al., 2003). It has been shown that collecting activity in Thailand is uneven and erratic (Parnell et al., 2003), so for this reason, the genus most likely occurs in other unsurveyed (or less surveyed) surrounding Changwat. This genus is widespread throughout this Indo-Burmese, Sino-Himalayan region.

The genus *Cratoxylum* has a wide distribution range in Thailand, Burma, South China, India and Himalaya. The easternmost boundary for this genus appears to be the Philippines as there are no records for any countries more eastern than this. The genus is also restricted to Asia, with no records found in America, Africa, Europe or Australia (Stevens, 2007).

5.10 Distribution of Cultivated Species

It is hard to comment on the distribution of cultivated species as they are distributed by man and therefore will have a wider distribution range. Also herbarium collections for cultivated species are usually underrepresented. For example *Mesua ferrea* is widely cultivated in Thailand but there are only 16 herbarium collections for cultivated specimens and a total of 110 collections for *Mesua ferrea* in Thailand. In Southeast Asia, *Mesua ferrea* is cultivated as an ornamental tree as it has big showy flowers. This species has become naturalised in Thailand. *Clusia major* occurs in Thailand and this is also a cultivated species. Only one record for this species exists to date and there has been no evidence of it becoming naturalised in Thailand. There are no records for this species from other Southeast Asian countries.

5.11 Plant collecting density and spread: Clusiaceae and Hypericaceae of Thailand

From the herbarium material available within Thailand and from worldwide herbaria, the collection density of Clusiaceae in Thailand is 0.2 collections per $100km^2$ (1,028 collections) and the collection density of Hypericaceae in Thailand is 0.3 collections per $100km^2$ (1,317 collections). This number is well below the mean number of collections

in Thailand which is 1.3 collections per 100km^2 (Parnell, 2000). However, this figure itself is very low and categorises Thailand as a generally undercollected country (Parnell et al., 2003).

An analysis of collection density for each species in Thailand was undertaken. The number of collections within forest per 100km^2 per Changwat was calculated. The figure presented for each species is based on the type of ecological habitat that each species occurs in, and the size (in km^2) of that habitat in Thailand.

Table 5.2 Number of collections for each species within forest per 100km^2 per Changwat.

Species	No. of collections within forest per 100km^2 per Changwat
Calophyllum inophyllum	0.048
Calophyllum pisiferum	0.026
Calophyllum soulattri	0.020
Calophyllum calaba	0.075
Calophyllum tetrapterum	0.029
Calophyllum teysmannii	0.020
Calophyllum dryobalanoides	0.005
Calophyllum macrocarpum	0.007
Calophyllum rupicolum	0.004
Calophyllum sclerophyllum	0.010
Calophyllum symingtonianum	0.000
Calophyllum thorelii	0.017
Calophyllum touranense	0.001
Calophyllum polyanthum	0.056
Total (*Calophyllum*)	**0.318**
Kayea elegans	0.007
Kayea ferruginea	0.017
Kayea kunstleri	0.156
Total (*Kayea*)	**0.180**

Species	No. of collections within forest per 100km^2 per Changwat
Mammea siamensis	0.038
Mammea brevipes	0.005
Mammea harmandii	0.006
Total (*Mammea*)	**0.049**
Mesua ferrea	0.064
Total (*Mesua*)	**0.064**
Cratoxylum chinense	0.181
Cratoxylum formosum subsp. *formosum*	0.098
Cratoxylum maingayi	0.017
Cratoxylum neriifolium	0.031
Cratoxylum formosum subsp. *pruniflorum*	0.099
Cratoxylum arborescens	0.023
Total (*Cratoxylum*)	**0.449**
Hypericum japonicum	0.086
Hypericum napaulense	0.000
Hypericum hookerianum	0.042
Hypericum henryi subsp. *hancockii*	0.015
Hypericum siamense	0.015
Hypericum patulum	0.000
Total (*Hypericum*)	**0.158**

It can be seen that all of the species are well below the mean number of collections for Thailand. *Calophyllum* and *Cratoxylum* have the highest number of collections for the Clusiaceae and Hypericaceae families respectively in Thailand, but both fall well below the mean number of collections for Thailand.

Within the genus *Calophyllum*, *Calophyllum calaba* has the highest number of collections, followed by *C. polyanthum* and *C. inophyllum*. All of these species are found in every habitat type (see vegetation types above) in Thailand and so are more easily collected than those species with specific habitat types such as *C. teysmannii* which only grows in peat swamp forests. All of the collection density figures for this genus are very low, even though some species are widespread throughout Thailand and are found growing in all vegetation types. *Calophyllum calaba* with the highest collection density has only 0.001 collections per km^2.

The genus *Kayea* only occurs in Peninsular Thailand. No records exist for this genus above the Isthmus of Kra. Again all collection densities are extremely low with *K. kunstleri* having the highest collection density at 0.156 collections within forest per $100km^2$ per Changwat, which is only 0.002 collections per km^2 which is a substantially low figure.

All species within the genus *Mammea* occur in evergreen forests and *M. brevipes* is also found in deciduous forests. Only the species *M. siamensis* is relatively widespread, with *M. brevipes* and *M. harmandii* only having few records in Thailand. All collection density figures are very low.

Mesua ferrea occurs in all habitat types in Thailand but has a low collection density at 0.064 collections within forest per $100km^2$ per Changwat.

The genus *Cratoxylum* has the highest collection density (0.449 collections per $100km^2$) but it is still extremely low. *Cratoxylum chinense, C. formosum* subsp. *pruniflorum* and *C. formosum* subsp. *formosum* have the highest collection densities respectively and all three species occur in every habitat type in Thailand and are more widespread than

other species with specific habitat requirements, *e.g. C. maingayi* which is found in peat swamp forests. However the collection densities are all very low.

All species in the genus *Hypericum* occur in deciduous forests and bog areas. Most only occur in the north and northeastern floristic regions and all have an extremely low collection density with *H. japonicum* having the highest collection density at 0.086 collections within forest per 100km^2 per Changwat.

The number of collections per Changwat was also calculated and it was found that Chiang Mai (Changwat No. 2) had the highest number of collections per Changwat for all genera and the total number of collections (%) was 19.7%. It was found that the distribution of collections is very uneven in Thailand and also that some Changwat had zero collections. This result fits with the results of Parnell et al. (2003), in which it was found that 19.9% of all collections in Thailand came from Chiang Mai and three Changwat had no collections for any of the surveyed families and eleven Changwat had ten or fewer collections.

The collection density for each genus per 100km^2 per Changwat was also calculated and it was found that Phuket (Changwat No.67) had the highest collection density for the genera *Calophyllum* (Clusiaceae) (1.6 collections per 100km^2 per Changwat) and *Cratoxylum* (Hypericaceae) (3 collections per 100km^2 per Changwat). The high collection density for this Changwat may be because it is an island and islands are more popular to collect on (Parnell et al., 2003).

These results reiterate the results found by Parnell et al. (2003) in which it was found that the collecting activity in Thailand is unevenly spread and also that Thailand is an undercollected country.

5.12 Disjunct Distributions

Species with disjunct distributions may previously have had a wider range of distribution than at present or the distribution may have since been fragmented or could be continuous with no existing collections.

a) Disjunct Distributions within SE Asia and the Surrounding regions

An example of this is the following species: *Hypericum hookerianum* (South China, Burma, Thailand, Java (Indonesia)). Perhaps this species moved from Thailand to Indonesia when the Sunda shelf was exposed and when these islands were joined to the mainland (Heywood et al., 1995).

b) Disjunct Distributions within Thailand

In Thailand, there are many apparent gaps. Within the Clusiaceae family, the genus *Mammea* has no collections for the northeast, east and south of Thailand except for *Mammea siamensis*, which is also cultivated. *Mammea* occurs mainly in the southwest and central floristic regions, with few specimens from Peninsular Thailand. The genus *Mesua* does not occur in the northeast or centre of Thailand, but it is found in neighbouring Laos and Cambodia. In the Hypericaceae family, the genus *Hypericum* is mainly concentrated in the north and northeastern regions of Thailand, with records for *Hypericum japonicum* in the southeast and the peninsula. At present it is difficult to know if these gaps are real or if they are a result of the low numbers of collections for the two families in Thailand. However, it is most likely that at least some of these disjunctions are due to the low collection density for the families and because a lot of collections come from easily-accessible areas such as islands, trails in national parks and along roads, and fewer collections come from areas with poor communications which are difficult to access (Parnell et al., 2003).

5.13 Endemic Taxa and Conservation

From this study, it has been shown that some taxa are endemic to Thailand. Of the 21 Clusiaceae taxa studied, 1 (4%) is endemic to Thailand (*Mammea harmandii*). *Mammea harmandii* occurs in several provinces in Thailand (Chiang Rai, Nakhon Ratchasima and Saraburi). From the locations available on the herbarium specimens, this species does not appear to be recorded from inside any National Parks or protected areas. It has been recorded in the grounds of a temple in Chiang Rai and the locations on the specimens from Nakhon Ratchasima are districts within the Changwat. The specimens from Saraburi are from a forest but this forest does not appear to be in a

protected area. Therefore this species may or may not occur within protected areas in Thailand.

Of the 12 Hypericaceae taxa studied 1 (8.3%) is endemic to Thailand (*Hypericum siamense*). *H. siamense* occurs only in Pha Daeng National Park on Doi Chiang Dao. Pha Daeng National Park covers an area of 1,123.336km^2 in Chiang Mai in Northern Thailand.

Cratoxylum formosum subsp. *pruniflorum* is the only species found to be endemic to both Thailand and the neighbouring countries (Burma, South China, Cambodia, Laos and Vietnam). All other species (excluding those endemic to Thailand) from both families were found in some of Indochina and the surrounding regions listed in Table 5.1 (above). The number of endemic species may be overestimated as Thailand has a higher recent collecting density compared to surrounding countries which have yet to be fully explored botanically (Parnell et al., 2003).

At generic level, the Clusiaceae has three genera endemic to Asia, namely *Poeciloneuron, Mesua* and *Kayea*. Of these three, the genera *Mesua* and *Kayea* occur in Thailand. The genus *Poeciloneuron* has three species, which are found in the Western Ghats of India (Stevens, 2007). The Hypericaceae has two genera endemic to the region, *Cratoxylum* and *Lianthus*. *Cratoxylum* is found in Thailand and *Lianthus* is only known from Yunnan, China (Stevens, 2007).

The collections of endemic species for the Clusiaceae and Hypericaceae families are not sufficient. As discussed earlier, some endemic species have a restricted distribution due to special requirements. Most of the genus *Hypericum* is restricted to altitudes above 1,000m and on exposed edges. Therefore, such areas as these need to be protected for conservation. Even though most of the collections for this genus have been made inside a National Park, some areas are still at risk from destruction due to the increasing number of tourists venturing from marked trails and also due to natural and manmade fires.

Due to the poor data available for Burma, Cambodia, Laos and Vietnam, it is difficult to interpret the distribution range of the Thai taxa. Most species found in Thailand are

likely to be found in neighbouring countries but are as yet uncollected. If they only occur in Thailand, then these species are probably only found here due to specialised niche requirements or due to the presence of natural barriers. For this reason much more fieldwork needs to be undertaken in the neighbouring countries of Thailand and also in areas of Thailand which are poorly collected (*e.g.* along parts of the Lao and Cambodian borders and in areas with poor communications) (Parnell et al., 2003).

Regarding Burma, Cambodia, Laos and Vietnam, these countries have conservation strategies set up. However there is little active management. For example Laos has 17 forest reserves set up covering 1,280km^2 but they have no protective measures implemented (Heywood et al., 1995) and Burma only has an alarming 2.1% of the land surface legally protected (Clarke, 1999).

Overall more collections are needed and an effective management strategy needs to be implemented in this region in order to conserve and protect the remaining biodiversity.

Chapter 6

Computer-based key

6.1 Introduction

One of the main aims of this project is to produce a computer-based web-based multi-access key for the Flora of Thailand. No element of the flora has yet been published in this format. This has been noted by Middleton (2003) who indicated that the project would benefit from a web accessible format because there are always changes which need to be made to the Flora especially for an undercollected region like Thailand and that this format allows for updates and changes to be made in a much easier way than do printed media.

6.2 The importance of computer-based web-based keys

Taxonomists publish information about biological organisms that is of great importance to the scientific community. However, this information is published in journals or books such as floras or monographs and may be difficult to access, (Gewin, 2002, Bisby, 1984) use and understand. Godfray (2002) noted that taxonomy is an information-rich subject which often requires many images and illustrations. Based on this he noted that the web is the perfect place for this information to be conveyed as the output of much taxonomy is expensive printed monographs or specialised journals, and not attractive, easily-accessible places like the World Wide Web. The World Wide Web allows for images and illustrations to be uploaded and descriptions and other information updated without the expense of having to print later editions or supplements. Published texts can therefore be considered to limit the usefulness of the information contained. For example, if one wishes to find out all of the native species that grow in Ireland and have white flowers, then one would have to extract from Webb et al. (1996) every individual description and manually note which species have white flowers and are native to Ireland. However, such information as this can be stored in databases and makes tasks such as this simple and obtainable, even to those who are not taxonomists or bioinformatists (Schram, 2006). It is time to 'envision virtual monographs, revisions, floras, and faunas' as 'living dynamic works rather than static documents' (Wheeler at al., 2004).

Therefore, online databases allow for far easier data revision and data retrieval (Schram, 2006, Allkin & Bisby, 1988) and for a wide range of uses. They enable taxonomists to provide more flexible information services to the scientific community and to the general public (Schram, 2006, Allkin & Bisby, 1988).

6.3 The use of computer-based web-based databases to date

So far, the majority of botanical databases are curatorial systems designed to manage specimen collections (Pankhurst, 1984). These databases contain little descriptive information about specimens or taxa.

Those taxonomic databases that do exist are usually individual databases that taxonomists have set up to aid their personal work (Shao et al., 2002). They usually vary in data format and both the hardware and software systems also vary. Therefore, these inconsistencies and variations among interface and hardware and software requirements have hindered the integration and distribution of these databases (Shao et al., 2002).

6.4 Taxonomy: a dwindling profession

In order for taxonomy to shed its dusty image and become an attractive and vibrant area of science, an evolution in the methods used is of utmost importance (Wheeler, 2004, Gewin, 2002, Godfray, 2002, Schram et al., 1996). It is becoming evermore important now that publications are available online and taxonomic identification keys should be no exception to this. This medium allows for the dwindling number of taxonomists (6,000 taxonomists worldwide (Wilson, 2003)) to work together and access information with less difficulty. 'Sharing complete and updated biodiversity information is fundamental to economic utilisation and biodiversity conservation' (Shao et al., 2002).

The transition from traditional taxonomy to a combination of the old methods with new procedures and technology will make this essential area of Biology more appealing and exciting to the next generation of taxonomists. These new methods of scientific research and presentation of information are more up to date and less wasteful of labour than the current procedures of taxonomy (Godfray, 2002, Heywood, 1984).

That is not to say that this transition will be easy and quick to achieve. Schram (2006) and Wheeler et al. (2004) noted that one of the main problems facing systematists today is the lack of information available about existing species and collections and the misidentification of so many organisms and plants. However, even with these difficulties and time consuming jobs which need to be completed before information technology can be fully implemented, Schram (2006) indicated that it is of extreme importance that these tasks are completed, even if taxonomists become distracted from describing new species and are slowed down in their current work.

One such organisation that is trying to combat the problem of the declining number of systematists is the American National Science Foundation (NSF). In 1995 NSF set up a program called Partnerships for Enhancing Expertise in Taxonomy (PEET) which was specifically designed to address the problem of a lack of trained taxonomic specialists 1) in poorly known groups and 2) that will be the next generation of researchers in this field (Schram et al., 1996). All projects that apply for funding from PEET have to train new taxonomists and they must also convert current expertise into electronic databases. All products produced must also have broad accessibility to the scientific community (PEET Website, accessed 7/10/08). This initiative is a new and exciting way to allow young taxonomists to learn from highly trained experts in their chosen field and to carry on this work.

6.5 The changing face of taxonomy

The face of taxonomy is now slowly beginning to change. At present, there are databases available online that deal with particular groups of organisms *e.g.* Crayfish Home Page (http://crayfish.byu.edu), Antbase (http://www.antbase.org), FishBase (http://www.sp2000.org), AlgaeBase (http://www.algaebase.org/) World Virus Database (http://www.ICTVonline.org), Legumes (http://www.ildis.org) and IOPI (http://www.iopi.org) (Schram, 2006, Shao et al., 2002). These databases allow for basic information to be accessed online and also for interactive identification to be carried out. For example, FishBase, includes basic information on the worlds' fishes, it also has a specimen photo for every species, distributional data, bibliographic data, a curatorial database and an inquiring system for Chinese fish names of the world fishes (Shao et al., 2002). The Crayfish Home Page is an easy to use site which contains all sorts of practical and useful data, including a complete taxonomy of the group, regional

faunal lists, photographs of species and biogeographic distributions, as well as links to other sites (Schram, 2006). It is easy to navigate and universally accessible to the general public as it does not assume that the user will know a name to begin with before any data can be accessed (Schram, 2006). It is 'an easy to use bottom up site' (Schram, 2006).

Another noticeable change is the expansion of databases that were previously used as curatorial databases only. One such example is the BRAHMS (Botanical Research and Herbarium Management System) database software. This was created in 1985 and is now used worldwide not only for curating herbaria, but also for digitising species and collection data, for catalysing botanical research initiatives, for underpinning conservation decision-making and for facilitating the publication of floras, monographic accounts and checklists (BRAHMS Website, accessed 18/5/08). One of the principle aims of BRAHMS is to encourage the online publication of floristic and monographic datasets.

To date, even though there are noticeable changes occurring in the use of the Internet and interactive keys and databases to convey scientific information, there has been little collaboration between groups working on different organisms and little effort has been made to gather all of this information and make it available in one giant database. This is also starting to change in the form of different initiatives. Examples of such are the All Species Foundation (http://www.all-species.org) and the Catalogue of Life Project (http://www.catalogueoflife.org). The former aims to name and describe all living species and make it available online (maybe overoptimistically, within a single human generation) and also wants to encourage the creation of digital images of at least half of all type specimens (Gewin, 2002), thus making them easily accessible. The latter aims to establish a federation of interoperable databases documenting and describing all of the species currently known to science by 2011 (Bisby et al., 2002; Gewin, 2002). To date, this project consists of a compilation of approximately 50 databases (Bisby et al., 2002). It is estimated that the finished project will contain approximately 200 component databases (Gewin, 2002).

6.6 Linnaeus II and the Clusiaceae and Hypericaceae computer-based key

Linnaeus II Software was chosen in order to produce this database and key. This software is specifically designed for taxonomy and biodiversity specialists. Linnaeus II software is an instrument which can be used by specialists to create their own biodiversity and taxonomic database. The software allows the user to create databases, identification keys, distribution maps and utilise images.

Linnaeus II software was developed by the ETI Biodiversity Centre. This is a non-governmental organisation and it is in operational relation with UNESCO (van Hertum & Schalk, 2004). This centre is dedicated to improving the quality, quantity and accessibility of taxonomic and biodiversity information. Through the work of this organisation, such information is becoming more readily available on a global scale. The ETI's mission is to create innovative computer-based, web-based systems which facilitate biodiversity documentation and species identification (van Hertum & Schalk, 2004).

On completion, all new computer-based keys are peer-reviewed before being electronically published and made available to the public via the World Wide Web or in CD format. Therefore by completing this key, I will make a contribution to the completion of a world biodiversity database.

6.7 Materials and Methods

Materials: The licence for the Linnaeus II software (Windows Version 2.5) was obtained from the ETI Biodiversity Centre in the Netherlands through the following website: http://www.eti.uva.nl. This software runs on PC and Mac computers. In this case, a PC was used (Dell Optiplex GX620). The system requirements for a PC and Mac are an up to date Windows package such as Windows Vista or Windows XP and Mac OS X native (version 10.1 or higher) respectively. Windows XP Professional was used for this project.

Methods and Results: The Linnaeus II user guide was used in order to learn how to upload images, to insert species descriptions and to create identification keys and databases.

The following is a brief overview of the functions of each module available on the software. A brief list of methods used to upload data to each module is also provided with each module overview. Please see Appendix 4 (accompanying CD-ROM) for the finished computer-based key. The modules used were standard modules available with the software:

The Navigator Module

The interface of the Linnaeus II software is standard. This offers a uniform product which makes the database and keys more accessible and transferable. The Navigator module is the central point of the project and is used to navigate around Linnaeus II. The following screenshot shows the standard interface from the Phylogenetic Revision of the Thai Clusiaceae (Subfamily Kielmeyeroideae) & Hypericaceae:

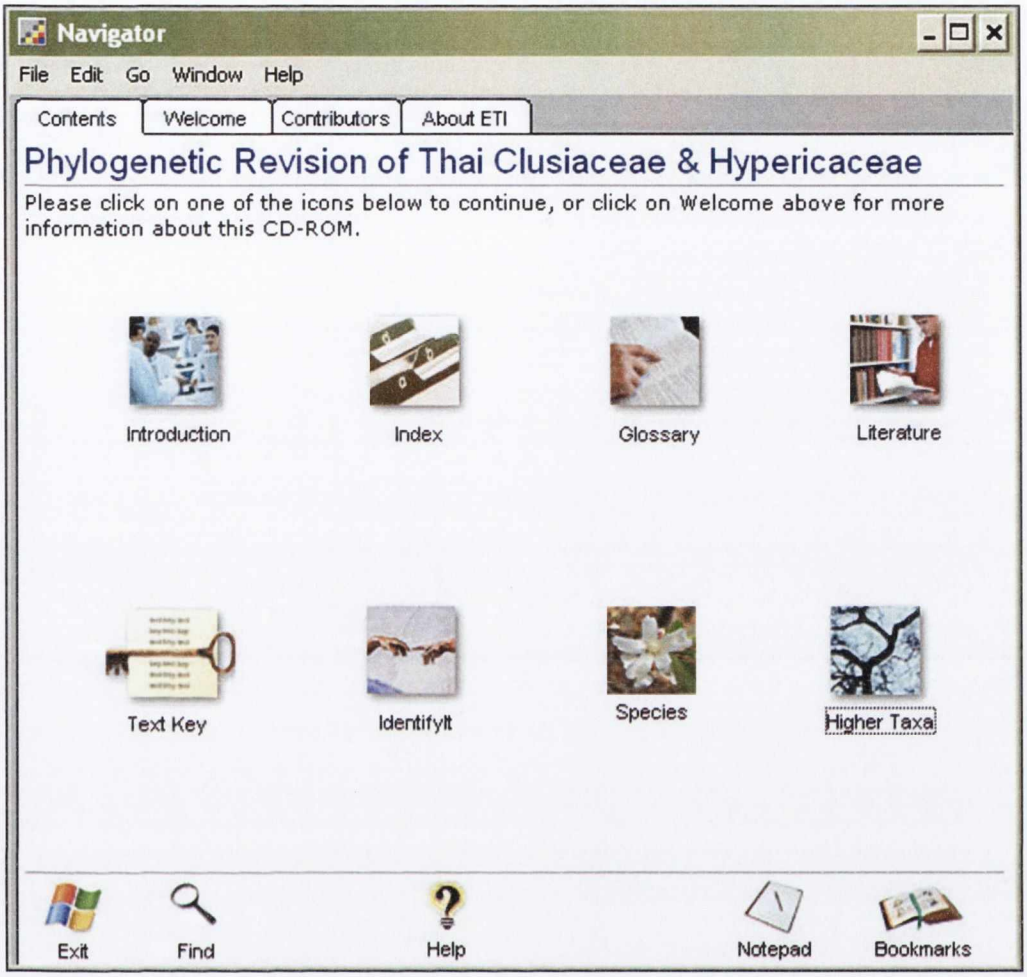


Figure 6.1 Standard Interface on opening Linnaeus II software. Navigator module.

Figure 6.1 shows the Navigator module with the standard modules available on Linnaeus II. These include: the Introduction module, the Index module, the Glossary module, the Literature module, the Text Key module, the Identify It module, the Species module and the Higher Taxa module. Each of these modules will be explained in more detail below.

The Introduction Module

This section allows the user to input general information and introductory material about the subject of study. In this section, I have included a general introduction to the two families, as well as an introduction to the sister groups of the Clusiaceae and Hypericaceae. This module contains background information on Thailand, such as the size of the country, the number of inhabitants, information regarding the economic

growth and development of Thailand and information about the number of endangered and threatened plant species in Thailand. A summary of the Flora of Thailand Project is included here also, as well as some brief notes about the descriptions and the sources of the illustrations and images used. This module also contains data and information on the identification characters and measurements used. The information found in the Introduction module is edited versions of the material included in Chapters 1 and 2 of the thesis respectively. Figures 6.2 – 6.4 show screenshots of some of the pages from the Introduction module (See Appendix 4 for the completed introduction):

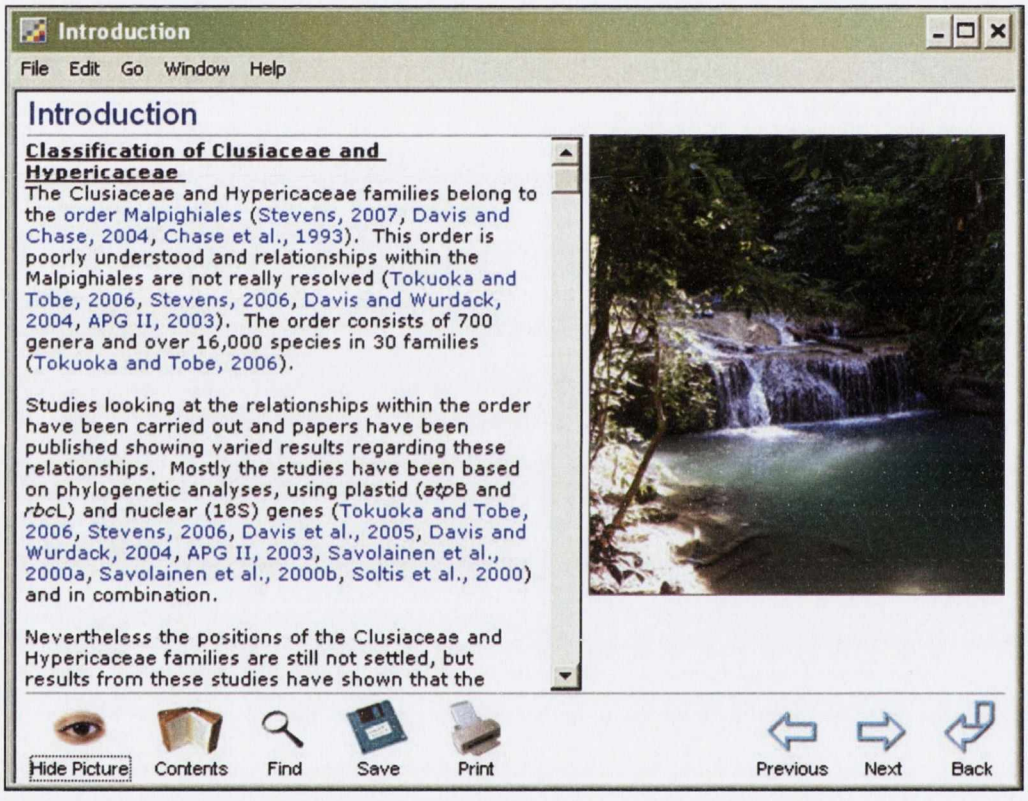


Figure 6.2 Introduction Module. Classification of the Clusiaceae and Hypericaceae. (All words in blue are hyperlinked to references, species or the glossary).

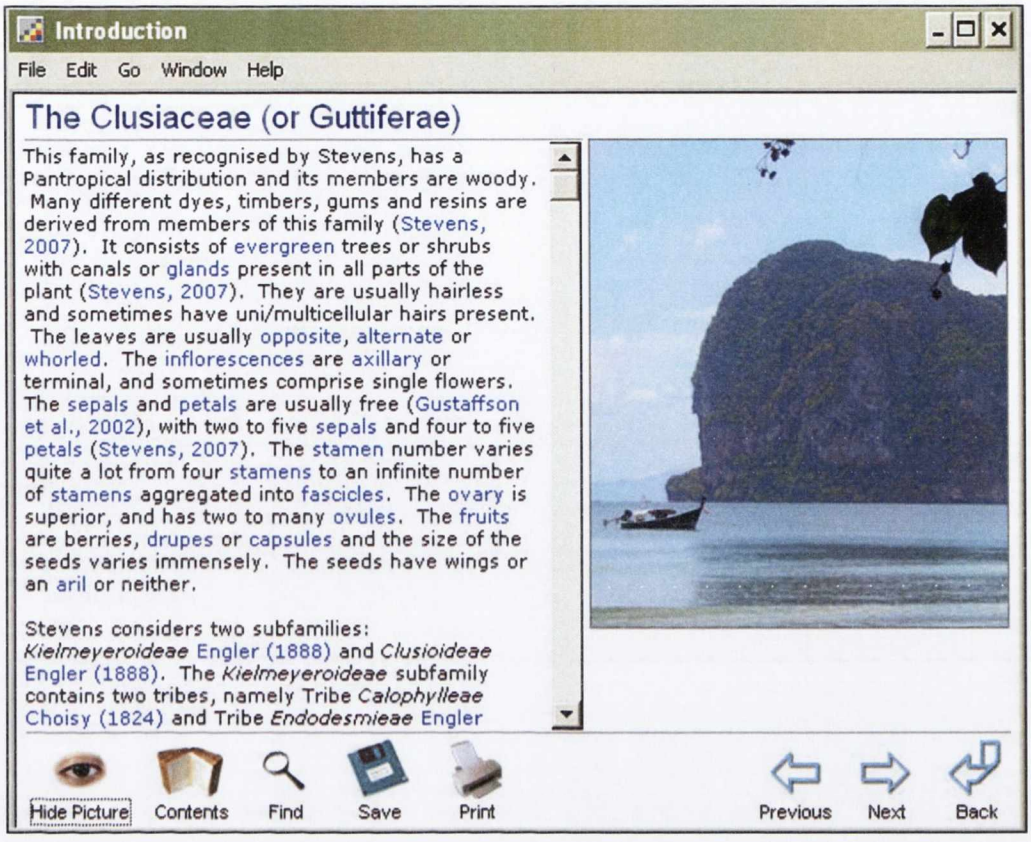


Figure 6.3 Introduction Module. The Clusiaceae family.

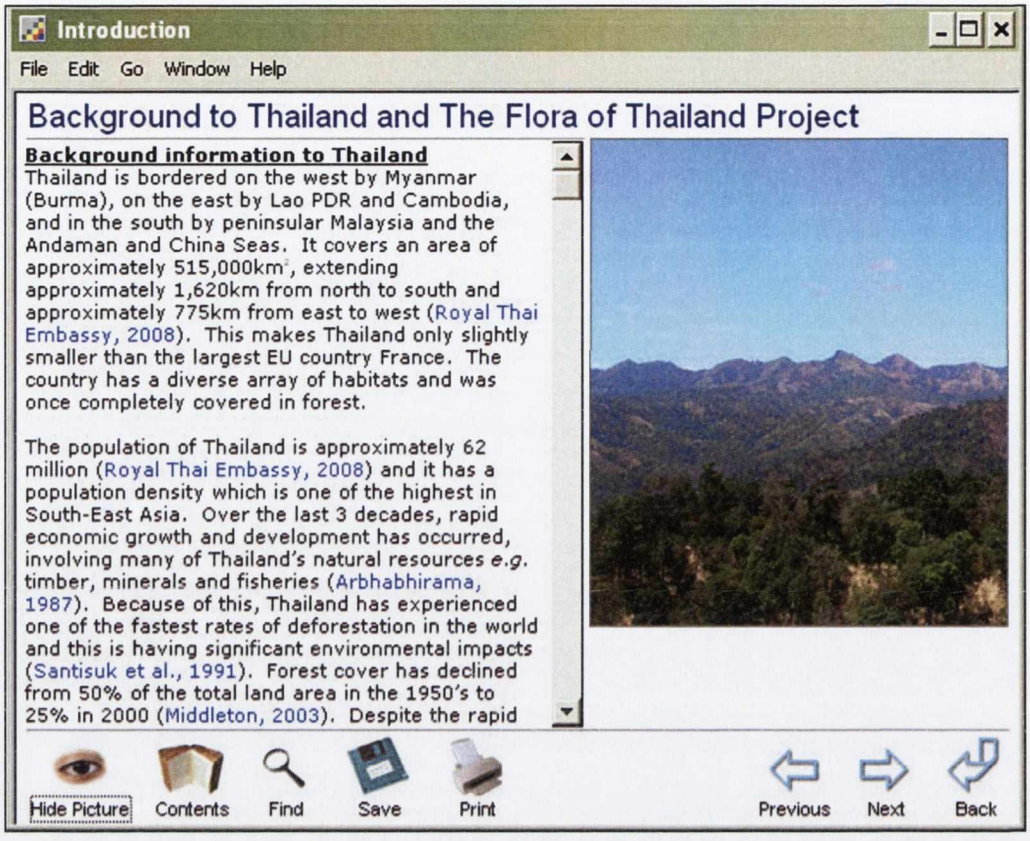


Figure 6.4 Introduction Module. Background information on Thailand and information on The Flora of Thailand Project.

The Introduction Module Methods

In order to upload information to the Introduction Module, the following steps were completed:

- To open the Introduction module, the icon in the Navigator window was clicked.
- To add information to the Introduction, the lock icon was clicked to unlock the page.
- New pages were added by choosing Entry>New Topic and then the name of the new page was entered *e.g.* Background to Thailand and The Flora of Thailand Project.
- The order of the pages was then changed by selecting Entry>Sort Topics. This opened the Sort Topics box and from here the pages were manually moved up or down in order of preference.

The Index Module

This lists all of the species and taxa described in the database modules. It also includes synonyms, common names and epithets. These are listed in alphabetical order. In this case the Index module includes 33 species and all synonyms associated with the 33 taxa of Thai Clusiaceae and Hypericaceae as detailed in Chapter 3 of the thesis and also in the Species Module of the accompanying CD. Figure 6.5 shows a screenshot of a page from the Index module, showing the species found in the database in alphabetical order.

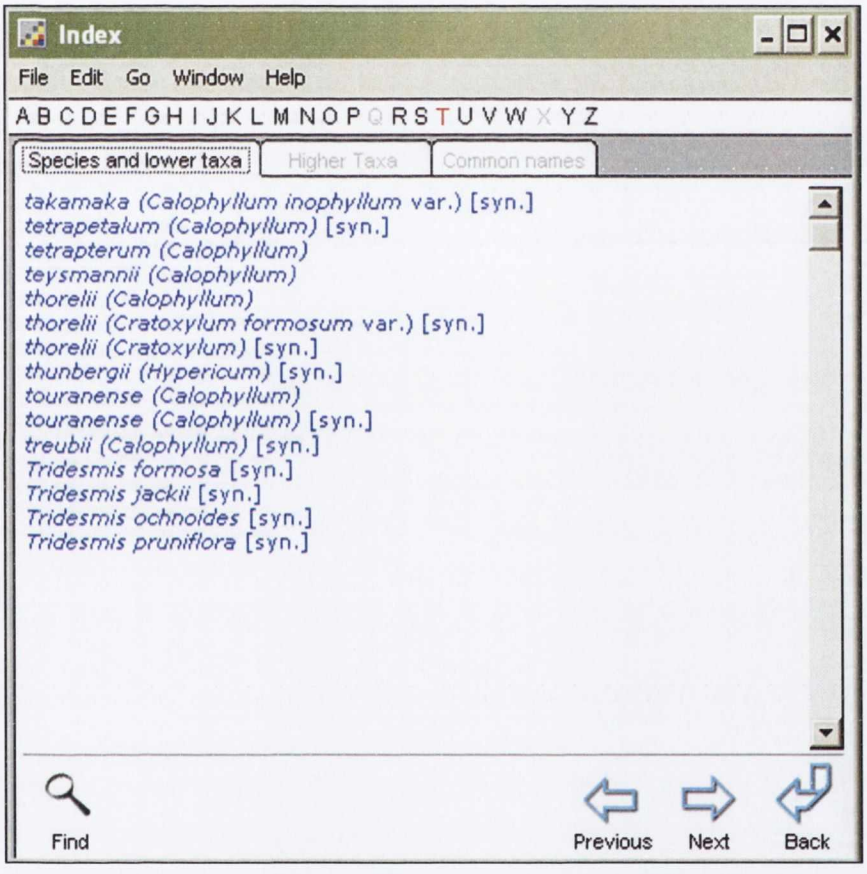


Figure 6.5 The Index Module showing the species beginning with 'T'.

Each letter highlighted in black contains a species or lower taxa and can be viewed by clicking the letter of choice. This opens the chosen page. The above screenshot shows the species beginning with the letter 'T,' which is highlighted in red in the Alphabet list.

The Index Module Methods

- The Index Module is accessed via the icon in the Navigator window.
- The text cannot be edited in the Index Module as it is a summary of the information that exists in the database. However the lists can be updated. This was done in the following way: the Entry tab was clicked and Update Index was chosen from the menu. This can take a few minutes depending on the number of taxa in the database.

The Glossary Module

This contains definitions for the terms used throughout the keys and species descriptions. This makes the key more accessible to people who are not specialists in these families. Terms are described here, and where possible, have accompanying illustrations and synonyms of the botanical terms. It contains one page for each term. Terms, definitions and illustrations were taken from Webb et al. (1996) and Harris et al. (2004) (with permission). Some of the terms described here are also described in Chapter 2 (General Morphology) and all terms with accompanying definitions are also included in Appendix 5 in the thesis. Figure 6.6 shows an example of one of the terms in the glossary with an accompanying illustration. See Appendix 4 for the completed glossary with definitions, images and synonyms.

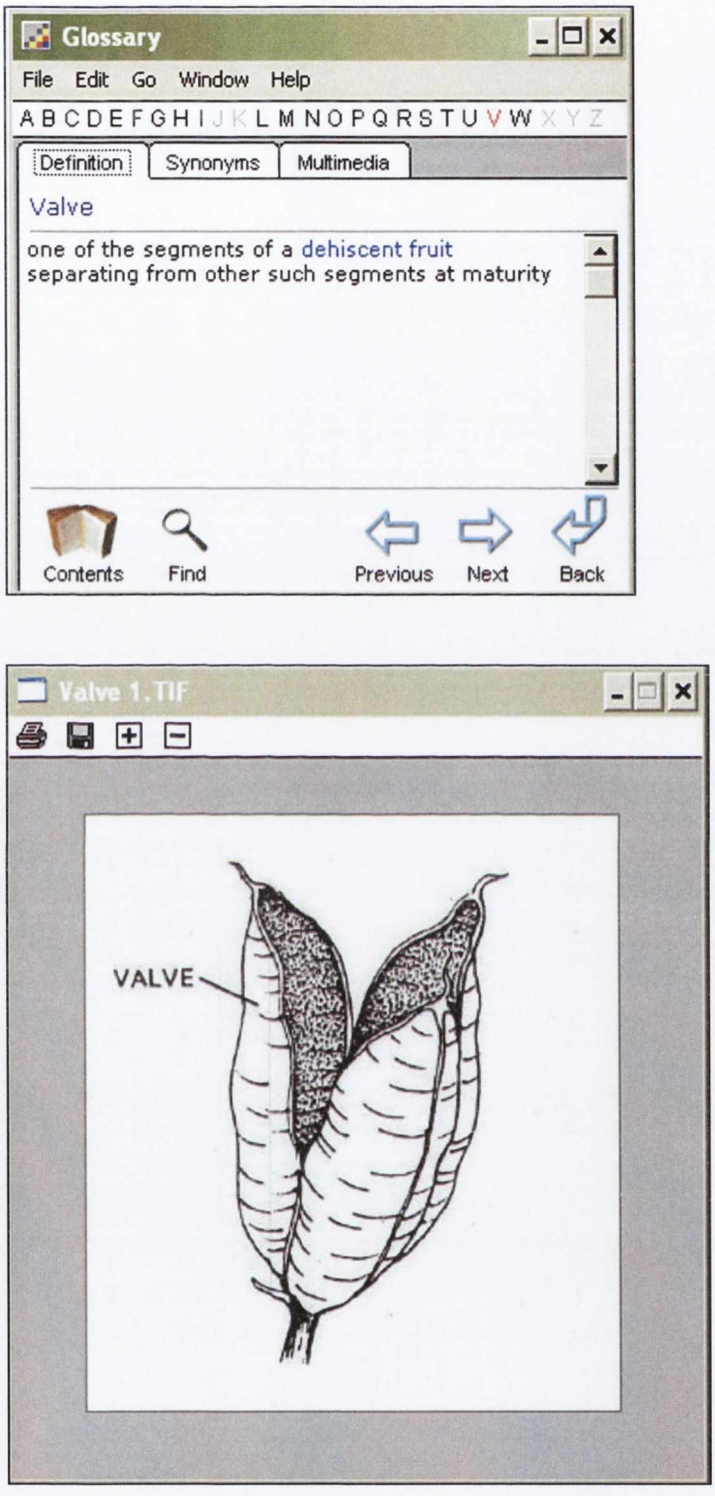


Figure 6.6 The Glossary Module showing the term and definition of 'Valve', with an accompanying illustration.

The terms in the Glossary module can be browsed by clicking on the Previous and Next buttons or by clicking on a letter in the Alphabet list. This will show the first definition found beginning with that letter and the Next and Previous buttons can then be used to navigate through the list of terms beginning with that letter. Alternatively the Go function can be used to move directly to a term of choice.

The Glossary Module Methods

- Clicking the icon in the Navigator window opened the Glossary Module.
- New pages were added to the Glossary by choosing Entry>New Term. This opened a new dialogue box, where the new term was added. A new page was added for each new term.
- The terms were then sorted by alphabetical order by choosing Entry>Sort Terms.
- Multimedia files were added where possible. These were in the form of illustrations to accompany the definitions. In order to add the illustrations, Entry>Edit Multimedia was selected. The illustrations were then selected to accompany specific terms.

The Literature Module

This module contains the literature references for all the information added throughout the database. All references used for the creation of the computer-based key have been included in the Literature module and also in the references section of the thesis. The literature that is used both for the computer–based key and the hard-copy element of the thesis has an asterisk beside it in the references section of the thesis to indicate that the reference occurs on the CD-ROM also. The literature specific to each individual species is provided on a page attached to each individual species' description and is also included in the Literature module. The references are arranged alphabetically and contain one reference per page. Figure 6.7 shows a screenshot of a reference extracted from the CD-ROM (See Appendix 4 for a full list of references):

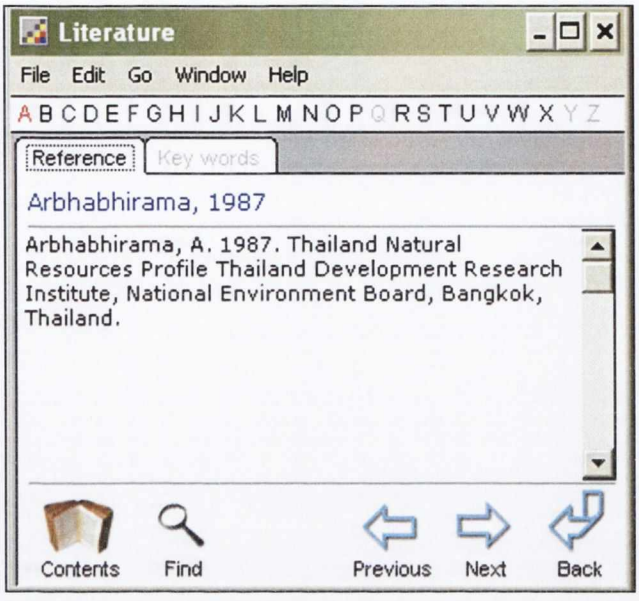


Figure 6.7 The Literature Module showing a screenshot of a reference entry.

The Literature Module Methods

- The Literature Module was selected from the Navigator window. To add a new reference, Entry>New Reference was selected. A new box opened in which the name of the new reference was entered. A new page was selected for each new reference.
- The references were then sorted by alphabetical order by selecting Entry> Sort References.

The Text Key

This is an electronic version of the dichotomous key found in Chapter 3 of the thesis. This electronic key has a hierarchical structure of pages that can be run through by clicking various character choices until a species is identified. Figure 6.8 shows an example of the first page from the text key. See Appendix 4 for the completed Text Key or Chapter 3 of the thesis.

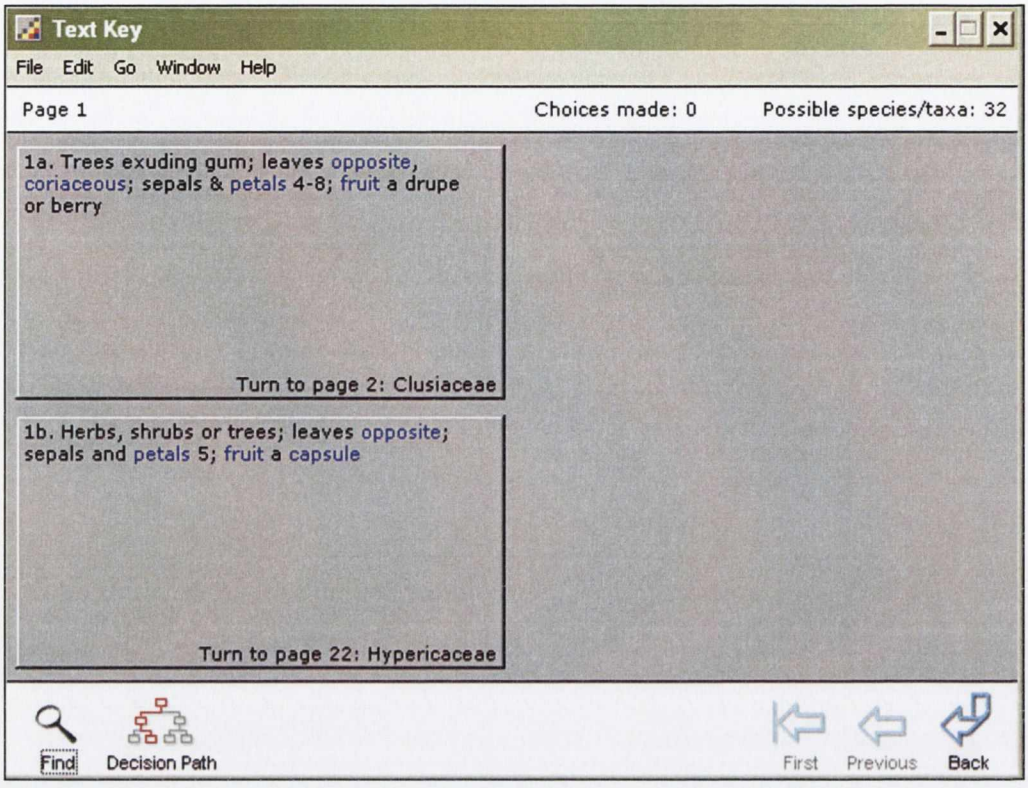


Figure 6.8 Page 1 of the text key. Two choices to distinguish between the Thai Clusiaceae and Hypericaceae.

The Text Key Methods

- To start building a text key, Edit>Edit Choice was selected. This opened a dialogue box, where text was entered (*e.g.* see figure 6.8 above) and the destination was also selected here. The destination of the choice must be specified. That is, if the destination of the choice will lead to a new page or an existing page *e.g.* a species, or another choice. If the choice leads to a new page, the name of the new page is then specified here also. The pages are then automatically renumbered depending on the choices that have been made in the Edit Choice page. The pages will automatically be renumbered if the destination of a page is changed too.
- Pages were also inserted in between two existing pages. This was done as follows: Entry>Insert Page. The new page was then named.
- To update the key, Update Key was selected from the Decision Path window.

Identify It

This module forms the multiple-access key. It is based on a matrix of character states (Character states are explained in the Introduction Module (on CD) and also in Chapter 2 of the thesis) and objects, namely species. The characters must define the observation of a single feature precisely (*e.g.* leaf shape) and they then have a set of mutually exclusive alternative states or values (*e.g.* lanceolate, elliptic etc.). This module is probably the most important and useful tool in this database as it allows for information to be easily extracted or reordered depending on the different needs of the users. Figure 6.9 shows an example from the Identify It module. Please refer to Appendix 4 for the completed interactive multiple-access key.

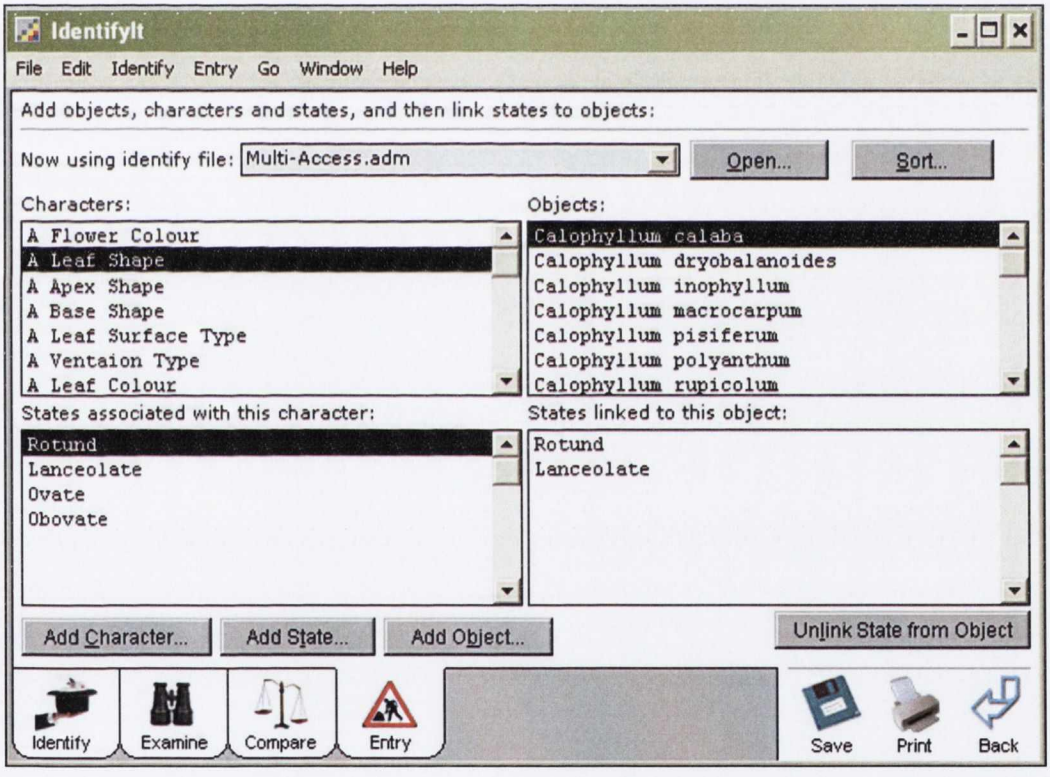


Figure 6.9 Identify It Module showing the characters, states associated with each character and the objects (or species) that have this character and state. This screenshot shows that *Calophyllum calaba* has both rotund and lanceolate shaped leaves.

Identify It Methods

- Identify It was opened by clicking the icon in the Navigator window. A new Untitled file opened automatically. A new file was created by choosing New Identify File.
- Entry mode must then be selected to add information. This was done by clicking the Entry tab at the bottom of the window. Editing and data entry was then carried out in this mode.
- Characters were added as follows: Entry was selected, followed by the Character submenu. New characters were added by clicking Add Character and then the name of the new character was entered. When all characters were added, the order of the characters was then rearranged by selecting Change Entry Order. The order of the characters can then be manually rearranged by using the Move Up and Move Down buttons. Characters were also renamed by selecting the Rename Character button.
- States were then added as follows: Entry was selected, followed by the State submenu. New states were added by clicking Add State and the name of the new state was then entered.
- Objects were then added by selecting the Object submenu from the Entry menu. This opened the commands for entering and changing objects. New objects were added by selecting Add Object. The Object dialogue box then opened in which the name of the new object (species) was added. The object was then defined by linking character states to it. This was done as follows: the list of character states was clicked to select a character; the list of states was selected to choose the state that was to be linked to the object. Link State to Object was then chosen from the Entry menu. This links the character state to the object. This can be undone also by highlighting the selected character and object and choosing Unlink State.

The Species Module

This module contains text and multimedia information. Species descriptions and photographs of the species are found here, along with synonyms, taxonomic information and literature applicable to each individual species. The species descriptions,

synonyms, taxonomic information and literature are also found in Chapter 3 (Taxonomic Treatment) of the thesis. The images are only found on the CD-ROM. In order to create descriptions, certain characters were chosen, namely: Habit, Branchlets, Leaves, Inflorescence, Calyx, Corolla, Stamens, Ovary, Fruit, Seeds, Distribution, Phenology, Ecology, Altitude, Uses, and Local name (Characters are explained in the Introduction Module (on CD) and in Chapter 2 of the thesis). An example of a completed description is shown below in Figure 6.10 (See Appendix 4 or Chapter 3 for the completed species descriptions):

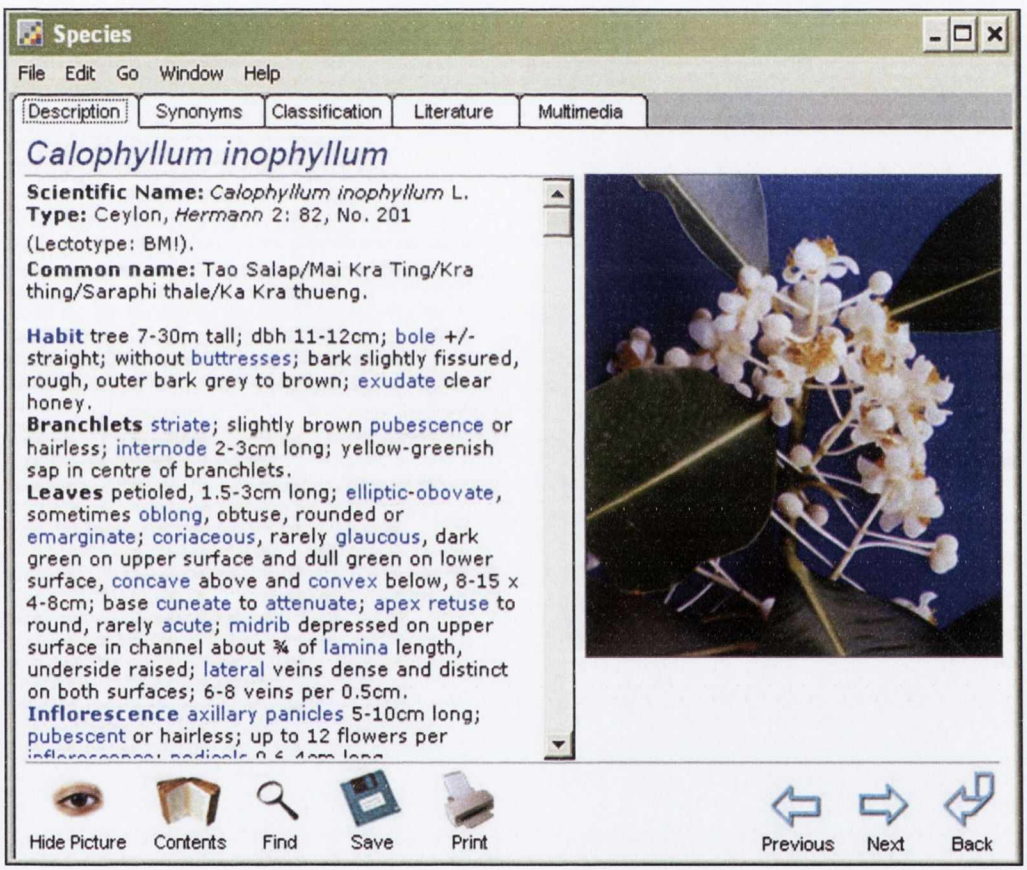


Figure 6.10 An example of a completed description of *Calophyllum inophyllum* found in the Species Module.

The Species Module Methods

- To add new species to the Species Module, the Species Module icon was selected in the Navigator window. Entry>New Taxon was selected. A new dialogue box then opened where the level of the new taxon can be selected *e.g.* species, and its name can then be entered.

- A standard taxonomic description was then entered into the Description field.
- Synonyms were added under the Synonyms tab and Literature applicable to each species was added under the Literature tab via the Literature Module. This was done in the following way: Entry> Link to References was chosen in the Species Module. This opened the list of references. The references that were applicable to that species were individually highlighted and then ok was selected. When this was complete the Literature Module was opened and Entry>Update Literature was selected. This automatically updated and added all of the selected references to the Literature page in the Species Module.

Working with multimedia

In order to upload images, the files must be saved in JPEG or TIFF format. To use image files as overview pictures, they must have a height of 281 pixels and a width of 241 pixels. They must also be saved as 72 dpi (dots per inch) resolution and a bit depth of 32 bits. In order to edit the images, Adobe Photoshop CS Version 8.0 was used. Figure 6.11 shows an example of an uploaded image which has been edited and resized in order to be used as an overview picture (See the Species Module in Appendix 4 to view the available images accompanying the taxonomic descriptions):

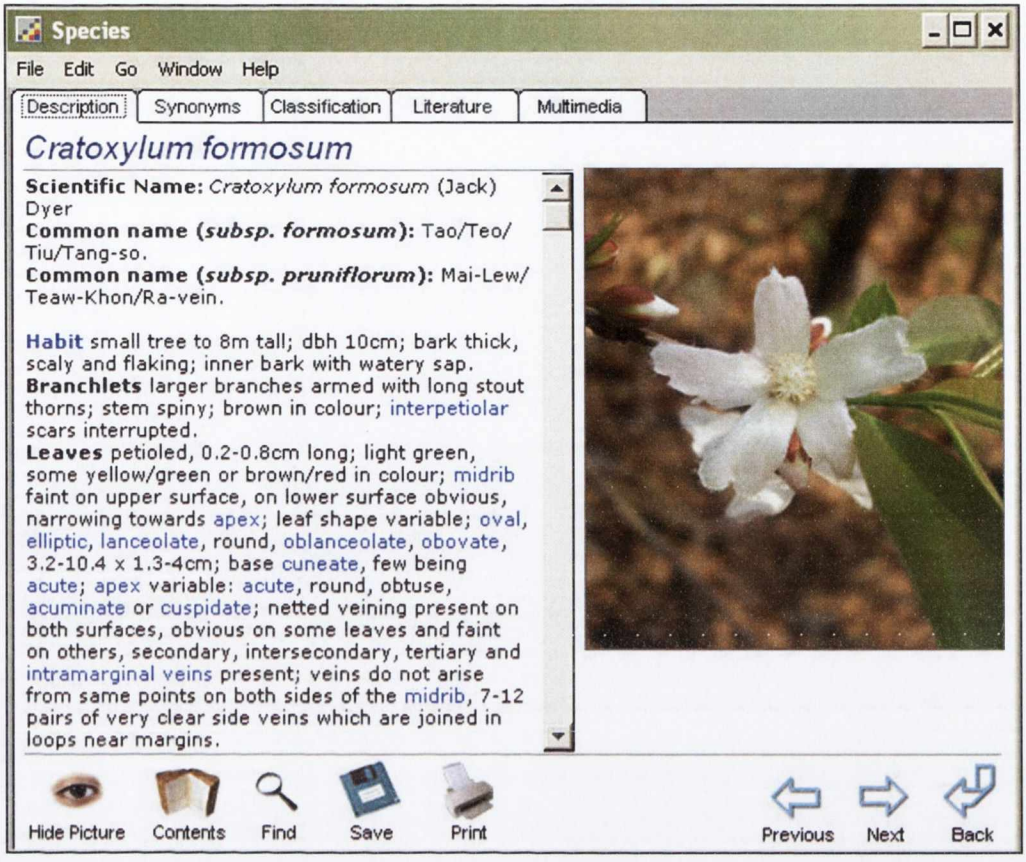


Figure 6.11 An example of an uploaded image accompanying a species description.

The Higher Taxa Module

This module contains information on taxa above species level. In this module, I have included brief information about the position of the two families within Kingdom Plantae. Descriptions of the two families and the genera they contain are found here and each description is accompanied by distribution information. Figure 6.12 shows an example of a description in the Higher Taxa module.

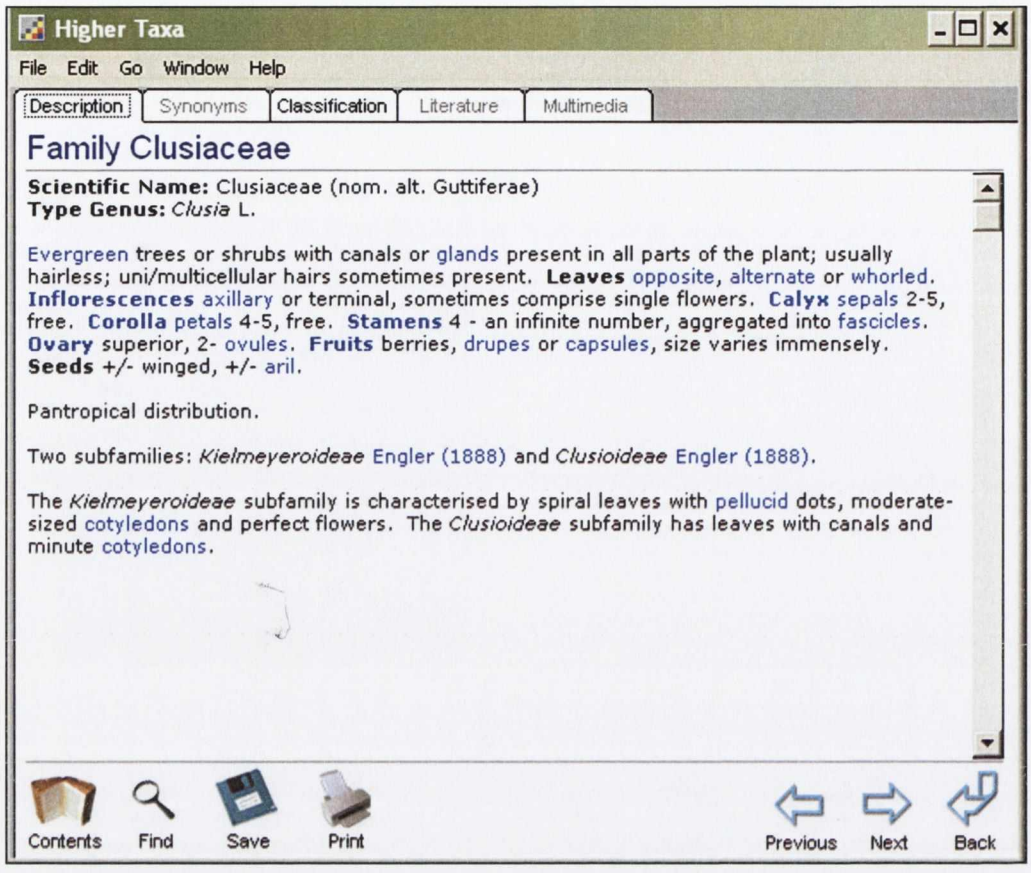


Figure 6.12 Example of a page from the Higher Taxa Module showing information on the Clusiaceae family.

The Higher Taxa Module Methods

- To add information to the Higher Taxa module, the icon was clicked in the Navigator module and pages were added to the module by choosing Entry>New Taxon. A standard description for each taxon was entered. All taxa were added in this way. The pages were then rearranged in the following way: Entry>Sort Taxa and the taxa were manually sorted by moving pages up and down.

6.8 Conclusions

Overall, the software offers a user-friendly interface that is easily accessible for uploading data and images and it is easy to browse. On completion, the finished product will be sent to the ETI Biodiversity Centre where hyperlinking of words used in the species descriptions and in other modules will be linked to the glossary in order to allow for easy navigation between terms and definitions.

It is hoped that the completed computer-based database and key will be a significant contribution to the Flora of Thailand project and also to a world biodiversity database.

OVERALL FINDINGS AND GENERAL SUMMARY AND DISCUSSION

The circumscriptions of the Clusiaceae and Hypericaceae families of Thailand were reconsidered on the basis of morphological, molecular and biogeographical observations. Floristic treatments of the Clusiaceae and Hypericaceae for the Flora of Thailand project have been prepared in Chapter 3. One key to the two families is provided as well as keys to the genera and their species. Species descriptions accompanied with typifications, synonyms, lists of specimens examined, distribution maps and illustrations have been provided. In total, 21 species of Clusiaceae and 12 species of Hypericaceae have been recognised for Thailand.

No new species were found and only one name change was found necessary: *Cratoxylum cochinchinense* (Lour.) Blume was changed to *Cratoxylum chinense* (Retz.) Merr. based on priority of publication.

Some important characters to aid identification of the Clusiaceae in the field are: the bark exudate, the sepal and petal number (this can help one to identify a member of this family to genus level) and the number of ovules in the ovary can also be a useful character. Characters important for the identification of the Hypericaceae include the habit as they vary from shrubs (*Hypericum* spp.) to large trees (*Cratoxylum* spp.). The presence of short, sharp, pointed projections on the bole is a useful field character to recognise some taxa from the genus *Cratoxylum*. Glands on the leaves can be easily seen in the light and leaf colour can aid in identification also. Ecological habitat is important too as the *Hypericum* taxa generally grow on high, exposed mountain and cliff edges.

Scanning Electron Microscopy (SEM) of the leaf surfaces in the genus *Calophyllum* was carried out to see if there were any differences between the species based on the number and types of veins present, the number and types of stomata present and the texture of the leaf surfaces (See Appendix 1). The results showed that there is variation both within and between species in the Thai *Calophyllum*. A separate analysis that did not account for the above variation within a species was performed and this showed that *Calophyllum pisiferum* and *Calophyllum rupicolum* are quite similar to one another and

certain species grouped more closely together (See Chapter 2 for results). However these results are only an estimation of similarities between the *Calophyllum* species in Thailand.

The molecular analyses showed that the Hypericaceae are monophyletic. The Clusiaceae are paraphyletic in the analyses but there is no evidence against the monophyly of the family as there is no support in the strict consensus. The decision to separate the Guttiferae into the Clusiaceae and Hypericaceae is supported through the findings in this study as to keep the two families together would mean the Podostemaceae would have to be included, making the family polyphyletic and creating a highly heterogeneous unit that would be very hard to identify macromorphologically (Gustafsson et al. 2002). The results showed that all genera are monophyletic. Further investigations need to be carried out to resolve the relationships between the Thai Hypericaceae and the Thai and South American Clusiaceae.

An IUCN status was also applied to each species at the regional level for Thailand to assess how many species are: Critically Endangered (CR), Near Threatened (NT), Least Concern (LC) or Data Deficient (DD). This was carried out based on a set of criteria (see IUCN Red List of Threatened Species: http://www.iucnredlist.org/static/programme for the set of criteria used in the assessment). Six species were Critically Endangered (CR), two species were Near Threatened (NT), 19 taxa were of Least Concern (LC) and six taxa were Data Deficient (DD). One of the main areas to assess is the habitat of each individual species and it was found that this played a major role in the status level assigned to each taxon as Peat Swamp Forests and Mangroves are under serious threat in Thailand and these areas are home to many Thai taxa of *Calophyllum*.

The distribution of the Clusiaceae and Hypericaceae in Thailand, South East Asia and surrounding regions was examined and it was found that the two families occur in Africa, South Asia and Himalaya, Burma, South China, Laos, Cambodia, Vietnam, Malaysia, Indonesia, Philippines and Australia. The Thai Clusiaceae are most similar to those of Malaysia and the region to the east of Thailand in terms of numbers of the same taxa. The Thai Hypericaceae appears to have its centre of distribution in the east and they seem to have speciated in a westerly direction towards Thailand. However, the

genus *Hypericum*, a more temperate genus that is found mainly in Northern Thailand, seems to have originated in the northwest and speciated south through Thailand; perhaps Thailand is at the easternmost boundary for this genus.

Within Thailand, the distribution of the two families was considered and it was found that they occupy some of the same ecological habitats and some different habitats also. For example, both families occur in evergreen and deciduous forests, but only the Clusiaceae occur along shorelines and in Peat Swamp Forests, while only the Hypericaceae are found in rice fields and on exposed ridges. The Clusiaceae are found from sea level to 1,950m above sea level and the Hypericaceae can reach up to 2,600m high, on the highest summit in Thailand.

The collection density for each family in Thailand was calculated and it was found that both families had substantially low numbers of collections at 0.2 collections per $100km^2$ for the Clusiaceae and 0.3 collections per $100km^2$ for the Hypericaceae respectively. Of the 21 species of Clusiaceae and 12 species of Hypericaceae revised, one species in each family was found to be endemic to Thailand, namely *Mammea harmandii* (Clusiaceae) and *Hypericum siamense* (Hypericaceae) respectively. One species in the Hypericaceae, namely *Cratoxylum formosum* subsp. *pruniflorum* is endemic to Thailand and the surrounding countries (Burma, South China, Cambodia, Laos and Vietnam). However, these species may not be endemic to Thailand (and the surrounding countries) as the areas surrounding Thailand have even lower numbers of herbarium collections and very little collecting activity. For this reason, an estimation of the number of endemic taxa can only be specified (see above and Chapter 5).

A CD-ROM was created for the two families in Thailand (see Appendix 4). The CD-ROM provides additional drawings and photographs that are not found in the printed version and also a multiple-access key, as well as an electronic dichotomous key. The multiple-access key has many advantages over the traditional dichotomous key as the user can select what characters to use in the identification. This is extremely beneficial compared to traditional keys as sometimes a particular part of a plant (*e.g.* flower) may not be available but is needed in order to complete the identification using the standard dichotomous keys. The CD-ROM also provides the user with a comprehensive list of useful references and is very easy to navigate.

Future Work to be carried out

The project has yielded some interesting findings and results. Many discoveries have been made in terms of areas that need improvement and also which taxa are more vulnerable than others. One major area that needs extensive improvement and further work is to increase the numbers of collections not only for the Thai Clusiaceae and Hypericaceae but also for all families of plants occurring in Thailand and the surrounding regions. Fieldwork urgently needs to be carried out in areas where the numbers of collections are substantially low or where there are no collections and in areas that are more difficult to access as these remote areas tend to be data deficient (Parnell, 2003).

Fieldwork is one essential component that is needed but only if it is done to a high uniform standard. Ideally the aim of every collector is to collect the exact same data and type of material for each taxon in order to contribute to the world DNA bank (Hodkinson et al., 2007). For this reason, the importance of good collecting technique cannot be emphasised enough as specimens in herbaria are concentrated sources of biodiversity information (Parnell, 2000). An ideal amount of data for an individual specimen would include a detailed label with information on the species (such as flowering, fruiting and a brief description), the altitude, location (including grid references, area, district, county and country), the habitat and ecology, a photograph and a dried sample in silica gel for DNA analysis and where possible seeds for future propagation (Hodkinson et al., 2007). An increase in the number of collections of the more rare Thai Clusiaceae and Hypericaceae taxa will allow for more observations to be made about the morphology of the species especially flower observations and the phenology of the species.

Collaboration also needs to be initiated between Thailand and the surrounding countries and data needs to be shared. This would allow for a much more comprehensive database and for more accurate information to be gained. This is only starting to become possible now as the countries surrounding Thailand (Laos, Cambodia, Vietnam and Burma) have begun to document their floras.

Laos, Cambodia and Vietnam

The flora of Laos, Cambodia and Vietnam is currently being revised in *Flore du Cambodge, du Laos et du Viêtnam* (1960-present) (Newman et al., 2007). These countries found to the east of Thailand are poorly known botanically and this is mainly due to their tumultuous history of war from the end of World War II until the 1990s (Thomas et al., 2007). The numbers of collections for these countries are very low and it is estimated that there are roughly three collections per $100km^2$ for Laos, four collections per $100km^2$ for Cambodia and 14 collections per $100km^2$ for Vietnam respectively, compared to 1,700 specimens per $100km^2$ for the United Kingdom (Newman et al., 2007). Few national herbaria exist in these countries: Laos has no national herbarium and only four small herbaria exist in or near Vientiane (Newman et al., 2007). However during the last decade botanical research in these countries has gradually become active and the number of biodiversity surveys in these regions has increased as well as the number of herbarium collections (Newman et al., 2007) and the number of areas designated National Biodiversity Conservation Areas (Robichaud et al., 2001). As well as this, cooperation with foreign botanists and their institutions is on the rise and thus opening the doors for more collaboration and exchange of information.

Burma (Myanmar)

To date, no modern account of the plants of Burma exists and there are few herbarium collections both in and out of the country. Prior to World War II, there were some investigations and botanical exploration in Burma when the entire British colonial system was explored botanically (India and parts of Asia) but after World War II, the number of botanical investigations sharply decreased (Kress et al., 2003). The country is exceptionally rich in plant biodiversity and it is estimated that there are approximately 11,800 species housed within the borders of Burma. However, this estimation may be inaccurate as Burma has yet to be intensively explored botanically (Kress et al., 2003). It was noted by Frodin (2001), that, of all of tropical Asia, Burma has had the smallest proportion of its flora collected and the flora still remains botanically poorly known or unknown. To date, a checklist of the flora of Myanmar has been produced (2003) but this is only a preliminary list, as substantial collecting efforts need to be completed throughout numerous habitats and vegetation types before an inventory of the entire country can be completed. A comprehensive account of the entire flora of Myanmar is

now underway and it involves a number of worldwide herbaria and institutions including: Forest Research Institute in Yezin (RAF), Smithsonian Institution (US), Royal Botanic Gardens Kew (K), Harvard University (GH) and Royal Botanic Gardens Edinburgh (E). It is hoped that this collaboration will eventually lead to a complete revision for the families of plants occurring in Burma.

Due to the newly revived collecting activity in the regions surrounding Thailand, the data available and the number of species endemic to Thailand (and the surrounding regions) can be more accurately estimated. This will allow for educated decisions to be made regarding the biodiversity and conservation of the region of Indo-China and perhaps in the future, extensive policies may be prepared for the entire area (Burma, Thailand, Cambodia, Laos and Vietnam).

The Thai *Calophyllum* genus still remains a somewhat troublesome genus to include in traditional taxonomic dichotomous keys, as the dichotomous keys created for this genus often require the user to have the flower present in order to identify the species correctly. This is not ideal. The SEM work did not highlight any major differences between the species and also because of the variability present within species this method of identification would not be a very reliable identification tool. Therefore, it may be beneficial to do some anatomical work on this genus to see if any major differences are found between the species or perhaps morphometrics on the leaves as these techniques may yield results that are less variable within a species and thus a more useful additional tool to aid identification.

The molecular work carried out during this research project has yielded some preliminary results that need to be investigated further. Due to the unforeseen problems regarding the amount of time DNA amplification and sequencing took in order to gain successful sequences, the number of species used in the analysis was low (see Chapter 4 for a discussion on techniques to improve DNA amplification and sequencing in the future). For this reason, the results and interpretations of the Thai taxa of Clusiaceae and Hypericaceae were confined to family level, with limited discussion and interpretation made at the generic level.

Future molecular work to be done will include: more extensive numbers of samples and species being sequenced for the Thai Clusiaceae and Hypericaceae. If possible samples from every species will be included in the analysis as well as samples from the two most closely related families (Bonnetiaceae and Podostemaceae) for all gene regions. A larger number of gene regions will also be sequenced to study the variation within the two families. Collaboration with Dr. Mats Gustafsson (University of Aarhus, Denmark) will also occur where my data will be added to a larger dataset for the Clusiaceae and Hypericaceae of the world. A combined molecular and Biogeographical distribution analysis will be carried out on the more extensive dataset as well as attempts to infer the timing of the origin of the Clusiaceae and Hypericaceae.

For future constructing of computer-based keys, a different software programme may be considered. Even though the Linnaeus II software was user-friendly and easy to use, the software often crashed unexpectedly. This is apparently due to problems with the software that have still not been rectified. This means that if regular backing up does not occur (*i.e.* every few hours) large amounts of data entered and keys etc. created can be lost and irretrievable. This is very time-consuming. Perhaps the DELTA system (DEscription Language for TAxonomy) will be utilised for future computer-based keys, as it is a flexible method for encoding taxonomic descriptions for computer processing. The DELTA-format data can be used to produce taxonomic descriptions, conventional or interactive keys, cladistic or phenetic classifications, and information-retrieval systems (Dallwitz et al., 1993 onwards).

Overall the thesis has provided a comprehensive taxonomic account of the Clusiaceae and Hypericaceae in Thailand, which will be used for the Flora of Thailand project.

* Asterisk indicates the references are also on the CD-ROM in the Literature Module

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APPENDICES

Appendix 1 Completed matrix with scores for SEM Analysis of *Calophyllum* leaf surfaces.

Character List	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	0	0
C. calaba	1	1	1	1	0	0	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	1	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	1
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0	1	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0	1	1	0
C. calaba	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1	0	0	1
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	0	0	1	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	0	1	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	0	0	1	0	0	1	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	0	1	1	1	0	0	1	0	0	1	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	0	1	0	1	1	1	0	0	1	0	0	1	0	0
C. calaba	0	1	0	1	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0

Appendix 1 continued.

Character List	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	0	1	1	1	1	1	0	0	0	0	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1	1	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	0
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	0	1	1	1	0	1	1	0	0	0	0	0
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	0	0	1	0	0
C. calaba	0	1	0	1	0	0	0	0	1	0	1	1	1	1	1	1	0	1	0	0	0	0	1	0
C. calaba	0	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	0	0
C. calaba	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	1	0
C. calaba	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	1	1	0	0	0	0	1	0	0
C. calaba	0	1	0	0	0	1	0	0	1	0	1	1	0	1	1	1	0	0	0	0	0	1	1	0
C. dryobalanoides	1	-	1	0	0	0	0	0	0	0	1	-	0	-	1	-	1	-	0	-	0	-	0	-
C. dryobalanoides	1	1	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0	1	1	0	0
C dryobalanoides	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	1	1	0	0	0	0	1	0	0

Appendix 1 continued.

Character List	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
C dryobalanoides	0	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	0	1	1	0	0	0	0	0
C. inophyllum	0	1	0	0	0	1	0	0	0	0	1	1	0	1	1	1	0	0	1	0	0	0	0	0
C. inophyllum	1	1	0	0	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0	0
C. inophyllum	0	1	0	0	0	0	0	1	0	0	1	1	0	0	1	1	1	0	0	0	0	1	0	0
C. inophyllum	0	1	0	0	0	0	0	1	0	0	1	1	0	0	1	1	1	0	0	0	0	1	0	0
C. inophyllum	1	1	1	0	0	0	0	1	0	0	1	1	0	1	1	1	0	0	0	0	0	1	1	0
C. macrocarpum	0	1	0	1	0	0	0	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0
C. macrocarpum	0	1	0	1	0	0	0	0	1	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0
C. pisiferum	0	1	0	0	0	0	0	1	0	1	1	1	0	0	1	1	0	0	1	0	0	1	0	0
C. pisiferum	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	0	1	-
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C. pisiferum	0	-	0	0	0	0	0	0	1	0	1	-	0	-	0	-	0	-	0	-	0	-	0	0
C. pisiferum	0	1	0	1	0	0	0	0	1	1	0	1	0	0	1	1	1	1	0	0	0	0	0	0

Appendix 1 continued.

Character List	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
C. pisiferum	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
C. pisiferum	0	1	0	0	0	0	0	1	0	1	1	1	0	0	1	1	1	0	0	0	0	1	0	0
C. polyanthum	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0
C. polyanthum	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0
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C. polyanthum	0	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	1	1	0
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C. polyanthum	0	1	0	1	0	0	0	0	0	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0
C. polyanthum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
C. rupicolum	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0
C. rupicolum	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
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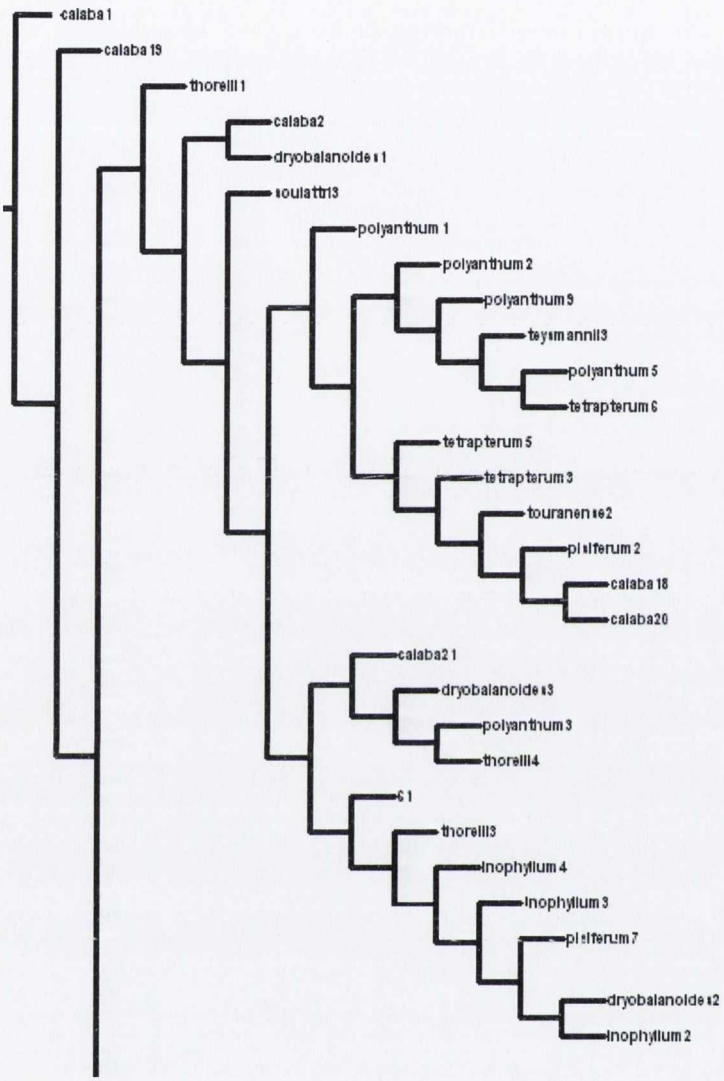
Appendix 1 continued.

Character List	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
C. sclerophyllum	0	1	0	1	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1	1	0	0
C. soulattri	0	1	0	1	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	0	0	1	0	0
C. soulattri	0	1	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	1	0	0
C. soulattri	0	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	1	0	0
C. soulattri	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	0
C. tetrapterum	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	0
C. tetrapterum	0	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	0	1	0	0
C. tetrapterum	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0
C. tetrapterum	0	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	0	1	1	0	0	0	0	0
C. tetrapterum	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0
C. tetrapterum	0	1	0	1	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0
C. tetrapterum	0	1	0	1	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	1	1	0
C. teysmannii	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0

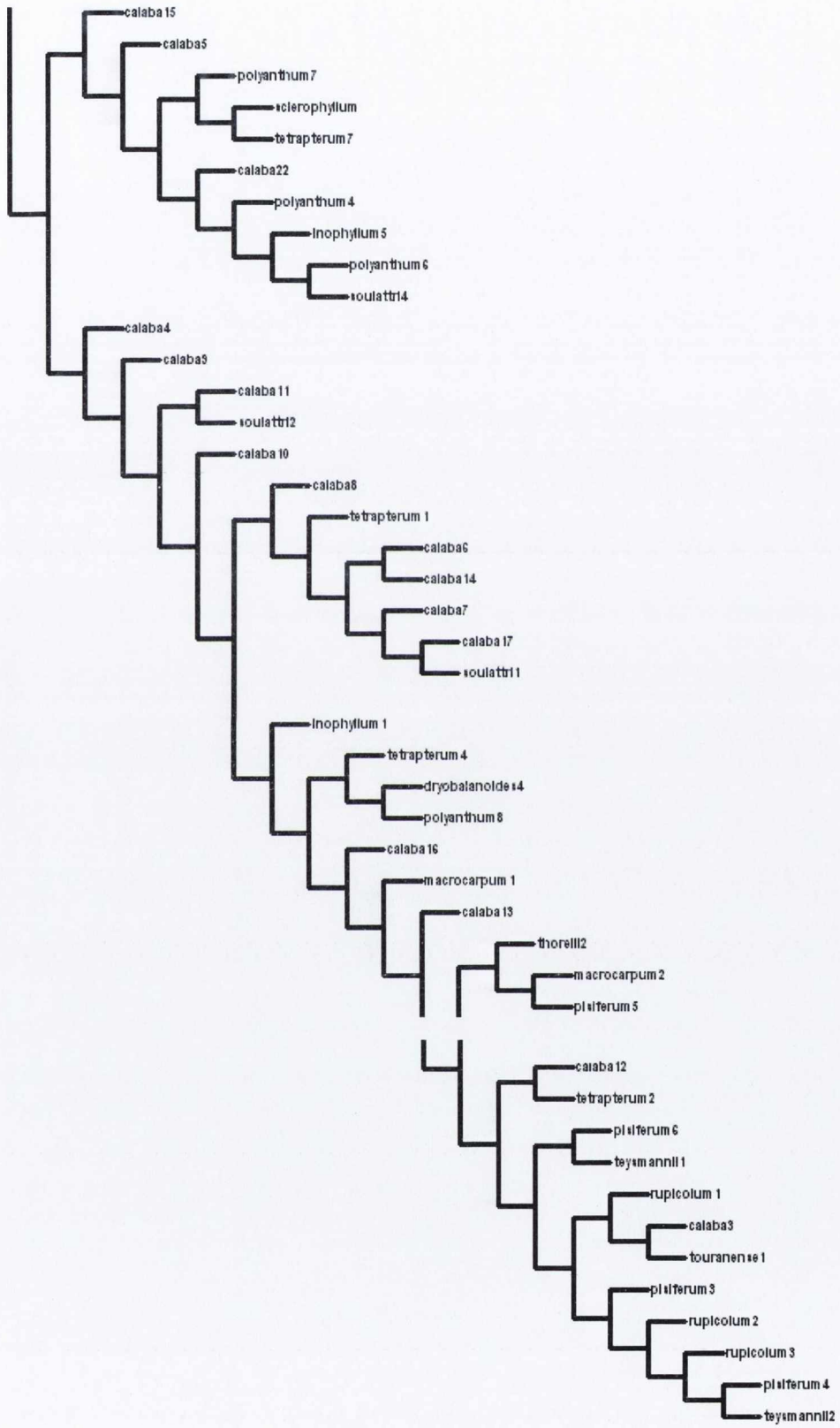
Appendix 1 continued.

Character List	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
C. teysmannii	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0
C. teysmannii	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
C. thorelii	0	1	0	1	0	0	0	0	1	0	1	1	0	1	1	1	1	0	0	0	0	1	0	0
C. thorelii	0	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0
C. thorelii	0	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0
C. thorelii	0	1	0	0	0	0	0	1	0	0	1	1	1	0	1	1	1	0	0	0	0	1	0	0
C. thorelii	0	1	0	0	0	0	0	1	0	0	1	1	0	1	0	1	0	0	0	0	0	1	0	0
C. touranense	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	1	0	0	0	0	1	0
C. touranense	0	1	0	1	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1

Appendix 2 Consensus Tree produced by WinClada for *Calophyllum* leaf surfaces analysis.



Appendix 2 continued.



Appendix 3 Taxa and vouchers of all sequences.

Taxon		Voucher/Herbarium	Origin
Cratoxylum	*chinense* (Retz.) Merr.	C.M. Byrne 3 / TCD	Thailand: Khon Kaen
Cratoxylum	*formosum*	C.M. Byrne 4 / TCD	Thailand: Khon Kaen
Cratoxylum	*chinense* (Retz.) Merr.	C.M. Byrne 5 / TCD	Thailand: Khon Kaen
Cratoxylum	*chinense* (Retz.) Merr.	C.M. Byrne 6 / TCD	Thailand: Loei
Calophyllum	*?*	C.M. Byrne 7 / TCD	Thailand: Loei
Cratoxylum	*chinense* (Retz.) Merr.	C.M. Byrne 8 / TCD	Thailand: Khon Kaen
Hypericum	*henryi* H. Lév. & Vaniot subsp. *hancockii* N. Robson	C.M. Byrne 9 / TCD	Thailand: Chiang Mai
Hypericum	*henryi* H. Lév. & Vaniot subsp. *hancockii* N. Robson	C.M. Byrne 10 / TCD	Thailand: Chiang Mai
Hypericum	*henryi* H. Lév. & Vaniot subsp. *hancockii* N. Robson	C.M. Byrne 11 / TCD	Thailand: Chiang Mai
Calophyllum	*pisiferum* Planchon & Triana	C.M. Byrne 13 / TCD	Thailand: Chiang Mai
Calophyllum	*sp.*	C.M. Byrne 14 / TCD	Thailand: Chiang Mai
Calophyllum	*sp.*	C.M. Byrne 15 / TCD	Thailand: Trang
Cratoxylum	*sp.*	C.M. Byrne 16 / TCD	Thailand: Trang
Cratoxylum	*formosum* (Jack) Dyer subsp. *formosum* (Jack) Dyer	C.M. Byrne 18 / TCD	Thailand: Trang
Cratoxylum	*chinense* (Retz.) Merr.	C.M. Byrne 19 / TCD	Thailand: Trang
Calophyllum	*sp.*	C.M. Byrne 20 / TCD	Thailand: Trang
Cratoxylum	*chinense* (Retz.) Merr.	C.M. Byrne 21 / TCD	Thailand: Prachin Buri
Cratoxylum	*formosum* (Jack) Dyer subsp. *formosum* (Jack) Dyer	C.M. Byrne 22 / TCD	Thailand: Prachin Buri
Cratoxylum	*formosum* (Jack) Dyer subsp. *formosum* (Jack) Dyer	C.M. Byrne 23 / TCD	Thailand: Prachin Buri
Cratoxylum	*sp.*	C.M. Byrne 24 / TCD	Thailand: Chachaeongsao

Appendix 3 continued.

Taxon		Voucher/Herbarium	Origin
Mammea	*siamensis* (Miq.) T. Anderson	C.M. Byrne 25 / TCD	Thailand: Chachaeongsao
Mammea	*siamensis* (Miq.) T. Anderson	C.M. Byrne 26 / TCD	Thailand: Sa Kaeo
Mammea	*siamensis* (Miq.) T. Anderson	C.M. Byrne 27 / TCD	Thailand: Trat
Calophyllum	*polyanthum* Wallich	C.M. Byrne 28 / TCD	Thailand: Trat
Hypericum	*hookerianum* Wight & Arnott	Mats H.G. Gustafsson 830 / TCD	Thailand: Chiang Mai
Hypericum	*kamtschaticum* Ledebour	K. Senni S3187 / MAK	Unknown
Malpighia	*glabra* Linnaeus		Tropical America
Podostemon	*sp.*	Wongnak 895 / AAU	Thailand
Clusia	*viscida* Engler	Mats H.G. Gustafsson 478 / AAU	Ecuador
Tovomita	*weddeliana* Planchon & Triana	Mats H.G. Gustafsson 507 / AAU	Ecuador

Appendix 4 CD-ROM of the Revision of the Thai Clusiaceae and Hypericaceae. See accompanying CD-ROM.

Appendix 5 Glossary of terms used on the accompanying CD-ROM.

A

Abaxial

The side away from the axis.

Accrescent

Becoming larger with age, as a calyx which continues to enlarge after anthesis.

Acuminate

Gradually tapering to a sharp point and forming concave sides along the tip.

Acute

Tapering to a pointed apex with more or less straight sides.

Aequilateral

Equal-sided.

Alternate

Borne singly at each node, as leaves on a stem; borne between rather than over other organs, as stamens between the petals.

Amplexicaul

Clasping the stem, as the base or stipules of some leaves.

Anther

The upper part of a stamen, in which the pollen is produced.

Anthesis

The flowering period, when the flower is fully expanded and functioning.

Apex

The tip; the point which is farthest away from the point of attachment of the leaf.

Apical

Located at the apex or tip.

Apiculate

A short sharp slender projection at one end.

Apiculus

A short sharp projection at one end.

Aril

A fleshy and usually brightly coloured cover found on certain seeds that develops from the ovule stalk and partially or entirely envelops the seed.

Attenuate

Tapering gradually to a narrow tip or base.

Auricle

A small, ear-shaped appendage.

Axil

The angle between a leaf and the stem just above its point of attachment.

Axillary

Positioned in or arising in an axil.

B

Basifixed

Attached by the base.

Bole

The main trunk or stem of a tree, sometimes covered in bark.

Bract

A reduced leaf or leaflike structure at the base of a flower or inflorescence.

Bracteole

A small bract, often secondary in nature; a bractlet.

Buttress

With props or supports, as in the flared trunk of some trees.

C

Caducous

Falling off easily or very early compared to similar structures in other plants.

Calyx

The outer perianth whorl; collective term for all of the sepals of a flower.

Capsule

A dry, dehiscent fruit formed from two or more carpels, usually containing numerous seeds.

Concave

Hollowed out or curved inward.

Connate

Fusion of like parts; as the fusion of staminal fascicles into a tube.

Connective

The portion of the stamen connecting the two pollen sacs of an anther.

Convex

Rounded and curved outward on the surface.

Cordate

Notched or indented at the base, where the stalk is attached.

Coriaceous

With a leathery texture.

Corolla

The collective name for all of the petals of a flower; the inner perianth whorl.

Corymb

A raceme or panicle in which the flowers that arise from lower down on the axis have longer stalks than those that arise higher up, so that all the flowers are brought to about the same level and the inflorescence has a flat top.

Corymbose

Having flowers in corymbs.

Cotyledon

A primary leaf of the embryo; a seed leaf.

Cuneate

Wedge-shaped, triangular and tapering to a point at the base.

Cuspidate

Tipped, with a short, sharp, abrupt point.

Cyme

An inflorescence in which the terminal or central flower is the first to open, subsequent flowers being produced on branches which arise below it. This flower terminates the main axis, whereas in a raceme the axis continues to grow as long as flowers are being produced. Sometimes the branches of a cyme arise on one side only, so as to produce the appearance of a somewhat coiled raceme.

Cymules

A small cyme or a small section of a compound cyme.

D

Deciduous

Falling off, not evergreen, not persistent.

Decussate

Arranged along the stem in pairs, with each pair at right angles to the pair above or below.

Dehiscence

The opening at maturity of fruits and anthers.

Dehiscent

Splitting when ripe, so as to release the seed while the fruit remains attached to the plant.

Dentate

Toothed along the margin, the teeth directed outward rather than forward.

Denticulate

Dentate with very small teeth.

Distal

Toward the tip, or the end of the organ opposite the end of attachment.

Dorsal

Pertaining to the back or outward surface of an organ in relation to the axis, as in the lower surface of a leaf; abaxial.

Drupe

A fleshy, indehiscent fruit with a stony endocarp surrounding a usually single seed, as in a peach or a cherry.

E

Ellipsoid

A solid body elliptic in long section and circular in cross section.

Elliptic

In the shape of an ellipse, or a narrow oval; broadest at the middle and narrower at the two equal ends.

Emarginate

With a notch at the apex.

Embryo

The young plant within a seed.

Entire

Not toothed, notched or divided, as the continuous margins of some leaves.

Erose

With the margin irregularly toothed, as if gnawed.

Eucamptodromous

When the veins run outwards but curve markedly before reaching the margin and unite with the vein above, thereby forming a loop .

Evergreen

Having green leaves through the winter; not deciduous.

Exudate

A substance exuded or extracted from a plant.

F

Fascicle

A tight bundle or cluster.

Fasciculate

Arranged in fascicles.

Filament

The stalk of the stamen, on which the anther is borne.

Foliate

Having leaves, leaf-like.

Fruit

A ripened ovary and any other structures which are attached and ripened with it.

G

Gland

An appendage, protuberance, or other structure which secretes sticky or oily substances.

Glaucous

Covered in a waxy coating that is usually bluish/white in colour.

Globose

Globe-shaped; spherical.

H

Habit

The general appearance, characteristic form, or mode of growth of a plant.

Heartwood

The innermost, usually somewhat darker wood of a woody stem.

Heterostylous

With styles of different lengths in flowers of the same species.

Homostylous

With styles of more or less constant length in flowers of the same species.

I

Imbricate

Arranged in a tight spiral, so that the outermost member has both edges exposed and at least the innermost member has both edges covered.

Inflorescence

The flowering part of a plant; a flower cluster; the arrangement of the flowers on the flowering axis.

Inter

Between or among.

Internode

The length of stem which lies between 2 successive nodes.

Interpetiolar

Between the petioles.

Intersecondary Veins

Veins which arise from the midrib and are of moderate size between the secondary and tertiary veins. They generally originate from the midrib and have a course parallel or nearly so to the secondary vein. They sometimes join with a secondary vein.

Intramarginal

Within or near the margin.

Intramarginal veins

Defined as the first pair of secondary veins encountered when moving apically from the base of the lamina. They closely parallel the leaf margin and often fuse with secondary veins.

Involute

With the margins rolled inward toward the upper side.

L

Lamina

The thin and flat part of the leaf, as in the leaf blade.

Lanceolate

Somewhat tapered at both ends and about three to four times as long as broad.

Lateral

Borne on or at the side.

Latex

A colourless to more often white, yellow or reddish liquid, produced by some plants, characterised by the presence of colloidal particles of terpenes dispersed in water.

Ligulate

With a ligule; strap-shaped.

Ligule

A strap-shaped organ.

Locule

The chamber or cavity of an organ, as in the cell of an ovary containing the seed or the pollen bearing component of an anther.

M

Midrib

The central rib or vein of a leaf or other organ.

Midvein

The central vein.

N

Nerve

A prominent, simple vein or rib of a leaf or other organ.

Node

A point on the stem, often thickened, to which a leaf or leaves are attached.

O

Oblanceolate

Inversely lanceolate, with the attachment at the narrower end.

Oblique

With unequal sides, especially a leaf base; slanting.

Oblong

Two to four times longer than broad with sides that are almost parallel.

Obovate

Inversely ovate, with the attachment at the narrower end.

Opposite

Borne across from one another at the same node, as in a stem with two leaves per node.

Oval

Broadly elliptic, the width over one half the length.

Ovary

The expanded basal portion of the pistil that contains the ovules.

Ovate

Egg-shaped in outline and attached at the broad end.

Ovoid

A three-dimensional figure that is egg-shaped.

Ovule

An immature seed.

P

Panicle

A branched raceme, *i.e.* an inflorescence in which the branches, themselves racemes, are arranged like the flowers in a simple raceme; also, more loosely, any freely branched inflorescence that is not obviously a cyme or corymb.

Paniculate

Having flowers in panicles.

Papyraceous

Papery in texture and usually colour.

Parallelodromous

When the veins enter the blade at the base and run more or less parallel to the margin without branching from base to tip

Patent

Spreading or expanded, as in widely spreading branches or broadly expanded petals.

Pedicel

The stalk of a single flower of an inflorescence.

Peduncle

The stalk of a solitary flower or of an inflorescence.

Pellucid

Transparent or translucent.

Peltate

Attached by the centre; a flat structure borne on a stalk attached to the lower surface rather than to the base or margin.

Persistent

Remaining attached after similar parts are normally dropped, after the function has been complete.

Petal

An individual segment or member of the corolla.

Petiolate

With a petiole.

Petiole

A leaf stalk.

Pistil

The female reproductive organ of a flower, typically consisting of a stigma, style and ovary.

Procumbent

Lying or trailing on the ground but not rooting at the node.

Prominent

Standing out from the surrounding surface, as raised veins on the surface of a leaf.

Puberlous

Minutely pubescent; with fine short hairs.

Pubescent

Covered with short, soft hairs, bearing any kind of hairs.

Punctate

Dotted with pits or translucent, sunken glands or with coloured dots.

Q

Quadrangular

Four-angled.

R

Raceme

An inflorescence in which a number of stalked flowers are arranged along a single, unbranched axis, which continues to grow during the development of the flowers, so that the oldest flowers are at the base and the youngest at the tip.

Radicle

The part of the plant embryo which will develop into the primary root.

Reflexed

Bent backward or downward.

Reticulate

In the form of a network; net-veined.

Retuse

With a shallow notch present in an otherwise round or blunt apex.

Rind

A thick outer covering.

Rotund

Round.

S

Sapwood

The outer, newer, usually somewhat lighter wood of a woody stem; the wood that is actively transporting water.

Secondary Veins

Veins which are smaller in size than the midrib and which arise from the midrib.

Sepal

A segment of the calyx.

Sessile.

Attached directly, without a stalk, as a leaf without a petiole.

Solitary

Occurring singly and not borne in a cluster or group.

Spathulate

Like a spatula in shape, with a rounded blade above gradually tapering to the base.

Stamen

The male reproductive organ of a flower, consisting of anther and filament.

Stigma

The uppermost part of the carpel, usually sticky or rough, on which the pollen germinates.

Striate

Marked with parallel lines or grooves.

Style

The narrowed portion of the pistil connecting the stigma to the ovary.

Sub

Meaning under, slightly, somewhat, or almost.

Subcordate

Almost cordate.

Subglobose

Almost spherical.

Suborbicular

Almost round/orbicular in shape.

T

Tepals

A segment of a perianth which is not differentiated into calyx and corolla.

Terete

Round in cross section; cylindrical.

Ternate

In three's, as a leaf which is divided into three leaflets.

Tertiary Veins

Finer than secondary veins and intersecondary veins and generally apparently run at right angles to the secondary veins.

Tomentose

With a covering of short, matted or tangled, soft, wooly hairs (tomentum).

Trinerved

Three-nerved, with the nerves all arising from near the base.

U

Umbel

A flat-topped or convex inflorescence with the pedicels arising more or less from a common point, like the straits of an umbrella.

Umbellate

In umbels; umbel-like.

V

Valve

One of the segments of a dehiscent fruit separating from other such segments at maturity.

W

Whorled

With parts arranged in whorls, as in a leaf arrangement with three or more leaves arising from a node.