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# SYSTEMATICS OF THE GENUS GMELINA L. (LAMIACEAE) IN SOUTHEAST ASIA

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2009



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# In memory of my deceased father,

## for my mother

## and

# for my elder brother

# who made so many sacrifices in life

# to get me here.

## ABSTRACT

The systematics of *Gmelina* is investigated using morphological, anatomical, palynological and molecular data.

The genus is revised for Southeast Asia and 31 taxa are recognised consisting of 26 species, 1 subspecies, and 4 varieties; with a very few exceptions (5 species) all are endemic to this territory. Based on calyx characters a revised new infrageneric classification is proposed. The genus is divided in two sections: section *Asiaticum* M. H. Rashid & J. Parnell and section *Annameticum* M. H. Rashid & J. Parnell.

7 species, 1 subspecies, and 3 varieties have been reported as new to science: *viz. G. chindwinse* M. H. Rashid & J. Parnell, *G. obovata* M. H. Rashid, *G. obovata* var. *glabrata* M. H. Rashid, *G. obovata* var. *kutaiensis* M. H. Rashid, *G. parnellii* M. H. Rashid, *G. palawensis* var. *matanoeca* M. H. Rashid, *G. rotundifolia* M. H. Rashid & J. Parnell, *G. spectabilis* Ridl. ex M. H. Rashid & A. J. Paton, *G. tubularis* M. H. Rashid, *G. tubularis* M. H. Rashid & A. J. Paton, *G. tubularis* M. H. Rashid, *G. tubularis* M. H. Rashid & A. J. Paton, *G. tubularis* M. H. Rashid, *G. tubularis* M. H. Rashid & A. J. Paton, *G. tubularis* M. H. Rashid, *G. tubularis* M. H. Rashid & A. J. Paton, *G. tubularis* M. H. Rashid, *G. tubularis* M. H. Rashid & A. J. Paton, *Rashid* & A. J. Paton, *G. tubularis* M. H. Rashid, *G. tubularis* M. H. Rashid & A. J. Paton, and *G. yangonensis* M. H. Rashid.

Two taxa are elevated to varietal and specific level respectively, *G. philippensis* f. *tarnsitoria* Moldenke to *G. elliptica* var. *transitoria* (Moldenke) M. H. Rashid, and *G. uniflora* var. *villosa* Bakh. to *Gmelina borneoense* M. H. Rashid. Due to the prior use of the epithet *"villosa*" in *Gmelina villosa* Roxb. and *G. asiatica* L. var. *villosa* (Roxb.) Bakh. (valid name *Gmelina elliptica* Smith) a new name is needed and *Gmelina borneoense* is chosen. *G. balansae* Dop is merged with *G. racemosa* (Lour.) Merr.

2 species, G. lepidota and G. tonkinensis, are reported as new records for Indonesia.

Leaf surface anatomy using SEM and petiolar anatomical investigation is carried out and these anatomical characters (such as trichome types and density, vasculature etc.) proved taxonomically important and taxon-specific.

Pollen morphology of 24 taxa of 21 *Gmelina* species also exhibits taxonomic importance and five types of surface patterns are recognised. With only one exception, all grains are isopolar (heteropolar in *G. lepidota*).

Three plastid DNA regions, *tm*L intron, *tm*L-F intergenic spacer, and *atp*B-*rbc*L are sequenced to infer phylogenetic infrageneric and intergeneric relationships of *Gmelina*. The *atp*B-*rbc*L analysis is the least informative. The monophyly of *Gmelina* was weakly supported with the inclusion of an unidentified *Gmelina sp*. in the *tm*L-F analysis. The combined analysis also supports *Gmelina* as monophyletic if the unidentified *Gmelina sp*. is excluded from the genus.

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## CHAPTER 1

## **General Introduction and Objectives**

#### 1.1. Systematics and Biodiversity

**Systematics** is the scientific study of biological diversity that exists on Earth and its evolutionary history. **Biodiversity** or **biological diversity** is the sum total of all life forms on Earth. It is the variety and variability of all species of plants, animals and microorganisms in the world, the genes they contain and as well as the ecosystem they compose. "*Biological diversity* means the variability among living organisms from all sources including *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystem" (http://www.cbd.int/convention/convention.shtml; Rushton 2000). The word "biodiversity" was coined by Thomas Lovejoy in the mid 1980s to confine the concentration of research into the variety and richness of life on Earth. The word has rapidly popularised and now widely used (Jeffries 2006).

**Biodiversity** is a precious "genetic library" maintained by natural ecosystems (Ehrlich & Wilson 1991) on earth and is the product of hundreds of millions of years of evolutionary history and is reflected in the variety and diversity of life observable in the world today (Department of the Environment, Sport and Territories-hereafter DEST, 1993).

### 1.2. Southeast Asia: the study area

Southeast Asia is an area of 4,506,600km<sup>2</sup>, bounded roughly by the Indian subcontinent on the west, China on the north, and the Pacific Ocean on the east. The area lies between latitudes 20°N and 16°S, and longitudes 95° to 130°E. The average temperature varies from 21°C to 32°C (http://www.blueplanetbiomes.org/se\_asian\_rnfrst.htm).

The region includes the following countries- Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar (Burma), Philippines, Singapore, Thailand, and Vietnam (Figure 1).

The floristic region Southeast Asia is the center of diversity of the genus *Gmelina* and therefore chosen as study area.

### 1.2.1. Southeast Asian Biodiversity

Tropical ecosystems are the most ancient, and diverse (Laurance 1999), and are exceptionally species rich and major reserviors of much of the biodiversity on Earth (Heywood & Stuart 1992, Myers *et al.* 2000; Brook *et al.* 2003); and forests are habitats with the greatest abundance and diversity of species in the world. Though they cover only 7% of the earth's land surface they probably sustain over half of its life forms (Wilson 1998; Laurance 1999). It has been estimated that in tropical forests, which represent 3.5% of the total forest

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cover, 27% of the world's total number of higher plant species can be found there and of those 14% are endemic to tropical regions (Bryant 1999).

With approximately 41,000 vascular plant species, the Malesian region is among the most species-rich areas in the world (Roos 1993; Roos *et al.* 2004). Together with the richness and diversity of the southeast Asian flora the presence of living 'primitive' plant families such as Magnoliaceae, Winteraceae, Proteaceae, and Fagaceae, means that Southeast Asia and the adjacent south-west Pacific region is considered as the *Cradle of the angiosperms*; the main centre of evolution from which plants radiated and colonised the rest of the world (Audley-Charles 1987; Molnar 2001).

Conservation International identified 34 biodiversity hotspots as those areas containing exceptionally high endemic species and facing immense habitat loss; each has more than 1500 endemic plant species and has lost at least 70% of their original habitat (Mittermeier *et al.* 2004, www.biodiversityhotspots.org). Southeast Asia overlaps with four of these (Indo-Burma; Sundaland; Wallacea; and the Philippines (Figure 1.1), and in terms of species richness and endemism the region floristically ranks as one of the highest in the world (Sodhi *et al.* 2004; Corlett 2009).

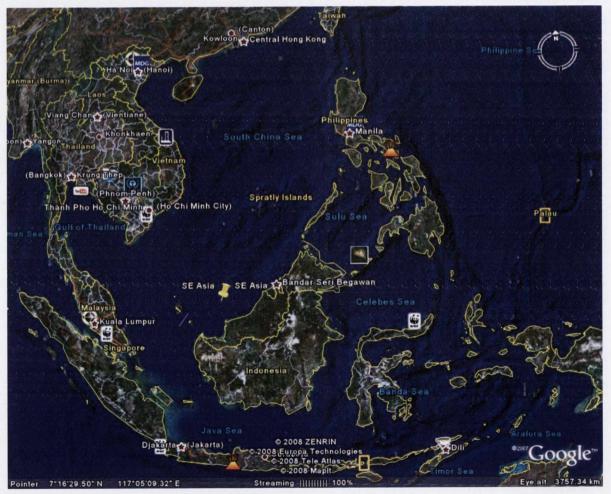
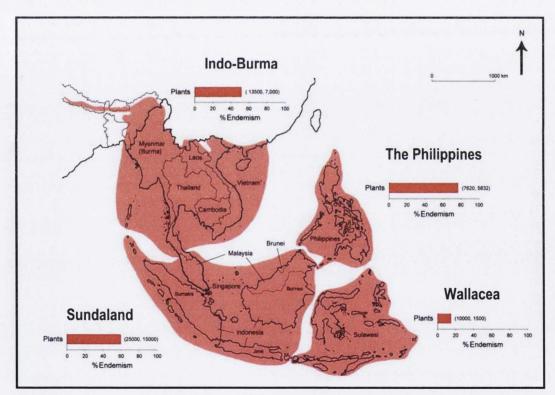


Figure 1. Map of Southeast Asia (obtained from http://earth.google.com).

#### 1.2.1. 1. Southeast Asian Biodiversity in Crisis

Currently global biodiversity is decreasing at an alarming rate; this is referred to as the "biodiversity crisis". Tropical forests are now seriously imperiled by anthropogenic activities, including deforestation and habitat degradation (Laurance 1999), over exploitation of plant and animal populations (Milner-Gulland & Akçakaya 2001), and introduction of invasive species (Novacek & Cleland 2001; Brook *et al.* 2003). Humans are extracting natural resources at unprecedented levels. About half of the world's original forest cover has already been cleared for agriculture and forest products, while another 30% has subsequently become degraded or fragmented (Sodhi & Brook 2006). Some 85% of global forest loss occurs in the tropical rain forests (Sodhi & Brook 2006).

Using the United Nation's Food and Agriculture Organisation's (hereafter FAO) data on forest cover change in 1980s, Laurance (1999) estimated that 15.4 million hectares (an average of 1.2%) of existing tropical forests are degraded or destroyed every year by direct human activities, which affect 91% of threatened plants (International Union for the Conservation of Nature and Natural Resources - hereafter IUCN, 2008).



**Figure 1.1**. Species richness and endemism in Southeast Asia. The four biodiversity hotspots overlapping Southeast Asia are highlighted. (Modified from Sodhi *et al.* 2004. Obtained from: Conservation International (2008) http://www.biodiversityhotspots.org.)

8,000 years ago, Southeast Asia was almost entirely densely clothed by diverse tropical forests, which contains about 26% of the world's tropical plant species and is also one of the most ecologically threatened areas of the world (Sodhi & Brook 2006; 2008). Today, this highly biodiverse region has the highest global rate of forest loss, with deforestation rates at least more than double those of other tropical areas (Hannah *et al.* 1995; Laurance 1999; Achard *et al.* 2002). Considering forest conversion relative to the existing forest cover in the region, Asia clearly tops the list (Laurance 1999), with 1.5 million hectare of forest cleared each

year from the four main Indonesian islands of Sumatra, Kalimantan, Sulawesi and Irian Jaya alone (DeFries *et al.* 2002). This report is supported by Achard *et al.* (2002) and Sodhi & Brook (2006) who confirm that rates of deforestation and forest degradation are among the highest in Southeast Asia (Figure 1.2).

Population density and economic growth are clearly associated with forest loss in Southeast Asia (Sodhi *et al.* 2004; Sodhi & Brook 2006). Massive anthropogenic habitat modifications, forest clearance for shifting cultivation (Figure 1.3) and the over-exploitation of wildlife in Southeast Asia are clear-and-present dangers to its biodiversity (Myers 1994; Panayotou & Sungsuwan 1994; Sodhi *et al.* 2004).

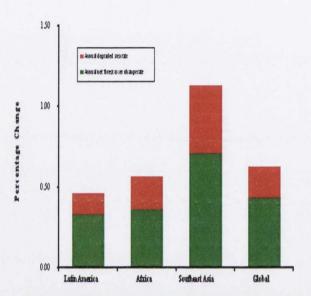




Figure 1.2 Mean annual estimates of deforestation in the Tropics during 1990-1997( data from Achard *et al.* 2002).

Figure 1.3 Forest clearance in tropical forests.

FAO has estimated that shifting cultivation has been responsible for the removal of 70% of Southeast Asian forests (Whitmore 1998). Due to forest clearance, in northwest Borneo approximately 40% of the endemic species have been lost and in the Philippines the past 50 years has seen two thirds of the forests removed (Wilson 1998). The region also has poorly enforced protected areas and in the Philippines, Myanmar, Laos, Cambodia and Vietnam conservation is not a high priority (Heywood & Stuart 1992). Worryingly, even the so-called 'protected forests' are also shrinking and fragmenting (Curran *et al.* 2004; DeFries *et al.* 2005). If the current rates of deforestation continues, the dire predictions are that three quarters of Southeast Asian biodiversity may be wiped out by 2100 (Sodhi *et al.* 2004; Sodhi & Brook 2006, 2008).

In 2003, IUCN listed three plant and eight animal species as 'extinct' in Southeast Asia. The numbers of threatened species that are either 'Critically Endangered' (CE), or 'Vulnerable' (VU) ranges from **19** (CE) to **683** (VU) species of vascular plants in Southeast Asia (IUCN 2003; Sodhi *et al.* 2004; Sodhi & Brook 2006; **Table 1**). The loss of many of these regional populations is likely to result in global extinctions because of the highest proportion of endemic species in the region (Brook *et al.* 2003; World Resources Institute - hereafter WRI, 2003a; Sodhi *et al.* 2004; Sodhi & Brook 2006; 2008). For example, almost 60% of the 29,375 vascular plant species in Indonesia do not occur anywhere else (WRI 2003b; Sodhi *et al.* 2004; Sodhi & Brook 2006).

So far rates of extinction have been based on inadequate information (Whitmore 1998). In 2007, IUCN listed a total of 8,394 threatened plant species (around 3% of those so far described). As approximately only 4% of the world's plants have been evaluated, the exact percentage of threatened species is likely to be much higher (IUCN 2008). Species inventories are therefore necessary so that formulations of extinction rates may be calculated and areas for conservation can be identified (Reid 1992). One of the problems conservationists are facing is that tropical areas are poorly explored and inventories of species are non-existent or incomplete (Heywood & Stuart 1992). It has been estimated that globally there are 300,000 (Myers *et al.* 2000); or 223,000 to 422,000 (Govaerts 2001; IUCN 2004) flowering plant species; but a complete assessment of

Country		V	ascular Plants	
country	RC	тн	ED	% of known species
Myanmar	7,000	38	1,071	15.3
Laos	8,286	19		
Vietnam	10,500	145	1,260	12.0
Thailand	11,625	84		•
Cambodia		31		
Malaysia	15,500	683	3,600	23.2
Singapore	2,282	54	2	0.1
Indonesia	29,375	383	17,500	59.6
Brunei	6,000	101	7	0.1
Philippines	8,931	212	3,500	39.2

**Table 1**. Number of known Vascular plants in Southeast Asia. RC= Recorded; TH = Threatened; and ED = Endemic. - = No data. Lowest and highest threatened species number is highlighted (Data from IUCN 2003; WRI 2003b).

global plant diversity is a daunting task. However, an initiative has been under taken to provide a preliminary assessment of the conservation of all known plant species by 2010 (IUCN 2004). There is common will to conserve the world's biodiversity as indicated by 150 governments signing up to of the Conservation of Biological Diversity strategy in the Earth Summit in 1992 (Bryant 1999). In approaching assessments of diversity, there is an urgent need to catalogue the number of species in the world. In the quest for assessing biodiversity, Taxonomy and Systematics have emerged as essential tools for the effective quantification of diversity. It has been stated that "There should be no surprise. Without taxonomy to give shape to the bricks, and systematics to tell us how to put them together, the house of biological sciences is a meaningless jumble" (May 1990).

The reason for conserving biodiversity is not just for purely idealistic reasons. In particular the removal of tropical forests can have global as well as local consequences (WRI 2000). The tropical ecosystem is a reservoir of untapped resources, genetic diversity and many plant species have medicinal applications. The destruction of the habitat of perhaps undescribed but medicinally useful plants means that treatments for known and future as yet unknown diseases will be lost (DEST 1993). Undisturbed tropical forests act as a globally significant carbon sink (Gaston *et al.* 1998, De Camargo *et al.* 1999; Laurance 1999). Burning and removal of these forests increases the level of carbon dioxide in the atmosphere resulting in a heating of the

earth's surface and consequently changes in global climates (Brown & Pearce 1994, Whitmore 1998, WRI 2003a). If climate change is inevitable, and it appears that is so, then the retention of at least some areas of tropical forest may be important for adaptation to change. The potential gene pool in tropical species could be used to tailor agricultural species to changing environmental conditions (DEST 1993). It appears therefore that tropical ecosystems and hence a large proportion of the world's biodiversity are under severe threat. In order to control the destruction of these areas, systematic revisions play a very vital role in the monitoring of biodiversity and in providing the basis for conservation measures. Species inventories and a better understanding of tropical environments also has an essential part to play in the exploitation of new natural resources and in the control of global climate change. To quote from Boontawee *et al.* (1995) " There is an urgent need to explore, identify, protect, and manage the available forest biodiversity properly for future sustainable utilization."

### 1.3. Phytogeographical setting

This study involves a revision of the genus *Gmelina* L. in Southeast Asia, which includes the countries: Brunei, Singapore, Myanmar (Burma), Thailand, Cambodia, Laos, Vietnam, Malaysia, the Philippines, and Indonesia. The area has been divided into several floristic regions; the most clearly defined of which, Malesia, contains the second most extensive rainforest (apart from the Amazon basin) in the world (Whitmore 1984). Malesia was first recognised as floristic region by Heinrich Zollinger in 1875 and Van Steenis further developed the concept of this floristic region in the 20<sup>th</sup> century (Van Steenis 1950). The region includes six countries: Brunei, Indonesia, Malaysia, Papua New Guinea, the Philippines and Singapore (Johns 1995).

### 1.3.1. Phytogeography of Malesia

The delimitation of this area is defined by four contacts or bridges with adjacent floral regions where there are changes in floristic composition and numbers of plant genera (Van Steenis 1950). The northwestern frontier of Malesia is at the Isthmus of Kra linking Thailand to Malaya. The flora of Malay Peninsula distinctly differs from that of Indochina and is closely allied to the floras of Sumatra and Borneo (together Sunda Shelf). This supports at least 375 genera which do not occur in Indochina and, conversely, 200 genera from Indochina have not penetrated into the Sunda Shelf (Van Steenis 1950). This 'demarcation-knot' occurs slightly to the north of Malaysia, near the line joining Alor Star-Singora in Thailand (Van Steenis 1950; Johns 1995). The clearly defined northern boundary formed between the Philippines and Taiwan; where 265 genera from Taiwan do not occur in the Philippines and conversely 421 Philippine genera do not occur in Taiwan. The strongest line of demarcation is in the east between New Guinea and Australia where there are over 644 genera in New Guinea (Van Steenis 1950, Johns 1995).

Within Malesia there are also phytogeographic boundaries. The flora of the Malay Peninsula is broadly similar to that of Sumatra and Borneo, which reflects a historic land connection between the regions (Morley 1998). The Malay Peninsula has 36 genera that are not found in the rest of Malesia, Sumatra has 17 endemic genera and Borneo 59 (Davis *et al.* 1986). The difference between these areas is due to migration, evolution, and

competition against a backdrop of tectonic activity and sea level change (Whitmore 1984, Johns 1995). The other major phytogeographical area is defined by Wallace's Line which extends through the Lesser Sunda Islands and along the west side of the Philippines between Palawan and Mindoro (Van Steenis 1950). This boundary was based on examination of the differences in the fauna between Sulawesi and Borneo but is generally less distinct for plant species. The region for the different faunal and floristic composition either side of this boundary is due to the presence of two large continental shelves in Southeast Asia: in the west, the largest continental shelf in the world, the Sunda shelf, comprises Sumatra, Malaysia, Java, Borneo and the Philippine island of Palawan; in the east, the Sahul shelf encompasses New Guinea, the Torres straits, Louisiade Archipelago and the Solomon Islands (Johns 1995). New Guinea is the greatest centre of generic development in Malesia with some 124 endemic genera, which is more than the in Lesser Sunda Islands and the Malay Peninsula combined (Davis *et al.* 1986). The richness and diversity of this flora is out of proportion to the age of the island which only became fully emergent in the Miocene (14Ma) (Hall 1998).

The diversity of the flora of New Guinea is due to the heterogeneous composition of the island, which contains elements of both east and west Malesia. The rise and fall of sea levels and topographic diversity has meant that rapid speciation has also taken place in many plant groups on the island (Morley 2000). The Philippines, Sulawesi and other islands of central Malesia were thought to represent a distinct element due to their separation from the other regions by deep water (Johns 1995). Recent evidence using tectonic reconstruction has shown however that Sulawesi contains elements of eastern Borneo and that the Philippines have at various times come into contact with the other regions of Malesia (Hall 1998). The distinct flora of Sulawesi may therefore be due to contributions from both eastern and western Malesia coupled with high rates of endemism due to accelerated speciation on the extensive areas of ultramafic rock (Johns 1995). The flora of Java is thought to have its closest affinity with that of Sumatra and Borneo but due to anthropogenic interference and different climatic conditions in the east and west of the island it is somewhat distinct with 10 endemic genera (Davis et al. 1986). The genera, which are mainly absent from Borneo and Sumatra but present in Java, occur in Southeast Asia above the Isthmus of Kra reflecting similar climatic conditions in the two distinct regions (Van Steenis 1950). The flora of Java is poor with just 4,500 species compared to the rest of Malesia- 15,000 in Borneo, 10,000-15,000 in Sumatra, and 8,000-10,000 in the Malay Peninsula. This is thought to be due to large scale forest clearance in Java which has caused extinction of many of the island's endemic genera (Johns 1995). This floristically rich region of Malesia which contains perhaps 60,000 flowering plant species (Davis et al. 1986; WRI 2003) is the subject of the Flora Malesiana project which was conceived by Van Steenis and begun in 1984. The aim of the project is to provide taxonomic revisions for all of the families in the region and possibly 70% of them have now been covered. Taxonomic treatments have however concentrated on the smaller groups and, as the number of species is not evenly distributed across families, only 15-20% of the species have been published (Johns 1995; Roos 1995). Geesink (1990) evaluated the progress and estimated that the completion of Flora Malesiana would take another 160 years. Roos (2003) summarized that from 1991-2001 only just over 2200 species have been treated (i.e. 200 species/year). The present rate of progress indicates that Flora Malesiana will not be completed before 2135, which is similar to Geesink's conclusion over a decade ago (Roos 2003).

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#### 1.3.2. Phytogeography of Indochina

The other floristic regions, which are covered in this portion of the study, are countries of Indochina comprising of Vietnam, Laos, Cambodia, Thailand, Myanmar, and the mainland Malaysia (http://www.answers.com/topic/indochina).

Indochina was once almost entirely forested by different types of forests (Hamilton & Davis 1995). Peninsular Thailand and Indochina have some floristic similarities to the Malay Peninsula, and as more genera are discovered in Peninsular Thailand, the boundary between Malesia and this region becomes less distinct (Gray et al. 1991). Thailand is about the area of France in size with 513,115km<sup>2</sup> (Gray et al. 1991). The central plain is an area of low relief and elevation of just 200-500m from north to south (Sternstein 1976). The country is delineated by two mountain systems: the Central Cordillera in the west along the Myanmar border is part of the mountain system originating from the southeast corner of the Tibetan massif (Sternstein 1976) and in the east is the Cordillera of Annam, which transverses Laos and Vietnam (Gray et al. 1991). Thailand therefore contains six physiographic regions, which correspond to the topography, and climatic regions in the different areas (Gray et al. 1991; Rundel & Boonpragob 1995). The northern part of the country comprises parallel north-south orientated mountain ranges, which alternate with elongate, often wide, alluvial valleys in between (Gray et al. 1991). Steep limestone ridges and volcanic plateau are present in several areas (Sternstein 1976). The highest peak in Thailand, Doi Inthanon, at 2,576m is found in this region. Southwards from this area is the central plain which is one of the most fertile agricultural regions in the country (Gray et al. 1991). The northeast of the country is defined by the Khorat Plateau, a sandstone region which cover nearly one third of the country and is a large basin which slopes downwards to southeast from an elevation of 150-200m along its western and northern margins (Rundel & Boonpragob 1995). To the north of the central highlands is a complex assemblage of strongly incised plateaus and steep limestone ridges (Sternstein 1976). The southeastern region consists of low hills to the north and mountains to the east, which are a continuation of the Cardamon Mountains of Cambodia. The coast around this area is fringed by rocky, forested islands (Rundel & Boonpragob 1995). The southwest, along the Myanmar border represents a continuum of the mountains from the north but valleys are narrower and several tributaries of the larger river systems originated here (Sternstein 1976). The peninsular region is a continuation of the western ranges, the backbone of which is formed by short longitudinally oriented ridges, which rarely exceed an elevation of 1,000m (Rundel & Boonpragob 1995). On the west side the mountains extend to the sea and the coast is very irregular, studded with estuaries and some 275 offshore islands. The eastern side of the peninsula consists of long stretches of coastal plain and beach (Gray et al. 1991).

Thailand's flora is very rich consisting of some 15,000 (Gray *et al.* 1991) or 12,500 flowering plant species (Parnell 2000), which inspired a growing interest in the flora of the region from the first half of the 20<sup>th</sup> century. The country has a long history of plant collecting from the first collection of Kaempfer in 1690 (Larsen 1979) until the present day. The flora of the region is currently being revised under the auspices of the *Flora of Thailand* project, which was conceived during the Thai-Danish botanical expedition of 1958-1959 (Larsen & Warncke 1966; Santisuk *et al.* 1991). It was estimated that between 80 and 154 years would be needed to

complete the Flora, but significant progress is being made and the project will require approximately another 30 years for completion (Parnell 2000). According to the IUCN List of Threatened Plants (Walter & Gillett 1998), there are 27 endangered (E), 21 vulnerable (V), and 33 rare species in Thailand, probably these figures are greatly underestimated due to lack of data on many plant groups (Middleton 2003).

Laos is landlocked country lies in the center of the Southeast Asian peninsula, and surrounded by Thailand, Myanmar, China, Vietnam and Cambodia. The Mekong River forms the country's western border and the Annamite Mountains form its eastern border with Vietnam. The total land area is approximately 237,000km<sup>2</sup> (Central Intelligence Agency - hereafter CIA, 2008), an area similar to that of the United Kingdom. Laos mainly consists of rugged mountains with some plains and plateaus in the west and south of the country. The country straddles many biogeographic zones: the Himalayas and China in the north and the Indo-Malayan in the south which influenced the floristic composition. The highest point in the country is Phou Bia, an extension of the Xiangkhouang plateau, reaching up to 2,820m (Hamilton & Davis 1995). The longest border is with Vietnam, defined by the Cordillera of Annam. The Mekong runs along the border with Thailand and this area consists of flood plains and alluvial terraces. The northwest of the country contains parallel northwest orientated mountain ranges, which rarely exceed 1,000m. To the east of this region is a low-lying area, which is defined by the Ngum River and the Nam Ngum Reservoir. In the south the Bolovens plateau is surrounded by an irregular assortment of low mountains interspersed by narrow valleys. The southeast is flat demarcated by the Mekong, which has its widest point in Laos in this region. The country contains approximately 27,000km<sup>2</sup> of tropical lowlands and hill evergreen forests, which occur along the Cordillera of Annam and the Bolovens plateau, although above 1,000m the forests have been extensively converted to grassland (Davis et al. 1986). Due to its relative isolation, surrounded by mountains in the north and east, 69.9% of the country has remained forested (CIA 2008).

Cambodia, with an area of 181,040km<sup>2</sup> in the southwestern part of the Indochinese peninsula, is bordered on the north by Thailand and by Laos, on the east and southeast by Vietnam, and on the west by the Gulf of Thailand and by Thailand. The Tônle Sap Basin or Great Lake and the Mekong Lowlands dominate the landscape of Cambodia and the latter traverses the country from north to south. This river largely controls the hydrology of the country. During the northeast monsoon the flow of the river reaches its maximum in June and floods the adjacent area for four to seven months. At this time the Tônle Sap achieves its maximum area and from 2.600km<sup>2</sup> to approximately 10,000km<sup>2</sup> (Kingdom of Cambodia 2008increases http://www.countrystudies.us/cambodia/htm). The central plain, which covers three quarters of the country, is an area of low relief with elevations of less than 100m. Surrounding this area in the west and southwest are the Cardamon Mountains and Elephant range which form part of the natural southern border with Thailand. The highest peak in the country, Phum Aôral (1,810m), is found in the Cardamon Range, which consists of northwest orientated mountains separated by narrow valleys. A strip of coastal plain, which faces the Gulf of Thailand, borders the two mountain ranges. The northern border with Thailand is defined by the Dangrek Mountains, which adjoin the Khorat plateau of Thailand. In the east a series of north-south orientated mountain ranges, the Chhlongh highlands, merge with the southern portion of the Cordillera of Annam in

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Vietnam. The country is covered by about 10.5 million hectares of forest (approximately 59.2% of the land area) (CIA 2008).

Vietnam is located in the southeastern margin of the Indochinese peninsula and occupies about 329,560km<sup>2</sup>, larger than Italy and almost the size of Germany (CIA 2008). An elongated S-shaped country borders the Gulf of Thailand, Gulf of Tonkin, and South China Sea alongside China, Laos, and Cambodia. The border with Laos, Cambodia, and China is defined by the Cordillera of Annam, which runs from the north to the south of the country. The north and northwest regions are defined by a high rugged mountains separated by narrow, steep valleys. The highest peak, Fan Si Pan (3,144m), part of the Hoà Liên range, is located in this region, near the border with southern China. A low flat delta in the south and northeast and mountains in the west and north dominate the topography of Vietnam. The Red river flows through the northwest and drains the plains of the northeast, flowing into Gulf of Tonkin at Phong. To the east of the Red river is a randomly orientated assortment of high mountains, interspersed by broad valleys and plains. Along the east coast, bordering the Cordillera of Annam is a narrow stretch of coastal plain and river flood plains which extends to the south of the country. The southeast, dominated by high east-west orientated mountains, is interspersed with valleys and broad plains. The low-lying southern tip of Vietnam is defined by the Mekong, which flows into the South China Sea at four points in this region. Vietnam has a total of 19.0 million hectares as designated forest land (Rehab 2008), approximately 25% of the land area (CIA 2008) is forested with tropical rainforest in submontane and montane regions and semi-deciduous forests in the northwest and south. 11 new species including eight plants (five orchids), one snake and two butterflies have been discovered in Vietnam between 2005 and 2006 (http://rainforests.mongabay.com/20vietnam.htm).

Myanmar covers an area about 678,500km<sup>2</sup> roughly the size of France and Belgium combined; located in the western portion of mainland Southeast Asia. It is bordered by China to the north and northeast, Laos to the east, Thailand to the southeast, the Andaman Sea and Bay of Bengal to the south and southwest, Bangladesh to the west, and India to the northwest (CIA 2008).

A major topographical feature of Myanmar is the Irrawaddy basin. Since its deltaic plains are very fertile, it is considered to be the most important part of the country covering about 47,000km<sup>2</sup>. The Irrawaddy basin is a fertile expanse, which sits within the tropical monsoon belt, and one of the world's great rice-growing regions. (http://www.geographia.com/myanmar/). Hkakabo Razi, the highest peak in Southeast Asia at 5,881m, is located in Myanmar. Myanmar has a total of 32.22 million hectares of forest area, almost half (49%) of the land area (CIA 2008) is covered in forests that comprise of teak, rubber, cinchona, acacia, bamboo, ironwood, mangrove, coconut, betel palm with northern highlands comprise of oak, pine and many varieties of rhododendron. Many tropical fruits are found, citrus, bananas, mangoes, and guavas in the coastal region (http://www.asianinfo.org/asianinfo/myanmar/pro-geography.htm). The extensive deciduous forests of Myanmar, for example, cover wide areas and are dominated by only one or two tree species, teak - *Tectona grandis* L. f., and the smaller leguminous ironwood tree- *Xylia xylocarpa* (Roxb.) Theob. (Encyclopedia Britannica 2008).

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#### 1.4. Lamiaceae sensu lato (s.l.)

Lamiaceae *s.l.* is the seventh largest flowering plant family. The number of genera and species are variously reported as: 220 genera and some 4,000 species Hedge 1992); over 250 genera and 6,000 species (Thorne 1992); 258 genera and 6,970 species (Zomlefer 1994); 236 genera and about 7,173 species (Harley *et al.* 2004) 233 genera and about 6,870 species (Heywood *et al.* 2007); 252 genera and 6,800 species (Judd *et al.* 2008); and 238 genera and 6,500 species (Mabberley 2008); and is regarded as being one of the most highly evolved plant families, at least from the viewpoint of floral structure (Hedge 1992). It belongs to the order Lamiales and is related to Verbenaceae, Acanthaceae, Scrophulariaceae, Gesneriaceae, Lentibulariaceae, Buddlejaceae and Bignoniaceae based on 18S rDNA, *atp*B and *rbcL* gene sequences, but the relationships within the order are still unclear (Savolainen *et al.* 2000a,b; Soltis *et al.* 2000; Soltis *et al.* 2005). The family contains several genera of the former Verbenaceae that have been transferred to it (Cantino *et al.* 1992) it also has an almost cosmopolitan distribution, but is absent from the coldest regions of high latitude or altitude (Harley *et al.* 2004), and is most species- rich in the Mediterranean to Central Asian region. Lamiaceae *s.l.* is a family of herbs, shrubs and trees, and is economically very important in several parts of the world. In Southeast Asia, the family contains the most valuable native tropical hardwood, teak (*Tectona grandis*), which has long played an important role in the region's economy.

Hedge (1992) recognised six areas of high diversity and centers of origin of Lamiaceae *s.l.* Harley *et al.* (2004) added the 7<sup>th</sup> Indomalesian region (Southeast Asia), the centre of diversity of the subfamilies Viticoideae and Symphorematoideae. The genus *Gmelina* L. is endemic to this region (Harley *et al.* 2004).

#### 1.4.1. Taxonomic History of Lamiaceae

de Jussieu first used the name Lamiaceae in 1789. The name Lamiaceae is one of the eight family names not ending in -aceae. This name is legitimised by long usage and treated as validly published but Lamiaceae is valid as an alternative name (ICBN 1988, Article 18.5 & 18.6).

The foundations of Lamiaceae classification were laid by Bentham (1832-1836) in his *Labiatarum genera et species*, the first monographic treatment of the family. He divided the family into 11 tribes. In his modified account of Lamiaceae in de Candolle's *Prodromus Systematis Naturalis Regni*, Bentham (1848) reconsidered the delimitation of the tribes, combining some of them, and recognised eight tribes. In 1876 Bentham & Hooker added more genera to the eight tribes. Bentham's works were the basis of all subsequent workers who modified some his tribes, by either upgrading them into subfamilies or stepping them down to lower ranks.

The next global account was that of Briquet in *Die natürlichen Pfanzenfamilien* (1895-1897), who considered there to be eight subfamilies. Briquet's treatment displaced Bentham's classification. This system was modified by Melchior (1964) and remains the most widely used today.

Later important treatments were those of Erdtman (1945) and Wunderlich (1967). Erdtman recognised two subfamilies of Lamiaceae, on the basis of pollen morphology: the *Lamioideae* with tricolpate and *Nepetoideae* 

with hexacolpate pollen. He did not recognise tribes or subtribes. Wunderlich (1967), with some changes, provided a classification more or less correlated to that of Briquet, he divided the family into six subfamilies.

Since then, the classification of the family has remained unchanged until Cantino *et al.* (1992) adopted the classification suggested by Junell (1934) and proposed a revised classification of the family Lamiaceae. This new classification was influenced by the results of the phylogenetic analyses of Cantino (1992a, b) which both examined Lamiaceae/Verbenaceae boundary. The results from Cantino's analyses suggest that Lamiaceae *sensu stricto* (*s.s.*) is polyphyletic and Verbenaceae is paraphyletic. These results led them to propose the transfer of about two-thirds genera including *Gmelina* from Verbenaceae to the Lamiaceae in order to make the family and subfamilies monophyletic. In all, they recognised eight subfamilies: Ajugoideae, Chloanthoideae, Lamioideae, Nepetoideae, Scutellarioideae, Teucrioideae, Viticoideae (consisting of some genera of former Verbenaceae including *Gmelina*) and a new subfamily Pogostemonoideae (Endl.) P. D. Cantino, Harley & Wagstaff. This classification was mostly adopted by Thorne (1992); and the recognition of the transferred genera under Lamiaceae is now being accepted elsewhere *e.g.* Zomlefer (1994); Harley *et al.* (2004); Soltis *et al.* (2005); Heywood *et al.* (2007) and Judd *et al.* (2008). This broader view of the Lamiaceae leaves a more narrowly circumscribed Verbenaceae which now includes only the subfamily Verbenoideae with the exclusion of the tribe Monochileae (Cantino 1992a,b). Table 1.2 shows familiar Southeast Asian genera, which have been transferred to Lamiaceae, and which still remain in Verbenaceae.

Genera transferred to Lamiaceae	Genera remain in Verbenaceae		
Callicarpa L., Caryopteris Bunge, Clerodendrum L.,			
Garretia Fletcher, Glossocarya Wall. ex Griff., Gmelina L.,	Duranta L., Lantana L., Lippia L., Petrea L.,		
Hymeopyramis Wall. ex Griff., Paravitex Fletcher,	Phyla Lour., Stachytarpheta Vahl, Verbena L.		
Premna L., Tectona L., Teijsmanniodendron Koord.,			
Tsoongia Merr., Vitex L.			

 Table 1.2 Familiar Southeast Asian Verbenaceous genera that have been transferred to Lamiaceae and the genera which still remain in Verbenaceae (Modified from Suddee 2001).

The results of a combined analysis of the *rbcL* and *ndhF* genes (Wagstaff *et al.* 1998) support the monophyly of Lamiaceae *s.l.* in which five large clades are supported; these correspond to Nepetoideae, Scutellarioideae, Lamioideae and combined Pogostemonoideae + Lamioideae, Teucrioideae (including *Ajuga*). *Petitia* and *Vitex* form a smaller, sixth clade. Subfamily Viticoideae appears as an unresolved polyphyletic group near the base of Lamiaceae *s.l.* They recommended the inclusion of *Ajuga* and related genera in subfamily Teucrioideae.

Lamiaceae have long been considered a close relative to Verbenaceae. The difficulties of distinguishing the two families have long been addressed and are emphasised here because the two families as delimited traditionally are diverse and economically important in the Southeast Asian region. The traditional difference between the two families is in their gynoecial structure. Generally, Lamiaceae (*s.s.*) are distinguished from Verbenaceae (*s.l.*) by having a clearly four-lobed ovary with gynobasic style and an unlobed ovary with terminal style in Verbenaceae. However, there are some intermediate forms of these characters that can be

found in the members of both families. In some members of the Lamiaceae, the ovary can range from unlobed to shallowly-lobed to deeply-lobed, and the style from shallowly sunken to fully gynobasic, e.g. in Lamioideae and Nepetoideae, the ovary is deeply 4-lobed and the style gynobasic, while in the other subfamilies the stylar position is usually terminal or may be intermediate, with the ovary unlobed, or lobed less deeply (Harley et al. 2004). In Verbenaceae, the ovary is usually unlobed but it can be lobed to halfway (Cantino 1992a). Thus the boundary between the two families is indistinct (Cronguist 1981; Cantino 1992a, b; Hedge 1992; Wagstaff & Olmstead 1997). The family falls within the gamopetalous families related to Scrophulariaceae, but its closest relative is uncertain (Heywood et al. 2007). In most studies, Lamiaceae and Verbenaceae clades appear distantly related within Lamiales (Olmstead and Reeves 1995; Wagstaff & Olmstead 1997; Wagstaff et al. 1998; Savolainen et al. 2000a, 2000b; Soltis et al. 2000; Albach et al. 2001). The most recent findings of Olmstead et al. (2000, 2001) suggest that the closest relatives of Verbenaceae s.s. are Pedaliaceae. Acanthaceae, Bignoniaceae, Scrophulariaceae, and Martyniaceae rather than Lamiaceae (Figure 1.4.). In the both analyses, Paulowniaceae appear to be a sister group of Lamiaceae. Firm morphological data are still lacking to support these conclusions which are only based on molecular data. But combined molecular, chemical and morphological data also supports Myoporaceae as sister to Lamiacae, and Acanthaceae nested to Verbenaceae Bremer et al. (2001).

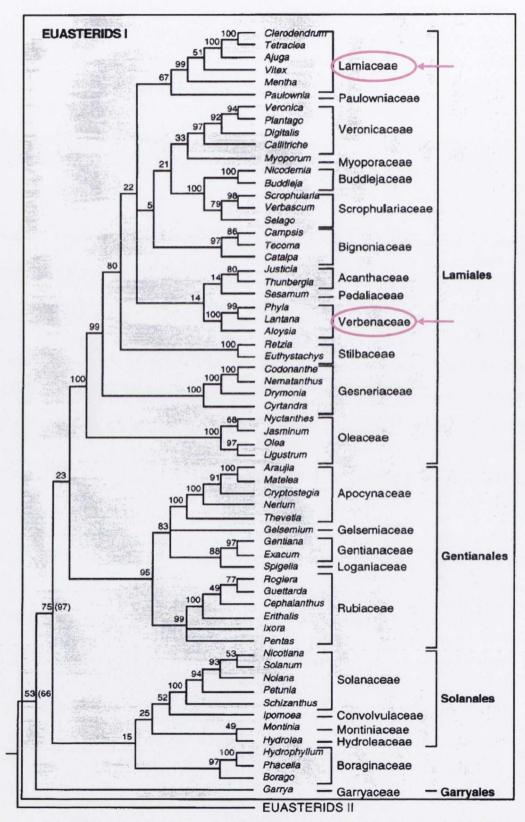
Harley *et al.* (2004) identified some major changes to the latest classification of the family proposed by Cantino *et al.* (1992) and recognised seven subfamilies: Symphorematoideae; Viticoideae; Ajugoideae (with subfamily Teucrioideae); Prostantheroideae (with the inclusion of tribe Chloantheae (= Chloanthoideae); Scutellarioideae; Lamioideae (with subfamily Pogostemonoideae); and Nepetoideae. Mabberley (2008) recognises this classification. Cantino *et al.* (1992) placed ten genera including *Tectona* (important tropical timber-Teak) in group VIII as *Incertae sedis* (position uncertain).

Heywood *et al.* (2007) recognised six subfamilies of family Lamiaceae: Viticoideae, Ajugoideae, Prostantheroideae, Scutellarioideae, Lamioideae, and Nepetoideae.

Verbenaceae as circumscribed by Cantino *et al.* (1992) now only includes subfamily *Verbenoideae* (excluding tribe *Monochileae*, a group that Junell (1934) suggested be retained in Verbenaceae). In Verbenaceae (*s.s.*) the ovules are attached directly on the carpel margins whereas in the Lamiaceae (*s.l.*) the ovules attached laterally on false septa (Junell 1934). The monophyly of the Lamiaceae (*s.l.*) was also supported by analysis of *rbcL* (Wagstaff & Olmstead 1997), *rbcL* and *ndhF* genes (Wagstaff *et al.* 1998) (with the inclusion of *Congea tomentosa* in both works). Gross morphological characters which support this new division include inflorescence structure; racemose in Verbenaceae and cymose in the Lamiaceae; and flower structure, Verbenaceae having more or less regular hypocrateriform corollas with included anthers and the Lamiaceae with zygomorphic corollas (rarely actinomorphic) and usually exserted stamens.

Of the seven subfamilies, the least satisfactory, as circumscribed by Cantino *et al.* (1992), is the Viticoideae, which is clearly paraphyletic, or possibly polyphyletic. Recent molecular studies (Olmstead, unpublished data) indicate that *Hymenopyramis* is sister to *Petraeovitex* and the two are not close to other genera of Viticoideae. According to the same study, both *Callicarpa* L. and *Tectona* are relatively basal, *Callicarpa* being weakly

supported as sister group to Prostantheroideae, while *Tectona* is weakly supported as sister group to most of the family (Harley *et al.* 2004). The removal of these four genera to *Incertae sedis* would leave the Viticoideae more homogeneous. At present, different kinds of data (molecular or morphological) give conflicting results, and it is clear that the whole group is in need of much more detailed studies (Harley *et al.* 2004).



**Figure 1.4** Strict consensus tree of eight most-parsimonious trees based on *ndhF* sequences (Taken from Olmstead *et al.* 2000) showing relationships of Lamiaceae and Verbenaceae (arrowed) with other families

#### 1.4.2. Floristic History of Lamiaceae in Southeast Asia and Neighbouring regions

South East Asian Lamiaceae are still very poorly known. The floristic works on the family mainly have concentrated on Africa and South America. The first account of Lamiaceae in Southeast Asia was that of Lourerio's (1790) *Flora Cochinchinensis*. This work was based on his collections from Hué and the neighbouring regions in Southern Vietnam.

In South Asia and Burma, the most important account was that of Bentham (1830). Other important works which appeared in the same period of time were those of Roth (1821), Don (1825), and Roxburgh (1832), in which several new species were described. Afterwards, there was a long gap until Hooker (1885) produced an account of Lamiaceae in his monumental work *Flora of British India*, describing several new species. This work still remains one of the most useful references for the flora of South Asia and neighbouring regions.

In 1890, Prain added some new species of Lamiaceae to the Flora of British India. Subsequently, Cooke (1906), Duthie (1911), Haines (1922), Gamble (1924), Gandhi (1976), Rani & Matthew (1983) and many others contributed to regional Indian Floras.

Collett and Hemsley (1891), Pottinger and Prain (1898), Gage (1904), Smith and Ramaswami (1913), and Merrill (1941) recorded several Burmese taxa; Mukerjee (1940) revised the whole family in the Indian Empire, including Myanmar (Burma); Trimen (1895b), and Cramer (1981) described some Sri Lankan taxa and Clement (1999) provided an account for Bhutanese Lamiaceae.

For South China and neighbouring regions, Forbes & Hemsley (1890), and Diels (1912) described many new species of Lamiaceae. In 1913, Dunn recorded some new species from Southern China, later in 1915, he produced a key for the Chinese Lamiaceae. Subsequently, Kudo (1929), Wu (1959), Wu & Li (1975; 1977) contributed to Lamiaceae of East Asian Flora.

The knowledge of Indochinese Lamiacae is less comprehensive than for other neighbouring regions. There was no successor to the work of Lourerio (1790) until Prain (1904) established the genus *Nosema* based on material from Thailand. Consequently, Hosseus (1910 & 1911) and Craib (1911, 1912b & 1914) recorded several new Thai Lamiaceae. Later, Murata (1970, 1971, 1976, and 1977) contributed several species of the Lamiaceae as new to Thailand; most of his new species belong to the tribe *Ocimeae*.

The major revision of the family in Indochina was that of Doan (1936). He revised the family in the region for *Flore Générale de l'Indo-Chine* and contributed many new species. His work was mainly based on limited material collected mostly by the French botanists during the French colonial era. However, all Doan's new taxa were described in French lacking latin diagnoses and, are invalid according to ICBN code (Article 36.1) and several specimens he cited under the same name can now be distinguished as different species (Suddee *et al.* 2004).

Phuong (1982a, b) provided an account for Vietnamese Lamiaceae and added several new taxa. Later, Hô (1993b), Budantsev (1999) and Phuong (2000) also contributed to this account.

Contribution to the knowledge of the Lamiacae of the Malesian region include: Blume (1826); Miquel (1858-1859); Sleensen (1959); Backer & Bakhuizen van den Brink (1965); Blanco (1837); Merrill (1912); Ridley (1923b); and Keng (1969). Blume (1825 and 1826) '*Bijdragen tot de flora van Nederlandsch Indië*' was the first major account for the region.

The last major floristic work for the family in Southeast Asia was Lamiaceae of the Malesian region by Keng in 1978 for *Flora Malesiana*.

There has been no complete revision of the family for the whole region. In addition, in most areas the collections still remain very scanty. Exploration in order to gather more information as well as a taxonomic revision of this economically and ethnobotanically important family for Southeast Asian are much needed.

#### 1.4.3. Economic significance

Lamiaceae are economically important and its uses have long been recognised. Many species of the subfamily Viticoideae are forest trees and some of these, such as various species of *Gmelina* and *Vitex*, are important for their timber which is of high commercial value. *Tectona grandis*, commercially known as teak, is one of the world's most important and valuable timber trees (Harley *et al.* 2004; Heywood *et al.* 2007). *G. arborea* is used for planking, furniture, musical instruments, picture frames, match sticks (Dastur 1952; Rajendran & Daniel 2002). Traditionally, the family is well known for the many aromatic plants which have been widely used since antiquity, especially in the Mediterranean region and in many parts of Asia. In some cases, these plants are economically very significant (Harley *et al.* 2004).

The subfamily Nepetoideae are well known for producing aromatic oils and includes numerous culinary or aromatic herbs such as sage (*Salvia*), Mint (*Mentha*), Marjoram or Oregano (*Origanum*), Thyme (*Thymus*), Lavendar (*Lavandula*), Rosemary (*Rosmarinus*), Basil (*Ocimum*), Lemon Balm (*Mellisa*), Savory (*Satureja*), Mountain Tea (*Sideritis*), and Catmint (*Nepeta*) (Harley *et al.* 2004; Heywood *et al.* 2007).

#### 1.5. The genus Gmelina L.: an overview

The genus *Gmelina* L. is a member of the family Lamiaceae (sub-family Viticoideae, and tribe Viticeae) with about 33 (Munir 1984; Harley *et al.* 2004) or about 35 (Rajendran & Daniel 2002) to *ca.* 40 species (Mabberley 2008). Moldenke (1984) reported the genus comprises about 48 specific and subspecific taxa. The species are found in Eastern Asia, Australia, New Guinea and New Caledonia (Moldenke 1984; Munir 1984; Rajendran & Daniel 2002; Harley *et al.* 2004; Mabberley 2008, **Figure 1.5**) and introduced in several African and South American countries (Moldenke 1984).

The genus was first described by Linnaeus in 1753, and is named in honour of John George Gmelin, a German Professor of Chemistry and Natural History at Petersburg and whose Flora of Siberica, is of great reputation and merit (Smith 1819; Moldenke 1984; Munir 1984). Linnaeus (1753) in his sexual system of classification) included a little over 50 species of Verbenaceae and grouped them into three classes. He placed the genus *Gmelina* with one species (*G. asiatica* L.) in the class *Didynamia Angiospermia* without assigning it to any family. This treatment was followed by many later authors.

Adanson (1763) proposed famille Verbenae or les Vervènes and divided it into two sections on the basis on fruit characters and placed the genus *Gmelina* in the section: A *Fruit en Baye ou en Capsule*.

Based on inflorescence type, Jussieu (1789) subdivided his natural order Vitices or les Gattiliers into three sections. He included the genus Gmelina in the section Flores opposité corymbosi. Later in 1806 Jussieu, more preferably termed the order Verbénacées and reduced the sections into two keeping Gmelina in the section Flores opposité corymbosi.

In 1799, Ventenat proposed the family Pyrénacées (Pyrenaceae) with four sections referring to the pyrenes produced by most of the genera, and placed the genus *Gmelina* in the section *Fleurs dispos*ées *en corymbe Péricarpe charnu*.

Saint-Hilaire (1805) was the first to the latin name Verbenaceae (les Verbenacées) citing Verbenae Adans. and Vitices Juss. in synonymy. Based on the type inflorescence he classified the family in three sections with *Gmelina* in section *Première*: *Fleurs opposées sur un corymbe rameux*.

Dumortier (1829) was the first to divide the family Verbenaceae into two tribes: Verbenae Dumort., and Viticeae Dumort., and placed the genus *Gmelina* L. in the tribe Viticeae Dumort. This tribe was accepted by Bartling (1830); Lindley (1836); Spach (1840); Schauer (1847); Walpers (1852); Miquel (1858-59); Bentham (1870; 1876); Clarke (1885); Durand (1888); King & Gamble (1909); Fletcher (1938b); and Endlicher (1841). However, Bartling (1830) and Spach (1840) renamed the tribes as "sections."

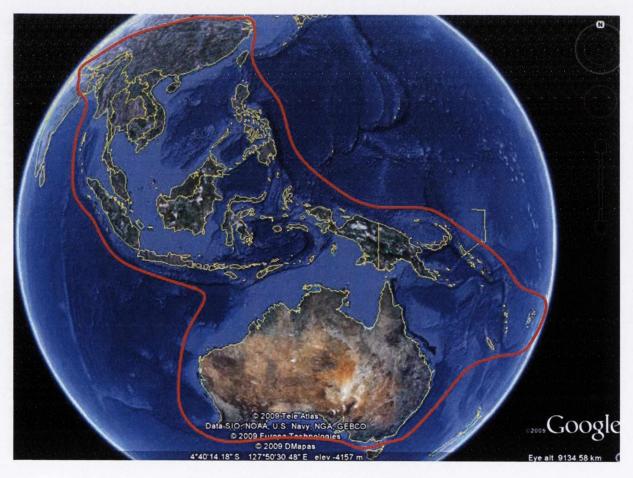


Figure 1.5 Natural distributions of the genus Gmelina L.

Endlicher (1838, 1841) divided the family into three tribes: Lippieae, Lantaneae, and Aegiphileae with *Gmelina* in the tribe Lantaneae. This classification was followed by some later authors: Meisner (1840); Brongniart (1843); Dietrich (1843); and Walpers (1845).

Schauer (1847) in his monographic treatment recognised three tribes and ten subtribes and placed *Gmelina* in subtribe Viticeae Schauer under tribe Viteae Schauer.

In 1876, Bentham divided the family into eight tribes, and raised the subtribe Viticeae with genus *Gmelina* to tribe Viticeae (Dumort.) Benth.

Briquet (1895) reclassified and divided Verbenaceae into seven subfamilies and 13 tribes. He raised the tribe Viticeae to a subfamily Viticoideae Briq. consisting four tribes: Callicarpeae, Tectoneae, Viticeae, and Clerodendreae. He kept the genus *Gmelina* in the tribe Viticeae. This classification was accepted by Dalla Torre & Harms (1904); Lam (1919); Junell (1934); Moldenke (1959, 1971); and Moldenke & Moldenke (1946). In the same treatment Briquet (1895) subdivided the genus into two sections: Microstromatae and Bracteosae, based mainly on the size, colour, and venation of the floral bracts. These infrageneric sections were adopted by Dalla Torre & Harms (1904); Moldenke (1959, 1971); and Moldenke & Moldenke (1946). However, most taxonomists do not recognise infrageneric divisions for the genus.

#### 1.5.1. The diversity of *Gmelina* in Southeast Asia and adjacent areas

Lourerio (1790) was the first to record *Gmelina* species (*G. asiatica*) from Southeast Asia in his *Flora Cochinchinensis*.

Later in 1819, Smith recorded five *Gmelina* species from this region, namely *G. asiatica* L. (native of Java, Amboina, and other part of East Indies); a new species G. *elliptica* Smith (he presumed it was native to East Indies); *G. parvifolia* Roxb. (common in every forest); *G. arborea* Roxb. (sent from coast of Coromandel); and with doubt *G.? indica* Burm. (native of Java).

In 1825, Roxburgh recognised five species *viz*. *G. arborea*, *G. asiatica* Willd., *G. oblongifolia* Roxb., *G. parviflora* Roxb., *and G. villosa* Roxb. in his *Flora Indica*. In the same year, Blume (1825) recorded two *Gmelina* species: *G. asiatica* and *G. parviflora* L. from Nederlandsch Indië (Indonesia).

Chamisso (1832) recorded the first species *Gmelina philippensis* Cham. from the Philippines, as a new species. In 1837, Blanco described two new species- *G. asiatica* Blanco, and *G. inermis* Blanco from the Philippines.

Miquel (1856) listed four species from Indonesia, adding *G. villosa* Roxb., and *G. macrophylla* Wall. to Blume's (1825) list.

Clarke (1885) in *Flora of British India* and Brandis (1921) in *Indian trees* recognised five species: *G. arborea*, *G. asiatica*, *G. hystrix* Schult. ex Kurz, *G. oblongifolia*, and *G. villosa*.

Bentham (1870) published a detailed account of the Australian Verbenaceae and listed three *Gmelina* species: *G. macrophylla* (R. Br.) Benth., *G. leichhardtii* (F. Muell.) Benth., and *G. fasciculiflora* Benth. Of these, *G. fasciculiflora* Benth. was described as a new species. In 1984, Munir's revision of the genus in this area added

*G. elliptica* Smith, and *G. schlechteri* to the list, which are newly recorded for this area. *G. fasciculiflora* and *G. leichhardtii* are endemic to Australia.

Scheffer (1876) recorded a new species G. lepidota Scheff. from New Guinea.

In 1877, Kurz reported three species, *G. arborea*, *G. asiatica*, and *G. hystrix* from Myanmar (Burma). Later, Lace (1922) added *G. villosa* to the list. Subsequently, Nair (1963) recognised only *G. arborea* in *The families of Burmese flowering plants*. In 2003, Kress & Kyi reduced *G. hystrix* as synonym to *G. philippensis* and added *G. elliptica* to the Burmese flora. Recently, Nobuyuki & Hidetoshi (2007) recorded *G. tomentosa* from Myanmar for the first time.

In Philippines, Vidal (1886) recognised two species: G. *villosa*, and G. *hystrix*. Later, Merrill (1912; 1917) reduced G. *hystrix* to G. *philippensis* as a synonym and retained G. *villosa*. In the following year, he reduced both Blanco's (1837) species G. *asiatica* Blanco and G. *inermis* Blanco to G. *philippensis*. Afterwards in 1923, he reduced G. *villosa* as synonym to G. *elliptica*.

Trimen (1895a) listed two *Gmelina* species *viz*. *G. arborea*, and *G. asiatica* from Sri Lanka in his A Hand-book to the Flora of Ceylon. Further revision by Moldenke & Moldenke (1983) added *G. philippensis* to the flora.

Dop (1914) recorded three new species viz. G. delavayana Dop from China, G. balansae Dop, and G. lecomtei Dop from Indochina. In 1933, he added G. arborea Roxb., G. hainanensis Oliv., and a new species G. annamensis Dop to the Indochinese flora. He reduced his G. balansae Dop to a new variety G. lecomtei var. annamitica Dop. Again in 1935, he added G. asiatica, G. hystrix Schult. ex Kurz, and G. villosa Roxb. to the flora.

In 1917, Backer recognised *G. moluccana* (Bl.) Backer as a new combination from *Vitex moluccana* Blume. from Nederlandsch Indië (Indonesia).

Lam (1919), in his treatment of Verbenaceae of the Malayan Archipelago, recognised 12 species: *G. arborea, G. asiatica, G. dalrympleana* (F. Muell.) Lam, *G. glandulosa* Hallier f., *G. uniflora* Stapf., *G. villosa, G. macrophylla, G. lepidota, G. palawensis* Lam, *G. ledermanni* Lam, *G. schlechteri* Lam, and *G. integrifolia* Hunter ex Ridl. Of which, *G. palawensis, G. ledermanni* and *G. schlechteri* were newly described by him.

In 1921, Lam & Bakhuizen van den Brink, in a treatment of Verbenaceae for the Dutch East-Indies (Indonesia) and surrounding countries recorded only eight species and three new varieties *viz. G. arborea, G. asiatica, G. asiatica* var. *phillipensis* (Cham.) Bakh., *G. asiatica* var. *villosa* (Roxb.) Bakh., *G. lepidota, G. macrophylla* (R. Br.) Benth., *G. moluccana, G. palawensis, G. schlechteri, G. uniflora* Stapf., and *G. uniflora* var. *villosa* Bakh. Of these, *G. lepidota, G. macrophylla*, and *G. schlechteri* are from New Guinea.

Ridley (1923a) listed G. Asiatic, G. villosa, and G. hystrix in the flora of Malay Peninsula.

In 1929, Bakhuizen van den Brink recognised two species *G. macrophylla* and *G. papuana* Bakh. Of which, latter as new species from Papua New Guinea.

Craib (1912a) recognised *G. arborea* and *G. villosa* in Thailand. Subsequently, Fletcher (1938a) contributed three new *Gmelina* species to the flora of Thailand, *G. attenuata* Fletcher, *G. paniculata* Fletcher, and *G. tomentosa* Fletcher. In the same year Fletcher (1938b) added *G. arborea*, *G. asiatica*, *G. villosa*, and *G. hystrix* to his previous list.

In 1940, Moldenke recorded two new species, G. speciosa Mold. and G. tonkinensis Mold. from Tonkin, Vietnam.

Masamune (1942) listed three species: G. asiatica, G. uniflora, and G. elliptica from Borneo.

Backer & Bakhuizen van den Brink (1965) revised the family Verbenaceae for the Flora of Java and recognised two *Gmelina* species: G. *elliptica* and G. *philippensis*.

In 1958, Moldenke again contributed two new species, *G. brasii* Mold. and *G. smithii* Mold. to the genus from Papua New Guinea.

Tebbs (1982) recorded only *G. arborea* from Nepal. Subsequently, Keng (1990) recorded three *Gmelina* species- *G. asiatica*, *G. elliptica*, and *G. philippensis* from Singapore.

Hô (1993a) recorded eight species and one variety in Vietnam, namely: *G. annamensis*, *G. arborea*, *G. asiatica*, *G. elliptica*, *G. hainanensis*, *G. lecomtei*, *G. lecomtei* var. *annamitica*, *G. philippensis*, and *G. racemosa*. In 2003, he added *G. speciosa*, and *G. tonkinensis* and excluded previously recorded *G. arborea*.

Shou-Liang & Gilbert (1994) contributed seven species to the flora of China, viz. G. arborea; G. asiatica; G. chinensis Benth.; G. delavayana; G. hainanensis; G. lecomtei and G. szechwanensis K. Yao.

Atkins (1996) listed two species G. asiatica; G. uniflora and one variety G. asiatica var. villosa in Brunei Darussalam.

In 2002, Rajendran & Daniel produced a Monograph of the Indian Verbenaceae and listed *G. arborea*; *G. asiatica*; *G. elliptica*; and added *G. thothathriana* Rajendran & Daniel as new species.

Mabberley & de Kok (2004) revised the family Lamiaceae from New Caledonia and recognised five species in their treatment: *G. evoluta* (Däniker) Mabb., *G. lignum-vitreum* Guillaumin, *G. neocaledonica* Moore, *G. magnifica* Mabb, and *G. tholicola* Mabb. Of which, the last two taxa are described as new species. All species are endemic to this area.

In 2004, Sam et al. recorded only G. arborea from both Laos and Vietnam. Subsequently, Newman et al. (2007) listed eight species in A Checklist of the Vascular Plants of Lao PDR: G. arborea, G. asiatica, G. balansae, G. delavayana, G. elliptica, G. lecomtei, G. philippensis, and G. racemosa.

The genus has not been revised locally or regionally as a whole from the study area (Southeast Asia). Based on the above literature, the taxonomic diversity of the genus as currently recorded in Southeast Asia is summarized in **Table 1.3** below.

Table 1.3. Summary (based on the literature) of the diversity and distribution of species of the genus Gmelina in Southeast Asia and adjacent areas.

TAM         CM         IX         CM         IX         TM         CM         IX         CM         IX		-	_			-		THN	CAM	MAL	SIN	QNI	BRN	PHL	PNG	MLN	AII
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Mold.       Mold. <td< td=""><td>G. neocaledonica Moore</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>&gt;</td><td></td></td<>	G. neocaledonica Moore															>	
Wold:       Wold: <td< td=""><td>G. oblongifolia Roxb.</td><td></td><td></td><td>&gt;</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>	G. oblongifolia Roxb.			>													
Moldl.         Moldl.<	G. palawensis Lam															>	
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is       is <td< td=""><td>G. racemosa (Lour.) Merr.</td><td></td><td></td><td></td><td></td><td>&gt;</td><td>&gt;</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>	G. racemosa (Lour.) Merr.					>	>										
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Iran & Daniel	G. sessilis White & Francis															>	
Iran & Daniel <ul> <li></li></ul>	G. smithii Mold.															>	
Iran & Daniel   Iran & Daniel   Chrack Daniel   Chrack Driver, DK = Pakestari, IN = India; SRL = Sri Lanka; BD = Bangladesh; MYN = Myanmar; LAO = Laos; VTN = Vietnam; THN = Thailand; CAM = Cambodia; MAL = Malaysia;																	
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CHN = China; PK = Pakistan; IN = India; SRL = Sri Lanka; BD = Bangladesh; MYN = Myanmar; LAO = Laos; VTN = Vietram; THN = Thailand; CAM = Cambodia; MAL = Malaysia;	G. vitiensis (Seem.) Sm.															>	
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#### 1.6. Objectives of the Project

There has been no generic revision or molecular study of the genus *Gmelina* throughout Southeast Asia. Therefore, a revision of the genus would be a significant contribution to the systematics of the family Lamiaceae. In addition, an understanding of *Gmelina*'s phylogeny and its relationships with other genera of the subfamily *Viticoideae* is crucial to the development of a phylogeny for the family as a whole. Thus the objectives of the project are:

- To explore the species diversity of the genus *Gmelina* in Southeast Asia and to identify all species occurring in this area;
- To gap fill, i.e. to try to augment and increase our knowledge of previously recorded species of and their distribution in the Southeast Asia;
- To provide a complete account of the genus Gmelina for Southeast Asia. The result of the study will provide a basis for the future completion of accounts of Lamiaceae for the local Flora; viz. Flora of Malesiana; Flora of Thailand; Flore du Cambodge, and Flore du Laos et du Vietnam;
- To study a phylogenetic relationships within Gmelina and allied genera.
- To provide petiolar and leaf surface anatomical information of the genus Gmelina.
- To provide palynological information of the genus Gmelina.

# CHAPTER 2

# **Taxonomic Treatment**

## 2.1. Introduction

Morphology is the base of a taxonomic study and morphological features are traditionally used in the identification of species. Characters of plants that are visible are described and the differences in these characters that can be used to differentiate the species are determined.

The general objective of this chapter is to provide a taxonomic revision of the genus *Gmelina* in South East Asia. Additionally specimens from the neighboring regions, *i.e.*, Papua New Guinea, China, Bhutan, Nepal, Pakistan, India, Bangladesh, and Sri Lanka have also been studied for comparison, and to assure species delimitations are not geographical artefacts.

The aims of this chapter are:

- To provide species descriptions, including details of synonymy and typification, ecological information, conservation status, uses, illustrations or images, and distribution maps; and
- To construct keys to the species of Southeast Asian Gmelina;
- To test Briquet's hypothesis of sectional classification of Gmelina;
- To provide the basis for the future completion of accounts on Gmelina for the Flora of Malesiana; Flora of Thailand; Flore du Cambodge, du Laos et du Vietnam.

#### 2.2. Material and Methods

This revision was undertaken at the Herbarium, Department of Botany, School of Natural Science, Trinity College Dublin (TCD) and sometimes at the Herbarium, Royal Botanic Gardens, Kew (K). Study of the available herbarium collections was extremely important in this taxonomic study. Approximately 1,500 herbarium specimens were examined from the following herbaria: A, ABD, BKF, BM, CAL, CANB, DACB, E, GH, K, KEPONG, L, LINN (microfiches), MO, NY, P, PNH, S, SING, TEX, TCD, US. Additionally three other herbaria, BM, CAL, and S were visited and specimens examined.

All herbarium acronyms follow Index Herbariorum (Holmgren et al. 1990) and Index Herbariorum: A Global Directory of Public Herbaria and Associated Staff (Holmgren & Holmgren 1998, regularly updating: http://sweetgum.nybg.org/ih/).

Dimensions given in the descriptions are based on herbarium specimens, for dry specimens, flowers were softened in water containing a small amount of detergent (*ca*.1% of washing-up liquid) prior to examination. A Leica MZ 12 stereomicrosope was used in this study; measurements were taken using a graticule and a ruler.

Species are arranged alphabetically under each section. Most of the major Floras and publications in Southeast Asia, and neighbouring regions are cited where appropriate. Almost all types of accepted names and synonyms have been seen and are indicated by (!) after the herbaria abbreviation. For the accepted names, when there is no holotype or previous lectotypification, a lectotype or neotype has been chosen and justifications of typification are given following the Vienna Code 2006 of the International Code of Botanical Nomenclature (ICBN).

All specimens cited under each species have been seen and examined in detail and are arranged by country, major division, locality, geographical information (where available), collection date, collectors name and collection no., and herbaria where lodged. Vernacular names and geographical distribution and ecological information (such as habitat and altitude and/or latitude) were taken from the specimens' label and from the literature. The present study determined the conservation status of all species based on available information and specimen data by applying IUCN Red List categories (IUCN 2001).

#### 2.3. Species Concept

Species are the currency of biology (Agapaw *et* al. 2004), the fundamental units of biodiversity and the basis for all classification systems (Davis 1978). An understanding of the species concept is basic to an understanding of biological diversity (Conservation Monitoring Centre 1992).

It is vital to clarify the species concept in taxonomic revision. The argument over how species should be defined is the subject of much debate (Minelli 1993; Agapow *et al.* 2004) and more than 20 different concepts proposed (Mayden 1997). However, as a universally accepted unique species concept has not yet emerged (Luckow 1995), the morphological species concept or taxonomic species concept (Davis & Heywood 1963) is probably the closest and was therefore taken in this account. They define a species as:

"assemblages of individuals with morphological features in common and separable from other such assemblages by correlated morphological discontinuities in a number of features."

In the present study morphological differences were used to delimit taxa and to produce the account of South East Asian *Gmelina*. Taxonomic decisions were based mainly on morphological information gathered from the large number of herbarium specimens studied.

There is a need to recognise infraspecific taxa when variation occurs within a species and discontinuities exist. The problem is how to delimit subspecies or varieties when there is no consistent method of delimitation. In this taxonomic account, subspecies will be recognised if taxa possess either or both clear geographical or ecological distinctions and where their morphology is distinct but with more minor features than those that distinguish the species. Varieties are recognised when taxa possess less clear cut geographical (are more or less sympatric) and/or ecological distinctions.

## Gmelina L.

Gmelina L., Sp. Pl. 2: 626 (1753); Gen. Pl. ed. 5: 274 (1754); Burman f., Fl. Ind. 132 (1768); Gaertner, Fruct. Sem. Pl. 1: 268, t. 56, f. 5 (1788); A. L. Juss., Gen. Pl. 2: 108 (1789); Lour., Fl. Cochinch. 2: 376 (1790); Necker, El. Bot. 1: 356 (1790); Schreb., Gen. Pl. 2: 412 (1791); Roxb. Pl. Corom. 2: 32, t. 162 (1798); Willd., Sp. Pl. 3: 313 (1800); A. St. Hil., Expos. Fam. 1: 248 (1805); A. L. Juss., Ann. Mus., 7: 75 (1806); Sprengel, Syst. Veg. 2: 765 (1825); Blume, Bijdr. Fl. Ned. Ind. 814 (1826); Reichb., Consp. Reg. Veg. 117 (1828); Dumort, Anal. Fam. Pl. 22 (1829); Sprengel, Gen. Pl. 2: 481 (1831); Cham. In Linnaea 7: 109 (1832); Roxb. Pl. Ind. 3: 82 (1832); Blanco, Fl. Filip. Edn. 1: 492 (1837); Endl., Gen. Pl. 1: 636, no. 3704 (1838); Meisner, Pl. Vasc. Gen. 1, Tab. Diagn. 291 (1840); Pl. Vasc. Gen. 2, Comment 200 (1840); Spach, Hist. Natur. Veg. Phan. 9: 232 (1840); Endl. Ench. Bot. 312 (1841); Dietr., Syn. Pl. 3: 372, 613 (1843); Walp., Rep. Bot. Syst. 4: 97 (1845); Schauer, in DC. Prod. 11: 678 (1847); Walp., Ann. Bot. Syst. 3: 239 (1852); Mig., Fl. Ned. Ind. 2: 865 (1858); Benth., Fl. Aust. 5: 64 (1870); Pfeiffer, Nomen. Bot. 1(2): 1468 (1874); Benth. & Hook. f., Gen. Pl. 2: 1153 (1876); Muell., Syst. Cens. Aust. Pl. 1: 103 (1882); C. B. Clarke in Hook. f., Fl. Brit. Ind. 4: 581 (1885); Vidal, Rev. Pl. Vasc. Filip. 210 (1886); Durand, Gen. Phan. 321 (1888); Oliv. in Hook. f., Icon. Pl. 19, t. 1874 (1889); Briq., in Engl. & Prantl, Plfanzenfam. 4(3a): 173 (1895); Trimen, Handb. Fl. Ceylon 3: 355 (1895); Craib, Contrib. Fl. Siam Dicot. 164 (1912); Dalla Torre & Harms, Gen. Siphon. 433, no. 7188 (1904); Robinson, in Philipp. J. Sci. 7(6): 414 (1912); H. J. Lam, Verbenac. Malay. Arch. 214 (1919); Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 68 (1921); Bartling, Ord. Natur. Pl. 180 (1830); Junell, Symb. Bot. Ups. 4: 92 (1934); Dop in Lecomte, Fl. Gén. Indo-Chine 4: 841 (1935); Fletcher, Kew Bull. Misc. Inf. 10: 422 (1938); Lemee, Dict. Descrip. Syn. Gen. Pl. Phan. 8b: 656 (1943); Taylor, Ind. Kew. Suppl. 12: 63 (1959); Résumé Verbenac. etc. 276, 297, 298, 318, 320, 395, 397 (1959); Nair, Fam. Burm. Fl. Plants 1: 200 (1963); Backer & Bakh. F., Fl. Java 2: 606 (1965); Mold., Fifth Summary Verbenac. etc. 1& 2: 472, 523, 524, 526, 569, 572, 739, 742 (1971); Farr et al., Index Nom. Gen. Pl. 2: 730 (1979); Mold., Sixth Summary Verbenac. etc. 375, 394, 405, 408, 409, 412, 423, 445 (1980); Tebbs in Hara et al. Enum. Fl. Pl. Nepal 3: 147 (1982); Mold. & Mold. in Dassan., Rev. Handb. Fl. Ceylon 4: 390 (1983); Mold., Phytologia 55 (5): 308 (1984); Munir, Jour. Adelaide Bot. Gard. 7(1): 91-116 (1984); Nicolson et al. in Regnum Veg. 119: 261 (1988); Smith, Fl. Viti. Nova 5: 203 (1991); Hô, Illus. Fl. Vietnam 2:1045 (1993); Chen & Gilbert, Fl. China 17: 33 (1994); Coode et al. Checklist of Fl. Pl. Brun. 330 (1996); Long in Grierson & Long, Fl. Bhutan 2(2): 928 (1999); Rajendran & Daniel, Indian Verbenac. 155 (2002); Rajendran & Daniel, Indian Verbenac. 153 (2002); Hô, Illus. Fl. Vietnam 2:830 (2003); Kress et al., Checklist Pl. Myanmar 45: 389 (2003); Harley et al. in Kubitzki, Fam. & Gen. Vasc. Pl. 195 (2004); Sam et al., Trees of Laos and Vietnam, Blumea 49: 343 (2004); Mathew, William Roxburgh's plants of the coast of Coromandel, Blumea 49: 402 (2004); Newman et al., Checklist Vasc. Pl. Laos 356 Type: G. asiatica L., Sp. Pl. 2: 626 (1753). (2007).

Cumbulu Rheede, Hort. Malab. 1: 75, Fig. 41 (1678). Type: H. M. 1: Fig. 41! (= Gmelina arborea!).

Tittius (alba et rubra), Rumphius, Herb. Amboin. 3: 38, t. 20 (1743). Type: H. A. 3: t. 20! (= Gmelina moluccana!).

Cumbulu Adans., Fam. Pl. 2: 199 (1763). Type: as for Cumbulu Rheede.

Trees, or shrubs, sometimes climbing or scrambling; stems sometimes armed with spines; branchlets subterete, glabrous or pubescent, armed or unarmed. Leaves simple decussate-opposite, exstipulate, petiolate, entire or irregularly lobed, usually with large gland patches near base, often abaxially grey mealy, petiole canaliculated above. Inflorescence racemes, panicles or cymose, terminal and/or axillary, erect or pendent, compound, branched, or seldom reduced to single flower; bracts foliaceous or petaloid, conspicuous. Flowers bisexual, zygomorphic, hypogynous. Calyx campanulate to somewhat tubular or infundibular, 4- or 5- toothed to sinuate or truncate, sometimes conspicuously lobed, often with large glands on surface. Corolla infundibular, oblique, bilabiate, (4-)5 lobed, upper lip 2-lobed or entire, lower lip 3-lobed, midlobe largest, projecting forward; tube slender, narrow below, incurved and widely funnel-shaped upwards, greatly enlarged at throat. Stamens 4, didynamous, slightly exserted above the corolla tube or almost included, inserted in the lower part of the corolla-tube, filaments filiform, glabrous or sparsely glanduliferous; anthers oblong or elliptic, with one ovule in each locule; style filiform, slightly exserted or included, glabrous or sparsely glanduliferous, rarely sparsely pilose; stigma minutely and unequally bi-lobed. Fruit a fleshy, succulent drupe with hard pyrenes, 4-seeded (rarely 2-seeded).

### Infrageneric classification of Gmelina

1. Calyx truncate or subtruncate or with obsolete 4or 5- sinuate dentate

section Asiaticum

- Calyx bilabiate and/or conspicuously 5-lobed

section Annamaticum

Section Asiaticum M. H. Rashid & J. Parnell sect. nov.

Plantas frutex vel arbores. Calyces truncatus vel subtruncatus cum obsoletus 4 vel 5 sinuatus dentatus, corolla 4 vel 5 lobis.

Type: G. annamensis Dop

This section consists of 19 species and 2 varieties, and is distinguished from the section *Annamaticum* in the habit, number of floral parts and calyx structure.

## Key to the species of section Asiaticum

1. Tree, calyx truncate or obsoletely 5 sinuate dentate, corolla 5-lobed	2
- Shrub or small tree, calyx truncate or obsoletely 4 sinuate dentate, corolla 4 or 5-lobed	3
2. Both leaf surfaces and mature petioles glabrous or glabrescent	4
- Leaves abaxially pubescent, mature petioles puberulent to pubescent	7
3. Leaves large, 10-25X7-15cm; inflorescence glabrous; calyx truncate, glabrous, corolla	5-lobed
	5. G. dalrympleana
- Leaves small, 0.5-12X0.5-9cm; inflorescence tomentose or pubescent; calyx truncate of	or obsolotely 4
sinuate dentate, externally pubescent, corolla 4-lobed	9
4. Leaves 15-25X10-20cm, calyx pubescent	16. G. schlechteri
- Leaves 5.5-20X3-8.5cm, calyx glabrous or lepidote	5
5. Leaves lepidote beaneath; inflorescence pubescent; calyx externally lepidote	7. G. lepidota
- Leaves not lepidote beaneath; inflorescence glabrous; calyx glabrous on both sides	6

6. Leaves 5.5-12X3-6cm, basally acuminate, petiole 1.5-2.5cm long; inflorescence termi	
twigs, glabrous and brunnescent or nigrescent	8. G. misoolensis
- Leaves 11-16X7.5-11cm wide, basally acute or rounded, petiole 2-7cm long; Infloresc	
axillary, glabrous	10. G. palawensis
7. Leaf apex long-acuminate or caudate, base cordate or truncate; petiole 3-15cm long;	
	1. G. arborea
<ul> <li>Leaf apex acute or short-acuminate or obtuse, base subacute or obtuse to rounded; p ovary pilose or pubescent</li> </ul>	petiole 1.5-10cm long; 8
8. Leaves 10-40X7-35cm; calyx cyathiform or cupuliform, 5-10X3-7mm, densely ville	ous outside, sparsely
pubescent inside, style apically glandular and sparsely pilose, 2.5-3cm long	9. G. moluccana
- Leaves 10.5-19.5X6-15.5cm, calyx broadly campanulate, 9-15X5.5-10mm, pubesce	ent outside, glabrous
inside; style apically glandular, 3-3.7cm long	14. G. racemosa
9. Upper leaf surfaces glabrous or subglabrous, abaxially glanduliferous	10
- Both leaf surfaces, or only lower surfaces, tomentulose to tomentose or pubescent	11
10. Leaf base long attenuate, petiole glabrous	3. G. attenuata
- Leaf base acute, cuneate, obtuse or rounded, petiole pubescent	12
11. Lower leaf surface pubescent or tomentose; inflorescence terminal	14
- Leaves tomentose on both surfaces; inflorescence terminal and/or axillary	15
12. Inflorescence with conspicuously large, coloured bracts	13. G. philippensis
- Bracts not showy or coloured as above	13
13. Leaves small, entire or 3-5 lobed, 0.5-5X0.5-3cm, petioles puberulent; inflorescences axillary, calyx campanulate, <i>ca</i> .1cm long	s terminal and/or 2. <i>G. asiatica</i>
<ul> <li>Leaves large, entire, 7-13X5-8cm, petioles pubescent; inflorescences terminal, caly 3-5mm long</li> </ul>	x small, infundibular, 11. <i>G. paniculata</i>
14. Leaves thin chartaceous, petiole to 6.5cm long; ovary and style glabrous	18. G. tonkinensis
<ul> <li>Leaves subcoriaceous; petiole to 4cm long; ovary glabrous or apically villous, style sparsely glandular</li> </ul>	e glabrous or apically 16
15. Leaves lanceolate, petiole short (to 6mm); calyx infundibular; style glabrous	19. G. yangonensis
<ul> <li>Leaves elliptic or ovate or rotundate, petiole to 4cm long; calyx campanulate; style ap or sparsely glandular</li> </ul>	bically sparsely pilose 17

16. Leaves rotundate or orbicular, petiole lanate, to 1.5cm long, ovary apically villous, style glabrous

## 15. G. rotundifolia

-	Leaves elliptic or broadly-elliptic or ovate-elliptic, petiole pubescent, to 4cm long,	ovary glabrous, style
	basally glabrous, apicaly sparsely glandular	6. G. elliptica
17.	Leaf base sub-cuneate or rotundate, petiole to 4cm long; ovary glabrous	17. G. tomentosa
-	Leaf base cuneate, petiole to 2m long; ovary pilose or velutinous	18
18.	Leaves elliptic or ovate, apex obtuse, petiole tomentose; ovary apically velutinous, apically glanduliferous	style sparsely pilose, 12. <i>G. parnellii</i>
-	Leaves broadly ovate, apex acuminate, petiole lanate; ovary apically pilose, sty apically sparsely glandular	le sparsely glabrous, 4. G. chindwinse

1. Gmelina arborea Roxb., Hort. Beng. 46 (1814). Roxb., Pl. Corom. 3: 41, t. 246 (1819) & Fl. Ind. 3: 84 (1832); Smith in Rees, Cycl. 16: no. 4 (1810); Schauer in A. DC., Prodr. 11: 680 (1847); Wight Icon. Pl. Ind. Orient. 4(3): 12, t. 1470 (1849); Kurz, Forest Fl. Brit. Burma 2: 264 (1877); C. B. Clarke in Hook. f., Fl. Brit. India 4: 581 (1885); Brig. in Engl. & Prantl, Nat. Pflanzenfam 4(3a); 173 (1895); Trimen, Handb. Fl. Ceylon 3: 355 (1895); Robinson, in Philipp. J. Sci. 7(6): 414 (1912); Craib, Contrib. Fl. Siam Dicot. 164 (1912); Lam, Verbenac. Malay Arch. 219 (1919); Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 68 (1921); Brandis, Indian Trees 509 (1921); Lace, List trees, shrubs & climbers of Burma 2: 131 (1922); Gamble, Fl. Madras 1097 (1924); Haines, Bot. Bihar Orissa 1296 (1925); Dop, Rev. Bot. Appliq. Agric. Trop. 13: 894 (1933); Dop in Lecomte, Fl. Gén. Indo-Chine 4: 843 (1935); Fletcher, Kew Bull. Misc. Inf. 10: 422 (1938); Taylor, Ind. Kew. Suppl. 12: 63 (1959). Nair, Fam. Burm. Fl. Plants 1: 200 (1963); Tebbs in Hara et al. Enum. Fl. Pl. Nepal 3: 147 (1982); Mold. & Mold. in Dassan., Rev. Handb. Fl. Ceylon 4: 390 (1983); Mold. in Phytologia 55(6): 337 & 55(7): 424 (1984); Nicolson et al. in Regnum Veg. 119: 261 (1988); Chen & Gilbert, Fl. China 17: 33 (1994); Long in Grierson & Long, Fl. Bhutan 2(2): 928 (1999); Rajendran & Daniel, Indian Verbenac.155 (2002); Hô, Illus. Fl. Vietnam 2:1045 (1993) and 2:830 (2003); Kress et al., Checklist Pl. Myanmar 45: 389 (2003); Sam et al., Trees of Laos and Vietnam, Blumea 49: 343 (2004); Mathew, William Roxburgh's plants of the coast of Coromandel, Blumea 49: 402 (2004); Newman et al., Checklist Vasc. Pl. Laos 356 (2007). Type: Rheede, Hort. Malab. 1: t. 41 (holotype image!).

Premna arborea Roth, Nov. Sp. Pl. 287 (1821). Type: Ind. Orient. Observavit oculatiss, Benjamin s.n.

- G. rheedii Hook. in Curtis, Bot. Mag. 74 [ser. 3, 4]: Pl. 4395 (1848). Type: as for G. arborea.
- G. arborea var. glaucescens C. B. Clarke in Hook. f., Fl. Brit. Ind. 4: 582 (1885); Mold. in Phytologia Mem. 2: 549 (1980); Mold. & Mold. in Dassan., Rev. Handb. Fl. Ceylon 4: 394 (1983); Mold. in Phytologia 55: 471 (1984). Type: Khasia Mts. Alt. 0-2000', J.D.H(ooker) & c. s.n. (K!).
- G. arborea var. canescens Haines, Forest FI. Chota Nagpur 82 (1910); Mold. in Phytologia Mem. 2: 549 (1980); Mold. in Phytologia 55: 469 (1984). Type: Sontal Pargana, Haines s.n. (K!).
- G. arborea f. dentata Mold. in Phytologia 8(1): 14 (1961). Mold. & Mold. in Dassan., Rev. Handb. Fl. Ceylon 4: 391 (1983); Type: Jhajra, Siwalik & Jaunsar, India, 14 March 1922, Azizullah Shah s.n. (UC).

A medium-sized to large deciduous tree, to 30m tall, unarmed, widespreading, rapidly growing, often branched to the base when young; trunk straight, diameter of up to 4.5m; bark smooth, pale-ashy-grey or greyish-yellow with blackish patches and conspicuous circular lenticles, rather corky, inside of the bark rapidly turns brown on exposure and exfoliates into thick woody plates or scurfy flakes. The blaze is pale orange and mottled with darker orange colour; branches few or numerous, spreading, forming a large shady crown; branchlets are unarmed and young parts yellowish-tomentose. **Leaves** decussate-opposite, mostly rather soft and limp; leaf-blades broadly ovate, cordate or deltoid-ovate, 10-25cm long and 7-20cm wide, apically long-acuminate or caudate, entire on mature plants but strongly toothed or lobed on young plants, usually cordate

or truncate basally, with a short cuneate attenuation towards the petiole, young leaves densely tomentose above, becoming glabrous when mature, permanently densely fulvous-tomentellus with stellate hairs beneath, crowded with very small black glands (glanduliferous) just above the petiole on the basal attenuation, the lateral secondary veins are 5-10 pairs, the lowest pair sub-basal; petioles cylindric, 3-15cm long, puberulent or glabrous. Inflorescence terminal and axillary, paniculate; composed of 6-12 decussate-opposite cymes, to 30cm long, fulvous-tomentose throughout, erect, 7.5-39cm long, racemose; bracts linear or linear-lanceolate, acuminate, densely villous on both surfaces, 0.3-1cm long, caducous; calyx broadly campanulate or cupuliform with 5 small, sinuate, triangular-acute teeth, 3-7mm long, 3-5mm wide, teeth 0.5-1mm long, externally densely appressed pubescent with or without 1-4 discoid nectariferous glands, internally glabrous; corolla infundibular, oblique, large, showy, varying from yellow to orange or brilliant orange to reddish or brownish-yellow, tubular below, the limb bilabiate, densely pubescent externally, glanduliferous hairy inside, 2.5-5cm long, 2.5-3.5cm wide; upper lip bi-lobed, lobes ovate or oblong, obtuse, 1-1.5cm long, 0.8-1.0cm wide at base; lower lip 3-lobed, the median lobe largest, ovate, acute, projecting forward, 1.5-2.0cm long, 1.2-1.5cm wide at base; lateral lobes obovate-rounded, sub-obtuse, ca. 1.7cm long, 1cm wide at base; stamens 4, didynamous, exserted from the mouth of the corolla tube; filaments slender, glabrous, longer pair 1.5-2.0cm long, shorter pair 1.0-1.5cm long; anthers oblong, 0.25-0.3cm long; ovary glabrous, ovate to subglobose, ca. 5cm long and 3cm wide, 4-loculed, each locule 1-ovulate; style slender, glabrous, ca. 2cm long; stigma subulate, glabrous, minutely bifid, lobes unequal, longer lobe ca. 1.5mm long, the other minute. Drupes obovoid or ellipsoid-obovoid, 1.8-3.5cm long, 1.5-2.5cm wide; seated on the un-enlarged fruiting-calyx, succulent, aromatic, bitter-sweet, orange-yellow when mature with a bony endocarp; seeds 1-3. Figure 2.1.

**Ecology**: In open, semi-evergreen or wet deciduous forests; alt. 50-1800m; *Flowering*: April to May; *fruiting*: May to July.

**Distribution:** Myanmar, Laos, Vietnam, Thailand, Malaysia, Indonesia, Singapore, and Philippines. **Map 2.1**. Native from Pakistan, Bhutan, and India east through Bangladesh, Myanmar (Burma), and Thailand to Indo-China, Malaya, Indonesia, Philippines and north to southern China. Introduced in many parts of tropical Africa and South America and elsewhere; extensively cultivated for paper-pulp, lumber, shade, and ornament (Moldenke & Moldenke 1983; Moldenke 1984).

Vernacular names: Gamar (Bangla); Gam har (Hindi); Kumil (Tamil); Bulang, Yemane (Malaya Peninsula); Chor (NE Thailand); Jamani (Bornean); Saw (Laotian).

**Use**: This species is a valuable source of timber and paper-pulp. It coppices well and is suitable as a shade or ornamental tree in gardens, parks, or along avenues (Moldenke 1984).

Leaf paste is applied for relief of headache in fevers. Flowers are given in blood diseases. Root is used as bitter or bittersweet tonic, stomachic, laxative, galactogogue, and is an ingredient of the ayurvedic *Dasamula* (ten roots) which is used in the treatment of many diseases; taken with licorice, honey, and sugar it increases the secretion of milk (Moldenke 1984; Rajendran & Daniel 2002).

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Figure 2.1. G. arborea. Reproduced from Wight's Icones Plantarum Indiae Orientalis, p. 390, t. 1470 (1850). In colour: Wight's Neilgherry Plants, t. 193 (1851).

The wood is known and sold as *Gumhar*. It is used in the manufacture of the decks of boats, furniture, planking, Venetian blinds, light cooperage, cattle bells, picture-frames, and sandals. It is durable under water, and resembles teak in its colour, compactness, easy workability, resistance to cold and humidity as well as to the serious ravages of termites and shipworms. It is used in naval construction, to make small boats and canoes, and in Myanmar, for mine-timbers. It is highly esteemed for planking, furniture, door panels, well-lining, house-posts, toys, drums, Indian musical instruments (i.e. *Sitars*), ornamental cabinet-work, carving, plates and trays, bridge construction, railroad ties, boxes and packing cases, carriages and palanquins, shafts, axles, and yokes, grain measures, agricultural instruments, tree-calipers, carved images, lacquered receptacles, and clogs. In Hindustan it is used to make the cylinders for *dholucks* drumps; in Assam it is employed in the making dugouts, matchsticks, artificial limbs, native stethoscopes, and sluices. The wood-pulp is widely used worldwide for making wrapping, writing, and printing paper. In Bangladesh the wood is used chiefly for boat-and ship-building (Moldenke & Moldenke 1983; Moldenke 1984; Rajendran & Daniel 2002).

The fruits are described as bitter and sweet, sour and acrid. They are used medicinally as a cooling agent, diuretic, tonic, aphrodisiac, and alterative, as an astringent to the bowels, to promote the growth of hair, and in treating leprosy, ulcers, and consumption. It also provides a very persistent yellow dye (Moldenke 1984).

The leaves are sometimes used as fodder by cattle. The juice of the tender leaves, as a decoction, is demulcent; mixed with milk and sugar it is used in treating gonorrhea, coughs, and catarrh of the bladder. Leaf paste is applied to the head in treating headache during fevers (Moldenke 1984).

Proposed Conservation status: A fairly common and widespread species. Least concern (LC).

**Typification:** Robinson (1912) reported that the name *G. arborea* was validly published by Roxburgh in *Hortus Bengalensis* 46:1814 with a reference to the effectively published *Hortus Malabarica* 1: t. 41(1678). Moldenke & Moldenke (1983) cited *Roxburgh* s.n. (NY!, photo NY!) as the type. Nicolson *et al.* (1988) and Rajendran & Daniel (2002) pointed out that this cannot become a type. Rajendran & Daniel (2002) also pointed out that even *Icones Roxburgh* t. 71 (K, CAL photo!) would not be a type.

In 1984, Moldenke reported that the species was based on *Rottler* s.n., probably deposited at Kew, originally from the Coromondel coast of India. However, I did not find any collection of Rottler at Kew. Being the only quoted specimen in the protologue, *Hortus Malabarica* 1: t. 41(1678), was confirmed as the type by Rajendran & Daniel (2002).

**Notes:** *G. arborea* var. *canescens* Haines and *G. arborea* var. *glaucescens* C. B. Clarke were based on differences in the indumentums on lower leaf surfaces. The former has canescent-pubescent leaf beneath and in latter has glaucous. Rajendran & Daniel (2002) noted that this was not a consistent character of taxonomic significance. Hence, they merged these two varieties in *G. arborea*.

#### Specimens examined:

Thailand: Western: Northern: Huai Krasa, about 90km south of Tak, 1100m, 16º05'N, 99º09'E, 18 March 1968, Hansen & Smitinand 12952 (L, P); Lamphun, Mae Tah, Doi Kuhn Dahn National Park, trail to Daht Muey Falls, 850m, 1 March 1994, Maxwell 94-294 (A); Lampang, Muang Bahn (Pan), Jae Sawn National Park, above Dawn Chai village, 700m, 16 February 1996, Maxwell 96-232(A); Jae Sawn National Park, off the main dirt road to Bah Miang village, 1150m, 29 March 1996, Maxwell 96-454 (A); Chiang Mai, Doi, South Chiang Mai, 700m, 14 July 1909, Kerr 540 (BM,TCD); Chiang Mai, Hot, 1-2km from Kong Loy Village to Mae Tho, 24 February 1979, Koyama et al. 15535 (NY); Chiang Mai, Mae Dang, Doi Sahm Meun, Huay Muang, 1360m, 27 February 1990, Maxwell 90-252 (A, MO); Chiang Mai, Chiang Dae, Doi Chiang Dao Animal Sanctuary, Bah Giah Station, 1275m, 6 March 1995, Maxwell 95-229 (A); Nan, Tah Wang Pah, Peh Twang, Nahm Han Village, 300m, 15 March 2000, Maxwell 00-128 (A); Phayoa, Pan, Doi Luang National Park, east side, Bu Gang/ Fan National Park headquarters, 525m, 4 April 1997, Maxwell 97-305 (A). Eastern: Pukio, Chiang Pum, ca. 900m, 25 February 1931, Kerr 20271 (BM); Nakon Ratchasima, Korat, Bukanun, ca. 400m, 6 January 1924, Kerr 9856 (BM). North-Eastern: Loei, Phu Luang, 5 December 1967, Bunchuai 1338 (BKF). South-Western: Kanchanaburi, Kwae River Basin Exp., near Neecky, near Wangka, 150m, 25-28 April 1946, Kostermans 85 (L- 2 sheets, P- 2 sheets); Saraburi, Pak Chong to Khao Yai National Park, 300m, 14º30'N, 101º30'E, 30 March 1987, Soejarto et al. 5843 (A, MO).

Vietnam: Annam, Quang Tri, 600m, 18 March 1927, *Poilane* 13635 (P); Mekong, March 1877, *Harmand* 1377 (P).

Laos: Sayabouri, expedition to Me-Kong, 1866-1868, *Thorel* s.n. (P); Unknown locality, 4 October 1913, *Dussaud* 76 (P); Muang Xay, ca. 900m, 8 April 1932, *Kerr* 20965 (BM).

**Malaysia:** *Malaya Peninsula*: Puchong, Ayer Hitam Forest Reserve, 9 August 1966, *Carrick* J.C. 1511 (SING); Kuala Lampur, Gombak Reserve, 8 October 1925, *Strugnell* 10548 (SING); Ulu Gombak, Selangor, May 1928, *Strugnell* 13949 (SING); Kepong, Selangor, Forest Research Institute, 17 March 1975, *Putz* FRI 021976 (K, L); Kelantan, Ulu sat Forest Reserve, 17 June 1968, *Suppiah* KEP 104572 (L); *Sabah:* Sandakan, Elophura, Kabili Forest Reserve, 25 September 1947, *Kadir* A50 (SING); Sandakan, Elophura, Compt. 13, Sepilok Forest Reserve, 10 March 1952, *Kadir* A971 (SING); Sandakan, Jalan Padang Sepilok, 30m, 17 September 1962, *Brand* 30999 (KEPONG, L, SING).

Indonesia: Borneo: Around field station, 9 March 1990, Ambri & Arifin W98 (A).

Philippines: Mindanao: North Cotabato, Kidapawan, Mount Apo, 7º3'N, 125º3'E, March-April 1991, *Gaertan et al.* PPI 2606 (K).

Singapore: unknown locality, 1891, unknown 2784 (SING).

Myanmar: Aaunglaung, 28 February 1930, *Sawlzatz* 9 (AB); Pyinmana, 120m, March 1913, *unknown* s.n. (K); Pyinmana, 28 February 1930, *unknown* 101 (NY); North Burma: Vernay-Cutting, Valley of the Nmai Hka, ±300m, 6 April 1939, *Kingdon Ward* K. W. 493 (NY); Falam, 1800m, 2 April 1938, *Dickason* 7288 (A);

Kyaikkami (Amherst), Kyain, February 1938, *Dickason* 6898 (A, L); Kyaikkami (Amherst), Kyaikdon, 30m, 19 January 1912, Lace 5597 (TCD); Tenasserim, 27 April 1877, *Gallatly* 957 (TCD);

#### Cultivated:

Philippines: Palawan: Municipality Brookes Point, Towns Park, 12 April 1989, *Soejarto et al.* 6533 (MO, NY); Municipality Brookes Point, Mainit, base of eastern slopes of Mantalingajan Range, 12 April 1989, *Soejarto et al.* 6536 (L, NY). **Sri Lanka**: Evabedda, Arboretum, 1200m, 27 June 1952, *Worthington* 5932(K). **Malaysia**: *Sarawak*: Semengoh arboretum nursery, planted on flat ground, 1 July 1971, Chai & Paie S.29349 (L, SING); *Malay Peninsula*: Penang Botanic Garden, undated, *unknown* s.n. (SING). **Indonesia**: Bogor Botanic Gardden, February 2007, *Mahdiana & Kusnadi* XI.G.149a (TCD). **Singapore**: Singapore Botanic Gardens, 1904, *unknown* s.n. (A). **Domonica Island**: Pedernales, CAbo Rojo, Cultivate din Seb=nior staff residence, 10m, 17°54'N, 71°40'E, 15 April 1987, *Howard et al.* 39067 (A). **Hawaiian Island**: Haukulu, Section 23, Row 7, Tree No. 0086-1, Introduction 5350, 6 December 1964, *Osgood* 57 (A). **Peru**: Coronel Portillo province, Dept. Ucayali, Bosque Von Humboldt, *ca.* 200m, 25 June 1981, *Young* 1053 (MO).

#### Specimens examined from the neighbouring countries:

Bangladesh: Chittagong: Korerhat-Naitilla, 60m, 22°50'N, 91°30'E, 25 April 1994, *Huq & Mia* 10273 (A). Chittagong Hill Tracts: *Dr. King's collector* 451 (P); Rangamati, 50ft, 19 March 1899, *Gage* 15 (BM, L); Chunati Reserve Forest, 27 February 1966, *Majumder & Islam* 38 (GH, K, L).

Bhutan: South Bhutan, Mangde Valley, 1000m, 9 May 1937, Ludlow & Sherriff 3004 (BM).

India: Tamilnadu: Madras, Cat. No. 1817/I, 1830 unknown coll. (1830); Madras state, Coimbatore, near Attakatti, ±500m, 30 March 1965, Ramamurthy 2287b (L); Salem, Namakkal, Kolli hills Ghat Road, 600m, 17 April 1979, Matthew & Manoharan 22780 (A); Uttarakhand: Dehradun, 6 April 1929, Shamsuddin, s.n. (A); Dhulani-chauki, 4 March 1929, Doval s.n. (MO): Dehradun and vicinity, 670m, 19 April 1928, Singh 332 (NY): Siwalik & Jaunsar. Lachhiwala, 28 April 1921, Mukherjee 89 (US); Jhanu, April & May, Ram 103 (P); Kaluwala, 8 April 1921, Choudhury 86 (A); Assam: Hathigaon, May 1902, Chatterjee s.n. (GH); Jaboocka, near Naga Hill, April 1899, Dr. Parain's collector 929 (A); Charduar Reserve, 60-120m, March 1971, Tessier-Yandell 13 (K); Burnihat, Khasi Hills, 60m, 30 May 1949, Chand 1582 (L); South Lushai Hills, Near Fort Lungleh, 900-1200m, April 1899, Gage 248 (A); Sangau, Lushai Hills, 1200m, 22 April 1953, Koelz 33086 (L); Amgori, 20 April 1895, unknown, 11164 (P); Cherrapunjee, 1200m, 5 May 1952, Koelz 29685 (L); Cherrapunjee, 1200m, 12 May 1952, Koelz 29854 (L); Chota Nagpur. Hazaribagh, 600m, 22 March 1952, Kerr 2178A (BM); Karnataka: Mysore, Hassan District, Kempuhole, Shiradi, 12 April 1969, Saldanha 13298 (US; MO); Near Bagi, 26 February 1969, Saldanha 12824 (MO, US -2 sheets); Road to Malgod, 13 March 1970, Saldanha 16581 (US); Maysore & Carnatic, undated, Thomson s.n. (GH, P, TCD); Maharastra: Bombay, North Konkan, Karjat, 8 April 1949, Farnandes 245 (A); Khandala, Kune stream, 14 March 1943, Santapau 1679 (NY); Bombay Presidency, Merda forest, 28 March 1951 Fernandes 2317 (A); South India: Salem, Hosur Taluk, 3000' (900m), 1 April 1932, Yeshoda 374 (A, NY); Nilghiri Mountains, undated, Jhonson s.n.(TCD); *Sikkim*: Numbongkung, Tista valley below feni, 270m, 1 May 1913, *unknown* 581 (BM, P); Sikkim, 300-1200m, undated, *Hooker* s.n. (NY, TCD, P- 3 sheets); *Jharkhand*: Santhal Pargana, Buris, 1 June 1907, *Haines* 2772 (ABD, K); Unkonwn locality, *Roxburgh* s.n. (BM - 2 sheets).

Nepal: East Nepal, Kankai Khola, 300m, 26º48'N, 87º50'E, 3 April 1967, *Stainton* 5768 (BM); West Nepal, Golmura, 600m, 28º55'N, 80º35'E, 22 March 1965, *Stainton* 4806 (BM); Ilam district, Mechi zone, Suktien Tea Garden, 400m, 4 April 1967, *Nicolson* 3138 (BM, US).

Sri Lanka: Halaba-Jangula, 26 June 1931, *Simpson* 8245 (BM); Kadugannawa, Poilakanda, 550m, 18 April 1940, *Worthington* 887(K); Summit, Peradeniya, Ganoruwa jungle behind Botanical Garden, 500m, 14 April 1969, *Kostermans* 23131 (L); Central Province, Kandy district, Bible rock, 790m, 19 March 1974, *Sumithraarachi* DBS 161 (US); North-western province, Kurunegala, Badagomuwa Forest Reserve, 7°30'N, 80°23'E, 15 February 1975, *Sumithraarachi* DBS 663 (MO); Monaragala, Medagama-Dambagalla, 2 May 1975, *Jayasuriya* 1989 (MO).

China: Yunnan: Lan-Tsang Hsein, 1200m, May 1936, Wang 77642 (A); Dah-meng-lung, Che-li Hsien, grave, near village, 900m, August 1936, Wang 77642 (A); Yuls forest, 1200m, undated, Henry 12886 (A, NY-Image);

Hong Kong: Chinese University Hong Kong, 9 May 1997, *Hu & Yung* 022 (K); Wu Kau Tang, N. T., 16 June 1999, *Hu & But* 23373 (A).

Gmelina asiatica *L*. Sp. Pl., 2: 626 (1753). Lam., Tabl. Encycl. 3 (2): t. 542 (1794); Roxb., Pl. Corom. 2: 32, t. 162 (1803) & Fl. Ind. 3: 87 (1832); Rottler in Ges. Naturf. Freunde Berlin Neue Schriften 4: 184 (1803); Smith in Rees, Cycl. 16: no. 1 (1810); Schauer in A. DC., Prod. 11: 679 (1847); Miq., Fl. Neder. Ind. 2: 866 (1856); Kurz, Forest Fl. Brit. Burma 2: 265 (1877); C. B. Clarke, in Hook. f., Fl. Brit. India 4: 581 (1885); Briq. in Engl. & Prantl, Nat. Pflanzenfam 4(3a): 173 (1895); Trimen, Handb. Fl. Ceylon 355 (1895); Lam, Verbenac. Malay Arch. 219 (1919); Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 69 (1921); Merr. in Philipp. J. Sci. 19: 377 (1921); Brandis, Indian Trees, 509 (1921); Lace, List trees, shrubs & climbers of Burma 2: 131 (1922); Ridl., Fl. Malay Penins. 2: 622 (1923); Dop in Lecomte, Fl. Gén. Indo-Chine 4: 845 (1935); Fletcher, Kew Bull. Misc. Inf. 10: 423 (1938); Moldenke & Moldenke, in Dassanayake & Fosberg, Rev. Handb. Fl. Ceylon 4: 394 (1983); Moldenke, Phytologia 55 (7): 473 (1984); Verdcourt, *Reg. Veg.* 127: 50 (1993); Chen & Gilbert, Fl. China 17: 33 (1994); Coode *et al.* Checklist of Fl. Pl. Brun. 330 (1996); Rajendran & Daniel, Indian Verbenac.161 (2002); Hô, Illus. Fl. Vietnam 2:1045 (1993) & 2:829 (2003); Kress *et al.*, Checklist trees Myanmar, in Contr. US Nat. Herb. 45: 389 (2003); Mathew, William Roxburgh's plants of the coast of Coromandel, *Blurnea* 49: 402 (2004); Newman *et al.*, Checklist Vasc. Pl. Laos 356 (2007). Type: Herb. Hermann 230 [BM! lectotype chosen by Verdcourt (1993)].

- G. coromandelica Burm. f., Fl. Indica 32 (1768). Type: Habitat in India utraque (G).
- G. lobata Gaertn., Fruct. Sem. Pl. 1: 268 (1788).

- *G. parvifolia* Roxb., Pl. Coromandel 2: 31, t. 162 (1798). Smith in Rees, Cycl. 16: no. 3 (1810); Spreng., Syst. Veg. 2: 765 (1825); Schauer in A. DC., Prod. 11: 679 (1847). Type: Icon. Roxb. t. 318!.
- G. parviflora Roxb. Fl. Indica 3: 88 (1832).

Premna parvifolia Roth. Nov. Pl. Sp. 388 (1821).

- G. inermis Blanco, Fl. Filip.1: 493 (1837).
- G. integrifolia Hunter, Journ. Straits Bran. Roy. Asiat. Soc. 53: 101 (1909); Prain, Ind. Kew. Suppl. 4: 99 (1913).
- G. asiatica var. typica Bakh. in H. J. Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 69 (1921).
- G. asiatica f. lobata Mold. Phytologia 32(1): 47 (1975); Brenan, Ind. Kew. Suppl. 16: 130 (1981). Type: Smithsonian Camp, Marai Villu, Wilpattu National Park, Sri Lanka, 30June 1969, Wirawan et al. 899 (holotype NY!; isotypes GH!, L!, MO!,).
- G. asiatica f. parvifolia (Roxb.) Mold. Phytologia 55(1): 42 (1984); Devise, Ind. Kew. Suppl. 18: 142 (1987).

G. asiatica f. inermis (Wight.) Mold. Phytologia 55(1): 42 (1984); Devise, Ind. Kew. Suppl. 18: 142 (1987).

A large straggling or scrambling, mostly deciduous bush or bushy shrub, sometimes climbing, very variable in size and habit, to 4m tall, or rarely a semi-evergreen tree to 10m tall, usually spiny (especially when young), armed, rarely unarmed, much-branched; branches decussate-opposite, lenticellate, bark yellowish- or brownish-white, thin, smooth; wood hard; branchlets rigid, often compressed, pubescent when young; twigs frequently much abbreviated and apically spinose, these axillary spines sometimes leaf-bearing. Leaves decussate-opposite, leaf-blades chartaceus, entire or 3-5 lobed, sometimes irregularly lobed, very variable, varying from oval or ovate to elliptic, obovate, sub-rhomboid, or triangular, 0.5-5(-12)cm long and 0.5-3(-6)cm wide, acute to cuneate or sometimes rounded at base, apically acute or obtuse or rarely acuminate, glabrous or sub-glabrous on both surfaces when mature, often more or less pubescent when young, dark green and shiny above, pale-green, glaucescent, and densely white-glanduliferous beneath, the lateral secondary veins 3-4 pairs, distinct beneath, veins and veinlets puberulent, petioles slender, 0.5 to 3cm long, puberulent and white glandular. Inflorescences racemose, terminal and/or axillary, more or less pendulous, to 12cm long, densely pubescent to tomentose or appressed-tomentose, and with white glandular, few to many flowered; peduncles to 5mm long, pubescent; bracts green, usually rather small, lanceolate or ovate, ca.1cm long, 0.6cm wide, apically cuspidate, caducous, occasionally large and leafy, pubescent on both surfaces, marginally ciliate; calyx campanulate, ca. 1cm long, 0.6cm wide, the rim truncate, or very shortly or obscurely 4-toothed, the teeth very small, triangular, apically acute, about 3-6mm long, externally pubescent and glanduliferous, internally glabrous, with 2 to many, large, discoid nectariferous glands; corolla infundibular, oblique, large, showy, yellow or bright-yellow to jasmine-yellow, the limb bilabiate and 4-lobed, 4-5cm long, externally finely pubescent with appressed strigose hairs, internally glabrous, 2-5.5cm long; upper lip entire, ovate or oblong, apically acute, reflexed, 1-1.5cm long, 0.8-1.0cm wide at base; lower lip 3-lobed, the median lobe largest, ovate, apically acuminate, projecting forward, 1.3-3.5cm long, 1.2-1.6cm wide at base; lateral lobes ovate, apically sub-obtuse, *ca.* 1-1.5cm long, and 0.6-1.2cm wide at base; the tube narrow, incurved, apically ampliate into a broad ventricose throat, finely pubescent outside, glabrous within; **stamens** 4, didynamous, almost included, inserted about the middle of the corolla tube near the top of slender portion; filaments slender, smooth, apically sparsely glandular, longer pair 2.0-2.3cm long, shorter pair 1.0-1.2cm long; anthers oblong, 0.25-0.3cm long; **ovary** glabrous, conical, *ca.* 5cm long and 2.5cm wide, 4-loculed, each locule 1-ovulate; *style* slender, slightly exserted, glabrous, 2-3.5cm long; *stigma* subulate, glabrous, obscurely bifid, lobes unequal, longer lobe *ca.* 1.5mm long, other minute. **Drupes** obovoid-pyriform to subglobose, yellow when ripe, black in mature, fleshy, juicy, 1.5-3cm long and 1-3cm wide, glabrous, 1- or 2-seeded. **Figure 2.2**.

**Ecology**: In open scrub, along streams in the ever green forest. Alt. from sea level up to *ca*.1000m. *Flowering* & *fruiting*: almost throughout the year.

**Distribution:** Laos, Vietnam, Cambodia, Thailand, Indonesia, Malaysia, Singapore, Brunei, and Philippines. **Map 2.1**.

A widely distributed species, occurring from India, Sri Lanka, and Bangladesh, through Myanmar (Burma) and Thailand, to Malaya and Indo-China, east to Indonesia, north to southern China, and west to Réunion and Mauritius. It is widely cultivated in various parts of North, central, and South America, the West Indies, Europe, Asia, and Africa, as well as on some Pacific islands like Hawaii, mostly as a specimen tree in Botanic Gardens. In a few cases it appears to have become locally naturalized to a limited extent (Moldenke 1984).

#### Vernacular names: Têng Kao (Thai); Bulang (Malay).

**Uses**: The leaves pounded and mixed with a little coral lime are applied to the body for certain diseases of yellowish swellings (Malaya). The root is used in the treatment of gonorrhoea, catarrh of the bladder, rheumatism, and as a blood purifier. Bark is said to aid fermentation of toddy. Leaves show antibiotic activity. The fruit is reported to be edible. Wood is used for fences and making churning sticks (Moldenke & Moldenke 1983; Rajendrann & Daniel 2002).

#### Proposed Conservation status: A fairly common and widespread species. Least concern (LC).

**Typification**: Moldenke & Moldenke (1983), Moldenke (1984), and Rajendran & Daniel (2002) indicated 780-2 (LINN) as the type of *G. asiatica*. But Verdcourt (1993) chose Herb. Hermann 230 (BM-000594589) as the lectotype and noted "Moldenke & Moldenke (in Dassanayake & Fosberg, *Revised Handb. Fl. Ceylon* 4: 394. 1983) and Moldenke in *Phytologia* 55: 480 (1984) indicated 780-2 (LINN) as type, but this sheet is not annotated by Linnaeus and is not original material for the name." The present investigation agrees with Verdcourt (1993).

#### Specimens Examined:

Thailand: Northern: Lampang Province, Me Ta, 360m, 18 March 1926, Winit 1653 (BKF); Chiang Mai Province, Bo Luang table-land, along road from Bo Luang to Om Koi, 12 June 1968, van Beusekom & Phengkhlai 1158 (K, L, P); Bo Luang, 18º 10'N 98º 22'E, 1000m, 1 July 1968, Larsen et al. 1918 (L); Phitsanulok province, Pong Pa, 10 May 1967, Phusomsaeng 211 (BKF); Nakhon Sawan Province, Raheng, Me kor, 60m, 20 July 1915, Winit 414 (BKF); Lamphun Province, Me Lee, ca.480m, 16 July 1915, Winit 412 (A, BKF). North-eastern: Phetchaburi province, ca. 100m, 31 March 1921, Kerr 5724 (BM). Eastern: Ubon province, Ubon, near river, 8 June 1932, Lakshnakara 859 (BM); Nakhon Ratchasima province, Sakaerat, 14º 30'N 102º 00'E, 400m, 21 June 1989, Gentry & Niyomdham 66745 (M0); Nakhon Ratchasima province, Sakaerat, 14º 30'N 102º 00'E, 400m, 20 June 1989, Gentry & Niyomdham 66681 (M0). South-western: Ayutthaya Province, Angtawang, 24 December 1929, Put 2552 (BM). Central: Saraburi province, Sahm Lahn, 14º 30'N 101º 10'E, 100m, 18 May 1974, Geesink et al. 6782 (L); Sahm Lahn, 125m, 14 April 1974, Maxwell 74-286 (L); Sahm Lahn Forest, Muang district, 150m, 1 June 1974, Maxwell 74-559 (L); Nakhon Pathom, Dawn Tam, 10 May 1932, Kerr 21527 (BM); Chaiyaphum, Chawng Sam Maw, ca. 200m, 31 January 1931, Kerr 19974 (BM); Dom Bang, Suphan Buri, 19 May 1923, Kerr 7005 (BM); Takuapa, 6 May 1973, Geesink & Santisuk 5223 (L); Bo Luang, Chiang Mai, 18º 45'N 98º 25'E, ca. 1000m, 7 June 1973, Geesink et al. 5793 (L). South-eastern: Chon Buri Province, Makham, ca. 50m, 18 June 1960, Smitinand & Jhon 6860 (BKF).

Laos: Champassak Province, Pathumphon district, Xe Pian NBCA, between Ban Thangbeng and Ban Phalay-Thong, 28 April 1999, *Klackenberg* 1283 (S); unknown locality, 23 June 1892, *Orléans* s. n. (P).

Vietnam: unknown locality, 20 May 1929, *Evrard* 2346 (P); Cochin china: undated 1868, *Baudouin* s. n. (P); April 1867, *Germain* 78 (P); 1862-1866, *Thorel* 60 (A, P-2 sheets); undated, *Pierre* s.n. (P-2 sheets); Phiong Mai, 19 May 1882, *Bon* 1579 (P); Saigon, Road to Cholen, 24 June 1864, *Leevre* 390 (P); unknown locality, Tohatrang, 14 May 1920, *Hayata* 457 (P); Bình Thuận Province, Tour Cham, 14 July 1921, *Evrard* 437 (P); unknown locality, 20 May 1929, *Evrard* 2680 (P); Annam, unknown locality, 4 May 1922, *Poilane* 3171 (A, P); Ho Chi Minh City, Esso's oil port at Ho Chi Minh river, 15 November 1962, *Hummel* s.n. (S).

**Cambodia**: *Pursat Province*: Pendon Press, 200m, 30 April 1965, *Martin* 555 (P); Kol Totung, 14 July 1965, *Martin* 705 (P); Kampot Province: 14 March 1905, *Geoffray* 439 (P); unknown locality, 24 June 1929, *Bejeaud* 17 (P); Sre Âmbel, La Khang, Choeng, Po Bang, 13 May 1928, *Poilane* 15306 (L, P).

Indonesia: Java: 5 May 1927, Coert 491 (L); 10 April 1932, Coert 1098 (L); Sumatra: Gunung Leuser Nature Reserve, Atjeh, 21 July 1979, Wilde & Wilde-Duyfjes 18945 (MO, L); West Sumatra, Mt. Bungso near Batu Sangkar, 7 September 1957, Meijer 7217 (L); North Sumatra, Sumuran, Sipirok, 8 March 1983, Zahro 83 (L). Kalimantan (Borneo), locality unknown, 20 March 1997, Kessler et al. PK2194 (K, E); East Borneo, Berau, 13 October 1963, Kostermans 21273 (L); Samboja Kuala, 20 June 1991, Ambri & Arifin AA137 (K); East Bali, Kunu, 15 October 1985 Balgooy 5270 (L); Celebes (Sulawesi), Palulolu Pertamina, 22 April 1979, Hennipman 5018 (L); West Timor: Msafi, 7 June 1981, Kooij 1302 (L)

**Singapore**: Pasir Kis, 6 February 1949, *Sinclair* 5556 (US); Bedoh by seashore, 6 March 1928, *Holthum* s. n. (SING); unknown locality, 23 August 1933, *Holthum* s. n. (SING); Unknown locality, October 1861, *Anderson* 135 (BM, P).

Malaysia: Perak: Batu Gajah, 26 June 1924, Burkill & Haniff 13384 (SING); Kuala Kangsar, Kota Iawa, 20 October 1924, Haniff 15570 (SING). Sabah: Sandakan, Tambisan, 9 September 1975, Saikeh & Aban SAN 82322 (L). Negri Sembilan: Batang Malaka, Senda Rubber Estate, 18 June 1938, Fujimoto 3044/18 (SING); Tringganu, August 1889, Ridley s. n. (SING). Penang: unknown locality, 24 September 1918, Juhoor s.n. (SING). Sarawak: Serian, 16 January 1955, Brooke 9566 (L);

Brunei: *Tutong*, Telisai, 26 March 1993, *Coode* 7399 (K); Pasir Puteh, Telisai, 10 July 1993, *Cowley* 32 (KEPONG); Danua, Tutong, 13 March 1965, *Collector unknown* 3770 (L- 2 sheets).

Philippines: Zambales, Iba, Sitio, 27 December 1954, Santos 6148 (L); Basilan, Lamitan, 4 June 1948, Santos 4530 (L); Luzon, Balara, December 1952, Mati 31 (L).

#### Cultivated

Malaysia: Penang: Botanic Gardens, Penang, 24 September 1918, Juhoor s. n. (SING).

Indonesia: Bogor Botanic Gardden, February 2007, Mahdiana & Kusnadi XV.J.A.15 (TCD).

#### Specimens examined from the neighbouring countries:

China: Kwangsi: undated, 1901, Henry, 166 (NY); Kwangtung: Luo-fu Shan, 3 October 1978, K'tung 78 (L).

India: *Maharashtra*: Karjat, North Konkan, Bhipuri, Bhipuri power station, 10 February 1949, *Fernandes* 88 (A, K,US); Karjat, North Konkan, Beside railway line Neral to Matheran, ca. 10m, 9 April 1949, *Fernandes* 246 (A); *Tamil Nadu*: Salem District: Hosur Taluk, 100m, 28 March 1933, *Yeshoda* 142 (NY,A); Carnatic, Salem district, Attur taluk, Periakalrayans, Jadayagoundan jagir east, Thaembadi aru, 275m, 20 September 1978, *Venugopal & Manoharan* 17412 (A); *Karnataka*: Mysore, 1859, *Thomson* s. n. (GH; P); Pondichery, Peninsula India, 1835, *Perrottetl* 49 (P- 2 sheets); Uttar Pradesh, Lucknow, 29 March 1967, *Sharma & Asalm* 68646 (A); Unknown locality, Undated, *Wallich* 2654 (A); *Kolkata*, unknon locality, July 1815, *collector unknown* 592 (S).

Sri Lanka: North-western Province: Puttalam district, Wipattu, 21 May 1976, Cramer 4673 (US, L Marai Villu, Smithsonian Camp, Wilpattu National Park, 30 June 1969, *Wirawan et al.* 899 (GH, L, MO, NY); Kurunegala district, Batalagoda Tank, 5 February 1973, *Townsend* 73/41 (K).*North Central Province*: Anuradhapura district, Sulankulama, Anuradhapura-puttalam Road, 29 August 1974, *Trivengadum & Waas* 419 (NY, P); Marai Villu, Wilpattu National Park, 31 December 1968, *Fosberg et al.* 50933 (MO, US); Wilpattu National Park, 24 January 1974, *Moldenke et al.* 28226 (MO, US).*Central Province*: Matale district, Ereu, a Tank ca. 5 miles ESE of Dambulla, ±200m, 11 October 1974, *Davidse* 7406 (L, MO). *Southern Province*: Hambantota district, Ruhuna National Park, block 1, Rakina Wewa, near Gonalabbe Lewaya, 2m, 5 April 1968, *Fosberg* 

50237 (US); Main Yala road, past Buttawa plain, 4-10m, 23 January 1968, *Comanor* 829 (MO, NY); Karaugaswala, Buttawa Beach area, 8-15m, 28 January 1968, *Comanor* 883 (NY); Ruhuna National Park, Block 1, Rakinawala, 22 October 1968, *Cooray* 68102203R (MO, NY); Ruhuna National Park, Rakinawala, 18 March 1970, *Cooray* 70031809R (MO-2 sheets, NY). *Uva Province*: Moneragala district, 7 miles east of Bibile, 245m, 28 November 1970, *Fosberg & Sachet* 53158 (MO,US). *Eastern Province*: Trincomalee, north end of Kinniyai ferry, 10-20m, 1 May 1970, *Gould & Cooray* 13666 (US); Moneragala district, Lahugala Tank, southeast corner in forest on dry land, 36m, 25 July 1967, *Mueller-Dombois & Comanor* 67072545 (US); Amparai, Lahugala Tank, 27 November 1970, *Fosberg & Sachet* 53060 (US); Kitulana, Lahugala sanctuary, 30m, 14 November 1967, *Comanor* 592 (NY, MO).

Locality unknown: undated, 1854, Thwaites 1952 (P); Unknoen Locality, Sept., Dec., 1853, Harvey (TCD);

#### Cultivated

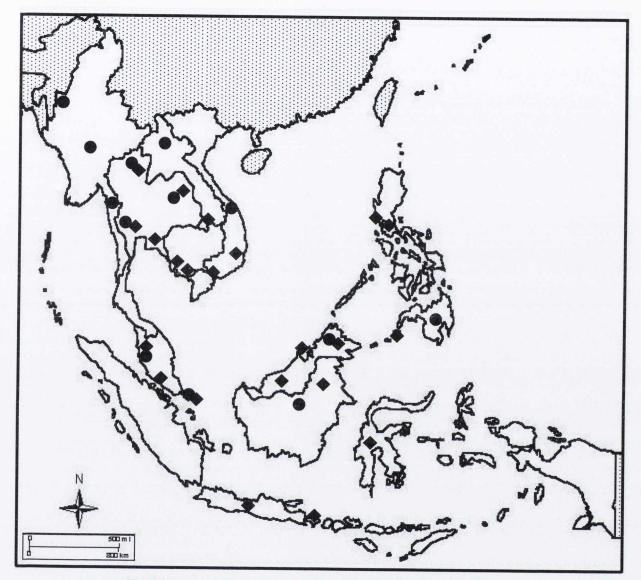
Sri Lanka: Central Province: Kandy district, Peradeniya Botanic Garden, 18 January 1974, *Moldenke et al.* 28175 (US).

**3. Gmelina attenuata** *Fletcher*, Kew Bull. Misc. Inf. 5: 203 (1938). Fletcher, Kew Bull. Misc. Inf. 10: 422 (1938); Mold. Known Geogr. Dist. Verbenaceae, ed. 1, 60 & 93 (1942) and ed. 2, 137 & 186 (1949); Salisbury, Ind. Kew. Suppl. 10: 100 (1947); Mold. Résumé 178 & 456 (1959); Mold. Fifth Summ. 1: 296 (1971) and 2: 879 (1971); Mold. Phytol. Mem. 2: 286 & 549 (1980); Mold., Phytologia 55 (7): 497 (1984). Type: Thailand: Chiang Mai, Payap, 04 July 1922, *Kerr* 6224 (BM! **lectotype designated here**, isolectotype E!).

A shrub to 5m tall; branchlets tetragonal, variegated with brown, the young parts pubescent and with white sessile glandular hairs, later almost glabrous and much less glandulose, sparsely lenticellate with prominent leaf-scars. **Leaves** decussate-opposite; 3-6 sunken glands at and near base beneath, scattered punctate throughout, inconspicuous above, prominent beneath; *leaf-blades* elliptic or subobovate, chartaceus or sub-coriaceous, 5.5-12(-16)cm long and 2-5(-7.5)cm wide, entire or irregularly lobed, sometimes acutely 3-5-lobed, slightly recurved, apically acute or sub-acuminate, basally long-attenuate, glabrous above, lower surface covered with sessile, round, white glandular trichomes; midrib and the 3-5 pairs of secondaries prominent beneath; the seconadries parallel; tertiaries transverse; *petioles* glabrous, 0.5-2(-5.5)cm long, brown, canaliculated above. **Inflorescence** nodding, terminal, paniculate, 2.5(-8)cm long, densely fulvous-tomentose; *bracts* persistent, conspicuous, membranous, sessile or subsessile, elliptic, acute or sub-acuminate, 2-4.5X1.2-2.5cm, adaxially puberulent and sparsely white glandular throughout, abaxially puberulous, eventually glabrous, margin ciliate, 2 sunken glands near the base; *bracteoles* sessile,



Figure 2.2. G. asiatica. Taken from Icon Roxburghianae, t. 318.



Map 2.1 Southeast Asian distribution of G. arborea ( $\bullet$ ); and G. asiatica ( $\bullet$ ).

lanceolate, sub-acuminate, fulvous-pubescent, 5-6mm long; **calyx** campanulate, 4-6 black nectariferous glands interspersed near the top, rim truncate, somewhat sinuate 4-lobulate, 4-5mm long and 3-4mm wide, externally fulvous-tomentose and with sessile, white glandular trichomes, internally glabrous, slightly extended in fruit; **corolla** dull yellow outside, bright yellow inside, infundibular, 4-5cm long, membranous, bilabiate, corolla externally tomentose, internally glabrous, lobes glandular hairy; upper lip entire, to 1.5cm long and 1.2cm wide at base, lower lip 3-lobed, apically rounded, the median lobe largest, 1.5-2.2cm long and 1.0-1.5cm wide at base, ovate-oblong, apically obtuse, the lateral lobes semicircular, apically rounded, 1.0-1.3cm long and 1.0-1.2cm wide at base; tube 2.5-3.0cm long, slender below and abruptly dilated upward; **stamens** 4, didynamous, mostly included, inserted about the middle of the corolla tube near the top of lower slender part; *filaments* filiform, incurved, glabrous, with scattered short gland-tipped hairs, longer pair 2.0-2.3cm long, shorter pair 1.5-1.7cm long; *anthers* oblong, 3-5mm long, lobes free and divergent in the lower halves; **ovary** obovoid-globose, apically sparsely pubescent, glabrous elsewhere, 2-4mm long and 1.5-2.0mm wide, 4-locular with one ovule in each locule; *style* 3-3.5cm long, slightly inserted, filiform, glabrous, with sparsely glandular hairs; *stigma* subulate, glabrous, obscurely bi-lobed, lobes unequal, longer lobe ca.1mm long, other minute. **Fruit** not seen. **Figure 2.3**.

**Ecology**: Open grassy places or Dipterocarp forests; partly open degraded primary evergreen forest; rocky areas, granite bedrock. Alt. 1100m-1300m; *Flowering:* June-July.

Distribution: Endemic to Northern Thailand. Map 2.2.

Vernacular name: Unknown.

**Proposed Conservation status:** This species is confined to northern Thailand only. Due to its narrow distribution the species is considered as Vulnerable (VU).

**Typification**: The protologue cites only a type specimen (*Kerr* 6224) without indicating the herbarium which it is lodged in. There are two type specimens lodged at BM and E. The BM specimen is relatively more complete, and therefore, it is designated here as the lectotype.

**Specimens examined**: **Thailand**: *Northern*: Chiang Mai, Payap, 04 July 1922, *Kerr* 6224 (lectotype BM, Isolectotype E); Lampoon, Mae Tah, Doi Kuhn National Park, sumit of Doi Hoa Chang, peak to the South of the sumit, 03 June 1994, *Maxwell*, 94-676 (A, BKF); Maesanaam Pine Improvement Center, 11 July 1995, *Pooma* 1040 (BKF); Lampang, Muang Bahn (Pan), Jae Sawn National Park, ridge near Bahang Bah Mahk Village, off the dirt road leading to Bah Miang Village, 23 June 1996, *Maxwell*, 96-866, (A).



Figure 2.3. G. attenuata. (Maxwell 94-676, A).

**4. Gmelina chindwinse** *M. H. Rashid* **sp. nov.** similis *G. parnellii* and *G. tomentosa*, sed folia late ovatus, apices acuminatus et bases cuneatus differt. Type: Myanmar, Upper Burma, Upper Chindwin, April 1890, Oliver 97 (holotype K!).

Shrub; branchlets obtusely tetragonal, densely tomentose when young, gradually glabrescent when mature, lenticellate. Leaves decussate-opposite; petioles very slender, channelled above, 1-1.5cm long, tomentose or lanate and glanduliferous, hairs long; blades sub-coriaceous, broadly ovate, rarely elliptic, 5.5-10.5cm long and 5-6cm wide, apex acuminate, base cuneate or sub-cuneate; margin entire and ciliate, tomentulose and sparsely glanduliferous above, densely tomentose and glanduliferous beneath; secondaries 4-5 pairs; conspicuous above. Inflorescence terminal, racemose, 2.5-3.5cm long, densely lanate, hairs long; peduncle short, to 5mm long; flowers sub-sessile; bracts caducous, foliaceous, ovate-lanceolate, apex acuminate, base sub-acute to rounded, 4-4.5X2.0-2.5mm, stalked (6-8mm), both surfaces lanate and glanduliferous; bracteoles linear lanceolate to narrowly elliptic, apex caudate, sessile, lanate above, tomentulose beneath; calyx small, tubular-campanulate, 4.5-5mm long and 3-4mm wide; rim truncate with 4 obsolete, sinuate teeth, tooth to 0.5mm long; externally appressed tomentose and white glanduliferous with 3-5(-7) large black nectariferous glands interspersed; glabrous inside; corolla (colour unknown), infundibular, 3-4cm long, membranous, bilabiate, 4-lobed, externally appressed fulvous-tomentose, internally glabrous; upper lip entire, lobe ovate, apically sub-acute or obtuse, 6mm long and wide at base, lower lip 3-lobed, the median lobe largest, ovate, apically obtuse, 12mm long and 9mm wide at base; the lateral lobes ovate, apically acute, 6mm long and 5mm wide at base; tube slender below and abruptly ampliate upward; stamens 4, didynamous, included, inserted at the base of corolla tube, from where tube expands; filaments filiform, incurved, longer pair 18-20mm long, glabrous, apically sparsely glanduliferous, shorter pair 10mm long, glabrous throughout; anthers oblong, 3mm long, lobes free and divergent in the lower halves; ovary obovoid-globose, pilose at apex, glabrous elsewhere, 3-3.5mm long and 2-2.5mm wide, 4-locular with one ovule in each locule; style filiform, 15-16mm long, included, sparsely glandular; stigma subulate, glabrous, minutely bi-lobed, lobes unequal. Drupes not seen. Figure 2.4.

Ecology: Alt. unknown. Flowering: April.

Distribution: Endemic to Myanmar. Map 2.2.

Vernacular name: Unknown.

**Proposed Conservation status:** This species is known only from the single type specimen, collected in 1890, and has not been re-collected since. Thus, the species is likely to be extinct due to habitat alterations. EX.

**Note**: *Gmelina chindwinse* can be confused with *G. parnellii* and *G. tomentosa* in having tomentose leaves and inflorescences. However, *G. chindwinse* is distinct from these because of its broadly ovate leaves with acuminate apex and cuneate base.

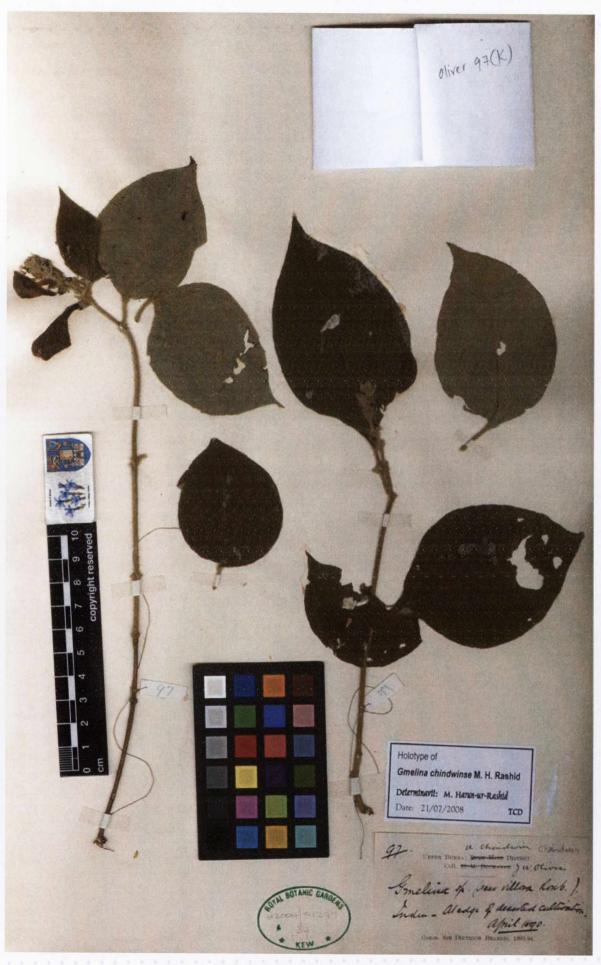


Figure 2.4. Holotype of G. chindwinse (Oliver 97, K).

Etymology: This new species is named after its home locality Upper Chindwin in Myanmar.

**Specimens examined**: **Myanmar**: *Sagaing*, Upper Burma, Upper Chindwin, April 1890, Oliver 97 (K, holotype).

**5. Gmelina dalrympleana** (*F. Muell*) *H. J. Lam*, Verbnac. Malay. Arch. 223 (1919). Hill, Ind. Kew. Suppl. 6: 92 (1926); White, Proc. Roy. Soc. Qld. 38: 259 (1927); Junell. Symb. Bot. Ups. 4: 92 (1934); Moldenke, Résumé Verbnac. etc. 201, 202, 209, 285, 296, 297, 386 (1959); Moldenke, Fifth Summary Verbenac. etc. 1: 333, 336, 338, 346, & 441 (1971), and 2: 523, 524, 716, 721, 879 (1971); Chipp., Proc. Linn. Soc. NSW. 96: 256 (1972); Moldenke, Sixth Summary Verbenac. etc. 1: 327, 328, 337, 409 (1980); Bains, Aust. Pl. Gen. 167 (1981); Beadle, Veg. Aust. 180 (1981); Moldenke, Phytologia 56(1): 35 (1984); Munir, J. Adelaide Bot. Gard. 7(1): 109 (1984). Type: Australia, Queensland, Rockingham Bay, undated, *Dallachy* s.n. (MEL 583504! lectotype images - **lectotype designated** by Munir (1984).

Vitex dalrympleana F. Muell, Fragm. 4: 128 (1864), **basionym**; Fragm. 5: 72 (1865). Type: as for *G. dalrympleana*.

- G. macrophylla (R. Br.) Benth. Fl. Aust. 5: 65 (1870) nom. Illeg., non Wall. ex Schau. (1874). F. Muell. Syst. Cens. Aust. Pl. 1: 103 (1882); Bail, Synop. Qld. Fl. 378 (1883); F. Muell., Descrip. Notes Pap. Pl. 8: 46 (1886); Maiden, Usef. Nat. Pl. Aust. 550 (1889); F. Muell., Sec. Syst. Cens. Aust. Pl. 1: 173 (1889); Schumann in Schumann & Hollr., Fl. Kais.-Wilhelmsand 120 excl. Hollrung 651; F. M. Bail., Cat. Indig. & Natur. Pl. Qld. 35 (1890); Schumann & Lauterb., Fl. D. Schutzgeb. Südsee 524 (1901); Banks & Sol. ill. Aust. Pl. Cook's Voy. 2: 74, t. 238 (1901); Bail., Qld. Fl. 4: 1178 (1901); Pulle in Lorentz, Nova Guinea 8(2): 402 (1910); Bail., Comp. Cat. Qld. Pl. 386 (1913); Ewart & Davies, Fl. N. Terr. 238 (1917); Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenz. Ser. 3: 68 (1921); Bakh., J. Arn. Arb. 10: 72 (1929) excl. Descrip.; Beer & H. J. Lam, Blumea 2: 226 (1936); Francis, Aust. Rain-For. Trees 454 (1951). Type: Australia, Queensland, Cape Grafton, undated 1768-1771, Banks & Solander s.n. (BM!)
- *Vitex macrophylla* R. Br. Prod. Fl. Nov. Holl. 512 (1810) **basionym of** *G. macrophylla* (R. Br.) Benth. (1870); Schau. in DC. Prod. 11: 695 (1847); Seemann, J. Bot. 3: 258 (1865); F. Muell, Fragm. 6: 153 (1868). Type: as for *G. macrophylla* (R. Br.) Benth.
- Ephielis simplicifolia Sol. ex Seemann, J. Bot. 3: 258 (1865); Fl. Viti. 5: 189 (1866). Type: as for G. macrophylla (R. Br.) Benth.

A tall shrub or small tree (2-) 4-15(-25)m high. **Stem** straight, glabrous, 5-40cm diameter with bark often greyish and cracked or fissured. **Leaves** broadly ovate, ovate-oblong or elliptic-obovate, entire, apex obtuse or sub-obtusely acuminate, somewhat cuneate, rounded or cordulate at base, with a pair of nectariferous glands at the base of the lamina below the first pair of nerves, (6-)10-25(-36.5)cm long, (5-)7-15(-23)cm broad, coriaceous, glabrous but not shining above; glabrous or sparsely pubescent beneath, primary nerves

more prominent beneath; secondaries (5-)7-8 pairs; petiole glabrous, canaliculated above, (0.5-)1-2.5(-4)cm long. Inflorescence terminal, rarely terminal and axillary, more or less pyramidal, paniculate cymes, 12-25(-30)cm long, 6-15(-20)cm across, glabrous. Flowers almost sessile or shortly pedicellate, pedicel glabrous, 1-1.5mm long; bracts caducous, oblong-ovate, glabrous, 2-5(-8)mm long; calyx dark blue, campanulate, truncate or somewhat sinuate, often irregularly cleft, glabrous or sub-glabrous, with nectariferous glands on the anterior side, 4-5(-6)mm long, 3-3.5mm broad at the top, persistent, somewhat accrescent and expanded under the fruit; corolla purple-pink, red-blue, or blue with yellow throat and mauve lip, 1.5-2.5(-3)cm long, externally appressedly pubescent excepting lower part of the tube, internally tube glabrous, lobes papillose on the inner faces, bi-labiate, 5-lobed, upper lip 2-lobed, lobes oblong, (5-)6-9mm long, 4-5mm broad at base, lower lip 3-lobed, the mid-lobe largest, oblong, with a yellow marking at the base, (7-)8-10mm long, 5-6mm broad at the base, the lateral lobes oblong-ovate, 5-9mm long, 3-5mm broad at the base, tube oblique, abruptly dilating above the calyx, 8-13mm long, (6-)7-9mm broad distally; stamens 4, didynamous, ascending under the upper lip, somewhat exserted, inserted in the lower part of the corolla tube; filaments filiform, flattened, incurved in the upper half, glabrous, sometimes with glandular hairs in the upper third, longer pair 9-13mm long, shorter pair 7-11mm long, anthers 2-2.5mm long, lobes oblong, free and divergent in the lower half. Ovary oblong-obovoid, glabrous, 1.5-2mm long, 1-1.5mm long in diameter, 4-locular with one ovule in each locule; style exserted, filiform, incurved in the upper half, glanduliferous, dense in the upper third, (1.2-)1.5-2cm long; stigma glabrous, unequally bi-lobed, longer lobe 2-2.5mm long, other minute. Fruits fleshy, glabrous, obvoid-truncate, (8-)10-15 (-18)mm long, (5-)7-10mm in diameter, pink scarlet or red, turning black when dry. Figure 2.5.

**Ecology**: Occasional on the edge of rain-forest, scattered through savannah forest. Alt. 3-600m. *Flowering*: January to March; *Fruiting*: July to December.

**Distribution**: Indonesia, Papua New Guinea, and Australia. In Indoensia *G. dalrympleana* is confined to Irian Jaya. **Map 2.2**.

Vernacular names: Dalrymple's White Beech; Queensland Beech; or long-leaved Gmelina (Australia) (Munir 1984); Bas (Mooi Language-Schram BW 12296; Moll BW 11700).

Uses: The timber is useful for flooring boards and planking (Munir 1984).

**Proposed Conservation status:** *G. dalrympleana* distributed only in Indonesia, Papua New Guinea and Australia. In Indonesia it is confined to Irian Jaya, and in Australia it is found only in Queensland where it occurs mainly in the northern and eastern parts of Cape York Peninsula. Therefore, this species considered as Vulnerable (VU) (IUCN 2001).

**Notes**: Munir (1984) notes that "Bentham (1870) regarded *Vitex macrophylla* R. Br. as this species and, therefore, named it *Gmelina macrophylla*. This name was readily accepted for the species by the majority of botanists. The name *G. macrophylla*, however, was already applied by Wallich ex Schauer (1847) to a different species in the genus, therefore, Bentham's name became a later homonym and thus illegitimate".

One of Banks & Solander's (s.n.) collection from Cape Grafton, Queensland, was described by Robert Brown (1810) as *Vitex macrophylla* R. Br., and the same collection in the BM was later used by Seemann (1865) in describing *Ephielis simplicifolia* Seemmann. Since there is no other known duplicate of this collection, therefore, it may be regarded as the holotype for both the names, which are now included in the sysnonymy of *G. dalrympleana*."

*G. dalrympleana* is morphologically similar to *G. schlechteri* in its glabrous lamina and two nectariferous glands at the base; corolla tube glabrous inside; glabrous ovary; and obovoid-truncate fruits. However, this species can easily be identified by its glabrous or sub-glabrous calyx and glabrous ovary lacking glands at the top.

Munir (1984) assumed that *G. vitiensis* (Seem.) A. C. Smith may have been cultivated in Fiji and reduced it to *G. dalrympleana* and stated that since the publication of Seemann's Flora Vitiensis (1865-73), *Gmelina* has never been reported wild from any part of the Fijian Islands. Smith (1991) commented that "Munir (1984) was certainly incorrect for several reasons. It is highly improbable (or even impossible) for the tree to have been cultivated and to have come to maturity in 1855 on the seldom visited island of Ngau. .....the species occurs in dense and undisturbed forest and is well known to Fijian foresters. *G. vitiensis* differs from *G. dalrympleana* in the usual absence of glands at base of leaf blades, the pale, minutely squamellate puberulense on the lower surfaces and on calyx exteriors, the smaller inflorescence, the shorter calyces and corollas, and the smaller anthers, among other characters." Smith (1991) retains it as a separate species.

#### Specimens Examined:

Indonesia: Malaku Isalnds and New Guinea, unknown locality, 29 August 1907, *Branderhorst* 23 (K); Djalan Kp. Keliki, 8 August 1941, *Anta* 250 (A); New Guinea, West Papua, Warsamson Valley, East of Sorong, 50m, 21 July 1961, *Schram* BW 12296 (L); Warsamson Valley, East of Sorong, ca. 30m, 2 August 1961, *Moll* BW 11700 (L); Bomberai Peninsula, Armina, Sjuga-Wagura area, 17 May 1962, *Moll* BW 13044 (L).

Papua New Guinea: Western Province, Western Division, Fly river, undated 1885, Bauerlen 544 (NY); Wuroi, Oriomo river, 10-30m, January-March 1934, Brass 5753 (A, BM, NY); Daru Island, March 1936, Brass 6319 (A, L); Lake Daviumba, Middle Fly river, September 1936, Brass 7666 (A, L); Tarara, Wassi Kussa river, December 1936, Brass 8539 (A, L); Daru Island, Daru subdistrict, 3m, 9° 05'S 143° 10'E, 21 September 1972, *Streimann & Lelean* NGF 18459 (A); behind Wanabul village on road to Bulla, 10m, 27 April 1981, *Leach* UPNG 3853 (A, K, L). *Cultivated*: Morobe district, Lae sub-district, Lae Botanic Garden, *ca.* 30m, 6° 45'S 147° 00'E, 23 February 1968, *Ridsdale* NGF. 33855, LBG No. E2063 (L).

Australia: Queensland, Cape Grafton, undated 1768-1771, *Banks & Solander* s.n. (BM); North Queensland, Daintree river, 12 December 1929, *Kajewski* 1466 (A, NY); Queensland, Bamaga Mission, 11.2km Southwest of Cape York, east to mill and beyond, Lat. 11<sup>o</sup> 1' Long. 142<sup>o</sup> 3', 24 October 1965, *Smith* 12390 (A).

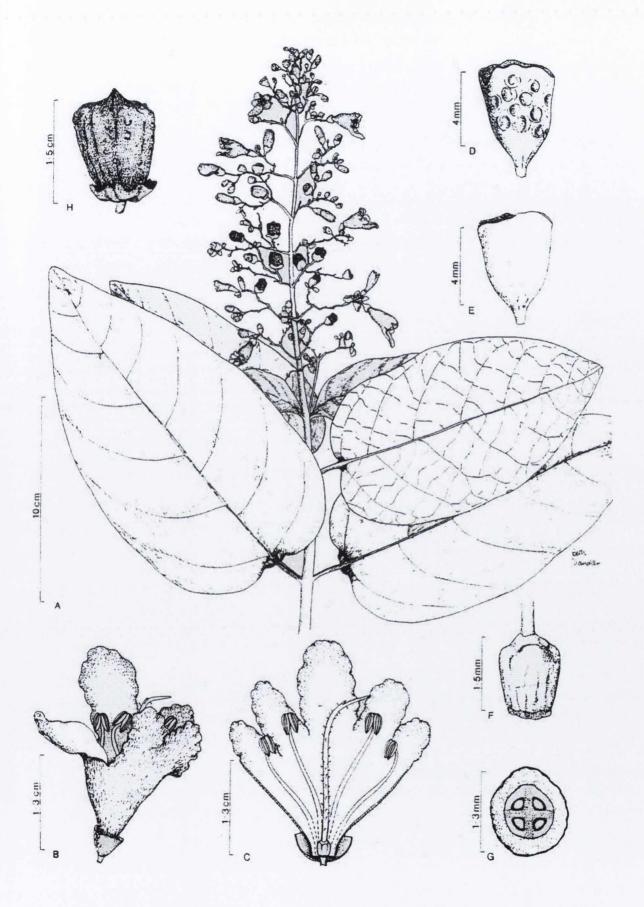


Figure 2.5. *G. dalrympleana*. A habit drawing of branch; **B** flower; **C** dissected flower; **D** calyx shows nectariferous glands on anterior side; **E** calyx shows nectariferous glands free posterior side; **F** ovary; **G** transverse section of ovary; **H** fruit with persistent calyx. (Taken from Munir 1984).

6. Gmelina elliptica *Smith* in Rees, Cyclop. 16: no. 2 (1810). Merr., Enum. Philip. Fl. Pl. 3: 399 (1923); Meeuse, Blumea 5: 73 (1942); Backer & Bakh. f., Fl. Java 2: 606 (1965); Moldenke, Phytologia Mem. 2: 549 (1980); Moldenke, Phytologia 56 (1): 43 (1984); Munir, J. Adelaide Bot. Gard. 7(1): 95 (1984); Rajendran & Daniel, Indian Verbenac.166 (2002); Hô, Illus. Fl. Vietnam 2:1045 (1993) & 2:830 (2003); Kress *et al.*, Checklist Pl. Myanmar 45: 389 (2003); Newman *et al.*, Check list Vasc. Pl. Laos 356 (2007). Type: East Indies, Herb. Linn. 780-1, undated (LINN, holotype Microfiche, K!; Photo, K!; NY!; TEX!).

*Gmelina villosa* Roxb., Hort. Beng., 46 (1814), *nom. nud.*; Fl. Ind. 3: 86 (1823); Wall. Numer. List. 87, no. 1816 (1828); Walp., Rep. Bot. Syst. 4: 98 (1845); Schauer in A. DC., Prodr. 11: 679 (1847); Miq., Fl. Ned. Ind. 2: 867 (1858); Miq., Fl. Ind. Bat. Suppl. 1: 242 (1860); C. B. Clarke in Hook. f., Fl. Brit. Ind. 4: 582 (1885); Vidal, Rev. Pl. Vas. Filip. 210 (1886); Briq. in Engl. & Prantl, Nat. Pflanzenfam 4(3a): 173 (1895); Vidal, Rev. Pl. Vasc. Filip. 210 (1886); Kuntze, Rev. Gen. Pl. 507 (1891); Koord. & Val., Bijdr. Boom. Java 7: 197 (1900); Merr., Philip. Bureau Forest. Bull. 1: 51 (1903); Dict. Pl. Names Philip. Isl. 153 (1903); Rev. Sp. Blanco, Fl. Filip. 68 (1905); King & Gamble, J. As. Soc. Beng. 74: 824 (1908); Craib, Aber. Univ. Stud. 57: 164 (1912); Merr., Interp. Rumph. Herb. Amb. 454 (1917); H. J. Lam, Verbenac. Malay. Arch. 217 (1919); Brandis, Indian Trees, 509 (1921); Lace, List trees, shrubs & climbers of Burma 2: 134 (1922); Ridley, Fl. Malay Pen. 2: 623 (1923); Hook., Bot. Misc. 1: 284 (1830); Dop in Lecomte, Fl. Gén. Indo-Chine 4: 846 (1935); Fletcher, Kew Bull. Misc. Inf. 10: 423 (1938); Merr., J. Arnold. Arbor. 33: 226 (1952). Type: Roxburgh s.n. (BM!, lectotype chosen here).

Radix deiparae Rumpf. Herb. Amb. 2: 124, t. 39 (1741). Type: Herb. Amb. 2: tab. 39 (in book!).

- *G. asiatica* sensu Wall. Cat. No. 1818 (1828). Kurz, For. Fl. Brit. Burma 2: 265 (1877) non Linn.; sensu Blanco, Fl. Filip. edn. 1: 492 (1837), non Linn.; ed 2: 344 (1845).
- G. asiatica L. var. villosa (Roxb.) Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenz. Ser. III, 3: 70 (1921). Bakh.
  & Lam in Lam & Bakh., Bull. Jard. Bot. Buitenz. Ser. III, 4: 285 (1922); Heyne, Nutt. Pl. Ned. Ind. edn.
  2:1320 (1927); Coode et al. Checklist of FI. Pl. Brun. 331 (1996). Type: as for G. villosa Roxb.

A scrambling spinescent shrub, or several-stemmed small tree, sometimes a thorny vine or climber, (1.5-)2.5-10(-15)m high, and 3-15(-30)cm in diameter. **Stem** with olive-coloured bark, bark thin, lenticellate; branchlets spreading and drooping, often spinescent, fulvous-villous; spines axillary, straight, 0.5-3cm long, the young shoots terete, tawny-villous. **Leaves** decussate-opposite, *petiole* slender, fulvous-pubescent, channelled above, (0.5-)1-4(-5)cm long; *leaf-blades* entire or sometimes acutely 3-lobed, chartaceus or subcoriaceous, flat, elliptic to broadly elliptic, ovate-elliptic, ovate to broadly ovate, or somewhat trapeziform, apex sub-acute to acute or obtuse, base acute to cuneate or sometimes rounded to obtuse, (3-)5-10cm long, (2-)3-6(-8)cm wide, the upper surface pubescent when young, glabrous and dark-coloured in mature, the lower surface densely fulvous-tomentose, or sometimes tomentulose and white glanduliferous, the lateral secondary veins 3-4 pairs. **Inflorescence** terminal, racemiform, few to rather many-flowered, 2-6(-10) cm long, fulvous-tomentose; *peduncles* to 1.5cm long; *bracts* green, foliaceous, rarely petaliod and showy; caducous,

lanceolate or broadly lanceolate or ovate-lanceolate, apex acute or acuminate or cuspidate, 10-20X4-8mm, pubescent on both surfaces. Flowers pendent, very shortly pedicellate; calyx campanulate, with 4 small teeth on top, 3-4(-5)mm long, and 3-4mm broad, persistent, slightly expanded under the fruit, externally tomentose, and white glanduliferous, with 3-7 nectariferous glands on the anterior side, glabrous within; corolla infundibular, oblique, mostly yellow or bright-yellow, membranous, bilabiate, softly pubescent with appressed strigose hairs, and white glanduliferous outside, glabrous inside, (3-)3.5-4.5cm long, basally tubular, tube very slender below, incurved, then abruptly and obliquely dilating upwards; the limb 4-lobed, upper lip entire, ovate, apically obtuse, 6-10mm long, 8-13mm broad at the base; lower lip 3-lobed, the middle lobe largest, broadly ovate-oblong, apically obtuse, 8-17mm long, 9-12mm broad at the base, the lateral lobes ±rounded in outline, 5-10mm long, 8-12mm broad at the base; stamens 4, didynamous, 2 reduced in size, almost included, inserted about the middle of the corolla-tube, near the top of slender portion; filaments filiform, incurved, the longer pair 1.6-2.2cm long, sparsely glanduliferous, the shorter pair 8-10mm long, glabrous throughout; anthers oblong, lobes free and divergent in the lower halves, 1.5-2.5mm long; ovary obovoid-globose, glabrous, 1.5-2.5mm long, 1-2mm wide, 4-loculed, each locule 1-ovulate; style slightly exserted, filiform, glabrous or with sparsely glandular hairs, 2.2-3.7cm long; stigma subulate, glabrous, minutely 2-lobed, lobes unequal. Drupes subglobose or globose to ellipsoid, ovoid or obovoid, (1-) 1.5-2cm long, 0.8-1.3cm in diameter, glabrous, fleshy, yellow when ripen, 1- or 2-seeded; pyrenes hard and woody, oblong-obovate, about 1.3cm long and 0.8cm wide, smooth.

#### Key to the varieties of G. elliptica

I. Leaves densely pubescent beneath; bracts green

var. elliptica

- Leaves tomentulose and white glanduliferous beneath; bracts rather petaloid, showy var. transitoria

#### i var. elliptica

Leaves chartaceus or subcoriaceous, elliptic, ovate-elliptic, ovate to broadly ovate, or somewhat trapeziform, apex sub-acute to acute or obtuse, base acute to cuneate or sometimes rounded to obtuse (3-) 5-10X(2-)3-6(-8)cm, densely fulvous-tomentose beneath; bracts green, foliaceous, caducous, lanceolate or broadly lanceolate or ovate-lanceolate, apex acute or acuminate or cuspidate, 10-20X4-8mm, pubescent on both surfaces. **Figure 2.6**.

**Ecology**: In open evergreen scrub; open thickets, along streams in evergreen forest; coastal forest or on sandy soil; on limestone; savannah with forested dry gullies. Alt. from sea level up to *ca.* 650m. *Flowering* & *fruiting*: almost throughout the year.

**Distribution**: Laos, Vietnam, Cambodia, Thailand, Indonesia, Malaysia, Singapore, Brunei, Philippines, and Palau Island. **Map 2.2**.

Miquel (1858) listed this variety from Sumatra, Java, Malacca, Celebes, and Bali. Lam (1919) gave its distribution as being from Nicobar, Burma (Myanmar), Siam (Thailand), Malay Peninsula and Archipelago, Philippines, Palau Islands and Indonesia. Bakhuizen (1921) recorded the natural distribution of this taxon as Burma (Myanmar), Thailand, Malacca, Nicobar Islands, Pulu Pinang, Malaya, Philippines, and Indonesia. In addition to these localities, Moldenke (1971, 1980) recorded it from Jamaica, Belgian Congo, Mauritius, India, Indochina, Caroline Island and Riouw Archipelago. He stated that this taxon is cultivated in Java, India, England, Belgium, Congo, Mozambique, Zaire, Brazil, Porto Rico, Florida, Hawaiian Islands and Tahiti.

Vernacular names: Thawng Maew, Tongnaeo; Ching chai, Tam mia (Thai). Kutang (Murut); Pako Bulang Gajah, Bulangan, (Malay, Kelantan); Belingkot (Sabah). Wareng, Pundanga, Kayu palapi (Sulawesi), Kayu Bulang, Pako Bulangan Keche (Melaka); Bidara (Buton), Tanggalasi (Kendari); Lombaul (Lesser Sunda Island); Pohong, Taring pelandok (Borneo). Talungund (Visayas); Bangana (Minadanao).

**Uses**: Leaves cathartic (*Haniff & Said* 13253, on the herbarium sheet; Rajendrann & Daniel 2002). The powdered leaves are heated and applied externally for pale and impure blood (*Haniff & Said* 13253, on the herbarium sheet). Usually used as firewood in East Flores, Indonesia. Infusion of the fruits is used for eye troubles (Rajendrann & Daniel 2002).

Proposed Conservation status: A fairly common and widespread species. Least concern (LC).

**Typification**: The name *G. villosa* was first published by Roxburgh in his *Hortus Bengalensis* (1814); this was a *nomen nudum*, however, and the name was not validly published until Roxburgh (1832) provided a description in his *Flora Indica*. The name also appeared in Wallich's catalogue No. 1816, page 87 (1828). Roxburgh (1832) noted the plant to be a native of Pulo Pinang (Penang) in Malaya, from where it was introduced into the Botanic Gardens at Calcutta (Kolkata) by Dr. W. Hunter in 1802. Moldenke (1984) and Munir (1984) pointed out that the type specimen of *G. villosa* is possibly deposited in Kew. While examining the specimens there I did not find any Roxburgh's collection for this species; however, a specimen lodged in British Museum (BM) is accompanied by a label "Herb. Wallich 1816" and a handwritten label "*Gmelina villosa* R" and the backside of the specimen is stamped "India". Hence, this specimen is interpreted here as original material of Roxburgh and accordingly chosen as the lectotype of *G. villosa*.

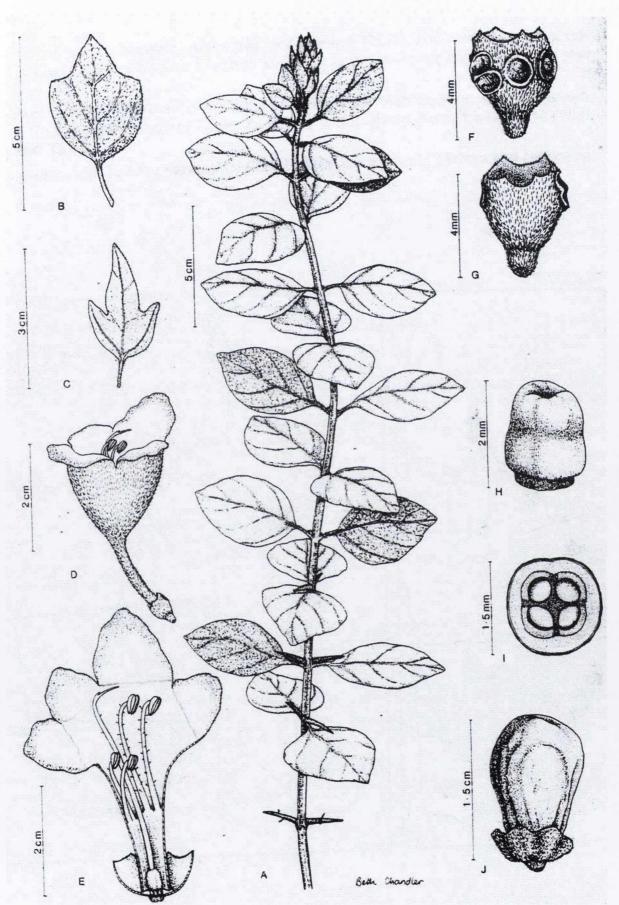


Figure 2.6. *G. elliptica* var. *elliptica*. A habit drawing of branch; **B** & **C** lobed leaves; **D** flower; E dissected flower; F calyx shows nectariferous glands on anterior side;. **G** calyx shows nectariferous glands free posterior side; **H** ovary; I transverse section of ovary; J fruit with persistent calyx. (Taken from Munir 1984).

### **Specimens Examined:**

Thailand: Northern: Nakhon Sawan, Paknampo, 15-50m, July 1920, Vanpruk 1013 (BKF); Chiang Mai, Bo Luang table-land, along road from Bo Luang to Om Koi, 12 June 1968, van Beusekom & Phengkhlai 1158 (L); Phitsanulok, Salut, 18 January 1918, Kerr 14171 (BM); Phitsanulok, 25 June 1920, Groff 6142 (A, NY); Kamphaeng Phet, Mae-Wong National Park, 11 July 1999, Chayamarit 1531 (BKF). North-eastern: Nong Khai, Sriracha, 70m, 30 March 1923, Marcan 1207 (ABD). Eastern: Nakhon Ratchasima, Pak Thong Chai, 13 March 1969, Phengnaren 639 (BKF, L). South-western: Kanchanaburi, Kanburi, ca. 100m, 7 March 1924, Kerr 10577 (BM); Kanchanaburi, near Kannyu, about 100km north-west of Kanburi, 200m, 17 July 1946, Kostermans 1191 (A, L-2 sheets, P); Kanchanaburi, Kanburi, Wang Yai, Sai Yoke, 8 April 1949, Charoenmayu 415 (A); Kanchanaburi, thai-yok, vongyai, 8 April 1949, Prichar.415 No. 5454 (BKF); Kanchanaburi, 17 March 1959, Sangkhachand 821 (BKF); Kanchanaburi, Erwan National Park, between Khwae Noi and Mae Klong river, along path from guesthouse up to the hills, ca. 200-600m, 18 April 1968, van Beusekom & Phengkhlai 498 (K, L, P); Kanchanaburi, Erawan, 14°20'N 99°55'E, 75m, 3 July 1974, Larsen & Larsen 34046 (L, P); Kanchanaburi, 23 March 1975, Indrapong et al. 130 (BKF, L); Phetchaburi, Kaeng Krachan National Park, 19km marker on route 3432 from park HQ, 12°52'N 99°35'E, 200m, 25 August 1995, Parnell et al. 95-420 (TCD); Ratchaburi, Tah Rua, ca. 6m, 12 May 1916, Winit 411 (BKF); Ratchaburi, Suan Phung, 10 April 2006, Sankaew & Atchara SS & AT 427 (TCD); Uthai Thani, Ban-Rai, 20 July 1962, Sangkhachand 990 (BKF); Parachuap Khiri Khan, Hui Gang, ca. 50m, 2 July 1924, Kerr 10740 (BM); Parachuap Khiri Khan, Hua Hin, Kow Dow, 200m, 1 August 1976, Maxwell 76-470 (L). Central: Ayutthaya, Bang Pa In, 7m, 28 July 1923, Marcan 1419 (BM); Suphan Buri, Dom Bang, ca. 20m, 19 May 1923, Kerr 7005 (BM); Saraburi, Pukae, 25 November 1955, Tenm & Willium. 17157; No. 8509 (BKF); Krung Thep, Bangkok, 8 April 1926, Kerr 10666 (ABD, BM). Peninsular. Phangnga, Ko Mak, 18 February 1966, Hansen & Smitinand 12371 (L, P); Phangnga, Takuapa, 9°0'N 98°10'E, 6 May 1973, Geeesink & Santisuk 5223 (L-2 sheets); Phuket, Near airport, 9 May 1968, van Beusekom & Phengkhlai 498a (K, L, P); Phuket, west of Ban Bo Han, 8°7'N 98°18'E, 8 October 1970, Charoenphol et al. 3428 (L); Phuket, Kamala beach, 8 July 1979, Niyomdham et al. 241 (BKF, K, L, P); Phuket, Khao Pra Taeo Wildlife Research Center, 29 December 1983. Fukuoka & Ito T-35665 (BKF); Phuket, Kathem district, freedom beach, 100m, 27 January 1991, Collector unknown 91109 (L); Songkhla, Na Tawer, 15 July 1928, Rabil 76 (BM); Songkhla, Kao-noi, 24 February 1941, Premratsamie 1970 (BKF); Songkhla, Prince of Songkhla University, Haad Yai, field behind Biology building, 25m, 29 January 1979, Congdon & Hamilton 241 (A); Songkhla, Muang district, Suan Dtoon Falls, 200m, 12 February 1985, Maxwell 85-179 (A, BKF); Songkhla, Boripath waterfall, 07°0'N 100°12'E, 100-200m, 9 November 1990, Larsen et al. 41229 (MO); Pattani, Promontory of Pattani, 6°52'N 101°16'E, 20 October 1970, Charoenphol at al. 4093 (K, L, P); Narathiwat, Khas Tam Yong, 29 May 1973, Chaiaman 422 (BKF); Narathiwat, Khas Chana, Kahiwotai, 12 September 1985, Niyomdham et al. 976 (BKF, L, P); Surat Thani, Bang Bao, ca. 100m, 8 August 1955, Smitinand 2909 (BKF). Locality unknown: Along nature trail, 11 March, Congdon 451 (A); Padanm Besan, ca. 200m, 24 December 1927, Kerr 13622 (BM).

Laos: Ban Keun Road, 185m, 24 July 1955, Malahide 52 (BM).

Vietnam: Hồ Chí Minh: Saigon, Gâss tee hú, 22 May 1920, Hiep 147 (P); Saigon, 15 November 1917, Hiep 36389 (P); Saigon, 3 January 1919, Hiep 147 (P). Hà Tĩnh: Calin trap, 11 January 1903, Spire 1543 (P). Đồng Nai: Biên Hòa, February 1877, Pierre s.n. (P).

**Cambodia**: *Kampong Thom*: Kachap, Kampong Svay, 16 September 1919, *Béjaut* 14 (P). *Svay Reing*: March 1870, *Pierre* 1212 (A, P-2 sheets). *Phnom Penh*: Kampot, 9 October 1911, *Lecomte & Finet* 1679 (P). *Unknown locality*, undated, *Guinet* 35 (P); Unknown locality, undated 1963, *Guinet* 160 (P); Unknown locality, undated 1883-1885, *Couderc* 35 (P).

**Singapore**: Chan Chu Kang, undated 1896, *Ridley* s.n. (SING); 6 mile Changi Road, 13 January 1933, *Teruya* 2163 (SING); Seletar Airfield, 7 August 1948, *Betty Allan* s.n. (SING); Siglap, among Chinese houses by roadside, near seashore, 18 February 1950, *Sinclair* 6414 (US); undated 1996, *Joseph Lai* LJ 114 (SING); Geylang, undated, *Teruya* 1302 (K, SING); Unknown locality, and date, *Thomson* 641 (GH); *Thomson* 641 (GH); Unknown locality, date, and *Collector* s.n. (SING 0026756- 2 sheets); Unknown locality, and date, *Hullett* 566 (SING).

Malaysia: Perak: Batu Kuran, 12 May 1924, Haniff & Said 13253 (SING); Durian Sabatang, 30 September 1924, Hanif 15295 (SING); Batu Gajah, July 1925, Mills s.n. (SING); Upper Perak, Sumpitan, 27 May 1927, Bonar 9671 (SING); Sungai Krian Estate, sea level, 3 January 1939, Spare 1822, Singapore Field No. 36731 (KEPONG); Dindings, Pangkor Isalnd, North end of Teluk Gedong, 7m, 10 July 1955, Burkill & Shah HMB 290 (A, SING); Bota Kiri, near Ipoh, 15-30m, 11 March 1958, Mohd. Shah 322 (K, SING); Ipoh, 2 miles, north of Gopeng, Gunong Pipit Limestone, 30m, 9 March 1971, Chin 793 (L); Pulau Langkawi, Pasir Hitam lookout, Scrub along roadside, 30m, 12 November 1979, Benjamin C. Stone 14271 (A); Ipoh, Mahtab Perguman, 21 January 1987, Guan 34276 (A, K,KEPONG, L). Melaka: Unknown locality, 3 November 1884, Vwabriss 49 (SING); Chunana, Puteh, 5 February 1885, Vwabriss 364 (SING); Malacca seashore, 29 May 1885, Vwabriss 1628 (SING); Alor Gajah, April 1889, Hervey 112 (SING); Unknown locality, date, and Collector (BM-000835018). Negeri Sembilan: Bukit Sŭtŭ, 9 November 1885, Collector unknown 2106 (SING); Senda Estate, Batang Malaka, 20 July 1936, Fujimoto 3089 (SING); Seremban, 25 August 1938, Strugnall 47115 (KEPONG). Sarawak: Serian, beside a path between paddy fields, 16 January 1955, Brooke 9566 (L); unknown locality and date, Moulton's native collectors s.n. (BM-000835028). Palau Pinang (Penang): Unknown locality, 18-20 March 18846, Didrichsen 3650 (A); Common coast, September 1885, Curtis 454 (SING); Waterfall stone guarry, 24 March 19., Curtis s.n. (SING); Penang Hill, January 1921, Ridley s.n. (SING); Raunt Archipelago, 2 July 1921, Bünnemeyer 6532 (SING); Penang Beach, 17 June 1989, Swanborn ML 894 (L). Kelantan: Kuala Lebir, July 1904, Gimlette s.n. (SING); Kota Baku, 21 April 1939, Corner s.n. (SING). Kedah: Langkawi, September 1890, Curtis s.n. (SING); State land, Belukar, 27 November 1930, Dolman 21459 (SING); Langkawi, 11-18 February 1940, Batten Pooll s.n. (SING); Near Sanatorum, 14

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February 1950, *Collector unknown* 71203 (KEPONG); Pokok Sena, 12 April 1968, *Sidek Bin Kiah* S. 359 (A, SING); Sungai Patani, Hedge of Rest House, 22 February 1978, *Collector unknown* FRI 27167 (KEPONG).

Pahang: Kuala Pahang, May 1890, Ridley s.n. (SING); Kuala Pahang, 19 August 1889, Ridley s.n. (SING); Temerloh, near the Rest House, 6 June 1916, Hashim 683 (SING); Temerloh, 31 August 1919, Hamid 4800 (SING); Kuala Tembeling, 26 January 1921, Seimund 139 (SING); Cameron Highlands, November 1939-January 1940, Batten Pooll s.n. (SING); Kuantan, ca. 75m, 03°40'N 103°05'E, 27 February 1990, Soepadmo & Suhaimi S.115 (MO, NY). Perils: Besdi Haugal, undated, 1910, Ridley 14942 (SING); Basi Bukit Lagi, 16 November 1929, Henderson 22826 (SING); Arau, 13 July 1936, Comer s.n. (SING); Kaki Bukit Forest Reserve, beside the tunnel, 1 March 1972, Chan FRI 19923 (A, K, KEPONG, L, SING). Johor: Pulau Aor, 28April 1927, Henderson 18209 (SING), Selangor, Selangor, 7 June 1900, Ridley s.n. (SING); 7 M.S. Batu tiga, Klang, 25 September 1968, T. & P. 180 (K, SING). Sabah: Unknown locality, April 1917, Villamil 315 (NY-Photo); unknown locality, July-September 1923, Castro & Melegrito 1334 (A); Lok Kalankali, Timbun Mata Forest Reserve, 27 August 1938, Keith 44598 (KEPONG); Sandakan, 45m, 9 August 1938, Keith 9932 (SING); Timbun Mata Forest Reserve, 19 July 1938, Symington 35391 (KEPONG); Tenom, 15 May 1939, Angian 49094 (KEPONG); Kalawat, 8 April 1950, Henderson SF38965 (SING); Sandakan, Keningau district, Petikang Laut, 275m, 11 July 1961, Arumpad SAN. 15304 (L); Sandakan, Tawau district, Mile 15, Kula Apas road, 8 September 1962, Aban Gibot SAN 31238 (KEPONG); Sandakan, Keningau district, Mile 11 (Road to Pensiangan), 14 March 1963, Madani 35034 (L); Sandakan, Tambisan, Ganduman Forest Reserve, South of Kampung Tegupi, 5m, 9 September 1975, Saikeh & Aban 82322 (L); Keningua district, Kitua, 9 September 1982, Amin 95465 (K); Keningau district, Ulu Sungai, Pingas-Pingas, along the riverside, 19 March 1988, Fidis & Asik 122120 (K); Nabawan district, 55km Jalan Nabawan/Sepulut, Ulu Sungai Nabawan, Along the river side, 19 February 1990, Asik Mantor SAN 128347 (KEPONG); Keningua district, Lagud Sebrang, Agriculture Research Station, Tenom, 220m, 4 January 1992, Coode 7158 (A, K); Pensiangan district, Pisgon, Hillside, 23 February 1995, Krispinus 139647 (KEPONG, SING). Kuala Lampur, Gombak Setia, East of the road side, ca. 150m, 6 September 1963, Kasim & Mahmud 550 (K). Terengganu: Kemaman, 29 July 1932, Corner s.n. (SING); Dungun, 1 May 1968, Soepadmo Mahmud 9138 (A); H. S. Bukit Bauk, Dungun, Terengganu Hill forest, ca. 120m, 14 June 1982, Khairuddin FRI 31800 (A, KEPONG, L, SING). Malay Archipelago: Unknown locality, near Singapore, undated 1880, Kunstler 103 (K).

**Indonesia**: *Bali*: Lesser Sunda Island (Nusa Tenggara), Alor, Kabola peninsula, Adang-Sabandar-Alor ketjil, 4 May 1938, *Jagg* 469 (A, BM); East Bali, Kanu, 150m, 15 October 1985, *van Balgooy* 5270 (L). *Bangka-Belitung*: Muntok, 30m, 10 October 1917, *Bünnemeijer* SING). *Java*: Residency Pekalongan, Saebah, undated 1885, *Koorders* 13491β (L); Depok, 11 August 1896, *Hallier* s.n. (L); Residency Pekalongan, Saebah, 12 April 1897, *Koorders* 27601β (A); Samarang, undated 1898, *Koorders* 9736β (L, SING); 28172β (L); & 25213β (L); Besocki, undated 1898, *Koorders* 21323β (L) & 30220β (L, SING); Residency Depok, undated 1900, *Soegandiredjo* 267 (L); Residency Preanger, Tjigelong bij Sanjindangan, ± 500m, 31 October 1909, *Bakhuizen van den Brink* 391 (L); Batavia, Gjitajam, 27 August 1922, *Bakhuizen van den Brink* s.n. (L, SING); West Java, Antjol, near Djakarta, 8 August 1953, Meijer 1793 (L); West Java, Pelabuhan ratu (Queen's port), 6 April 1982, Aya Nitta 15439 (A); West Java, Miramare, 19km east of Pameungpeuk Forest Reserve, near the coast, 7º43'S 107º53'E, 16 April 1984, Leeuwenberg 13247 (L-2 sheets). Sumatra: Unknown locality, 1881-82, Forbes 1576 (GH, L, NY) & 2642 (L-2 sheets); Gandong!, 75-100m, undated 1908, Elbert s.n. (L-0412793); East Coast, Asahan, Hessa, 27 August 1928, Toroes 1120 (A, SING); East Coast, Siman Poeloe, Batoe Bara, 24 September 1928, Toroes 1440 (NY, SING); Pulau Rangsang, Sumatera Tengah, October 1930, Teruya 1569 (SING); Near Peureulah, Sea level, 3 January 1932, Walter & Bangham 628 (A, NY); Near Idi, Sea level, 4 January 1932, Walter & Bangham 667 (A, NY); East Coast, Aer Kandis, near Rantu Parapat, Bila, 28 May - 26 June 1932, Toroes 2541(A, NY) & 2546 (NY); East Coast, Asahan, Hoeta Padang, near the Continental Plantation Company concession, Novemeber-December 1932, Krukoff 4422 (A, NY); East Coast, Asahan, Hoeta Padang, near the Continental Plantation Company concession, near stream, Novemeber-December 1932, Krukoff 4450 (A, L, NY, SING); East Coast, Kajoe Marijang, LanggaPajoeng, on the Soengei Kanan, 7- 30 March 1933, Toroes 3351 (NY); East Coast, Kajoe Barijang, LanggaPajoeng, on the Soengei Kanan, 7- 30 March 1933, Toroes 3603 (NY); East Coast, Kajoe Garijang, Saboegan, on the Soengei Kanan, 31 March - 06 April 1933, Toroes 3694a (NY); East Coast, Kajoe Garijang, Laboehan Batoe, Kota Pinang district, Si Mangi Angin, on the Soengei Kanan, 15 April - 16 May 1933, Toroes 3962 (NY); Padang Lawas, Poelo Liman, 29 August -3 September 1933, Toroes 5357 (A, NY); Residency Atjeh, Gajolanden, from Pendeng via Oreng to Gadjah, 600m, 26 February 1937, van Steenis 9315 (A, SING); Atjeh, Koeala Kepong, O'van Troemon, 1-5m, 2 September 1941, Asdat 191 (SING); North Sumatra Atjeh, Gunung Leuser Nature Reserves, Southern part of the Reserves, Alas River Valley, near the mouth of the Renun river, ca. 50km south of Kutacane, 50-125m, ca. 3ºN-97º50'E, 21 July 1979, de Wilde & de Wilde-Dufjes 18945 (L, MO); East Coast, undated, Yates 856 (A). West Sumatra: Painan, roadside to Kambang, 29 December 1983, Rahayu & Maskuri 508 (L-2 sheets); Sijunjung, along the road Trans-Sumatra, 200m, March 1984, Setiabudi SB 1 (L). Borneo: South Borneo, Hayup, 25 October 1909, Winkler 2270 (BM, P); East Borneo, Berau, slopes of Mount Njapa on Kelai river, 50m, 13 October 1963, Kostermans 21273 (L, MO,NY); South Borneo, Baku Randjang, 20 August 1965, Sauoeur 946 (L); Pedidi, Panji, Tenggarong, ±10m, 10 May 1983, Rahayu 93 (L); East Kalimantan, Samboja Kuala, 10m, 20 June 1991, Ambri & Arifin AA137 (A, K, L-2 sheets); East Kalimantan, road Lampe area, 1km from Samboja, 50m, 117ºE 1ºS, 18 May 1995, Ambri et al. AA1199 (A); South Kalimantan, along road from Simpang ampat to Pengaron, 25m, 26% 615'S 42% 931'E, 10 November 1996, Kessler et al. PK1780 (A, E, K); Kalimantan, Ketapang, Gunung Palung National Park, coastal forest, 5m, 1º10'N 109º55'E, 1 March 1997, Laman et al. TL 529 (A, K, NY). Riau Islands: Anambas, Terempak, Siantan, 31 March 1928, Henderson 20147 (SING). Sulawesi: Manado, Afd. Donggala, Paloe, 50m, 3 November 1930, Collector unknown 2286 (A); Near cape Batu Angus, by sea, 23 June 1954, Alston 15996 (BM, L); Northeast Sulawesi, Minahasa, Tasikoki, near Kema, Southeast of Mount Klabat, Roadside, 5 July 1956, Forman 407 (L); Padang Pandjang, near Pajakumbuh, 550m, 1 August 1957, Meijer 7181 (A); Buton Island, Bau-bau, Wakunti forest, 200m, 26 June 1978, Widjaja 551 (L); Southeast Sulawesi, Kendari, Una'aha, Abuki, 150m, 4 October 1978, Prawiroatmodio & Maskuri 1173 (L); Southeast Sulawesi, Kendari, Una'aha, Laweha, 100m, 12

October 1978, Prawiroatmodjo & Maskuri 1082 (A, L); Central Sulawesi, ca. 25km south of Palu, ca. 100m, 0º30'-1º30'S, 119º30'-120º30'E, 21 April 1979, van Balgooy 2955 (L); Central Sulawesi, Palulolu Pertamina, Along road Palu-Donggala, 17km from Palu, 0-30m, 0º30'-1º30'S 119º30'-120º30'E, 22 April 1979, Hennipman 5018 (L); Desa Mario, Palopo, Kab. Lauwa, 80m, 8 April 1984, Ramlanto Ram. 113 (A, L); Kendari, Kab. Unaha, Sampara, G. Abesu, 70m, 6 November 1986, Amir 70 (L); Tengah, Luwuk area, Coast road, Sinua towards western end of northern promontory, ± sea level, 0°45'S 122°58'E, 12 October 1989, Coode 5908 (L); Gorontalo, Cagar Alam Panua, On edge of disturbed forest, 250m, 0°28'N 121°56'E, 4 July 2002, Mendum et al. 137 (E). Maluku (Moluccas) Isalnd: Locality, date, and Collector unknown, Herb. Lugd. Bat. no. 908267-.844 (L); Ambon, 0-100m, 2 April 1910, Kornassi nr. 1079 (L); West Ceram (Maluku), Kaibobo, 0-200m, 16 July 1918, Rutten nr. 1667 (L). East Nusa Tenggara: West Flores, South part of Mountain Ndete, 100m, 14 April 1965, Kostermans 22152 (L); West Timor, Oëmlu, 7 JUne 1981, C. W. Kooj 1303 (L); East Flores, Ile Mandiri, Larantuke, ± 200m, 17 April 1984, Afriastini 1528 (L). West Nasu Tenggara: Lombok, Rindjani-Vulkangebirge, North site, 750m, 30 April 1909, Elbert I750 (L); Sumbawa, Sultanat Bima, 375m, 8 December 1909, Elbert 3676 (L); Sumbawa, Sultanat Bima, 200m, 13 December 1909, Elbert 3909 (L); Sumbawa, Residency Nae-Pandende-Rora-Bima, 600m, 3 October 1982, Danimihardja 2214 (L); North of Sumbawa, Bay of Sanggar, Littoral and sublittoral close to Sanggar, 8º22'S 118º17.9'E, 22 September 1984, Collector unknown Snellius-II 11151 (L- 2 sheets); East Sumba, Ngallu, North of Baing, ca. 4-5km NW of Paranda, "Gunung Laipupu", 300m, 9º12'S 120º33'E, 5 February 1994, McDonald & Sunaryo 4340 (A, KEPONG- 2 sheets, SING).

**Brunei**: *Tutong*: Telisai, 8km down road from Sungai Liang towards Tutong, 4º42'N 114º31'E, 10m, 26 March 1993, *Coode* 7399 (K); Telisai, Pasir Puteh, 13km southwest of Tutong, North of highway, 4º45'N 114º35'E, 10m, 10 July 1993, *Cowley et al.* 32 (KEPONG, L); *Belait*: Lumut, 24 July 1965, *Collector unknown* 4049 (L-2 sheets).

Philippines: Minadanao Islands: Agusan del Norte: Butuan subprovince, Mlnadanao, March-July 1911, Weber 1028 (A). Basilan: Isabela Island, 17 January 1904, Hallier 3515 (L) & 4295a (L); Unknown locality, February 1926, Pascua 30231 (NY); Unknown locality, 20m, 1 December 1930, Salaudin 31384 (NY, SING). Bukidnon: Unknown locality, July-August 1913, Escritor 21403 (GH); Vicinity of Tanculan, July 1916, Fenix 26124 (A); So. Dagunbaan, 75m, 17 December 1932, Santos 31523 (NY). Cotabato: Cotabato to Davao, Roadside, 22 January 1940, David Fairchild 163 (A). Davao: Mindanao, March 1904, Copeland 346 (NY); Santa Cruz, SE Mindanao, 17 June 1905, Williams 3041 (NY); Davao district, Todaya (Mountain Apo), 350m, October 1909 Elmer 12013 (A, L, MO, NY); Coronon valley, near Santa Cruz, 335m, March 1964, unknown ANU 1595 (K). Lanao: Mindanao, roadside between Maria Cristina Falls and Overton, 29 August 1938, Zwickey 17 (A). Sulu: Jolo, Cabucan Island, January-February 1957, Kondo & Edaño 38839 (A, SING). Zamboanga: Basilan city, Lamitan district, Bario Ubit, 10km east of University of Philippines, 4 June 1948, Santos 4530 (L). Visayas Islands: Capiz: Panay, May-June 1918, Ramos & Edaño 31488 (L); Guimaras: Isalnd of Guimaras, August 1903, Ritchie 38 (NY). Iloilo: Miagao, C. N. Bababuoy, Talungon, September-

October 1958, *Vidal* 3440 (A). *Negros Occidental*: Island of Negros, Dumaguete (Cuerons mountains), March 1908, *Elmer* 9646 (A, MO, NY). **Luzon Islands**: *Marinduque*: Bo. Matuya-tuya, Torrijos, 3 July 1955, *Santos E. Dueñas* 23099 (L). *Masbate*: Island of Masbate, May-June 1904, *Clark* 1003 (NY); 7-R Ranch, Sitio Kalunakan, Brgy. Matiputon, Milagros, 650m, 12º13.1'N 123º30.5'E, 12 February 1994, *Barbon et al.* 12650 (GH). *Oriental Mindoro*: Bulalacao, April 1903, *Merrill* 914 (GH, K, MO, NY, SING); Mindodro, February-April 1908, *Merritt* 9798 (MO); Bo. Manaul, Mansalay, 4-5m, 18 December 1952, *Sulit* 17009 (A, L, PNH). Unknown locality, undated 1819, *Perrottet* s.n. (P). *Laguna province*: Calauan, October 1958, *Vidal* 3439 (A).

Locality undetermined: Birma (Burma) and Malay Peninsula, undated, Herb. Griffith. 6057/1 (GH, P); Mauritius or Madagascar, undated, *Justice Blackburn* (GH, NY- presented by Admiral Bowles, 17 July 1863); Unknown Locality, East coast, undated, *unknown collector* 95 (BM).

# Cultivated:

**Malaysia**: *Palau Pinang (Penang)*: Cultivated in Botanic gardens, undated, *Curtis* s.n. (SING). **Indonesia**: *Java*: Cultivated at Buitenzorg, Undated, Her. Hort. Bot.Bogor. XV.F. 5 (NY) & XV.F. 6 (NY). **Puerto Rico**: Mpio, de Loiza, along the Rio Grande de Loiza, at Santa Catalina, just north of the old bridge by the old mill, 10-20m, 27 August 1989, *Taylor* 9156 (NY); Mun. Mayagüez, Bo. Miradero, Tropical Agricultural Research Station (TARS), adjacent to University of Puerto Rico campus, 25m, 18°12'45"N, 67°08'W, 15 November 1993, *Nee* 44213 (NY); Mayagüez, Tropical Agricultural Research Station (TARS), Plot 29, 25 February 1985, *Liogier* 35401 (NY); Mayagüez, US Federal Experiment Station, 11 August 1954, *Schubert & Winters* 271 (NY). **Hawaiian Island**: Oahu Island, Manoa Valley, HSPA Forest Nursery, 4 October 1933, *Yuncker* 3687 (NY). **USA**; Florida, Miami, Plant Introduction Station, 24 July 1971, *Gillis* 11029 (MO); Jamaica and New York Botanical Garden, Public Gardens, Phillipsfield near Bowden, 1 March 1909, *Harris & Britton* 10784 (NY); Florida, Lee County, Sanibel Isalnd, Tradewinds Development, the snow garden, in a shaded border, 7 May 1977, *Brumbach* 9237 (NY).

### Specimens examined from the neighbouring countries:

Palau Island: Arekalong, 10 April 1936, Takamatsu 1646 (NY).

India: Calcutta, undated 1834, *Wallich* s.n. (TCD); Calcutta, undated 1837, *Wallich* s.n. (P); North Nicobar, Towards HQ Car Nicobar, 3 October 1976, *Nair* 4572 (L); Bombay, unknown date, and *Collector* (TCD); Unknown locality, date, and *Collector* (TCD- accompanied with *G. asiatica* on single sheet).

China: Kwangsi Province, undated 1901, *Henry* 166 (NY); Luo-fu Shan, Kwangtung, 3 October 1978, *K'tung* 78- 6403 (L).

Caroline Islands: Palau Island, Koror, August 1932, Kanehira 2068 (NY); 9 August 1939, Tuyama 7209 (A)

### Cultivated:

China: Yunnan, Xishuanbanna, 600m, undated 1980, Chow & Wan 80202 (K, MO, NY- 2 sheets);

India: In Calcutta Botanic Garden, undated 1863, *unknown collector* s.n. (P with hand drawing); In Calcutta Botanic Garden, undated 1866, *Anderson* 28 (P); In Calcutta Botanic Garden, undated, *unknown collector* s.n. (NY).

Mauritius: Unknown locality, date, and Collector (TCD).

Caroline Islands: Palau Island, 6 July 1929, Kanehira 198 (NY).

ii. var. transitoria (Moldenke) M. H. Rashid stat.. & var. nov.

Type: Philippines, Guimaras province, Guimaras Island, Buenarista-Bo. Mabini, 100m, 1 March 1950, Sulit 3601 (Herb. No. 11741) (A! lectotype chosen here, L-2 sheets! isolectotype).

G. philippensis f. transitoria Moldenke, Phytologia 18(4): 210 (1969). syn. nov. Type: as for G. elliptica var. bracteata.

Leaves chartaceus, elliptic to broadly elliptic, apex sub-acute, base acute obtuse, (3-)4.5-8.5X3.5-5cm, tomentulose and white glanduliferous beneath; bracts rather petaloid, bright, showy, caducous, ovate-lanceolate, apex acuminate, 10-18X5-8mm, puberulent on both surfaces. **Figure 2.7**.

Distribution: Endemic to Guimaras Island, Philippines. Map 2.2.

Proposed Conservation status: Data Deficient (DD). This variety known only from type specimens.

**Typification**: Moldenke reported that the type specimen is lodged at United States National Herbarium, Washington (US). However, there is no *Gmelina* type specimen available in US. It seems that the original collections are in the Philippines National Herbarium (PNH). There are three syntypes from A and L. Therefore, being relatively more complete and having an original label, the A specimen is chosen here as lectotype.

**Notes**: Moldenke (1969, 1984) noted "this specimen is in many ways intermediate between *G. philippensis* and *G. elliptica*, and might be a natural hybrid between them", and he recognised as *G. philippensis* f. *transitoria*.

Apart from the showy colourful bracts, which it shares with *G. philippensis*, this specimen is more similar to *G. elliptica* (rather green). Therefore, in the present investigation, it is given varietal rank under *G. elliptica*.

## Specimens examined:

Philippines: Guimaras province, Guimaras Island, Buenarista-Bo. Mabini, 100m, 1 March 1950, Sulit 3601 (Herb. No. 11741) (A lectotype, L-2 sheets, isolectotype).

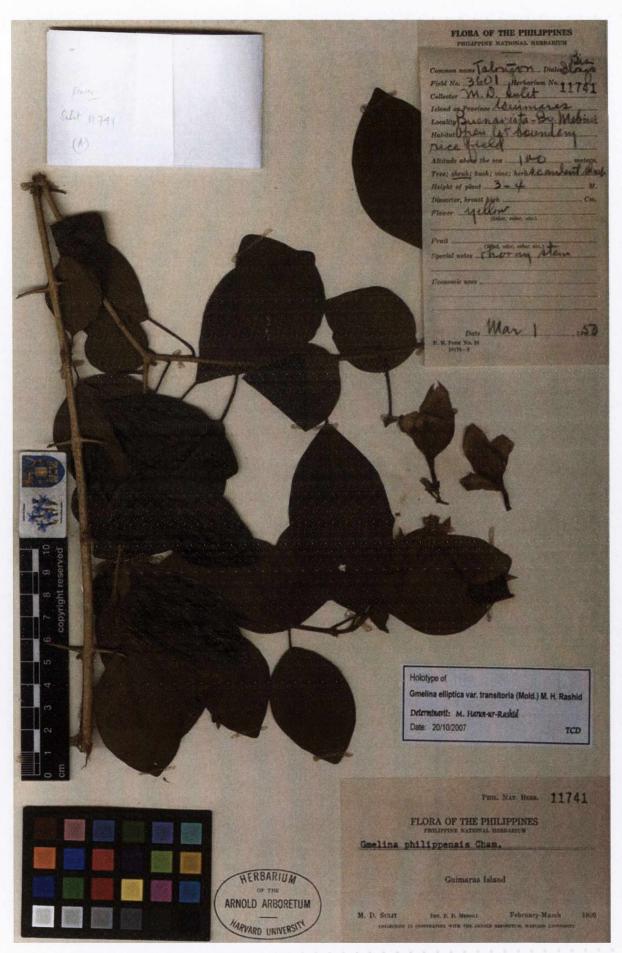
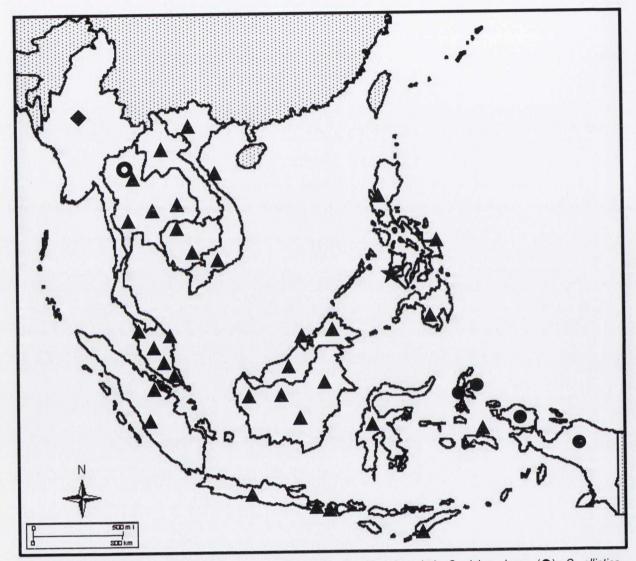


Figure 2.7. Holotype of G. elliptica var. transitoria. (Sulit 11741, A).



**Map 2.2** Southeast Asian distributions of *G. attenuata* ( $\bigcirc$ ); *G. chindwinse* ( $\blacklozenge$ ); *G. dalrympleana* ( $\bigcirc$ ); *G. elliptica* var.elliptica ( $\bigstar$ ); and *G. elliptica* var. transitoria ( $\bigstar$ ).

7. Gmelina lepidota Scheff., Ann. Jard. Bot. Buitenz. 1: 41 (1876). Lam, Verbenac. Malay. Arch. 221 (1919); Bakh., in Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 71 (1921); Mold. Known Geogr. Dist. Verbenaceae, ed. 1: 93 (1942) and ed. 2: 186 (1949); Mold. Fifth Summ. 1: 339 (1971) and 2: 880 (1971); Mold. Phytol. Mem. 2: 549 (1980); Mold., Phytol. 56 (2): 115 (1984). Type: Papua New Guinea, Tow Island, Poleo Tow, 18 August 1871, *Teysmann* 6744 (holotype BO, holotype photograph NY!, TEX!, holotype fragment NY!, isotype L!).

Gmelina lepidota var. lanceolata Moldenke, Phytol. 6: 325 (1958). Mold., Phytol. 56(2): 116 (1984). Type:
 Papua New Guinea, Bismarck Archipelago, New Britain, Nantambu, open bay, 500m, June 1945, Mair
 NGF 1894 (holotype LAE, isotype L! (2 sheets), isotype fragment TEX!) syn. nov.

A large tree to 30m tall, trunk to 60cm in diameter; bark brown, rough; branchlets terete, ferruginuouspubescent; sparsely lenticellate. Leaves decussate-opposite; petioles 1.5-3cm long, glabrous, canaliculated above; leaf-blades sub-coriaceous, many small sunken glands scattered beneath; narrowly elliptic to elliptic, or lanceolate, rarely ovate or obovate, 9.5-20cm long, 5-8.5cm wide, apically sharply acute or shortacuminate, basally acute to acuminate, rarely abruptly acute or obtuse, margin entire, glabrous and shiny above, densely brown-lepidote with minute scales beneath; midrib and veinlets glabrous, conspicuous above, prominent beneath; the secondaries 4-6 pairs. Inflorescence lax, terminal, paniculate, pyramidal, 4-9cm long, ferruginuous-puberulent; flowers shortly pedicellate; bracts oblanceolate, 5-8mm long, to 3mm wide, glabrous above, pubescent beneath; bracteoles persistent, lanceolate, 2-4mm long, 1-2mm wide, puberulent above, pubescent beneath; calyx small, about 5mm long, campanulate or cupular, the rim truncate or minutely 5dentate, teeth subulate or triangular, acute; externally lepidote, internally glabrous, slightly extended in fruit; corolla infundibular, white with median lobe of the lower lip yellow at the center, margin violet, 1.2cm long, externally ferruginous-pubescent, the tube internally glabrous excepting the villous-pubescent ring at the base of stamens, lobes pubescent; limb, bilabiate, upper lip 2-lobed, ovate, apically shortly acute, 3-5mm long, 2.5-3mm wide at base, lower lip 3-lobed, the median lobe longer, 7-12mm long and 4-6mm wide at base, oblong, obtuse, the lateral lobes ovate, obtuse, 5mm long and 4mm wide at base; tube obligue, slender below, abruptly dilating above the calyx; stamens 4, didynamous, exserted, inserted near the base of corolla tube; filaments filiform, incurved, densely pilose, apically with short glandular hairs, longer pair 15-18mm long, shorter pair 13-16mm long; anthers oblong, 1.5-2mm long, lobes free and divergent in the lower halves; ovary obovoid, apically pubescent, glabrous elsewhere, 2.5-2.8mm long, about 1.5mm wide, 4-locular with one ovule in each locule; style 1.5-1.8cm long, exserted, filiform, glabrous, apically sparsely glanduliferous; stigma subulate, glabrous, unequally bi-lobed, longer lobe 1.7mm long, other minute. Drupes ovoid or ellipsoid, obtuse, pale purple, 1.5-2.5cm long, 0.8-2.0cm wide, glabrous. Figure 2.8.



Figure 2.8. Isotype of G. lepidota. (Teysmann 6744, L).

**Ecology**: Rather dense microphyll forest 20m high, with very little undergrowth. Very dry steep hillsides, with loose serpentine boulders covered by a thick mat of roots and litter; secondary forest. Alt 30m-1000m. *Flowering & fruiting:* May to November.

**Distribution**: Moluccas Island (Indonesia) to Bismarck Archipelago and Western province (Papua New Guinea). **Map 2.3**.

Vernacular name: Namavue (Papua New Guinea).

Uses: Used for dugout canoes (Irian Jaya, Indoensia).

**Proposed Conservation status:** *G. lepidota* distributed only in Moluccas Island, Indonesia, and Bismarck Archipelago and Western province in Papua New Guinea. Due to its narrow distribution the species is therefore considered as Vulnerable (VU).

**Notes**: *G. lepidoata* var. *lanceolata* Moldenke recognised from a single specimen *Mair NGF*1894 from deep volcanic soil in a rainforest, at 500m altitude, open bay, New Britain, Bismarck Archipelago, Papua New Guinea. Moldenke noted "The variety differs from the typical form of the species having lanceolate and more elongated leaf blades, acuminate apex and abruptly acute base, and 12-22.5cm long and 3-6cm wide leaf size, native to New Britain". All available specimens, distributed from Moluccas Island (Indonesia) to Bismarck Archipelago and Western province (Papua New Guinea), from altitudes ranging 30m to 1000m have this type of leaf, on which Moldenke's variety based. The variety occurs in deep volcanic soil. I believe, the variation due to only ecological factors and it is not justifiable to maintain it as a separate taxon. Hence it is reduced to *G. lepidota*.

This species has not been recorded from Indonesia before. It is therefore, recorded here for the first time from this territory (Indonesia).

**Specimens examined:** Indonesia: *North Moluccas*, Morotai, 1000m, 20 May 1949, *Kostermans, Main & Aden* 1292 (fragment NY); Morotai, G. pare 2, 1000m, 28 May 1949, *Main & Aden (exp. Kostermans)* 1276 (P, SING); Morotai, G. pare 2, 1000m, 28 May 1949, *Main & Aden (exp. Kostermans)* 1292 (A, L, P, SING); Obi island (west part), Jikodolong, ca. 1º 28' S, 127º 30' E, 100m, 26 November 1974, *Vogel* 4342 (L- 2 sheets; MO); Obi island (west part), Jikodolong, ca. 1º 28' S, 127º 30' E, 95m, 26 November 1974, *Vogel* 4338 (L, MO); *Irian Jaya*, West Irian, above Hollandia, (Sukurnapura) Jayapura, ca. 350m, 15 August 1966, *Kostermans & Soegeng* 369 (A, K, L); West Irian, In town of (Sukurnapura) Jayapura, ca. 150m, 04 August 1966, *Kostermans & Soegeng* 148 (L); Hollandia, 100m, 17 January 1957, *Versteegh & Kalkman* BW 4696 (A). **Papua New Guinea**: *Tow Island*, Poleo Tow, 18 August 1871, *Teysmann* 6744 (holotype photograph NY, TEX, holotype fragment NY, isotype L); Bismarck Archipelago: New Britain, Nantambu, open bay, 500m, June 1945, *Mair* NGF1894 (isotype L-2 sheets, isotype fragment TEX); New Britain, Limestone pothole region, Talasea, 10 mile south of Cape Ruge, 5º 35' S, 147º 24' E, 200m, 10 May 1966, *Frodin* 

NGF26744 (L); New Britain, Talasea, Mountain Tangis, Western slopes, 500m, 5° 39'S and 148° 18'E, 29 May 1966, *Frodin* NGF 26866 (L); Western district, Terrain of Papua, middle Fly river, Near lake Daviumbu, ca. 30m, 04 October 1967, *Pullen* 7436 (L).

**8. G. misoolensis** *Moldenke*, Phytologia 4(1): 54 (1952). Moldenke, Résumé 203 & 456 (1959); Taylor, Ind. Kew. Suppl. 12: 63 (1959); Moldenke, Fifth Summary Verbenac. etc. 1: 338 (1970) & 2: 491, 523, 524, 716 (1971); Moldenke, Phytol. Mem. 2: 328, 549 (1980); Moldenke, Phytologia 55: 335 (1984), and 56 (2): 118 (1984). Type: Indonesia, Raja Ampat Islands, Misool, Fakal, near New Guinea Island, 40m, 30 September 1948, *Pleyte* 1087 (holotype BO; holotype images NY!, TEX!, isotype fragment NY!).

A tree, to 12m tall; trunk to 12cm in diameter at breast height; branches and branchlets rather stout, glabrous, often white- or grey-flecked; principal internodes 1-7cm long; nodes not annulate. Leaves decussate-opposite; *petioles* rather slender, 1.5-2.5cm long, nigrescent on drying, glabrous, flattened above, *leaf blades* coriaceous, bright-green and very shiny and very smooth on both surfaces, elliptic, 5.5-12cm long, 3-6cm broad, apically rounded or obtuse, margin entire, often somewhat revolute in drying, basally acuminate; midrib rather coarse, flat above, very prominent beneath; secondaries very slender, 4-6 pairs, arcuate-ascending, anastomosing in many loops several mm from the margins beneath, flat above, prominulous beneath; veinlets reticulation sparse, flat above, very slightly subprominulous beneath on the larger parts only. Inflorescence paniculate, terminating short axillary twigs, 9-18cm long, brunnescent or nigrescent throughout in drying; *peduncles* slender, 2-3.5cm long, glabrous; rachis similar to the peduncles, greatly elongated, composed of 5-10 sympodia, strict, glabrous; *pedicels* very slender, about 2mm long, glabrous. Flowers not seen; *fruiting-calyx* campanulate, about 3mm long and 5mm wide, nigrescent, glabrous on both surfaces, truncate, split to the base into 2 subequal, quadrate lobes when mature. Drupaces obovate, green when young, red when ripe, about 12mm long.

Ecology: Fruiting in September.

Vernacular name: Batan me.

Distributions: Endemic to Misool, Raja Ampat Islands, Indonesia. Map 2.3.

**Proposed Conservation status:** Moldenke described this species based on a single type specimen (*Pleytel* 1087) collected in 1948. Since then there are no other collections. Thus, the species is likely to be extinct. EX.

**Note**: Moldenke (1984) commented "This species thus far known to me only from the original collection." While examining all available *Gmelina* specimens from relevant herbaria, I did not find any *G. misoolensis* specimen. I have seen only holotype images and isotype fragments. Therefore, the species description is adopted here from Moldenke (1954, 1984).

9. Gmelina moluccana (*Blume*) Backer ex Heyne, Nutt., Pl. Ned. Ind. 3: 118 (1917). Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenz. Ser. 3: 67 (1921); Hill, Ind. Kew. Suppl. 7: 104 (1929); Bakh., J. Arnold Arbor. 16: 72 (1935); Moldenke, Phytologia 56 (2): 118 (1984). Type: *Tittius* (alba et rubra), Rumphius, Herb. Amboin. 3: 38, t. 20 (1743)! lectotype designated here).

Tittius (alba et rubra), Rumphius, Herb. Amboin. 3: 38, t. 20 (1743). nom. illeg. Type: as for G. moluccana.

- Vitex moluccana Blume, Bidjr. Fl. Ned. Ind. 14; 813 (1826). Basionym; Miq., Fl. Ned. Ind. 2: 865 (1856). Type: as for *G. moluccana*.
- *G. macrophylla* Wall. Numer. List. 50, no. 1819 (1828); Miq., Fl. Ned. Ind. 2: 867 (1856); Briq. in Engl. & Prantl, Nat. Pflanzenfam 4(3a): 173 (1895); *H. J. Lam*, Verbenac. Malay. Arch. 224 (1919).
- G. glandulosa Hallier, f., Meded. Rijks Herb. Leid. 37: 57 (1918). Hill, Ind. Kew. Suppl. 6: 92 (1926). Type: Indonesia, Moluccas Islands, Banda Group, Ay Island, June 1821, *Reinwardt* 1362 (L! lectotype designated here 3-sheets).
- G. moluccana f. glandulosa (Hallier, f.) Moldenke, Phytologia 56 (2): 121 (1984). Type: as for G. glandulosa.
- G. salomonensis Bakh., J. Arnold Arbor. 16: 72 (1935); Hill, Ind. Kew. Suppl. 9: 125 (1938). Type: Solomon Islands, Isabel Island, Tiratoña, 600m, 8 December 1932, Brass 3309 (holotype BO, holotype images NY!, TEX!, isotype A!, isotype fragment NY!)
- G. moluccana var. elliptica (Moldenke) Moldenke, Phytologia 19: 435 (1970). Moldenke, Phytologia 56 (2): 126 (1984) & 56 (3): 154 (1984). Type: Solomon Islands, north-western Santa Isabel, along the Kolokofa River, *ca.* 58m, 6 April 1966, *Teona* s.n. (BSIP 6371) (holotype US, holotype image TEX!)
- G. salomonensis var. elliptica Moldenke, Phytologia 18(2): 71 (1969). Type: as for G. moluccana var. elliptica.
- G. moluccana f. glabrescens (Moldenke), Moldenke, Phytologia 19: 435 (1970). Type: Solomon Islands, Bougainville Island, Buin, Karngu, on the seashore, 10 October 1930, Kajewski 2228 (holotype BO, holotype images NY!, TEX!, isotype A!, isotype fragment NY!).
- G. salomonensis f. glabrescens Moldenke, Phytologia 4(3): 178 (1953). Devise, Ind. Kew. Suppl. 18: 142 (1987). Type: as for G. moluccana f. glabrescens.
- G. sessilis f. ramiflora (Moldenke) Moldenke, Phytologia 56 (3): 178 (1984). Type: Indonesia, New Guinea, West Papua (Hollandia), Bernhard Bivak, 50m, 26 July 1938, *Meijer Dress* 371 (holotype BO; holotype image TEX!; isotype fragment NY!).
- G. sessilis var. ramiflora Moldenke, Phytologia 4 (3): 178 (1953). Type: as for G. sessilis f. ramiflora.

A large, tall, erect, leafy, much-branched canopy tree, often to 40m high. Trunk often buttressed, straight or crooked; bole cylindric, to 25m; branchlets thick, obscurely tetragonal, sparsely lenticellate, the younger parts densely appressed ferruginous-or ochraceous-pubescent or rufous-tomentose, eventually glabrescent,

greyish, terete, shiny. Leaves decussate-opposite, large, simple, petiolate, held horizontally, usually clustered at the ends of the branches; petioles stout, sub-terete, slightly sulcate or canaliculated above, 1.5-10cm long, 2-5mm wide, densely ferruginous-puberulent or brown-pubescent with simple hairs in the sulcation and apically when young, later glabrescent; leaf-blades large, coriaceous, oval or ovate to broadly ovate or ovoid, sometimes oblong-elliptic, obovate-subrotund, or obovate, apically very shortly acuminate to blunt or obtuse, basally subacute or obtuse to rounded or subcordate, margin entire or lightly and irregularly sinuate, 10-40cm long, 7-35cm broad, dull or glossy dark-green above, paler and light-or grey-green beneath, adaxially densely pilose or finely villous when young, finally glabrous (except for the ferruginous-puberulent larger venation), abaxially softly brown-villious or ferruginous-puberulent to rufous-tomentose (except for the glabrous larger venation), with 2 rather large concave glands at the base beneath, secondaries pinnate, 8-18 pairs, impressed above, prominulently raised beneath. Inflorescence mostly terminal, sometimes also axillary, racemose, pyramidal-paniculate, 15-30cm long, 10-25cm wide, very densely appressed ferruginous short-villous, many flowered, pedunculate, peduncle 10-15cm long, densely brown-tomentose; bracts foliaceous, bracteoles small, linear or lanceolate-oblong, 5-10mm long, 2-3mm wide, apically and basally acute or acuminate, tomentose on both surfaces. Flowers rather large, subsessile, drooping; calyx cyathiform or cupuliform, subbilobed, subtruncate or the rim unequally, obtusely and very shortly 5-dentate, 5-10mm long, 3-7mm broad at the top, externally densely ferruginous-villous or rufous-tomentellous with 2-4 black, nectariferous glands, internally sparsely pubescent or subglabrous, scarcely expanded under the fruit, fruiting calyx somewhat accrescent, almost flat or marginally reflexed; corolla showy white or whitish to purplish-pink, pale-mauve, pale-blue, blue, pale-violate, or purple, often with yellow throat, sometimes white with purple lower lip, or red with purple yellow stripes, nigrescent in drying, 2.5-3cm long, externally densely ferruginous-strigulose or with long, brown, silky hairs, lower part glabrescent, internally tube glabrous, lobe inner faces densely glandular, 5lobed, upper lip 2-lobed, lobes broadly ovate, apically obtusely rounded, 5-10mm long, 4-5mm broad at base, lower lip 3-lobed, the mid-lobe largest, with a yellow marking at the base, 7-12mm long, 3.5-6mm broad at the base, 2 lateral lobes similar to the upper ones, tube slender below, apically ampliate, 1.5-2cm long; stamens 4, didynamous, slightly or scarcely exserted, inserted in the lower part of the corolla tube; filaments terete, apically incurved, sparsely short-pilose with glandular hairs, longer pair 9-13mm long, shorter pair 7-11mm long, anthers 2.5-3mm long, subsagittate, glabrous. Ovary ovate-oblong, basally glabrous, apically densely pubescent, 2-3mm long, 1-1.5mm wide, 4-locular with one ovule in each locule; style subexserted, filiform, terete, incurved in the upper half, sparsely glandular-pilose, 2.5-3cm long; stigma subulate, minutely unequally bi-lobed, longer lobe subulate, other minute. Drupes rather large, fleshy, shiny, oblong or subobovate to ovoid, ovoid-globose, or rounded, 1.5-3cm long, 1.2-2cm in diameter, green with purple dots to greenish-red or red when young, in maturing very dark-blue, purple, purplish-black, or black, shiny, apically depressed, at first farinose, finally glabrous, the nut-like endocarp obovate, thickly woody, apically flattened. Figure 2.9.

Ecology: Primary forests and light woods; coastal and low-ridge rainforests; in well drained secondary forests on flat plains; in forests on sandy loam soil; sandy clayey soil in primary forest; in orange-brown clay of general lowland rainforests; in grasslands. Alt. sea level to 1400m. *Flowering*: March-June, August-November; *Fruiting*: March, May-July; and September- December.

**Distribution**: Native to the Moluccas Islands (Indonesia), and New Guinea, New Britain, and the Solomon Islands in Papua New Guinea. **Map 2.3**.

Vernacular names: Arakoko; Caju titti; Daun titti; Gow; Hai; Kajoe titi mera; Omormi; Ossogee; Titti; Toehoe; and Toeroe (Moldenke 1984); Anjoes (Kostermanns 442, bb. 33600); Nassa-onggoe (Kamtoek language-Kalkman BW 6209); Karto; (Solomon Island, kajewski 2228); Koko (Brass 3309); Bas (Mooi language-lwanggin BW 5720); Na Sisimbem Ende (Madang Province, PNG- Tim Platts-Mills TPM 39).

**Uses**: It is a valuable timber tree in New Guinea in canoe-making. The wood is used for light construction, boat decking, planking, furniture, turnery, joinery, and moldings (Moldenke 1984) and very suitable for native vessels (Uphof 1968).

**Proposed Conservation status:** *G. moluccana* is distributed only in Indonesia and Papua New Guinea. In Indonesia it is confined to Moluccas Islands and New Guinea. The species is used by native people as a timber tree and due to habitat deforestation, it could be considered as Vulnerable (VU).

**Typifications**: While describing *G. moluccana*, Backer did not refer to any type specimen but did mention *Tittius* Rumphius, which was published in Herbarium Amboinense in 1743 along with an image. Therefore, the image is designated here as the lectotype of *G. moluccana*.

Hallier, f. (1917) mentioned the specimens, *Reinwardt* 1362 and *de Vriese* s.n. (sterile) from Ay Island and Neira respectively from Moluccas Islands for his species *G. glandulosa* without indicating which herbarium the specimen was lodged in. Hence, one of the more complete specimens from 3 sheets of *Reinwardt* 1362 deposited at L is designated here as the lectotype.

### Specimens Examined:

Indonesia: *Moluccas Islands*, Banda, ± 40m, 2 December 1920, *Boschproefst*. Bb. 13439 (L); Banda Group, Ay Island, June 1821, *Reinwardt* 1362 (L-3 sheets); Halmahera, North Galela, 10m, 21 September 1921, *Beguin* 1746 (K, NY); Tanimber-eilanden, Loeroemboen, ± 60m, 20 April 1938, *NIFS* bb. 24431 (A, L, SING); Boeroe, 24 April 1938, *Wae Mole* 193 (NY); Morotai, Mountain Permatang, along river Sangowo, 500m, 23 May 1949, *Main& Aden* 941 (K); Toliwang, Halmahera, 15 October 1951, *Idjan & Moehtar* 321 (A, K, SING); West Ceram, Kairatu, Gemba, 0-5m, 6 June 1959, *Kuswata & Soepadmo* 103 (L, NY, SING); Insulam, undated 1859-1860, *de Vries & Teijsmann* s.n. (L, Herb. Ludg. Batav. No. 908.267-280); Ambon Island, Amboina, July-Novemver 1913, *Robinson* 296 (BM, K, NY); Banda, *ca.* 40m, undated, *Bell* 32 (NY); Ternate, Amo (Kastella), *ca.* 60m, 14 April 1950, *Bish* 4 (A, L). *New Guinea*, Papua, Jayapura (Hollandia), Sabronsamon, Southwest of Lake Sentani, *ca.* 180m, 13 August 1957, *Kalkman* BW 6209 (A, KEPONG);

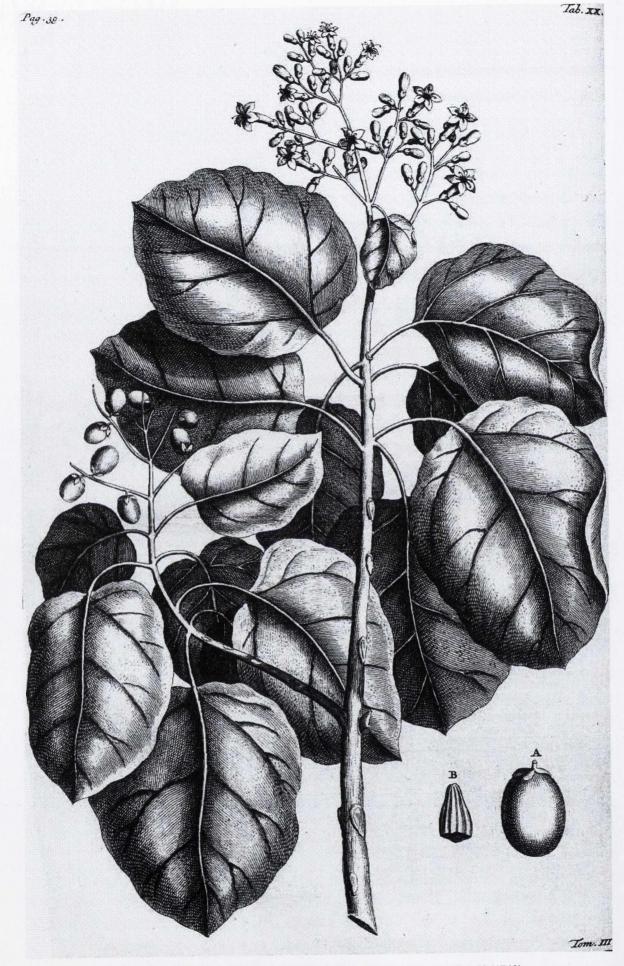


Figure 2.9. G. moluccana. Taken from Rumphius, Herb. Amboin. 3: 38, t. 20 (1743).

Sidai, about 65km west of Manokwari, 5-20m, 31October 1957, *Koster* BW 6828 (A). West Papua, Bernhard Bivak, 50m, 26 July 1938, *Meijer Dress* 371 (NY; image TEX); Bernhard Bivak, ±50m, 26 July 1938, *NIFS* bb. 25693 (A along with bb. 28955, K, L); Bernhard Camp, Idenburg River, 150m, April 1939, *Brass & Versteegh* 13580 (A); Berap (Nimboeran), 9 August 1939, *NIFS* bb. 28955 (A along with bb. 25693); Manokwari, Warnapi, 15km north of Ransiki, *ca.* 40m, 24 September 1948, *Kostermanns* 442, bb. 33600 (A); Manokwari, Maepi II, 15m, 28 October 1954, *Koster* BW 1104 (KEPONG); Manokwari, Sidai, 25 March 1955, *Schram* BW 1805 (KEPONG); Manokwari, Oransbari, 30 March 1955, *Brouwer* BW 2522 (A); *ca.* 25km east of Sorong, Warsamson River, ± 60m, 14 November 1957, *Iwanggin* BW 5720 (L). *Java*?, unknown locality, undated, *Collector unknown* s.n. (L, Herb. Ludg. Batav. No. 908.265-723).

Papua New Guinea: Bougainville Province, Solomon Islands, Bougainville Island, Buin, Karngu, on the seashore, 10 October 1930, Kajewski 2228 (A, NY; images NY,TEX); Isabel Island, Tiratoña, 600m, 8 December 1932, Brass 3309 (A, NY; images NY, TEX); New Georgia, near Munda, 3 October 1945, Walker & White BSIP 169 (A); Makira, Makira Harbour, 19 March 1946, Walker BSIP 257 (A); Western Solomons, Gizo Island, Block 6, 16 June 1965, Bengough BSIP 4510 (A); North-western Santa Isabel, along the Kolokofa River, ca. 58m, 6 April 1966, Teona s.n. (image TEX). Madang Province, Madang District, Madang subdistrict, Gogol River, 30.5m, 5º10'S 145º25'E, 10 September 1969, Katik NGF 46540 (A); Salember village, Adelbert Mountains, 650m, 5º30'S 145º25'E, December 1996, Tim Platts-Mills TPM 39 (A). Morobe Province, Morobe district, Sattelberg, 1006m, 5 June 1936, Clemens 3219 (A, L); Morobe district, foothills near Yalu area, Lae, ca. 100m, 5 November 1945, Vickery NGF 1428 (L-2 sheets); Morobe district, Plantation area 1953-54, Bulolo, TNG, 24 July 1953, Grev 5217 (A); Morobe district, Bupa village above Wampit River, 762m, 3 March 1964, Millar NGF 23247 (L); Morobe district, Wagau, TNG, 1100m, 6º50'S 146º50'E, 17 January 1965, Sayers NGF 21642 (BM, L, NY); Lae sub-province, near NWA campsite, Lae-Bulolo road, 600m, 7º00'S 146º30'E, 28 June 1980, Wiakabu et al. LAE 73347 (A, L); PNG University campus, beside clinic building, 8 August 1984, Simaga 303 (K); Basu river, near Sim village, edge of selectively logged tract adjacent to streambed, est. eleveation 245-305m, 10 December 1992, Takeuchi 8605 (A). Kaiser-Wilhelmsland, Wobbe, 200m, 30 August 1907, Schlehter 16441 (A, K, MO). Sandaun Province, Aitape district, a few miles SE of Tadji airstrip near Airtape, about 8m, January 1945, Smith NGF 1221 (A, K); West Sepik district, VAnimo subdistrict, Ossima, ca. 30m, 2º56'S 141º17'E, 31 January 1969, Streimann & Kairo NGF 39293 (A). Western Highlands Province, Baiyer river sub-province, beside the lodge, Baiyer river sanctuary, 1130m, 5º35'S 144º10'E, 5 June 1980, Wiakabu et al. LAE 73468 (L). National Capital district, Central district, Port Moresby sub-district, 61m, 9º15'S 147º20'E, December 1963, Kumul NGF 13071 (K). Manus Province, Manus Island, Mt. Dremsel, TNG, ca. 548m, 2º10'S 146º55'E, 21 June 1971, Stone & Streimann 10336, LAE 53636 (L). New Britain district, New Britain, JKacquinet Bay, April 1945, Mair NGF 1854 (L).

Solomon Islands: San Cristoval Island, Waimamura, 12 September 1932, Brass 2860 (A-2 sheets, BM).

**10. Gmelina palawensis** *H. J. Lam*, Verbenac. Malay. Arch. 224 (1919). Bakh., in Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 68 (1921); Hill, Ind. Kew. Suppl. 6: 92 (1926); Kanehira, Fl. Micrones. 457 (1933); Mold., Phytol. 56 (3): 157 (1984). Type: Palau Islands, Marikyoku, Main Island, 17 July 1929, *Kanehira* 387 (NY!, **neotype designated here**).

- G. palawensis var. celebica Mold., Phytol. 3: 417 (1951). Mold., Phytol. 56(3): 159 (1984). Type: Indonesia, Greater Sunda Island, Sulawesi (Celebes), Malili, 02 August 1929, Kjellberg 2001 (holotype BO, holotype images NY!, TEX!, isotype S!) syn. nov.
- G. palawensis var. dinagatensis Mold., Phytol. 3: 418 (1951). Mold., Phytol. 56(3): 160 (1984). Type: Philippines, Dinagat island, s.n. 1901/1902, Ahern 461, (holotype BO, holotype images NY!, TEX!, isotype fragment NY!) syn. nov.

A medium-sized tree 5-25m tall, trunk to 70cm in diameter; branchlets terete, with greyish-brown, smooth bark; densely lenticellate. Leaves decussate-opposite, long petiolate; petioles 2-5(-9)cm long, glabrous, canaliculated above; leaf-blades coriaceous or subcoriaceous, elliptic or broadly elliptic, obovate to rarely ovate or broadly ovate, obcordate, or oblong, (7-)11-16(-23)cm long, (3.5-)7.5(-11)cm wide, apically acute or obtusely acute or acuminate or rarely obtuse, basally acute or rounded, rarely attenuate, sometimes asymmetric, margin entire, glabrous on both surfaces, shiny above, basally with few glands above and below the main veins, the secondaries 4-7 pairs; tertiaries scleriform. Inflorescence lax, terminal and/or axillary, elongate, racemiform, glabrous, basally foliaceous, (5-)9-16(-19)cm long; peduncles 1.5-5.5cm long; pedicels 3-12mm long; bracts elliptic or obovate, basally attenuate, apically acute, 8-17mm long, 3-8mm wide, glabrous; bracteoles persistent, narrowly elliptic, sub-sessile or sessile, 3-9mm long, 2.5-5mm wide, glabrous. Flowers fragrant, 2-2.5cm long; calyx small, 3.5- 6mm long, cupuliform, the rim truncate or very obsoletely 5dentate, externally glabrous, with 3-8 nectariferous glands, internally glabrous, slightly extended and often cleft in fruit; corolla white with purple lip, or white with yellow center, magenta to pink or purple, pale pink or cream coloured, lip slightly darker with a yellow honey mark or pinkish with white inside, infundibular, externally densely golden-fulvous tomentose except the lower part, internally the tube glabrous, inner face of the lobes papillate; the tube 1-1.5cm long, oblique, slender below, abruptly dilating above the calyx; the limb bilabiate with 5 sub-equal lobes, upper lip 2-lobed, lobes elliptic-oblong, apically obtuse 5-7mm long, 2.5-5mm wide at base, lower lip 3-lobed, the median lobe longer, broadly elliptic-ovate, apically obtusely acute, 8-9mm long and 3.5-6mm wide at base, the lateral lobes broadly ovate-oblong, apically obtuse, 5.5-8mm long and 3-5mm wide at base; stamens 4, didynamous, included, inserted about the middle of the corolla tube; filaments thickened, incurved, longer pair 1.2-18mm long, shorter pair 1-16mm long, basally densely pilose, apically glanduliferous, anthers with thickened connectives, lobes oblong, free and divergent in the lower halves, 1.5-2mm long; ovary obovoid, glabrous, 2-2.5mm long, about 1.5mm wide, 4-locular with one ovule in each locule; style sub-exserted, 1.5-2.5cm long, glabrous or sparsely glanduliferous throughout; stigma subulate, glabrous, minutely or conspicuously bi-lobed, lobes unequal, longer lobe 2-3mm long, other minute to 0.7mm long. Drupes obovoid, lavender or magenta, 1.5-2.5cm long, 0.6-2cm wide, glabrous.

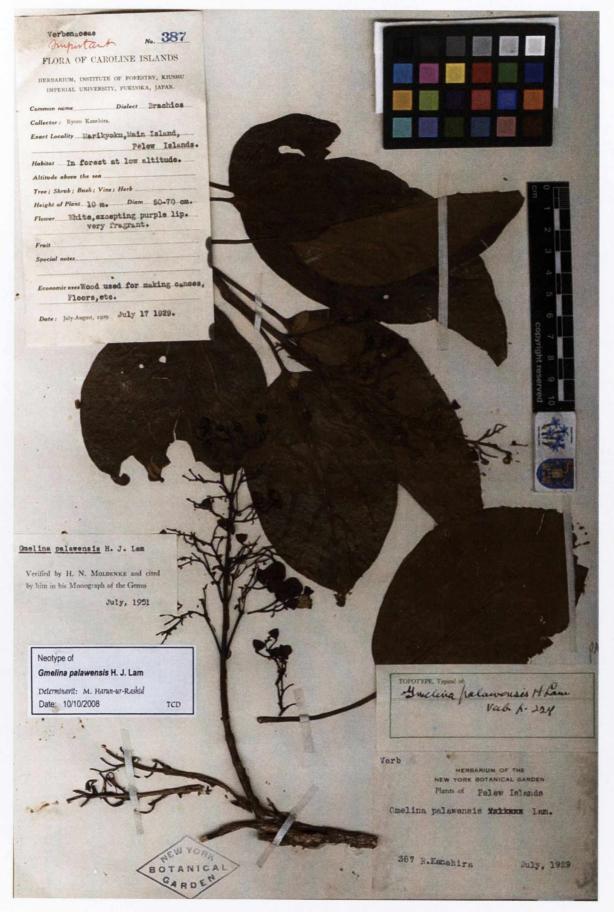


Figure 2.10. Neotype of G. palawensis. (Kanehira 387, NY).

### Key to the varieties of G. palawensis

Inflorescence terminal, style sparsely glandular throughout, stigma minutely bi-lobed i var. palawensis
 Inflorescence terminal and axillary, style glabrous, stigma conspicuously bi-lobed ii var. matanoeca

#### i var. palawensis

Leaves long petiolate, 2-5(-9)cm long, glabrous; lamina elliptic or broadly elliptic, obovate to rarely ovate or broadly ovate, obcordate, or oblong, (7-)11-16(-23)X(3.5-)7.5(-11)cm; Inflorescence terminal; corolla white with purple lip, or white with yellow center, magenta to pink or purple, pale pink or cream coloured; *style* 1.5-1.8cm long, sparsely glanduliferous throughout; *stigma* subulate, minutely bi-lobed, lobes unequal, longer lobe to 2mm long, other minute. **Figure 2.10**.

**Ecology**: Primary forest; low open vegetation of scattered shrubs and sprouting stumps of cut trees; deep red clayey soil derived from ultrabasic rock; alluvial flat, water front along lake. Alt. sea level to 600m. *Flowering & fruiting:* February to December.

Distribution: Celebes Island (Indonesia), Mindanao Island (Philippines), and Palau Islands. Map 2.3.

Vernacular names: Brachios, Emakumeri (Asmat Language, Irian Jaya, Indonesia); Brachios, La eos (Palau Islands).

**Uses**: Wood used for making canoes, floors (Kanehira 387), house construction (Fosberg 47522) etc. (Palau Islands).

**Proposed Conservation status:** This species does not have a wide range of distribution. It is confined to Celebes in Indonesia, Mindanao Island in Philippines and Palau Islands. Due to its narrow distribution the species is considered as Vulnerable (VU).

**Typification**: *G. palawensis* was described by H. J. Lam (1919) on Ledermann's nos. 14420 and 14331, and Raymundus's nos. 114 and 310 from Palau Islands. The whereabouts of its type, however, was not mentioned in the protologue. Moldenke (1984) mentioned that these specimens were all deposited in the BO. However, during the present investigation, *Gmelina* materials from all relevant herbaria including BO were examined, but none of these syntypes as found. Perhaps it was deposited in B, and was destroyed during the Second World War. As a result, a neotype is selected here.

Of all the specimens of *G. palawensis* examined form Palau Islands, the topotype specimen collected by Kanehira (no. 387), now preserved in NY, is very typical of this species, and is, therefore, designated here as the neotype.

Specimens examined: Indonesia: *Greater Sunda Island:* Sulawesi (Celebes), Malili, ±300m, 27 January 1925, *Boschproefstation* bb. 8560 (L, NY); Malili, 0m (Sea level), 02 August 1929, Malili, Kawaka, 19 November 1930, *Boschproefstation* Cel. II-441 (L, NY); *Kjelberg* 2001 (holotype images of *G. palawensis* var. *celebica* NY, TEX, isotype S); Malili, 17 March 1933, *s.n.*, Cel. III-35 (L); Malili, 25m, 03 February 1934, *Collector unknown* Cel. IV-128 (A, L); Malili, 25m, 03 February 1934, *Waturandang*, 134 (NY); Malili, 5m, 17 October 1934, *Collector unknown* Cel. III-167 (A); Malili, *ca.* 25m, 18 October 1934, *Collector unknown* Cel. III-167 (A); Malili, *ca.* 25m, 18 October 1934, *Collector unknown* Cel. III-167 (A); Malili, Boschafd. Batoe mati. ±600m, 18 November 1937, *Collector unknown* Cel. IV-189 (L); Malili, Boschafd. Batoe mati. ±600m, 18 November 1937, *Collector unknown* bb. 23574 (A, L); Selatan, Soroako, South shore of Lake Matano, 400m, 2º 31' S, 121º 21'E, 10 June 1979, Vogel 5707 (K); Selatan, Luha Island in Lake Towuti, 300m, 2º 45'S, 121º 33'E, 18 July 1979, Vogel 6367 (L); South-east of Soroako, Lake Matano, 400m, 2º15'-3º S, 121º-121º 45'E, 28 June 1979, *Balgooy* 3797 (A, K, L, MO); Soroako, 500m, 2º 15'-3º S, 121º -121º 45'E, 03 July 1979, *Balgooy* 3858 (A, L, MO); Malili, of 9km road to Ujung Pandang, 20m, 10 December 1994, *Sidiyasa et al.* 1326 (A, K). *Irian Jaya* (Nederlands New Guinea): South New Guinea, Asmat region, Erma, 0m (Sea level), 01 July 1957, *Nautje* BW 6555 (L).

**Philippines Island**: Surigao, Mindanao, undated 1902, *Ahern* 461(holotype of *G. palawensis* var. *dinagatensis* fragment NY; images NY, TEX).

Palau Islands: Marikyoku, Main Island, 17 July 1929, *Kanehira* 387 (NY-neotype); Aimiriik, August 1932, *Kanehira* 1923 (NY); Aimiriik, July 1933, *Kanehira* 2280 (NY); Arumogui-hukin-sinrin, 17 September 1933, *Hosakawa* 6969 (L); Malakal Island, Volcanic slopes, 28 December 1962, *Stone* 4578 (L); Babelthuap Island, Gaspan, 100m, 1 January 1963, *Stone* 4618 (L); Malakal Island, 30-50m, 25 August 1965, *Fosberg* 47522 (GH, NY).

ii var. matanoeca *M. H. Rashid* var. nov., a var. *palawensis* inflorescentia terminales et axillaris (non unus terminales), stylus omnino glabra (non sparsus glandulosus), stigma conspicue bilobatus differt.

Type: Indonesia, Celebes, Surroundings of Matano lake, near Soroako, Northeast of Malili, ultrabasic region, 2°35'S 121°20'E, 22 July 1976, *Meijer* 11514 (MO!, holotype; L!-2 sheets, isotypes).

Leaves petiolate, 2-3cm long, glabrous; lamina obovate, rarely elliptic, 11-19X5-9.5cm; Inflorescence terminal and axillary; corolla purplish with yellow dots on mid-lobe; *style* 2.5cm long, glabrous; *stigma* conspicuously bi-lobed, lobes unequal, longer lobe 3mm long, the other 0.7mm. **Figure 2.11**.

Ecology: Ultrabasic soil. Alt. unknown. Flowering & fruiting: July.

Distribution: Endemic to Celebes, Indonesia. Map 2.3.

Vernacular name: Not known.

Uses: Not known.

Proposed Conservation status: Data deficient (DD). Only known from the type collection so far.

Etymology: The variety is named after its home locality Lake Matano, Celebes, Indonesia.

**Specimens examined**: Indonesia: Celebes, Ultra basic region, Surroundings of Matano lake, near Soroako, Northeast of Malili, 2º35'S 121º20'E, 22 July 1976, *Meijer* 11514 (L-2 sheets, isotypes; MO, holotype).

**11. Gmelina paniculata** Fletcher, Kew Bull. Misc. Inf. 5: 204 (1938). Fletcher, Kew Bull. Misc. Inf. 10: 422 (1938); Mold. Known Geogr. Dist. Verbenaceae, ed. 1: 93 (1942) and ed. 2: 186 (1949); Salisbury, Ind. Kew. Suppl. 10: 100 (1947); Mold. Résumé 178 & 456 (1959); Mold. Fifth Summ. 1: 296 (1971) and 2: 879 (1971); Mold. Phytol. Mem. 2: 286 & 549 (1980); Mold., Phytologia 56 (3): 161 (1984). Type: Thailand: Prachin Buri, Aran Pratet, 18 October 1928, *Put* 2086 (E! **lectotype chosen here**; isolectotype K!).

A small tree, branches terete or obtusely tetragonal, brown, spinose, at first slightly pubescent with the hairs more numerous at the nodes when young, eventually glabrous; sparsely lenticellate; spines axillary, 8-10mm long. Leaves decussate-opposite; petioles 1.5-3cm long, brown in drying, canaliculated above; pubescent; leaf-blades chartaceus, 5-6 sunken glands at and near base beneath, a few glands scattered on the surface, broadly ovate or elliptic, 7-13cm long, 5-8cm wide, apically subacuminate, basally subcuneate, margin entire or slightly revolute, sparsely ciliate, glabrous or slightly pubescent above, lower surface covered with white rounded or quadrangular sessile glands; midrib and veinlets conspicuous and glabrous above, prominent and puberulent beneath; the secondaries in 4 or 5 pairs, tertiaries scleriform beneath. Inflorescence dense, terminal, paniculate, 2-4cm long, densely pubescent and covered with long-stalked, multicellular glandular trichomes; bracts caducous, ovate or lanceolate, 2.5-10mm long, 1-5mm wide, bracteoles persistent, lanceolate, 3-6mm long, 1-2mm wide, pubescent above, glabrous beneath; calyx small, infundibular, marked with large black, nectariferous glands, tube 3-5mm long, rim 4-dentate, the teeth deltoid, acute, 1mm long and 1.5mm wide, externally pubescent and with long-stalked, multicellular glandular trichomes; internally glabrous, slightly extended on fruiting; corolla colour unknown, 2-3cm long, externally glandular-pubescent, internally glabrous and lobes apically glandular-pubescent; limb bilabiate, upper lip entire, oblong, apically obtuse, 3-5mm long, 4-4.5mm wide at base, lower lip 3-lobed, lobes all apically rounded, the median lobe largest, 5-6.5mm long and 4-6mm wide at base, broadly ovate-oblong, the lateral lobes semicircular, 3-4mm long and 5-6mm wide at base; tube 2-2.5cm long, slender below for up to about half of its length, then abruptly dilating upward;

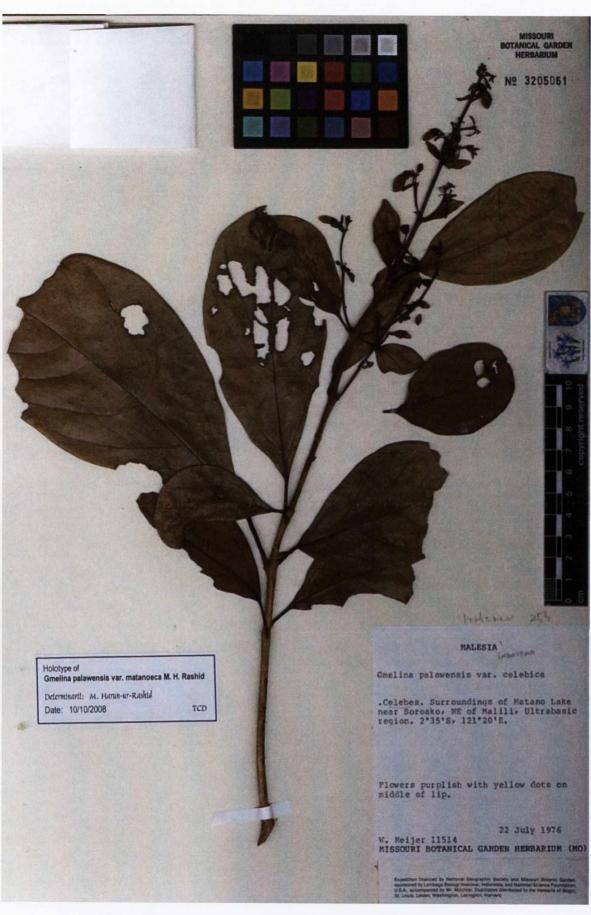
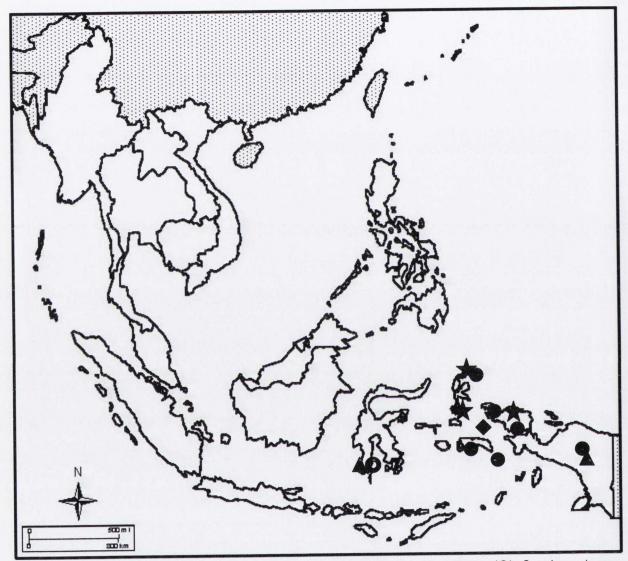


Figure 2.11. Holotype of G. palawensis var. matanoeca. (Meijer 11514, MO).



**Map 2.3** Southeast Asian distributions of *G. lepidota* ( $\star$ ); *G. misoolensis* ( $\bullet$ ); *G. moluccana* ( $\bullet$ ); *G. palawensis* var. *palawensis* ( $\star$ ) and *G. palawensis* var. *matanoeca* ( $\bullet$ ).

**stamens** 4, didynamous, subexserted, inserted about the middle of the corolla tube near the top of lower slender part; filaments filiform, incurved, glabrous, apically with short gland-tipped hairs, longer pair 14-20mm long, shorter pair 7.5-10mm long; *anthers* oblong, 2.5-3mm long, lobes free and divergent in the lower halves; **ovary** obovoid, glabrous, 2.5-2.8mm about 1.5mm wide, 4-locular with one ovule in each locule; **style** 3-3.5cm long, exserted, filiform, glabrous; *stigma* subulate, glabrous, obscurely bi-lobed, lobes unequal, longer lobe 1mm long, other minute. **Drupes** ovoid, 1.5-2cm long, 1cm wide, externally slightly pubescent.

Ecology: Alt. unknown. Flowering & fruiting: October.

Distribution: Endemic to South-eastern Thailand. Map 2.4.

Vernacular name: Unknown.

**Proposed Conservation status:** This species is only known from the type specimens collected in 1928 and there is no recent collection. The species is likely to be extinct due to habitat alteration since then. EX.

**Typification**: This species was described by Fletcher based on Put's collection No. 2086 from Thailand. The whereabouts of its type, however, was not mentioned in the protologue. During the present investigation two type specimens have been found, deposited at E and K. The E specimen is chosen as the lectotype being relatively more complete and having an original label on it.

Specimens examined: Thailand: South-Eastern: Prachin Buri, Krabin, Aranya, 18 October 1928, Put 2086 (E lectotype, K isolectotype).

**12. Gmelina parnellii** *M. H. Rashid* **sp. nov.** similis *G. tomentosa*, sed folia bases cuneatus vel subacutus (non subcuneatus vel rotundatus); inflorescentia unus terminales (non terminales et axillaris); stylus sparsus pilosus et glandulosus (non gląbra et sparsus glandulosus); ovarium velutinous (non glabra) differt. Type: Thailand, Kamphaeng Phet, *ca.* 90m, 23 March 1913, *Kerr* 2991 (holotypus K!, isotypus-BM!, TCD!).

Straggling shrub to 2m high; branchlets obtusely tetragonal, densely tomentose when young, pubescent when mature, lenticellate. **Leaves** decussate-opposite; *petioles* very slender, 1-2cm long, densely tomentose; *blades* sub-coriaceous, mostly elliptic, or ovate to ovate-oblong, 3.5-7.5(-9.5)cm longm 2.5-5(-7)cm wide, apex obtuse, rarely acute or retuse, base cuneate or sub-acute; margin entire and ciliate, tomentulose above, densely tomentose and glanduliferous beneath; secondaries mostly 4, rarely 5 pairs; conspicuous above, prominent beneath; tertiaries transverse. **Inflorescence** terminal, racemose, drooping, 2-4cm long, fulvous-tomentose; *peduncle* 4-6mm long; *flowers* very short pedicellate; *bracts* foliaceous, caducous, sessile, ovate, apex acuminate, base cuneate, 1.5-2.0X1.0-1.2cm; *bracteoles* caducous, sessile, small, 1.3-2x3-6mm, narrowly elliptic to narrowly ovate to lanceolate, apex long acuminate, base attenuate, both surfaces tomentose; **calyx** small, campanulate, 4-5mm long and 3-4mm wide; rim with 4 minute, sinuate teeth, tooth

0.5-0.9mm long; externally densely tomentose and white glanduliferous with numerous large, black nectariferous glands interspersed; glabrous inside; **corolla** yellow, infundubular, 3-4.5cm long, membranous, bilabiate, 4-lobed, externally tomentulose or strigose and white glanduliferous, internally glabrous; upper lip entire, lower lip 3-lobed, upper lobe and lower lateral lobes all ± rounded, apically obtuse, 8-10mm long and 7mm wide at base, the median lobe largest, 15-20mm long and 10-12mm wide at base, broadly ovate-oblong, apically acute, projecting forward; tube slender below and abruptly ampliate upward; **stamens** 4, didynamous, subexserted, inserted near the base of corolla tube, top of lower slender pair 10-12mm long, glabrous throughout; *anthers* oblong, 2.5-3mm long, lobes free and divergent in the lower halves; **ovary** ovoid, velutinous at apex, glabrous elsewhere, 2.0-2.5mm long and 1.5-2.0mm wide, 4-locular with one ovule in each locule; *style* 2.8-3.0cm long, exserted, filiform, sparsely pilose, apically glandular; *stigma* subulate, glabrous, obscurely bi-lobed, lobes unequal. **Drupes** not seen. **Figure 2.12**.

Ecology: Alt. ca. 90m. Flowering: March.

Distribution: Endemic to Northern Thailand. Map 2.4.

Vernacular name: Unknown.

**Proposed Conservation status:** This species is only known from type collections from 1913, and there are no recent collections. The species is likely to be extinct due to habitat disruption. EX.

**Note**: This species resembles *G. tomentosa*; both have tomentose leaves and inflorescences, and a similar calyx. However, it differs from *G. tomentosa* having mostly elliptic leaves with a shortly attenuate or cuneate base (rather than ovate leaves with a subcuneate or rotundate base), and terminal inflorescence (rather than terminal and axillary). In addition *G. parnellii* has an ovary with a velutinous apex rather than the glabrous apex in *G. tomentosa*.

**Etymology**: *Gmelina parnellii* is named in honour of Professor John A. N. Parnell, Trinity College Dublin, who has long been involved with "Flora of Thailand Project" and contributing to the Thai Flora through his indefatigable fieldwork, and expert eye.

Specimens examined: Thailand: Northern: Kamphaeng Phet, ca. 90m, 23 March 1913, Kerr 2991 (holotype K, isotypes-BM, TCD).

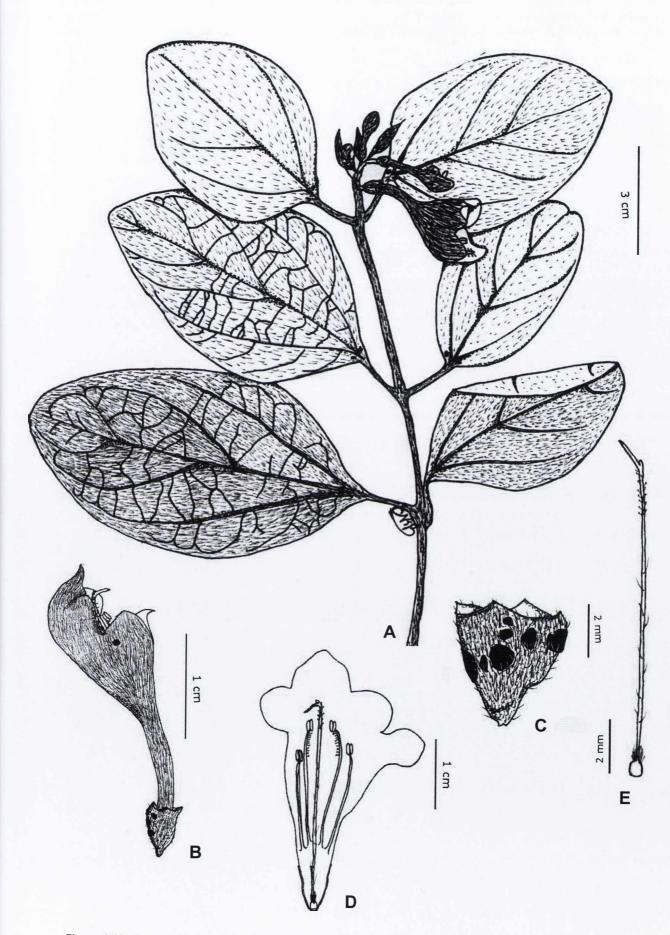


Figure 2.12. G. parnellii. A habit; B flower; C calyx; D dissected flower; E pistil. (all from Kerr 2991, K). Drawn by Cliodhna Ní Bhroin.

**13. Gmelina philippensis** *Cham.*, Linnaea 7: 109 [as *"Gmelina (asiatica?) philippensis*"] (1832). Jackes. in Hook. f. & Jacks., Ind. Kew. 1: 1040 (1893); Schau. in A. DC., Prod. 11: 679 (1847); Kurz, For. Fl. Brit. Burma 2: 265 (1877); Gamble, Man. Indian Timb., ed. 2: 539 (1902); Merr. Fl. Manila 405 (1912); Merr. Sp. Balanco. 335 (1918); Hallier, f., in Meded. Rijks-Herb. 37: 60 (1918); Merr., Enum. Philip. Fl. Pl. 3: 399 (1923); Gamble, Fl. Pres. Madras 6: 1098 (1924); Merr., Lour. Fl. Cochinch., Trans. Amer. Philos. Soc. 34 (2): 335 (1935); Cooke, Fl. Pres. Bombay, ed. 2,2: 505 (1958); Backer & Bakh., Fl. Java 2: 607 (1965); Burkill, Dict. Econ. Prod. Malay Penins. 1: 1106 (1966); Mold. & Mold., in Dassanayake & Fosberg, Rev. Handb. Fl. Ceylon 4: 399 (1983); Phytologia 56 (3): 161(1984); Hô, Illus. Fl. Vietnam 2:1047 (1993) & 2:831 (2003); Kress *et al.*, Checklist Pl. Myanmar 45: 389 (2003); Newman *et al.*, Checklist Vasc. Pl. Laos 356 (2007). Type: Philippines, Luzon, Manila, undated, *Collector unknown* s.n. (LE holotype, holotype image K!).

- *Gmelina? finlaysoniana* Wall., Num. List 215 (1832). Schau. in A. DC., Prod. 11: 680 (1847); Kuntze, Rev. Gen. Pl. 2: 507 (1891).
- G. finlaysoniana var. hystrix Kuntze, Rev. Gen. Pl. 2: 507 (1891).
- G. finlaysoniana var. silvestris Kuntze, Rev. Gen. Pl. 2: 507 (1891).
- *G. finlaysoniana* var. *silvestris* f. *colourata* Kuntze, Rev. Gen. Pl. 2: 507 (1891). Type: Vietnam, Cap St. James, undated, *Kuntze* s.n. (NY! lectotype chosen here).
- *G. philippensis* f. *colourata* (Kuntze) Mold., Phytologia 55: 234 (1984); Devise, Ind. Kew. Suppl. 18: 142 (1987). Type: as for *G. finlaysoniana* var. *silvestris* f. *colourata* Kuntze.
- G. finlaysoniana var. silvestris f. viridibracteata Kuntze, Rev. Gen. Pl. 2: 507 (1891). Type: Vietnam, Cap St. James, 18 March 1875, Kuntze 3928 (NY! lectotype chosen here)
- G. philippensis f. viridibracteata (Kuntze) Mold., Phytologia 55 (4): 234 (1984); Devise, Ind. Kew. Suppl. 18: 142 (1987). Type: as for G. finlaysoniana var. silvestris f. viridibracteata Kuntze.
- G. asiatica Lour. (non L.) Fl. Cochinch. 376 (1790). Type: Vietnam, Tourane and Vicinity, May-July 1927, Clemens & Clemens 3152 (K! lectotype chosen here; isolectotypes A!, P!, NY!, US!).
- G. asiatica Blanco, Fl. Filip., ed. 1: 493 (1837) [not G. asiatica Kurz (1902), nor L. (1753), nor Wall. (1831)]
- G. asiatica L. in H. J. Lam, Verbenac. Malay. Arch. 221 (1919). Type: Philippines, Luzon, Benguet province, Baguio, March 1907, Elmer 8934 (L! lectotype chosen here).
- *G. asiatica* var. *philippinensis* (Cham.) Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenz. Ser. III, 3: 70 (1921). Type: as for *G. asiatica* L.
- G. hystrix Schult. ex Kurz, Journ. Asiat. Soc. Beng. 39 (2): 81 (1870). C. B. Clarke in Hook. f., Fl. Brit. Ind. 4: 582 (1885); Vidal, Rev. Pl. Vas. Filip. 210 (1886); Kurz, For. Fl. Brit. Burma 2: 265 (1877); Hook. f., Curtis's Bot. Mag. 120 (ser. 3, 50): t. 7391 (1894); Briq. in Engl. & Prantl, Nat. Pflanzenfam 4(3a): 173 (1895); Brandis, Indian Trees, 509 (1921); Lace, List trees, shrubs & climbers of Burma 2: 133 (1922);

Ridl. Fl. Malay Penin. 2: 622 (1923); Dop, in Lecomte & Humbert, Fl. Gén. Indo-chine 4: 842 (1935); Fletcher, Kew Bull. Misc. Inf. 10: 422 (1938). Type: Thailand, Bangkok, in gardens, *Teysmann* 5946 (BO).

G. bracteata Burck, Ann. Jard. Bot. Buitenzorg 10: 98, Pl. 7, fig. 5 & 6 (1891).

G. inermis Naves in Hallier, Meded. Rijks-Herb. 37: 60 (1918) [not G. inermis Blanco 1837, nor Wight 1831].

A moderately sized to large, dense, attractive, straggling or scandent, usually spinose shrub, woody climber, stout bush, undershrub, or small shrubby tree, 3-7m tall, sometimes sprawling or prostrate; trunk often armed with spines to 5cm long. Stems usually several from ground level, divaricate, dwarfed branchlets spinescent, spines horizontal, 0.25-1.5cm long, youngest branchlets hispid-pubescent; bark yellowish-lenticellate. Leaves decussate-opposite, petioles slender, puberulent to glabrescent, 0.5-2.5(-4)cm long; leaf-blades entire or distantly toothed to slightly few-lobed, sub-coriaceous, somewhat leathery, ovate, oblong, or elliptic to rhomboid-elliptic or obovate, rarely orbicular, 1.5-10cm long, 1.5-6cm wide, apex acute to sub-acute or obtuse, cuneate or short attenuate towards the base, glabrous and shiny above, pale and often glaucous with white glandular hairs beneath, puberulent only on the larger veins, 2-6 sunken glands at and near base beneath, inconspicuous above, prominent beneath, the lateral secondary veins 3-5 pairs. Inflorescence terminal, rarely axillary, cymose, strobiliform, (2-5.5-)10-20(-40)cm long, dense, pendulous, many-flowered, the cymes arranged in racemiform clusters in the axils of large, persistent, foliaceous and very conspicuous, rather petaloid, showy bracts; bracts membranous, pale green outside, pale green with pink inside, yellow, permanently green or yellowish green, or maroon, purplish, reddish-purple, or purple to red or brownish-red, sometimes striped or purple-veined, 1.5-4X1-3.5cm, broadly oval or ovate to obovate or orbicular and concave, margin shortly ciliate, sessile, apically obtuse to mucronate or short-apiculate, cuneate towards the base, glabrescent or puberulent on both surfaces. Flowers pendulous, in 1-flowered cymules, sessile or subsessile, easily detached, 4.5-7cm long, slightly fragrant; calyx green or pale yellowish green, campanulate, sub-truncate or with 4 obsolete dentate at the rim, short, externally strigose pubescent, with 2-4 nectariferous glands, internally glabrous, 5-6mm long and 2.5-4mm wide at the top, slightly expanded in fruit; corolla bright-yellow or light lemon-yellow to orange-yellow or golden, pubescent outside, glabrous with apically glandular lobes inside, irregularly narrow-campanulate, basally slender tubular, tube incurved and inflated upwards; the limb 4-(-5)lobed, upper lip entire, ovate, apically obtuse, ca. 10mm long and wide at the base; lower lip 3-lobed, the middle lobe largest, broadly ovate-oblong, apically obtuse, 15-17mm long, 10-12mm broad at the base, the lateral lobes ovate, acute or somewhat rotund, 10-12mm long, 8-10mm broad at the base; stamens 4, didynamous, sub-exserted, inserted at the middle corolla-tube or near the top of slender portion; the filaments yellow, filiform, incurved, the longer pair 2-2.3 cm long, glabrous, with apically glandular hairy, the shorter pair 1-1.3 cm long, glabrous throughout, anthers sub-reniform, 2-3mm long; ovary obovoidglobose, glabrous, 4-locular with one ovule in each locule; style exserted, glabrous, 3.5-4cm long; stigma conspicuously bilobed, longer lobe 1mm long, other shorter. Drupes obovoid to globose, glabrous, fleshy,

pendulous, about 2.5cm long, yellow or yellowish, externally smooth, soft and watery when mature; *pyrenes* very hard, 2-celled. Figure 2.13.

**Ecology**: edge of thickets along stream; open fields; pasture thickets; in clay soil of open forest; common in deciduous forests; common in hedges and secondary growth, very sandy soil. Alt. 30m-1025m. *Flowering & fruiting*: almost throughout the year.

**Distribution**: Myanmar, Cambodia, Vietnam, Thailand, Malaysia, Singapore, Indonesia, Philippines, China and Papua New Guinea. **Map 2.4**.

Native to the Philippine Islands; also (perhaps originally introduced) from India eastward through Thailand, Burma, and Indochina to Indonesia; rather widely cultivated for ornament in private gardens and public parks in many parts of tropical Asia, Africa, and America (Moldenke 1984).

Vernacular names: Samma nga (Thai); Talungon; Sowsow (Philippine); Cây-tu-hú (Vietnam).

**Uses**: Fruit used as a remedy for coughs; mixed with lime (Kapor) and applied externally to the throat (Hooker's hand note on sheet).

In the Philippines, the ripe fruit juice is used in the treatment of soreness of toes due to excessive and prolonged wetness (*Elmer* 8934, Field note); in Malaya, the leaves and fruit are crushed with lime and applied to the throat as a remedy for coughs. In Indonesia the juice of roots is used as a purgative and in treating over fatigue; and the root extract (used internally) and leaf extract (used externally) is employed as an excitant, discutient, and in the treatment of the joints and nerves (Moldenke 1984).

Proposed Conservation status: A fairly common and widespread species. Least concern (LC).

**Typification**: Chamisso (1832) first published this species as *"Gmelina (asiatica?) philippensis*" which is what is written on the type specimen. Moldenke in Phytologia 56 (3): 166 (1984) noted that the type specimen was originally deposited in the Berlin herbarium, now lamentably destroyed. However, the holotype image lodged at Kew indicates that the type is at LE.

**Note**: Merrill (1935) noted on Loureiro's plant from Cochinchina; "*Habitat in Sylvis Cochinchinae*." Loureiro referred his material to *G. asiatica* L. but expressed doubt. His description conforms better with the characters of *G. philippensis* Cham. than with *G. asiatica* L., and the former is well represented by *Clemens* & *Clemens* 3152 from near Loureio's classical locality. Hence this specimen is designated here as the lectotype of Loureiro's *G. asiatica*.

### Specimens Examined:

Myanmar: Irrawaddy division, Rulz Mines district, Sampanego, Left bank of Irrawaddy, 5 July 1911, Lace 5362 (K).

**Cambodia**: *Mondulkiri province*, Pech Chenda, Lorth stream, on the roadside about 9km north of Senmonorum, 315m, 744750E 1386310N, 30 January 2001, *Monyrak et al.* 452 (K). *Stung Treng province*, expedition to Mekong, undated 1866-1868, *Thorel* 2655 (P).

Vietnam (Annam): *Nha Trang province*, 24 August 1918, *Chevalier* 38580 (P); Nha-trang and Vicinity, 11-26 March 1911, *Robinson* 1344 (P, NY); Phu Khanh, Day Mong Nhain, 11 May 1922, *Poilane* 3212 (P). *Da Nang* (Tourane), 1 June 1920, *Poilane* 1455 (A, P); Tourane and Vicinity, May-July 1927, *Clemens & Clemens* 3152 (A, K, P, NY, US); Turon (Turong), undated, *Collector unknown* note B. 5. 18 (NY). *Dong Nai province*, 28 April 1934, *Poilane* 218 (P). *Hoa Binh*, 8 September 1916, *Chevalier* 29971 (P). *Lam Dong province*, Da Lat and Vicinity, March-April 1932, *Squires* 920 (A, BM, MO, NY, P); *Ho Chi Minh* City, Saigon, 13 December 1918, *Hiep* 147 (P); Cap St. James, 18 March 1875?, *Kuntze* 3928 (NY- 2 sheets); Dac Lac, 400-500m, 15 March ??, *Schmid* 1133 (P).

Thailand: *Northern*: Hueykaew arboretum, 350m, 22 April 1994, *Pooma* 804 (BKF); Phrae province, Nu Chwa, *ca.* 150m, 4 April 1913, *L. V. P.* 461 (BKF); Phitsanulok, Pā Māk, Tac Tāng Mêo, 100m, 6 April 1924, *Kerr* s.n. (BM); Chiang Mai, Mae Tuem, Zi Blae (Karen) village, Mae Rah ah watershed station area, 1025m, 14 July 1999, *Petrmitr* 495 (A). *Central*: Bangkok, undated 1899, *Zimmermann* 71 (L, BM); Bangkok, 13 June 1920, *Kerr* s.n. (BM); Bangkok, 25 June 1920, *Kerr* s.n. (BM); Bangkok, 25 June 1920, *Kerr* s.n. (BM); Bangkok, 25 May 1924, *Kerr* 10704 (BM); Bangkok, Bangkhen, 20 March 1958, *Surapat* 357 (US). *Peninsular*: Nakhon Si Thammarat, Nagoru, 17 July 1941, *Kingdon Ward* 37548 (SING); Pattani, Kok Po, under 50m, 5 April 1928, *Kerr* 15069 (K, BM); Surat Thani, Kaw (Ko) Samui, *ca.* 50m, 9 March 1927, *Kerr* 12293 (BM); Kaw (Ko) Samui, 19 November 1927, *Put* 1319 (BM); Unknown locality, 11 February 1973, *BS*, *SP* & *SPN* 1557 (BKF). Province unknown, Nadhawn-srithamarat, Kaolaoung, 10 July 1951, *Sitinand* 230 (BKF). Unknown locality, undated 1859, *Schomburgk* 331 (P); Unknown locality, February 1863, *Schomburgk* s.n. (K); Unknown locality, foot of hill, undated, *Collector unknown* 380 (ABD); Tong Long, 22 July 1929, *Rabil* 145 (BM).

Indo-china: unknown locality, undated, Talmy 256 (P).

Malaysia: Kelantan: Kampong, Duri Belongan, 11 March 1914, Hooker s.n. (K); Borneo, Sarawak: Kapit, 18 June 1929, Clemens & Clemens 5414 (Herb. No. 21089) (A, NY); Johor: Biserat, undated, Vaughan 453 (L); Johore Balera?, 14 December 1891, Nougchi 29 (SING).

**Singapore**: Unknown locality, by the road, front of the office, 16 July 1892, *Ridley* s.n. (BM); Unknown locality, undated, *Collector unknown* 2796 (SING); Cluny Road?, undated, *Collector unknown* s.n. (BM).

Philippines: *Luzon Island*: *Bataan province*: Manila, Philippine Islands, undated, *collector unknown* s. n. (K-holotype image); Balic-balic, 17 May 1890, *Loher* 4426 (K); Lammao River, Mt. Mariveles, 13 November 1903, *Williams* 196 (NY); Lammao River, March 1904, *P. T. Barnes* 362 (K-with *H. N. Whitford* 395 on same sheet, NY, SING); Lammao River, Mt. Mariveles, June 1904, *H. N. Whitford* 395 (K-with *P. T. Barnes* 362 on same sheet, NY); Lammao River, Mt. Mariveles, August 1904, *T. E. Borden* 1780 (NY); Lamas forest reserve, October 1906, *Foxworthy* 1564 (NY); Lamao, March 1909, *Lilles* Bureau Agric No. 16 (L); Manila and Vicinity,

February-April 1911, *Merrill* 7564 (BM, MO, L). *Benguet province*, Baguio, March 1907, *Elmer* 8934 (A, NY, L). *Bulacan province*: Angat, February 1919, *Ramos & Edano* 34141 (SING); Vicinity of Kay Tianak and Ipo, 8 September 1935, *Bartlett* 14697 (A, NY); Meycauayan, 14 May 1938, *Fenix* 220 (A); Busil-busil, Sibul, San Miguel de Mayumo, c. n. Baliangan, October 1958, *Vidal* 3439<sup>bis</sup> (A). *Laguna province*: Los Baños (Mt. Maquiling), June-July 1917, *Elmer* 18278 (A, BM, GH, L, MO, NY); unknown locality, 26 May 1950, *Deguilia* 29 (A). *Naic Carute province*: unknown locality, 7 July 1935, *Barlett* 14557 (A). *Rizal Province*: unknown locality, January 1906, *Foxworthy* 112 (NY); Vicinity of Kay Tianak and Ipo, Antipolo, October 1914, *Merrill, Species Blancoanae* No. 122 (A, BM, GH, NY, L); Montalban, 8 February 1953, *Manayon* 59 (L); Antipolo, 200m, 1 July 1954, *Mendoza* 20446 (PNH); Novaliches, 14 February 1960, *Ramos* 40862 (BM, SING). *Pangasinan province*: Mt. San Isidro, Labrador, November 1917, *Fenix* 30092 (A, BM, L). **Visayas**: *Iloilo province*: Nagpana, Barotac Viejo, 100-150m, 11º02'N 122º15'E, 14 November 1989, *Madulid et al.* 7214 (A).

# Additional specimens examined from neighbouring countries:

Papua and New Guinea: Lae Botanic Gardens, 6 June 1968, *Collector unknown* 50 (A). China: *Hong Kong*, Sek Kong, 9 June 1975, *Shiu Ying Hu* 13755 (A, K).

#### Cutivated:

Thailand: South-western: Bangkok, 1 April 1958, Larsen 7953 (ABD); Temple garden, 28 May 1922, Marcan 847 (ABD, BM). Indonesia: Java: Cultivated at Buitenzorg, Undated, Her. Hort. Bot.Bogor. XV.F. 8 & 8a (NY).

Singapore: Arboretum, Singapore Botanic Garden, 11 June 1924, *Nur* s.n. (K, NY). Papua New Guinea: Lae Botanic Garden, 6 June 1968, *Collector unknown* 50 (A). Cochinchina: Cultivated, undated, 1862-1866, *Thorel* 1319 (P). India: South India: Kerala, Trivandrum, Travancore, Museum Park, 16 January 1934, *Erlanson* 5333 (NY); Zoological Garden, Trivandrum, South India, 18 December 1957, *Sethi & Negi* (Raizada's Collector) 25778 (L). Pakistan: *Multan*, 23 June 1965, *Siddiqi & Nasir* 3550 (K); *Karachi*, Gandhi Garden, 7 June 1977, *Jeha* 7742 (A). Sri Lanka: *Central* province, Peradeniya Kandy district, Sri Lanka Botanic Garden, in outdoor cultivation in Section E, ca. 470m, 18 January 1974, *Moldenke et al.* 28140 (US).

**China**: *Taiwan*: Taipei, University Campus, 1 June 1961, *Huang* 2388 (MO). **French Guiana**: Saül, Saül and vicinity, *ca*. 200m, 3°37'N 53°12'W, cultivated in village, 23 September 1989, *Mori et al.* 21054 (NY); Jardin, Prés de Montsinéry, 52°30' O 4°53'N, 30 May 2000, *Prévost* 3870 (NY). **West Indies**: Trinidad, South of Biology Building, ICTA, 30m, 1 April 1963, *Bhorai* B. 591 (A, NY); Tobago, de Vertueil garden, 15 March 1963, *Andrews* 3-81 (NY); Tobago, Crown Point, by Tropikist beach Hotel, 20 March 1993, *Clement & Ryves* TB 93/001 (BM); Grenada, Botanic Garden, St. Georges, 4-10 March 1979, *Howard* 18784 (A, NY); St. Vincent, Cultivated in Botanic Garden, 24 February 1972, *Howard* 18054 (NY); Montserrat, private gardens, Woodlands, 23 February 1980, *Howard* 19705 (NY). **Saint Lucia**: Vieux Fort to Soufriere, cultivated at Hotel Vieux Fort, 30 January 1985, *Howard et al.* 19991 (A). **Virgin Isalnd**: Just east of Yellow Cliff Bay, 15 January 1980, *Fosberg* 59260 (BM). **Venezuela**: Caracas, Jarcin Boanico, 13 November 1968, *De Wolf* 2009 (A, NY). **Domonica Island**: Roseau, Cultivated in the Botanic Garden, 30 May 1940, *Hodge* 3904 (GH). **Kenya**:

Nairobi, Peter Greensmith's Nurseries, 200m, November 1976, *Stinrock* 80 (A). **Puerto Rico**: Municipio Mayagüez, City Mayagüez, US Department of Agriculture, Tropical Agricultural Research Station, adjacent to main administration building in lawn, 10-20m, 18º12'30"N 67º08'15"W, 6 November 1994, *Zanoni* 47258 (NY). **USA**: Florida, Lee County, Sanibel Isalnd, Tradewinds Development, the snow garden, in a shaded lot border, 18 November 1977, *Brumbach* 9316 (NY).

Unknown Locality: Veli, 24 January 1933, Kuriakose s.n. (NY).

**14. Gmelina racemosa** (*Lour.*) *Merr.*, Trans. Amer. Phil. Soc., ser. 2, 24(2): 336 (1935); Hill, Ind. Kew. Suppl. 9: 125 (1938); Moldenke, Known Geogr. Distrib. Verbenac., ed. 1: 58, 59 & 93 (1942), and ed. 2: 135, 136 & 186 (1949); Moldenke, Fifth Summary Verbenac. etc. 1: 301, 523 & 524 (1971), and 2: 879 (1971); Sixth Summary Verbenac. etc. 1: 327, 328, 337, 409 (1980); Moldenke, Phytologia, 56(3): 173 (1984); Hô, Illus. FI. Vietnam 2:1047 (1993) & 2:831 (2003); Newman *et al.*, Checklist Vasc. PI. Laos 356 (2007). Type: Vietnam, Tonkin, Quâng Nam Province, Dā Nang (Tourane), Mount Bani, 25km from Dā Nang, July 1927, *Clemens & Clemens* 3980 (K! **neotype designated here**, isoneotypes A!-2 sheets, P!, NY!, US!).

Lantana racemosa Lour., Fl. Cochinch., ed. 1,2: 376 (1790). Type: as for G. racemosa.

G. racemosa Wight ex, Wall. Numer. List. 50, no. 1819 (1828).

- G. balansae Dop, Bull. Soc. Bot. France 61: 322 (1914). Prain, Ind. Kew. Suppl. 5: 115 (1921); Moldenke, Fifth Summary Verbenac. etc. 1: 301, 523 & 524 (1971), and 2: 879 (1971); Sixth Summary Verbenac. etc. 1: 327, 328, 337, 409 (1980); Moldenke, Phytol. Mem. 2: 290, 293, & 549 (1980); Moldenke, Phytologia 55 (7): 498 (1984); Newman *et al.*, Checklist Vasc. Pl. Laos 356 (2007). Type: Vietnam, Tonkin, Mont-Bavi, Lankok Valley, Balansa 3806 (P!, lectotype designated here; isolectotypes A!, K!, L!, isolectotype type image & fragment NY!). *syn. nov.*
- G. lecomtei Dop, Bull. Soc. Bot. France 61; 322 (1914). Prain, Ind. Kew. Suppl. 5: 115 (1921); Dop, Verbenaceae, Fl. Indo-china, 847 (1935); Moldenke, Known Geogr. Distrib. Verbenac., ed. 1: 58, 59 & 93 (1942), and ed. 2: 135, 136 & 186 (1949); Hô, Illus. Fl. Vietnam 2:1046 (1993); Chen, Fl. China 17: 33 (1994); Hô, Illus. Fl. Vietnam 2:830 (2003) Newman *et al.*, Checklist Vasc. Pl. Laos 356 (2007). Type: Vietnam, Annam, Tinh Nghe An province, between Chapa and Muong-Xen, January 1912, *Lecomte & Finet* 421 (P!).
- G. lecomtei var. annamitica Dop, Rev. Bot. Appliq. Agric. Trop. 13: 896 (1933); Dop in Lecomte, FI. Gén. Indo-Chine 4: 849 (1935); Hô, Illus. FI. Vietnam 2:1046 (1993) & 2:831 (2003). Type: Vietnam, Mekong-Hué, September 1877, Harmand s.n. (P!, isotypes A!, K!, P! isotype fragment A! ).



Figure 2.13. G. philippensis. [Taken from Curtis's Botanical Magazine 120: t. 7391 (1894)].

G. speciosa Moldenke, Phytologia 1(12): 418 (1940). Moldenke, Known Geogr. Distrib. Verbenac., ed. 1: 59 & 93 (1942), and ed. 2: 136 & 186 (1949); Salisbury, Ind. Kew. Suppl. 10: 100 (1947); Hô, Illus. Fl. Vietnam 2:831 (2003). Type: as for *G. balansae*.

A tree, 7-25m tall; bark finely fissured, young branchlets 4-angled and fulvous-tomentulose when young, becoming terete and glabrous, lenticellate with prominent leaf-scars. Leaves decussate-opposite; petioles slender, 2.5-7(-9.5)cm long, puberulent to pubescent, canaliculated above, channel densely tomentose, hair simple; leaf-blades subcoriaceous or coriaceous, ovate to broadly ovate, ovate-elliptic to rotund, orbicular or obcordate to deltoid, sometimes elliptic-lanceolate or obovate, margin entire or obscurely sinuate, 10.5-19.5(-23)cm long, and 6-15.5(-19)cm wide, apically acute to obscurely acuminate, rounded, rarely emarginate, basally cuneate to truncate or rounded, glabrous and shiny above, somewhat pitted, nigrescent on drying, glandular glaucous and velutinous-tomentose beneath, numerous black glands near the base, prominent beneath; secondaries 3-6 pairs, oblique, prominent, straight or slightly arcuate; veinlets very slender, transverse, parallel or sub-parallel. Inflorescence cymose, sometimes terminal and axillary, lax, 10-30cm long, few-flowered, arranged in corymbiform panicles, lightly fulvous-tomentose, the branching di-or trichotomous; bracts foliaceous, caducous, ovate to elliptic, ovate-oblong or linear-lanceolate, 4-7mm long, apically acute to shortly acuminate or obtuse, basally attenuate or cuneate, glabrous above, glandular and pubescent beneath; peduncle 2.5-5cm long, pedicles 4-7mm long. Flowers large, 3-5.5cm long, 2.5-3.5cm wide, fragrant; calyx broadly campanulate, 9-15mm long, 5.5-10mm broad on top, externally glandular and pubescent, often apically with some minute black glands, internally glabrous, the rim truncate, often with 5 very small or obsolete teeth; corolla campanulate, white-pale purple or pink-purple, yellowish-violet, yellow with purple, inner face of lower lobe strikingly yellow, externally pruinose or pubescent, somewhat puberulent on the middle, internally tube glabrous, lobe inner faces papillose, the tube basally cylindric, apically broadly dilated, bilabiate, the lobes 5, subequal, rounded, marginally ciliate, upper lip 2-lobed, lobes semicircular or ovate-oblong, apically obtuse, sometimes truncate, 10-18mm long, 9-13mm broad at the base, lower lip 3lobed, the middle lobe largest 15-25mm long, 10-17mm broad at the base, broadly-ovate or semicircular, apically acute, the lateral lobes semicircular or ovate-oblong, apically obtuse, 10-17mm long, 9-14mm broad at the base: stamens 4, didynamous, subexserted; inserted near the base of corolla tube; filaments sparsely glanduliferous, longer pairs 17-25mm and shorter pairs 13-20mm long; anthers pendulous, the thecae subparallel, oblong, basally acute, 2.5-3mm long; ovary ovoid, apically pilose, glabrous elsewhere, 2.5-3mm long, about 2.5mm wide, 4-locular, each cell 1-ovulate; style 3-3.7cm long, apically decurved, upper 2/3 glanduliferous, basally glabrous; stigma unequally bifid, the longer lobes 0.8-1.5mm and shorter lobes to 0.5mm long. Drupes green then turning yellow, ovoid, or obovoid to globose, 1.5-4.5cm long, 0.7-2cm wide, apically depressed. Figure 2.14.

Ecology: Open forests; dry evergreen forest; on granite soil. Alt. 0-950m. Flowering & fruiting: May to September.

Distribution: Thailand, Loas, Vietnam and China. Map 2.4.

Vernacular name: So hin (Thai).

**Proposed Conservation status:** In Vietnam it is recorded only from Tonkin. In Thailand it is known only from Bungkhla district, Phu Wua wildlife sanctuary, and in China the species is confined to Yunan. Therefore this species could be considered as Vulnerable (VU).

**Typification**: Loureiro's type has not yet been found *either* at P or BM. While revising the species *G*. *racemosa* Merrill commented "Loureiro's description definitely applies to *Gmelina* and to a species in the group with *G. chinensis* Benth., *G. hainanensis* Oliv., *G. balansae* Dop, and *G. lecomtei* Dop. Among these it agrees best with the characters of *G. hainanensis*, from which I do not think that *G. balansae* can be distinguished......*Clemens* 3980 from Mount Bana, near, Tourane, flowers yellow with purple, probably represents Loureiro's species."

Therefore, being relatively the most complete specimen, that lodged at K is designated here as the neotype.

Dop refers to three syntypes from Tonkin, Vietnam, *Harmand* s.n. from Mekong-Hué, *Bon* 5413, and *Balansa* 3806, and one *Spire* 233 from Laos for his *G. balansae* without indicating any herbarium where the specimens are lodged. Dop worked at P, therefore, the P specimen (*Balansa* 3806) is chosen here as the lectotype.

**Notes**: Merrill (1935) mistakenly reduces *G. chinensis* and *G. hainanensis* to *G. racemosa*, while *G. racemosa* can easily be distinguished by having a truncate calyx and 5-lobed corolla, rather than the 4-lobed corolla in *G. chinensis*, and clearly 5-lobed calyx in *G. hainanensis*.

*G. balansae* differs from *G. racemosa* only in the degree of hariyness on the petiole and calyx, however these characters are not consistent. Therefore, *G. balansae* cannot be treated as a separate species.

Specimens Examined: Vietnam: Tonkin, *Thù'a Thiên-Huê Province*, Mekong-Hué, September 1877, *Harmand* s.n. (A, K, P). Mt. Bavi, Lankok Valley, 24 June 1887, *Balansa* 3806 (A, K, L, NY, P). *Thanh Hoá Province*, unknown locality, 11 June 1892, *Bon* 5413 (P-3 sheets). *Tinh Nghe An Province*, between Chapa and Muong-Xen, January 1912, *Lecomte & Finet* 421 (P); road to Chapa, 950m, July 1943, *Petelot* 8484 (A, NY). *Phú Tho Province*, Lõi Aho, 0m, 4 June 1918, *Fleury* 37550 (P). *Quâng Nam Province*, Dā Nang (Tourane), Bois Mons forest, 100m, 24 July 1923, *Poilane* 7333 (A, P); Dā Nang, 600m, 15 August 1923, *Poilane* 7533 (K, P); Dā Nang, Mount Bani, 25km from Dā Nang, July 1927, *Clemens & Clemens* 3980 (A-2 sheets, K, P, NY, US). *Tuyên Quang Province*, unkwon locality, June 1925, *Petelot* 1941 (NY); Huê la Reserve forest, undated, *Fleury* 37989 (A). *Vĩnh Phúc Province*, Vĩnh Yên, April 1935, 50m, *Petelot* 5733 (A, P-2 sheets); Mt. Bavi, to Sontay, 100m, 2 June 1941, *Petelot* 6849 (NY). Unknown locality: January 1912, *Lecomte & Finet* 125 (K); **Thailand**: *Northeastern*, Nong Khai, Bungkhla district, Phu Wua wildlife sanctuary, nature trail from headquarter, 18º14' 41"N 103º 57' 58"E, 200m, 27 August 2001, *Pooma et al.* 2805 (BKF-2 sheets); Nong Khai, Bungkhla district, Phu Wua wildlife sanctuary, headquarter area, 18º14' 79"N 103º 57' 67"E, 200m, 20 May 2004, *Pooma et al.* 4144 (TCD).



Gmelina racemosa (Lour.) Merr

Figure 2. 14. G. racemosa. (Source: Forest Herbarium Thailand, BKF website http://www.dnp.go.th/.../plant\_illustrations.html). **15. Gmelina rotundifolia** *M. H. Rashid* & *J. Parnell* **sp. nov.** Ab aliis gregis foliis rotundus ad late ovatus vel orbicularis, conspicue parvus bilabiatus clyces differt. Type: Myanmar, Toungoo, near Kyaukkyi, alt. 30m, 11 August 1911, *Lace* 5397 (K! holotype).

Large scrambling shrub; branchlets obtusely tetragonal, densely tomentose when young, gradually puberulent when mature, lenticellate. Leaves decussate-opposite; petioles very slender, channelled above, 7-15mm long, tomentose or lanate, glanduliferous; blades sub-coriaceous, rotund or orbicular to broadly ovate, 5.5-10.5cm long, 4-9cm wide, apex acuminate, base subacute or rounded; margin entire and ciliate, glabrescent above with veins and veinlets puberulent, densely white glanduliferous and tomentose beneath; secondaries 4-5 pairs; conspicuous above, very prominent beneath. Inflorescence terminal, paniculate, 3.5-7.0cm long, densely tomentose; bracts caducous, sessile, 18-20X5-6mm, obovate, apex acuminate, base attenuate with a few sunken black glands near the apex; bracteoles linear lanceolate to narrowly elliptic or oblanceolate, apex long acuminate, both bracts and bracteoles pubescent above, puberulent beneath; calyx small, tubularcampanulate, 5-6.5mm long and 4-5mm wide; rim conspicuously bilabiate with 4 minute, sinuate teeth, teeth to 0.5mm long; externally appressed tomentose and white glanduliferous with 2-3 large, black nectariferous glands interspersed; glabrous inside; corolla (colour unknown), infundubular, 4-5cm long, membranous, bilabiate, 4-lobed, externally strigillose-pubescent and sparsely white glanduliferous, internally glabrous; upper lip entire, lobe ovate, apically obtuse, 4-7mm long and 6-7.5mm wide at base, lower lip 3-lobed, the median lobe largest, ovate-oblong, apically obtuse, 12-16mm long and 10-13mm wide at base; the lateral lobes ovate, apically obtuse, 5-10mm long and 7.5-10mm wide at base; tube not incurved; stamens 4, didynamous, subexserted, inserted at the base of corolla tube, from where tube expanded; filaments filiform, incurved, longer pair 18-20mm long, glabrous, apically sparsely glanduliferous, shorter pair 10-13mm long, glabrous throughout; anthers oblong, 2.5-3mm long, lobes free and divergent in the lower halves; ovary obovoid, villous at apex, glabrous elsewhere, 3mm long and 2mm wide, 4-locular with one ovule in each locule; style filiform, 2.5-3cm long, sub-exserted, glabrous; stigma subulate, glabrous, minutely bi-lobed, lobes unequal, longer lobe ca. 1.5mm long, other minute. Drupes obovoid-globose, 15-20mm long and 10-12mm wide, apically sparsely pilose, becoming glabrous later. Figure 2.15.

Ecology: Alt. 30m. Flowering and fruiting: August.

Distribution: Endemic to Myanmar. Map 2.5.

Vernacular name: Unknown.

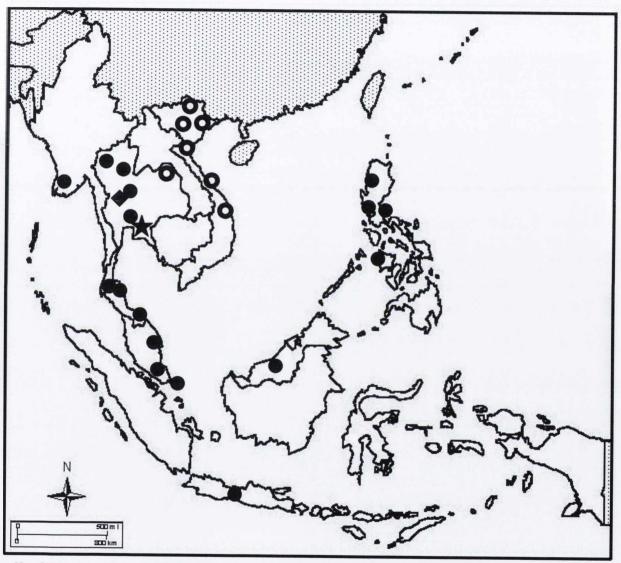
**Proposed Conservation status:** This species is known only from the single type specimen collected in 1911, and has not been re-collected since. The type locality Toungoo is now a large city. Thus, the species is likely to be extinct due to habitat alterations. EX.

**Note**: A very distinctive species with rotund to broadly ovate or orbicular leaves and conspicuously bi-labate and small calyx. Only found once in near Kyaukkyi, Toungoo in Myanmar.

Etymology: Gmelina rotundifolia is characterised by its rotund to broadly ovate or orbicular leaf shape for which it is named.

# Specimens examined:

Myanmar: Toungoo, near Kyaukkyi, 30m, 11 August 1911, Lace 5397 (K holotype).



Map 2.4 Southeast Asian distributions of *G. paniculata* (★); *G. parnellii* (♦); *G. philippensis* (●) and *G. racemosa* (●).

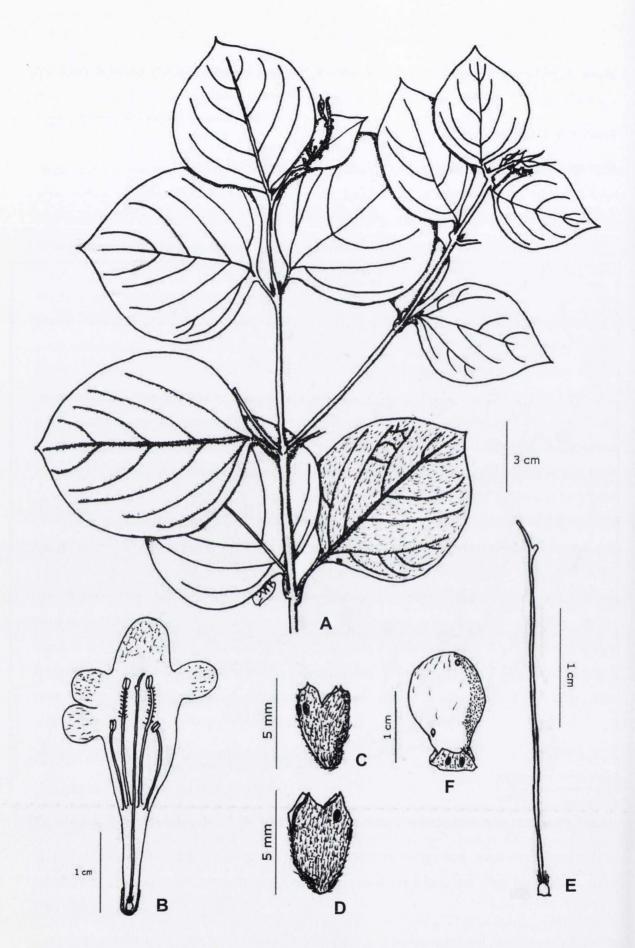


Figure 2.15. *G. rotundifolia.* A habit; B dissected flower; C bilabiate calyx; D calyx showing nectariferous glands on anterior side; E pistil; F. drupe (all from *Lace* 5397, K). Drawn by Cliodhna Ní Bhroin.

**16. Gmelina schlechteri** *H. J. Lam*, Verbnac. Malay. Arch. 226 (1919). Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 68 (1921); Hill, Ind. Kew. Suppl. 6: 92 (1926), and 7: 104 (1929); Munir, J. Adelaide Bot. Gard. 7(1): 106 (1984). Type: Papua New Guinea, Central District, Nunumai, *ca.* 12km North of Amazon Bay, *ca.* 120m, 149<sup>o</sup> 23'E 10<sup>o</sup> 11'S, 21 June 1969 (CANB! neotype images- neotype chosen by Munir (1984); isoneotype L!-2 sheets).

- G. dalrympleana (F. Muell.) H. J. Lam var. schlechteri (H. J. Lam) Moldenke, Phytologia 4(3): 178 (1953).
   Moldenke, Résumé Verbnac. etc. 201-203, 297 (1959); Moldenke, Fifth Summary Verbenac. etc. 1: 333, 336, 338 (1971) and 2: 524 (1971); Moldenke, Sixth Summary Verbenac. etc. 323, 327, 328 (1980); Moldenke, Phytologia 56(1): 39 (1984). Type: as for above.
- *G. macrophylla* auct. non Benth.: Schumann in Schumann & Hollr., Fl. Kais.-Wilh. Land 120 (1889), quoad spec. *Hollrung* 651, Augusta Station, New Guinea.

A tree 8-20(-40)m high. Stem erect, unbuttressed straight bole, up to 1m diameter, crown broad; branchlets pubescent and glandular, the main trunk glabrous with smooth grey or tessellated rough brown bark. Leaves broadly elliptic-oblong, entire, apex obtuse or shortly acuminate, truncate or somewhat cuneate at base, rarely rounded, with a pair of nectariferous glands at the base of the lamina below the first pair of nerves, (10-)15-25(-36)cm long, (5-)10-20(-25)cm broad, coriaceous, glabrous, dull green above, pale beneath, rugose or tessellated on both surfaces; primary nerves sub-pubescent, secondaries 6-10 pairs, prominent beneath; petiole pubescent and glandular, becoming glabrescent later, canaliculated above, (1.5-)2.5-4.5(-8)cm long. Inflorescence terminal paniculate cyme, more or less pyramidal, 15-25(-30)cm long, 10-18(-20)cm across, ferruginous-pubescent. Flowers sessile or short pedicellate of 1-1.5mm long; bracts caducous, elliptic or elliptic-oblong, glabrous above, densely pubescent beneath, 2-5mm long, 1.5-3mm broad; calyx campanulate, dark purple-green, externally densely pubescent with nectariferous glands, glabrous inside, 3-4(-5)mm long, 3(-4)mm broad at the top, persistent, truncate or obsoletely 5-dentate, teeth to 0.5mm long, somewhat accrescent and expanded under the fruit; corolla white, or yellow, lilac, mauve or pale lilac, cream with purple, creamy white with mauve markings, 1.5-2.5cm long, externally appressedly pubescent, internally tube glabrous, lobes papillose, bi-labiate, 5-lobed, upper lip 2-lobed, lobes oblong to ovate-oblong, 5-7mm long, 3.5-5mm broad at base, lower lip 3-lobed, the mid-lobe largest, oblong-ovate, apically obtuse, 10-12mm long, 5-6mm broad at the base, darker with yellow dots inside at the base, the lateral lobes oblong or oblongovate, 5-8.5mm long, 3-6mm broad at the base, tube oblique, abruptly dilating above the calyx, (7-)10-12mm long, (5-)7-10mm broad at the top end; stamens ascending under the upper lip, somewhat exserted, inserted on the lower part of the corolla tube; filaments filiform, flattened, incurved and with glandular hairs in the upper half, longer pair 8-11mm long, shorter pair 6-9mm long, anthers 1.5-2.5mm long, lobes oblong, free and divergent in the lower half. Ovary obovoid-globose, glabrous often with small deciduous glands at the top, 1.5-2mm long, 1-1.5mm wide in the upper half, 4-locular with one ovule in each locule; style filiform, exserted, sparsely pilose and glandular hairy, incurved in the upper half, 15-20mm long; stigma subulate, sparsely

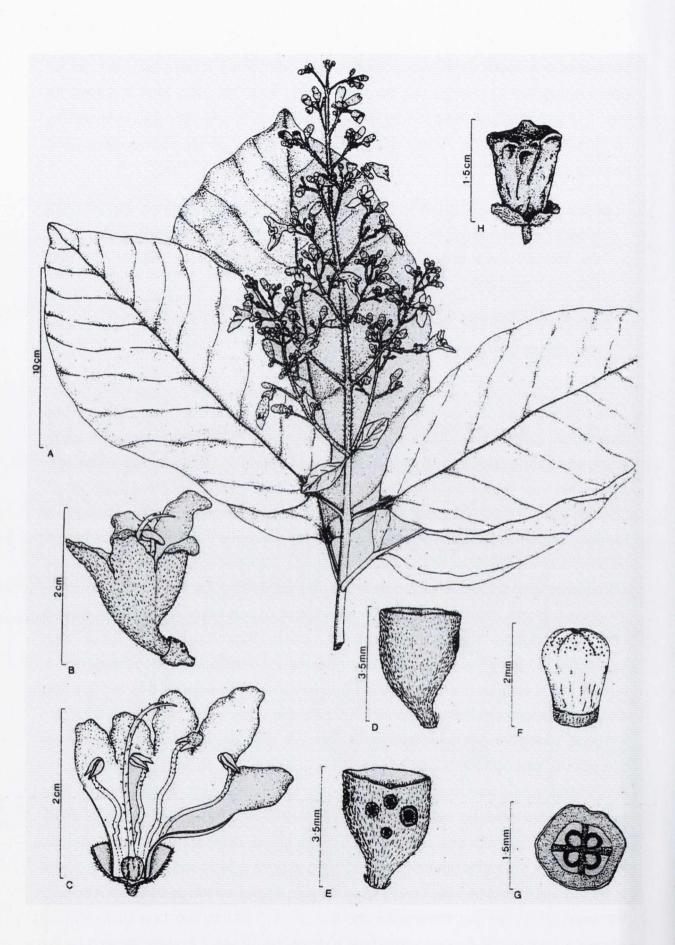


Figure 2.16. *G. schlechteri*. A habit drawing of branch; B flower; C dissected flower; D calyx shows nectariferous glands on anterior side; E calyx shows nectariferous glands free posterior side; F ovary; G transverse section of ovary; H fruit with persistent calyx. (Taken from Munir 1984).

glandular, unequally bi-lobed, longer lobe 1.5-2mm long, other minute. **Fruits** pendulous, obvoid-truncate or with a small knob on top, (8-)10-15(-17)mm long, (6-)8-11mm in diameter distally, glabrous, purple, bright blue, reddish-purple or purple-pink and glossy when fresh, turning black and dull when dry. **Figure 2.16**.

**Ecology**: In fringing forest on banks of small perennial streams; riverine forest; coral limestone covered by primary rain forest; in disturbed rain forest on hill slope; on the river bank; on flat land in lowland rainforest; in Oak forest on a ridge; in juvenile rainforest on fairly clayey soil. Alt. 5m-*ca*.1340m. *Flowering & fruiting*: almost through over the year.

**Distribution**: Indonesia, Papua New Guinea, and Australia. In Indoensia *G. schlechteri* is found only in the Moluccas and confined in Aroe Island. **Map 2.5**.

Vernacular names: Adun mangai laplabai; Adoen (Aroe Island); Along-aya (upper Waria); Boa (Yekora language); Boing (Waskuk); Bauma, Pó'a (Orokaiva language, Mumuni); Immeree (Asmat Language).

**Uses**: Timber tree (*Balgooy* 6610); timer used for canoes (*Hoogland & Craven* 10167); fruits eaten by cassowaries (*Millar* NGF. 37668).

**Proposed Conservation status:** *G. schlechteri* does not have a wide distribution. This species occurs only in Indonesia, Papua New Guinea and Australia. In Indonesia it is confined to Aroe Island, Moluccas; in Papua New Guinea it is distributed in eastern and northern divisions; and it is only in the Northern Territory in Australia where it occurs mainly in the north-west. It is therefore considered as Vulnerable (VU).

**Notes**: *G. schlechteri* is closely related to *G. dalrympleana* in its glabrous lamina and having two nectariferous glands at the base; corolla tube glabrous inside; glabrous ovary and obovoid fruits. Nevertheless, *G. schlechteri* may easily be identified by its calyx, which is densely pubescent and ovary sparsely glandular at the top.

## Specimens Examined:

Indonesia: *Moluccas*: Aru (Aroe) Island, Dosinamalaoe, Pulau Kobroor, ±10m, 30 May 1938, *Neth. Ind. For. Service* bb.25330 (A, L); Aru (Aroe) Island, Ngaibor, Pulau Trangan, ±20m, 1 July 1938, *Neth. Ind. For. Service* bb.25474 (A, L, SING); Aroe Island, Pulau Trangan, Kp. Ngaibor, 1 July 1938, *Buwalda* 5431 (A, L, NY); Aru (Aroe) Island, Pulau Trangan, West of Sia, 10m, 6<sup>o</sup> 49'S 134<sup>o</sup> 16'E, 23 October 1994, *Balgooy* 6610 (K); Aru Archipelago, Kobroor, *ca.* 8km SE of Jirlay, 25 October 1994, *Nooteboom* 5880 (A, KEPONG). South Division, Papua, Asmat Region, Erma, 0m, 24 July 1957, *Nautje* BW 6508 (L-sterile); Asmat Region, Erma, 0m, 9 August 1957, *Nautje* BW 6582 (L-sterile); 6km Southwest of Bernhard Camp, Idenburg River, 1400m, February 1939, *Brass* 12751 (L);

Papua New Guinea: Kaiser Wilhelm's land, Augusta Station, undated 1887, *Hollrung* 651 (NY); Eastern Division, Aisa river, 11 May 1926, *Brass* 1376 (A-2 sheets, K); Ihu, Vailala River, 12 February 1928, *Brass* 959 (A, NY); Eastern Division, Fife Bay, November 1930, *Turner* 128 (BM); Isuarava, *ca.* 1060m, 24 February 1936, *Carr* 15748 (L, NY); Papua, Mile Bay area, *ca.* 460m, March 1945, *Smith* 1345 (L); Territory of Papua,

Northern Division, Robinson Bay, ca. 1km inland of Iwaia village, ca. 100m, 13 July 1953, Hoogland & Macdonald 3422 (A, L); Territory of Papua, Northern Division, between Ambasi and Devatutu villages, ca. 10m, 27 July 1953, Hoogland 3405 (A, L); Modewa, Modewa Bay, 100m, 17 December 1956, Brass 28910 (A). National Capital District Province, Central District, Maigo, near Marshall lagoon, 30m, 10º 10'S 148º 10'E, 18 October 1963, Kairo NGF.17260 (A, L, K); Centrtal District, Nunumai, ca. 12km North of Amazon Bay, ca. 120m, 149º 23'E 10º 11'S, 21 June 1969 (L-2 sheets, isoneotype). East Sepik Province, Sepik District, near Ambunti, ca. 90m, 31 May 1966, Hoogland & Craven 10167 (A, L-2 sheets); Sepik District, Ambunti subdistrict, ca. 213m, 1 August 1966, Hoogland & Craven 10.799 (A, L-2 sheets); Hunstein Range (Mt. Samsai), near stie Camp 4, Crestline of main ridge to summit, 1000m, 4º31'S 142º43'E, 24 July 1990, Takeuchi 6373 (K). Morobe Province, Morobe District, Kui, TNG, 122m, 7º 25'S 147º 16'E, 3 November 1966, Henty NGF. 28077 (A, K, L); Morobe District, Morobe sub-district, Wampit, Bupu village, ca. 1310m, 6º 50'S 146º 35'E, 13 July 1967, Millar NGF. 22979 (L); Morobe District, Lae sub-district, Lasanga Island, TNG, ca. 305m, 7º 25'S 147º 15'E, 4 November 1969, Streimann NGF. 44257 (A, L); Morobe District, Morobe sub-district, Paiawa, ca. 3m, 7º 35'S 147º 15'E, 12 May 1970, Johns NGF, 47311 (GH, L); Morobe district, Lae sub-district, Saru River, 7 miles Southeast of Garaina, TNG, 610m, 7º 55'S 147º 14'E, 20 July 1970, Streimann & Students NGF. 47995 (A, L); Morobe district, Lae sub-district, mouth of Mo River, 5m, 7º 45'S 147º 35'E, 31 January 1972, Streimann NGF. 24350 (A, L); Southeast of Lae on the coast, opposite Lasanga IsaInd, 50-150m, 7º 25'S 147º 10'E. 10 November 1973. Jacobs 9536 (L- 2 sheets); Opo Cree, near Anna village, 40m, 4º 50'S 147º 30'E. 4 March 1978, Karenga et al. LAE 73871 (A, K, L); Basu river, 5m, 6º 40'S 147º 10'E, 27 June 1980, Rau 609 (L). Western Highlands Province, Western Highlands District, Hagen Sub-District, Road above Baptist Mission, ca. 1340m, 5º 35'S 144º 10'E, 9 July 1968, Millar NGF. 37668 (K, L). Western Province, Western district, ca. 11 miles North of Weam Patrol Post, ca. 12m, 1 September 1967, Paijmans 373 (L). South of Basu forestry camp, Plot 56 (7.20 147.10), 30 June 1977, Conn et al. 288 (A, L).

Australia: Northern Territory: Sandstone tableland, between Gerowie Creek and Mary River, *ca.* 305m, 13<sup>o</sup> 30'S 132<sup>o</sup>E, 4 October 1946, *Blake* 17169 (MO).

**17. Gmelina tomentosa** Fletcher, Kew Bull. Misc. Inf. 5: 203 (1938). Fletcher, Kew Bull. Misc. Inf. 10: 423 (1938); Mold., Known. Geogr. Dist. Verbenaceae, ed. 1: 60 & 93 (1942) and ed. 2: 138 & 186 (1949); Salisbury, Ind. Kew. Suppl. 10: 100 (1947); Mold. Résumé 178 & 456 (1959); Mold. Fifth Summ. 1: 296 (1971), and 2: 880 (1971); Mold. Phytol. Mem. 2: 286 & 549 (1980); Mold., Phytologia 56(3): 181 (1984); Mathew, William Roxburgh's plants of the coast of Coromandel, *Blumea* 49: 402 (2004); *non.* Tanaka & Nagamasu, Acta Phytotax. Geobot. 57(3): 235 (2006). Type: Thailand: Rachisima, Korat, Ban Chum Seng, 23 May 1929, *Noe* 211 (BM! **lectotype chosen here**; isolectotypes K!, E!).

Large shrub, 2.5-3m tall; branchlets obtusely tetragonal, conspicuously tomentose when young, finally glabrous, lenticellate, armed with a few 5-7mm long spines. Leaves decussate-opposite; petioles very slender, 1-4cm long, densely tomentose; *blades* sub-coriaceous or thick-chartaceous, ovate or oval, or elliptic, rarely orbicular (when young), 3-6(-8)cm long, 3-5(-7.5)cm wide, apically sub-acute or obtuse, basally subcuneate or rotundate, margin entire and ciliate, fulvous-tomentose above, densely fulvous-tomentose and white glanduliferous beneath; midrib conspicuous above, prominent beneath; secondaries 4-6 pairs, conspicuous above, prominent beneath; tertiaries transverse. Inflorescence terminal and axillary, racemiform, paniculate, 2-5cm long, tomentose; peduncle to 5mm long; flowers sub-sessile; bracts caducous, sessile, small, 2-4x1-1.5mm, lanceolate, apex acute, densely tomentose; calyx small, campanulate, 3-3.5mm long and 3-4mm wide, rim with 4 minute, sinuate teeth, teeth to 0.5mm long, with 2-3(-4) large, black nectariferous glands interspersed; externally densely tomentose and white glanduliferous, internally glabrous; tube about 3mm long, slightly extended under the fruit; corolla colour unknown, infundubular, 4-4.5cm long, membranous, bilabiate, 4-lobed, externally tomentulose or strigose and white-glanduliferous, internally glabrous, upper lip entire, lobe ovate, 1cm long and wide at base, lower lip 3-lobed, all lobes apically rounded or obtuse, the median lobe largest, 1.5-2.0cm long and 1.2-1.8cm wide at base, broadly ovate-oblong, the lateral lobes ovate, 1.0-1.5cm long and 1.0-1.3cm wide at base; tube 2.5-3.0cm long, slender below for up to about half of its length, then abruptly dilating upward; stamens 4, didynamous, mostly included, inserted near the base of corolla tube, top of lower slender part; *filaments* filiform, incurved, longer pairs 2.0-2.3cm long, glabrous, apically sparsely glandular hairy, shorter pairs 0.9-1.0cm long, glabrous throughout; anthers oblong, 2.5-3mm long, lobes free and divergent in the lower halves; ovary obovoid-globose, glabrous, 2.0-3.0mm long and 1.5-2.0mm wide, 4-locular with one ovule in each locule; style 3-3.5cm long, sub-exserted, filiform, glabrous or with sparsely glandular hairs; stigma subulate, glabrous, obscurely and unequally bilobed, longer lobes 1.5-2.0mm long, other minute. Drupes obovoid or sub-globose, 8-11mm long and 5-6mm wide, glabrous, fleshy. Figure 2.17.

Ecology: Alt. unknown. Flowering & fruiting: May.

Distribution: Endemic to Eastern Thailand. Map 2.5.

Vernacular name: Chawng Meo.

**Proposed Conservation status:** This species is only known from type specimens collected in 1929 and there are no recent collections. The locality is a town and the species likely to be extinct due to habitat alteration. EX.

**Typification**: Fletcher (1938) cites the type specimen (Noe 211) without indicating the herbarium where the specimen is lodged in the protologue. There are three type specimens deposited at BM, E and K. Fletcher worked at E, and almost certainly saw the material materials at BM and K (A. Paton *pers. com.*). Being relatively more complete and having an original label the BM specimen is chosen here as the lectotype.

**Specimens examined**: **Thailand**: *Eastern*: Nakhon Ratchasima, Korat, Ban Chum Seng, 23 May 1929, *Noe* 211 (BM lectotype, E, K isolectotypes).

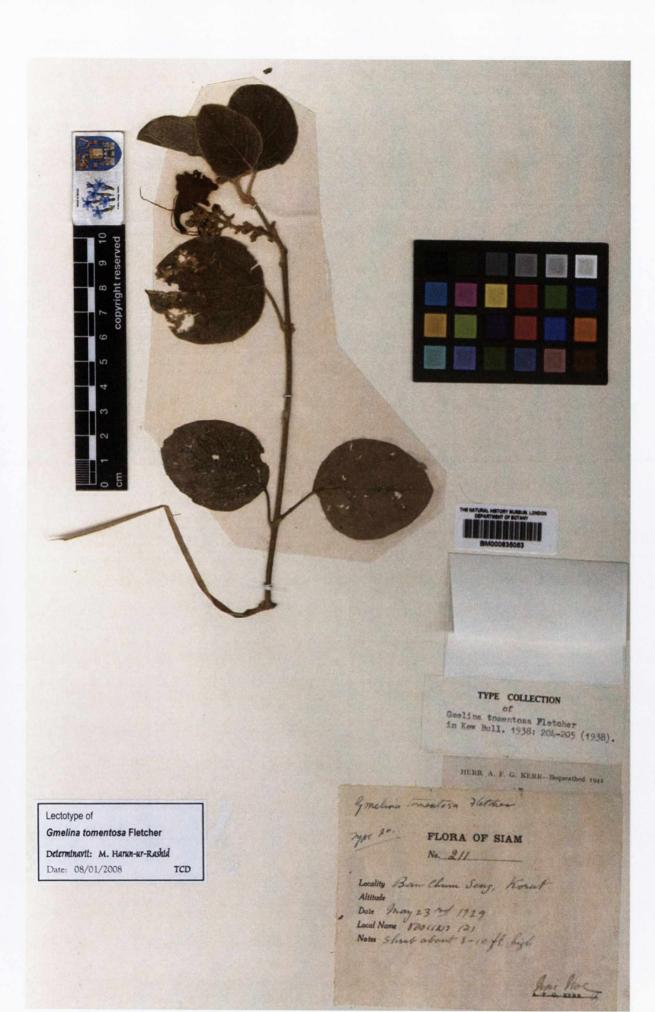


Figure 2.17. Lectotype of G. tomentosa. (Noe 211, BM).

**18. Gmelina tonkinensis** *Moldenke*, Phytologia 1: 419 (1940). Moldenke, Known Geogr. Dist. Verbenaceae, ed. 1, 59 & 93 (1942); Hill & Salisb., Ind. Kew. Suppl. 10: 100 (1947); Moldenke, Known Geogr. Dist. Verbenaceae, ed. 2, 136 & 186 (1949); Salisbury, Ind. Kew. Suppl. 10: 100 (1947); Moldenke, Résumé 176 & 456 (1959); Moldenke, Fifth Summ. 1: 301 (1971), and 2: 880 (1971); Moldenke, Phytol. Mem. 2: 293 & 549 (1980); Moldenke, Phytologia 56 (3): 182 (1984); Hô, Illus. Fl. Vietnam 2:831(2003). Type: Vietnam: Tonkin, along the sides of the road leading from Tuchap to the rocks of Notre Dame, May-June 1887, *Balansa* 3807 (holotype LE; isotypes A!, K!, L!, P!, isotype photograph NY!; isotype fragment NY!).

A somewhat spiny shrub, 3-3.5m high; branchlets very slender, densely short-pubescent with fulvous hairs when young, eventually glabrous, sparsely but prominently lenticellate. Leaves decussate-opposite; petioles very slender, (2-)3.5-6.5cm long, densely pubescent with fulvous hairs, canaliculated above; leaf-blades thinchartaceus or membranous, mostly ovate rarely elliptic or deltoid, 3.7-9(-13)cm long, 3.0-7.5(-10)cm wide. apically acute or short-acuminate, basally cordate or truncate to abruptly acute, margin entire, rarely lobulate, margin sparsely ciliate, puberulent (especially along the larger venation) above eventually glabrous; pubescent beneath and covered with round, sessile, white glandular trichomes, 4-5 sunken glands at and near base beneath, few glands scattered; midrib and veinlets conspicuous and glabrous above, prominent and pubescent beneath; the secondaries 4-6 pairs, tertiaries scleriform. Inflorescence lax, terminal, racemiform, 3-5cm long, densely pubescent and covered with white glandular hairs; pedicel 3-4mm long, bracts foliaceous, caducous, elliptic or ovate, 0.9-1.8X0.7-1.0cm, short acuminate, pubescent above, tomentose and white glanduliferous beneath; bracteoles persistent, lanceolate, 3-4.5mm long, 0.5-0.7mm wide, pubescent and white glanduliferous above, glabrous beneath; calyx small, campanulate, 5-7mm long, 3-4mm wide, rim subtruncate with 4 small, sinuate teethed, externally densely tomentose and white glanduliferous, and 4-5 large, black nectariferous glands interspersed; internally glabrous; corolla vellow or bright yellow, campanulate, 4-4.5cm long, bilabiate, upper lip entire, semicircular, 8-12mm long and 11-13mm wide at base, lower lip 3-lobed, the median lobe largest, 1.8-2.0cm long and 1.6-1.7cm wide at base, ovate, apically acute, the lateral lobes ovate, apically obtuse, 8-10mm long and 9-12mm wide at base; tube 2.5-3.0cm long, slender below for up to about half of its length, dilating upward, externally pubescent, internally glabrous, lobes ciliate; stamens 4, didynamous, included, inserted about the middle of the corolla tube near the top of lower slender part; filaments filiform, not curvate, glabrous, longer pair 18-20mm long, shorter pair 10-12mm long; anthers elliptic, 2-2.5mm long, lobes free and divergent in the lower halves; ovary obovoid, glabrous, 2.5-3.0mm about 2mm wide, 4-locular with one ovule in each locule; style filiform, glabrous, 2.5-2.8cm long, included; stigma subulate, glabrous, bi-lobed, lobes unequal, longer lobe 1.0-1.5mm long, other minute. Drupes obovoid, 2-2.5cm long and 2cm wide, glabrous, fleshy, immature fruit yellow-green. Figure 2.18.

Ecology: Alt. unknown. Along the road side. Flowering & fruiting: April-June.

Distribution: Vietnam and Indonesia (Kwangen). Map 2.5.

Vernacular name: Unknown.

**Proposed Conservation status:** This species has very narrow and disjunct distributions in Tonkin, Vietnam and Kwangen, Indonesia. The latest collection was made in 1931, the localities are now in densely populated areas. Therefore, this species likely to be extinct (EX).

**Note**: This species has not been recorded from Indonesia before. Therefore, *G. tonkinensis* is recorded here for the first time from this territory.

#### Specimens examined:

**Vietnam** (*Annam*): *Tonkin*, May-June 1887, Balansa 3807 (isotypes A, K, L, P; isotype photograph NY; isotype fragment NY); *Tonkin*, undated 1883-1891, *Bon* s.n. (P); *Hanoi*, Bois de Co-Phah, 10 May 1891, *Balansa* 4593 (P); *Tonkin*, May 1891, *Balansa* 4972, (K); *Trá Vinh Province*, road to Doluong, April 1931, Pételot 4536 (NY, P); unknown locality, and undated, *Bon* 5462 (P).

Indonesia: Java, Kwangen, undated, Collector unknown 166 (K, presented by Dr. A. Henry in 1898).

	Isotype of Gmelina tonkinensis Moldenke Determinavil: M. Harun-ur-Rashtid Date: 10/01/2008	TCD IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
		4 5 6 7 8 9 10 copyright reserved
B. BALANSA PL. DU TONKIN - 1885-1880 N. 3837 Adrivseau en fen oprinen. Elevette jaune, puils chemme jau sed. Bendte jaune, puils chemme jau sed.		X
HERB. L. PIERRE		Herber Musham Fors Franker HERB. MUS. PARIS Joeline Allose Conf
Hab. Cochinebina. Coll. L. Pierre. 18	· ···	VIETNAM, (Tu Plug) Hon Binh

Figure 2.18. Isotype of G. tonkinensis. (Balansa 3807, P).

**19. Gmelina yangonensis** *M. H. Rashid* **sp. nov.** ab aliis gregis foliis parvus lata lanceolatus vel ovatuslanceolatus et brevissimus petiolus differt. Type: Myanmar, Yangon (Rangoon), Mingaladon, 27 April 1932, *Parkinson* 14368 (holotypus A!).

Shrub or small tree, 3-5m tall; branchlets obtusely tetragonal, densely tomentose when young, gradually puberulent in mature, lenticellate. Leaves decussate-opposite; petioles very slender, short, to 6mm long, tomentose; blades subcoriaceous, broadly lanceolate or ovate-lanceolate, rarely elliptic, 3.5-6cm long, 2.5-3.5cm wide, apex acuminate, base rotundate; margin entire and ciliate, tomentulose above, densely tomentose and glanduliferous beneath; secondaries mostly 4-5 pairs; conspicuous above, much prominent beneath. Inflorescence terminal and axillary, racemose, 4-5cm long, tomentose; peduncle 9-15mm long; pedicel short, 2-6mm long; bracts caducous, sessile, small, 8-12mm long and 2-4mm wide, lanceolate or oblanceolate to narrowly elliptic, apex caudate, tomentulose above, puberulent beneath with a few sunken glands scattered apically; calyx small, infundibular, 4.5-5.5mm long and 3-4mm wide; rim with 4 minute, sinuate teeth, tooth to 0.5mm long; externally densely tomentulose and white glanduliferous with 4-7 large, black, nectariferous glands interspersed; glabrous inside; corolla vellow, infundubular, 3-3.5cm long, membranous, bilabiate, 4-lobed, externally appressed tomentulose or strigose, internally glabrous; upper lip entire, lobe ovate, apically obtuse, 10-12mm long and 10mm wide at base, lower lip 3-lobed, the median lobe largest, 13-15mm long and 10-12mm wide at base, ovate-oblong, apically obtuse; the lateral lobes ovate, apically acute, 10-12mm long and 8-8.5mm wide at base; tube slender below and abruptly ampliate upward; stamens 4, didynamous, included, inserted near the base of the corolla tube at top of lower slender part; filaments filiform, incurved, longer pair 18-20mm long, glabrous, apically sparsely glanduliferous, shorter pair 10-12mm long, glabrous throughout; anthers oblong, 2.5-3mm long, lobes free and divergent in the lower halves; ovary obovoid, glabrous, apically velutinous, 2.0-2.5mm long and 1.3-1.5mm wide, 4-locular with one ovule in each locule; style 3.0-3.5cm long, sub-exserted, filiform, glabrous; stigma subulate, glabrous, minutely bi-lobed, lobes unequal, longer lobe ca. 1mm long, other minute. Drupes not seen. Figure 2.19.

Ecology: Alt. unknown. Flowering: April-May.

Distribution: Endemic to Myanmar. Map 2.5.

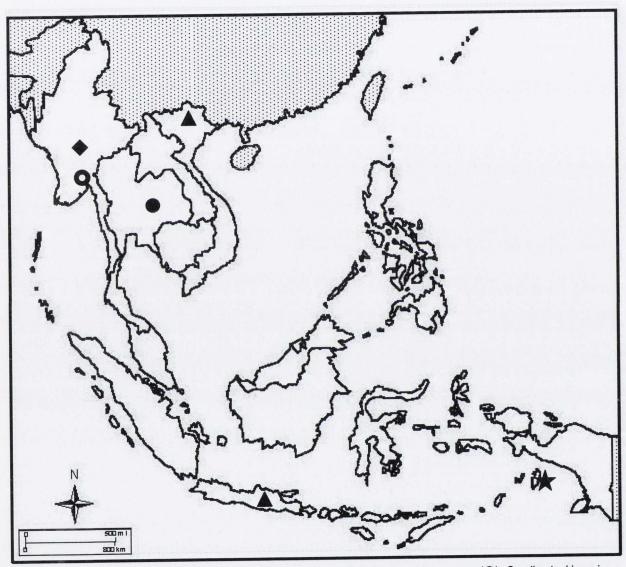
Vernacular name: Unknown.

**Proposed Conservation status:** This species is only known from two specimens collected in 1932 from Mingaladon and Yegin, Yangon (Rangoon), Myanmar. Since then there has been no recent collection. Mingaladon is a town and Yegin is a much populated area. Thus, the species is likely to be extinct due to habitat alterations. EX.

**Note**: This species is easily distinguished from the other species of the genus by the smaller, broad lanceolate or ovate-lanceolate and short petiolate leaves.

Etymology: The epithet *yangonensis* refers to the Yangon (formerly Rangoon), where the type collection was made.

Specimens examined: Myanmar: Yangon (Rangoon): Mingaladon, 27 April 1932, Parkinson 14368 (holotype A); Yegin, 20 May 1932, Parkinson 14426 (A).



**Map 2.5** Southeast Asian distributions of *G. rotundifolia* ( $\diamond$ ); *G. schlechteri* ( $\bigstar$ ); *G. tomentosa* ( $\bigcirc$ ); *Gmelina tonkinensis* ( $\triangle$ ) and *G. yangonensis* ( $\bigcirc$ ).



Figure 2.19. Holotype of G. yangonensis. (Parkinson 14368, A).

Section Annameticum M. H. Rashid & J. Parnell sect. nov.

Plantas scandens vel frutex vel arbores. Calyces bilabiatus et/vel conspicue 5 lobis, corolla 5 lobis. Type: *G. annamensis* Dop

This section consists of 7 species, 1 subspecies and 2 varieties, and is distinguished from the section *Asiaticum* in the habit, number of floral parts and calyx structure.

## Key to the species of section Annameticum

1. Inflorescence axillary, flowers solitary, corolla externally pilose	26. G. uniflora
<ul> <li>Inflorescence terminal and/or axillary, 1-few flowered cymes or racemes, corolla e puberulent</li> </ul>	externally glabrous or 2
2. Shrub or tree; inflorescence terminal	3
- Woody climber or climbing shrub; inflorescence terminal and/or axillary	4
3. Calyx infundibular, lobes 2mm long; corolla red, puberulent; style glabrous, apically sp	barsely glandular 20. <i>G. annamensis</i>
<ul> <li>Calyx broadly campanulate, lobes 5-11mm long; corolla white, glabrous; style sparsel pilose</li> </ul>	y glandular, apically 22. G. hainanensis
4. Leaves 10-30X7-14cm, both surfaces hirtellous or tomentulose, petiole densely villous	s; corolla puberulent 21. <i>G. borneoense</i>
<ul> <li>Leaves 7-20X4-11cm, glabrous above, glabrous or hirtellous beneath, petiole glabrous glabrous</li> </ul>	s or pilose; corolla 5
5. Petiole pilose; calyx long tubularis, 1.5-3.5cm long, tube glabrous, lobes tomentose ins	side; ovary glabrous 25. G. tubularis
- Petiole glabrous; calyx infundibular, 1-2.2cm long, puberulent or sericeous or l pilose	lanate inside; ovary 6
6. Calyx externally puberulent, internally pubescent, lobes 3-4mm long	24. G. spectabilis
- Calyx externally sericeous, internally tube sericeous or lanate, rarely glabrous, l pubescent or lanate	lobes 4-12mm long, 23. G. obovata

**20. Gmelina annamensis** *Dop*, Rev. Bot. Appliq. Agric. Trop. 13: 894 (1933). Dop in Lecomte, FI. Gén. Indochine 4: 845 (1935); Hill, Ind. Kew. Suppl. 9: 125 (1938); Mold. Known Geogr. Dist. Verbenaceae, ed. 1: 93 (1942) and ed. 2: 186 (1949); Mold. Résumé 176 (1959); Mold. Fifth Summ. 1: 301 (1971) and 2: 879 (1971); Mold. Phytol. Mem. 2: 293 (1980); Mold., Phytologia 55 (5): 336 (1984); Ho, Illus. FI. Vietnam 2:1045 (1993) and 2:829 (2003). Type: Vietnam (Annam), between Lang-lut-ha and Lang-pa-ka, Quang Tri, at 700m altitude, 10 May 1927, *Poilane* 13301 (P!, **lectotype designated here**; isolectotype fragment A!).

A tree, 10 to 12m tall; branchlets pubescent when young, becoming glabrescent, with brown, striate lenticellate bark. Leaves decussate-opposite, rigidly chartaceous or subcoriaceous, petioles 3-5.5cm long, glabrous, channelled above, leaf-blades broadly ovate or ovate-elliptic, 8-15cm long, 5-10cm wide, apically acute or shortly acuminate, margin entire, basally acute or truncate-acute, glabrous, and slightly rugose above, silvery-white and lightly pubescent beneath; midrib prominent beneath; secondary veins 8, the two lowermost issuing from the leaf-base; veinlets subparallel, 4-5 sunken glands at and near base beneath, inconspicuous above, prominent beneath; Inflorescence lax, terminal, paniculate, 6-11cm long, puberulent; bracts foliaceous, persistent, elliptic-lanceolate, acute, 3-4cm long, 1.3-1.8cm wide, 3-veined, glabrous, and slightly rugose above, covered with very small black glands, silvery-white and lightly pubescent beneath. Flowers short pedicellate, 3.5-4.5cm long; calyx conic or infundibular, 1.7-2.0cm long, tube 1.1cm long, the limb plainly bilabiate, 5-lobed, the upper lip 6mm long and 11mm wide, three-lobed; the lower lip 5mm long and 9mm wide, all lobes ovate, unequal, 2mm long, apically acute, slightly extended in fruit, externally puberulent and glandular hoary, covered with numerous, very small, black, sunken nectariferous glands, internally glabrous, margin sparsely ciliate; corolla infundibular, red, bilabiate, puberulent and glandular, 5lobed, lobes all rotundate, marginally ciliate, lower lip 3-lobed, the median lobe largest, 1.2-1.7cm long, 0.9-1.4cm wide at base, the laterals 1.0-1.4cm long, and 0.8-1.3cm wide at base, tube 2-3cm long, basally coarctate, internally glabrous; stamens 4, didynamous, included, inserted from about the middle of the corolla tube near the top of lower slender part; filaments filiform, glabrous, apically with sparse gland-tipped hairs, longer pair 2.5-2.7cm long, shorter pair 1.8-2cm long; anthers elliptic, 2.5-3.0mm long; style 2.5-3.8cm long, filiform, glabrous but apically sparsely glanduliferous, slightly surpassing the stamens; stigma subulate, glabrous, obscurely bi-lobed, lobes unequal, longer lobe ca. 1mm long, other minute; ovary ovoid-globose, 3.0-3.5mm long, 2.0-2.5mm wide, apically pubescent, glabrous elsewhere, 4-locular with one ovule in each locule. Fruits drupe, ovoid, pubescent, 3cm long, 1.5cm wide, greyish, apically flat. Figure 2.20.

Ecology: Altitude 700m. Flowering & fruiting: May-June.

Distribution: Endemic to Vietnam. Map 2.6.

#### Vernacular name: Cây cle.

Uses: Termites cannot attack the wood (Dop 1935). Wood used for making columns (pillars) (Dop 1935).

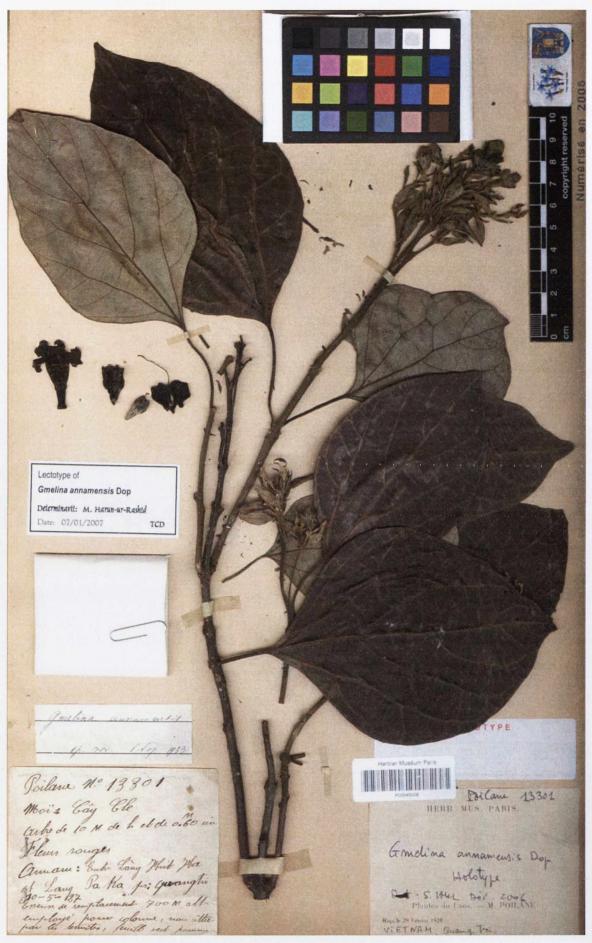


Figure 2.20. Lectotype of G. annamensis (Poilane 13301, P).

**Proposed Conservation status:** This species is known only from the type and one other collection from the type locality, collected in 1924 and 1927. Since then there has been no recent collection. There was the battle of *Khe Sanh*, or *Operation Scotland and Operation Pegasus*, conducted in Quang Tri Province in 1968. In addition, Quang Tri is the major city in the province. Therefore, the species is likely to be extinct due to habitat interference. EX.

**Typification**: Dop, who first validly published the name *G. annamensis*, cites no specimen. He noted "*Cette* espèce nouvelle provident d'une rècolte de POILANE en Annam, entre Lang-lut-ha et Lang-pa-Ka, dans la province de Quantri, à une altitude de 700m. Ce collecteur ajoute que le bois non attaqué par les termites est utilisé pour la confection de colonnes" which exactly matches with the topotype specimen Poilane 13301, lodged at P. Therefore this specimen is designated here as lectotype.

Specimens examined: Vietnam (Annam): Massif, Dong-cho, Quang Tri, 02 June 1924, *Poilane* 10723, (A, K). between Lang-lut-ha and Lang-pa-ka, Quang Tri, 700m, 10 May 1927, *Poilane* 13301 (lectotype P; isolectotype fragment A).

## 21. Gmelina borneoense M. H. Rashid stat. & nom. nov.

Type: Indonesia, Kalimantan (South Borneo), Soengei, Bloe-oe, undated 1896-97, *Jaheri* (exp. Nieuwenhuis) 1463. (BO! **lectotype designated here**; lectotype images NY!, TEX!; Isolectotype L!).

G. uniflora var. villosa Bakh. in Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 66 (1921); Fedde & Schust., Justs Bot. Jahresber. 53(1): 1074 (1932); Mold. Résumé 193 & 456 (1959); Mold. Fifth Summ. 1: 325 (1971), and 2: 880 (1971); Mold. Phytol. Mem. 2: 315 & 549 (1980); Mold., Phytologia 56(4): 312 (1984). Type: as for *G. borneoense*.

Climber, *ca.* 13m tall; branchlets terete, densely ferruginuous-tomentose when young, finally only densely resinous-punctate and sparsely lenticellate, internodes glabrous, leaf scar prominent. Leaves decussate-opposite; *petioles* terete, 1.5-6cm long, obsoletely sulcate above, densely ferruginuous-villous; *leaf-blades* sub-coriaceous, broadly elliptic or obovate or obovate-elliptic, 10-30cm long, 7-14cm wide, margin entire and ciliate, apex abrupt acute or acuminate or cuspidate, base obtuse to rounded or cuneate, a pair of black nectariferous glands at the base of lamina below, the glands much pronounced adaxially, hirtellous and shining above, midrib and venations densely pilose; abaxially tomentulose, and glanduliferous throughout, scattered punctuate; secondaries 4-5 pairs, veinlets transverse, distinct beneath. Inflorescence terminal and axillary, solitary or paired, 1-3 flowered, short pedunculate, peduncles 6.5-10mm long, densely rufous-tomentose, *bracts* and *bracteoles* foliaceous, caducous, sessile, lanceolate, 7-15mm long, 2.5-3mm wide,

apex acute, hiding the calyx, rufous-tomentose on both surfaces; **calyx** tubular, 1.5-2cm long and 5-6.5mm wide, externally densely rufous-sericeous and sparsely glanduliferous, internally very densely velutinous, lobes densely tomentose, unequally 5-laciniate lobed, lobes deltoid, 5-10mm long, 2.5-4mm wide at the base, apically acuminate, sometimes connate to each other, accresent in fruit; **corolla** colour unknown, narrow, tubular, basally slender, subventricose-ampliate, 2.5-4cm long, 7-8mm wide, tube 2.5cm long, the tube externally basally glabrous, apically puberulent and glanduliferous; internally glabrous, 5-lobed, upper lip bilobed, lobes small, broadly ovate to semicircular, apically rounded, 5-7mm long, 5mm wide at the base; lower lip 3-lobed, the mid-lobe largest to 1cm long, 7-10mm wide at the base, ovate-oblong, two lateral lobes similar to upper lobes; **stamens** 4, didynamous, subexserted, inserted about the middle of the corolla tube, top of the lower slender part; *filaments* filiform, apically incurved and sparsely glandular, longer pairs 1.5-1.7cm and shorter pairs 1-1.2cm long; *anthers* 2.5-3.5mm long; **ovary** ovoid-globose or oblong, 2.0-3.0mm long and 1-1.5mm wide, apically densely pilose, glabrous elsewhere, 4-locular, each locule 1-ovulate; *style* 3-3.5cm long, sub-exserted, filiform, terete, basally glabrous, apically sparsely glanduliferous; *stigma* truncate, glabrous, obscurely and unequally bi-lobed, longer lobe to 2mm long, other minute. **Drupes** green, oblong or obovate, 2.5-3.5cm long and 1.5-2cm wide, apically densely farinose eventually glabrescent, fleshy. **Figure 2.21**.

Ecology: Riparian forest. Alt. unknown. Flowering & fruiting: March.

Distribution: Endemic to Borneo (hence the specific epithet). Map 2.6.

Vernacular name: Akar Ankaleh (Iban, Sarawak).

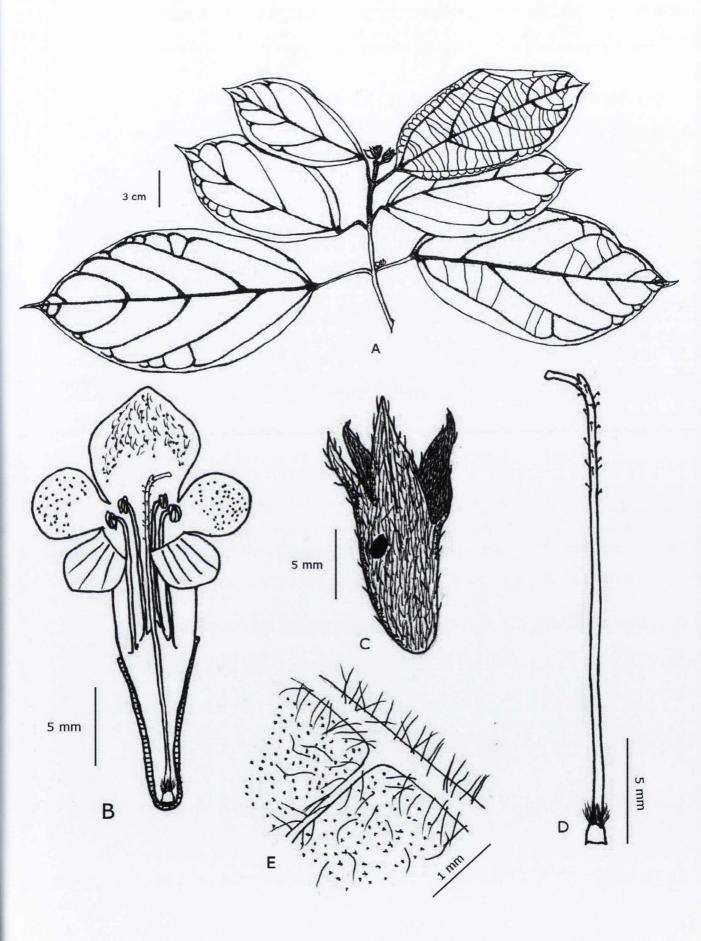
**Proposed Conservation status:** This species is only known from type specimen collected and two other specimens. For lack of additional information, it is considered as Data Deficient (DD).

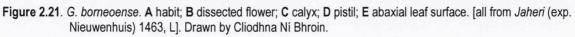
**Typification**: Bakhuizen (1921) recognises *G. uniflora* var. *villosa* based on three Jaheri's collections 1109, 1300, and 1463 from Kalimantan, Indonesia. Among this more complete specimen Jaheri 1463 lodged at L, is designated here as lectotype.

Etymology: The species epithet refers to its home locality.

**Note**: Bakhuizen's *G. uniflora* var. *villosa* is quite distinctive from its type in having longer and wider leaves (10-30 X 7-14cm; rather than 9.5-15 X 7.5-10cm) with acuminate or cuspidate apex (rather than obtuse or short-acuminate), both leaf surfaces hairy (rather than glabrous), longer petiole to 6cm with densely ferruginuous-villous indumentums (rather than to 2.5cm and glabrescent); lanceolate, and caducous bracts (rather than ovate and persistent); tubular calyx with densely velutinous internal surface (rather than campanulate and glabrous). These characters are good enough in justifying it as a separate species.

*G. uniflora* var. *villosa* is raised to species status. A new name is needed due to the prior use of the epithet "*villosa*" in *Gmelina villosa* Roxb., and *G. asiatica* L. var. *villosa* (Roxb.) Bakh. (valid name *Gmelina elliptica* Smith), hence a new name *Gmelina borneoense* is chosen.





**Specimens examined**: **Malaysia**: Sarawak, 4<sup>th</sup> Division, Marudi, Tinjar, Ulu Sg. Dapoi, 31 March 1965, *Ilias Pa'ie* S.22903 (KEPONG, K). **Indonesia**: Kalimantan (South Borneo), Soengei, Bloe-oe, undated 1896-97, *Jaheri* (exp. Nieuwenhuis) 1300 (L, NY); *Jaheri* (exp. Nieuwenhuis) 1463. (L- Isolectotype; images of isolectotype-TEX, NY).

**22.** Gmelina hainanensis *Oliv.* in Hook., Icon. Pl. 19: sub pl. 1874 (1889), in nota sub textu ad Forbes & Hemsl., Journ. Linn. Soc. Lond. Bot. 26: 257(1890); Durand & Jacks., Ind. Kew. Suppl. 1, imp. 1, 185 (1902); P'ei, Mem. Sci. Soc. China 1 (3): [Verbenac. China] 120 (1932); Dop, Rev. Bot. Appliq. Agric. Trop. 13: 894 (1933); Dop in Lecomte, Fl. Gén. Indo-Chine 4: 844 (1935); Mold., Résumé Verbenac. etc., 174 & 456 (1959); Mold., Fifth Summary Verbenac, etc. 1: 289 & 292 (1971) and 2: 880 (1971); Mold., Phytol. Mem. 2: 279, 281, & 549 (1980); Mold., Phytol. 56 (2): 107 (1984); Chen, Fl. China 17: 33 (1994); Hô, Illus. Fl. Vietnam 2:1046 (1993) & 2:830 (2003). Type: China, Hainan, undated, *B. C. Henry* 13 (K! holotype).

A tall tree or erect woody shrub, 3-22m tall and 3-18cm in diameter at breast height with a spreading crown; branchlets pubescent when young, glabrous later; buds brownish-grey woolly, leaf scars and lenticels very prominent. Leaves exstipulate, decussate-opposite; petioles (1.5)3-5(-7.5)cm long, canaliculated above, brown-pubescent eventually glabrescent; leaf-blades thick-chartaceus, shiny green and glabrous above, sometimes tessellated, downy-pubescent or minutely hispidulous and glandular-hairy beneath; margin entire, ovate to broadly ovate or broadly elliptic, rarely sub-rotundus or deltoid, apically short acuminate to acute or rarely cuspidate, basally shortly attenuate to cuneate, or truncate to rarely rounded-cuneate, (5-)7-13(-19)cm long, 4-9(-12.5)cm wide, secondaries 3-4 pairs, prominently elevated beneath; numerous sunken glands at and near base beneath, inconspicuous above, prominent beneath. Inflorescence terminal, cymosepaniculate, dense; 6-15(-22)cm long, fulvous-tomentose, peduncles 1-3cm; bracts foliaceous, caducous, subsessile, ovate to ovate-lanceolate, rarely deltoid, apex acuminate, base short attenuate, 8-20mm long, 5-10(-25)mm wide, glabrescent above, pubescent and glanduliferous beneath, numerous black glands scattered and prominent beneath. Flowers fragrant, irregular; calyx broadly campanulate, 13-20mm long and 12-15(-20)mm wide at the top, pale-green, conspicuously bilabiate, 5-lobed, lobes large, broadly ovate-deltoid, 5-11mm long, 7-10mm wide at base, externally pubescent and glanduliferous with scattered numerous large, discoid glands, internally glabrous or glandulose, accrescent and spreading in fruit; corolla broadly campanulate, white or pinkish-white, yellowish-white or red to cream, often maroon or purple to lavender and orange within, about 2.5-4.5cm long, 2cm wide at the throat, tube about 2.5cm long; externally glandular, margin ciliate, and internally the tube glabrous, lobes glandular; bilabiate, 5-lobed, upper lip bi-lobed, lobes oblong-obtuse, lower lip 3-lobed, the middle lobe ovate-obtuse to semicircular, 1.5-2cm long and 1.5cm broad at the base, lateral lobes semicircular, both upper lobes and lateral lobes ca.10-13mm long and broad; stamens 4, didynamous; almost included, inserted in the lower part of the corolla tube, the filaments sparsely

glandular, the longer pairs 20-25mm long and the shorter pairs 16-18mm long, anthers oblong, 3-3.5mm long; **ovary** obovoid-truncate, densely pilose, 2.5-3mm long, about 2.5mm wide, 4-locular, each cell 1-ovulate; *style* sparsely glandular-pilose, 2.5-3.5cm long; *stigma* unequally bi-lobed, truncate, longer lobes 1.5-3mm long, others minute, sparsely glandular. **Drupes** obovoid-truncate, 2-3cm long, and 1.3-2.2cm wide, equaling the fruiting calyx, glaucescent, grey, green, greenish yellow or bluish-green. **Figure 2.22**.

**Ecology**: On cleared hillsides or sparse forests; in mixed or light woods; in thickets; in dense shade; on dry clayey soil or on sandy soil. Alt. 300-1300m. *Flowering & fruiting*: March-September.

Distribution: Guangdong, Guangxi, Hainan in China; S Jiangxi in Vietnam. Map 2.5.

Vernacular names: Loi Tho Hai Nam (Vietnam); Hainan shizi, Shizi, Gepiong Gong (China); Shek Tsz, Shek Tsz Shue, Shek Tzi Shu, and Song Tsio Gun (Moldenke 1984).

**Uses**: Wood is valuable in boat making (Moldenke 1984); McClure noted "Wood is commercially valuable, fide our host" (*McClure* 20049);

**Proposed Conservation status:** Conservation of *G. hainanensis* is considered as Vulnerable (VU) according to IUCN Red List criteria. (IUCN 2001; IUCN 2008, IUCN Red List of Threatened Species. <www.iucnredlist.org>; downloaded on 27 October 2008). In China the species is known only from the mountain ranges of the south and west of Hainan Island, and very rarely from Kwangsi and Kwangtung provinces. In Vietnam it is recorded only from Tonkin. Although parts of the range are designated nature reserves, the habitat is generally subject to logging and clearance (IUCN 2008).

**Note**: Merrill (1935) mistakenly reduces *G. hainanensis* to *G. racemosa*, while it is quite distinctive, the latter having a lobed calyx rather than a truncate calyx.

## Specimens Examined:

**Vietnam**: *Tonkin*, Thù'a Thiên-Huê Province, Mekong Hué, September 1877, *Harmand* 1901 (P); locality unknown, April 1885, *Balansa* 937 (P); Quảng Ninh, Taai Wong Mo Shan and vicinity, Ha-Coi, Chan Uk village, near Chuk-phai, 10-20 June 1939, *Tsang* 29235 (A, L, P); Quảng Ninh, Taai Wong Mo Shan and vicinity, Ha-Coi, Tong Fa market, 11-23 September 1939, *Tsang* 29546 (A, K, L, P); Sai Wong Mo Shan (Sai Vong Mo Leng), Dam-ha district, Lung Wan village, 18 May -05 July 1940, *Tsang* 29869 (A, K, L, P); Kau Nga Shan and vicinity, Tien-yen district, 23 September-7 October 1940, *Tsang* 30588 (A, L, P).

## Additional Specimens examined:

China: *Hainan Province*: Unknown locality, undated, *B. C. Henry* 13 (K holotype); Fan Ya, open grassy hillside, 25 April 1922, *McClure* 9281) (A, NY); Noh Pong Sahn, Taam-chau district, Shek Taz Shue, 17 September 1927, *Tsang* 904 (Herb. Lingnan Univ. No. 16403, NY); Shui Mei Shan, Taam Chau district, 25 May 1928, *Tsang* 500 (Herb. Lingnan Univ. No. 17249- A, BM, K, NY); Hung Mo Shan and vicinity, Lai (Loi)



Figure 2.22. *G. hainanensis*. A Habit drawing of branch; B dissected flower; C opened calyx showing pistil. (Taken from Chen 1994).

area, 06 May 1929, Tsang et al. 97 (Herb. Lingnan Univ. No. 17628, A, NY); Southwest Poting, Ling shin, 25 April 1932, Ko 52188, (A, NY, US); Longmoon, Seven Fingor Mountains, 07 May 1932, Liang 61767 (NY, US); Tung Koo Shan and vicinity, Wen-ch'ang district, near Shan Hoi village, 4-25 August 1932, Fung 20370 (BM, NY); Yaichow, ca. 500m, 28 March 1933, How 70453 (MO, NY); Ka Chik Shan and vicinity, Ch'angkiang district, 20 April 1933, Lau 1582 (BM, NY); Ngai district, between T'ang K'iu (Din-Kio) and Po T'eng Shi (BoDeng), 23 May 1932, McClure 20049; (BM, K, MO,NY); Pak Shik Ling and vicinity, Ching Mai district, Ku Tung village, Shek Tzi Shu, 15 March 1933, Lei 450 (K, NY);Hitcho, Yaichow, 300m, 25 May 1933, How 70801(L, MO, NY); Yeung Ling Shan, Ngai district, Song Tsio Gun (Lois), 13 June 1932, Lau 75 (K, MO, NY); Unknown locality, 07 July 1933, Wang 32777 (NY); Yaichow, half way of the mountain, 08 July 1933, Liang 61985 (NY); Dung Ka to Mo San, 500m, 18 August 1933, Chun & Tso 43542 (L, NY); Yaichow, 26 September 1933, Liang 63162 (NY); Unknown locality, 26 February 1934, Liang 65340 (NY, US); Tai Pin, 320m, 21July 1935, Gressitt 1077 (A, BM, MO); Bak Sa, 1 April 1936, Lau 26008 (A); Loktung, 10 June 1936, Lau 27058 (A): Hau T'ong Shan, Sin-fung district, Fuk Lung Monastery, 1-19 June 1938, Taam 808 (A, K, US). Kwangsi Province: Bin Long, Miu Shan, North Luchen, border of Kweichow, 1220m, 14 June 1928, Ching 5995 (NY). Kwangtung (Guangdong) Province: Kung P'ing Shan and vicinity, T'aan Faan, Fang Ch'eng district, 15-24 August 1936, Tsang 26664 (A, K, P), and 26666 (A, K, P).

**23. Gmelina obovata** *M. H. Rashid* **sp. nov.** similis *G. spectabilis*, sed comparate minor leaves et sericeus calyx (non puberulus) differt. Type: Malaysia, North Borneo, Sabah, Ranua-Poring road, Ranua, 19 June 1957, *Sinclair et al.* 9263 (L! holotype).

Woody climber to 30m, clambering shrub or small tree to 9m; bole brownish, bark pale brown, inner bark yellow, branchlets quadrangular, becoming terete and glabrous, lenticellate with prominent leaf-scars. **Leaves** decussate-opposite; *petioles* quadrangular, becoming terete, canaliculated above, 1.5-5.5cm long, puberulent, canal pubescent, eventually glabrous; *leaf-blades* subcoriaceous or coriaceous, mostly obovate to oblanceolate, oblong or obovate-oblong, margin entire, glabrous, 7-19cm long, and 4-9(-13)cm wide, apically acute, or acuminate, obtuse to cuspidate, basally cuneate or obtuse, adaxially bright green, glossy, and glabrous, abaxially pale green and dull, glabrous and glandular glaucous, sometimes hirtellous, scattered punctate, a pair of black nectariferous glands at the base of lamina below, much pronounced adaxially; secondaries 3-6 pairs, veinlets transverse or scleriform, prominent beneath. **Inflorescence** terminal or/and axillary, cyme 1-3 flowered, fulvous-tomentose; *bracts* foliaceous, caducous, sessile or subsessile, lanceolate, to 2cm long, 3mm wide, apex acuminate, base attenuate or cuneate, pubescent and glanduliferous above, tomentose beneath; *peduncles* 7-10mm and *pedicles* 3-4mm long, densely strigose. **Flowers** slightly fragrant, 4-5cm long, 1-1.5cm wide; **calyx** pale green, tubular or infundibular, 15-22mm long, 5-15mm broad on top, accresent in fruit, externally ferruginous-sericeous, with few scattered small, black nectariferous glands,

internally tube sericeous or lanate, sometimes glabrous; lobes pubescent or lanate, the rim 5-lobed, sometimes connated each other appears as 4-lobed, lobes narrow triangular or ovate-oblong, apically obtuse or acute to long acuminate, rarely aristate, 4-12mm long, 3-5mm wide at base; corolla long-tubular, white to creamy-white or pale yellow, yellow in throat, externally glabrous or puberulent, and white glanduliferous, tube glabrous inside, inner face of mid-lobes papillose, the tube basally slender, subventricose-ampliate, bilabiate, 5-lobed, upper lip 2-lobed, upper lobes ovate-obtuse or semicircular 8-10mm long, 8-10mm broad at the base, lower lip 3-lobed, the mid-lobe largest 12-15mm long, 8-15mm broad at the base, broadly-ovate, apex acute, the lateral lobes same as upper lobes; stamens 4, didynamous, included; inserted near the base of corolla tube, on top of the slender part; filaments glabrous, longer pairs 15-20mm and shorter pairs 11-15mm long; anthers pendulous, oblong, 2.5-3mm long; ovary ovoid or obovoid, glabrous throughout or apically densely (sometimes sparse) pilose, glabrous elsewhere, 2-3.5mm long, 1.5-2.5mm wide, 4-locular, each cell 1ovulate; style 2-3.5cm long, apically decurved, basally glabrous, apically sparsely stalked-glanduliferous, sometimes upper 2/3 sparsely pilose and stalked-glanduliferous; stigma glabrous or basally sparse-glandular, truncate, obscurely and unequally bifid, the longer lobes 1-2.5mm and others minute. Drupes pale green, creamy yellow, light green to orange, in ripening yellow or lemon yellow, smooth sweet-smelling, oblong or ellipsoid, obovoid, apically truncate, sometimes with small knob on top, 2-4cm long, 1/1.7-2.5cm wide.

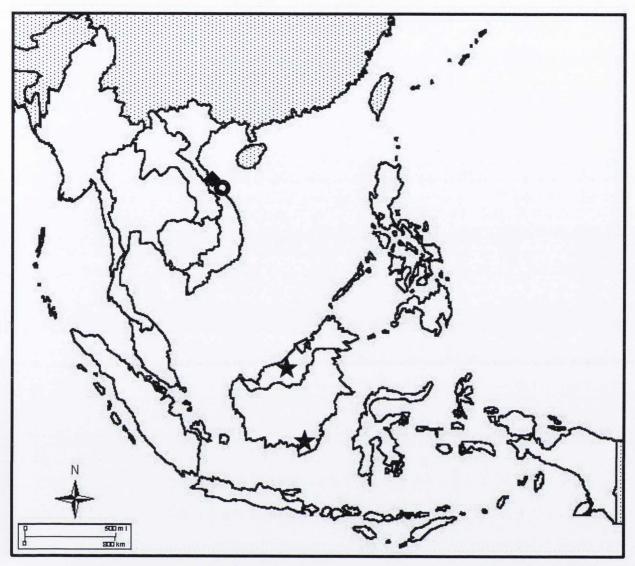
**Note**: This species could be easily confused with *G. spectabilis*; both species have a similar type of inflorescence, calyx and corolla, but *G. obovata* differs in having relatively smaller leaf size, externally sericeous calyx rather than puberulent.

## Key to the varieties of G. obovata

1. Corolla white or creamy-white; calyx tube lanate inside, lobes triangular, apex acuminate	2
- Corolla yellow; calyx tube glabrous inside, lobes ovate-oblong, apex obtuse	var. kutaiensis
2. Ovary apically pilose, glabrous elsewhere	var. obovata
- Ovary glabrous throughout	var. glabrata

## i var. obovata

Woody climber to 30m long, or clambering shrub or small tree to 9m tall; leaves glabrous above, glabrous and glandular glaucous beneath, 7-13cm long, and 4-9(-13)cm wide; flowers white to creamy-white, with dark yellow throat; calyx tube sericeous or lanate inside, lobes tomentose, triangular, apex long-acuminate, 4-7mm long and 3-4mm wide at base; ovary apically sparse to densely pilose, glabrous elsewhere; style basally glabrous, apically stalked glandular; stigma glabrous. **Figure 2.23**.



Map 2.6 Southeast Asian distributions of G. annamensis ( $\blacklozenge$ ); G. borneoense ( $\bigstar$ ) and G. hainanensis ( $\bigcirc$ ).

**Ecology**: secondary forest at roadside; mixed lowland forest; tropical rain forests; montane forests; disturbed forest; along the riverside and gentle slope, near coco plantation; edge of rice fields, hillside; ultramafic; alluvial soil, sandstone. Alt. 30m-1525m. *Flowering & fruiting*: almost throughout of the year.

Distribution: Brunei and Borneo. Map 2.7.

Vernacular names: Akar Inklis (Iban name, Brunei); Korum kum (Dusun Penampang, Sabah); Mangkong (Dusun Tambato, Sabah).

Uses: Unknown.

**Proposed Conservation status:** This species does not have a wide distribution. It is confined to Brunei and Malaysian Borneo. Due to its limited distribution and habitat alterations the species could be considered as Vulnerable (VU).

Etymology: The species epithet refers to its mostly obovate leaf shape.

**Specimens examined**: **Brunei**: Tutong district, Upstream from Belabau, Ladan Hills Forest Reserve between Tutong and Bata Rivers, 30m, 29 March 1990, *Coode et al.* 6379 (KEPONG, K); Temburong district, Batu Apoi, Selapon, Kerangan Batu Semawat, West-north-west of village, 30m, 4º40.518'N 115º11.902'E, 30 January 1994, *Dransfield* 7488 (KEPONG-2 sheets, K, SING); Tutong district, Rambai, Kanpong BEnutan, Jalan Kadit Benutan, 8 July 1996, *Kalat et al.* BRUN 17671 (K); Temburong district, Amo, Ulu Temburong National Park, near park headquarters, *ca.* 75m, 4º33'N 115º9'E, 2 August 2002, *Middleton et al.* 830 (K).

Malaysia: Sabah, Kabayan-Koang, 183-396m, 3 November 1931, Holltum 25116 (BM, K, NY); Tambunan, Tambato, 762m, 23 February 1934, Puasa-Angian 4005 (K, L); Penampang, 21km, Tambunan, 366m, 29 June 1936, Keith 5975 (K); Ranua, near rest house, edge of rice fields, hill side, 610m, 9 May 1955, Collenette 7 (BM); Ranua-Poring road, Ranua, 19 June 1957, Sinclair et al. 9263 (L holotype); Ranua district, Kg. Tontolob, Mile 64, Ranua-Tambunan Road, Trail to Kg. Pinawantai, 731m, 11 June 1980, Leopold & Petrus SAN 92508 (K); Telupid district, Ulu Telupid, Sangai Taviu, 18 May 1984, Amin et al. SAN 60078 (KEPONG, K); Nabawan district, Sg. Maadum, Syt. Benawood, logged area, 18 May 1987, Jimpin SAN 104315 (KEPONG-2 sheets, K); Keningau district, Ulu Sungai Motud, logged area, 16 June 1987, Jimpin SAN 119450 (KEPONG, K); Sepulut district, Labang, Sepulut forest, 14 October 1988, Fidilis SAN 125236 (KEPONG, K); Keningau district, Pisagon, logged area, 11 January 1990, Sumbing SAN 128261 (KEPONG, K); Nabawan district, Syrikat Undan, behind logging area, 10km Jalan Nabawan/Pandowan, 12 February 1990, Fidilis SAN 128110 (K); Amin & Francis SAN 121637 (KEPONG, K); Sipitang district, Meligan Forest Reserve, 1220-1525m, 16 July 1991, Madani SAN 132659 (KEPONG); Pensiangan district, Pensiangan Keyu Forest Reserve, 23 July 1992, Collector unknown SAN 136025 (KEPONG); Kota Belud district, along the trail from Kiau to Tohubang River, 21 September 1993, Madani & Madani SAN 134774 (KEPONG, K). Sarawak, Sri Aman district, Skerang, Entalin, 5 March 1986, Ilias Paie S. 51884 (K).

Indonesia: *Kalimantan*, Kalimantan Timur, around Jelini, along Sungai Belayan, northwest of Tabang, 100-150m, 7 January 1979, *Murata et al.* B-1148 (L); Kalimantan Timur, around Jelini, along Sungai Belayan, northwest of Tabang, 100-150m, 8 January 1979, *Murata et al.* B-1212 (L); East Kalimantan, P.T. ITCI, Road Kenangan to Penajam, at km 6 junction, road to the right, 50m, 25 March 1995, *Kessler et al.* PK 878 (K).

ii. var. glabrata M. H. Rashid var. nov. a var. obovata et var. kutaiensis ovarium glabra (non pilosus) differt.

Type: Indonesia, East Kalimantan (east Borneo), East Kutai, Sangkulirang subdivision, along Menubar Range, 10m, 24 June 1951, *Kostermans* 5427 (holotype K!, isotypes A!, L!).

Climber to 20m tall, 8cm in diameter; branchlets cylindrical; leaves 13-19cm long, and 6.5-11cm wide, glabrous above, glabrous and glandular glaucous beneath; flowers white, with dark yellow throat; calyx tube sericeous or lanate inside, lobes tomentose, triangular, apex long-acuminate, 7-8mm long and 3-4mm wide at base; ovary glabrous throughout; style basally glabrous, apically stalked glandular; stigma glabrous. **Figure 2.24**.

Ecology: Secondary forests; dry land on loam soil with limestone. Alt.10m. Flowering & fruiting: June.

Distribution: Endemic to east Borneo, Indonesia. Map 2.7.

Vernacular name: Unknown.

Uses: Unknown.

Proposed Conservation status: Data Deficient (DD). This species is known only from the type specimens.

Etymology: The epithet, glabrata, refers to its glabrous ovary.

**Specimens examined**: Indonesia: East Kalimantan (east Borneo), East Kutai, Sangkulirang subdivision, along Menubar Range, 10m, 24 June 1951, *Kostermans* 5427 (K-holotype, isotypes A, L).

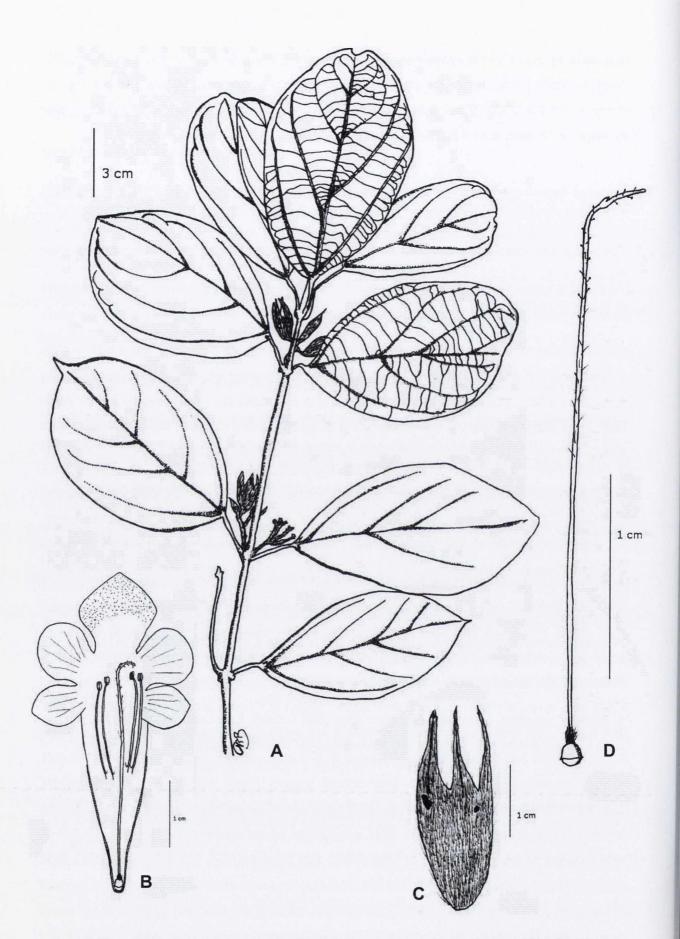


Figure 2.23. Holotype of *G. obovata* var. *obovata*. A habit; B dissected flower; C calyx; D pistil. (all from *Sinclair et al.* 9263, L). Drawn by Cliodhna Ni Bhroin.

iii. var. kutaiensis *M. H. Rashid* var. nov. a var. *obovata* et var. *glabrata* calyx tubus glabra internus (non lanatus), lobis ovatus-oblongus (non triangulus), apices obtusus (non longus-acuminatus) differt. Type: Indonesia, East Kalimantan (east Borneo), Central Kutai, Belanjan Range, G. Kelopok, near Tabang, 100m, 19 April 1955, *Kostermans* 10.521(holotype K!, isotypes BM!, L!, NY!, SING!).

Climber to 20m tall, 8cm in diameter; leaves glabrous above, hirtellous and glandular glaucous beneath, 9.5-18.5cm long and 4-7.5cm wide; flowers pale yellow with dark yellow throat; calyx tube glabrous inside, lobes tomentose, ovate-oblong, apex obtuse, 4-7mm long and 3-4mm wide at base; ovary apically densely pilose, glabrous elsewhere; style upper 2/3 sparsely pilose and stalked glandular; stigma basally sparse glandular. **Figure 2.25**.

Ecology: Yellow sandy soil. Alt. 100m. Flowering & fruiting: April.

Distribution: Endemic to East Borneo, Indonesia. Map 2.7.

Vernacular name: Unknown.

Uses: Unknown.

**Proposed Conservation status:** Data Deficient (DD). This species is known only from the type specimens.

Etymology: The epithet, kutaiensis, refers to its home locality, Kutai.

Specimens examined: Indonesia: East Kalimantan (east Borneo), Central Kutai, Belanjan Range, G. Kelopok, near Tabang, 100m, 19 April 1955, *Kostermans* 10.521 (K-holotype; isotypes- BM, L, NY, SING).

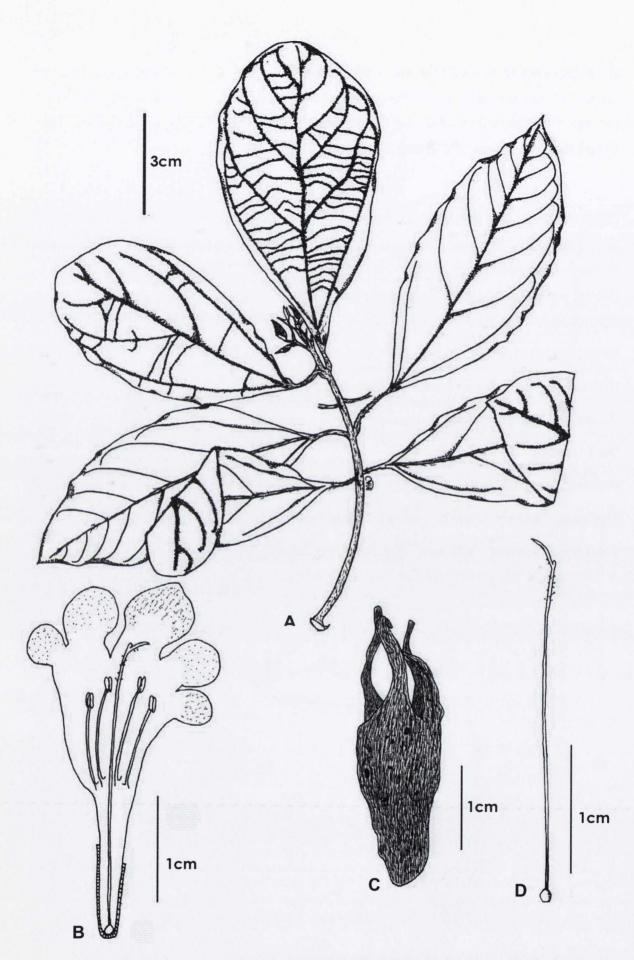
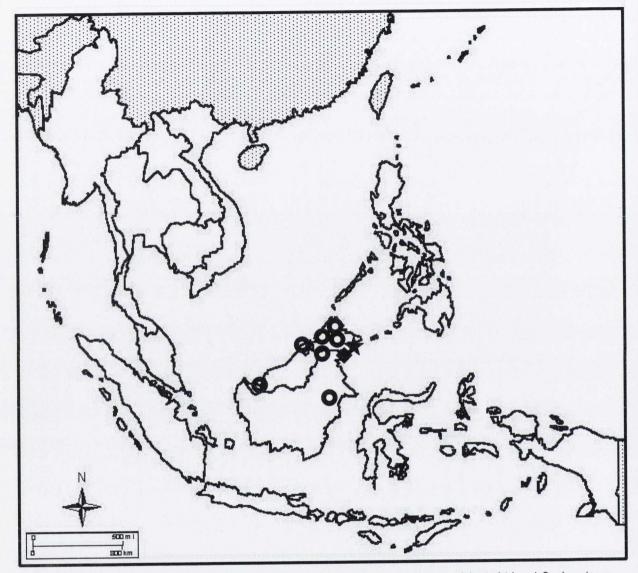


Figure 2.24. Holotype of *G. obovata* var. *glabrata*. A habit; B dissected flower; C calyx; D pistil. (all from *Kostermans* 5427, K). Drawn by Cliodhna Ní Bhroin.



Figure 2.25. Holotype of *G. obovata* var. *kutaiensis*. A habit; B dissected flower; C calyx, a external calyx lobesurface; b internal calyx lobe surface; D pistil. (all from *Kostermans* 10.521, K). Drawn by Cliodhna Ni Bhroin.



**Map 2.7** Southeast Asian distributions of *G. obovata* var. *obovata* ( $\bigcirc$ ); *G. obovata* var. *glabrata* ( $\bigstar$ ) and *G. obovata* var. *kutaiensis* ( $\blacklozenge$ ).

**24. Gmelina spectabilis** *Ridl. ex M. H. Rashid & A. J. Paton* **sp. nov.** ab aliis gregis foliis grandis; calyx infundibularis et acuminatus ad longior-acuminatus differt. Type: Malaysia, Borneo, Sarawak, Kuching, 9 January 1895, *Haviland & Hose* 919<sup>K</sup> (holotype K!).

Straggling or climbing shrub, or woody climber, ca. 7m high, stem ca. 3cm diameter, branchlets quadrangular, greyish green or pale grey, becoming terete and glabrous, lenticellate with prominent leaf-scars. Leaves decussate-opposite; petioles quadrangular, canaliculated above, 1.5-7cm long, puberulent, eventually glabrescent or glabrous, leaf-blades subcoriaceous or coriaceous, broadly elliptic to obovate, oblong or obovate-oblong to oblanceolate, rarely obcordate or oval, margin entire, 11-20(-25-29)cm long, and 7-11(-16)cm wide, apically acute, acuminate or obtuse to cuspidate, rarely retuse, basally cuneateauriculate, glabrous above, glabrescent and glandular glaucous, scattered punctuate beneath, a pair of black nectariferous glands at the base of lamina below, much pronounced adaxially; secondaries 3-6 pairs, prominent beneath; veinlets transverse or scleriform. Inflorescence terminal or/and axillary, cyme 1-3 flowered, puberulent and white glanduliferous; *bracts* foliaceous, caducous, sessile or subsessile, lanceolate, to 1cm long, apically acute, basally attenuate or cuneate, pubescent and glanduliferous above, pubescent beneath; peduncles 7-8mm and pedicles 2-3mm long, densely pubescent. Flowers slightly fragrant, large, 3-5cm long; calyx green, infundibular, 10-18mm long, 3-7mm broad on top, accresent in fruit, externally glandular and puberulent, lobe margin pubescent, with apically numerous minute black glands, internally pubescent, the rim 5-lobed, lobes deltoid, apically acute to acuminate, 3-4mm long, 2-3mm wide; corolla narrow-infundibular, white or cream with yellowish streak inside, externally glabrescent or glabrous, lobes glanduliferous, internally tube glabrous, lobes glanduliferous, the tube basally slender, subventricoseampliate, bilabiate, 5-lobed, upper lip 2-lobed, upper lobes semicircular 6-8mm long, 7-11mm broad at the base, lower lip 3-lobed, the middle lobe largest 12mm long, 8-11mm broad at the base, broadly-ovate, apically acute, lateral lobes similar to upper lobes; stamens 4, didynamous, included; inserted near the base of corolla tube, on top of the slender part; filaments glabrous, longer pairs 14-17mm and shorter pairs 13-15mm long; anthers pendulous, oblong, 3-4mm long; ovary ovoid, apically densely pilose, glabrous elsewhere. 2-3mm long, about 2.5mm wide, 4-locular, each cell 1-ovulate; style 2-3.5cm long, apically decurved, basally glabrous or puberulent, apically stalked-glanduliferous; stigma truncate, obscurely and unequally bifid, the longer lobes 1.5mm and others minute. Drupes yellowish green, or pale green, oblong, or obovoid, 2-5cm long, 1.5-2.5cm wide. Figure 2.26.

**Ecology**: Secondary forest; secondary vegetation; riverine forest; hillside; roadside; sandy gravel; light yellow sandy soil; yellow clayey sandy soil; clay rich alluvium river bank. Alt. 5-61m. *Flowering*: January to May; *Fruiting*: July to October.

Distribution: Brunei and Malaysian Borneo (Sabah and Sarawak). Map 2.8.

Vernacular names: Akar Engkalis (Iban name, Brunei); Akar Enkeleh (Iban name, Sarawak); Akar Salukar (Sandakan, Sabah).

**Uses**: Crushed and boiled stem & bark extract is taken to ease labour during childbirth (Sarawak, *Chai et al.* S.37616).

**Proposed Conservation status:** This species does not have a wide distribution, confined to Brunei and Malaysian Borneo (Sabah and Sarawak). Due to it's limited distribution and habitat alterations the species could be considered as Vulnerable (VU).

**Note**: This species is readily identifiable by its larger leaves, infundibular calyx with acuminate or long acuminate lobes.

Ridley identified the specimen as *G. spectabilis* but the species was not validly published. Hence, the name is validated here and described.

Specimens examined: Brunei: Belait district, Bukit Sawat, Kampong Merangking, Jalan Bukit Sawar-Merangking, 5m, 28 July 1997, *Ahmad et al.* BRUN 18370 (SING); Bukit Sawat, Jalan Merangking-Buau, 29 July 1997, *Said & Eri* BRUN 18573 (SING). **Malaysia**: *Sabah*, Ranua district, 23 July 1988, *Amin & Francis* SAN 121637 (KEPONG); Sandakan, L. Datu district, Malambabula Nam Hing Co., 275m, 28 November 1962, *Chai* SAN.31738 (K). *Sarawak*, unknown locality, undated 1865-68, *Beccari* 2950 (K); near Kuching, August 1892, *Haviland* 919<sup>I</sup> (K); Kuching, September 1892, *Collector unknown* s.n. (K); Betong division, Saribas, Spaoh, Kalong, May 1893, *Haviland* 1547 (K); Kuching, 1 November 1894, *Haviland & Hose* 919L (K); Kuching, 9 January 1895, *Haviland & Hose* 919M (GH); Kuching, 9 January 1895, *Haviland & Hose* 919<sup>K</sup> (K holotype); Kapit district (7<sup>th</sup> Division), Kuching, Batu Kitang, January 1964, *Ashton* S.22088 (K); Sg. Banyau, Ng. Mujong, 6 May 1976, *Chai et al.* S.37616 (KEPONG); 4<sup>th</sup> division, Ulu Sungai Berar, Gunong Mulu National Park, 61m, 3 October 1977, *Chai* S. 39629 (KEPONG, K, L, MO).

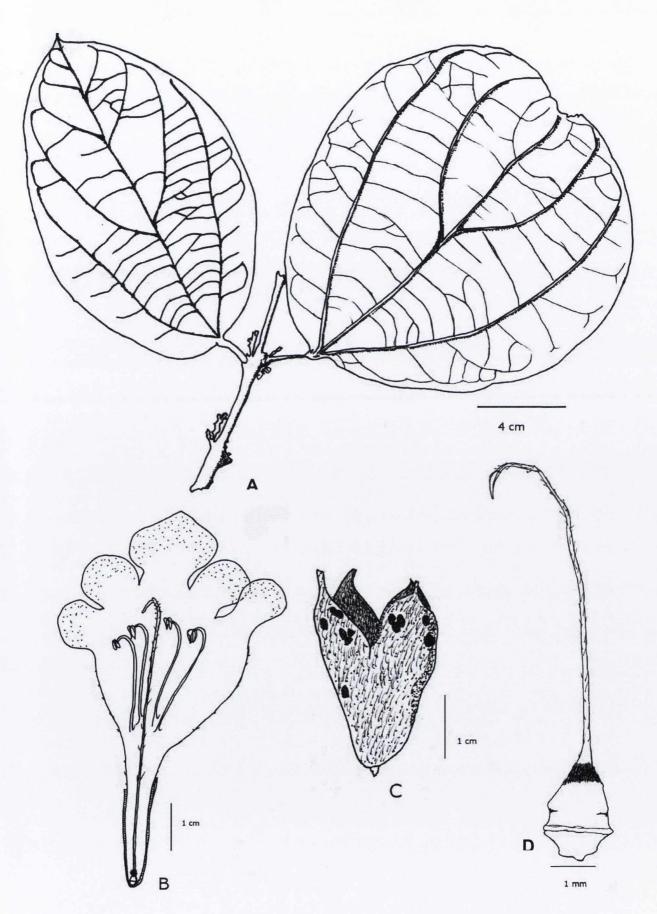


Figure 2.26. *G. spectabilis*. A habit; B dissected flower; C calyx; D pistil. (all from *Haviland & Hose* 919K, K). Drawn by Cliodhna Ní Bhroin.

**25. Gmelina tubularis** *M. H. Rashid* **sp. nov.** Ab aliis gregis *Gmelina* calyx longior-tubular vel tubularcampanulatus, 1.5-3.5cm longa et 9-18mm lata, cum ore constricta; corolla angustus-infundibularis cum fere depressus in calyx differt. Type: Indonesia, Kalimantan (South Borneo), Bukit Raya, Tumbang Atey, 75m, 113°2'E 1°2'S, 29 January 1983, *Veldkamp* 8453<sup>A</sup> (holotype L!- 2 sheets).

Climber to canopy height ca. 30m; branchlets terete, densely ferruginuous-tomentose when young, finally glabrous lenticellate, leaf scar prominent. Leaves decussate-opposite; petioles sub-terete, 1.5-4.5cm long, sulcate above, puberulent or densely ferruginuous-pilose, glanduliferous; leaf-blades sub-coriaceous or coriaceous, elliptic, ovate or obovate to oblanceolate, oblong or oval, 8.5-17cm long, 4-8.5cm wide, margin entire and glabrous or ciliate, apex acute, acuminate to long-acuminate or cuspidate, rarely obtuse, base cuneate or attenuate or auriculate, 2-5 black nectariferous glands at the base of lamina below, much pronounced adaxially, glabrescent to glabrous, midrib and venation subglabrous to densely pilose; abaxially glabrous and white glanduliferous matted, or pubescent, scattered punctuate, midrib and venation glabrous or densely ferruginous-pilose; secondaries 3-5 pairs, veinlets transverse, distinct beneath. Inflorescence terminal and axillary, solitary or paired, 1-3 flowered, puberulent or ferruginous-pilose, peduncles densely hirsute or pilose, 1-3cm long, bracts foliaceous, green, persistent or caducous, sessile, ovate or ovate to elliptic or elliptic-lanceolate, 9-22mm long, 4-10mm wide, apex acute or acuminate to long acuminate, adaxially puberulent to pubescent and glanduliferous, abaxially glabrous or puberulent; calyx green, longtubular or tubular-campanulate with short mouth, 1.5-3.5cm long and 9-18mm wide, externally glabrous to subglabrous or densely ferruginous-pilose and glanuduliferous, internally tube glabrous, lobe inner faces densely tomentose, bilabiate, unequally 5-laciniate lobed, lobes deltoid, (3-)9-12mm long, (1.5-)3-7mm wide at the base, apically acuminate, sometimes connated lobe appear as 4-lobed, accresent in fruit; corolla white or pale yellow with darker yellow guides on lower side of throat, narrow infundibular, 3-4cm long, 1-1.5cm wide, basally slender, subventricose-ampliate, almost sunken into the calyx, glabrous except inner face of mid-lobe papillose, 5-lobed, upper lip bi-lobed, lobes small, semicircular, 10-11mm long, 8-9mm wide at the base; lower lip 3-lobe, the mid-lobe largest, 14-15mm long, 9-10mm wide at the base, obovate-obtuse, two lateral lobes similar to upper lobes; stamens 4, didynamous, included, inserted near the base of corolla tube, top of the lower slender part; *filaments* filiform, terete, apically incurved, glabrous, longer pairs 1.5-1.7cm and shorter pairs 1-1.3cm long; anthers 3-4mm long; ovary ovoid-oblong, to 3mm long and 1-1.5mm wide, glabrous, 4locular, each locule 1-ovulate; style 2.5-3cm long, included, filiform, terete, basally glabrous, apically sparsely glanduliferous; stigma truncate, glabrous, obscurely and unequally bi-lobed, longer lobe 1-2mm long, other minute. Drupes green then yellow, obovate or ovoid-globose, 3-3.5cm long and 1.5-2.5cm wide, glabrous, fleshy.

**Note**: This species differs from all of its congeners in having a glabrous or rarely pilose long-tubular or tubularcampanulate calyx with a short mouth, 1.5-3.5cm long and 9-18mm wide; narrow-infundibular corolla which is almost sunken into the calyx.

#### Key to the subspecies of G. tubularis

- Leaves glabrous and glanduliferous, petiole and inflorescence puberulent; calyx glabrous or subglabrous; corolla white; fruits obovate, 3X1. 5cm
   i subsp. tubularis
- Leaves abaxially pubescent and glanduliferous, petiole and inflorescence densely ferruginuous-pilose; calyx densely ferruginous-pilose; corolla pale yellow; fruits ovoid-globose, 3.5X2. 5cm **ii subsp. pilosa**

#### i subsp. tubularis

Leaves elliptic, ovate or obovate to oblanceolate, apex acuminate to long-acuminate or cuspidate, 8.5-17cm long, 4-8.5cm wide, margin glabrous, abaxially white glanduliferous matted and scattered punctuate; petioles 1.5-4.5cm long, puberulent and glanduliferous. Inflorescence puberulent, calyx tubular or campanulate, 1.5-3.5cm long and 9-18mm wide, externally glabrous; corolla white with darker yellow on lower side of throat; fruits obovate, 3cm long and 1.5cm wide. **Figure 2.27**.

**Ecology:** Primary forest or much disturbed dipterocarp forest. Shallow valley along ridge, moderate slope, damp Igneous (Andesitic) derived soils. Alt. 75m-850m. *Flowering & fruiting:* January to July.

Distribution: Endemic to Borneo. Map 2.8.

Vernacular name: Unknown.

Proposed Conservation status: Data Deficient (DD). Known only from very few specimens.

Etymology: The epithet, tubularis, refers to the long-tubular calyx.

**Specimens examined**: Indonesia: Kalimantan (South Borneo), Bukit Raya, Tumbang Atey, 75m, 1°2'S 113°2'E, 29 January 1983, *Veldkamp* 8453<sup>A</sup> (L- 2 sheets, holotype). **Malaysia**: Sarawak, Kapit (7<sup>th</sup>) division, Foothills of Bukit Batu, Balang/Balleh watershed ridge, extreme headwaters of Balleh river, *ca.* 850m, 1°35'N 114°33'E, 7 July 1969, *Anderson & Ilias Pa'ie* S.28480 (K); Sarawak, Kapit (7<sup>th</sup>) division, Ulu Batang Balui, Balanga, Ulu Sungai, Kebhor, 28 March 1989, *Ching* S.62317 (K).

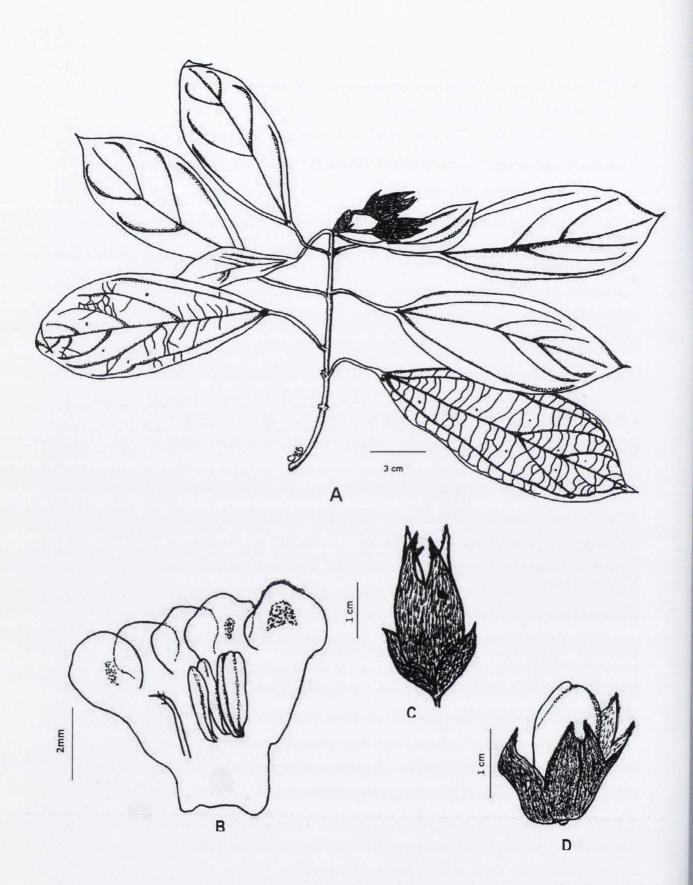


Figure 2.27. *G. tubularis* subsp. *tubularis*. A habit; B dissected immature flower; C calyx with persistent bracteoles; D drupe with persistent calyx. (all from *Veldkamp* 8453<sup>A</sup>, L). Drawn by Cliodhna Ní Bhroin.

ii subsp. **pilosa** *M. H. Rashid* **subsp. nov.** a subsp. *tubularis* foliis adaxialis glabrescent (non glabrous), abaxialis dense ferruginous-pilosus et glanduliferous (non glabrate et glanduliferous); inflorescence et calyx ferrugineus-pilose (non puberulent vel glaber); corolla pallidus-fulvous (non alba); fructus ovoid-globose, 3.5X2.5cm (non obovate, 3X.5cm) differt. Type: Indonesia, Kalimantan (South Borneo), Kab. Kotawaringin Timur, 62km from Sangai, *ca.* 100m, 112°31'E 1°29'S, 28 September 1996, *Argent et al.* 9627 (holotype K!).

Leaves oblong or oval, apex acute, 10.5-13cm long, 7.5-8.5cm wide, margin ciliate, abaxially pubescent and white glanduliferous; *petioles* 2-3cm long, densely ferruginuous-pilose and glanduliferous; Inflorescence ferruginous-pilose; calyx long-tubular, 3-3.5cm long and 10-15mm wide, externally densely ferruginous-pilose and glanuduliferous; *corolla* pale yellow with darker yellow on lower side of throat; fruits ovoid-globose, 3.5cm long and 2.5cm wide. **Figure 2.28**.

**Ecology:** Roadside in logged over lowland mixed dipterocarp forest. Alt. *ca*.100m. *Flowering & fruiting:* September.

Distribution: Endemic to South Borneo. Map 2.8.

Vernacular name: Unknown.

Proposed Conservation status: Data Deficient (DD). This variety is only known from the type specimen.

Etymology: The epithet, *pilosa*, refers to its pilose petiole, inflorescence, and calyx.

**Specimens examined: Indonesia**: Kalimantan (South Borneo), Kab. Kotawaringin Timur, 62km from Sangai, *ca.* 100m, 112º31'E 1º29'S, 28 September 1996, *Argent et al.* 9627 (K- holotype).



2000

#### Holotype of Gmelina tubularis subsp. pilosa M. H. Rashid Determinanti: M. Hana-wr-Roshid Date: 21/07/2008 TCD

# LNC H1087198 FLORA OF CENTRAL KALIMANTAN

gradina spectabilis Ridley

No. 9627 Date: 28.9.96

Family: Bignopiaceae Verben

DET SAHKINS

Name: ct. Nycucatos? Grashin a

Collector: G. Argent, A. Saridan, P. Wilkie.

Locality: Km 62 from Sangai, Kab. Kotawaringin Timur, c. 1°29'S 112°31'E.

Habitat: Roadside in logged over lowland mixed dipterocarp forest.

Alt. c. 100m.

Notes: Liana. Flowers pale yellow with darker yellow guides on lower side of throat. Calyx persistant on fruit which is green passing to pale yellow.

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Figure 2.28. Holotype of G. tubularis subsp. pilosa (Argent et al. 9627, K).

**26.** Gmelina uniflora *Stapf* in Hook. Icon. PI. 24: PI. 2391 (1895). Durand & Jacks, Ind. Kew. Suppl. 1, Imp.1: 185 (1902); H. J. Lam, Verbenac. Malay. Arch. 217 (1919); Bakh., in Lam & Bakh., Bull. Jard. Bot. Buitenzorg 3(3): 65 (1921); Merr. Bibliog. Enum. Born. PI. 515 (1921); Stapf, Ind. Lond. 3: 299 (1930); Fedde & Schust., Justs Bot. Jahresber. 53(1): 1074 (1932); Durand & Jacks, Ind. Kew. Suppl. 1, Imp. 2: 185 (1941); Mold. Known Geogr. Dist. Verbenaceae, ed. 1: 65 & 93 (1942) and ed. 2: 146 & 186 (1949); Durand & Jacks, Ind. Kew. Suppl. 1, Imp. 3: 185 (1959); Mold. Résumé 192, 193, & 456 (1959); Mold. Fifth Summ. 1: 325 (1971) and 2: 880 (1971); Mold. Phytol. Mem. 2: 315 & 549 (1980); Mold., Phytologia 55 (6): 311 (1984); Coode *et al.* Checklist of FI. PI. Brun. 331 (1996). Type: Indonesia, South Kalimantan, Bangarmassing (Banjarmasin), 1857-1858, *Motley* 1204 (holotype K!).

A small tree; branchlets terete, moderately yellowish-brown when young, glabrescent later, sparsely lenticellate, leaf scar prominent. Leaves decussate-opposite, subcoriaceous, petioles terete, 1.5-2.5cm long, fulvous-puberulent, eventually glabrescent, sparsely glanduliferous, canaliculated above, leaf-blades broadly elliptic or obovate-elliptic, 9.5-15cm long, 7.5-10cm wide, margin entire, apically obtuse or shortly acuminate or acute, basally rounded, abrupt towards the petiole with a pair of black nectariferous glands at the base of lamina below, much pronounced adaxially, glabrous, and shining above, glandular glaucous and scattered punctuate beneath, main veins sparsely short pilose, secondary veins 4-5 pairs, veinlets transverse, distinct beneath. Inflorescence axillary, single-flowered, pubescent and white glanduliferous; bracts foliaceous, persistent, sessile, broadly-ovate, apex acuminate, base rounded, 8-10mm long, 4-6mm wide, adaxially fulvous-velutinuous and sparsely glandulose, abaxially glabrous. Flowers long pedicellate, pendulose, 3.5-4.5cm long, pedicel 1-1.5cm long; calyx campanulate, 2-2.5cm long, 0.7-1.5cm wide on top, slightly extended in fruit, externally appressed rufous-tomentose, and glandular hoary, with numerous, very small, black, sunken nectariferous glands, internally tube glabrous, inner face of lobes densely tomentose, 5-lobed, often some connate to each other, lobes large, deltoid, 7-10mm long, 5-7mm wide at base, apically acute; corolla infundibular, subventricose-ampliate, pale-yellowish, somewhat white, externally pilose and glanduliferous, basally glabrous, internally sparsely glandular; bilabiate, 5-lobed, upper lip bi-lobed, lobes small, semicircular; lower lip 3-lobe, middle lobe enlarged to 1cm long, oblong-obtuse, lateral lobes semicircular, the tube 2.5cm long; stamens 4, didynamous, included, inserted from about the middle of the corolla tube near the top of lower slender part; filaments filiform, sparsely glandular, longer pair 1.8cm long, shorter pair 1.5cm long; anthers elliptic, 2.5mm long; style slender, ca. 3cm long, glabrous with apically sparsely glanduliferous; stigma subulate, obscurely bi-lobed, lobes unequal; ovary ovoid-globose, apically pilose, glabrous elsewhere, 4locular with one ovule in each locule. Fruits unknown. Fig. 2.29.

Distribution: Endemic to South Kalimantan, Indonesia. Map 2.8.

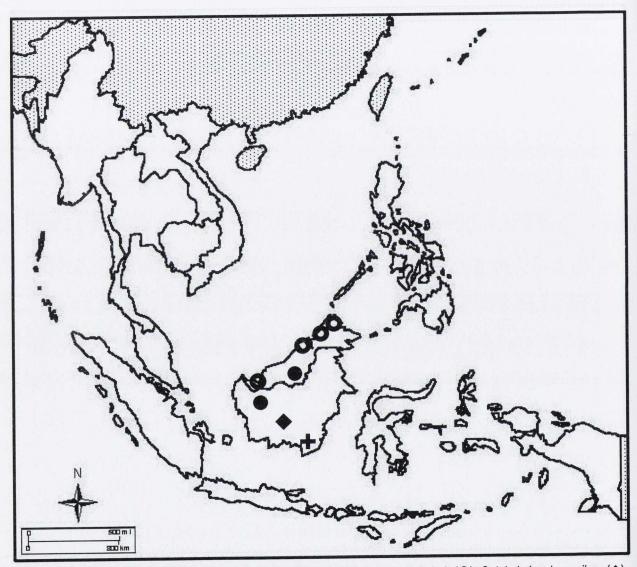
Vernacular name: Not known.

Uses: Not known.

**Proposed Conservation status:** This species is only known from the type specimens collected in 1857-58, and there are no recent collections. The species is likely to be extinct due to habitat alterations. EX.

Note: No ecological information has been recorded.

**Specimens examined**: Indonesia: South Kalimantan, Bangarmassing (Banjarmasin), 1857-1858, *Motley* 1204 (K holotype).



**Map 2.8** Southeast Asian distributions of *G. spectabilis* ( $\bigcirc$ ); *G. tubularis* subsp. *tubularis* ( $\bigcirc$ ); *G. tubularis* subsp. *pilosa* ( $\blacklozenge$ ) and *G. uniflora* ( $\blacklozenge$ ).

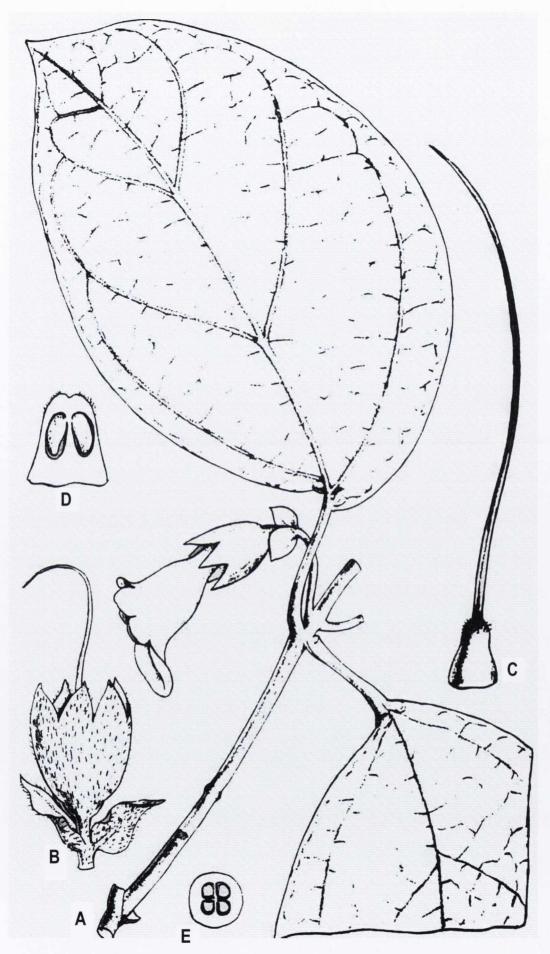


Figure 2.29. G. uniflora. A habit; B calyx with persistent bract; C pistil; D vertical section of ovary; E transverse section of ovary. [Taken from Hook. Icon. Pl. 24: Pl. 2391 (1895)].

# 2.5 Discussion

The genus *Gmelina* has not until now been revised for Southeast Asia. The monographic work of Moldenke (1984) mostly was a compilation of all published species.

In the present investigation a total of 31 *Gmelina* taxa, consisting of 26 species, 1 subspecies and 4 varieties are recognised in Southeast Asia (Table 2.1). Among these, 7 species, 1 subspecies, and 3 varieties have been reported as new to science: *viz. G. chindwinse* M. H. Rashid & J. Parnell, *G. spectabilis* M. H. Rashid & A. J. Paton, *G. obovata* M. H. Rashid, *G. obovata* var. *glabrata* M. H. Rashid, *G. obovata* var. *kutaiensis* M. H. Rashid, *G. parnellii* M. H. Rashid, *G. palawensis* var. *matanoeca* M. H. Rashid, *G. rotundifolia* M. H. Rashid & J. Parnell, *G. tubularis* M. H. Rashid, *G. tubularis* subsp. *Pilosa* M. H. Rashid & A. J. Paton, and *G. yangonensis* M. H. Rashid.

Two taxa are elevated to varietal and specific rank respectively, *G. philippensis* f. *transitoria* Moldenke to *G. elliptica* var. *transitoria* (Moldenke) M. H. Rashid, and *G. uniflora* var. *villosa* Bakh. to *Gmelina borneoense* M. H. Rashid. Due to the prior use of the epithet "villosa" in *Gmelina villosa* Roxb., and *G. asiatica* L. var. *villosa* (Roxb.) Bakh. (valid name *Gmelina elliptica* Smith) a new name is needed and *Gmelina borneoense* is chosen. *G. balansae* Dop is merged with *G. racemosa* (Lour.) Merr.

*G. chindwinse*, *G. rotundifolia*, and *G. yangonensis* are endemic to Myanmar; *G. parnellii* is endemic to Thailand; two species, namely *G. borneoense* and *G. tubularis* are confined to Borneo; *G. spectabilis* is distributed in Brunei, Sabah and Sarawak; *G. obovata* is confined to Brunei and Borneo. *G. tubularis* subsp. *pilosa* is endemic to South Kalimantan; two East Kalimantan varieties are, *G. obovata* var. *glabrata*, and *G. obovata* var. *kutaiensis*; *G. palawensis* var. *matanoeca* is endemic to Celebes Islands, Indonesia.

Two species, *G. lepidota* and *G. tonkinensis* are recognised in Indonesia for the first time, hence, are new records for this territory.

Indonesia shows the greatest center of *Gmelina* diversity containing 11 species, 1 subspecies, and 3 varieties, almost all of which are endemic to this territory. Thailand has the second largest diversity with 4 endemic species, followed by Myanmar and Malaysia (3 endemic species), Vietnam (2 endemic species), and a single variety *G. elleiptica* var. *transitoria* is confined to the Guimaras Islands, Philippines.

The recognition of more than these taxa would be difficult to justify because many species are very morphologically variable. Any keys to more narrowly circumscribed taxa would be unworkable. For example, *G. balansae* differs from *G. racemosa* only in the degree of hariiness on the petiole and calyx; however these characters are not consistent. Therefore, *G. balansae* was not considered as a separate species.

# Infrageneric Classifcation

Based on bracts character alone Briquet (1895) divided the genus into two sections: monotypic *Bracteosae*, and *Microstromatae* (includes all species except *G. philippensis*). This infrageneric classification has not been widely Taken subsequently. The present study revised this classification and, based on calyx characters, the genus is divided in two sections: section *Asiaticum* M. H. Rashid & J. Parnell and section *Annameticum* M. H. Rashid & J. Parnell. (Table 2.1).

# 2.6 Conclusions

This chapter has proposed a new infrageneric classification of the genus *Gmelina*. It has provided a comprehensive and up to date taxonomic treatment of Southeast Asian *Gmelina* with keys to the species and varieties, detailed descriptions and up to date nomenclature, typifications, ecological information, conservation status, uses, illustrations or images, and distributional maps. The outcome of the work will be modified and submitted to *Flora Malesiana* and *Flora of Thailand*; and will contribute to the *Flore du Cambodge, Flore du Laos et du Vietnam*.

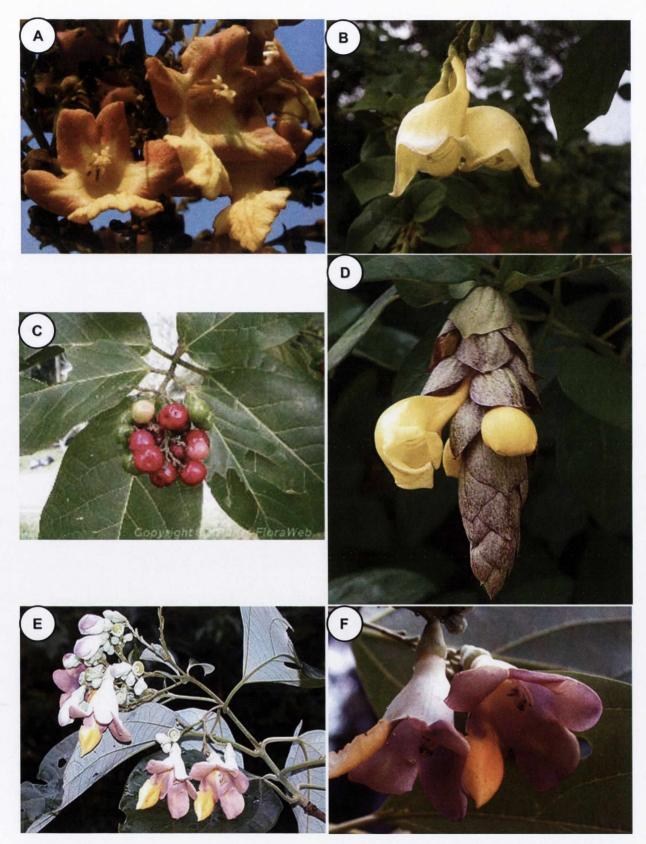
Table 2.1 List of *Gmelina* species recognised in Southeast Asia in the present investigation.

Section Asiaticum M. H. Rashid & J. Parnell sect. nov. (19 species and 2 varieties)

- G. arborea Roxb.
- G. asiatica L.
- G. attenuata Fletcher
- G. chindwinse M. H. Rashid & J. Parnell sp. nov.
- G. dalrympleana (Muell) H. J. Lam
- G. elliptica Smith
- G. elliptica var. transitoria (Moldenke) M. H. Rashid stat. & var. nov.
- G. lepidota Scheff.
- G. misoolensis Moldenke
- G. moluccana (Blume) Backer
- G. palawensis H. J. Lam
- G. palawensis var. matanoeca M. H. Rashid var. nov.
- G. paniculata Fletcher
- G. parnellii M. H. Rashid sp. nov.
- G. philippensis Cham.
- G. racemosa (Lour.) Merr.
- G. rotundifolia M. H. Rashid & J. Parnell sp. nov.
- G. schlechteri H. J. Lam
- G. tomentosa Fletcher
- G. tonkinensis Moldenke
- G. yangonensis M. H. Rashid sp. nov.

Section Annameticum M. H. Rashid & J. Parnell sect. nov. (7 species, 1 subspecies, and 2 varieties)

- G. annamensis Dop
- G. borneoense M. H. Rashid stat. & nom. nov.
- G. hainanensis Oliv.
- G. obovata M. H. Rashid sp. nov.
- G. obovata var. glabrata M. H. Rashid var. nov.
- G. obovata var. kutaiensis M. H. Rashid var. nov.
- G. spectabilis Ridl. ex M. H. Rashid & A. J. Paton sp. nov.
- G. tubularis M. H. Rashid sp. nov.
- G. tubularis subsp. pilosa M. H. Rashid subsp. nov.
- G. uniflora Stapf



**Figure 2.30**. A. Inflorescence of *G. arborea* (www.kepu.net.cn/); B. Inflorescence of *G. asiatica* (www.mytho-fleurs.com); C. Inflorescence of *G. dalrympleana* (http://floraweb.nparks.gov.sg); D. *G. philippensis* (www.toptropicals.com/pics) E & F. *G. racemosa* (Pooma, www.dnp.go.th).

# CHAPTER 3

# Anatomical Investigations

# 3.1 Introduction

Plant anatomy is one of the oldest botanical fields initiated by the microscopical studies of Nehemiah Grew and Marcello Malpighi in 1671 (Morton 1981; Mauseth 1988). In the middle 1800's systematic anatomy had its beginning with the contributions of Sanio, Radlkofer, Vesque and others (Dickison 1975). Application of the anatomical method toward the solution of systematic problems was strongly advocated by Fristch (1903). The first comprehensive, systematic summary of anatomical information was provided by Hans Solereder, whose "*Systematic Anatomy of the Dicotyledons*" in two volumes which was published in English in 1908. These landmark volumes provided the basis of all subsequent work on comparative vegetative anatomy and are still indispensable reference sources. In 1950, a monumental work "*Anatomy of the Dicotyledons*" by C. R. Metcalfe and L. Chalk appeared in two volumes, again dealing with aspects of vegetative anatomy, although emphasizing wood structure as a systematic and phylogenetic tool (Dickison 1975).

The earlier taxonomists relied on externally visible morphological features, particularly of the flower and used them as the basis of their classification systems. But it is felt that the plants have to be studied in their entirety, to arrive at a more plausible, reasonable and meaningful conclusion for judging their taxonomic status, affinities and phylogeny (Reddy and Radhakrishnaiah 1991).

Anatomical characters of plants have been employed for systematic purposes for over 150 years (Judd *et al.* 2008), and they are often extremely useful in solving problems of phylogenetic relationships because they can often suggest with greater confidence, the homologies of morphological character states, and they can help in the interpretation of evolutionary directionality (Stuessy 2009).

Metcalfe (1968) has stated that anatomy of the vegetative organs of flowering plants can be taxonomically useful in the following ways: 1) the identification of fragmentary material; 2) the preliminary identification of herbarium specimens; and 3) as an aid toward establishing the interrelationships of taxa at and above the species level.

It is generally realized that anatomical characters are just as valuable as morphological ones, and must not be neglected. Some anatomical features obtained from pollen, wood, leaf epidermis and cuticle, trichomes and stomata, and petioles are diagnostic and now commonly used in routine identification, rather than being confined to use in problems of phylogeny or classification (Stace 1989).

Nowadays virtually every anatomical aspect of plants has been studied by taxonomists, and the quantity of information accumulated is enormous (Stace 1989). Vegetative anatomical characters have been used with more regularity than floral ones. If additional data are required to solve a taxonomic problem, then looking

inside the leaves, stems and roots could potentially yield different information than that from reproductive organs (Stuessy 2009).

Leaves are extremely varied anatomically and provide numerous significant systematic data (Carlquist 1961; Dickison 1975; Stuessy 2009). Within the leaves, data can be obtained either from the petiole, blade or cotyledons.

## 3.1.1 Epidermis

Epidermal features are of considerable taxonomic importance. The *epidermis* varies in the number of cell layers, the size and shape of individual cells, the thickness of cell walls, and the occurrence of papillae or the various kinds of hairs. These epidermal features provide useful evidence for plant identification (Metcalfe and Chalk 1950; Judd *et al.* 2008).

Trichomes are epidermal outgrowths of considerable value for taxonomic purposes. The numbers of species that are completely devoid of trichomes represent a minority of the Magnoliophyta and environmental conditions influence more the length, size and density than types of trichomes (Duarte & Lopes 2005). These outgrowths play a role in plant defense especially with regard to phytophagous insects, avoiding insect feeding and oviposition responses, and the nutrition of larvae (Metcalf & Chalk 1979). They may be involved in the regulation of temperature and water-repellency as well (Neinhuis & Barthlott 1997).

Leaf vestiture has long been used as a character of prime importance in the identification of vegetative material (Hardin 1981). The leaf epidermis is generally a useful character for the classification and identification of species and genera, and for the discussion of relevant phylogenetic problems (Stace 1984; Jones 1986; Baranova 1992; Chen *et al.* 2008).

Families may frequently be recognised by the occurrence of one or more distinctive types of hair or trichome. Trichomes may occur on the entire leaf surface, or may be restricted to certain areas, or at the margins (Rudall 1992). Trichome characters are very variable and are of most value for the determination of species or genera (Metcalfe and Chalk 1950). Trichomes have been most employed taxonomically to compare species within genus (Hannan 1988; Länger *et al.* 1995; Zarre 2003; González & Arbo 2004). For example, trichome structure taxonomically is very useful in the large genus *Hedera* L. (Araliaceae). The Himalayan species *H. nepalensis* Koch is distinguished from its European relative *H. helix* L. in having scaly trichomes as against stellate (Singh 2004).

The epidermis contains pores or stomata. Stomata are usually classified by the relationships of their subsidiary cells. Arrangement of the subsidiary cells is taxonomically very valuable. A variety of stomatal forms occur in vascular plants. On leaves, stomata may be found on both surfaces (amphistomatic), or only on the abaxial surface (hypostomatic), or in rare cases (such as on floating leaves) on the adaxial surface (epistomatic) only (Rudall 1992). Vesque (1889) distinguished four main stomatal types, which he named after the families in which they are well exemplified or first observed: *Ranunculaceous type*, *Cruciferous type*, *Rubiaceous type*, and *Labiatous or Caryophyllaceous type*. Metcalfe and Chalk (1950) discussed the

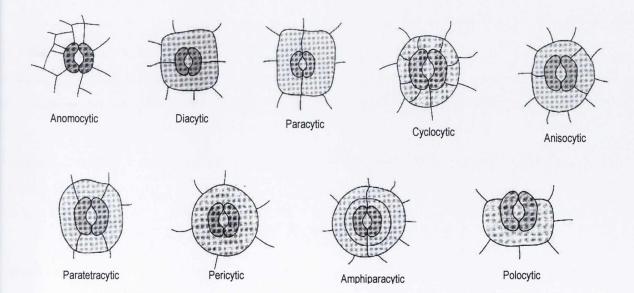
difficulties of Vesque's technical terms, indicating that the "the types occur in many other families besides those after which they are originally named" and proposed new terminology, such as, anomocytic (*Ranunculaceous*), anisocytic (*Cruciferous or Brassicaceous*), diacytic (*Caryophyllaceous*), and paracytic (*Rubiaceous*). They added a fifth type, actinocytic to the four classic types. Stace (1965) described the different stomatal types and included sixth type, cyclocytic. In 1961, Metcalfe recognised a seventh stomatal type, tetracytic. Van Cotthem (1968) in his doctoral thesis (cited in Van Cotthem 1970) proposed five new stomatal types hypocytic, pericytic, desmocytic, polocytic and staurocytic in the ferns, which brings the total number of well-defined stomatal types to 12. In 1970, Van Cotthem added three further types, hexacytic, epicytic and hemiparacytic. Stace (1989) lists 35 types of stomata in vascular plants. Some important stomatal types are shown in Figure 3.1.

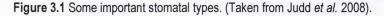
Generalized epidermal cells combined with stomatal chracers have been utilized taxonomically (Stuessy 2009) such as the closely related families Acanthaceae and Scrophulariaceae are distinguished by the presence of diacytic stomata in the former and anomocytic in the latter (Singh 2004).

The *cuticle* is a waxy coating over the epidermis, and it varies in thickness and surface texture, various epicuticular wax particles may be deposited on top of the cuticle (Judd *et al.* 2008).

# 3.1.2 Hypodermis

Characters of the internal tissues of leaves are also important. In some leaves, a *hypodermis* may be formed from one or more differentiated layers of cells beneath the epidermis. The *mesophyll* may be differentiated into palisade and spongy layers, and the number of cell layers in each may vary. The distribution and shape of mesophyll cells and the presence or absence of intercellular spaces may also be diagnostic characters (Judd *et al.* 2008).





# 3.1.3 Secretory elements

Several plant species contain specialized cells or group of cells that produce latex, resins, mucilage, or essential oils (Metcalfe and Chalk 1950; Metcalfe 1966). The presence or absence of these substances, form and distribution of laticifers and secretory canals or cavities are often taxonomically significant (Judd *et al.* 2008).

# 3.1.4 Crystals

Crystals are common in vascular plants, are usually located in cells, variously shaped (Figure 3.2) and usually composed of calcium oxalate, calcium carbonate, or silica. Druses (spherical groups of crystals), raphides (needle-like crystals), and crystal sand are the most common types.

Calcified bodies (cystoliths) sometimes occur in specialized cells and are highly characteristic of certain families, e.g. Acanthaceae, Urticaceae (Metcalfe and Chalk 1950; Judd *et al.* 2008).



Figure 3.2 Crystal types. A) Druse-like. B) Prismatic form. C) Raphides. D) Cystolith (Taken from Judd et al. 2008).

# 3.2 Systematic anatomy of petiole

The petiole is a leaf organ, which connects the lamina with the stem. Although its tissues are comparable to the primary tissues of the stem, considerable variation exists in the distribution of vascular bundles (Esau 1964).

The petiole is of considerable taxonomic importance, as its structure appears to be little affected by environmental change (Metcalfe and Chalk 1950). Much of the early work in systematic anatomy was based on an examination of the young stem and leaf alone, the root received but little attention. The petiole has suffered the worst neglect, while it has a much higher taxonomic value than is commonly realized (Hare 1943).

Vesque (1885) appears to be the first to suggest that, the middle of the petiole is the most stable and reliable zone for sections for comparative purposes to be taken. This hypothesis is supported by several subsequent workers, such as Mathew and Shah (1997); Kocsis and Borhidi (2003). Vesque (1885) studied a number of families and used the petiole anatomy to separate genera and families previously united.

According to Hare (1943) "Petiole characters are highly constant and can therefore be used with confidence, but their value for purposes of classification varies widely at different taxonomic levels." The first comprehensive survey of petiolar anatomy was that published in 1879 by Casimir de Candolle. He surveyed twenty families and described several fundamental concepts of the vascular structure he encountered. He proposed the terminology of an "open system" for the bundles arranged in an arc in cross section versus a "closed system" for bundles formed a circle.

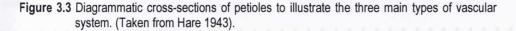
Petit (1886) studied 500 species in 300 genera of 48 families and proposed a variation on the use of "open" and "closed" systems of de Candolle. He recognised an "open system" with distinct or separate bundles, and a "closed system" with fused bundles. He found that herbaceous plants showed distinct bundles (open) while in shrubby or woody plants the bundles were fused in an arc or a ring. He also noted that sclerenchyma was generally lacking in herbaceous plants and present in woody plants, and placed a high value for classification on this tissue (Petit 1886; Howard 1974).

There are several classifications of the vascular pattern types of the petiole. Hare (1943) proposed a simple classification of the vascular structure in transverse section: U-shaped, I-shaped, and O-shaped or hollow cylindrical (Figure 3.3). Each type consists either of separate vascular bundles or of a solid mass of vascular tissue. The commonest types are the U-shaped and O-shaped, the I-shaped is less frequent in plants. In some families (for example Proteaceae) the petiole has a high diagnostic value at the generic level (Hare 1943).

**O** Type

Type

**U** Type



Xylem and phloem may be arranged in various ways in the petiole (Figure 3.4). Metcalfe and Chalk (1950) devised a classification in which nine types of steles were recognised, varying from the arc to the open or fused ring of xylem and phloem.



Figure 3.4 Diagrammatic cross-sections of common petiole vascular patterns. (Taken from Judd et al. 2008).

# 3.3 Review of anatomical features of the family Lamiaceae

Anatomical study of the family has been rather neglected (Bokhari and Hedge 1971). Apart from the general study pertaining to the anatomy of Lamiaceae *s. s.* and Verbenaceae *s. l.* by Solereder (1908), and Metcalfe and Chalk (1950), there is relatively very little published information on the antomy of the Lamiaceae *s. l.*, a rather surprising situation given the size and economic importance of the family (Abu-Asab and Cantino 1987).

Unless otherwise mentioned, much of this information is derived from Solereder (1908), and Metcalfe and Chalk (1950).

# 3.3.1 Stem

Stems are commonly quadrangular in cross-section (Figure 3.5), with a *subepidermal* layer of collenchyma, often restricted to angles, or sometimes along the sides (e.g. *Pycnostachys* Hook.) and forming a closed ring in some genera of subfamilies Nepetoideae (*Aeollanthus* Mart. ex Spreng., *Plectranthus* L'Hér., *Anisochilus* 

Wall. ex Benth.) and Lamioideae (Chelonopsis Miq., Colquhounia Wall., Pogostemon Desf.) (Harley et al. 2004). In Tectona L.f., stone cells are associated with the collenchymatous cortex. Collenchyma is apparently absent from the cortex of various genera of Westringieae and also from Cuminia Colla. The cortex of a number of species, some of semi-aquatic habitats, have large intercellular spaces e.g. in Mentha L., Stachys L., Pogostemon and Prunella L. (Harley et al. 2004). An endodermis is reported in Holmskioldia Retz. and Scutellaria L., and also in many genera of Lamioideae and Nepetoideae, where it is said to be often suberized (Harley et al. 2004). However, Metcalfe and Chalk (1950) made no mention of the endodermis in any genera of the more woody subfamilies: Symphorematoideae, Viticoideae, Ajugoideae or Prostantheroideae. Cork is produced, either superficially or in deeper layers of the stem in many genera. The pericycle may contain isolated bundles of sclerenchymatous cells or may form a continuous ring in Ajuga L., Cymaria Benth., Marrubium L., Tectona, Clerodendrum L. and Sphenodesma Griff, while in the species of last two genera and in Oxera Labill. stone cells are associated with the fibres (Metcalfe and Chalk 1950; Harley et al. 2004). However, the sclerenchymatous elements seem to be less well developed in the pericycle of many Lamioideae and Nepetoideae, and are reported (Metcalfe and Chalk 1950; Harley et al. 2004) as absent from Lamium L., Galeopsis L., Comanthosphace S. Moore (Lamioideae) and from Mentha, Thymus L., Micromeria Benth., Monarda L., Lallemantia Fisch. & Mey, Horminum L. and Prunella (Nepetoideae). Primary vascular bundles usually include four principal ones, opposite the stem angles (in cross-section). Secondary phloem includes fibres in various groups, and associated stone cells are also reported in Symphorematoideae and in Tectona and Callicarpa L. (Metcalfe and Chalk 1950; Harley et al. 2004). A similar character is found in various genera of Prostantheroideae: tribe Chloantheae: Chloanthes R. Br., Cyanostegia Turcz. and Pityrodia R. Br., while in tribe Westringieae, Hemiandra R. Br. was found to have the phloem fibres forming a continuous cylinder. Phloem fibres are also reported in species of Scutellaria and Tinnea Kotschy ex Hook. f. (Scutellarioideae) and in Meriandra Benth., Cunila Royen ex L., and Hoslundia Vahl. Xylem vessels usually have simple perforations. Xylem develops into a continuous cylinder at a very early stage in most groups, though exceptions are reported in Horminum (Nepetoideae) and Physostegia Benth. (Lamioideae), and the cylinder is often traversed by narrow rays. Broader, lignified rays occur in more woody species of Vitex L. (Viticoideae) and Tectona. Medullary bundles are reported in Tectona and in Teijsmanniodendron Koord. (Viticoideae) (Metcalfe and Chalk 1950; Harley et al. 2004).

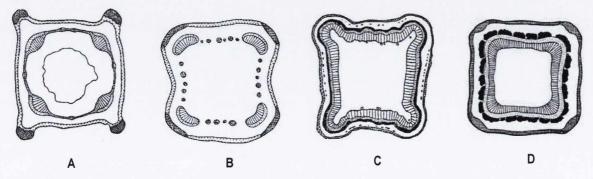


Figure 3.5 Diagrammatic cross-sections of Stems. A) *Glechoma hederacea* L. B) *Physostegia virginiana* Benth. C) *Tectona grandis* L. D) *Meriandra bengalensis* (Roxb.) Benth. [A-C taken from Metcalf & Chalk (1950); D taken from Bokhari & Hedge (1971)].

Rudall (1980) reported semi-ring-porous or ring-porous, or semi-ring-porous to diffuse *wood* in Hyptidinae (Nepetoideae) with vessels typically arranged in small groups in a tangential pattern, with simple perforations (except rarely in some *Vitex* species), occasionally scalariform in some Hyptidinae, though vessels are said to be mostly solitary in *Hoslundia* (Nepetoideae). Spiral thickening is reported in a range of genera. *Vessel* element dimensions are often minute to medium-sized but can cover a wide range; this is probably related to habit and xeromorphy (Rudall 1980). In Hyptidinae, intervascular pitting is alternate, with small bordered pits. In several Viticoid genera, tyloses with large, simple pits have been recorded (Harley *et al.* 2004). *Parenchyma* is paratracheal and rather sparse in most genera, though more abundant and aliform or confluent in some species of *Aegiphila* (Ajugoideae), *Gmelina* L. (Viticoideae), *Callicarpa* and *Peronema* (Metcalfe and Chalk 1950; Harley *et al.* 2004). *Rays* are often heterocellular and vary from 1-12 cells wide. Rudall (1985) reported perforated ray cells in *Hyptis hagei* Harley. Pits of rays are simple and small, or elongated in Hyptidinae (Rudall 1981), pits of fibres small, and in some genera, septate (Harley *et al.* 2004). *Crystals* are rather rare but needle-shaped crystals are recorded in some species of *Gmelina*, *Premna* and *Vitex* (Metcalfe and Chalk 1950).

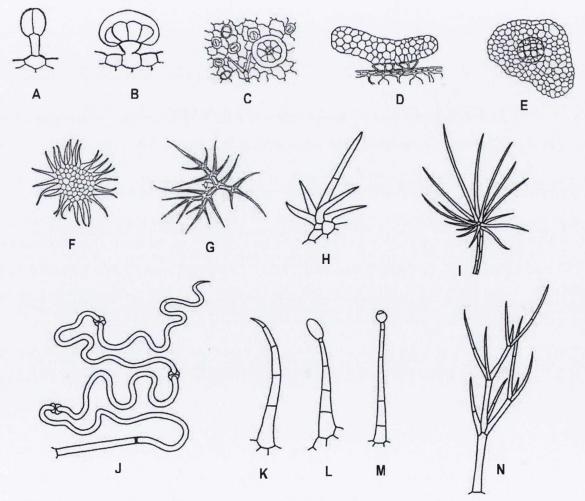
## 3.3.2 Leaf

Leaves of Lamiaceae are usually dorsiventral, but many examples of isobilateral leaf types are reported. Leaves may be persistent or deciduous especially in dry habitats. Rarely, leaves may be deciduous at onset of flowering, as in *Madlabium* Hedge and some species of *Plectranthus* (Harley *et al.* 2004).

Rudall (1979; 1980) studied leaf and twig anatomy of 25 species on the genus *Eriope* Humb. & Bonpl. ex Benth., and leaf anatomy of the subtribe Hyptidinae respectively. She found that twig anatomy is very uniform but leaf anatomy showed considerable variation between the species in the genus *Eriope* and in the subtribe Hyptidinae and is taxonomically useful at species level.

Cantino (1990) examined leaf trichomes and stomata of Lamiaceae and Verbenaceae and found that multicellular eglandular trichomes (Figure 3.6) were widespread in Lamiaceae and usually more frequent on the abaxial surface of the lamina. Variation in the subsessile glandular trichomes, which possess a very small stalk obscured by the much larger head (Figure 3.6B), appears taxonomically significant in some cases. Cantino (1990) recognised eleven types of subsessile glandular trichomes based on head cell-number (one to many) and presence or absence of tangential walls and partial or tertiary radial walls. The most complex type, with a many-celled head, described as broad and scale-like, was found only in species of Symphorematoideae, Viticoideae and Ajugoideae. Variation in the capitate glandular trichomes with a relatively smaller head and obvious stalks (Figure 3.6A, L, & M), appear to have less taxonomic importance. *Zhumeria* Rech. F. & Wendelbo and *Meriandra* (Nepetoideae) appear to be unique in the family in having glandular dendroid trichomes (Bokhari and Hedge 1976). *Non-glandular hairs* may be unicellular or multicellular, and simple and uniseriate (Figure 3.6K), or marrubioid (Figure 3.6J) or branched in various ways (Figure 3.6G, H, I, & N). Unicellular hairs are widespread throughout the family, and are nearly always accompanied by multicellular hairs, which distinguish Lamiaceae from most

Verbenaceae (which are characterized by the possession of unicellular hairs only, in almost all genera) (Harley *et al.* 2004). In the Prostantheroideae, however, species of tribe Westringieae have only unicellular trichomes except in very few cases, while the tribe Chloantheae is characterized by the possession of branched multicellular hairs, often in great profusion. Branched, multicellular hairs are also a feature of many Symphorematoideae, especially on the involucral bracteoles where they appear stellate (Figure 3.6G-I, N). Several genera of Lamioideae, *Comanthosphace, Rostrinucula* Kudo, *Leucosceptrum* Sm., *Gomphostemma* Wall. ex Benth., *Phlomis* L. and *Marrubium*, possess branched hairs. Two species of *Scutellaria* (Scutellarioideae) also possess such trichomes, but they are absent elsewhere in this subfamily. In the Nepetoideae, the presence of branched hairs is often a valuable diagnostic character at species level. They are present in tribe Mentheae: especially in subtribe Salviinae: *Zhumeria, Meriandra, Perovskia* Kar., *Rosmarinus* L., *Lepechinia* Willd., *Chaunostoma* Don., and several species of *Salvia* L. In subtribe Nepetinae branched hairs are found in one section of *Nepeta* L., and in Menthinae and tribe Ocimeae they occur sporadically in a number of genera, while in Ajugoideae they appear to be restricted to a few species of *Teucrium* L. Very characteristic multicellular peltate trichomes are found in the *Squamata* section of *Clerodendrum* (Figure 3.6D-E) and some of *Pityrodia* and *Chloanthes*.



**Figure 3.6**. Trichomes of Lamiaceae. B, C & G) Lavandula vera DC. D & E) Clerodendrum squamatum Vahl. A & F) Pityrodia salvifolia R. Br. H) Pityrodia bartlingii Benth. I) Phlomis orientalis Mill. J) Leucas helianthemifolia Desf. K) Salvia candelabrum Boiss. L) Coleus barbatus Benth. M) Teucrium abutiloides L'Hér. N) Notochaete hamosa Benth. [A-G taken from Solereder (1908); H-N taken from El-Gazzar & Watson (1970)].

Often there are several different types of trichomes on the same leaf. For example, there are two or more sizes of glandular hair, and branched or unbranched non-glandular hairs in *Hyptis* Jacq., *Lavandula* L., *Rosmarinus*, and *Thymus* (Rudall 1992).

*Extrafloral nectaries* on the leaves have been reported in *Clerodendrum, Amasonia* L.f., *Monochilus* Fisch. & C. A. Mey (Ajugoideae) and in *Callicarpa*. In some species of *Ocimum* L. (Nepetoideae: Ocimeae), they can develop in place of the abscission scar of deciduous bracts. *Hydathodes* occur at the leaf margins of some species of Hyptidinae (Rudall 1980).

According to Metcalfe and Chalk (1950) the *stomata* of Lamiaceae are commonly diacytic and often intermixed with anomocytic, and in Verbenaceae they are mostly diacytic, paracytic or anomocytic. In 1970, El-Gazzar and Watson found the anisocytic type in the family Lamiaceae.

Inamdar and Bhat (1972) studied 33 species of the Lamiaceae and reported the stomata as diacytic, transitional between paracytic and diacytic, and anomocytic. They noted abnormal stomata with a single guard cell in *Leucas aspera* Link, and *L. zeylanica* R. Br., and contiguous stomata in *Coleus amboinicus* Lour.

Rudall (1979, 1980) noted much variation in distribution and also presentation of stomata in both *Eriope* and other Hyptidinae (Nepetoideae), which includes many xeromorphic species and a wide range of habit. Stomata could be sunk in pits or in grooves, sometimes surrounded by hairs or glands, or in hairy species, may be raised.

Cantino (1990) reported 10 types of stomata both in the families Lamiaceae and Verbenaceae with anomocytic and diacytic stomata the most frequently encountered types. Diallelocytic stomata with three subsidiary cells also occured widely and were found in almost all species of subfamily Nepetoideae examined. However they appeared to be absent from Prostantheroideae, where anisocytic stomata are particularly common. Paracytic stomata are very rare in Nepetoideae, but characteristic of *Prostanthera* Labill. (Prostantheroideae), *Trichostema* L., and *Oxera* (Ajugoideae), and members of Symphorematoideae and *Petraeovitex* Oliv. Other stomatal types tend to occur with lesser frequency, or show little correlation with taxonomy. The distribution of stomata on the leaf can vary greatly, with the abaxial surface often more densely covered. In some species, the stomata are restricted to the abaxial surface only.

The leaf *cuticle* can be thickened, especially in species from more xeric habitats. In 1980, Rudall noted characteristic striation patterns on leaf cuticles of some species of Hyptidinae and variation in cuticular pattern between different populations of *Eriope hypenioides* Mart. ex Benth. (Nepetoideae: Ocimeae). Cells of the *epidermis* may be smooth to papillose (*Bystropogon*) or bullate in some genera, and can have wavy to straight anticlinal walls (Rudall 1980). A *hypodermis* of large cells is reported below the adaxial epidermis of leaves of *Rosmarinus* (Nepetoideae). Some species of *Hyptis* which showed many macromorphological similarities are grouped in two sections with aid of presence or absence of a hypodermis (Rudall 1985).

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In *Vitex* (Viticoideae), the *mesophyll* is composed of a compact palisade tissue, a condition apparently similar to that found in some *Salvia* (Nepetoideae) species. In some species of Hyptidinae (Rudall 1980) and in *Amasonia* and the related *Monochilus* (Ajugoideae), a multi-layered palisade mesophyll has been reported, while also in these genera, the vascular tissue is without sclerenchyma (Harley *et al.* 2004). Rudall (1980) reported bundle sheath extensions in different species of Hyptidinae both with and without lignification.

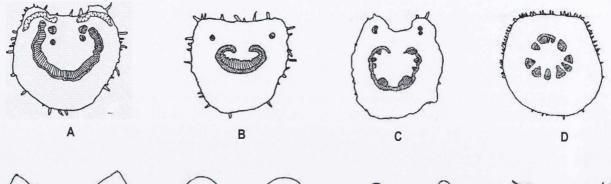
#### 3.3.3 Petiole

Transverse sections in the mid-region of the petiole exhibit distinctive variation in vascular structure of each genus. The petiole in cross-section most frequently exhibits an arc of widely spaced vascular bundles. This may be deeply crescentic in Callicarpa and Vitex (Viticoideae, Figure 3.7A), some genera of Teucrioideae (Figure 3.7B-C); or a moderately deep arc in *Physostegia* (Lamioideae, Figure 3.7J) and various genera of Nepetoideae (Figure 3.7F, I); or shallow in some species of Perovskia Kar. (Figure 3.7K), and Meriandra (Figure 3.7L). In some cases this median arc has incurved ends, e.g. in species of Caryopteris Bunge and Clerodendrum (Teucrioideae, Figure 3.7B-C) and Ballota L. (Lamioideae, Figure 3.7J); in some cases the vascular tissue is continuous, as it is in Melittis L. (Lamioideae) and various other genera of Nepetoideae (Metcalfe and Chalk 1950; Harley et al. 2004); the vascular arc may tend towards a cylinder, as in various genera of Lamioideae e.g. Leonurus L., Phlomis and Stachys (Figure 3.7H) and in some species of Hyptis (Nepetoideae) (Metcalfe and Chalk 1950; Harley et al. 2004). In Phlomis tuberosa L. the cylinder consists of numerous separate bundles (Figure 3.7G), while in Oxera (Ajugoideae) the numerous bundles are collateral (Figure 3.7D) (Metcalfe and Chalk 1950; Harley et al. 2004). Accessory bundles frequently occur, especially in the petiolar wings, and indeed were found in all genera of Lamioideae, Viticoideae (Figure 3.7A), Teucrioideae (Figure 3.7B-C) and Nepetoideae (Figure 3.7K-M) examined (Bokhari and Hedge 1971; Harley et al. 2004). In Congea and Symphorema (Symphorematoideae), 1-2 additional bundles were also reported on the adaxial side of the petiole. In the subfamily Nepetoideae, some genera have large wings e.g. Meriandra (Figure 3.7L), and Dorystoechas Boiss. & Heldr. ex Benth. (Figure 3.7M), but in Horminum (Figure 3.7I) and Perovskia (Figure 3.7K) the wings are less distinct (Bokhari and Hedge 1971).

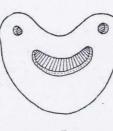
Bokhari and Hedge (1977) observed that the petioles of all species in the desert group *Salvia* are generally winged except in *S. trichocalycina* and *S. tebesana*, and the main median vascular bundle is accompanied by two smaller subsidiary vascular bundles which are usually present in the wings.

In the genus *Eriope* outline of the petiole transverse sections varies in size and shape; either more or less oval or with adaxial surface flattened or grooved. Vasculature is simple and generally with either four distinct vascular bundles or two vascular arcs (Rudall 1979).

In subtribe Hyptidinae, the outline is usually oval, sometimes adaxially flattened or concave; some species with lateral wings, and one species *Hyptis lucida* Phol ex Benth. with characteristics distinct ridges on both adaxial and abaxial surfaces. Petiole vasculature varies from simple to complex with several different types e.g. *Hyptis macrantha* A. St.-Hil. ex Benth. has characteristics petioles with a ring of traces, sometimes with medullary traces (Rudall 1980).











F

G

н

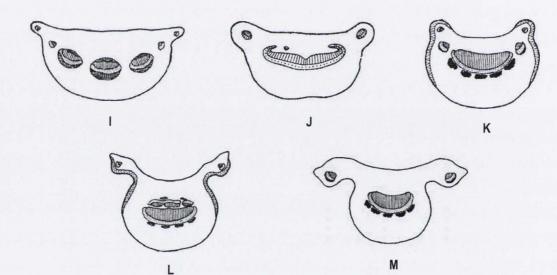


Figure 3.7 Diagrammatic transverse sections of Petioles. A) Vitex negundo L. B) Caryopteris tangutica Maxim. C) Clerodendrum fargesii Dode. D) Oxera pulchella Labill. E) Galeopsis tetrahit L. F) Lallemantia canescens Fisch.& C.A. Mey. G) Phlomis tuberosa L. H) Stachys betonica Benth. I) Horminum pyrenaicum L. J) Ballota rupestris Vis. K) Perovskia scrophulariifolia Bunge. L) Meriandra bengalensis (Roxb.) Benth. M) Dorystoechas hastata L. (I and K-M taken from Bokhari & Hedge (1971); the remainder taken from Metcalfe & Chalk (1950)).

Large sac-like secretory cells have been reported in the mesophyll of *Brazoria* Engelm. & A. Gray, and *Physostegia*; large solitary crystalline inclusions are present in parenchymatous tissues of *Tectona* (Harley *et al.* 2004). Abu-Asab and Cantino (1987) report sac-like idioblasts in the leaf mesophyll of three related genera, *Brazoria, Warnockia* M. W. Turner, and *Physostegia* of subfamily Lamioideae.

Budantsev and Lobova (1997) studied fruit morphology and anatomy in the tribe Nepeteae.

## 3.4 Review of Anatomical studies in the genus Gmelina

There is no detailed comprehensive anatomical survey on the subfamily Viticoideae, in particular on the genus *Gmelina*. Neither has there been any comprehensive specific petiolar anatomical nor leaf surface study on the genus. Sporadically, one to three species from the genus along with other members of the family have been treated in the following studies:

In 1928, W. D. Francis studied the vegetative anatomy (mostly concentrated on wood anatomy) of *Gmelina leichhardtii* (F. Muell.) Benth., the Australian white beech, and observed that the stomata are confined to the abaxial surface of leaves and that peculiar four-limbed glands are most frequent on this surface.

Metcalfe and Chalk (1950) recorded needle-shaped crystals in some species of Gmelina, Premna and Vitex.

In 1953, Chowdhury investigated the secondary xylem of the genus *Gmelina*. He studied 12 species and all species showed remarkably uniform gross-structure except *G. hainanensis*; he pointed out that taxonomic species could not be differentiated on the basis of wood anatomy.

Inamdar (1969) studied the epidermal structure and ontogeny of stomata in the leaves of 14 species of the Verbenaceae *s. l.* including only *G. arborea* from the genus. He concluded that the great majority of the stomata are diacytic and some are anisocytic, paracytic, anomocytic or with one subsidiary cell in this family, and noted anomocytic stomata, abnormal stomata with a single guard cell, grouped stomata, and contiguous stomata in *G. arborea* (Figure 3.8A-B), and different types of trichome e.g. simple uniseriate filiform (Figure 3.8C), simple uniseriate filiform trichome with terminal silicified cell (Figure 3.8D), hooked trichomes with terminal silicified cell (Figure 3.8E), capitate glandular (Figure 3.8F-G), uniseriate filiform, long-stalkeed peltate glandular trichome (Figure 3.8H) were observed in this species.

El-Gazzar and Watson (1970) studied 68 species studied from Verbenaceae *s.l.*, and observed paracytic type stomata along with most common anomocytic only in *G. philippensis* whereas most of verbenaceous species have predominantly anomocytic stomata.

Bhatt *et al.* (1979) studied the stomatal structure and ontogeny of the lamina of 13 genera and 26 species of the Verbenaceae *s.l.* They observed mostly anomocytic, and rarely diacytic, stomata in *G. asiatica* whereas in *G. philippensis* diverse types of stomata *viz*: anomocytic, anisocytic, diacytic and paracytic were reported. Stomata were scattered and occured at equal distance from each other or were widely separated in *G. philippensis;* abnormalities with aborted guard cells and 2-4 contiguous stomata have been noted in *G. asiatica* and four contiguous stomata in *G. philippensis* (Bhatt *et al.* 1979).

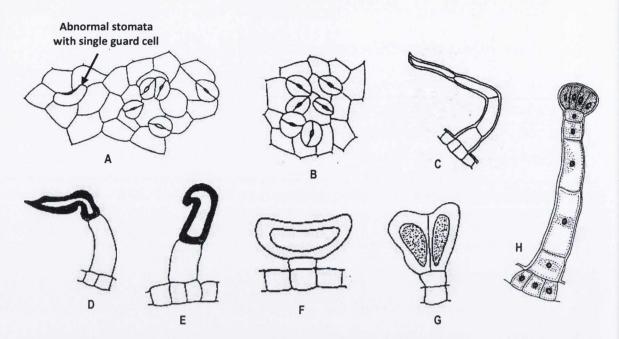


Figure 3.8. Leaf surface features of *G. arborea*. A) Showing anomocytic stomata; abnormal stomata with single guard cell. B) Contiguous and grouped stoma. C) Simple uniseriate filiform trichome. D) Simple uniseriate filiform trichome with terminal silicified cell. E) Hooked trichome with terminal silicified cell. F) Capitate glandular trichome with a unicellular broad terminal head cell. G) Capitate glandular trichome with two-celled head. H) Uniseriate filiform peltate glandular trichome. (Taken from Inamdar 1969).

Mathew and Shah (1981) studied *G. arborea*, *G. asiatica*, and *G. philippensis* along with other 32 species of Verbenaceae *s.l.* for the structure and development of stomata and reported ten types of stomata and 24 combinations. They noted that the anomocytic type is the most frequent in all three species, but the transitional types were also encountered in the *G. philippensis*; and sinnaute anticlinal epidermal cell in *G. arborea*, straight or slightly wavy in *G. asiatica* and *G. philippensis*.

In 1984, Rao and Dev found calcium oxalate crystals in *Gmelina* and *Tectona*. In *Gmelina*, crystals are in the form of a sheaf of long acicular raphides and distributed on either side from ray initials to phloem and xylem, while in *Tectona* crystals are grouped in more or less spherical clusters (druses) and are restricted towards phloem.

Subsequently, Mathew and Shah (1984) concluded that the rectangular prismatic aggregate crystals in *Citharexylum* Mill., the sclerotic crystal sac in *Tectona* and the styloids with one or both ends forked in *G. arborea* are characteristic of these taxa and could be used for taxonomic purposes.

Kaushal and Tripathi (1984) reported diacytic and anomocytic stomata in *G. philippensis*. They also reported that uniseriate bi-cellular, pointed non-glandular hairs and fan-shaped, large, 8-celled head glandular trichomes present throughout the leaf surface.

In 1987, Mathew and Shah studied petiolar anatomy of 35 taxa of Verbenaceae *s.l.* but included only two species from the genus - *G. arborea*, and *G. philippensis*; and reported a crescent shaped vascular pattern in *G. philippensis*, and dissected cylinder of collateral bundles without medullary bundles in *G. arborea*.

In 1990, a leaf epidermal anatomical study of 127 and 59 genera in Lamiaceae *s.s.* and Verbenaceae *s.l.* respectively was undertaken by Cantino, which included only three species from the genus. *G. delavayana* 

Dop, *G. moluccana* Backer ex Heyne, and *G. racemosa* (Lour.) Merill., with emphasis on the morphology of stomata and trichomes. He observed that anomocytic and diacytic stomata were most frequent in the both families; but diacytic stomata were absent from all three *Gmelina* species; multicellular glandular trichomes were widespread and usually more frequent on the abaxial surface of the lamina, but they were absent from *G. moluccana*. He concluded that variation in the sub-sessile glandular trichomes, which possess a very small stalk obscured by the much larger head, appeared taxonomically significant in some cases.

Mathew and Shah (1990) studied anatomically and morphologically 35 species of 15 genera in the family Verbenaceae *s.l.* including *G. arborea* and *G. philippensis* and concluded that the circumscription of the genera *Gmelina* and *Clerodendrum* needs refinement as in all analyses *G. arborea, C. viscosum* Vent., and *C. splendens* G. Don formed a distinct cluster, in contrast *G. philippensis* formed a different cluster along with other species of *Clerodendrum, Lantana* L., *Vitex* etc. These results also suggested similarity between cluster formation and phytogeographical distribution of the taxa as the Philippine element (*G. philippensis*) always remained isolated from the Indo-Malayan element (*G. arborea*).

In 2003, Ingole and Patil surveyed petiolar anatomy of some species in Verbenace *s.l.*, two species-*G. arborea*, and *G. philippensis* from the genus *Gmelina*. Acicular crystals in the cortex and perivascular sclerenchyma were observed in both species; a single median crescentic vascular strand was observed in *G. philippensis*, and an almost closed dissected arc was observed in *G. arborea*.

Yashodhara *et al.* (2004) studied 26 taxa belonging to seven genera of the tribe Viticeae, and reported 4celled peltate glandular trichomes on the abaxial surfaces in all three *Gmelina* species, *G. arborea*, *G. asiatica*, and *G. philippensis*. This type of trichome was also observed on the petiole in all *Gmelina* species studied.

So (2004) records 4-5 maculate glands between veins at leaf base in two cultivated species *G. arborea*, and *G. chinensis* Benth. in Hong Kong.

Albert and Shah (2004) studied the stem-node-leaf continuum in *G. arborea*. The node exhibits a unilacunar single composite trace of five vascular strands, and cortical strands are located on either side of the adaxial groove of the petiole. Subsequently, in 2005 they studied vascular differentiation in the petiole of the species. The vascular meristem of the species consists of an arc of meristematic cells. The initial differentiation of vascular tissue and pith occurs in this arc.

## 3.5. Objectives:

Therefore, the main objectives of this study are:

- To fill the data gap on the leaf epidermal and petiolar anatomical characters of *Gmelina*
- To explore the relationship between Gmelina and Premna using anatomical data, and
- To investigate the possibility of additional micro-morphological characters of taxonomic utility in the genus Gmelina.

# 3.6 Scanning Electron Microscopy (SEM): Leaf surface

#### 3.6.1 Materials and Methods

Micro-morphological studies of *Gmelina* have been examined and illustrated for the first time. In the present study only herbarium specimens were used.

The epidermal characters of the mature leaves of 40 accessions of 19 *Gmelina* species, and six accessions of six *Premna* species have been examined (Table 3.1). Few genera are sister to *Gmelina* e.g. *Premna, Callicarpa, Tectona* etc.; but previous phylogenetic analyses show that *Premna* is closely related to *Gmelina*. Therefore, *Premna* was chosen to evaluate the phylogeny. The leaf samples were taken from the mid-lamina position of the herbarium specimens, which is considered to be the least variable (Wilkinson 1989); and a ca. 8mm<sup>2</sup> portion cut from about halfway down the leaf close to the mid-vein. Whenever possible it was taken from the flattest area where no lateral veins were present. Two sections of both adaxial and abaxial surfaces were prepared for each specimen. The sections were mounted on electron microscope stubs using double sided adhesive tabs. The stubs were then coated with approximately 350Å gold in a Polaron SC500 sputter coater and the samples were examined and photographed in a Hitachi S4300 electron microscope.

Species representing the broad geographical distribution were studied from different parts of its distribution to determine whether there were significant differences in plants from different regions or habitats.

## 3.6.2 Results

The leaf micromorphology of the following 40 specimens of 19 species from the genus *Gmelina* has been analysed of which 14 have not been investigated earlier and the remaining six species are reinvestigated. In addition to that, the surfaces of six species from the genus *Premna* have also been studied.

The descriptions which follow emphasize the mature state of the adaxial and abaxial leaf surfaces. The immature forms are generally more densely pubescent, and the cuticular patterns are not yet formed. During maturation, the expansion of the lamina tends to spread the trichomes further apart and some may drop off. Epicuticular wax usually is not well developed until the leaf is mature (Hardin 1981, Hardin & Phillips 1985). The images of the foliar surfaces of *Gmelina* and *Premna* are presented in Figures 3.9.1- 3.9.23 and the observations of characteristics are summarized in Table 3.1.

The general classification scheme of trichomes is based on El-Gazzar and Watson (1970); and Pyne (1978); but the typologoical classification of glandular trichomes is based on Cantino (1990).

## G. annamensis Dop

### (Figure 3.9.1A-D. Vietnam)

Adaxial: lustrous and glabrous; cuticle tessellated with protruding cells, shallow grooves present. Abaxial: densely glandular-pilose; sub-sessile, peltate glandular trichomes with 4-celled head forming a dense covering on the areolae; uniseriate, acicular multicellular, trichomes sparsely distributed, basal cell short and broad, terminal cell much longer, erect or curvate; cuticle ridged mainly on veins. **Stomata**: anomocytic, confined abaxially (hypostomatic), very frequent, small, outline ± circular to broadly elliptic, rim prominent, aperture broad; trichomes obscuring stomata.

#### G. arborea Roxb.

#### (Figure 3.9.1E-H. Malay Peninsula)

Adaxial: glabrescent; a few sessile, capitate glandular trichomes, and uniseriate, attenuate multicellular eglandular trichomes scattered; cuticle smooth or slightly ridged, somewhat glaucous. Abaxial: glandular-tomentose; sub-sessile, peltate glandular trichomes with 2-celled head forming a dense covering on the areolae, long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells frequently distributed; cuticle ridged. **Stomata**: anomocytic, confined abaxially (hypostomatic), infrequent, small, outline broadly elliptic, rim prominent, aperture narrow; trichomes obscuring stomata.

# G. arborea Roxb.

(Figure 3.9.2A-D. Thailand)

Adaxial: glabrescent; sessile, capitate glandular trichomes scattered; cuticle smooth or slightly ridged. Abaxial: glandular-tomentose; sub-sessile, peltate glandular trichomes with 2-celled head forming a dense covering on the areolae along with long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells; cuticle ridged. **Stomata**: anomocytic, confined abaxially (hypostomatic), frequent, small, outline broadly elliptic, rim prominent, aperture narrow; trichomes obscuring stomata.

## G. arborea Roxb.

(Figure 3.9.2E-H. Indonesia)

Adaxial: glabrous; a few sessile, capitate glandular trichomes rarely scattered; cuticle conspicuously ridged. Abaxial: glandular-tomentulose; sub-sessile, peltate glandular trichomes with 2-celled head forming a dense covering on the areolae; uniseriate, acicular, multicellular eglandular trichomes with swollen junctions between cells sparsely distributed, basal cell short and disc like, terminal cell much longer, curvate; cuticle ridged; epicuticular wax particles present. **Stomata**: anomocytic, confined abaxially (hypostomatic), frequent, small, outline broadly elliptic, rim prominent, aperture broad; trichomes almost obscuring stomata.

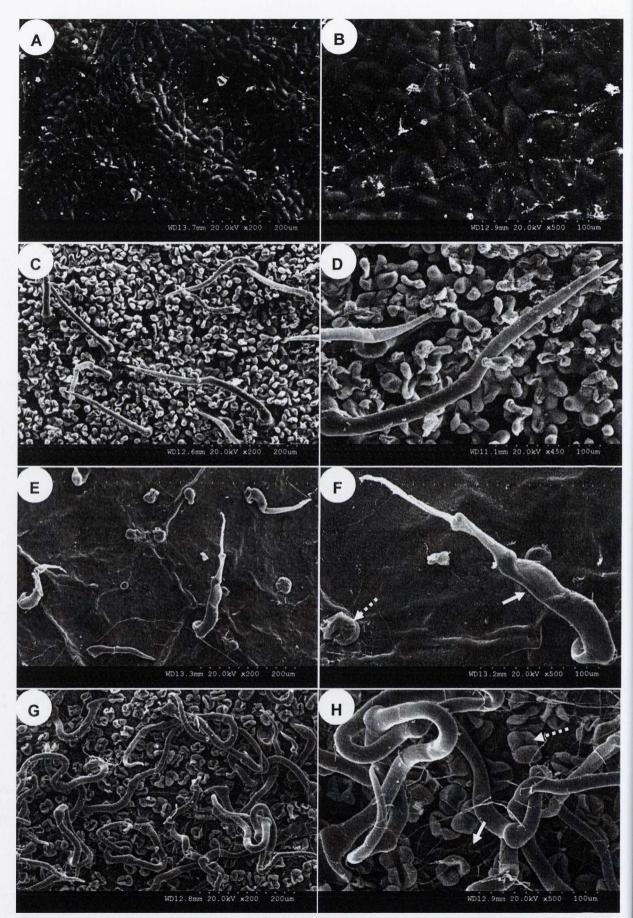


Figure 3.9.1 SEM micrographs of leaf surfaces. A-D. *G. annamensis* (Vietnam) A. Adaxial surface X 200. B) Adaxial surface X 500. C) Abaxial surface X 200. D) Abaxial surface X 450. Long arrow indicates acicular trichome; short arrow shows stoma. (All from *Poilane* 13301, A). E-H. *G. arborea* (Malay Peninsula). E. Adaxial surface X 200. F. Adaxial surface X 500. Solid and dashed arrows indicate attenuate and capitate glandular trichomes respectively. G. Abaxial surface X 200. H. Abaxial surface X 500 Upper dashed arrow shows peltate gland, short arrow indicates stoma; arrow head shows swollen junction of cell joint. (All from *Carrick* 1511, SING).

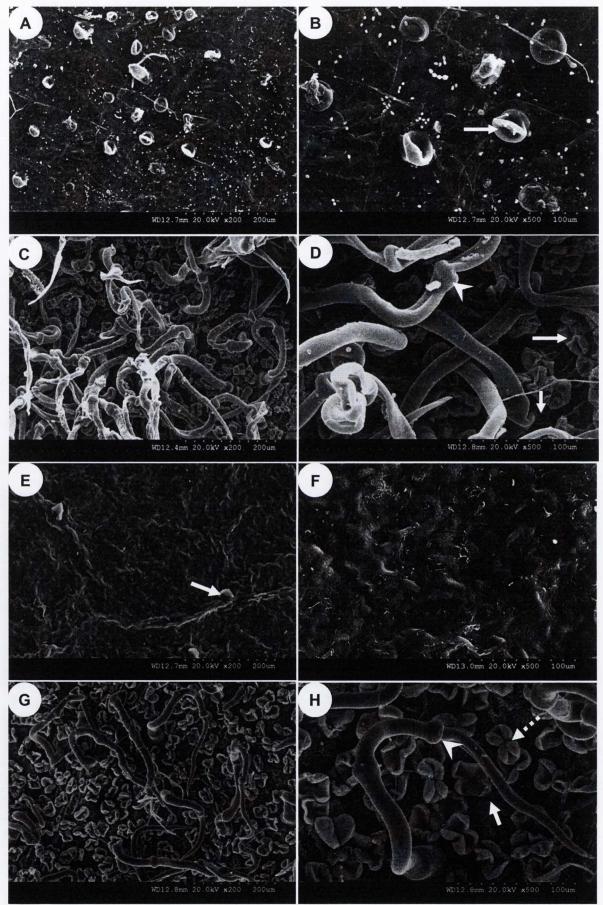


Figure 3.9.2 SEM micrographs of leaf surfaces. A-D. *G. arborea* (Thailand). A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow indicates sessile, capitate gland. C) Abaxial surface X 200. D) Abaxial surface X 500. Arrow head indicates swollen junction of cell joint; upper arrow indicates peltate gland; lower arrow shows stoma. (All from *Maxwell* 00-28, A). E-H. *G. arborea* (Indonesia). E) Adaxial surface X 200. Sessile, capitate gland arrowed. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Arrow head indicates swollen junction of cell joint; upper dashed arrow indicates peltate gland; lower arrow shows stoma. (All from *Maxwell* 00-28, A). E-H. *G. arborea* (Indonesia). E) Adaxial surface X 200. Sessile, capitate gland arrowed. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Arrow head indicates swollen junction of cell joint; upper dashed arrow indicates peltate gland; lower arrow shows stoma. (All from *Brand*, 30999, L).

## G. arborea Roxb.

(Figure 3.9.3A-D. Vietnam)

Adaxial: mostly glabrous; a few capitate trichomes rarely scattered; cuticle smooth or slightly ridged. Abaxial: glandular- tomentulose; sub-sessile, peltate glandular trichomes with 2-celled head forming a dense covering on the areolae; uniseriate, acicular, multicellular eglandular trichomes with swollen junctions between cells sparsely distributed, basal cell short and disc like, terminal cell longer, curvate; cuticle ridged; epicuticular wax particles present. Stomata: anomocytic, confined abaxially (hypostomatic), frequent, small, outline broadly elliptic, rim prominent, aperture broad; trichomes almost obscuring stomata.

## G. arborea Roxb.

# (Figure 3.9.3E-H. Philippines)

Adaxial: mostly glabrous; sessile, a few capitate glandular trichomes rarely scattered; distinctive cuticular ridges forming undulated and irregular cells. Abaxial: glandular- tomentulose; sub-sessile, peltate glandular trichomes with 2-celled head forming a dense covering on the areolae; uniseriate, acicular, multicellular eglandular trichomes with swollen junctions between cells sparsely distributed, basal cell short and disc like, terminal cell longer, curvate; cuticle ridged. **Stomata**: anomocytic, confined abaxially (hypostomatic), frequent, small, outline elliptic, rim prominent, aperture broad; trichomes obscuring stomata.

# G. arborea Roxb.

## (Figure 3.9.4A-D. India)

Adaxial: glabrous; a very few sessile, capitate glandular trichomes rarely scattered; cuticle smooth, somewhat glaucous. Abaxial: densely glandular; sub-sessile, peltate glandular trichomes forming a dense covering on the areolae, head mostly 2-celled, rarely 3- or 4-celled; cuticle ridged. **Stomata**: anomocytic, confined abaxially (hypostomatic), very frequent, small, outline elliptic or broadly elliptic, rim prominent, aperture broad.

## G. arborea Roxb.

#### (Figure 3.9.4E-H. Sri Lanka)

Adaxial: glabrescent; a few sessile capitate glandular trichomes, and uniseriate, attenuate, multicellular eglandular trichomes rarely scattered; cuticle conspicuously reticulate ridged. Abaxial: glandular- tomentose; sub-sessile, peltate glandular trichomes with 2-celled head forming a dense covering on the areolae along with long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells; cuticle ridged. Stomata: anomocytic, confined abaxially (hypostomatic), infrequent, outline broadly elliptic, rim prominent, aperture broad; trichomes almost obscuring stomata.

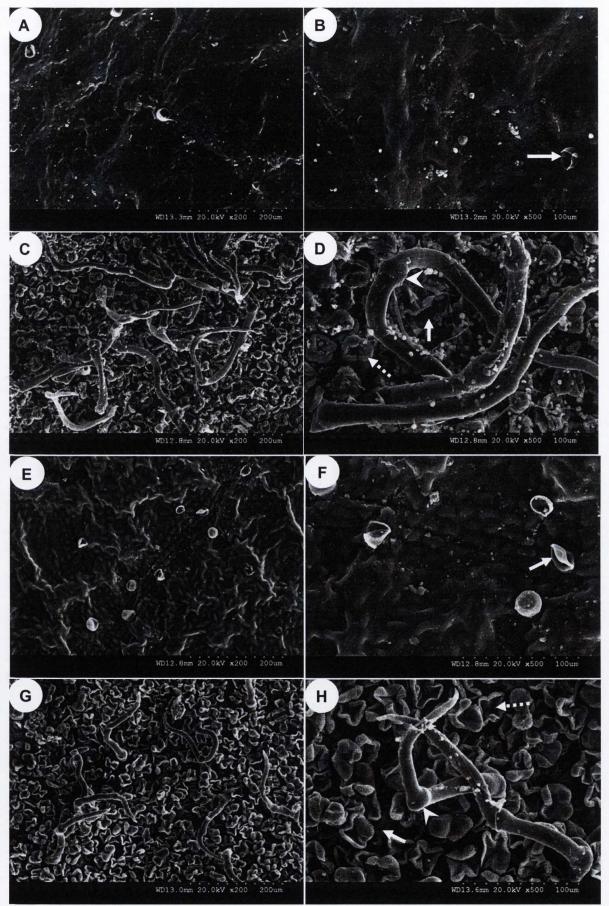


Figure 3.9.3 SEM micrographs of leaf surfaces. A-D. *G. arborea* (Vietnam). A) Adaxial surface X 200. B) Adaxial surface X 500. Trichome abscission scar arrowed. C) Abaxial surface X 200. D) Abaxial surface X 500. Arrow head indicates swollen junction of cell joint; dashed arrow indicates peltate gland; solid arrow shows stoma. (All from *Poilane* 13635, P). E-H. *G. arborea* (Philippines). E) Adaxial surface X 200. F) Adaxial surface X 500. Arrow indicates sessile, capitate gland. G) Abaxial surface X 200. H) Abaxial surface X 500. Arrow head indicates swollen junction of cell joint; dashed arrow indicates peltate gland; solid arrow shows stoma. (All from *Soejarto et al.* 6533, MO).

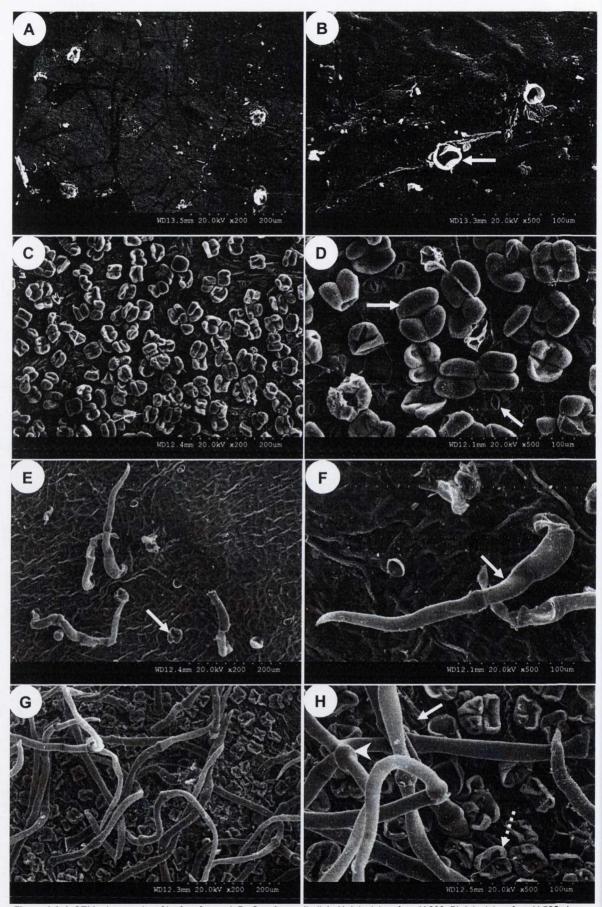


Figure 3.9.4. SEM micrographs of leaf surfaces. A-D. *G. arborea* (India). A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow indicates sessile, capitate gland. C) Abaxial surface X 200. D) Abaxial surface X 500. Upper arrow indicates peltate gland; lower arrow shows stoma. (All from *Balakund* 81, NY). E-H. *G. arborea* (Sri Lanka). E) Adaxial surface X 200. Arrow indicates sessile, capitate gland. F) Adaxial surface X 500. Arrow shows attenuate eglandular trichome. G) Abaxial surface X 200. H) Abaxial surface X 500. Solid arrow indicates stoma; arrow head indicates swollen junction of cell joint; dashed arrow shows peltate glandular trichome. (All from *Worthington* 887, K).

# G. asiatica L.

Adaxial: glabrous; cuticle smooth or slightly ridged, somewhat glaucous. Abaxial: glandular; sub-sessile, peltate glandular trichomes with 4-celled head frequently present; cuticle conspicuously ridged; epicuticular wax particles present **Stomata**: anomocytic, confined abaxially (hypostomatic), almost sunken, frequent, small, outline broadly elliptic, rim prominent, aperture narrow, rarely broad.

# G. asiatica L.

# (Figure 3.9.5E-H. Cambodia)

Adaxial: glabrous; cuticle smooth or slightly ridged, somewhat glaucous. Abaxial: glandular; sub-sessile, flattened and disc-shaped, peltate glandular trichomes frequently distributed, head mostly 8-celled or rarely 4-celled; cuticle ridged; epicuticular wax particles present. Stomata: anomocytic, confined abaxially (hypostomatic), abundant, small, somewhat sunken, outline broadly elliptic, rim prominent, aperture broad.

# G. asiatica L.

### (Figure 3.9.6A-D. Malaysia)

Adaxial: glabrous; cuticle smooth apart from distinctive reticulate ridges, somewhat glaucous; epicuticular wax particles present. Abaxial: sparsely glandular; sub-sessile, flattened and disc-shaped peltate glandular trichomes frequently distributed, head mostly 8-celled or rarely 4-celled; cuticle ridged; epicuticular wax particles present. Stomata: anomocytic, confined abaxially (hypostomatic), frequent, almost sunken, small, outline broadly elliptic, rim prominent, aperture broad.

## G. asiatica L.

#### (Figure 3.9.6E-H. Thailand)

Adaxial: mostly glabrous; a few capitate glandular trichomes rarely scattered, head 4-celled; cuticle distinctively reticulate ridged; epicuticular wax particles present. Abaxial: glandular; sub-sessile, peltate glandular trichomes with 4-celled head frequent; a very few uniseriate, acicular, multicellular eglandular trichomes with swollen junctions between cells scattered, surface warty; cuticle conspicuously ridged. Stomata: anomocytic, confined abaxially (hypostomatic), very frequent, small, somewhat sunken, outline broadly elliptic, rim prominent, aperture broad.

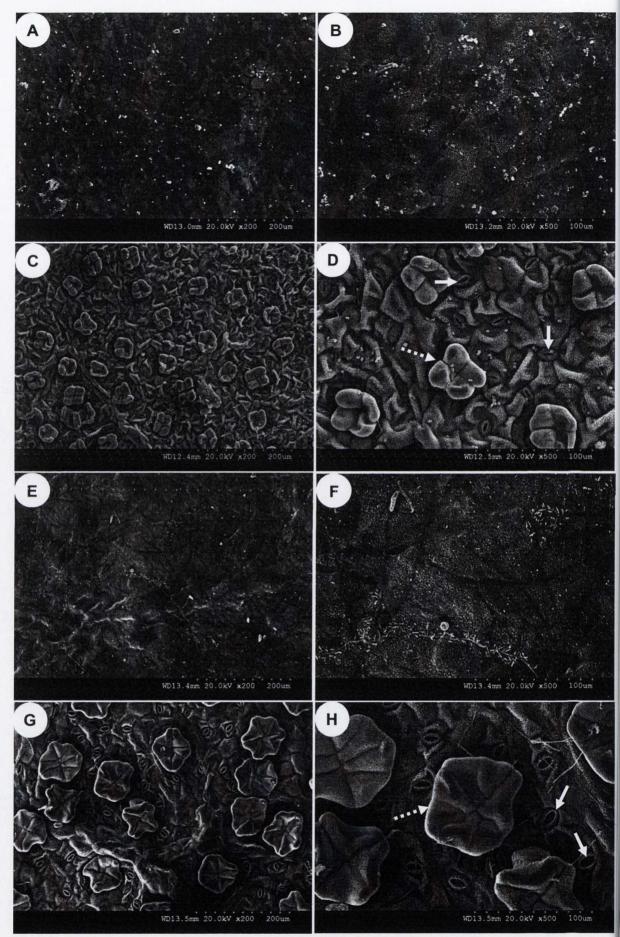


Figure 3.9.5 SEM micrographs of leaf surfaces. A-D. *G. asiatica* (Vietnam). A) Adaxial surface X 200. B) Adaxial surface X 500. C) Abaxial surface X 200. D) Abaxial surface X 500. Dashed arrow indicates sub-sessile, peltate gland; solid arrows show stomata. (All from *Evrard* 2680, P). E-H. *G. asiatica* (Cambodia). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Dashed arrow indicates sub-sessile, peltate gland; Solid arrows show stomata. (All from *Mari* & *Mari* A555, P).

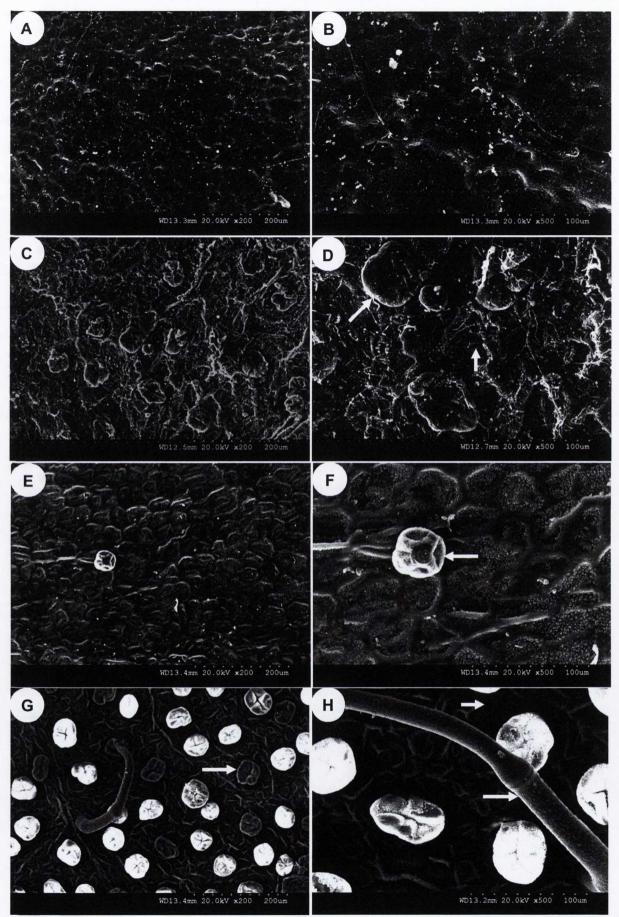


Figure 3.9.6 SEM micrographs of leaf surfaces. A-D. *G. asiatica* (Malaysia). A) Adaxial surface X 200. B) Adaxial surface X 500. C) Abaxial surface X 200. D) Abaxial surface X 500. Upper arrow indicates sub-sessile, peltate gland; lower arrow shows stoma. (All from *Ridley* s.n., SING). E-H. *G. asiatica* (Thailand). E) Adaxial surface X 200. F) Adaxial surface X 500. Sessile, capitate, trichome arrowed. G) Abaxial surface X 200. Arrow indicates peltate, sub-sessile glandular trichome. H) Abaxial surface X 500. Upper arrow shows stoma; lower arrow indicates acicular trichome. (All from *Kerr* 21527, BM).

### G. asiatica L.

#### (Figure 3.9.7A-D. Philippines)

Adaxial: glabrous; cuticle smooth, sparsely tessellated, somewhat glaucous, shallow grooves present; epicuticular wax particles present. Abaxial: sparsely glandular; almost sunken, sessile, flattened and disc-shaped peltate glandular trichomes sparsely distributed, head mostly 8-celled or rarely 4-celled; cuticle smooth, shallow grooves present. Stomata: anomocytic, confined abaxially (hypostomatic), abundant, almost sunken, outline broadly elliptic, rim prominent, aperture broad, rarely narrow.

# G. asiatica L.

# (Figure 3.9.7E-H. Sri Lanka)

Adaxial: mostly glabrous, glaucous; very few capitate glandular trichomes with 4-celled head, and acicular eglandular trichomes along the veins rarely scattered; cuticle mostly smooth, distinctively ridged along the veins; epicuticular wax particles present. Abaxial: densely glandular; disc-shaped, sub-sessile, peltate glandular trichomes forming a dense covering on the areolae, head mostly 4-celled, rarely 2-celled; cuticle conspicuously ridged; epicuticular wax particles present. Stomata: anomocytic, confined abaxially (hypostomatic), almost sunken, infrequent, small, outline broadly elliptic, rarely circular, rim prominent, aperture narrow, rarely broad.

## G. attenuata Fletcher.

#### (Figure 3.9.8A-D. Thailand)

Adaxial: mostly glabrous; cuticle distinctively reticulate ridged, lumina somewhat glaucous; epicuticular wax particles present. Abaxial: glandular; sub-sessile, peltate glandular trichomes frequently present, head mostly 2-celled, rarely 3-celled; cuticle conspicuously ridged; epicuticular wax particles present Stomata: anomocytic, confined abaxially (hypostomatic), very frequent, outline elliptic, rim inconspicuous, aperture broad.

# G. chinensis Benth.

#### (Figure 3.9.8E-H. Hong Kong)

Adaxial: glabrous; cuticle smooth or obscurely ridged, epicuticular wax particles rarely present. Abaxial: glandular-pilose; sub-sessile, peltate glandular trichomes scattered, head 2- or 4-celled; and uniseriate, acicular, mostly uni-cellular or multicellular eglandular trichomes rarely distributed mainly along the veins; cuticle smooth with shallow grooves, distinctively ridged along the veins; epicuticular wax particles present. **Stomata**: anomocytic, confined abaxially (hypostomatic), abundant, small, outline narrowly elliptic or broadly elliptic, rim inconspicuous, aperture broad.

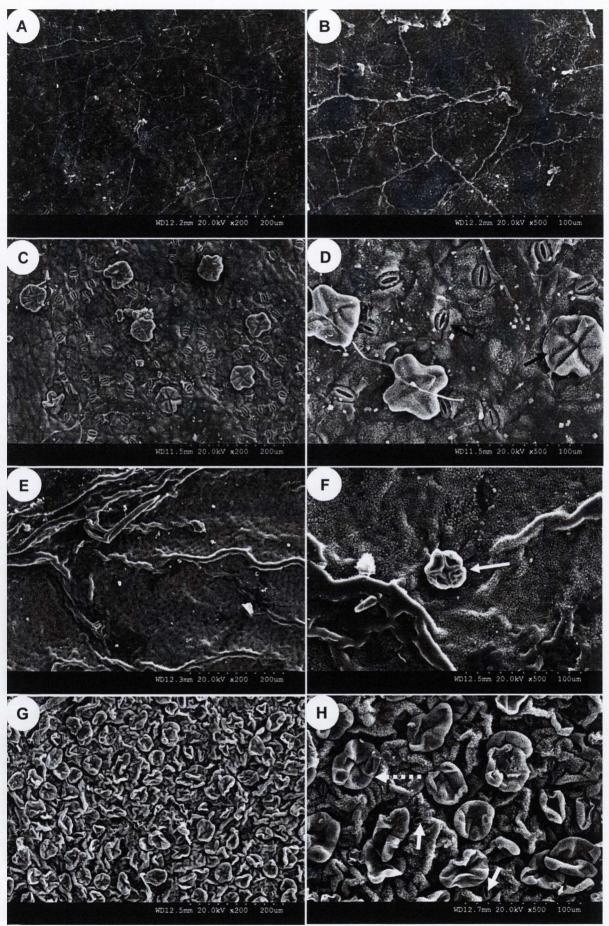
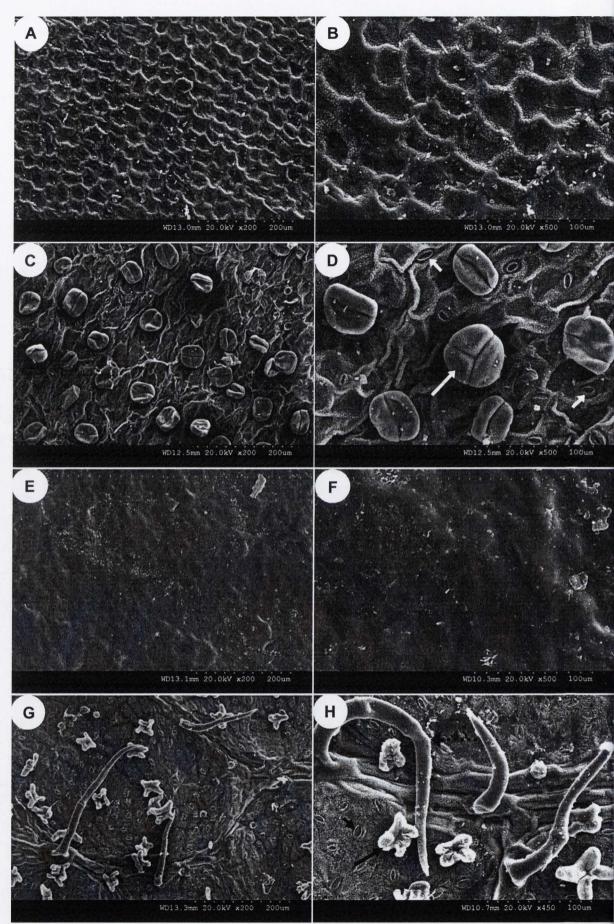


Figure 3.9.7 SEM micrographs of leaf surfaces. A-D. *G. asiatica* (Philippines). A) Adaxial surface X 200. B) Adaxial surface X 500. C) Abaxial surface X 200. D) Abaxial surface X 500. Upper arrow shows stoma, lower arrow indicates peltate, sessile, sunken trichome. (All from *Mati* 31, L). E-H. *G. asiatica* (Sri Lanka). E) Adaxial surface X 200. Arrow shows capitate gland. F) Adaxial surface X 500. Arrow indicates sessile, capitate gland G) Abaxial surface X 200. H) Abaxial surface X 500. Upper dashed-arrow indicates sessile, peltate gland; lower short arrows show stomata. (All from *Sumitharrarchi* DBS 764, US).



**Figure 3.9.8** SEM micrographs of leaf surfaces.A-D. *G. attenuata*. (Thailand). A) Adaxial surface X 200. B) Adaxial surface X 500. C) Abaxial surface X 200. D) Abaxial surface X 500. Short arrows indicate stomata; long arrow shows sub-sessile, peltate tri-cellular gland. (All from *Kerr* 6224, E).E-H. *G. chinensis* (Hong Kong). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Short arrow indicates stoma; long dashed arrow indicates acicular trichome; long-solid arrow shows sessile capitate glandular trichome. (All from *Chan* 1073, A).

### G. delavayana Dop

#### (Figure 3.9.9A-D. China)

Adaxial: mostly glabrous; a few sessile capitate glandular trichomes rarely scattered; cuticle farinose, conspicuously ridged. Abaxial: densely glandular; sub-sessile, peltate glandular trichomes forming a dense covering on the areolae; head mostly 2-celled, rarely 4-celled; cuticle conspicuously ridged; epicuticular wax particles present. **Stomata**: anomocytic, confined abaxially (hypostomatic), almost sunken, infrequent, small, outline broadly elliptic, rim inconspicuous, aperture broad.

#### G. elliptica Smith

### (Figure 3.9.9E-H. Thailand)

Adaxial: glabrous; a few uniseriate, acicular eglandular trichomes rarely scattered; cuticle smooth; epicuticular wax particles present. Abaxial: tomentose; long uniseriate, acicular, multicellular eglandular trichomes with swollen junctions between cells frequently distributed, basal cell short and disc like, terminal cell longer, curvate or twisted; sessile, peltate glandular trichomes with 4-celled head sparsely present; cuticle tessellated; epicuticular wax particles present. **Stomata**: anomocytic, confined abaxially (hypostomatic), frequent, small, outline elliptic or narrowly elliptic, rim inconspicuous, aperture narrow.

#### G. elliptica Smith

#### (Figure 3.9.10A-D. Vietnam)

Adaxial: glabrescent; uniseriate, simple acicular, acicular-spiral or acicular-geniculate multicellular eglandular trichomes rarely scattered; cuticle conspicuously ridged. Abaxial: tomentose; long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells forming a dense covering on the areolae; cuticle inconspicuously ridged. Stomata: anomocytic, confined abaxially (hypostomatic), frequent, small, outline elliptic or narrowly elliptic, rim inconspicuous, aperture broad, rarely narrow.

#### G. elliptica Smith

#### (Figure 3.9.10E-H. Malaysia)

Adaxial: glabrescent; uniseriate, simple acicular, multicellular eglandular trichomes scattered; cuticle scurfy with conspicuous ridges along the veins. Abaxial: tomentose; long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells forming a dense covering on the areolae; a few sessile, peltate glandular trichomes scattered, head 2-celled; cuticle conspicuously ridged. Stomata: anomocytic, confined abaxially (hypostomatic), very frequent, small, outline elliptic, rim inconspicuous, aperture narrow.

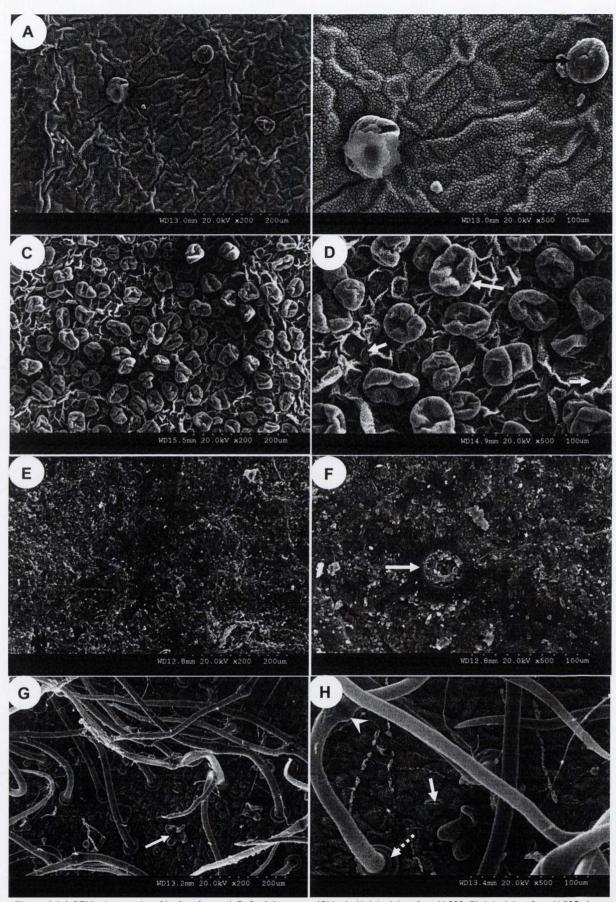


Figure 3.9.9 SEM micrographs of leaf surfaces. A-D *G. delavayana* (China). A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow indicates sessile, capitate gland. C) Abaxial surface X 200. D) Abaxial surface X 500. Short arrows indicate stomata; long arrow shows sub-sessile, peltate gland. (All from *Forrest* 11662, BM). E-H. *G. elliptica* (Thailand). E) Adaxial surface X 200. F) Adaxial surface X 500. Egandular trichome abscission scar arrowed. G) Abaxial surface X 200. Arrow shows sessile, peltate gland. H) Abaxial surface X 500. Arrow head indicates swollen junction on cell joint, dashed arrow indicates disc like basal cell; solid arrow shows stoma. (All from *Parnell et al.* 95-420, TCD).

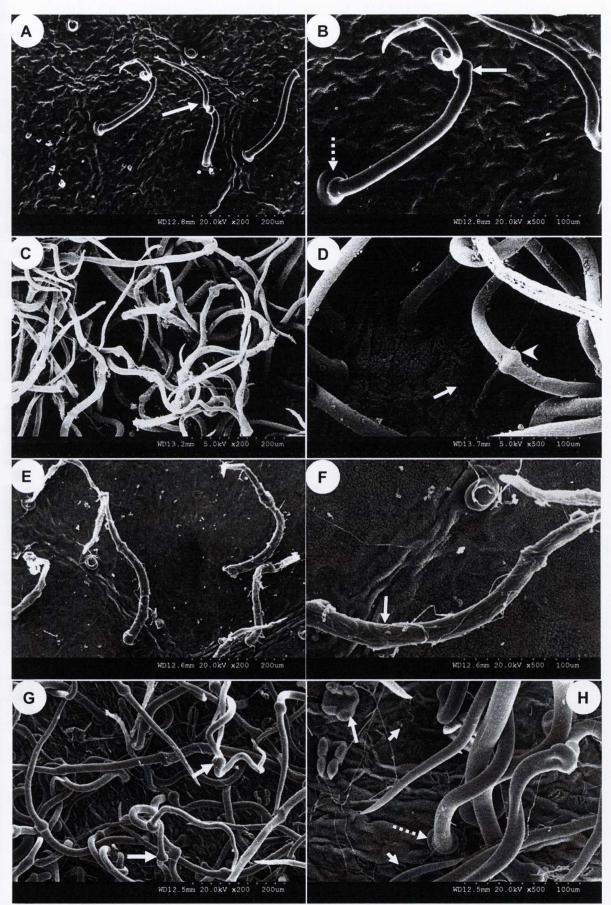


Figure 3.9.10 SEM micrographs of leaf surfaces. A-D. G. elliptica (Vietnam). A) Adaxial surface X 200. Acicular-geniculate trichome arrowed. B) Adaxial surface X 500. Soild arrow shows spiral eglandular trichome; dashed arrow indicates disc like base of the trichome. C) Abaxial surface X 200. D) Abaxial surface X 500. Arrow head indicates swollen junction on cell joint; solid arrow shows stoma. (All from *Hiep* 147, P). E-H. G. elliptica (Malaysia). E) Adaxial surface X 200. F) Adaxial surface X 500. Arrow indicates acicular trichome. G) Abaxial surface X 200. Arrows indicate swollen junctions of cell joint. H) Abaxial surface X 500. Short arrows indicate stomata; long-solid arrow indicates sessile, peltate gland; dashed arrow shows disc like basal cell of eglandular trichome. (All from *Guan* 34276, K).

## G. elliptica Smith

#### (Figure 3.9.11A-D. Indonesia)

Adaxial: glabrescent; uniseriate, simple acicular, multicellular eglandular trichomes rarely scattered, basal cell very short and conspicuously disc like; cuticle tessellated, shallow grooves present; epicuticular wax minutely present. Abaxial: tomentose; long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells forming a dense covering on the areolae, basal cell very short and conspicuously disc like; a few sub-sessile, peltate glandular trichomes scattered, head 2-celled; cuticle ridged, much pronounced along the veins; epicuticular wax particles present. Stomata: anomocytic, confined abaxially (hypostomatic), frequent, outline elliptic to broadly elliptic, rim prominent, aperture narrow; trichomes almost obscuring stomata.

## G. elliptica Smith

# (Figure 3.9.11E-H. Brunei)

Adaxial: glabrous; cuticle conspicuously ridged. Abaxial: glandular-tomentose; sessile, peltate glandular trichomes with 2- or 4-celled head, along with long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells forming a dense covering on the areolae; cuticle conspicuously ridged, much pronounced along the veins. **Stomata**: confined abaxially (hypostomatic), trichomes obscuring stomata.

### G. elliptica Smith

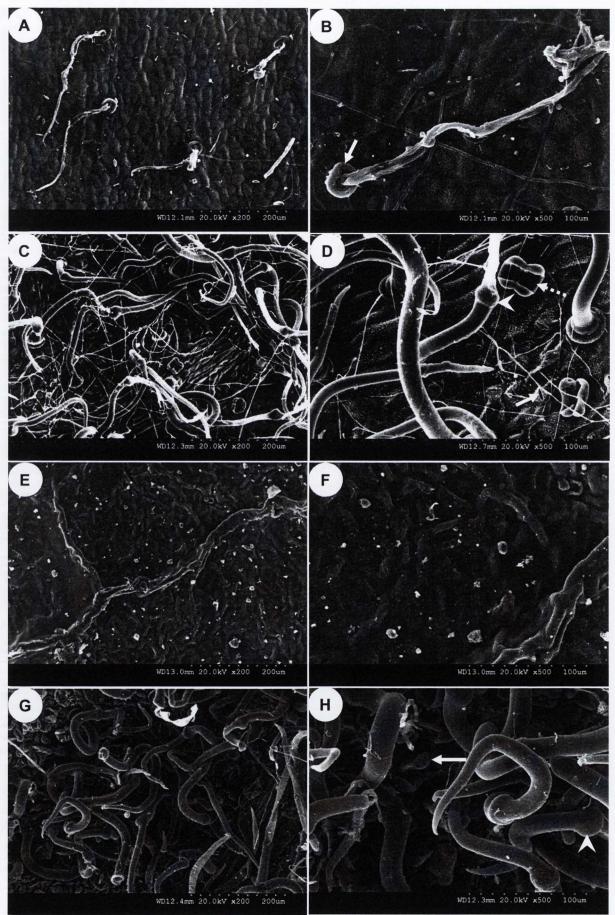
#### (Figure 3.9.12A-D. India)

Adaxial: glabrescent; uniseriate, acicular, multicellular eglandular trichomes with swollen junction between cells rarely scattered, basal cell very short and disc like, terminal cell much longer, curvate; cuticle distinctively ridges, forming undulated and irregular cells. Abaxial: tomentose; uniseriate, long crisped, acicular, multicellular eglandular trichomes with swollen junctions between cells frequently distributed, basal cell short and disc like, terminal cell much longer, twisted together; sessile, peltate glandular trichomes scattered, head 2- or 4-celled; cuticle tessellated; epicuticular wax particles present. Stomata: anomocytic, confined abaxially (hypostomatic), very frequent, small, slightly sunken, outline elliptic or narrowly elliptic, rim inconspicuous, aperture narrow.

## G. hainanensis Oliv.

#### (Figure 3.9.12E-H. China)

Adaxial: lustrous and mostly glabrous; a few sessile, capitate glandular trichomes rarely scattered; cuticle tessellated, shallow grooves present; epidermal cells radially-arranged at the base of trichomes. Abaxial: extremely densely glandular-tomentose; sub-sessile, peltate glandular trichomes with 4-celled head forming a dense covering on the areolae along with uniseriate, acicular, curly multicellular eglandular trichomes; cuticle ridged. Stomata: anomocytic, confined abaxially (hypostomatic), infrequent, small, outline elliptic, rim prominent, aperture narrow; trichomes obscuring stomata.



**Figure 3.9.11** SEM micrographs of leaf surfaces. A-D. *G. elliptica* (Indonesia). A) Adaxial surface X 200. B) Adaxial surface X 500. Arow indicates disc like basal cell of acicular trichome. C) Abaxial surface X 200. D) Abaxial surface X 500. Dashed arrow shows sessile, peltate gland; lower arrow indicates stoma; arrow head shows swollen junction of cell joint. (All from *Tores* 5357, A). E-H. *G. elliptica* (Brunei). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Arrow shows sessile, peltate gland; arrow head indicates swollen junction of cell joint. (All from *Tores* 5357, A). E-H. *G. elliptica* (Brunei). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Arrow shows sessile, peltate gland; arrow head indicates swollen junction of cell joint. (All from *Coode* 7399, K).

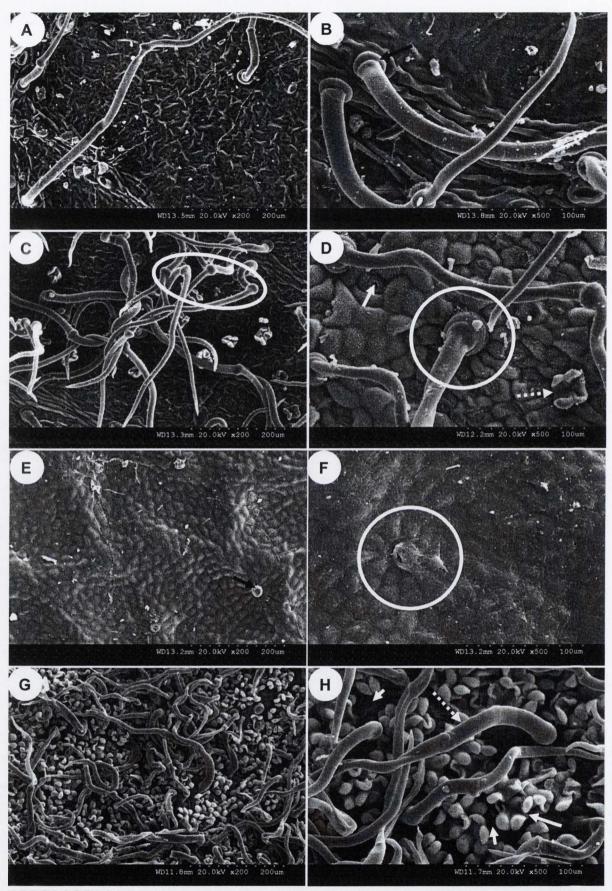


Figure 3.9.12 SEM micrographs of leaf surfaces. A-D. G. elliptica (India). A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow indicates disc like base of acicular trichome. C) Abaxial surface X 200. Swollen junctions on cell joints circled. D) Abaxial surface X 500. Solid arrow indicates stoma; dashed arrow shows sessile, peltate gland; disc-like basal cell and radiating epidermal cells circled. (All from *unknown* s.n., BM). E-H. G. hainanensis (China). E) Adaxial surface X 200. Arrow indicates sessile glandular trichome. F) Adaxial surface X 500. Radiating epidermal cells circled. G) Abaxial surface X 200. H) Abaxial surface X 500. Short arrows indicate stomata; long-solid and dashed arrows indicate sessile, glandular trichome and acicular, eglandular trichomes respectively. (All from *How* 70801, P).

# G. hainanensis Oliv.

#### (Figure 3.9.13A-D. Vietnam)

Adaxial: glabrous; a very few sessile, capitate glandular trichomes rarely scattered; cuticle conspicuously ridged. Abaxial: glandular-pilose; sub-sessile, peltate glandular trichomes with 4-celled head forming a dense covering on the areolae; uniseriate, acicular, mostly bi-cellular eglandular trichomes sparsely distributed, basal cell very short and broad, terminal cell much longer and curvate; cuticle slightly ridged; epicuticular wax particle present. **Stomata**: anomocytic, confined abaxially (hypostomatic), frequent, small, outline elliptic, rim incospicuous, aperture narrow, trichomes almost obscuring stomata.

# G. lepidota Scheff.

## (Figure 3.9.13E-H. Moluccas, Indonesia)

Adaxial: glabrous; cuticle smooth or inconspicuously ridged; epicuticular wax particles present. Abaxial: lepidote; sub-sessile, peltate star-shaped, multicellular glandular trichomes completely covered the surface, head 8-celled; a few sessile, sunken, patelliform glandular trichomes rarely scattered; dense trichomes obscuring cuticle. **Stomata**: trichomes obscuring stomata.

# G. lepidota Scheff.

#### (Figure 3.9.14A-D. Irian Jaya, Indonesia)

Adaxial: glabrous; cuticle smooth to slightly ridged. Abaxial: lepidote; sub-sessile, peltate, star-shaped multicellular glandular trichomes forming a dense covering on the areolae, head 8-celled; and a few uniseriate, acicular, filiform unicellular eglandular trichomes scattered; layer of epicuticular wax covered the cuticle. **Stomata**: trichomes and epicuticular wax obscuring stomata.

# G. moluccana (Blume) Backer

(Figure 3.9.145E-H.

Indonesia)

Adaxial: glabrescent; a few uniseriate, attenuate multicellular eglandular trichomes rarely scattered, basal cell very short, terminal cell much longer and curvate; and asciiform, multicellular glandular trichomes rarely distributed along the veins; cuticle ridged. Abaxial: glabrescent; a few acicular, bi-cellular eglandular trichomes rarely scattered along the veins, basal cell very short, terminal cell much longer and erect; cuticle conspicuously ridged with swollen and irregular inter-stomatal cells. Stomata: anomocytic, confined abaxially (hypostomatic), abundant, small, outline elliptic, somewhat protruding, rim prominent, aperture narrow.

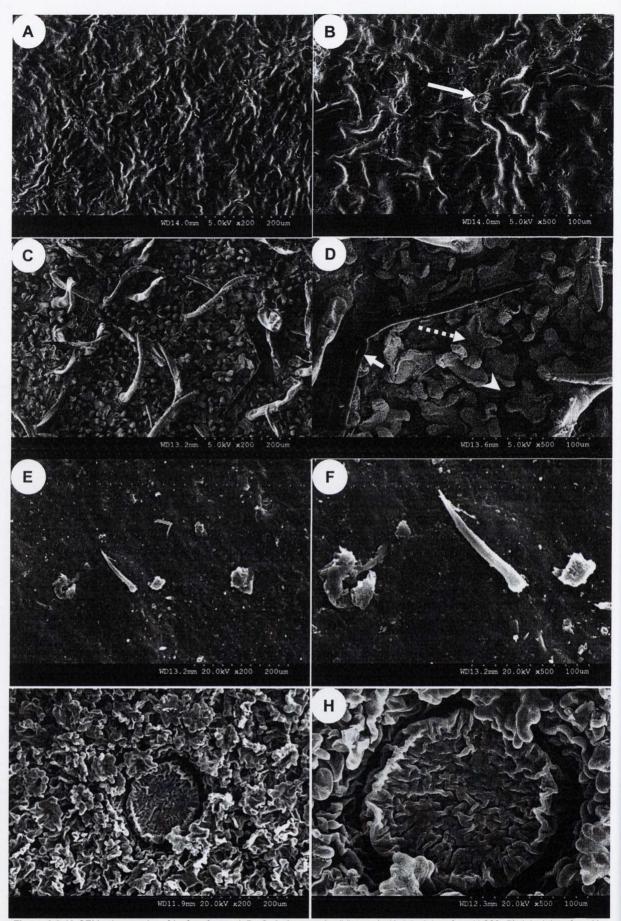


Figure 3.9.13 SEM micrographs of leaf surfaces. A-D. *G. hainanensis* (Vietnam). A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow indicates sessile, capitate gland. C) Abaxial surface X 200. D) Abaxial surface X 500. Dashed arrow shows sessile, peltate gland; short arrow indicates acicular, eglandular trichome. arrow head indicates stomata (All from *Tsang* 29235, A). E-H. *G. lepidota* (Moluccas, Indonesia). A) Adaxial surface X 200. B) Adaxial surface X 500. C) Abaxial surface X 200. Arrow shows sunken, patelliform gland. D) Abaxial surface X 500. Sunken, patelliform gland enlarged. (All from *Vogel* 4342, MO).

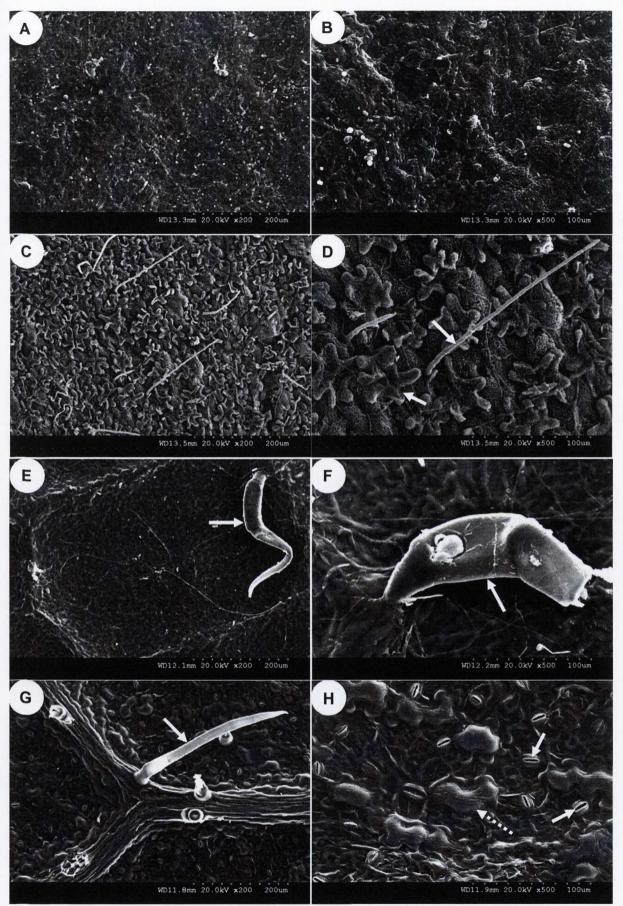


Figure 3.9.14 SEM micrographs of leaf surfaces. A-D. *G. lepidota* (Irian Jaya, Indonesia). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Upper arrow indicates unicellular, acicular trichome; lower short arrow shows sessile, star-shaped peltate gland. (All from *Kosterman & Soegans* 396, A). E-H. *G. moluccana* (Indonesia). A) Adaxial surface X 200. Uniseriate, attenuate trichome arrowed. B) Adaxial surface X 500. Arrow indicates asciiform trichome. C) Abaxial surface X 200. Arrow shows acicular, eglandular trichome. D) Abaxial surface X 500. Arrows indicate stomata; dashed arrow shows swollen interstomatal cell. (All from *Robinson* 296, NY).

Adaxial: glabrous; cuticle smooth or inconspicuously ridged; capitate glandular trichomes rarely scattered; epicuticular wax particle present. Abaxial: glabrous; cuticle distinctively ridged or wrinkled and deeply grooved. Stomata: anomocytic, confined abaxially (hypostomatic), very abundant, large, outline elliptic or somewhat circular, rim distinctly prominent, aperture narrow or broad.

#### G. palawensis H. J. Lam

(Figure 3.9.15E-H. Palau Island)

Adaxial: glabrous, cuticle distinctively ridged; sessile, capitate glandular trichomes rarely scattered. Abaxial: glabrous; cuticle ridged, shallow grooves present. **Stomata**: anomocytic, confined abaxially (hypostomatic), very abundant, large, outline elliptic or somewhat circular, rim distinctly prominent, aperture broad, rarely narrow.

### G. paniculata Fletcher

#### (Figure 3.9.16A-D. Thailand)

Adaxial: glabrous; cuticle wrinkled, distinctive ridges forming undulated and irregular cells. Abaxial: glandular; sub-sessile, peltate glandular trichomes frequently distributed, head mostly 2-celled, rarely 4-celled; cuticule conspicuously ridged; epicuticular wax particles present. **Stomata**: anomocytic, confined abaxially (hypostomatic), abundant, slightly sunken, outline broadly elliptic, rim inconspicuous, aperture broad, rarely narrow.

# G. philippensis Cham.

#### (Figure 3.9.16E-H. Philippines)

Adaxial: mostly glabrous with some distinctive lumps; cuticle smooth or slightly ridged. Adaxial: sparsely glandular, subsessile, multicellular, flattened and disc-shaped peltate glandular trichomes sparsely distributed, head mostly 4-celled, rarely 8-celled, basally almost sunken; cuticle tessellated, shallow grooves present. **Stomata:** anomocytic or rarely paracytic; confined abaxially (hypostomatic), abundant, large, almost sunken, outline narrowly elliptic, rim prominent, aperture narrow.

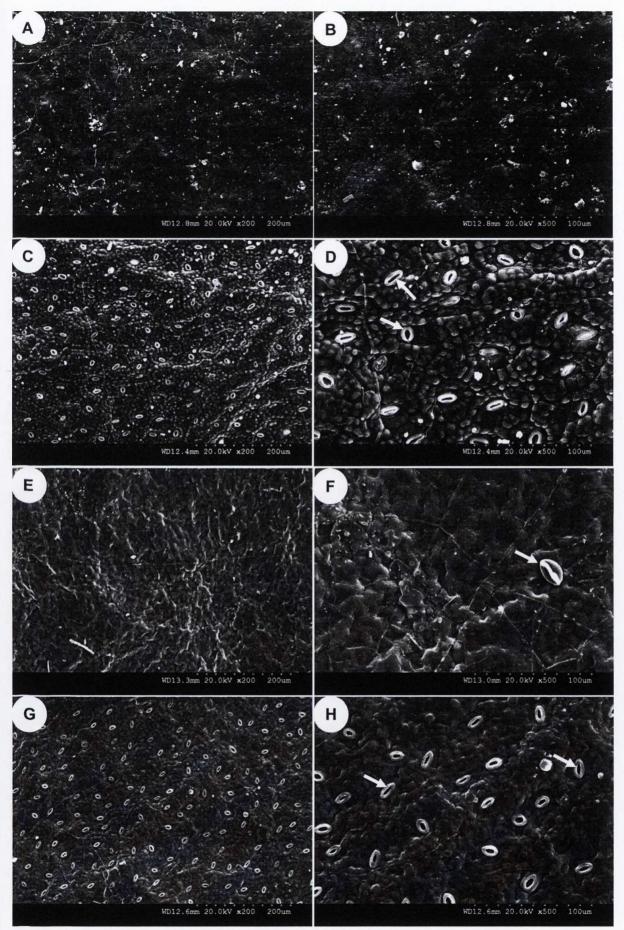


Figure 3.9.15. SEM micrographs of leaf surfaces. A-D. *G. palawensis* (Indonesia). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Arrows indicate stoma. (All from *Boschproefstan* bb 8560, NY). E-H. *G. palawensis* (Palau Island). A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow shows sessile, glandular trichome. C) Abaxial surface X 200. D) Abaxial surface X 500. Arrows indicate stomata. (All from *Kanehira* 2280, NY).

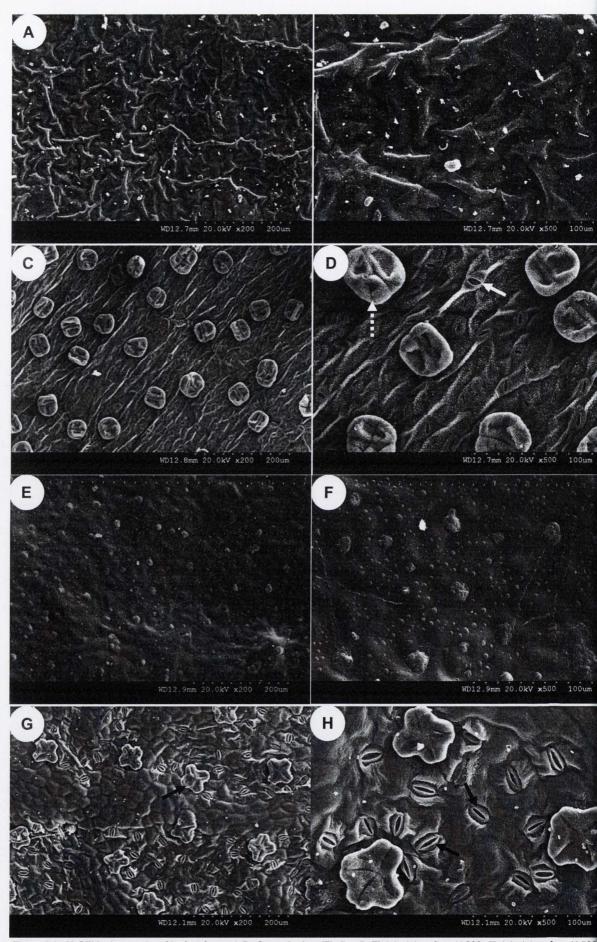


Figure 3.9. 16 SEM micrographs of leaf surfaces. A-D. *G. paniculata* (Thailand). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. H) Abaxial surface X 500. Dashed arrow shows peltate gland; solid arrow indicates stoma. (All from *Pu* 2806, E). E-H. *G. philippensis* (Philippines). A) Adaxial surface X 200. B) Adaxial surface X 500. C) Abaxial surface X 200. Peltate gland arrowed. D) Abaxial surface X 500. Arrows indicate stomata. (All from *Fenix* BOS 30092, A).

# G. philippensis Cham.

Adaxial: glabrous; cuticle smooth or somewhat glaucous. Adaxial: sparsely glandular; sessile, multicellular, flattened and disc-shaped peltate glandular trichomes sparsely distributed, head 8-celled, basally almost sunken; cuticle tessellated, shallow grooves present. **Stomata:** anomocytic or rarely paracytic; confined abaxially (hypostomatic), abundant, large, almost sunken, outline elliptic, rim prominent, aperture narrow.

## G. racemosa (Lour.) Merr.

# (Figure 3.9.17E-H. Vietnam)

Adaxial: mostly glabrous; a few sessile, capitate glandular trichomes rarely scattered; epidermal cells radially-arranged at the base of glandular trichomes, vein-associated epidermal cells elongated; cuticle tessellated, shallow grooves present. Abaxial: extremely densely glandular-pilose; sub-sessile, peltate glandular trichomes with 4-celled head forming a dense covering on the areolae; uniseriate, acicular, mostly bi-cellular or rarely multicellular eglandular trichomes frequently distributed, basal cell very short, terminal cell much longer, mostly erect, rarely curvate; cuticle ridged; epicuticular wax present. Stomata: anomocytic, confined abaxially (hypostomatic), outline elliptic, rim prominent, aperture broad; trichomes almost obscuring stomata.

#### G. racemosa (Lour.) Merr.

#### (Figure 3.9.18A-D. Thailand)

Adaxial: glabrous; a very few sub-sessile, stellate trichomes rarely scattered; cuticle inconspicuously ridged. Abaxial: glandular-pilose; sub-sessile, peltate glandular trichomes forming a dense covering on the areolae, head mostly 2-celled or rarely 4-celled; uniseriate, acicular, multicellular eglandular trichomes sparsely distributed, basal cell very short and broad, terminal cell much longer and curvate; a very few sub-sessile, profusely branched stellate trichomes rarely scattered; cuticle slightly ridged. **Stomata**: anomocytic, confined abaxially (hypostomatic), frequent, small, outline elliptic, rim inconspicuous, aperture broad, trichomes almost obscuring stomata.

# G. schlechteri H. J. Lam

#### (Figure 3.9.18E-H. Indonesia)

Adaxial: glabrous; a few sessile, multicellular, hyaline peltate glandular trichomes with long central ray very rarely scattered; cuticle inconspicuously ridged; epicuticular wax particle present. Abaxial: glabrous; a few sessile, capitate, multicellular glandular trichomes very rarely distributed; distinctive cuticular ridges forming undulated and irregular cells; epicuticular wax particle present. Stomata: anomocytic, confined abaxially (hypostomatic), frequent, large, outline elliptic, rarely circular, rim prominent, aperture narrow.

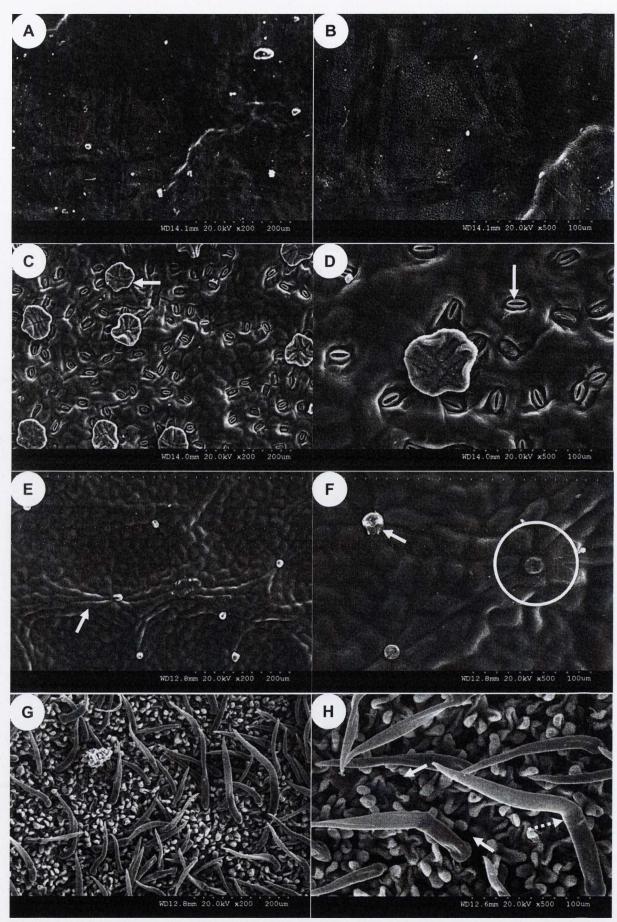


Figure 3.9.17 SEM micrographs of leaf surfaces. A-D. G. philippensis (Cambodia). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. Arrow shows sessile, peltate gland. H) Abaxial surface X 500. Arrow indicates stoma. (All from *Meng et al.* 452, K). E-H. G. racemosa (Vietnam). A) Adaxial surface X 200. Elongated vein-associated epidermal cell arrowed. B) Adaxial surface X 500. Arrow indicates capitate gland; radiating epidermal cells circled. C) Abaxial surface X 200. D) Abaxial surface X 500. Solid arrows indicate stomata; dashed arrow shows acicular, eglandular trichome. (All from *Clemens* 3980, A).

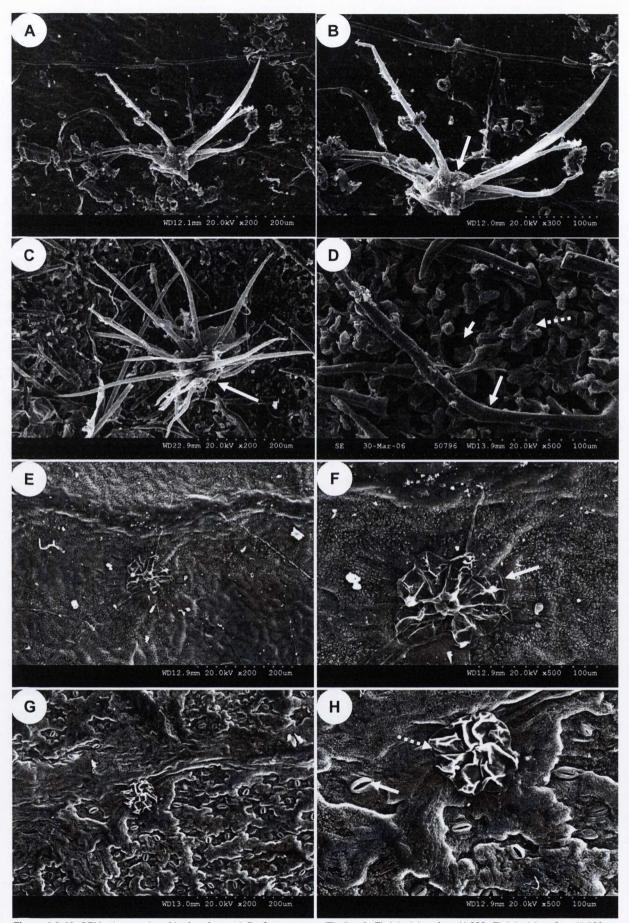


Figure 3.9.18. SEM micrographs of leaf surfaces. A-D. *G. racemosa* (Thailand). E) Adaxial surface X 200. F) Adaxial surface X 500. Arrow indicates sub-sessile, stellate trichome.G) Abaxial surface X 200. Arrow shows sub-sessile, stellate trichome. H) Abaxial surface X 500. Long arrow indicates uniseriate, acicular trichome; long dashed arrow shows sessile, peltate gland; short arrow indicates stoma. (All from *Pooma et al.* 2805, BKF). E-H. *G. schlechteri*. A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow shows hyaline, sessile, peltate gland. C) Abaxial surface X 200. D) Abaxial surface X 500. Solid arrow indicates stomata; dashed arrow shows sessile, capitate gland. (All from *Bagooly* 6610, K).

## G. spectabilis Ridl. ex M. H. Rashid & A. J. Paton

(Figure 3.9.19A-D. Malaysia)

Adaxial: glabrous; cuticle smooth, somewhat glaucous; epicuticular wax particle present. Abaxial: glandular; sub-sessile, peltate glandular trichomes frequently distributed, head mostly 2-celled, rarely 4-celled; a few sunken, disc like calvitium (bald spot) rarely scattered; cuticle smooth or slightly ridged; epicuticular wax particle present. **Stomata**: anomocytic, confined abaxially (hypostomatic), frequent, small, almost sunken, outline elliptic, rim inconspicuous, aperture narrow.

## G. tomentosa Fletcher

(Figure 3.9.19E-H. Thailand)

Adaxial: tomentose; long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells forming a dense covering on the areolae, basal cell very short and disc like, terminal cell much longer and twisted; cuticle inconspicuously ridged, much pronounced along the veins, epidermal cells radially-arranged at the base of trichomes; epicuticular wax particles present. Abaxial: tomentose; long crisped, acicular, multicellular marrubioid eglandular trichomes with swollen junctions between cells forming a dense covering on the areolae, basal cell very short and disc like, terminal cell much longer and twisted; cuticle conspicuously ridged, epidermal cells radially-arranged at the base of trichomes; epicuticular wax particles of trichomes; epicuticular wax particles covering on the areolae, basal cell very short and disc like, terminal cell much longer and twisted; cuticle conspicuously ridged, epidermal cells radially-arranged at the base of trichomes; epicuticular wax particles minutely present. Stomata: anomocytic, confined abaxially (hypostomatic), infrequent, small, outline narrow-elliptic, rim inconspicuous, aperture narrow, rarely broad.

# G. tonkinensis Moldenke

Adaxial: glabrescent; a few uniseriate, acicular, multicellular eglandular trichomes rarely scattered, mostly along the veins, basal cell short, surface warty, base broad and conspicuously disc like; terminal cell much longer and curvate; cuticle conspicuously ridged, more pronounced along the veins; epicuticular wax particles present. Abaxial: sparsely glandular-pilose; uniseriate, simple acicular or acicular-geniculate, multicellular eglandular trichomes sparsely distributed, mostly along the veins, surface warty, basal cell short and broad, conspicuously disc like; terminal cell curvate; sessile, peltate glandular trichomes with 4-celled head sparsely distributed; cuticle distinctively ridged; epicuticular wax particles present. Stomata: anomocytic, confined abaxially (hypostomatic), frequent, small, outline elliptic, rim conspicuous, aperture narrow, rarely broad.

# G. uniflora Stapf

# (Figure 3.9.20E-H. Indonesia)

(Figure 3.9.20A-D. Vietnam)

Adaxial: glabrous; a few sessile, capitate glandular trichomes rarely scattered with distinctive spread base, head two-celled; cuticle conspicuously reticulate ridged, lumina inconspicuously striated. Abaxial: densely glandular; sessile, peltate glandular trichomes frequently distributed, head 2-celled, rarely 4-celled; a few subulate bicellular, eglandular trichome rarely scattered, basal cell very short and narrow, terminal cell much longer and erect; cuticle smooth; epicuticular wax particle present. *Stomata*: anomocytic, confined abaxially (hypostomatic), infrequent, small, outline narrow-elliptic, rim inconspicuous, aperture narrow, rarely broad.

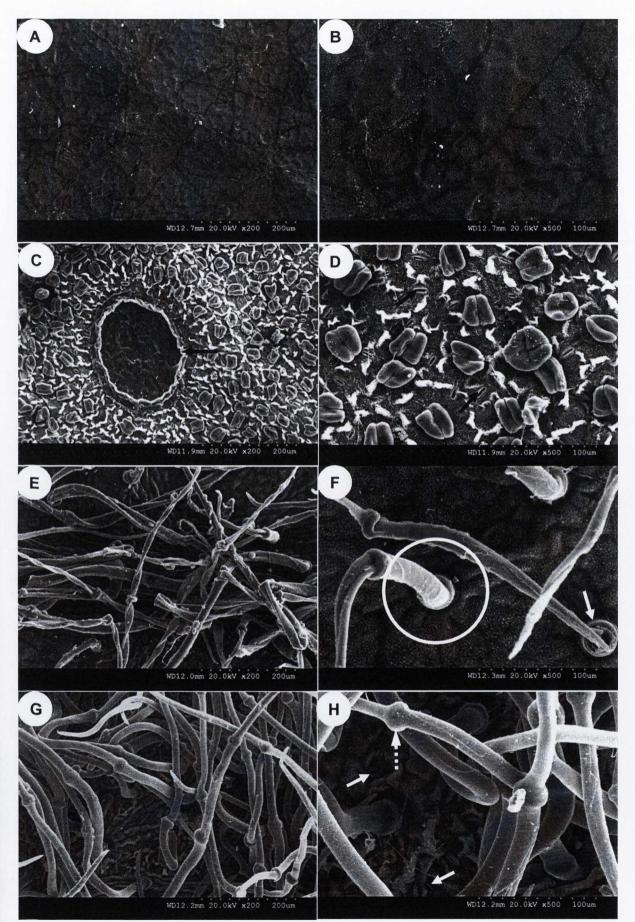


Figure 3.9.19 SEM micrographs of leaf surfaces. A-B. G. spectabilis (Indonesia). E) Adaxial surface X 200. F) Adaxial surface X 500. G) Abaxial surface X 200. Arrow indicates sunken calvitium (bald spot). H) Abaxial surface X 500. Solid arrows indicate stomata; dashed arrow shows sessile, peltate gland. (All from *Havilad & Hose* 919, K). E-H. G. tomentosa. E) Adaxial surface X 200. F) Adaxial surface X 500. Arrow indicates disc like basal cell of marrubioid trichome; radiating epidermal cells circled. G) Abaxial surface X 200. H) Abaxial surface X 500. Short arrows indicate stomata; long dashed arrow shows swollen cell joint of marrubioid trichome. (All from *Noe* 211, E).

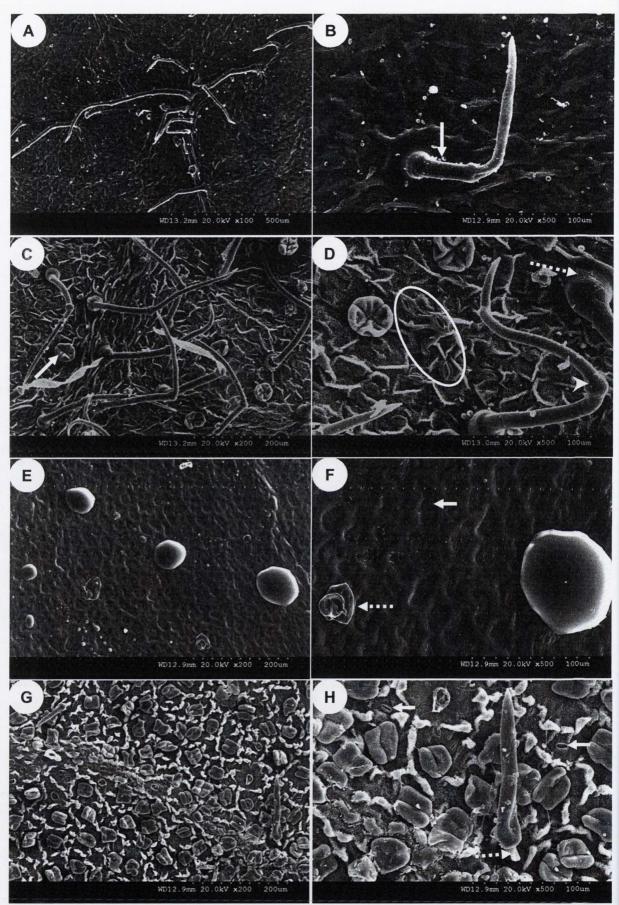


Figure 3.9.20 SEM micrographs of leaf surfaces. A-D. G. tonkinensis. A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow indicates acicular trichome. C) Abaxial surface X 200. Arrow shows sessile, peltate gland D) Abaxial surface X 500. Stomata are circled; dashed arrow and arrow head indicate disc like basal cell and swollen junction of acicular-geniculate trichome respectively. (All from *Balansa* 3807, P). E-H. G. uniflora. E) Adaxial surface X 200. F) Adaxial surface X 500. Upper solid arrow indicates slightly striated lumina; lower dashed arrow shows sessile, capitate gland with spread base. G) Abaxial glandular surface X 200. H) Abaxial surface X 500. Short arrows indicate stomata; lower dashed arrow shows short and narrow base of subulate eglandular trichome. (All from *Motley* 1204, K).

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# Premna cordifolia Roxb.

Adaxial: glabrous; cuticle smooth, tessellated, shallow grooves indicating undulated anticlinal walls; epicuticular wax minutely present. Abaxial: glabrous; cuticle smooth, tessellated, cell walls distinctly sinuate. Stomata: paracytic; confined abaxially (hypostomatic), frequent, large, somewhat sunken, outline broadly elliptic or rarely oblong, rim distinctly prominent, aperture long and broad.

# P. divaricata Wall

# (Figure 3.9.21E-H. India)

Adaxial: glabrous; a few attenuate trichomes rarely scattered, mainly along the veins, base broad; cuticle distinctly reticulate ridged; lumina inconspicuously coarse. Abaxial: glabrous; cuticle conspicuously ridged. **Stomata**: paracytic; confined abaxially (hypostomatic), frequent, large, a few small, outline broadly elliptic, rim distinctly prominent, aperture narrow, rarely broad.

# P. latifolia Roxb.

# (Figure 3.9.22A-D. India)

Adaxial: glabrous; a few attenuate, multicellular eglandular trichomes with warty surface rarely scattered, mainly along the veins; cuticle smooth, tessellated with shallow grooves, conspicuously ridged along the veins. Abaxial: glabrescent; small, sessile, capitate gland with 4-celled head rarely present; a few attenuate, multicellular eglandular trichomes scattered mainly along the veins; cuticle smooth, tessellated, shallow grooves present, conspicuously ridged along the veins. **Stomata**: anomocytic or rarely paracytic; confined abaxially (hypostomatic), frequent, large, outline broadly elliptic, rim prominent, aperture narrow.

### P. pyramidata Wall.

#### (Figure 3.9.22E-H. Myanmar)

Adaxial: glabrous; a few sessile, capitate glandular trichomes with 2-celled head; and small, sub-sessile, with short arms, stellate trichomes rarely scattered; cuticle smooth. Abaxial: densely stellate; large, sub-sessile, profusely branched, long armed, stellate trichomes with long central ray, frequently distributed; cuticle ridged, much pronounced along the veins. **Stomata**: anomocytic or rarely paracytic; confined abaxially (hypostomatic), frequent, large, outline broadly elliptic, somewhat sunken, rim prominent, aperture narrow.

# P. racemosa Wall.

# (Figure 3.9.23A-D. India)

Adaxial: glabrous; cuticle distinctively reticulate ridged; lumina smooth. Abaxial: glabrous; sessile, capitate glandular trichomes rarely scattered, head 2-celled; cuticle conspicuously striated; epicuticular wax particles present. Stomata: paracytic; confined abaxially (hypostomatic), abundant, large, outline elliptic, rim distinctly prominent, aperture narrow.

# P. resinosa Schauer

# (Figure 3.9.23E-H. Kenya)

Adaxial: glabrous; sessile, multicellular, dome-shaped peltate glandular trichomes rarely scattered, base sunken; cuticle tessellated, sinuate cell walls forming distinctly angular cells. Abaxial: mostly glabrous; sessile, multicellular, saucer-shaped, peltate glandular trichomes sparsely distributed, almost sunken; cuticle tessellated, sinuate cell walls forming distinctly angular cells. Stomata: paracytic; confined abaxially (hypostomatic), abundant, large, outline broadly elliptic or oblong, rim distinctly prominent, aperture narrow.

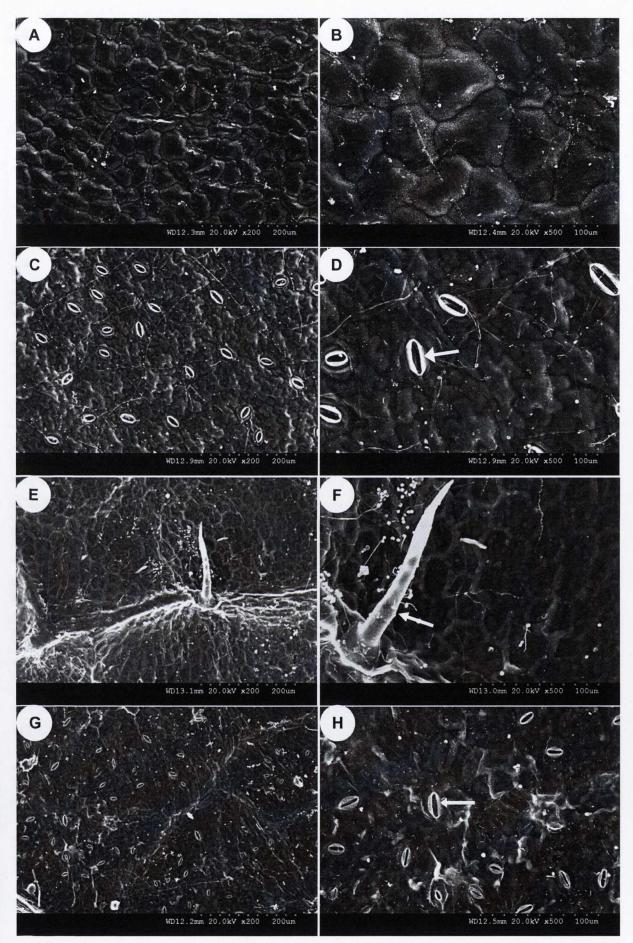


Figure 3.9.21. SEM micrographs of leaf surfaces. *P. cordifolia* (India). A) Adaxial surface X 200. B) Adaxial surface X 500. C) Abaxial surface X 200. D) Abaxial surface X 500. Arrow indicates stoma. (All from *Clarke* 40762, A). E-H. *P. divaricata* (India). E) Adaxial surface X 200. F) Adaxial surface X 500. Arrow indicates attenuate trichome. G) Abaxial surface X 200. H) Abaxial surface X 500. Arrow indicates stoma. (All from *Parkinson* 662, K).

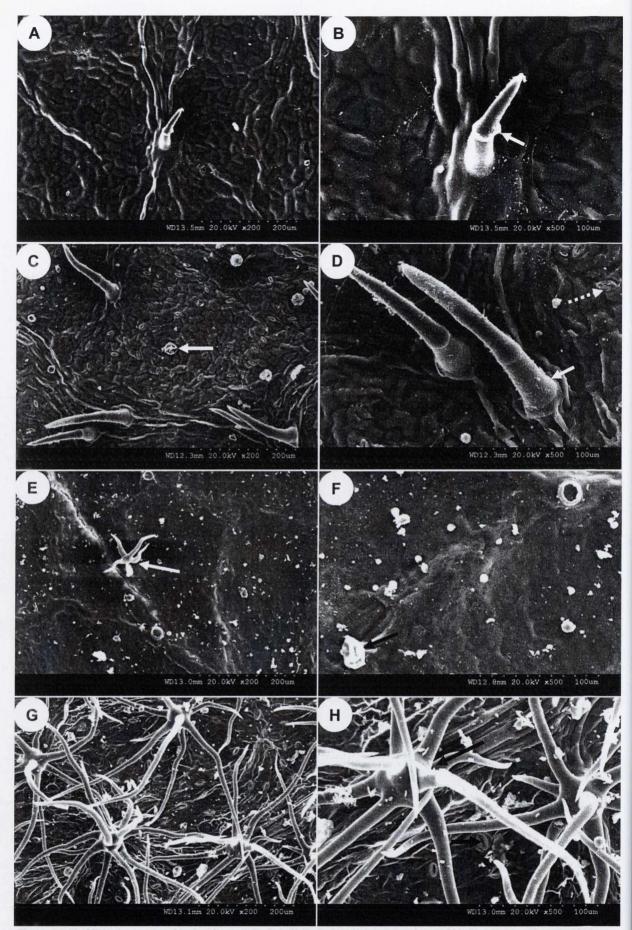


Figure 3.9.22. SEM micrographs of leaf surfaces. A-D. *P. latifolia* (India). A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow indicates attenuate trichome. C) Abaxial surface X 200. Arrow indicates sessile, capitate gland. D) Abaxial surface X 500. Upper dashed arrow indicates stoma and lower short arrow shows attenuate trichome. (All from *unknown collectc*. s.n., K). E-H. *P. pyramidata* (Myanmar). E) Adaxial surface X 200. Stellate trichome arrowed. F) Adaxial surface X 500. Arrow indicates sessile, capitate gland. G) Abaxial surface X 200. H) Abaxial surface X 500. Upper arrow indicates profusely branched stellate trichome with long central ray; lower arrow shows stoma. (All from *Lace* 6246, K).

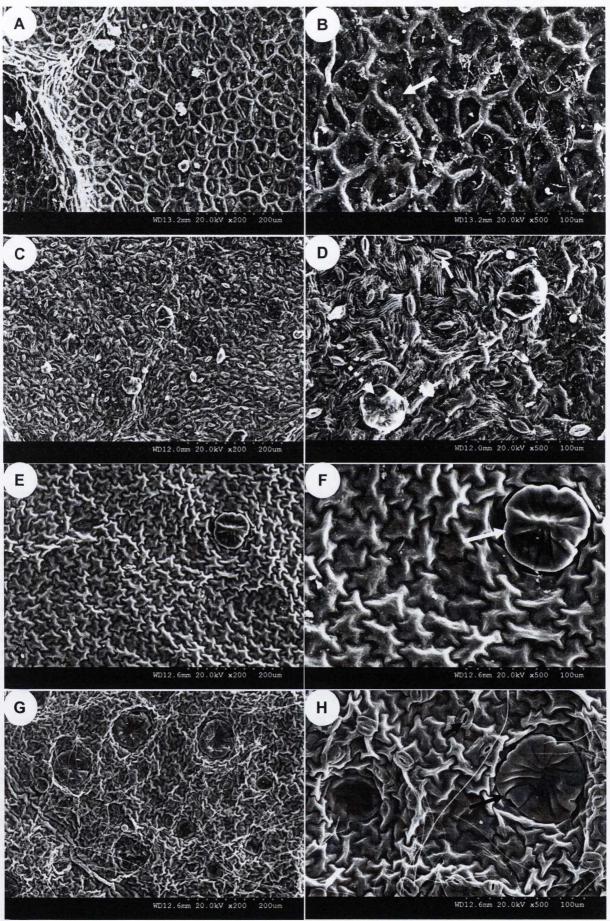


Figure 3.9.23. SEM micrographs of leaf surfaces. A-D. *P. racemosa* (India). A) Adaxial surface X 200. B) Adaxial surface X 500. Arrow indicates smooth lumina. C) Abaxial surface X 200. D) Abaxial surface X 500. Long dashed arrow indicates capitate gland; short arrow shows stoma. (All from *unknown collector*, s.n., K). E-H. *P. resinosa* (Kenya). E) Adaxial surface X 200. F) Adaxial surface X 500. Arrow shows sessile, peltate gland. G) Abaxial surface X 200. H) Abaxial surface X 500. Long arrow shows sunken multicellular, peltate gland; short arrows indicate stomata. (All from *Robertson* 5913, K).

		Egland	Eglandular Trichomes		Gland	Glandular Trichomes	les		Cuticle		
Taxa	Locality	Type * 8 Occurance (AB = aboxial) (AD = adoxial)	No. of cells (U= unicellular) (B= bicellular) (M= multicellualar- uniseriate)	Frequency + (abaxially)	Type + & Occurance (AB = oboxiol) (AD = odoxiol)	Peltate Head No. of cell (rarely)	Frequency <b>†</b> (abaxially)	Pattern * (RD= ridged); (RR= reliculate ridged) (SM= smooth) (ST= striated) (TS= tessellate);	Stormata type (AN = Anomocytic) (PA = Paracytic) (?= Obscured)	Stomata Density ?	Epicuticular Wax
Section .	Section Asiaticum										
G. arborea	Thailand	MA (AB)	Σ	Dense	CP (AD); PL (AB)	2	Dense	SM to RD (AD); RD (AB)	AN	Frequent	I
:	Vietnam	AC (AB)	Σ	Sparse	CP (AD); PL (AB)	2	Dense	SM to RD (AD); RD (AB)	AN	Frequent	•
	Indonesia	AC (AB)	Ψ	Sparse	PL (AB)	2	Dense	RD (AD + AB)	AN	Frequent	·
:	Malay Peninsula	AT (AD); MA (AB)	Ψ	Frequent	CP (AD); PL (AB)	2	Dense	SM (AD); RD (AB)	AN	Infrequent	1
:	Philippines	AC (AB)	Σ	Sparse	CP (AD); PL (AB)	2	Dense	RD (AD + AB)	AN	Frequent	1
	India	ı	1	ı	CP (AD); PL (AB)	2 (3 or 4)	Dense	SM (AD); RD (AB)	AN	Frequent	1
:	Sri Lanka	AT (AD); MA (AB)	Ψ	Frequent	CP (AD); PL (AB)	2	Dense	RR (AD); RD (AB)	AN	Infrequent	
G. asiatica	Thailand	AC (AB)	Μ	Rare	CP (AD); PL (AB)	4	Frequent	RR (AD); RD (AB)	AN	Frequent	+
	Vietnam	'	1	1	PL (AB)	4	Frequent	SM to RD (AD); RD (AB)	AN	Frequent	+
	Cambodia	1	ı	I	PL (AB)	8 (4)	Frequent	SM to RD (AD); RD (AB)	AN	Frequent	·
	Malaysia	•	1	1	PL (AB)	8 (4)	Frequent	RR (AD); RD (AB)	AN	Frequent	•
	Philippines	•	1	i	PL (AB)	8 (4)	Sparse	SM to TS (AD); RD (AB)	AN	Abundant	•
	Sri Lanka	•	1	1	CP (AD); PL (AB)	4 (2)	Dense	SM to RD (AD); RD (AB)	AN	Infrequent	•
G. attenuata	Thailand	•	1	ı	PL (AB)	2 (3)	Sparse	RR (AD); RD (AB)	AN	Frequent	+
G. chinensis	Hong Kong	AC (AB)	U or M	Rare	PL (AB)	2 or 4	Sparse	SM (AD + AB)	AN	Abundant	•
G. delavayana	China	1	1	1	CP (AD); PL (AB)	2 or 4	Dense	RD (AD + AB)	AN	Infrequent	•
G. elliptica	Thailand	AC (AD+AB)	Σ	Frequent	PL (AB)	4	Rare	SM (AD); TS (AB)	AN	Frequent	·
:	Vietnam	AC/AG/ASP (AD); MA (AB)	Σ	Dense		,	ı	RD (AD + AB)	AN	Frequent	1
	Indonesia	AC (AD); MA (AB)	Μ	Dense	PL (AB)	2	Rare	TS (AD); RD (AB)	AN	Frequent	•
:	Brunei	MA (AB)	Ψ	Dense	PL (AB)	2 or 4	Dense	RD (AD + AB)	2	5	1
:	Malaysia	AC (AD); MA (AB)	Σ	Dense	PL (AB)	2	Rare	SM (AD); RD (AB)	AN	Frequent	•
	India	AC (AD+ AB)	Ψ	Frequent	PL (AB)	2 or 4	Rare	RD (AD); TS (AB)	AN	Frequent	•

Table 3.1 Summary of the leaf surfaces characters in the taxa examined.

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		Eglai	Eglandular Trichomes		Gland	Glandular Trichomes	les		Cuticle		
Таха	Locality	Type* & Occurance (AB = dboxid) (AD = ddoxid)	No. of cells (U= unicellular) (B= bicellular) (M= multicellualar- uniseriate)	Frequency <b>†</b> (abaxially)	Type✦ & Occurance (AB = abaxial) (AD = adaxial)	Peltate Head No. of cell (rarely)	Frequency + (abaxially)	Pattern# (RD= ridged) (RR= reticulate ridged) (SM= smooth) (ST= striated) (TS= tessellate);	Stomata type (AN= Anomocytic) (PA= Paracytic) (?= Obscured)	Stomata Density ?	Epicuticular Wax
G. lepidota	Moluccus, Indonesia	I	I	I	PA + PL (AB)	8 (11)	Dense	SM (AD); ? (AB)	2	2	+
:	Irian Jaya, Indonesia	AC (AB)	n	Scattered	PL (AB)	80	Dense	SM (AD); ? (AB)	2	ć	•
G. moluccana	Indonesia	AT (AD); AC (AB)	B (AB); M (AD)	Rare	(DA) SA	•	Rare	RD (AD + AB)	AN	Abundant	1
G. palawensis	Indonesia		ı	1	,	ı	1	SM (AD); RD (AB)	AN	Abundant	•
:	Palau Island	•	ı	1	,	,	1	RD (AB + AD)	AN	Abundant	1
G. paniculata	Thailand	-	ı	1	PL (AB)	2 (4)	Frequent	RD (AB + AD)	AN	Abundant	٠
G. philippinensis	Philippines		1	I	PL (AB)	4 (8)	Sparse	SM (AD); TS (AB)	AN or PA	Abundant	ı
:	Cambodia	1	1	1	PL (AB)	8	Sparse	SM (AD); TS (AB)	AN or PA	Abundant	ı
G. racemosa	Vietnam	AC (AB)	Ψ	Frequent	CP (AD); PL (AB)	4	Dense	TS (AD); RD (AB)	AN	2	•
:	Thailand	AC (AB); ST (AD + AB)	Ψ	Scattered	PL (AB)	2 or 4	Dense	RD (AB + AD)	AN	2	1
G. schlechteri	Indonesia			1	PL (AD); CP (AB)	80	Rare	RD (AB + AD)	AN	Frequent	+
G. tomentosa	Thailand	MA (AD + AB)	Σ	Dense	1		ı	RD (AB + AD)	AN	Infrequent	٠
G. tonkinensis	Vietnam	AC/AG (AD); AC (AB)	M	Sparse	PL (AB)	4	Sparse	RD (AB + AD)	AN	Frequent	•
Section Annameticum	ameticum										
Gmelina annamensis	Vietnam	AC (AB)	Σ	Sparse	PL (AB)	4	Dense	TS (AD); RD (AB)	AN	2	
G. hainanensis	China	AC (AB)	Σ	Dense	PL (AB)	4	Dense	TS (AD); RD (AB)	AN	Infrequent	1
:	Vietnam	AC (AB)	В	Sparse	PL (AB)	4	Dense	RD (AB + AD)	AN	~	+
G. havilandii	Malaysia	1	•	1	CA + PL (AB)	2 (4)	Frequent	SM (AB + AD)	AN	Frequent	+
G. uniflora	Indonesia	SU (AB)	В	Rare	PL (AB)	2 (4)	Dense	RR (AD); SM (AB)	AN	Infrequent	÷
Genus Premna	emna										
Premna cordifolia	India	I	I	I	1	1	1	TS (AB + AD)	PA	Frequent	÷
P. divaricata	India	AT (AD)	D	1	1	ı	ı	RR (AD); RD (AB)	PA	Frequent	•
P. latifolia	India	AT (AD + AB)	В	Scattered	CP (AB)	4	Rare	TS (AB + AD)	AN or PA	Frequent	
P. pyramidata	Myanmar	ST (AD + AB)	¥	Frequent	CP (AD)	2	1	SM (AD); RD (AB)	AN or PA	Frequent	•
P. racemosa	India	•	1	•	CP (AB)	2	Rare	RR (AD); ST (AB)	PA	Abundant	+
P. resinosa	Kenya		1	•	PL (AD + AB)	>10	Sparse	TS (AB + AD)	PA	Abundant	,

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Table 3.1 Continued

# 3.6.3. Discussion

The stomata of the Lamiaceae are described by Metcalfe and Chalk (1950) as mostly diacytic, and often intermixed with anomocytic. Cantino (1990) concluded that anomocytic and diacytic were the most frequent types in both Lamiaceae and Verbenaceae.

All *Gmelina* species investigated in the present study are hypostomatic and stomata are mostly anomocytic, which is in tune with the previous observations made in the few species of the genus [El-Gazzar and Watson 1970; Mathew and Shah 1981; and Cantino 1990).

Stomata are somewhat frequent in most of the species, but much more abundant in *G. moluccana*, *G. palawensis*, *G. paniculata*, *G. philippensis*, *G. racemosa*, and in *P. racemosa* and P. *resinosa*; although they are much less frequent in *G. delavayana*, *G. hainanensis*, *G. tomentosa* and in *G. uniflora*. The stomata are not visible in *G. hainanensis*, *G. lepidota*, and *G. racemosa* as the surfaces are almost completely covered by trichomes. As trichomes obscuring stomata to some extend in almost all species, it was not possible to calculate stomatal index.

#### Synopsis of the trichome types in Gmelina and Premna

According to Solereder (1908) the information on trichomes of Lamiaceae and Verbenaceae is rather scanty. There is generally a greater diversity of trichome types on the abaxial surface. A wide variety of trichome types have been found in this study. They are very variable both in size and density. The indumentum in most of the species is much denser on the abaxial surfaces, which tends to diminish the importance of trichomes as a sun-shade adaptation (Husain *et al.* 1990). The present study reveals (Table 3.1) that the two main trichome types are glandular and eglandular and these can be further subdivided as follows.

#### I. Glandular trichomes

The glandular trichomes constitute an important taxonomic character of the Lamiaceae and Verbenaceae (Cantino 1990; Navarro & Oualidi 2000). In the present investigation the following five morphological types of glandular trichomes can be recognised:

a) **Asciiform**: Hatchet-shaped trichomes. This type of trichome occurs rarely, scattered only on the adaxial surface of *G. moluccana* (Figure 3.9.15B). The term "Asciiform" follows Pyne (1978). This type has not been reported earlier either in any member of Lamiaceae or Verbenaceae.

b) **Calvitium**: An area lacking hairs or a bald spot. This distinct type of trichome is sparsely distributed on the abaxial surface of *G. spectabilis* (Figure 3.9.13G) and this distintive type of indumentum allows this species to be easily differentiated from other species. The term "Calvitium" used here follows Pyne (1978). This type has not been reported earlier either in any member of the Lamiaceae or Verbenaceae.

c) **Capitate**: A sessile or sub-sessile glandular trichome with a spherical head. These have been found to be sparsely or rarely scattered only on the adaxial surface of *G. arborea* (Figures 3.9.1E-F, and 3.9.2A-B -

3.9.4E-F); *G. asiatica* (Figure 3.9.6E-F, and 3.9.7E-F); *G. delavayana* (Figure 3.9.9A-B); and *G. racemosa* (Figure 3.9.18A-B & E-F); and in *G. schlechteri* (Figure 3.9.19C-D) they rarely occur only on the abaxial surface. In *P. latifolia* (Figure 3.9.22C-D) and *P. racemosa* (Figure 3.9.23C-D) they also occur on the abaxial surfaces. Generally they are unicellular or bicellular, but multicellular trichomes are reported in *G. asiatica* and *G. schlechteri*. The term "Capitate" follows Inamdar (1969) reported in *G. arborea*; and Pyne (1978). This type was applied to similar trichomes in *Morus rubra* L. (Hardin 1981).

d) **Patelliform**: Pan-shaped or saucer-shaped multiseriate trichomes. This type is rarely found scattered on the abaxial surface of *G. lepidota* (Figure 3.9.14C-D) and this species can be easily differentiated from other species by this distinctive type of indumentum. The term "Patelliform" was used by Yashodhara *et al.* (2004) and reported on the abaxial surface in *G. arborea*. I have not seen such hairs in *G. arborea*.

e) **Peltate**: Scales or lepides; sessile or stalked trichomes with flattened heads which consist either of a single cell developed as a flat structure, or of a varying number of cells arranged in one or more layers with circularor quadrangular- or irregular wavy-margins. These type of trichomes occur on the abaxial surface of almost in all taxa examined, but are absent from Vietnamese populations of *G. elliptica, G. moluccana, G. palawensis,* and *G. tomentosa*; in *G. schlehctrii* (Figure 3.9.19A-B) hyaline peltate trichomes with a long central ray has been recorded on the adaxial surface. The density of these peltate trichomes varies from rare in a few species e.g. *G. elliptica* (Figure 3.9.11C-D), *G. paniculata* (Figure 3.9.16G-H), and *G. philippensis* (Figure 3.9.17C-D & G-H) to dense in many species e.g. *G. annamensis* (Figure 3.9.1C-D), *G. arborea* (Figure 3.9.3C-D), *G. lepidota* (Figure 3.9.14C-D & G-H) etc. In *Premna* this type of trichomes was only observed in in *P. resinosa* (Figure 3.9.23E-H) where they occur on both surfaces, adaxially the trichomes are dome-shaped (Figure 3.9.23E-F), but abaxially, saucer-shaped (Figure 3.9.23G-H). The term "Peltate" follows Pyne (1978) and was applied to similar trichomes in *G. philippensis* (Kaushal and Tripathi 1984). They have been found in some species of tribe Viticeae including *G. asiatica*, and *G. philippensis* (Yashodhara *et al.* 2004) which are in accordance with the present investigation; and in *Fraxinus* L. species (Hardin and Beckmann 1982).

The hyaline, sessile, peltate glandular trichomes with a long central ray which occur in *G. schlechteri* have not been observed in any other species of Lamiaceae or Verbenaceae. By this type of indumentum it can be easily differentiated from other species.

Following the descriptions and typology of Abu-Asab and Cantino (1987); and Cantino (1990), and based on the cell numbers and the cell-wall configuration, the peltate glands correspond to types 2, 3, 4, 8 and 11. Type 2 (Figures 3.9.2G-H; 3.9.20G-H) and type 4 (Figures 3.9.5C-D; 3.9.12G-H) are the most frequently observed types, while type 8 is less common and type 3 is rarely observed in Indian *G. arborea* (Figure 3.9.4C-D) and *G. attenuata* (Figure 3.9.8C-D). Type 11 is very rarely found in *G. lepidota* (Figure 3.9.14C-D); and frequently observed in *P. resinosa* (Figure 3.9.23G-H).

# II. Eglandular trichomes

It is known that the same hair type can evolve independently in different lines (Metcalfe and Chalk 1950). The eglandular trichomes observed in this investigation can be divided as follows:

### 1. Simple, unbranched trichomes

a) Acicular: A slender, tapered, 1-4 celled, uniseriate, straight to variously curved trichome with a very slightly swollen base, and generally with swollen junctions between cell joints when multicellular. The terminology used here follows Pyne (1978) and Hardin (1981). Considering the trichome types found throughout the genus *Gmelina*, this type is most frequent and have been observed on the abaxial surfaces in the most of the species examined (Figures 3.9.1C-D; 3.9.2G-H; 3.9.12G-H; 3.9.13C-D; 3.9.18C-D; and 3.9.20C-D; etc.); whilst I have also found them on the adaxial surfaces in *G. elliptica* (Figures 3.9.10G-H; 3.9.11A-B and 3.9.12A-B). In *G. lepidota* from Irian Jaya, Indonesia, the acicular trichomes are unicellular and differ from these found in the same species from the Moluccas. This type is absent from all the *Premna species* investigated. This type of trichome has been reported in *G. arborea* by Inamdar (1969).

The term "Acicular" was applied to similar trichomes in some species of *Morus* L. and *Maclura pomifera* L. (Hardin 1981); in the species of *Fraxinus* (Hardin and Beckmann 1982); and in *Rhus* L. (Hardin and Phillips 1985).

b) **Acicular-geniculate**: Bent abruptly, as at the knee. The term used here follows Pyne (1978). This type of trichome occurs on the adaxial surface of Vietnamese populations of *G. elliptica* (Figure 3.9.10A-B) from Vietnam, and on the abaxial surface of *G. tonkinensis* (Figure 3.9.20C-D). This type has not been reported earlier from any member of Lamiaceae or Verbenaceae.

c) **Acicular-spiral**: Shaped as a corkscrew or contorted. The term used here follows Pyne (1978). This type of trichome is reported only on the adaxial surface of Vietnamese *G. elliptica* (Figure 3.9.10A-B), and recognized here for the first time for any species of Lamiaceae or Verbenaceae.

d) Marrubioid: Long, crisped, acicular, uniseriate multicellular hairs with swollen junctions between cells. This type of trichomes is observed on the abaxial surfaces of *G. arborea* (Figure 3.9.2C-D; 3.9.3C-D; 3.9.4G-H), *G. elliptica* (Figure 3.9.10 & 11C-D & G-H), and both surfaces in *G. tomentosa* (Figure 3.9.19E-H). The term "Marrubioid" is used here coined by El-Gazzar and Watson (1970) and applied to *Leucas helianthemifolia* Benth.

**1a. Attenuate**: Gradual tapered from a conspicuous swollen base; short to long, and straight to curvate. Long and straight and sometimes curvate attenuate trichomes were observed adaxially in *G. arborea* (Figure 3.9.2A-B; 3.9.4G-H), and short and curvate ones in *G. moluccana* (Figure 3.9.15A); and short and straight ones in *P. divaricata* (Figure 3.9.21E-F), and *P. latifoia* (Figure 3.9.22A-B). The term used here follows Pyne (1978) and was applied to similar trichomes in *Broussonetia papyrifera* Vent., and *M. microphylla* Buckley (Hardin 1981).

**1b**. **Subulate**: Awl-shaped, tapering from a broad base to a sharp point. The subulate trichomes occurred in *Gmelina* are bi-cellular with a very short and narrow basal cell. This type of trichome very rarely scattered on the abaxial surface in *G. uniflora* (Figure 3.9.20G-H); and absent from *Premna*. The terminology "Subulate" used here follows Pyne (1978).

## 2. Branched trichomes

Stellate banched trichmoes are observed in both *Gmelina* and *Premna*, which Bokhari and Hedge (1971) reported as very unusual in the family Lamiaceae.

a) **Stellate**: Trichomes which are star-shaped or branched as a star with rays projecting from centre. Stellate, profusely branched with long arms trichomes were rarely observed on both surfaces only in *G. racemosa* from Thailand (Figure 3.9.18E-G), and very rarely, adaxially (Figure 3.9.22E) and densely on the abaxial surface (Figure 3.9.22G-H) in *P. pyramidata*. The terminology "Stellate" used here follows El-Gazzar and Watson (1970) as applied in *Ph. orientalis* (Figure 3.9.6I); *Solanum* (Roe 1971); *Phlomis* (Pyne 1978; and Azizan & Cutler 1982). Recently, the term was used for trichomes in *Teucrium* (Navarro & Oualidi 2000), and *Tectona grandis* (Bandyopadhyay *et al.* 2004).

There are basically seven vestiture types among the species as described below.

- i. Glabrous or glabrescent: Devoid of trichomes (Figures 3.9.1A-B, 3.9.5A-B, 3.9.8A-B, 3.9.9A-B, 3.9.14G-H, 3.9.15E-H, 3.9.21A-H), or a very few glandular and/or eglandular trichomes rarely scattered (Figures 3.9.2E-F, 3.9.4E-F, 3.9.15A-D, 3.9.19A-D, 3.9.22A-B).
- Glandular: peltate glandular trichomes throughout the surface. The relative density varies between sparsely (Figures 3.9.6C-D, 3.9.7C-D, 3.9.16E-F, 3.9.17C-D) and densely glandular (Figures 3.9.6G-H, 3.9.19C-D, 3.9.13C-D, 3.9.20G-H).
- iii. Glandular-pilose: a mixture of both sparsely distributed glandular and acicular, eglandular trichomes (Figures 3.9.8G-H, 3.9.18C-D, 3.9.20C-D).
- iv. Glandular-tomentose: surface densely covered with the mixture of both glandular and eglandular trichomes (Figures 3.9.1G-H, 3.9.2-3C-D & G-H, 3.9.12G-H).
- v. Lepidote: covered with small, scurfy scales (Figures 3.9.14C-D & G-H).
- vi. Tomentose: densely woolly with soft, matted, interwoven eglandular trichomes (Figures 3.9.10C-D, 3.9.19G-H); sometimes with sparsely or rarely scattered glandular trichomes (Figures 3.9.10G-H, 3.9.11C-D & G-H, 3.9.12C-D).
- vii. Stellate: surface covered with much-branched stellate trichomes (Figure 3.9.22G-H).

There is generally a greater diversity of trichome types on the abaxial surface.

# Variability

With respect to the characters observed on the foliar surfaces, both qualitative and quantitative (see Table 3.1) variation occurs.

## Interspecific variation:

Except for *G. tomentosa*, all taxa examined are adaxially glabrous to glabrescent. In *G. tomentosa* both surfaces are tomentose; in contrast, both surfaces are glabrous to glabrescent in *G. moluccana*, *G. palawensis* and in *G. schlechteri*.

Glandular trichomes are absent only from *G. tomentosa*, whilst eglandular trichomes are absent from *G. asiatica*, *G. delavayana*, *G. lepidoata*, *G. philippensis*, *G. spectabilis*, and *G. uniflora*. However, both types of trichomes are observed in *G. annamensis*, *G. arborea*, *G. chinensis*, *G. elliptica*, *G. hainanensis*, *G. racemosa*, and *G. tonkinensis*.

Uniseriate, multicellular eglandular trichomes are widespread in almost all taxa examined, though unicellular trichomes were observed in *G. chinensis*, *G. lepidota* and in *P. divaricata*.

*G. lepidota* is distinctive from all other species examined because its abaxial surface covers lepidote trichomes with distinct "Patelliform" multiseriate trichomes or filiform, unicellular eglandular trichomes. *G. moluccana* differs in having "Asciiform" glandular trichomes and conspicuous swollen inter-stomatal ridges. The distinct type "Calvitium" indumentum was observed only in *G. spectabilis*.

Peltate glandular trichomes are widespread abaxially in the most of the species, mostly they are 2- or 4celled, but ones with 8-cells are also encountered in *G. asiatica*, *G. lepidota*, *G. philippensis*, and *G. schlechteri*; and 3-cells headed trichomes rarely observed in Indian *G. arborea* and in *G. attenuata*, and 11celled headed ones are rarely found in *G. lepidoata* but are much more frequent in *P. resinosa*.

A distinctive type of hyaline, sessile, peltate glandular trichome with a long central ray occurs in *G. schlechteri*; by which it can be easily distinguished from other species.

Capitate glandular trichomes are rarely scattered on the adaxial surface of *G. arborea*, *G. delavayana*, and *G. racemosa*; and rarely occur on the abaxial surface in *G. schlechteri*. Generally they are unicellular or bicellular, but multicellular hairs were found in *G. asiatica* and *G. schlechteri*.

The subulate trichomes with a very short and narrow basal cell were only rarely scattered in G. uniflora.

The cuticle in most species is generally smooth to ridged on the adaxial surfaces and mostly ridged on the abaxial surfaces, with some intraspecific variation found in *G. arborea*, *G. asiatica*, and in *G. elliptica*. Glaucous adaxial surfaces, due to the presence of epicuticular wax, was observed consistently in *G. asiatica* and some populations of *G. arborea*, and *G. elliptica*.

In general, the cells surrounding the trichomes do not differ from the other epidermal cells. However, in some cases e.g. *G. hainanensis* (Figure 3.9.12E-F), *G. racemosa* (Figure 3.9.18A-B), and *G. tomentosa* (Figure

3.9.19E-F), epidermal cells surrounding the trichomes on the adaxial surfaces radiated out from the trichome basal cell. In contrast, in Indian *G. elliptica* (Figure 3.9.12C-D), these types of radiated cells were observed on the abaxial surface.

Cantino (1990) reported multicellular glandular trichomes as widespread and usually more frequent on the abaxial surfaces in *G. delavayana*, and *G. racemosa*, but they were absent from *G. moluccana*; which is tune with the present investigation.

All *Premna* species examined are almost glabrous on both surfaces except for *P. pyramidata* which is densely stellate on the abaxial surface. Intraspecific variation

In *G. arborea*, eglandular trichomes are absent from Indian material and capitate glandular trichomes are found adaxially in all populations with the exception of populations from Indonesia.

Peltate glandular trichomes are consistently distributed abaxially in populations of *G. asiatica*; however they are adaxially glabrous except from the specimens in Thailand and Sri Lanka.

In *G. elliptica*, radiated trichome basal cells were observed on the abaxial surface of Indian population of *G. elliptica*, whereas they were not seen in other populations; specimens from Vietnam were the most variable in having acicular-geniculate and acicular-spiral trichomes, but lacking glandular trichomes. Peltate glandular trichomes are sparsely or rarely distributed abaxially in *G. elliptica*, while the abaxial surface is densely covered with this type of trichome in the population from Brunei.

The populations of *G. lepidota* from Irian Jaya, Indonesia have filiform, unicellular, acicular trichomes whilst specimens from the Moluccas, Indonesia are devoid of eglandular trichomes.

# 3.7 Petiolar Anatomy of Gmelina

# 3.7.1 Materials and Methods

The petiole characters of 48 accessions of *Gmelina*, includes 22 species and one variety, and six *Premna* species have been examined (Table 3.2). In the present study only herbarium material was studied.

In the petiole, the number, position and shape of the vascular bundles vary at different levels and it is essential that sections of strictly comparable portions of the petioles of each species should be taken (Bokhari & Hedge 1971). Therefore, transverse sections were taken from the middle region of fully grown petioles.

Between one and eight petioles were sectioned from each species depending on the extent of its geographical distribution. Species representing the broad geographical distribution were studied from different parts of its distribution to determine whether there were substantial differences in plants from different regions.

Only one petiole per herbarium specimen was used. Small pieces of mature dried petiole were revived by soaking them in 5% sodium hydroxide (NaOH) for three days at room temperature, and then fixed in 70% FAA for 24 hours. Petiole sections of all taxa were obtained using standard methods of wax embedding and sectioning (Thammathaworn 1995, English version by Prajaksood 2006. See **Appendix I**).

Following the dehydration in a graded tertiary butyl alcohol (TBA) series, sections of paraffin embedded materials were cut at 10-15µm thickness on the Leica SM 2000R sliding microtome with the feather disposable microtome blade (S35), and holder No. 240D. The sections were affixed to the slide using 0.5% aqueous gelatin. The sections were then stained with toluidine blue (0.5 % in aqueous), cleared in pure xylene and mounted permanently in DPX mountant for microscopy.

From each sample 10-20 sections were examined. Photomicrographs were taken on an Olympus BX60 compound microscope fitted with an Olympus camedia C-5060 digital camera.

Quantitative characters *viz.* i) petiole length, ii) cross sectional area of the petiole; iii) vascular bundle area in TS; iv) distance from vascular bundle to adaxial and abaxial surfaces; v) number of vascular bundles; and vi) vascular bundle area (VBA) proportion to the cross sectional area (CSA) were studied. All measurements were based on an average of 10 readings using Olympus DP-Soft software. The values are graphically represented.

The representative permanent slides of each species have been deposited in the Herbarium (TCD), Department of Botany, Trinity College, University of Dublin, Ireland.

# 3.7.2. Results

The petiole anatomy of the following 42 accessions of 23 taxa from the genus *Gmelina* has been studied of which only two species, *G. arborea* and *G. philippensis* have been investigated earlier, and thus remaining 20 species have been investigated for the first time. In addition to that, six species (one accession from each species) from the genus *Premna* have also been studied.

The photomicrographs of the petiole transverse sections of *Gmelina* and *Premna* are presented alphabetically below in Figures 3.10.1-3.10.42 and 3.10.43-3.10.48 respectively; features observed are summarized in Table 3.2 and presented graphically in Plots 3.1-3.5.

### G. annamensis Dop

## (Figure 3.10.1, Vietnam)

OUTLINE: oval, distinctly ridged throughout, adaxially almost flattened with slight depression; abaxially convex; lateral wing absent. Cross sectional area: 1,259,000µm<sup>2</sup>. EPIDERMIS: one cell layer, surface smooth, cells ± isodiametric, appearing square to anticlinally elongated; periclinal cell walls cutinized, cuticle rather thin (< 5µm), anticlinal cell walls sinuous. Trichomes: multicellular trichomes most abundant on adaxial side, otherwise evenly distributed. VASCULATURE: main vascular bundle O-shaped, closed; amphicribal or hadrocentric *i.e.* xylem and phloem are in the form of concentric rings (xylem is at the centre surrounded by phloem); peripheral, ten discrete, bi-collateral bundles form a lobed cylinder; relatively close to the adaxial side; additional group of phloem occurs internally (inner phloem) towards the pith region, adaxially two additional vascular bundles located very close to the main vascular cylinder; two medullary vascular bundles located near the adaxial end of the median bundle. Xylem fibres: present. Main vascular bundle area: 387,880µm<sup>2</sup>; two additional vascular bundles area: 7,189µm<sup>2</sup>, and 8,302µm<sup>2</sup>; two medullary vascular bundles area: 2,035µm<sup>2</sup>, and 5,135µm<sup>2</sup>. Vascular bundles area proportion to the cross sectional area: 32.60%. Perivascular phloem fibres: abundant, sclerenchymatous; scelreids distributed in discrete bundles alongside the main and the additional vascular bundles. CORTEX: subepidermal cells ± rectangular, consisting two to three layers of cork cells, with thin or thick cell walls, inner cells much larger, polygonal. **PITH:** pith area broad, cells parenchymatous, cells polygonal, cell walls sinuous with intercellular space; two medullary bundles present in pith. CRYSTAL: absent.

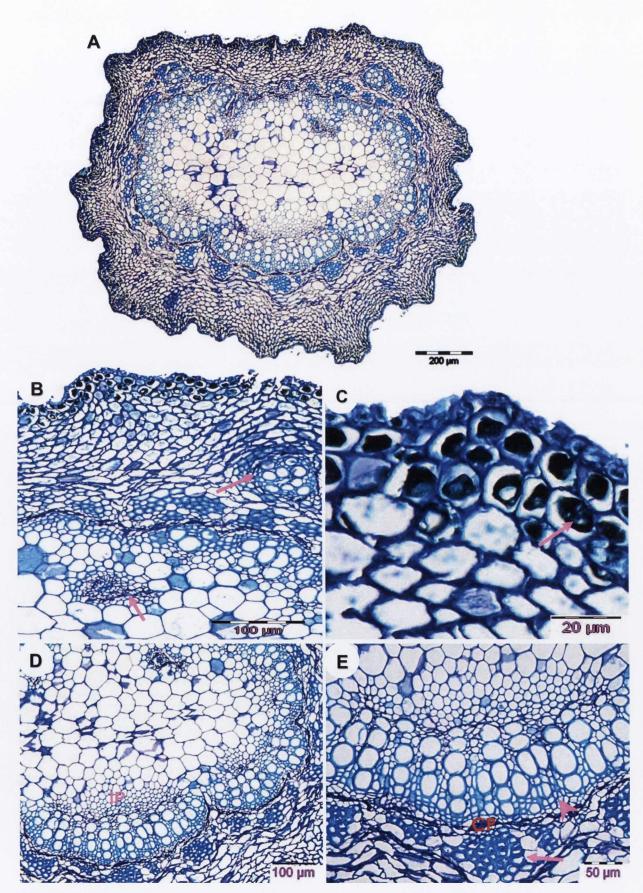


Figure 3.10.1. Petiole transverse section of *G. annamensis* (Vietnam). A) Outline. B) Adaxial side enlarged. Upper arrow indicates additional vascular bundle; lower arrow shows medullary bundle. C) Enlarged abaxial side. Cork cell is arrowed. D) Showing lobed, hadrocentric main vascular bundle. IP= inner phloem. E) Enlarged vascular bundle. Arrow head indicates xylem fibres; arrow shows sclerenchymatous fibres or phloem fibres; CP = Crushed phloem. (All from *Poilane* 13301, P).

# G. arborea Roxb.

#### (Figure 3.10.2, Thailand)

**OUTLINE:** obovate with two lateral wings; adaxially grooved, abaxially convex, undulate. *Cross sectional area:* 1,817,300µm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric, periclinal cell thin cutinized, anticlinal cell walls sinuous; cells much enlarged and swollen at base of hairs. *Trichomes:* both glandular and eglandular trichomes sparsely distributed throughout, some scattered branched trichomes present. **VASCULATURE:** main vascular bundle amphicribal or hadrocentric, eight to ten discrete, bicollateral bundles form dissected cylinder with obscurely incurved ends, narrowly open adaxially; peripheral; adaxially two additional vascular bundles located close to the main vascular bundle; adaxially closer than abaxially. *Xylem fibres:* present. *Main vascular bundle area:* 352,500µm<sup>2</sup>; *two additional vascular bundles area:* 4,500µm<sup>2</sup>, and 5,750µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 19.96%. *Perivascular phloem fibres:* discrete, sclerenchymatous, and distributed alongside the main vascular bundle, and also the lateral vascular bundles. **CORTEX:** collenchymatous cells ± rectangular or angular; parenchymatous cells larger. **PITH:** pith area large, cells parenchymatous, cells polygonal, cell walls straight with intercellular spaces. **CRYSTAL:** absent.

# G. arborea Roxb.

#### (Figure 3.10.3, Vietnam)

**OUTLINE:** obovate with two obscure lateral wings; undulate, adaxially almost flattened to slightly concave, abaxially convex. *Cross sectional area: ca.* 2,290,680µm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric. *Trichomes:* sparse adaxially, otherwise glabrous. **VASCULATURE:** main vascular amphicribal or hadrocentric; eight discrete, bi-collateral bundles form dissected cylinder, narrowly open adaxially, peripheral; phloem rather crushed; adaxially two additional vascular bundles located close to the main vascular bundle; adaxially closer than abaxially. *Xylem fibres:* present. *Main vascular bundle area:* 423,500µm<sup>2</sup>; *two additional vascular bundles area:* 4,395µm<sup>2</sup>, and 5,130µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 18.90%. *Perivascular phloem fibres:* sclerenchymatous, many discrete bundles distributed alongside the main and the additional vascular bundles. **CORTEX:** cells angular, parenchyma cells larger than the collenchymas, cell walls sinuous. **PITH:** pith area large, cells parenchymatous, cells polygonal, cell walls straight with intercellular spaces. **CRYSTAL:** desmidoid, rhombic, acicular, and druse-like crystals are observed in cortex, and acicular are in pith.

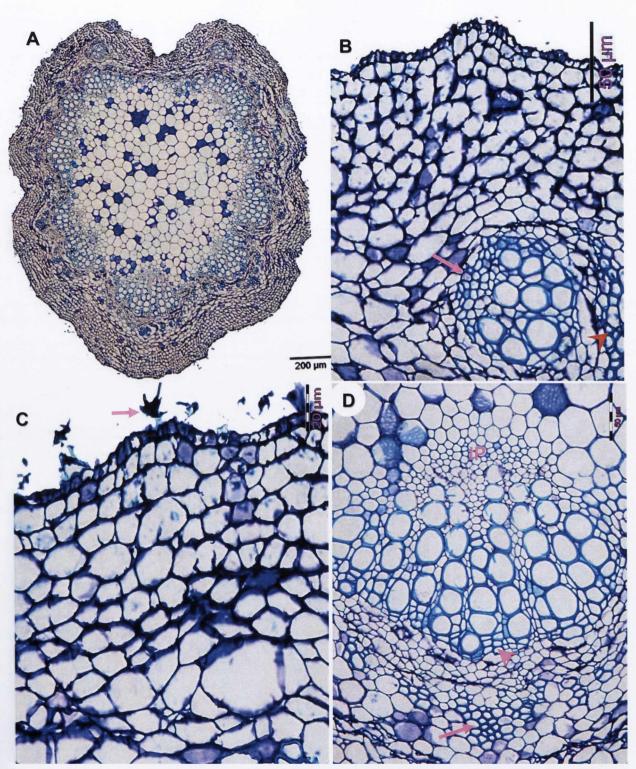
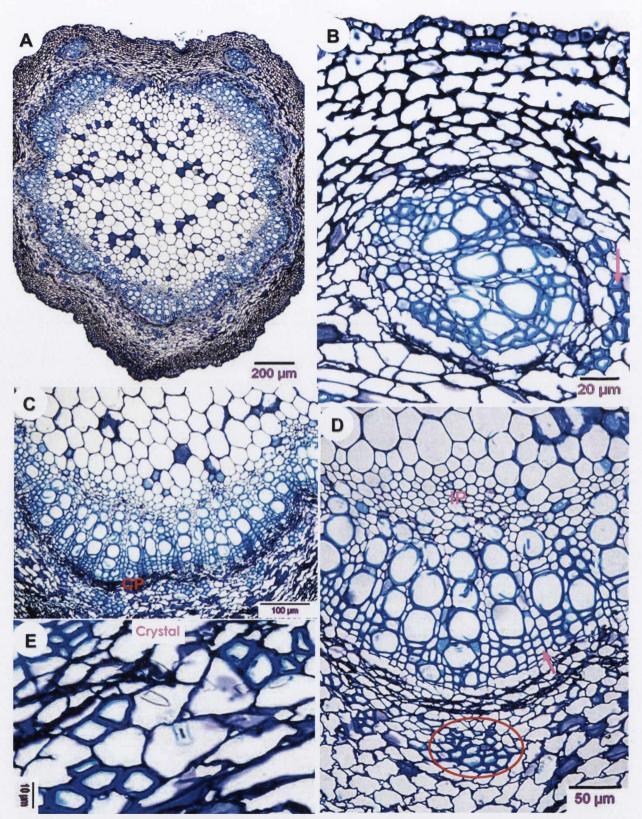


Figure 3.10.2. Petiole transverse section of *Gmelina arborea* (Thailand). A) Outline. B) Adaxial side enlarged; additional vascular bundle is arrowed; arrow head indicates perivascular fibres. C) Branched trichome is arrowed. D) Hadrocentric vascular bundle enlarged. Upper arrow indicates xylem fibres; lower arrow indicates perivascular phloem fibres; IP= inner phloem. (All from *Maxwell* 00-128, A).



**Figure 3.10.3**. Petiole transverse section of *G. arborea* (Vietnam). A) Outline. B) Enlarged adaxial side showing additional vascular bundle. Arrow indicates perivascular phloem fibres. C) Main vascular bundle enlarged. CP= crushed phloem. D) Enlarged hadrocentric vascular bundle. Arrow indicates xylem fibres; Perivascular phloem fibres circled; IP= inner phloem. E) Showing crystals in cortex. (All from *Poilane* 13635, P).

# G. arborea Roxb.

### (Figure 3.10.4, Malay Peninsula)

**OUTLINE:** rectangular, adaxially convex to concave, abaxially convex with two prominent grooves; slightly ridged; lateral wings absent. *Cross sectional area:* 1,666,942µm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric; periclinal walls thick, anticlinal walls sinuous. *Trichomes:* both glandular and eglandular trichomes densely distributed over the petiole. **VASCULATURE:** main vascular bundle O-shaped, almost closed; amphicribal or hadrocentric; 10-12 discrete, bi-collateral bundles form dissected cylinder; almost equidistant from the both sides; adaxially two additional vascular bundles located close to the main vascular bundle. *Xylem fibres:* absent. *Main vascular bundle area:* 299,671µm<sup>2</sup>; *two additional vascular bundles area:* 3,970µm<sup>2</sup>, and 3,690µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 18.40%. *Perivascular phloem fibres:* absent. **CORTEX:** collenchyma cells thick; parenchyma cells angular; cell walls sinuous; parenchyma cells larger than the collenchymas. **PITH:** parenchymatous; pith area moderately broad, cells angular, walls sinuous. **CRYSTAL:** absent.

# G. arborea Roxb.

## (Figure 3.10.5, Philippines)

**OUTLINE:** circular, abaxially convex, slightly undulated; lateral wings absent. *Cross sectional area:* 1,565,077µm<sup>2</sup>. **EPIDERMIS:** one cell layer, consisting cork cells, surface with wavy striations, cells anisodiametric; cell walls thick. *Trichomes*: sparsely distributed over the petiole. **VASCULATURE:** main vascular bundle O-shaped, closed; amphicribal or hadrocentric; about 10 discrete, bi-collateral bundles form a complete ring, peripheral; almost equidistant from the both sides; adaxially two additional vascular bundles located close to the main vascular bundle. *Xylem fibres*: present. *Main vascular bundle area*: 397,357µm<sup>2</sup>; *two additional vascular bundles area*: 4,911µm<sup>2</sup>, and 3,888µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 26%. *Perivascular phloem fibres*: sclerenchymatous, many discrete bundles distributed alongside the main and the additional vascular bundles. **CORTEX:** two to three layers of supepidermal collenchyma cells consist of cork cells, collenchymas angular; parenchyma cells larger than the collenchymas, almost circular. **PITH:** pith area large, cells parenchymatous, cells polygonal, cell walls straight to sinuous with intercellular spaces. **CRYSTAL:** absent.

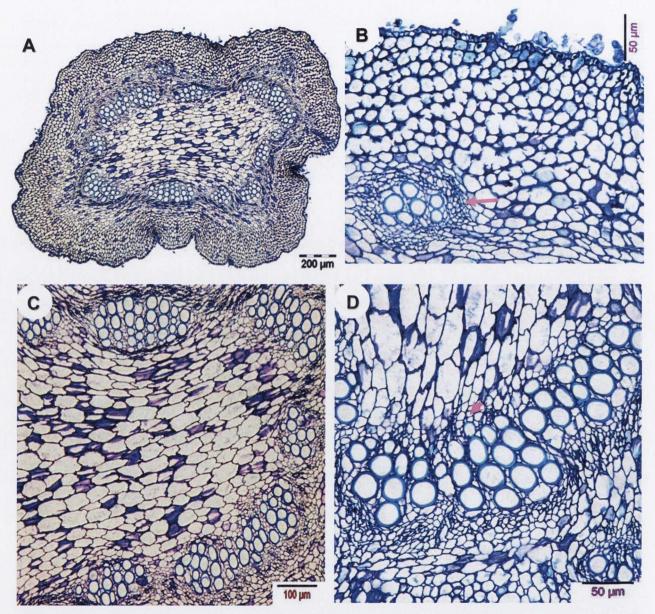


Figure 3.10.4. Petiole transverse section of *G. arborea* (Malay Peninsula). A) Outline. B) Enlarged adaxial side. Arrow shows additional vascular bundle. C) Enlarged main vascular bundle. D) Hadrocentric vascular bundle enlarged. Arrow indicates short inner phloem. *Note absence of xylem fibres and perivascular phloem fibres.* (All from *Carrick* 1511, SING).

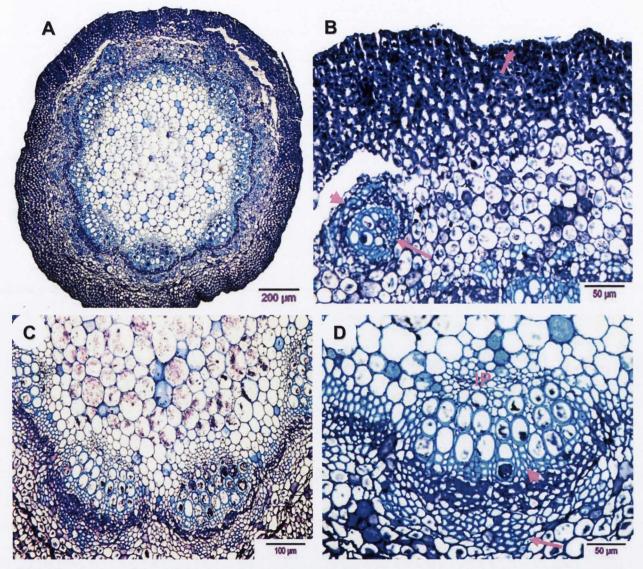


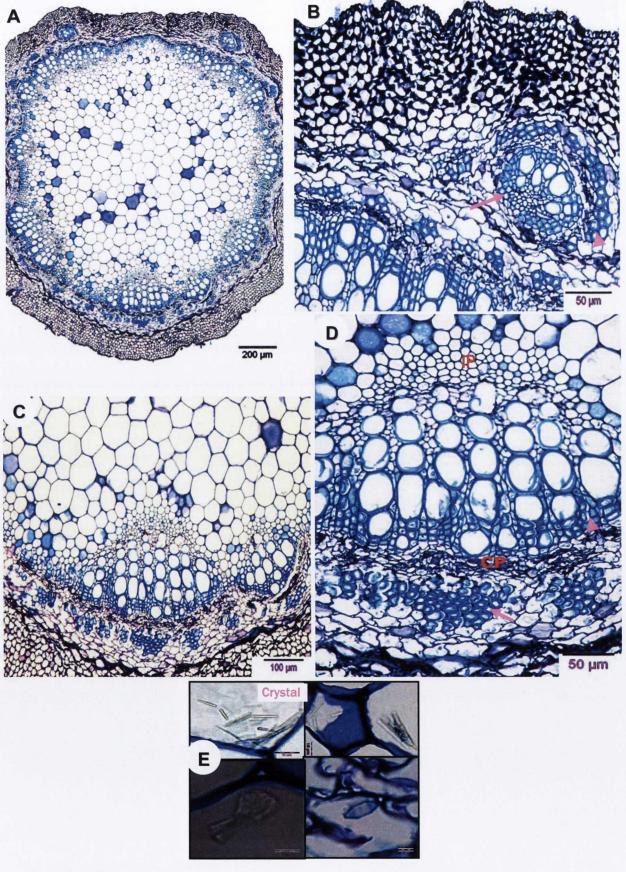
Figure 3.10.5. Petiole transverse section of *G. arborea* (Philippines). A) Outline. B) Enlarged adaxial side; Upper arrow indicates epidermis with cork cells; lower arrow shows additional vascular bundle; arrow head shows perivascular phloem fibres. C) Enlarged main vascular bundle. D) Hadrocentric vascular bundle enlarged. Arrow head indicates xylem fibres; arrow shows perivascular phloem fibres; IP= inner phloem. (All from *Soejarto et al.* 6533, MO).

OUTLINE: obovate, adaxially almost flattened with slight depression, abaxially convex; undulate; lateral wing absent. Cross sectional area: 2,398,500 µm<sup>2</sup>. EPIDERMIS: one cell layer, surface undulate, cells anisodiametric, anticlinally elongated, cell walls thickened, periclinal cell walls cutinized, cuticle rather thin. Trichomes: short-stalked glandular and multicellular trichomes most abundant on adaxial side, and evenly distributed throughout. VASCULATURE: main vascular bundle amphicribal or hadrocentric; nine to ten discrete vascular bundles form a cylinder, peripheral; narrowly open adaxially; almost equidistant from both sides; adaxially two additional vascular bundles located very close to the main vascular cylinder. Xylem fibres: present. Main vascular bundle area: 745,046µm<sup>2</sup>; two additional vascular bundles area: 2,380µm<sup>2</sup>, and 4,100µm<sup>2</sup>. Vascular bundles area proportion to the cross sectional area: 31.33%. Perivascular phloem fibres: abundant, sclerenchymatous, distributed in discrete bundles alongside the main and the lateral vascular bundles, CORTEX: subepidermal collenchyma cells ± rectangular to angular, with thick cell walls: parenchyma cells larger than the collenchymas, angular. PITH: pith area large, cells parenchymatous, cells polygonal, cell walls straight with intercellular spaces. CRYSTAL: different types of solitary and aggregated crystals are observed both in pith and cortex; viz. in both pith and cortex solitary acicular and desmidoid crystals are observed; and in pith solitary hour-glass-shaped, crystalline mass, solitary widely rhombic, acicular aggregates, and styloid with forked ends are observed.

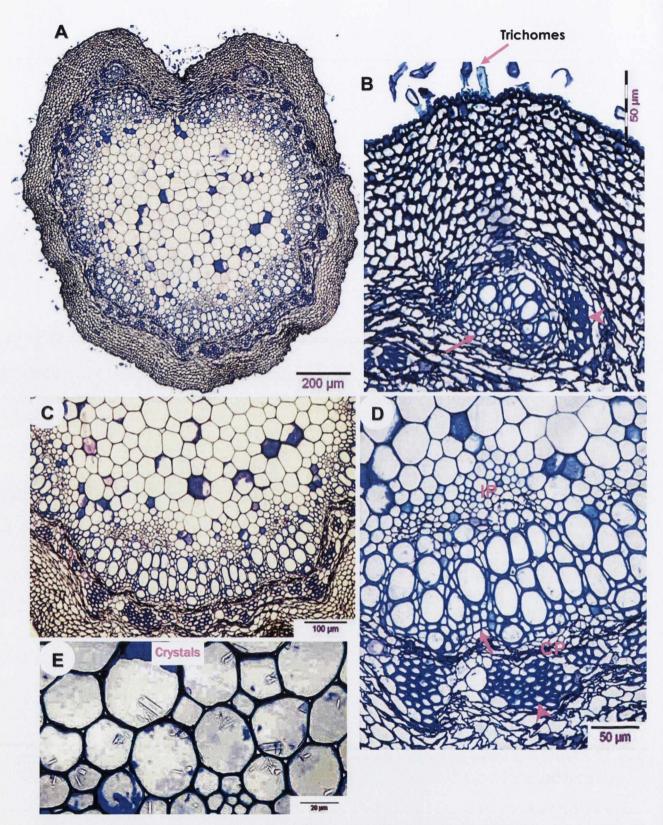
## G. arborea Roxb.

## (Figure 3.10.7, Sri Lanka)

**OUTLINE:** obovate with two short lateral wings; adaxially grooved, abaxially convex; undulate. *Cross sectional area*: 1,176,940μm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric, cell walls thickened, periclinal cells cutinized, cuticle rather thin, anticlinal cell walls sinuous; cells much enlarged and raised at the base of hairs. *Trichomes:* both glandular and eglandular trichomes most abundant on adaxial side, and evenly distributed throughout. **VASCULATURE:** main vascular bundle amphicribal or hadrocentric; 15 discrete, bi-collateral bundles form dissected cylinder, narrowly open adaxially, peripheral; almost equidistant from the both sides; adaxially two additional vascular bundles located very close to the main vascular bundle. *Xylem fibres*: present. *Main vascular bundles area*: 221,255μm<sup>2</sup>; *two additional vascular bundles area*: 2,993μm<sup>2</sup>, and 2,540μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 19.27%. *Perivascular phloem fibres*: abundant, sclerenchymatous, and distributed in discrete bundles alongside the main vascular bundle and also the lateral vascular bundles. **CORTEX**: subepidermal collenchyma cells ± rectangular to angular, with thick cell walls; parenchyma cells larger than the collenchymas, angular. **PITH**: pith area large, cells parenchymatous, cells polygonal, cell walls straight with intercellular spaces. **CRYSTAL**: acicular, and rhombic crystals are abundant in pith and few rhombic crystals are observed in cortex.



**Figure 3.10.6**. Petiole transverse section of *G. arborea* (Hong Kong). A) Outline. B) Adaxial side enlarged. Arrow indicates additional vascular bundle; arrow head shows perivascular phloem fibres. C) Enlarged main vascular bundle. IP= inner phloem. D) Hadrocentric vascular bundle enlarged. Arrow head indicates xylem fibres; arrow indicates perivascular phloem fibres; CP= crushed phloem. E) Crystals in pith and cortex. Clockwise- from top left acicular aggregates, styloid with forked ends, elliptic, and hour-glass-shaped. (All from *Hu* & Yung 022, K).



**Figure 3.10.7**. Petiole transverse section of *G. arborea* (Sri Lanka). A) Outline. B) Adaxial side enlarged. Arrow indicates additional vascular bundle; arrow head shows perivascular phloem fibres. C) Enlarged main vascular bundle. D) Hadrocentric vascular bundle enlarged. Arrow indicates xylem fibres; arrow head indicates perivascular phloem fibres; CP= crushed phloem; IP= inner phloem. E) Crystals in pith and cortex. (All from *Worthington* 887, K).

#### (Figure 3.10.8, Cambodia)

**OUTLINE:** almost circular to oval with two long prominent lateral wings; slightly ridged, adaxially deeply grooved, abaxially convex. *Cross sectional area:* 537,840µm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface smooth, somewhat papillate; cell isodiametric or anisodiametric; periclinal cell walls thick. *Trichomes:* present in the adaxial groove. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median crescentic arc, almost equidistant but slightly closer abaxially, phloem rather squashed; two small additional vascular bundles present in the middle of lateral wings. *Xylem fibres:* absent. *Main vascular bundle area:* 43,610µm<sup>2</sup>; *two additional vascular bundles area:* 1,333µm<sup>2</sup>, and 1,162µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 8.57%. *Perivascular phloem fibres:* absent. **CORTEX:** consists of thick-walled collenchymatous cells and thin-walled parenchymatous cells, collenchyma cells rectangular; parenchyma cells polygonal; parenchyma cell walls not sinuous. **PITH:** parenchymatous; pith area very narrow, cells angular, walls sinuous. **CRYSTAL:** absent.

### G. asiatica L.

#### (Figure 3.10.9, Vietnam)

**OUTLINE**: almost circular to oval with two lateral wings; slightly ridged, adaxially grooved, abaxially convex, and undulate. *Cross sectional area*: 391,602µm<sup>2</sup>. **EPIDERMIS**: one cell layer, surface with wavy striations, cells anisodiametric, cell walls thin. *Trichomes*: trichomes sparsely distributed over the petiole, rather dense in the adaxial groove. **VASCULATURE**: main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median crescentic arc, almost equidistant but slightly closer abaxially, phloem rather squashed; two small additional vascular bundles present in the middle of lateral wings. *Xylem fibres*: absent. *Main vascular bundle area*: 49,751µm<sup>2</sup>; *two additional vascular bundles area*: 3,680µm<sup>2</sup>, and 3,687µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 14.58%. *Perivascular phloem fibres*: absent. **CORTEX**: consists of thick-walled collenchymatous cells and thin-walled parenchymatous cells, collenchyma cells rectangular; parenchyma cells polygonal. **PITH**: pith area small; parenchymatous; cells angular, walls sinuous. **CRYSTAL**: absent.

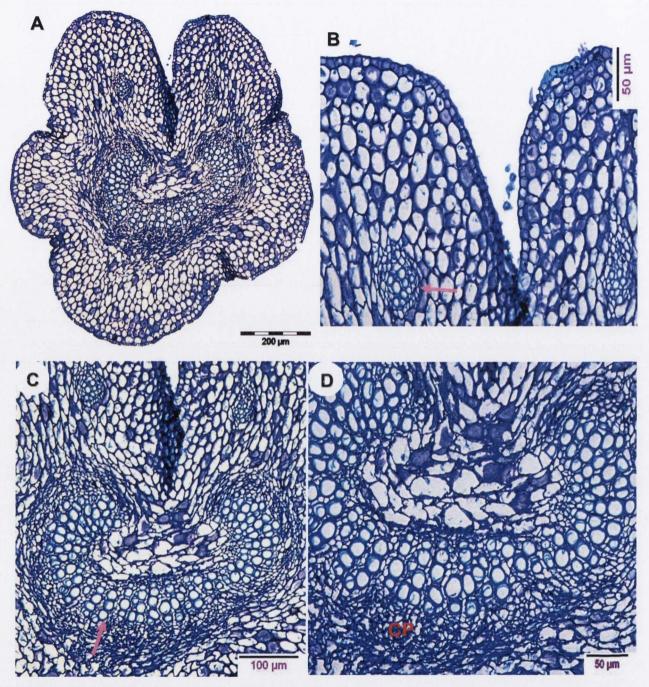


Figure 3.10.8. Petiole transverse section of *G. asiatica* (Cambodia). A) Outline. B) Enlarged adaxial side; additional vascular bundle is arrowed. C-D) Main vascular bundle enlarged. Arrow indicates crescentic arc vascular bundle; CP= crushed phloem. Note absence of xylem fibres and perivascular phloem fibres. (All from Poilane 15306, P).

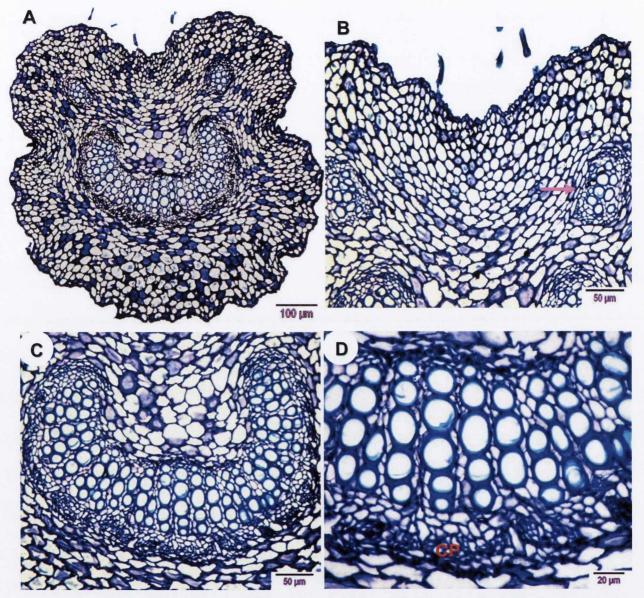


Figure 3.10.9. Petiole transverse section of *G. asiatica* (Vietnam). A) Outline. B) Enlarged adaxial side; additional vascular bundle is arrowed. C) Main vascular bundle enlarged. D) Enlarged vascular bundle. CP= crushed phloem. *Note absence of xylem fibres and perivascular phloem fibres*. (All from *Evrard* 2680, P).

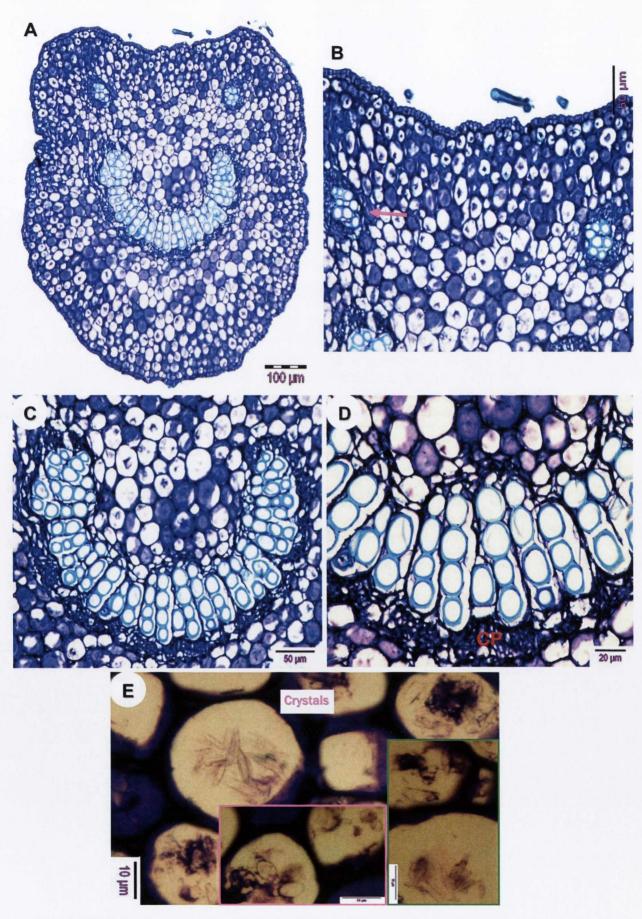
## (Figure 3.10.10, Thailand)

**OUTLINE:** globose to obovate, adaxially slightly concave, abaxially convex, lateral wings absent; slightly undulate. *Cross sectional area*: 408,264µm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric, elongated; periclinal cell walls cutinized, anticlinal cell walls sinuous. *Trichomes*: trichomes sparse adaxially. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median crescentic arc, almost equidistant but slightly closer adaxially, phloem rather squashed; two small additional vascular bundles located adaxially in between lateral wings and the tip of the main vascular bundle ends. *Xylem fibres*: absent. *Main vascular bundle area*: 44,600µm<sup>2</sup>; *two additional vascular bundles area*: 2,852µm<sup>2</sup>, and 2,843µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 12.32%. *Perivascular phloem fibres*: absent. **CORTEX:** consists of thick-walled collenchymatous cells and thin-walled parenchymatous cells; collenchyma cells almost circular; parenchyma cells polygonal and larger than the collenchyma. **PITH:** pith area small; parenchymatous; cells abundant in pith.

# G. asiatica L.

### (Figure 3.10.11, Brunei)

**OUTLINE**: globose with two prominent lateral wings; adaxially prominently grooved, abaxially convex, and slightly undulate. *Cross sectional area*: 125,303µm<sup>2</sup>. **EPIDERMIS**: one cell layer, surface with wavy striations, cells anisodiametric, elongated; periclinal cell walls cutinized. **VASCULATURE**: main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median crescentic arc, almost equidistant but slightly closer abaxially, phloem rather squashed; two small additional vascular bundles present in the middle of lateral wings. *Xylem fibres*: absent. *Main vascular bundle area*: 20,374.5µm<sup>2</sup>; *two additional vascular bundles area*: 438µm<sup>2</sup>, and 1,129µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 17.51%. *Perivascular phloem fibres*: absent. **CORTEX**: consists of thick-walled collenchymatous cells and thin-walled parenchymatous cells; collenchyma cells almost circular; parenchyma cells polygonal and larger than the collenchyma. **PITH**: pith area small; parenchymatous; cells polygonal with intercellular spaces. **CRYSTAL**: absent.



**Figure 3.10.10**. Petiole transverse section of *G. asiatica* (Thailand). A) Outline. B) Adaxial side enlarged. Arrow indicates additional vascular bundle. C) Enlarged main vascular bundle. D) Vascular bundle enlarged. CP= crushed phloem. E) Crystals in pith. *Note absence of xylem fibres and perivascular phloem fibres*. (All from *Kerr* 21257, BM).

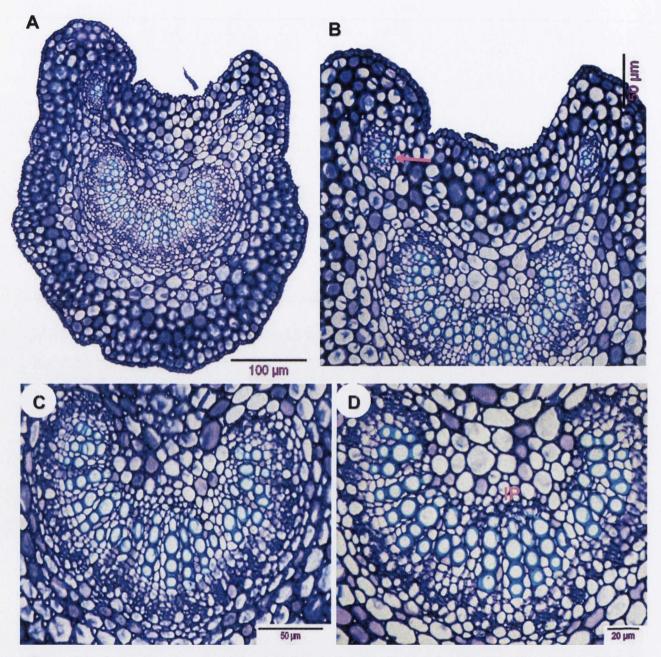


Figure 3.10.11. Petiole transverse section of *G. asiatica* (Brunei). A) Outline. B) Enlarged adaxial side; additional vascular bundle is arrowed. C-D) Crescentic arc main vascular bundle enlarged. IP= inner phloem. *Note absence of xylem fibres and perivascular phloem fibres*. (All from *Niel* 3770, L).

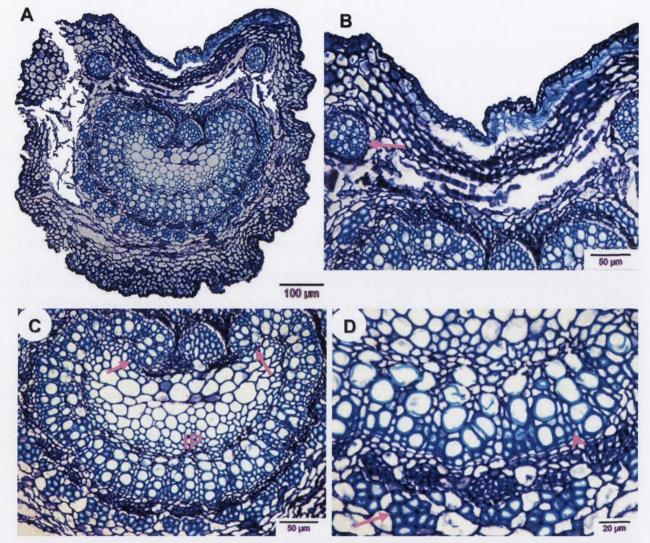
#### (Figure 3.10.12, Indonesia)

**OUTLINE**: obovate with two lateral wings; adaxially grooved, abaxially convex, ridged or undulate. *Cross sectional area*: 353,526µm<sup>2</sup>. **EPIDERMIS**: one cell layer, surface with wavy striations, cells anisodiametric; periclinal cell walls cutinized. **VASCULATURE**: main vascular bundle O-shaped with two prominently incurved ends, closed; amphicribal or hadrocentric; one long bi-collateral strand with prominently incurved ends, and one very small bi-collateral bundle between two ends of long strand, form a median dissected cylinder; abaxially closer; adaxially two additional vascular bundles located at base of lateral wings. *Xylem fibres*: present. *Main vascular bundle area*: 98,292µm<sup>2</sup>; *two additional vascular bundles area*: 5,567µm<sup>2</sup>, and 4,368µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 30.61%. *Perivascular phloem fibres*: abundant, sclerenchymatous; discrete bundles of Perivascular phloem fibres distributed alongside the main vascular bundle, rarely present along the lateral vascular bundles. **CORTEX**: consists of thick-walled collenchymatous cells and thin-walled parenchymatous cells; cells polygonal, inner cells much larger. **PITH**: pith area narrow, cells parenchymatous, cell walls straight to sinuous with intercellular space. **CRYSTAL**: absent.

# G. asiatica L.

#### (Figure 3.10.13, Malaysia)

**OUTLINE:** obovate with two lateral wings; adaxially deeply grooved, abaxially flat to slightly concave. *Cross sectional area*: 591,407µm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric; periclinal cell walls cutinized, anticlinal cell walls sinuous. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median crescentic arc, almost equidistant but slightly closer abaxially, phloem rather squashed; two small additional vascular bundles present in between lateral wings and main vascular bundle. *Xylem fibres*: absent. *Main vascular bundle area*: 67,324µm<sup>2</sup>; *two additional vascular bundles area*: 4,933µm<sup>2</sup>, and 6,222µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 13.27%. *Perivascular phloem fibres*: absent. **CORTEX**: subepidermal cells collenchymatous, inwards cells parenchymatous; collenchyma cells almost circular; parenchyma cells larger than collenchyma cells and polygonal, cell walls sinuous. **PITH:** pith area very narrow; parenchymatous; cells polygonal with sinuous walls and intercellular spaces. **CRYSTAL:** absent.



**Figure 3.10.12**. Petiole transverse section of *G. asiatica* (Indonesia). A) Outline. B) Adaxial side enlarged. Arrow indicates additional vascular bundle. C) Enlarged main vascular bundle. IP= inner phloem; incurved ends arrowed. D) Hadrocentric vascular bundle enlarged. Arrow indicates perivascular phloem fibres; arrow head shows xylem fibres. (All from *unknown collector* 11.918-271, L).

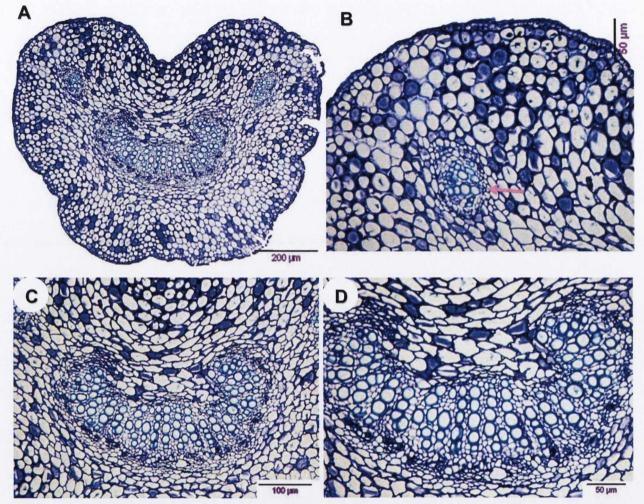


Figure 3.10.13. Petiole transverse section of *G. asiatica* (Malaysia). A) Outline. B) Enlarged adaxial side; additional vascular bundle is arrowed. C-D) Crescentic arc main vascular bundle enlarged. *Note absence of xylem fibres and perivascular phloem fibres*. (All from *Ridley* s. n., SING).

**OUTLINE:** obovate with two lateral wings; adaxially concave, abaxially convex with prominent grooves; distinctly ridged. *Cross sectional area*: 565,820µm<sup>2</sup>. **EPIDERMIS:** one cell layer, consisting cork cells, surface smooth, cells anisodiametric, outer periclinal cell walls thick. *Trichomes:* eglandular trichomes dense adaxially. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; one very small and one large bi-collateral trace form a median crescentic arc with moderately incurved ends; almost equidistant but slightly closer abaxially; phloem rather squashed; three additional vascular bundles (one in one side and two unequal sizes in other side) are present near the tips of the main vascular bundle ends. *Xylem fibres*: absent. *Main vascular bundle area*: 55,568µm<sup>2</sup>; *three additional vascular bundles area*: 3,635µm<sup>2</sup>, 4,678µm<sup>2</sup>, and 1,429µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 11.29%. *Perivascular phloem fibres*: absent. **CORTEX**: collenchyma cells circular to rectangular consisting one to two layers of cork cells; parenchyma cells polygonal, anticlinal cell walls sinuous; parenchyma cells larger than the collenchymas. **PITH:** pith area very narrow; parenchymatous; cell polygonal with sinuate walls and intercellular spaces. **CRYSTAL:** acicular and rhombic crystals present in pith.

# G. asiatica L.

### (Figure 3.10.15, Sri Lanka)

**OUTLINE**: obovate with two lateral wings; prominently ridged, adaxially broadly concave, abaxially concave to slightly convex, undulate. *Cross sectional area*: 98,454µm<sup>2</sup>. **EPIDERMIS**: one cell layer and anisodiametric; adaxially angular, abaxially rectangular to angular with thick periclinal wall; anticlinal walls sinuous. *Trichomes*: long, eglandular and multicellular trichomes very dense in adaxial groove. **VASCULATURE**: main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median crescentic arc, almost equidistant but slightly closer abaxially; phloem rather squashed; two small additional bundles occur in the lateral wings. *Xylem fibres*: present. *Main vascular bundle area*: 10,697µm<sup>2</sup>; *two additional vascular bundles area*: 576µm<sup>2</sup>, and 599µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 12.06%. *Perivascular phloem fibres*: few Perivascular phloem fibres are scattered alongside the main arc. **CORTEX**: thick walled collenchymatous cells angular, parenchyma cells larger and polygonal, cell walls sinuous. **PITH**: pith area very narrow with thick walled parenchymatous cells; cells almost circular with intercellular spaces. **CRYSTAL**: absent.

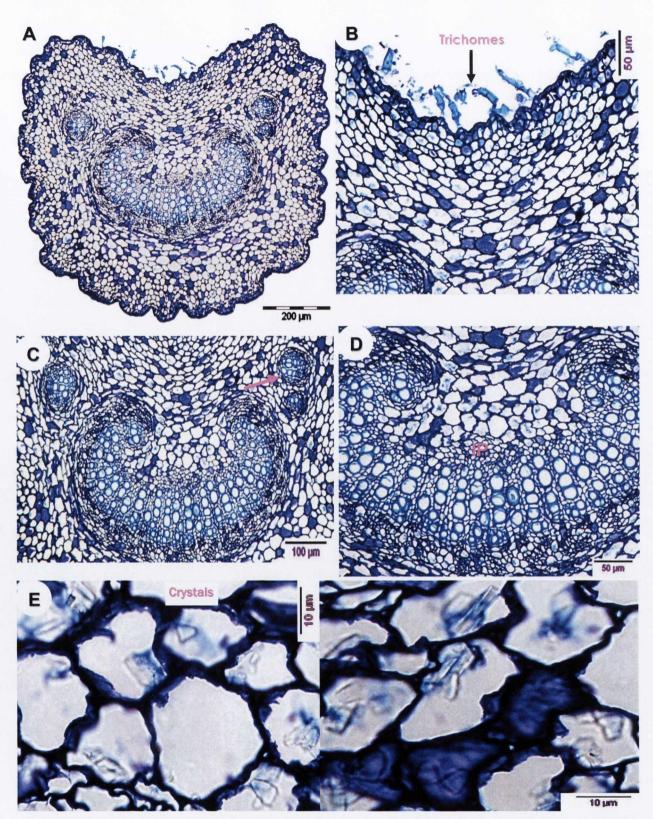


Figure 3.10.14. Petiole transverse section of *G. asiatica* (Philippines). A) Outline. B) Enlarged adaxial side. C) Enlarged main vascular bundle; additional vascular bundle is arrowed. D) Vascular bundle enlarged. IP= inner phloem. Note absence of xylem fibres and perivascular phloem fibres. E) Showing crystals in pith. (All from Mati 31, L).

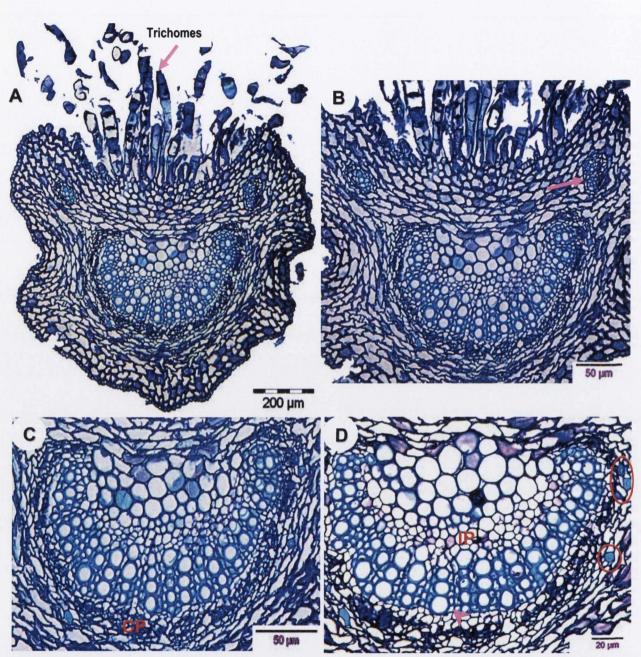


Figure 3.10.15. Petiole Transverse section of *G. asiatica* (Sri Lanka). A) Outline. B) Adaxial side enlarged. Arrow shows additional vascular bundle. C-D) Enlarged hadrocentric vascular bundle. Perivascular phloem fibres circled; CP= crushed phloem; IP= inner phloem. Arrow head indicates xylem fibres. (All from *Sumitharrarchi* DBS 764, US).

# G. attenuata Fletcher

#### (Figure 3.10.16, Thailand)

**OUTLINE**: obovate with two distinct lateral wings; adaxially prominently grooved, abaxially convex with distinct ridges. *Cross sectional area*: 780,525µm<sup>2</sup>. **EPIDERMIS**: one cell layer and anisodiametric; cell walls thick. *Trichomes*: very few short-stalked glandular trichomes sparsely present. **VASCULATURE**: main vascular bundle U-shaped with two prominently incurved ends; amphicribal or hadrocentric, open adaxially; four bi-collateral traces form a median dissected crescentic arc with invaginated ends, the central trace is longer; phloem rather crushed; almost equidistant but slightly closer adaxially; two small additional vascular bundles occur in the lateral wings. *Xylem fibres*: present. *Main vascular bundles area*: 74,123µm<sup>2</sup>; *two additional vascular bundles area*: 1,298µm<sup>2</sup>, and 1,683µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 9.88%. *Perivascular phloem fibres*: few mass of sclrenchymatous perivascular phloem fibres scattered alongside the main arc. **CORTEX:** collenchymatous cells almost circular to angular; parenchyma cells larger and polygonal, cell walls sinuous. **PITH:** pith area narrow with angular parenchymatous cells; cell walls sinuous with intercellular spaces. **CRYSTAL:** absent.

# G. borneoense M. H. Rashid

## (Figure 3.10.17, Indonesia)

**OUTLINE**: circular with two long prominent lateral wings; ridged, adaxially deeply grooved, abaxially convex to undulate. *Cross sectional area*: 1,561,370μm<sup>2</sup>. **EPIDERMIS**: one cell layer, cells small, anisodiametric, cell walls thick, cutinized. *Trichomes*: dense adaxially, otherwise sparsely distributed over the petiole. **VASCULATURE**: main vascular bundle U-shaped with very much incurved ends, open adaxially; amphicribal or hadrocentric; long, single bi-collateral trace forming a peripheral crescentic arc with invaginated ends; phloem rather crushed; relatively closer abaxially; two additional vascular bundles located on the very top of lateral wings. *Xylem fibres*: present. *Main vascular bundles area*: 551,993μm<sup>2</sup>; *two additional vascular bundles area*: 19,317μm<sup>2</sup>, and 20,477μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 37.90%. *Perivascular phloem fibres*: Sclerenchymatous; distributed in discrete bundles alongside the main and the additional vascular bundle. **CORTEX**: three layers of subepidermal collenchyma cells contain cork cells; collenchymas globular to angular; parenchyma cells large, angular to polygonal, cell walls sinuous. **PITH**: pith area broad; parenchymatous, cells polygonal, cell walls straight. **CRYSTAL**: absent.

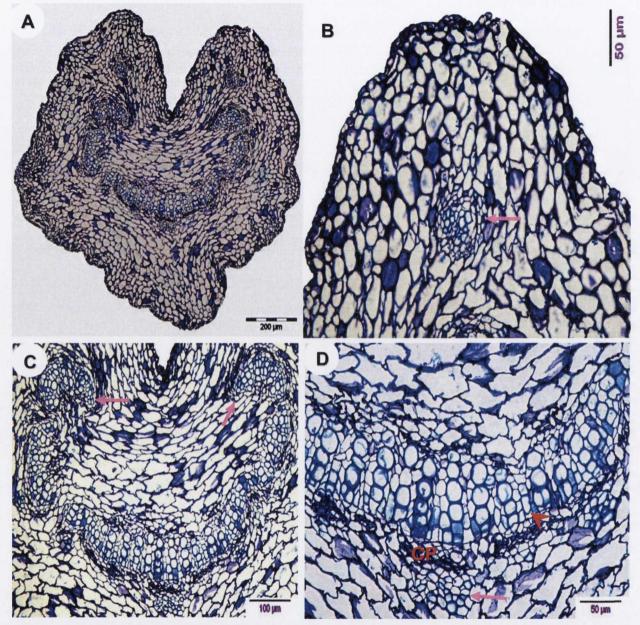


Figure 3.10.16. Petiole transverse section of *G. attenuata* (Thailand). A) Outline. B) Enlarged adaxial side. Arrow shows additional vascular bundle. C) Enlarged main vascular bundle. Incurved ends arrowed. D) Hadrocentric vascular bundle enlarged. Arrow head shows xylem fibres; arrow indicates perivascular phloem fibres; CP= crushed phloem; IP= Inner Phloem. (All from *Kerr* 6224, E).

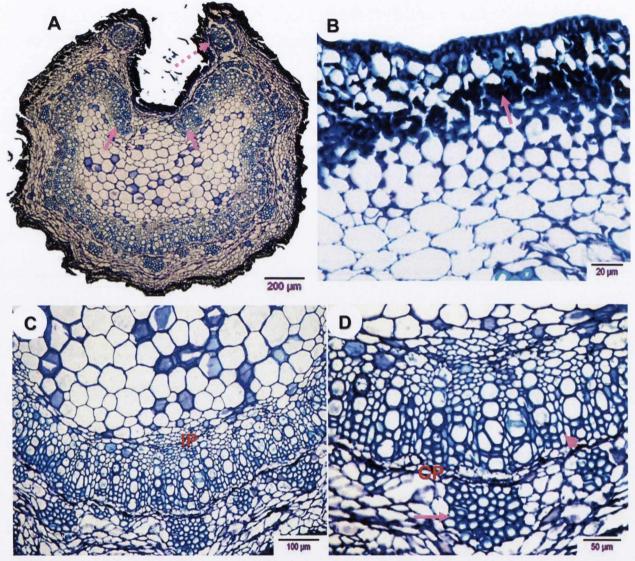


Figure 3.10.17. Petiole transverse section of *G. borneoense* (Indonesia). A) Outline. Upper dashed arrow indicates additional vascular bundle; lower solid arrows show very much incurved end. B) Adaxial side enlarged. Arrow indicates cork cells. C) Hadrocentric main vascular bundle enlarged. IP= inner phloem. D) Enlarged vascular bundle. Arrow head indicates xylem fibres; arrow shows perivascular phloem fibres; CP= crushed phloem. (All from *Jaheri* 1300, K).

## G. chinensis Benth.

**OUTLINE:** rectangular to obovate with two obscure lateral wings; prominently ridged, adaxially almost flattened with a deep, broad hollow; abaxially convex with distinct ridges. *Cross sectional area*: 1,084,720μm<sup>2</sup>. **EPIDERMIS:** one cell layer; cell small and anisodiametric, abaxially cutinized; cell walls thick. *Trichomes:* sparsely present adaxially. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; long, single bi-collateral strand forms a continuous crescentic arc, almost equidistant, slightly closer adaxially; two additional vascular bundles present adaxially near the tip of the main vascular bundle ends. *Xylem fibres*: present. *Main vascular bundle area*: 177,415μm<sup>2</sup>; two additional vascular bundles area: 3,958μm<sup>2</sup>, and 4,026μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 17.09%. *Perivascular phloem fibres*: sclerenchymatous, abundant; distributed in discrete bundles alongside the main and the additional vascular bundles. **CORTEX:** two to three layers of subepidermal collenchyma cells with cork cells, cells polygonal; parenchyma cells larger, walls sinuous. **PITH:** pith area large; parenchymatous, cells polygonal, cell walls straight with intercellular spaces. **CRYSTAL:** absent.

### G. delavayana Dop

#### (Figure 3.10.19, China)

**OUTLINE:** oval with two distinct lateral wings; adaxially deeply grooved; abaxial surface flattened to undulate. *Cross sectional area:* 185,941μm<sup>2</sup>. **EPIDERMIS:** one cell layer; cell small and anisodiametric. **VASCULATURE:** main vascular bundle U-shaped with very prominently incurved ends, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median cresentic arc with invaginated ends; phloem rather squashed; almost equidistant from the both sides; two additional vascular bundles present in the lateral wings. *Xylem fibres*: absent. *Main vascular bundle area*: 26,635μm<sup>2</sup>; *two additional vascular bundles area*: 1,177μm<sup>2</sup>, and 900μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 15.44%. *Perivascular phloem fibres*: absent. **CORTEX:** parenchyma cells larger than the collenchymas, cells angular, walls sinuous. **PITH:** pith area narrow; parenchymatous, cells angular to polygonal, cell walls sinuous. **CRYSTAL:** absent.

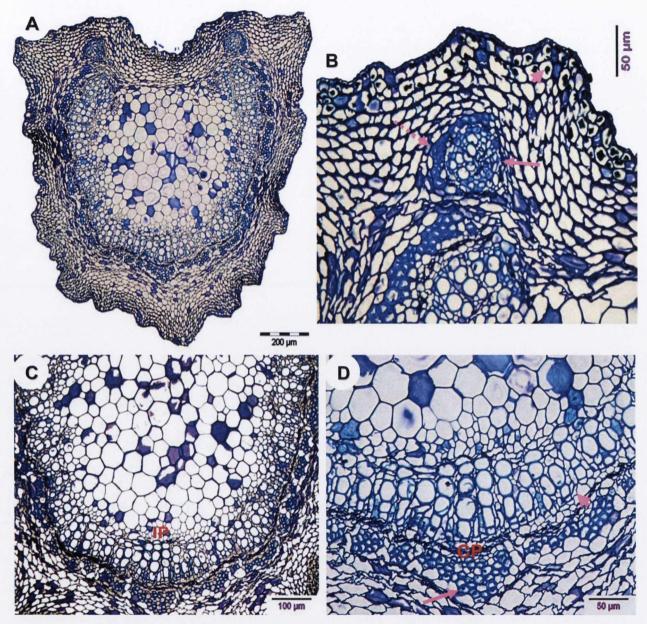


Figure 3.10.18. Petiole transverse section of *G. chinensis* (Hong Kong). A) Outline. B) Enlarged adaxial side. Arrow head shows cork cells; solid arrow indicates additional vascular bundle; dashed arrow shows perivascular phloem fibres. C) Enlarged main vascular bundle. IP= inner phloem. D) Vascular bundle enlarged. Arrow head shows xylem fibres; arrow indicates perivascular phloem; CP= crushed phloem fibres. (All from *Chan* 1073, A).

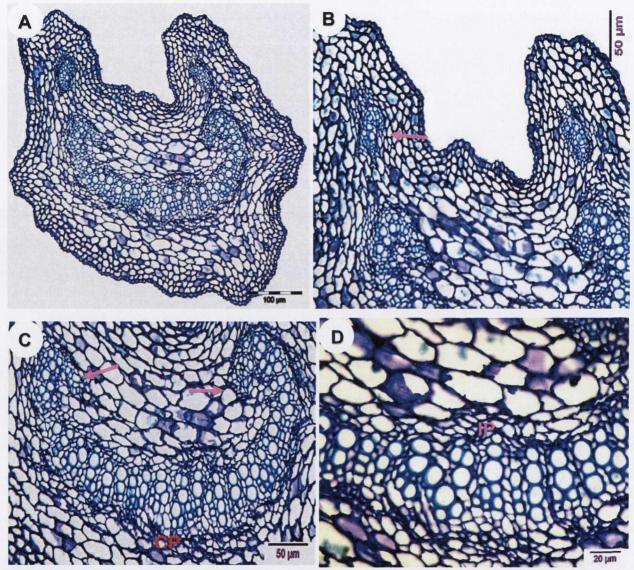


Figure 3.10.19. Petiole transverse section of *G. delavayana* (China). A) Outline. B) Adaxial side enlarged. Arrow shows additional vascular bundle. C) Enlarged hadrocentric main vascular bundle. Incurved ends arrowed; CP= crushed phloem. D) Vascular bundle enlarged. IP= inner phloem. *Note absence of xylem fibres and perivascular phloem fibres*. (All from *Heinr*. 3373, A).

# G. elliptica Smith

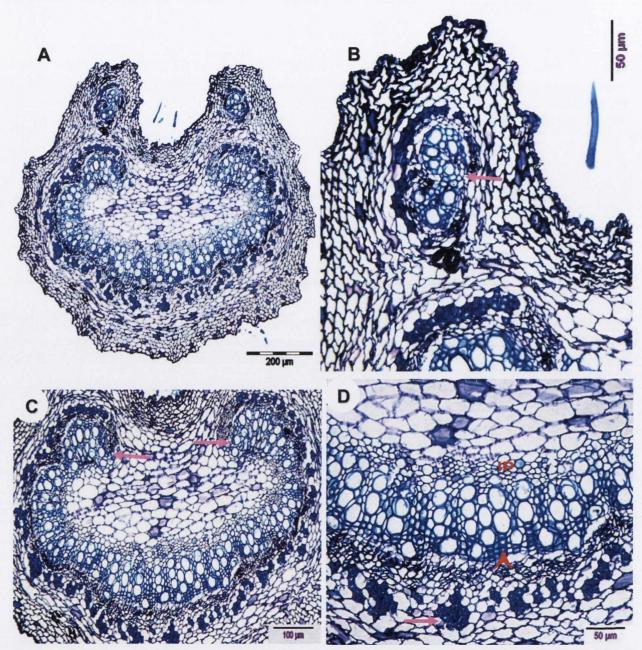
### (Figure 3.10.20, Vietnam)

**OUTLINE:** oval with two prominent lateral wings; adaxially deeply grooved, abaxially convex to concave, undulate. *Cross sectional area:* 491,000μm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric, cells more or less papillate, cell walls thin. *Trichomes:* present in the adaxial groove, very few scattered over the petiole. **VASCULATURE:** main vascular bundle U-shaped with prominently incurved ends, open adaxially; amphicribal or hadrocentric; single, bi-collateral strand forms a median crescentic arc with invaginated ends; almost equidistant but slightly closer abaxially; three additional vascular bundles present in lateral wings; one large in one wing and two small in other. *Xylem fibres:* present. *Main vascular bundle area:* 95,780μm<sup>2</sup>; *three additional vascular bundles area:* 6,943μm<sup>2</sup>, 2,253μm<sup>2</sup>, and 2,588μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 21.90%. *Perivascular phloem fibres:* abundant, many mass of Perivascular phloem fibres distributed in discrete bundles alongside the main and the additional vascular bundles. **CORTEX:** collenchyma cells angular, anticlinal cell walls sinuous; parenchyma cells larger than the collenchymas. **PITH:** pith area narrow; parenchymatous; cells angular, walls sinuous. **CRYSTAL:** absent.

# G. elliptica Smith

#### (Figure 3.10.21, Thailand)

**OUTLINE:** oval with two prominent lateral wings; adaxially deeply grooved, abaxially slightly concave to convex, and undulate. *Cross sectional area:* 284,180μm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric; anticlinal cell walls sinuous. *Trichomes:* sparsely distributed over the petiole; branched trichomes occasionally observed in the adaxial groove. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral bundle forms a median crescentic arc with one inconspicuously incurved end; almost equidistant but slightly closer abaxially; phloem rather squashed; two additional vascular bundles present in lateral wings. *Xylem fibres:* absent. *Main vascular bundles area*: 35,118μm<sup>2</sup>; *two additional vascular bundles area*: 2,156μm<sup>2</sup>, and 1,804μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 13.75%. *Perivascular phloem fibres:* absent. **CORTEX:** collenchyma cells polygonal, anticlinal cell walls sinuous; parenchyma cells larger than the collenchymas. **PITH:** pith area very narrow; parenchymatous; cells polygonal with sinuous walls and intercellular spaces. **CRYSTAL:** absent.



**Figure 3.10.20**. Petiole transverse section of *G. elliptica* (Vietnam). A) Outline. B) Enlarged adaxial side; additional vascular bundles arrowed; arrow head shows perivascular phloem fibres. C) Enlarged hadrocentric median arc. Incurved ends arrowed. D) Vascular bundle enlarged. Arrow head shows xylem fibres; arrow indicates Perivascular phloem fibres; IP= inner phloem. (All from *Hiep* 147, P).

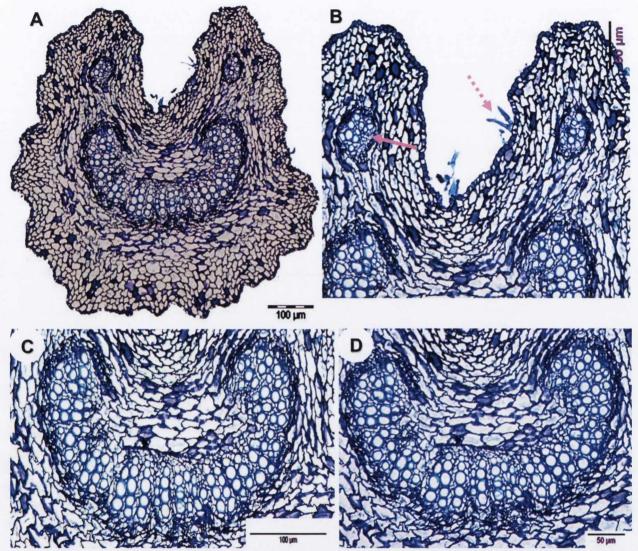


Figure 3.10.21. Petiole transverse section of *G. elliptica* (Thailand). A) Outline. B) Adaxial side enlarged. Dashed arrow shows branched trichomes; solid arrow indicates additional vascular bundle. C-D) Enlarged main vascular bundle. *Note absence of xylem fibres and perivascular phloem fibres*. (All from Geesink & Santisuk 5223 (L)].

# G. elliptica Smith

## (Figure 3.10.22, Indonesia)

**OUTLINE:** oval with two lateral wings; ridged; adaxially with two prominent hollows; abaxially convex, undulate. *Cross sectional area*: 497,940µm<sup>2</sup>. **EPIDERMIS:** one cell layer; anisodiametric, anticlinal cell walls thick. *Trichomes:* sparsely distributed over the petiole. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single, bi-collateral strand forms a median crescentic arc with one upward end, almost equidistant but slightly closer abaxially, phloem rather squashed; two additional vascular bundles present in the lateral wings. *Xylem fibres*: present. *Main vascular bundle area*: 136,517µm<sup>2</sup>; *two additional vascular bundles area*: 4,950µm<sup>2</sup>, and 4,615µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional area*: 29.38%. *Perivascular phloem fibres*: few Perivascular phloem fibres rarely scattered in two sides of median vascular bundle, absent from both adaxial and abaxial side, and also from additional vascular bundles. **CORTEX:** collenchyma cells polygonal, anticlinal cell walls sinuous; parenchyma cells larger than the collenchymas. **PITH:** pith area narrow; parenchymatous; cells angular, walls sinuous with intercellular spaces. **CRYSTAL:** absent.

### G. elliptica Smith

#### (Figure 3.10.23, Malaysia)

**OUTLINE:** oval with two lateral wings; undulate, adaxially concave or moderately grooved; abaxially flattened to slightly concave with wavy striations. *Cross sectional area:* 494,380μm<sup>2</sup>. **EPIDERMIS:** one cell layer; surface with wavy striations, cell small, anisodiametric. *Trichomes:* sparsely distributed over the petiole. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand form a median crescentic arc with obscurely incurved ends, phloem rather squashed; equidistant from the both sides; two additional vascular bundles present in the lateral wings. *Xylem fibres:* absent. *Main vascular bundle area:* 74,906μm<sup>2</sup>; *two additional vascular bundles area:* 3,234μm<sup>2</sup>, and 3,525μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 16.52%. *Perivascular phloem fibres:* absent. **CORTEX:** collenchyma cells polygonal, anticlinal cell walls sinuous; parenchyma cells larger than the collenchymas. **PITH:** pith area very narrow; parenchymatous; cells polygonal, walls sinuous with intercellular spaces. **CRYSTAL:** absent.

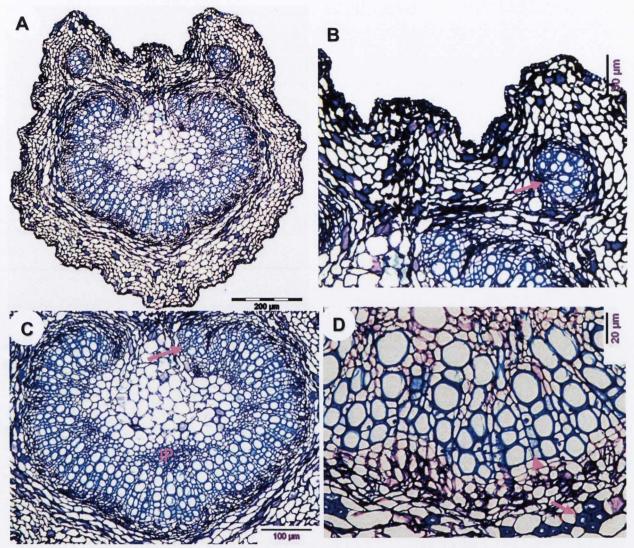
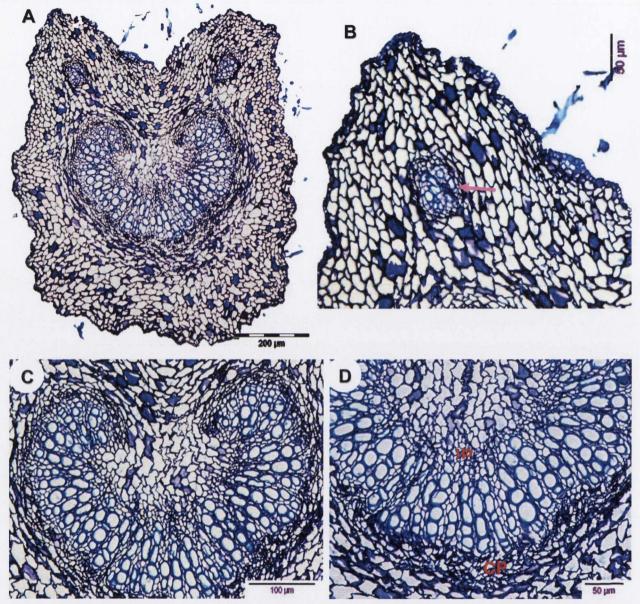


Figure 3.10.22. Petiole transverse section of *G. elliptica* (Indonesia). A) Outline. B) Enlarged adaxial side. Arrow shows additional vascular bundle C) Median hadrocentric vascular bundle enlarged. Arrow shows upward end; IP= inner phloem. D) Enlarged vascular bundle. Arrow head indicates xylem fibres; arrow shows scattered perivascular phloem fibres. (All from *Laman et al.* LT 529, A).



**Figure 3.10.23**. Petiole transverse section of *G. elliptica* (Malaysia). A) Outline. B) Enlarged adaxial side. Arrow shows additional vascular bundle. C) Enlarged hadrocentric median vascular bundle with obscurely incurved ends. D) Vascular bundle enlarged. CP= crushed phloem; IP= inner phloem. *Note absence of xylem fibres and perivascular phloem fibres.* (All from *Guan* 34276, K).

## G. elliptica Smith

**OUTLINE:** oval with two prominent lateral wings; undulate, adaxially deeply grooved, abaxially convex to concave. *Cross sectional area*: 620,673µm<sup>2</sup>. **EPIDERMIS:** one cell layer; anisodiametric to isodiametric, cell walls thick. *Trichomes:* sparsely distributed over the petiole. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand form a median crescentic arc, almost equidistant from the both sides, slightly closer adaxially; phloem rather squashed; two additional vascular bundles present in the lateral wings. *Xylem fibres*: absent. *Main vascular bundle area*: 58,886µm<sup>2</sup>; *two additional vascular bundles area*: 2,624µm<sup>2</sup>, and 3,048µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 10.40%. *Perivascular phloem fibres*: absent. **CORTEX:** collenchyma cells almost circular; parenchyma cells larger than the collenchymas, polygonal, cell walls sinuous. **PITH:** pith area very narrow; parenchymatous; cells angular, walls sinuous with intercellular spaces. **CRYSTAL:** absent.

## G. elliptica Smith

### (Figure 3.10.25, India)

**OUTLINE:** oval with two prominent lateral wings; undulate, adaxially deeply grooved, abaxially convex with ridges. *Cross sectional area:* 403,248 µm<sup>2</sup>. **EPIDERMIS:** one cell layer; surface with wavy striations, cells anisodiametric, cell walls thick. *Trichomes:* dense adaxially otherwise sparse. **VASCULATURE:** main vascular bundle U-shaped with moderately incurved ends, open adaxially; single long trace forms a median crescentic arc with invaginated ends; abaxially closer; two additional vascular bundles present in the lateral wings. *Xylem fibres:* present. *Main vascular bundle area:* 94,674µm<sup>2</sup>; *two additional vascular bundles area:* 4,581µm<sup>2</sup>, and 4,955µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 25.84%. *Perivascular phloem fibres:* many mass of Perivascular phloem fibres distributed in discrete bundles alongside the main and the additional vascular bundles. **CORTEX:** collenchyma cells polygonal, anticlinal cell walls sinuous; parenchyma cells larger than the collenchymas. **PITH:** pith area small; parenchymatos; cell oval to circular with intercellular spaces. **CRYSTAL:** absent.

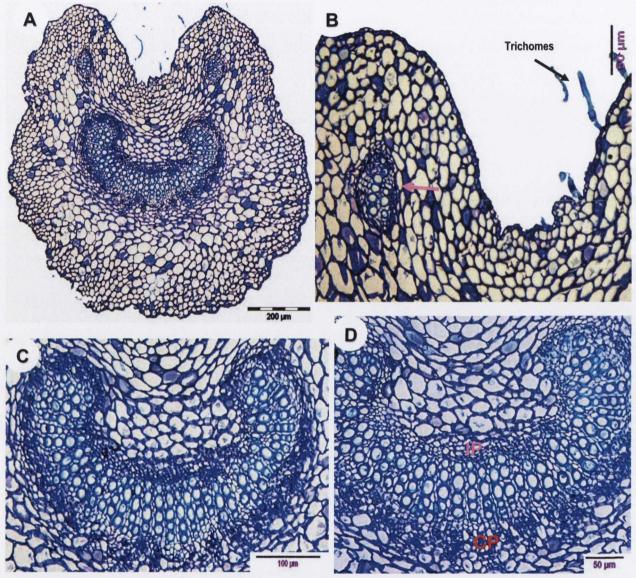
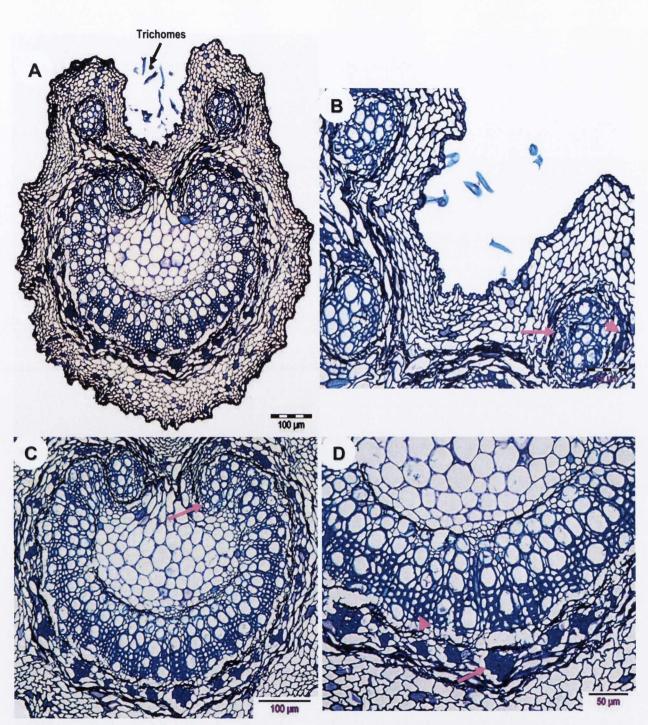


Figure 3.10.24. Petiole transverse section of *G. elliptica* (Philippines). A) Outline. B) Enlarged adaxial side. Arrow shows additional vascular bundle. C-D) Main vascular bundle enlarged. CP= crushed phloem; IP= inner phloem. *Note absence of xylem fibres and perivascular phloem fibres*. (All from *Merrill* 914, A).



**Figure 3.10.25**. Petiole transverse section of *G. elliptica* (India). A) Outline. B) Enlarged adaxial side; additional vascular bundle is arrowed; arrow head indicates Perivascular phloem fibres along the additional vascular bundle. C) Main vascular bundle enlarged. Arrow shows incurved end. D) Enlarged vascular bundle. Arrow head indicates xylem fibres, arrow shows Perivascular phloem fibres. (All from *unknown collector* s.n., BM).

#### G. hainanensis Oliv.

**OUTLINE:** rectangular with two lateral wings; adaxial grooved, prominently ridged, abaxially distinctly ridged. *Cross sectional area*: 737,611µm<sup>2</sup>. **EPIDERMIS:** one cell layer, cell isodiametric to anisodiametric with cork cells; cell walls thin. *Trichomes*: eglandular trichomes sparsely present. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; many small discrete, bi-collateral bundles form dissected crescent, arranged at the periphery up to the lateral wing; closer adaxially, additional vascular bundles absent; two traces of medullary vascular bundles hanging towards the pith from each end of the main vascular bundle. *Xylem fibres*: present. *Main vascular bundle area*: 241,474µm<sup>2</sup>; *two medullary vascular bundles area*: 12,903µm<sup>2</sup> and 12,128µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional area*: 36.13%. *Perivascular phloem fibres*: abundant, sclerenchymatous; distributed in discrete bundles over the main vascular bundles. **CORTEX**: subepidermal cell consisting two to three layers of cork cells; parenchyma cells larger than the collenchymas, cells polygonal, and walls sinuous. **PITH**: pith area large; parenchymatous; cells rectangular to polygonal, cell walls sinuous; two traces of medullary vascular bundles hanging in pith region. **CRYSTAL**: absent.

### G. lepidota Scheff.

#### (Figure 3.10.27, Indonesia)

**OUTLINE:** rectangular, coarsely ridged, adaxially flattened to slightly grooved; abaxially flattened to slightly depressed; lateral wings absent. *Cross sectional area*: 744,808µm<sup>2</sup>. **EPIDERMIS:** one layer with cork cells, surface with wavy striations, cells isodiametric to anisodiametric, cutinized, cuticle rather thin. *Trichomes:* sparse over the petiole. **VASCULATURE:** main vascular bundle U-shaped prominently incurved ends, open adaxially; amphicribal or hadrocentric; three bi-collateral bundles forming dissected median dissected crescent with invaginated ends; relatively close to the adaxial side; adaxially two additional vascular bundles present close to the main vascular bundle*Main vascular bundle area*: 89,100µm<sup>2</sup>; *two additional vascular bundles area*: 3,738µm<sup>2</sup>, and 3,770µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 12.97%. *Perivascular phloem fibres*: absent from the main vascular bundle, perivascular phloem fibres rarely present along the additional vascular bundle. **CORTEX**: subepidermal collenchyma cells angular with three layers of cork cells; parenchyma cells polygonal, cell walls sinuous. **PITH**: pith area very narrow, consisting five to six layers of large, angular parenchymatous cells, cell walls sinuous with intercellular space. **CRYSTAL**: absent.

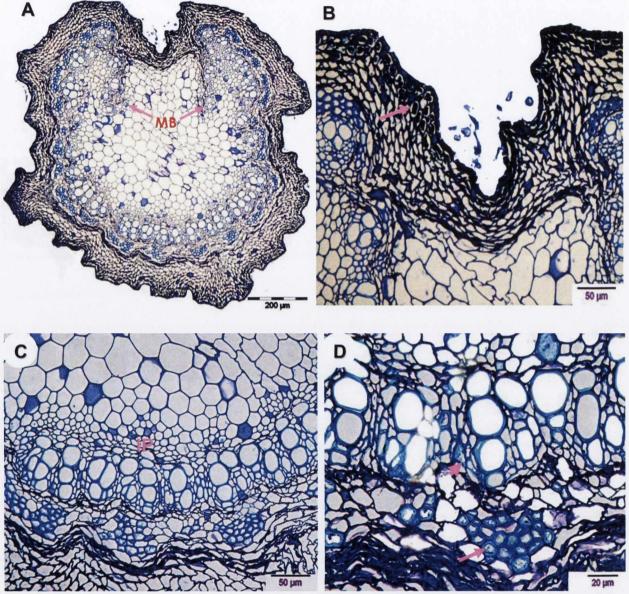


Figure 3.10.26. Petiole transverse section of *G. hainanensis* (China). A) Outline. Medullary bundles (MB) are arrowed. B) Enlarged adaxial side. Arrow shows cork cells. C) Main vascular bundle enlarged. IP= inner phloem. D) Enlarged vascular bundle. Arrow indicates perivascular phloem fibres; arrow head shows xylem fibres. (All from *Henry* s. n., K).

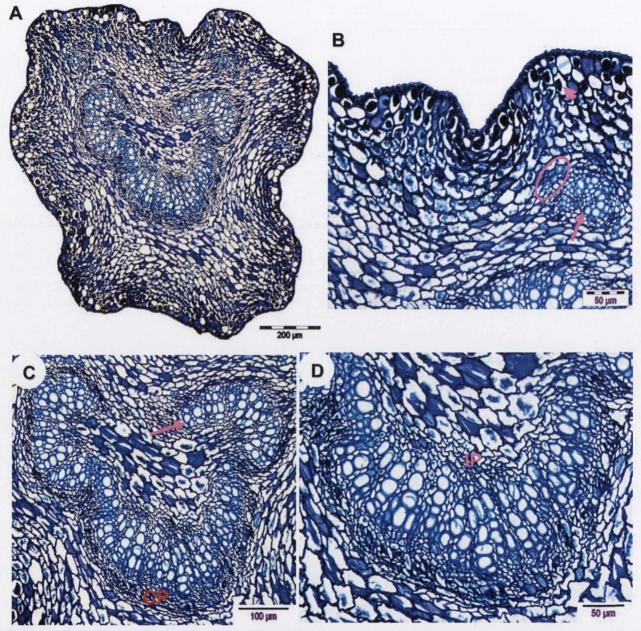


Figure 3.10.27. Petiole transverse section of *G. lepidota* (Indonesia). A) Outline. B) Enlarged adaxial side. Arrow head shows cork cells; arrow indicates additional vascular bundle; scattered perivascular phloem fibres circled. C-D) Main vascular bundle enlarged. Arrow shows incurved ends. IP= inner phloem; CP= crushed phloem. Note absence of xylem fibres and perivascular fibres. (All from Vogel 4338, L).

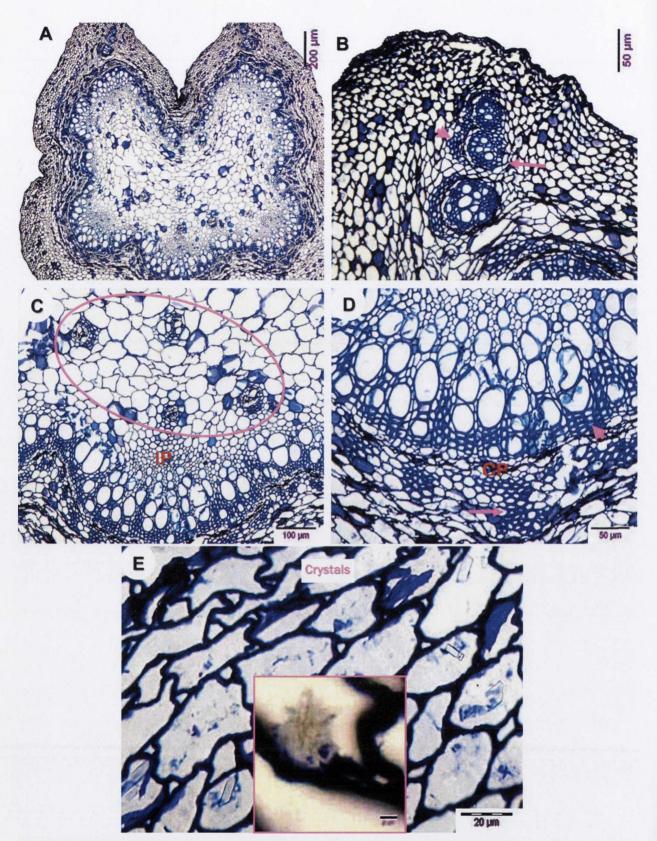
## G. moluccana (Bl.) Backer ex Heyne

**OUTLINE:** obovate with two very prominent lateral wings; adaxially deeply grooved, abaxially convex. *Cross sectional area: ca.* 2,582,500µm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric, some cells slightly domed; periclinal cell walls thin cutinized. *Trichomes:* glandular multicellular trichomes sparse. **VASCULATURE:** main vascular bundle O-shaped, closed; amphicribal or hadrocentric; single bi-collateral continuous strand form a lobed cylinder, arranged at the periphery; phloem rather crushed; relatively close to the adaxial side; four additional vascular bundles present in lateral wings; in two in each wing. Nine discrete medullary vascular bundles scattered in the pith region. *Xylem fibres:* present. *Main vascular bundle area:* 951,180µm<sup>2</sup>; *four additional vascular bundles area:* 5,108µm<sup>2</sup>, 5,526µm<sup>2</sup>, 3,375µm<sup>2</sup>, and 7,812µm<sup>2</sup>; *nine medullary vascular bundles area:* 1,420µm<sup>2</sup>, 1,516µm<sup>2</sup>, 4,477µm<sup>2</sup>, 2,419µm<sup>2</sup>, 932µm<sup>2</sup>, 3,573µm<sup>2</sup>, 3,909µm<sup>2</sup>, 3,871µm<sup>2</sup>, and 2,422µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 38.62%. *Perivascular phloem fibres:* abundant, sclerenchymatous; distributed in discrete bundles alongside the main and the additional vascular bundles. **CORTEX:** collenchymatous cells circular to globular with thick cell walls; parenchymatous cells polygonal with sinuous cell walls. **PITH:** pith area large; parenchymatous, cells polygonal, cell walls sinuous with intercellular space; few medullary vascular bundles scattered in pith. **CRYSTAL:** acicular, druse-like and rhombic crystals are abundant in cortex.

### G. obovata M. H. Rashid

(Figure 3.10. 29, Malaysia)

**OUTLINE:** oval with two prominent lateral wings; distinctly ridged, adaxially deeply grooved, abaxially concave to convex. *Cross sectional area*: 912,001µm<sup>2</sup>. **EPIDERMIS:** one cell layer with cork cells, anisodiametric, cell walls thick, cutinized. *Trichomes*: dense adaxially, sparse throughout. **VASCULATURE:** main vascular bundle U-shaped with very much incurved ends, open adaxially; amphicribal or hadrocentric; five bi-collateral discontinuous traces form a crescentic arc with invaginated ends, two adaxial traces much longer; phloem rather crushed; closer abaxially; two rather small additional vascular bundles present in lateral wings. *Xylem fibres*: absent. *Main vascular bundle area*: 169,606µm<sup>2</sup>; *two additional vascular bundles area*: 5,102µm<sup>2</sup>, and 3,615µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 19.55%. *Perivascular phloem fibres*: absent. **CORTEX**: subepidermal collenchyma cells angular to polygonal, thick walled; cell walls sinuous. **PITH:** pith area narrow; parenchymatous, cells globular to polygonal, cell walls sinuous; central cells much larger, peripheral cells smaller and angular. **CRYSTAL**: absent.



**Figure 3.10.28**. Petiole transverse section of *G. moluccana* (Indonesia). A) Outline. B) Enlarged adaxial side. Arrow indicates additional vascular bundles; arrow head show perivascular phloem fibres. C) Enlarged hadrocentric main vascular bundle. Medullary vascular bundles circled; IP= inner phloem. D) Enlarged vascular bundle. Arrow head indicates xylem fibres; arrow shows perivascular phloem fibres; CP= crushed phloem. E) Crystals in cortex; Inset- Druses. (All from *Boschaproefstan* bb. 13439, L).

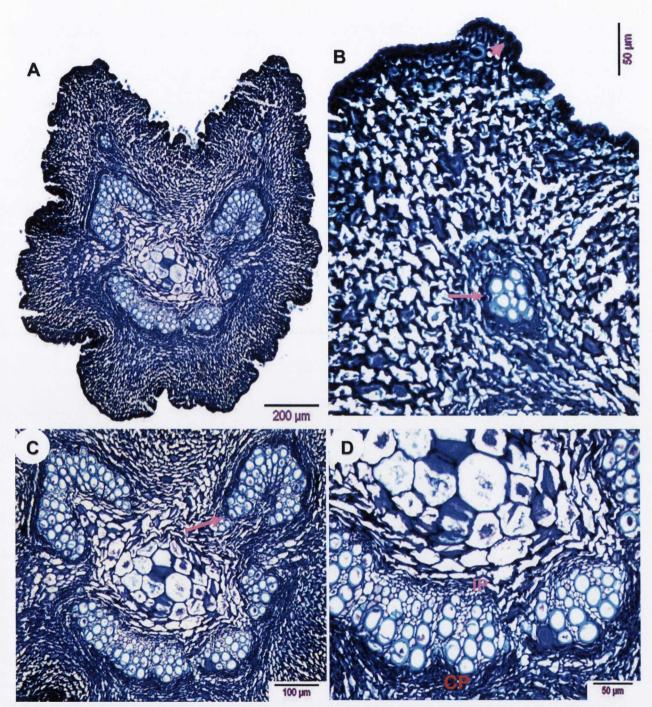


Figure 3.10.29. Petiole transverse section of *G. obovata* (Malaysia). A) Outline. B) Adaxial side enlarged. Arrow indicates additional vascular bundle; arrow head shows cork cells in epidermis. C) Hadrocentric main vascular bundle enlarged. Arrow shows very much incurved end. D) Enlarged vascular bundle. CP= crushed phloem; IP= inner phloem (crushed). *Note absence of xylem fibres and perivascular phloem fibres.* (All from *Sinclair* 9263, L).

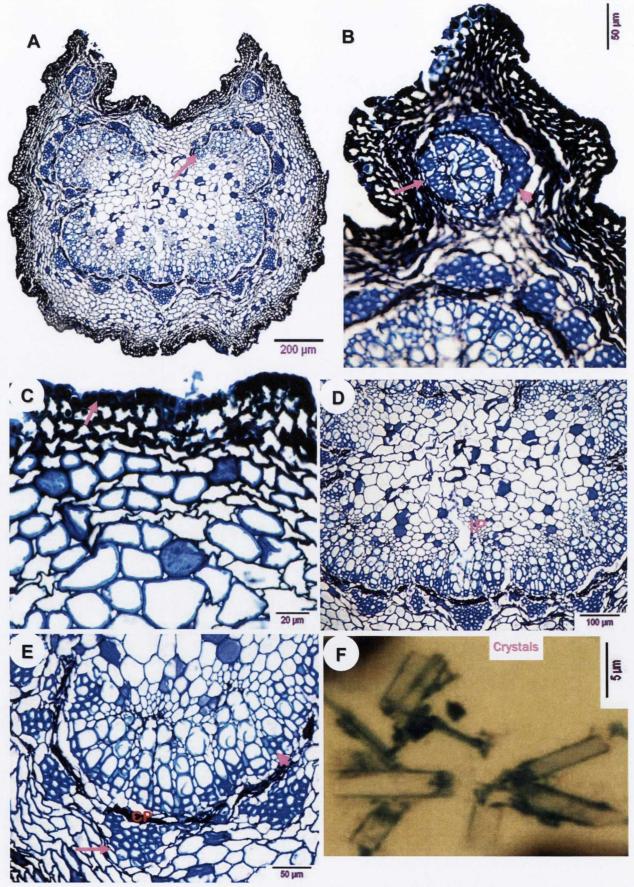
#### G. obovata var. kutaiensis M. H. Rashid

**OUTLINE:** oval with two long prominent lateral wings; ridged, adaxially deeply grooved, abaxially almost flat, undulate. *Cross sectional area*: 1,158,196µm<sup>2</sup>. **EPIDERMIS:** one cell layer with cork cells, anisodiametric, cell walls thick, cutinized. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; three bi-collateral traces form a distinctly three-lobed median crescentic arc with invaginated ends, central trace much longer, both apical traces reniform; phloem rather crushed; closer abaxially; two small additional vascular bundles present in lateral wings. *Xylem fibres*: absent. *Main vascular bundle area*: 403,104µm<sup>2</sup>; *two additional vascular bundles area*: 13,788µm<sup>2</sup>, and 9,531µm<sup>2</sup>. *Vascular bundles area* proportion to the cross sectional area: 36.82%. Perivascular phloem fibres: mass of sclrenchymatous fibres frequently distributed in discrete bundles alongside the main vascular bundle, and almost covering the additional vascular bundles. **CORTEX:** subepidermal collenchyma cells angular to polygonal, cell walls sinuous. **CRYSTAL:** rod-shaped crystals present in pith.

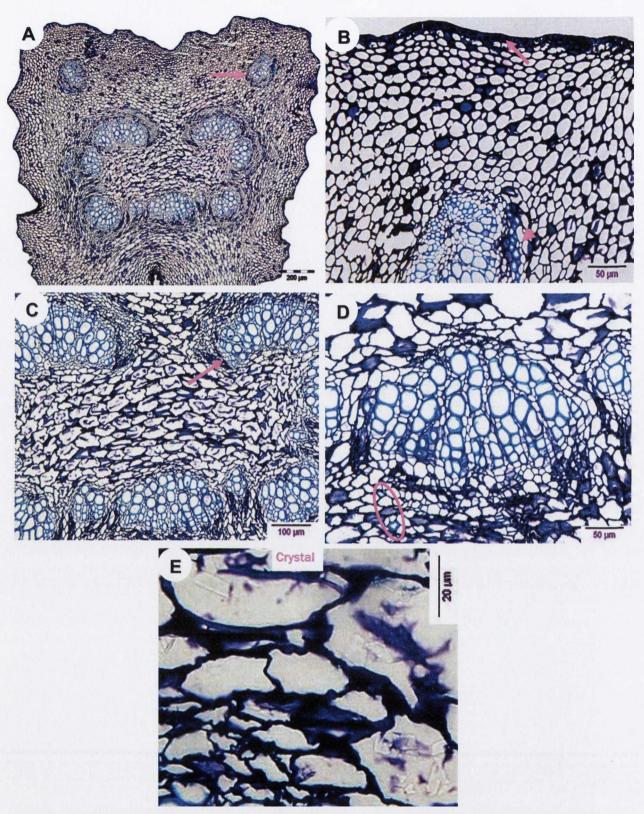
#### G. palawensis Lam

### (Figure 3.10.31, Indonesia)

**OUTLINE:** rectangular with two obscure lateral wings; distinctly ridged throughout, adaxially flattened to slightly grooved, undulate; abaxially deeply grooved. *Cross sectional area:* ca. 2,325,035µm<sup>2</sup>. **EPIDERMIS:** one cell layer with cork cells, surface smooth, cells anisodiametric; periclinal cells thinly cutinized. **VASCULATURE:** main vascular bundle open adaxially, 9 to 12 discrete collateral bundles form a median crescentic arc with invaginated ends; equidistant from both sides; two additional vascular bundles present in two obscure wings. *Xylem fibres:* absent. *Main vascular bundle area:* 297,582µm<sup>2</sup>; *two additional vascular bundles area:* 15,160µm<sup>2</sup>, and 13,290µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 14.02%. *Perivascular phloem fibres:* very few sclerenchymatous fibres rarely scattered alongside the main and the additional vascular bundles. **CORTEX:** subepidermal collenchyma cells small, globular; parenchyma cells polygonal, gradually becoming larger towards the pith, cell walls sinuous. **PITH:** pith area narrow; parenchymatous, cells polygonal, cell walls sinuous. **CRYSTAL:** rhombic crystals present in pith and cortex.



**Figure 3.10.30**. Petiole transverse section of *G. obovata* var. *kutaiensis* (Indonesia). A) Outline. Arrow shows prominently incurved end. B) Adaxial side enlarged. Arrow indicates additional vascular bundle; arrow head shows perivascular phloem fibres. C) Arrow indicates epidermis containing cork cells. D) Hadrocentric main vascular bundle enlarged. IP= inner phloem. E) Enlarged vascular bundle. Arrow shows perivascular phloem fibres; CP= crushed phloem. *Note absence of xylem fibres*. F) Crystals in pith. (All from *Kostermann* 10.521, L).



**Figure 3.10.31**. Petiole transverse section of *G. palawensis* (Indonesia). A) Outline; additional vascular bundle is arrowed. B) Enlarged adaxial side. Arrow indicates epidermis with cork cells. Arrow head shows perivascular phloem fibres along the additional vascular bundle. C) Main vascular bundle enlarged. Arrow indicates incurved end. D) Enlarged vascular bundle. Perivascular phloem fibres are circled. *Note absence of xylem fibres*. E) Showing crystals in pith. (All from *Boschaproefstan* bb. 23574, A).

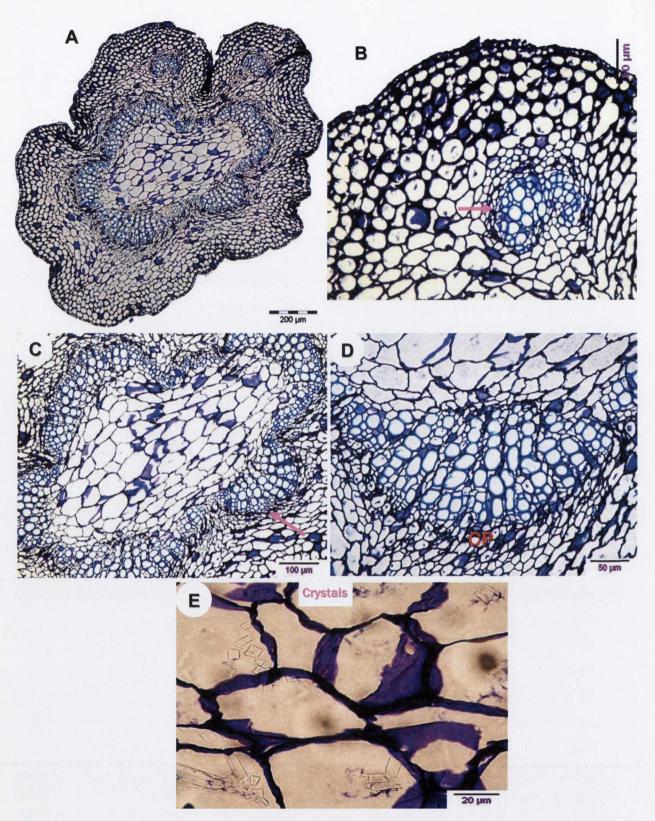
#### G. paniculata Fletcher

**OUTLINE:** oval with two prominent lateral wings, coarsely ridged, adaxially deeply grooved, abaxially convex. *Cross sectional area:* 1,160,868μm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface smooth, cells anisodiametric; periclinal cells thin, cutinized, cell walls thick. *Trichomes*: sparsely distributed over the petiole. **VASCULATURE:** main vascular bundles O-shaped, obscurely open adaxially; six to eight discrete, collateral bundles forming a median dissected, lobed-cylinder; equidistant from the both sides; phloem rather squashed; two reniform additional vascular bundles present in lateral wings. *Xylem fibres*: absent. *Main vascular bundles area*: 170,425μm<sup>2</sup>; *two additional vascular bundles area*: 8,066μm<sup>2</sup>, and 7,275μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 16.00%. *Perivascular phloem fibres*: absent. **CORTEX:** subepidermal collenchyma cells circular to globose with thick cell walls; parenchyma cells polygonal, larger, cell walls sinuous. **PITH:** pith area small; parenchymatous, cells polygognal, cell walls sinuous. **CRYSTAL:** acicular, and rhombic crystals most abundant in the pith.

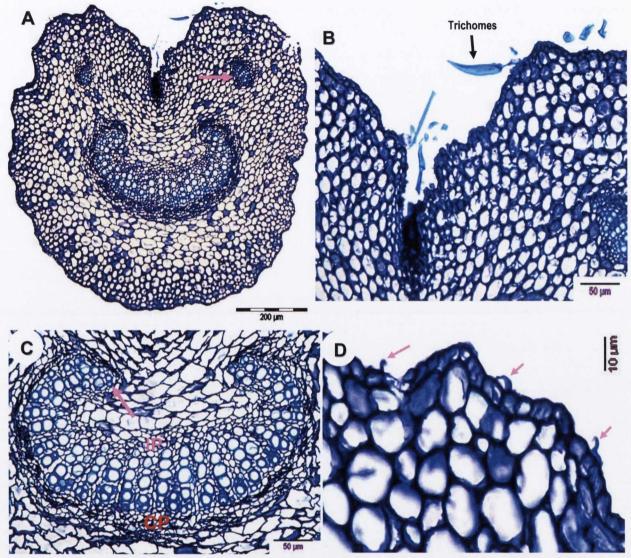
### G. philippensis Cham.

### (Figure 3.10.33, Philippines)

**OUTLINE:** semicircular with two prominent lateral wings; undulate, adaxially deeply grooved, abaxially convex. *Cross sectional area:* 500,940µm<sup>2</sup>. **EPIDERMIS:** one cell layer, somewhat papillate; cells anisodiametric; periclinal cell walls thick. *Trichomes:* eglandular trichomes present adaxially, few scattered hooked trichomes. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median crescentic arc with moderately incurved ends, almost equidistant, slightly closer abaxially; phloem rather squashed; two small additional vascular bundles present in the middle of lateral wings. *Xylem fibres:* absent. *Main vascular bundle area:* 51,053µm<sup>2</sup>; *two additional vascular bundles area:* 1,520µm<sup>2</sup>, and 2,156µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 10.92%. *Perivascular phloem fibres:* absent. **CORTEX:** subepidermal collenchyma cells circular to globose with thick cell walls; parenchyma cells polygonal, gradually becoming larger towards the pith, cell walls sinuous. **PITH:** pith area very narrow, consisting only four to five layers of parenchyma cells; cells angular, walls sinuous. **CRYSTAL:** absent.



**Figure 3.10.32**. Petiole transverse section of *G. paniculata* (Thailand). A) Outline. B) Enlarged adaxial side. Arrow indicates additional vascular bundle. C) Main vascular bundle enlarged. Arrow shows lobed vascular bundle. D) Enlarged vascular bundle. CP= crushed phloem. *Note absence of xylem fibres and perivascular phloem fibres*. E) Showing crystals in pith. (All from *Put* 2806, E).



**Figure 3.10.33**. Petiole transverse section of *G. philippensis* (Philippines). A) Outline. Arrow shows additional vascular bundle. B) Enlarged adaxial side. Trichomes arrowed. C) Hadrocentric main vascular bundle enlarged. Arrow indicates incurved end. IP= inner phloem; CP= crushed phloem. *Note absence of xylem fibres and perivascular phloem fibres*. D) Enlarged epidermis showing hooked trichomes (arrowed). (All from *Fenix* BOS 30092, A).

#### G. philippensis Cham.

**OUTLINE:** semicircular with two prominent lateral wings; adaxially deeply grooved, abaxially convex, somewhat undulate. *Cross sectional area*: 671,062µm<sup>2</sup>. **EPIDERMIS:** one cell layer, cells ± isodiametric with cork cells, periclinal cell walls thick. *Trichomes*: eglandular trichomes sparse. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand forms a median crescentic arc with prominently one inward and other upward end; phloem rather squashed; almost equidistant but slightly closer abaxially; two small additional vascular bundles present almost below the lateral wings. *Xylem fibres*: absent. *Main vascular bundle area*: 57,020µm<sup>2</sup>; *two additional vascular bundles area*: 2,380µm<sup>2</sup>, and 2,141µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 9.17%. *Perivascular phloem fibres*: absent. **CORTEX:** subepidermal collenchyma cells circular to globose with thick cell walls; parenchyma cells polygonal, gradually becoming larger towards the pith, cell walls sinuous. **PITH:** pith area small, consists of angular to polygonal parenchyma cells; cell walls sinuous. **CRYSTAL:** absent.

### G. racemosa (Lour.) Merr.

## (Figure 3.10.35, Vietnam)

OUTLINE: globose with two obscure lateral wings; undulate, adaxially concave, abaxially convex. Cross sectional area: 1,518,020 µm<sup>2</sup>. EPIDERMIS: one cell layer; surface with wavy striations, cell small, domed, anisodiametric, cell much enlarged and raised at the base of trichomes, cell walls thick. Trichomes: both glandular, and eglandular trichomes dense throughout. VASCULATURE: main vascular bundle U-shaped with obscurely incurved ends, open adaxially; amphicribal or hadrocentric; 10 discrete, bi-collateral bundles form a dissected crescent with obscurely incurved ends, peripheral; abaxially closer; adaxially two rather large additional vascular bundles located very close to the top of the main vascular bundle; phloem rather crushed; four small medullary vascular bundles scattered in pith, two close to two additional vascular bundles and two near the tip of two main vascular bundle ends. Main vascular bundle area: 370,029µm<sup>2</sup>; two additional vascular bundles area: 18,579µm<sup>2</sup>, and 12,760µm<sup>2</sup>; four medullary vascular bundles area: 615µm<sup>2</sup>, 1,647µm<sup>2</sup>  $2,490 \mu$ m<sup>2</sup>, and  $4,589 \mu$ m<sup>2</sup>. Xylem fibres: present. Vascular bundles area proportion to the cross sectional area: 27.05%. Perivascular phloem fibres: abundant, sclerenchymatous; distributed in discrete bundles alongside the main and the additional vascular bundles. **CORTEX:** outer collenchyma cells oval to angular, thick walled, inner parenchyma cells larger, polygonal, cell walls sinuous. PITH: pith area large; parenchymatous, cells globular to polygonal, cell walls straight with intercellular spaces; few medullary vascular bundles scattered in pith. CRYSTAL: absent.

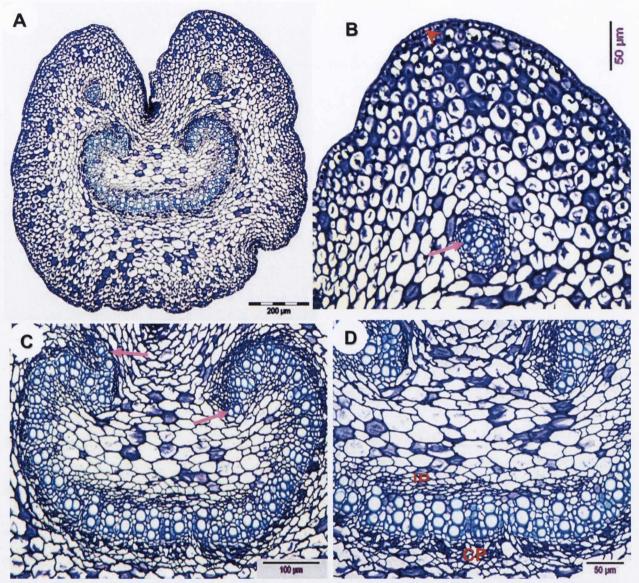
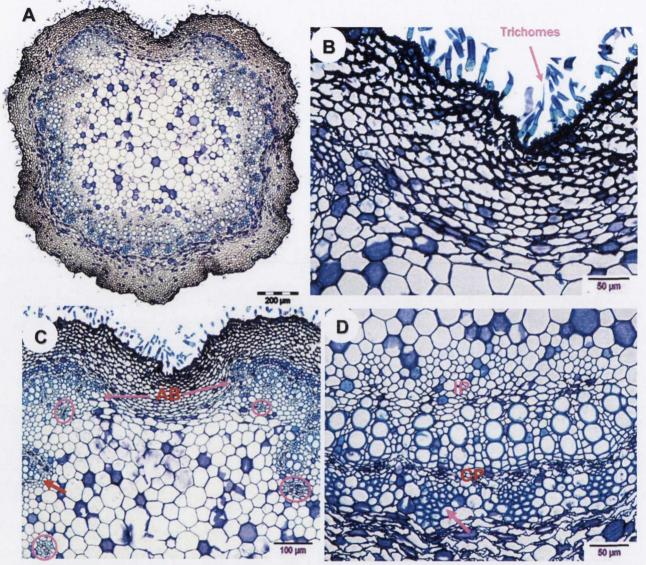


Figure 3.10.34. Petiole transverse section of *G. philippensis* (Cambodia). A) Outline. B) Enlarged adaxial side. Arrow head shows cork cells; arrow indicates additional vascular bundle. C) Main vascular bundle enlarged. Upper arrow shows upward end; lower arrow indicates incurved end. D) Enlarged hadrocentric vascular bundle. IP= inner phloem; CP= crushed phloem. *Note absence of xylem fibres and perivascular phloem fibres.* (All from *Meng et al.* 452, K).



**Figure 3.10.35**. Petiole transverse section of *G. racemosa* (Vietnam). A) Outline. B) Adaxial groove enlarged. Trichomes rrowed. C) Enlarged adaxial side. Two long additional vascular bundles (AB) are arrowed; short arrow shows one incurved end of main vascular bundle; medullary bundles circled. D) Main vascular bundle enlarged. Arrow indicates perivascular phloem fibres; arrow head shows xylem fibres; IP= inner phloem; CP= crushed phloem. (All from *Clemens* 3980, A).

## G. racemosa (Lour.) Merr.

**OUTLINE:** globose to obovate with three prominent ridges; adaxially almost flattened with slight depression, abaxially convex, undulate; lateral wings very obscure to absent. *Cross sectional area: ca.*1,001,945µm<sup>2</sup>. **EPIDERMIS:** one cell layer with cork cells, thick cutinized; surface with wavy striations, cells small, anisodiametric, much enlarged and raised at the base of trichomes, cell walls thick. *Trichomes:* both glandular, and eglandular trichomes densely distributed over the petiole. **VASCULATURE:** main vascular bundle U-shaped; open adaxially, amphicribal or hadrocentric; eight discrete, bi-collateral bundles form dissected crescentic arc with incurved ends, peripheral, central bundle much longer; adaxially closer; adaxially two additional vascular bundles located very close to the main vascular bundle. *Medullary bundles:* two small medullary bundles observed in pith. *Xylem fibres:* present. *Main vascular bundle area:* 440,220µm<sup>2</sup>; *two additional vascular bundles area:* 11,210µm<sup>2</sup>, and 10,890µm<sup>2</sup>. *Xylem fibres:* present. *Vascular bundles area proportion to the cross sectional* area: 46.14%. *Perivascular phloem fibres:* sclerenchymatous; perivascular phloem fibres distributed in discrete bundles alongside the main and the lateral vascular bundles. **CORTEX:** subepidermal cell consisting two to three layers of cork cells, cells globular to angular, thick walled, parenchyma cells polygonal, large, cell walls sinuous. **PITH:** pith area large, parenchymatous; cell walls straight with inter cellular spaces. **CRYSTAL:** absent.

#### G. schlechteri Lam

#### (Figure 3.10.37, Indonesia)

**OUTLINE:** transversely oval with two very prominent, long lateral wings; undulate, adaxially deeply grooved; abaxially convex. *Cross sectional area: ca.* 2,000,012µm<sup>2</sup>. **EPIDERMIS:** one cell layer; surface with wavy striations, cell small, anisodiametric, angular, outer periclinal cell walls thick. *Trichomes:* absent. **VASCULATURE:** main vascular bundle O-shaped and many lobed, closed; amphicribal or hadrocentric, single bi-collateral strand form a conspicuously five-lobed median cylinder; relatively close to the abaxial side; four additional vascular bundles present; two in each of the lateral wing, located at the tips of the main vascular cylinder; phloem rather crushed. *Xylem fibres:* present. *Main vascular bundle area:* 755,820µm<sup>2</sup>; *four additional vascular bundles area:* 6,775µm<sup>2</sup>, 8,180µm<sup>2</sup>, 3,199µm<sup>2</sup>, and 13,336µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 39.36%. *Perivascular phloem fibres:* sclerenchymatous; mass of fibres distributed in discrete bundles alongside the main and the additional vascular bundles, abundant abaxially. **CORTEX:** subepidermal collenchyma cells globular, thick walled; parenchyma cells polygonal, large, cell walls sinuous. **PITH:** pith area very narrow; parenchymatous, cells polygonal, cell walls sinuous with intercellular spaces. **CRYSTAL:** absent.

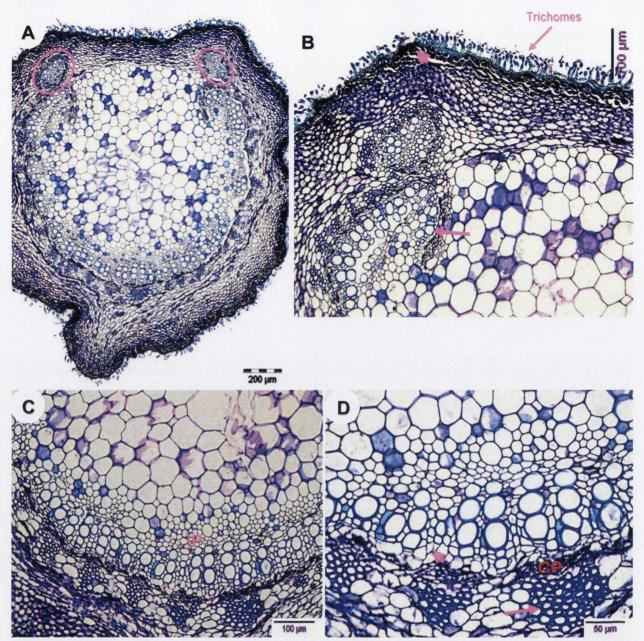


Figure 3.10.36. Petiole transverse section of *G. racemosa* (Thailand). A) Outline. Two small additional vascular bundles circled. B) Adaxial side enlarged. Trichomes arrowed; arrow head indicates cork cells; lower arrow shows incurved main vascular bundle end. C) Hadrocentric main vascular bundle enlarged. IP= inner phloem. D) Enlarged vascular bundle. Arrow head indicates xylem fibres; arrow shows perivascular phloem fibres; CP= crushed phloem. (All from *Pooma et al.* 2805, BKF).

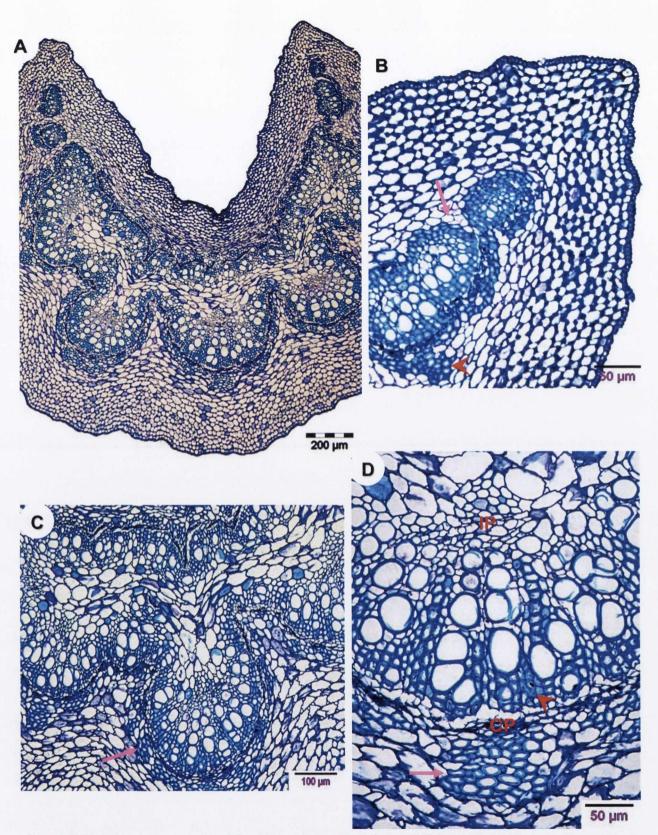


Figure 3.10.37. Petiole transverse section of *G. schlechteri* (Indonesia). A) Outline. B) Enlarged adaxial side. Arrow shows additional vascular bundles; arrow head indicates perivascular phloem fibres. C) Arrow indicates lobed main vascular bundle. D) Hadrocentric vascular bundle enlarged. Arrow head indicates xylem fibres; arrow shows perivascular phloem fibres; IP= inner phloem; CP= crushed phloem. (All from *unknown collector* bb 25474, L).

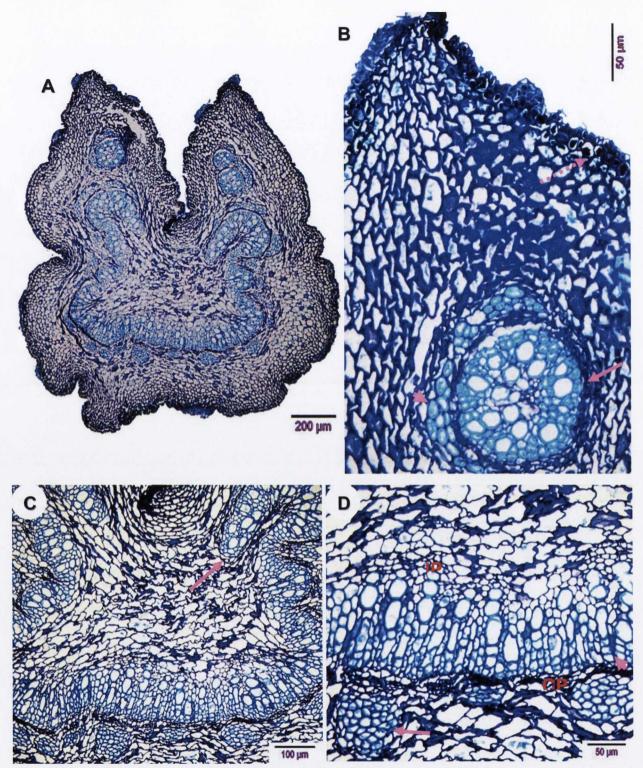
#### G. spectabilis Ridl. ex M. H. Rashid & A. J. Paton

**OUTLINE:** rectangular with two very long, prominent lateral wings; distinctly ridged, adaxially deeply grooved, abaxially concave. *Cross sectional area:* 1,384,477 µm<sup>2</sup>. **EPIDERMIS:** one layer with cork cells, surface with wavy striations, cells anisodiametric, elongated, cutinized, cuticle rather thick. *Trichomes:* sparse over the petiole. **VASCULATURE:** main vascular bundle U-shaped, large, convoluted; amphicribal or hadrocentric, open adaxially; three to four bi-collateral strands form a large, wide, distinctly lobed median vasculature with prominent invaginated ends, central strand crescentic, much longer, two adaxial strands very much incurved; phloem rather crushed; closer abaxially; three additional vascular bundles occur in the lateral wings; one in one wing and two in other. *Xylem fibres:* present. *Main vascular bundle area:* 352,947µm<sup>2</sup>; *three additional vascular bundles area:* 21,088µm<sup>2</sup>, 8,528µm<sup>2</sup>, and 15,253µm<sup>2</sup>. *Xylem fibres:* present. *Vascular bundles area proportion to the cross sectional* area: 28.73%. *Perivascular phloem fibres:* mass of sclrenchymatous perivascular phloem fibres scattered in discrete bundles alongside the main and additional vascular bundles. **CORTEX:** subepidermal cell containing cork cells; collenchyma cells angular, thick walled; parenchyma cells larger and polygonal, cell walls sinuous. **PITH:** pith area broad with angular parenchymatous cells; cell walls sinuous. **CRYSTAL:** absent.

## G. tomentosa Fletcher

#### (Figure 3.10.39, Thailand)

**OUTLINE:** ± circular to globose with two lateral wings; prominently ridged, adaxially conspicuously grooved, abaxially convex to concave, undulate. *Cross sectional area*: 167,305μm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric, angular; periclinal walls thick, anticlinal walls sinuous. *Trichomes*: both glandular and eglandular trichomes densely distributed over the petiole. **VASCULATURE:** main vascular bundle U-shaped, open adaxially; amphicribal or hadrocentric; single bi-collateral strand form a median crescentic arc, equidistant from both sides; two additional vascular bundles present in lateral wings. *Xylem fibres*: absent. *Main vascular bundle area*: 26,936μm<sup>2</sup>; *two additional vascular bundles area*: 1,103μm<sup>2</sup>, and 1,186μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 17.47%. *Perivascular phloem fibres*: absent. **CORTEX**: both collenchyma and parenchyma cells angular to polygonal with sinuous cell walls; collenchymas with thick wall. **PITH:** pith area narrow; parenchymatous; cells angular or polygonal, walls sinuous with intercellular spaces. **CRYSTAL:** absent.



**Figure 3.10.38**. Petiole transverse section of *G. spectabilis* (Indonesia). A) Outline. B) Adaxial side enlarged. Upper dashed arrow shows epidermis containing cork cells; lower arrow indicates additional vascular bundle; arrow head shows perivascular phloem fibres. C) Main vascular bundle enlarged. Arrow indicates very much incurved end. D) Enlarged vascular bundle. Arrow head indicates xylem fibres; arrow shows perivascular phloem fibres; IP= inner phloem; CP= crushed phloem. (All from *Haviland & Hose* 919, K).

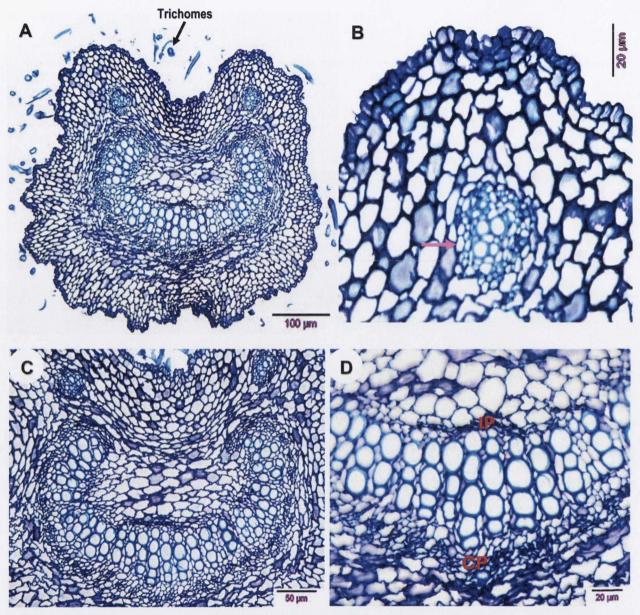


Figure 3.10.39. Petiole transverse section of *G. tomentosa* (Thailand). A) Outline. Trichomes are arrowed. B) Adaxial side enlarged. Arrow shows additional vascular bundle. C) Hadrocentric main vascular bundle enlarged. D) Enlarged vascular bundle. IP= inner phloem; CP= crushed phloem. *Note absence of xylem fibres and perivascular phloem fibres*. (All from *Noe* 211, E).

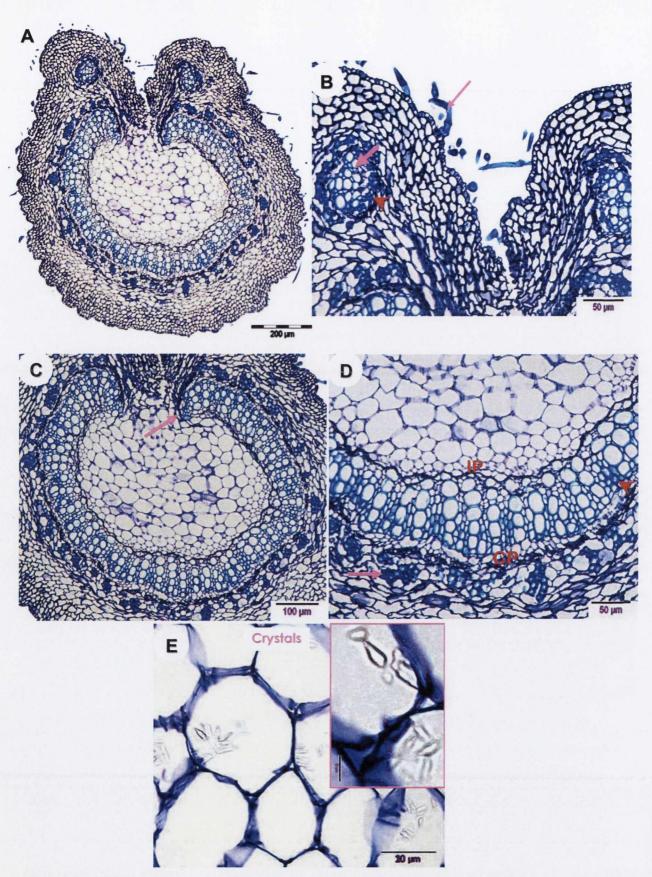
## G. tonkinensis Moldenke

**OUTLINE**: oval with two lateral wings; undulate, adaxially deeply grooved, abaxially convex. *Cross sectional area*: 612,140µm<sup>2</sup>. **EPIDERMIS**: one cell layer, surface with wavy striations, cells anisodiametric, angular; periclinal walls thick, anticlinal walls sinuous. *Trichomes*: trichomes dense adaxially, sparse throughout. **VASCULATURE**: main vascular bundle U-shaped, narrowly open adaxially; amphicribal or hadrocentric; single bi-collateral strand form a median cresentic arc, ends moderately incurved, closer to the abaxial side; two additional vascular bundles present in lateral wings. *Xylem fibres*: present. *Main vascular bundle area*: 115,204µm<sup>2</sup>; *two additional vascular bundles area*: 1,894µm<sup>2</sup>, and 1,907µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 19.44%. *Perivascular phloem fibres*: abundant, sclerenchymatous; distributed in discrete bundles alongside the main vascular bundle and covering the additional vascular bundles. **CORTEX**: subepidermal collenchyma cells globular, cell walls thick, paprenchyma cells larger, polygonal with sinuous cell walls. **PITH**: pith area broad; parenchymatous; cells angular with intercellular spaces, cell walls not sinuous. **CRYSTAL**: elliptic and rhombic crystals are observed in pith.

## G. tubularis M. H. Rashid & A. J. Paton

(Figure 3.10.41, Malaysia)

**OUTLINE**: rectangular with two long prominent lateral wings; ridged, adaxially deeply grooved, abaxially convex to undulate. *Cross sectional area*: 899,233µm<sup>2</sup>. **EPIDERMIS**: one cell layer, cells small, anisodiametric, cell walls thick, cutinized. **VASCULATURE**: main vascular bundle U-shaped with very much incurved ends, open adaxially; amphicribal or hadrocentric; long, four to five bi-collateral traces forming a wide, sinuate, dissected crescentic arc with invaginated ends, central trace much longer; phloem rather crushed; relatively closer abaxially; two additional vascular bundles located in the middle of the lateral wings. *Xylem fibres*: present. *Main vascular bundle area*: 217,346µm<sup>2</sup>; *two additional vascular bundles area*: 9,686µm<sup>2</sup>, and 9,756µm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 26.33%. *Perivascular phloem fibres*: sclerenchymatous; distributed in discrete bundles alongside the main and the additional vascular bundle. **CORTEX**: subepidermal collenchyma cells globular to angular, cork cells scattered; collenchymas thick walled; parenchyma cells polygonal, cell walls sinuous. **PITH**: pith area moderately broad; parenchymatous, cells polygonal, cell walls sinuous. **CRYSTAL**: absent.



**Figure 3.10.40**. Petiole transverse section of *G. tonkinensis* (Vietnam). A) Outline. B) Adaxial side enlarged. Upper arrow indicates trichomes; lower short arrow shows additional vascular bundle; arrow head shows perivascular phloem fibres. C) Enlarged hadrocentric main vascular bundle. Arrow shows incurved end. D) Vascular bundle enlarged. Arrow head indicates xylem fibres; arrow shows perivascular phloem fibres; CP = crushed phloem; IP= inner phloem. E) Crystals in pith. (All from *Balansa* 3807, E).

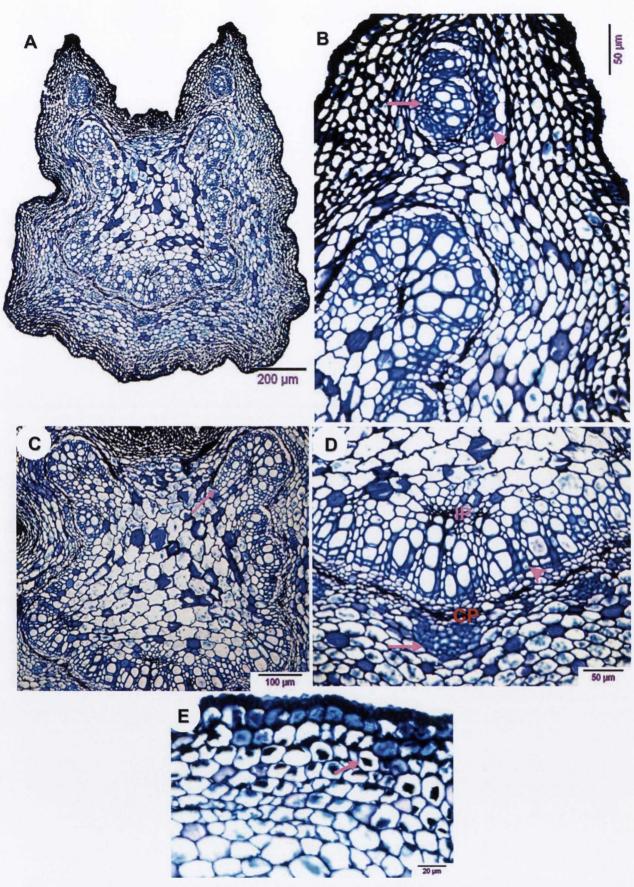


Figure 3.10.41. Petiole transverse section of *G. tubularis* (Malaysia). A) Outline. B) Adaxial side enlarged. Arrow indicates additional vascular bundle; arrow head shows perivascular phloem fibres. C) Hadrocentric main vascular bundle enlarged. Arrow shows very much incurved end. D) Enlarged vascular bundle. Arrow head indicates xylem fibres; arrow shows perivascular phloem fibres; CP= crushed phloem; IP= inner phloem. E) Abaxial side enlarged. Cork cells at cortex is arrowed. (All from *Ching* S. 62317, K).

# G. uniflora Stapf.

**OUTLINE:** ± circular to globose with two long prominent lateral wings; slightly undulate, adaxially deeply grooved, abaxially convex. *Cross sectional area: ca.* 2,110,293μm<sup>2</sup>. **EPIDERMIS: one** cell layer, cells small, anisodiametric, anticlinal cell walls thick. **VASCULATURE:** main vascular bundle U-shaped with incurved ends, open adaxially; amphicribal or hadrocentric; three bi-collateral traces form a distinctly three-lobed median dissected crescentic arc with invaginated ends, central trace much longer, both adaxial traces reniform; parenchymatic ray evenly distributed in the main vascular bundle; phloem rather crushed; slightly closer abaxially; two rather small additional vascular bundles located in lateral wings. *Xylem fibres*: present. *Main vascular bundle area:* 584,837μm<sup>2</sup>; *two additional vascular bundles area:* 9,175μm<sup>2</sup>, and 8,938μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 28.57%. *Perivascular phloem fibres:* Sclerenchymatous; perivascular phloem fibres sparsely distributed in discrete bundles alongside the main vascular bundle, almost covering the additional vascular bundles. **CORTEX:** two layers of subepidermal collenchyma cells contain cork cells; collenchymas ± rectangular to angular; parenchyma cells large, angular to polygonal. **PITH:** pith area broad; parenchymatous, cells polygonal, walls sinuous. **CRYSTAL:** solitary hourglass-shaped crystals observed in pith.



**Figure 3.10.42**. Petiole transverse section of *G. uniflora* (Indonesia). A) Outline; additional vascular bundle is arrowed. B) Adaxial side enlarged. Arrow indicates cork cells; arrow head shows perivascular phloem fibres along the additional vascular bundle. C) Hadrocentric main vascular bundle enlarged. Arrows show prominently incurved end of main vascular bundle; IP= inner phloem. D) Enlarged vascular bundle. Arrow head indicates xylem fibres; arrow shows Perivascular phloem fibres; CP= crushed phloem; PR= parenchyma ray. E) Hourglass-shaped crystals in pith. (All from *Motley* 1204, K).

(Figure 3.10.43, India)

**OUTLINE:** globose to obovate with two inconspicuous lateral wings; adaxially concave, undulate, abaxially convex. *Cross sectional area:* 917,870μm<sup>2</sup>. **EPIDERMIS:** one cell layer, cells rectangular, anisodiametric, contains cork cells, cell walls thickened, periclinal cells cutinized, some cells domed. *Trichomes:* absent. **VASCULATURE:** main vascular bundle U-shaped with obscurely incurved ends, open adaxially; amphicribal or hadrocentric; five bi-collateral, discrete traces form a wide, peripheral crescentic arc; central trace much longer; phloem rather crushed; abaxially closer. *Xylem fibres:* present. *Main vascular bundle area:* 325,787μm<sup>2</sup>; *additional vascular bundles:* absent. *Vascular bundles area proportion to the cross sectional* area: 35.50%. *Perivascular phloem fibres:* sclerenchymatous; Perivascular phloem fibres sparsely distributed in discrete bundles alongside the main vascular bundle. **CORTEX:** cortical region is small, two to three subepidermal cell layers containing cork cells, cells angular, and walls sinuous. **PITH:** pith area large; parenchymatous, cells polygonal, large, cell walls straight with intercellular spaces. **CRYSTAL:** absent.

## P. divaricata Wall.

#### (Figure 3.10.44, India)

**OUTLINE**: oval with two long, prominent lateral wings; adaxially deeply grooved with two very distinct wings, prominently ridged; abaxially convex. *Cross sectional area*: 808,588μm<sup>2</sup>. **EPIDERMIS**: one cell layer, surface with wavy striations, cell irregular, papillate, anisodiametric, cell walls sinuous. *Trichomes*: ±10 cells long glandular or eglandular trichomes dense in adaxial groove, and sparse throughout. **VASCULATURE**: main vascular bundle open adaxially; six to seven discrete, collateral bundles form a crescentic arc with invaginated ends, central bundle longest; six very small to moderate size discrete additional vascular traces present in one of the lateral wing, and three in other wing; phloem rather squashed; abaxially closer. *Main vascular bundle area*: 129,058μm<sup>2</sup>; *additional vascular bundles area*: (43.43 + 553.85 + 867.77 + 1100.44 + 4088.84 + 3834.57=) 10,889μm<sup>2</sup>, and (4930.64 + 1603.47 + 4245.82=) 10,780μm<sup>2</sup>. *Xylem fibres*: absent. *Vascular bundles area proportion to the cross sectional* area: 18.64%. *Perivascular phloem fibres*: few *Perivascular phloem fibres* very sparsely distributed in the abaxial side of the main vascular bundle; much dense and covering the additional bundles apically. **CORTEX**: cortical cells collenchymatous, angular, outer cells smaller and thick walled, inner cells large, polygonal, cell walls sinuous. **PITH**: pith area narrow; parenchymatous; cell polygonal, walls sinuous. **CRYSTAL**: acicular, rod-shaped, elliptic, and rhombic crystals are most abundant both in cortex and pith.

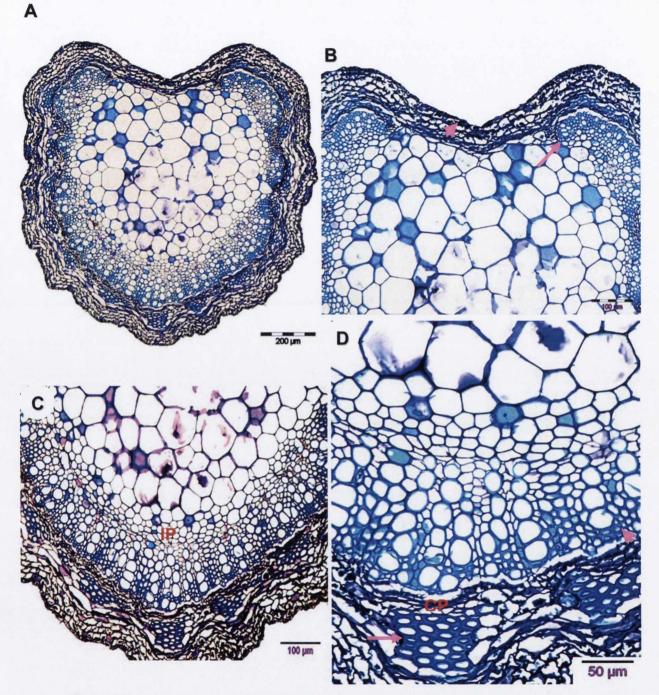
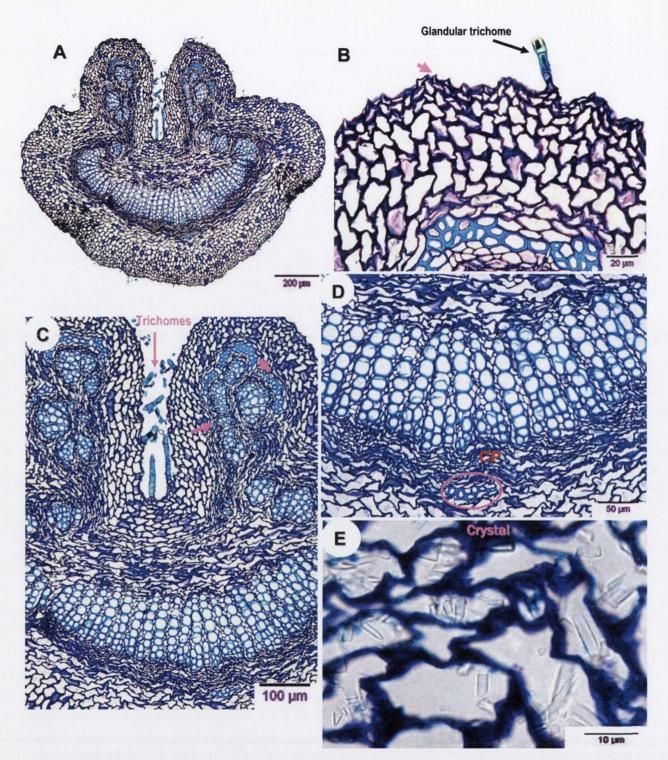


Figure 3.10.43. Petiole transverse section of *P. cordifolia* (India). A) Outline. B) Adaxial side enlarged. Arrow head indicates cork cells in epidermis; arrow shows incurved end. C) Hadro centric main vascular bundle enlarged. IP= Inner phloem. D) Enlarged vascular bundle. Arrow shows Perivascular phloem fibres; arrow head indicates xylem fibres; CP= crushed phloem. (All from *Clarke* 40762A, K).



**Figure 3.10.44**. Petiole transverse section of *P. divaricata* (India). A) Outline. B) Adaxial side enlarged. Arrow indicates multicellular glandular trichomes; arrow head shows papillate epidermis. C) Hadrocentric main vascular bundle enlarged. Arrow shows long multicellular trichomes in adaxial groove; lower short and solid arrow indicates additional vascular bundle; arrow head shows Perivascular phloem fibres. D) Enlarged vascular bundle. Sclerenchymatous sheath circled. CP= crushed phloem. *Note absence of xylem fibres*. E) Crystals in pith. (All from *Parkinson* 662, K).

### P. latifolia Roxb.

#### (Figure 3.10.45, India)

**OUTLINE**: globose to obovate with two very distinct wings; adaxially deeply grooved, ridged, abaxially convex to slightly concave. *Cross sectional area*: 579,670μm<sup>2</sup>. **EPIDERMIS**: one cell layer, surface with wavy striations, cells irregular, papillate, anisodiametric, cell walls sinuous, cells much enlarged and raised at the base of hairs. *Trichomes*: sparse throughout. **VASCULATURE**: main vascular bundle open adaxially; three discrete, collateral traces form a dissected crescentic arc with invaginated ends, central traces longest, two apical traces prominently incurved; adaxially closest. *Main vascular bundle area*: 84,992μm<sup>2</sup>; *additional vascular bundles*: absent. *Xylem fibres*: absent. *Vascular bundles area proportion to the cross sectional* area: 14.66%. *Perivascular phloem fibres*: absent. **CORTEX**: cortical cells angular, outer cells smaller and thick walled, inner cells large, polygonal, cell walls sinuous. **PITH**: pith area narrow; parenchymatous; cells polygonal, walls sinuous, a mass of *Perivascular phloem fibres* present in the middle of pith region. **CRYSTAL**: solitary, and aggregated acicular, elliptic and rhombic crystals are most abundant both in cortex and pith.

# P. pyramidata Wall.

### (Figure 3.10.46, Myanmar)

**OUTLINE**: rectangular with short lateral wings; ridged, adaxially flattened to concave, abaxially convex to slightly concave. *Cross sectional area*: 1,258,730µm<sup>2</sup>. **EPIDERMIS**: one cell layer, surface with wavy striations, cells anisodiametric, cell walls sinuous, cells at base of hairs much enlarged and raised. *Trichomes*: multi-cellular, branched trichomes dense throughout. **VASCULATURE**: main vascular bundle O-shaped, peripheral, closed; amphicribal or hadrocentric; 13-15 bi-collateral traces form a continuous irregular about seven-lobed ring; adaxially closest; phloem rather crushed. *Xylem fibres*: present. *Main vascular bundle area*: 467,285µm<sup>2</sup>; *additional vascular bundles*: absent. *Vascular bundles area proportion to the cross sectional* area: 37.12%. *Perivascular phloem fibres*: sclerenchymatous; abundant, distributed in discrete bundles alongside the whole main vascular bundle ring. **CORTEX**: cortical cells angular, outer cells smaller and thick walled, inner cells large, polygonal; cell walls sinuous. **PITH**: pith area broad, consisting of parenchymatous cells with intercellular space, cell walls straight. **CRYSTAL**: solitary acicular with pointed ends, aggregated acicular and rhombic crystals are most abundant both in cortex and pith.

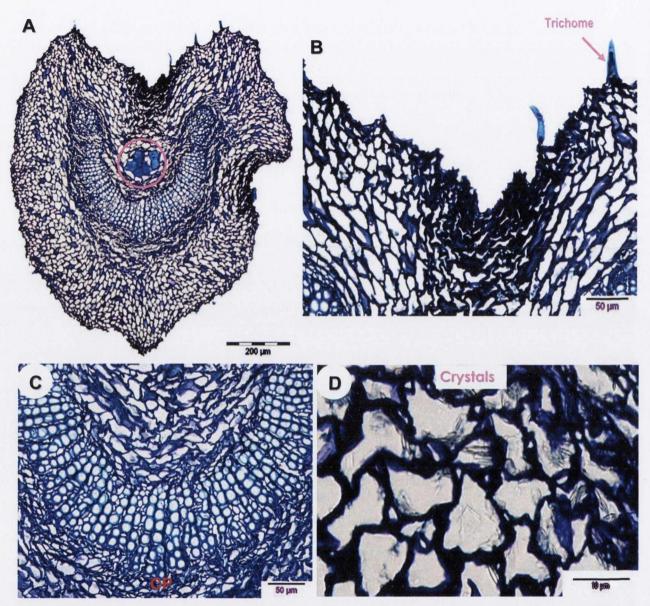
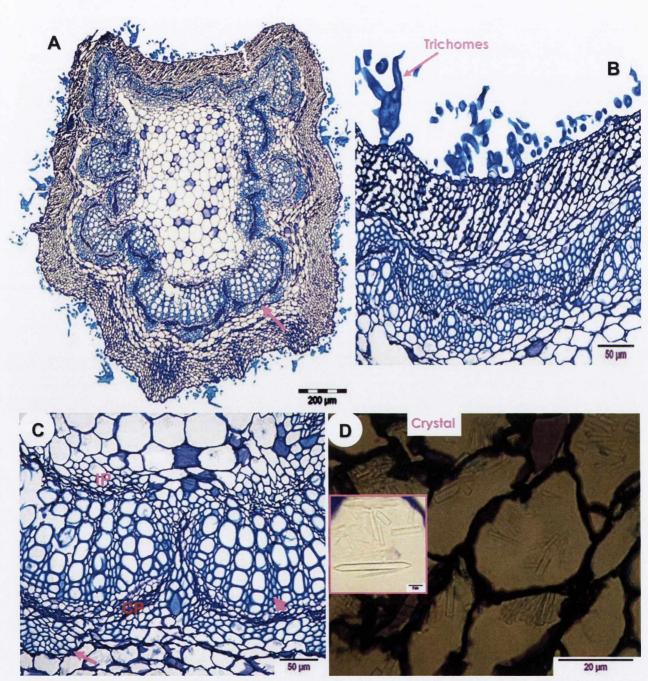


Figure 3.10.45. Petiole transverse section of *P. latifolia* (India). A) Outline. Sclereid mass circled. B) Adaxial side enlarged. Arrow indicates multicellular glandular trichome. C) Main vascular bundle enlarged. CP= crushed phloem. *Note absence of xylem fibres and perivascular phloem fibres*. D) Crystals in pith. (All from *Unknown collector* s. n., K).



**Figure 3.10.46**. Petiole transverse section of *P. pyramidata* (Myanmar). A) Outline. Arrow shows lobed main vascular bundle. B) Adaxial side enlarged. Arrow indicates branched, multicellular trichomes. C) Hadrocentric main vascular bundle enlarged. Arrow shows perivascular phloem fibres; arrow head indicates xylem fibres; CP= crushed phloem; IP= inner phloem. D) Crystals in pith. (All from *Lace* 6246, K).

#### P. racemosa Wall.

#### (Figure 3.10. 47, India)

**OUTLINE**: oval with two very long, distinct lateral wings; ridged, adaxially deeply grooved, abaxially convex to slightly concave. *Cross sectional area*: 496,687μm<sup>2</sup>. **EPIDERMIS**: one cell layer, surface with wavy striations, cells anisodiametric, cell walls sinuous, cells thin cutinized. *Trichomes*: sparse throughout. **VASCULATURE**: main vascular bundle U-shaped with very much incurved ends, open adaxially; amphicribal or hadrocentric; four to five discrete, bi-collateral vascular traces form a crescentic median arc with invaginated ends, central bundle longest; abaxially closer; four additional vascular bundles present, two in each lateral wing located at the bottom of the wing and close to the main vascular bundle. *Xylem fibres*: present. *Main vascular bundle area*: 59,043μm<sup>2</sup>; *four additional vascular bundles area*: 3,108μm<sup>2</sup>, 4,428μm<sup>2</sup>, 4,076μm<sup>2</sup>, and 5,353μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 15.30%. *Perivascular phloem fibres*: absent. **CORTEX**: collenchymatous cells angular to polygonal, thick walled; parenchyma cells larger, polygonal cell walls sinuous. **PITH**: pith area very narrow, consisting only two layers of parenchymata cells, cells polygonal, and walls sinuous with intercellular space. **CRYSTAL**: absent.

## P. resinosa Schauer

#### (Figure 3.10.48, Kenya)

**OUTLINE:** obovate with two short lateral wings; ridged adaxially shallowly grooved, abaxially convex. *Cross sectional area:* 1,453,324μm<sup>2</sup>. **EPIDERMIS:** one cell layer, surface with wavy striations, cells anisodiametric, cell walls sinuous, periclinal cell walls thick. *Trichomes:* multi-cellular trichomes sparse. **VASCULATURE:** main vascular bundle U-shaped, open adaxially, single collateral strand form a crescentic arc, phloem rather squashed; abaxially closer. *Xylem fibres:* absent. *Main vascular bundle area:* 167,101μm<sup>2</sup>; *two additional vascular bundles area:* 3,478μm<sup>2</sup>, and 4,454μm<sup>2</sup>. *Vascular bundles area proportion to the cross sectional* area: 12.04%. *Perivascular phloem fibres:* absent from along the main vascular bundle; mass of Perivascular phloem fibres apically almost covering the additional vascular bundles. **CORTEX:** adaxial collenchyma cells globular to angular, abaxially angular, thick walled; parenchyma cells polygonal, cell walls sinuous. **PITH:** pith area very narrow; parenchymatous cells polygonal, walls sinuous with intercellular space. **CRYSTAL:** absent.

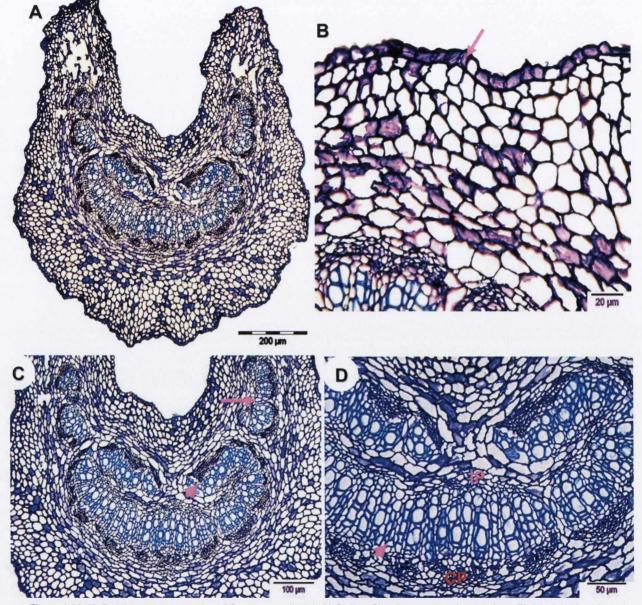


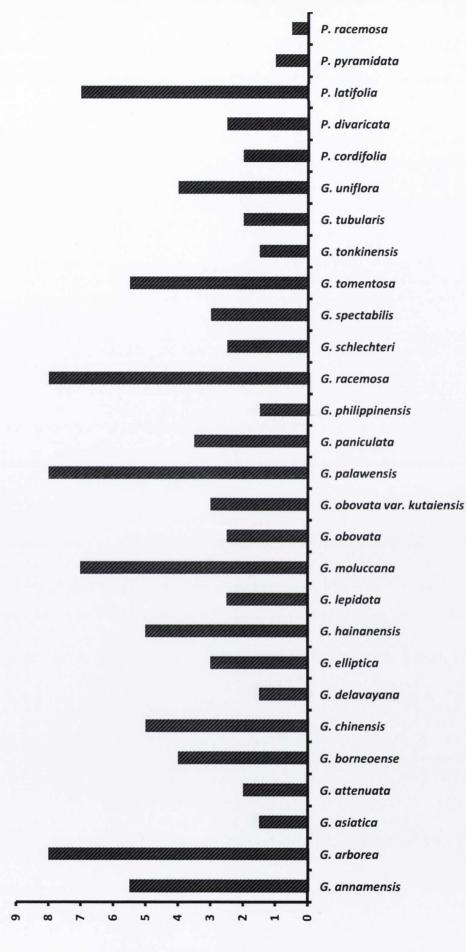
Figure 3.10.47. Petiole transverse section of *P. racemosa* (India). A) Outline. Showing very long lateral wings. B) Adaxial side enlarged. Arrow indicates epidermis. C) Hadrocentric median and additional vascular bundles enlarged. Arrow shows additional vascular bundles; arrow head indicates incurved end. D) Enlarged vascular bundle. Arrow head indicates xylem fibres; CP= crushed phloem; IP= inner phloem. *Note absence of perivascular phloem fibres*. (All from *Unknown collector* 6023, K).



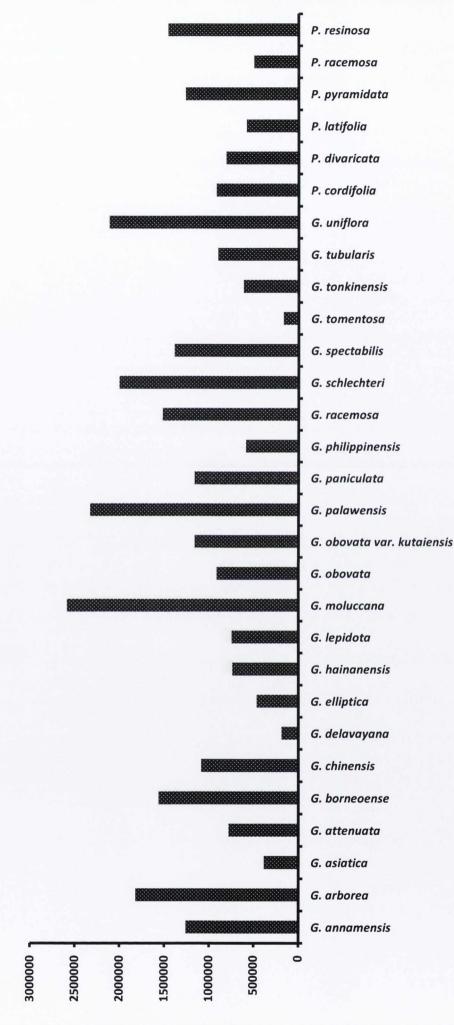
**Figure 3.10.48**. Petiole transverse section of *P. resinosa* (Kenya). A) Outline. Arrow shows additional vascular bundle. B) Adaxial side enlarged. Upper long arrow indicates trichome; lower short arrow shows Perivascular phloem fibres. C-D) Main vascular bundles enlarged. CP= crushed phloem. *Note absence of perivascular phloem fibres*. (All from *Robertson* 5913, K).

										Main Vas	Main Vascular Bundle						Pith	3	Crystals
Таха	Locality	Outline	Indumentum	Adaxial groove (+/-) (0bscure=?)	Lateral wings (+/-) (0bscure=?)	Cork Cells (+/-)	Vasculature (Medan=M) (Peripheral=P)	Pattern	Vascular System (0pen=0) (Oox=0 (Narrowly open=±0)	Vascular System (Galateral) (Bi-calateral)	Incurvation of ends ★	No. of Vascular Traces	Perivascular Phloem Fibres (+/-)	Xylem Fibres (+/-)	Additional Vascular Bundles	Area +	Medullary Bundles (+/-)	In Pith (+-)	In Cortex (+/-)
Section Asiaticum																			
G. arborea	Thailand	Oborate	Hispidaelous	+	ć	•	٩	Dissected oplinder	0∓	Bi-collateral		8-10	+	+	2	_		•	'
:	Vietnam	Oborate	Hispidalous	•	ć	+	a.	Dissected oplinder	40	Bi-collateral	1	8	+	+	2			+	+
:	Malay Peninsula	hectangular	Pubescent	+			W	Dissected oplinder	40	Bi-collateral	1	10 - 12	•	•	2	MB		1	1
:	Philippines	Circular	Glabrous			+	٩	Dissected oplinder	0	Bi-collateral	1	10	+	+	2			•	•
:	Hong Kong	Oborate	Gabress	1		•	٩	Dissected oplinder	0∓	Bi-collateral	1	10	÷	+	2		•	+	+
:	Sri Lanka	Oberate	Pabescent	+	+		٩	Dissected of Inder	40	Bi-cultural	•	15	+	+	2	_		+	+
G. asiatica	Cambodia	Gircular to oral	Paberskent, groove pabescent	+	+		W	Crescentic	0	Bi-collateral		-		•	2	z		1	•
:	Vietram	Circular to eval	Patheralent	+	+	1	×	Crescentic	0	Bi-collateral	•	-	•	•	2	z		•	'
:	Thailand	Globose to oborate	Densely glandular-puberulent	•	•	•	W	Crescentic	0	Bi-collateral	1	-	•	1	2	z		+	'
:	Brunei	Giabose	Densely glandular-puberulent	+	+	•	w	Crescentic	0	Bi-collateral	1	-			2	z		•	•
:	Indonesia	Obovate	Glandwair	+	+	•	W	Dissected opfinder	U	Bi-collateral	+	2	+	+	2	z		•	•
:	Malay sia	Obovate	Paberalent	+	+		W	Crescentic	0	Bi-culateral	1	+	1	•	2	z		•	•
:	Philippines	Oborate	Patherakant to glabrous	+	÷	+	W	Crescentic	0	Bi-colateral	•	-		•	3	z	,	+	•
:	Sri Lanka	Obovate	Glandedar-perberalent	+	+	+	W	Crescentic	0	Bi-cullateral	•	-		+	2	z			•
G. attenuata	Thailand	Oborate	Gabress	+	+	•	W	Dissected crescent	0	Bi-collateral	+	4	+	+	2	z	,	•	•
G. chinensis	Hong Kong	Rectangular to obovate	Glabrescent: groove pubescent	+	4	+	٩.	Crescentic	0	Bi-collateral	•	-	÷	÷	2		•	•	•
G. delavayana	China	Dral	Glabrons	+	+	•	W	Crescentic	0	Bi-collateral	+	-	1	•	2	z		•	•
G. elliptica	Vietram	Oral	Densely publicant	+	+	•	W	Crescentic	0	Bi-collateral	+	-	+	+	3	z		•	•
:	Thailand	Drad	Pablescent	+	+	•	W	Crescentic	0	Bi-collateral	~	-	1	•	2	z		•	•
:	Indonesia	lend	Pabescent	+	+	•	W	Crescentic	0	Bi-culateral	•	-	1	+	2	z	•	•	•
:	Malaysia	Qual	Pallescent	+	+		W	Crescentic	0	Bi-culateral	i	-	1	•	2	z	•	•	•
:	Philippines	Dral	Densely pubescent	+	+	•	W	Crescentic	0	Bi-collateral		-	1	•	2	z	•	•	•
:	India	Oral	Pabescent	+	+	•	W	Crescentic	0	Bi-culateral	+	-	+	+	2	z		•	•
G. lepidota	Indonesia	Nectangular	Glabrous	+		+	W	Dissected crescent	0	Bi-collateral	+	3	I		2	z		•	•
G. moluccana	Indonesia	Oborate	Glabrescent	+	+	•	٩.	Cylindric	c	Bi-collateral		-	+	+	4	_	+	+	'

				1															
										Main Vasc	Main Vascular Bundle						Pith	0	Crystals
Taxa	Locality	Outline	Indumentum	Adaxial groove Lateral wings (+/-) (0bxunr=?) (0bxunr=?)	Lateral wings (+/-) (0bscure=?)	Cork Cells (+/)	Vasculature (Median=M) (Peripheral=P)	Pattern	Vascular System (0pen=0) (Uase=() (Narrowly open=±0)	Vascular System (Galateral) (Bi-colateral)	Incurvation of ends +	No. of Vascular Traces	Perivascular Phloem Fibres (+/-)	Xylem Fibres (+/-)	No. of Additional Vascular Bundles	+ Area	Medullary Bundles (+/-)		In Pith In Cortex (+/-)
G. palawensis	Indonesia	Rectangular	Gkbrows	+	i	+	W	Dissected crescent	0	Collateral	+	9-12		,	2	z	1	+	+
G. paniculata	Thailand	Oral	Pubescent	+	+		W	Dissected cylinder	U	Collateral	•	6-8	1	1	2	S	I	+	•
G. philippensis	Philippines	kmicircular	Glabrescent: groove pubescent	+	+		М	Crescentic	0	Bi-collateral	+	1	1	1	2	z		•	•
:	Cambodia	<b>Semicircular</b>	Glabrons	+	+	+	W	Crescentic	0	Bi-collateral	‡	-	1	1	2	S	•	•	•
G. racemosa	Vietnam	Globoxe	pubescent	+	6	•	d	Dissected crescent	0	Bi-collateral	+	10	+	+	2	_	+	1	1
:	Thaland	Globose to oborate	Publicitant or tomentose	6	•	+	d.	Dissected crescent	0	8 i-collateral	+	8	+	+	2	_	•	•	•
G. schlechteri	Indonesia	Transversely oval	Glabrous	+	+	•	W	Cylindric	U	Bi-collateral	1	-	+	+	4	z	•	•	•
G. tomentosa	Thailand	± Circular to globoxe	Tomentose	+	+		W	Crescentic	0	Bi-collateral	•	-		•	2	z	•	•	•
G. tonkinensis	Vieham	Dral	Pubescent	+	+		W	Crescentic	40	Bi-collateral	+	-	+	+	2	8	•	+	•
Section Annameticum	ameticum																		
G. annamensis	Vietnam	lero	Puberalent to glabrous	•	•	+	Ч	Dissected cylinder	U	Bi-collateral	•	10	+	+	2	8	+	•	•
G. borneoense	Indonesia	Greater	Villosa or pubescent	+	+	+	d	Crescentic	0	Bi-collateral	* *	-	+	+	2	8	1	1	1
G. hainanensis	China	Rectangular	Pubescent	+	+	+	٩.	Dissected crescent	0	Bi-collateral	•	>10	÷	÷	0	_	+	•	•
G. obovata	Malaysia	Oral	Glabrows	+	+	+	W	Dissected crescent	0	Bi-collateral	ŧ	5	1	1	2	z	1	1	•
G. obovata var. kutaiensis	Indonesia	Oral	Glabrons	+	+	+	W	Dissected crescent	0	Bi-collateral	+	3	+	ı	2	8	1	+	•
G. spectabilis	Indonesia	Rectangular	Patientent	+	+	+	W	Dissected crescent	0	Bi-collateral	**	3-4	+	+	3	8	1	•	•
G. tubularis	Malaysia	Rectangular	Pubescent	+	+	+	W	Dissected crescent	0	Bi-collateral	**	4-5	÷	+	2	MB	•	•	•
G. uniflora	Indonesia	± Circular to globose	Glabrescent	+	+	+	W	Dissected creacent	0	Bi-collateral	‡	3	+	+	2	8		+	•
Genus Premna	remna																		
P. cordifolia	India	Globose to oborate	Glabrons	+	2	+	٩	Dissected creacent	0	Bi-collateral	i	5	+	+	1	_	1	1	•
P. divaricata	India	Oral	Pubescent	+	+	1	W	Dissected crescent	0	Collateral	1	6-7	+	•	9	z	•	+	+
P. latifolia	India	Globose to oborate	Pabescent	+	+	1	W	Dissected crescent	0	Collateral	‡	3	1	1	ı	z	•	+	+
P. pyramidata	My anmar	Rectangular	Tomentose	+	ż	•	٩.	Dissected cylinder	U	Bi-collateral	1	13 - 15	+	+	1	8	•	+	+
P. racemosa	India	Oral	Glabrous to sparsely hairy	+	+	1	W	Dissected creacent	0	Bi-collateral	<b>‡</b>	4-5	1	+	4	z	•	•	•
P. resinosa	Kenya	Obowate	Glabroux; groore pubescent	+	+	•	W	Crescentic	0	Collateral		-	+	•	2	z	•	•	•



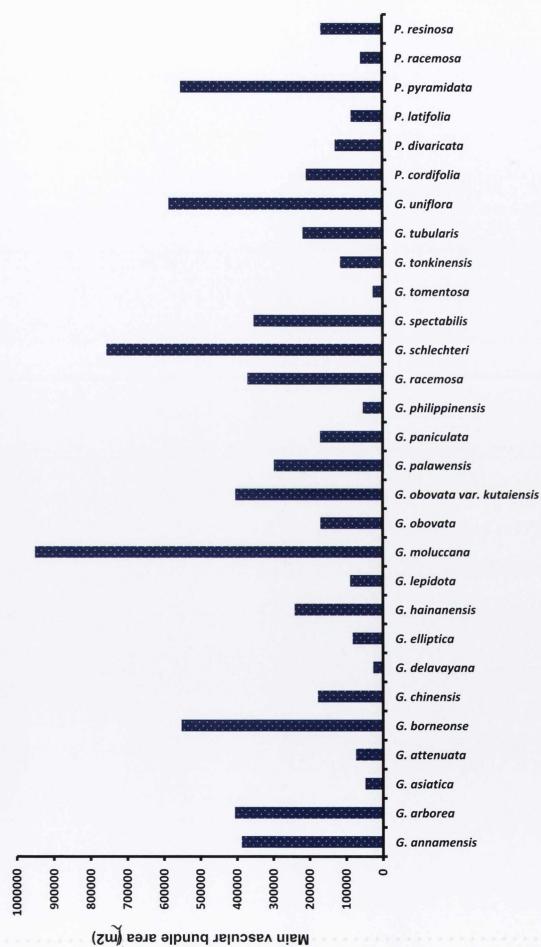
Petiole length (cm)

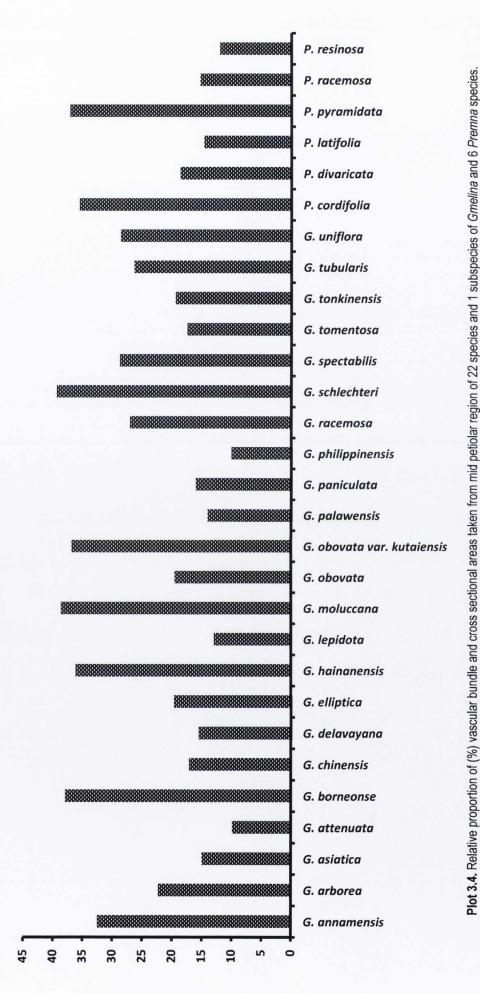


Plot 3.2. Cross sectional area (µm<sup>2</sup>) of 22 species and 1 subspecies of Gmelina and 6 Premna species assessed in mid petiolar region.

280

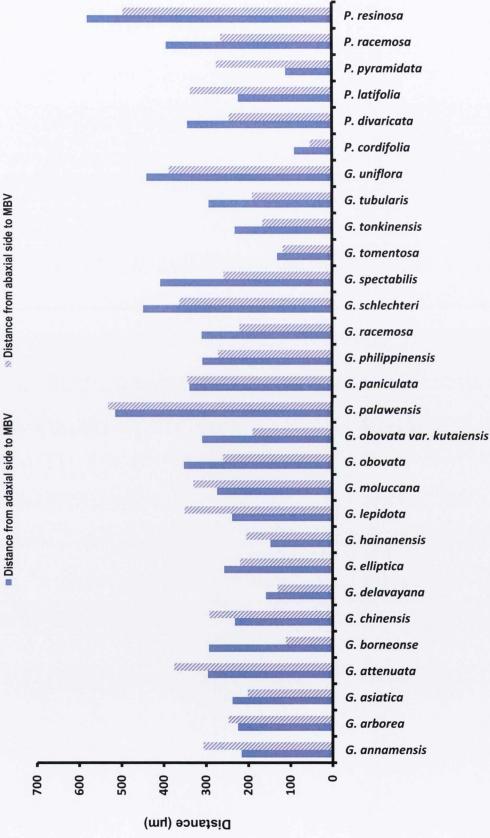
## Cross sectional area (µm<sup>2</sup>)





Relative proportion (%)

© Distance from abaxial side to MBV





## 3.7.3. Discussion

There has been no comprehensive specific petiolar anatomical study on the genus *Gmelina*. With the exception of *G. arborea* and *G. philippensis*, petiolar anatomy of the genus *Gmelina* has not been studied previously, so the description of the anatomical characters is given here for the first time.

Mathew & Shah (1987), and Ingole & Patil (2003) traced different dimensional aspects of petiolar anatomy of 35 and 20 taxa of Verbenaceae *s. l.* respectively including two *Gmelina* species, *G. arborea* and *G. philippensis* with a view to reveal the structural diversity and evaluate the contribution of petiolar anatomy to the taxonomy of Verbenaceae *s. l.* According to them different vascular configurations are taxon specific and can be used as a taxonomic marker. They held that the variation patterns in the petiolar anatomy of the different taxa has an adaptive significance. They reported an almost closed dissected arc in *G. arborea* and single median crescentic arc in *G. philippensis*. The present study substantiates these observations, but I have not seen perivascular sclerenchyma and crystals in *G. philippensis*, which Ingole & Patil (2003) reported.

The length of the petiole is within a range of 0.5-9cm, with the maximum in *G. palawensis*. The cross sectional area of the petiole in different taxa varies considerably. It is highest in *G. moluccana* (2,582,500 $\mu$ m<sup>2</sup>) (Figure 3.10.29A) and lowest in *G. tomentosa* (167,305 $\mu$ m<sup>2</sup>) (Figure 3.10.37A). Petiole length (Plot 3.1) and cross sectional areas (Plot 3.2) are related with habit. All tree species in *Gmelina* have the relatively longer petiole and larger cross sectional area than shrubby species. These characters would not necessarily be recommended for identifying *Gmelina* species as the length and size of petiole would differ within the same species depending on the age of the leaf and its environment. However, in conjunction with other characters it is a useful interspecific differentiating character.

The outline of petiole is a good character for identifying *Gmelina* species. Petiole outlines vary from oval or globose to obovate or rectangular in transections. In seven species petiole outlines are rectangular (Table 3.2); circular with convex abaxial surface in *G. borneoense* (Figure 3.10.17A); and in the remaining 21 species, the petioles are oval or obovate or globose to obovate in shape (Table 3.2). Adaxial grooves are present in most *Gmelina* species and vary in size, but are absent from *G. annamensis* (Figure 3.10.1A) and *G. racemosa* (Figure 3.10.36A); populations of *G. arborea* from Vietnam, Philippines and Hong Kong also show a dorsiventrally flattened outline (Figures 3.10.3A; 30.10.5A & 6A) whereas, all other populations of the species are adaxially grooved.

Apart from the adaxial groove, two lateral wings are present in almost all taxa; they are very prominent and long in a few (Table 3.2) e.g. *G. borneoense* (Figure 3.10.17), *G. elliptica* (Figure 3.10.21), *G. delavayana* (Figure 3.10.19), *G. spectabilis* (Figure 3.10.38), *G. schlechteri* (Figure 3.10.37), *G. tubularis* (Figure 3.10.41), and *G. uniflora* (Figure 3.10.42) etc.; they may be small or indistinct in *G. chinensis* (Figure 3.10.18), *G. palawensis* (Figure 3.10.31), and *G. racemosa* (Figure 3.10.35-36); or absent in *G. annamensis* (Figure 3.10.1A), and *G. lepidota* (Figure 3.10.38A). The character is not constant between specimens of the same

species e.g. in *G. arborea*, the Sri Lankan element (Figure 3.10.7A) has two short lateral wings, whereas, these are absent from other populations; in *G. asiatica* the lateral wings are present in all polulations except Thai specimen (Figure 3.10.10A).

The extent of separation of the vascular bundle from the adaxial and abaxial surfaces depends on the depth of the curve of the main vascular bundle and length of the lateral wings. In the present study, almost all species show equidistant vasculature. However, vascular bundles are found closer abaxially (i.e. abaxial cortex layer shorter), in *G. borneoense*, *G. spectabilis*, *G. obovata*, *G. obovata* var. *kutaiensis*, *G. schlechteri*, and *G. tubularis*, etc. (Plot 3.5).

In *Gmelina* the petioles are hairy except for *G. attenuata*, *G. delavayana*, *G. lepidota*, *G. obovata*, *G. obovata*, *var. kutaiensis*, *G. schlechteri*, and *G. palawensis*, which are completely glabrous (Table 3.2). However, the degree of hairiness varies from puberulent to tomentose or densely pubescent (Table 3.2).

The vascular system has received most attention in the study of petiole anatomy. Howard (1962, 1979) has reviewed the terminology and ontogeny of the petiolar vascular systems. The vascular bundles are arranged in an arc or a ring and vary in number. Two vascular patterns are observed in *Gmelina* and *Premna*. The first is the closed system in which the vascular system is arranged in the form of a cylinder, either in discrete bundles in *G. annamensis* (Figure 3.10.1); *G. paniculata* (Figure 3.10.32) or as a continuous layer in *G. moluccana* (Figures 3.10.29); *G. schlechteri* (Figure 3.10.37) etc. The second is the open or arc system in which the vascular pattern is single stranded e.g. *G. asiatica* (Figures 3.10.10), *G. elliptica* (Figure 3.10.21), *G. philippensis* (Figure 3.10.33-34) or continuous *G. lepidota* (Figures 3.10.38) or discrete *G. palawensis* (Figure 3.10.31).

Peripheral vascular bundles are present in four species, and in the remaining 18 species vascular bundles are arranged in the centre of the petiole. The number of bundles varies greatly between species, and in most of the petioles the vascular bundles are small on the adaxial side becoming larger towards the abaxial side, with the central vascular bundle being largest.

In all specimens of *Gmelina* species examined, the vascular structure consists of a principal bundle accompanied by additional bundles in the wings with the exceptions in *G. hainanensis* (Figure 3.10. 26), where they are absent. The vascular bundles are bicollateral in all taxa, whereas, in *G. palawensis* (Figure 3.10.31), and *G. paniculata* (Figure 3.10.32) vascular bundles are collateral.

The number of vascular bundles ranges from mostly 1 to many, with the maximum number 8-15 are observed in *G. annamensis* (Figure 3.10.1); *G. arborea* (e.g. Figures 3.10.2-7); *G. hainanensis* (Figure 3.10.26); *G. palawensis* (Figure 3.10.31); and *G. racemosa* (Figure 3.10.35-36). On the basis of shape, eight main types of petiole vascularizations can be recognised within the genus *Gmelina*:

i) *Crescentic*: single strand crescentic arc present in *G. asiatica* (Figure 3.10.10); *G. chinensis* (Figure 3.10.18); *G. elliptica* (Figure 3.10.21); *G. philippensis* (Figure 3.10.33-34); *G. tomentosa* (Figure 3.10.39); and *G. tonkinensis* (Figure 3.10.40).

ii) *Crescentic with invaginated ends*: this pattern only observed in *G. delavayana* (Figure 3.10.19); populations of *G. elliptica* from Vietnam (Figure 3.10.20) and Indonesia (Figure 3.10.22); and *G. borneoense* (Figure 3.10.17).

iii) *Dissected crescent with medullary bundles*: this type of vasculature is found in *G. hainanensis* (Figure 3.10.26).

iv) *Dissected crescent with invaginated ends*: this pattern are observed in the maximum eight taxa, *G. attenuata* (Figure 3.10.16); *G. lepidota* (Figure 3.10.38); *G. palawensis* (Figure 3.10.31); *G. spectabilis* (Figure 3.10.38); *G. obovata* (Figure 3.10.29), *G. obovata* var. *kutaiensis* (Figure 3.10.30); *G. tubularis* (Figure 3.10.41); and *G. uniflora* (Figure 3.10.42).

v) Dissected crescent with invaginated ends and medullary bundles: only *G. racemosa* (Figure 3.10.35) shows this pattern of vasculization.

vi) *Cylindric*: this pattern is present only in two species, *G. moluccana* (Figure 3.10.28) and *G. schlechteri* (Figure 3.10.37).

vii) *Dissected cylinder*: this type is observed in *G. arborea* (Figure 3.10.5); *G. paniculata* (Figure 3.10.32); and the Indonesian specimen of *G. asiatica* (Figure 3.10.12).

viii) Dissected cylinder with medullary bundles: Only G. annamensis (Figure 3.10.1) shows this type of vasculature.

With a few exceptions mostly only one additional vascular bundle is observed below each dorsal lateral wing in all taxa. However, three additional vascular bundles, one in one wing and two in the other wing are present in *G. spectabilis* (Figure 3.10.38); this pattern also occurs exceptionally in the Philippines element of *G. asiatica* (Figure 3.10.14) and the *G. elliptica* specimen from Vietnam (Figure 3.10.20), whereas all other populations of these two species have single additional vascular bundles in each wing (Table 3.2). Two additional vascular bundles are present in each wing in *G. moluccana* (Figure 3.10.28) and *G. schlechteri* (Figure 3.10.37, Table 3.2). These are absent from *G. hainanensis* (Figure 3.10.26; Table 3.2).

Xylem fibres are present in some species, giving added rigidity to the petiole (Table 3.2). An important feature of this character is the occurrence together of perivascular fibres and xylem fibres in almost all species. However, perivascular phloem fibres are found in those species where xylem fibres are absent, e.g. *G. obovata* var. *kutaiensis* (Figure 3.10.30). However, both perivascular and xylem fibres are absent from *G.* 

asiatica, G. delavayana, G. lepidota, G. palawensis, G. paniculata, G. philippensis, G. tomentosa, and G. obovata (Table 3.2).

Hare (1943) postulated that "the characteristic vascular anatomy of the petiole has arisen primarily in response to mechanical needs - it takes precisely the forms best suited to sustain the continuous vertical flexure resulting from the weight of the leaf, as well as the intermittent lateral stresses due to wind action". Hare (1943) therefore concluded that the distinctive feature of the petiole anatomy should be regarded as mainly adaptive and functional, and consequently of little phylogenetic significance. However, Hare (1943) is also of the opinion that other factors must have brought about the wide diversity of detail in petioles of different plants and that the immense variety of anatomical structures of the petiole is of real taxonomic value.

Medullary vascular bundles seem to be taxon-specific and correlated with a particular habit. Mathew & Shah (1987) reported medullary bundles to be of general occurrence in woody species, but they were not commonly found in the present investigations, being restricted to tree species only, such as *G. annamensis*; *G. hainanensis*; *G. moluccana*; and *G. racemosa* (Table 3.2). The number of medullary vascular bundle varies in different taxa (2-9) with the maximum number in *G. moluccana* (Figure 3.10.28C).

The cortex and pith area can be narrow or wide. The majority of the species have a narrow cortex with exception *G. palawensis* which has a wide cortex, both in adaxially and abaxially (Figure 3.10.32). There is therefore a relationship as, taxa with a narrow cortex have wider pith and *vice versa*.

Crystals are less common in the species studied, and are considered as potentially a useful taxonomic characters. Crystals are present only in seven species of *Gmelina*, e.g. acicular and/or rhombic crystals are present both in pith and cortex in *G. palawensis* (Figure 3.10.31E); these are observed only in pith of *G. paniculata* (Figure 3.10.32E); acicular and druses are found in pith of *G. moluccana* (Figure 3.10.28E); elliptic and rhombic crystals are present in the pith region of *G. tonkinensis* (Figure 3.10.37E); hour-glass-shaped and rod-shaped crystals are observed in the pith of *G. obovata* var. *kutaiensis* (Figure 3.10.30F) and *G. uniflora* (Figure 3.10.42E).

Out of the 22 species of the genus *Gmelina* studied, *G. moluccana* (Figure 3.10.28A) and *G. schlechteri* (Figure 3.10.37A) distinctly stand apart from others in having a completely lobed cylinder, enclosing pith; *G. uniflora* containing parenchymatic ray in the vascular bundle (Figure 3.10.42D); and *G. hainanensis* (Figure 3.10.26) in lacking additional vascular bundles.

Differences are thus observed in the number and patterns of vascular bundles, presence of lateral wings, medullary vascular bundles, perivascular phloem fibres, and xylem fibres, and cork cells in the petioles of the genus *Gmelina* (Table 3.2). These characters could make a meaningful contribution to the phylogenetic study of this genus.

Almost similar types of vascularization in different species of *Gmelina* and *Premna* suggests the close relationship between two genera.

## 3.7.4. Conclusion

Opinions differ as regards the taxonomic value of the anatomy of the petiole in the recognition of taxa. Hare (1943) has shown that characters derived from the petiole could be of real service to the taxonomists if used with discretion and understanding. Howard (1979) has also demonstrated the possibility of using a combination of petiole anatomical characteristics to create a key to sterile material of a local flora.

The study of the anatomy of *Gmelina* has resulted in new descriptions of the anatomy of leaves of the genus. New observations have been made, particularly of the leaf surfaces and petiole anatomy, which has not been previously described for the genus. The study has resulted in the identification of several characters which may be taxonomically informative.

The leaf anatomy of the genus *Gmelina* has a few clearly distinctive characteristics which make possible the immediate recognition of certain taxa. Among the best of these are the branched trichome on leaf surfaces in *G. racemosa* (Figure 3.9.18); glabrous leaf surfaces on both sides in *G. palawensis* (Figure 3.9.15-16); lepidote leaf surface in *G. lepidota* (Figure 3.9.14); parenchymatic rays in the vascular bundle of *G. uniflora* (Figure 3.10.42); lobed vascular bundles in *G. moluccana* (Figure 3.10.28) and *G. schlechteri* (Figure 3.10.37).

The relative homogeneity of many anatomical characters reflected the close relationships existing between the various group of species. For example, the mutual similarity in petiole anatomy of *G. asiatica*, *G. elliptica*, and *G. philippensis* shows similarity in other characters as well; however they could be differentiated by their leaf surface indumentum and inflorescence characters.

The present investigation confirms that leaf surface anatomy and patterns of petiole vasculature, inconjunction with some other characters of petiole anatomy, are taxon-specific. These features have a taxonomic importance and are useful in identification of different species of *Gmelina* and *Premna*.

# CHAPTER 4

## **Palynological Investigations**

## 4.1. Introduction

Scanning electron microscopy is a wonderful tool for the investigation of plant surfaces (Endress *et al.* 2000) which provides an image of exceptionally minute objects of incomparable depth of field. Features observable with SEM provide useful information relevant to the phylogeny of the angiosperms (Cole & Behnke 1975; Stuessy 1979). Heywood (1968 and 1969) has demonstrated and reviewed the usefulness of SEM in plant systematics and has suggested that this ultrastructural device represents one of the most powerful taxonomic tools for systematic research.

The use of SEM has enabled enormous advances in the study of fine micromorphology of the pollen grain and has revealed many characters of taxonomic importance which cannot be accurately observed with the light microscope (Harley & Ferguson 1990). Now the employment of SEM in any study involving pollen morphology is routine and is an "essential part of the illustrative method that holds its own unique position in elucidating exine structure and ornamentation" (Harley & Ferguson 1990).

Palynology is the study of pollen and spores. The term "Palynology" was first introduced by Hyde & Williams in 1944, from the Greek words *Paluno* meaning "to sprinkle" and *Pale* meaning "dust"; cognate with the Latin "*Pollen*" means flour or dust. Palynology is unique in that one can obtain ample valuable taxonomic information from so little material in such a short time (Walker & Doyle 1975). Nevertheless, the field is relatively juvenile (Stuessy 2009). Application of pollen morphology in plant taxonomy is best evidenced in the flowering plants and the largest variety of pollen morphotypes occurs among the angiospermous plants (Nair 1964). Constant features and the exine sculpturing make pollen grains highly recognizable objects by which genera or even species may be identified (Moore & Web 1978). Pollen morphology has long been recognized as an important parameter in determining phylogenetic relationship among genera and families.

Pollen characters provide valuable information for various research areas, such as taxonomy, evolution, genetics, pollination and plant breeding, allergy studies, melissopalynology, forensic science, tracing plant geography, geology, climatic change studies, and the study of human impact on vegetation (Kim & Song 1998; www.kew.org/scihort/palyn.html). Although pollen grains are small and the features only observable with the aid of compound light and scanning electron microscopes, Keating (1979) indicates "The usefulness of palynology has become so obvious that it is now routinely incorporated into most systematic and evolutionary studies."

Evolutionary trends in pollen wall stratification provide significant phylogenetic information, thus palynological studies make tremendous contributions to the systematics and phylogeny of angiosperms (Perveen 2000). Micro-characteristics such as pollen morphology prove a useful tool in resolving taxonomical and phylogenetic relationships at infra- and supra-generic levels (Kaya & Kutluk 2007). Pollen surface projections are potential sources of systematic characters (Judd *et al.* 2008).

Pollen morphological studies for the family Lamiaceae have been sporadic (Harley *et al.* 1992) but pollen characters have also shown great taxonomic utility and have been used in the classification of the Lamiaceae. Erdtman (1945) divided the family into two subfamilies based on aperture number and number of nuclei - *Lamioideae*: tricolpate and bi-nucleate pollen; to which can be added *Ajugoideae*, *Chloanthoideae*, *Pogostemonoideae*, *Scutellarioideae*, *Teucrioideae* and *Viticoideae* following the classification of Cantino *et al.* (1992); and the second group *Nepetoideae*: contains hexacolpate and tri-nucleate pollen grains.

Following from the early work, pollen characteristics of Lamiaceae have continued to show great taxonomic significance and have been used in the classification of the family. Wunderlich (1967) used palynological and embryological data to produce a classification of the Labiatae. Her results strongly support Erdtman's subfamilial classification. Cantino & Sanders (1986) used mainly pollen characters along with some other additional characters to evaluate subfamilial classification of Lamiaceae and suggested that Erdtman's subfamilies appear to be the primary phenetic groupings of the family. Subsequently, several palynological studies have been carried out in the family, such as: *Trichostema* L. (Abu-Asab & Cantino 1989); *Stachys* (Demissew & Harley 1992); subtribe *Ociminae* (Harley 1992); tribe *Ocimeae* (Harley *et al.* 1992); tribe *Mentheae* (Wagstaff 1992); subfamily *Lamioideae* (Abu-Asab & Cantino 1993); tribe *Ajugeae* (Abu-Asab & Cantino 1993a); tribe *Prostanthereae* (Abu-Asab & Cantino 1993b); subfamilies *Lamioideae* and *Pogotemonoideae* (Abu-Asab & Cantino 1994); *Teucrium* (Dönmez *et al.* 1999); *Nepeta* (Jamzad *et al.* 2000); *Lycopus* (Moon & Hong 2003); *Acinos* (Kaya & Kutluk 2007); *Marrubium* (Akgül *et al.* 2008) and the subtribe *Nepetinae* (Moon *et al.* 2008).

Abu-Asab & Cantino (1992) showed that pollen is usually isopolar and mostly tricolpate in subfamily Lamioideae. The exceptions are *Halostachys* with four colpi, while one species of *Marrubium* and many species of *Sideritis* have tetra-zonocolpate or hexa-zonocolpate pollen. These exceptions within Lamioideae are considered to be derived. They recognised seven types of exine surface sculpturing pattern: *spinulose, verrucate, suprareticulate, suprarugulate, psilate, granulate,* and *suprareticulate-spinose*. According to Abu-Asab & Cantino (1992) derived character states with variation patterns - *reticulate, spinulose,* and *verrucate - supratectal* sculpturing suggest a polyphyletic origin for the Lamiaceae.

There have been no palynological studies on the genus *Gmelina* or even on the subfamily Viticoideae. Only a few notes on pollen of the genus are available in Mathew & Shah (1988) and Abu-Asab & Cantino (1993a).

## 4.2. Objectives

Thus, the objectives of this study are:

- To elucidate the palynological diversity within the genus Gmelina;
- To gap fill the palynological knowledge of the genus Gmelina;
- To explore the relationship between Gmelina and Premna; and
- To evaluate the systematic significance of the resulting data.

The compilation of the observations would contribute to understanding the phylogeny of the family Lamiaceae.

## 4.3. Materials and Methods

The present study was mainly based on herbarium specimens. Anthers were removed from herbarium specimens representing 21 *Gmelina* species (24 accessions), and one *Premna* species were acetolyzed using the procedure outlined by Parnell (1991, 2003). Anthers were crushed in 12ml tubes with approximately 1ml of 50% acetone, suspended for 5 minutes using a whirly-mix and centrifuged for 8-10 minutes at 2,500rpm. The pellet was then transferred into a fresh tube and then repeatedly dehydrated by re-suspension in increasing acetone concentrations (60% - 100%), the penultimate re-suspended pellet was sieved and the final pellet put onto a SEM stub and allowed to dry overnight in a dessicator. The stubs were then coated with approximately 350Å gold in a Polaron SC500 sputter coater and the samples were examined and photographed in a Hitachi S4300 electron microscope. Detailed protocol is in **Appendix 2**.

All collections examined, together with pollen morphological data are summarized in Table 4.1. Measurements of the length of the polar length (P), equatorial width (E), colpus length, colpus width, and muri width were measured using *ImageJ* software (http://rsb.info.nih.gov/ij/). The mean and range of polar length and equatorial width were calculated, and the mean polar length divided by the equatorial width to ascertain pollen shape (P/E ratio). All quantitative data for the pollen descriptions are given as means based on 3-5 random measurements. Measurements were taken using ImageJ image processing programme. Pollen grains of all representative species from the section *Annameticum*, and 14 species of 15 taxa from the section *Asiaticum* have been examined, arranged alphabetically under each section and illustrated in Figures 4.1-4.8. Additionally, data obtained from Abu-Asab & Cantino (1993a) for *G. brasii* are provided in the Table 4.1. under section *Asiaticum*. Polar length and equatorial width of each taxon are presented graphically in Plot 4.1.

The palynological terminology and morphological concepts are adopted in accordance with Erdtman (1952); Walker & Doyle (1975); Abu-Asab & Cantino (1992); Punt *et al.* (2007); and Halbritter *et al.* (2005).

## 4.4. Results

Pollen grains of the representative species examined are illustrated in **Figures 4.1- 4.8**. The observations of all *Gmelina* species examined are provided alphabetically under each section followed by the single species of *Premna*:

## Section: Asiaticum

#### G. arborea Roxb. (Figures 4.1A-B)

Pollen isopolar, prolate spheroidal, tri-zonocolpate; polar outline elliptic, polar axis 25.8-33.5µm, equatorial axis 22.4-31.5µm; colpi wide, acute towards the pole, colpus membrane psilate; sexine ornamentation microreticulate; muri psilate, deep, rounded, interrupted and ridged; lumina narrow, tectum minutely perforate.

## G. asiatica L. (Figures 4.1C-D)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 30.0-32.0µm, equatorial axis 20.1-21.0µm; colpi narrow, acute towards the pole, colpus membrane psilate; sexine ornamentation microreticulate; muri psilate, shallow to somewhat deeper, rounded, interrupted; lumina narrow, elongated, indistinct, tectum sparsely perforate.

## G. attenuata Fletcher (Figures 4.1E-F)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 28.9-30.5µm, equatorial axis 20.9-21.7µm; colpi wider, obtuse towards the pole, colpus membrane psilate; sexine ornamentation suprareticulate; muri psilate, shallow, flat, interrupted, wider than lumina; lumina narrow, distinct, polygonal, interrupted, tectum indistinctly perforate.

#### G. chinensis Benth. (Figures 4.2A-B)

Pollen isopolar, subprolate, tri-zonocolpate; polar outline elliptic, polar axis 29.1-29.9µm, equatorial axis 22.4-25.3µm; colpi narrow, colpus membrane psilate; sexine ornamentation suprareticulate; muri psilate, deeper, rounded, wider than lumina, interrupted; lumina small, distinct, angular to elongate, tectum indistinctly perforate.

## G. delavayana Dop (Figures 4.2C-D)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 28.1-30.9µm, equatorial axis 16.5-17.7µm; colpi narrow, colpus membrane psilate; sexine ornamentation suprareticulate with interrupted ridges; muri psilate, shallow, rounded to somewhat flat, wider than lumina, interrupted; lumina small, distinct, polygonal, tectum indistinctly perforate.

## G. lepidota Scheff. (Figures 4.2E-F)

Pollen heteropolar, subprolate, tri-zonocolpate; polar outline elliptic, polar axis 24.6-16.8µm, equatorial axis 21.5-23.8µm; colpi wide, acute towards the pole, colpus membrane psilate; sexine ornamentation rugulate; muri psilate, shallow or somewhat deeper, interrupted; lumina narrow, rarely slightly wide, interrupted, distinct, tectum sparsely perforate.

## G. moluccana Backer ex Heyne (Figures 4.3A-B)

Pollen isopolar, oblate spheroidal, tri-zonocolpate; polar outline circular, polar axis 21.2-25.0µm, equatorial axis 26.1-31.8µm; colpi wide, acute towards the pole, colpus membrane psilate; sexine ornamentation rugulate; muri shallow, ridged, very narrow, interrupted; lumina narrow, indistinct, tectum not perforate.

## G. palawensis H. J. Lam (Figures 4.3C-D)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 27.5-30.9µm, equatorial axis 16.6-17.8µm; colpi narrow, acute towards the pole, colpus membrane sparsely granular; sexine ornamentation microreticulate-granulate; muri shallow or somewhat deeper, rounded, interrupted, with distinct supramural granules; lumina indistinct, tectum sparsely perforate.

## G. paniculata Fletcher (Figures 4.3E-F)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 34.1-35.1µm, equatorial axis 18.2-19.1µm; colpi narrow, acute towards the pole, colpus membrane psilate; sexine ornamentation suprareticulate; muri psilate, shallow, rounded; lumina large, distinct, wider than muri, polygonal, tectum distinctly perforate.

## G. philippensis Cham. (Figures 4.4A-B)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 34.5-35.4µm, equatorial axis 21.4-24.7µm; colpi narrow, acute towards the pole, colpus membrane granular; sexine ornamentation suprareticulate; muri psilate or rarely granulate, shallow, flat, interrupted; lumina large, distinct, wider than muri, elongated to polygonal, tectum distinctly perforate and sparsely granular.

## G. racemosa (Lour.) Merr. (Figures 4.4C-F)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 25.4-44.0µm, equatorial axis 18.0-28.7µm; colpi narrow, acute towards the pole, colpus membrane psilate; sexine ornamentation rugulate or microreticulate; muri psilate or somewhat coarse, deeper, rounded, wider than lumina; lumina narrow, tectum sparsely perforate.

#### G. schlechteri H. J. Lam (Figures 4.5A-B)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 31.5-33.7µm, equatorial axis 19.6-21.7µm; colpi wide, obtuse towards the pole, colpus membrane mostly psilate or rarely echinate; sexine ornamentation suprareticulate-granulate; muri psilate or with sparse supramural granules, shallow or somewhat deeper, rounded to somewhat flat, wider than lumina; lumina small, distinct, tectum distinctly perforate.

## G. tomentosa Fletcher (Figures 4.5C-D)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 31.0-31.8µm, equatorial axis 16.5-17.3µm; colpi narrow, acute towards the pole, colpus membrane psilate; sexine ornamentation suprareticulate-spinulose; muri psilate or with sparse supramural spinules, shallow or somewhat deeper, rounded to somewhat flat, interrupted; lumina small to large, distinct, elongated to polygonal, tectum sparsely perforate.

## G. tonkinensis Moldenke (Figures 4.5E-F)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 34.2-35.0µm, equatorial axis 19.4-21.0µm; colpi narrow, obtuse towards the pole, colpus membrane psilate; sexine ornamentation suprareticulate; muri psilate, deep, rounded, interrupted; lumina large, distinct, polygonal, wider than muri, tectum distinctly perforate.

## Section: Asiaticum

#### G. annamensis Dop (Figures 4.6A-B)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 25.8-31.1µm, equatorial axis 13.3-21.8µm; colpi narrow, acute towards the pole, colpus membrane psilate; sexine ornamentation rugulate; muri psilate, somewhat flat, wider than lumina, shallow, interrupted and ridged; lumina narrow to indistinct, angular to elongate, tectum not perforate.

## Gmelina borneoense M. H. Rashid (Figures 4.6C-D)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 31.5-33.7µm, equatorial axis 19.6-21.7µm; colpi narrow, obtuse towards the pole, colpus membrane psilate; sexine ornamentation microreticulate; muri psilate, shallow, rounded, interrupted; lumina narrow to indistinct, tectum sparsely perforate.

#### G. hainanensis Oliver (Figures 4.6E-F)

Pollen isopolar, prolate or subprolate, tri-zonocolpate; polar outline elliptic, polar axis 31.0-32.6µm, equatorial axis 18.7-19.5µm; colpi narrow, acute towards the pole, colpus membrane psilate; sexine ornamentation suprareticulate; muri psilate, shallow, flat, interrupted; lumina small, elongated to polygonal, interrupted, distinct, tectum perforate.

## Gmelina obovata M. H. Rashid (Figures 4.7A-B)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 32.7-35.7µm, equatorial axis 22.3-23.8µm; colpi wide, acute towards the pole, colpus membrane psilate; sexine ornamentation rugulate; muri psilate, shallow to somewhat deeper, rounded, interrupted; lumina narrow to indistinct, tectum sparsely perforate.

#### Gmelina obovata var. Kutaiensis M. H. Rashid (Figures 4.7C-D)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 28.9-32.2µm, equatorial axis 22.4-24.0µm; colpi narrow, acute towards the pole, colpus membrane psilate; sexine ornamentation microreticulate; muri psilate or minutely granular, shallow or somewhat deeper, rounded, interrupted; lumina elongated to narrow or indistinct, tectum sparsely perforate.

## G. spectabilis Ridl. ex M. H. Rashid & A. J. Paton (Figures 4.7E-F)

Pollen isopolar, prolate, tri-zonocolpate; polar outline elliptic, polar axis 28.1-30.5µm, equatorial axis 22.3-23.1µm; colpi wide, acute towards the pole, colpus membrane psilate; sexine ornamentation microreticulate; muri psilate, shallow or somewhat deeper, rounded, interrupted; lumina narrow, somewhat distinct; tectum sparsely perforate.

## Gmelina tubularis M. H. Rashid & A. J. Paton (Figures 4.8A-B)

Pollen isopolar, prolate spheroidal, tri-zonocolpate; polar outline elliptic, polar axis 28.7-31.8µm, equatorial axis 25.5-30.5µm; colpi wide, acute towards the pole, colpus membrane psilate; sexine ornamentation rugulate; muri psilate, shallow, rounded, interrupted; lumina narrow to indistinct, tectum sparsely perforate.

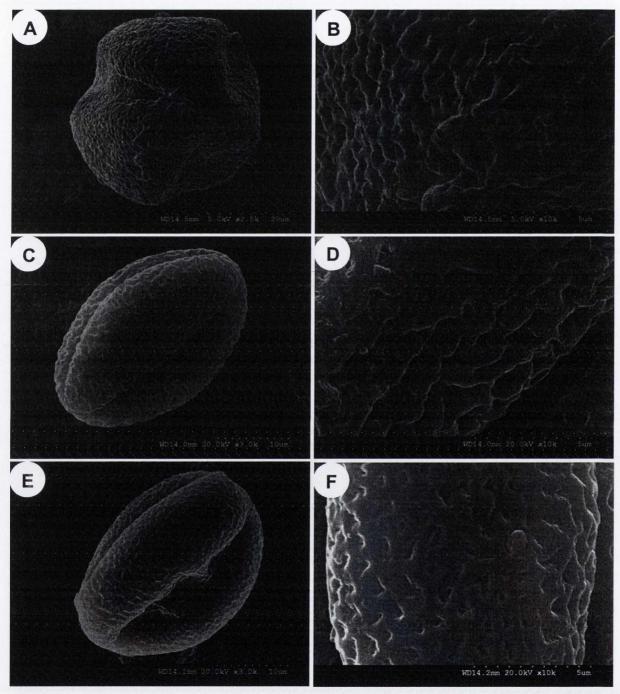
## G. uniflora Stapf. (Figure 4.8C)

Pollen isopolar, prolate spheroidal, tri-zonocolpate; polar outline elliptic, polar axis 27.4-29.2µm, equatorial axis 25.3-27.9µm; colpi wide, colpus ends acute towards the pole, colpus membrane psilate; sexine ornamentation rugulate; muri psilate, shallow or somewhat deeper, rounded, interrupted; lumina narrow to indistinct, tectum minutely perforate.

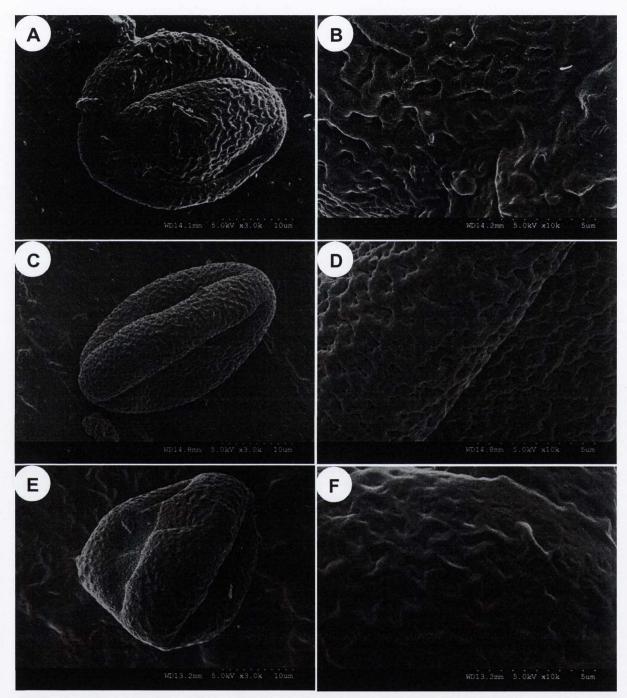
## Premna latifolia Roxb. (Figures 4.8D-E)

Pollen small, isopolar, oblate spheroidal, tri-zonocolpate; polar outline circular, polar axis 10.5-13.8µm, equatorial axis 13.2-16.4µm; colpi wide, colpus ends acute towards the pole, colpus membrane coarsely granular; sexine ornamentation psilate-foveolate, foveolae are distributed regularly over the whole surface.

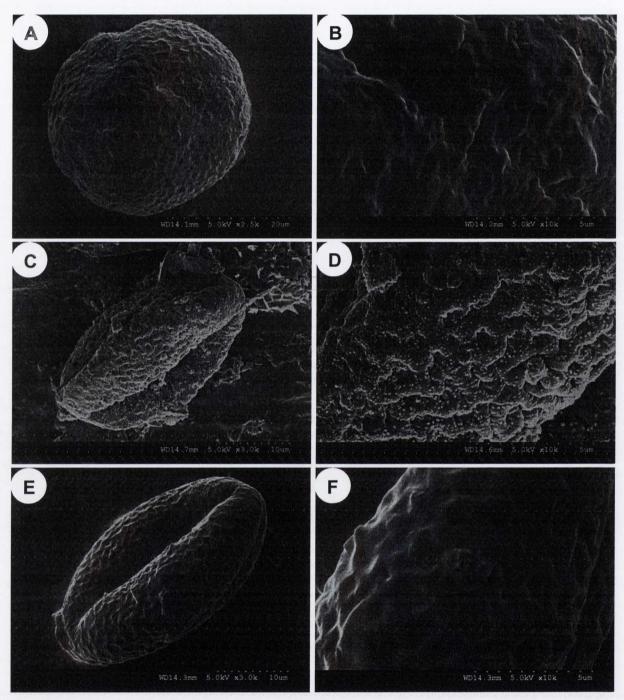
## Section: Asiaticum



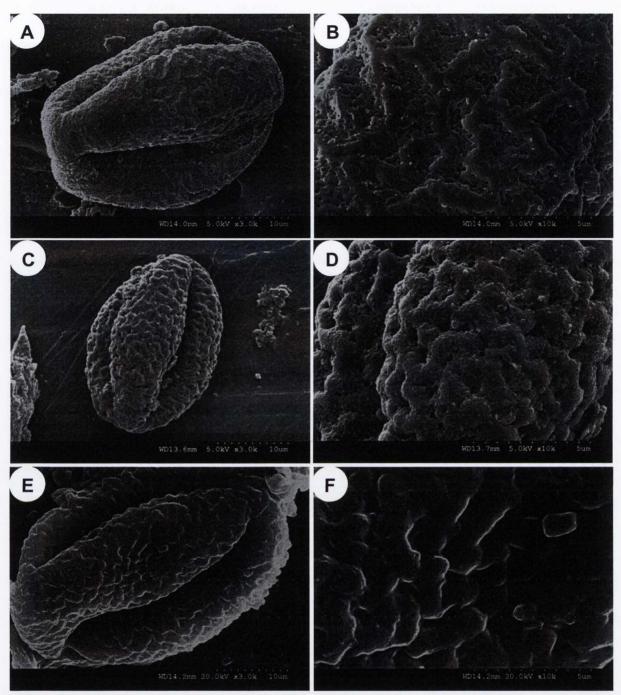
**Figure 4.1**. SEM micrographs of pollen. A-B) *G. arborea* [*Maxwell* 95-305, Thailand (A)]. A. whole grain, polar view; B. close up apocolpial reticulum. C-D) *G. asiatica* [*Kerr* 21527, Thailand (BM)]. C. whole grain, equatorial view; D. close up mesocolpial reticulum and aperture. E-F) *G. attenuata* [*Kerr* 6224, Thailand (BM)]. E. whole grain, equatorial view; F. close up mesocolpial reticulum and aperture.



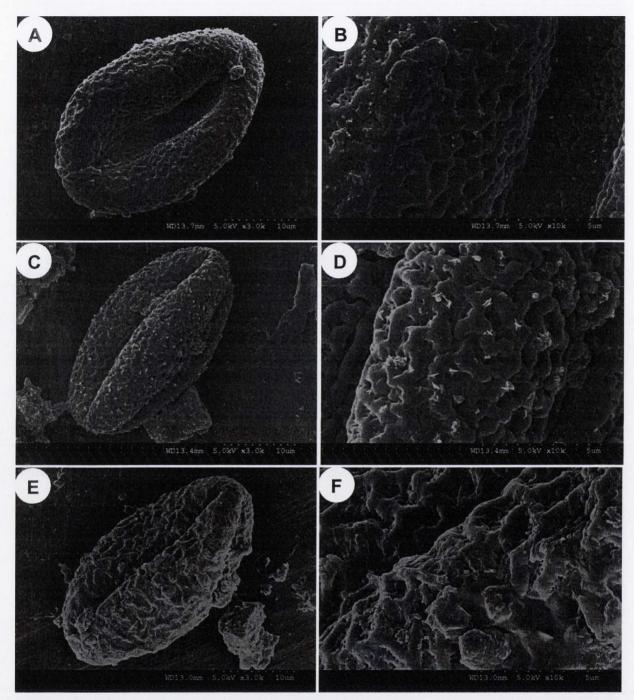
**Figure 4.2**. SEM micrographs of pollen. A-B) *G. chinensis* [*Chan* 1073, Homg Kong (A)]. A. whole grain, equatorial view; B. close up mesocolpial reticulum and aperture. C-D) *G. delavayana* [*Handel-Mazzetti nr.* 3373, China (A)]. C. whole grain, equatorial view; D. close up mesocolpial reticulum and aperture. E-F) *G. lepidota* [*Main & Aden* 1292, Indonesia (L)]. E. whole grain, equatorial view; F. close up mesocolpial reticulum.



**Figure 4.3**. SEM micrographs of pollen. A-B) *G. moluccana* [*Herb. Lugd. Bat.* 909.109.416, Indonesia (L)]. A. whole grain, polar view; B. close up apocolpial reticulum and aperture. C-D) *G. palawensis* [*Stone* 4578, Indonesia (L)]. C. whole grain, equatorial view; D. close up mesocolpial reticulum and aperture. E-F) *G. paniculata* [*Put* 2086, Thailand (E)]. E. whole grain, equatorial view; F. close up mesocolpial reticulum and aperture.



**Figure 4.4**. SEM micrographs of pollen. A-B) *G. philippensis* [*Monyrak et al.* 452, Cambodia (K)]. A. whole grain, equatorial view; B. lose up mesocolpial reticulum. C-D) *G. racemosa* [*Pooma et al.* 4144, Thailand (TCD)]. C. whole grain, equatorial view; D. close up mesocolpial reticulum and aperture. E-F) *G. racemosa* [Balansa 3806, Vietnam (L)]. E. whole grain, equatorial view; F. close up mesocolpial reticulum and aperture.



**Figure 4.5.** SEM micrographs of pollen. A-B) *G. schlechteri* [*Nooteboom nr.* 5800, Indonesia (KEP)]. A. whole grain, equatorial view; B. close up mesocolpial reticulum and aperture. C-D) *G. tomentosa* [*Noe* 211, Thailand (E)]. C. whole grain, equatorial view; D. close up mesocolpial reticulum, and aperture. E-F) *G. tonkinensis* [*Balansa* 3807, Vietnam (P)]. E. whole grain, equatorial view; F. close up mesocolpial reticulum and aperture.

## Section: Annameticum

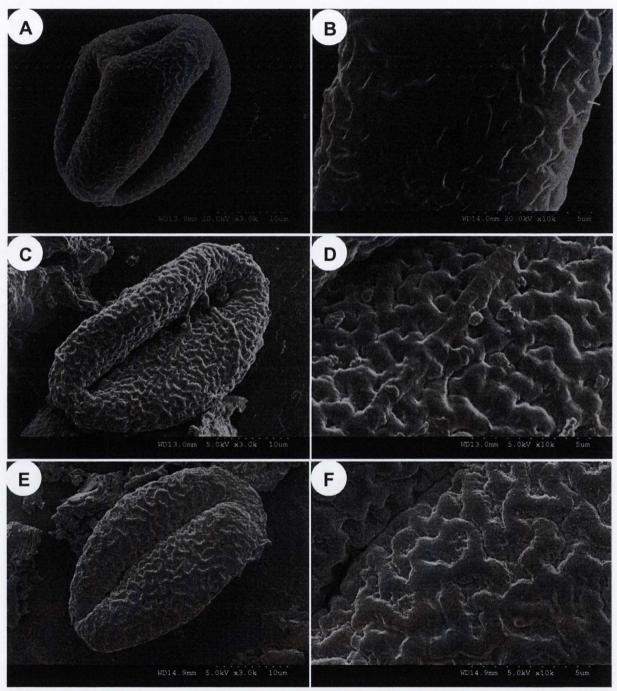
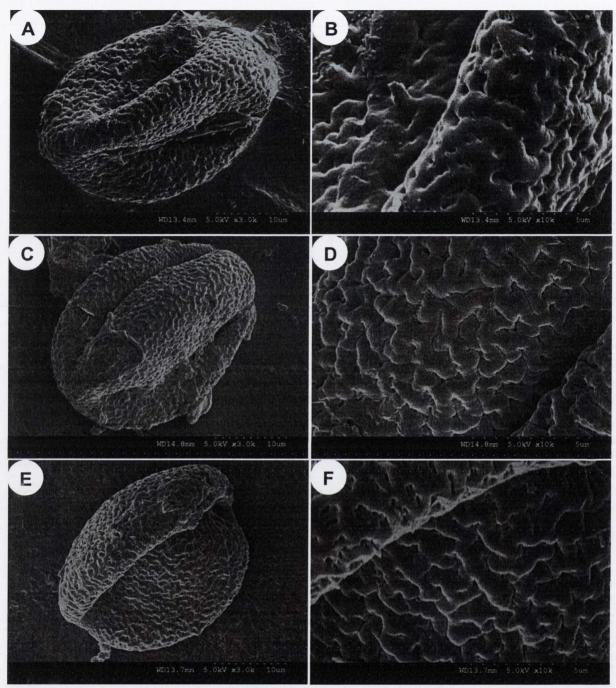
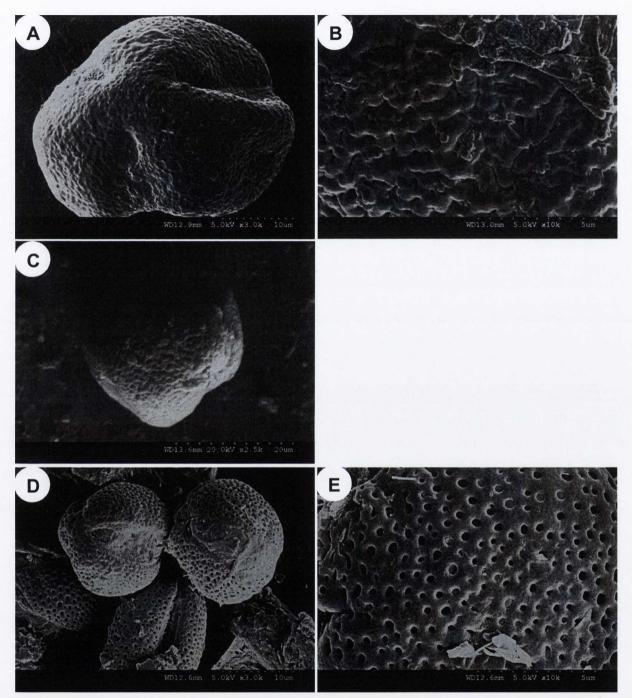


Figure 4.6. SEM micrographs of pollen. A-B) *G. annamensis* [*Poilane* 13301, Vietnam (P)]. A. whole grain, equatorial view; B. close up mesocolpial reticulum and aperture. C-D) *G. borneoense* [*Jaheri* 1300; Indonesia (L)]. G. whole grain, equatorial view; H. close up mesocolpial reticulum and aperture. E-F) *G. hainanensis* [*Tsang* 29235, Vietnam (A)]. G. whole grain, equatorial view; H. close up mesocolpial reticulum and aperture.



**Figure 4.7**. SEM micrographs of pollen. A-B) *G.obovata* [*Sinclair et al.* 9263, Indonesia (L)]. A. whole grain, equatorial view; B. close up mesocolpial reticulm and aperture. C-D) *G.obovata* var. *kutaiensis* [*Kosterman* 10.521; Indonesia (SING)]. C. whole grain, equatorial view; D. close up mesocolpial reticulum and aperture. E-F) *G. spectabilis* [*Haviland & Hose* 919, Indonesia (A)]. E. whole grain, polar view; F. close up apocolpial reticulum.



**Figure 4.8**. SEM micrographs of pollen. A-B) *G. tubularis* [*Veldkamp* 8453<sup>A</sup>, Indonesia (L)]. A. whole grain, polar view; B. close up apocolpial reticulum. C) whole grain and equatorial view of *G. uniflora* [*Motley* 1204, Indonesia (K)]. D-E) *Premna latifolia* [*s.n.* India (K)]. D. whole grains; E. close up surface sculpture.

## 4.5. Discussion

The pollen morphology of Gmelina species is taxonomically important.

All *Gmelina* species except *G. arborea*, *G. brasii*, and *G. philippensis* have been investigated here for the first time. *G. arborea* and *G. philippensis* have been examined by Mathew & Shah (1988); and Abu-Asab & Cantino (1993a) examined *G. arborea*, and *G. brasii*; their results conform to the present study. However, the pollen size and shape of *G. philippensis* I recorded differs from Mathew & Shah (1988). Pollen data of *G. brasii* has been adopted from Abu-Asab & Cantino (1993a).

All grains examined are isopolar with only one exception, heteropolar in *G. lepidota* (Figure 4.2E), trizonocolpate and more or less radially symmetrical. In polar view grains are circular and in equatorial view, elliptic. The pollen shape ranges mostly from prolate (P/E 1.3-1.88), subprolate (P/E 1.14-1.23) or oblate spheroidal (P/E 0.94) to prolate spheroidal (P/E 1.06-1.11). Average (mean) dimensions are: Polar length (21.0-)23.4(-26.0) to  $(42.0-)42.9(-44.0)\mu$ m; Equatorial width (16.5-)16.7(-17.3) to  $(32.0-)33.4(-35.0)\mu$ m. Colpus length (11.1-)14.1(-15.7) to  $(29.3-)30.0(-30.3)\mu$ m; Colpus width (0.7-)0.8(0.9) to  $(9.1-)10.6(12.4)\mu$ m (Table 4.1). The muri are rounded and shallow, mostly psilate and rarely granulate to spinulose; lumina are mostly indistinct, small, rarely large, interrupted, angular to elongated, sometimes with secondary reticulate perforations. Differences in pollen shape and aperture types are not particularly significant as prolate, subprolate or prolate spheroidal grains and tri-zonocolpate are dominant in all species.

Following the circumscription of the pollen grain size classes of Erdtman (1952), all *Gmelina* species examined fall in the medium sized group (25-50µm); though pollen of *Premna latifolia* (Figure 4.8D) is smaller in size and falls in the small sized (10-25µm) group (Table 4.1; Plot 4.1).

A plot of polar length (P) and equatorial width (E) shows differences among the species (Plot 4.1). Analysis of the mean P and E values shows that *G. tubularis* possess the largest pollen. *P. latifolia* has the shortest polar length and equatorial width and therefore the smallest pollen; and in *Gmelina*, the longest polar length is recorded in Vietnamese population of *G. racemosa* and *G. philippensis*, whereas, *G. brasii* possess the shortest polar length (among the Southeast Asian species *G. lepidota* has the shortest polar length); and *G. tomentosa* shows the shortest equatorial width. Unlike all other species examined, equatorial width is longer than the polar length in *G. brasii*, *G. moluccana;* and *P. latifolia* (Table 4.1; Plot 4.1).

All the species examined possess differences in polar length and equatorial width, whilst *G. arborea*, *G. lepidota*, *G. moluccana*, *G. tubularis*, *G. uniflora*, and *P. latifolia* show the least difference (Plot 4.1).

The widest colpus is recorded in *G. moluccana*, and *G. spectabilis*; and the narrowest in *G. delavayana*, and *G. hainanensis*.

According to Brochmann (1992), sculptural ornamentation of pollen is useful in ascertaining relationships among species. In the genus *Gmelina*, I recognise five types of sculptural patterns:

- i) Suprareticulate: supratectal ridges form a reticulate pattern
- ii) Suprareticulate-spinulose or -granulate: sculpture composed of a suprareticulum bearing spines or granular elements
- iii) Microreticulate: reticulate exine where the lumina are smaller than 1µm in diameter
- iv) Microreticulate-granulate: sculpture composed of a microreticulum bearing granular elements
- v) Rugulate: exine bears irregular, undulating supratectal ridges

The exine in species I examined has two types of tectum: *psilate*, and *spinulose or granulate*. They are referred as Type I and Type II respectively.

The psilate tectum (Type I) is observed in almost all of the species examined, except *G. palawensis* (tectumgranulate, Figure 4.3C-D), *G. schlechterii*, and *G. tomentosa* (tectum-spinulose, Figures 4.5A-B and 4.5C-D respectively) which are fall in Type II.

## Pollen Type I

This pollen type is characterised by psilate tectum. This is the most common pollen type among *Gmelina* species. Three subtypes are defined based mainly on sculptural ornamentations:

**Subtype I** has microreticulate surface ornamentations; elongated to narrow lumina with minute or sparsely perforate tectum. In this subtype muri may be deep as in *G. arborea* (Figure 4.1A-B), *G. racemosa* (Figure 4.4C-D), and *G. borneoense* (Figure 4.6C-D); or shallow to somewhat deeper in *G. asiatica* (Figure 4.1C-D), *G. spectabilis* (Figure 4.7E-F), and in *G. obovata* var. *kutaiensis* (Figure 4.7C-D).

**Subtype II** has suprareticulate ornamentations with distinct lumina and sparse to distinct tectum perforations. In this subtype muri may be deep and lumina polygonal, as in *G. chinensis* (Figure 4.2A-B), *G. tonkinensis* (Figure 4.5E-F); or shallow muri and polygonal lumina in *G. hainanensis* (Figure 4.6E-F), and *G. philippensis* (Figure 4.4A-B), or muri shallow to somewhat deeper with elongated or polygonal lumina in *G. attenuata* (Figure 4.1E-F), *G. delavayana* (Figure 4.2C-D), and in *G. paniculata* (Figure 4.3E-F).

**Subtype III** sculptural ornamentation rugulate, lumina mostly narrow, rarely small and indistinct. In this subtype pollen shape may be prolate as in *G. annamensis* (Figure 4.6A-B), and in *G. obovata* (Figure 4.7A-B); or subprolate in *G. lepidota* (Figure 4.2E-F); or oblate spheroidal in *G. moluccana* (Figure 4.3A-B); or prolate spheroidal in *G. tubularis* (Figure 4.8A-B), and in *G. uniflora* (Figure 4.8C).

## Pollen Type II

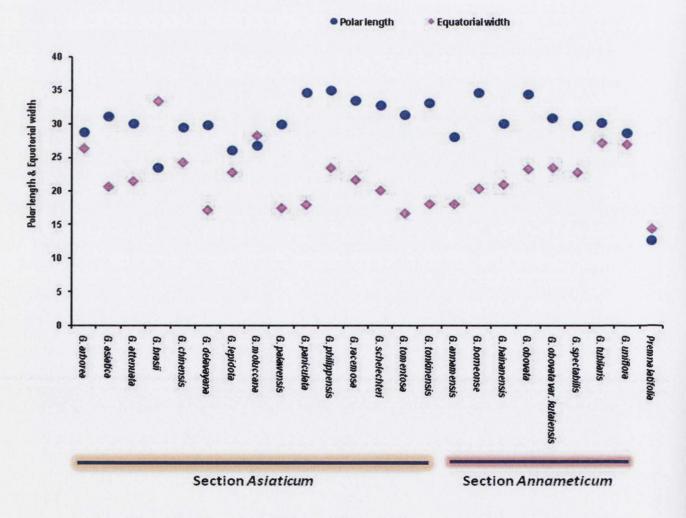
Granulate or spinulose tectum (Pollen Type II) is observed only in a small group of *Gmelina* species, which can be further divided in to two subtypes:

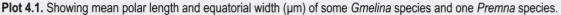
**Subtype I** has microreticulate-granulate ornamentations observed in *G. palawensis* (Figure 4.3C-D) and G. *schlechterii* (Figures 4.5A-B).

Subtype II with suprareticulate-spinulose ornamentations, as only in G. tomentosa (Figures 4.5C-D).

Infrageneric classification proposed in Chapter 2 is not well supported by the palynological data. However, the pollen of all species belong to the section *Annameticum* are isopolar and have psilate muri; while species of the section *Asiaticum* have isopolar or heteropolar pollen; and their muri psilate and/or psilate-granulate, or psilate-spinulose.

Only one *Premna* species was examined in this study. Both size and surface ornamentation (Figure 4.8D-E) shows its incongruence with the *Gmelina*. Further palynological observations of more species might show greater resolutions of its relationships to the genus *Gmelina*.





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Column 1: Species; Column 2: Vouchers+; Column 3: Polar length (P); Column 4: Equatorial width (E); Column 5: P/E ratio; Column 6: Shape; Column 7: Colpus length; Column 8: Column 9: Muri width; Column 10: Polarity; Column 11: Sculpture.

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1	2	3	4	2	9	_	8	6	10	11
Section: Asiaticum										
G. arborea	Maxwell 95-305; Thailand (A)	(25.8-) 28.7 (-33.5)	(22.4-) 26.4 (-31.5)	1.09	Prolate spheroidal	(11.1-) 14.4 (-18.5)	(3.5-) 4.2 (-5.1)	0.6	Isopolar	Microreticulate
G. asiatica	Kerr 21527; Thailand (BM)	(30.0-) 31.1 (-32.0)	(20.1-) 20.7 (-21.0)	1.51	Prolate	(21.3-) 23.2 (-25.6)	(1.0-) 1.2 (-1.3)	0.8	Isopolar	Microreticulate
G. attenuata	Kerr 6224; Thailand (BM)	(28.9-) 30.1 (-30.5)	(20.9-) 21.5 (-21.7)	1.41	Prolate	(21.9-) 22.9 (-23.6)	(2.8-) 4.2 (-5.0)	0.6	Isopolar	Suprareticulate
G. brasii*	1	(21.0-) 23.4 (-26.0)	(32.0-) 33.4 (-35.0)	0.7	Euoblate-suboblate	ı	1	ţ	Isopolar	ı
G. chinensis	Chan 1073; Homg Kong (A)	(29.1-) 29.5 (-29.9)	(22.4-) 24.3 (-25.3)	1.21	Subprolate	(16.7-) 19.3 (-21.4)	(0.8-) 1.6 (-1.8)	0.8	Isopolar	Suprareticulate
G. delavayana	Handel-Mazzetti nr. 3373; China (A)	(28.1-) 29.8 (-30.9)	(16.5-) 17.2 (-17.7)	1.73	Prolate	(23.4-) 24.8 (-26.4)	(0.7-) 0.8 (-0.9)	0.6	Isopolar	Suprareticulate
G. lepidota	Main & Aden 1292; Indonesia (L)	(24.6-) 26.0 (-26.8)	(21.5-) 22.8 (-23.8)	1.14	Subprolate	(18.5-) 20.3 (-21.1)	(3.4-) 3.7 (-4.0)	0.5	Heteropolar	Rugulate
G. moluccana	Herb. Lugd. Bat. 909.109.416; Indonesia (L)	(23.0-) 26.8 (-29.4)	(26.1-) 28.3 (-31.8)	0.94	Oblate spheroidal	(15.5-) 17.3 (-19.0)	(9.1-) 10.6 (-12.4)	0.6	Isopolar	Rugulate
G. palawensis	Stone 4578; Indonesia (L)	(27.5-) 29.9 (-30.9)	(16.6-) 17.5 (-17.8)	1.71	Prolate	(24.4-) 24.8 (-25.4)	(0.9-) 1.1 (-1.3)	0.9	Isopolar	Microreticulate-granulate
G. paniculata	Put 2086; Thailand (E)	(34.1-) 34.7 (-35.1)	(18.2-) 18.0 (-19.1)	1.85	Prolate	(27.7-) 28.1 (-28.5)	(2.0-) 2.4 (-2.7)	0.6	Isopolar	Suprareticulate
G. philippensis	Monyrak et al. 452; Cambodia (K)	(34.5-) 35.0 (-35.4)	(21.4-) 23.5 (-24.7)	1.49	Prolate	(25.4-) 26.6 (-27.6)	(1.7-) 2.5 (-2.9)	0.9	Isopolar	Suprareticulate
G. racemosa	Pooma et al. 4144; Thailand (TCD)	(25.4-) 26.1 (-26.6)	(18.0-) 18.3 (-18.6)	1.43	Prolate	(18.7-) 19.2 (-19.4)	(0.7-) 1.0 (-1.2)	0.9	Isopolar	Microreticulate
	Blansa 3806; Vietnam (L)	(42.0-) 42.9 (-44.0)	(25.7-) 27.3 (-28.7)	1.57	Prolate	(29.3-) 30.0 (-30.3)	(1.1-) 1.4 (-1.8)	0.8	Isopolar	Rugulate
G. schelechteri	Nooteboom nr. 5800; Indonesia (KEP)	(31.5-) 32.8 (-33.7)	(19.6-) 20.1 (-21.7)	1.63	Prolate	(20.7-) 21.7 (-22.2)	(3.7-) 3.9 (-4.0)	0.8	Isopolar	Suprareticulate-granulate
G. tomentosa	Noe 211; Thailand (E)	(31.0-) 31.4 (-31.8)	(16.5-) 16.7 (-17.3)	1.88	Prolate	(24.1-) 24.9 (-25.6)	(1.1-) 1.2 (-1.4)	0.7	Isopolar	Suprareticulate-spinulose
G. tonkinensis	Balansa 3807; Vietnam (P)	(32.0-) 33.1 (-33.7)	(17.7-) 18.1 (-18.4)	1.83	Prolate	(24.6-) 25.1 (-25.8)	(0.9-) 1.2 (-1.4)	0.8	Isopolar	Suprareticulate
Section: Annameticum										
G. annamensis	Poilane 13301; Vietnam (P)	(25.8-) 28.1 (-31.1)	(13.3-) 18.1 (-21.8)	1.55	Prolate	(14.8-) 19.5 (-24.9)	(1.2-) 1.6 (-1.8)	0.7	Isopolar	Rugulate
G. borneoense	Jaheri 1300; Indonesia (L)	(34.2-) 34.6 (-35.0)	(19.4-) 20.4 (-21.0)	1.7	Prolate	(24.5-) 24.8 (-25.1)	(2.0-) 2.7 (-3.4)	0.9	Isopolar	Microreticulate
G. hainanensis	Tsang 29235; Vietnam (A)	(31.0-) 32.0 (-32.6)	(18.7-) 19.1 (-19.5)	1.68	Prolate	(24.6-) 25.1 (-25.4)	(1.4-) 1.5 (-1.6)	0.8	Isopolar	Suprareticulate
G. obovata	Sinclair et al. 9263; Sabah, Malaysia (L)	(32.7-) 34.4 (-35.7)	(22.3-) 23.3 (-23.8)	1.48	Prolate	(17.8-) 19.6 (-21.6)	(3.0-) 3.6 (-4.5)	0.9	Isopolar	Rugulate
G. obovata var. kutaiensis	Kosterman 10.521; Sarawak, Malaysia (K)	(28.9-) 30.9 (-32.2)	(22.4-) 23.5 (-24.0)	1.31	Prolate	(20.6-) 21.8 (-23.4)	(0.9-) 1.1 (-1.5)	0.8	Isopolar	Microreticulate
G. spectabilis	Haviland 1547; Sarawak, Malaysia (K)	(28.1-) 29.7 (-30.5)	(22.3-) 22.8 (-23.1)	1.3	Prolate	(23.7-) 24.1 (-24.5)	(1.8-) 2.6 (-3.1)	0.9	Isopolar	Microreticulate
G. tubularis	Veldkamp 8453A; Kalimantan, Indonesia (L)	(28.7-) 30.2 (-31.8)	(25.5-) 27.2 (-30.5)	1.11	Prolate spheroidal	(12.4-) 13.6 (-15.0)	(5.5-) 6.0 (-6.3)	0.7	Isopolar	Rugulate
G. uniflora	Motley 1204; Indonesia; (K)	(27.4-) 28.6 (-29.2)	(25.3-) 27.0 (-27.9)	1.06	Prolate spheroidal	(13.3-) 14.1 (-15.7)	(3.0-) 3.5 (-4.0)	0.7	Isopolar	Rugulate
Premna latifolia	Hooker s.n.; India (K)	(10.5-) 12.6 (-13.8)	(13.2-) 14.4 (-16.4)	0.88	Oblate spheroidal	(11.4-) 12.0 (-14.0)	(3.7-) 5.0 (-6.0)	0.6	Isopolar	Psilate-foveolate
* Date farm Abor Arch & Construct (1003-b)										

The differences between the species in pollen characteristics allowed construction of a key to species:

1 Pollen surface granulate or spinulose	2
- Pollen surface psilate	5
2 Sculpture microreticulate, densely granular	G. palawensis
- Sculpture suprareticulate, spinulose or sparsely granular	3
3 Muri with supramural spinulose	G. tomentosa
- Muri sparsely granular	4
4 Muri flat, lumina large	G. philippensis
- Muri rounded or somewhat flat, lumina small	G. schlechterii
5 Pollen isopolar	6
- Pollen heteropolar	G. lepidota
6 Equatorial width larger than polar length	G. brasii
- Equatorial width not larger than polar length	7
7 Sculptural ornamentations reticulate	8
- Sculptural ornamentations rugulate	19
8 Ornamentation microreticulate	9
- Ornamentation suprareticulate	14
9 Pollen shape prolate	10
- Pollen shape prolate - spheroidal	G. arborea
10 Muri deep; polar length < 30 $\mu$ m; equatorial width < 20 $\mu$ m	G. racemosa*
- Muri shallow or somewhat deeper; polar length $30\mu m$ or more; equatorial width > 20	0μm 11
11 Colpus ends obtuse towards the pole	G. borneoense
- Colpus ends acute towards the pole	12
12 Polar length to $30 \mu m$ ; lumina narrow, somewhat distinct	G. spectabilis
- Polar length > 30μm; lumina indistinct	13
13 Equatorial width 22-24 $\mu m$ ; colpus length 20-23 $\mu m$	obovata var. kutaiensis
- Equatorial width 20-21μm; colpus length 21-25μm	G. asiatica
14 Lumina wider	15
- Lumina narrow	17
15 Muri flat	G. hainanensis
- Muri rounded	16
16 Colpus width > 20μm; Muri shallow	G. paniculata
- Colpus width < 20μm; Muri deep	G. tonkinensis
17 Pollen prolate; colpus wider; muri flat	G. attenuata
- Pollen subprolate or prolate; colpus narrow; muri rounded to somewhat flat	18
18 Pollen subprolate; muri deeper; lumina angular to elongate	G. chinensis

G. delavayana
G. moluccana
20
21
22
G. annamensis
G. obovata
G. tubularis
G. uniflora

<sup>\*</sup> Unlike all others (23.4 - 34.6µm), the longest pollen grain was found in the Vietnamese population of *G. racemosa* (42 - 44µm), whereas the pollen of Thai population has 25.4-26.6µm polar length (Table 4.1). The pollen grain of the Thai population is taken as more likely representatives as it is within the normal length range in the genus.

# **CHAPTER 5**

# Phylogeny of Gmelina

The genus *Gmelina* belongs to tribe Viticeae and subfamily Viticoideae. The recent re-classification of the family Lamiaceae by Harley *et al.* (2004), and molecular phylogenetic work has shown that the subfamily Viticoideae is not a natural group, and the placement of economically important genera such as *Tectona* and *Vitex* is uncertain. The Viticoideae are also poorly known taxonomically, and are hence becoming a new focus for Lamiaceae research. The phylogenetic study of the genus *Gmelina* presented here will contribute to the systematic understanding of this group.

## 5.1. Introduction to cladistics and phylogenetics

One of the most popular methods used in the field of biological systematics is cladistics, which was first introduced by the German entomologist Willi Hennig in 1950 in the book *Grundzüge einer Theorie der Phylogentischen Systematik* later translated into English in 1965 & 1966 under the title *Phylogenetic Systematics*. Hennig offered a precise definition of biological relationship and how this relationship may be discovered. Mayr (1969) coined the term *Cladism* or *Cladistics*. The use of cladistics has continued to expand (Steussy 2009). In many ways, cladistic techniques offer explicit reconstructions of phylogenetic relationships and have now become central to all aspects of comparative biology (Steussy 2009). Several related methods (Table 5.1) have also recently gained prominence including maximum likelihood and Bayesian approaches to phylogenetics (Holder and Lewis 2003; Soltis *et al.* 2004, 2007; Stuessy 2009).

Method	Advantages	Disadvantages	Software
Neighbour Joining	Fast	Information is lost in compressing sequences into distances; reliable estimates of pairwise distances can be hard to obtain for divergent sequences	PAUP* MEGA PHYLIP
Parsimony	Fast enough for the analysis of hundreds of sequences; robust if branches are short (closely related sequences or dense sampling)	Can perform poorly if there is substantial variation in branch lengths	PAUP* NONA MEGA PHYLIP
Minimum evolution	Uses models to correct for unseen changes	Distance corrections can break down when distances are large	PAUP* MEGA PHYLIP
Maximum likelihood	The likelihood fully captures what the data tell us about the phylogeny under a given model	Can be rohibitively slow (depending on the thoroughness of the search ansd access to computational resources	PAUP* PAML PHYLIP
Bayesian	Has a strong connection to the maximum likelihood method; might be a faster way to assess support for trees than maximum likelihood bootstrapping	The prior distributions for parameters must be specified; it can be difficult to determine whether the Markov chain Monte Cario (MCMC) approximation has run for long enough	MrBayes BAMBE

Table 5.1. Comparison of different phylogenetic methods (Taken from Holder and Lewis 2003).

In cladistic analysis, observations are translated into discrete characters, and character states are coded. Hennig defined two types of homologous characters: *plesiomorphic*, which occur in the ancestral morphotypes, and *apomorphic*, which occur in the descendants. Cladistic methods determine the sister group relationships of taxa, which includes the most closely related taxa with shared apomorphies. It expresses their hierarchy in terms of branching diagrams, called *cladograms*.

In character definition, assessment of homology is important. Homology denotes shared common ancestry and is thus qualitative (Doyle & Davis 1998). The degree of similarity is a valid criterion for hypothesising homology. Analogous structures are similar in appearance or function but have different origins. Homoplasy is interpreted as similarity that has different origin and is therefore not homologous.

In cladistics, groups of taxa are classified hierarchically into nested sets or clades. One of the principal aims of cladistics is to determine monophyletic groups that are derived from a single ancestor. Polyphyletic groups arise from more than one ancestor. A paraphyletic group includes only some descendants of a common ancestor. In cladistic analyses three steps are undertaken: characters and taxa selection; coding characters; and determination of cladograms that best explain the distribution of characters over the taxa (Kitching *et al.* 1998).

Of the two types of homologies, shared ancestral characteristics (*sympleisiomorphy*) and shared derived characters (*synapomorphy*) are of differing value to phylogenetic analysis (Scotland 1992). The common possession of characteristics, which have remained unchanged for long periods of time, cannot be evidence of close relationships; therefore sympleisiomorphic characters are not informative for establishing evolutionary relationships within a study group (Hennig 1966). The possession of shared derived characters is, however, informative of phylogenetic relationships between groups of organisms. In essence, the presence of common apomorphic traits in a group is an indication of that they have a shared ancestry *i.e.* that they are a monophyletic group. Of course concepts of what indicates pleisiomorphic or apomorphic characteristics are all relative. The presence of sepals and petals in one group of plants may be considered as a synapomorphy but at a different level in the same group it may be considered a sympleisiomorphy. The idea of relativity is important because what constitutes a monophyletic group at one hierarchical level does not at another (Minelli 1993). Therefore characters change from being informative to uninformative at different levels of hierarchy in the phylogenetic tree).

#### 5.1.1. Molecular phylogenetics

Molecular phylogenetics can be used as a method for assessing classification of taxa at different ranks according to their genetic affinities and phylogenetic relationships. It has been implemented in different plant families and provided valuable data for phylogeny reconstruction. The use of molecular data in plant systematics has become an essential tool to understanding the relationships among taxa at different levels (Soltis & Soltis 1995; Holder and Lewis 2003; Soltis *et al.* 2004, 2005; Judd *et al.* 2008).

The field of molecular systematics has been developed rapidly in recent years (Kuzoff & Gasser 2000; Savolainen & Chase 2003; Soltis *et al.* 2004; Stace 2005; Mathews 2009). Rapid improvements in

molecular techniques, in particular wide use of the polymerase chain reaction (PCR) that makes DNA amplification and sequencing accessible have led to many changes in the field of plant systematics. Molecular data have been extensively used to investigate relationships in flowering plants (Taberlet *et al.* 1991; Kita *et al.* 1995; Bayer & Starr 1998; Savolainen *et al.* 2000a, 2000b; APG II 2003; Savolainen & Chase 2003; Soltis *et al.* 2004, 2005, 2007; Qiu *et al.* 2005; Mathews 2009). The plastid genome, chloroplast DNA (cpDNA) has been widely used as source of characters for phylogeny reconstruction (*e.g.,* Chase *et al.* 1993; Savolainen *et al.* 2000a, 2000b; Soltis *et al.* 2000; Kelchner 2002; Qiu *et al.* 2005; Judd *et al.* 2008; Steussy 2009) but nuclear and mitochondrial DNA is also used (Soltis *et al.* 2000; Bergthorsson *et al.* 2003, 2004; Stace 2005; Qiu *et al.* 2005; Judd *et al.* 2008; Goremykin *et al.* 2009; Steussy 2009).

Although nucleic acid sequencing is a relatively new approach in plant systematics, the power of the technique and the data generated have made it become one of the most utilized of the molecular approaches for inferring phylogenetic history. DNA sequence data are highly informative for molecular phylogenetics, and comparative analyse of DNA sequences is becoming increasingly important in plant systematics (Doyle *et al.* 1992; Savolainen & Chase 2003; Qiu *et al.* 2005; Judd *et al.* 2008; Mathews 2009; Stuessy 2009). The primary challenge to using nucleotide characters for lower level phylogenetic studies is the identification of easily amplified and relatively rapidly evolving, but unambiguously alignable DNA, regions that can provide sufficient, suitable variation within a short segment of DNA.

Unlike animals, in addition to the nuclear (nDNA) and mitochondrial DNA (mtDNA) plants also have chloroplast DNA (cpDNA) genome. Because of its complexity and repetitive properties, the nuclear genome is little used in systematic botany. It is often more technically demanding to work with because of allelic differences and pseudogenes. The mitochondrial genome can be used at the species level due to rapid changes in its structure, size, configuration, and gene order (Palmer & Herbon 1988; Luo & Boutry 1995; Bergthorsson *et al.* 2003, 2004; Knoop 2004; Seberg & Peterson 2006; Goremykin *et al.* 2009; Steussy 2009). On the other hand, cpDNA is popular for phylogenetic analysis because of the relative abundance of cpDNA that facilitates easy extraction and analysis, and because different parts of the genome evolve at different rates (Clegg & Zurawski 1992; Bakker *et al.* 1999). The latter feature makes the chloroplast genome suitable for phylogenetic analyses at different taxonomic levels, from the intraspecific level (*e.g.* Clegg *et al.* 1984a; 1984b; Lavin *et al.* 1991; Kim *et al.* 1992; Mort *et al.* 2007) to the family level and above (Chase *et al.* 1993; Bremer *et al.* 2002; APG II 2003; Qiu 2005; Soltis *et al.* 2007). cpDNA sequence variations are now widely used to investigate interspecific relationships (Taberlet *et al.* 1991; Soltis *et al.* 1998; Hodkinson *et al.* 2002).

Molecular data have been used to investigate and resolve phylogenetic relationships within the Lamiaceae *s. l.* (*e.g.*, Kaufmann & Wink 1994; Wagstaff *et al.* 1995, 1997, 1998; Steane *et al.* 1997, 1999; Wagstaff & Olmstead 1997; Cantino *et al.* 1999; Jamzad *et al.* 2003; Steane *et al.* 2004; Paton *et al.* 2004). Cantino *et al.* (1992) found that subfamily Viticoideae were paraphyletic and might be outlying within the family; however, *rbcL* sequences suggested that the Viticoideae were either paraphyletic or polyphyletic

(Wagstaff & Olmstead 1997). Monophyly of the subfamily was not supported by either *rbcL* and *ndh*F or the combined analysis (Figure 5.1) in the study by Wagstaff et al. (1998), where the Viticoideae was not resolved. Only a few members of Viticoideae have been included in previous studies and no phylogenetic studies have been carried out to resolve the relationships within the genus *Gmelina*, its tribe Viticeae or even its subfamily Viticoideae.

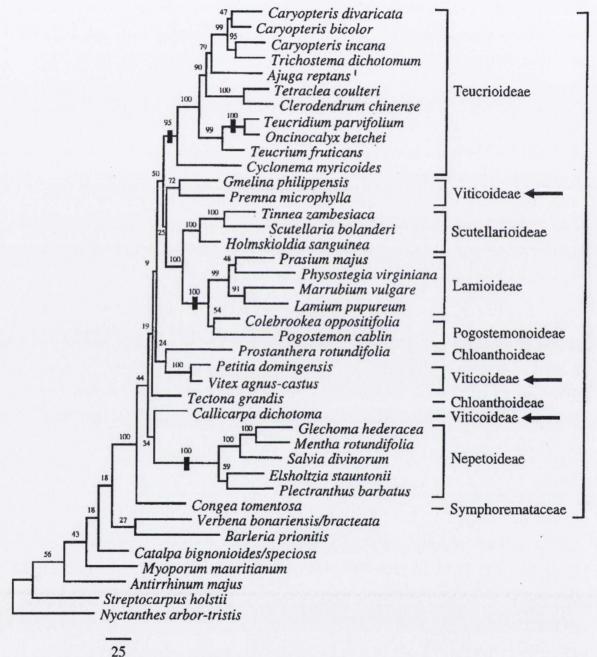


Figure 5.1. Single most parsimonious tree resulting from combined *rbcL* and *ndh*F data sets. Bootstrap values and the presence of indels indicated by bold bars (Taken form Wagstaff *et al.* 1998). Arrows highlight the non-monophyly of Viticoideae

### 5.2. Systematics of Gmelina: genetic regions implemented

Non-coding chloroplast DNA sequences are increasingly becoming useful tools for phylogenetic studies (Hodkinson et al. 2002; Tam et al. 2004; Qiu et al. 2005; Judd et al. 2008; Stuessy 2009; Sungkaew et al. 2009). Consequently, three non-coding regions- *trnL* intron, intergenic spacer between *trnL* and *trn*F, and *atpB-rbcL* intergenic region have been sequenced in this thesis. The *trnL-trn*F (hereafter *trnL-F*) intron and intergenic spacer region (Figure 5.2), *ca.*~500-900bp, lies in the large single copy region of the plastid genome. It includes two large non-coding regions: the *trnL* intron [between *trnL* (UAA) 5' exon and *trnL* (UAA) 3' exon] and the *trnL-F* intergenic spacer [between *trnL* (UAA) 3' exon and *trnF* (GAA) gene]. Previous systematic studies have shown that the *trnL-F* non-coding regions are useful in resolving phylogenetic relationships between closely related taxa (Taberlet *et al.* 1991; Soltis *et al.* 2000) and has been widely used for phylogenetic studies (*e.g.*, Gielly & Taberlet 1994, 1996; Kita et al. 1995; Bayer & Starr 1998; Kelchner 2000; Sheahan & Chase 2000; Hodkinson et al. 2002; Tam *et al.* 2004; Stuessy 2009; Sungkaew et al. 2009). Primer positions for amplification are also shown in Figure 5.2.

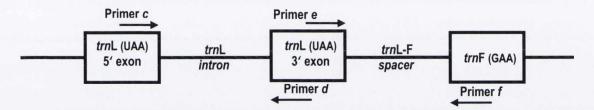
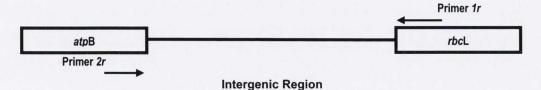
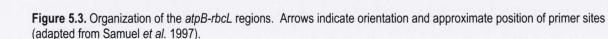


Figure 5.2. Organization of the *trnL-trn*F regions. Arrows indicate orientation and approximate position of primer sites (adapted from Taberlet *et al.* 1991).

The *atp*B-*rbc*L intergenic spacer (Figure 5.3), *ca.*~900bp (Soltis & Soltis 1998), has been widely used in plant systematics. It was amplified by using forward primer 2*r* and reverse primer 1*r* of Samuel et al. (1997). The *atp*B-*rbc*L intergenic region, which is non-coding region between the 3'ends of *atp*B and *rbc*L. It is particularly useful within and between genera, and species level (Manen *et al.* 1994; Natali *et al.* 1995; Savolainen *et al.* 1994, 1995; Soltis and Soltis 1998; Sungkaew *et al.* 2009).





#### 5.3. Aims and objectives

There has been no molecular study of the genus *Gmelina*. An understanding of its phylogeny and its relationships with other genera of the Viticoideae is crucial to the taxonomic understanding for the family as a whole. To my knowledge the *atpB-rbcL* region has never been used in phylogenetic studies of the family Lamiaceae. Therefore, in this study, the *trnL*-F and *atpB-rbcL* regions of cpDNA were sequenced to evaluate:

- the monophyly of Gmelina;
- the monophyletic groups within Gmelina;
- the phylogenetic relationships within Gmelina and allied genera (to see if they could be used for infrageneric classification);
- morphological character evolution with Gmelina;
- biogeographic patterns of Gmelina in a phylogenetic context.

### 5.4. Materials and methods

#### **Material Collection**

In this study mostly herbarium specimens were used with the permission from relevant herbaria. A few silica gel dried samples were collected from Bogor Botanic gardens and Thailand, and *G. schlechteri* was collected from Australia by Dr Trevor Hodkinson (TCD) in the alternative preservative solution of saturated CTAB. Initially 90 accessions (including outgroup) were sampled, but finally 50 accessions were successfully sequenced (**Appendix 3**). *Phlomis* was used as an out group because it is distantly related to *Gmelina* and the other taxa included in the ingroup but sufficiently similar to allow for reliable alignment of DNA sequences. *Gmelina* belongs to subfamily Viticoideae and tribe Viticeae. *Phlomis* belongs to subfamily Lamioideae.

#### Isolation of Total Genomic DNA

Total genomic DNA (tDNA) was extracted using a modification of the CTAB (hexadecyltrimethylammonium bromide) method of Doyle & Doyle (1987) and detailed in Hodkinson *et al.* (2007). In this study used 0.2g of fresh and clean dried leaf silica gel and 0.3g of material obtained from herbarium specimens to extract tDNA (see **Appendix 4**: Protocol 1). The supernatant was precipitated using isopropanol and kept at -20°C for 2-3 weeks.

#### Washing and purification of DNA

The crude total genomic DNA was then washed and purified using wash buffer (70% ethanol) and JETQUICK Spin Column respectively (see **Appendix 4**: Protocol 2 & 3). Each clean tDNA sample was then quantified using gel electrophoresis (see **Appendix 4**: Protocol 4). The DNA was then transferred into a 1.5ml microcentifuge centrifuge tube and stored at -20°C until used or at -80°C for long periods.

### Amplification of DNA target regions using PCR

The *tm*L-F and *atp*B-*rbc*L regions of cpDNA were amplified by the PCR. Amplification of the *tm*L-F regions (Figure 5.1) were carried out using the *forward primer c* and the *reverse primer f* (Taberlet *et al.* 1991). Since the DNA extracts were made from herbarium specimens, in some cases, *tm*L-F had to be amplified in two parts: with primer pairs "*c*" and "*d*" (to amplify the intron), and "*e*" and "*f*" (for amplification of the spacer). The *atp*B-*rbc*L spacer (Figure 5.2) was amplified using the *forward primer 2r* and the *reverse primer 1r* (Samuel *et al.* 1997). Each of the amplifications was carried out on a Biosystems GeneAmp PCR System 9700 for 30 cycles of the PCR reactions (see **Appendix 4**: Protocol 5). Sequences of all primers used are shown in Table 5.2. The amplification of the target fragment began with an initial premelt at 94°C for 1 min., followed by 30 cycles of denaturation at 95°C for 45 sec., annealing at 50°C (*tm*L-F) or 52°C (*atp*B-*rbc*L). A final extension of 72°C for 7 min. was also included. The PCR products were then quantified by gel electrophoresis (see **Appendix 4**: Protocol 4) and then purified by using JETQUICK Spin Columns (see **Appendix 4**: Protocol 3) and stored in a -20°C freezer prior to sequencing.

Target regions	Primer base sequences	References
trnL-F	5'-CGAAATCGGTAGACGCTACG-3'	
	5'-ATTTGAACTGGTGACACGAG-3'	Taberlet <i>et al.</i> 1991
	5'-GGGGATAGAGGGACTTGAAC-3'	
	5'-GGTTCAAGTCCCTCTACTCC-3'	
atpB-rbcL	5'-GAAGTAGTAGGATTGATTCTC-3'	Comucil of al. 1007
dipe not	5'-GTTTCTGTTTGTGGTGACAT-3'	Samuel et al. 1997

Table 5.2. Gene regions and primers used in this study

#### Purification of PCR product

All successful PCR products were purified prior to sequencing following the same procedures of Protocol 3 (see **Appendix 4**: Protocol 3). The only exception was that in this case sterile ultra pure water was used instead of TE buffer as the elution buffer.

### Cycle sequencing and purification

The clean PCR products were sequenced using BigDye Terminator v.1.1 cycle-sequencing kits (Applied Biosystems) and carried out on an Applied Biosystems GeneAmp® PCR System 9700. The sequencing reaction consisted of 1 to  $4\mu$ L of purified PCR product,  $1\mu$ L of Big Dye Cycle Sequencing Mix,  $1.8\mu$ L of sequencing buffer,  $0.7\mu$ L of primer and sterile ultra pure water (see **Appendix 4**: Protocol 6). Forward and reverse strands were sequenced in separate reaction. The cycle sequencing products were then purified using an ethanol and sodium acetate (see **Appendix 4**: Protocol 7), and the purified sequence products were then dried at room temperature overnight between tissue papers to remove any traces of ethanol and sodium acetate.

#### **DNA Sequencing**

The dried cycle sequencing products were re-suspended by using 25µL Hi-Di<sup>™</sup> Formamide and denatured prior to sequencing on the ABI Prism<sup>™</sup> 310 Genetic Analyzer machine (Applied Biosystems) using POP6 polymer (Applied Biosystems). Instruments were loaded using the run module SEQ POP6 RAPID (1.0-mL)E (**Appendix 4**: Protocol 8). The raw sequence data were analyzed using ABI Prism<sup>™</sup> DNA Sequencing Analysis Software, version 3.4.1., and assembled using Auto Assembler Software, version 2.1.

#### Data Analysis

The successful DNA sequences were edited and assembled using AutoAssembler Software, version 2.1. The sequences were then imported into PAUP 4.0 Beta 2 (Swofford 1998) for alignment, and aligned by eye using Se-AI v. 2.0a11 (Rambaut 1996) following the guidelines of Kelchner (2000). By meticulously editing the electropherograms base by base a number of incorrectly called bases were identified and corrected. Where alignment was questionable every polymorphic nucleotide within the final aligned matrix was checked against the original electropherogram to ensure that they were correct. Any sequence with large amounts of heterogeneity or that were poor quality were repeated or omitted from the final analysis. Regions of the sequence alignment that contained a substantial number of alignment gaps were omitted from the analyses, as the positional homology within these regions is generally uncertain (Swofford *et al.* 1996). Gaps were coded as missing data. All data were then analyzed by maximum parsimony using heuristic search options in PAUP 4.0 Beta 2. Searches included 1,000 replicates of random stepwise addition sequence (saving no more than 100 trees per replicate to reduce time spent swapping large islands of trees) with tree bisection-reconnection (TBR) branch-swapping per replicate. Bootstrapping included 1,000 replicates and the same heuristic search settings as the individual searches except that simple addition sequence was used instead of random stepwise addition.

#### 5.5 Results

#### 5.5.1 Analysis of trnL-F

The aligned *trn*L-F matrix was 1,907 bp long of which 599 characters were excluded. A total of 1,308 characters were included of which 1,184 characters were constant; 479 variable characters were parsimony uninformative and 244 characters were potentially parsimony informative. The heuristic search of the *trn*L-F matrix produced 55 equally most-parsimonious trees, each of consisting 1,441 steps with a consistency index (CI) of 0.68 and retention index (RI) of 0.53. One of these trees is shown in Figure 5.4 with bootstrap values and strict consensus information. Bootstrap (BS) percentages ( $\geq$ 50%) are described as weak (50-74%), moderate (75-84%), and high (85-100%).

Two distinct clades were present in the *tm*L-F trees. **Clade I** contained all the *Gmelina* species. The monophyly of *Gmelina* was weakly supported (65% BS) with the inclusion of an unidentified *Gmelina sp.* Within Clade I, two subclades could be recognised in the strict consensus tree. The first subclade (A) consisted of two groups: I) *G. annamensis* and *G. lepidota* were grouped together (80% BS), and *G. attenuata* was their sister species; group II) contained *G. brassi, G. sessilis, G. smithii, G. dalrympleana,* and two outlying species *G. fasciculiflora* and *G. elliptica.* Within this group *G. brassi, G. sessilis, G. sessilis, G. smithii, G. dalrympleana,* and two fascicularia was sister to the others; *G. brassi, G. sessilis, G. smithii, G. dalrympleana* were grouped together (85% BS). *Gmelina sesillis* and *G. smithii* were sister taxa (92% BS). The grouping of *G. arborea* and *G. elliptica* was not supported by the strict consensus.

The second subclade (**B**; Figure 5.4) contained G. *arborea*, G. *asiatica*, G. *elliptica*, G. *palawensis*, G. *philippensis*, and G. *schlechteri* but the relationships within it were not well resolved in the strict consensus tree or supported by bootstrapping.

The remaining taxa (grade **C**) were successively sister to the clades A and B. It includes *G. elliptica*, *G. philippensis*, *G. palawensis* var. *novoguineensis*, *G. moluccana*, *G. ledermanii*, and an un identified *Gmelina sp*. Among these, one branch containing two *G. elliptica* species was well supported (80% BS).

**Clade II** comprised genera *Callicarpa, Premna, Tectona* and *Vitex*. This clade is sister to *Gmelina*. Within this clade groupings of *Callicarpa* species (97% BS), and *Premna* species (94% BS) were highly supported. However, *Vitex peduncularis* and *V. negundu* were sister taxa with weak (67% BS) bootstrap support and *T. grandis* was their sister species (in the strict consensus but not supported by bootstrapping).

#### 5.5.2 Analysis of atpB-rbcL

The final aligned *atpB-rbcL* matrix had a total length of 1,572 characters, from which 595 characters were excluded; 977 characters were included of which 621 were constant, 248 variable characters were found representing 15.7% of the aligned region and 108 characters were parsimony informative. The heuristic search of *atpB-rbcL* matrix produced 1,760 equally parsimonious trees, each of consisting 577 steps with a consistency index (CI) = 0.77 and retention index (RI) = 0.57. One of these trees is shown in Figure 5.5 with bootstrap values and strict consensus information included.

The monophyly of *Gmelina* was not resolved but there was no strong evidence against their monophyly (Figure 5.5). **Clade I** is present in the strict consensus tree. It has one subclade (**A**) that is present in the strict consensus tree, and contained *Callicarpa, Premna, Tectona* and *Vitex. Gmelina arborea, G. elliptica* and G. *attenuata* were unresolved relative to this group. The other taxa of this clade were not resolved.

#### 5.5.3 Analysis of combined trnL-F and atpB-rbcL

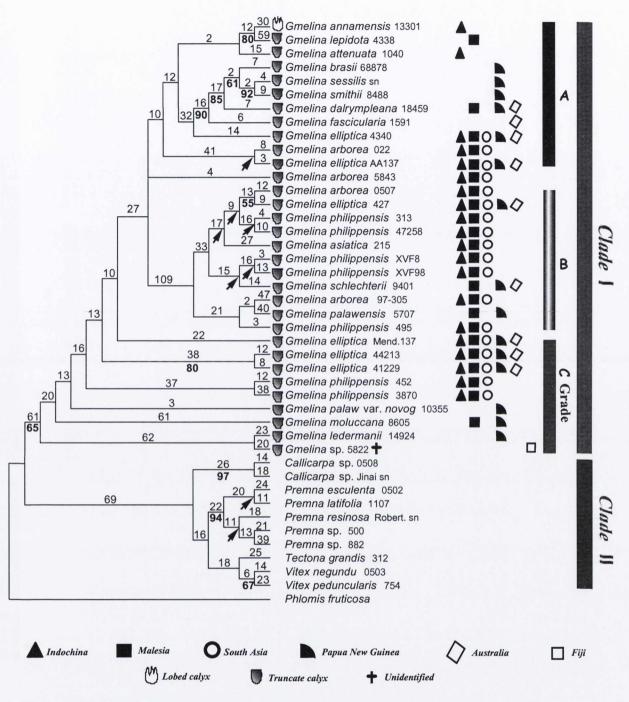
The combined *trn*L-F and *atp*B-*rbc*Lmatrix matrix was 3,814 bp long of which 1,525 characters were excluded. 2,289 characters were included of which 1,368 characters were constant, 302 variable characters were parsimony uninformative and 619 characters were informative. The heuristic search of *trn*L-F matrix produced 98 equally most-parsimonious trees, each of consisting 1,565 steps, CI = 0.75 and RI = 0.57. Figure 5.6 shows one of the most parsimonious trees with branch length and bootstrap values; branches which collapse in the strict consensus tree are shown with arrows.

Two main clades were resolved. *Gmelina* was monophyletic in the strict consensus but with only 65% bootstrap support. Except for an unidentified *Gmelina sp.* all other *Gmelina* species belonged to **Clade I**, within which three subclades (A, B, C) and an unresolved small outlying grade (*G. palawensis* var. *novoguineensis*, *G. arborea*, *G. palawensis*, and *G. moluccana*) could be identified. An unsupported group (**A**) could be divided in to five groups: Group I) contained *G. sessilis*, *G. smithii*, *G. brassi*, *G. dalrympleana*, *G. fascicularia*, and genetically distant species *G. ledermanii*. Within this subclade *G. sessilis*, *G. smithii*, *G. brassi*, and *G. dalrympleana* formed a well supported monophyletic group (88% BS) and *G. fascicularia* was their sister species (88% BS); *G. sessilis*, and *G. smithii* were grouped together (91% BS); group II) contained a group of *G. annamensis* and *G. lepidota* with moderate support (79% BS); group III) contained two *G. philippensis* species but this branch was not supported by strict consensus or bootstrap; group IV) contained two *G. elliptica* species; and group V) included another two *G. elliptica* species.

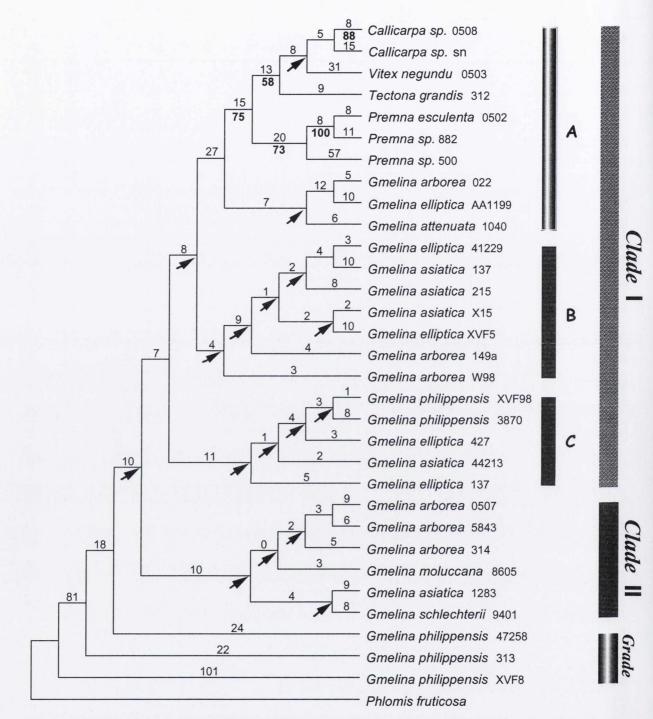
The second subclade (**B**) was present in the strict consensus and could be divided into two groups: group I) contained *G. arborea, G. asiatica,* and *G. elliptica*; group II) comprises *G. arborea, G. elliptica, G. attenuata,* and *G. asiatica.* 

Subclade (C) was also present in the strict consensus and could be divided into two groups: group I) included *G. schlechteri, G. asiatica, G. arborea,* and *G. elliptica*; and group II) contained a monophyletic group of *G. philippensis* species.

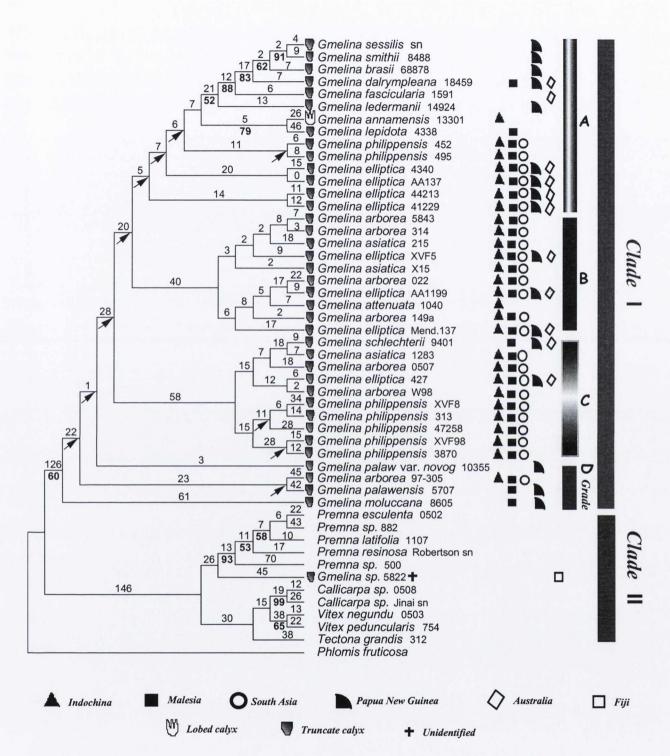
The second group **Clade II** could be divided in to two groups: group I) contained a highly supported monophyletic *Premna* (93% BS) and an outlying but unsupported species *Gmelina sp.*; group II) contained a highly supported *Callicarpa* (99% BS), grouping with Vitex with T. *grandis* as their sister species.

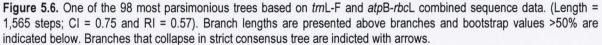


**Figure 5.4.** One of the 55 most parsimonious trees based on *trn*L-F sequence data. (Length = 1,907 steps; CI = 0.68 and RI = 0.53). Branch lengths are presented above branches and bootstrap values >50% are indicated below. Branches that collapse in strict consensus tree are indicated with arrows.



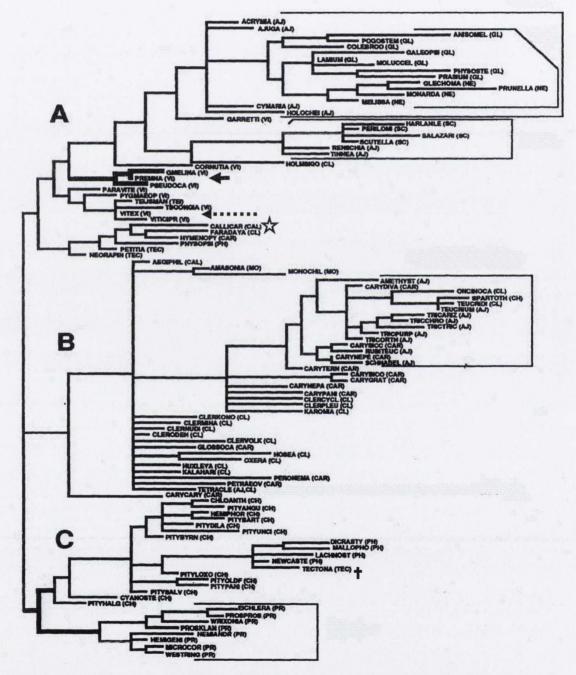
**Figure 5.5.** One of the 1,760 most parsimonious trees based on *atpB-rbcL* sequence data. (Length = 577 steps; CI = 0.77 and RI = 0.57). Branch lengths are presented above branches and bootstrap values >50% are indicated below. Branches that collapse in strict consensus tree are indicated with arrows.





## 5.6. Discussion and Conclusions

An analysis of phylogenetic relationships within the genus *Gmelina* using molecular data was undertaken here for the first time. The sister group of *Gmelina* was found to be a group including *Premna*, *Callicarpa*, *Tectona* and *Vitex*. A close relationship was also found between *Gmelina*, *Premna*, *Vitex*, and *Calicarpa* in the analyses based on morphological and palynological data by Cantino (1992a, b). The results showed that *Gmelina* and *Premna* are sister to each other (Figure 5.7- clade **A**) but the placement of *Vitex*, *Callicarpa* are outside of this group, and *Tectona* is placed in the outlying clade **C** (Figure 5.7).



**Figure 5.7.** Strict consensus tree derived from morphology-based caldistic analysis of primitive genera of Lamiaceae *s.s.* and those group of Verbenaceae *s.l.* that appear to be most closely related to the Lamiaceae. Thickened stems indicate the most parsimonious rooting positions. Short arrow indicates *Gmelina* and *Premna* grouping; long dashed arrow shows *Vitex; Callicarpa* is starred; and **†** shows *Tectona*. (Taken from Cantino 1992a).

The *atpB-rbcL* analysis was the least informative in this thesis. The trees indicate that *Gmelina* is not monophyletic because *Premna, Tectona, Vitex,* and *Callicarpa* are all nested within it. However, there is no strong evidence (supported by bootstrapping) from this gene region against the monophyly of *Gmelina.* This gene region had not been tested before to infer any phylogenetic groups in the Lamiaceae, and in the present study has shown that it is of limited use for inferring infrageneric relationships of *Gmelina* except as part of a combined analysis.

The monophyly of *Gmelina* was weakly supported (65% BS) with the inclusion of unidentified *Gmelina sp.* in the *trn*L-F analysis. Therefore, the main differences between trees produced by the separate *atp*B-*rbc*L and *trn*L-F matrices were that the *atp*B-*rbc*L placed several other genera, such as - *Callicarpa, Premna, Tectona,* and *Vitex* within the *Gmelina* clade instead of inferring a monophyletic *Gmelina* (as in the case of the *trn*L-F analysis). The *trn*L-F trees placed these genera outside the genus with 65% bootstrap support.

The combination of two gene regions *tm*L-F and *atp*B-*rbc*L resulted in well resolved but weakly supported trees. *Gmelina* was supported as monophyletic with 60% BS. Within the *Gmelina* clade three main lineages and a small group of unresolved species could be identified (Figure 5.6). The result also showed that *Gmelina* was only monophyletic if *Gmelina sp.* was excluded from the genus. However, this unidentified Fijian specimen is morphologically distinct from all other *Gmelina* species having a united to adherent and globular calyx with small pore on the top, equally bi-lobed stigma; deeply lobed ovary; and lacking nectariferous glands both in leaves and calyx; while generally *Gmelina* has nectariferous glands in leaf base and on the calyx; infundibular or campanulate calyx; inconspicuously unequally bi-lobed stigma; and unlobed ovary. Therefore, morphology would also support the exclusion of this unidentified *Gmelina sp.* from *Gmelina*. However, this species was one of two most outlying of all *Gmelina* species in the *tm*L-F analysis. No sequence was produced for *atp*B-*rbc*L because of sequencing difficulties. Therefore the combined analysis had to treat the *atp*B-*rbc*L sequence of *Gmelina sp.* as missing data and placed the taxon based on evidence from *tm*L-F only.

Populations of the same species from different geographical regions were not grouped together in the molecular analysis. For example in *trn*L-F analysis, *G. arborea* distributed in subclade A and B; *G. asiatica*, and *G. philippensis* were positioned in subclade B; and *G. elliptica* in subclade A. However, these three species were also scattered in an unresolved grade C. In the combined analysis, *G. arborea* was distributed in subclade B and C; *G. asiatica*, and *G. elliptica* was scattered in all subclades A, B and C; and G. *philippensis* distributed in subclade A and C. However, there is no bootstrap support or evidence from the strict consensus to indicate they should be separated. The timber species *G. arborea*, and ornamental species *G. philippensis* are widely planted, and *G. asiatica* and *G. elliptica* are widely distributed species. These morphologically similar timber and ornamental species show cryptic diversity as the monophyly of these species were not supported in molecular analysis. Therefore, there is a chance for these to be hybridized.

Proposed sectional classifications in the present study (see Chapter 2) were not supported by molecular analysis. In both *tm*L-F and combined analyses Indochinese species and the only representative of the section *Annameticum*, *G. annamensis* grouped together with Malesian *G. lepidota* of section *Asiaticum* with 80% and 79% bootstrap support respectively. However, morphologically and anatomically they are distinctive but genetically their grouping could possibly have been caused branch attraction (Felsenstein 1978; Philippe *et al.* 2005). *Gmelina annamensis* was also embedded within the members of the section *Asiaticum* in the combined dataset. Three endemic species of Papua New Guinea *G. brassi, G. sesillis*, and *G. smithii*; widely spread species *G. dalrympleana*; and an Australian species *G. fasciculiflora* made a strongly supported monophyletic group with 90% and 88%BS in *tm*L-F and combined datasets respectively. This monophyletic group made a weakly supported (52% BS) group with another Papua New Guinean endemic species *G. ledermanni* in *tm*L-F data; however this grouping was not supported in *tm*L-F analysis. In *tm*L-F dataset this species grouped with an unidentified *Gmelina* sp. from Fiji and had an outlying placement in the *Gmelina* clade. However in combined analysis this unidentified *Gmelina* sp. was embedded within the sister group of *Gmelina*.

The mostly widely distributed taxa *G. arborea*, *G. asiatica*, *G. elliptica*, *G. philippensis*, and *G. schlechteri*, and *G. palawensis* (restricted to Malesia and Papua New Guinea) made a group in *trn*L-F analysis (Figure 5.4 - subclade **B**). This grouping was supported by the strict consensus; however was not supported in combined analysis.

In both *trn*L-F and combined analyses, within the **Clade II** (the sister group of *Gmelina*) the monophyly of the genera *Callicarpa* (97% and 99% BS respectively) and *Premna* (94% and 93% BS respectively) were strongly supported. However, monophyly of the genus *Vitex* was weakly (67% and 65% BS) supported. This was incongruent with Cantino (1992a,b), where their placement were scattered (Figure 5.7).

The placement of the other taxa remains problematic but it is anticipated that further analyses with more taxa from the section *Annameticum* (however, DNA extractions from two other members of the section *Annameticum* e.g. *G. chinensis* and *G. hainanensis* had not successfully been amplified), possibly from fresh leaf materials and/or silica gel materials, and sequences from more gene regions e.g. *mat*K, *ndh*F (Steane *et al.* 2004), *rps*16 (Paton *et al.* 2004), and nuclear ITS (Jamzad *et al.* 2003; Steane *et al.* 2004) could resolve these issues.

# CHAPTER 6

# **General Discussion and Conclusion**

*Gmelina* was previously recorded as having 37 species. Southeast Asia contains 17 species of which 9 are endemic. The present revision of the genus in Southeast Asia recognises a total of 31 *Gmelina* taxa, consists of 26 species, 1 subspecies and 4 varieties in that area (Chapter 2, Table 2.1). Among these, 7 species, 1 subspecies, and 3 varieties have been reported as new to science: *viz. G. chindwinse* M. H. Rashid & J. Parnell, *G. obovata* M. H. Rashid, *G. obovata* var. *glabrata* M. H. Rashid, *G. obovata* var. *kutaiensis* M. H. Rashid, *G. parnellii* M. H. Rashid, *G. palawensis* var. *matanoeca* M. H. Rashid, *G. rotundifolia* M. H. Rashid & J. Parnell, *G. spectabilis* M. H. Rashid & A. J. Paton, *G. tubularis* M. H. Rashid, *G. tubularis* M. H. Rashid, *M.* H. Rashid, *M.*

Two taxa are elevated to varietal and specific rank respectively, *G. philippensis* f. *tarnsitoria* Moldenke to *G. elliptica* var. *transitoria* (Moldenke) M. H. Rashid, and *G. uniflora* var. *villosa* Bakh. to *Gmelina borneoense* M. H. Rashid. Due to the prior use of the epithet "villosa" in *Gmelina villosa* Roxb., and *G. asiatica* L. var. *villosa* (Roxb.) Bakh. (valid name *Gmelina elliptica* Smith) a new name is needed and *Gmelina borneoense* is chosen. *G. balansae* Dop is merged with *G. racemosa* (Lour.) Merr.

Indonesia shows the greatest center of *Gmelina* diversity containing 11 species, 1 subspecies, and 3 varieties, almost all of which are endemic to this territory. Thailand has the second largest diversity with 4 endemic species, followed by Myanmar and Malaysia (3 endemic species), Vietnam (2 endemic species), and a single variety *G. elleiptica* var. *transitoria* is confined to the Guimaras Islands, Philippines.

Two species, *G. lepidota* and *G. tonkinensis* are recognised in Indonesia for the first time, hence, are new records for this territory.

A comprehensive and up to date taxonomic treatment of Southeast Asian *Gmelina* has been provided with keys to the species and varieties, detailed descriptions and up to date nomenclature, typifications, ecological information, conservation status, uses, illustrations or images, and distributional maps. The outcome of the work will be modified and submitted to *Flora Malesiana* and *Flora of Thailand*; and will contribute to the *Flore du Cambodge, Flore du Laos et du Vietnam*.

Based on calyx characters a revised new infrageneric classification is proposed. The genus is divided in two sections: section *Asiaticum* M. H. Rashid & J. Parnell and section *Annameticum* M. H. Rashid & J. Parnell.

There is no detailed comprehensive anatomical survey on the subfamily Viticoideae, in particular on the genus *Gmelina*. Neither has there been any comprehensive specific petiolar anatomical nor leaf surface study on the genus. Therefore, the study of the anatomy of *Gmelina* has resulted in new descriptions of the anatomy of leaves of the genus. New observations have been made, particularly of the leaf surfaces and

petiolar anatomy. The study has resulted in the identification of several characters which may be taxonomically informative.

The epidermal characters of the mature leaves of 40 taxa of 20 *Gmelina* species, and 6 *Premna* species have been examined (Chapter 3, Table 3.1). Species representing the broad geographical distribution were studied from different parts of its distribution to determine whether there were significant differences in plants from different regions or habitats. 14 species have been investigated for the first time and the remaining six species are reinvestigated.

All *Gmelina* species investigated in the present study are hypostomatic (stomata confined abaxially) and mostly anomocytic, which is in tune with the previous observations made in the few species of the genus (El-Gazzar and Watson 1970; Mathew and Shah 1981; and Cantino 1990).

Vestiture has been found to be useful source of diagnostic characters in *Gmelina*. Two main trichome types eglandular and glandular; and basically seven vestiture types *viz*. glabrous or glabrescent, glandular, glandular-pilose, glandular-tomentose, lepidote, tomentose, and stellate occur in *Gmelina*. The type and distribution of trichomes can be used to distinguish between species with similar appearance or previously confused species. For example, *G. asiatica* and *G. elliptica* are superficially similar, but the former has glandular sessile trichomes and the latter has long, multicellular eglandular trichomes. Having both surfaces tomentose *G. tomentosa* is distinctive from all of its congeners; in contrast, both surfaces are glabrous to glabrescent in *G. moluccana*, *G. palawensis* and in *G. schelechteri*.

Distinctive types of trichome such as *asciform* in *G. moluccana*; *calvitium* in *G. spectabilis*; *patelliform* in *G. lepidota*; hyaline, sessile peltate glandular with a long central ray in *G. schlechteri* make these species readily distinguishable from all other members of the genus. None of these types have been reported earlier from any member of Lamiaceae or Verbenaceae. Vietnamese populations of *G. elliptica* differ from others in having *acicular-geniculate* and *acicular-spiral* eglandular trichomes. These types also have not been observed in any other species of Lamiaceae or Verbenaceae. The populations of *G. lepidota* from Irian Jaya, Indonesia have filiform, unicellular, acicular trichomes whilst specimens from the Moluccas, Indonesia are devoid of eglandular trichomes.

Yashodhara *et al.* (2004) reported *patelliform* trichomes in *G. arborea*; such hairs have not been seen in the present investigation. Cantino (1990) reported multicellular glandular trichomes as widespread and usually more frequent on the abaxial surfaces in *G. delavayana*, and *G. racemosa*, but they were absent from *G. moluccana*; which is tune with the present investigation.

The petiolar anatomical characters of 48 accessions of 22 *Gmelina* species, and six *Premna* species have been examined (Table 3.2, Chapter 3), of which only two species, *G. arborea* and *G. philippensis* have been investigated earlier, and thus the remaining 20 species have been investigated fro the first time.

Photomicrographs of the petiole transverse sections of *Gmelina* and *Premna* are presented; features observed are summarized in Table 3.2 and presented graphically in Plots 3.1-3.5 (Chapter 3).

The cross sectional area of the petiole in different taxa varies significantly. It is highest in *G. moluccana*  $(2,582,500\mu m^2)$  (Figure 3.10.29A) and lowest in *G. tomentosa*  $(167,305\mu m^2)$  (Figure 3.10.39A). Petiole length (Plot 3.1) and cross sectional areas (Plot 3.2) are related with habit. All tree species in *Gmelina* have the relatively longer petiole and larger cross sectional area than shrubby species. These characters would not necessarily be recommended for identifying *Gmelina* species as the length and size of petiole would differ within the same species depending on the age of the leaf and its environment. However, in conjunction with other characters it is a useful interspecific differentiating character.

On the basis of main vascular bundle shape eight main types of petiole vascularization can be recognised within the genus Gmelina i.e. crescentic, crescentic with invaginated ends, dissected crescent with medullary bundles, dissected crescent with invaginated ends, dissected crescent with invaginated ends and medullary bundles, cylindric, dissected cylinder, and dissected cylinder with medullary bundles etc.

Adaxial grooves are present in most *Gmelina* species and vary in size, but are absent from *G. annamensis* (Figure 3.10.1A). Peripheral vascular bundles are present in four species, and in the remaining 18 species vascular bundles are arranged in the centre of the petiole. Differences are thus observed in the number and patterns of vascular bundles, presence of lateral wings, medullary vascular bundles, perivascular phloem fibres, and xylem fibres, and cork cells in the petioles of the genus *Gmelina* (Table 3.2).

The leaf anatomy of the genus *Gmelina* has a few clearly distinctive characteristics which make possible the immediate recognition of certain taxa. Among the best of these are branched trichomes on leaf surfaces in *G. racemosa* (Figure 3.9.18E-G); glabrous leaf surfaces on both sides in *G. palawensis* (Figure 3.9.15-16); lepidote leaf surface in *G. lepidota* (Figure 3.9.14C-D); parenchymatic ray in the vascular bundle of *G. uniflora* (Figure 3.10.42D); lobed vascular bundle in *G. moluccana* (Figure 3.10.29A) and *G. schlechteri* (Figure 3.10.38A); and *G. hainanensis* (Figure 3.10.26) in lacking additional vascular bundles.

The relative homogeneity of many anatomical characters reflected the close relationships existing between the various group of species. For example, the mutual similarity in petiole anatomy of *G. asiatica*, *G. elliptica*, and *G. philippensis* is linked with similarity in other characters; however they could be differentiated by their leaf surface indumentum and inflorescence characters.

The present investigation confirms that leaf surface anatomy and patterns of petiole vasculature, in conjunction with some other characters of petiole anatomy are taxon-specific. These features have a taxonomic importance and are useful in identification of different species of *Gmelina* and *Premna*. However, both petiolar and leaf surface anatomy do not shed any light to the proposed infrageneric classification of the genus. The very similar types of vascularization in different species of *Gmelina* and *Premna* suggest the close relationship between two genera.

There have been no palynological studies on the genus *Gmelina* or even on the subfamily Viticoideae. An attempt was made and 21 *Gmelina* species (24 taxa), and one *Premna* species were acetolyzed (Chapter 4). All *Gmelina* species except *G. arborea, G. brasii,* and *G. philippensis* were investigated here for the first

time. *G. arborea* and *G. philippensis* were examined by Mathew & Shah (1988); and Abu-Asab & Cantino (1993a) examined *G. arborea*, and *G. brasii*; their results conform to the present study. However, the pollen size and shape of *G. philippensis* differs from Mathew & Shah (1988) in the present investigation.

All grains examined are isopolar with only exception in *G. lepidota* which are heteropolar (Figure 4.2E), trizonocolpate and more or less radially symmetrical; they possess differences in polar length and equatorial width, whilst *G. arborea*, *G. lepidota*, *G. moluccana*, *G.tubularis*, *G. uniflora*, and *P. latifolia* show the least difference (Plot 4.1). The widest colpus was recorded in *G. moluccana*, and *G. spectabilis*; and the narrowest in *G. delavayana*, and *G. hainanensis* (Table 4.1).

Five types of surface patterns can be recognised in the genus Gmelina, e.g. suprareticulate, suprareticulatespinulose or-granulate, microreticulate, microreticulate-granulate, and rugulate. The exine ornamentation showed two types of tectum: psilate, and spinulose or granulate. The psilate tectum was observed in almost all of the species examined, except tectum-granulate in *G. palawensis* (Figure 4.3C-D), and tectumspinulose in *G. schlechteri* (Figures 4.5A-B), and *G. tomentosa* (Figures 4.5C-D).

Only one *Premna* species was examined in this study. Both size and surface ornamentation (Figure 4.7D-E) shows its incongruence with *Gmelina*. The pollen morphology of *Gmelina* species is taxonomically important

There have been no phylogenetic studies to resolve the relationships within the genus *Gmelina*, its tribe Viticeae or even its subfamily Viticoideae. An analysis of molecular phylogenetic relationships within *Gmelina* and allied genera using three plastid DNA regions, *trn*L intron, *trn*L-F intergenic spacer, and *atp*B-*rbc*L was undertaken here for the first time.

The sister group of *Gmelina* was found to be a group including *Premna*, *Callicarpa*, *Tectona* and *Vitex*. Cladistic analysis based on morphological and palynological data by Cantino (1992a, b) also show a close relationship between *Gmelina*, *Premna*, *Vitex*, and *Calicarpa*; but the placement of *Vitex*, *Callicarpa* were outside of this group, and *Tectona* is placed in the outlying clade C (Figure 5.7, Chapter 5).

The *atp*B-*rbc*L analysis was the least informative in this thesis. The trees indicate that *Gmelina* is not monophyletic because all sister group taxa nested within it. However, there is no strong evidence (supported by bootstrapping) from this gene region against the monophyly of *Gmelina*. This gene region had not been tested before to infer any phylogenetic groups in the Lamiaceae, and in the present study has shown that it is of limited use for inferring infrageneric relationships of *Gmelina*.

The monophyly of *Gmelina* was weakly supported (65% BS) with the inclusion of an unidentified *Gmelina sp.* in the *trn*L-F analysis. The main differences between trees produced by the separate *atp*B-*rbc*L and *trn*L-F matrices were that the *atp*B-*rbc*L placed all sister genera, within the *Gmelina* clade instead of inferring a monophyletic *Gmelina* (as in the case of the *trn*L-F analysis). The *trn*L-F trees placed these genera outside the genus with 65% bootstrap support.

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The combination of two gene regions *tm*L-F and *atp*B-*rbc*L resulted in well resolved but weakly supported trees. *Gmelina* was supported as monophyletic with 60% BS. Within the *Gmelina* clade three main lineages and a small group of unresolved species could be identified (Figure 5.6, Chapter 5). The result also showed that *Gmelina* was only monophyletic if an unidentified *Gmelina sp.* was excluded from the genus. Having distinct morphological characters than other *Gmelina* species would also support the exclusion of this Fijian specimen.

Populations of the same species from different geographical regions were not grouped together in the molecular analysis (Figure 5.5 & 5.6, Chapter 5). However, there is no bootstrap support or evidence from the strict consensus to indicate they should be separated.

Proposed sectional classification in the present study (see Chapter 2) was not supported by anatomical, palynological and molecular data, however the genus could be well divided into sections based on calyx charcter.

It is anticipated that further analyses with increasing the number of taxa from the section *Annameticum*; possibly from fresh leaf materials and/or silica gel materials, and sequences from more gene regions e.g. *mat*K, *ndh*F, *rps*16 and nuclear ITS could resolve these issues.

### Conclusions

The thesis has investigated systematics of the genus *Gmelina* in Southeast Asia and provided an up to date taxonomic account, which would contribute to the Lamiaceae systematics and to the local Flora; *viz. Flora of Malesiana; Flora of Thailand ; Flore du Cambodge, Flore du Laos et du Vietnam.* 

Briquet's (1895) sectional classification was assessed and a revised infrageneric classification of *Gmelina* has been proposed.

The phylogenetic relationships within *Gmelina* and allied genera inferred using three plastid DNA regions. Leaf surfaces and petiolar anatomy, and palynological investigations were carried out for the first time for the genus. Pollen from only one *Premna* species was examined; further palynological observations of more species might show greater resolutions of its relationships to the genus *Gmelina*.

More samples especially fresh and/or in silica gel, and sequences from more gene regions could allow for better resolution in the molecular study of the genus.

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# **APPENDIX I**

#### **PARAFFIN METHOD**

#### Cutting specimens and Fixation (70%FAA)

- Cut the specimens into pieces, approximately 1 cm long.
- Place the specimens in 5% NaOH and leave for 3 days for reviving.
- Pour 70% FAA in a vial (small glass bottle) with a secure lid (called Fixative vial); make up to <sup>3</sup>/<sub>4</sub>.
- Rinse the specimens with 70% FAA
- Place the specimens in Fixative vial containing 70% FAA

(Preparation of 70% FAA: Formalin 5ml, Glacial Acetic Acid 5ml and 70% Ethyl Alcohol 90ml, mix well).

#### Suctioning

This step is used to ensure that the fixative and chemical substances in the next steps gets into every cell of the tissue. The specimens in the vials were placed into the desiccator. The desiccator was connected to a vacuum pump. The specimens were suctioned at 25 in Hg Vacuum for about 30-60 minutes, or until air bubbles stopped appearing, whichever occurred first (It is vital to ensure there are no air bubbles left, as air bubbles do not allow any solution transport through them). Once all the vials had been suctioned, they were left for 24 hours at room temperature.

#### Washing

Pour out the fixative into the "Used FAA" labeled container then fill the vial with 50% Ethyl alcohol and rinse the specimens down. Leave the specimens in alcohol for about 10 minutes. Repeat the washing 3 times.

#### Dehydration [Tertiary Butyl Alcohol (TBA) series]

The series of TBA grade I, II, III, IV and V were prepared as follows:

	TBA Grade (ml)				
	1	II	Ш	IV	V
Distilled water	50	30	15	0	0
Ethyl alcohol 95%	40	50	50	45	0
Tertiary Butyl Alcohol	10	20	35	55	75
Ethyl alcohol 100%	0	0	0	0	25
Total % of Alcohol	50	70	85	95	100

Rinse the specimens with the TBA series using the same method as used for washing. Leave the specimens in each TBA grade for 24 hours. Then rinse the specimens with absolute TBA and leave in

absolute TBA for 24 hours then repeat the rinse with absolute TBA 3 times to ensure that all water is removed and that the wax will be infiltrated the specimens.

The TBA series is important as it removes all water from the tissue. This is extremely important, as the paraffin will not work if there is any water left in the tissue. Note that the tissue was hard after the TBA series was completed.

#### Infiltration

- Prepare an oven at 60°. Place paraffin wax (Paraplast/Paramat, which has a melting point of 60°) in a jug in the oven and leave until the wax is melted.
- Meanwhile, prepare a mixture of absolute TBA: paraffin oil (TBA:Oil) (1:1).
- Rinse the specimens with the TBA:Oil mixture and then leave in the mixture for about 1 hour at room temperature.
- Meanwhile, prepare vials with melted wax (about and leave the wax to set at room temperature.
- Take out the specimen from the TBA:Oil mixture and place on top of the wax vial and fill the vial with some the same mixture (TBA:Oil); leave the vial in the hot oven for 24 hours.
- Pour the melted wax and mixture off into the "Used paraffin" paper container then quickly replace with pure fresh melted wax and leave the vial in the oven for 24 hours.
- Repeat the step 6 two more times to ensure complete infiltration.

#### Embedding

- Prepare embedding paper base moulds (for specimens which length is > 5mm) or stainless steel base moulds (for specimens which length is ≤ 5mm). Place these and the plastic holder moulds into the hot oven.
- Pour the melted wax into the base mould which is kept warm on the hotplate; take a specimen from the vial and put into the base mould containing melted wax.
- Move the base mould from the hotplate to the table and then set the specimens upright position (for transverse section cutting) using a warm needle to manipulate them into position, then put the plastic warm holder mould on top of the base mould to form a set and pour the melted wax on top until the set is full and leave at room temperature without moving the mould to let the wax set. In case of paper base moulds, whenever the wax in the paper base mould is set, take the paper off and trim the wax into a "cubic block", with the specimen in the center. For the specimen with the length > 5mm, as unable to put the holder mould on top of the paper base mould, prepare the "block without specimens" (make the block using the set of stainless steel base mould and plastic holder without specimen in the wax) then stick the "block without specimen" together with the "cubic block" using a hot spatula touching each surface of the blocks to melt the wax and then press them to form one piece.
- Trim the blocks into a trapezoid shape.
- Keep the blocks in refrigerator for at least 15 minutes.

## Microtoming

To cut the blocks on a sliding microtome using disposable blades to 10-15µm thickness, set the clearance angle to 5°-10°. The thin pieces with specimens produced by cutting the block are called "sections" or "ribbons".

#### Affixing section to slide

- Melt 0.5g of Gelatin powder with 500-600ml hot water in a beaker, then add 500-400ml tap water to make 1000ml and then put the beaker on the drying plate (at 50°C). The gelatin acts like a mild glue.
- Place the section gently into the warm gelatin solution; keep the shiny surface up and leave for a minute to extend the section.
- Lift the section using a cleaned, twin frosted microscope slide; to do this, the slide was slip into the water under the ribbon and then gently remove from the water with the ribbon adhered to it.
- Arrange the position of the section on the slide as desired using a needle. Then leave the slide to stand beside the drying plate to drain the solution for a few minutes.
- Keep the dry slides into the microscope slide cases.

### **Prestaining and Staining**

As the stain (toluidine blue) is water based, it is necessary to remove the embedding wax from the sections prior to staining.

- Prepare toluidine blue stain using toluidine blue 0.5 g in tap water 100 ml, stir well, filter, paper then keep in bottle.
- Prepare a Coplin's staining jar with solution for each step as follows: (Transferring the slides to each other solution under a fume hood).

Step	Solution	Time in solution	Purpose
1	Absolute Xylene	10 mins	Removes embedding wax
2	Absolute Xylene:Absolute alcohol (1:1)	3-5 mins	Stops action of xylene
3	Absolute ether: Absolute alcohol (1:1)	3-5 mins	Stops action of xylene
4	Absolute alcohol	3-5 mins	Dehydrates
5	Alcohol 95%	3-5 mins	Dehydrates
6	Alcohol 70%	up-down 3 times	Dehydrates
7	Alcohol 50%	up-down 3 times	Dehydrates
8	Alcohol 30%	up-down 3 times	Dehydrates
9	Toluidine blue	up-down 3 times or few seconds	Stains
10	Wash with tap water in beaker	up-down 3 times	washes off excess stain
11	Alcohol 30%	up-down 3 times	Removes more excess stair
12	Alcohol 50%	up-down 3 times	Dehydrates
13	Alcohol 70%	up-down 3 times	Dehydrates
14	Alcohol 95%	up-down 3 times	Dehydrates
15	Absolute alcohol	up-down 3 times	Washes and clears
16	Absolute Xylene:Absolute alcohol (1:1)	3-5 mins	Washes and clears
17	Absolute Xylene	3-15 mins	Washes and clears

## **Mounting and Labeling**

The slides can then be mounted permanently in DPX mountant for microscopy. Label slides with plant name, plant organ (petiole), collector(s) and collection number, transverse section, toluidine blue.

# **APPENDIX 2**

## ACETOLYZE PROTOCOL

- Placed sample in a 12ml tube together with approximately 1ml of 50% Acetone.
- Crushed thoroughly with the transfer pipette, and vortexed the solution for 10 seconds.
- Left the sample to stand for approximately 5 minutes (caution allow the same amount of time for standing in the subsequent washes)
- Centrifuged for 10 minutes at 2500rpm and discarded supernatant as much as possible (*caution -not to remove any pellet, where most pollen is*)
- Transferred the entire pellet to a fresh tube, washing with 60% Acetone and filtered through a Sieve placing on top of a funnel (*caution – clean the sieve and funnel between samples, and use separate transfer pipette* for each sample).
- Repeated the operation from Step 3 by increasing concentrations until 100%.
- Centrifuged for 5 minutes at 2500rpm and decanted supernatant.
- Once all washes were done, the samples were placed in 100% Acetone for a few minutes.
- Removed as much liquid as possible with the transfer pipette and placed the suspension (maximum 3 drops) on the SEM stubs.
- The stubs then were left overnight in a Dessicator for drying.
- The stubs were gold-coated in a Polaron SC500 sputter coater and the samples were examined in a Hitachi S4300 electron microscope.

# **APPENDIX 3**

Table 5.3. Voucher specimens used in this molecular study. Total DNA was extracted mostly from herbarium specimens, except those marked with (\*) that were extracted from silica gel material, and with (+) which was extracted from CTAB material.

Таха	Origin Voucher		Date	Herbarium =	Genebank No.	
14.84	Ungin	Voucher	Date		trn L-F	atp B-rbc L
melina annamensis	Laos	Poilane 13301	29/02/1928	Р		
arborea*	India	Mahdiana & Kusnadi XI 149a	Feb-07	BO		
arborea	Indonesia	Ambri & Arifin W98	09/03/1990	A		
arborea	Thailand	Soejarto et al. 5843	30/03/1987	MO		
arborea*	Thailand	SS & AT 314	-	-		
arborea	Hong Kong	Hu & Yung 022	09/05/1997	К		
G.arborea*	Bangladesh	Rashid 05-07	09/05/2005	•		
G.arborea	Thailand	Maxwell 97-305	04/04/1997	А		
G. asiatica*	Indonesia	Mahdiana & Kusnadi XV 15	Feb-07	BO		
6. asiatica	Laos	Klackenberg 1283	28/04/1999	SW		
G. asiatica*	Thailand	SS & AT 215		•		
G. atten uata	Thailand	Pooma et al. 1040	1 1/0 7 /1 99 5	BKF		
6. brasi	PNG	Croffetal. LAE 68878	23/11/1976	к		
6.dalrympleana	PNG	Streimann & Lelean NGF 18459	21/09/1972	А		
G. elliptica	Indonesia	McDonald & Sunaryo 4340	05/02/1994	A		
. elliptica	In do ne sia	Ambri etal. AA1199	18/05/1995	А		
. elliptica	Thailand	Larsen et al. 41229	09/11/1990	мо		
. elliptica	Indonesia	Mendum et al. 137	19/04/2002	E		
. e lliptica	Indonesia	Ambri & Arifin AA 137	20/06/1991	А		
6.elliptica*	Indonesia	Mahdiana & Kusnadi XV F.5	Feb-07	во		
. elliptica*	Thailand	SS & AT 427	10/04/2006	TCD		
. elliptica	Puerto Rico	Nee 44213	15/11/1993	NY		
fascicularia	Australia	Gray 1591	13/12/1979	A		
ledermanni	PNG	Takeuchiet al. 14924	14/01/2001	A		
lepidota	Indonesia	Vogel 4338	26/11/1974	L		
. moluc can a	PNG	Takeuchi 8605	10/12/1992	A		
.palawensis	Indonesia	Vogel 5707	10/06/1979	к		
. palawensis var. novoguinensis	New Guinea	Takeuchi 10355	21/07/1995	A		
, philippinensis	Cambodia	Monyraketal. 452	30/01/2001	к		
, philippinensis	Thailand	Petmitr 495	14/07/1999	A		
, philippinensis*	Philippines	Mahdiana & Kusnadi XV F. 8	Feb-07	во		
<ul> <li>Philippinensis*</li> </ul>	India	Mahdiana & Kusnadi XV F. 98	Feb-07	BO		
, philippinensis*	Thailand	SS & AT 313				
, philippinensis	Guayane	Prevost 3870	30/05/2000	NY		
, philippinensis	?	Zanoni 47258	06/11/1994	NY		
i. sessilis	Cambodia	s. n.	16/02/1945	A		
. s che le chterii <sup>*</sup>	Australia	SJ 9401	10/02/1040	<u> </u>		
. smithii	PNG		03/08/1082	٨		
melina sp.	Fiji	Streinnann 8488 Smith 5822	03/08/1982 26/08/1947	A		
			20/08/1947	^		
allicarpa sp.*	Bangladesh	Rashid 05-08				
allicarpa sp.*	Thailand	Jinais.n.				
remna esculenta*	Bangladesh	Rahman 05-02				
. la tifolia*	Bangladesh	Rahman 1107	-	-		
. resinosa	<b>The Heat</b>	Robertson s. n.	22/09/1989	к		
remna sp.*	Thailand	SS & AT 500				
remna sp.*	Thailand	SS & AT 882	- 1914			
ectona grandis*	Thailand	SS & AT 312				
ite x n eg u nd u*	Bangladesh	Rahman 05-03	•			
. peduncularis*	Thailand	SS & AT 754				
hlomis fruticosa	Ireland	Fresh leaves	10110-1-02			

## **APPENDIX 4**

## **MOLECULAR PROTOCOLS**

#### Caution: gloves should be worn at all times

#### Protocol 1: Isolation of total genomic DNA using CTAB

Materials	Equipment
Wiaterials         Leaf sample (Mostly obtained from herbarium specimens; silica gel dried/CT solution)         2xCTAB Buffer (100mM Tris-HCl pH 8.0; 1.4M NaCl; 20mM EDTA; 2%CTAB)         CI (24:1 Chloroform: Isoamyl alcohol)         Isopropanol (2-propanol)         EDTA (Ethylene Diamine Tetra Acetate)         CTAB (Hexadecyl-Trimethyl-Ammonium Bromide)	Equipment Balances & Weighing boats Scissors Water Bath: Grant SUB14/Memmert W200 30ml capped centrifuge tubes Mortars & Pestles Fume hood Pipettes (P200, P5000) & tips Edmund Bühler KL-2 horizontal shaker Transfer pipettes 50ml Centrifuge tubes Harrier 15/ 80 centrifuge
	Measuring Cylinder

- Preheat 10ml of 2xCTAB extraction buffer in labeled 12ml capped centrifuge tubes, and pestles and mortars for each sample in a water bath at 65°C.
- Weigh out 0.2-0.3g (0.2g silica gel material; 0.3g herbarium material) of leaf material, cut up into small pieces. Extractions were carried out in a fume hood. Using initially a small amount of extraction buffer the leaf material was ground up using a preheated pestle and mortar. When the leaf material was almost ground to a pulp the remainder of the extraction buffer was added.
- The slurry was then placed back into the 12ml centrifuge tube, sealed and incubated at 65°C for approximately 10 minutes with occasional mixing.
- 10ml of CI was then added to each tube and mixed gently; any gas was released and the lid tightened.
- The tubes were placed on a shaker in a horizontal position for approximately 30 minutes.
- All samples were then centrifuged at 4500rpm for 10 minutes.
- The samples were then carefully removed so as not to disturb the layers. The supernatant containing the DNA was transferred carefully into 50ml centrifuge tubes using a transfer pipette.
- An equal volume of isopropanol was added and the tubes inverted to precipitate the DNA.
- ◆ All samples were stored at -20°C for at least a week to further precipitate the DNA.

#### Protocol 2: Washing of total Genomic DNA

Materials	Equipment
Crude tDNA from Protocol 1	Centrifuge
Wash buffer	Measuring cylinder
(70% ethanol)	Fume hood
TE Buffer (10mM Tris-HCl pH 8, 1mM EDTA)	Transfer pipettes
	1.5ml microcentrifuge tubes

- The crude tDNA was centrifuged at 2,500rpm for 10 minutes to pellet the DNA.
- The supernatant was poured off and then 3ml of washing buffer was added to each tube, and mixed gently.
- The samples were centrifuged once more at 2,500rpm for 5 minutes to pellet the DNA again.
- The supernatant was decanted off and the tubes were placed upside down for 5 minutes on paper towel to drain away the excess buffer.
- The tubes were then turned right way up and allowed to air dry in a fume hood for approximately 25-30 minutes to remove all traces of ethanol.
- The DNA pellets were suspended in 0.5ml of TE buffer (used transfer pipette to help the dissolving).
- The eluted DNA samples (the crude total DNA) were then transferred to properly labeled 1.5ml microcentrifuge tubes and stored in -20°C until used or in -80°C freezer for long periods.

## Protocol 3: Purification of total genomic DNA/PCR products using JETQUICK PCR Purification Spin Column Technique

Materials	Equipment
The crude total DNA (or amplified PCR products PCR purification) TE Buffer (10mM Tris/HCl, pH 8.0) or Sterile Water JETQUICK PCR Purification Spin Kit/250: Solution H1 (Binding) (contains concentrated guanidine hydrochloride, ED Tris/HCl and Isopropanol) Solution H2 (Wash, reconstituted) (contains ethanol, NaCl, EDTA and Tris/HCl) (diluted with 140 ml 95-100% ethanol prior to use)	1.5ml microcentrifuge tubes Pipettes (P20, P200 and P1000) & Tips Heating block: Grant QBT2 Microcentrifuge (Microlite Thermo IEC) Whirl Mixer JETQUICK spin columns (filter tubes) & the recei tubes (wash tubes)

- ◆ An aliquot of TE Buffer or sterile water (50µl per sample) was preheated at 65°C.
- 100µl of the washed tDNA or 50µl amplified PCR products were transferred to 1.5ml microcentrifuge tubes; 400µl of Solution H1 was added and mixed thoroughly.
- Filter tubes were placed into the wash tubes (the prepared spin column); the mixture (DNA sample & H1) was transferred to the prepared spin column and then centrifuged at 13,000rpm for one minute.
- Discard the through flow and replaced the filter tubes once more into the wash tubes; added 500µl of reconstituted solution H2 and centrifuged at 13,000rpm for one minute.
- Discard the residual solution and replaced the filter tubes. Each sample was then centrifuged again at 13,000rpm for one minute to make sure the completely removal of residual solution H2.
- Discard the wash tubes and inserted the spin column into the new labeled 1.5ml microcentifuge tubes; 50µl of TE Buffer (in case of tDNA) or sterile water (in case of PCR products) was added directly to the center of the filter tubes to ensure DNA elution.
- The samples were then incubated at room temperature for one minute and then centrifuged at 13,000rpm for two minutes. The filter tubes were discarded.
- The purified tDNA/PCR products in the micro centrifuge tubes was then stored at -20°C.

# Protocol 4: Quality and quantification assessment of tDNA/PCR products using agarose gel electrophoresis

Materials	Equipment
Agarose gel - 80ml of 1.2% w/v	Parafilm
(Agarose - 1.2-1.5g; 1xTBE Buffer - 100 ml; Ethidium bromide - 2µl)	Pipette (P20) & Tips
Loading Dye (Bromophenol Blue 0.25% w/v and Sucrose 40% w/v)	Gel rig (Horizon 11.14 Life Technologies; GIBCO BRL Horizontal Electrophoresis Apparatus)
1xTBE Buffer (Boric	Power pack (EC105, E-C Apparatus Corporation)
acid - 0.89M; Trisma Base - 0.89M; Na2EDTA - 0.02M	UV Light Box (UVP Dual-intensity Transilluminator)
The crude tDNA or PCR products	Microwave
1KB Ladder	Kodak EDAS camera & Computer systems

#### Procedure

Prior to proceed, make sure the gel tank tray is completely covered by the 1xTBE buffer solution.

- The gel tank tray was prepared by placing the comb into the right slot to produce wells in the gel where the DNA samples to be loaded.
- 2µl of loading dye for each sample were placed on a Parafilm piece.
- 6μl of the crude total DNA or 4μl of amplified PCR products were then mixed thoroughly with the Loading dye.
- The mixture was then pipetted into a well on the gel. Additionally, 1µl of the molecular weight ladder also loaded to quantify the DNA.
- Once all samples were loaded onto the gel, the tank covered with the lid and connected to the power pack and run for 30 minutes at 125V.
- The Agarose gel was then placed above a UV light box and the DNA samples were visualized and quantified. The agarose gel was then placed on the UV light box and visualized the DNA bands. The photograph of the DNA bands on the gel was taken as the reference using a Kodak EDAS camera system. Samples were quantified by comparing intensity of fluorescence of DNA.

### Protocol 5: DNA amplification Polymerase Chain Reaction (PCR)

Mater	rials	Equipment
Purified DNA: 2(-4)µI Master Mix: Ultra pure water: 10x Reaction Buffer: dNTPs (each at 10mMI): Forward Primer: Reverse Primer: MgCl <sub>2</sub> ( 25 mM): Promega <i>Taq</i> DNA Polymerase <b>Total</b> : <b>Total Reaction Volume: 50µ</b> I/: Primers concentration = 100ng	48.00(-46.00)µl sample	0.5ml & 1.5ml microcentrifuge tubes (labeled) Pipette & Tips Micro centrifuge: Micro Centaur MSE Ice Whirl mixer (Fison Scientific Equipment) Applied Biosystems GeneAmp <sup>®</sup> PCR System 9700

#### Procedure

- All purified tDNA samples and reagents were thawed and placed on ice.
- Each DNA sample was transferred in a separate 0.5ml labeled microcentrifuge tube, purified water was added if needed to make up template volume to 3µl.
- ♦ A master mix of purification reagent was prepared made in a 1.5ml microcentrifuge tube, adding all reagents according to the table stated above. The master mix was then vortexed to mix thoroughly.
- 48(-46)µl of master mix was aliquated into each 0.5ml tube of tDNA.
- 50µl of total reaction volume of each sample was then centrifuged briefly.
- The samples were then placed into Applied Biosystems GeneAmp<sup>®</sup> PCR System 9700. The total PCR reactions were than run with the following thermal cycling parameters:

Step	Cycles	Temperature	Time
Premelt	1	95°C	1 min.
Denature	30	95°C	45 sec.
Anneal	30	52°C	45 sec.
Extension	30	72°C	2 min.
Final extension	1	72°C	7 min.
Soak	-	4°C	∞

The amplified PCR products were then quantified using gel electrophoresis (see protocol 5.4) and subsequently purified (see protocol 5.3). The purified PCR products were then stored at -20°C.

# Protocol 6: Cycle Sequencing (Big Dye Terminator Kits)

#### Procedure

- Thawed all reagents and clean PCR products and kept on ice.
- Placed 1µl Pink Mix into each labeled 0.2ml microcentrifuge tube.
- Prepared two types of Master Mix (for Forward and Reverse primers) in 0.5ml microcentrifuge tubes separately, adding all reagents according to the table stated above and then vortexed.
- 6(5)µl of Master Mix was then added into each 0.2ml tube containing Pink Mix.
- 3(4)μl of each PCR product was added into the mixture, so the total volume of reaction reagents reached to 10μl.
- All samples were then centrifuged briefly prior to placing on the thermal cycler machine, Applied Biosystems GeneAmp<sup>®</sup>
   PCR System 9700 and run with the following thermal cycling parameters:

Step	Cycles	Temperature	Time
Denature	28	96°C	10 sec.
Anneal	28	50°C	5 sec.
Extension	28	60°C	4 min.
Soak	-	4°C	00

The Cycle sequenced DNA samples were then purified and (or) stored at -20°C.

## Protocol 7: Purification of the Cycle Sequenced product

Material	s	Equipment
Cycle sequenced product: Master Mix (Precipitate reagents 100% Ethanol (EtOH): 3M Sodium Acetate (NaOAc)	<b>10µI</b> ): <b>(1x) 52µI</b> 50µI 2µI	0.5ml microcentrifuge tubes (labeled) 1.5ml microcentrifuge tubes Pipettes & Tips
Wash reagent: 70% Ethanol (EtOH)	300µІ	Paper towels Heating block: DNA Thermal Cycler 480 Microcentrifuge (Microlite Thermo IEC)

- The Master Mix of precipitate reagents was prepared in a 1.5ml tube, adding all reagents according to the table stated above and vortexed to mix thoroughly.
- The cycle sequenced product was transferred to a labeled 0.5ml tube; 52µl of Master Mix was then added to each tube.
- The sample tubes were incubated at room temperature for 5-10 minutes and then placed on ice or in a -20°C freezer for a further 30 minutes.
- All samples were then centrifuged at 13000rpm for 25minutes. The supernatant was carefully discarded.
- ◆ 300µl of 70% EtOH was then added to each tube and centrifuged at 13000rpm for 15 minutes.
- The supernatant was carefully discarded and repeated step 5 and drained off the supernatant. All the tubes were then placed upside-down on paper towels to complete drain off.
- The pelleted purified Cycle sequenced products were then laid horizontally on paper towels to air-dry overnight and then stored at -20°C.

# Protocol 8: Denaturing of purified Cycle sequenced products prior to sequencing using the ABI Prism<sup>™</sup> 310 Genetic Analyser

Materials	Equipment
Purified Cycle sequenced products Template Suppression Reagent (TSR) or Hi-Di™ Formamide	0.5ml microcentifuge centrifuge tubes (labeled) Pipettes & Tips Whirl mixer (Fison Scientific Equipment) Micro centrifuge: Micro Centaur MSE Perkin Elmer DNA Thermal Cycler 480 Septa for 0.5ml microcentrifuge tubes

- ◆ 25µl of TSR or Hi-Di™ Formamide was added to each dried cycle sequenced DNA pellet.
- ◆ The samples were then vortexed slightly and heated for 5 minutes at 95°C.
- The DNA samples were then chilled on ice 3-5 minutes, vortexed once more and then centrifuged briefly.
- The tube lids were cut off and replaced by septa needed for the automated sequencer.
- ◆ The samples were then run and analysed on an ABI PRISM™ 310 Genetic Analyser.