การศึกษาอนุกรมวิธานของใบไม้วงศ์มะม่วง (Anacardiaceae) และวงศ์ถั่ว (Leguminosae) ในยุคเทอร์เชียรีจากแอ่งลี้ และแอ่งแม่เมาะ ภาคเหนือของประเทศไทย โดยการวิเคราะห์ลักษณะโครงสร้างของใบ

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SYSTEMATIC STUDY OF TERTIARY LEAVES OF ANACARDIACEAE AND LEGUMINOSAE FROM LI AND MAE MOH BASINS, NORTHERN THAILAND, USING LEAF ARCHITECTURAL ANALYSIS

Mr. Prakart Sawangchote

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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

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ประกาศ สว่างโชติ : การศึกษาอนุกรมวิธาน ของใบไม้วงศ์มะม่วง (Anacardiaceae) และวงศ์ถั่ว (Leguminosae) ในยุคเทอร์เชียรีจากแอ่งลี้ และแอ่งแม่เมาะ ภาคเหนือของประเทศไทย โดยการวิเคราะห์ลักษณะโครงสร้างของใบ
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คำสำคัญ: เทอร์เชียรี วงศ์มะม่วง วงศ์ถั่ว ประเทศไทย ลักษณะโครงสร้างของใบ

ได้บรรยายลักษณะและจำแนกชนิดของใบไม้ยุคเทอร์เชียรี 10 ชนิด ใน 7 สกุล ของวงศ์มะม่วงและวงศ์ถั่ว จากตะกอนแอ่งน้ำจืดของแอ่งลี้และแอ่งแม่เมาะในภาคเหนือของประเทศไทยที่มีอายุระหว่าง สมัยโอลิโกซีน ถึง สมัยไมโอซีน นอกเหนือจากวิธีการวิเคราะห์โครงสร้างใบไม้ตามแนวทางเดิมแล้ว ยังได้นำเสนอ การใช้ศัพท์บัญญัติเพิ่มเติม และ การจำแนกชนิด ของแบบเส้นประสานที่ขอบใบ เพื่อการศึกษาทางอนุกรมวิธาน ทุกพันธุ์รวมทั้งสกุล *Adenanthassia, Antheroporum* และ *Semecarpus* เป็นพันธุ์และสกุลไม้ยุคเทอร์เชียรีชนิดใหม่ของโลก *Mangifera paleoindica* และ *Cassia paleosiamea* แนะว่าประเทศไทยอาจเป็น (หนึ่งใน) แหล่งกำเนิด ส่วนพันธุ์ไม้มะม่วง 3 ชนิดที่พบชี้ให้เห็นว่า สกุลมะม่วงมีวิวัฒนาการ และ ความหลากหลายมายาวนาน ในขณะที่ สกุล *Semecarpus* อาจเป็นหลักฐานการกำเนิดในช่วงต้นๆ ในภาคเหนือของไทย อนุวงศ์ถั่วทั้งสามบ่งชี้ว่าวงศ์นี้มีความหลากหลายมาตั้งแต่สมัยโอลิโกซีนถึงสมัยไมโอซีน สกุล *Adenanthassia* และ *Pithecellobium* มีนัยสำคัญต่อการวิเคราะห์การแพร่กระจายระหว่าง อเมริกาใต้ แอฟริกา อินเดีย และ เอเชีย ต่อไป ซากใบไม้ดึกดำบรรพ์เขตร้อนเหล่านี้กับซากดึกดำบรรพ์ในเขตอบอุ่นที่พบในงานวิจัยก่อนๆ ชี้ว่ามีการอยู่ร่วมกันของไม้สน กับไม้มีดอกจำพวกใบกว้างที่ผลัดใบ และ มีใบเขียวตลอดปีจากเขตภูมิอากาศทั้งสอง นอกจากนี้ยังได้สร้างรูปวิธานสองแบบสำหรับ 35 ชนิดพันธุ์ที่มีใบเดี่ยวในวงศ์มะม่วง พร้อมกับชุดรูปภาพตัวอย่างแห้ง และ ตัวอย่างที่ทำให้เห็น เส้นใบ เพื่อประโยชน์ในงานวิจัยในอนาคต

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ปีการศึกษา 2546	ลายมือชื่ออาจารย์ที่ปรึกษา........................
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....................
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....................

PRAKART SAWANGCHOTE: SYSTEMATIC STUDY OF TERTIARY LEAVES OF ANACARDIACEAE AND LEGUMINOSAE FROM LI AND MAE MOH BASINS, NORTHERN THAILAND, USING LEAF ARCHITECTURAL ANALYSIS.

THESIS ADVISOR: PAUL J. GROTE, Ph.D. 330 PP. ISBN 974-533-320-4

TERTIARY/ANACARDIACEAE/LEGUMINOSAE/THAILAND/LEAF ARCHITECTURE

Ten species of Tertiary leaves belonging to seven genera of Anacardiaceae and Leguminosae were described and identified from the lacustrine deposits of the Li and the Mae Moh basin, Northern Thailand, Oligocene-Miocene in age. Apart from conventional leaf architectural analysis, the supplemental terms and classification of marginal venation patterns (MVP) of extant leaves were proposed and applied for taxonomic purposes. All the species and the genera *Adenanthassia*, *Antheroporum*, and *Semecarpus* are new to the world's Tertiary flora. *Mangifera paleoindica* and *Cassia paleosiamea* suggest that Thailand might be (one of) the area(s) of origin of *M. indica* and *C. siamea*, respectively. Three species of *Mangifera* indicate a long history of evolution and diversification while the genus *Semecarpus* may document the early emergence in Northern Thailand. The presence of the three leguminous subfamilies indicates diversification of the family since the Oligocene to the Miocene. The genera *Adenanthassia* and *Pithecellobium* are significant to future analysis of migration between South America, Africa, India, and Asia. These Thai tropical species and warm temperate ones of previous studies suggest coexistence of conifers with deciduous-evergreen broadleaf angiosperms. Two leaf keys to 35 simple-leaf anacardiaceous species were constructed and a photographic archive of herbarium and cleared leaf specimens of extant species is provided for future research.

School of Biology — Student's Signature.......................................

Academic Year 2003 — Advisor's Signature.......................................

Co-advisor's Signature..................................

Co-advisor's Signature..................................

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In the world of paleobotany we may learn about plants that flourished and vanished as time passes. In the world of mankind…one thing that could exist beyond changing of time and evolution is friendships and kindness passed among us.

Prakart Sawangchote

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List of Abbreviations

BATV	Branching angle of tertiary veins
BKF	Bangkok Forest Herbarium
BKF SN	Serial number of specimen of Bangkok Forest Herbarium
CMArC	Complete column of MAr (see MAr and PMArC)
DSV	Discrete Secondary Veins
ELMA	Exmedial Loop and/or Multiangle of secondary veins
ELMAF	First ELMA
ELMAL	Last ELMA
F	Fimbrial vein or fimbriate
FEV	Free Ending Veinlets
IV	Intramarginal Veins
LBELMA	Lower Border of ELMA
LMV	Looped Marginal Veins
MVP	Marginal Venation Pattern or type of MVP
MAr	Marginal Areoles
MArC	Column of MAr
MUV	Marginal Ultimate Venation
NLR	Nearest Living Relative
P	Primary vein
PMArC	Partial MArC
PSU	Prince of Songkla University

List of Abbreviations (Continued)

PSUH	PSU Herbarium
PSU SN	Serial number of specimen of PSU
S	Secondary vein
Se	Ending of Secondary Vein
SMAr	Solitary MAr
SUT	Suranaree University of Technology
T	Tertiary vein
ZFVMA	Zone of Free ending Veinlets and Marginal Areoles

Chapter I

Introduction

1.1 Research rationale

Global climate and vegetation changes have been of a continued interest to earth scientists for decades. Their interest is not restricted to the time of the emergence of human beings but throughout the geological past. Shortly stated, they are learning about the impact of large-scale environmental changes on ancient life and how these findings may help us resolve today's environmental controversies. To understand the processes of change we require data on the taxonomy of the fossils, evolution, paleoecology, paleogeography, paleoclimate, and other geological related subjects worldwide. Various fields of study, including paleobotany, can serve as the tools to achieve the above mentioned goal.

Besides the reconstruction of the complicated history of the plant kingdom, paleobotany can also play a key role in many areas of geology and paleoecology and be an important source of paleoclimate information. On land, the useful sources of proxy data for past climates are morphological characteristics of fossil plant assemblages, in particular, leaves of flowering plants. In practice, the first priority of studies may be set either on systematics or on paleoclimate. After taxomomic study, phytogeography, evolution, paleoecology, and paleoclimate will usually be conducted. Although there are about sixty Cenozoic basins in Thailand, very little taxonomic work particularly on plant macrofossils has been done. As a consequence, a clear picture of evolution, phytogeography, paleovegetation, paleoecology, and paleoclimate of the region (i.e., SE Asia) can hardly be obtained. Like a jigsaw puzzle, paleobotanists' work in Thailand can serve for achievement of the objectives of paleobotany as mentioned above and can contribute part of the picture of how climate and vegetation have been changing. With the priority of study kept in mind, the objectives of this study will then emphasize systematics.

1.2 Research questions

1) To which taxonomic affinities do selected fossil leaves found in different layers of the geological column at Li basin and Mae Moh basin belong?

2) Are there any changes in plant assemblages (as identified in 1) in these layers?

3) What did the paleovegetation look like? Under which types of climate did these vegetation types exist?

4) From an evolutionary and paleogeographical point of view, will there be any relationships among Thailand and other regions of the world during this period?

5) How valid is using the modern leaves to identify the fossil leaves based on leaf architecture (morphology and venation pattern) in this study?

1.3 Research objectives

1) To study taxonomic affinities of selected fossil leaves from Li Basin and Mae Moh basin by means of leaf architectural analysis and comparison with living and fossil taxa.

2) To critically study morphology and venation patterns[1] of modern leaves and to evaluate the validity of using such characters for determining fossil affinities.

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[1] Cuticular analysis was omitted due to failure in preparing cuticle from the fossil leaves

3) To construct leaf keys and picture archives of selected modern leaves to which the fossils have close affinities.

4) To examine changes (if any) in plant assemblages in different layers of the Tertiary deposits.

5) To attempt to reconstruct plant communities and their environments by application of uniformitarianism to the fossil species and their NLRs. The evolutionary aspects and paleogeography will also be described where data is available.

The objectives 4) and 5) will be restricted to the limited taxa investigated (see 1. 4)

1.4 Scope and limitations of the study

1) Fossil leaves studied will be restricted to *some* selected taxa found in some layers of the whole sedimentary logs of Li and Mae Moh basins. The reason is that the emphasis in this study is on what was mentioned in the first two main research objectives. In addition, this work is just a part of building up the floral succession in stratigraphic sequence in order to understand the floral history, paleoecology and phytogeography.

2) Clearing leaves will be performed on every taxon considered to be a possible NLR except for the taxa that are already in the SUT cleared-leaf collections (and are of good quality). Due to the failure in preparing cuticle from the fossils, the cuticle preparation of modern leaves is therefore not performed.

3) According to 1) the changes in plant assemblages in different layers of deposition will be restricted to the taxa investigated in this study and to the evidence from authors working in the same areas.

4) Concerning reconstruction of paleovegetation, paleoclimate, and evolutionary aspects of the taxa studied and paleogeographical points of view, the interpretation will be restricted to what can be mentioned from the initial and limited taxa investigated.

1.5 Expected results

1) Initial data on systematics, paleovegetation, paleoclimate, paleogeography and evolutionary aspects of the studied taxa based on fossil leaves.

2) Built up reference collections of modern leaves (cleared leaves and pictures of herbarium sheets with close up of venation patterns) and fossil leaves and leaf keys to some selected modern taxa for various aspects of future research.

1.6 Definition of the key terms: leaf architecture, gross form, and venation pattern

Anatomically, a leaf is composed of three principal tissue systems, epidermis, mesophyll, and vascular tissue or veins (Taylor and Taylor, 1993, 174-175). The veins are composed of xylem and phloem and the arrangement and anastomoses (with some exception, e.g., *Ginkgo*) of veins in particular patterns are called venation patterns.

The term “leaf architecture” was first used for dicotyledonous leaves by Hickey (1971, in Hickey, 1973) and Delevoryas and Gould (1971, in Hickey, 1973). It denotes the placement and form of those elements constituting the outward expression of leaf structures, including venation pattern, marginal configuration, leaf shape, and gland position. According to the elements of the leaves that are organized into certain definite structural patterns capable of description, Hickey therefore mentioned the appropriateness of the term because of its conforming to the definition of the term “architecture”. Dilcher (1974) used the terms gross form (gross leaf form) and fine features for angiosperm leaves. The former includes size, shape, nature of the margins, form of the apex, base and petiole, positioning of glands and nature of venation while the latter covers fine venation patterns and cuticular features. Even though the term cuticular features are not included in the meaning of the term leaf architecture by Hickey (1971, 1973), the incorporation of the cuticular features into the manual of leaf architecture (LAWG, 1999), may imply that this term covers the cuticular features. I therefore adopted Dilcher’s two terms mentioned as two components (venation and cuticle) of the term leaf architecture. Hickey (1973), Dilcher (1974) and Taylor and Taylor (1993) provided good reviews of the history of using leaf architecture analysis in the description of fossil leaves, its significance to taxonomic study of the fossil leaves, and examples of studies.

Because cuticular analysis is not included in this study, the term leaf architecture was then used with two components, “gross form” and “venation pattern”. The gross form includes size, shape, margin, gland position, texture, and attachment whereas the venation pattern includes type of venation, and all features of primary veins, secondary veins, tertiary veins, higher order venation, and areoles.

Chapter II

Research Review

2.1 A brief overview of paleobotany and its significance

Paleobotany is the method by which the complicated history of the plant kingdom can be reconstructed (Taylor and Taylor, 1993). Even though Paleobotany can be approached from two perspectives, one biological and the other more geological in scope, the answers to the questions being asked by Paleobotanists need integration of both areas of expertise. The following aspects of studies are based on different backgrounds of the Paleobotanists: to reconstruct the entire plants, to identify the living plants or other fossil plants to which the fossil is most closely related (taxonomic study of the fossils), to study the origin and subsequent evolution of major groups of plants, and to examine fossil plants in relationship to form and functions. In addition, Paleobotany also plays a key role in many areas of geology, such as biostratigraphy, or correlation of rock units. For paleoecology, botanical and geological information are involved. Paleobotany is an important source of paleoclimate information as well. Various plant parts, including leaves, wood, flowers, fruits, pollen, and spores, may be discovered from different depositional environments. In the way of practice, most fossil plants will be firstly studied with respect to their systematics and paleophytogeography, before studies of Paleoecology and paleoclimate are attempted.

This practical way conforms to the statement that “*Paleobotany has always been an important part of plant systematics*” (Dilcher, 2001), and that “*usually an attempt is made to sort out such mixing (of various plant communities) before any paleoclimatic interpretation is put forward*” (Dilcher, 1973). The Leaf Architecture Working Group (LAWG) (1999) has expressed the idea of priority of study that “*Because morphotypes may represent different taxonomic levels with different biological significance, they should not be used uncritically to assess floral diversity, composition, or paleoclimate*”. After morphotypes and their living relatives have been identified, biostratigraphic, Paleoclimatic, or other forms of analysis will then be possible. Bande and Prakash’s (1986) statement also supports the significance of study priority: “*Enough data are now available in India regarding its Tertiary vegetation to enable attempt to reconstruct the paleovegetation and paleoclimate etc. However, the same can not be said regarding the region of Southeast Asia”*.

For the case of fossil leaves, paleoecology and Paleoclimate can be conducted via analysis of leaf architecture.

2.2 Leaf fossils and their study

Leaves often represent the majority of angiosperm remains. They are commonly found in allochthonous depositional sites where drastic changes in leaf characteristics are the obvious result of transportation and fragmentation. The study of angiosperm leaves is therefore fraught with difficulties and can produce bias in the results (Stewart and Rothwell, 1993). Attempts have been made and are being made, since the work of von Ettingshausen in 1861, to understand the nature of venation patterns and their significance in taxonomic use in both modern and fossil leaves. Dilcher (1974) has given a good review on the progress of this field of study. He also provided examples of studies that related ecological variation with venation characters. In the study of the Miocene flora of Kreuzau, Germany, Ferguson (1971) noted the effects of the environment (e.g., arid climate and humid climate) on the processes of transportation and on the composition of the fossil flora at the sites of deposition. In a study of plant remains from 19 species, Chaney (1952, cited in Graham, 1999) pointed out three factors that controlled entrance into the fossilization process (mostly interpreted by study of leaves). The most important factor was the distance from the depositional basin. The second most important factor was durability of the organs entering the pools. The last factor was the weight-to-area ratio of the organ. These taphonomic factors should be kept in mind when paleoenvironments, composition of the flora (i.e., leaf assemblage), and vegetation types are to be interpreted via leaf remains.

2.3 Tertiary floras, reconstruction of Tertiary plant communities, and paleoclimates

The Tertiary period started about 65 MA and ended at 2.5 MA. This period was the time of evolutionary development of the modern vegetation (and modern leaf physiognomy), climate, and landscape (Millar, 1996; Stewart and Rothwell, 1993). Numerous Tertiary floras have been described from various major fossil localities. All of the studies concern systematics and inevitably, more or less, evolution, biogeography, paleoclimate, and paleoecology.

From the taxonomic and paleogeographic point of view, a number of studies are available for comparative studies of Tertiary floras in Thailand. The samples include Bande and Prakash (1986), Awasthi and Mehrotra (1990), Awasthi and Prasad (1990), Awasthi and Srivastava (1990), Axelrod (1992), Awasthi and Mehrotra (1995), Haomin and Yahui (1995), Yucheng and Yahui (1995), Mehrotra, Awasthi and Dutta (1997), Mehrotra, Dilcher and Awasthi (1998), and Greenwood, Vadala and Douglas (2000). Concerning details of particular fossil taxa, referencess are available from almost all important regions such as America, Europe, and Asia. Details of the specific taxa related to the ones described in this study will be mentioned in the chapters on results and discussion.

Some studies concern similarity and biogeographical relationships among the fossil floras. Tertiary fruits and seeds in the London Clay were studied (Reid and Chandler, 1933; Chandler, 1961; Collinson, 1983, in Taylor and Taylor, 1993) with nearly 250 species identified and only about one third of the genera referable to extant forms. Many of the taxa are tropical in distribution, and the most closely comparable modern flora is considered to be the forests of Southeast Asia. Manchester (1999) compared Tertiary floras of North America with those of Europe and Asia and documented a long history of floristic interchange. The routes and timings of intercontinental dispersals through the Tertiary are also discussed.

Christophel and Greenwood (1988, 1989) studied the role of changes in climate to the vegetation of Australia during the Tertiary. From the biogeographical and paleoclimatic point of view, this study provided a method to detect foliar physiognomic signatures of modern leaf litter that can be used to interpret and reconstruct early Tertiary leaf assemblages. Based on plant megafossils and published studies, Christophel (1989) divided the Australian Tertiary into three units: Eocene, Oligo-Miocene and Pliocene. Key taxa in the Eocene include Casuarinaceae, Proteaceae, Fagaceae, Podocarpaceae and Lauraceae. Many known Eocene deposits are interpreted as warm, humid rain forest. Oligo-Miocene floras are the result of climatic deterioration, with greater occurrence of sclerophylly and xerophylly, reduction of tropical taxa and the earliest records of Mimosaceae, Chenopodiaceae, and Poaceae. These trends continue into the Pliocene, which is not well represented in Australia. Stewart and Rothwell (1993) have given a good concise review of Tertiary climate and vegetation during the Paleocene and Eocene.

Concerning reconstruction of Tertiary plant communities, Gastaldo and Ferguson (1998) have given the remarks that the use of multidisciplinary data sets from a wide variety of geological and biological disciplines can provide a more reliable framework on which reconstructions of Tertiary plant communities can be based.

Taylor and Taylor (1993) gave some examples of well-known and well-documented studies such as the Columbia Plateau Upper Miocene floras. These studies served as an example of the interface of biological and geologic data necessary for a complete analysis of fossil plant communities and their history.

The Eocene floras of western Kentucky and Tennessee are also some of the better known Tertiary floras that provided an excellent example of why caution and careful evaluation of the fossils must precede generalizations about past climate. The juxtaposition of the tropical taxa (e.g., *Sabal*, *Philodendron*, *Ficus*, and *Ocotea*) and montane taxa (e.g., *Podocarpus*[1] and *Pinus*) that today do not coexist suggests that the climate tolerances of some of these taxa may have changed since the Miocene (Taylor and Taylor, 1993).

A controversy of paleoclimate interpretation of Tertiary floras can happen due to different methods of inference. For example, the Eocene sites in the Mississippi Embayment have been regarded as representative of a tropical rain forest based principally on the identification of certain taxa. An analysis of the area based on foliar physiognomy suggests, to the contrary, that during the Eocene the area experienced a seasonally dry to slightly moist, warm temperate to cool subtropical regime (Dilcher, 1973).

Some other studies (i.e., Uhl and Mosbrugger, 1999; Jacobs and Deino, 1996; Gastaldo and Ferguson, 1998; Collinson, 1983; Burrows, 1980; Greenwood, 1992), which concern views mentioned above and will not be mentioned in detail here, are also important in making estimation of climatic parameters and paleoecological interpretation more reliable.

2.4 Tertiary floras of Thailand and their implications for paleoclimate interpretation

In Thailand, these areas of research are just at the starting point. Limited numbers of the fossil specimens, their incompleteness, and, crucially important, lack of references of modern plants or vegetation of the region, make both taxonomic study and paleoclimatic inferences difficult and less valid. As a result, quite few studies of Tertiary floras of Thailand, or even of other periods, have been documented. The following are the examples so far available.

2.4.1 Study of pollen

Palynofloras of several Tertiary basins have been studied and the results show that floras were primarily of temperate elements (Ratanasthien, 1984; Meesuk, 1986; Watanasak, 1988; and Songtham et al., 2000, Songtham et al., 2001). The ages of these temperate basins were dated back to Oligocene to Early Miocene (Songtham et

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[1] *Podocarpus* can also be tropical

al., 2001). Wattanasak (1988), by using palynological assemblages, pointed out that the past communities of Nong Ya Plong Tertiary basin (Central Thailand) was temperate forests. Based on Midtertiary palynological assemblages from fourteen stratigraphic sequences in nine basins in Thailand, Watanasak (1990) has constructed two palynological zones, SIAM-1 and SIAM-2. The SIAM-1 zone is characterized by assemblages comprising high frequencies of gymnospermous pollen such as *Tsugaepollenites igniculus*, *Piceaepollenites alatus* and *Pinuspollenites* sp. The SIAM-2 zone is characterized by influxes of tropical taxa and decreasing proportions of the temperate taxa. The tropical taxa include, for example, *Avicennia* sp., *Dipterocarpus* sp. and *Pandaniidites texus.*

After examining palynofloras of Krabi basin, Songtham and Wattanasak (1999) indicated that the deposition occurred predominantly in marginal marine terrestrial environments under a humid climate with seasonal rainfall in a tropical region, a geographic setting not much different from the present day.

Songtham (2000) studied the palynoflora of Na Hong Basin, Mae Chaem district, Chiang Mai province, and two palynological zones were divided as *Pediastrum* Zone in the lower part and the *Inaperturopollenites dubius* Zone in the upper part. The depositional environments were identified as lacustrine and fluviolacustrine respectively. The paleoclimate was determined to be warm temperate and the basin was dated back to Late Oligocene to Early Miocene. By the study of palynofloras, Songtham et al. (2001) have identified 4 palynological zones and their paleovegetations of Ban Pa Kha coal mine, Li basin, Lamphun province. The depositional environments of these 4 zones are, from the bottom to the top, fluvial system, lacustrine deposits, coal, and lake or pond environment. It was suggested that the change of paleovegetation and the corresponding climate was from warm temperate to tropical. By palynological analysis performed on some Tertiary basins of northern Thailand, including Mae Moh, Li, Na Hong, Mae Lamao, and Chiang Muan basins, Songtham et al. (2003) recognized two main palynological assemblages; warm temperate (Oligocene-Early Miocene) and tropical assemblages (Early-Middle Miocene), which were believed to have resulted from changing the position from temperate latitude to tropical latitude by movement southward or southeastward of the Southeast Asian landmass. These changes occurred during Oligocene to Early or Middle Miocene.

2.4.2 Study of macrofossils

Endo (1964, 1966) described fossils plants from Li Basin (presumably from Ban Pa Kha mine, pers. comm, C. Chonglakmani) as follows: conifers; *Glyptostrobus europaeus* (Brongn.) Heer, *Sequoia langsdorfii* Endo, *Taxodium thaiensis* Endo, and angiosperms, *Ficus eowightiana* Endo, *Alnus thaiensis* Endo, *Carpinus* (?) sp., *Fagus feroniae* Ung., *Quercus* cf. *lanceaefolia* Roxb., *Quercus protoglauca* Endo, *Salix* ? sp., and *Sparganium thaiensis* Endo. He suggested that the climate of Li basin was warm temperate at the time of deposition.

In addition, leaves of *Bauhinia* sp., *Podogonium knorrii* Heer, (= *Podocarpium podocarpum* (A. Braun) Herendeen, (see Herendeen, 1992)), and *Apocynophyllum* sp., considered to be Miocene, have also been described from the Mae Sot Basin, Tak province, western Thailand (Endo and Fujiyama, 1965). Yabe (2002) has also reported fruits of *Acer* from Ban Pa Kha mine.

From the preliminary results of the project "*Changes in plant diversity over geologic time during the Cenozoic in Thailand*", Grote, Chonglakmani, and Benyasuta (1999) pointed out that needles and cones from Lamphun appear to show affinity to *Sequoia* (Taxodiaceae), and one leaf type from Krabi is a species of palm (Arecaceae). Silicified wood from the Northeast comprises at least 9 species from the Miocene and 5 from the late Jurassic. Wood showing affinity to *Terminalia* (Combretaceae) is quite common. Additional specimens may be *Intsia* or *Afzelia* (Caesalpiniaceae) and *Hopea* (Dipterocarpaceae).

Investigations of an assemblage of angiosperms and gymnosperms leaves, twigs, seeds, and cones from a layer of paper coal occurring at the top of a thick layer of lignite in Li basin indicated that this assemblage may represent a mixed forest of angiosperms and gymnosperms, dominated by *Sequoia* (Grote, 2000). Besides, the form genus *Podocarpoxylon*, with affinity to Podocarpaceae, was also identified from chacoalified wood, which may indicate forest fires occurred in the dried lignite-forming swamp (Grote, Chonlakmani, and Benyasuta, 2001). Benyasuta (2003) identified 18 species of petrified angiosperm wood (Miocene to Pleistocene in age) from Nakhon Ratchasima, Chaiyaphum and Khon Kaen province. Most taxa show a resemblance to the modern taxa distributed in dry evergreen and mixed decidous forests of the Korat Plateau at present.

2.5 Previous studies of anacardiaceous fossils

The emergence of the Anacardiaceae can be dated back to the Cretaceous of Argentina and by the Paleogene they are represented in southern England and Oregon (Raven and Axelrod, 1974). Grote (1989) has listed previous studies of fruits attributed to the Anacardiaceae the age of which range from Lower Eocene to Pliocene. He also described and placed fossil fruits *Campanurbia lenticularis* gen. et. sp. nov. morphologically close to the recent genus *Dracontomelum*.

Recently, the poorly understood phytogeographic and phylogenetic relationships were studied and the result supports the idea of a Southeast Asian origin for the family. Two dispersion routes were proposed to link the American taxa and Asian taxa, one via the Northern hemisphere: Southeast Asia – Europe – North America – South America, and the other via Southern hemisphere: Southeast Asia – Africa – South America – North America (Martínez, Terrazas, and Cevallos-Ferriz, 1999). American fossil taxa seem to receive much more attention with regard to the study of taxonomic affinities, evolution, and phytogeography, as documented by various authors (e.g., Martínez and Cevallos-Ferriz, 2001; Ramírez and Cevallos-Ferriz, 2002). The Asian taxa, on the other hand, had received less attention to those aspects of study. Tertiary Asian anacardiaceous fossils so far reported were mostly from India and Nepal, but some were from Japan, China. These tropical Anacardiaceous fossils are mostly from leaves, although some are from woods, fruits and seeds. Examples of anacardiaceous wood, which have similarity with wood of extant *Gluta*, were reported by Mehrotra, Awasthi and Dutta (1999) and by Poole and Davies (2001) from India and Bangladesh, respectively. Konomatsu and Awasthi (1999) described a leaf impression and a seed of *Swintonia butwalensis* of Middle-Upper Miocene, Nepal.

The tropical genera of Tertiary fossil leavess including *Bouea*, *Dracontomelum*, *Gluta*, *Lannea*, *Mangifera*, *Nothopegia*, *Parishia*, *Spondias* and *Swintonia* were reported from different ages and different localities of India and Nepal and summarized in Table 2.1 (Lakhnapal and Awasthi, 1984; Awasthi and Prasad, 1990;

Bande and Srivastava, 1990; Awasthi and Srivastava, 1990; Bande, 1992; Antal and Awasthi, 1993; Awasthi and Mehrotra, 1995; Arya and Awasthi, 1996; Prasad and Awasthi, 1996; Mehrotra, Dilcher, and Awasthi, 1998; Konomatsu and Awasthi, 1999).

Table 2.1 Previous studies on anacardiaceous fossils (mostly leaves), so far available and reviewed, from India and Nepal.

Authors	**Location**	**Age**	**Year of publication**	**Taxon found**	**Organ**
1. Lakhnapal and Awasthi	India	Late Tertiary	1984	*Mangifera someshwarica*	Leaves
2. Awasthi and Prasad	Western Nepal	Neogene (Miocene-Pliocene)	1990	*Mangifera someshwarica*, *Gluta*, and *Swintonia*	Leaves
3. Bande and Srivastava	India	Late Cenozoic	1990	*Spondias*	Leaves
4. Awasthi and Srivastava	India	Middle Miocene	1992	*Gluta*	Leaves
5. Bande	India	Paleogene	1992	*Dracontomelum*	Not clearly mentioned
6. Antal and Awasthi	West Bengal, India	Middle Miocene-Pliocene	1993	*Nothopegia*, and *Bouea*	Leaves
7. Awasthi and Mehrotra	Assam, India	Oligocene	1995	*Lannea*, *Mangifera someshwarica*, and *Parishia*	Leaves
8. Arya and Awasthi	Himachal Pradesh	Lower Miocene	1996	*Gluta miocenica*	Leaves
9. Prasad and Awasthi	Western Nepal	Neogene (Miocene-Pliocene)	1996	*Bouea*, and *Swintonia*	Leaves
10. Mehrotra and Dilcher & Awasthi	Northeast India	Upper Paleocene	1998	*Eomangiferophyllum damalgiriensis*	A leaf
11. Konomatsu and Awasthi	West central Nepal	Middle-Upper Miocene	1999	*Swintonia butwalensis*	A leaf and a seed

Fossil leaves of *Melanorrhoea* (= *Gluta*), *Pistacia* and *Rhus* were reported from Tertiary localities of China (Hu and Chaney 1940; Li and Yahui, 1995; Liu and Yahui, 1995). Among these Asian taxa, the genus *Mangifera*, particularly *M. indica*, seems to receive more attention on the areas of origin and evolution due to its popularity as a tropical fruit tree and its economic value. *Mangifera* fossil leaves from Japan (Matsuo, 1967) and India have been reported (Lakhanpal and Awasthi, 1984; Awasthi and Prasad, 1990; Awasthi and Mehrotra, 1995). The oldest *Mangifera* – like fossil leaf, *Eomangiferophyllum damalgiriensis*, was considered to be the precursor to the extant genus which evolved, by the Paleocene, within Peninsular India. Afterward, members of the genus migrated east and west and diversified in the Malaysian and Sumatran rain forest after land connections were formed between the Indian and the Asian Plates at the end of Eocene / beginning of Oligocene (Mehrotra, Dilcher, and Awasthi, 1998). In the previous studies of Tertiary fossil leaves (Endo, 1964, 1966) and pollen (Ratanasthien, 1984; Meesuk, 1986; Wattanasak, 1988; Watanasak, 1990; Songtham, 2000; Songtham et al., 2000, Songtham et al., 2001) in Thailand, no fossil species showed affinities to Anacardiaceae. In addition to the fossils mentioned above, Barkley (1957) listed published anacardiaceous fossil species including those in *Anacardium*, *Spondias*, *Dracontomelum*, *Lannea*, *Rhus*, *Schmaltzia*, *Toxicodendron*, *Searsia*, *Pistasia*, *Metopium*, and *Schinus*. He also listed form genera by various authors such as *Spondiocarpus* Warburg, 1897, *Spondicarya* Reid & Chandler, 1933, *Anacardiophyllum* Ettinghausen (1869 = *Anacardites* Saporta in Heer, 1861, and in Berry, 1924), *Columbicarpum* Reid, 1933, *Daphnophyllum* Heer, 1874, *Pseudosclerocarya* Reid & Chandler, 1933, *Xylocarya* Reid & Chandler, 1933, *Labatocarpum* Reid & Chandler, 1933, *Trilobium* Saporta in Heer, 1861 (*Heterocalyx*

Saporta 1873, *Getonia* Unger, 1847, *Folliculites* Zenker, 1833, *Rhoipites* Wodehouse, 1933, *Anacardioxylon* Felix, 1882, *Semecarpites* Fritel, 1912, *Teschia* Reid & Reid, 1915, *Protameris* Unger ex Schimper, 1850, and *Sumatroxylon* Berger, 1923. Among these, *Semecarpites* Fritel, 1912 was related to the modern genus *Semecarpus* and related to the fossils in this study. Knowledge of distributions patterns of both temporal and spatial scales of the fossil and modern genera is still in need, particularly in SE Asia, to understand their origin and dispersion.

2.6 Taxonomy of recent Anacardiaceae

Anacardiaceae was treated, by Cronquist (1981), in subclass Rosidae, order Sapindales. Genera and species numbers of both hemispheres were estimated to be about 73 genera and 600 species (Lawrence, 1971) or up to 850 species (Bompard and Schnell, 1997). Most of them are chiefly pantropical and subtropical in distribution (Cronquist, 1981, Takhtajan, 1997) while some may be distributed into warm temperate regions (Takhtajan, 1997) or even into the north temperate areas of Eurasia (Lawrence, 1971). The Angiosperm Working Group (APG, 1998), places Anacardiaceae in Eudicot; core Eudicot; Rosid; Eurosid II; and Sapindales.

2.6.1 Classification system of the family

I. Takhtajan (1997) divided the family into 4 subfamilies

1. Anacardioideae: Leaves simple, entire. *Anacardium*, *Androtium*, *Buchanania*, *Bouea*, *Fegimanra*, *Gluta*, *Mangifera*, *Swintonia*.
2. Spondioideae: Leaves usually pinnate, rarely simple.
   - 2.1 Spondieae: *Spondias*, *Dracontomelon*, *Sclerocarya*, *Choerospondias*, *Poupartia*, *Pegia*, *Lannea*, *Tapirira*, etc.

2.2 Rhoeae (Rhoideae): *Sorindeia*, *Trichoscypha*, *Parishia*, *Campnosperma*, *Euroschinus*, *Schinus*, *Schinopsis*, *Blepharocarya*, *Cotinus*, *Heeria*, *Comocladia*, *Metopium*, *Rhus*, *Toxicodendron*, *Astronium,* etc.

2.3 Semecarpeae: *Nothopegia*, *Melanochyla*, *Semecarpus*, *Drimycarpus*, *Holigarna*.

3. Juliannioideae: *Orthopterygium*, *Amphipterygium*.

4. Pistacioideae: *Pistacia*.

Not all the genera are listed in the classification of Takhtajan, but they are listed in the internet location below.

II. In the page http://biodiversity.uno.edu/delta/, by Watson, L., and M. J. Dallwitz (1992 onwards), 70 genera (71, when *Pistacia* was added) were listed as follows: *Actinocheita*, *Anacardium*, *Androtium*, *Antrocaryon*, *Apterokarpos*, *Astronium*, *Baronia*, *Bonetiella*, *Bouea*, *Buchanania*, *Campnosperma*, *Cardenasiodendron*, *Choerospondias*, *Comocladia*, *Cotinus*, *Cyrtocarpa*, *Dracontomelon*, *Drimycarpus*, *Ebandoua*, *Euleria*, *Euroschinus*, *Faguetia*, *Fegimanra*, *Gluta*, *Haematostaphis*, *Haplorhus*, *Harpephyllum*, *Heeria*, *Holigarna*, *Koordersiodendron*, *Lannea*, *Laurophyllus*, *Lithrea*, *Loxopterigium*, *Loxostylis*, *Mangifera*, *Mauria*, *Melanochyla*, *Metopium*, *Micronychia*, *Montagueia*, *Mosquitoxylum*, *Nothopegia*, *Ochoterenaea*, *Operculicarya*, *Ozoroa*, *Pachycormus*, *Parishia*, *Pegia*, *Pentaspadon*, *Pistacia,* *Pleiogynium*, *Poupartia*, *Protorhus*, *Pseudoprotorhus*, *Pseudosmodingium*, *Pseudospondias,* *Rhodosphaera,* *Rhus,* *Schinopsis,* *Schinus,* *Sclerocarya,* *Semecarpus,* *Smodingium*, *Solenocarpus*, *Sorindeia*, *Spondias*, *Swintonia*, *Tapirira*, *Thyrsodium,* *Toxicodendron,* *Trichoscypha*.

2.6.2 The genus *Mangifera* L.

Sixty nine *Mangifera* species were recognized in the classification system of Kostermans and Bompard (1993, in Mukherjee, 1997). Sixteen species occurring in Thailand were listed in a preliminary checklist by Chayamarit (1994), *Mangifera caloneura*, *M. camptosperma*, *M. cochinchinensis*, *M. duperreana*, *M. flava*, *M. foetida*, *M. gedebe*, *M. griffithii*, *M. indica*, *M. lagenifera*, *M. linearifolia*, *M. macrocarpa*. *M. odorata*, *M. pentandra*, *M. quadrifida* and *M. sylvatica*. Eiadthong (2000) mentioned that 20 species existed in Thailand. The ones that are not in the list by Chayamarit (1994) are *M. caesia*, *M. gracilipes*, *M. laurina*, and *M. longipetiolata*. In Chayamarit (1994), the last one is the synonym of *M. quadrifida*. More details are available in chapter V discussions.

2.6.3 The genus *Semecarpus* Lin. f.

Semecarpus is also a tropical genus comprising about 75 species and occurring in India, Sri Lanka, Myanmar, Indo-China, Taiwan, Thailand, throughout the Malesian region, Northern Australia and the Pacific islands east to Fiji (Sosef, Hong, and Prawirohatmodjo, 1998). Presumably, there are three species in Thailand, namely; *S. cochinchinensis*, *S. curtisii*, and *S. reticulata* (Chayamarit, 1994). More details are available in chapter V discussions.

2.7 Previous studies of leguminous fossils

A comprehensive review on the history of leguminous fossils, from both phylogenetic and biogeographic points of view, was provided by Herendeen and Dilcher (1992). Based on the limited and largely uncertain pollen and wood fossil record, the family was believed to have evolved since the Upper Cretaceous. From the Paleocene to Lower Eocene, the fossil record (mostly from pollen and wood) is more informative, and the floras from southeastern North America and southern England provide the most significant early (pre-Middle Eocene) assemblages of fossil legumes (Herendeen, Crepet, and Dilcher, 1992). By the Middle Miocene, the extensive diversification took place and all three subfamilies are present. Concerning phytogeographic relationships, the brief context is presented in 5.5 of chapter V. Numerous Tertiary fossil legumes have been described from various parts of the world, including North, South and Central America, Europe, Africa, China, India and New Zealand, and some details of fossil studies in each tribe, biogeography and systematic and phylogenetic implications can be studied from this review. Because of the high diversity of the subfamilies and large number of studies, the details or examples of the fossil genera or species and other related aspects will not be mentioned in this section but will be addressed in chapter V.

From the previous Tertiary fossil studies of Thailand, leguminous fossils are relatively rare. Endo and Fujiyama (1965) described leaves of *Bauhinia* sp. and *Podogonium knorrii* from Mae Sot Basin, Tak province (thought to be Miocene in age). Prakash (1979) assigned some fossil wood collected from the Northeast to *Cynometroxylon parainaequifolium*, *Millettioxylon indicum* and *Pahudioxylon sahnii*. Benyasuta (2003) found four species of leguminous fossil wood from the Northeast including *Albizia lebbeck*, *Dialium cochinchinensis*, *Millettia leucantha* and *Pahudioxylon sahnii*. Among the palynofloras at Na Hong basin (thought to be Oligocene to Early Miocene in age) (Songtham, 2000) and Li basin (Watanasak, 1988; Songtham, 2003) in the north of Thailand, no taxa associated with Leguminosae were found.

2.8 Taxonomy of modern Leguminosae

2.8.1 Classification system of the family

In Cronquist's classification system (1988) the order Fabales (subclass Rosidae) consists of 3 families and about 18,000 species, widely distributed throughout the world. The Fabaceae comprise more than 12,000 species, the Mimosaceae about 3,000, and the Caesalpiniaceae more than 2,000. The Leguminosae was treated by Takhtajan (1997) as a single family Fabaceae with 3 subfamilies, Caesalpinioideae, Mimosoideae, and Faboideae (Papilionoideae). The Angiosperm Working Group (APG, 1998), places Leguminosae in Eudicot; core Eudicot; Rosid; Eurosid I; and Fabales.

One hundred and two genera with 614 species were estimated to be indigenous to Thailand (Niyomdham, 1994). Among these Thai taxa, 71 genera and 450 species belong to Faboideae (Niyomdham, 1994), 11 genera and 51 species to Mimosoideae (Neilsen, 1985), and 20 genera and 113 species to Caesalpinioideae (Larsen, Larsen, and Vidal, 1984)

2.9 Some basic information on Li Basin and Mae Moh Basin

2.9.1 Location

Li and Mae Moh basin, in northern Thailand, are among the sixty Cenozoic basins scattered throughout both onshore and offshore regions of Thailand (Uttamo, 1998). Li Basin is in Li district, Lamphun province, 17° 45′ N latitude and 99° 00′ E longitude, approximately 600 km north of Bangkok and 150 km south of Chiangmai City. Mae Moh Basin is in Mae Moh district, Lampang province, at 18° 18′ 12″ N latitude, 99° 44′ 02″ E longitude, approximately 630 km north of Bangkok and 125 km SE of Chiangmai City (Fig. 2.1).

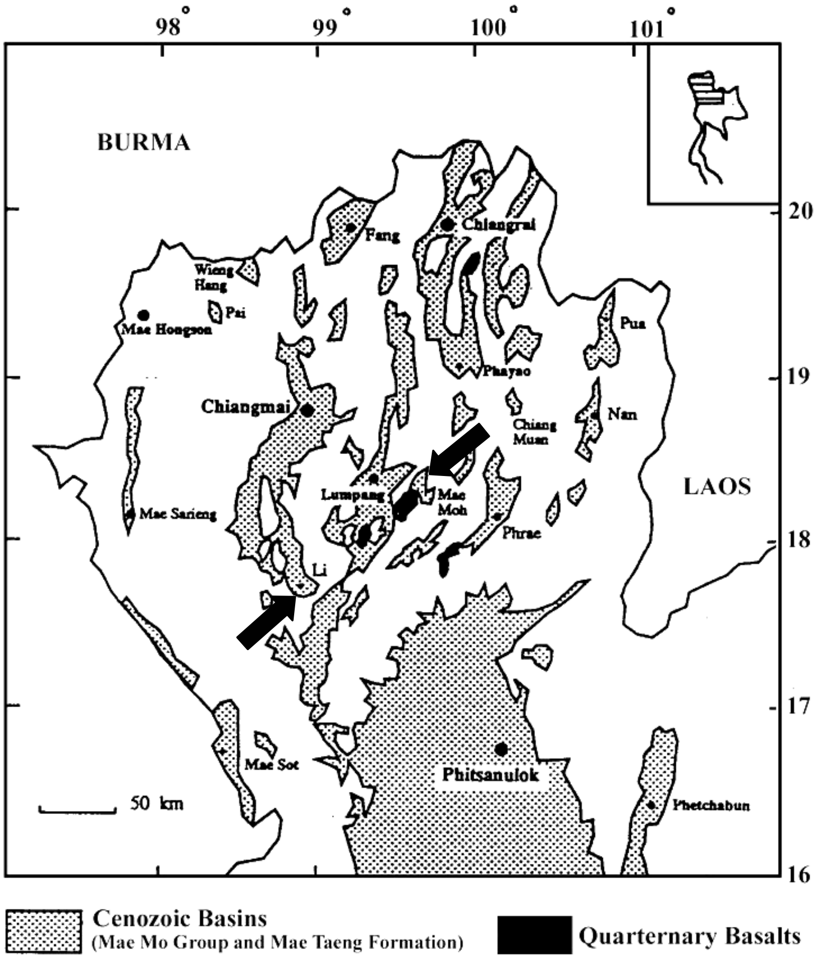


Fig. 2.1 Distribution of Cenozoic basins in northern Thailand and location of Li and Mae Moh basins in this study (black arrows) (after Uttamo, 1998).

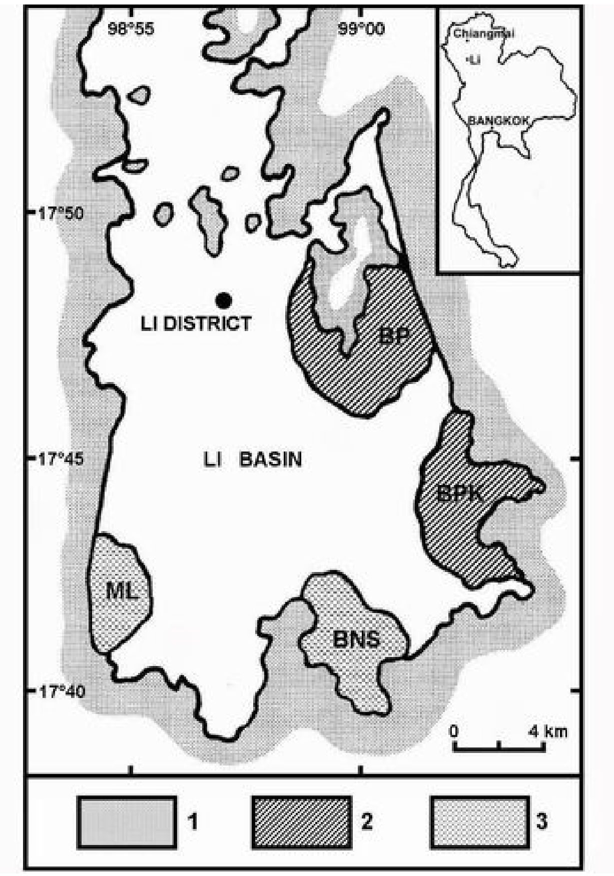


Fig. 2.2 Geological map of Li Basin (redrawn and modified from Snansieng and Maneekut, 1985, in Ginsburg, Mein and Tassy, 1991). 1 = Pre-Tertiary rocks, 2 = Paleogene sub-basins, 3 = Neogene sub-basins. BP, BPK, BNS, and ML = Ban Pu, Ban Pa Kha, Ban Na Sai, and Mae Long sub basins respectively. The Paleogene sub-basins, Ban Pu and Ban Pa Kha, were later determined to be Oligocene to Miocene by Wattanasak (1990), Songtham (2001), respectively.

2.9.2 Geological characteristics

Li basin is elliptical elongate in shape in a NNW-SSE direction (Fig. 2.2) and covers an area of 270 sq.km. with a maximum width of 18 km and maximum length of 21 km. (Tantusuparuk, 1991 cited in Uttamo, 1998).

The basin was subdivided into 4 sub-basins (Fig. 2.2): Ban Pu, Ban Pa Kha, Ban Nasai and Mae Long. The former two sub-basins were determined to be Paleogene in age and the latter two were Neogene (Ginsburg, Mein, and Tassy, 1991).

The basin is a smooth depression surrounded by ancient rocks (Fig. 2.2): series of Early and Middle Paleozoic with a predominance of quartzite and sandstone, Late Paleozoic and Triassic series with a predominance of limestone. Quaternary sediments (laterite and gravels of Pleistocene age, conglomeratic sandstone laid in terraces and recent floodplains) fill up the center of the depression. (Ginsburg, Mein, and Tassy, 1991). The Paleocene sequence crops out in the eastern part of the basin, particularly in the mining area and consists of shale, mudstone, sandstone, oil shale and coal beds. In contrast, the Neogene sequence is exposed in the western and southern sub-basins and is composed of marlstone, calcareous mudstone, claystone, shale and coal beds (Jitapunkul, 1992, and Tantasupalak, 1991, cited in Uttamo, 1998).

Mae Moh Basin is oval in shape, north-south trending, covering an area of 104 sq km. The basin is underlain by a basement of folded and faulted Triassic limestone, sandstone, and shale. The floor of the basin is covered by Pleistocene to Recent alluvium, except for the south where the Tertiary sequence is covered partly by Pleistocene basalt. The Tertiary deposits of the basin are known as the Mae Moh Group and subdivided into three formations, the Huai King formation, the Na Khaem formation and the Huai Luang formation (Fig. 3.2). More details are in Uttamo (1998). These two basins, as others in Northern Thailand, are rich in coal deposits. Large lignite deposits have been exploited by the open pit method (Uttamo, 1998)

2.9.3 Lithofacies

The sediments of Ban Pa Kha and Ban Pu sub-basins consist chiefly of shale, mudstone, sandstone, oil shale and coal beds of swamp and lacustrine origin (Snansieng and Maneekut, 1985, cited in Ginsburg, Mein, and Tassy, 1991).

At Ban Pa Kha coal field, the fossil plants (mostly leaves) were found quite abundantly in the overburden unit and the middle layer unit. However, the middle layer seems to be richer in fossil leaves than the overburden (Fig. 3.1 in Chapter III). The lithofacies, in which the fossil leaves expected to be found, are usually composed of claystone, mudstone, and siltstone. At Ban Pu coal field, fossil leavess were found in hard and soft siltstone of the lower coal seam and interburden. Fossil wood was also found in conglomerates of the interburden. Between Ban Pa Kha and Ban Pu, fossil leavess seem to be more abundant in the former coal field than in the latter (see details in Uttamo, 1998).

The Cenozoic stratigraphy of the Mae Moh Basin, modified from Sompong et al (1996) and Chaodamrong (1985) by Uttamo (1998) was simplified and is shown in Figure 3.2 in Chapter III. At the Mae Moh Basin, lithofacies of different environments were recognized from 3 sections studied by Uttamo (1998). The depositional environments determined included low energy back swamp or flood basins, shallow lake, intertidal flat, brackish water, sand-dominated river system, and braided stream. He also found fossil leaves in the claystone bed.

2.9.4 Age determination

The age determination of Li Basin varied among authors. From comparison of fossil leaves of Ban Pa Kha to those of Fushun in northeastern China, Endo (1964, 1966) considered this basin to be Upper Eocene. Studying pollen form Ban Pu mine, Watanasak (1990) determined the age to be Upper Oligocene to Lower Miocene. Songtham et al. (2001) used pollen evidence at Ban Pa Kha mine to date this basin back to Oligocene to Early Miocene.

By using pollen and spores at Ban Pu and Ban Pa Kha, Ratanasthien (1984) gave the age of Li Basin as Oligocene-Early Miocene Based on rodent fossils (discovered near Na Sai sub-basin), Li Basin was determined to be Middle Miocene in age (Chaimanee, 1998). The climate under which this Li fossil flora flourished was determined to be warm temperate (Endo, 1964) or warm temperate to tropical (Songtham, 2003).

Ban Pa Kha sub-basin, where fossil leavess in this study were collected, covers an area of 8 sq. km, and is located in the SE part of the Li Basin (Fig. 2.1). The Tertiary sequence of this sub-basin consists of 5 units (Fig. 3.1), including the overburden (20-150 m thick), the upper coal seam (10-15 m thick), the middle layer (10-15 m thick), the lower coal seam (15-20 m thick), and the underburden (more than 30 m thick) (Uttamo, 1998). The sub-basin was dated back to the long age range from Oligocene to Early Miocene (Songtham, 2001) or back to Lower Oligocene (Ratanasthien, 1984).

The age of the Mae Moh basin was considered to be younger than that of the Li basin. Javanaphet (1969, in Watanasak, 1989) gave the age of the basin from Miocene to Pleistocene whereas Buravas (1973, in Watanasak, 1989) determined the basin to be Miocene.

2.10 Modern vegetation types of the northern Thailand

The vegetation types that were indicated to cover the northern Thailand are as follow: seasonal rain forest (or semi-evergreen forest or dry evergreen rain forest) dominated by Dipterocarpaceae below 1000 m, lower montane forest or hill evergreen forest with oak species above 700 m, deciduous dry dipterocarp forest, mixed deciduous forest with teak and non-teak, and lower montane pine forest (IUCN, 1986 cited in http://www.forest.go.th/Botany/Flora/Forest_type.htm; Smitinand, 1977). From the UNEP Environmental Assessment Program for Asia and the Pacific in 1996, 5 forest types of Thailand were recognized viz. tropical evergreen forest, mixed deciduous forest, scrub forest, dry dipterocarp forest, and pine forest (Fig. 2.3). All these forest types cover the northern part of Thailand. Two principal forest types, evergreen and deciduous forests can further be subdivided as presented in Table 2.2. Manasanan (http://www.gisdevelopment.net/aars/arcs/1992/agrif/agrifor007pf.htm) classified the forest areas in Lamphun province into dry dipterocarp forest, mixed deciduous forest and evergreen forest. A detailed classification of the types of vegetation cover was also provided by Smitinand (1977).

Information, more or less complete, of the flora of the forest types in Northern Thailand is available in Smitinand (1977), in a field guide to forest trees of northern Thailand (Gardner, Sidisunthorn, and Anusarnsunthorn, 2000), in Queen Sirikit Botanical Garden’s book series (e.g., Nanakorn, 1996-1998, vol. 3-5), etc.

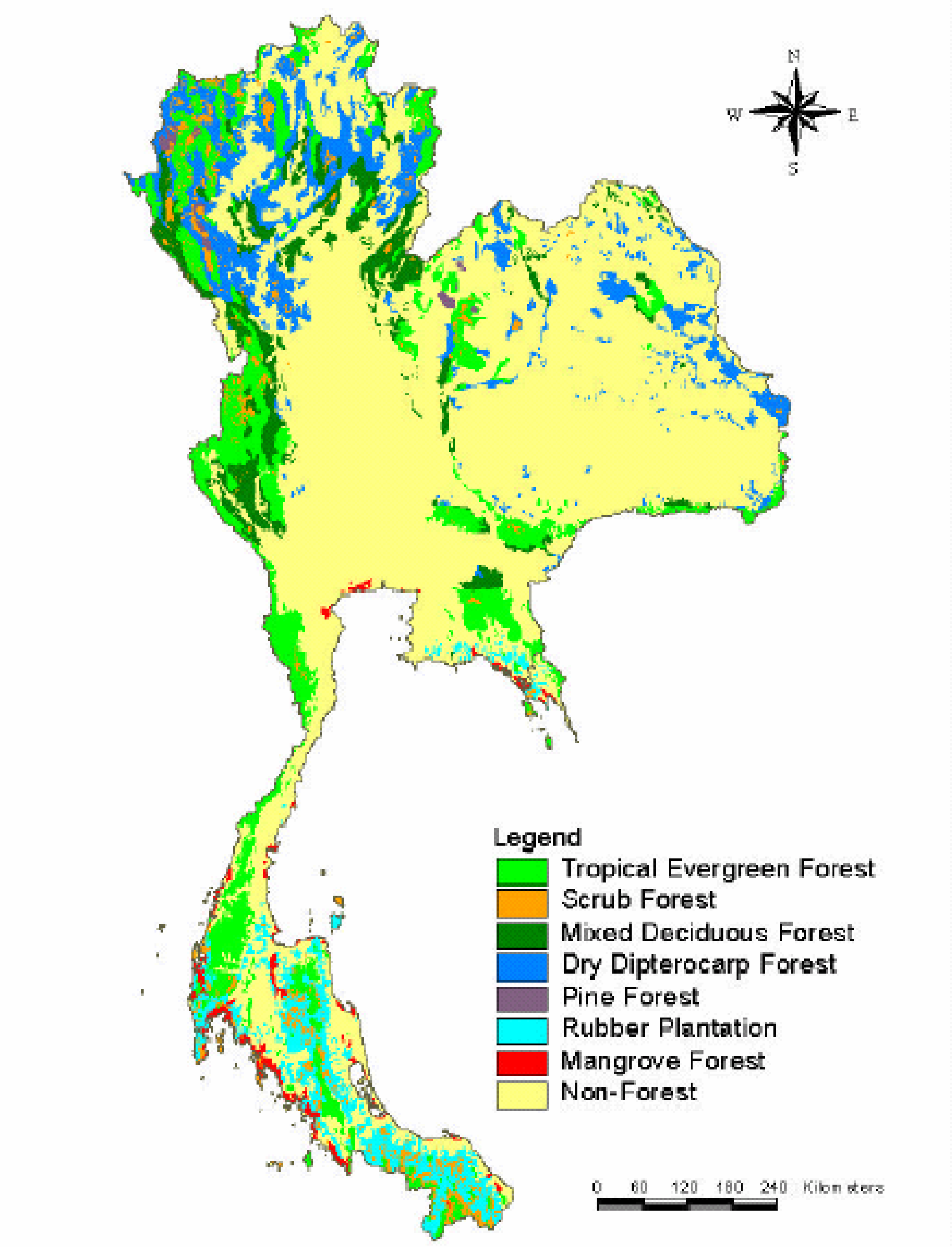


Fig. 2.3 Forest classification map of Thailand according to UNEP Environmental Assessment Program for Asia and the Pacific in 1996.

Table 2.2 Subtypes of evergreen and deciduous forests and their dominant species according to UNEP Environmental Assessment Program for Asia and the Pacific in 1996.

Forest types	Forest distribution	Elevation range (m)	Dominant Species
1 Evergreen Forest			
1.1 Tropical Evergreen Forest	- Along the wet belt of the country with high rain fall and no dry period		
1.1.1 Tropical Rain Forest	- South-eastern and Peninsular regions	0-100	- *Dipterocarpus* spp., *Hopea* spp., *Shorea* spp., *Anisoptera* spp., Palm, Rattans, bamboos and climbers etc.
1.1.2 Dry Evergreen Forest	- Scattered all over the country along the depressions and along the valleys of low hill ranges.	~ 500	- *Dipterocarpus* spp., *Hopea ferrea*, *Anisoptera costata*, *Alstonia scholaris*, *Tetrameles nudiflora* etc.
1.1.3 Hill Evergreen Forest	- Scattered all over the country	~ 1000	- *Quercus* spp., *Lithocarpus* spp., *Castanopsis* spp., etc.
1.2 Coniferous	- Scattered in small pockets in the North, Northeast, East and Southwest regions.	200-1600	- *Pinus* spp., etc.
1.3 Swamp	- Scattered in the wet regions of the country		
1.3.1 Fresh Water	- Along depression inland		- *Dyera costulata*, *Palaquium gutta*, *Scaphium* spp., *Hopea lattifolia*, *Heritiera littolaris* etc.
1.3.2 Mangrove	- Along river estuaries and muddy coastlines on the west coast, south and southeast		- *Rhizophora apiculata*, *Rhisophora macronata*, *Sonneratia* spp., *Bruguiera* spp., etc
1.4 Beach	- Common along the east coast, occur on coastal dunes, rocky seashores and elevated coasts		- *Casuarina equisetifolia* etc.
2 Deciduous Forest			
2.1 Mixed Deciduous	- Scattered all over the country	50-600	- *Tectana grandis*, *Xylia kerri*, *Dalbergia cultrata*, *Dalbergia oliveri*, *Albizia lebbeck*, *Acacia* spp., etc.
2.2 Dry Deciduous	- Scattered all over the country	100-600	- *Shorea obtuse*, *Shorea siamensis*, *Dipterocarpus* spp., *Phyllanthus emblica* etc.
2.3 Savannah	- North, Northeast and in the eastern regions		- *Careya arborea*. *Acacia siamensis*, *Acacia catechu* etc.

Chapter III

Materials and Methods

3.1 Materials

3.1.1 Fossil leaves

A number of fossils were collected, by research team from Suranaree University of Technology, from Li Basin (Fig. 2.1), Lamphun Province, and Mae Moh basin (Fig. 2.2), Lampang Province. Almost all the specimens are detached and fragmentary, including leaves, twigs, seeds, and cones. The preliminary report on the Li flora was briefly mentioned in 2.4 of Chapter II. In this study, leaves with affinities close to those of two modern families, Anacardiaceae and Leguminosae, were selected for systematic study by application of leaf architecture analysis.

3.1.1.1 Anacardiaceous fossil leaves

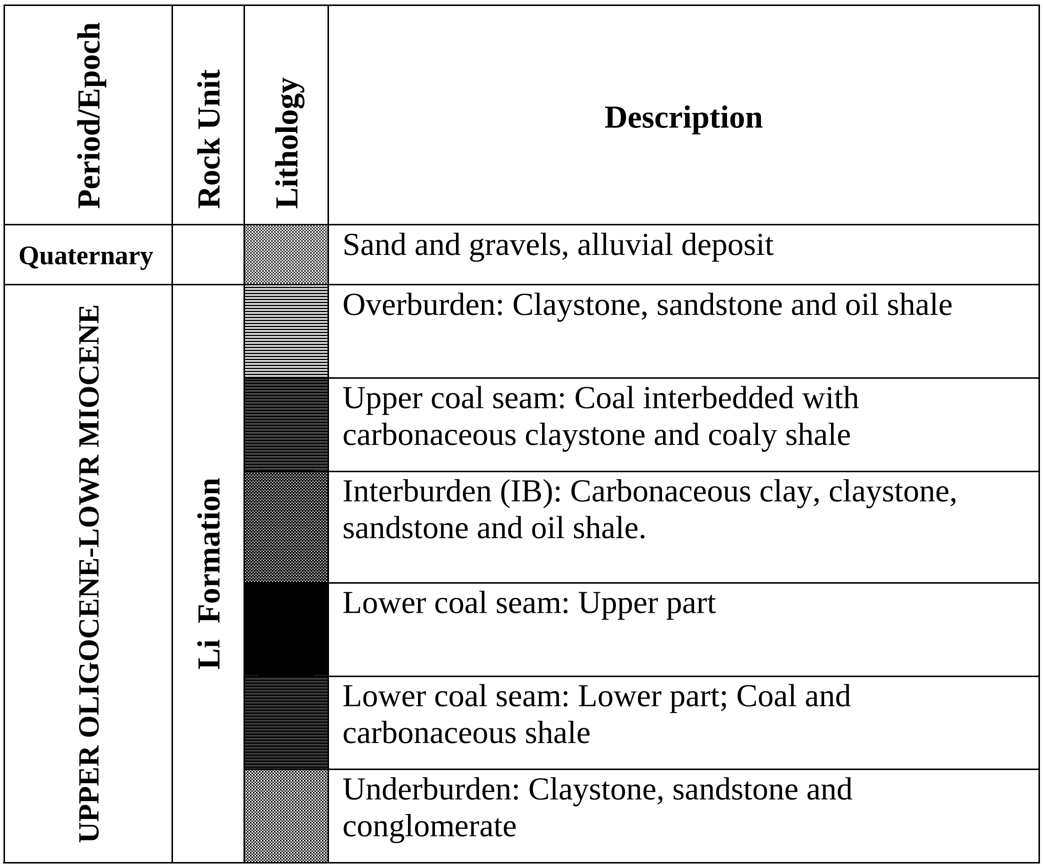
Five specimens were collected from the middle layer (i.e. interburden) which lies between the upper and lower coal seems of Ban Pa Kha Sub-basin, Li basin (Table 3.1, Fig. 3.1).

3.1.1.2 Leguminous fossil leaves

Four specimens were also collected from the lower part of the middle layer (IB) of Ban Pa Kha Sub-basin, Li Basin (Table 3.2, Fig. 3.1). Another 5 fossils were collected from the layer (Interburden, IB) lying between two lignite seams (K zone and Q zone) of Mae Moh Basin (Table 3.2, Fig. 3.2).

Table 3.1 Anacardiaceous fossils and their location of deposition in the stratigraphic sequence of Ban Pa Kha Sub-basin. IB = interburden.

Fossil code	**Stratigraphy/Matrix Description**	**Specimen condition**	**Type of preservation**
SUT 083	IB; below upper coal seam / light grey Sandstone	Apical and basal most part missing	Carbonized
SUT 224	IB; Just above lower coal seam / red brown Claystone	Apical most part, basal 1/3 missing	Carbonized/pyritized
SUT 672	IB; Just above lower coal seam / light brown Claystone	Apical 1/4 missing	Compression/impression
SUT 728	IB; Just above lower coal seam / dark brown Oil shale	Petiole missing	Pyritized
SUT 845	Upper IB; Just above lower coal seam / light brown Claystone	Apical 1/5 missing	Pyritized

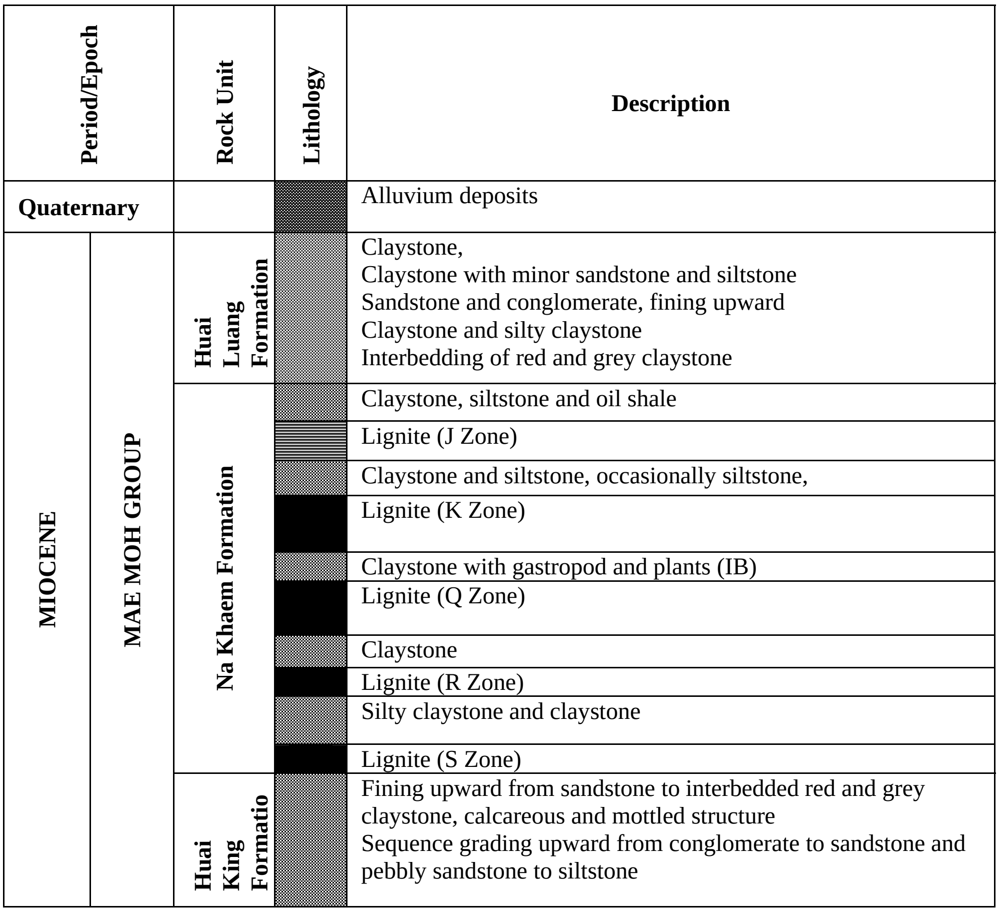


Period/Epoch	**Rock Unit**	**Lithology**	**Description**
Quaternary		▒	Sand and gravels, alluvial deposit
UPPER OLIGOCENE-LOWR MIOCENE	**Li Formation**	▤	Overburden: Claystone, sandstone and oil shale
		▤	Upper coal seam: Coal interbedded with carbonaceous claystone and coaly shale
		▒	Interburden (IB): Carbonaceous clay, claystone, sandstone and oil shale.
		■	Lower coal seam: Upper part
		▤	Lower coal seam: Lower part; Coal and carbonaceous shale
		▒	Underburden: Claystone, sandstone and conglomerate

Fig. 3.1 Cenozoic sequence of Ban Pa Kha sub-basin. Thickness of each unit is not to scale (Simplified from Uttamo, 1998). Lower Miocene was added according to Songtham (2001).

Table 3.2 Leguminous leaf fossils and their location of deposition in the stratigraphic sequence of Ban Pa Kha Sub-basin, Li basin and MaeMoh basin. IB = interburden.

Fossil code	**Mine**	**Stratigraphy/Matrix description**	**Specimen condition**	**Type of preservation**
SUT 224-1	BPK	Lower part of IB/red brown clay	Almost complete	Pyritized
SUT 665	BPK	Lower part of IB/laminated brown clay	Upper 2/3	Pyritized
SUT 706	BPK	Lower part of IB/brown clay	Incomplete/outline	Pyritized
SUT 718	BPK	Lower part of IB/brown clay	Complete	Pyritized
SUT 1018	Mae Moh	IB/unconsolidated light grayish-brown silty claystone	Complete/outline	Pyritized
SUT 1023	Mae Moh	IB/unconsolidated light grayish-brown silty claystone	Lower half	Pyritized
SUT 1028	Mae Moh	IB/unconsolidated light grayish-brown silty claystone	Lower half	Pyritized
SUT 1051	Mae Moh	IB/unconsolidated light grayish-brown silty claystone	Lower half	Pyritized
SUT 1149	Mae Moh	IB/unconsolidated light grayish-brown silty claystone	Almost complete/petiolule missing	Pyritized



Period/Epoch		**Rock Unit**	**Lithology**	**Description**
Quaternary			▓	Alluvium deposits
MIOCENE	**MAE MOH GROUP**	**Huai Luang Formation**	▒	Claystone, Claystone with minor sandstone and siltstone Sandstone and conglomerate, fining upward Claystone and silty claystone Interbedding of red and grey claystone
		Na Khaem Formation	▒	Claystone, siltstone and oil shale
			▤	Lignite (J Zone)
			▒	Claystone and siltstone, occasionally siltstone,
			■	Lignite (K Zone)
			▒	Claystone with gastropod and plants (IB)
			■	Lignite (Q Zone)
			▒	Claystone
			■	Lignite (R Zone)
			▒	Silty claystone and claystone
			■	Lignite (S Zone)
		Huai King Formatio	▒	Fining upward from sandstone to interbedded red and grey claystone, calcareous and mottled structure Sequence grading upward from conglomerate to sandstone and pebbly sandstone to siltstone

Figure 3.2 Cenozoic sequence of Mae Moh Basin. Thickness of each layer is not to scale (Simplified from Uttamo, 1998).

3.1.2 Recent leaves: possible Nearest Living Relatives (NLRs)

3.1.2.1 Tracking down NLRs

The taxonomic studies of the fossil leaves were performed by comparison of leaf architecture of the fossils to those of the modern (living) leaves. My guidelines for tracking down NLRs are as follows:

1. Differentiation of fossil leaves being studied (i.e. are there any fossil leaves that can be grouped together according to the concept of morphotypes)
2. Comparison of fossil leaves to possible NLRs can be done by the following steps
   - 2.1 Recognition of gross forms and venation patterns of fossil leaves and then comparison with leaves of living species. At the first step of tracking down NLRs, beside experience, studies of herbarium specimens, the literature, and the leaf atlas of both fossil and living plants can help make it easy and more intensive. For example, leguminous trees listed in “The field guide to the forest trees of Northern Thailand” are useful for studying, in part, the distribution of members of the Leguminosae to which some of the fossils in this study belong. Virtual herbaria from the Internet are also helpful in accessing pictures of herbarium sheets. Some examples are the virtual herbarium of the New York Botanical Garden (www.nybg.org) and lists of URLs for online herbaria of vascular plant images (www.bloominc.org.html/digibarialist.html).
   - 2.2 We might select any classification system to follow for tracking down possible NLRs. For example, one fossil leaf may be similar to a species of Anacardiaceae. Therefore, other families in the order Sapindales to which

the Anacardiaceae belong should be examined even though such taxonomic classification may not reflect any similarity in leaf architecture. Ferguson (1971) gave some guidelines for taxonomic study of fossil leaves in the topic “Taxonomic approach with regard to the leaf remains”.

3.1.2.2 Sources of NLRs for analysis

According to the anacardiaceous and leguminous characteristics of the fossil leaves, the modern leaves of Anacardiaceae, Leguminosae and some other families the leaves of which are similar were selected for comparison. Specimens from the Bangkok Forest Herbarium (BKF), the herbarium of Prince of Songkla University (PSUH, unofficial abbreviation to use in this study), and the herbarium of Suranaree University of technology (SUTH, unofficial abbreviation to use in this study) were examined. Most of the examined species were photographed. In addition, observing and collecting of the plants in natural and cultivated population were also performed. The specimens of possible NLRs and other species with similar leaf architecture were taken for clearing. Cleared leaf collections of SUT and Dilcher’s cleared leaf collection (housed at the Florida Museum of Natural History, Gainvesville, Florida, USA.) were also examined. Leaves of eighty six genera and approximately 383 species of Leguminosae mostly from BKF, PSUH, some from SUTH, some from virtual herbaria in the Internet and some from the field were examined. Among these, 74 genera were native to Thailand (approx. 72.5 % of estimated 102 native genera (Niyomdham, 1994)). From Dilcher’s collection, 141 genera and approx. 450 species of cleared leguminous leaves were examined. Of these 141 genera and 450 species, 21 genera and 12 species are repeats of the ones examined in Thailand. Therefore, 206 genera (approx. 31.7 % of the estimated 650 genera worldwide (Niyomdham, 1994)) and approx. 821 species (Approx. 4.5 % of the estimated 18,000 species worldwide (Niyomdham, 1994)) of leguminous plants were examined. Eight Thai anacardiaceous genera with simple leaves (from 10 genera) and approx. 34 species (from 44 expected species) were examined. Among the species examined, some are not native to Thailand and some that are native were not examined because the specimens were not available (See details in the Appendix E and the preliminary checklist of this family by Chayamarit, 1994). More than a thousand photographs of herbarium specimens of 59 genera and approx. 301 species of Leguminosae and 8 genera and approx. 30 species of Anacardiaceae were taken. In addition, cleared leaves of approx. 51 species in 30 genera of Leguminosae and approx. 29 species in 8 genera of Anacardiaceae were photographed. Furthermore, cleared leaves of 2 species of Apocynaceae, 21 of Euphorbiaceae, 1 of Lecythidaceae, 1 of Sapindaceae, 1 of Sapotaceae, 1 of Thymeliaceae and 1 of Zygophyllaceae were also included. The pictures of herbarium specimens and cleared leaves were stored in a compact disc (CD). The examined species of Anacardiaceae, Leguminosae and some other families are listed in appendix D (50 genera, approx. 111 species) and appendix E (86 genera, approx. 383 species). Leaves of some of the listed species are not similar to the fossils but they were examined because they belong to the families some listed species of which have leaves that look similar to the fossils.

3.1.3 Scientific instruments & chemicals

The following items are some of the scientific instruments & chemicals used in this study.

3.1.3.1 Stereo microscope (Nikon SMZ800), compound microscope (Olympus CH-2), camera lucida (drawing tube).

3.1.3.2 Dental engine, hand pieces, dental burs (applied for removing and cutting matrix that overlays fossil leaves).

3.1.3.3 $NaHClO_2$, KOH, NaOH, H_2O_2, HF, Alcohol series (Absolute, 90% and 75% alcohol), Collodion®, Permount®, Nail varnish, Safranin, Toluene, Xylene, etc.

3.2 Methods for preparation of specimens before analysis of leaf architecture

Generally the gross forms of both modern and fossil leaves were analyzed, based on the outline of leaf architectural classification described in Hickey (1973), Dilcher (1974), Hickey and Wolf (1975), and Leaf Architecture Working Group (1999), before any treatment of those specimens were performed. The analyses of fine venation patterns usually need treatments of the specimens. The methods for preparation of fossils and modern leaves before these analyses are mainly based on those proposed in Dilcher (1974) with greater or lesser degree of modification. The techniques and guidelines, e.g. for extraction of fossils from the matrices and for photographing, are also available in Jones and Rowe (1999).

3.2.1 Clearing modern angiosperm leaves for venation analysis

After gross forms of leaves of possible NLRs were studied, the leaves were cleared for venation analysis by one of the methods, with minor modification, described in Dilcher (1974). This method will be briefly mentioned as follows: place the dried leaf in a beaker of 10 % NaOH (or 5% for a delicate leaf); heat slowly just under boiling point (70°C was used); and maintain the heat until the leaf becomes translucent (normally it requires 5-10 minutes or shorter or longer depending on the thickness of the leaf). Next, wash in water 2 times, then bleach the leaf in 50% commercial bleach solution (Haiter®, with 6% Na HCl O_2, was used) for 10-15 minutes or more (usually it took more time for the leaves in this study) until the leaf becomes cream colored or white. Then, wash in water 2 times, dehydrate in an ETOH series of 50%, 75%, leaving the leaf about 10-15 minutes in each solution. After this, place the leaves in staining solution of 1% safranin O in 95% ETOH for 20 minutes or longer, then wash the stain out in absolute ETOH until the desired level of staining is obtained. Transfer the leaf to a solution of equal parts of absolute ETOH and xylene, transfer to 100% xylene, then mount the leaf between two glass slides using Permount® as mounting medium. Place the slides on a drying table, weight them, and check each day, adding more mounting medium as needed, store the slides in a cabinet for further analysis.

Other than the cleared leaves, the photographs of species taken by oblique lighting technique are also useful. These photos include whole herbarium sheets, close-ups of the whole leaf and close-ups of the middle leaf portion to show higher vein orders (probably up to FEV in many species).

3.2.2 Study of venation patterns of fossil angiosperm

3.2.2.1 Before analysis

The fossils collected from the field were unpacked, cleaned, trimmed (if necessary) and stored. Further exposure was sometimes needed to yield optimum information on the gross leaf form and fine venation. The preservation types and the nature of the fossil leaves are important in deciding whether or not the fossils are treated for venation analysis or for cuticular analysis (Dilcher, 1974).

3.2.2.2 Untreated fossil leaves

All the fossils were studied in the laboratory in the same condition as they were found in the field. Apart from studying the specimens themselves, the photographs taken by the following techniques help make examination more convenient and deeper in details.

Oblique-lighting photography is a technique of choice for study of leaf gross forms and gross venation patterns of untreated fossil leaves. In addition, line drawings of the fossils were made to clarify the venation patterns.

In addition, photographs of different portions of the whole fossil were taken with a stereomicroscope at high magnification to make the venation show up. The pictures of all portions were then printed and placed together with clear tape. Translucent paper(s) were placed on these butted pictures and attached by clear tape. A drawing could be easily made by placing these transparent papers and butted pictures on a light box. The translucent paper(s) with line drawings was (were) scanned. If there was more than one paper scanned, all were butted together by using some picture software or by printing out all the pictures and having them butted together, and scanned again. The line drawings could be made by using a camera lucida attached to a stereomicroscope but I found it difficult to draw quite large specimens (e.g. anacardiaceous fossil leaves) with high magnification. In addition, it is time consuming and can cause fatigue.

Fine venation patterns of (total or partially) pyritized anacardiaceous and leguminous fossils (e.g., SUT 224, SUT 728, SUT 845 and SUT 1149) were examined under a stereomicroscope. By applying a small amount of water on the pyritized portions, excellent fine venations was obsrevable. Photographs of fine venation of these fossils were taken while the thin film of water was still on the fossil surfaces.

3.2.2.3 Special treatments for fossil leaves

Some fossils that could be transferred and treated were treated for fine venation (and cuticular) analysis as shortly mentioned below.

Transfers of compressed leaf remains

For leaf remains preserved as compressions in a variety of matrices and varying states of preservation, various transfer techniques were developed to remove them from the matrixes for fine venation and cuticular analysis. Some of those mentioned in Dilcher (1974) were attempted in this study with different degrees of success. The technique modified by E. Fjeldso Christensen has been tried for SUT 672 and I found that Collodion is less effective than nail varnish (Figs. 3.3) in holding the fossil material, especially when it was in

Fig. 3.3 Part of compressed leaf of SUT 672 was transferred by using clear nail varnish before clearing process (for cleared specimen, see Figs. 4.20 M, N, O).

the bleach solution (Haiter®). The venation patterns from cleared specimena can be seen in Figs. 4.20 M, N, O. SEM was also attempted with the fossil leaf fragments without success.

The treatments of anacardiaceous and leguminous fossils in this study are presented in Table 3.3 and Table 3.4

Table 3.3 Treatments of anacardiaceous fossils

Fossil	**Treatment**
SUT 083	Transfer and treatment failed to yield good venation pattern
SUT 224	Transferred leaf material yielded no good venation pattern / Water application on the surface of pyritized portion shown excellent venation pattern
SUT 672	Transferring and treatment of part of leaf material gave moderately clear view of venation pattern but yielded poor quality view of stomatal complex
SUT 728	The same as SUT 224
SUT 845	The same as SUT 224

Table 3.4 Treatments of leguminous fossils

Fossil	**Treatment**
SUT 224-1	The same as SUT 224
SUT 665	The same as SUT 224
SUT 706	The same as SUT 224
SUT 718	The same as SUT 224
SUT 1018	The same as SUT 224
SUT 1149	The same as SUT 224
SUT 1023	The same as SUT 224
SUT 1028	The same as SUT 224
SUT 1051	The same as SUT 224

3.3 Analysis of leaf architecture and presentation of the results

After the fossils and their possible NLRs or other similar taxa were prepared, venation patterns (and analysis of gross forms can be repeated) will be analyzed based on outline of leaf architectural classification described in Hickey (1973), Dilcher (1974), Hickey and Wolf (1975), and Leaf Architecture Working Group (1999).

Five parts of the results will be presented in the order below.

Part 1: Invention of supplemental terms and analysis and classification of marginal venation patterns.

Based on or related to features of venation in marginal areas described in these methods, supplemental terms for describing marginal venation patterns (MVP) were invented and used as an adjunct taxonomic tool. The marginal venation patterns were also classified to various types. These terms and classification help make comparison of fossils with modern leaves and identification of fossils more valid.

Part 2: Systematic description and affinity of fossil leaves.

Gross forms and venation patterns of the fossil leaves were described and compared with those of modern leaves and other fossils based on the outline of leaf architecture classification mentioned above and by the application of additional terms and classification of MVP from Part 1.

Part 3: Leaf architecture of some selected possible NLRs

Gross forms and venation patterns of all the modern species studied were summarized and also presented in tables and graphs.

Part 4: Leaf keys to some selected possible NLRs

Leaf keys of some selected simple anacardiaceous leaves were constructed. They are meant to be temporary ones and can be modified or augmented with some new species later. For possible NLRs of leguminoceous fossils, leaf key were not constructed, but the pictures showing both whole leaves and clear leaves are available on compact disc.

Part 5: Descriptions of some selected possible NLRs

Only descriptions of those anacardiaceous species in the keys are provided.

Chapter IV

Results

4.1 Anacardiaceous modern and fossil leaves

4.1.1 Supplemental terms

4.1.2 Classification of MVP with ELMA of some selected simple modern leaves

4.1.3 Systematic descriptions and affinities of the fossil leaves

4.1.4 Leaf architecture of some selected modern species with simple leaves

4.1.5 Leaf keys to some selected modern species with simple leaves

4.1.6 Descriptions of some selected modern species with simple leaves

4.2 Leguminous modern and fossil leaves

4.2.1 Systematic descriptions and affinities of the leguminous fossil leaves

4.2.2 Classification of MVP with ELMA of leguminous modern leaves

4.2.3 Leaf architecture of leguminous modern leaves

4.1 Anacardiaceous modern and fossil leaves

4.1.1 Supplemental terms

It is appropriate to firstly state that supplemental terminology and classification of characters presented herein are the results of careful studies and of the attempt to fill the gap (at least for particular tropical plants in my study) in the description of terms presented in well-known leaf architectural studies (Dilcher, 1974; Hickey, 1973; Hickey and Wolf, 1975 and Leaf Architecture Working Group, 1999). These terms and classification still need extension of application and evaluation. To do so, comments and suggestions are crucially important and welcomed.

1. Marginal venation pattern (MVP)

The venation pattern of marginal areas of any leaf may or may not comprise repeated sets of two major parts, namely, 1) exmedial loop and/or multiangular shape (ELMA, details mentioned below), and 2) marginal ultimate venation (MUV). MUV that can be incomplete, looped or fimbriate as described in Dilcher (1974) will be considered here as the basic feature of MVP of any leaf. On the contrary, not all the leaves have ELMA as a component of their MVP. MVP that has both components will be called *MVP with ELMA* while the ones without ELMA will be called *MVP without ELMA*. The ELMAs lie on the exmedial side of all secondary veins (e.g., Figs 4.1A-B), and lying next to them and toward the leaf margin is the MUV (e.g. shaded area in Fig. 4.1B). In any type of MUV, areoles can be present lining the outer borders of ELMAs and will be called marginal areoles (MAr) that may be solitary or consecutively arranged as a column (details mentioned in topic MAr and MArC).

2. Exmedial loop and/or multiangle (ELMA) of secondary veins

An area of leaf tissue of different shapes formed by two adjacent secondary veins

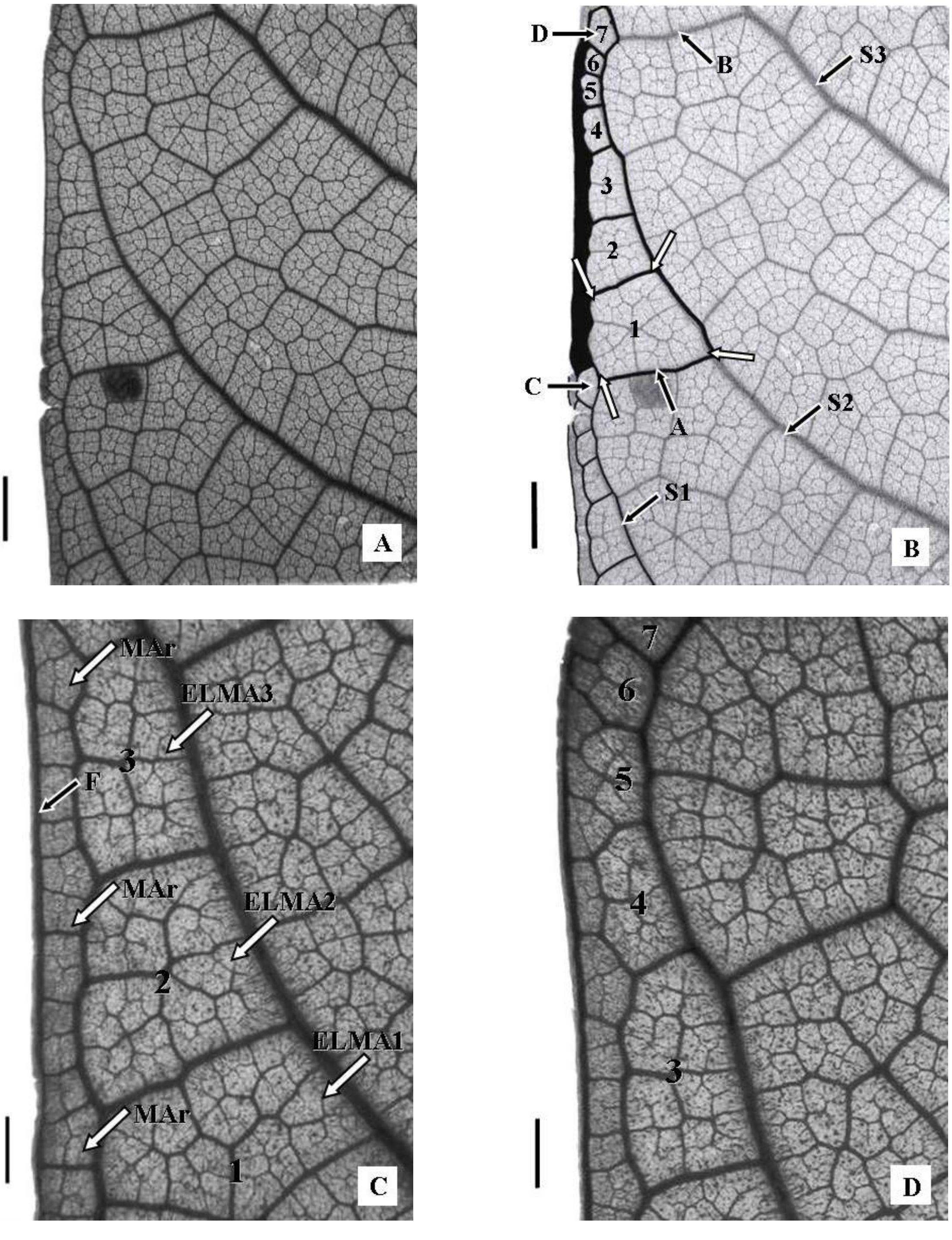


Fig. 4.1 Features of MVP. (A) Close-up of marginal portion of a leaf of *Semecarpus cochinchinensis*. (B) Four solid white arrows point to the four corners of the first ELMA. Number 1 to number 7 indicate counting of seven ELMAs, starting from the first to the last ELMA, respectively. Arrow A points to the tertiary vein that does not coalesce with other tertiaries and is the lower border of the first ELMA of secondary vein 2 (S2). Arrow B points to the tertiary vein that is the lower border of the first

ELMA of the superadjacent secondary vein 3 (S3). The last ELMA (number 7) of the infra-adjacent secondary vein (S2) is located at the same level with this tertiary vein. Arrows C and D point to the last ELMA of two adjacent secondaries (S1 and S2), which are located at the same level with tertiary veins that are the lower border of the first ELMA of S2 and S3 respectively. (C) ELMA1-ELMA3 in (A) were magnified to show that they can be easily distinguished from marginal areoles (MAr), one border of which is the fimbrial vein (F). (D) ELMA number 4-7 are rather small and difficult to distinguish from marginal areoles. Scale bar = 2 mm in A-B, 1 mm in C-D. Specimen for leaf clearing was obtained from Bangkok Forest Herbarium (BKF SN 118520).

and tertiary veins (cross veins according to Dilcher, 1974) lying between them is refered to as an ELMA. These ELMAs are located on the exmedial side of each secondary vein (Fig. 4.1). They may be composed of only a single areole (e.g., most ELMAs in Figs. 4.14A-B, 4.15) to several areoles (e.g., most ELMA in Figs. 4.12, 4.13). Each ELMA is surrounded by four borders: upper, lower, outer and inner border (Fig. 4.3). The upper and lower borders are formed by tertiary veins while the outer and inner ones are formed by adjacent secondary veins. The upper and lower borders branch from the exmedial side of the secondary vein (the inner border) with different branching angles (Fig. 4.5) and join with the infra-adjacent secondary vein (the outer border) or with an infra-adjacent secondary that is fused with a fimbrial vein. In leaves with percurrent/forked tertiary veins, the tertiary veins that are lower borders of ELMAs differ from the others lying below and between the same two secondary veins in that they will not coalesce with other tertiary veins and have clear courses running between two adjacent secondary veins (e.g., Figs. 4.1A-D). Small ELMAs, which comprise a single areole, located at the upper part of the column of ELMA (e.g., Figs. 4.1, 4.12-4.14) have the same features as an areole does, but they are still considered to be ELMAs whenever they meet the criteria mentioned above, especially lying on the exmedial side of secondary veins.

By this definition, ELMAs can be clearly seen with the pinnate eucamptodromous type of venation (Dilcher, 1974) or with weakly brochidodromous venation (Leaf Architecture Working Group, 1999). In brochidodromous (Fig. 4.9) and craspedodromous leaves (Fig. 4.10) ELMAs were determined to be absent.

3. Number of ELMAs

Counting starts at the first ELMA formed by the first tertiary vein branched from the exmedial side of the secondary vein that does not coalesce with the others, and continues until the last one located at the same level as the tertiary vein that forms the first ELMA of the superadjacent secondary vein (Figs. 4.1A-B). In cases of leaves in which most of the tertiary veins are percurrent/simple, it is rather hard to determine the first ELMA due to similarity between the tertiary vein presumed to be the lower border of the first ELMA and the others that lie below it. However, the first ELMA can possibly be determined by observing the first notch on the infra-adjacent secondary vein at which the lower and outer border of this first ELMA meet (Fig. 4.2A-B). By this counting system, there will be sets of ELMAs (e.g., Fig. 4.1B) equal to the number of secondary veins and these sets of ELMAs can be a useful guide for comparison of marginal venation pattern.

As for leaves of genera of Anacardiaceae examined in this study, decrease in number of ELMAs in the same leaf can occur near apical or basal regions where secondary veins are placed close together and the outer border of ELMAs tend to be discontinuous (Figs. 4.2C-D). For prevention of misinterpretation of number in such a case, counting the number of ELMAs should be performed at various parts of the fossil leaves should be made at the same regions. Concerning the relationship of size of the leaves of the same species and number of ELMAs, it has been observed that

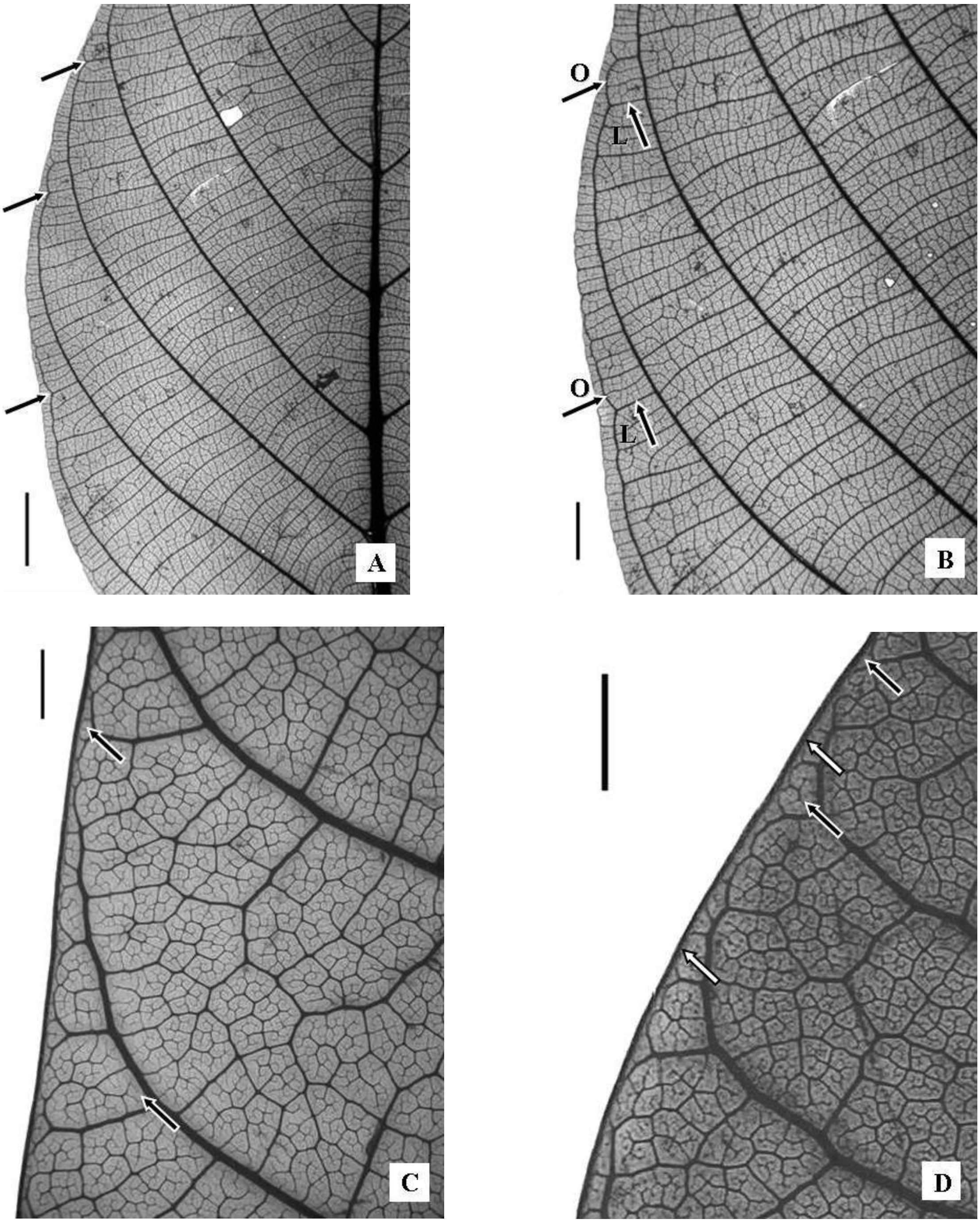


Fig. 4.2 Locating the first ELMA and variable ELMA number. (A) A cleared leaf of *Uncaria* sp. shows the first notch on each secondary vein (Arrows). (B) The outer and lower border (O and L, respectively) of each first ELMA meet at these notches and the ELMA, which has these borders as its constituents, will be called the first ELMA of each secondary vein. (C), (D) Cleared leaf of *Mangifera indica*: trend of reduction in number of ELMAs from the middle toward the apical part of the leaf is illustrated by distances between black arrows in (C) and (D) respectively. Also the ELMAs near apex are not as clearly seen as the one in the middle part of leaf. The outer borders of the ELMAs in this case tend to be discontinuous particularly near the apex (white

arrows in D). (A), (B) were from SUT cleared leaf (Grote 99-114). (C), (D) were from specimen collected from Koksamrong District, Lopburi (Sawangchote 001). Scale bar = 1 cm in A, 5 mm in B, 2 mm in C-D.

numbers of ELMAs in leaves of different sizes, at the same regions of the leaves, are rather consistent in each species.

In some instances, secondary veins may end at a level lower than the lower border of the first ELMA of the superadjacent secondary (Fig. 4.4, 4.15, 4.17). The ELMA which is normally located at the lower border of the first ELMA of the superadjacent secondary vein will be no longer called the last ELMA because it is not on the exmedial side of the secondary vein. Instead, it may be simply called marginal areoles (MAr, Fig. 4.15) or freely ending veinlets (FEV, Figs. 4.17) depending on its features. The last ELMA in this case will then be located below the ending point of the secondary veins (Figs. 4.15, 4.17).

4. Borders of ELMA

There are four borders of each ELMA (Fig. 4.3): upper and lower borders derived

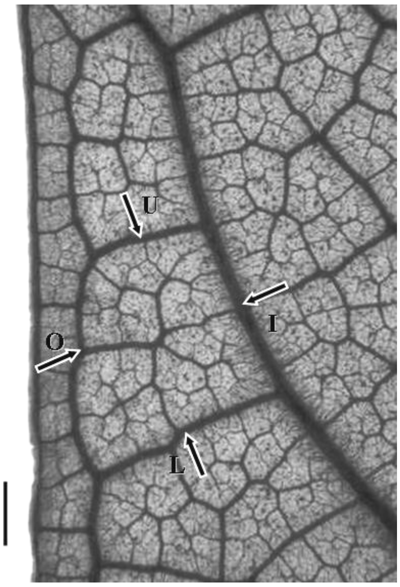


Fig. 4.3 Four borders of an ELMA in *Semecarpus cochinchinensis* (BKF SN 118520). O = outer, I = inner, U = upper, L = lower. Scale bar = 1 mm.

from tertiary veins, and outer and inner ones derived from two adjacent secondary veins. In some cases where secondary veins reach the margin at a level lower than the lower border of the first ELMA of the superadjacent secondary vein, the secondary will be determined as discrete and the outer borders of ELMAs will then be part of those discrete secondary veins (DSV, Figs. 4.4, 4.15, 4.17).

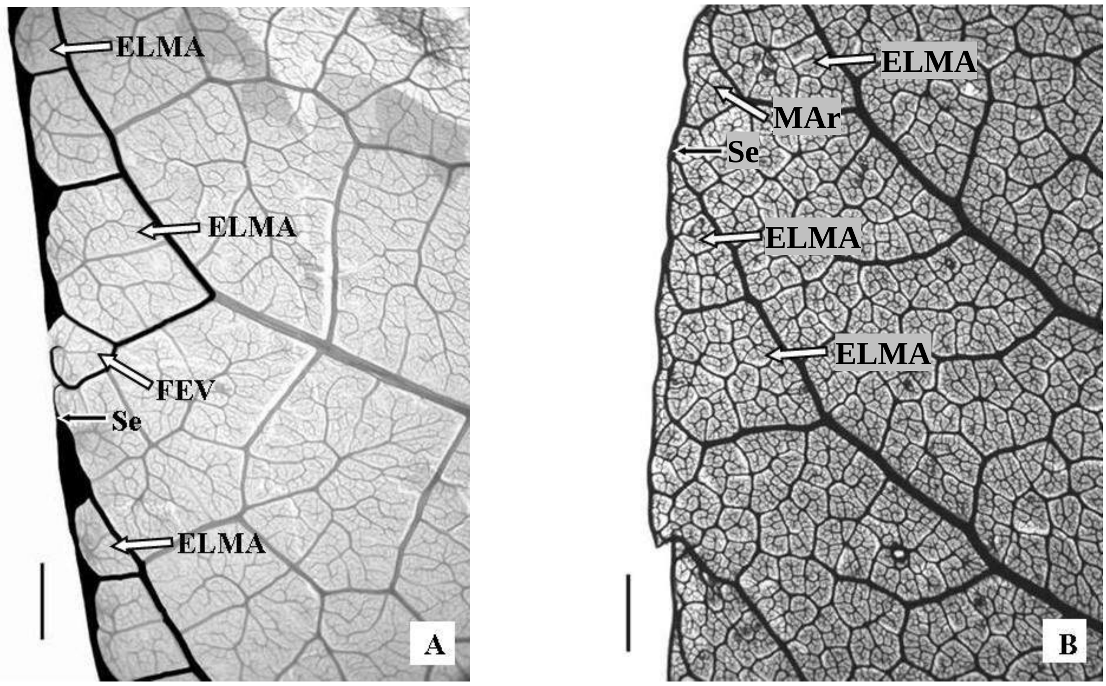


Fig. 4.4 Ending of secondary veins below the lower border of the first ELMA. (A) *Buchanania sessifolia*. Se = ending of secondary vein. FEV = an example of free ending veinlets. Shaded areas = zone of free ending veinlets and marginal areoles (ZFVMA, marginal areoles are the so-called looped marginal ultimate venation in Dilcher, 1974). (B) *Buchanania* sp. FEVs were not found in this species; instead, marginal areoles form at the equivalent position at which FEVs were found in *Buchanania sessifolia*. (A) was obtained from Bangkok Forest Herbarium (BKF SN 002502). (B) was from SUT cleared leaf (Grote 190). Scale bar = 2 mm in A-B.

5. Branching angle of tertiary veins (BATV)

The angle measured above the point of branching of tertiary veins from secondary veins and between the admedial side of these tertiary veins and the exmedial side of the secondary vein they branch from is here referred to as the branching angle of tertiary veins (BATV) (Fig. 4.5). The categories of these angles follow that of the angle of divergence of the secondary veins as described in Dilcher 1974.

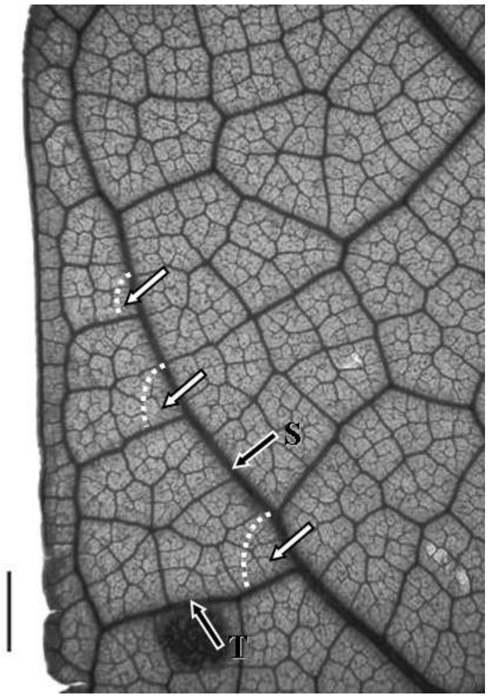
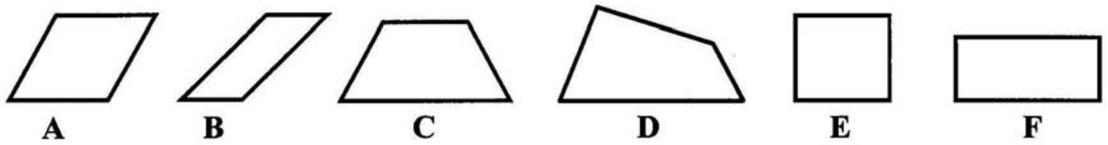


Fig. 4.5 Marginal portion of a cleared leaf of *Semecarpus cochinchinensis* (BKF SN118520) shows branching angles of tertiary veins (BATV) (white arrows). S, T = secondary and tertiary vein respectively. Scale bar = 2 mm.

6. Shape of ELMA

Shape of ELMA will be determined, in part, by the shape of the areoles (Dilcher, 1974). Other than this, special shapes may occur and the descriptions will be up to authors' consideration (Fig. 4.6). The examples of ELMAs in Figure 4.1A were determined, from lower to upper ones, to be quadrilateral to polygonal (Fig. 4.6G).



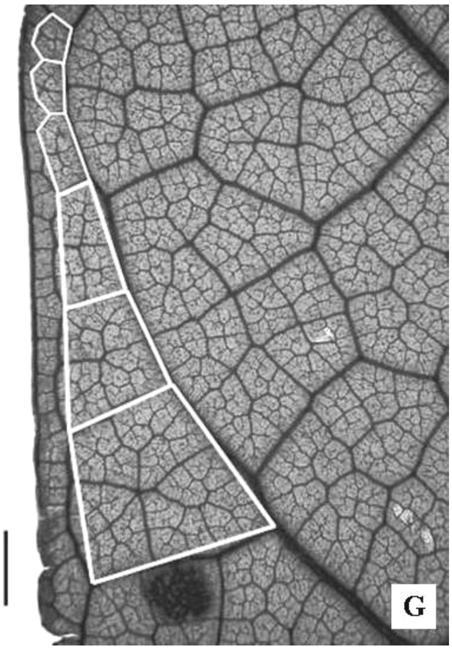


Fig. 4.6 Shapes of ELMA. (A), (B) Rhombus and rhomboid of parallelograms. (C), (D) Trapezoid and trapezium of quadrilaterals. (E), (F) Square and oblong of rectangles. (G) *Semecarpus cochinchinensis* (BKF SN118520) with the borders of its ELMAs made approximately straight for shape determination. Scale bar = 2 mm.

7. Marginal areoles (MAr)

Areoles located along the outermost areas of the leaf margin or lying next to ELMAs and toward the leaf margin (e.g., Fig. 4.1C-D), are referred to as marginal areoles (MAr). These may be formed by recurved marginal ultimate venation and identified as looped marginal ultimate venation according to Dilcher (1974). In cases where higher order veins are fused to form a fimbrial vein, these areoles will have this vein as their outermost border (Fig. 4.1C). In some cases where sizes of ELMAs are rather small, lie close to the margin, and look the same as marginal areoles (e.g., Figs. 4.1D, 4.12, 4.13), they're still identified as ELMA by holding the rule that these ELMA located on exmedial side of secondary veins. One MAr can be often found between two adjacent ELMAs and this MAr will be called solitary MAr (Figs. 4.12, 4.13).

8. Column of marginal areoles (MArC)

The phrase, column of marginal areoles (MArC), is used to describe a column of two or more MArs that lie along the outer border of ELMAs. In some instances where ELMAs have their outer borders lying close to the leaf margin, the column will be identified as absent (Fig. 4.7). The number of columns may be one (e.g., Fig. 4.1) or more (Fig. 4.16) and can be a complete (CMArC, Fig. 4.1B) or a partial marginal areole column (PMArC, Figs. 4.12, 4.13).

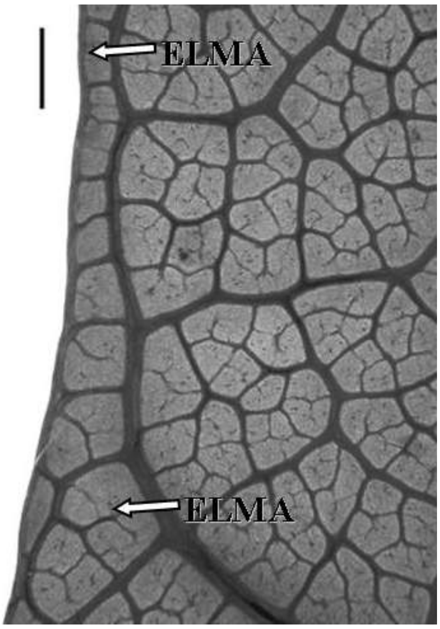


Fig. 4.7 ELMAs lying close to the leaf margin and column of marginal areoles is absent in *Melanochyla bracteata* (BKF SN105458). Scale bar = 1 mm.

9. Fimbriate (F)

The character fimbriate (F) is defined as weak or strong according to the relative thickness of the fimbrial vein in comparison with the secondary vein of the same leaf. If the thickness is about the same as that of the secondary veins that curve up and run parallel to it, it will be determined as strong (Fig. 4.8 A). If it is less than that of the secondary veins, the leaf will be defined as weak fimbriate (Fig. 4.8 B).

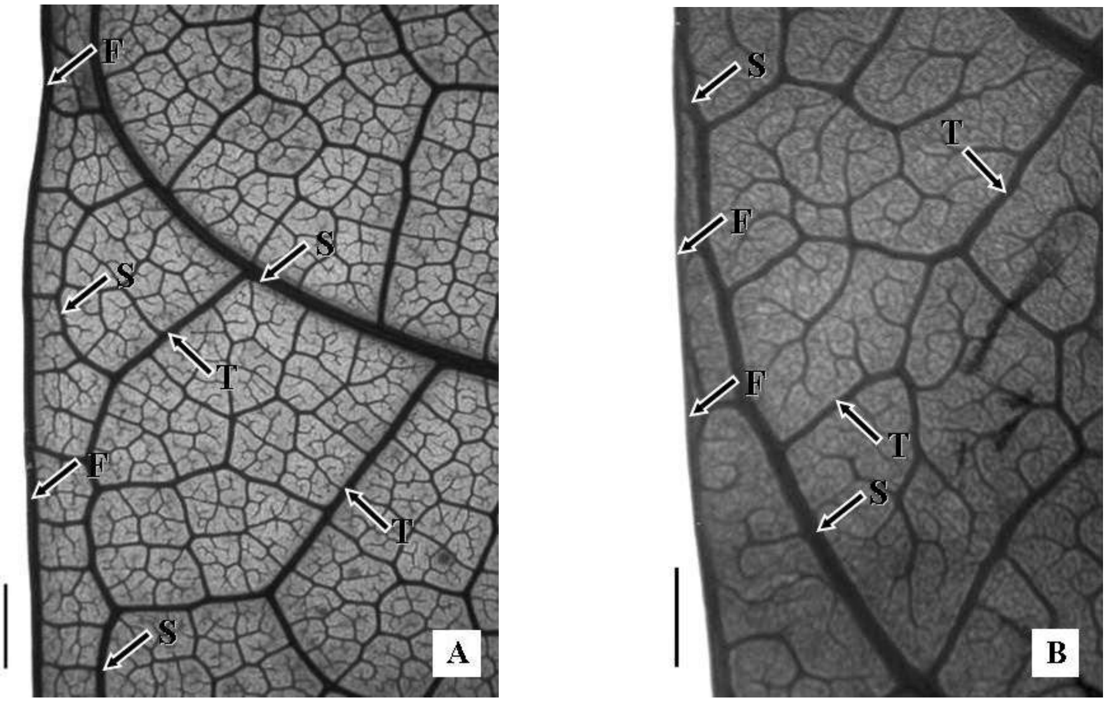


Fig. 4.8 Strong and weak fimbrial veins. (A) Strong fimbrial vein of *Semecarpus curtisii*. (B) Weak fimbrial vein of *Bouea oppositifolia*. F = fimbrial vein, S = secondary veins that diminish in size apically, T = tertiary veins. (A), (B) were from Bangkok Forest Herbarium (BKF SN 118520, SN 126073 respectively). Scale bar = 2 mm in A, 1 mm in B.

10. Absence of ELMA

In addition to presence of ELMA, two examples of leaves without these ELMAs are shown here for comparison. MVPs of *Alstonia scholaris* (Fig. 4.9) and *Bridelia ovata* (Fig. 4.10) show the absence of ELMA (i.e., MVP without ELMA). In case of *Alstonia scholaris,* the secondary veins join together in a series of prominent arches (i.e., brochidodromous) or even form an intramarginal vein if they join each other at obtuse angles. For *Bridelia ovata*, the terms for describing of ELMA can not be applied to the freely branching secondary veins (simple craspedodromous) it possesses.

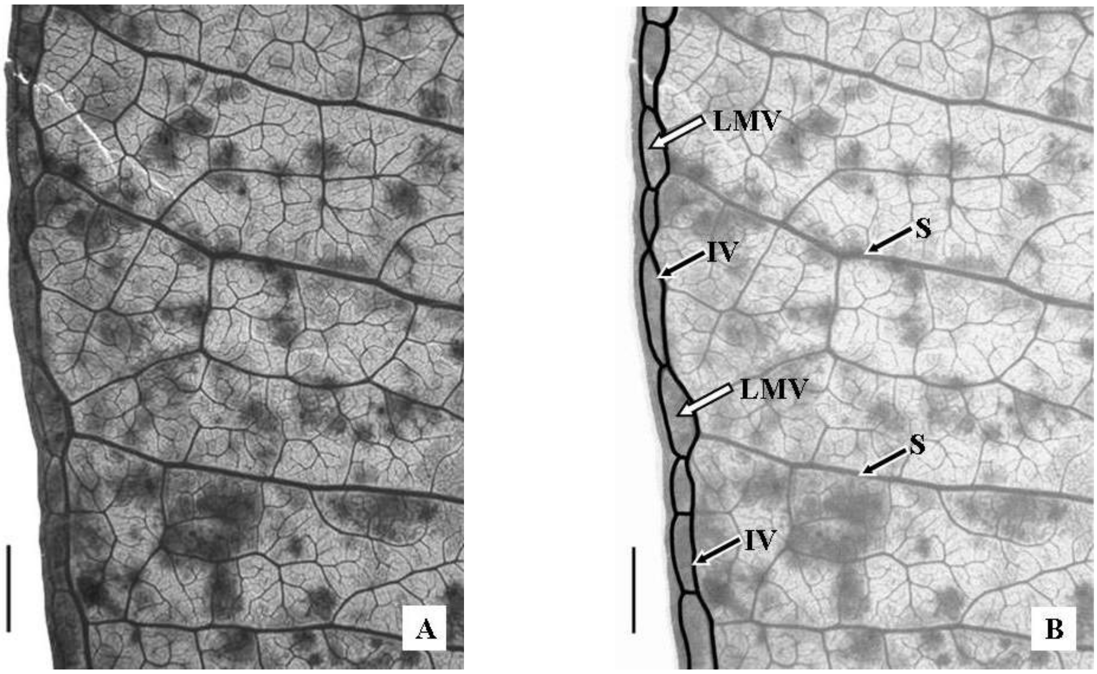


Fig. 4.9 Example of a leaf with absence of ELMA. (A) ELMAs are absent in *Alstonia scholaris*. (B) Line drawing to clearly show IV (intramarginal vein) and LMV (looped marginal ultimate venation). S = secondary vein. Scale bar = 2 mm. Specimen collected from tree cultivated in SUT campus (Sawangchote 002).

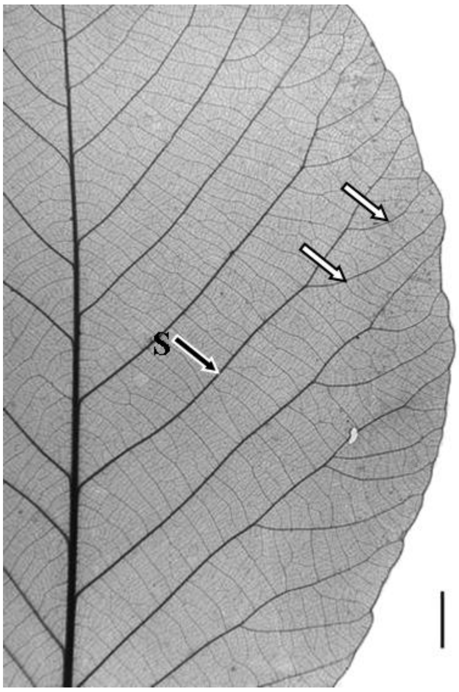


Fig. 4.10 ELMAs are absent in *Bridelia ovata*, the venation of which is simple craspedodromous. In this venation type, the secondary vein (black arrows) and its branches (white arrows) terminate at the margin. Specimen is from SUT cleared leaf (Grote 56-44). Scale bar = 5 mm.

4.1.2 Classification of MVP with ELMA

After careful examination of cleared leaves of anacardiaceous genera with simple leaves, I categorized types of MVP according to features of ELMA they posses; presence or absence of fimbrial veins; and presence, absence and arrangement of marginal areoles.

For each type of MVP, two figures are shown. The first figure shows the MVP of a leaf of the representative species. The second one is the lightened first figure with line drawings made on it to clearly show ELMAs, marginal ultimate venation, and their surrounding components as defined in the section “Supplemental terms”.

I. When marginal ultimate venation is fimbriate (i.e. fimbrial veins present)

1. *Type I*: ELMAs, counted from the first to the last on each secondary vein, have their outer border lined with CMArC. These areoles be may arranged into one or more columns, with different thicknesses, and the outer border of which is part of the fimbrial vein (Fig. 4.11).

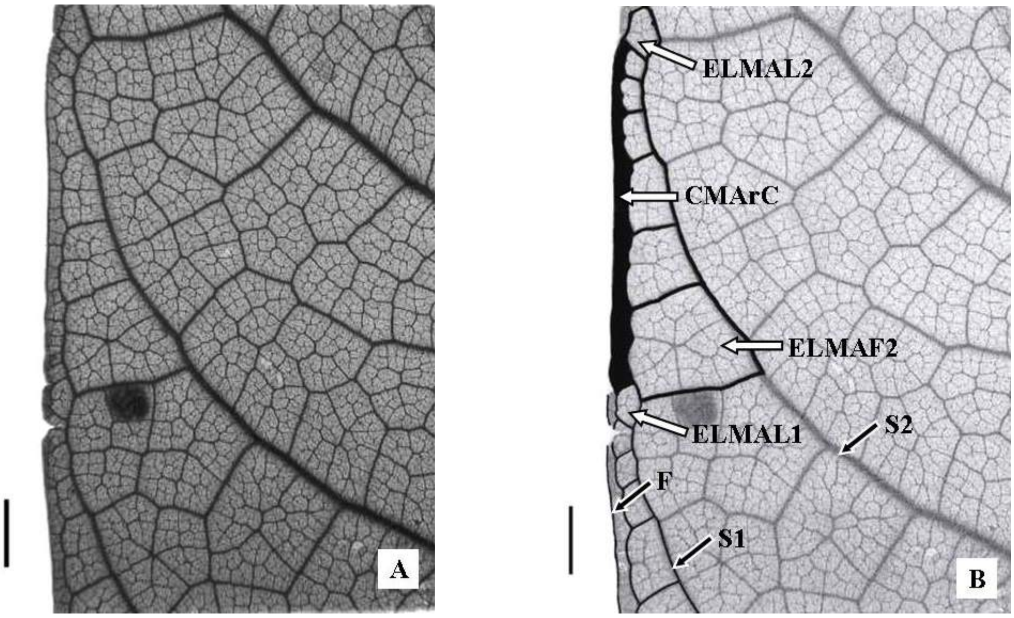


Fig. 4.11 (A) Type I MVP as present in *Semecarpus cochinchinensis* (BKF SN 118520). (B) ELMAL1 and ELMAL2 = last ELMA of secondary vein 1 (S1) and

secondary vein 2 (S2) respectively; ELMAF2 = first ELMA of S2, shaded area represents CMArC. F = fimbrial vein running along the leaf margin and forming the outer border of CMArC. Seven ELMAs of S2 were counted in this case. Scale bar = 1 mm.

2. *Type II*: One or more ELMAs (normally the ones at the base of MArC) have their outer borders lined with PMArC and the rest of the ELMAs have SMArs intervening between every two adjacent ELMAs (Fig. 4.12).

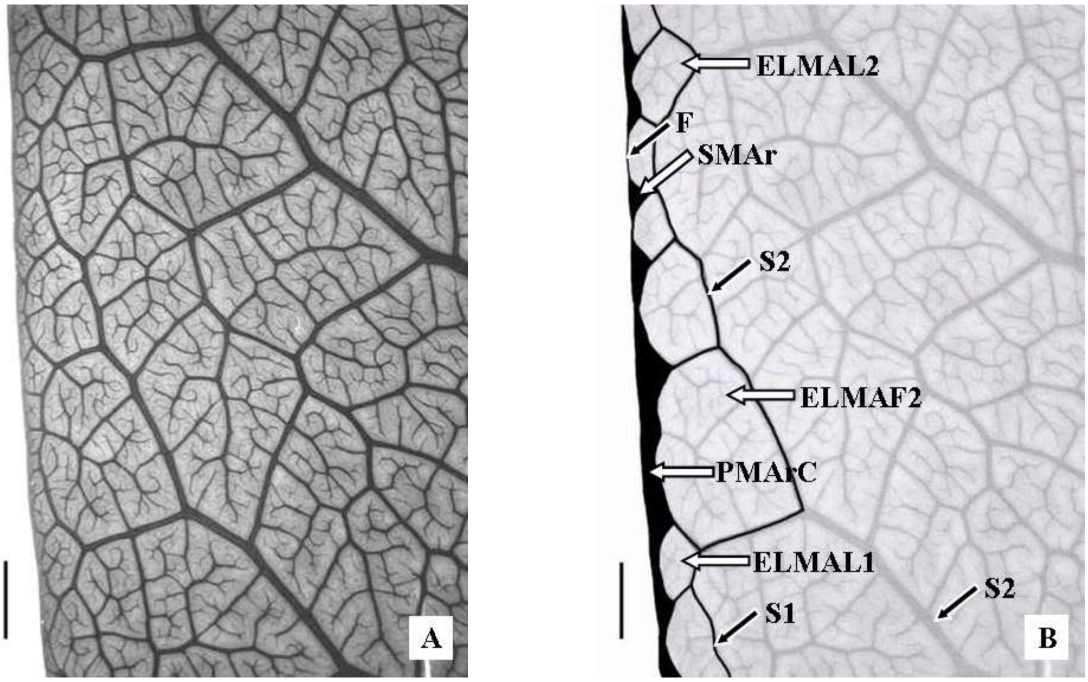


Fig. 4.12 (A) Type II MVP as present in *Buchanania arborescens* (PSU SN 180409). (B) ELMAL1 and ELMAL2 = last ELMA of S1 and S2 respectively, ELMAF2 = first ELMA of S2. Note SMAr that intervenes between two ELMAs and those MArs arranged in PMArC. Scale bar = 2 mm.

3. *Type III*: One or more ELMAs (normally the ones at the base of the column of ELMAs) have their outer borders lined with PMArC, some of them have SMArs intervening between two adjacent ELMAs, and some, normally at the higher part of the ELMA column, have their outer borders fused with the fimbrial vein and have no SMArs intervening between them (Fig. 4.13).

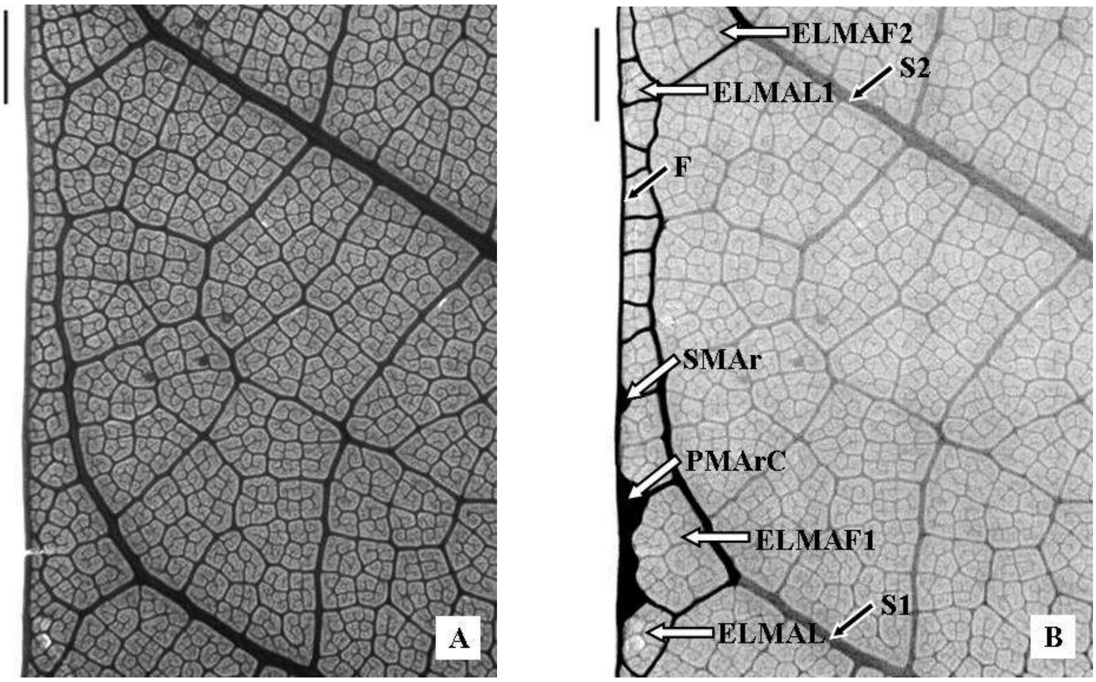


Fig. 4.13 (A) Type III MVP as present in *Mangifera pentandra* (BKF SN 088210). (B) ELMAL1 = last ELMA of S1, ELMAF1 and ELMAF2 = first ELMA of S1 and S2, respectively. Note SMAr and PMArC located at lower portion of column of ELMA. Scale bar = 2 mm.

4. *Type IV*: All ELMAs have their outer borders, full length or in part, lying close to or fused with fimbrial vein and have these fused veins as their outer borders. As a result, the marginal areole column is absent and there may or may not be solitary marginal areoles interveneing between two ELMAs (Fig. 4.14).

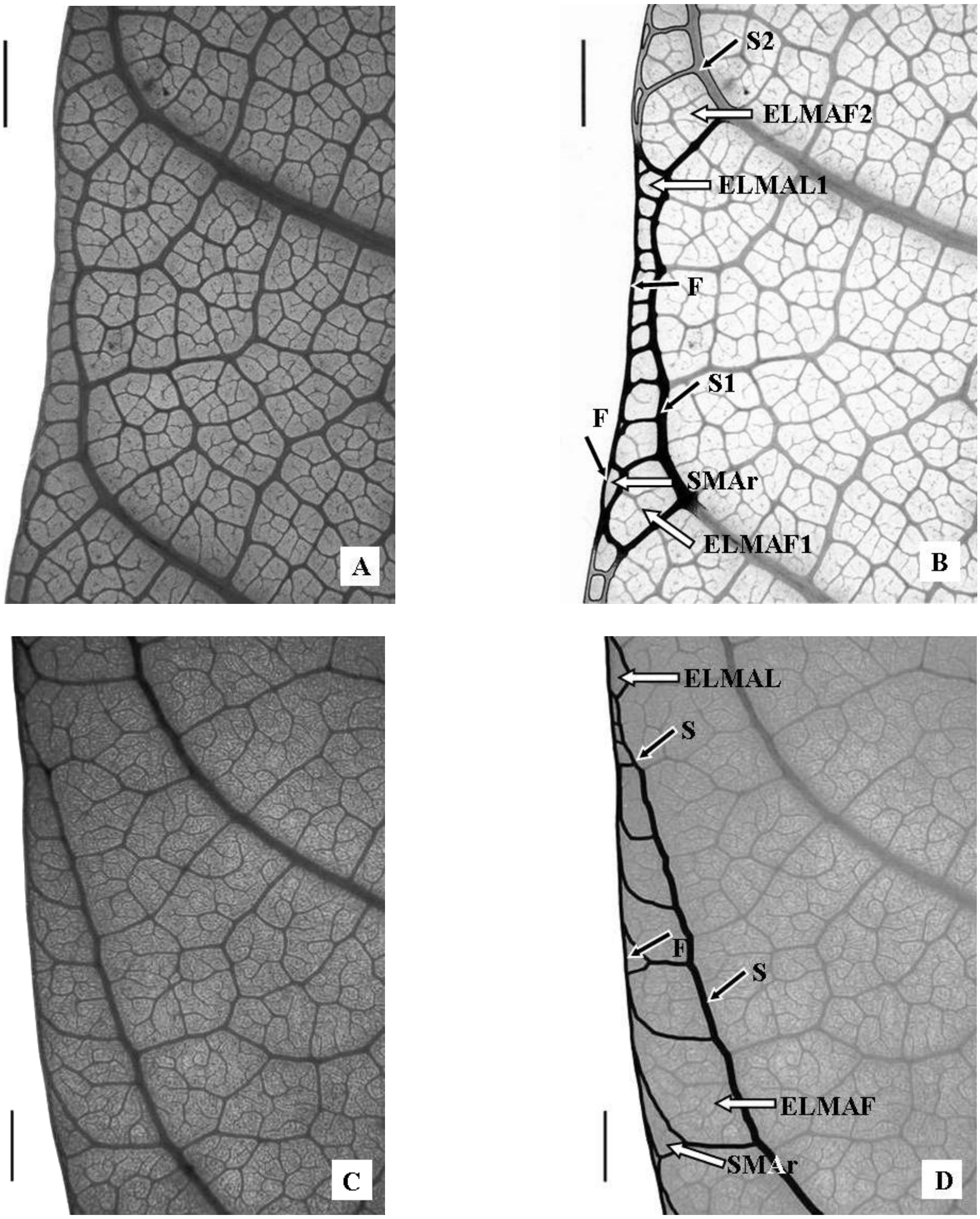


Fig. 4.14 (A), (B) Type IV MVP as present in *Melanochyla bracteata* (BKF SN 105458) that has intermediate type III-IV. (C), (D) Type IV as present in *Bouea macrophylla* (BKF SN 126889). See similar explanations in previous figures. Scale bar = 1 mm in A-B, 2 mm in C-D.

5. *Type V*: All ELMAs have their features like type IV except that the last ELMA is at a level lower than that of the lower border of the first ELMA of the superadjacent

secondary vein. That is secondary veins which are inner borders of the ELMAs reach the margin of the leaf at a level lower than that of the lower border of the first ELMA (Fig. 4.15) of the superadjacent secondary vein. In this case, the outer borders of ELMAs are viewed as discrete secondary veins as mentioned in the topic "Borders of ELMAs".

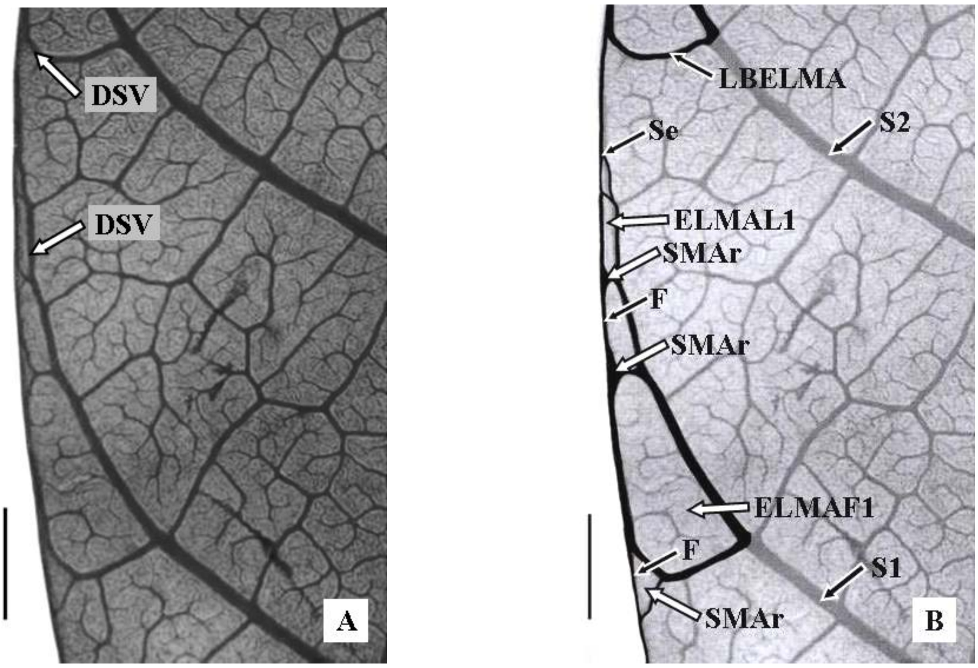


Fig. 4.15 (A) Type V MVP as present in *Bouea oppositifolia* (BKF SN 084983). (B) S1 ending at leaf margin (Se) lower than the lower border of first ELMA of the superadjacent secondary (LBELMA). The ELMAL1 is then at a level lower than LBELMA (in the previous case, they are at the same level). The loop formed at this level will then be called SMAr instead of the last ELMA as defined earlier. Note: SMAr of S1 is weakly formed, but SMAr of S2, at the level of LBELMA is not formed. Scale bar = 1 mm.

II. When marginal ultimate venation is looped or mixed looped and incomplete (i.e. fimbrial veins absent).

The classification of types of MVPs in this case follows the same principles as presented in those with fimbrial veins. However, MVPs so far examined in leaves without fimbrial veins in this study show 2 types as follows:

6. *Type VI*: ELMAs with their outer borders lined by more than one CMArC. This may be considered to be equivalent to sets of loops outside the main brochidodromous loop found in festooned brochidodromous leaves and described in Leaf Architecture Working Group (1999). In this type of MVP, sets of ELMAs and marginal ultimate venation are not as clearly seen as in other types (Fig. 4.16).

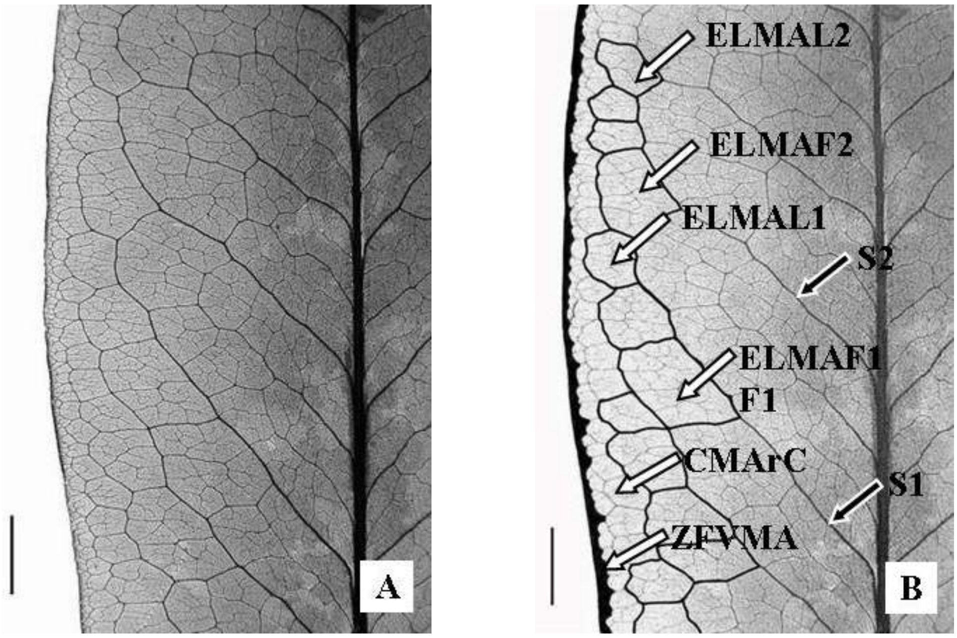


Fig. 4.16 (A) Type VI ELMA as present in *Buchanania siamensis* (SUT-cleared leaf collection, Grote 190-4). (B) A line drawing was made on ELMAs of each secondary vein and two CMArC were recognized in this case. Shaded areas represent ZFVMA. Scale bar = 5 mm.

7. *Type VII*: ELMAs with their outer border lying close to the leaf margin or to marginal areoles (looped marginal ultimate venation, LMV, as described in Dilcher (1974)). As in type IV and V, the MArC is absent (Fig. 4.17).

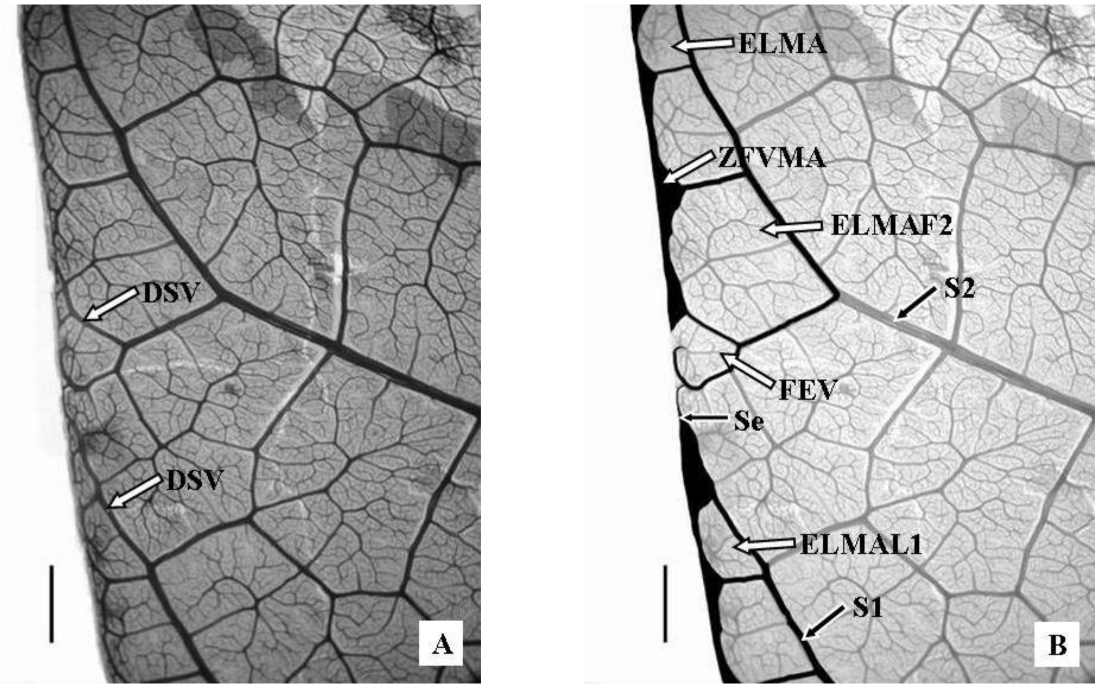


Fig. 4.17 (A) Type VII MVP as present in *Buchanania sessifolia* (BKF SN 002502). (B) As mentioned in Fig. 4.15, the secondary in this case ended (Se) at leaf margin lower than the lower border of first ELMA of the superadjacent secondary vein. MUV in this species was diagnosed to be intermediate between incomplete and looped. Shaded areas represent ZFVMA. Compare FEV with SMAr in Fig. 4.15. Scale bar = 2 mm.

Variations in types of MVPs and related characters as mentioned should be kept in mind when we attempt to make use of them for taxonomic ranking. In cases where there are more than one type of MVP in the same leaf, the type present as the majority should be used for the first diagnosis, and the type less dominant will be the second, and so on. For example, type III is predominant with some type IV in *Melanochyla bracteata*, so the diagnosis will then be Type III-IV. As so far studied, MVPs are usually present as only one type in a species, and present as two close types in some species as mentioned. As a consequence, clearing the whole leaf or clearing parts that cover possible variation is necessary. If clearing the whole leaf is not possible (e.g., obtaining only part of leaf specimens from the herbarium), adjunct photographs of venation at the margin of leaf specimens taken by using the oblique-lighting technique can be used to help identify type of MVPs.

4.1.3 Systematic descriptions and affinities of the fossil leaves

Illustrations presented in this part are the concise ones. The whole sets of pictures (of larger sizes) of the fossil and modern leaves studied are available in plates 1-40 and in the photographic archive in CD attached. Angle of divergence of tertiary veins is the combination of two letters; the first and the second indicate the angle on the exmedial side and on the admedial side of the secondary vein, respectively. The combinations are as follows: AA, AR, AO, RA, RR, RO, OA, OR, and OO (A = acute angle, O = obtuse angle, R = right angle).

Systematic description

Division----Magnoliophyta.

Order----Sapindales (Burserales according to Takhtajan (1997)).

Family----Anacardiaceae Lindl.

Genus----*Mangifera* Linn.

Species----*Mangifera paleoindica* sp. nov. Sawangchote, Grote and Dilcher.

Holotype---- Specimen number SUT083 (Plate 36, Figs. 4.18 I, H, R, T, W, and V), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

Locality---- Li Basin, Amphoe Li, Lamphun Province, Northern Thailand, 17° 45′ N, 99° 00′ E, locality number 002.

Age---- Approx. Late Oligocene – Early Miocene.

Number of specimens---- The material comprises only a single carbonized well-preserved leaf compression.

Etymology----The specific epithet refers to the similarity of leaf architecture between the fossil and the extant *Mangifera indica*.

Description: Leaf simple, preserved lamina length 12 cm (estimated lamina length 15 cm), width 3.2 cm; symmetrical, narrow oblong; apex missing; base missing; margin entire; texture probably coriaceous, pronounced plication of leaf blade; venation pinnate, eucamptodromous; primary vein stout, markedly curved; estimated number of secondary veins 20 pairs, 0.3-1.0 cm apart, opposite, subopposite and alternate, moderately thick, angle of divergence moderate to wide acute (54°-85°), upper slightly more acute than lower and more acute on one side than on the other, mostly straight most of the distance to margin and some uniformly curved, MVP presumably type II, not all sets of ELMAs seen but approximately 5-6 in number, gradually diminishing in size apically, quadrilateral, BATV wide acute and right angle; intramarginal vein absent; intersecondary veins frequent, strong, mostly simple, some composite, proceeding 1/2-2/3 of the distance between midvein and leaf margin; tertiary vein angles of origin AA, AR, RR with acute angle predominantly wide (65°-80°), percurrent/forked, oblique in relation to the midvein, tertiary vein angle possibly decreasing outwards, predominantly alternate and close; quaternary and quinternary veins thick and orthogonal; highest vein order 7, highest vein order showing excurrent branching possibly 6; marginal ultimate venation is not clearly seen but possibly fimbriate; areoles well developed, oriented, mostly quadrangular, some pentagonal, size mostly medium; FEV not clearly seen (Figs. 4.18T-U).

Affinities: Six species of *Mangifera*, namely, *Mangifera chamaoensis* (the name is from the herbarium sheets at BKF, and probably unofficial identification), *M. collina* Kosterm., *M. flava* Evard, *M. indica* L., *M. linearifolia* Kosterm., and *M. sylvatica*

Roxb., and one species of *Melanochyla*, namely, *Melanochyla bracteata* King (Figs. 4.18A-G), were compared with this fossil leaf due to similarity in leaf shape and

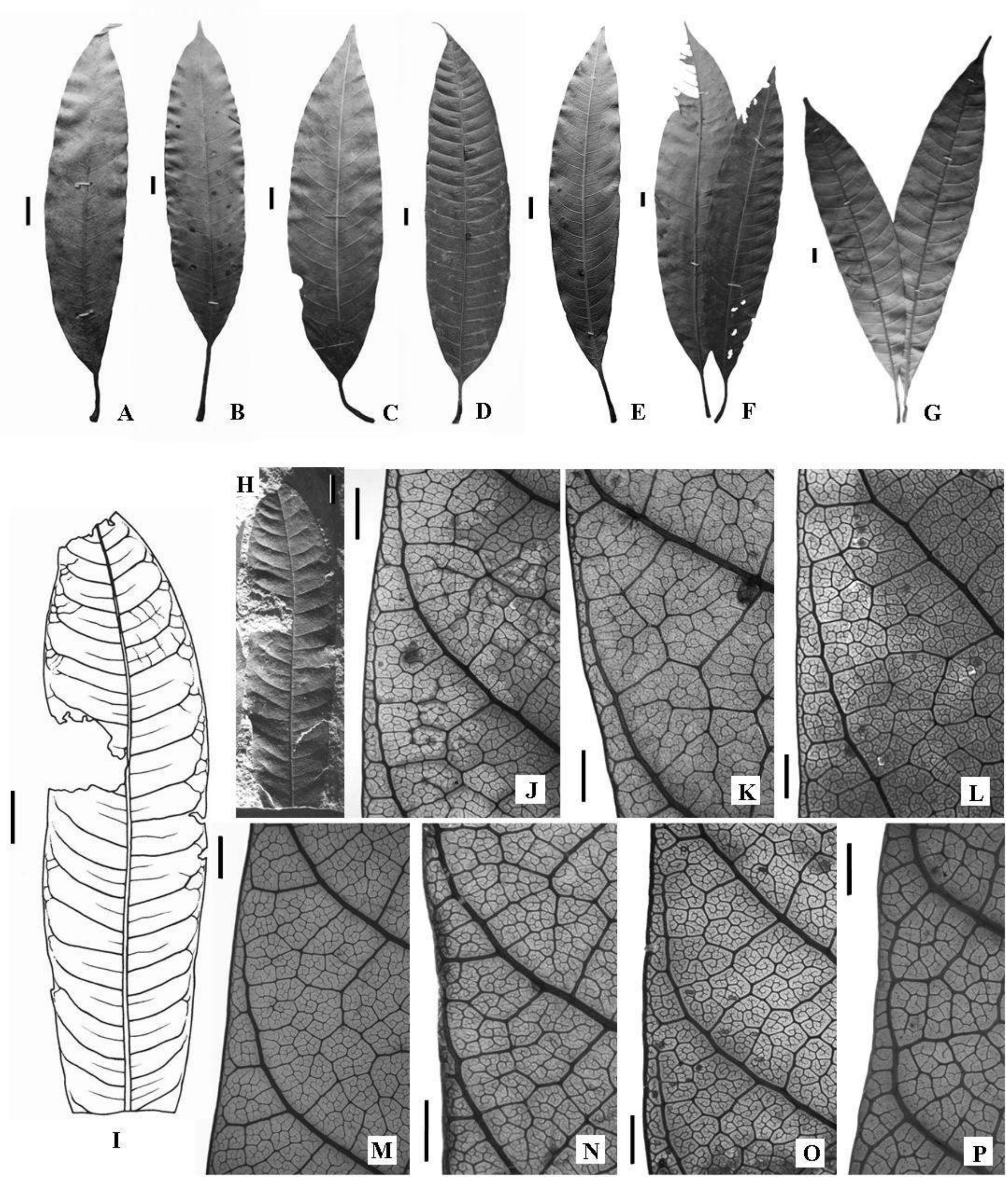
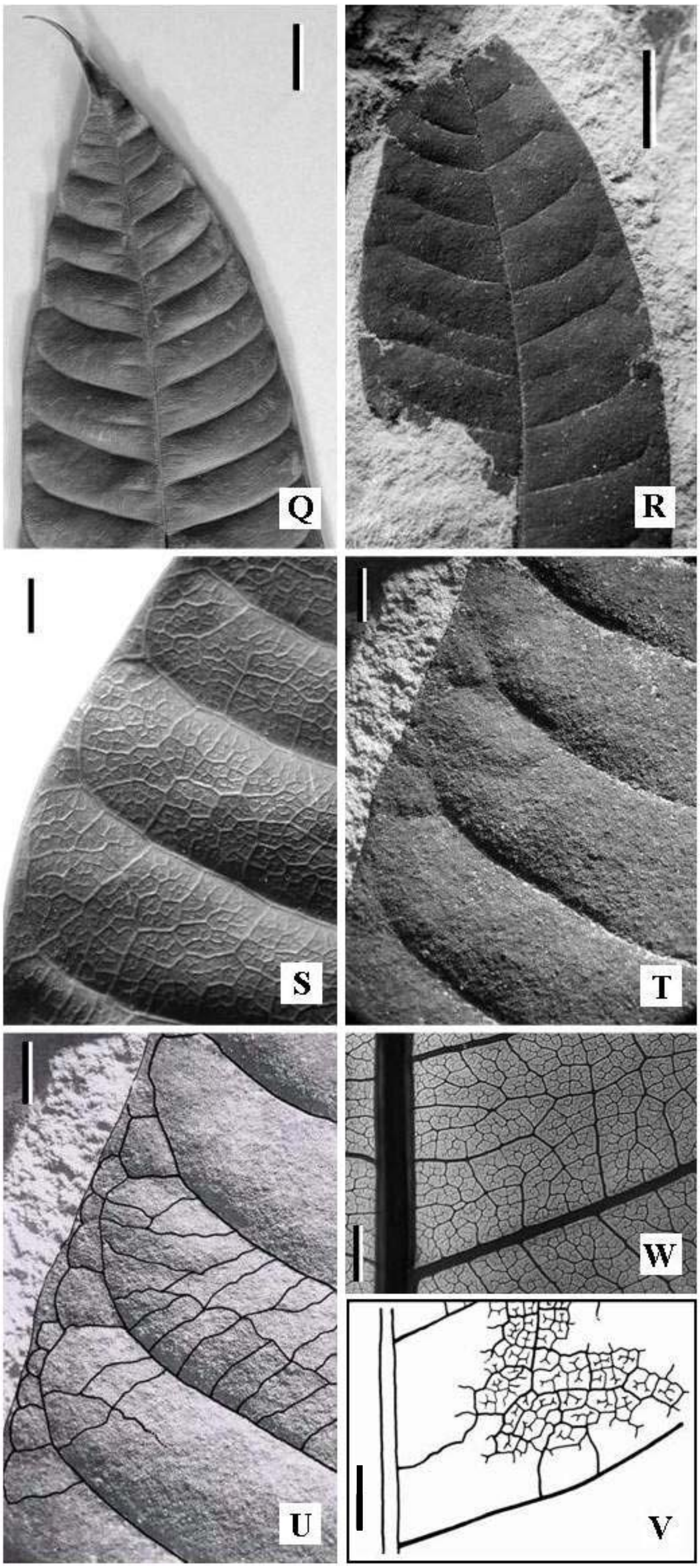


Fig. 4.18 *Mangifera paleoindica* and its possible NLRs. (A-G) Narrow elliptic to narrow oblong leaves of *Mangifera chamaoensis*, *M. collina*, *M. flava*, *M. indica*, *M. linearifolia*, *M. sylvatica*, and *Melanochyla bracteata*, respectively, that are more or



less similar to *Mangifera paleoindica* shown in (H) and (I). (J-P) Part of the cleared leaf of each species in (A- G) respectively. (D), (H), (Q), (R) The distinct plication present in *M. indica* (D, Q) (not common in the species) and *Mangifera paleoindica* (H, R) which was not found in the rest of the species shown here. Also note the similarity in angle of divergence of secondary veins, distance between adjacent veins, intersecondary veins, and pronounced cross veins of *M. indica* and *Mangifera paleoindica*. (S), (T) Close-up of leaf margin of *M. indica* and *Mangifera paleoindica* in (Q), (R), respectively. (U) Line drawing made on (T) under stereomicroscope to show orientation of tertiary veins and MVP type II that are similar to those in *M. indica* in (S). (V) Line drawing of part of fossil leaf showing well-developed areoles that are similar to those of *M. indica* in (W). Scale bar = 1 cm in A-I, Q-R, 2 mm in J-P, S-U, 1 mm in V, W.

venation patterns. Leaf shape, number and course of secondary veins, type of tertiary veins, and characters of intersecondary veins are common features shared between *Melanochyla bracteata* and the fossil. However, the differences in type of MVP and number of ELMA (Figs. 4.18P, U) are crucially important in distinguishing the fossil from this modern species. Variation in leaf shape, based on length/width ratio (l/w), among species of *Mangifera* is of concern as well, but we are still able to use this feature as the first tool to narrow down the number of potential living relativess to the six species mentioned above. These modern *Mangifera* species have similar leaf shape with, and have size range and l/w ratio overlapping or close to that of the fossil. Among these, *M. collina*, on average, has broader leaf blades (not the one shown), type IV of MVP and a larger number of ELMAs (Fig. 4.18K). *M. chamaoensis* also has MVP type IV with a smaller number of ELMAs than *M. collina* while *M. linearifolia* has intermediate type III and IV (Figs. 4.18J, N). *M. indica, M. flava* and *M. sylvatica* have type III of MVP and larger number of ELMA (Figs. 4.18L, M, O). For *M. indica*, some leaves have similar numbers of ELMA as the fossil. *M. indica*, therefore, seems to share the most features in common with the fossil. Nevertheless, examination of leaves of *M. indica* clearly showed a high level of variation in size and shape that overlapped the characters of the fossil. Some trees of this species have leaves that share many common features with the fossil such as leaf size and shape, number and angle of divergence of secondary veins, abundance and features of intersecondary veins (Figs. 4.18D, H-I, Q-R), development and size of areoles (Figs. 4.18V-X), overlapping of type of MVP (*M. indica* can have mixed type II and III of MVP in the same individual leaf, and the fossil presumably has type II (Figs. 4.18M, S-U)), and plication of the leaf blade in particular (Figs. 4.18Q-R). Plication between two adjacent secondary veins of the leaf blade as expressed in the fossil is also found as a variation in leaves which is not quite common among trees of *M. indica* and other *Mangifera* species. Of all the species of *Mangifera* examined, only *M. indica* (in some trees) and *M. quadrifida* (Fig. 4.19G) show pronounced plication. Also, leaves of *M. odorata* shown in Fig. 12 in Ding Hou (1978) have pronounced plication. Owing to these shared similarities of the fossil and *M. indica*, this fossil is therefore named *Mangifera paleoindica*.

Division----Magnoliophyta.

Order----Sapindales (Burserales according to Takhtajan (1997)).

Family----Anacardiaceae Lindl.

Genus----*Mangifera* Linn.

Species----*Mangifera intermedia* sp. nov. Sawangchote, Grote and Dilcher

Holotype----Specimen number SUT224 (Plate 37, Figs. 4.19 H, I, Q, R, S, and T), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

Locality**----**Li Basin, Amphoe Li, Lamphun Province, Northern Thailand, 17° 45′ N, 99° 00′ E, locality number 002.

Age----Approx. Late Oligocene – Early Miocene.

Number of specimens----The material comprises only a single partially carbonized and pyritized well-preserved leaf compression.

Etymology----The specific epithet refers to the similarity of leaf architecture of the fossil to that of three extant species of *Mangifera*, namely, *M. caloneura*, *M. duperreana* and *M. indica*.

Description: Leaf simple, symmetrical, narrow oblong; preserved lamina length 11.5 cm, width 4 cm, estimated lamina length 14 cm, apex missing; basal most part missing but presumably acute normal to acute cuneate; petiole missing; margin entire; texture probably coriaceous; type of venation pinnate eucamptodromous; primary vein stout, very slightly curved at basal 1/3; estimated number of secondary veins 21 pairs, 0.4-0.8 cm apart and closer at base, opposite, subopposite and alternate, moderately thick, angle of divergence wide acute to right angle (70°-100°), upper more acute than lower and more acute on one side of the leaf than on the other; most of secondary veins are uniformly straight most of the distance to margin but with some uniformly curved; MVP type I, approximately 5-6 obvious ELMAs, gradually diminishing in size apically, mostly quadrilateral; BATV wide acute and right angle; intramarginal vein absent; intersecondary veins frequent, strong, simple to composite, proceeding 1/4-1/2 of the distance between midvein and leaf margin; tertiary veins mostly AR, RA and RR with acute angles predominantly wide (75°-80°), percurrent / forked, oblique in relation to the midvein, tertiary vein angle decreasing outward, predominantly alternate and close; quaternary and quinternary veins thick and orthogonal; highest vein order 7, highest vein order showing excurrent branching 6; marginal ultimate venation strongly fimbriate; areoles very well developed, oriented, mostly quadrangular and pentagonal, medium sized (mostly 0.3-0.5 mm); FEV mostly branched once, some twice (highest vein order may not be observed due to preservation process) (Figs. 4.19Q-T).

Affinities: Based on l/w ratio, SUT 083 and SUT 224 (approx. 4.88 and 3.5, respectively) were both categorized as narrow oblong leaves, but SUT 224 is broader. Furthermore, SUT083 and SUT224 also share many characteristics in common such as number of, and distance between, secondary veins, abundance and features of intersecondary veins (Figs. 4.18H-I, 4.19H-I), type and other features of tertiary vein (Figs. 4.18U, 4.19Q), features of quaternary and quinternary veins, and presence of well developed areoles (Figs. 4.18V, 4.19Q-T). Owing to their similarities, SUT224 might have been identified as the same species as SUT083. In addition, *M. indica*, which is the nearest living relative (NLR) of SUT083, also possesses oblong leaves with a close l/w ratio and very similar venation pattern to those of SUT224 (Fig. 4.19E). However, there are two major differences between SUT224 and SUT083. The first one is that SUT224 has MVP type I, while SUT083, even though not all these marginal venation patterns were clearly seen, has type II (Figs. 4.18T-U, 4.19Q-R). The second is that the angle of divergence of secondary veins of SUT224 are more obtuse than those in SUT083 (70°-100° in SUT224 and 54°-85° in SUT083) (Figs. 4.18H-I, 4.19H-I). Of all *Mangifera* spp. examined in this study, there were no clearly seen MVP type I as was seen in SUT224. However, the closest MVP to that of the fossil was found in *M. caloneura* Kurz. and *M. duperreana* Pierr, namely, intermediate type I & II (Figs. 4.19K-L). The angles of divergence of secondary veins of *M. duperreana* are mostly approx. 72°-90° with some most basal angles approx. 50° (i.e., upper more obtuse than lower), whereas those of *M. caloneura* are mostly

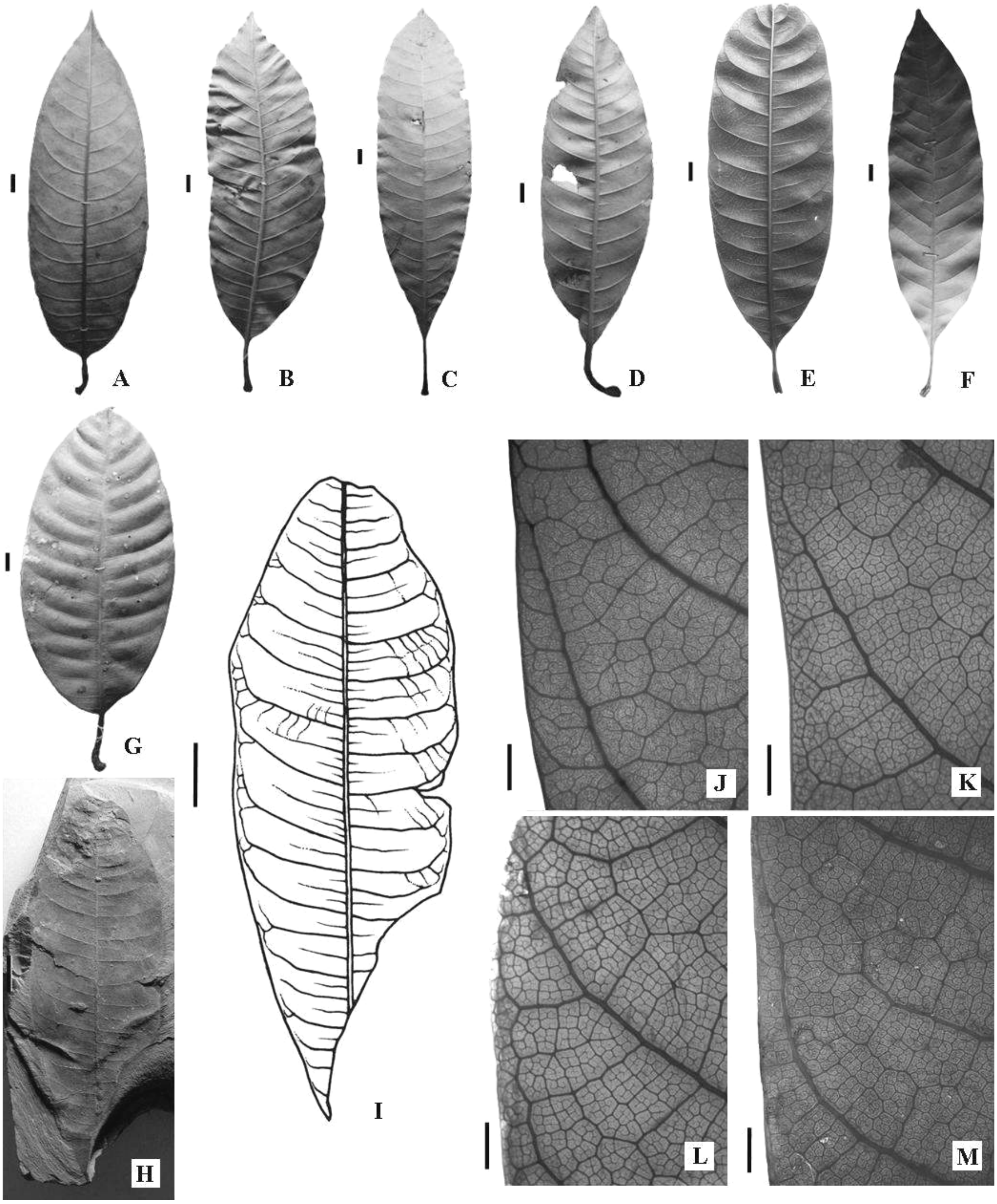
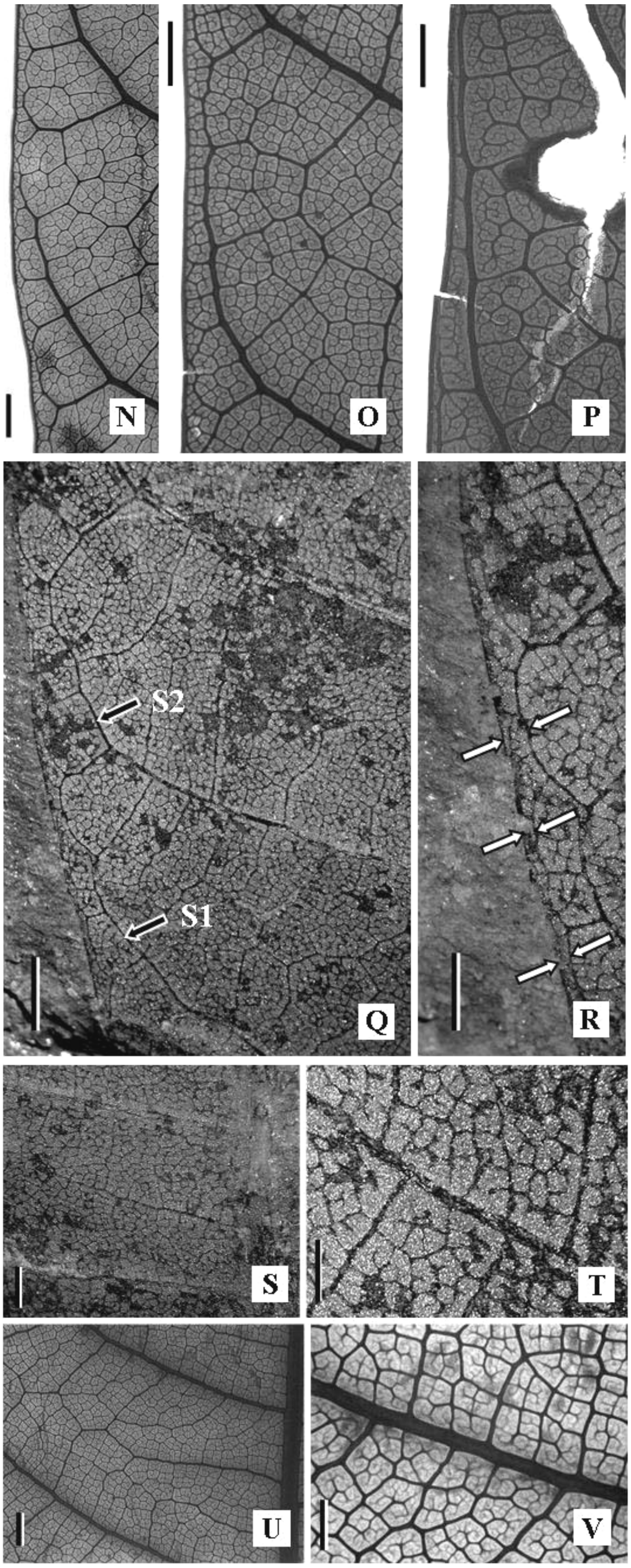


Fig. 4.19 *Mangifera intermedia* and its possible NLRs. (A-G) Oblong to elliptic leaves of *Bouea macrophylla*, *Mangifera caloneura*, *M. duperreana*, *M. foetida*, *M. indica* (relatively broad oblong leaf), *M. pentandra*, and *M. quadrifida* respectively, that are more or less similar to *Mangifera intermedia* shown in (H). (I) Line drawing of *Mangifera intermedia*. (J-P) Part of the cleared leaf of each species in (A-G), respectively. (Q) MVP of the fossil. (R) Magnified portion of (Q) showing MArC (area between heads of two adjacent arrows) that lie along the outer border of ELMAs; middle two arrows are at the level of last ELMA of S1 in (Q) and upper two are at first ELMA of S2 in (Q). (S), (U) Comparison of intersecondary veins and



orientation of tertiary veins of the fossil and *M*. *duperreana* (which is one of the closest NLRs) respectively. (T), (V) Comparison of areoles of the fossil and *M*.

duperreana. Scale bar = 1 cm in A-I, 2 mm in J-Q, U, 1 mm in R-S, V, 0.5 mm in T.

approx. 70°-81° with those toward the apex most approx. 46° (i.e., upper more acute than lower). When comparing the angles of divergence of these two modern species with those of the fossil, those of *M. caloneura* seem to be closer than those of *M. duperreana*. Abundance and orientation of intersecondary veins of these two species are also similar to those of the fossil (Figs. 4.19S, U). The leaf base of *M. duperreana* is acute normal to acute cuneate which is closer to that of SUT224 than is that of *M. caloneura* (Figs. 4.19B-C, H-I). Areoles of the fossil and these two modern *Mangifera* spp. are very well-developed and oriented but the sizes of those of the fossil are closer to those of *M. duperreana* (Figs. 4.19K-L, Q, T, V). Other than *M. indica*, *M. caloneura*, and *M. duperreana*, the following species are also close to this fossil: *M. collina* (some leaves are broader than the one shown in Fig. 4B), *M. foetida* Lour., *M. pentandra* Hook. f., and *M. quadrifida* Jack. These species have shapes and l/w ratios close to those of SUT224, but their types of MVP are different and other features are also less similar to this fossil (Figs. 4.19D, F-G, M, O-P).

In addition, *Bouea macrophylla* Griff. was brought into comparison with similarities in leaf shape, number and angle of divergence of secondary veins, and distance between secondary veins (Fig. 4.19A). Type IV of MVP, very distinct shape of ELMA (Claw-like), and moderately developed areoles in *B. macrophylla* provide the major important evidence for this species to be excluded from the list of potential close living relatives (Fig. 4.19J). From the above detailed comparison, *M. caloneura*, *M. duperreana* and *M. indica* seem to equally share most of the examined features with the fossil, more than the other species. The fossil is therefore named *Mangifera intermedia*.

Division---- Magnoliophyta.

Order----Sapindales (Burserales according to Takhtajan (1997)).

Family----Anacardiaceae Lindl.

Genus----*Mangifera* Linn.

Species----*Mangifera buchananioides* Sawangchote, Grote, Dilcher.

Holotype----Specimen number SUT672 (Plate 38, Figs. G, H, M, N and O), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

***Locality*----**Li Basin, Amphoe Li, Lamphun Province, Northern Thailand, 17° 45′ N, 99° 00′ E, locality number 002.

Age---- Approx. Late Oligocene – Early Miocene.

Number of specimens---- Only one specimen, most of the leaf area of which is impression with some compressed leaf material preserved.

Etymology----The specific epithet refers to the sharing of some features between the fossil and the extant *Buchanania sessifolia*.

Description: Leaf simple; preserved lamina length 16.2 cm (estimated lamina length18.5 cm), width 4.8 cm; symmetrical, narrow elliptic-narrow obovate; apex missing; base acute cuneate (or long tapering); margin entire; texture probably coriaceous; petiole approximately 1 cm long, inflated; venation pinnate, eucamptodromous; primary vein stout, straight; estimated number of secondary veins 22 pairs, 0.5-0.8 cm apart, mostly opposite, subopposite or some altenate, moderately thick, angle of divergence mostly wide acute to right angle (70°-85°), only a few most basal angles moderately acute (55°), upper angles slightly more acute than lower; secondary veins uniformly straight most of the distance to margin; intersecondary veins frequent, relatively weak, mostly composite, proceeding 1/3-1/2 of the distance from midvein to leaf margin; although few areas of MVP were seen (from bleached and stained specimens) and fimbrial veins are difficult to identify the MVP is most likely to be type I (and possibly type II) with approximately 5-6 ELMA, quadrilateral; branching-off angles of tertiary veins (BATV) wide acute and right angle; intramarginal vein absent; tertiary veins angles of origin AA, AR, RR (acute angles predominantly wide, 65°-80°), percurrent / forked, oblique in relation to the midvein, tertiary vein angle decreasing outward, approximately parallel near midvein, alternate or opposite, very close; quaternary and quinternary veins thick and randomly oriented; highest vein order and highest vein order showing excurrent branching probably 7 and 6 respectively; marginal ultimate venation possibly fimbriate; areoles well developed, oriented, pentagonal and polygonal, size probably medium (mostly less than 1 mm across); free ending veinlets not clearly seen but probably branched 1-2 times.

Affinities: From the first glance, SUT 672 and SUT 845 are rather similar in shape (Figs. 4.19H-I, 4.20G-H). However, SUT 845 is oblanceolate while SUT672 is narrow elliptic. SUT 672 has a lower l/w ratio than SUT 845 does (3.85 and 4.9, respectively). From the preservation, SUT 845 seems to have a more coriaceous texture, the secondary veins are more pronounced than those of SUT 672, the endings of secondary veins have feature of forking, and intersecondary veins are more pronounced and more abundant. Furthermore, the petiole is relatively longer in SUT 845. Hence, SUT 672 was considered to have different affinities than SUT 845.

Compared with SUT 672, SUT 224 has a similar shape, has a similar number of and distance between secondary veins, shares type of MVP, has a similar number and shape of ELMA, and similar BATV. However, with the following differences of SUT224: smaller size, broader leaf blade, base more acute than cuneate, more pronounced and more frequent intersecondary veins, I still prefer to separate SUT 672 from SUT 224. Leaves of similar l/w ratio, size and shape were compared with SUT672. They included *Alstonia macrophylla* Wall. ex G. Don., *A. scholaris* (L.) R. Br., *Buchanania sessifolia* Blume, *Gluta renghas* L., *Mangifera caesia* Jack and *Semecarpus cochinchinensis* Engl. (Figs. 4.20A-F, 4.21E). The two species of *Alstonia* possess a brochidodromous type of venation which is clearly different from that of SUT672 (Figs. 4.9A-B, 4.20I, N-O). Although *Gluta renghas* has the closest MVP to that of the fossil but the steeper angle of divergence of secondary veins (Figs. 4.20D, H), different shape and larger number of ELMA, more acute BATV, and relatively poorly developed areoles (Figs. 4.20J, N-O) can lead to the exclusion of this species as a potential NLR. With *Semecarpus cochinchinensis* (Figs. 4.21E, M), the fossil also shares size, leaf shape, type of MVP, and similar number of ELMA. However, the relatively larger size of the primary vein, smaller number of and larger distance between secondary veins, and far more acute angle of divergence of secondary veins make *S. cochinchinensis* less likely to be the NLR. *Buchanania arborescens* (Blume) Blume (picture not shown), although sharing the type of MVP, possesses a smaller number of secondary veins, approx. larger distance between adjacent secondary veins, steeper angle of divergence of secondary veins, more pronounced and more frequent intersecondary veins, and longer petiolar length. The areoles in *B. arborescens* are also less developed than those in the fossil. *B. sessifolia*

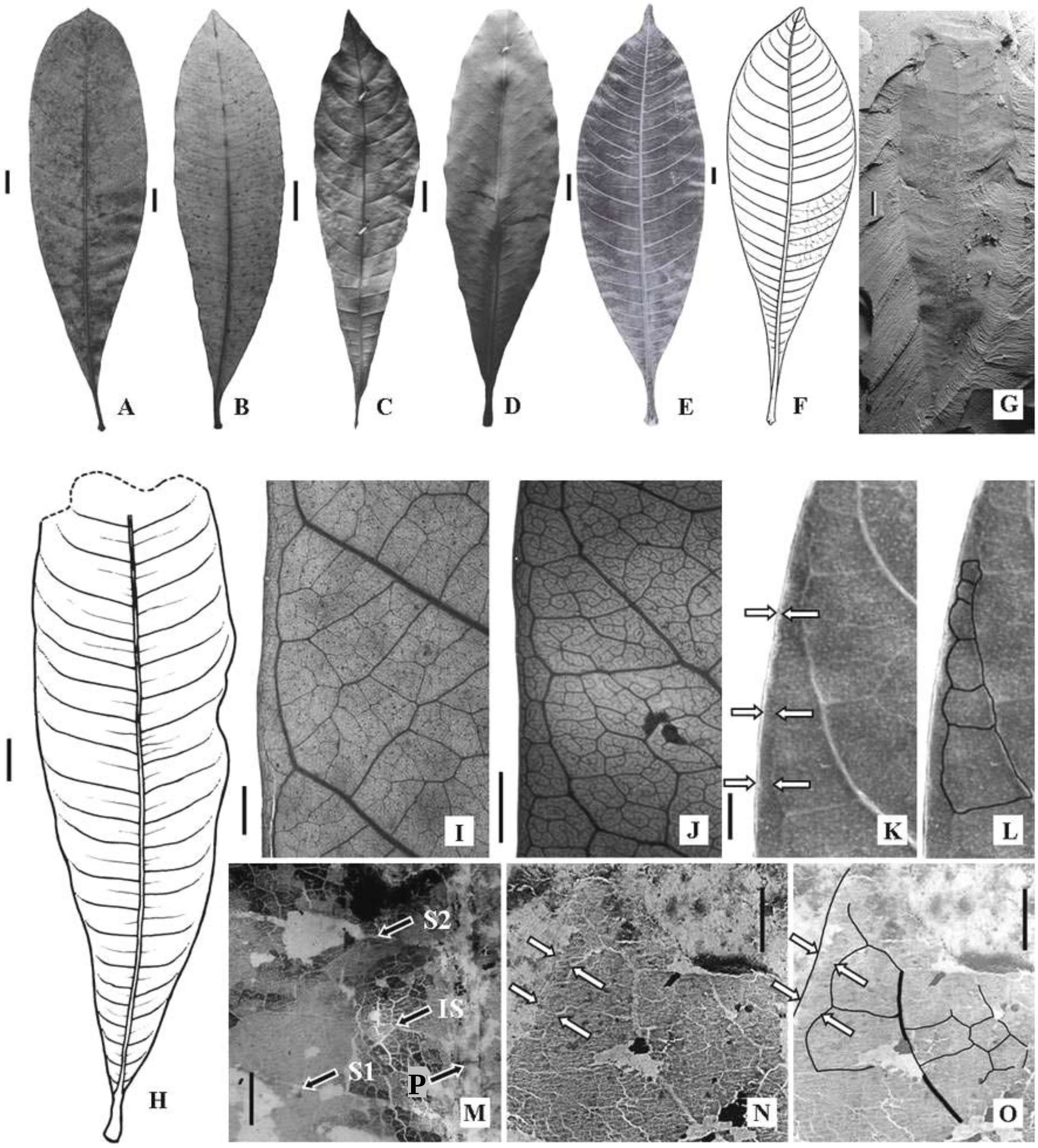


Fig. 4.20 *Mangifera buchananoides* and its possible NLRs. (A-E) Narrow elliptic to narrow obovate leaves of *Alstonia macrophylla*, *A. scholaris*, *Buchanania sessifolia*, *Gluta renghas*, and *Mangifera caesia* that are more or less similar to *Mangifera buchananoides* shown in (G). (F) A line drawing of *M. caesia* in Kuchummen (1989) shows closer leaf shape to the fossil than (E) does. (H) Line drawing of the fossil. (I-J) Part of the cleared leaf of (A), (D), respectively. Cleared leaves of *A. scholaris* and *B. sessifolia* are shown in Figs. 4.9A-B and Figs. 4.17A-B, respectively. (K-L) Type of MVP was estimated on a leaf of *M. caesia* which was not cleared. Space between heads of two adjacent arrows in (K) is the width of MArC that gradually decreases apically and is clearly shown in (L). (M) Intersecondary vein and well developed aeoles of the fossil. (N) Part of MVP of the fossil observed from cleared leaf material.

Space between heads of two adjacent arrows is the width of MArC. (O) Line drawing made on (N) to clearly show mentioned features. Scale bar = 1 cm in A-H, 2 mm in I-L, 1 mm in M-O.

shows more similarities in leaf shape, size, number and angle of divergence of secondary veins (in some leaves), and length of petiole with the fossil than *B. arborescens* does. Furthermore, the orientation and angle of divergence of tertiary veins and BATV of both the fossil and *B. sessifolia* are also similar (Figs. 4.17A-B, 4.20N-O). However, different type of MVP, lack of the feature of admedial ramification and possession of more developed areoles of the fossil (Figs. 4.20M-O) make it significantly different from *B. sessifolia*. When compared with all *Mangifera* species in this study, SUT 672 seems to share the feature of well developed areoles with those *Mangifera* species, unlike the species of *Gluta* and *Buchanania*. However, of the species examined, only *M. lagenifera* Griff. (picture not shown) and *M. caesia* possessed leaves with a relatively long cuneate base and relatively short petiole as in the fossil and *B. sessifolia*. *M. caesia* also shares the following features with the fossil: size, similar l/w ratio, thickness of primary vein, length of petiole, number of and angle of divergence of secondary veins, distance between adjacent secondary veins, similar type of MVP and number of ELMA, and similar BATV. Compared with *B. sessifolia*, these two *Mangifera* spp. share more similarities with the fossil. Because of its features that are closest to those of *M. caesia*, and *M. lagenifera*, and because of some features it shares with *B. sessifolia*, the fossil is then named *Mangifera buchananioides* Sawangchote, Grote and Dilcher.

NB: Some species of other genera in Apocynaceae (e.g., *Cerbera manghas* and *C. odollum*; details in section on modern species examined.) were also similar in size, and shape of leaf, and in number, course, and angle of divergence of secondary veins, but they all have a brochidodromous type of venation. The fossil was also roughly compared with line drawings of some species shown in Tree Flora of Malaya by Kuchummen (1989). *Gluta macrocarpa* and *Gluta malayana* have a similar leaf shape and cuneate base as in the fossil; however, both of them have broader leaves and the former has smaller leaf size.

Division---- Magnoliophyta.

Order----Sapindales (Or Burserales according to Takhtajan (1997)).

Family----Anacardiaceae Lindl.

Genus----*Semecarpus* Linn. f.

Species----*Semecarpus paleosiamensis* sp. nov. Sawangchote, Grote and Dilcher.

Holotype----Specimen number SUT728 (Plate 39, Figs. G, H, O, P, Q and R), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

***Locality*----** Li Basin, Amphoe Li, Lamphun Province, Northern Thailand, 17° 45′ N, 99° 00′ E, locality number 019.

Age---- Approx. Late Oligocene – Early Miocene.

Number of specimens---- The material comprises only a single pyritized well-preserved leaf-compression.

Etymology---- The specific epithet refers to the existence of the species in Thailand in the geological past (Siam = Thailand).

Description: Leaf simple, symmetrical, shape intermediate between narrow oblong and narrow elliptic; preserved lamina length 10.8 cm, estimated lamina length 11.2 cm, width 2.2 cm; apex acuminate; base acute cuneate, petiole missing; margin entire; texture probably coriaceous; type of venation pinnate, eucamptodromous; primary vein stout, markedly curved; secondary veins estimated at 25 pairs, 0.3-0.6 cm apart, opposite, subopposite or alternate, thick, angle of divergence narrow to wide acute (35°-71°), upper more acute than lower and more acute on one side than on the other, mostly straight most of the distance to margin and bending up sharply near leaf margin, some uniformly curved; MVP type I, approximately 5-7 obvious ELMAs, gradually diminishing in size apically, quadrilateral and rectangular, BATV wide acute and right angle; intramarginal vein absent; intersecondary vein frequent, strong, simple to composite, proceeding 1/6-2/3 of the distance from midvein to leaf margin; tertiary veins with angle of origin RR, RA, AA with acute angles predominantly wide (70°-80°), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decreasing outward, alternate or opposite, close; quaternary and quinternary veins thick and orthogonal; highest vein order 7, highest vein order showing excurrent branching 6; marginal ultimate venation not completely seen but presumably strongly fimbriate; areoles well developed, oriented, mostly quadrangular and pentagonal, size medium (mostly 0.3-0.5 mm), FEV branched up to 3 times (Figs. 4.21H-I, O-R).

Affinities: This fossil leaf also shows a venation pattern that is very similar to that of SUT845. The differences between these two fossil leaves are leaf shape and type of MVP. Furthermore, the preservation of SUT728 is very flat and less prominent than that of SUT 845 (Figs. 4.21G, 4.22E). SUT728 possesses MVP type I, but SUT845 has MVP type II and III (Figs. 4.21O-P). The difference in leaf shape is not so significant that these two fossil leaves can be separated because this difference in leaf shape may only reflect the common variation found among leaves of any individual species. But type of MVP, as so far examined in this study, is rather constant in the same leaf or in the same species. These two fossil leaves were, therefore, determined to have different affinities.

The leaves of four modern species of Anacardiaceae, *Bouea oppositifolia* (Roxb.) Meisn., *Gluta elegans* (Wall.) Hook. f., *Mangifera indica*, *Semecarpus cochinchinensis*, and *Semecarpus* sp. were compared with this fossil leaf. In addition, one species of Sapindaceae, *Nephelium lappaceum* L. is shown as an example of a leaf that has similar leaf shape but a different venation pattern (Figs. 4.21A, I). Although the presence of weak sigmoid-curved primary veins and rough leaf shape were shared between the leaves of these modern species and the fossil, some additional features are crucial in discriminating some of these modern leaves from the fossil. The leaf base of *N. lappaceum* is not cuneate as in the fossil and it is asymmetric. Although it shares a eucamptodromous type of venation, the leaf of *N. lappaceum* dose not possess intersecondary veins. In addition, the tertiary veins are more strongly percurrent/simple and the areoles are paxillate, quadrangular, with no veinlets or with simple veinlets. *B. oppositifolia* and *G. elegans* have narrow to wide elliptic leaves, with a smaller number of secondary veins, and less developed areoles. *S. cochinchinensis* shows less resemblance in leaf shape than the other species do, it has a general venation pattern in common with the fossil, but clearly has a smaller number and different course of secondary veins. *M. indica* and *Semecarpus* sp., when compared with the other species mentioned above, share more common features. The *M. indica*, with a leaf with a sigmoid-curved primary vein could have been considered

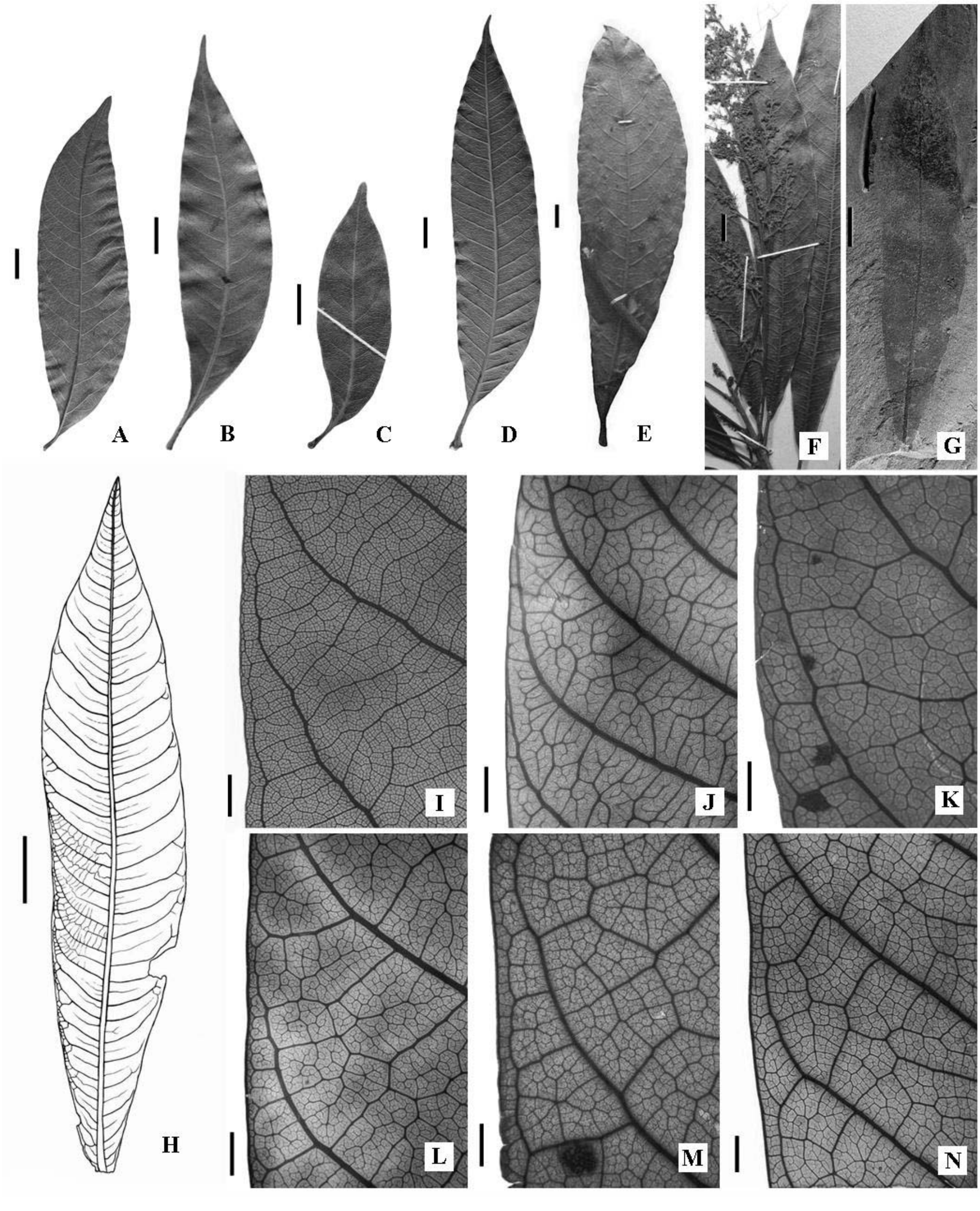
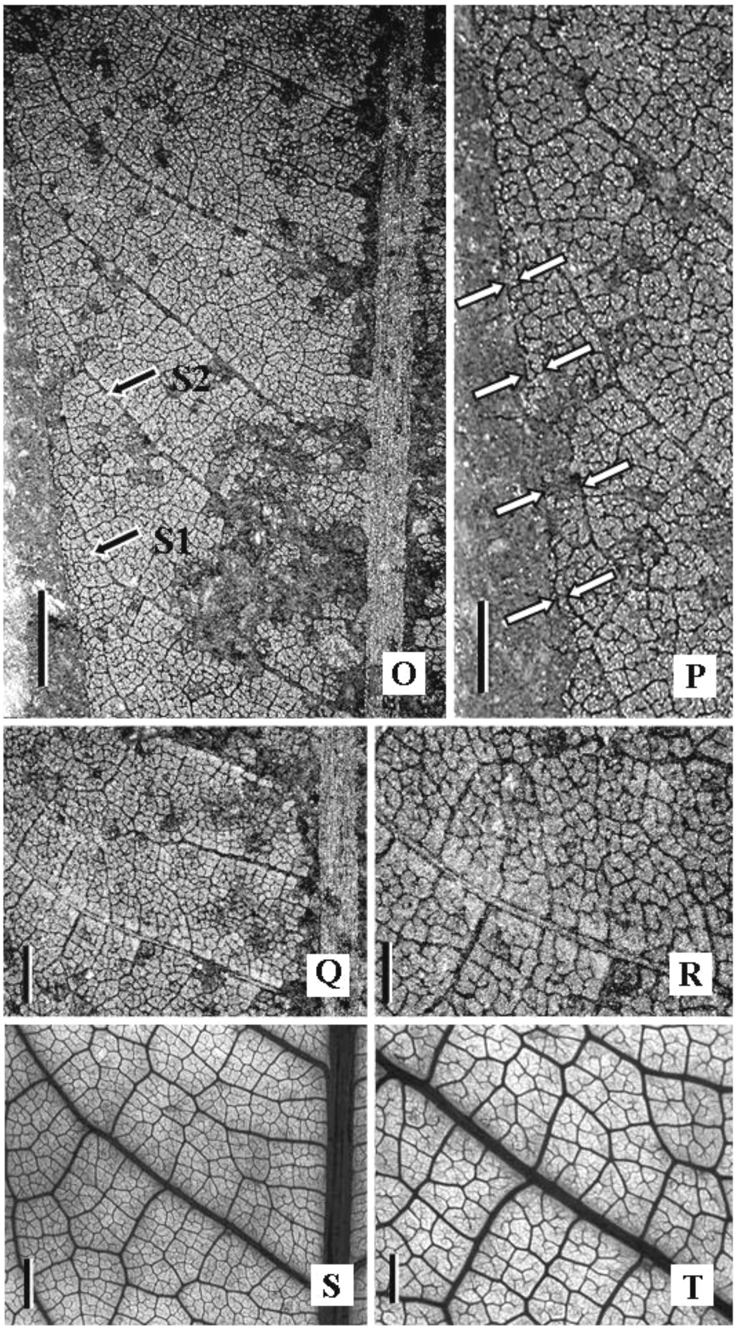


Fig. 4.21 *Semecarpus paleosiamensis* and its possible NLRs. (A-D), (F) Leaves with slightly sigmoid primary vein of *Nephelium lappaceum*, *Bouea oppositifolia*, *Gluta elegans*, *Mangifera indica*, and *Semecarpus* sp. (PSU SN180478, see Fig.4.22D for comparison), respectively, that are more or less similar to *Semecarpus paleosiamensis* shown in (G). (E) *Semecarpus cochinchinensis* was brought into comparison on the basis of similarity of MVP. (H) Line drawing of the fossil. (I-N) Part of the cleared leaf of each species in (A-F), respectively. (O) MVP of the fossil. (P) Magnified portion in (O) showing MArC (area between heads of two adjacent arrows) that lie



ELMA of S1 in (O) and the pair of arrows above these are at the level of the first ELMA of S2 in (O). (Q), (S), comparison of intersecondary veins and orientation of tertiary veins of the fossil and *Semecarpus* sp., respectively. (R), (T) Comparison of areoles of the fossil and *Semecarpus* sp., respectively. Scale bar = 1 cm in A-H, 2 mm in I-O, S, 1 mm in P-Q, T, 0.5 mm in R.

nearest living relative of this fossil if the base were cuneate, instead of normal acute.

To use this character to distinguish *M. indica* from the fossil, hundreds of leaves of this species were examined and a long cuneate base as present in *S. cochinchinensis*, *Semecarpus* sp. and in this fossil, was never observed. Moreover, the range of variation in angle of divergence of secondary veins in most leaves of *M. indica* (51°-61°) is more narrow than that of *Semecarpus* sp. (43°-69°) and of the fossil (35°-71°). In spite of the incompleteness of the marginal venation in the fossil, the MVP can be determined to be type I (Figs. 4.21O-P), which is more similar to that of *S. cochinchinensis* (Type I) than to that of *Semecarpus* sp. (Type III) and *M. indica* (Intermediate type II, III). In conclusion, the fossil leaf shares more features with the genus *Semecarpus* than with *Mangifera*, and with *Semecarpus* sp. in particular. This fossil was then named *S. paleosiamensis* sp. nov. Sawangchote, Grote and Dilcher.

Division---- Magnoliophyta.

Order----Sapindales (Burserales according to Takhtajan (1997)).

Family----Anacardiaceae Lindl.

Genus----*Semecarpus* Linn. f.

Species---- *Semecarpus paleomangiferoides* sp. nov. Sawangchote, Grote and Dilcher.

Holotype----Specimen number SUT845 (Plate 40, Figs. E, F, I, J, K, L, and M), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

Locality---- Li basin, Amphoe Li, Lamphun Province, northern Thailand, 17° 45′ N, 99° 00′ E, locality number 019.

Age: Approx. Late Oligocene – Early Miocene.

Number of specimens---- The material comprises only a single pyritized well-preserved leaf compression.

Etymology----The specific epithet refers to the sharing of some features between the fossil and the extant *Mangifera linearifolia*.

Description: Leaf simple, preserved lamina length 8.4 cm, width 2.3 cm; estimated lamina length 11.7 cm; symmetrical, oblanceolate; apex missing; base cuneate; margin entire; texture probably coriaceous, petiole 1.0 cm, strongly inflated; type of venation eucamptodromous; primary vein stout, markedly curved at basal 1/3; secondary veins estimated at 28 pairs, 0.2-0.8 cm apart, mostly subopposite or alternate, thick, angle of divergence mostly moderate to wide acute (50°-76°) with some at right angle (80°-88°) at about lower 1/6 in particular, upper slightly more acute than lower and more acute on one side than on the other, mostly straight most of the distance to margin and bending up sharply to join with the secondary veins above, some uniformly curved; MVP intermediate between type II and III, approximately 5-7 ELMAs, gradually (Fig. 4.22I) or rapidly (Fig. 4.22J) diminishing in size apically, quadrilateral and rectangular, BATV wide acute or right angle; intramarginal vein absent; intersecondary veins frequent, strong, simple to composite, proceeding 1/3-4/5 of the distance from midvein to leaf margin; tertiary vein angle of origin mostly RR and AR with acute angle predominantly wide (65°-80°), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decreasing outward, predominantly alternate and close; quaternary and quinternary veins thick and orthogonal; highest vein order 7, highest vein order showing excurrent branching 6; marginal ultimate venation fimbriate; well developed areoles, oriented, mostly quadrangular and pentagonal, size small to medium (mostly 0.25-0.35 mm), FEV mostly simple or branched once, a few twice or three times (most of the higher vein order can not be observed due to the preservation process) (Figs. 4.22E-F, I-M).

Affinities: Seven species with presence of oblanceolate leaves, namely *Buchanania sessifolia*, *Drimycarpus laridus* (Hook. f.) Hou, *Mangifera linearifolia, Melanochyla angustifolia* Hook. f., *Semecarpus cochinchinensis*, *Semecarpus curtisii* King and *Semecarpus* sp. were compared to this fossil leaf (Figs. 4.20C, 4.22A-D). Oblanceolate leaves rarely occur among *Mangifera* spp., but are rather common in species of *Melanochyla* and *Semecarpus*. Of fifteen species of *Mangifera* described from Malaysia (Kochummen, 1989), oblanceolate leaves are only rarely found in *Mangifera quadrifida,* and these leaves have a lower l/w ratio than this fossil leaf and than *M. linearifolia* in this study. For *Semecarpus* sp., in addition to similarity in leaf shape, the venation patterns are almost the same as in *S. curtisii*. Therefore, these two specimens, based on these features, can possibly be considered the same when comparing with the fossil. Upon consideration of leaf shape (reflected mainly by l/w ratio), type of MVP, and number and course of secondary veins, *B. sessifolia*, *D. laridus*, and *S. cochinchinensis* were then firstly excluded. The rest of these potential living relatives are more similar in shape (l/w ratio up to 4 or greater) and number of secondary veins to SUT845. However, the character of having the course of the secondary veins mostly straight most of the distance to the margin and bending up sharply seems to be shared equally among *M. angustifolia, S. curtisii, S.* sp. and SUT845 (Figs. 4.22B-F). *M. angustifolia* and SUT845 have the same intermediate MVP type II and type III whereas *S. curtisii* and *M. linearifolia* have type III. Although *S. curtisii* and *Semecarpus* sp. have a different MVP type form that of SUT845, they still can be potential living relatives because of their similarity in features of areoles that are mostly well developed, oriented, predominantly quadrangular to pentagonal, and medium in size. FEV of *S. curtisii* and *Semecarpus* sp. are mostly branched 3 times while those of SUT845 are predominantly simple or branched once or sometimes twice or three times. This apparent feature of FEV in SUT845 may be the result of the process of fossilization that did not preserve the higher orders of FEV. The reticulation patterns of *S. curtisii* and *Semecarpus* sp. are the most similar to those of SUT845. On the contrary, although *M. angustifolia* has a similar MVP type with SUT845, the former has some different characters of areoles such as, mostly larger size (1-2 mm) and, as the result, a lower density of areoles less (as determined by observing and comparing their number in each ELMA or area between two adjacent tertiary veins), FEV mostly branched once or simple and curved or some areoles without veinlets, quinternary veins and FEV mostly thin, and some quaternary veins thin (Fig. 4.22G). These different characters altogether make reticulation of veins as a whole look relatively looser than those of *M. linearifolia*, *S. curtisii*, *Semecarpus* sp. and SUT845 (Figs. 4.18N, 4.21N, 4.22H, I). In conclusion, there are two major differences between SUT845 and *M. angustifolia*. The first is the larger size and lesser density of areoles in *M. angustifolia*; the second is the relatively weak and infrequent intersecondary veins in *M. angustifolia*. However, the marginal venation is the matter of doubt in placing this fossil leaf in the genus *Semecarpus*. In *S. cutisii*, the veinlets that join between the curving-up secondary veins and fimbrial veins at the margin are thick and have a relatively straight course. This makes the ELMAs mostly rectangular and quadrangular (Fig. 4.22H). Also this character is very consistent in the same leaf and among different leaves. In contrast, the course of such mentioned veinlets in SUT845 are less consistent than those of *S. curtisii*; some do

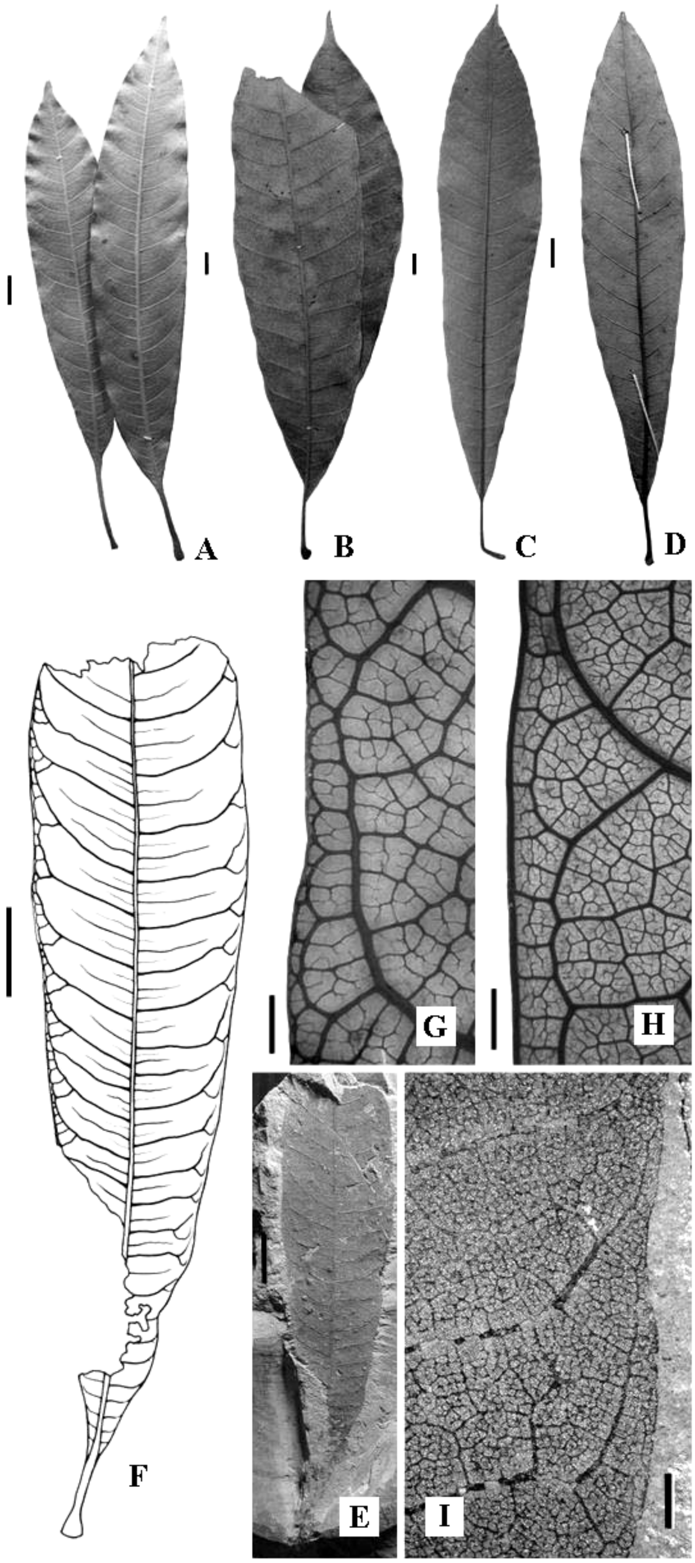
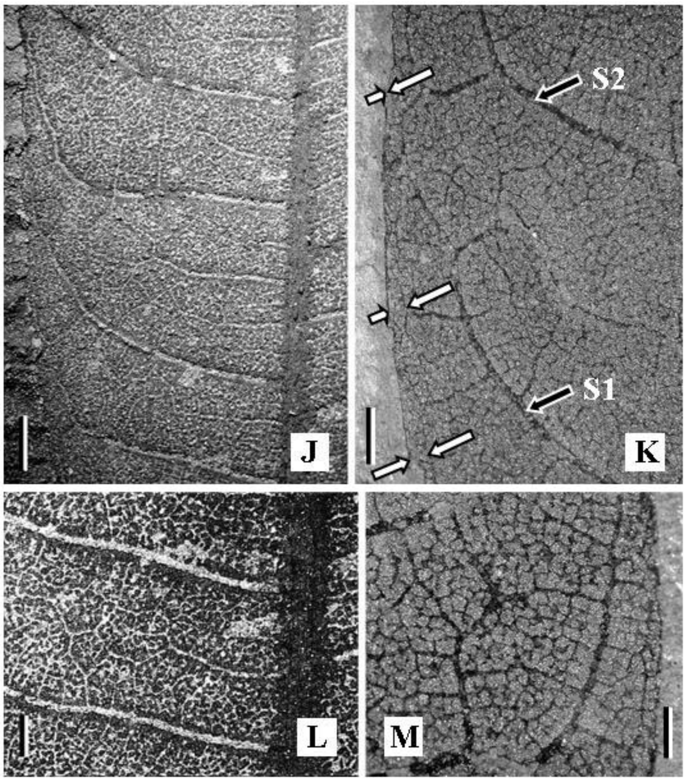


Fig. 4.22 *Semecarpus paleomangiferoides* and its possible NLRs. (A-D) Lanceolate or narrow elliptic lanceolate leaves of *Mangifera linearifolia*, *Melanochyla angustifolia*, *Semecarpus curtisii*, and *Semecarpus* sp. (PSU SN180478, oblanceolate



form), respectively, that are more or less similar to the fossil SUT845 shown in (E). (F) Line drawing of the fossil. (G-H) Part of the cleared leaf of *Melanochyla bracteata* and *Semecarpus curtisii*, respectively. (I) MVP of the fossil showing gradually diminishing in size of ELMAs. (J) In contrast to the MVP shown in (I), ELMAs in this marginal portion of the fossil show relatively rapid diminishing in size of ELMAs (similar to those of *M. linearifolia* in Fig. 4.18N). (K) Magnified portion of MVP showing PMArC (area between each of two adjacent arrows) that lie along the outer border of ELMAs; the most lower and most upper two arrows are at the level of the first and of the last ELMA of S1 respectively. Note that the last ELMA and the one below it have the outer borders fused with fimbrial vein at the leaf margin. The last ELMA is located at the same level as the first ELMA of S2. (L) Intersecondary veins and orientation of tertiary veins of the fossil. (M) Magnified portion in (I) showing areoles and MArC that are more clearly seen than in (K). Scale bar = 1 cm in A-F, 2 mm in G-H, J, 1 mm in I, K-L, T, 0.5 mm in M.

not run straight from the secondary veins to the fimbrial veins, but they mostly curve up, join with the superadjacent veinlets and form loops which are called ELMAs in this study. Some of them were not clearly seen but seemed to join curving-up secondary veins with fimbrial veins as seen in *S. curtisii* (Figs. 4.22I, K, M).

With *M. linearifolia*, SUT845 shares more similarity in marginal venation in that they have overlapping of MVP type III. Moreover, *M. linearifolia* and SUT845 share the following features; size (the lower limit of the size range of *M. linearifolia* is the closest to that of SUT845), a lanceolate shape of leaf (Fig. 4.22A), number and angle of divergence of secondary veins, number and characters of intersecondary veins, and having several small intersecondary veins that run parallel to main intersecondary veins. There are some differences of features of secondary veins between the fossil and *M. linearifolia* as follows; the upper secondary veins are more acute than lower in SUT845, but vice versa in *M. linearifolia* (especially at the base where the secondaries are perpendicular to the primary in SUT845 but moderately acute in *M. linearifolia*). The angle of divergence was clearly seen to be more acute on one side than on the other in *M. linearifolia*, but not in SUT845. Some secondaries are even right angles in SUT845, a feature not found in *M. linearifolia*. The secondaries veins are mostly uniformly curved in *M. linearifolia* but mostly straight most of the distance to the margin and bending up sharply to join with the above secondary veins (SUT845 shares this character more with *S. curtisii* and *M. angustifolia*). Furthermore, the areoles of *M. linearifolia* are less developed, larger in size on average (with less degree than in *M. angustifolia*), and relatively more irregular in shape (Figs. 4.18N, 4.22I, M).

With these similarities and differences, I propose to place the fossil into the genus *Semecarpus* rather than into the genera *Mangifera* and *Melanochyla*. However, the common features between SUT845 and *M. linearifolia* are to such a significant degree that they can not be ignored. To indicate the common features this fossil leaf shares with these two living species, I decide to name it as *Semecarpus paleomangiferoides* sp. nov. Sawangchote, Grote and Dilcher.

4.1.4 Leaf architecture of some selected modern species of Anacardiaceae with simple leaves.

Number of the specimens examined is one of the major limitations of analysis. However, this quantitative leaf architecture analysis is not planned to fulfill the statistical requirements but is only the attempt to make the variation in architecture of all the leaves examined to be more understandable and to be the preliminary work. Numbers of leaves examined vary from only three leaves of *Mangifera camptosperma* (from BKF herbarium sheet) to a hundred of leaves of *Mangifera indica* (from herbarium sheets and specimen from field collections). All the herbarium sheets of each species were examined for variations in shape, size and venation patterns. If number of leaves in herbarium sheets allow, at least 15 leaves of each species, which considered falling into smallest, medium to largest in size, were measured. If any species are found in the field (e.g., *Mangifera indica* and *M. duperreana*) additional examination will be performed. Concerning how to collect leaves from the field, the size range and variation in shape were considered as working with herbarium sheets. Minimum length and width and maximum length and width may or may not be in the same leaf. Therefore, minimum and maximum values of leaf area are obtained from the leaves the dimensions of which (length and width) yield those minimum and maximum values. The minimum and maximum values of length/width ratio were also calculated from the leaves with their dimensions provide those minimum and maximum values.

4.1.4.1 Laminar size

Based on the leaf dimensions, length and width, *Mangifera caesia* has the largest leaves with the length almost 42 cm and the width 12 cm while the smallest leaves, with a length and width 1.5x0.5 cm (measured from the same leaf and represent the smallest leaf area as well), possessed by *Buchanania siamensis*. Of 19 species with leaf length more than 20 cm, 11 species belong to *Mangifera*. From 18 species of *Mangifera*, 6 species have leaf length more than 30 cm. Detailed laminar sizes of each species (both smallest and largest leaves) are presented in Table 4.1.

Based on laminar size (determined by measuring the area of the leaf), the genus *Mangifera* still the has largest leaves and *Buchanania* has the smallest leaves. For the leaves of all 35 species, the laminar classes (Tables 4.2, 4.3) range from nanophyll to macrophyll. According to this classification system, 4 species of *Mangifera*, *Bouea macrophylla* and *Semecarpus curtisii* have the largest leaves (Macrophyll), and *Buchanania siamensis* has the smallest leaves (Nanophyll). These size differences, may suggest the influences of climate (rain fall in particular) on laminar size. *Buchanania siamensis* (also *B. lanzen* with much larger leaves coexist with *B. siamensis*) is confined to dry habitats such as open deciduous forests while the top ten species with largest leaves (For example) are confined mostly to moist habitats such as evergreen forests and peat swamp forests. Seven out of these ten species are distributed only in Peninsular Thailand (with relatively high precipitation) and 2 of them are distributed in the Peninsula and elsewhere (KEY I, II). For *Mangifera indica*, the natural distribution is still unclear. Classification of laminar size from maximum leaf area (LA) and minimum leaf area yield different numbers of species in each laminar class (Tables 4.2, 4.3). From minimum LA, the numbers of species of mesophyll: notophyll: microphyll: nanophyll is 6:10:18:1 (Table 4.2). On the other hand, maximum LA gives the number of species of macrophyll: mesophyll: notophyll: microphyll: as 7:23:4:1 (Table 4.3). Upon consideration of both maximum and minimum LA, microphyll and macrophyll are the most abundant laminar classes among these anacardiaceous species while nanophyll is the most uncommon. Leaves of the eighteen *Mangifera* spp. include all the classes except for nanophyll and make the genus the most variable in laminar size (may be due to more species and more leaves studied). Considering the variation in laminar size of each individual species, 4 *Mangifera* spp. have the widest range from microphyll to macrophyll. Another fifteen species of the following genera, *Bouea* (2), *Buchanania* (2), *Gluta* (1), *Mangifera* (5), *Melanochyla* (2), *Semecarpus* (1) and *Swintonia* (2) have laminar size falling into 3 contiguous classes (see range of laminar classes in Table 4.3). Seven species have laminar size of less variability, namely, *Buchanania arborescens*, *Mangifera pentandra*, *M. caloneura*, *M. duperreana*, *M. quadrifida*, *Semecarpus cochinchinensis*, and *Semecarpus* sp. The remaining 9 species have laminar size comprising 2 laminar classes. This high level of variation in size indicates that size can not be used as good character for taxonomic purposes.

Table 4.1 Width and length (cm) of leaves of anacardiaceous species. Maximum lengths were ascendingly sorted. min = minimum, max = maximum, W = width, L = length.

Plant name	**min L**	**max L**	**min W**	**max W**
Buchanania siamensis	1.5	6.5	0.6	3.2
Buchanania aborescens	11.5	14	3.5	4
Mangifera chamaoensis	7.5	14	1.8	3
Melanochyla nitida	10.5	14	4	5.5
Gluta elegans	7	14.5	2.5	4.5
Mangifera linearifolia	9.5	14.5	2.5	3.3
Gluta renghas	7.5	15	3	7.2
Drimycarpus lauridus	10.5	15.3	2.7	5.5
Mangifera microphylla	6.5	16	2	6.3
Mangifera camptosperma	11.2	16.3	3.5	4.6
Mangifera gedebe	9	16.5	2.5	4.9
Swintonia floribunda	4.7	16.7	1.8	7
Mangifera flava	9	17	2.6	4.6
Buchanania sessifolia	5.5	18.5	1.9	7
Swintonia schwenkii	7	18.5	2.5	5.6
Mangifera quadrifida	14	19.5	5	9.5
Buchanania lanzen	7	20.5	2.3	6
Bouea oppositifolia	5.5	21	1	5
Semecarpus sp.	15.6	21.3	3.1	4.1
Mangifera collina	13	22	4	5.7
Melanochyla angustifolia	15	24	4	6
Semecarpus cochinchinensis	18.5	24	4.8	6.7
Mangifera pentandra	17.5	25	5.3	6.3
Mangifera caloneura	15	26	5.5	7
Mangifera duperreana	16	26	5.2	7
Mangifera sylvatica	14	26	3	7.5
Mangifera macrocarpa	26	32	2.8	3.2
Bouea macrophylla	14	33	4.8	10.3
Mangifera foetida	7	33	2.3	10.6
Melanochyla bracteata	8.5	33.5	3	6.8
Semecarpus curtisii	8.5	34	3.4	9
Mangifera odorata	9	35	3.5	10
Mangifera griffithii	5.9	37	1.5	13
Mangifera indica	8.4	38	2	10
Mangifera caesia	9	41.5	3.5	12

Table 4.2 Minimum and maximum leaf areas (mm^2). Minimum values were ascendingly sorted and used for classification of laminar size. Laminar classes based on Webb (1955, cited in LAWG). Calculation based on LAWG (1999).

Plant name	min	max	max-min	Laminar class
Buchanania siamensis	60.00	1386.67	1326.67	NANOPHYLL
Bouea oppositifolia	366.67	7000.00	6633.33	MICROPHYLL
Swintonia floribunda	564.00	7793.33	7229.33	
Mangifera griffithii	590.00	32066.67	31476.67	
Buchanania sessifolia	696.67	8633.33	7936.67	
Mangifera microphylla	866.67	6720.00	5853.33	
Mangifera chamaoensis	900.00	2800.00	1900.00	
Buchanania lanzen	1073.33	8200.00	7126.67	
Mangifera foetida	1073.33	23320.00	22246.67	
Mangifera indica	1120.00	25333.33	24213.33	
Gluta elegans	1166.67	4350.00	3183.33	
Swintonia schwenkii	1166.67	6906.67	5740.00	
Gluta renghas	1500.00	7200.00	5700.00	
Mangifera gedebe	1500.00	5390.00	3890.00	
Mangifera flava	1560.00	5213.33	3653.33	
Mangifera linearifolia	1583.33	3190.00	1606.67	
Melanochyla bracteata	1700.00	15186.67	13486.67	
Drimycarpus lauridus	1890.00	5610.00	3720.00	
Semecarpus curtisii	1926.67	20400.00	18473.33	
Mangifera odorata	2100.00	23333.33	21233.33	NOTOPHYLL
Mangifera caesia	2100.00	33200.00	31100.00	
Mangifera camptosperma	2613.33	4998.67	2385.33	
Buchanania arborescens	2683.33	3733.33	1050.00	
Melanochyla nitida	2800.00	5133.33	2333.33	
Mangifera sylvatica	2800.00	13000.00	10200.00	
Semecarpus sp.	3224.00	5822.00	2598.00	
Mangifera collina	3466.67	8360.00	4893.33	
Melanochyla angustifolia	4000.00	9600.00	5600.00	
Bouea macrophylla	4480.00	22660.00	18180.00	
Mangifera quadrifida	4666.67	12350.00	7683.33	MESOPHYLL
Mangifera macrocarpa	4853.33	6826.67	1973.33	
Mangifera caloneura	5500.00	12133.33	6633.33	
Mangifera duperreana	5546.67	12133.33	6586.67	
Semecarpus cochinchinensis	5920.00	10720.00	4800.00	
Mangifera pentandra	6183.33	10500.00	4316.67	

Table 4.3 Minimum and maximum leaf areas. Maximum values were sorted and used for classification of laminar size. Na = nanophyll, mi = microphyll, ma = macrophyll, no = notophyll, me = mesophyll.

Plant name	**min**	**max**	**max-min**	**class (max)**	**range**
Buchanania siamensis	60.00	1386.67	1326.67	MICROPHYLL	na-mi
Mangifera chamaoensis	900.00	2800.00	1900.00	NOTOPHYLL	mi-no
Mangifera linearifolia	1583.33	3190.00	1606.67		mi-no
Buchanania aborescens	2683.33	3733.33	1050.00		no
Gluta elegans	1166.67	4350.00	3183.33		mi-no
Mangifera camptosperma	2613.33	4998.67	2385.33	MESOPHYLL	mi-me
Melanochyla nitida	2800.00	5133.33	2333.33		no-me
Mangifera flava	1560.00	5213.33	3653.33		mi-me
Mangifera gedebe	1500.00	5390.00	3890.00		mi-me
Drimycarpus luridus	1890.00	5610.00	3720.00		no-me
Semecarpus sp.	3224.00	5822.00	2598.00		me
Mangifera microphylla	866.67	6720.00	5853.33		mi-me
Mangifera macrocarpa	4853.33	6826.67	1973.33		no-me
Swintonia schwenkii	1166.67	6906.67	5740.00		mi-me
Bouea oppositifolia	366.67	7000.00	6633.33		mi-me
Gluta renghas	1500.00	7200.00	5700.00		mi-me
Swintonia floribunda	564.00	7793.33	7229.33		mi-me
Buchanania reticularta	1073.33	8200.00	7126.67		mi-me
Mangifera collina	3466.67	8360.00	4893.33		no-me
Buchanania sessifolia	696.67	8633.33	7936.67		mi-me
Melanochyla angustifolia	4000.00	9600.00	5600.00		no-me
Mangifera pentandra	6183.33	10500.00	4316.67		me
Semecarpus cochinchinensis	5920.00	10720.00	4800.00		me
Mangifera caloneura	5500.00	12133.33	6633.33		me
Mangifera duperreana	5546.67	12133.33	6586.67		me
Mangifera quadrifida	4666.67	12350.00	7683.33		me
Mangifera sylvatica	2800.00	13000.00	10200.00		no-me
Melanochyla bracteata	1700.00	15186.67	13486.67		mi-me
Semecarpus curtisii	1926.67	20400.00	18473.33	MACROPHYLL	no-ma
Bouea macrophylla	4480.00	22660.00	18180.00		no-ma
Mangifera foetida	1073.33	23320.00	22246.67		mi-ma
Mangifera odorata	2100.00	23333.33	21233.33		mi-ma
Mangifera indica	1120.00	25333.33	24213.33		mi-ma
Mangifera griffithii	590.00	32066.67	31476.67		mi-ma
Mangifera caesia	2100.00	33200.00	31100.00		no-ma

4.1.4.2 Length/width ratio (l/w) and leaf shape

Length width ratios of leaves studied were calculated and are presented in Table 4.4. From this l/w ratio, their shapes (Table 4.5) were interpreted based on categories in Dilcher (1974). The maximum ratio of *Mangifera macrocarpa* was up to 12, and the minimum ratio of *Buchanania siamensis* was as low as 1.7. *M. macrocarpa* also has greatest difference between maximum and minimum l/w while *Melanochyla nitida* has least difference (this may be subject, in part, to number of specimens examined). All the species examined have leaves of various shapes. There are at least 2 and up to 5 leaf shapes in each species. Nineteen, 8, 5, and 3 species have 2, 3, 4, and 5 leaf shapes, respectively. Among leaf shapes that were represented by more than 10 species, narrow elliptic is the most common shape (27 species), followed by narrow oblong and elliptic (15 species each for both shapes), and narrow obovate (12 species). Leaf shapes that were represented by more than 5 but less than 10 species are oblanceolate (8 species) and lanceolate (6 species). The rest were represented by less than 5 species (Table 4.5, Fig. 4.23). Linear and ovate are the most uncommon leaf shapes among these anacardiaceous species (1 species each for both shapes). In the genera *Mangifera* and *Semecarpus* to which the fossils studied belong, oblanceolate is the most uncommon shape in *Mangifera* (found only in *M. linearifolia*) but is rather common in *Semecarpus*.

Table 4.4 Maximum and minimum l/w ratio and their differences. Maximum values were ascendingly sorted.

	Minimum	**Maximum**	**Max-Min**
Mangifera griffithii	2.05	2.36	0.31
Buchanania siamensis	1.85	2.5	0.65
Melanochyla nitida	2.54	2.62	0.08
Mangifera quadrifida	2.05	2.8	0.75
Buchanania cf reticulata	2.6	2.93	0.33
Mangifera caloneura	2.92	3.18	0.26
Gluta elegans	2.8	3.22	0.42
Mangifera microphylla	2.53	3.25	0.72
Mangifera foetida	2.89	3.29	0.4
Swintonia schwenkii	2.8	3.3	0.5
Gluta renghas	1.7	3.33	1.63
Mangifera duperreana	3.26	3.4	0.14
Mangifera caesia	2.5	3.46	0.96
Mangifera odorata	2.57	3.5	0.93
Mangifera camptosperma	3.18	3.56	0.38
Bouea macrophylla	2.94	3.58	0.64
Buchanania sesilifolia	2.42	3.66	1.24
Semecarpus cochinchinensis	1.8	3.85	2.05
Drimycarpus luridus	2.8	3.85	1.05
Mangifera gedebe	3.6	3.86	0.26
Swintonia floribunda	3.55	3.89	0.34
Mangifera pentandra	3.65	3.89	0.24
Mangifera collina	3.26	4.13	0.87
Melanochyla angustifolia	3.52	4.33	0.81
Buchanania aborescens	2.2	4.38	2.18
Mangifera flava	3.46	4.46	1
Mangifera chamaoensis	4.55	4.64	0.09
Mangifera sylvatica	3.72	4.66	0.94
Mangifera indica	2.34	4.75	2.41
Semecarpus curtisii	2.5	4.89	2.39
Melanochyla bracteata	2.83	4.93	2.1
Semecarpus sp. *(PSU* SN180478)	5	5.16	0.16
Bouea oppositifolia	4.2	5.5	1.3
Mangifera linearifolia	3.69	6.22	2.53
Mangifera macrocarpa	4.28	12	7.72

Table 4.5 Shapes of leaves based on categories in Dilcher (1974). XX = common shape; X = less common, or rare shape; x = combination of both shapes. Any species with only X present in all shape types indicates equal occurrence of those shapes. ell

= elliptic; lanc = lanceolate; lin = linear; lor = lorate; n = narrow; oblo = oblong; oblan = oblanceolate; obo = obovate; ova = ovate; w = wide. The minimum l/w ratio of each shape type was indicated on top of those types.

	>10:1	6:1	3:1	3:1	3:1	3:1	2:1	2:1	2:1	1.5:1	1.5:1	1.2:1
Plant species	**lin**	**lor**	**n-oblo**	**n-ell**	**lanc**	**oblan**	**oblo**	**ell**	**n-obo**	**n-ell**	**ova**	**w-obo**
Bouea macrophylla				X				X				
Bouea oppositifolia			X	XX								
Buchanania aborescens				X					X			
Buchanania sessifolia						XX		X	X			X
Buchanania siamensis								X	X	X		X
Buchanania reticulata								X	X			
Drimycarpus luridus				X		X			X			
Gluta elegans			X	XX				X				
Gluta renghas				XX		XX		XX	XX	X		
Mangifera caesia				X	X		**x**		X		**x**	
Mangifera caloneura			X	X								
Mangifera camptosperma				X	X							
Mangifera chamaoensis			X	X								
Mangifera collina			X	X								
Mangifera duperreana			X	X					X			
Mangifera flava			X	X	X							
Mangifera foetida			X	X			X,x	X, **x**				
Mangifera gedebe			X	X								
Mangifera griffithii								XX	X			
Mangifera indica			X	XX	XX		X	X				
Mangifera linearifolia		X	X	X		X						
Mangifera macrocarpa	X	X										
Mangifera microphylla				X				X				
Mangifera odorata				X	X, **x**			**x**				
Mangifera pentandra			X	X								
Mangifera quadrifida				X				X				
Mangifera sylvatica			X, **x**	X, **x**								
Melanochyla angustifolia			X	X		X						
Melanochyla bracteata			X	X								
Melanochyla nitida								X	X			
Semecarpus cochinchinensis						X			X			X
Semecarpus curtisii						X			X			
Semecarpus sp.				X		X						
Swintonia floribunda				X	X		**x**	**x**				
Swintonia schwenkii				X			**x**	X, **x**				

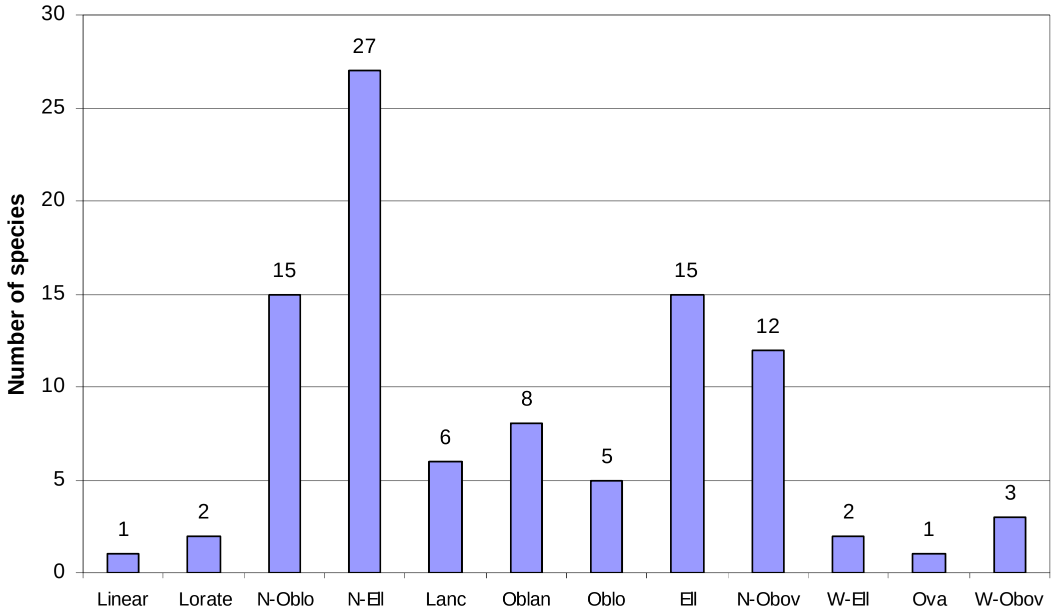


Fig. **4.23** Histogram showing numbers of species that possess each leaf shape (data from Table 4.5)

4.1.4.3 Apex, base, margin, texture and petiole

Six shapes of the leaf apex were recognized, acute, acuminate, attenuate, obtuse, rounded and emarginate. Acute and acuminate are the most common (present in 23 and 22 species, respectively). Obtuse, rounded, emarginate and attenuate are rather rare (present in 6, 3, 2 and 1 species, respectively). About half of the species have more than one shape of apex. For example, *Buchanania arborescens* has acute, rounded and emarginate apices. For the base, five shapes were recognized, acute normal, acute cuneate, decurrent, obtuse normal and rounded. Acute normal is the most common (Present in 26 species), followed by acute cuneate (present in 18 species). The rest of the shapes are rather rare (present in 4, 2 and 1 for obtuse-normal, decurrent and rounded, respectively). Margins of the all leaves of all species are entire. The textures are mostly coriaceous (present in 27 species), a few are very thick, chartaceous and intermediate between coriaceous and chartaceous (present in 3, 3 and 2 species, respectively). Petiolar length of all species range from 1-7.5 cm. *Swintonia* spp. possess approximately the longest petioles (4-7.5 cm) while *Buchanania* spp. possess the shortest ones (0.5-3.5 cm). The petioles are predominantly inflated and present in 26 species. Few of them are markedly inflated (*Magifera* spp.), intermediate between normal and inflated, and normal.

4.1.4.4 Type of venation

All studied species have a eucamptodromous type of venation. Some of them, such as *Bouea macrophylla*, *Mangifera duperreana,* and *Mangifera indica*, have one cross vein thicker than the others, and making the secondary veins look forked near the leaf margins (arrows in Fig. 4.24A). *Melanochyla angustifolia* has venation similar to brochidodromous (weak brochidodromous according to LAWG, (1999))

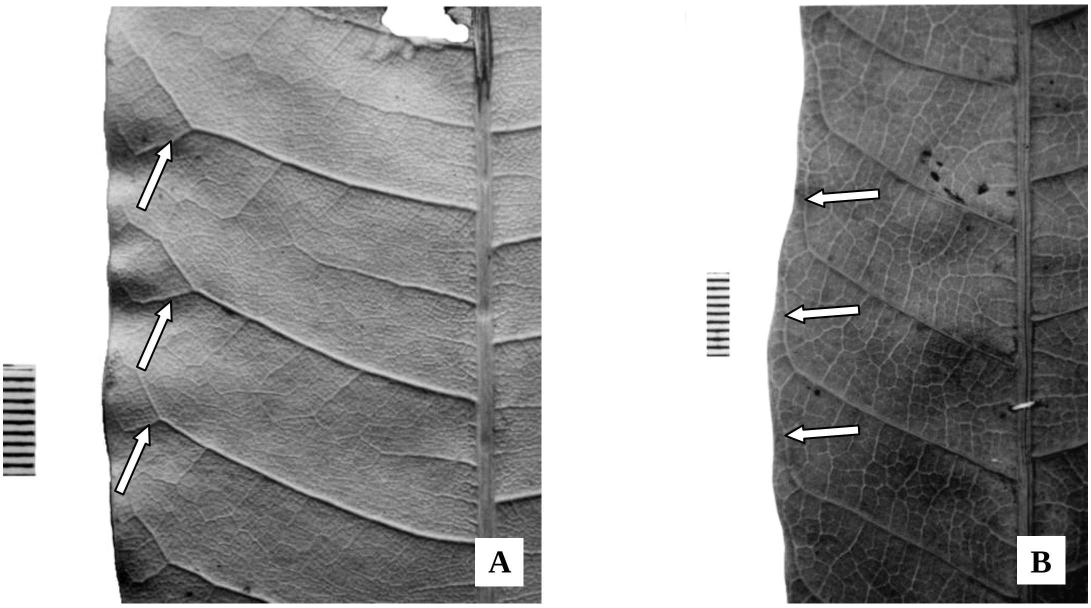


Fig. **4.24** Some special features of eucamtodromous venation. (A) Thick cross vein that make each secondary vein look forked at the end (arrows). (B) Eucamptodromous venation that looks similar to brochidodromous venation (arrows).

due to thick secondary veins that curve up to join with the superadjacent secondary veins (arrows in Fig. 4.24B). Primary veins are predominantly stout, followed by moderate. Massive and weak primary veins are rather rare. Straight primary veins are usually found mixed, more or less, with curved primary veins within a species.

4.1.4.5 Secondary veins and higher venation patterns

- Secondary veins

Numbers of secondary veins of all species range from 8-42 pairs (in *Buchanania siamensis* and *Mangifera macrocarpa*, respectively). Ten species have number of secondary veins less than 20 pairs (8-18). Twenty-two species have up to 20 but less than 30 pairs (15-28). Three species have up to 30 or more (14-42). For the genera with more than one species examined, *Mangifera* shows the greatest difference between maximum and minimum number of secondary veins (max-min = 33), followed by *Buchanania* (19), *Semecarpus* (16), *Melanochyla* (10), *Gluta* (9), *Swintonia* (5) and *Bouea* (4), respectively. The difference between minimum and maximum number of each species examined ranges between 2-19 pairs. Three categories were used for this range of difference; 2-5, 6-10, and 11-19. There are 21 species that have the differences less than 5 pairs. Nine species have the difference more than 5 but less than 10, and 5 species have the difference more than 10. Eighteen species of *Mangifera* are distributed across this range. Therefore, of all the genera, numbers of secondary veins vary rather a lot in the genus *Mangifera*. *Mangifera caesia*, *M. macrocarpa* and *M. indica* have differences between maximum and minimum number of secondary veins 19 of, 18 and 13, respectively. However, this may be due, in part, to the larger number of species examined in this genus and to the different number of specimens examined in each species. In general, the species of the same or different genera usually overlapping in the number of secondary veins, and this character can not be used alone as a diagnostic feature. Angles of divergence of the secondaries are predominantly moderate-wide acute. Some have moderate acute, moderate acute-right angle, and narrow-moderate acute. Angles of divergence can vary, from leaf to leaf, fairly a lot in a species, e.g., in *Mangifera indica*.

Intersecondary veins (ISV) are frequent in all species except for *Bouea oppositifolia* and *Mangifera microphylla*, which have less frequent and weak ISV. The ratio of number of species that possess very strong, strong, mixed strong and weak, and weak ISV is 1:9:3.5:4. These ISV proceed 1/10 to 4/5 of the distance between the midvein and leaf margin before they coalesce with tertiary veins. considering the distances they proceed, ISV in these species are mostly mixed simple and composite.

- Tertiary veins

All species have a percurrent/forked tertiary vein pattern. Some species, *Buchanania sessifolia*, *Mangifera camptosperma*, and *Melanochyla nitida*, have the feature of admedial ramification near the midvein. *Gluta elegans* and *Gluta renghas* seem to have mixed random reticulate and percurrent/forked pattern. Angles of origin are mostly a combination of wide acute angle and right angle (AA, AR, RA, RR). An obtuse angle is less likely to combine with a wide acute or right angle. There is no clear pattern of distribution of these combinations of angle of origin at the genus or species level.

- Quaternary and quinternary veins

Quaternary and quinternary veins are predominantly thick/orthogonal (22 species). Those species with thick/randomly arranged (2 species), thin/randomly arranged (3 species), and thin/orthogonal veins (3 species) are of low proportion. Two species of *Bouea* have thick/orthogonal quaternary veins but thin randomly arranged quinternary veins. *Melanochyla angustifolia* and *M. bracteata* have thick or thin and orthogonal quaternary veins while quinternary veins are thin and orthogonal. The genera B*ouea*, *Buchanania* and *Melanochyla* tend to have thin quaternary and quinternary veins with more or less random arrangement. These features (and small number of, or lack of, free ending veinlets, such as in *Melanochyla angustifolia*) make the fine reticulation appear to be looser than in other genera.

- Marginal ultimate venation (MUV)

Thirty-two species have fimbriate MUV. Of these, 8 species (especially *Drimycarpus luridus* and *Swintonia floribunda*) have strong fimbrial veins (the thickness close to that of secondary veins that lie close to them) and the rest have weaker ones. *Buchanania sessifolia* and *B. siamensis* have intermediate looped and incomplete MUV, while *Melanochyla nitida* has mixed looped and fimbriate MUV.

- Areoles

Four species of *Mangifera*, viz., *M. caloneuera*, *M. duperreana*, *M. odorata*, and *M. pentandra* have very well developed areoles (paxillate according to LAWG, 1999). Nineteen species have well developed areoles. Among these, 10, 3, 2, 2, 1 and 1 species belong to *Mangifera*, *Semecarpus*, *Melanochyla*, *Swintonia*, *Buchanania* and *Gluta* respectively. Moderately developed areoles were found in seven species, 4 of *Mangifera*, 2 of *Buchanania* and 1 of *Bouea*. *Gluta renghas* is the only species that shows poorly developed areoles. *Bouea oppositifolia*, *Buchanania sessifolia* and *Melanochyla nitida* have imperfect type of areoles. From these observation, four genera, *Bouea*, *Buchanania*, *Gluta* and *Melanochyla* tend to have poorly developed to imperfect areoles when compared to other genera. The well developed to very well developed areoles are mostly oriented and the rest are randomly oriented. Shapes of areoles are not consistent in individual species. Almost all the species have areoles of different shapes ranging from triangular to polygonal. Shapes of areoles are predominantly quadrilateral, pentagonal and polygonal, and these three shapes found in all genera. Irregular shape is less common and triangular shape is uncommon. A few species, such as *Buchanania sessifolia*, *B. siamensis*, *Gluta renghas* and *Melanochyla nitida* have areoles of irregular shape. Sizes of areoles range from medium to very large. Only four species have large to very large areoles and the rest have medium to large areoles. Free ending veinlets (FEVs) are rather consistent in each species in that the ranges of number of branching are narrow (such as 1-2, 3-4, 3-5) usually throughout the leaf areas. Most of the species examined have 3 up to 7 FEVs, while some have 3 FEVs or less. Of all genera, *Melanochyla* species have approximately smaller number of FEVs and *Mangifera* species have higher numbers. *Melanochyla angustifolia* has areoles with no FEVs or with unbranched or 1-branched FEVs, while *Mangifera odorata* has FEVs branched 3-7 times.

4.1.4.6 Types of MVP, number and shape of ELMA, and BATV

MVP appear to be more characteristic of the species than of the genera. All genera have some MVP overlapping with each other. However, each genus has its trend of clustering of MVP. *Bouea* has intermediate type IV and V. *Mangifera* and *Semecarpus* have predominantly type III. *Swintonia* has type IV. Species of *Buchanania*, *Gluta* and *Melanochyla* tend to have different types. Although *Buchanania* has types VI and VII that are not found in *Mangifera* species, it also shares types II and V with *Mangifera*. By consideration of MVP together with number and shape of ELMA, and BATV, there is still no suggestion of a clear cluster of features among these genera. However, combinations of these features and the others mentioned above can help distinguish, with limitation (e.g., in some species of *Mangifera*), to the level of species. Two species of *Bouea* share the same MVP with different number and shape of ELMA. The species in the genera *Buchanania*, *Gluta* and *Melanochyla* share no MVP but do share some ELMA numbers and shapea as well as BATV. Among 18 species of *Mangifera*, MVP type III is the most predominant (11 species), followed by type II (4 species), I & IV (3 species for both types), and V (1 species), respectively (some species possess two close types). Besides MVP type III, *Mangifera flava*, *M. indica*, *M. linearifolia*, *M. odorata*, *M. pentandra*, *M. quadrifida* and *M. sylvatica* also possess close number and similar shape of ELMA, and close BATV. For all the species, MVP type III is the most common and is present in *Gluta*, *Mangifera* and *Semecarpus*. Type IV is the second most common and is presented in *Bouea*, *Drimycarpus, Mangifera*, *Melanochyla* and *Swintonia*. Type II was found in *Buchanania*, *Mangifera* and *Melanochyla*. Types I & V show about the same prevalence, the former being found in *Mangifera* and *Semecarpus* and the latter being found in *Bouea*, *Buchanania* and *Mangifera*. Type VI was found only in *Buchanania siamensis* while type VII was found in *Buchanania sessifolia* and *Melanochyla nitida*. Frequency of each type of MVP among all 35 species is shown in Fig 4.25. In conclusion, types of MVP can be used, together with other characters, as the diagnostic character to separate to the species level (with limitation in species with many characters overlapping).

Table 4.6 Types of MVP, number and shape of ELMA, and BATV. Features in parentheses are less frequent. *c.* = approximately, brd = broad, irg = irregular, mod = moderate, most = mostly, na r = narrow, act = acute, peg = pentagonal, polg = polygonal, rt = right, agl = angle, obt = obtuse, rect = rectangular, rhd = rhomboidal, traz = trapezoidal, tri = triangular.

	Type of MVP with ELMA							**No of ELMA**	**Shape of ELMA**	**BATV**
Plant name	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**			
Bouea macrophylla				X	X			7-8	claw-like	nar act
Bouea oppositifolia				X	X			3-4	long&nar qua-rect	act-*c.* rt agl
Buchanania aborescens		X						5-6	brd rect	act-*c.* rt agl
Buchanania sessifolia							X	3-4	peg, qua	act-*c.* rt agl
Buchanania siamensis						X		3-4	peg, qua	wd act-rt agl
Buchanania lanzen					X			1-3	tri, qua,irg	mod act
Drimycarpus lauridus				X				7-8	qua	most rt agl
Gluta elegans			X					5-8	brd-nar long rect	approx rt agl
Gluta renghas	X							7-8	sq, brd rect	wd act-*c.* rt agl
Mangifera caesia	X	X						4-6	qua	wd act
Mangifera caloneura		X						6-8	most peg	wd act-rt agl
Mangifera camptosperma			X					7-8	peg, polg	wd act
Mangifera chamaoensis				X				9-10	qua, rect	wd act-rt agl
Mangifera collina				X				12-13	qua, rect	wd act-rt agl
Mangifera duperreana	X	X						5-6	qua,peg	wd act-obt
Mangifera flava			X					9-10	qua, rect	wd act-obt
Mangifera foetida				X				7-8	qua, (rect)	wd act-rt Agl
Mangifera gedebe			X					5-6	qua, (rect)	wd act-obt
Mangifera griffithii			X					7-8	qua, rect	wd act-rt agl
Mangifera indica		X	X					5-8, 8-11	qua, rect	wd act-rt agl
Mangifera linearifolia			X					10-11	qua, rect	wd act-rt agl
Mangifera macrocarpa					X			4-6	qua	most rt-(w act)
Mangifera microphylla			X					6-7	qua	wd act-rt agl

Cont. on next page

Cont. from prev. page	**Type of MVP with ELMA**							**No of ELMA**	**Shape of ELMA**	**BATV**
Plant name	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**			
Mangifera odorata			X					9-10	qua	most rt-(w act)
Mangifera pentandra			X					11-12	qua (pent, irg)	wd act-obt
Mangifera quadrifida			X					9-10	rhd-traz	wd act-obt
Mangifera sylvatica			X					8-10	qua (pent, irg)	most rt-(w act)
Melanochyla angustifolia		X	X					6-9	qua	wd act-obt
Melanochyla bracteata				X				7-10	qua	wd act-obt
Melanochyla nitida							X	3-4	qua	rt agl-obt
Semecarpus cochinchinensis	X							6-7	qua	most rt-(w act)
Semecarpus curtisii			X					7-10	qua, rect	wd act-rt-obt
Semecarpus sp.			X					6-8, 8-11	qua, (rect)	wd act-rt-obt
Swintonia floribunda				X				4-5	qua	most rt-(w act)
Swintonia schwenkii				X				2-3	qua	wd act

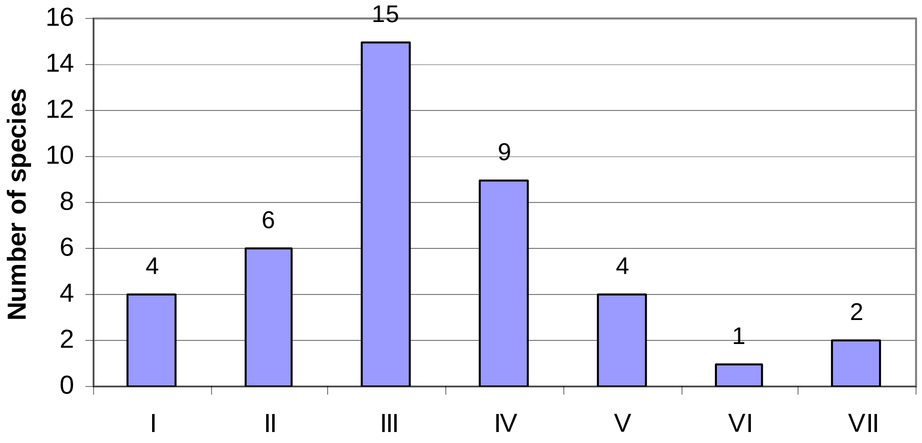


Fig. 4.25 Histogram showing numbers of species that possess each MVP type (data from Table 4.6)

4.1.4.7 Summary of leaf architecture

Among all species studied, *Mangifera* leaves (*M. indica* in particular) are most likely to be recognized by us due to its being widely cultivated. Leaves of *Bouea*, *Buchanania* (e.g., *B. reticulata*), *Melanochyla*, *Semecarpus* and *Swintonia* are also similar to those of *Mangifera* according to features they share. These fairly diagnostic features of *Mangifera* leaves can be drawn out as follow (Fig. 4.26):

- Size mostly mesophyll to microphyll
- Mostly narrow elliptic, followed by narrow oblong, elliptic and narrow obovate
- Apex mostly acute, acuminate; base mostly acute-normal, acute-cuneate
- Texture predominantly coriaceous
- Entire margin with more or less waving
- Petioles mostly long and swollen at the ends (inflated)
- Eucamptodromous type of venation
- Primary vein mostly stout to massive, straight, slightly to markedly curved
- Angle of divergence of secondary veins mostly moderate-wide acute
- Strong intersecondary veins that mostly run parallel to the secondary veins
- Percurrent/forked tertiary vein
- MUV mostly fimbriate
- Almost all species with well to very well-developed areoles, with poorly developed areoles rarely present
- MVP predominantly type II and III

The rest of the genera may have leaves that are not so similar to those of the above mentioned ones. However, a key to the leaves and leaf archives are presented in this study and individual experience of the researchers may help make identification easier.

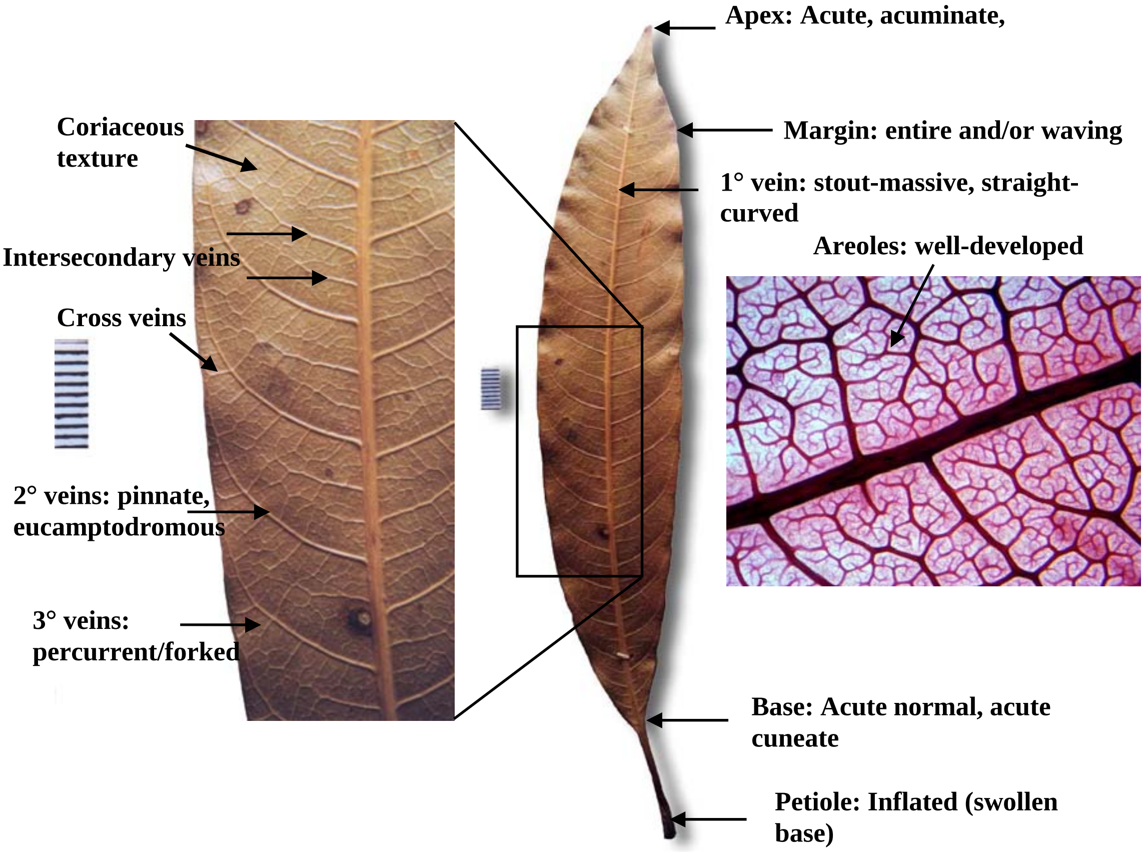


Fig. 4.26 Some diagnostic features of *Mangifera* spp. The one presented here is the leaf of *Mangifera linearlifolia*.

4.1.5 Leaf key to some selected modern species with simple leaves of Anacardiaceae.

- Two keys (Key I and II) were constructed with different orders of key characters used.
- The keys are based on 8 Thai anacardiaceous genera with simple leaves (from 10 genera) and approx. 34 species (from 44 expected species) that occur in Thailand.
- Ranges of distribution may make it easier for identification, so they were then included in the description. They are based mainly on Chayamarit (1994). The seven floristic regions of Thailand mentioned here are according to Smitinand, T. & Lasen, K. (1972) (Fig. 4.27 and Table 4.7). Some regions of distributions are based on Eiadthong et al. (2000).
- A quick guide to the leaf morphology of the species studied is presented in Fig. 4.28. *Mangifera odorata* was not included but the leaf morphology is very close to that of *Mangifera indica*. The number after each species name matches the number of each species in the key and in the description.
- Full descriptions of the leaves presented in this key are available in section 1.6. All the species in 1.6 were ordered alphabetically and the numbers matches the number of each species in this key.
- Awareness of variation in leaf shape and size within individual species can allow more effective identification. Shaded and sun leaves can be very different in size as the note in Ding Hou (1978) said, “Corner carefully collected specimens from various heights on a single tree to check the individual variation. The leaves on the lower

branches measured 23 by 9 am and a petiole of 6 ½ cm, those from the upper branches were 7 by 4 with a petiole of *c*. 1 cm”.

- Number of specimens examined is one of the major limitations of construction of this key. For example, there is only one specimen, with three leaves, of *Mangifera camptosperma* in the Bangkok Forest herbarium (BKF). In addition, information from descriptions from various sources, e.g., Ding Hou (1978), and Kuchummen (1989), are sometimes incorporated.

- For taxonomic study of fossil leaves, only a single specimen was usually examined and the range of l/w ratio was then impossible to calculate. To get as valid identification as we can, we should start with the l/w ratio that is closest to the fossil and see how similar this fossil is to the modern leaves. Then do the same with lower and higher l/w ratios, compare all the results.

It is not necessary that the fossil will fit all the characters found in modern leaves, this may due to these possible causes:

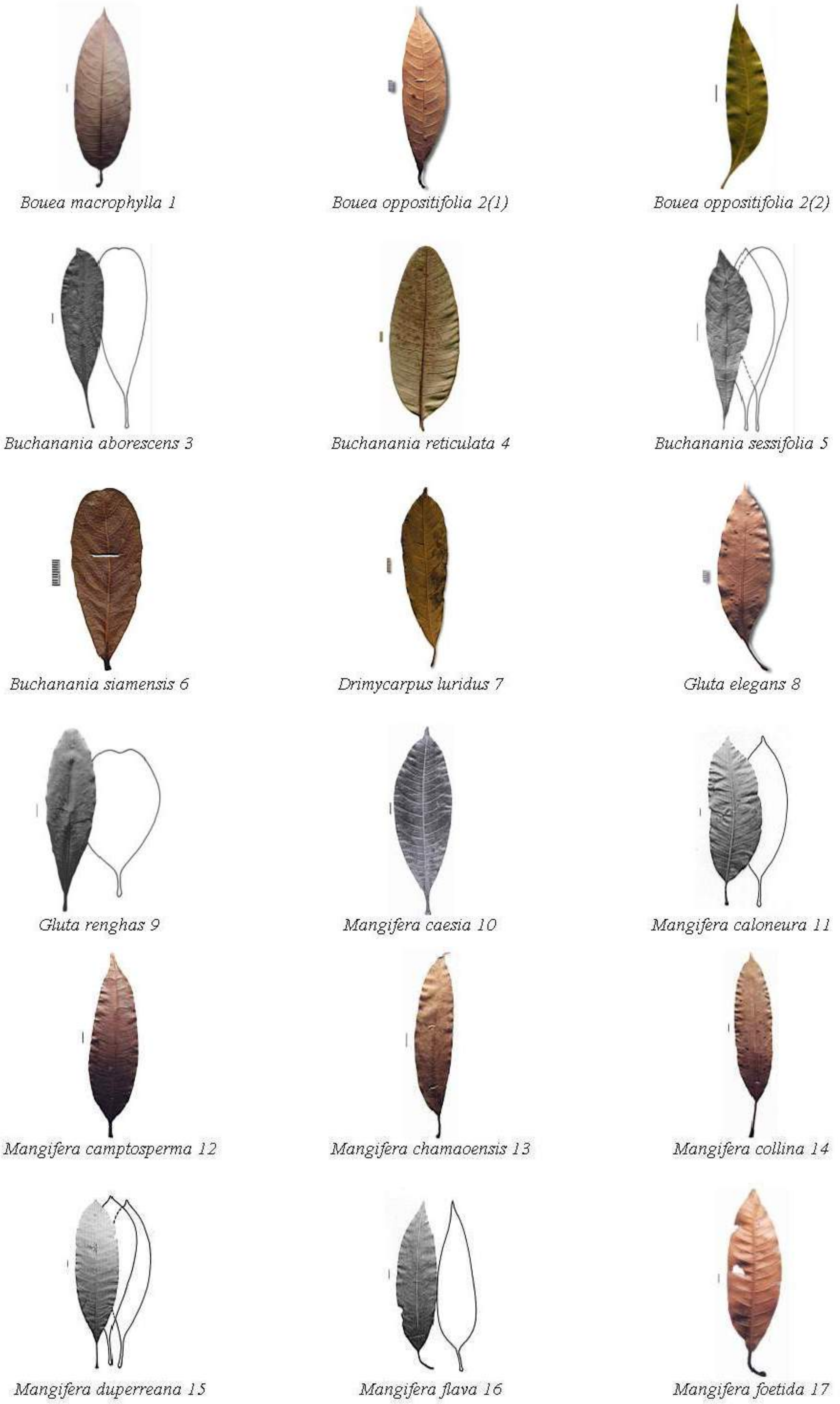
- Variation that we usually find among the leaves of the same species.
- Evolution of the plant that lead, to differences in vegetative or reproductive organs.
- Local or global extinction of the fossil leaf.

- A brief on “Identification of Anacardiaceae from vegetative characters” in Ding Hou (1978, page 408-409) is recommended for additional clues for identification from leaves.

Fig. 4.27 The seven floristic regions of Thailand according to Smitinand, T., & Larsen, K., eds. (1972). Flora of Thailand, Volume 2 Part 2. The map is from Flora of Thailand, Volume 7 Part 4 (Santisuk, T., & Larsen, K., 2002)

Table 4.7 Provinces in each floristic region according to the map in Fig. 4.27

N **Northern**	**NE** **Northeastern**	**E** **Eastern**	**SW** **Southwestern**	**C** **Central**	**SE** **Southeastern**	**PEN** **Peninsular**
1 Mae Hong Son	16 Phetchabun	27 Chaiyaphum	36 Uthai Thani	41 Chai Nat	56 Sa Kaeo	63 Chumphon
2 Chiang Mai	17 Loei	28 Nakhon Ratchasima	37 Kanchanaburi	42 Sing Buri	57 Prachin Buri	64 Ranong
3 Chaing Rai	18 Nong Bua Lum Phu	29 Buri Ram	38 Ratchaburi	43 Lop Buri	58 Chachoengsao	65 Surat Thani
4 Phayao	19 Udon Thani	30 Surin	39 Phetchaburi	44Suphan Buri	59 Chon Buri	66 Phangnga
5 Nan	20 Nong Khai	31 Roi Et	40 Prachuap Khiri Khan	45 Ang Thong	60 Rayong	67 Phuket
6 Lamphun	21 Sakon Nakhon	32 Yasothon		46 Phra Nakhon Si Ayutthaya	61 Chanthaburi	68 Krabi
7 Lampang	22 Nakhon Phanom	33Amnat Charoen		47 Saraburi	62 Trat	69 Nakhon Si Thammarat
8 Phrae	23 Mukdahan	34 Si Sa Ket		48 Nakhon Pathom		70 Phatthalung
9 Uttaradit	24 Kalasin	35 Ubon Ratchathani		49 Pathum Thani		71 Trang
10 Tak	25 Maha Sarakham			50 Nakhon Nayok		72 Satun
11 Sukhothai	26 Khon Kaen			51 Nonthaburi		73 Songkhla
12 Phitsanulok				52 Bangkok		74 Pattani
13Kamphaeng Phet				53 Samut Prakan		75 Yala
14 Phichit				54 Samut Songkhram		76 Narathiwat
15 Nakhon Sawan				55 Samut Sakhon		



Bouea macrophylla 1

Bouea oppositifolia 2(1)

Bouea oppositifolia 2(2)

Buchanania aborescens 3

Buchanania reticulata 4

Buchanania sessifolia 5

Buchanania siamensis 6

Drimycarpus luridus 7

Gluta elegans 8

Gluta renghas 9

Mangifera caesia 10

Mangifera caloneura 11

Mangifera camptosperma 12

Mangifera chamaoensis 13

Mangifera collina 14

Mangifera duperreana 15

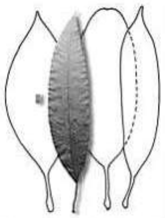
Mangifera flava 16

Mangifera foetida 17

Fig. 4.28 Common leaf shapes of anacardiaceous species with simple leaves. Bar = 1 cm


Mangifera gedebe 18


Mangifera griffithii 19


Mangifera indica 20


Mangifera linearifolia 21


Mangifera macrocarpa 22

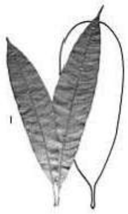

Mangifera microphylla 23


Mangifera pentandra 25


Mangifera quadrifida 26


Mangifera sylvatica 27


Melanochyla angustifolia 28


Melanochyla bracteata 29


Melanochyla nitida 30


Semecarpus cochinchinensis 31


Semecarpus curtisii 32


Semecarpus sp (PSU SN180478) 33


Swintonia floribunda 34


Swintonia schwenkii 35

Fig. 4.28 Continued

KEY I

The key was based firstly on l/w ratio, secondly on type of MVP, thirdly on leaf shape and fourthly on some selected distinct features (see table of range of l/w ratio, type of MVP, and leaf shape of all species appearing in this key). If the l/w ratio calculated falls into the borderline of the l/w ranges specified in the key, the examiners should try both the lower and higher l/w ratio.

1. Leaves with l/w ratio mostly 6 up to 12 (very rarely less than 6)

2. MVP type V, ELMA approx. 4-6; mostly lolate to linear; apex acute to acuminate; base acute normal; chataceous; size 26-32x2.8-3.2 cm ((1.25-)3.5-5x(9-)15-60 cm in Ding Hou (1978)); secondary vein 24-42 pairs. During this study, I have not seen any specimen in BKF, but they are available at PSU herbarium. The species was mentioned in Preliminary checklist by Chayamarit (1994) to distribute in Combodia, Malay Peninsula, and Malesia. Ding Hou (1978) also include lower Thailand (Peninsular) as distribution range

22. *Mangifera macrocarpa*

1. Leaves with maximum l/w ratio mostly more than 4, and some up to 6 or a little bit more (minimum-maximum l/w ratio approx. 2.2-6.22)

2. MVP type II

3. ELMA approx. 5-6, usually narrow elliptic, elliptic, narrow obovate to oblanceolate; chataceous; l/w ratio approx. 2.2-4.38; size 11.5-14x3.5-4 cm; secondary veins 16-18 pairs, intersecondary veins frequent and very strong, has characteristic of *admedial ramification* near the midvein. Distributed in Eastern, South-Eastern, Peninsula. In

evergreen forest, on rocky ground, by bank of stream, in scrub jungle along seashore, at low altitude up to 300 m

3. *Buchanania aborescens*

2. MVP type II & III

3. ELMA approx. 6-9; almost all oblanceolate or narrow elliptic; subcoriaceous; apex acuminate; base acute normal to acute cuneate; l/w ratio approx. 3.52-4.33; size 15-24x4-6 cm; secondary veins 20-22 pairs. Not listed in Preliminary checklist by Chayamarit (1994), Distributed in Malesia, Malay Peninsula, in the forest up to 360 m (Ding Hou, 1978)

28. *Melanochyla angustifolia*

3. ELMA approx. 5-8, 8-11 depending on individual leaf, leaf shape varies a lot (May due to plenty of specimens to be examined), mostly lanceolate, narrow oblong, elliptic, and narrow elliptic, oblong is not quite common, *pronounced plication* (*corrugation*) between secondary veins in some trees; apex acute, acuminate; base acute cuneate; l/w ratio approx. 2.34-4.75; size 8.4-38x2-10 cm; secondary veins (12-)18-31. In Thailand, true wild trees have not been reported. The ones so far collected may be the escapes from the cultivated ones, widely cultivated throughout the tropics of both hemispheres (Ding Hou, 1978)

20. *Mangifera indica*

2. MVP type III,

3. ELMA approx. 10-11; mostly lolate, narrow oblong, narrow elliptic, rarely oblanceolate; apex mostly acute; base acute normal; l/w ratio approx. 3.69-6.22; size 9.5-14.5x2.5-3.3 cm; secondary veins 18-25 pairs; *petiole markedly inflate*. *Endemic to Thailand*, Distributed in Eastern, Peninsula, in evergreen forests along river, on sandstone (Chayamarit, 1994; Eiadthong, 2000)

21. *Mangifera linearifolia*

3. Leaves usually oblanceolate, narrow obovate, narrow elliptic

4. ELMA approx. 7-10; usually oblanceolate, narrow obovate; apex acute, acuminate; base acute normal to acute cuneate; l/w ratio approx. 2.5-4.89; size 8.5-34x3.4-9 cm; secondary veins 20-22 pairs. Distributed in Peninsula, in evergreen and deciduous forests, usually on hill slopes, scrubs and bamboo forests, up to 100 m alt.

32. *Semecarpus curtisii*

4. ELMA approx. 6-8 or 8-11 depending on individual leaf; usually oblanceolate, narrow elliptic; apex acute, acuminate; base mostly acute cuneate, some acute normal; l/w ratio approx. 5-5.2; size 15.6-21.3x3.1-4.1 cm; secondary veins 21-27 pairs. Studied specimens were collected from a tree, approx. 20 m high, in Phuket province. Leaves of these specimens are similar to those of *S. curtisii* but relatively smaller and red brown when dried. *S. curtisii* is also relatively shorter (approx. 10 m)

33. *Semecarpus* sp.

3. Leaves mostly narrow elliptic, narrow oblong, elliptic and lanceolate respectively, rarely oblong (Three species in this group are very similar to each other, only leaves may be not enough for valid identification)

4. Leaves usually narrow oblong, narrow elliptic, l/w ratio approx. 4.55-4.64; ELMA approx. 9-10; size relatively smaller than *M. flava* and *M. sylvatica* in average (7.5-14x1.8-3 cm); secondary veins 15-23 pairs; intersecondary veins frequent and strong; dry leaves have pronounced venation patterns on both sides. The specimen eas collected from Khao Cha Mao National Park but not listed in Preliminary Checklist by Chayamarit (1994), probably endemic to Thailand (or be *M. flava*?)

13. *Mangifera chamaoensis*

4. Leaves usually narrow oblong, narrow elliptic, and *lanceolate*; apex acute; base acute normal; l/w ratio approx. 3.46-4.46; ELMA approx. 9-10; size relatively smaller than *M. sylvatica* (9-17x2.6-4 cm); secondary veins 15-20 pairs; intersecondary veins relatively less frequent and weaker. Distributed in South-Eastern (e.g. Khao Cha Mao National Park, Chantaburi), Peninsula, in lowland evergreen forest and bamboo thickets, 50-650 m alt.

16. *Mangifera flava*

4. Leaves usually narrow oblong, narrow elliptic; apex acute, acuminate; base acute cuneate; l/w ratio approx. 3.72-4.66; ELMA approx. 9-10; relatively larger in size (14-26x3-7.5 cm); secondary veins 26-28 pairs; intersecondary veins relatively more frequent and stronger. Distributed in Northern, North-Eastern, Peninsula, in evergreen forests, by stream, and on hill, 50-1500 m alt.

27. *Mangifera sylvatica*

2. MVP type IV

3. Leaves usually narrow oblong, narrow elliptic; apex acute to acuminate, base acute-normal; l/w ratio 3.26-4.13; ELMA approx. 12-13; size 13-22x4-5.7 cm; secondary veins 16-25 pairs, intersecondary veins frequent and strong; well developed areoles with free ending veinlets; quaternary and quinternary veins relatively thicker. Not listed in Preliminary checklist by Chayamarit (1994). Eiadthong (2000) reported this species from Chiang Mai in seasonal evergreen forest at relatively high altitude (800-1200 m)

14. *Mangifera collina*

3. Leaves usually narrow oblong, narrow elliptic, relatively larger in size (8.5-33.5x3-6.8 cm), leaf blade relatively slender (l/w ratio2.83-4.93), ELMA approx. 9-10, leaf tip normally longer, secondary veins 20-24 pairs, intersecondary veins frequent and strong; well developed areoles with or without free ending veinlets; quaternary and

quinternary veins relatively thinner. Distributed in Peninsula, scattered in peat swamp forest.

29. *Melanochyla bracteata*

2. MVP type IV, V

3. ELMA *long and narrow*, approx. 3-4; mostly narrow elliptic, some narrow oblong; apex acuminate; base acute-cuneate; leathery in texture; l/w ratio approx. 4.2-5.5; size 5.5-21x1-5 cm; secondary veins approx. 16-20 pairs, sunken above; intersecondary veins relatively weak and less frequent; *areoles relatively imperfect*; dried leaves usually have relatively faint tertiary or higher venation pattern. Distributed in Northern, Central, South-Eastern, South-Western, and Peninsula; edge of evergreen forests, up to 700 m alt.

2. *Bouea oppositifolia*

1. Leaves with maximum l/w ratio mostly less than 4

2. Minimum l/w ratio can be less than 2 (Min.-max. approx. 1.7-3.85), presence of wide elliptic and wide obovate leaves

3. MVP type I,

4. ELMA approx. 7-8; mostly narrow obovate, elliptic and narrow elliptic also common, rarely *wide elliptic*; apex obtuse; base acute-cuneate; l/w ratio 1.7-3.33; size 7.5-15x3-7.2 cm; secondary veins 18-20 pairs, relatively straight; *areoles poorly developed*, medium to large (1-2 mm). Distributed in Central and Peninsula, in scrub, about 20 m alt.

9. *Gluta renghas*

4. ELMA approx. 6-7; usually oblanceolate, narrow obovate, rarely *wide obovate*, *densely hairy*; apex acute, acuminate to round; base acute cuneate; l/w ratio 1.8-3.85; size 18.5-24x4.8-6.7 cm; secondary veins 11-14 pairs; areoles well developed, mostly medium (0.5-1 mm), some are large (2mm). Distributed in all seven floristic regions of Thailand, in deciduous forests, on rocky limestone hill, up to 450 m alt.

31. *Semecarpus cochinchinensis*

3. MVP type VI, ELMA rather small, approx. 3-4; elliptic to wide elliptic, narrow to wide obovate; apex round to *emarginated*; base acute normal; l/w ratio 1.85-2.5; size 1.5-6.5x0.6-3.2 cm; secondary viens 8-12 pairs; areoles moderately developed. Distributed in Northern and South-Western, common in open deciduous forest, on alluvial plain, 50-200 m alt.

6. *Buchanania siamensis*

2. Leaves with maximum l/w ratio normally less than 3 (Min.-max approx. 2.05-2.93)

3. MVP type III

4. ELMA approx. 7-8; usually elliptic, rarely narrow obovate, relatively broader leaf blade; apex acuminate; base acute normal to obtuse normal; l/w ratio 2.05-2.36; size 5.9-37x1.5-13 cm; *thickly leathery* (relatively smooth & shiny when dried like those of *Mangifera foetida*); secondary veins 9-13 pair; tertiary veins and higher order venation inconspicuous on dried

leaves; areoles well developed, mostly large (1-2 mm). Distributed in Peninsula, in lowland forest, up to 360 m alt.

19. *Mangifera griffithii*

4. ELMA approx. 9-10, usually elliptic, narrow elliptic; apex acute, base acute normal to obtuse normal; l/w ratio 2.05-2.8, size 14-19.5x5-9.5 cm; *strongly coriaceous, strongly plication* (corrugation) between secondary veins; secondary veins 12-16 pairs, elevated beneath, faint above; higher order venation rather inconspicuous on dried leaves but still clearer than in *M. griffithii*; areoles well developed, medium to large (0.5-1 mm). Distributed in Peninsula, in lowland forests

26. *Mangifera quadrifida*

3. MVP type V, ELMA approx. 1-3; elliptic, narrow obovate; apex obtuse to round; base acute normal to acute cuneate; l/w ratio 2.6-2.9; size 7.0-20.5x2.3-6.0 cm; coriaceous; secondary veins 16-27 pairs, prominent underneath; reticulation more conspicuous above; areoles well developed. Distributed in all floristic regions of Thailand, common in dry deciduous forest, on sandy, open scrub behind beaches, limestone range up to 450 m alt.

5. *Buchanania lanzen*

3. MVP type VI, ELMA rather small, approx. 3-4; elliptic to wide elliptic, narrow to wide obovate; apex round to *emarginated*; base acute normal; l/w ratio 1.85-2.5; size 1.5-6.5x0.6-3.2 cm; secondary viens 8-12 pairs; areoles moderately developed. Distributed in

Northern and South-Western, common in open deciduous forest, on alluvial plain, 50-200 m alt.

6. *Buchanania siamensis*

3. MVP type VII, ELMA approx. 3-4; usually elliptic, and narrow obovate; apex acuminate, base acute cuneate to acute decurrent; l/w ratio 2.54-2.62); size 10.5-14x4-5.5 cm; chataceous; secondary veins 14-16 pairs; tertiary veins mixed percurrent/forked and *admedial ramification*; *areoles imperfect*. Not listed in Preliminary checklist by Chayamarit (1994). Distributed in Malesia, Malay Peninsula, in forest up to 360 m (Ding Hou, 1978)

30. *Melanochyla nitida*

2. Leaves with maximum l/w ratio normally more than 3 but less than 4 (Min. –max. approx. 2.42-3.89)

3. MVP type I

4. ELMA approx. 6-7; usually oblanceolate, narrow obovate, *wide obovate*, *pubescent* beneath, sparsely *puberulous* above; apex acute, acuminate to round; base acute cuneate; l/w ratio 1.8-3.85; size 18.5-24x4.8-6.7 cm; secondary veins 11-14 pairs; areoles well developed, mostly medium (0.5-1 mm), some are large (2mm). Distributed in all seven floristic regions of Thailand, in deciduous forests, on rocky limestone hill, up to 450 m alt.

31. *Semecarpus cochinchinensis*

3. MVP mixed type I, II

4. ELMA approx. 5-6; usually narrow oblong and narrow elliptic, rarely narrow obovate; apex acute; base acute normal to acute cuneate; l/w ratio 3.26-3.4; size 16-26x5.2-7 cm; secondary veins 16-21 pairs; *areoles very well developed*. Distributed in Eastern, South-Eastern, Peninsula, scattered in deciduous forests, evergreen forests, up to 200 m alt.

15. *Mangifera duperreana*[*]

4. ELMA approx. 4-6; narrow elliptic, obovate, ovate-oblong, or lanceolate (one specimen examined is narrow elliptic, the rest are from Ding Hou, 1978); apex short acuminate or obtuse; base acute cuneate (to *long cuneate or tapered*); l/w ratio 2.5-3.46; size 9-41.5x3.5-12 cm; secondary veins 14-33 pairs. The species was not included in Preliminary checklist by Chayamarit (1994), but was reported to be cultivated in the Peninsular Thailand by Eiadthong (2000). Distributed in Malesia: Malay Peninsula, Sumatra (Ding Hou, 1978)

10. *Mangifera caesia*

3. MVP type II

4. ELMA approx. 7-8; narrow elliptic, narrow oblong; apex acute; base acute-normal; l/w ratio 2.92-3.18; size 15-26x5.5-7 cm; coriaceous (rather thick); secondary veins 16-24 pairs; areoles very well developed. Distributed in Northern, Eastern,

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[*] Considered to be synonymous with *M. caloneura* (# 24 in this key) according to Kostermans and Bompard (1993). With some different features of leaves I maintained their separation.

North-Eastern, South-Western, South-Eastern, Peninsula, in mixed deciduous and evergreen forests

11. *Mangifera caloneura*

3. MVP type III

4. So far examined no narrow obovate leaves, leaves usually narrow oblong, narrow elliptic

5. ELMA approx. 11-12; narrow elliptic, narrow oblong; apex acute, acuminate; base acute normal to acuminate; l/w ratio 3.65-3.89; size 17.5-25x5.3-6.3 cm; secondary veins 18-20 pairs; *areoles very well-developed* (*paxillate*). Distributed in South-Western, Peninsula, seasonal evergreen forest, lowland forests (Chayamarit, 1994; Eiadthong, 2000), one specimen was collected from margin of peat swamp forest

25. *Mangifera pentandra*

5. ELMA approx. 5-6; narrow elliptic, narrow oblong; apex acute; base acute normal; l/w ratio 3.6-3.86; size 9-16.5x2.5-4.9 cm; coriaceous; secondary veins 20-26 pairs; areoles well developed. Distributed in Peninsula, in lowland evergreen forests, peat swamp forests

18. *Mangifera gedebe*

4. Leaves usually narrow elliptic, elliptic-lanceolate, laneolate

5. ELMA approx. 7-8; narrow elliptic to lanceolate; apex acuminate; base acute-normal; l/w ratio 3.18-3.56;

size 11.2-16.3x3.5-4.6 cm; coriaceous; secondary veins 24-27 pairs; areole well developed. Distributed in North-Eastern, Central, South-Eastern, Peninsula, in evergreen forests, 20-200 m alt.

12. *Mangifera camptosperma*

5. ELMA approx. 9-10; narrow elliptic, elliptic-lanceolate, lanceolate; apex acute, acuminate; base acute normal; l/w ratio 2.57-3.5; size 9-35x3.5-10 cm; secondary veins 16-25 pairs, leaves may show *strong corrugation* between 2 secondary veins (In Ding Hou, 1989); areoles very well developed. Distributed in Northern, Southern, Eastern (Chayamarit, 1994; Eiadthong et al, 2000). Not common in evergreen forests, 400-1000 m alt.

24. *Mangifera odorata*

4. Leaves mostly narrow elliptic, often elliptic and narrow oblong

5. ELMA approx. 5-6; mostly narrow elliptic, often elliptic and narrow oblong, sometimes *sigmoid*; apex mostly acute, rarely obtuse; base acute–cuneate; l/w ratio 2.8-3.22; size 7-14.5x2.5-4.5 cm; coriaceous; secondary veins 11-15 pairs; areoles well developed; Distributed in Peninsula, common in evergreen forests, up to 600 m alt.

8. *Gluta elegans*

5. ELMA approx. 6-7; narrow elliptic, elliptic; apex acute, acuminate; base acute normal; l/w ratio 2.53-3.25; size 6.5-16x2-6.3 cm; coriaceous; secondary veins 14-16 pairs; areoles moderately developed, oriented, size mostly medium. Not listed in Preliminary checklist by Chayamarit (1994), and not in Kuchummen (1989), synonym with *M. griffithii* Hook. f. in Ding Hou (1978), , listed in classification of *Mangifera* species by Kostermans and Bompard (1993)[♦], distributed in west Malesia; in swamp of south Peninsular Malaysia, in coastal areas of east Sumatra and in western Borneo.

23. *Mangifera microphylla*

3. MVP type IV

4. ELMA approx. 7-8; mostly oblanceolate, narrow obovate; apex acuminate; base acute normal; l/w ratio 2.8-3.85; size 10.5-15.3x2.7-5.5 cm; secondary veins 12-16 pairs; *very thick fimbrial vein* (so-called marginal veins in Kuchummen, 1989; or marginal nerves in Ding Hou, 1978); areoles well developed.

[♦] By Kostermans and Bompard (1993), *M. griffithii* and *M. microphylla* are related and similar. *M. microphylla* has thinner leaves (Agreed with the Malaysian specimens examined by my self at BKF).

Not listed in Preliminary checklist by Chayamarit (1994) [♣], distributed in Malesia; Sumatra, Malay Peninsula, Borneo

7. *Drimycarpus luridus*

4. ELMA approx. 4-5; narrow elliptic or elliptic-oblong, lanceolate; apex acute, obtuse; base acute normal; l/w ratio 3.55-3.89; size 7-16.7x1.8-4.7 cm (the ones attached to inflorescence are as small as 0.8x2.8 cm); coriaceous; secondary veins 16-20 pairs, *very thick fimbrial vein*; areoles well developed. Distributed in Peninsula, in evergreen forests, 10-100 m alt.

34. *Swintonia floribunda*

4. ELMA approx. 7-8; narrow elliptic, oblong; apex acute base acute normal; l/w ratio 2.89-3.29; size 7-33x2.3-10.6 cm; coriaceous (shiny when dried like those of *Mangifera griffithii*); secondary veins 18-22 pairs; *faint tertiary or higher venation pattern on dry leaves*; areoles well developed. Distributed in Peninsula, in lowland evergreen forests, peat swamp forests.

17. *Mangifera foetida*

4. ELMA approx. 2-3; narrow elliptic (or elliptic-oblong), elliptic; apex acute to obtuse; base acute normal to obtuse normal; l/w ratio 2.8-3.3; size 7-18.5x2.5-5.6 cm; coriaceous;

[♣] One species, *Drimycarpus racemosus* was listed in this checklist but I did not see any during my study. Ding Hou (1978) noted that *D. luridus* resembles very much *D. racemosus*, but the leaves of the latter show a fairly distinct cross-bar like venation (probably percurrent-simple type of tertiary veins).

secondary veins 15-18 pairs, areoles well developed (less than *S. floribunda*). Distributed in Peninsula, edge of evergreen forests, about 50 m alt.

35. *Swintonia schwenkii*

3. MVP mixed type IV, V

4. ELMA approx. 7-8; narrow elliptic (more common), elliptic; apex acuminate; base obtuse-normal; l/w ratio 2.94-3.58; size 14-33x4.8-10.3 cm; coriaceous; *faint tertiary or higher venation pattern on dry leaves*; secondary veins 18-20 pairs; areoles moderately developed. Distributed in Peninsula, widely cultivated.

1. *Bouea macrophylla*

3. MVP type VI

4. ELMA approx. 3-4; leaves mostly oblanceolate, elliptic; apex mostly acuminate; base acute cuneate to decurrent (attenuate in Ding Hou, 1978); hairy beneath, especially on midrib and nerves; l/w ratio 2.42-3.66; size 5.5-18.5x1.9-7 cm; secondary veins 15-22 pairs; areoles imperfect. Distributed in Peninsula, common in open deciduous forests, on alluvial plain, 50-200 m alt.

4. *Buchanania sessifolia*

KEY II

- Based firstly on l/w ratio, then secondly on either leaf shape or type of MVP (see table of range of l/w ratios, type of MVP, and leaf shape of all species in this key).

1. Leaves with l/w ratio mostly 6 up to 12 (very rarely less than 6)

2. MVP type V, ELMA approx. 4-6; mostly lolate to linear; apex acute to acuminate; base acute normal; chataceous; size 26-32x2.8-3.2 cm ((1.25-)3.5-5x(9-)15-60 cm in Ding Hou (1978)); secondary vein 24-42 pairs. During this study, I have not seen any specimen in BKF, but they are available at PSU herbarium. The species was mentioned in Preliminary checklist by Chayamarit (1994) to distribute in Combodia, Malay Peninsula, and Malesia. Ding Hou (1978) also include lower Thailand (Peninsular) as distribution range

22. *Mangifera macrocarpa*

1. Leaves with maximum l/w ratio mostly more than 4, and some up to 6 or a little bit more (Min-max l/w ratio approx. 2.2-6.22)

2. Leaves mostly lolate, narrow oblong, narrow elliptic, rarely oblanceolate; apex mostly acute; base acute normal; l/w ratio approx. 3.69-6.22; size 9.5-14.5x2.5-3.3 cm; secondary veins 18-25 pairs; MVP type III, ELMA approx. 10-11; *petiole markedly inflate*. *Endemic to Thailand*, Distributed in Eastern, Peninsula, in evergreen forests along river, on sandstone (Chayamarit, 1994; Eiadthong, 2000)

21. *Mangifera linearifolia*

2. Leaves mostly narrow elliptic, some narrow oblong; apex acuminate; base acute-cuneate; leathery in texture; l/w ratio approx. 4.2-5.5; size 5.5-21x1-5

cm; secondary veins approx. 16-20 pairs, sunken above; intersecondary veins relatively weak and less frequent; *areoles relatively imperfect*; dried leaves usually have relatively faint tertiary or higher venation pattern; MVP type IV, V; ELMA *long and narrow*, approx. 3-4; Distributed in Northern, Central, South-Eastern, South-Western, and Peninsula; edge of evergreen forests, up to 700 m alt.

2. *Bouea oppositifolia*

2. Leaves usually oblanceolate or narrow obovate, some narrow elliptic, (Min.-max. l/w ratio aprox. 2.5-5.16)

3. MVP type III

4. ELMA approx. 7-10; usually oblanceolate, narrow obovate; apex acute, acuminate; base acute normal to acute cuneate; l/w ratio approx. 2.5-4.89; size 8.5-34x3.4-9 cm; secondary veins 20-22 pairs. Distributed in Peninsula, in evergreen and deciduous forests, usually on hill slopes, scrubs and bamboo forests, up to 100 m alt.

32. *Semecarpus curtisii*

4. ELMA approx. 6-8 or 8-11 depending on individual leaf; usually oblanceolate, narrow elliptic; apex acute, acuminate; base mostly acute cuneate, some acute normal; l/w ratio approx. 5-5.2; size 15.6-21.3x3.1-4.1 cm; secondary veins 21-27 pairs. Studied specimens were collected from a tree, approx. 20 m high, in Phuket province. Leaves of these specimens are similar to those of *S. curtisii* but relatively smaller and red

brown when dried. *S. curtisii* is also relatively shorter (approx. 10 m)

33. *Semecarpus* sp.

3. MVP type II & III, ELMA approx. 6-9; almost all oblanceolate or narrow elliptic; subcoriaceous; apex acuminate; base acute normal to acute cuneate; l/w ratio approx. 3.52-4.33; size 15-24x4-6 cm; secondary veins 20-22 pairs. Not listed in Preliminary checklist by Chayamarit (1994), Distributed in Malesia, Malay Peninsula, in the forest up to 360 m (Ding Hou, 1978)

28. *Melanochyla angustifolia*

2. Leaves usually narrow elliptic, elliptic, narrow obovate to oblanceolate; chataceous; l/w ratio approx. 2.2-4.38; size 11.5-14x3.5-4 cm; secondary veins 16-18 pairs, intersecondary veins frequent and very strong, has characteristic of *admedial ramification* near the midvein; MVP type II, ELMA approx. 5-6. Distributed in Eastern, South-Eastern, Peninsula. In evergreen forest, on rocky ground, by bank of stream, in scrub jungle along seashore, at low altitude up to 300 m

3. *Buchanania aborescens*

2. Leaves mostly narrow elliptic, narrow oblong, elliptic and lanceolate respectively, rarely oblong (Min.-max. l/w ratio approx. 2.34-4.93)

3. MVP mixed type II, III, ELMA approx. 5-8, 8-11 depending on individual leaf, leaf shape varies a lot (May due to plenty of specimens to be examined), mostly lanceolate, narrow oblong, elliptic, and narrow elliptic, oblong is not quite common, *strongly plication*

(*corrugation*) between secondary veins in some trees; apex acute, acuminate; base acute cuneate; l/w ratio approx. 2.34-4.75; size 8.4-38x2-10 cm; secondary veins (12-)18-31. In Thailand, true wild trees have not been reported. The ones so far collected may be the escapes from the cultivated ones, widely cultivated throughout the tropics of both hemispheres (Ding Hou, 1978)

20. *Mangifera indica*

3. MVP type III, leaves usually narrow oblong, narrow elliptic, lanceolate, l/w ratio approx. 3.46-4.66 (Three species in this group are very similar to each other, only leaves may be not enough for valid identification)

4. Leaves usually narrow oblong, narrow elliptic, l/w ratio approx. 4.55-4.64; ELMA approx. 9-10; size relatively smaller than *M. flava* and *M. sylvatica* in average (7.5-14x1.8-3 cm); secondary veins 15-23 pairs; intersecondary veins frequent and strong; dry leaves have pronounced venation patterns on both sides. The specimen was collected from Khao Cha Mao National Park but not listed in Preliminary Checklist by Chayamarit (1994), probably endemic to Thailand (or be *M. flava*?)

13. *Mangifera chamaoensis*

4. Leaves usually narrow oblong, narrow elliptic, and *lanceolate*; apex acute; base acute normal; l/w ratio approx. 3.46-4.46; ELMA approx. 9-10; size relatively smaller than *M.*

sylvatica (9-17x2.6-4 cm); secondary veins 15-20 pairs; intersecondary veins relatively less frequent and weaker. Distributed in South-Eastern (e.g. Khao Cha Mao National Park, Chantaburi), Peninsula, in lowland evergreen forest and bamboo thickets, 50-650 m alt.

16. *Mangifera flava*

4. Leaves usually narrow oblong, narrow elliptic; apex acute, acuminate; base acute cuneate; l/w ratio approx. 3.72-4.66; ELMA approx. 9-10; relatively larger in size (14-26x3-7.5 cm); secondary veins 26-28 pairs; intersecondary veins relatively more frequent and stronger. Distributed in Northern, North-Eastern, Peninsula, in evergreen forests, by stream, and on hill, 50-1500 m alt.

27. *Mangifera sylvatica*

3. MVP type IV

4. Leaves usually narrow oblong, narrow elliptic; apex acute to acuminate, base acute-normal; l/w ratio 3.26-4.13; ELMA approx. 12-13; size 13-22x4-5.7 cm; secondary veins 16-25 pairs, intersecondary veins frequent and strong; well developed areoles with free ending veinlets; quaternary and quinternary veins relatively thicker. Not listed in Preliminary checklist by Chayamarit (1994). Eiadthong (2000) reported this species from Chiang Mai in seasonal evergreen forest at relatively high altitude (800-1200 m)

14. *Mangifera collina*

4. Leaves usually narrow oblong, narrow elliptic, relatively larger in size (8.5-33.5x3-6.8 cm), leaf blade relatively slender (l/w ratio2.83-4.93), ELMA approx. 9-10, leaf tip normally longer, secondary veins 20-24 pairs, intersecondary veins frequent and strong; well developed areoles *with or without free ending veinlets*; quaternary and quinternary veins relatively thinner. Distributed in Peninsula, scattered in peat swamp forest.

29. *Melanochyla bracteata*

1. Leaves with maximum l/w ratio mostly less than 4

2. Minimum l/w ratio can be less than 2 (Min.-max. approx. 1.7-3.85), presence of wide elliptic and wide obovate leaves

3. MVP type I, ELMA approx. 7-8; mostly narrow obovate, elliptic and narrow elliptic also common, rarely *wide elliptic*; apex obtuse; base acute-cuneate; l/w ratio 1.7-3.33; size 7.5-15x3-7.2 cm; secondary veins 18-20 pairs, relatively straight; *areoles poorly developed*, medium to large (1-2 mm). Distributed in Central and Peninsula, in scrub, about 20 m alt.

9. *Gluta renghas*

3. MVP type I, ELMA approx. 6-7; usually oblanceolate, narrow obovate, rarely *wide obovate, densely hairy*; apex acute, acuminate to round; base acute cuneate; l/w ratio 1.8-3.85; size 18.5-24x4.8-6.7 cm; secondary veins 11-14 pairs; areoles well developed, mostly medium

(0.5-1 mm), some are large (2mm). Distributed in all seven floristic regions of Thailand, in deciduous forests, on rocky limestone hill, up to 450 m alt.

31. *Semecarpus cochinchinensis*

3. MVP type VI, ELMA rather small, approx. 3-4; elliptic to wide elliptic, narrow to *wide obovate*; apex round to *emarginated*; base acute normal; l/w ratio 1.85-2.5; size 1.5-6.5x0.6-3.2 cm; secondary viens 8-12 pairs; areoles moderately developed. Distributed in Northern and South-Western, common in open deciduous forest, on alluvial plain, 50-200 m alt.

6. *Buchanania siamensis*

2. Leaves with maximum l/w ratio normally less than 3 (Min.-max. l/w ratio approx. 2.05-2.93)

3. MVP type III

4. ELMA approx. 7-8; usually elliptic, rarely narrow obovate, relatively broader leaf blade; apex acuminate; base acute normal to obtuse normal; l/w ratio 2.05-2.36; size 5.9-37x1.5-13 cm; *thickly leathery* (relatively smooth & shiny when dried like those of *Mangifera foetida*); secondary veins 9-13 pair; tertiary veins and higher order venation inconspicuous on dried leaves; areoles well developed, mostly large (1-2 mm). Distributed in Peninsula, in lowland forest, up to 360 m alt.

19. *Mangifera griffithii*

4. ELMA approx. 9-10, usually elliptic, narrow elliptic; apex acute, base acute normal to obtuse normal; l/w ratio 2.05-2.8, size 14-19.5x5-9.5 cm; *strongly coriaceous*, *strongly plication* (corrugation) between secondary veins; secondary veins 12-16 pairs, elevated beneath, faint above; higher order venation rather inconspicuous on dried leaves but still clearer than in *M. griffithii*; areoles well developed, medium to large (0.5-1 mm). Distributed in Peninsula, in lowland forests

26. *Mangifera quadrifida*

3. MVP type V, ELMA approx. 1-3; elliptic, narrow obovate; apex obtuse to round; base acute normal to acute cuneate; l/w ratio 2.6-2.9; size 7.0-20.5x2.3-6.0 cm; coriaceous; secondary veins 16-27 pairs, prominent underneath; reticulation more conspicuous above; areoles well developed. Distributed in all floristic regions of Thailand, common in dry deciduous forest, on sandy, open scrub behind beaches, limestone range up to 450 m alt.

5. *Buchanania lanzen*

3. MVP type VI, ELMA rather small, approx. 3-4; elliptic to wide elliptic, narrow to *wide obovate*; apex round to *emarginated*; base acute normal; l/w ratio 1.85-2.5; size 1.5-6.5x0.6-3.2 cm; secondary viens 8-12 pairs; areoles moderately developed. Distributed in Northern and South-Western, common in open deciduous forest, on alluvial plain, 50-200 m alt.

6. *Buchanania siamensis*

3. MVP type VII, approx. 3-4, leaves usually elliptic, and narrow obovate, relatively narrower leaf blade (l/w ratio 2.54-2.62), size 10.5-14x4-5.5 cm, apex acuminate, base acute cuneate to acute decurrent, chataceous in texture, secondary veins 14-16 pairs

30. *Melanochyla nitida*

2. Leaves with maximum l/w ratio normally more than 3 but less than 4 (Min. –max. approx. 2.42-3.89)

3. Leaves usually oblanceolate, narrow obovate, wide obovate, elliptic

4. MVP type I, ELMA approx. 6-7; usually oblanceolate, narrow obovate, *wide obovate*, *pubescent* beneath, sparsely *puberulous* above; apex acute, acuminate to round; base acute cuneate; l/w ratio 1.8-3.85; size 18.5-24x4.8-6.7 cm; secondary veins 11-14 pairs; areoles well developed, mostly medium (0.5-1 mm), some are large (2mm). Distributed in all seven floristic regions of Thailand, in deciduous forests, on rocky limestone hill, up to 450 m alt.

31. *Semecarpus cochinchinensis*

4. MVP type IV, ELMA approx. 7-8; mostly oblanceolate, narrow obovate; apex acuminate; base acute normal; l/w ratio 2.8-3.85; size 10.5-15.3x2.7-5.5 cm; secondary veins 12-16 pairs; *very thick fimbrial vein* (so-called marginal veins in Kuchummen, 1989; or marginal nerves in Ding Hou, 1978); areoles well developed. Not listed in Preliminary checklist by

Chayamarit (1994), distributed in Malesia; Sumatra, Malay Peninsula, Borneo

7. *Drimycarpus luridus*

4. MVP type VI, ELMA approx. 3-4; leaves mostly oblanceolate, elliptic; apex mostly acuminate; base acute cuneate to decurrent (attenuate in Ding Hou, 1978); hairy beneath, especially on midrib and nerves; l/w ratio 2.42-3.66; size 5.5-18.5x1.9-7 cm; secondary veins 15-22 pairs; areoles imperfect. Distributed in Peninsula, common in open deciduous forests, on alluvial plain, 50-200 m alt.

4. *Buchanania sessifolia*

3. Leaves usually narrow oblong, narrow elliptic, narrow obovate

4. MVP mixed type I, (II), ELMA approx. 5-6; usually narrow oblong and narrow elliptic, rarely narrow obovate; apex acute; base acute normal to acute cuneate; l/w ratio 3.26-3.4; size 16-26x5.2-7 cm; secondary veins 16-21 pairs; *areoles very well developed*. Distributed in Eastern, South-Eastern, Peninsula, scattered in deciduous forests, evergreen forests, up to 200 m alt.

15. *Mangifera duperreana*

4. MVP type III, so far examined no narrow obovate leaves, leaves usually narrow oblong, narrow elliptic

5. ELMA approx. 11-12; narrow elliptic, narrow oblong; apex acute, acuminate; base acute normal to

acuminate; l/w ratio 3.65-3.89; size 17.5-25x5.3-6.3 cm; secondary veins 18-20 pairs; *areoles very well-developed* (*paxillate*). Distributed in South-Western, Peninsula, seasonal evergreen forest, lowland forests (Chayamarit, 1994; Eiadthong, 2000), one specimen was collected from margin of peat swamp forest

25. *Mangifera pentandra*

5. ELMA approx. 5-6; narrow elliptic, narrow oblong; apex acute; base acute normal; l/w ratio 3.6-3.86; size 9-16.5x2.5-4.9 cm; coriaceous; secondary veins 20-26 pairs; areoles well developed. Distributed in Peninsula, in lowland evergreen forests, peat swamp forests

18. *Mangifera gedebe*

3. Leaves usually narrow elliptic, elliptic-oblong, elliptic-lanceolate and lanceolate

4. MVP type I, II, ELMA approx. 9-10; narrow elliptic, elliptic-lanceolate, lanceolate; apex acute, acuminate; base acute normal; l/w ratio 2.57-3.5; size 9-35x3.5-10 cm; secondary veins 16-25 pairs, leaves may show *strong corrugation* between 2 secondary veins (In Ding Hou, 1989); areoles very well developed. Distributed in Northern, Southern, Eastern (Chayamarit, 1994; Eiadthong et al., 2000). Not common in evergreen forests, 400-1000 m alt.

24. *Mangifera odorata*

4. MVP type III, ELMA approx. 7-8; narrow elliptic to lanceolate; apex acuminate; base acute-normal; l/w ratio 3.18-3.56; size 11.2-16.3x3.5-4.6 cm; coriaceous; secondary veins 24-27 pairs; areole well developed. Distributed in North-Eastern, Central, South-Eastern, Peninsula, in evergreen forests, 20-200 m alt.

12. *Mangifera camptosperma*

4. MVP type IV, ELMA approx. 4-5; narrow elliptic or elliptic-oblong, lanceolate; apex acute, obtuse; base acute normal; l/w ratio 3.55-3.89; size 7-16.7x1.8-4.7 cm (the ones attached to inflorescence are as small as 0.8x2.8 cm); coriaceous; secondary veins 16-20 pairs, *very thick fimbrial vein*; areoles well developed. Distributed in Peninsula, in evergreen forests, 10-100 m alt.

34. *Swintonia floribunda*

3. Leaves usually narrow elliptic, obovate, ovate-oblong, or lanceolate

4. MVP type I, II, ELMA approx. 4-6; one specimen examined is narrow elliptic, the rest are from Ding Hou (1978); apex short acuminate or obtuse; base acute cuneate (to *long cuneate or tapered*); l/w ratio 2.5-3.46; size 9-41.5x3.5-12 cm; secondary veins 14-33 pairs. The species was not included in Preliminary checklist by Chayamarit (1994), but was reported to be cultivated in the Peninsular Thailand by Eiadthong

(2000). Distributed in Malesia: Malay Peninsula, Sumatra (Ding Hou, 1978)

10. *Mangifera caesia*

3. Leaves usually elliptic, narrow elliptic or narrow elliptic-oblong

4. MVP type II, ELMA approx. 7-8; narrow elliptic, narrow oblong; apex acute; base acute-normal; l/w ratio 2.92-3.18; size 15-26x5.5-7 cm; coriaceous (rather thick); secondary veins 16-24 pairs; areoles *very well developed*. Distributed in Northern, Eastern, North-Eastern, South-Western, South-Eastern, Peninsula, in mixed deciduous and evergreen forests

11. *Mangifera caloneura*

4. MVP type III

5. ELMA approx. 5-6; mostly narrow elliptic, often elliptic and narrow oblong, sometimes *sigmoid*; apex mostly acute, rarely obtuse; base acute–cuneate; l/w ratio 2.8-3.22; size 7-14.5x2.5-4.5 cm; coriaceous; secondary veins 11-15 pairs; areoles well developed; Distributed in Peninsula, common in evergreen forests, up to 600 m alt.

8. *Gluta elegans*

5. ELMA approx. 6-7; narrow elliptic, elliptic; apex acute, acuminate; base acute normal; l/w ratio 2.53-3.25; size 6.5-16x2-6.3 cm; coriaceous; secondary veins 14-16 pairs; areoles moderately developed, oriented,

size mostly medium. Not listed in Preliminary Checklist by Chayamarit (1994), and not in Kuchummen (1989), synonymous with *M. griffithii* Hook. f. in Ding Hou (1978), listed in classification of *Mangifera* species by Kostermans and Bompard (1993), distributed in west Malesia; in swamps of south Peninsular Malaysia, in coastal areas of east Sumatra and in western Borneo

23. *Mangifera microphylla*

4. MVP type IV

5. ELMA approx. 7-8; narrow elliptic, oblong; apex acute; base acute normal; l/w ratio 2.89-3.29; size 7-33x2.3-10.6 cm; coriaceous (shiny when dried like those of *Mangifera griffithii*); secondary veins 18-22 pairs; *faint tertiary or higher venation pattern on dry leaves*; areoles well developed. Distributed in Peninsula, in lowland evergreen forests, peat swamp forests

17. *Mangifera foetida*

5. ELMA approx. 2-3; narrow elliptic (or elliptic-oblong), elliptic; apex acute to obtuse; base acute normal to obtuse normal; l/w ratio 2.8-3.3; size 7-18.5x2.5-5.6 cm; coriaceous; secondary veins 15-18 pairs, areoles well developed (less than *S. floribunda*). Distributed in Peninsula, edge of evergreen forests, about 50 m alt.

35. *Swintonia schwenkii*

4. MVP mixed type IV, V

5. ELMA approx. 7-8; narrow elliptic (more common), elliptic; apex acuminate; base obtuse-normal; l/w ratio 2.94-3.58; size 14-33x4.8-10.3 cm; coriaceous; *faint tertiary or higher venation pattern on dry leaves*; secondary veins 18-20 pairs; areoles moderately developed. Distributed in Peninsula, widely cultivated

1. *Bouea macrophylla*

4.1.6 Description of some selected anacardiaceous species with simple leaves

These descriptions are based on examination of specimens from two main herbaria, BKF and PSU, some from the herbarium at SUT, and some from field collections (name list of examined specimens are in appendix D). Almost all the terms used in descriptions of fossil and living leaves in this study are mainly from "*Approaches to the identification of angiosperm leaf remains*" (Dilcher, 1974). For the description of the marginal venation, supplemental terms were used to make identification approach more to the species level. These supplemental terms are presented in Chapter IV, and the topic "Supplemental terms". In addition to description of leaves of Anacardiaceae, leaves of some other families with features similar to those of Anacardiaceae are briefly described.

Anacardiaceae

1. *Bouea macrophylla* Griff**.** (Plate 1)

Description: *Leaf* simple, symmetrical, rarely asymmetrical, narrow elliptic (more common), elliptic; size 14-33x4.8-10.3 cm; *apex* acuminate; *base* obtuse-normal; *margin* entire; *texture* coriaceous; *petiole* approximately 1-3 cm, inflate; *venation* pinnate, eucamptodromous (One or two cross veins are stronger than others and make it look like the secondary vein branches at the end); *primary vein* moderate, mostly straight; *secondary veins* 18-20 pairs, 0.5-1.5 cm apart and those at base are more closer, opposite, subopposite and alternate, thick, angle of divergence narrow to wide acute (42°-73°) to right angle (85°) and upper more acute than lower, most of them uniformly curved and some at about basal 1/5 are straight most of the distance to the margin; *MVP* mixed type IV and V, approximately 7-8 ELMA, shape claw-like (the tertiary veins sharply upturned and run close to the margin), branching-off angle narrow acute; intramarginal vein absent; *intersecondary veins* frequent, relatively weak, mostly composite. proceed 1/6-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, some AR, RA, and some RR near margin (Acute angles are predominantly wide (74°-80°)), percurrent/forked, oblique in relation to the midvein, relatively faint tertiary or higher venation pattern on dry leaves, tertiary vein angle decrease outward, approximately parallel near midvein, predominantly alternate, some subopposite, mixed close and distant; *quaternary veins* thick and orthogonal, quinternary veins somewhat thin and randomly oriented; highest vein order 8, highest vein order showing excurrent branching 7; *marginal ultimate venation* fimbriate; *areoles* moderately developed (Compare with *B. oppositifolia*), oriented, polygonal or irregular, variable in size from large to very large (approximately 1-4 mm), *free ending veinlets* branched 2-4 time depending on size of areoles (large areoles make them look like imperfect).

2. *Bouea oppositifolia* (Roxb.) Meisn. (Plate 2)

Description: *Leaf* simple, symmetrical, mostly narrow elliptic, some narrow oblong; size 5.5-21x1-5 cm; *apex* acuminate; *base* acute-cuneate; *margin* entire; *texture* coriaceous; *petiole* approximately 1-1.5 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, straight-markedly curved (s-shape); *secondary veins* 16-20 pairs, 0.5-1.2 cm apart, opposite, subopposite and alternate, thick, angle of divergence moderate acute (45°-63°) to right angle, quite uniform in some leaves and variable in the others (different specimens) e.g. some leaves secondary veins are uniformly curved whereas in other leaves they are both uniformly curved and straight most of the distance to margin; *MVP* type IV and V, approximately 3-4 small ELMA, long and narrow quadrilateral and rectangular in shape, branching-off angle acute to nearly right angle; intramarginal vein absent; *intersecondary veins* infrequent, relatively weak, mostly composite, proceed 1/4-1/2 of the distance between midvein and leaf margin; some leaves have relatively faint tertiary or higher venation pattern on dry leaves, *tertiary veins* angle of origin mostly AA, some AR, RA, and RR (acute angles are predominantly wide (65°-80°)), percurrent / forked, some admedial ramified near the midvein, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite, close; *quaternary* veins orthogonal; quinternary veins thick and randomly oriented (similar to *B. macrophylla*); highest vein order 12, highest vein order showing excurrent branching 13; *marginal ultimate venation* relatively weak fimbriate; *areoles* relatively imperfect, random arrangement, polygonal or irregular, size is difficult to determined but tend to be very large, *free ending veinlets* branching is hard to determined because of being imperfect.

3. ***Buchanania arborescens*** (Blume) Blume (Plate 3)

Description: Leave simple, symmetrical, narrow elliptic, narrow obovate; size 11.5-14x3.5-4 cm; *apex* acute normal, rarely round and slightly emarginate; *base* acute cuneate to decurrent; *margin* entire; *texture* coriaceous; *petiole* approximately 1.7-3.5 cm, normal to inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, slightly curved; *secondary veins* 16-18 pairs, 0.5-1.2 cm apart, opposite, subopposite and alternate, moderate in thickness, angle of divergence moderately acute (45°-62°), those at about apical 1/5 are more acute, uniformly curved; *MVP* type II, approximately 5-6 ELMA, broad rectangular in shape, branching-off angle acute to nearly right angle; intramarginal vein absent; *intersecondary veins* frequent (usually more than one between adjacent secondary veins), very strong, mostly simple, proceed 1/3-2/3 of the distance between midvein and leaf margin; *tertiary veins* angle of origin so far present mostly AA (acute angles moderate to wide (55°-80°)), mixed weak percurrent / forked; relationship to the midvein so far present oblique, changing in tertiary vein angle hardly seen, arrangement of tertiary veins so far present alternate; *quaternary* and *quinternary veins* relatively thin and randomly oriented; highest vein order 7; highest vein order showing excurrent branching 6; *marginal ultimate venation* fimbriate; *areoles* moderately developed, random arrangement, shape quadrangular to polygonal, variable in size from large to very large (approximately 1-4 mm), *free ending veinlets* branched up to three times.

4. *Buchanania reticulata* Hance (Plate 4)

Description: *Leaf* simple, symmetrical, elliptic, narrow obovate; size 7.0-20.5x2.3-6.0 cm; *apex* obtuse to round; *base* acute normal to acute cuneate; *margin* entire; *texture* coriaceous; *petiole* approximately 0.5-2.5 cm, normal; *venation* pinnate, eucamptodromous (may be considered as intermediate between simple craspedodromous and eucamptodromous because secondary veins tend to end at margin while there are still cross veins that form exmedial loops. Also see details in “classification of MVP” in chapter IV results); *primary vein* stout, straight to strongly curved; *secondary veins* approximately 16-27 pairs, 0.2-1.2 cm apart, predominantly alternate, thick, angle of divergence wide acute (68°-80°), upper more acute than lower, uniformly curved; *MVP* type V, approximately 1-3 *ELMA*, triangular, quadrilateral to irregular, branching-off angle moderate acute; intramarginal vein absent; *intersecondary veins* frequent, strong, mostly composite, proceed 1/3-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin predominantly AA, (acute angles are predominantly moderate, (60°-65°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle slightly decrease outward, mostly alternate and subopposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 11, highest vein order showing excurrent branching 10; *marginal ultimate venation* strong fimbriate; *areoles* well developed, oriented, variable in shape from triangular, quadrangular, polygonal to irregular, size medium to large (approximately 0.5-1.5 mm), *free ending veinlets* branched up to 6 times.

5. *Buchanania sessifolia* Blume (Plate 5)

Description: Leave simple, symmetrical, mostly oblanceolate, rarely elliptic and obovate; size 5.5-18.5x1.9-7 cm; *apex* acuminate-round; *base* acute cuneate to long tapering, acute normal, rarely round; *margin* entire; *texture* chataceous; *petiole* approximately 1-1.5 cm, normal to inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, mostly slightly curved at apical 1/3; *secondary veins* 15-22 pairs, 0.2-1 cm apart, opposite, subopposite and altenate, moderate in thickness, angle of divergence moderate to wide acute (45°-77°) to right angle (83°-90°) and upper more acute than lower, mostly uniformly curved but some at about basal 1/3 straight most of the distance to margin; *MVP* type VI, approximately 3-4 small *ELMA*, pentagonal and quadrilateral in shape, branching-off angle acute to nearly right angle; intramarginal vein absent; *intersecondary veins* frequent, relatively weak, mostly composite, proceed 1/4-3/4 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA and RR (acute angles are predominantly wide (65°-80°)), mixed percurrent / forked (clearly seen than that of *B. aborescens* and has feature like admedial ramified near the midvein), oblique in relation to the midvein, tertiary vein angle seemingly constant, alternate and subopposite, distant; *quaternary* and *quinternary veins* relatively thin and randomly oriented; highest vein order 9, highest vein order showing excurrent branching 8; *marginal ultimate venation* intermediate between looped and incomplete; *areoles* imperfect, random arrangement, irregular in shape, size is not determined, *free ending veinlets* not determined.

6. *Buchanania siamensis* Miq. (Plate 6)

Description: *Leaf* simple, symmetrical, elliptic to wide elliptic, narrow to wide obovate; size 1.5-6.5x0.6-3.2 cm; *apex* round to emarginate; *base* acute normal; *margin* entire; *texture* thickly coriaceous; *petiole* approximately 0.5 cm, normal; *venation* pinnate, eucamptodromous; *primary vein* thick, slightly-strongly curved, sometimes slightly zigzag; *secondary veins* 8-12 pairs, 0.3-2 cm apart, mostly alternate, rarely subopposite and opposite, moderate in thickness, angle of divergence narrow-moderate acute (36°-56°), mostly not uniformly curved and sometimes slightly zigzag as seen in *primary vein*; *MVP* type VII, approximately 3-4 small *ELMA*, quadrilateral to polygonal, branching-off angle wide acute to right angle; intramarginal vein absent; *intersecondary veins* frequent, relatively weak, almost all composite, proceed 1/4-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly OO, RR and combination of O and R, percurrent / forked, oblique in relation to the midvein, tertiary vein angle so far present seemingly constant, mostly alternate, relatively close; *quaternary* and *quinternary veins* relatively thin and orthogonal; highest vein order 9, highest vein order showing excurrent branching 8; *marginal ultimate venation* intermediate between looped and incomplete; *areoles* moderately developed, random arrangement, irregular in shape, size medium (approximately 0.3-1 mm) , *free ending veinlets* so far present branched up to 4 times.

7. *Drimycarpus luridus* (Hook.f.) Ding Hou (Plate 7)

Description: *Leaf* simple, symmetrical, narrow elliptic, narrow obovate, oblanceolate; size 10.5-15.3x2.7-5.5 cm; *apex* acuminate; *base* acute normal; *margin* entire; *texture* coriaceous; *petiole* approximately 1.5-2.5 cm, normal; *venation* pinnate, eucamptodromous; *primary vein* stout, slightly curved; *secondary veins* approximately 12-16 pairs, 0.3-1.6 cm apart, predominantly alternate, moderately thick, angle of divergence moderate acute (45°-50°), uniform, uniformly curved; *MVP* type IV, approximately 7-8 *ELMA*, predominantly quadrilateral, branching-off angle mostly right angle; intramarginal vein absent, *intersecondary veins* frequent, strong, mostly composite, proceed 1/5-3/4 of the distance between midvein and leaf margin (NB. almost half of the so-called intersecondary veins here may be considered to be tertiary veins concerning their size, angle of origin, and orientation); *tertiary veins* angle of origin predominantly RR, some AR and AO (acute angles are predominantly wide, (65°-80°)), mixed percurrent/forked and percurrent/simple, oblique in relation to the midvein, tertiary vein angle decrease outward, alternate, subopposite and opposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 8, highest vein order showing excurrent branching 7; *marginal ultimate venation* strong fimbriate; *areoles* well developed, oriented, variable in shape from quadrangular to polygonal and irregular, size medium to large (approximately 0.5-2 mm), free ending veinlets branched mostly 3 times.

8. *Gluta elegans* (Wall.) Hook.f. (Plate 8)

Description: *Leaf* simple, symmetrical, elliptic, narrow elliptic (common), narrow oblong; size 7-14.5x2.5-4.5 cm; *apex* mostly acute, rarely obtuse; *base* acute–cuneate; *margin* entire; *texture* coriaceous; *petiole* approximately .75-6.5 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, straight, slightly curved at lower 1/3, or sigmoid-curved; *secondary veins* 11-15 pairs, 0.5-1.7 cm apart, subopposite and alternate, moderately thick, angle of divergence narrow to moderate acute (39°-60°), upper and lower more acute than those in the middle, uniformly curved; *MVP* type III, approximately 5-8 *ELMA*, broad to narrow and long rectangular in shape, branching-off angle nearly right to right angle; and intramarginal vein absent; *intersecondary veins*, frequent, relatively weak, mostly composite, proceed 1/4-3/4 of the distance between midvein and leaf margin; *tertiary veins* angle of origin so far present AA, AR, AO and RA (acute angles are predominantly wide (67°-80°) and moderate (52°-64°), rarely narrow (40°)), mixed percurrent/forked and random reticulate, relationship to the midvein is not clearly seen but approximately oblique, predominantly alternate, predominantly close, some distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 9, highest vein order showing excurrent branching 8; *marginal ultimate venation* relatively weak fimbriate; *areoles* well developed, oriented, variable in shape from quadrangular to polygonal and irregular, size medium to large (approximately 0.5-2 mm), *free ending veinlets* branched 3 times or more.

9. *Gluta renghas* L. (Plate 9)

Description: *Leaf* simple, symmetrical, mostly narrow obovate, oblanceolate, narrow elliptic and elliptic, rarely wide elliptic; size 7.5-15x3-7.2 cm;

apex obtuse; *base* acute-cuneate; *margin* entire; *texture* coriaceous; *petiole* sessile up to 3 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, straight; *secondary veins* 18-20 pairs, 0.4-0.9 cm apart, opposite, subopposite and altenate, moderately thick, angle of divergence narrow to moderate acute (34°-53°) and upper more acute than lower, mostly straight most of the distance to and bend sharply at the leaf margin; *MVP* type I, approximately 7-8 *ELMA*, square to broad rectangular in shape, branching-off angle wide acute to nearly right angle; and intramarginal vein absent; *intersecondary veins*, frequent, relatively weak, mostly composite, proceed 1/4-2/3 of the distance between midvein and leaf margin; *tertiary veins* angle of origin so far present AA, AR, AO and RA (acute angles are predominantly wide (70°-80°) and moderate (60°-64°), mixed percurrent/forked and random reticulate, relationship to the midvein is not clearly seen but approximately oblique, predominantly alternate, predominantly close, some distant; *quaternary* and *quinternary veins* thick and random; highest vein order 7-9, highest vein order showing excurrent branching 6-8; *marginal ultimate venation* fimbriate; *areoles* poorly developed, random arrangement, highly irregular in shape, size of well defined areoles mostly medium to large (1-2 mm), *free ending veinlets* branched 3 times or more.

10. ***Mangifera caesia*** Jack (Plate 10)

Description: *Leaf* simple, symmetrical, narrow elliptic (only 1 specimen was examined with size 5.9x17.8 cm); size 9-41.5x3.5-12 cm (from Ding Hou, 1989); *apex* acuminate, *base* acute-cuneate, *margin* entire; *texture* coriaceous; *petiole* approximately 1.5-2.5(-6) cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, slightly curved; *secondary veins* approximately 22 pairs (14-33 in Ding Hou, 1978), 0.4-1.3 cm apart, mostly alternate and subopposite, rarely opposite, moderately thick, angle of divergence wide acute to right angle (70°-83°) and upper more acute than lower, mostly straight most of the distance to and bend sharply at the leaf margin; *MVP* type I, II, approx. 6-7 *ELMA* were determined from the photograph, quadrilateral, branching-off angle wide acute; intramarginal vein absent; *intersecondary veins*, frequent, relatively weak, mostly composite, proceed 1/4-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AR (acute angles are predominantly moderate to wide (60°-75°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle can not be determined, probably predominantly alternate, some subopposite and opposite, predominantly close, some distant; *quaternary* and *quinternary veins*, highest vein order, highest vein order showing excurrent branching can not be determined, *marginal ultimate venation* possibly fimbriate; all features of *areoles* can not be analyzed from the photograph.

11. ***Mangifera caloneura*** Kurz (Plate 11)

Description: *Leaf* simple, symmetrical, narrow elliptic, narrow oblong; size 15-26x5.5-7 cm; *apex* acute; *base* acute-normal; *margin* entire; *texture* coriaceous (very thick); *petiole* approximately 3-4 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, slightly to markedly curved; *secondary veins* 16-24 pairs, 0.4-1.2 cm apart and those at base are more closer, opposite, subopposite and alternate, thick, angle of divergence moderate to wide acute (46°-70°) and some at about basal 1/5 are right angle (81°-85°), upper more acute than lower, mostly uniformly straight most of the distance to and bend sharply at the leaf margin and some are uniformly curved; *MVP* type II, approximately 6-8 *ELMA*, gradually diminishing in size apically, pentagonal, polygonal, branching-off angle mostly wide acute to right; intramarginal vein absent; *intersecondary veins* frequent, relatively weak, mostly composite, proceed 1/8-2/3 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly RR, RA, some AA and AR (acute angles are predominantly wide (60°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle constant, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* somewhat thin and orthogonal; highest vein order 10, highest vein order showing excurrent branching 9; *marginal ultimate venation* fimbriate; *areoles* very well developed, oriented, mostly quadrangular and pentagonal, size mostly medium (0.5-1 mm), some are large (2 mm), almost all veinlets branched 3 times.

12. *Mangifera camptosperma* Pierre (Plate 12)

Description: *Leaf* simple, symmetrical, narrow elliptic, lanceolate; size 11.2-16.3x3.5-4.6 cm, *apex* acuminate, *base* acute-normal, *margin* entire, *texture* coriaceous, *petiole* approximately 1-1.5 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, straight-slightly curved at apical 1/3; *secondary veins* 24-27 pairs, 0.3-0.8 cm apart, opposite, subopposite and alternate, thick, angle of divergence moderate to wide acute (63°-75°), upper more acute than lower, relatively straight most of the distance to margin and some are uniformly curved; *MVP* type III, approximately 7-8 small *ELMA*, mostly quadrilateral, branching-off angle wide acute; and intramarginal vein absent; *intersecondary veins*, frequent, strong, mostly simple, proceed 1/4-2/3 of the distance between midvein and leaf margin (NB., several intersecondary veins between two secondary veins may merge to one and run to margin, and this character look similar to admedial ramification of tertiary veins); *tertiary veins* angle of origin mostly AR, rarely AO, RA and RR (acute angles are predominantly moderate to wide (47°-74°)), and exmedial angles are, in average, more acute than admedail angles), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite, predominantly close, some distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 9; highest vein order showing excurrent branching 8; *marginal ultimate venation* fimbriate; *areoles* well developed, oriented, variable from quadrangular, pentagonal, polygonal to irregular; size medium to large (0.5-2 mm), *free ending veinlets* branched 3 or more times.

13. *Mangifera chamaoensis* (still not included in preliminary checklist and in Thai plant names, being revised) (Plate 13)

Description: *Leaf* simple, symmetrical, narrow elliptic, narrow oblong; size 7.5-14x1.8-3 cm; *apex* acute, acuminate; *base* acute normal to acute cuneate; *margin* entire; *texture* coriaceous; *petiole* approximately1.8-2 cm (leaves of the same size may have different petiolar length), inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, slightly curved; *secondary veins* 15-23 pairs, 0.3-1.0 cm apart, opposite, subopposite and alternate, thick, angle of divergence moderate to wide acute (45°-74°), upper more acute than lower and somewhat uniform at about upper 1/2 and more acute on one side than on the other at about lower 1/2 of the leaf, mostly uniformly curved and some straight most of the distance to margin; *MVP* type IV, approximately 9-10 *ELMA*, quite uniform in shape, mostly rectangular and quadrilateral, branching-off angle wide acute to right angle; intramarginal vein absent; *intersecondary veins* frequent, very strong, mostly simple, proceed 1/3-4/5 of the distance between midvein and leaf margin; *tertiary veins* angle of origin predominantly AR, some AA, AO and RR (acute angles are predominantly moderate and wide (56°-80°)) and exmedial angles are, in average, more acute than admedail angles), percurrent/forked, oblique in relation to the midvein, tertiary vein angle quite constant, predominantly alternate, some subopposite, close; *quaternary* and *quinternary veins* thick and orthogonal, highest vein order 10, highest vein order showing excurrent branching 9; *marginal ultimate venation* fimbriate; *areoles* well developed, oriented, variable in shape from quadrangular to polygonal; size mostly medium (0.5-1 mm), some are large (2 mm), *free ending veinlets* branched 3 or more times (features of areoles are similar to those of *M. caloneura*)

14. *Mangifera collina* Kosterm. (not included in preliminary check list and in Thai plant names) (Plate 14)

Description: *Leaf* simple, symmetrical, narrow elliptic to narrow oblong, size 13-22x4-5.7 cm, *apex* acute to acuminate, *base* acute-normal, *margin* entire, *texture* coriaceous, *petiole* approximately 2-6 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, mostly straight; *secondary veins* 16-25 pairs, 0.4-1.4 cm apart, opposite, subopposite and alternate, thick, angle of divergence moderate to wide acute (50°-73°), those at about upper 1/6 of the leaf are more acute and slightly more acute on one side than on the other, relatively straight most of the distance to margin; *MVP* type IV (rather similar to those of *M. chamaoensis*), approximately 12-13 *ELMA*, quite uniform in shape, mostly rectangular and quadrilateral, branching-off angle wide acute to right angle; intramarginal vein absent; *intersecondary veins* frequent, relatively strong, mostly composite, proceed 1/5-1/3 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, rarely AR, RA and RR near margin (acute angles are predominantly wide (69°-78°)) and uniform among exmedial and admedial angles, percurrent/forked and has weak characteristic of admedial ramification near midvein, oblique in relation to the midvein, tertiary vein angle quite constant, predominantly alternate, some subopposite, close to distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 9; highest vein order showing excurrent branching 8; *marginal ultimate venation* fimbriate; *areoles* well developed, random, mostly polygonal and irregular; size mostly medium (0.5-1 mm), some are large (2 mm), *free ending veinlets* branched 3 or more times.

15. ***Mangifera duperreana*** Pierre. var. *siamensis* Craib (Plate 15)

Description: *Leaf* simple, symmetrical, narrow elliptic, narrow oblong, narrow obovate, size 16-26x5.2-7 cm; *apex* acute; *base* acute normal to acute cuneate; *margin* entire; *texture* coriaceous; *petiole* approximately 2.5-5 cm, normal to inflate; *venation* pinnate, eucamptodromous (one cross vein is stronger than others and makes it look like the secondary vein branches once at the end); *primary vein* stout, straight to slightly curved; *secondary veins* 16-21 pairs, 0.5-1.8 cm apart and somewhat closer at base, opposite, subopposite and alternate, thick, angle of divergence moderate to wide acute (50°-72°) or even right angle at basal part of some leaves and upper generally more obtuse than lower, mostly straight most of the distance to and bend sharply at the leaf margin; *MVP* intermediate between type I and II, approximately 5-6 *ELMA*, quadrilateral and pentagonal, branching-off angle wide acute to obtuse; intramarginal vein absent; *intersecondary veins* frequent, relatively strong, mostly composite, proceed 1/6-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, some AR, RA and RR (acute angles are predominantly wide (65°-70°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle quite constant, predominantly alternate, some subopposite, close to distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 9, highest vein order showing excurrent branching 8; *marginal ultimate venation* relatively weak fimbriate; *areoles* very well developed, oriented, mostly quadrangular and pentagonal, very consistent in size which is mostly medium (0.3-1 mm), almost all veinlets branched 3 times.

16. *Mangifera flava* Evrard (Plate 16)

Description: *Leaf* simple, symmetrical, narrow oblong-narrow elliptic, lanceolate; size 9-17x2.6-4.6 cm; *apex* acute; *base* acute normal; *margin* entire; *texture* coriaceous; *petiole* approximately 2-2.5 cm, normal to inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, slightly curved at apical 1/3; *secondary veins* 15-20 pairs, 0.5-1.2 cm apart, opposite, subopposite and alternate, thick, angle of divergence narrow to moderate acute (42°-65°), upper more acute than lower and more acute on one side than on the other, mostly uniformly curved and some are straight most of the distance to margin; *MVP* type III, approximately 9-10 obvious *ELMA*, mostly rectangular and quadrilateral in shape, branching-off angle wide acute to obtuse; intramarginal vein absent; *intersecondary veins* frequent, relatively weak, mostly composite, in some leaves they are weak and some are strong and proceed 1/10-1/3 to 3/4-4/5 of the distance between midvein and leaf margin respectively; *tertiary veins* angle of origin mostly AR and RR, rarely AA (acute angles are predominantly wide (65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle quite constant, predominantly alternate, some subopposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 11, highest vein order showing excurrent branching 10; *marginal ultimate venation* fimbriate; *areoles* well developed (same as *M. chamaoensis, M. collina, M.*

linearifolia, and *M. sylvatica*, but not as strongly developed as *M. duperiana*), oriented, mostly quadrangular and pentagonal, some irregular; well defined areoles are mostly medium (0.3-1 mm), *free ending veinlets* branched 3 to 5 times.

17. *Mangifera foetida* Lour. (Plate 17)

Description: *Leaf* simple, symmetrical, elliptic, narrow elliptic, oblong, narrow oblong; size 7-33x2.3-10.6 cm; *apex* acute *base* acute normal; *margin* entire; *texture* coriaceous; *petiole* approximately 3-5 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, slightly to markedly curved; *secondary veins* 18-22 pairs, 0.5-1.4 cm apart and somewhat closer at base, opposite, subopposite and alternate, very thick, angle of divergence moderate to wide acute (55°-65°), some at lower 1/3 are more acute on one side than on the other, mostly uniformly curved, some are straight most of the distance to margin; *MVP* type IV, approximately 7-8 *ELMA*, mostly quadrilateral, some rectangular, branching-off angle wide acute to right angle, after they branched off the secondary veins they upturned and run close to the margin; intramarginal vein absent; *intersecondary veins* frequent, strong, mostly composite, proceed 1/6-1/2 of the distance between midvein and leaf margin; relatively faint tertiary or higher venation pattern on dry leaves, *tertiary veins* angle of origin mostly AR and RR, rarely AA (acute angles are predominantly wide (65°-80°)) (quite similar to those of *M. flava*), percurrent/forked, oblique in relation to the midvein, tertiary vein angle slightly decrease outward, predominantly alternate, some subopposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 9, highest vein order showing excurrent branching 8; *marginal ultimate venation* fimbriate; *areoles* well developed (but not as well as *Mangifera* spp in a group of candidates for NLRs for SUT244, except for *Bouea macrophylla*), oriented, mostly quadrangular and pentagonal, very consistent in size which is medium (0.3-1 mm), veinlets branched 3-4 times.

18. ***Mangifera gedebe*** Miq. (Plate 18)

Description: *Leaf* simple, symmetrical, narrow elliptic, narrow oblong; size 9-16.5x2.5-4.9 cm; *apex* acute; *base* acute normal; *margin* entire; *texture* coriaceous; *petiole* approximately 3-3.7, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, markedly curved; *secondary veins* 20-26 pairs, 0.5-1.0 cm apart, opposite, subopposite and alternate, moderately thick, angle of divergence moderate to wide acute (56°-81°), upper more acute than lower, uniformly curved; *MVP* type III, approximately 5-6 inconspicuous (due to thick quaternary and quinternary veins) *ELMA*, mostly quadrilateral, some rectangular, branching-off angle wide acute to obtuse; intramarginal vein absent; *intersecondary veins* frequent, relatively strong, mostly simple, proceed 1/3-3/4 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA and AR, rarely AO near leaf margin (acute angles are predominantly moderate (37°-64°)) and exmedial angles are, in average, more acute than admedial angles), percurrent/forked, oblique in relation to the midvein, tertiary vein angle quite constant, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 9, highest vein order showing excurrent branching 8; *marginal ultimate venation* fimbriate; *areoles* well developed, oriented, variable from quadrangular, pentagonal, polygonal to irregular; well defined areoles are mostly medium (0.5-1 mm), some are large (up to 2 mm), *free ending veinlets* branched 3 to 5 times.

19. ***Mangifera griffithii*** Hook.f. (Plate 19)

Description: *Leaf* simple, symmetrical, elliptic, rarely narrow obovate; size 5.9-37x1.5-13 cm; *apex* acuminate; *base* acute normal to obtuse normal; *margin* entire; *texture* coriaceous; *petiole* approximately 0.7-1.6 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, very slightly curved; *secondary veins* 9-13 pairs, 0.4-1.0 cm apart, opposite, subopposite and alternate, moderately thick; angle of divergence moderate to wide acute (48°-69°) upper and lower more acute than in the middle, uniformly curved; *MVP* type III, approximately 7-8 *ELMA*, mostly quadrilateral and rectangular, branching-off angle wide acute to right angle; intramarginal vein absent; *intersecondary veins* frequent (may >1 between adjacent secondary veins), relaatively strong, simple and composite, proceed 1/3-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, rarely AR and AO near leaf margin (acute angles are predominantly wide (65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle slightly decrease outward, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* relatively thin and orthogonal; highest vein order 8, highest vein order showing excurrent branching 7; *marginal ultimate venation* fimbriate; *areoles* well developed, oriented, variable from quadrangular, pentagonal, polygonal to irregular; well defined areoles are mostly large (1-2 mm), *free ending veinlets* branched 3 to 5 times.

20. ***Mangifera indica*** Linn. (Plate 20)

Description: *Leaf* simple, mostly symmetrical, some asymmetrical at base, narrow elliptic and lanceolate are most common, elliptic, oblong and narrow oblong less common. As so far studied, oblanceolate leaves are not observed in this species;

size 8.4-38x2-10 cm; *apex* acute, acuminate; *base* acute cuneate; *margin* entire; *texture* coriaceous; *petiole* approximately 2-4 cm, inflate to markedly inflate; *venation* pinnate, eucamptodromous (one or two cross veins are stronger than others and make it look like the secondary vein branches at the end. This is true only on some variation of leaf form); *primary vein* moderate to stout, mostly slightly to markedly curved, rarely straight; *secondary veins* 18-31 pairs (sometimes, side with more obtuse angle has more veins), 0.5-1.4 cm apart, opposite, subopposite and alternate, moderately thick, angle of divergence moderate acute (51°-61°) and relatively uniform in some leaves, whereas in the others angle of divergence are moderate to wide acute (59°-77°) and upper more acute than lower, in some leaf variations they may be moderate to right angle (59°-85°), upper more acute than lower and more acute on one side than on the other, in some leaves mostly uniformly curved whereas in other leaves both uniformly curved and straight most of the distance to margin; *MVP* intermediate type II and III, approximately 8-11 obvious *ELMA*, mostly quadrilateral and rectangular, branching-off angle wide acute to right angle; intersecondary vein frequent, relatively strong, simple and composite, proceed 1/5-2/3 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, some AR, AO, and RA (acute angles are predominantly wide (65°-80°)), percurrent / forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* moderately thick and orthogonal, highest vein order 7, highest vein order showing excurrent branching 6; *marginal ultimate venation* fimbriate; *areoles* moderately to well developed (less than *Mangifera duperreana*) , oriented, quadrangular, pentagonal and polygonal; size medium to large (0.5-2 mm), *free ending veinlets* branched 3-5 times.

21. ***Mangifera linearifolia*** Korsterm. (Plate 21)

Description: *Leaf* simple, symmetrical, narrow oblong, lorate, narrow elliptic, oblanceolate; size 9.5-14.5x2.5-3.3 cm; *apex* mostly acute, rarely acuminate; *base* acute normal; margin entire; *texture* coriaceous; *petiole* approximately 1.5-3 cm, markedly inflate; *venation* pinnate, eucamptodromous; *primary vein* massive, markedly curved; *secondary veins* 18-25 pairs, 0.4-1.2 cm apart, mostly alternate and subopposite, thick, angle of divergence moderate to wide acute (47°-74°), upper more obtuse than lower and slightly more acute on one side than on the other, mostly uniformly curved, few are straight most of the distance to margin; *MVP* type III, approximately 10-11 obvious *ELMA*, mostly quadrilateral and rectangular, branching-off angle wide acute to right angle; intramarginal vein absent; *intersecondary veins* very frequent, very strong, mostly simple, proceed 1/3-4/5 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, some AR, AO and RA (acute angles are predominantly wide (65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 9, highest vein order showing excurrent branching 8; *marginal ultimate venation* fimbriate; well developed *areoles*, relatively less oriented, relatively more irregular in shape, quadrangular to pentagonal, well defined areoles are mostly medium (0.3-1 mm), some are large (up to 2), *free ending veinlets* branched3-4 times.

22. ***Mangifera macrocarpa*** Bl. (Plate 22)

Description: *Leaf* simple, symmetrical, lorate to linear; size 26-32x2.8-3.2 cm; *apex* acute to acuminate; *base* acute normal; *margin* entire; *texture* chataceous;

petiole approximately 3.5-5.5 cm, inflate; *venation* pinnate, eucamptodromous, *primary vein* moderate, straight; *secondary veins* 24-42 pairs, 0.3-1.2 cm apart, opposite, subopposite and alternate, moderately thick, angle of divergence moderate to right angle (60°-90°), upper more acute than lower, straight most of the distance to the margin; *MVP* type V, approximately 4-6 *ELMA*, mostly quadrangular, branching-off angle mostly right angle some wide acute; intramarginal vein absent; *intersecondary veins* frequent, relatively strong, mostly composite, proceed 1/5-3/4 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly RR, RA, and AA (acute angles are predominantly wide (65°-80°)), percurrent/forked, tertiary vein angle in relation to primary vein are difficult to determine due to the complicate coalescence of the tertiary veins, *quaternary* and *quinternary veins* thick and mostly orthogonal; highest vein order 7, highest vein order showing excurrent branching 8; *marginal ultimate venation* fimbriate; *areoles* well developed, oriented, variable in shape from quadrangular, pentagonal, polygonal to irregular, size medium to large (0.5-2 mm), *free ending veinlets* branched up to 3 times.

23. *Mangifera microphylla* Griff. ex Hook.f. (Plate 23)

Description: *Leaf* simple, symmetrical, narrow elliptic, elliptic; size 6.5-16x2-6.3 cm; *apex* acute, acuminate; *base* acute normal; *margin* entire; *texture* coriaceous; *petiole* approximately 1.5-2.5 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, straight-markedly curved; *secondary veins* 14-16 pairs, 0.6-1.2 cm apart, opposite, subopposite and alternate, moderately thick, angle of divergence moderate to wide acute (42°-71°), upper and lower more acute than in the middle and those in the middle somewhat variable, uniformly curved; *MVP* type III, approximately 6-7 small and inconspicuous *ELMA*, mostly quadrangular, some are irregular in shape, branching-off angle wide acute to right angle; intramarginal vein absent; *intersecondary veins* infrequent, relatively very weak, composite, proceed 1/10-1/5 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, rarely AR and RA (acute angles are predominantly wide (65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 11, highest vein order showing excurrent branching 10; *marginal ultimate venation* fimbriate; *areoles* moderately developed, oriented, variable in shape from quadrangular, pentagonal, polygonal to irregular, size mostly medium (0.5-1 mm), *free ending veinlets* branched 3 to 5 times.

24. ***Mangifera odorata*** Griff. (Plate 24)

Description: *Leaf* simple, symmetrical, narrow elliptic, elliptic-lanceolate, lanceolate; size 9-35x3.5-10 cm; *apex* acute, acuminate; *base* acute normal; margin entire; *texture* coriaceous; *petiole* approximately 4.5 cm, inflate to markedly inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, slightly curved; *secondary veins* 15-26 pairs, 0.4-1.7 cm apart, subopposite and alternate, thick, angle of divergence moderate to wide acute (55°-65°), upper more acute than lower, uniformly curved, some bend up sharply near leaf margin; *MVP* type III, approximately 9-10 small obvious *ELMA* (similar to those of *M. pentandra*), mostly quadrilateral, few pentagonal and irregular, branching-off angle predominantly right angle, some wide acute; intramarginal vein absent; *intersecondary veins* frequent (usually only one between adjacent secondary veins, in case of more than one, the additional ones usually relatively weak), strong, simple and composite, proceed 1/5-

2/3 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, some AR and RA (acute angles are predominantly wide (65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle mostly constant, alternate, close to distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 10, highest vein order showing excurrent branching 9; *marginal ultimate venation* strong fimbriate; *areoles* very well developed, oriented, variable in shape from quadrangular, pentagonal to polygonal; rather consistent in size which is medium (0.5-1 mm), *free ending veinlets* branched 3 to 7 times.

25. *Mangifera pentandra* Hook.f. (Plate 25)

Description: *Leaf* simple, symmetrical, narrow elliptic, narrow oblong; size 17.5-25x5.3-6.3 cm; *apex* acute, acuminate; *base* acute normal to acuminate; *margin* entire; *texture* coriaceous; *petiole* approximately 1-3 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, slightly curved; *secondary veins* 18-20 pairs, 0.6-2.2 cm apart, subopposite and alternate, thick, angle of divergence moderate to wide acute (51°-68°), upper more acute than lower and slightly more acute on one side than on the other, mostly straight most of the distance to margin, some are uniformly curved; *MVP* type III, approximately 11-12 small obvious *ELMA*, mostly quadrilateral, some pentagonal and irregular, branching-off angle wide acute to obtuse; intramarginal vein absent; *intersecondary veins* frequent, strong, mostly composite, proceed 1/4-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, some AR and RA (acute angles are predominantly wide 68°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle quite constant, alternate, subopposite and opposite, close to distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 8, highest vein order showing excurrent branching 7; *marginal ultimate venation* fimbriate; *areoles* very well developed, oriented, variable in shape from quadrangular, pentagonal to polygonal; very consistent in size which is medium (mostly 0.3-0.5 mm, some up to 1 mm), *free ending veinlets* branched 3 to 5 times.

26. *Mangifera quadrifida* Jack (Plate 26)

Description: *Leaf* simple, symmetrical, elliptic, narrow elliptic; size 14-19.5x5-9.5 cm; *apex* acute; *base* acute normal to obtuse normal; margin entire; *texture* coriaceous; *petiole* approximately 2-4 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, straight-slightly curved; *secondary veins* 12-16 pairs, 0.6-1.7 cm apart, opposite, subopposite and alternate, thick, angle of divergence moderate to wide acute (47°-79°) and right angle (86°), upper more acute than lower and slightly more acute on one side than on the other, uniformly curved; *MVP* type III, approximately 9-10 small inconspicuous *ELMA*, mostly rhomboidal and trapezoidal, branching-off angle wide acute to obtuse; intramarginal vein absent; *intersecondary veins* frequent, strong, mostly composite, proceed 1/4-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin AA, some AR and RA (acute angles are predominantly wide (65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite and opposite, close to distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 11, highest vein order showing excurrent branching 10; *marginal ultimate venation* fimbriate; *areoles* well developed, oriented, mostly polygonal, size mostly large (1-2 mm), *free ending veinlets* branched 3 to 5 times.

27. *Mangifera sylvatica* Roxb. (Plate 27)

Description: *Leaf* simple, symmetrical, narrow oblong-narrow elliptic; size 14-26x3-7.5 cm; *apex* acute, acuminate; *base* acute cuneate; *margin* entire; *texture* coriaceous; *petiole* approximately 2-5 cm, leaves of the same size may have different petiolar length, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, slightly to markedly curved; *secondary veins* 26-28 pairs, 0.7-1.4 cm apart, opposite, subopposite and alternate, thick, angle of divergence moderate to wide acute (53°-67°), upper may be more acute or obtuse than lower in each individual leaf or upper more acute than lower on one side and more obtuse on the other side of the same leaf, uniformly curved; *MVP* type III, approximately 8-10 small obvious *ELMA*, gradually diminishing in size apically, quadrilateral, pentagonal and irregular, branching-off angle mostly right angle, some wide acute; intramarginal vein absent; *intersecondary veins* frequent, strong, moslty composite, proceed 1/4-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, rarely AR and RA (acute angles are predominantly wide (65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle slightly decrease outward, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 10, highest vein order showing excurrent branching 9; *marginal ultimate venation* fimbriate; *areoles* well developed, oriented, mostly pentagonal, size medium to large (0.5-1 mm), *free ending veinlets* branched 3-4 times.

28. *Melanochyla angustifolia* Hook.f. (not included in Thai Plant Names) (Plate 28)

Description: *Leaf* simple, symmetrical, narrow oblong, narrow elliptic, oblanceolate; size 15-24x4-6 cm; *apex* acuminate; *base* acute normal to acute cuneate;

margin entire; *texture* coriaceous; *petiole* approximately 1.5-3 cm, inflate; *venation* pinnate, eucamptodromous (or weak brochidodromous according to Leaf Architecture Working Group); *primary vein* stout, slightly curved; *secondary veins* 20-22 pairs, 0.7-2.0 cm apart, mostly subopposite and alternate, thick, angle of divergence moderate to wide acute (62°-81°), upper more acute than lower and slightly more acute on one side than on the other, relatively straight most of the distance to margin and bend up sharply to join with the above secondary veins; *MVP* intermediate type II and III, proximately 6-9 small obvious *ELMA*, mostly approximately quadrilateral with curved outer borders, branching-off angle wide acute to obtuse; intramarginal vein absent; *intersecondary veins* frequent, relatively very weak, mostly composite, proceed 1/5-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly RR and RA, some AR, OA, OR, rarely AA (all acute angles are predominantly wide, 65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle quite constant, alternate, subopposite and opposite, close; *quaternary veins* thin or thick, *quinternary veins* thin and orthogonal; highest vein order 8, highest vein order showing excurrent branching 7; *marginal ultimate venation* fimbriate; well developed *areoles*, oriented, mostly quadrangular to pentagonal, size mostly large (1-2 mm), *free ending veinlets* mostly branched once or simple and curved, some have no veinlets. Due to mostly thin quinternary veins, thin free ending veinlets, and some thin quaternary veins, the reticulation of veins as the whole therefore look relatively clearly loose.

29. ***Melanochyla bracteata*** King (Plate 29)

Description: *Leaf* simple, symmetrical, narrow oblong, narrow elliptic; size 8.5-33.5x3-6.8 cm; *apex* acute, acuminate to cuneate; *base* acute normal to acute cuneate; *margin* entire; *texture* coriaceous; *petiole* approximately 2-5 cm, leaves of the same size may have different petiolar length, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, slightly to markedly curved; *secondary veins* 20-24 pairs, 0.5-1.4 cm apart, opposite, subopposite and alternate, moderately thick, angle of divergence moderate to wide acute (62°-76°), upper may be more acute or obtuse than lower in each individual leaf or upper more acute than lower on one side and more obtuse on the other side of the same leaf, relatively less straight than *Melanochyla angustifolia*, bend up sharply to join with the above secondary veins; *MVP* type IV, approximately 7-10 small obvious *ELMA*, mostly approximately quadrilateral with curved outer borders, branching-off angle mostly right angle to obtuse; intramarginal vein absent; *intersecondary veins* frequent, relatively strong, mostly composite, proceed 1/5-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly RR, some AR, RA and OA (acute angles are predominantly wide, 70°-79°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite and opposite, close; *quaternary veins* thin or thick and orthogonal, *quinternary veins* mostly thin and orthogonal; highest vein order 7, highest vein order showing excurrent branching 6; *marginal ultimate venation* fimbriate; *areoles* well developed, oriented, mostly quadrangular to pentagonal; size medium to large (0.5-2 mm), *free ending veinlets* branched 1-2 times.

30. *Melanochyla nitida* Ridl. (Plate 30)

Description: *Leaf* simple, symmetrical, elliptic, narrow obovate; size 10.5-14x4-5.5 cm; *apex* acuminate; *base* acute cuneate to acute decurrent; *margin* entire; *texture* chataceous; *petiole* approximately 1-1.5 cm, normal or inflate; *venation* pinnate, eucamptodromous (also has the character of admedial ramification near the primary vein); *primary vein* weak, straight; *secondary veins* 14-16 pairs, 0.4-1.4 cm apart, opposite, subopposite and alternate, moderately thick, angle of divergence moderate to wide acute (52°-76°), uniformly curved; *MVP* type VII, approximately 3-4 small *ELMA*, mostly quadrilateral, branching-off angle right angle or obtuse; intramarginal vein absent; *intersecondary veins* frequent, relatively weak, mostly composite, proceed 1/3-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin so far present mostly AR and RR (acute angles are predominantly wide (65°-75°)), comparatively slightly more acute than those in *M. angustifolia* and *M. bracteata*), mixed percurrent/forked and admedial ramified, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite, distant; *quaternary* and *quinternary veins* thin and randomly oriented; highest vein order 7, highest vein order showing excurrent branching 6; *marginal ultimate venation* intermediate between looped and fimbriate; *areoles* imperfect, random arrangement, shape irregular, well defined areoles are variable in size (0.5-2 mm), *free ending veinlets* branched up to 5 times.

31. *Semecarpus cochinchinensis* Engl. (Plate 31)

Description: *Leaf* simple, symmetrical, oblanceolate, narrow-wide obovate; size 18.5-24x4.8-6.7 cm; *apex* acute, acuminate to round; *base* acute cuneate; *margin* entire; *texture* chataceous; *petiole* approximately 1-1.5 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* massive, straight-markedly curved*; secondary veins* 11-14 pairs, 0.5-2.5 cm apart, opposite, suboposite and alternate, moderately thick, angle of divergence moderate acute (43°-60°), somewhat variable, uniformly curved; *MVP* type I, approximately 6-7 very obvious *ELMA*, mostly quadrilateral, branching-off angle mostly right angle, some wide acute; intramarginal vein absent; *intersecondary veins*, frequent (there are more than one between adjacent secondary veins), strong, simple and composite, proceed 1/8-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin AA, AR, RA and RR, few OA and OR (acute angles are predominantly wide (65°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite and opposite, close to distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 8, highest vein order showing excurrent branching 7; *marginal ultimate venation* strong fimbriate; *areoles* well developed, oriented, quadrangular, pentagonal to polygonal, size mostly medium (0.5-1 mm), some are large (2mm), *free ending veinlets* branched 1 to 3 times.

32. *Semecarpus curtisii* King (Plate 32)

Description: *Leaf* simple, symmetrical, oblanceolate, narrow obovate; size 8.5-34x3.4-9 cm; *apex* acute, acuminate; *base* acute normal to acute cuneate; *margin* entire; *texture* chataceous to coriaceous; *petiole* approximately 2-3.5 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, relatively straight; *secondary veins* 20-22 pairs, 0.5-1.8 cm apart, those at basal 1/6 were place closer than those arisen above, mostly subopposite and alternate, some opposite, thick, angle of divergence moderate to wide acute (50°-78°) and upper more acute than lower, straight most of the distance to margin; *MVP* type III, approximately 7-10 *ELMA*, mostly approximately quadrilateral, some rectangle, branching-off angle wide acute, right angle to obtuse; intramarginal vein absent; *intersecondary veins* frequent, mostly relatively weak (size mostly about that of tertiary veins), some strong, simple and composite, proceed 1/6-1/2 of the distance between midvein and leaf margin; *tertiary* *veins* angle of origin mostly RR, some AR and RA (acute angles are predominantly wide, 76°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle quite constant, predominantly alternate, some subopposite and opposite, close to distant; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 8, highest vein order showing excurrent branching 7; *marginal ultimate venation* strong fimbriate; *areoles* well developed, oriented, quadrangular, pentagonal to polygonal, size medium to large (0.5-2 mm), *free ending veinlets* branched 2 to 3 times.

33. *Semecarpus* sp. (PSU SN180478) (Plate 33)

Description: Leaf simple, symmetrical, narrow elliptic and oblanceolate; size 15.6-21.3x3.1-4.1 cm; *apex* acute, acuminate; *base* mostly acute cuneate, some acute normal; *margin* entire; *texture* coriaceous; *petiole* approximately 1.7-2.3 cm, normal to inflate; *venation* pinnate, eucamptodromous; *primary vein* stout, straight, weak S-curve (common) to strongly curved; *secondary veins* 21-27 pairs, 0.7-1.2 cm apart, those at basal 1/6 were place closer than those arisen above, mostly subopposite and alternate, some opposite, thick, angle of divergence moderate to wide acute (43°-69°) and upper more acute than lower, straight most of the distance to margin; *MVP* type III, approximately 6-8, 8-11 *ELMA* (in different individual leaves), mostly approximately quadrilateral, some rectangle, branching-off angle wide acute, right angle to obtuse; intramarginal vein absent; *intersecondary veins* very frequent (usually more than one between adjacent secondary veins), mostly relatively weak (size mostly about that of tertiary veins), some strong, mostly composite, proceed 1/6-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly RR, some AR and RA (acute angles are predominantly wide, 76°-80°)), percurrent/forked, oblique in relation to the midvein, tertiary vein angle quite constant, predominantly alternate, some subopposite and opposite, mostly close, some are distant (this may due to size of the leaves that, in average, are smaller than those of *Semecarpus curtisii*); *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 8, highest vein order showing excurrent branching 7; *marginal ultimate venation* very strong fimbriate; *areoles* well developed, oriented, quadrangular, pentagonal to polygonal, size mostly medium (0.5-1.0 mm), few are large (1.5 mm), almost all *free ending veinlets* branched 3 times.

34. *Swintonia floribunda* Griff. (Plate 34)

Description: *Leaf* simple, symmetrical, narrow elliptic (or elliptic-oblong), lanceolate; size 7-16.7x1.8-4.7 cm (leaves attached to inflorescence are as small as 0.8x2.8 cm); *apex* acute, obtuse; *base* acute normal; *margin* entire; *texture* coriaceous; *petiole* approximately 4-7 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, straight-slightly-curved; *secondary veins* 16-20 pairs, 0.5-1.2 cm apart, subopposite and alternate, moderately thick, angle of divergence moderate acute (45°-56°), upper may be more acute than lower on one side of the leaf and more obtuse on the other side, uniformly curved; *MVP* type V, approximately 4-5 inconspicuous *ELMA*, mostly quadrilateral, branching-off angle mostly right angle, some wide acute and they run close to the leaf margin; intramarginal vein absent; *intersecondary veins* frequent, relatively strong, simple and composite, proceed 1/8-1/3 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AA, AR, and AO (acute angles are predominantly wide (65°-75°)) in some leaves whereas predominantly moderate (57°-62°) in the others), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* thick and orthogonal; highest vein order 11, highest vein order showing excurrent branching 10; *marginal ultimate venation* very strong fimbriate; *areoles* well developed, relatively random, quadrangular, pentagonal to irregular, size medium to large (0.3-2 mm), *free ending veinlets* branched 3 to 5 times.

35. ***Swintonia schwenkii*** (Teijsm. & Binn.) Teijsm. & Binn. (Plate 35)

Description: *Leaf* simple, symmetrical, elliptic, narrow elliptic (or elliptic-oblong), elliptic; size 7-18.5x2.5-5.6 cm; *apex* acute to obtuse; *base* acute normal to obtuse normal; *margin* entire; *texture* coriaceous; *petiole* approximately 5-7.5 cm, inflate; *venation* pinnate, eucamptodromous; *primary vein* moderate, straight-slightly curved; *secondary veins* 15-18 pairs, 0.5-1.3 cm apart, subopposite and alternate, moderately thick, angle of divergence moderate to wide acute (45°-71°), upper more acute than lower and slightly more acute on one side than on the other, uniformly curved; *MVP* type V, approximately 2-3 inconspicuous *ELMA*, quadrangular, branching-off angle mostly wide acute; intramarginal vein absent; *intersecondary veins* frequent, weaker than in *S. floribunda*, mostly composite, proceed 1/6-1/2 of the distance between midvein and leaf margin; *tertiary veins* angle of origin mostly AR and RR, rarely AA (acute angle are predominantly wide (70°-80°), some are moderate (58°-60°) near leaf margin), percurrent/forked, oblique in relation to the midvein, tertiary vein angle decrease outward, predominantly alternate, some subopposite and opposite, close; *quaternary* and *quinternary veins* thick and relatively randomly oriented; highest vein order 11, highest vein order showing excurrent branching 10; *marginal ultimate venation* strong fimbriate; *areoles* well developed (less than *S. floribunda*), relatively random, mostly polygonal and irregular, size mostly large (1-2 mm), *free ending veinlets* branched mostly 3 times.

NB: In many cases of Anacardiaceous leaves, there are more than one intersecondary veins between two adjacent secondary veins. Usually, there is only one that is stronger than the rest.

4.1.7 Leaves of other families with features similar to those of Anacardiaceae.

Large numbers of modern leaves have been examined and listed in the appendix according to their more or less similarity shared with the fossil leaves studied. Nevertheless, a number of other species belonging to the same families with those shared similarities, that share no common features with the fossils were also listed. The purpose of doing so is to be sure that the comparisons of leaf architecture have covered as many leaves as possible and to remind of what we have done in leaf analysis. Not all these species were described but only the ones that, at least at first glance, look close to those of Anacardiaceae. The following are the examples of the ones with that close resemblance.

Apocynaceae

Alstonia macrophylla Wall. ex G. Don.: leaf shape and size is very similar to that of *Mangifera buchanaoides* (SUT 672), but the weak brochidodromous feature (according to Leaf Architecture Working Group) and intramarginal veins (not as pronounce as in *A. scholaris* or weak brochidodromous) are the major differences to separated them.

Alstonia scholaris (L.) R.Br.: The same as in the case of *Alstonia macrophylla*.

Cerbera manghas Linn. and ***Cerbera odollam*** Gaertn.; Leaf shape and venation are similar to some living *Mangifera* species (e.g. *Mangifera collina* and *Mangifera* *pentandra*) and SUT672, but petiole longer than SUT672 and strongly brochidrodromous.

Chilocarpus costatus Miq.: Shape and venation are similar to leaves of studied genera of Anacardiaceae, but venation strongly brochidodromous.

Holarrhena curtisii King & Gamb.: Leaf shape and venation more or less similar to those of some studied Anacardiaceous genera and SUT672, but secondary veins at about apical 1/3 are strongly brochidodromous.

Lecithidaceae

Barringtonia macrostachya Kurz: Venation very similar to *Mangifera* spp, but margin finely serrate, tip acuminate, very long petiole (longer than studied anacardiaceous genera on average), base long attenuate. In case of missing petiole and margin is not clear in fossil leaf, identification needs more examination in areoles, in higher venation orders or even in cuticular study.

Baringtonia pendura (Griff.) Kurz: Venation very similar to *Mangifera* spp., but serrate margin can be seen more clearly than in *Baringtonia macrostachya*. In case of missing petiole and margin is not clear in fossil leaf, identification should be done with care like in the case of *Baringtonia macrostachya*.

Bertholletia exelsa Humb. & Bonpl.: (not present in Thai Plant Names) Leaf shape and venation are similar to those of *Mangifera*. The differences are very fine crenulate or serrate margin and tertiary vein pattern is mixed percurrent/forked and exmedial ramified (very similar to that in *Mangifera gedebe*, but secondaries of *Bertholletia exelsa* are wavier). Leaf size is relatively larger and petiole is not swollen at the end (inflate).

Myristicaceae

Knema furfuracea (Hook. f. & Thomson) Warb.: shape, size, and venation type are similar to those of some species of *Mangifera* except for mixed opposite and alternate percurrent tertiary veins (or percurrent simple with some of them branched (according to Dilcher, 1974)) which is not present in *Mangifera* spp.

Knema globularia (Lam.) Warb.: of all species of *Knema* examined, this species is the most similar to species of *Mangifera* in leaf shape, size and venation type. Only gross venation analysis (to tertiary pattern) we may not be able to separate this from some species of *Mangifera*. However, if we can compare the venation to higher level we will clearly see that most of the areoles of *Knema globularia* have simple vienlets and veinlets that branched one time, rarely two times. Some of them have no veinlets. These characters are not found in *Mangifera* species. In addition, marginal ultimate venation in *Knema globularia* is mixed incomplete and looped which will not be found in *Mangifera* spp. as well.

Knema curtisii (King) Warb.: (not present in Thai Plant Names); in general appearance, leaves of this species are similar in shape, and in venation type to some species of *Mangifera* such as *Mangifera microphylla*, some variation of leaves of *Mangifera indica*. Anyway, leaves of this species have thinner petiole which is not swollen at the end, thinner secondary veins and intersecondary veins, and smaller in size in average.

Myrsinaceae

Ardisia colorata Roxb.: Leaf and shape are similar to leaves of studied Anacardiaceous genera such as *Bouea macrophylla* and some *Mangifera* species. However, size of intersecondary veins is not much different from that of secondary veins and this make distance between secondary veins somewhat variable. The secondary veins themselves are wavier in *Ardisia colorata*. Tertiary vein pattern of Ardisia colorata is mixed percurrent/forked and exmedial ramified.

Sapindaceae

Nephelium lappaceum L.; Leaf shape with sigmoid primary veins look similar to that of *Semecarpus paleosiamensis* (SUT 728), but the venation pattern is different. Courses of secondary veins, absence of intersecondary veins, different features of tertiary veins to areole are the evidences to exclude this species from potential NLRs.

Sapotaceae

Madhuca sp.; leaf shape is similar to that of *Mangifera buchananioides* (SUT 672), but the venation is distinctive. The lacking of intersecondary veins, mostly percurrent/simple tertiary veins, and lacking of ELMA are the marked differences.

4.2 Leguminous modern and fossil leaves

4.2.1 Systematic descriptions and affinities of the leguminous fossil leaves

Division----Magnoliophyta

Order----Fabales

Family----Fabaceae Lindl.

Subfamily---- Mimosoideae Kunth

Tribe----Mimoseae Bronn.

Genus---- *Adenanthassia* gen. nov. Sawangchote, Grote, Dilcher

Species---- *Adenanthassia paleothailandica* sp. nov. Sawangchote, Grote, Dilcher.

Holotype----Specimen SUT 1149 (Plate 41, Figs. 4.29I, S, T, and U), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

Paratype----SUT 1018 (plate 42, Figs. 4.29J, V, W, and X).

Locality----Mae Moh basin, Amphoe Mae Moh, Lampang Province, Northern Thailand, 18° 18′ 12″ N, 99° 44′ 02″ E; locality number 025.

Age---- Approx. Miocene.

Number of specimens---- Two pyritized specimens with different degree of clearness of venation pattern.

Etymology---- The specific epithet refers to the existence of the species in Thailand in the geological past.

Generic description: The same as description of species below.

Description: Leaflet, basal 3/4 strongly asymmetrical, apical 1/4 slightly asymmetrical, rhomboidal; 4x1.5 and 3.8x1.3 cm for SUT 1018 and. SUT 1149, respectively; apex round; base obtuse normal (without basal extension as seen in *Pithecellobium paleolampangensis* (white arrows in Figs. 4.29X and 4.33X)); margin entire; texture probably chartaceous; petiole 2.2 mm (complete in SUT 1018 and missing in SUT 1149); brochidodromous venation (clearly seen in SUT 1149) with secondary vein(s) and/or intersecondary vein(s) running between the two veins that form the arches (among these veins, only the ones with smaller size than the two that form arches will be called intersecondary veins), primary vein stout, slightly curved; secondary veins approx. 25 pairs, 0.1-0.2 cm apart, alternate, subopposite, or opposite, moderate, mostly slightly curved or zigzag, angle of divergence mostly wide acute (65°-75°); intramarginal vein absent, intersecondary veins frequent, rather strong; tertiary veins mixed percurrent/forked and reticulate; quaternary and quinternary rather thick and randomly oriented; highest vein order probably 5-6; marginal ultimate venation possibly fimbriate; areoles moderately developed, relatively random, variable in shape from quadrilateral to polygonal, probably medium to large (approx. 0.5-1.5 mm), veinlets branched 1-2 times (higher orders of fine size may not be preserved).

Affinity**:** Of all the modern species brought in comparison with the fossils, no species shares gross form and/or venation pattern more than *Adenanthera klainei*, *Cassia moschata* Kunth, *Diplotropis duchei* and *Gymnocladus chinensis* Baillon (Figs. 4.29A, C-D, F). *Cassia moschata* closely resembles fossils in gross form including size, shape, sub-angular shoulder and slender petiolule. Furthermore, number of secondary veins and their angle of divergence were shared. However, basal extension, weak brochidodromous venation, well developed areoles, smaller size of areoles and more FEV (the latter three characters make the venation look densely reticulation) that present in *Cassia moschata* (Figs. 4.29C, N) make it less likely to be NLR. *Cassia grandis* L.f., although share brochidodromous venation, has different shape, weaker intersecondary veins and weaker veins of the order higher than 3 (figs. 4.29L-M). *Gilletiodendra mildbraedii* (Harms) Vermoesen is also similar in shape (especially with SUT 1149 in Fig. 4.29I) but its mixed craspedodromous and reticulodromous venation is distinctive from that of the fossils. *Diplotropis duchei* has more symmetry shape (upper half), less pronounced distal shoulder, weaker brochidodromous venation, smaller areoles with more FEV. *Macrolobium gracile* Benth. and *Sesbania grandiflora* share less features than the others do.

The most similar venation patterns between the modern species and the fossil can be seen in *Adenanthera klainei* and *Gymnoclanus chinensis* (Figs. 4.29K, Q, T). The shared features include brochidodromous venation, angle of divergence of secondary veins, frequency and size of intersecondary veins, thick vein at an order higher than 3, size and shape of areoles, number of FEV, and MUV. However, *Adenanthera klainei* and *Gymnocladus chinensis* have lower l/w ratio than the fossils. The former has a shape more similar to the fossils than the latter does but the basal extension, short and stout petiolule and angular shoulder make it different from the fossils. Based on the venation and shape the fossils share with *Adenanthera klainei* and *Cassia moschata,* it was therefore decided to propose the name *Adenanthassia thailandica* gen. et sp. nov. Sawangchote, Grote, Dilcher. Part of the name *Adenanthera* precedes part of the genus name *Cassia* because the venation pattern, more similar to that of the fossils in *Adenanthera klainei* (and also some other species of the genus), was believed to be more stable than the shape (and also size) which are similar to leaves of *Cassia moschata*.

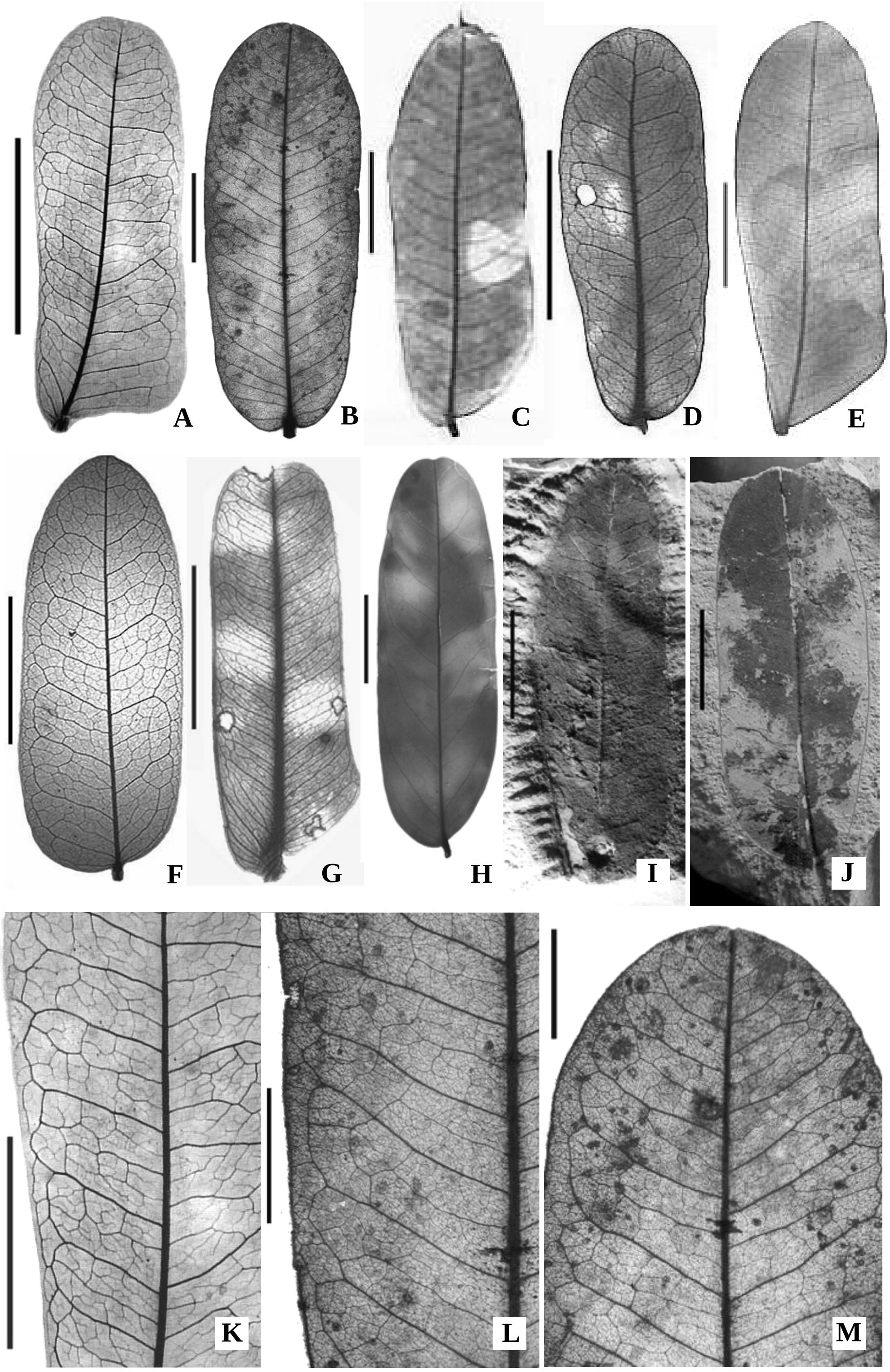
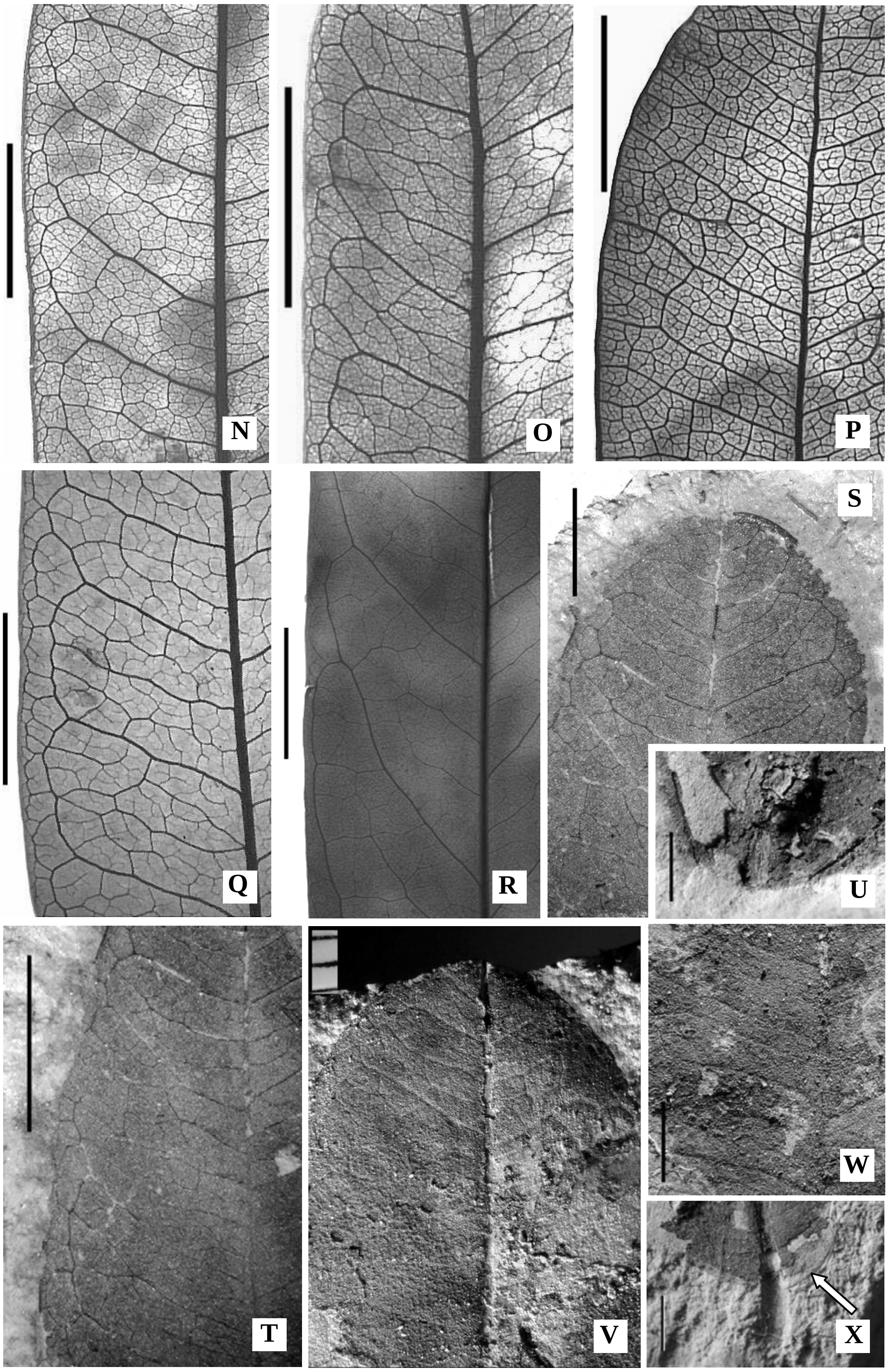


Fig. 4.29 *Adenanthassia paleothailandica* and its possible living relatives. (A-H) Leaves of *Adenanthera klainei*, *Cassia grandis*, *Cassia moschata*, *Diplotropis duckei*, *Gilletiodendron mildbraedii*, *Gymnocladus chinensis*, *Macrolobium gracile* and



Sesbania grandiflora, respectively. (I-J) Leaves of *Adenanthassia paleothailandica*, line drawing was on impression of the margin of the leaf in (J). (K-L, N-R) MVP of the species in (A-D, F, H), respectively, the MVP of the leaf in (G) is not shown. (M) Venation pattern at apical 1/3 of *Cassia grandis* showing resemblance to the leaves in (S, V). The venation at apical 1/3 is not available for the species from Dilcher's collection (A, C-E, F-G). (T) MVP of the leaf in (I). (W) Courses of secondary veins of the leaf in (J) that resemble the leaf in (T); MVP at the equivalent portion to the leaf in (T) was missing. (U, X) Close up of the base of the leaf in (I) and (J) respectively; the petiolules are more slender than those of *Pithecellobium paleolampangensis* in Figs. 4.33X. Scale bar = 1 cm in A-F, H-J, 5 mm in G, K-R, T, 3 mm in S, W, 2 mm in U, V, X.

Division----Magnoliophyta

Order---- Fabales Bromhead

Family---- Fabaceae Lindl.

Subfamily---- Mimosoideae Kunth

Tribe---- Ingeae Benth.

Genus---- *Albizia* Durazz.

Species----*Albizia paleoproceroides* sp. nov. Sawangchote, Grote, Dilcher

Holotype---- Specimen SUT 718 (Plate 43, Figs. 4.30H and K), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

Locality----Li basin, Amphoe Li, Lamphun Province, Northern Thailand, 17° 45′ N, 99° 00′ E, locality number 019.

Age---- Approx. Late Oligocene – Early Miocene.

Number of specimens---- One pyritized well-preserved leaf compression was studied.

Etymology----The specific epithet refers to the close similarity of leaf architecture between the fossil and the extant *Albizia procera*.

Description: Leaflet, asymmetrical, oblong; size 2.15x1.05 cm; apical most part missing; base rounded with distal extension; margin entire; texture probably chartaceous; petiole 1.5 mm long (impression); venation pinnate, eucamptodromous (also similar to compound agrophic according to LAWG, 1999), primary vein stout; secondary veins 7-8 pairs, most of them with proximal 2/3 straight and distal 1/3 curved, 0.12-0.5 cm apart, basal and apical adjacent veins closer together than the middle veins, opposite or alternate, thick, angle of divergence narrow to moderate acute (33°-53°), except most basal veins at most right angle, more acute on one side than on the other; MVP intermediate type I & VII, approximately 7-10 ELMA, mostly quadrilaterals, branching-off angle mostly right angle; intramarginal veins absent; intersecondary veins absent; tertiary vein angles of origin mostly AA, some AR, RA, or some RR near margin (acute angles predominantly wide (74°-80°)), mixed percurrent/forked and percurrent/simple, the simple ones recurved, oblique in relation to the midvein, tertiary vein angle increasing outward, predominantly alternate, mostly distant; quaternary and quinternary moderate and orthogonal; highest vein order 7, highest vein order showing excurrent branching 6; marginal ultimate venation probably fimbriate; areoles well developed, oriented, mostly pentagonal to polygonal, mostly medium sized (approx. 0.3-0.5 mm), veinlets branched 1-2 times (highest ones may be not well preserved).

Affinity**:** Twenty four species of *Albizia* from BKF and PSUH were examined and compared with the fossil. In addition, the pictures of herbarium specimens of 3 species collected from neighboring countries, Myanmar and China, and stored at New York Botanical Garden (NYBG) were also brought into comparison (all are listed in appendix E). As we know that leaflets of a leguminous species may vary to a large extent in shape and size, such variation was therefore investigated in every species and only the leaflets similar to the fossil were brought into comparison.

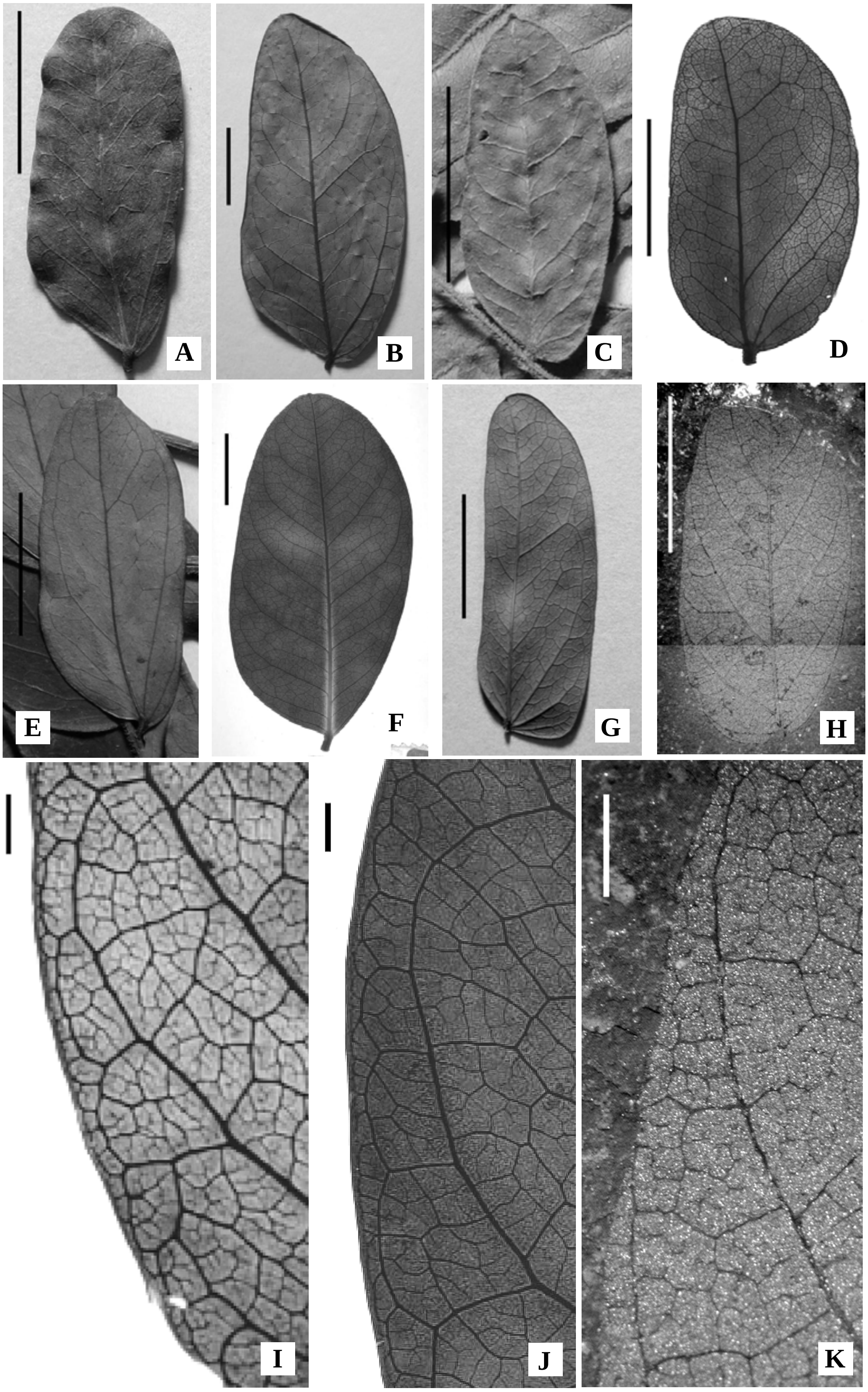


Fig. 4.30 *Albizia paleoproceroides* and its possible living relatives. (A-G) Leaf of *Albizia corniculata*, *A. crassiramea*, *A. ferruginea*, *A. lebbeck*, *A. millettii*, *A. procera*, and *A. odoratissima*, respectively, that are more or less similar to *Albizia*

paleoproceroides shown in (H). (I-K) MVP of *A. lebbeck*, *A. procera* and *A. paleoproceroides*, respectively. Scale bar = 1 cm in A-H, 1 mm in I-K.

Of all the species examined, no species looked exactly the same as the fossil. All the modern species illustrated here except *A. odoratissima* (L.f.) Benth (Fig. 4.30A-G) are more similar to the fossil than the other species which were not shown. These species have mixed eucamptodromous and brochidodromous (so-called weak brochidodromous according to Leaf Architecture Working Group (1999)). For example, *A. lebbeck* L. (Fig. 4.30D) has secondary veins on the distal side curved up and joined with superadjacent secondary veins. This make the venation on this side look more brochidodromous than on the other side that looks more eucamptodromous. *A. procera* (Roxb.) Benth. (Fig. 4.30F), on the other hand, has the same features as *A. lebbeck* does but exhibited on the opposite side. In contrast to the modern species, the fossil has secondary veins that run directly to the margin on both sides (Fig. 4.30H, K; Plate 43).Among the species shown in Fig. 4.30A-G, *A. procera* (Fig. 4.30F) is the most similar to the fossil and *A. lebbeck* seems to be the second. Both have leaflets that are about the same size (Fig.4.30F is an example of the bigger one). The distal basal half of the leaf in *A. procera* and in the fossil is broader than the proximal half. In contrast, *A. lebbeck* has the proximal basal half broader than the distal one. In addition, the leaf base of the fossil is rounder than those of *A. lebbeck* and *A. procera*. *A. procera* has a similar number of secondary veins with similar angles of divergence while *A. lebbeck* has a different arrangement of the secondary veins (e.g., forming marginal loops on the distal half of the leaf and having branching of the primary vein and some secondary veins from the points at the base that are close to each other). *A. lebbeck* and *A. procera* have MVP type I that is close to that of *A. paleoproceroides*

(Fig. 4.30I-K). Number and shape of ELMA of *A. paleoproceroides* are more similar to those of *A. procera*. Leaves of *A. procera* also share percurrent/forked tertiary veins with *A. paleoproceroides*. One clearly seen difference between *A. paleoproceroides* and *A. procera* is the presence of intersecondary veins in *A. procera* but their absence in *A. paleoproceroides*. Owing to more characters *A. paleoproceroides* being shared with *A. procera*, it is therefore given such a name.

Division----Magnoliophyta

Order----Fabales Bromhead

Family----Fabaceae Lindl.

Subfamily----Faboideae

Tribe---- Tephrosieae (Benth.) Hutch.

Genus----*Antheroporum* Gagnep.

Species----*Antheroporum paleolamphunensis* sp. nov. Sawangchote, Grote, Dilcher

Holotype----Specimen number SUT 1341 (Plate 44, Figs. 4.31F, K-M, O), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

***Locality*----**Li Basin, Amphoe Li, Lamphun Province, Northern Thailand, 17° 45′ N, 99° 00′ E; locality number 002.

Age---- Approx. Late Oligocene – Early Miocene.

Number of specimens---- Only one specimen; most of the leaf area was pyritized with less clearness of the venation pattern than that of SUT 718.

Etymology---- The specific epithet refers to the existence of the species in Lamphun Province, Thailand, in the geological past.

Description: Leaflet, symmetrical, narrow elliptic; size 8.5x 2.6 cm; apex attenuate (most apical part missing); base obtuse normal; margin entire; texture probably chartaceous; petiole 2 mm long; venation pinnate, eucamptodromous, primary vein stout, slightly curved; secondary veins approx. 7-8 pairs, 0.6-1.3 cm apart, alternate, moderately, uniformly curved, angle of divergence moderate acute (43°-57°), upper more acute than lower; MVP type I with probably 2 CMArC, approximately 8-10 ELMA, mostly quadrilaterals, branching-off angles mostly right angles; intramarginal vein absent, intersecondary veins frequent, rather strong; tertiary vein angles of origin mostly RR, AR, or RA (acute angles are predominantly wide (80-85°)), pattern not clearly seen but probably percurrent/forked, oblique in relation to the midvein, tertiary vein angle increasing outward, predominantly alternate, mixed close and distant; quaternary and quinternary moderate and orthogonal; highest vein order probably 6-7; marginal ultimate venation probably fimbriate; areoles seem to be well developed, oriented, probably variable in shape from quadrilateral to polygonal, probably mostly medium sized (approx. 0.3-0.5 mm), veinlets seeming to branch 1-2 times.

Affinity: Some species of the genera *Antheroporum*, *Archidendron* and *Crudia* were considered to have leaves with similar shape and venation to the fossil (Fig. 4.31A-D). *Antheroporum glaucum* Z. Wei, *Antheroporum pierrei* Gagnep., and *Archidendron* sp. are the most similar, whereas *Archidendron poilanei* (Kosterm) Nielsen and *Crudia lanceolata* Ridl. are the examples of leaves with less similarity. *Archidendron poilanei* leaves have a different leaf tip and base, while *Crudia lanceolata* leaves have a different leaf shape, and a larger number of the secondary veins with more obtuse angles of divergence. Furthermore, leaves of *Crudia* spp. usually have secondary veins curved up to form an arch (at the margin) and join with superadjacent secondary veins (making them look more brochidodromous than those of *Archidendron* and *Antheroporum* spp.). The species shown in Fig. 4.31A-C share with the fossil the size, similar leaf shape, close number of secondary veins and MVP type I (Figs. 4.31A-C, H, J, L). The number of CMArC of *Antheroporum pierrei* and *Archidendron* sp. is 2, while that of the fossil is not clearly seen but probably 2 (Figs. 4.31S, J, L). Angles of origin of tertiary veins of these species and of the fossil are also similar (mostly wide acute to right angle, in Fig. 4.30M, N). Furthermore, areoles in *Antheroporum glaucum*, *Antheroporum pierrei*, *Archidendron* sp. and the fossil (only some can be seen in the fossil) are well-developed, orientated and about the same size. Number and shape of ELMA of *Antheroporum pierrei* are closer to those of *Archidendron* sp. and the fossil (5-6 at base) than to those of *Antheroporum glaucum* (4-5 at base) (e.g., Figs. 4.31H, N, O). However, the leaf shape, shape of apex and base, number, angle of divergence and the courses of secondary veins and prominence of veins of *Antheroporum pierrei* seem to be shared most with the fossil. Hence the fossil is named *Antheroporum paleolamphunensis*.

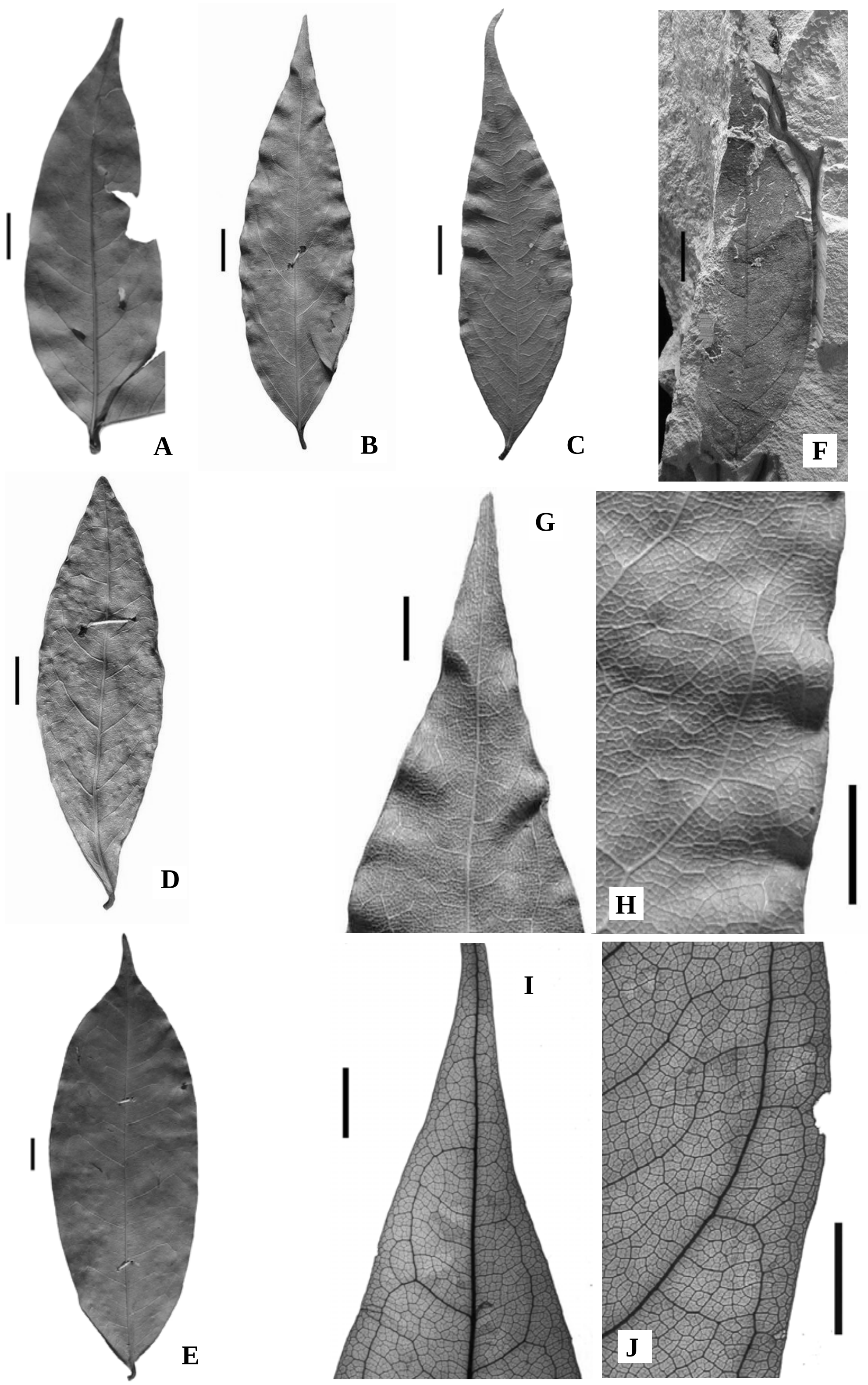
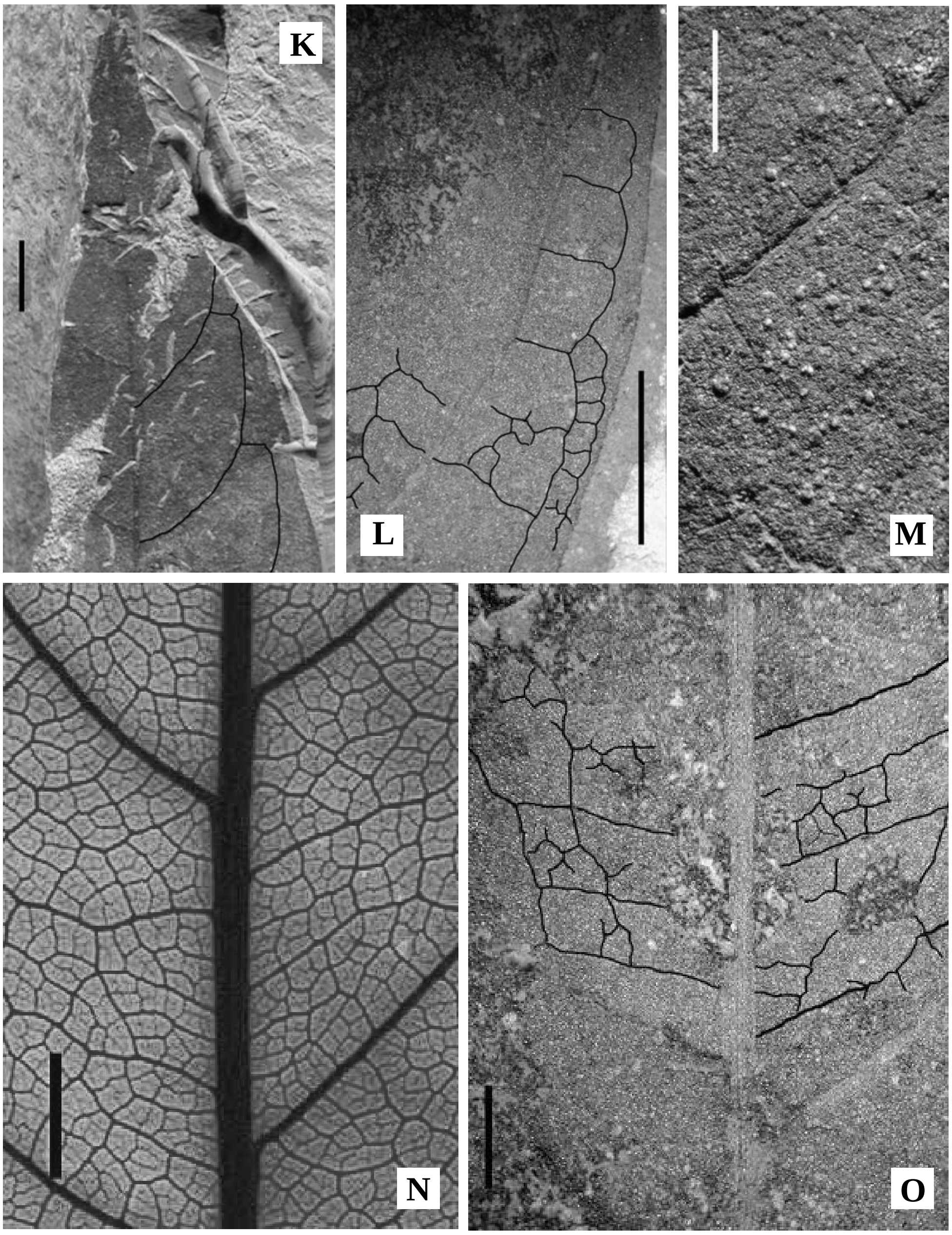


Fig. 4.31 *Antheroporum paleolamphunensis* and its possible living relatives. (A-E) Leaves of *Antheroporum glaucum, Antheroporum pierrei, Archidendron* sp.,



Archidendron poilanei, and *Crudia lanceolata*, respectively, that are more or less similar to *Antheroporum paleolamphunensis* shown in (F). (G, I, K) Similar apex shape and venation pattern of apical 1/3 of *Antheroporum pierrei*, *Archidendron* sp. and *Antheroporum paleolamphunensis*. (K) Line drawings were made on visible secondary veins of *Antheroporum paleolamphunensis*. (H, J, L) MVP of *Antheroporum pierrei*, *Archidendron* sp. and *Antheroporum paleolamphunensis*, respectively. (M) Tertiary vein angles of origin of *Antheroporum paleolamphunensis* that are similar to those of *Antheroporum pierrei*, and *Archidendron* sp. in H and J. (N, O) Comparison of intersecondary veins, orientation of tertiary veins, and size and shape of areoles of *Archidendron* sp. and *Antheroporum paleolamphunensis*, respectively. These similar features were also found in *Antheroporum pierrei* but not shown here. Scale bar = 1 cm in A-F, 5 mm in G-L, 2 mm in M-O.

Division----Magnoliophyta

Order----Fabales Bromhead

Family----Fabaceae Lindl.

Subfamily---- Caesalpinioideae Kunth.

Tribe---- Cassieae Bronn.

Genus----*Cassia* L.

Species----*Cassia paleosiamea* sp. nov. Sawangchote, Grote, Dilcher

Holotype----Specimen SUT 706 (Plate 46, Figs. 4.32D-E, L-M), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

Paratype----SUT 665 (Plate 45, Figs. 4.32C, J-K).

Locality---- Mae Moh basin, Amphoe Mae Moh, Lampang Province, Northern Thailand, 18° 18′ 12″ N, 99° 44′ 02″ E, locality number 019.

Age---- Approx. Miocene.

Number of specimens----Two pyritized moderately well preserved leaf compressions.

Etymology----The specific epithet refers to the close similarity of leaf architecture between the fossil and the extant *Cassia siamea*.

Description: Leaflet, slightly asymmetrical (especially at base of SUT 706), narrow elliptic; 3.6x1.5 (estimated 4.6x1.5) and 3.8x1.3 cm for SUT 665 and SUT 706 respectively; apex mucronate in SUT 706, but not clearly seen in SUT 665; base obtuse normal (SUT 706); margin entire; texture probably chartaceous; petiole missing; venation pinnate, eucamptodromous with weak brochidodromy toward the apex, primary vein moderate, almost straight; secondary veins 12-13 pairs, most of them having a slightly zigzag course and bending up sharply near the margin, 0.3-0.7 cm apart, opposite or alternate, moderate, angle of divergence moderately acute (48°-60°); MVP mixed type I and II, approximately 5-6 ELMAs, mostly quadrilateral, BATV mostly right angle; intramarginal vein absent; intersecondary veins frequent, rather strong; tertiary veins mixed percurrent/forked and reticulate; quaternary and quinternary veins rather thick and randomly oriented; highest vein order probably 6-7; marginal ultimate venation possibly fimbriate; areoles moderately developed, relatively random, variable in shape from quadrilateral to polygonal, probably mostly medium sized (approx. 0.5-1.0 mm); veinlets branched 2-3 times (higher orders may not be preserved).

Affinity: *Cassia paleosiamea* closely resembles *Cassia siamea* Lam.. The set of characters they share includes shape and size (Figs. 4.32A, C, D-E); mucronate apex (Figs. 4.32H, M); size and courses of primary vein; number, courses, and angle of divergence of secondary veins; frequency and size of intersecondary veins; tertiary vein pattern; and development, size and shape of areoles. They possess eucamptodromous venation with weak brochidodromy at the apical part and MVP mixed type I and II. They also have similar numbers of ELMA counted at the same region of the leaf (Figs. 4.32F-H, J-L). A difference is that the MArC in the fossil is slightly thicker than that of *Cassia siamea* (Figs. 4.32G, J). Nevertheless, not only this fossil and *Cassia siamea* have weak eucamptodromous venation at the apical part, but also leaves of a large number of leguminous species have this character. Examples are those in Figs. 4.32A-D, F, M, S, and V that are weakly brochidodromous all over the

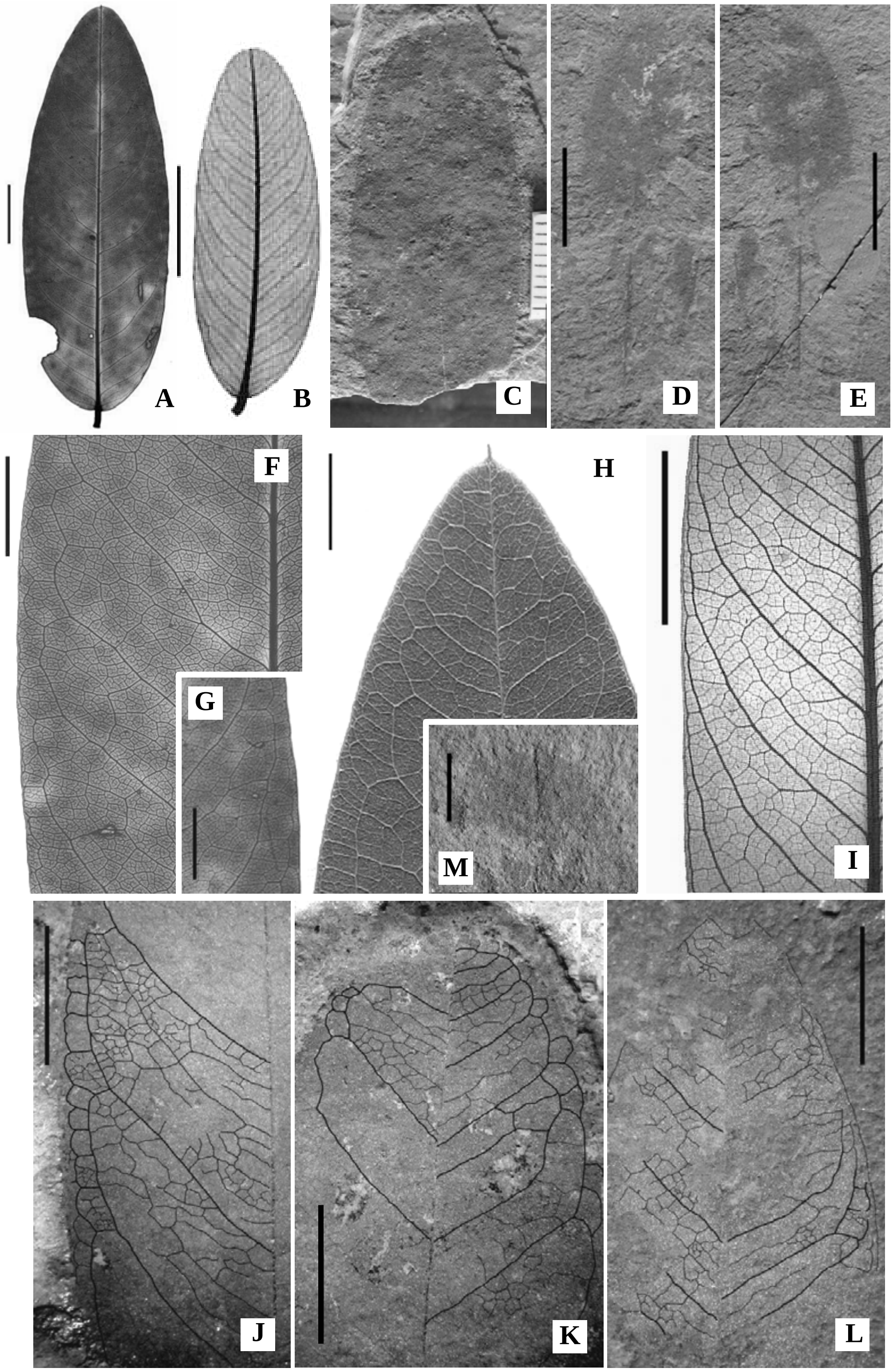


Fig. 4.32 *Cassia paleosiamea* and its possible living relatives. (A-B) Leaves of *Cassia siamea* and *Tipuana speciosa*. (C) *Cassia paleosiamea* with basal 1/5 missing (SUT 665). (D-E) Part and counter part of the specimen SUT 706. (F) Type II and (G) type I MVP found on the same leaf of *Cassia siamea*. (H, M) Mucronate apex of *Cassia siamea* and *Cassia paleosiamea* (specimen in D-E), respectively. (I) Type IV MVP of

Tipuana speciosa. (J) Line drawing made on marginal portion of the specimen in (C) to clearly show mixed type I and II MVP. (K) Apical 1/3 of the same specimen with line drawing showing weak brochidodromous venation. (L) Line drawing made on apical part of the specimen in (E). The shape of apical part in (H) is closer to that in (L) than to that in (K). Scale bar = 1 cm in A-E, 5 mm in F-K, 2 mm in L.

leaf blade. The fossil *Cassia paleosiamea* (Fig. 4.32K) might have been identified as *Adenanthassia paleothailandica* if only the venation pattern at the apical part were available for study (Figs. 4.32S, V). However, different MVP on the remaining parts of the leaves lead to different affinities to which the fossil leaves were assigned (Fig. 4.32J, Fig. 4.29T). *Cassia siamea* itself has highly varied leaves. Some leaves, which are not shown here, are broader and have an emarginate apex with extension of the primary vein like that shown in Fig. 4.32H. No matter what the shape and size of the leaves would be, the venation pattern was found to be the same. Some species of *Dalbergia*, e.g., *D. fusca* Pierre and *D. nigrescens* Kurz. var. nigrescens, have leaf shape and size, emarginate apex and venation pattern similar to *Cassia siamea*, but they don’t have extension of the primary vein at the apex (Fig. 4.35B). *Tipuana speciosa* Benth. (Fig. 4.32B) is an example in which detailed analysis of MVP can exclude it from being a near relative. It resembles *Cassia paleosiamea* in that it has similar leaf size and shape and eucamptodromous venation. The main difference is MVP type IV with small and narrow ELMA in *Tipuana speciosa* (Fig. 4.32I).

Division----Magnoliophyta

Order----Fabales Bromhead

Family----Fabaceae Lindl.

Subfamily---- Mimosoideae Kunth

Tribe---- Ingeae Benth.

Genus----*Pithecellobium* Mart.

Species---- *Pithecellobium paleolampangensis* sp.nov. Sawangchote, Grote, Dilcher

Holotype----Specimen SUT 1051 (Plate 49, Figs. L, V and X), paleobotanical collection, Center for Scientific and Technologic Equipment, Suranaree University of Technology, Suranaree subdistrict, Muang district, Nakhon Ratchasima province, Thailand.

Paratype----SUT 1023 (Plate 47, Figs. J and U), SUT 1028 (Plate 48, Figs. K and W).

***Locality*----**Mae Moh Basin, Amphoe Mae Moh, Lampang Province, Northern Thailand, 18° 18′ 12″ N, 99° 44′ 02″ E, locality number 025.

Age---- Approx. Miocene.

Number of specimens----Three pyritized specimens with different degrees of clearness of venation pattern.

***Etymology*----** The specific epithet refers to the existence of the species in Lampang Province, Thailand, in the geological past.

Description: Leaflet, asymmetrical, rhomboidal; length can not be determined, width 1.15, 1.5 and 1.8 cm in SUT 1051, SUT 1028 and SUT 1023, respectively; apical part missing; base obtuse normal with basal extension (possibly proximal, white arrows in Fig. 4.33X); margin entire; texture probably coriaceous; petiole 1 mm long (complete in SUT 1051 and incomplete in the other two); brochidodromous venation (most clearly seen in SUT 1051) with secondary vein(s) and/or intersecondary vein(s) running between the two veins that form the arches (similar to *Adenanthassia paleothailandica* in Fig. 4.29T); primary vein stout, straight or slightly curved; secondary veins of the preserved parts approx. 8-9 pairs, 0.1-0.3 cm apart, alternate, subopposite, or opposite, moderate, mostly slightly curved or zigzag, some with proximal 2/3 straight, angle of divergence moderate to wide acute (60°-75°); intramarginal vein absent, intersecondary veins frequent, rather strong; tertiary veins mixed percurrent/forked and reticulate; quaternary and quinternary veins rather thick and randomly oriented; highest vein order probably 5-6; marginal ultimate venation fimbriate; areoles moderately developed, relatively random, variable in shape from quadrilateral to polygonal, probably medium to large sized (approx. 0.5-1.5 mm), veinlets branching 2-3 times (higher orders of fine size may not be preserved).

Affinity: Unfortunately, none of the three fossils have the upper part of the leaf. Only the lower parts were therefore compared to the similar modern leaves shown in Figs. 4.33A-I (*Piptadenia paniculata* Benth., in Dilcher's collection is not shown here). These modern leaves have a more or less rhomboidal shape and a strongly asymmetrical base like those in the fossils (Figs. 4.33J-L). Brochidodromous venation similar to that of the fossils (Figs 4.33U-W) is present in *Archidendron clypearia* (Jack) Nielsen, *A. contortum* (Mart.) Nielsen, *Pithecellobium leucocalyx* Standl. and *P. macradenium* Pittier (Figs 4.33A-B, E, G). The rest of the species have more eucamptodromous or weaker brochidodromous venation (Figs. 4.33C-D, H-I). Among the leaves that share the type of venation, *P. leucocalyx* and *P. macradenium* seem to share more features than the remaining two species. These features include size, shape, distal convexity, number and courses of secondary veins, frequency and strength of intersecondary veins, orientation of veins higher than secondary order and development and other features of areoles. Between the two *Pithecellobium* species, *P. leucocalyx* shares fimbriate MUV with the fossil whereas *P. macradenium* has looped MUV. *A. clypearia* also shares many venation features as mentioned above, but the arches of secondary veins were lined up with two layers of higher order loops exmedially making these arches farther from the margin than those in the *Pithecellobium* species and in the fossils (Figs. 4.33M, P, Q, T-W). This feature may be viewed as MVP type VI (where the venation at the margin looks more eucamptodromous) and is also present in *A. contortum*, *Caesalpinia bondac* (L.) Roxb., *Piptadenia paniculata* and *Pithecellobium dulce* (Roxb.) Benth. Besides, the proximal half of the base of *A. clypearia* is also thinner and looks more wedge-shaped (white arrow in fig. 4.33Z) than those of the *Pithecellobium* species, *Samanea saman* Merr. and the fossils (Figs. 4.33E, G-H, J-L, X-Z). *S. saman* and *Stryphnodendron excelsum* Harms, on the other hand, have MVP equivalent to type II and IV, respectively (*S. saman* looks the most eucamptodromous). *P. lindsrefolium* is a species with distinctive strongly developed secondary veins in the proximal half that run submarginally up to apical third of the leaf.

Due to more similarities shared with *Pithecellobium* species, the fossil is therefore named *Pithecellobium paleolampangensis*.

N.B.: Although these fossils look similar to *Adenanthassia paleothailandica* in that they have an asymmetrical base and similar venation pattern they were still considered to have different affinities. The reason is that these fossils have stouter and relatively shorter petiolules. The upper part of the petiolule connected to the primary vein is expanded at a point higher than the points at which the margins meet the petiolule (black arrows in Fig. 4.33X). The size of this swollen petiolule is distinctly different from that of the primary vein.

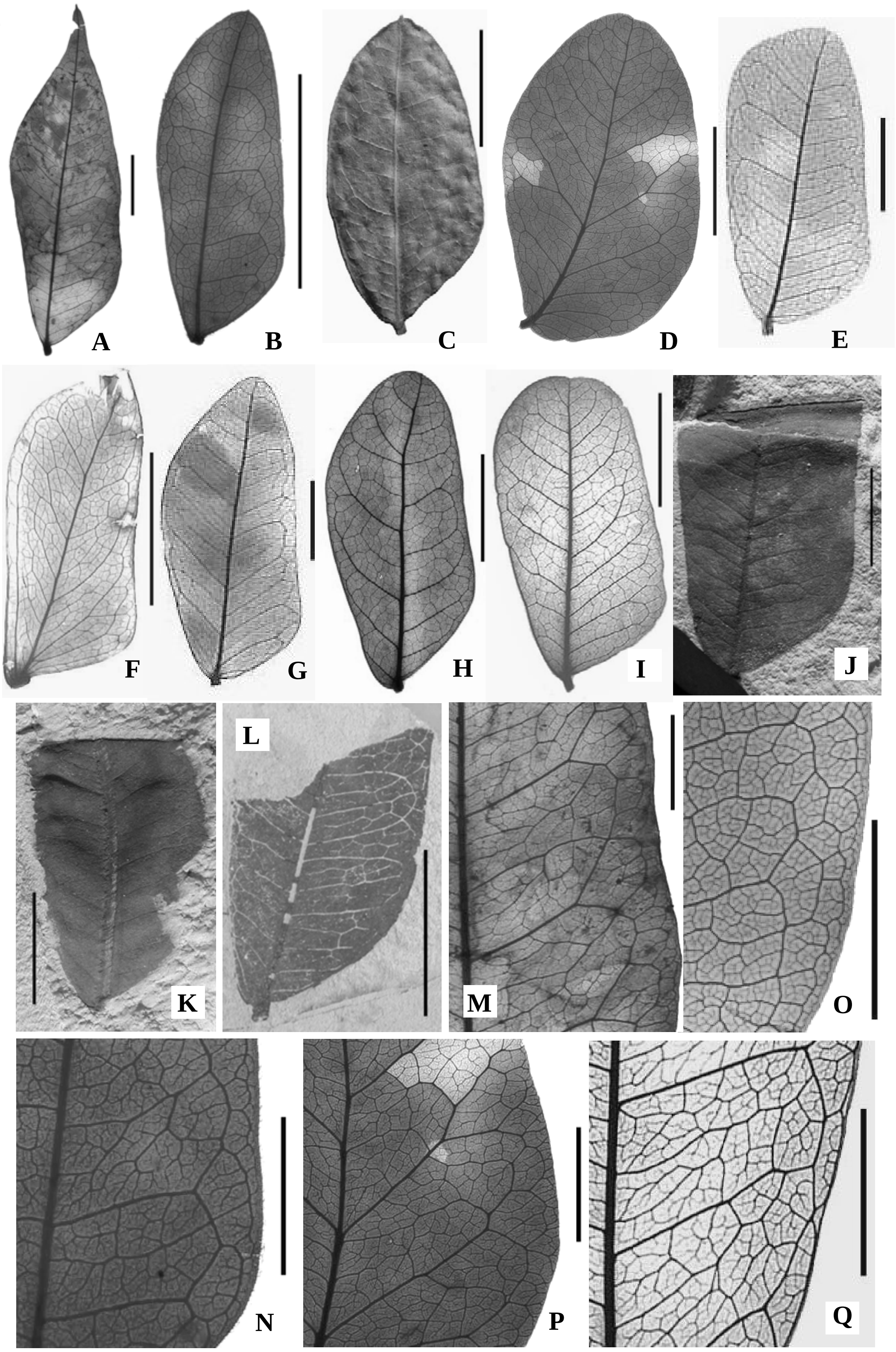
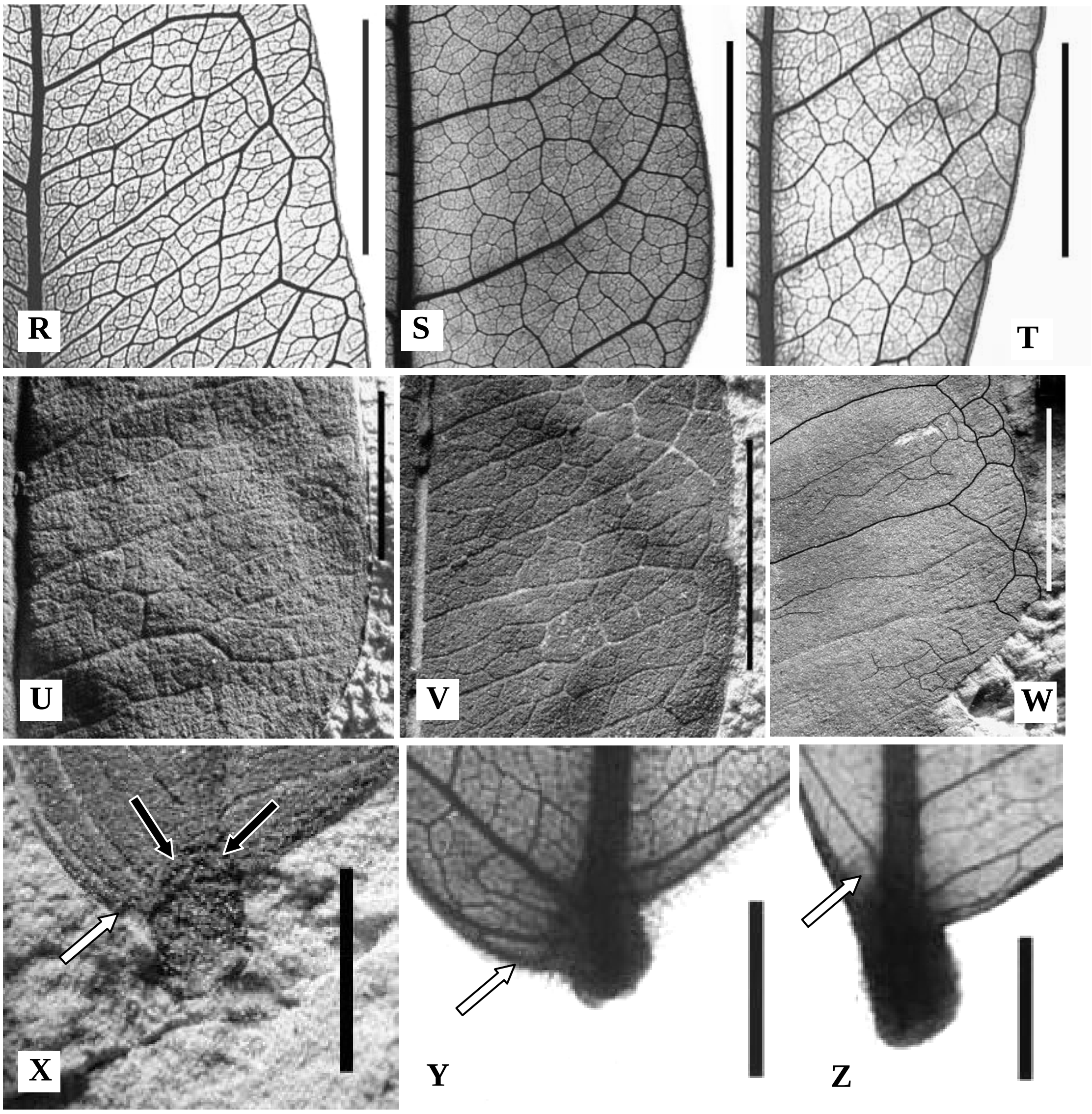


Fig. 4.33 *Pithecellobium paleolampangensis* and its possible living relatives. (A-I) Leaves of *Archidendron clypearia*, *A. contortum*, *Caesalpinia bondac*, *Pithecellobium dulce*, *P. leucocalyx*, *P. lindsrefolium*, *P. macradenium*, *Samanea saman* and



Stryphnodendron exelsum, respectively, that are more or less similar to *Pithecellobium paleolampangensis* shown in (J-L). (M-T) MVP of the above mentioned modern species, except *P. lindsrefolium*, respectively. (U-W) MVP of three fossils show different qualities of preservation. Line drawing was made on the specimen in (W) to demonstrate the same venation pattern as seen in (U-V). (X-Z) The most lower base shape and size and shape of petiolules of *P. paleolampangensis* (specimen in L), *S. saman* and *A. clypearia*, respectively (details in text). These features in *P. leucocalyx* and *P. macradenium* are not shown due to low resolution of the illustration from Dilcher's collection. However, it can be seen (in E, G) that these features are very similar to those shown in (X-Y) and different from those in (Z). Cleared leaves in (E-G, I) are from Dilcher's collection. Scale bar = 1 cm in A-L, 5 mm in M, O, P-W, 2.5 mm in N, 2 mm in X-Z.

4.2.2 Classification of MVP with ELMA of leguminous modern leaves

The details of MVP types of each genus or species of Leguminosae are not presented here as it was done for Anacardiaceae. However, the classification system of MVP applied to anacardiaceous modern and fossil leaves is applicable to the leguminous modern and fossil leaves as well. Some examples of these can be found in comparisons of the fossils with the modern leaves in the previous section. More studies on MVP types of leguminous leaves and leaves of other families are needed to make classification of MVP types cover all natural patterns and be as valid a taxonomic tool as possible.

4.2.3 Leaf architecture of leguminous modern leaves

Because of the size of the extant family and the great morphological diversity present in leaflets (and also in fruits), the comparisons were therefore performed as extensively as they could be The detailed architectural study, grouping of morphotypes and construction of the key(s) for any level of taxonomic rank were not attempted in this study. However, initiation of such a work is still in need and I hope to start with the plants of Thailand in the near future. As studied so far, leaves of Leguminosae are very variable in shape and size. Although the venation patterns seem to be more intraspecifically stable (as generally stated in LAWG, 1999), interspecific overlapping (i.e. different species with similar venation pattern) usually occurs. As a result, ranges of variability in size and shape of modern leaves are as worth studying as venation patterns because it is helpful at least for grouping and identification of the leaf fossils of the same morphotypes. The most recognizable and one of the most characteristic features among the leaflets of Leguminosae is the rhomboidal shape (Figs. 4.34A-B). This shape expressed in different l/w ratios, different degrees of asymmetry of apices and bases and degree of curvature of the margin (e.g., the so-called distal convexity in Fig. 4.34B). Other common characteristics include short attachment (petiolules for leaflets), emarginate and mucronate apex (among other types that can be found in other families) and a base with shoulders.

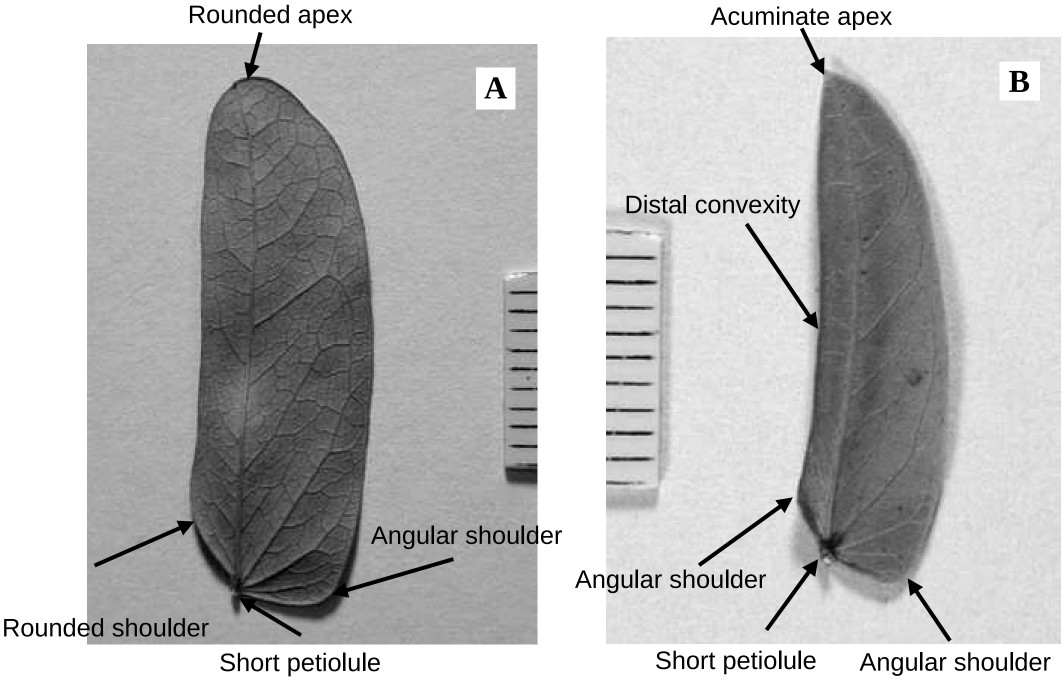


Fig. 4.34 Some features of some mimosoid leaflets with strongly asymmetrical apices and bases. (A) *Albizia odoratissima*. (B) *A. lebbekoides* (DC.) Benth.

Strongly asymmetrical bases of leaflets of other shapes are also a characteristic of the family (Fig. 4.35A). A large number of leguminous leaves (e.g., Fig. 4.35B) share characters with leaves of other families with which we are familiar and lead us to the difficult-to-answer question, “Is this leaf a leaflet?” It is more difficult in the case of symmetrical elliptic leaves that are common in a great number of plant families. Furthermore, the leaflets are easily detached from the rachis both during the dry season and during transportation, as we usually find them preserved.

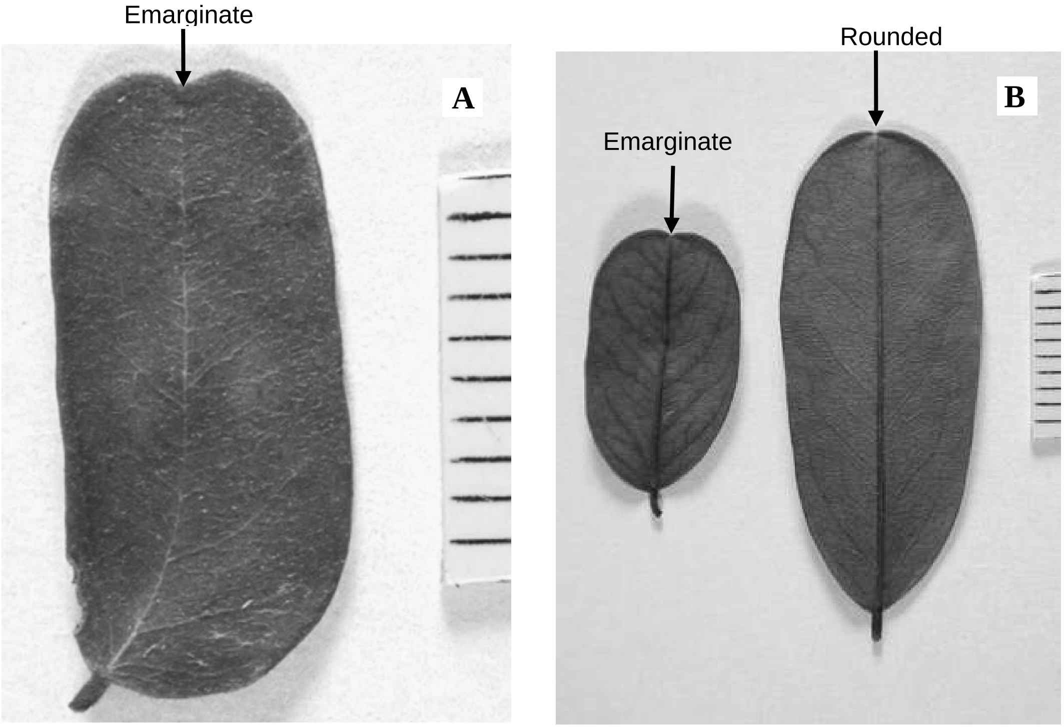


Fig. 4.35 Some features of some papilionoid leaflets. (A) *Dalbergia tamarindifolia* Roxb., shape oblong with strongly asymmetrical bases. (B) *D. stipulacea* Roxb., shape elliptic to oblong, may be symmetrical or slightly asymmetrical at base, apices may be rounded or emarginate. Petiolules are not as short as those in Figs. 4.34 A-B

Attention should also be paid to the asymmetrical or symmetrical leaflets of other families such as Connaraceae (e.g., Fig. 4.36A), Oxalidaceae (e.g., *Biophytum adiantoides* Wight. (Fig. 4.36B), and *B. sensitivum* (L.) DC.), and Zygophyllaceae (e.g., *Tribulus cistoides* L.). Besides morphological similarity, wrinkled pulvinus is also shared between Leguminosae and Conneraceae (Herendeen et al., 1992).

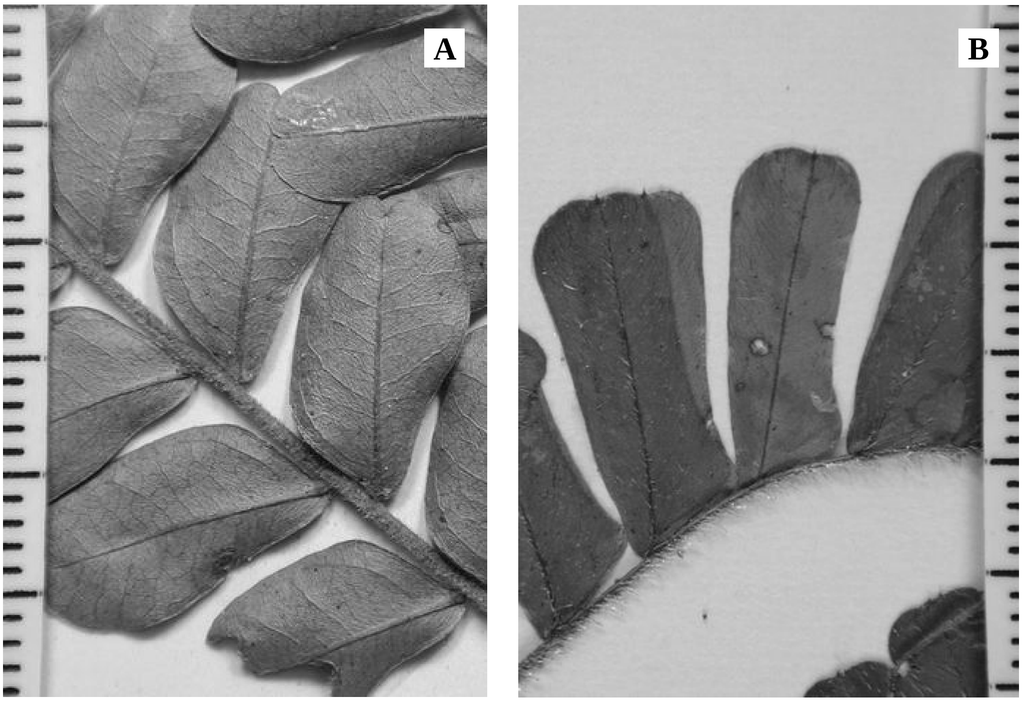


Fig. 4.36 Leguminous-like leaflets. (A) Rhomboidal leaflets of *Rourea* sp. (Connaraceae) (PSU SN 182055). (B) Oblong leaflet with strongly asymmetrical base, slightly asymmetrical subemarginate apex with primary vein extension, angular shoulder and distal convexity (*Biophytum adiantoides*, Oxalidaceae).

Chapter V

Discussion

5.1 Anacardiaceous fossil leaves

5.1.1 *Mangifera* L.

5.1.1.1 Fossils of *Mangifera*

Fossil leaves and wood with affinities to *Mangifera* were found and studied mostly in Southeast Asia. The first known fossil leaf impressions of *Mangifera* from Assam were discovered and reported in 1912 by Seward (Bompard and Schnell, 1997). Owing to the identification to present-day *M. pentandra*, Bompard and Schnell (1997) mentioned that the affinity of this fossil remains doubtful since it is not always easy to identify the different species even from fresh leaves. However, according to this finding, the emergence of the genus was indicated to be in mainland Southeast Asia during the Eocene. *M. takashimensis*, described by Matsuo (1967) from the Paleocene of Japan, is another fossil leaf the affinity of which, on the basis of its description and photograph, was not convincing. The only reliably identified species of fossil *Mangifera* was of a leaf first described from the Late Tertiary sediments of Bihar, India and named as *M. someshwarica*, by Lakhanpal and Awasthi (1984). It was successively recorded from the Siwalik sediments of Koilabas, Nepal (Prasad, 1994) and Oligocene sediments of Assam, India (Awasthi and Mehrotra, 1995). This fossil M*angifera* has an affinity close to *M. indica* and *M. sylvatica*. Apart from fossil leaves, fossil wood of *Mangifera* is also known from the Middle Miocene of Assam, Middle to Upper Miocene of West Bengal, Upper Miocene-Pliocene of Arunachal Pradesh and Pondicherry, Pliocene of Rajasthana and Neogene of Sumatra and Borneo (Mehrotra, Dilcher, and Awasthi, 1998).

5.1.1.2 On the origin of the genus and the common mango

The origins of the genus *Mangifera* and particulary the economically-important common mango *M. indica* have long been suggested with inevitable controversies occurring on the way of the development of the knowledge. Indo-Burma was considered by Valvilov (1926, available at http://www.horticultureworld.net/botany-taxonomy.htm) as the center of origin of the genus. Mukherjee (1951, 1953), based on the available study of the history, morphology, phyto-geographical distribution of all allied species, fossil records, and evidence of numerous wild and cultivated varieties in India, concluded that the genus had its origin somewhere in the Myanmar—Thailand—Indo-China area or in the Malayan area. Santapau (1966) and Simmonds (1976) proposed eastern India as the center of origin of the genus. With more recent studies and evidence, Mukherjee (1997) and Bompard and Schnell (1997) suggested Southeast Asia as the center of origin and diversity of the genus. For *M. indica*, the center of origin has been a matter of speculation for many years. Mukherjee (1951b) suggested that *M. indica* first appeared during the Quaternary period. He also proposed that there are mainly three centers of distribution in the India-Burma-Siam (former name of Thailand) area, the Philippines and the Malay Penninsula (Mukherjee, 1967). He also provided reasons to support his suggestion concerning the presence of wild *M. indica* and its allied species, *M. sylvatica* and *M. caloneura*, in the area, the history of cultivation and introduction, the finding of fossil and its Sanskrit name. According to his reasons, it is more likely that the Indo-Burma region was the center of origin of *M. indica* rather than Malay Peninsular. Popenoe (1974) suggested the native home of *M. indica* as being Eastern India, Assam to Burma or possibly further in the Malay region, which are similar areas to those proposed by Mukherjee (1967). With the aids of recent taxonomic and molecular evidence, it seems that the mango probably evolved within a large area including northwestern Myanmar, Bangladesh and northeastern India (Mukherjee, 1997). Recently, *Eomangiferophyllum damalgiriensis* was found in upper Paleocene sediments in northeastern India (Mehrotra, Dilcher, and Awasthi, 1998) and was believed to be the oldest fossil leaf related to the genus *Mangifera* and to be the ancestral stock for the living *Mangifera* species in the region. The finding of *Mangifera* fossil leaves in this study supports the idea of the possibility of Northern Thailand being the area of origin of the genus *Mangifera* and extends the possible area of origin of *M. indica* considered by Mukherjee (1951b, 1967, 1997). However, this finding does not support his idea of the first appearance of *M. indica* during Quaternary period.

5.1.1.3 Comparison of *Mangifera* fossil leaves

Compared with the Mangifera fossil leaaves in this study, *M. someshwarica* is about the same size as *M. intermedia* and *M. paleoindica*, but relatively smaller than *M. buchananoides*. They all share venation type, features of the primary vein, and presence of intersecondary veins. *M. someshwarica* has a percurrent/sinous type of tertiary veins that is different from that of *M.buchananoides*, *M. intermedia* and *M. paleoindica*. The leaf base of *M. someshwarica* is acute normal, while *M. buchananoides* has an acute-cuneate base. Angles of origin of tertiary veins of *M. someshwarica* are RA and RR which are closer to those of *M. intermedia* than to those of *M. buchananoides* and *M. paleoindica*. The shape of *M. someshwarica* is narrow elliptic, while that of *M. intermedia* and *M. paleoindica* is narrow oblong, and that of *M. buchananoides* is narrow elliptic-narrow obovate. The number of secondary veins of *M. someshwarica* is less than those of *M. buchananoides*, *M. intermedia,* and *M. paleoindica*, the distances between two of adjacent veins are approximately larger than those of the latter three species. The angle of divergence of secondary veins in *M. someshwarica* is approximately smaller than that of *M. intermedia*, larger than that of *M. paleoindica* and about the same as in *M. buchananioides*.

5.1.1.4 Distribution range of modern *Mangifera* species

Sixty nine *Mangifera* species were recognized from the classification system of Kostermans and Bompard (1993 in Mukherjee, 1997). As so far explored, the natural range of distribution is restricted to tropical Asia, extending as far north as 27° N latitude and as far east as the Caroline Islands. Exceptional ranges of distribution of some species can extend to the north of the tropic of Cancer, such as in China, Sikkim and southern China, at altitudes of 600-1000 m above sea level (Mukherjee, 1997). Wild mangoes (*Mangifera*) occur in India, Sri Lanka, Bangladesh, Myanmar, Sikkim, Thailand, Cambodia, Vietnam, Laos, southern China, Malaysia, Singapore, Indonesia, Brunei, the Philipines, Papua New Guinea, and the Solomon and Caroline Islands. The highest diversity, approx. 28 species, is in western Malesia, especially in peninsular Malaysia, Borneo and Sumatra, which represent the heart of the distribution range of the genus (Mukherjee, 1997; Lemmens, Soerianegara, and Wong, 1995; Bompard and Schnell, 1997). Fifteen species were described for the flora of Malaya and about 16 species occur in Thailand (Chayamarit, 1994).

Wild *M. indica* is mostly scattered in evergreen and deciduous forests up to 650 m above sea level. Truly wild trees of *M. indica* have been recorded in Bangladesh, northeastern India and in Myanmar (Fig. 5.1). India was the first place believed to be the center of domestication. Kochummen (1989) argued that Peninsular Malaysia and Borneo, based on the wild distribution of *M. indica* in these regions, should be included as one of the centers of domestication as well.

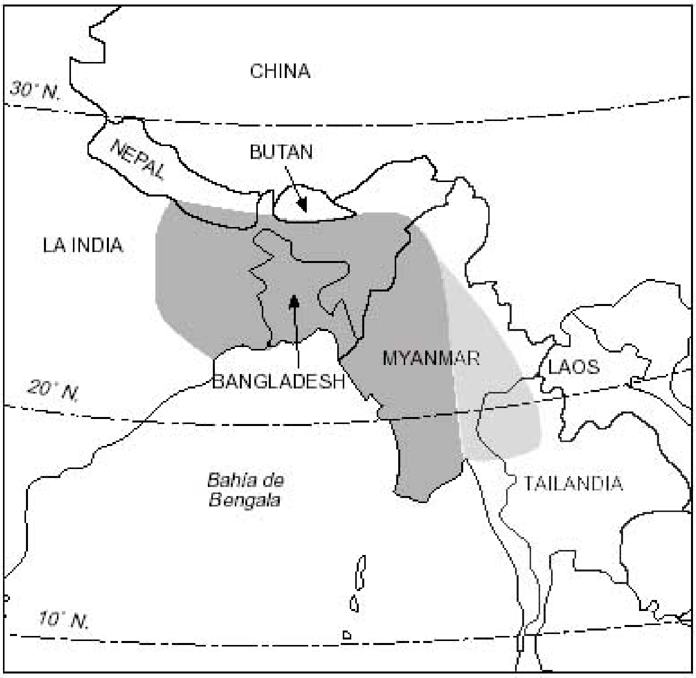


Fig. 5.1 Map of current distribution of *Mangifera indica*. India, Nepal, Bangladesh and Myanmar are claimed with more or less doubt to be places of origin of the common Mango (darker shading). With the fossil evidence of *Mangifera paleoindica* in this study, the hypothetical area of origin may extend into the north of Thailand (lighter shading). However, the current distribution of a species is not necessarily the same as the place of origin.
(map modified from Parrotta (year not specified); available: http://www.fs.fed.us/global/iitf/Mangiferaindica.pdf).

At present, two main centers of domestication of mangoes were recognized: India with monoembryonic mangoes, and Indochina, which was recognized as the home of polyembryonic mangoes. R.H. Hole's following statement seems to be in agreement with the ideas of Kochummen: "The so-called mangoes which are found in many parts of India are mostly forms escaped from cultivation, as shown by the fact that they are always near streams or footpaths in the jungle, where seeds have been thrown by passing natives" (Popenoe, 1974). Ding Hou (1978) also pointed out that *M. indica* is one of the species the range of distribution of which may be beyond their proper native range, so that it is almost impossible to indicate their proper place of origin. Bompard and Schnell (1997) considered that none of the vernacular names of *M. indica* in Southeast Asia (including "Mamuang, in the Thai language) exhibit signs of Indian influence. They also suggested that cognates of these names are also applied to primitive races of common mangoes in some parts of insular Southeast Asia. These examples of ideas can cast doubt on the origin of the species in India. From personal communication, Dr. Chayamarit at BKF, Bangkok, (October, 2003), who is currently working on a revision of the genus *Mangifera* in Thailand, mentioned that there seem to be wild *M. indica* trees in Thailand, but whether they are the escapes of the cultivated ones is still speculation. However, other than the fossil *Mangifera* species, Thailand also possesses two of the most primitive species within the genus, *M. duperreana* and *M. lagenifera*, and also possessed allied species of *M. indica*, namely, *M. sylvatica* and *M. caloneura*. *M. sylvatica* is distributed in the north, northeast and south, while *M. caloneura* is distributed in the northeast, southwest, southeast and south of Thailand. The existence of these most primitive and the allied species of *M. indica* can provide the additional evidence to propose the north of Thailand as one of the areas of the long history of evolution and diversification of the genus and of *M. indica* during the Oligocene or Miocene. Due to the importance, in part, of the existence of the wild *M. indica* to the evolution of the species, extensive plant collecting of the proposed areas of origin including Thailand will yield interesting new findings. In addition, with the aids of advanced methods of molecular biology and the study of fossils at a detailed spatial and temporal scale, the understanding of the origin, evolution, paleophytogeography and history of this genus can possibly be accomplished.

M. duperreana occurs from Myanmar through Thailand to Indo-china, and is scattered from lowland evergreen forests to deciduous and semideciduous forests. The distribution of this species in Thailand ranges from Eastern, Southeastern, to Peninsular Thailand (Chayamarit, 1994). Using the evidence of *M. caloneura* being phylogenetically older species of the section Euantherae and occurring in Myanmar, Thailand and Indochina, Mukherjee (1953) proposed, other than the Malay Peninsula, which has the highest number of species, this region as the area of origin of the genus as mentioned above (Bompard and Schnell, 1997). In Thailand, the distribution of this species ranges from Northern, Northeastern, Southwestern, Southeastern to Southern Thailand (Chayamarit, 1994; Gardner et al., 2000). According to the classification system of Kostermans and Bompard (1993, in Mukherjee, 1997), *M. duperreana* was reduced to *M. caloneura* (Subgenus *Mangifera*, section *Euantherae*) and *M. lagenifera* (Subgenus *Limus*). Because of 1) some floral differences of the specimens of *M. dupereana* and *M. caloneura* identified and kept at BKF, 2) the unfinished revision of this genus for Flora of Thailand (Chayamarit, personal communication); and 3) similarity of the venation patterns of their leaves, which did not affect the identification of the fossil leaf in this study, the separation of these two species were therefore reserved. In the Preliminary Checklist of the Family

Anacardiaceae of Thailand (Chayamarit, 1994), *M. caesia* was not reported. Anyway, recently this species was reported to be cultivated in the south of Thailand (Eiadthong et al., 2000). *M. caesia* is distributed in the regions south to Thailand, such as Sumatra and Peninsular Malaysia. *M. lagenifera* also has a similar range of distribution as *M. caesia* and extends to peninsular Thailand (Chayamarit, 1994). Both *M. caesia* and *M. lagenifera* inhabit places of potential preservation, such as lowland primary forest, swamp forest, and periodically inundated areas along rivers up to 450 m for *M. caesia*; and lowland forest up to 150 m and temporarily inundated places for *M. lagenifera*. If the uncertainty of identification is not brought into account, the existence of the fossil in the northern region and the distribution of the possible NLRs in the southern region of Thailand may indicate changing of range of distribution of the species due to changing of the environment or may indicate insufficient collecting of the living species.

5.1.2 *Semecarpus* L. f.

5.1.2.1 The first record of the genus

Semecarpites linearifolius was reported from France (Fritel, 1912; in Barkley, 1957, and in the Plant Fossil Record database (PFR) of the International Organization of Palaeoboatany (IOP)), where the extant *Semecarpus* does not occur. Attempts to reach this article have been made with no success and it seems that the affinities assigned to the fossil will be equivocal. Since then, the fossil history of the genus *Semecarpus* has not been reported even from within the modern range of the genus. Thus, these two fossil *Semecarpus* species are most likely to be the first fossil evidence within its modern range.

5.1.2.2 Distribution range of modern *Semecarpus* species

Semecarpus is also a tropical genus whose distribution range was mentioned in 2.6.3 of Chapter II. Presumably, there are three species in Thailand: *S. cochinchinensis*, *S. curtisii*, and *S. reticulata* (Chayamarit, 1994). *S. cochinchinensis* is distributed in deciduous forest, particularly on limestone hills throughout the country while *S. curtisii* grows in both deciduous and evergreen forest of the peninsular region. *S. reticulata* grows in evergreen forest in the north and the southwest regions.

5.2 Leguminous fossil leaves

5.2.1 *Adenanthassia* gen. nov. Sawangchote, Grote, Dilcher

5.2.1.1 The new genus with possible relationships to African and South American elements

Fossil pollen of *Adenanthera* sp. was reported from the Eocene of Africa by Guinet and Ferguson (1989, in Caccavari, 1996) and was considered to be the same as *Fillaeopsidites reticulata*, the modern counterpart of which is *Fillaeopsis discophora*, of the monospecific genus of Africa (Caccavari, 1996). The seemingly unequivocal species of the genus *Adenanthera*, identified from pollen, is *Adenanthera* aff. *macrocarpa* from the Miocene and the Pliocene of Argentina (Caccavari, 1996). *Adenantheroxylon pavoninium* was reported from the Upper Miocene of Assam, India (Prakash and Tripathi, 1968, in PFR), and from Miocene-Pliocene of Himachel Pradesh, India (Yadav, 1988, 1989, in PFR). As so far reviewed, no fossil leaflet of *Adenanthera* is reported from localities nearby such as India, Nepal, Burma, Vietnam, Java, Sumatra, Borneo and China or from elsewhere.

If the modern leaflet of this type is not beyond discovery, it is possible that the NLR(s) of this *Adenanthassia paleothailandica* no longer exist in Thailand at present and this species can probably be considered as an extinct species of Thailand. Due to incompleteness of the database available, doubt can be cast over such a hypothesis. The NLR(s) of the fossil species may or may not exist in some countries nearby or even far away. If the NLR of *Adenanthera paleothailandica* did not really have as Asian origin (as evidenced by comparisons in this study), it is possible that plants of American or African elements were distributed to Asia, flourished and then deteriorated, probably from Middle Miocene onward (more details in 5.3). If not, the factors responsible for this may be lacking of a complete taxonomic inventory of such a very diverse family in Thailand (or even localities nearby) that can cover all the existing species or lacking of access to complete databases of world legumes.

5.2.1.2 Distribution range of modern *Adenanthera* species

It is interesting that no modern Thai leguminous species so far described (and within my ability to examine), possesses the leaflets that share more features than the exotic species brought in comparison. The genus *Adenanthera* comprises 12 species occurring in Sri Lanka, southern Myanmar, Indochina, southern China, Thailand, Malesia, the Solomon Islands and northern Australia (Sosef et al., 1998; see list of species available in nomenclatural database at http://mobot.mobot.org/). *Adenanthera* species are found scattered in primary and secondary, evergreen to dry deciduous forests, but also in savanna like vegetation, from sea level to 900 m altitude (Sosef et al., 1998). Examination from the pictures of 9 species described in Flora Malesiana ((Mimosoideae of South East Asia; available at World Biodiversity Database (WBD), http://www.eti.uva.nl/Database/WBD.html), including *A. borneensis*, *A. forbesii*, *A. intermedia*, *A. kostermansii*, *A. malayana*, *A. marina*, *A. microsperma*, *A. novaguineensis* and *A. polita* showed that leaflets of all species have close similarity with those of *A. pavonina*. Only *A. pavonina*, with two varieties, *pavonina* and *microsperma*, occurs in mixed deciduous forests of Thailand (Neilsen, 1985; now *A. microsperma* is considered a separate species). This species has a lower l/w ratio, and looser reticulation than *Adenanthassia paleothailandica*. *Cassia moschata* Kunth (conspecific with *Cathartocarpus moschatus*, Don) is a plant of Central and Northern South America. *Adenanthera klainei* Pierre ex Baker f. is a plant of tropical Africa (nomenclatural database available at http://mobot.mobot.org/). The genus *Gymnocladus*, of which *G. chinensis* shares the venation pattern with *Adenanthassia paleothailandica*, has an eastern North American-eastern Asian distribution (and has long been considered to be a sister group to *Gleditsia*). For example, *Gymnocladus dioica* is the North American species whereas *G. chinensis* is the Asian species (Schnabel and Wendel, 1998).

5.2.2 *Albizia* Durazz.

5.2.2.1 The new species of *Albizia*

From the Plant Fossil Records (PFR), available at website of International Organization of Palaeobatany (IOP), *Albizia* species (for which organ is not specified) were recorded from Africa (Zaire and Ethiopia) and tropical and temperate Asia (India, Nepal, and China). The fossils designated as two modern species, *A. julibrissin* and *A. bracteata*, were found from the Miocene of Yunnan (some more details in PFR) which is not far from the Li basin where *A. paleoproceroides* was found. From India and Nepal, the Neogene leaflets of *A. siwalika* that has the affinity close to *A. gamblei* (= *A. lucidior*) were discovered (also in Awasthi, 1992; Antal and Awasthi, 1993). In addition, *A. miokalkara* from the Miocene of China (Hu and Chaney, 1940) was also included in this database. Numerous records are still not in the PFR and some of which related to this study will be mentioned herein including; wood of *Albizinium eolebbekianum* from Neogene of Myanmar and India (Prakash, 1975 in Awasthi, 1992; Prakash and Bunde, 1980 in Prakash and Bunde. 1986), *A. pondicherriense* from Neogene of India (Guleria, 1984 in Awasthi, 1992), and *A. arunachalensis* from late Miocene to Pliocene of India (Mehrotra et al., 1999), leaflets of *Albizia miokalkara* from Miocene of Japan (Ishida, 1970 in Antal and Awasthi, 1993) and *A. microfolia* (resembles modern *A. julibrissin*) from Middle Miocene to Lower Pleistocene of Nepal (Prasad and Awasthi, 1996).

Unfortunately pictures and descriptions of some fossil leaflets are not available for comparison. However, the ones assigned (close) to the modern species (*A.* cf. *antunesiana*, *A. bracteata* and *A. juliblissin*) can be assumed to be distinct from *A. paleoproceroides* according to differences in the leaflets' features compared with these modern species. *Albizia palaeolebbek* which resemble *A. lebbeck* is different from *A. paleoproceroides* as mentioned under 4.2.1.2.

5.2.2.2 Distribution range of modern *Albizia* species

The genus *Albizia* is represented by about 150 species and has a pantropical distribution, with centers of speciation in Africa, Madagascar and tropical America. It also occurs throughout the Asian tropics (Sosef et al., 1998). Thirteen species are indigenous to Thailand (Neilsen, 1985).Eight tree species of *Albizia* were documented to distribute in northern Thailand (Gardner et al., 2000) in which *Albizia paleoproceroides* has flourished. These species include *A. chinensis*, *A. crassiramea*, *A. garrettii*, *A. lebbeck*. *A. lebbekoides*, *A. lucidior*, *A. odoratissima* and *A. procera*. *Albizia procera* is distributed from India to Myanmar, Indochina, southern China, Taiwan, Thailand, Java, Borneo (rare), the Philippines, Sulawesi, the Lesser Sunda

Islands, the Moluccas, New Guinea and northern Australia (Sosef et al., 1998). In Thailand this species distributes throughout the country except peninsula which only Phuket was reported as place of occurrence (Neilsen, 1985). It inhabits in evergreen to mixed deciduous forests (both primary and secondary) and is commonly found in fire-induced grasslands or savannas in the northeast (Neilsen, 1985; and personal observation). The charcoalified wood fragments and paper coal discovered from a thick layer of lignite in the Ban Pu Subbasin of the Li Basin (Grote, 2000; Grote, Chonglakmani, and Benyasuta, 2001) may indicated that the forests existed under strongly seasonal climate and experienced forest fires. The Ban Pa Kha Subbasin, located southeast to the Ban Pu Subbasin, and the forests that flourished therein (from which *Albizia paleiproceroides* was described) might have experienced the same condition.

5.2.3 *Antheroporum* Gagnep.

5.2.3.1 The new genus and new species of Tertiary flora

No fossil *Antheroporum* has ever been reported. Therefore, this is the new genus and new species of the Tertiary flora.

5.2.3.2 Distribution range of modern *Antheroporum* species

The genus *Antheroporum* distributes in SW China, Indochina (Burma, Thailand and Vietnam) (Fourth International Legume Conference, News no. 49, Feb. 2002, http://www.rbgkew.org.uk/herbarium/legumes/beanbag49/news.html). The genus is one of the six genera belonging to the tribe Tephrosieae that are native to Thailand (Niyomdham, 1994). There is no detail information about the genus and species occur in Thailand. So far examined, there are only two species at BKF, *A. glaucum* collected from Erawan fall, Kanjanaburi Province and *A. pierrei* collected from Huay Yang fall, Prachuap Khirikhan. Form the place of collection, it indicates that these species prefer wet habitat in semi evergreen or semi deciduous forests. Gardner et al. (2000) do not have any species of this genus listed in their book of trees of northern Thailand. However, the distribution in SW China, Burma and Vietnam may correspond with distribution of this fossil record.

5.2.4 *Cassia* L.

5.2.4.1 The new species that help confirm Thailand (one of?) the area of origin

Numerous fossils, of different organs, having affinity to/close to *Cassia* were described from South America, SE Asia (e.g. Burma, Java, Sumatra, Borneo), temperate Asia (e.g. China), tropical Asia (e.g. India) and Europe (Bande and Prakash, 1986; Awasthi et al., 1990; Awasthi and Lakhanpal, 1990; Awasthi, 1992; Mehrotra et al., 1999; PFR). The age of those fossil *Cassia* range from the Cretaceous to the Pliocene. In the review of Tertiary flora of SE Asia, Bande and Prakash, (1986) list the fossil *Cassia* as follow; *Peltophoroxylon cassinodosum* (wood equivalent to *Cassia nodosa*) from Neogene of Burma, *Peltophoroxylon parenchymatosum* (wood equivalent to *C. siamea*) from Neogene of Java and Sumatra, leaflet of *Cassia australis* from Paleocene of Sumatra and of *Cassiophyllites* sp. (equivalent to Cassia sp.) from Paleocene of Borneo. Mehrotra et al. (1999) described *Cassinium borooahii*, which has the affinity close to *Cassia siamea*, from Late Miocene-Pliocene of India. Six species of *Cassinium* were previously described from the Tertiary exposures of India and Myanmar (Mehrotra et al., 1999). *Cassia marshalensis* was reported from the Middle to Late Miocene of the Gar flora in the northeastern China (Yusheng and Yahui, 1995). The genus *Cassia*, along with *Albizia* and *Dalbergia*, is believed to migrate from SE Asia to India during Neogene (Bande and Prakash, 1986). From the mentioned previous works there is no fossil leaf of *Cassia* that has the affinity close to *C. siamea* whereas previous works in Thailand show no fossils, of any organs, have affinity close to *Cassia* (more details in 2.7 of chapter II). Therefore, the *Cassia paleosiamea* may indicate the long evolution within SE Asia, at least during the Neogene. It also supports the idea of SE Asia, as its origin (Larsen et al., 1984; Anonymous, http://www.hear.org/pier/species/senna_siamea.htm). Being the fossil evidence that is very close to *Cassia siamea* in the region, Thailand is more likely to be place of the origin of this species.

5.2.4.2 Distribution range of modern *Cassia* species

The genus *Cassia* comprises about 400 species which are pantropic in distribution but concentrated in S. America. Twenty one species occur in Thailand (Larsen et al., 1984; Gardner, 2000). Eleven species are reported to occur in the north of Thailand. Among these, *C. fistula*, *C. garretiana*, *C. bakeriana*, *C. agnes*, *C. tomoriensis*, and *C. siamea* were listed as the six species native to the north of Thailand (Gardner et al., 2000).

Cassia siamea is also known as Siamese cassia or Thailand shower (Anonymous, http://www.hear.org/pier/species/senna_siamea.htm). It occurs in various types of forests at lower altitudes and is also commonly planted (Larsen et al., 1984). It can occupy the dry forests of Myanmar, Sri Lanka, Malaysia and Thailand (Ramesh Rao et al., 1972 in Mehrotra et al., 1999) as well as being able to establish on the moist soils along the river banks in northern Queensland of Australia (Anonymous, http://www.hear.org/pier/species/senna_siamea.htm).

5.2.5 *Pithecellobium* Mart.

5.2.5.1 The new species with possible relationships to African and South American elements

Fossil *Pithecolobium lucidum* was reported, by WGCPC (1978, in PFR), from temperate China, Manchuria and Liaoning. According to PFR, the genus is synonym of *Pithecellobium*. From morphological comparison of fruits and leaflets, Calvillo-Canadell and Cevallos-Ferriz (2002) found that during the Oligocene of NE Mexico *Pithecellobium* sp. occurred.

Pithecellobium leucocalyx (published in: Publications of the Field Columbian Museum, Botanical Series 4(8): 308. 1929, cited from http://mobot.mobot.org/cgi-bin/search_vast) is a plant of Central and North America whereas *P. macradenuim* is of Central and South America. *P. leucocacayx* was also identified (year of publication in parenthesis) as; *Albizia leucocalyx* (1992), *Balizia leucocalyx* (1996), *Samanea leucocalyx* (1928), (http://mobot.mobot.org/cgi-bin/search_vast). Whatever the name of *P. leucocalyx* will be, the morphology and the venation pattern, especially at lower half of the leaves, of this species and *P. macradenium* are very similar. Furthermore, all the genera but *Albizia* (which is believed to have originated outside of Africa) are African elements. Therefore, I reserved the name *P. leucocalyx* for this study. Besides, these two species, there are also African *Pithecellobium* species that share leaf similarity with *P. paleolampangensis*. Unfortunately, only pictures of herbarium sheets of these African species with only un-zoomed venation patterns are available for size and shape comparison. However, it is possible that these African or American species migrated to Asia via India after the connection of the Indian plate with Eurasia since the Miocene as mentioned in the case of *Adenanthassia paleothailandica* (more details in 5.3.).

5.2.5.2 Distribution range of modern *Pithecellobium* species

The genus *Pithecellobium* is distributed mainly in Central and South America, but with 3 species indigenous to Asia; 1 species, *P. dulce*, is introduced into Asia (Neilsen, 1985) including Thailand. One species, *P. tenue*, is endemic to Thailand, recorded from both poor mixed deciduous forests and bamboo jungles in limestone areas and from dry evergreen forests on granitic rock, alt. 200-900 m. Leaflets of this endemic species are distinctive from *P. paleolampangensis*.

5.3 The leaf flora and the palynoflora of the Ban Pa Kha subbasin

According to being botanical-based, this study will not therefore go in depth to the temporal variation in vegetation pattern (i.e., geological-based). However, from the observation of changing of the flora of the Ban Pa Kha through different layers, I noticed reduction of abundance of temperate conifers from lower layers (interburden, approx. 30 m. below upper thin coal seam) to upper layers, from which the leaves of conifers were not found, (overburden, approx. 30 m above upper thin coal seam) and vice versa for the subtropical and tropical angiosperm leaves. The thickness (about 60 meters apart) and the conformity of these layers make the observed change of plant community more likely to be temporal rather than spatial. This observation agrees with the changing from warm temperate to tropical palynological assemblages recognized from Li, Chiang Muan, Mae Moh, Mae Lamao, and Na Hong basins in northern Thailand by Songtham (2000, 2003). Besides, the finding in this study conforms with Wattanasak’s explanation (1988) of climate changing in Thailand from temperate in the Late Oligocene to warm or more tropical conditions during Early to

Middle Miocene. Based on palynofloras, Wattanasak (1988) concluded that the Li flora was dominated by temperate elements. The leaf fossils found in this study (in interburden of Ban Pha Ka sub basin) and from the ones studied by Grote (2000) and Grote and his colleagues (1999, 2001, 2003), suggest mixed tropical and temperate (conifers in particular, such as *Sciadopitys*) or subtropical floras. The so far identified tropical elements that coexist with temperate elements comprise 3 species of *Mangifera*, 2 species of *Semecarpus*, *Albizia* sp., *Antheroporum* sp, *Cassia* sp., and *Pithecellobium* sp. In contrast, from the palynoflora of Na Hong basin, Songtham (2000, 2003) has stated that “it’s clear that the temperate and tropical elements must have been deposited at different times”. Furthermore, the palynological evidence Songtham (2003) got from Li, Chiang Muan, Mae Moh, Mae Lamao, and the macrofossils from the studies by Endo (1964, 1966) and Fujiyama (2002) still support his idea of different times of deposition and rather clear demarcation of these two elements at least along the stratigraphic levels he studied. Although the first observation of reduction of temperate elements as evidenced by leaf fossils agrees with the findings of Songtham (2003) at the Ban Pa Kha subbasin, the time of emergence of the tropical elements seems to be the conflict (this is considered from the correspoding stratigraphic levels). With such mixing of leaf fossil evidence, it is of value to hypothesize whether the tropical elements (at Li basin) evolved earlier than it used to be postulated by palynological evidence. The bizarre existence of such a vegetation type (no modern counterpart) may be the product of the turning point of temperate to tropical climate during Oligocene to Miocene. As the temperate elements were getting smaller, the tropical ones were getting bigger. This probably coincided with the greatest latitudinal expansion of tropical rain forest that occurred at the beginning of the middle Miocene and extended northward as far as Japan (Morley, 1998). During this time, the vegetation cover of the southern Yunnan Province located close to the north of Thailand was also tropical and subtropical (Axelrod et al., 1996). Concerning this, Songtham et al. (2003) proposed that the tropical palynological assemblages resulted from changing the position from temperate latitude to tropical latitude by the moving southward or southeastward of the Southeast Asian landmass. These changes occurred during Oligocene to Early or Middle Miocene. However, latitudinal change in position may not be the only factor but also the remarkable reducing in elevated terrain of SE Asia during the Negene (global paleogeographic maps of Smith et al. (1994), cited in Morley, 1998). Existing and declining of the elevated and lowland terrain complied closely with (but was probably based partly on) the distribution of the Laurasian gymnosperm and temperate pollen (Morley, 1998). For the Mae Moh subbasin from which *Adenanthassia paleothailandica*, *Cassia paleosiamea*, and *Pithecellobium paleolampangensis* were discovered, such discussion will be skipped until we have enough information.

However, interpretation of the changing in dominance of temperate and tropical flora based on leaf fossils is beyond the scope of this study. In doing so, more intensive qualitative and quantitative and more geological-based studies on leaf floras of Thailand are needed. In addition, comparison of floristic composition and climatic fluctuation of Thailand with those of surrounding contemporary fossil localities such as China, India, Myanmar and etc. are crucially important.

5.4 Paleovegetaion at the Ban Pa Kha subbasin

Due to intensive studies, including this study, on leaf fossils at the Ban Pa Kha subbasin having been done and having been carried on more than at other subbasins, the vegetation type, based on leaf fossils, at the time of deposition will then be briefly discussed. Endo (1964.1966) compared the leaf flora of the Ban Pa Kha to those of the Fushun flora in northeastern China (Lat. 41° N) existing during the Upper Eocene under a warm temperate climate. Axelrod et al. (1996) placed the Fushun flora between Late Cretaceous – Eocene and the type of the forest was determined to be mesophytic forest occurring in regions characterized by a humid, warm temperate climate. The forest was composed of numerous broadleaved deciduous trees, including *Alnus*, *Betula*, *Corylus*, *Carpinus*, *Fagus*, *Quercus*, *Lindera*, *Hamamelis*, as well as some evergreen species of *Quercus*, *Cinnamomum*, and *Sabalites*. Along with these angiosperms, gymnosperms such as *Ginkgo*, *Metasequoia*, *Sequoia*, *Glyptostrobus* and *Keteleeria* were common. This flora has many genera in common with the Eocene and Oligocene floras of western North America (Axelrod et al., 1996). During the same period in the south of China, the forest that existed under a warmer and drier climate had *Brachyphyllum*, *Cinnamomum*, *Nectandra*, *Quercus*, *Ephedra*, Ulmaceae and Schizaeaceae as its constituents. Conifer pollen was less than in the contemporary floras of north China. The forest type in southern China was considered to be mixed deciduous and evergreen forest of subtropical aspect. The recent finding of tropical angiosperm leaves and leaflets as mentioned in 5.3 may indicate that the floras of the Ban Pa Kha subbasin were more evergreen and might have flourished under a more humid and warmer climate of tropical aspect. According to such mixing of conifers and angiosperms, the vegetation at the time of deposition at the Ban Pa Kha subbasin can be determined as mixed conifers with deciduous-evergreen broadleaf forest of tropical to subtropical climate. The existence of the papercoal at the corresponding layer of the Ban Pu subbasin (i.e., lower part of the middle layer between upper and lower main coal seam) and leaves with affinities close to deciduous/semideciduous species from the Ban Pa Kha and the Ban Pu subbasin such as, *Albizia* sp., *Alnus* sp., *Carpinus* sp., *Cassia* sp., cf. *Cyclobalanopsis* sp., *Pithecellobium* sp., and *Quercus* sp. (subgenus Cyclobalanopsis) (species other than the ones in this study are from Grote and Prakart, 2003; Grote, 2004), indicates the deciduousness of the vegetation. The conifers such as *Sequoia* (Cupressaceae), *Glyptostrobus* (Cupressaceae), and *Sciadopitys* (Sciadopytiaceae) (Grote and Sawangchote, 2003) that existed among the deciduous and evergreen broadleaf angiosperms probably are the relict taxa from the Paleogene time during which these taxa were common in the northern hemisphere (Axelrod et al., 1996; Kubitzki and Krutzsch, 1996) since Late Cretaceous – Eocene as mentioned above. Morley illustrated the extension of temperate conifer forest, during the Oligocene to earliest Miocene, almost to the equator. At latitudes below 20° N, this forest tended to occur at high altitude between 1000-2000 m. According to this, the conifers might have existed in high altitude of the north of Thailand and leaves of which (along with other angiosperms) probably were deposited in intermontane lacustrine environments. This may also agree with widespread of elevated terrain in SE Asia throughout the late Cretaceous and Early Tertiary as mentioned briefly in 5.3. The extinction of (some of ?) these conifers along with some other subtropical angiosperms at the Ban Pa Kha subbasin maybe took place from middle Miocene through the Pliocene, the same time as the extinctions in India and China (Awasthi, 1992; Axelrod et al., 1996). The latitudinal and altitudinal changes that may responsible for this were briefly mentioned in 5.3. Kubitzki and Krutzsch (1996) have provided a good review on the climatic changing accompanied by alteration in vegetation type and species composition in East and South East Asia. The detailed analysis of this is beyond the data existing and beyond the scope of this study; it is thus omitted.

5.5 Some fossil legumes and their possible dispersal routes between Africa, South America and Asia

The important plate tectonic events responsible for migration of plants between Asia and other continents (e.g., Africa South America, and Australia) were summarized in Raven and Axelrod (1974). Morley (1998) also provided a review of palynological evidence of dispersion from Gondwana, via the Indian plate, to SE Asia. With special reference to fossil legumes of the north of Thailand in this study, attention will be paid to the migration route between Africa and Asia. The Leguminosae were believed to have originated or at least undergone their primary radiation and differentiation into three subfamilies in West Gonwanaland, i.e., Africa and South America. Mimosoideae and Caesalpinioideae seem to have migrated between Africa and South America in Paleocene time and to Asia whereas Faboideae have radiated more extensively in Laurasia (Raven and Axelrod, 1974). Whether there was early migration of leguminous plants between Africa, India and Asia is still equivocal because of poor early fossil records in India, Africa and other countries in Asia including Thailand. Recent evidence that supports Africa as an earlier place of origin of Mimosoideae is the great diversity of the palynomorphs of this subfamily in the Eocene of Africa (Caccavari, 1996). More recently, a fossil leaf of *Acacia mahengense* was found from the Paleogene of Tanzania by Herendeen and Jacobs (2000). The migration of legumes from Africa and Southeast Asia to the Indian subcontinent and vice versa is documented since the Miocene, after India had established land connections with Africa and Asia (Awasthi, 1992). Awasthi (1992) raised some African and Southeast Asian legumes that migrated to India. Among those from Africa, *Adenanthera* and *Pithecellobium*, to which the fossils recorded in this study were assigned or related, were not included. By the middle Miocene, the Leguminosae became the most dominant, and then they started to deteriorate in India towards the close of the Pliocene. The vanished taxa include most of the African elements and some of Asian elements. Concerning the Tertiary legumes of South America, their relationships to the ones in this study may be considered the same way because close links between South America and Africa were evidenced especially by some leguminous taxa (Raven and Axelrod, 1981; Caccavari, 1996). Besides the identified leguminous leaflets, some collected from the Li and the Mae Moh basins have affinities possibly close to different taxa still left unidentified. According to this evidence, there probably are legumes that migrated along this hypothetical route (i.e., from western Gondwana), flourished in and deteriorated from the Tertiary floras of Thailand during the major extinction events mentioned in 5.3. There are also some examples of exchanges of the flora the explanation for the occurrence of which is difficult. *Caesalpinia pecorea* and *C. pacifica* are North American fossils which are most similar to *Gilletiodendron*, an extant genus that is now restricted to tropical Africa (Herendeen et al., 1992). *Podocarpium* (formerly *Podogonium*) is an extinct genus that may provide some evidence for floristic exchange between Africa, Europe and Asia. Based on mega- and microfossil records, *Podocarpium* would appear to have originated in China in the early Paleocene (Liu et al., 2001). It is closely related to several extant African genera, and has been reported from the Miocene of central Europe and China (Herendeen et al., 1992). Endo and Fujiyama (1965) described *Podogonium knorrii* (= *Podocarpium podocarpum* (Herendeen, 1992)) from Mae

Sod, Tak province, Thailand. If this fossil is unequivocally identified, it will provide another line of evidence of exchange between Africa and Asia.

The main radiation of the Leguminosae took place during the Neogene and was associated with climatic changes (Pollhill et al., 1981; Raven and Polhill, 1981 cited in Caccavari, 1996). Herendeen et al. (1992) addressed in their review of the fossil history of the Leguminosae that the modern range of distribution of some legume genera and other contemporaneous taxa are more restricted than in the past. This regional extirpation may be due to climatic changes.

The similarity of eastern North American and eastern Asia floras (known as the Arcto-Tertiary Geoflora) should also be kept in mind when discussing phytogeography because it may play, in part, a role in the similarity, for example, of the Fushun flora and the Li flora as indicated by Endo (1964, 1966) and may possibly be responsible for similarity between the Li flora and those from eastern North America (if any, when we have enough data). The evidences presented in this study could be the primer of future research on paleophytogeography.

5.6 Use of leaf morphology and venation pattern for leaf identification

Apart from this study of leaf morphology and venation pattern of anacardiaceous plants, Wilkinson (1971, cited in Ding Hou, 1978) provided anatomical characters of considerable diagnostic and systematic significance, e.g., trichomes and epidermis. Ding Hou (1978) also made a key to the papillose genera and species based on appearance and distribution of papillae at low magnification. The validity of identification of fossil or living leaves depends on a combination of these features. In the case of fossils, fine or diagnostic features may not be preserved or preserved with poor quality and inevitably lead to identification with more or less doubt. However, among these features, leaf morphology and venation patterns seem to be easily preserved and recognized. The database of leaf morphology and venation pattern (as presented in Anacardiaceous plants with simple leaves in this study) of plants with accepted taxonomic studies is therefore crucially important to serve for taxonomic study of leaf remains. In addition, more attention should be paid to the different taxa that share numerous features such as those of Leguminosae and Connaraceae (as mentioned and illustrated in 4.2.3 of Chapter IV). Straightforwardly speaking, the larger the database the more valid the identification will be.

5.7 Validity of using MVP as an adjunct taxonomic tool

On consideration of using MVP as adjunct features to identify fossil leaves to the species level, I found that types of MVP are rather consistent in each modern species (e.g., *M. indica* in Figs. 4.18D, M, 4.19E, N, and 4.21D, L) and can be used together with other morphological features of leaves to identify to species level (e.g., SUT 728 identified as *Semecarpus paleosiamensis*). However, definite identification is still faced with a degree of difficulty due to high species diversity within a genus, high levels of variation in size and shape of leaves in individual species (see 4.1.4.1 and 4.1.4.2 in Chapter IV); very small numbers of fossil specimens that can not reflect the range of variation; and overlapping in type of MVP of different modern species. Hybridization, e.g., *M. odorata* was proposed as an example of a hybrid swarm between *M. indica* and *M. foetida* (Ding Hou, 1978), may be responsible, in part, for similarities in leaf characteristics and other features of these species. To make identification closest to what it really is, we therefore need extensive study of modern leaf variation both in morphology and venation patterns. In addition, larger numbers of fossil leaves of the same expected affinity can certainly help make identification more valid. These valid taxonomic works can serve for analysis of the floral composition of the Li basin, paleoclimate, paleoecology, and paleophytogeography.

Chapter VI

Conclusions

6.1 On the results of the study

6.1.1 Systematic study of the fossils and its significance

Ten species belonging to seven genera of two families, Anacardiaceae and Leguminosae, were described from the Li and the Mae Moh basin northern Thailand. All the species and the genera *Adenanthassia*, *Antheroporum*, and *Semecarpus* are new to the Tertiary flora of the world. Two species, *Mangifera paleoindica* and *Cassia paleosiamea* provide evidence for the possibility that Thailand was be (one of) the area(s) of the origin of *M. indica* and *C. siamea*, respectively (The family and genera are the matter of origin of the higher systematic levels). Three species of *Mangifera*, in particular may indicate a long history of evolution that promoted diversification. The lack of reported fossils related to *Semecarpus*, from surrounding contemporaneous localities, might suggest the early emergence of the genus in northern Thailand. The presence of the three subfamilies of the legumes is the evidence of the diversification of the family since the Oligocene to the Miocene of Thailand. The leguminous genera, especially *Adenanthassia* and *Pithecellobium*, have significance to future analysis of migration between West Gondwana, India, and Asia.

6.1.2 Paleophytogeograhpy

On comparison with previous studies from Tertiary localities of SE Asia, the genera *Mangifera* and *Cassia* and *Albizia* seem to be more common than

Antheroporum, *Semecarpus* and *Pithecellobium*. Anacardiaceous fossil leaves are of Asian origin whereas leguminous ones are more likely to have originated from Africa and S. America. This suggests a possible dispersal route to Thailand via the Indian subcontinent. Furthermore, having no NLR in Thailand of some fossils may indicate extinction during climatic change as evidenced by the distribution ranges of the fossil and the modern taxa from previous studies. The more complete story of origin, diversification, exchanges from continent to continent, and paleogeography need more local and regional studies.

6.1.3 Paleovegetation and paleoclimate

By comparison with adjacent contemporaneous paleovegetation and with Tertiary palynofloras of Thailand, tropical leaf fossils of this study along with those of warm temperate elements suggests that the paleovegetation in the Li Basin was mixed conifers with deciduous-evergreen broadleaf angiosperms of a tropical to subtropical climate.

6.1.4 Leaf architecture of modern leaves of Anacardiaceae and Leguminosae and its significance for systematic study of fossil leaves

As we may know or be informed, shape and size can vary to a large extent among leaves, and it is hard (or even impossible as I learned from some distinguished taxonomists) to use this vegetative organ for taxonomic purposes. Detailed analysis of anacardiaceous species with simple leaves and the keys constructed in this study are supposed to be evidence that making use of leaf architecture as a taxonomic tool is possible. The additional terms and the classification of MVP are intended to be the refinement of the analysis of leaf architecture so far available. Using these terms and MVP for identification of the fossil leaves present herein yielded rather favorable results and suggests that the more features we examine the more valid the identification will be. In this study, classification of MVP can be applied to both families. Nevertheless, further studies on different families are needed to make the classification system cover as many natural types of MVP (and probably other features) as it can. In the very large families, such as Leguminosae, the very large overlapping of leaf architecture can certainly occur, and we will never know how much such overlapping there will be until we start working as a network that can cover all natural variation.

6.1.5 Two leaf keys, with descriptions, to anacardiaceous species with simple leaves

Two leaf keys, based on different priorities of leaf characters used, were constructed. A quick guide to the general morphology of each species was also provided along with the descriptions.

6.1.6 Photographic archive of herbarium specimens and cleared leaves

Approximately 1,638 photographs were stored in a CD for future research. Among these, approx. 543 are of cleared leaves of 8 families, 49 genera, and 181 species and approx. 1,095 are of herbarium specimens of 9 families, 82 genera, and 365 species.

6.2 Future research and suggestions

6.2.1 Leaf architectural study (i.e., systematic study) of leaves of modern plants should be promoted more because of its importance for fossil leaf research (and for some other aspects).

6.2.2 Leaf keys should be tested as to their validity and efficiency, with special reference to types of MVP, for identification to species level.

6.2.3 Extensive fossil leaf research is needed and should be more geologically-based to make it more comparable with palynological research. The joint projects or communication concerning stratigraphic layers for collecting specimens are important for comparative study.

6.2.4 Building up of reference collections and databases of leaf architecture is needed, and these should be more interchangeable.

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Appendices

Appendix A

List of plates of anacardiaceous modern leaves

Sources of specimens studied were specified in parentheses. SN = Serial Number, BKF = Bangkok Forest Herbarium, NYBG = New York Botanical Garden, PSU = Prince of Songkla University Herbarium, SUT = Suranaree University of Technology.

For explanations, see description of each species.

Plate 1. *Bouea macrophylla* (BKF SN 126886)

Plate 2. *Bouea oppositifolia* (BKF SN 084983)

Plate 3. *Buchanania arborescens* (PSU SN 180409)

Plate 4. *Buchanania reticulata* (Cleared leaf from SUT collection)

Plate 5. *Buchanania sessilifolia* (BKF SN 002502)

Plate 6. *Buchanania siamensis* (PSU SN 180428, SUT190_1)

Plate 7. *Drimycarpus luridus* (PSU SN 180435-1)

Plate 8. *Gluta elegans* (BKF 2071)

Plate 9. *Gluta renghas* (BKF SN 002628)

Plate 10 *Mangifera caesia* (Prof. Dilcher's collection)

Plate 11. *Mangifera caloneura* (BKF SN 038397)

Plate 12. *Mangifera camptosperma* (BKF SN 002934)

Plate 13. *Mangifera chamaoensis* (BKF 076791)

Plate 14. *Mangifera collina* (BKF SN 088843)

Plate 15. *Mangifera duperreana* (BKF 58080)

Plate 16. *Mangifera flava* (BKF 62550)

Plate 17. *Mangifera foetida* (BKF 40462)

Plate 18. *Mangifera gedebe* (BKF SN 105457)

Plate 19. *Mangifera griffithii* (BKF 091440)

Plate 20. *Mangifera indica* (BKF SN 097410)

Plate 21. *Mangifera linearifolia* (BKF SN 002938)

Plate 22. *Mangifera macrocarpa* (PSU collection & NYBG)

Plate 23. *Mangifera microphylla* (BKF 26702)

Plate 24. *Mangifera odorata* (Cleared leaf from SUT collection)

Plate 25. *Mangifera pentandra* (BKF 088210)

Plate 26. *Mangifera quadrifida* (BKF 20027)

Plate 27. *Mangifera sylvatica* (BKF 92772)

Plate 28. *Melanochyla angustifolia* BKF SN 092806

Plate 29. *Melanochyla bracteata* (BKF SN 105458)

Plate 30. *Melanochyla nitida* (BKF 082929)

Plate 31. *Semecarpus cochinchinensis* (BKF SN 118520)

Plate 32. *Semecarpus curtisii* (BKF SN 105458)

Plate 33. *Semecarpus* sp. (PSU SN 180478)

Plate 34. *Swintonia floribunda* (PSU SN 180483)

Plate 35. *Swintonia schwenkii* (BKF 4476)

PLATE 1

Bouea macrophylla

Fig. 1 bar 1cm

Fig. 2 bar 1cm

Fig. 3 bar 2 mm

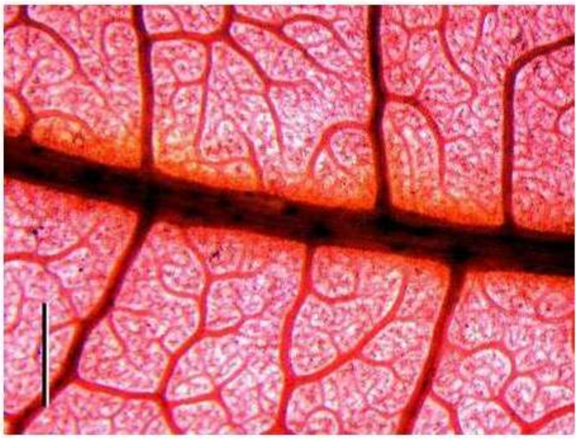


Fig. 4 bar 1 mm

PLATE 2

Bouea oppositifolia

Fig. 1 bar 1 cm

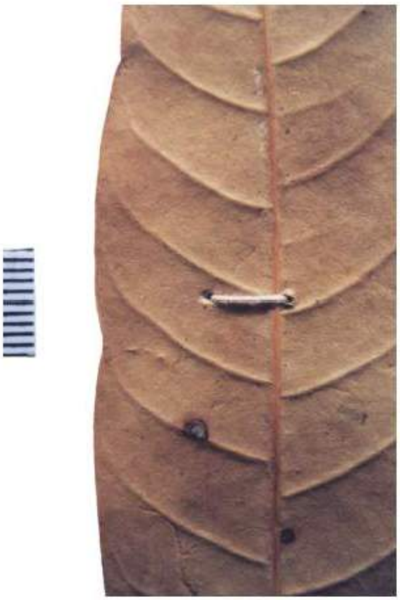


Fig. 2 bar 1 cm

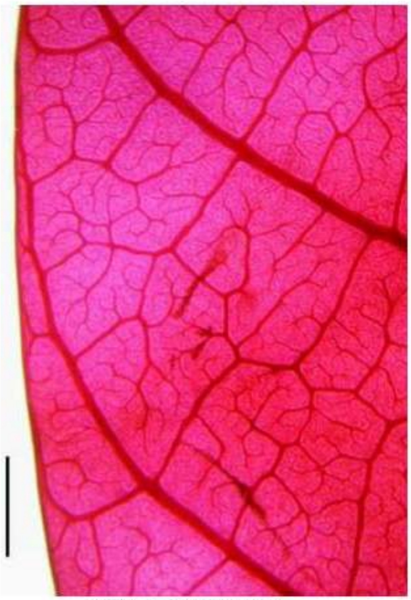


Fig. 3 bar 2 mm

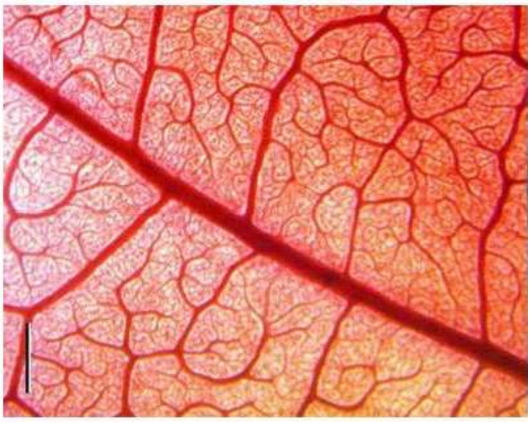


Fig. 4 bar 1 mm

PLATE 3

Buchanania arborescens

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

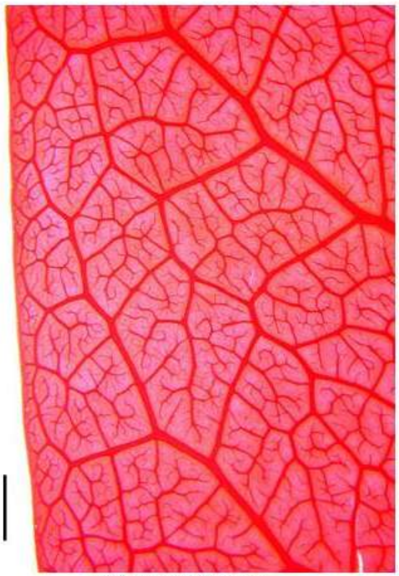


Fig. 3 bar 2 mm

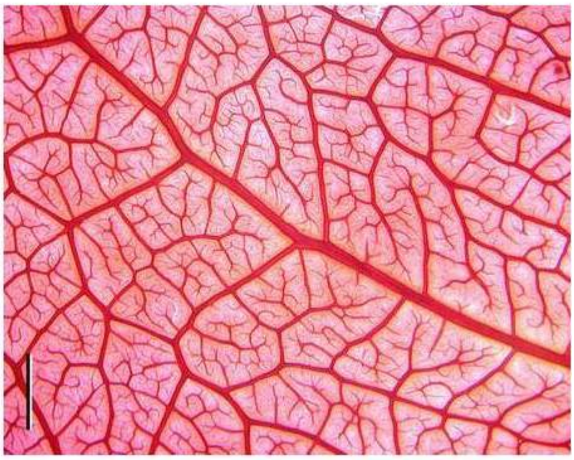


Fig. 4 bar 2 mm

PLATE 4

Buchanania reticulata

Fig. 1 bar 1 cm (SUT campus)

Fig. 2 bar 5 cm (SUT campus)

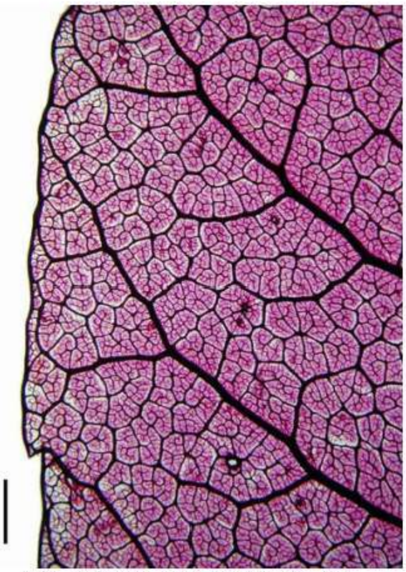


Fig. 3 bar 2 mm (SUT190_2)

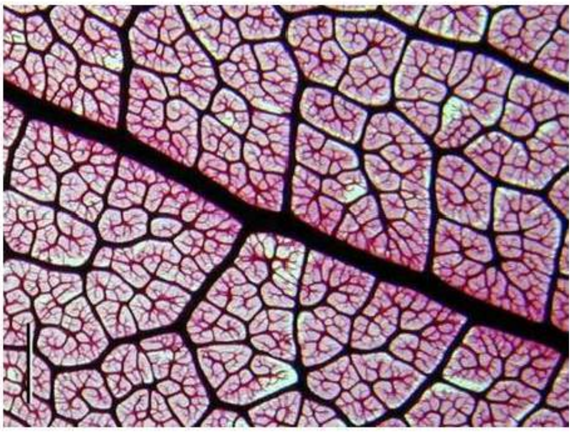


Fig. 4 bar1 mm (SUT190_2)

PLATE 5

Buchanania sessifolia

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

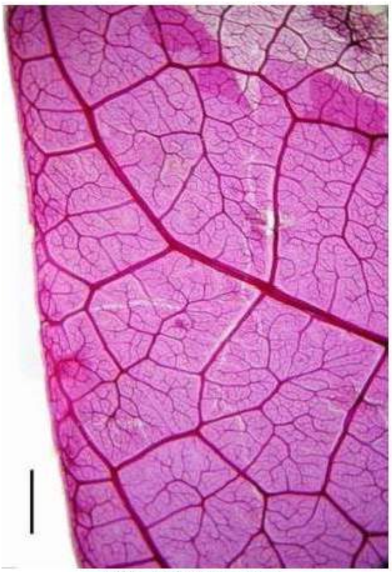


Fig. 3 bar 2 mm

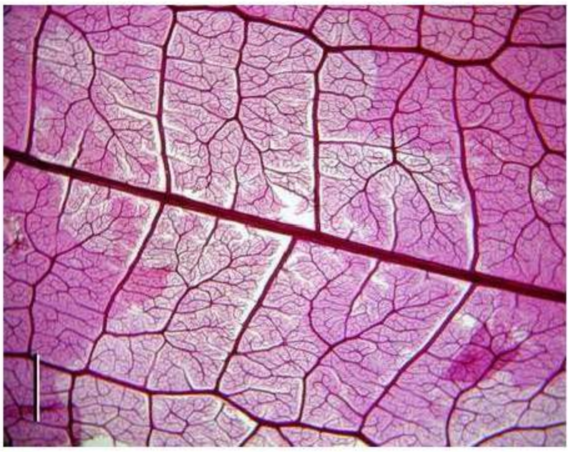


Fig. 4 bar 2 mm

PLATE 6

Buchanania siamensis

Fig. 1 bar 1 cm (PSU SN180428)

Fig. 2 (PSU SN180428)

Fig. 3 bar 5 mm (SUT190)

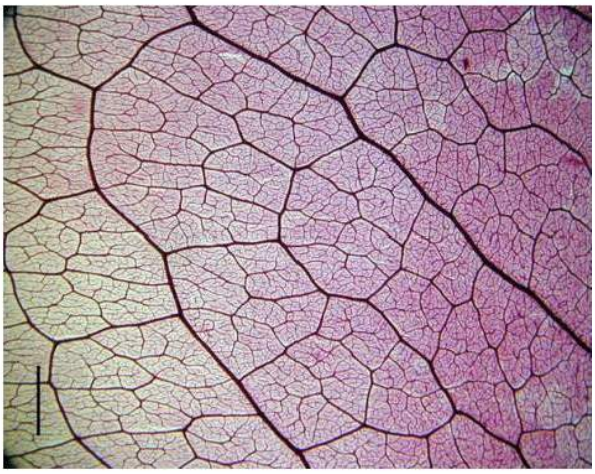


Fig. 4 bar 2 mm (SUT190)

PLATE 7

Drimycarpus luridus

Fig. 1 bar 1 cm

Fig. 2 bar 5 mm

Fig. 3 bar 2 mm

PLATE 8

Gluta elegans

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

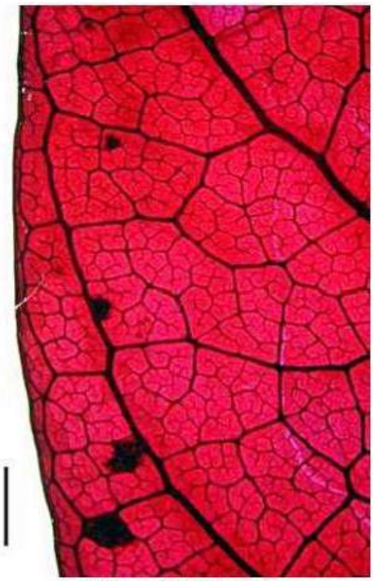


Fig. 3 bar 2 mm

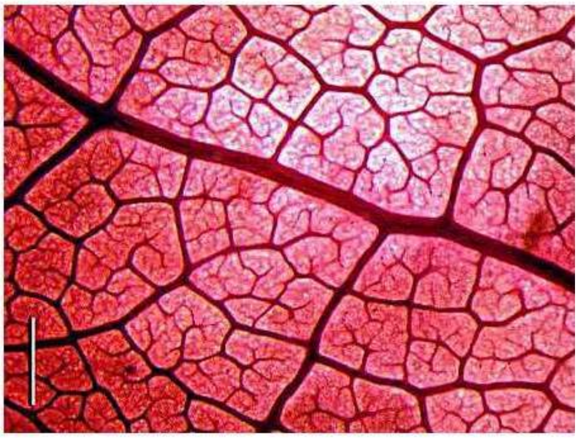


Fig. 4 bar 1 mm

PLATE 9

Gluta renghas


Fig. 1 bar 1 cm


Fig. 2 bar 1 cm

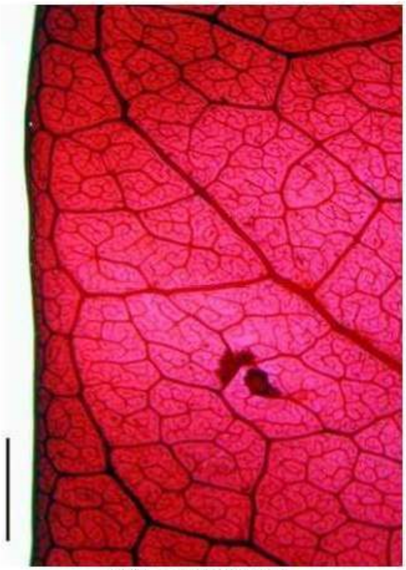


Fig. 3 bar 2 mm

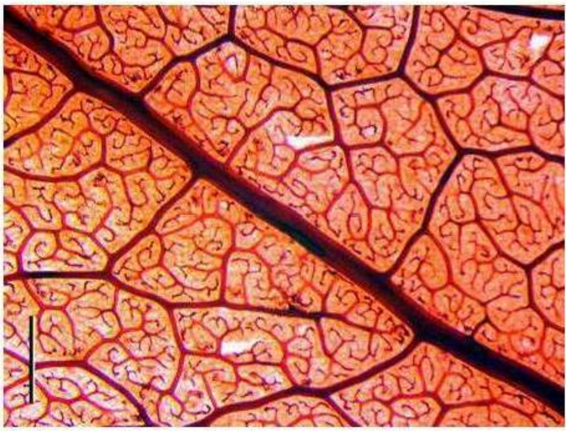


Fig. 4 bar 1 mm

PLATE 10

Mangifera caesia

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

PLATE 11

Mangifera caloneura

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

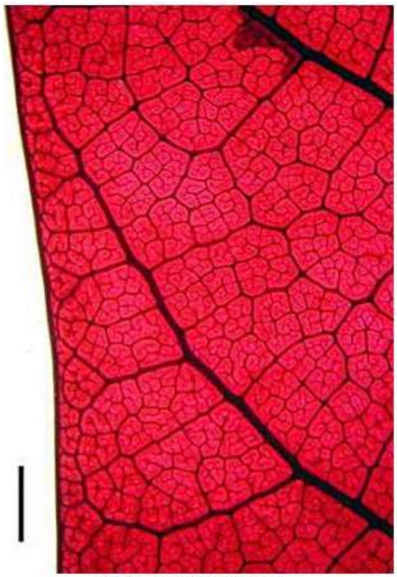


Fig. 3 bar 2 mm

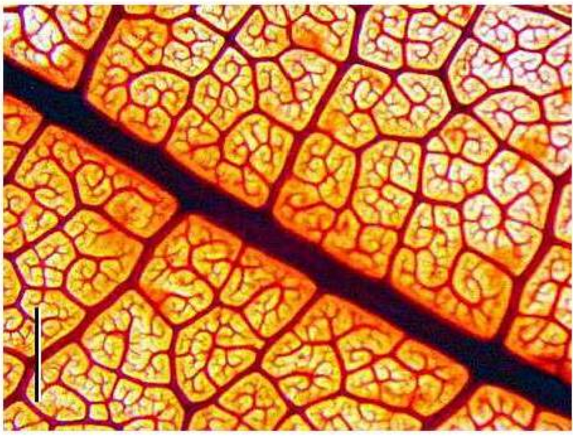


Fig. 4 bar 1 mm

PLATE 12

Mangifera camptosperma

Fig. 1 bar 1 cm

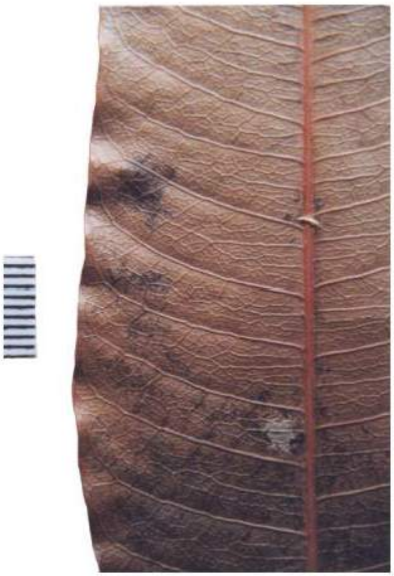


Fig. 2 bar 1 cm

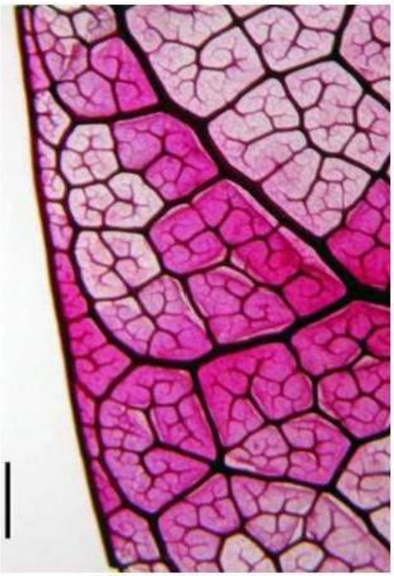


Fig. 3 bar 1 mm

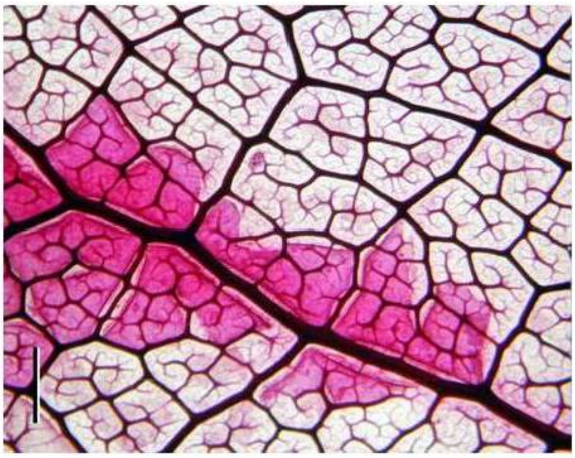


Fig. 4 bar 1 mm

PLATE 13

Mangifera chamaoensis

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

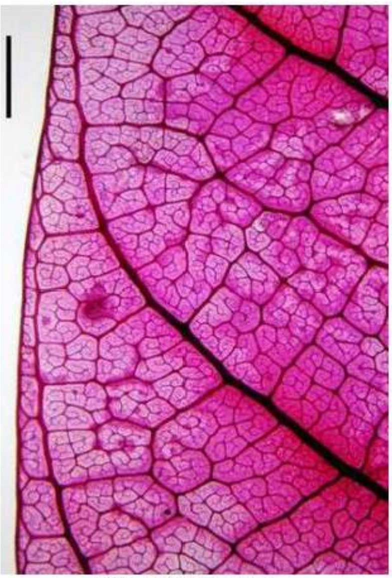


Fig. 3 bar 2 mm

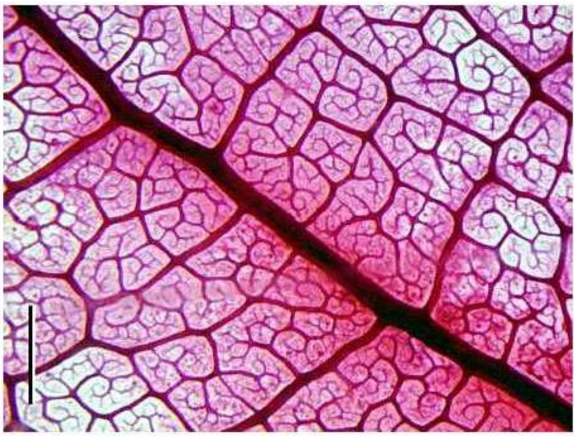


Fig. 4 bar 1 mm

PLATE 14

Mangifera collina

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

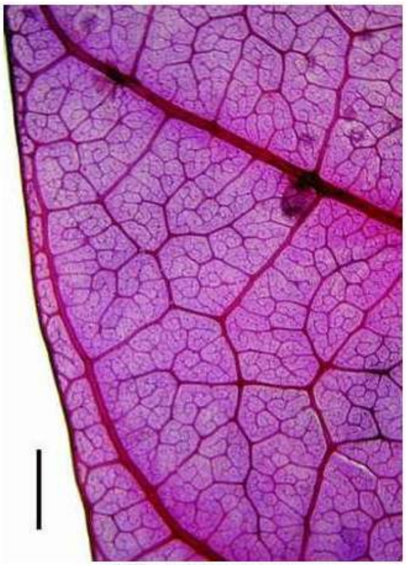


Fig. 3 bar 2 mm

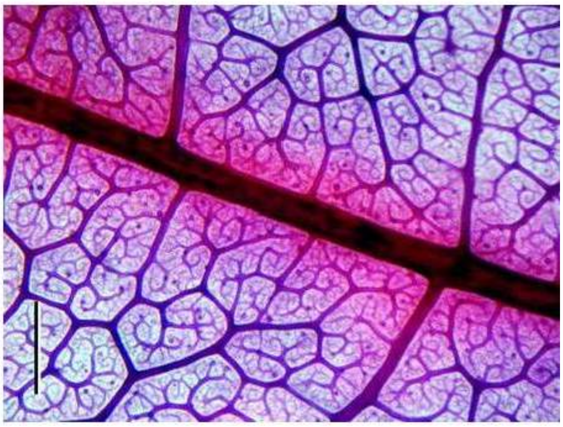


Fig. 4 bar 1 mm

PLATE 15

Mangifera duperreana

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

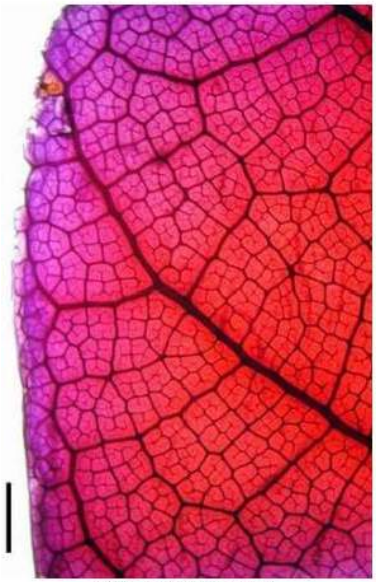


Fig. 3 bar 2 mm

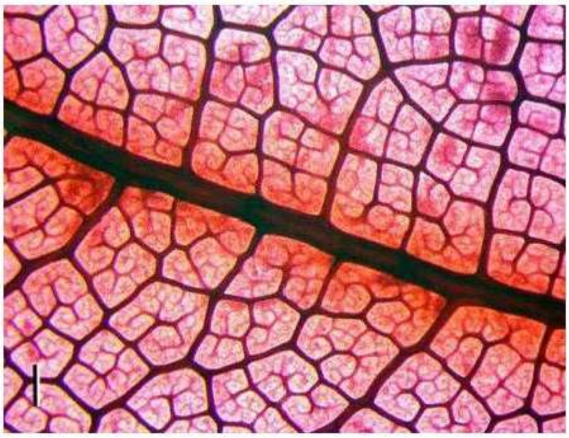


Fig. 4 bar 0.5 mm

PLATE 16

Mangifera flava

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

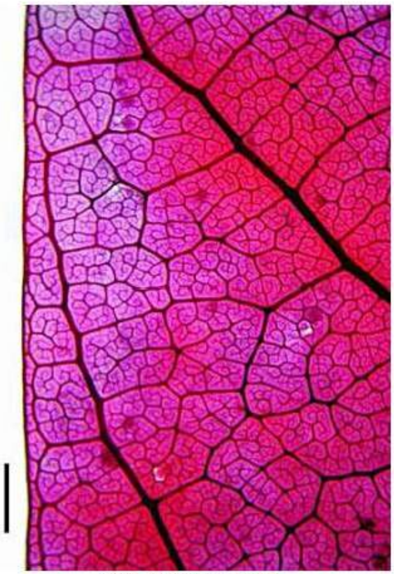


Fig. 3 bar 2 mm

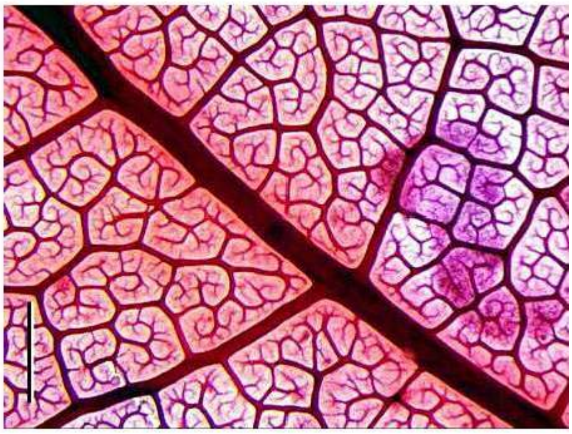


Fig. 4 bar 1 mm

PLATE 17

Mangifera foetida

Fig. 1 bar 1 cm

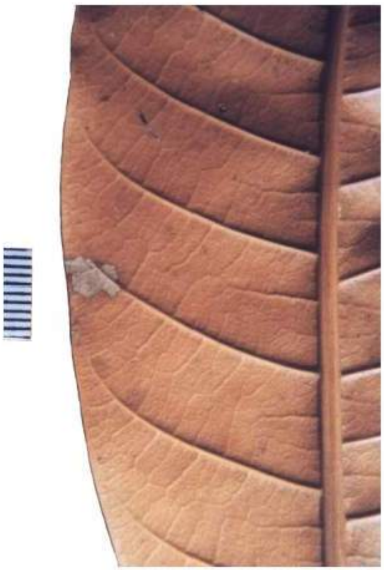


Fig. 2 bar 1 cm

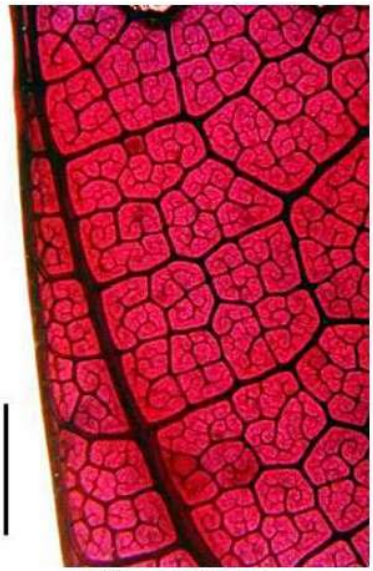


Fig. 3 bar 2 mm

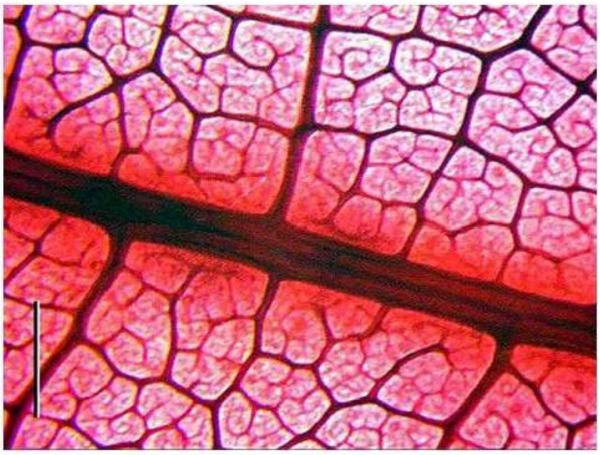


Fig. 4 bar 1 mm

PLATE 18

Mangifera gedebe

Fig. 1 bar 1 cm

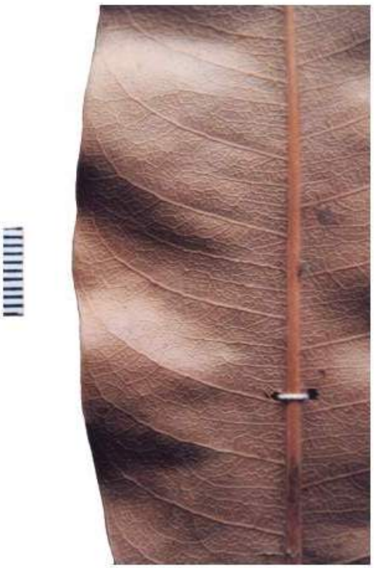


Fig. 2 bar 1 cm

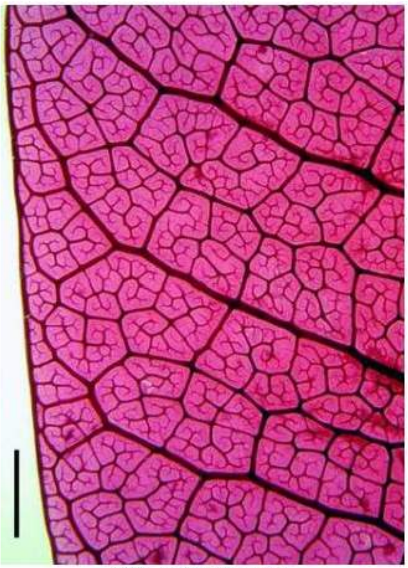


Fig. 3 bar 2 mm

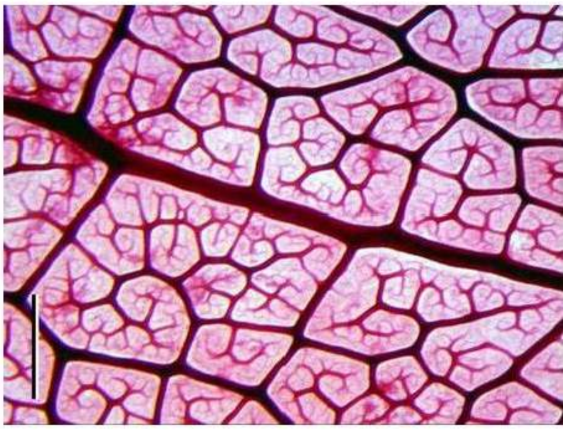


Fig. 4 bar 1 mm

PLATE 19

Mangifera griffithii

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

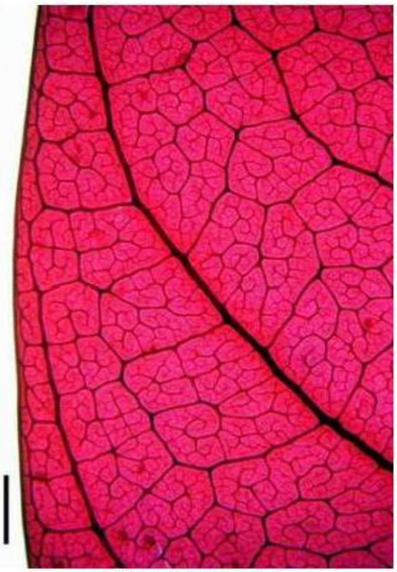


Fig. 3 bar 2 mm

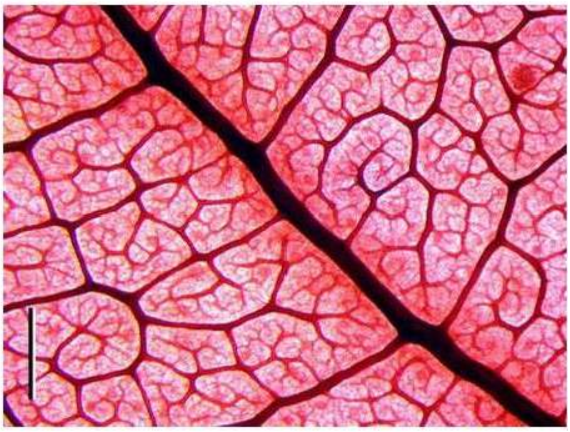


Fig. 4 bar 1 mm

PLATE 20

Mangifera indica

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

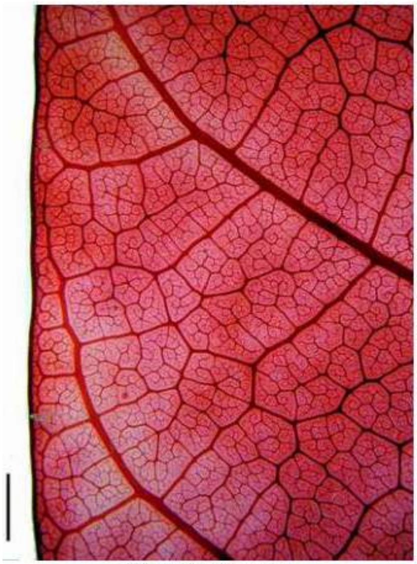


Fig. 3 bar 2 mm

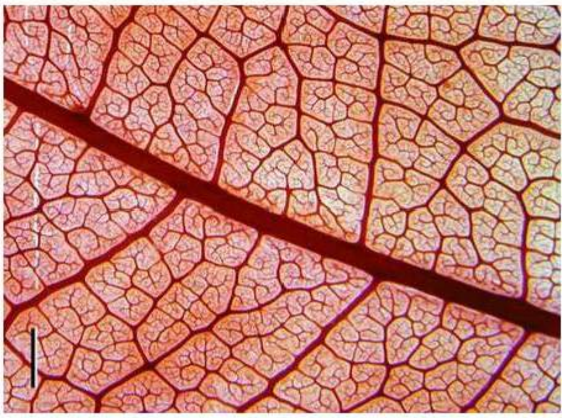


Fig. 4 bar 1 mm

PLATE 21

Mangifera linearifolia

Fig. 1 bar 1 cm

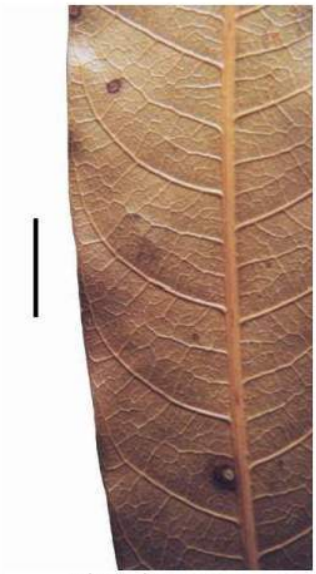


Fig. 2 bar 1 cm

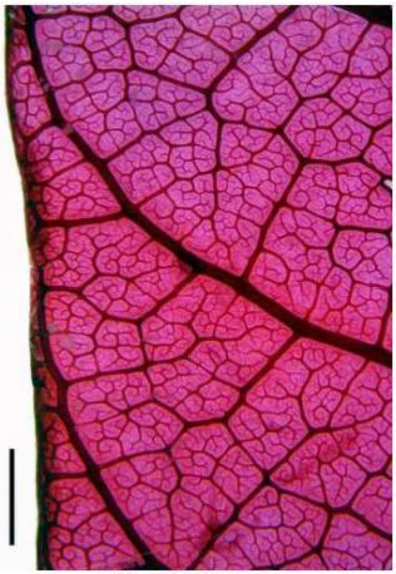


Fig. 3 bar 2 mm

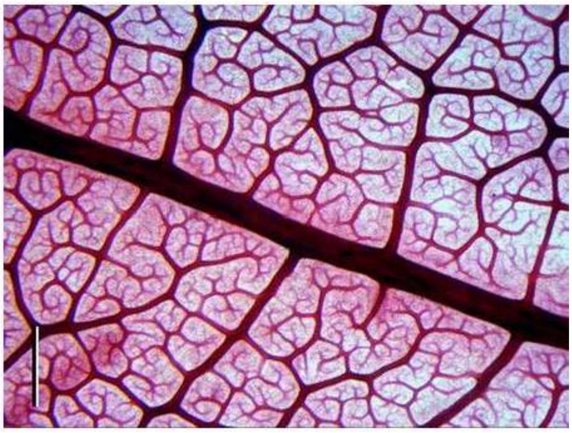


Fig. 4 bar 1 mm

PLATE 22

Mangifera macrocarpa

Fig. 1 bar 1 cm (PSU)

Fig. 2 From New York Botanical Garden

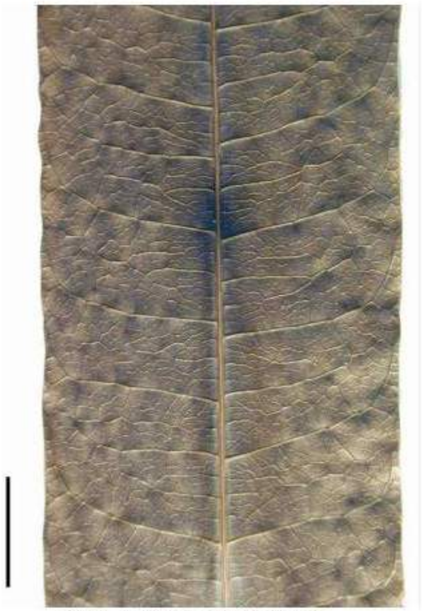


Fig. 3 bar 1 cm (PSU)

Fig. 4 bar 3 mm (PSU)

PLATE 23

Mangifera microphylla

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

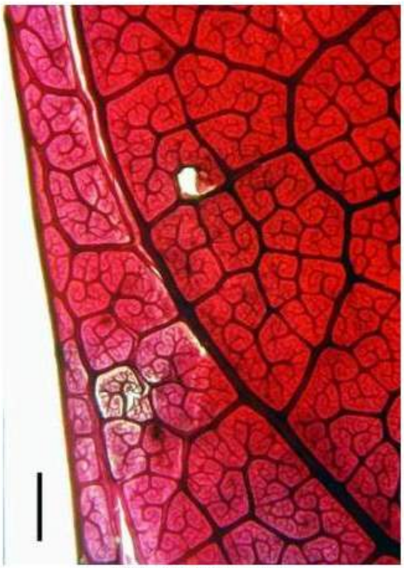


Fig. 3 bar 1 mm

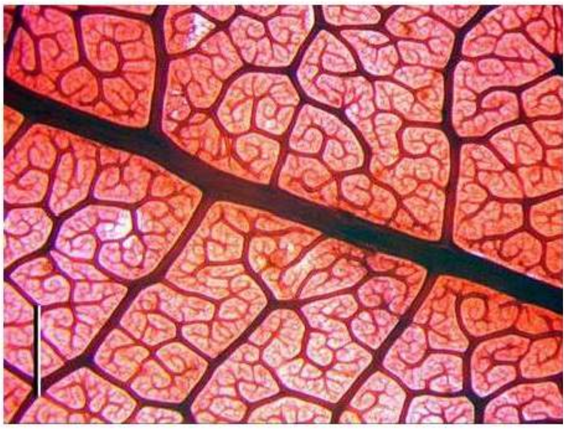


Fig. 4 bar 1 mm

PLATE 24

Mangifera odorata

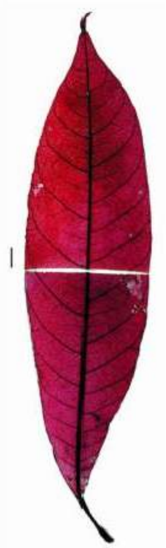


Fig. 1 bar 1 cm (SUT Collection)

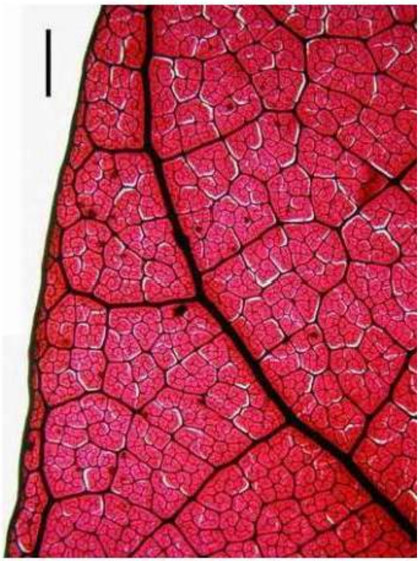


Fig. 2 bar 2 mm

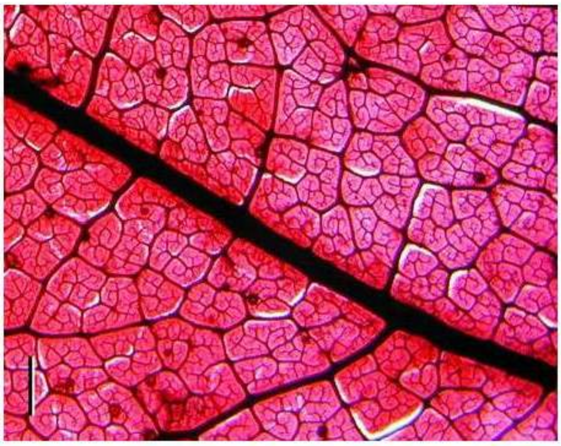


Fig. 3 bar 1 mm

PLATE 25

Mangifera pentandra

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

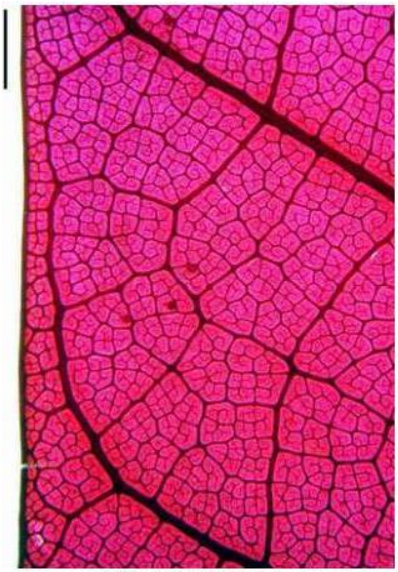


Fig. 3 bar 2 mm

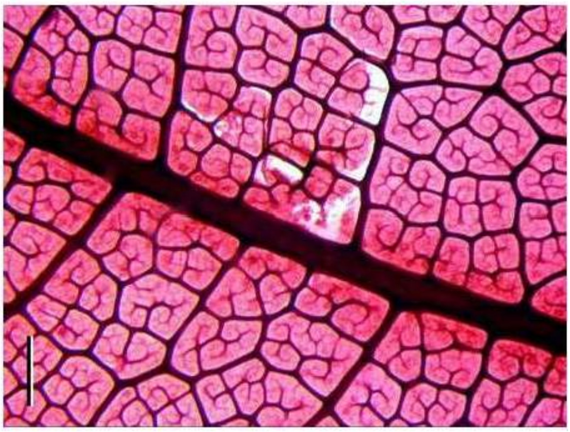


Fig. 4 bar 1 mm

PLATE 26

Mangifera quadrifida

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

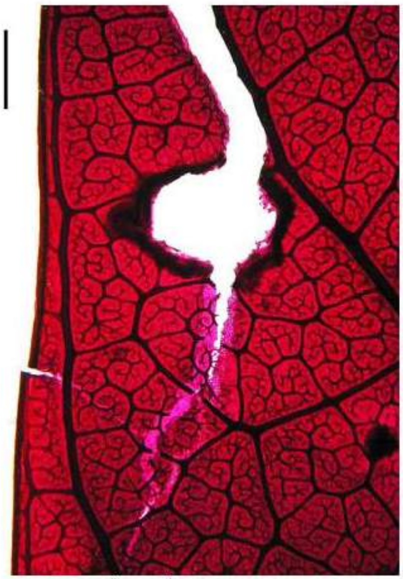


Fig. 3 bar 2 mm

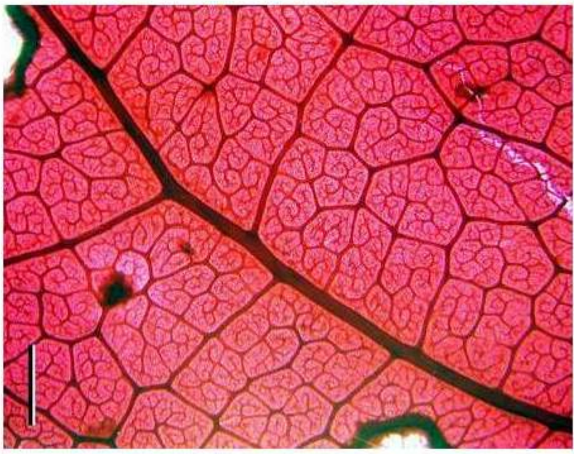


Fig. 4 bar 2 mm

PLATE 27

Mangifera sylvatica

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

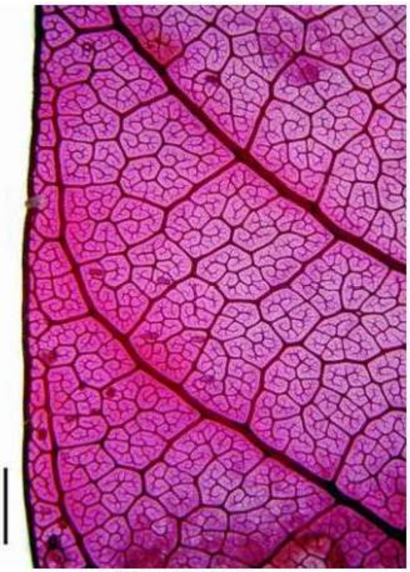


Fig. 3 bar 2 mm

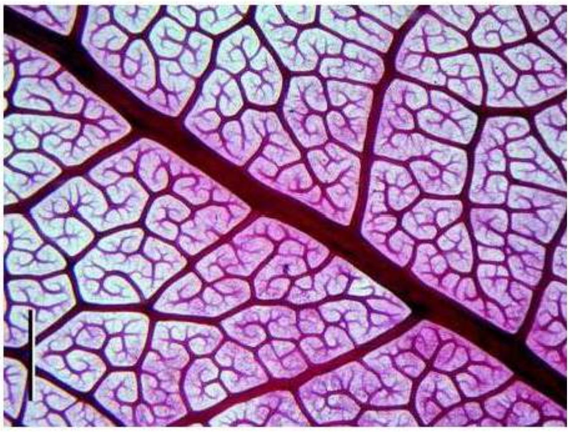


Fig. 4 bar 1 mm

PLATE 28

Melanochyla angustifolia

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

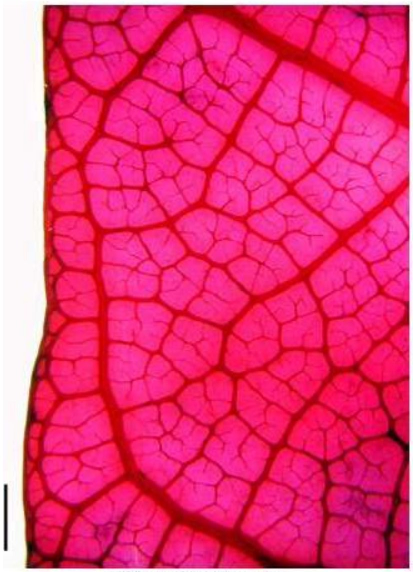


Fig. 3 bar 2 mm

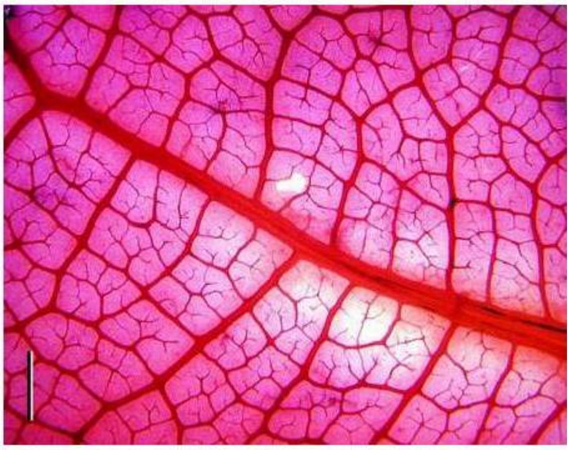


Fig. 4 bar 2 mm

PLATE 29

Melanochyla bracteata

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

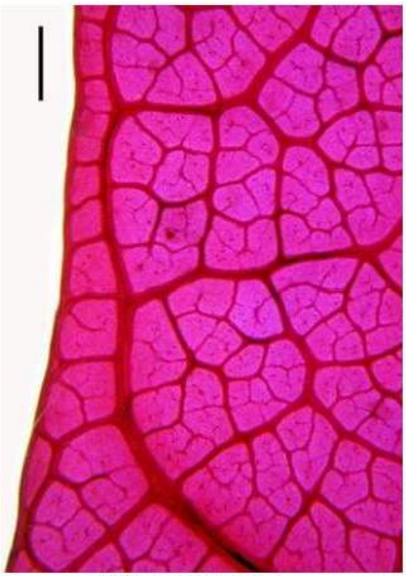


Fig. 3 bar 1 mm

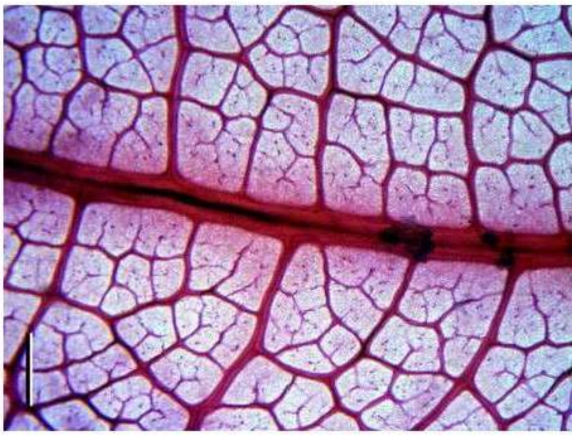


Fig. 4 bar 1 mm

PLATE 30

Melanochyla nitida

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

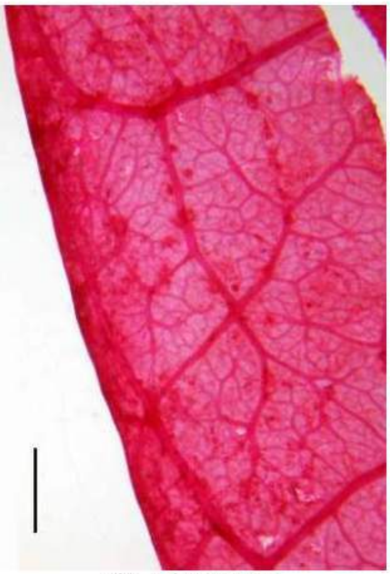


Fig. 3 bar 1 mm

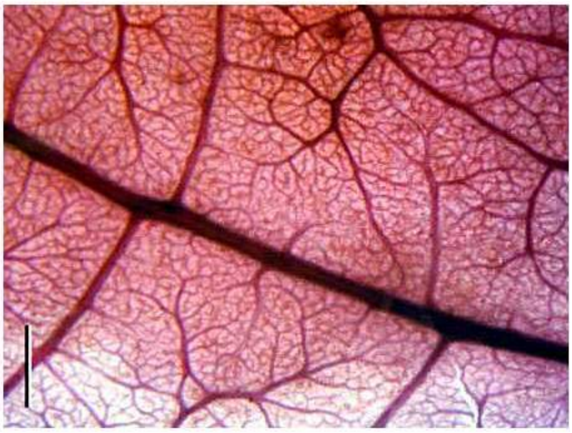


Fig. 4 bar 1 mm

PLATE 31

Semecarpus cochinchinensis

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

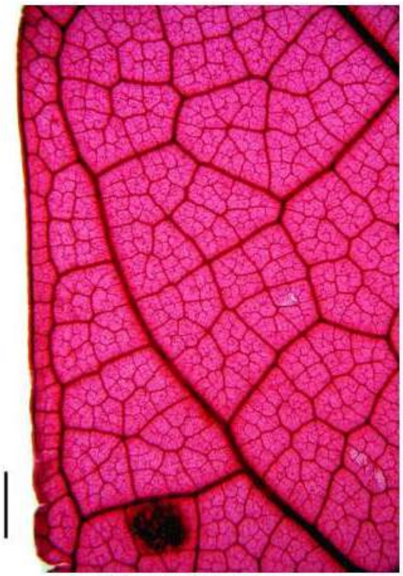


Fig. 3 bar 2 mm

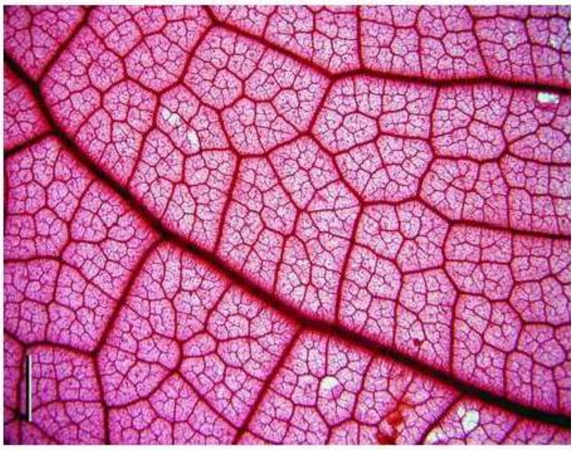


Fig. 4 bar 2 mm

PLATE 32

Semecarpus curtisii

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

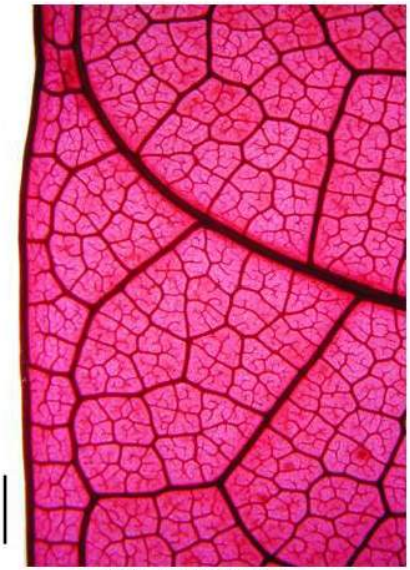


Fig. 3 bar 2 mm

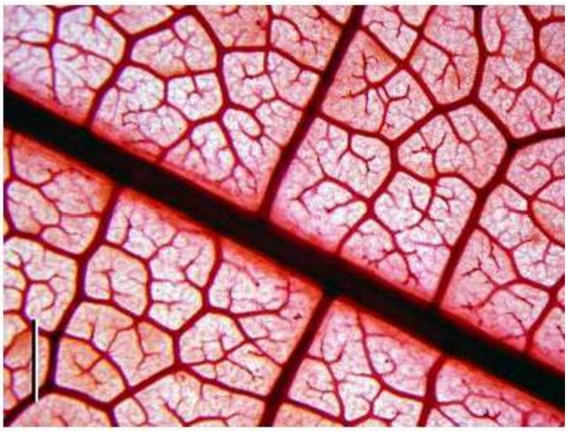


Fig. 4 ba1 mm

PLATE 33

Semecarpus sp.

Fig. 1 bar 1 cm

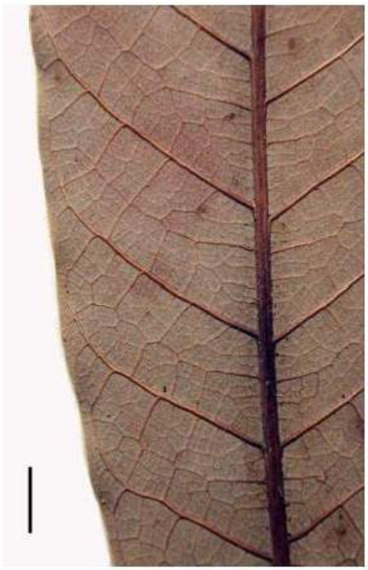


Fig. 2 bar 1 cm

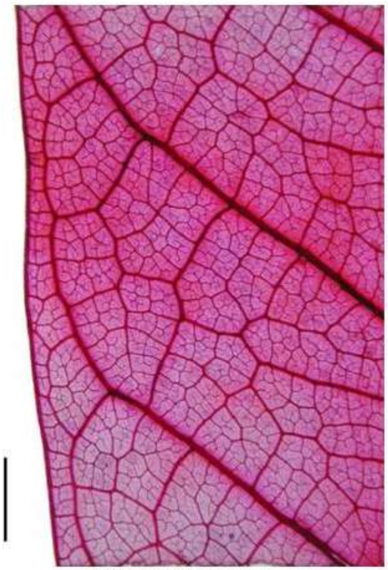


Fig. 3 bar 3 mm

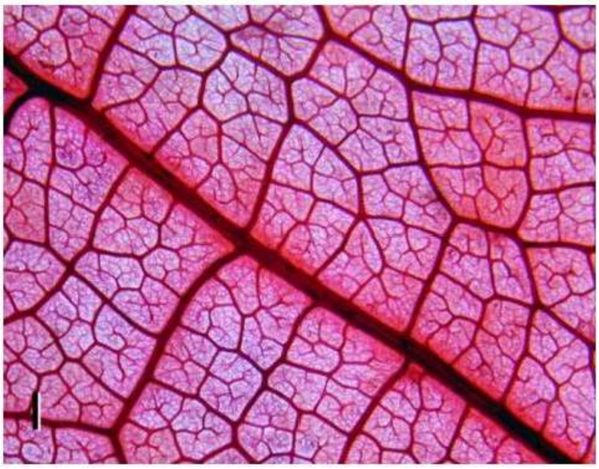


Fig. 4 bar 0.5 mm

PLATE 34

Swintonia floribunda

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

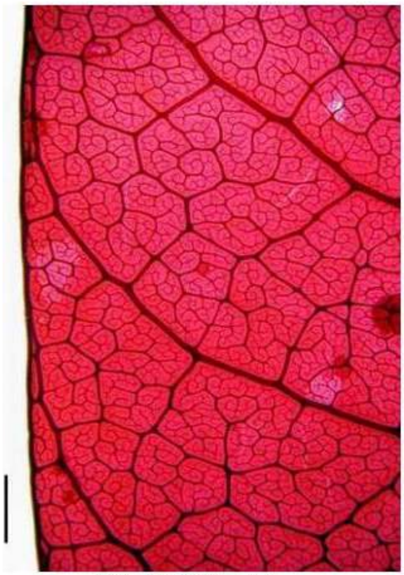


Fig. 3 bar 2 mm

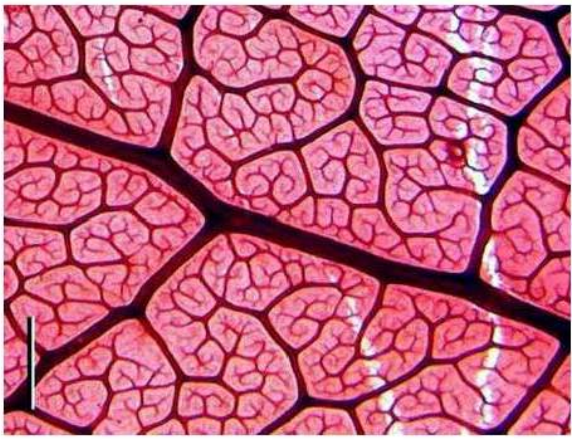


Fig. 4 bar 1 mm

PLATE 35

Swintonia schwenkii

Fig. 1 bar 1 cm

Fig. 2 bar 1 cm

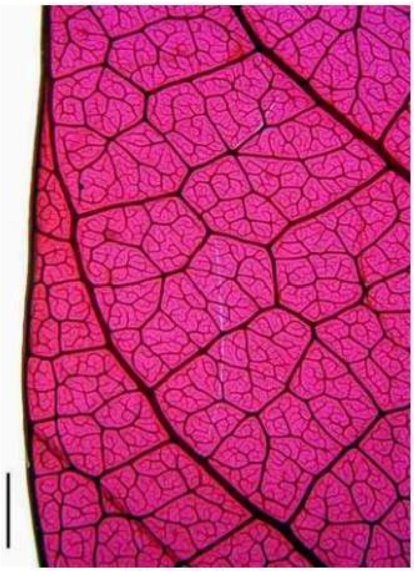


Fig. 3 bar 2 mm

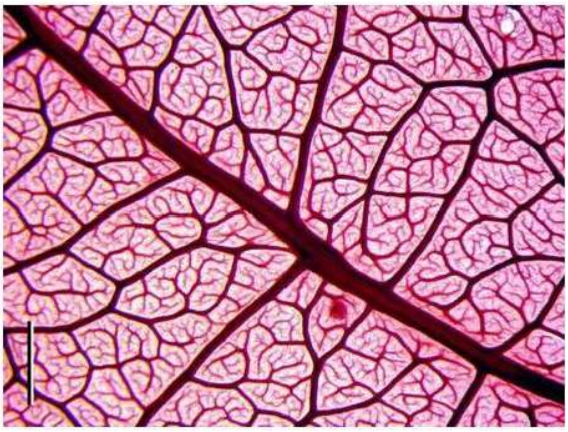


Fig. 4 bar 1 mm

Appendix B

List of plates of anacardiaceous fossil leaves

Codes of Specimen numbers of specimen are in parentheses. For explanations, see description of each species.

Plate 36 *Mangifera paleoindica* sp. nov. Sawangchote, Grote, Dilcher (SUT 083)

Plate 37 *Mangifera intermedia* sp. nov. Sawangchote, Grote, Dilcher (SUT 224)

Plate 38 *Mangifera buchananoides* sp. nov. Sawangchote, Grote, Dilcher (SUT 672)

Plate 39 *Semecarpus paleosiamensis* sp. nov. Sawangchote, Grote, Dilcher (SUT 728)

Plate 40 *Semecarpus paleomangiferoides* sp. nov. Sawangchote, Grote, Dilcher (SUT 845)

PLATE 36

Mangifera paleoindica sp. nov. Sawangchote, Grote, Dilcher

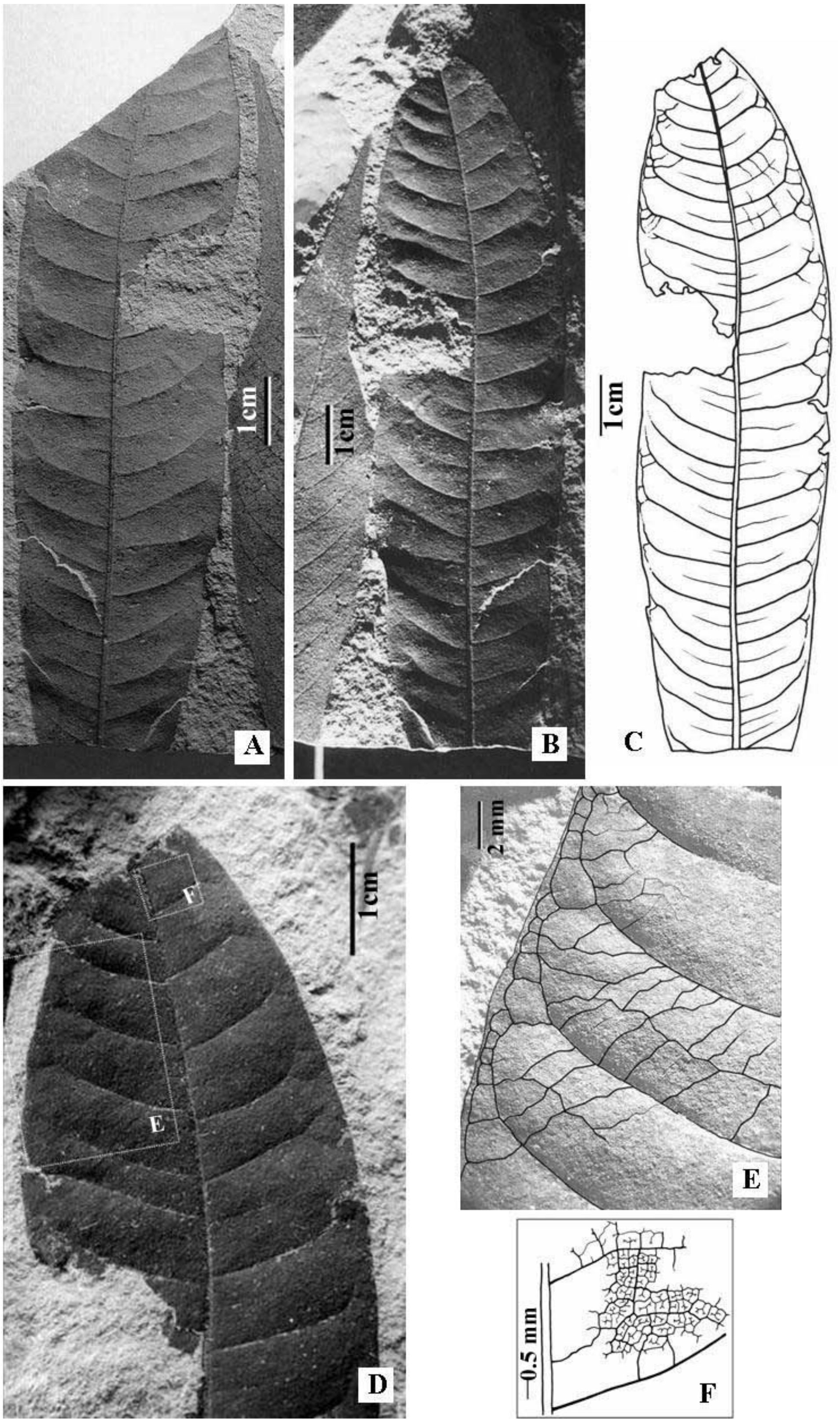


PLATE 37

Mangifera intermedia sp. nov. Sawangchote, Grote, Dilcher

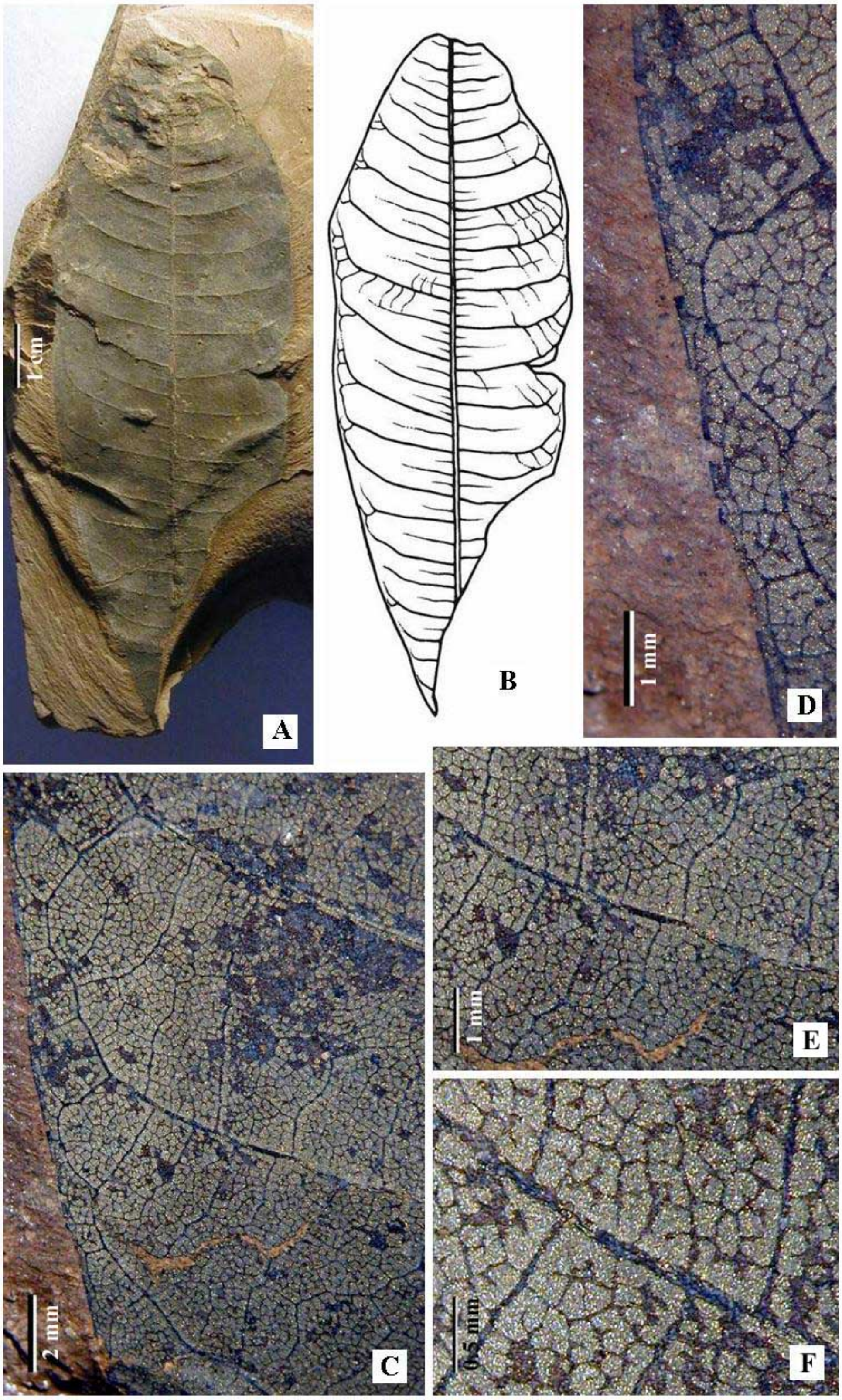


PLATE 38

Mangifera buchananoides sp. nov. Sawangchote, Grote, Dilcher

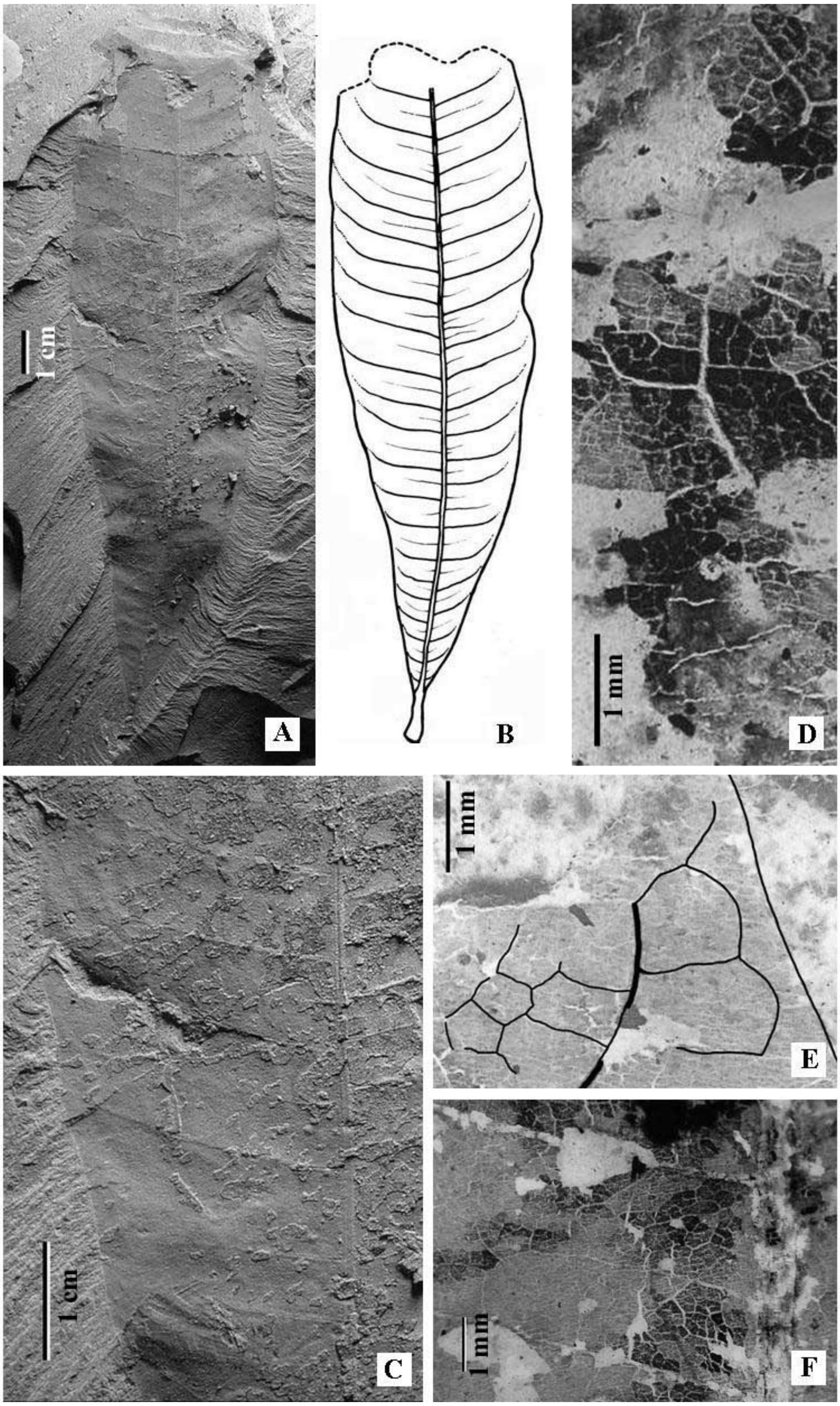


PLATE 39

Semecarpus paleosiamensis sp. nov. Sawangchote, Grote, Dilcher

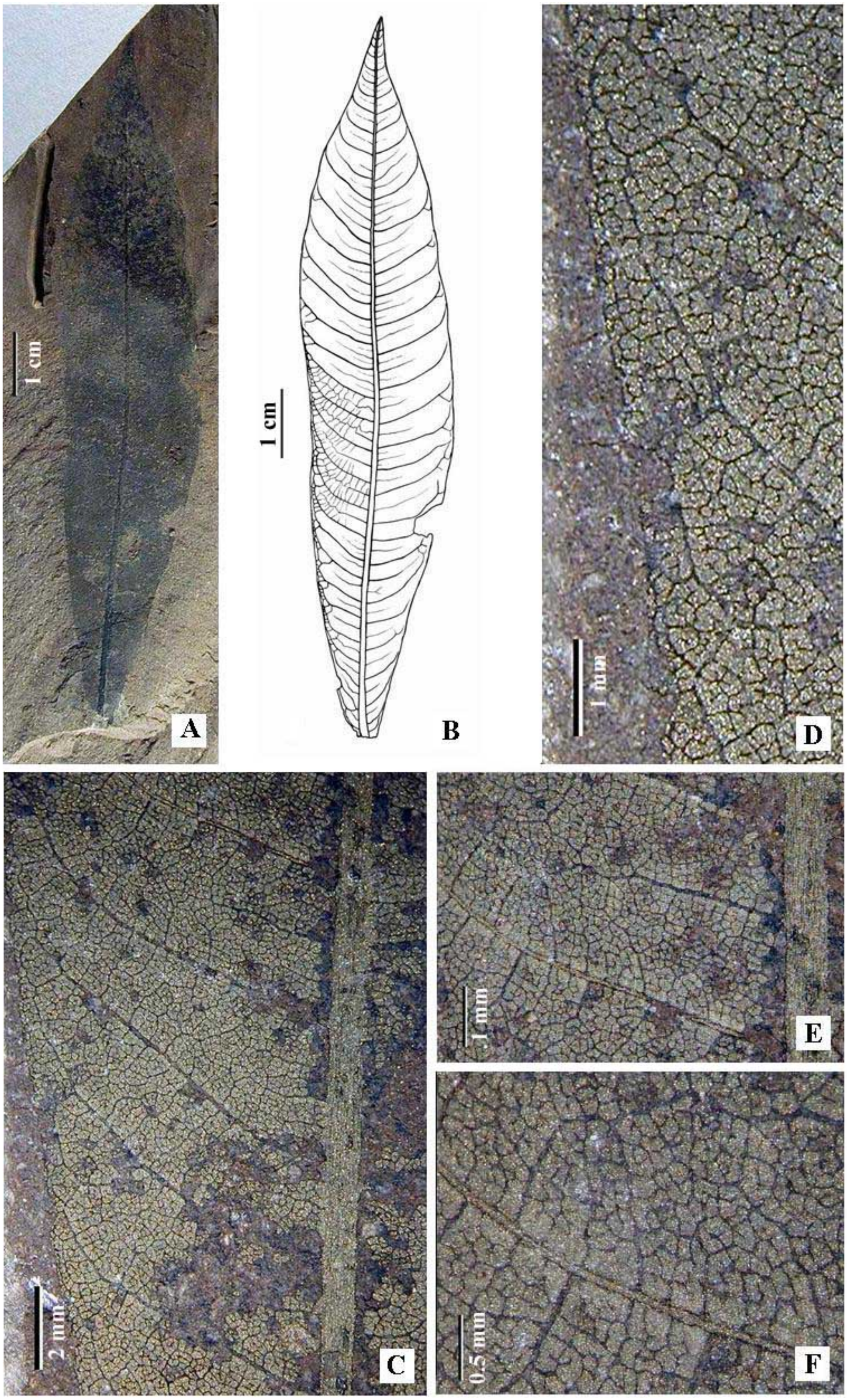
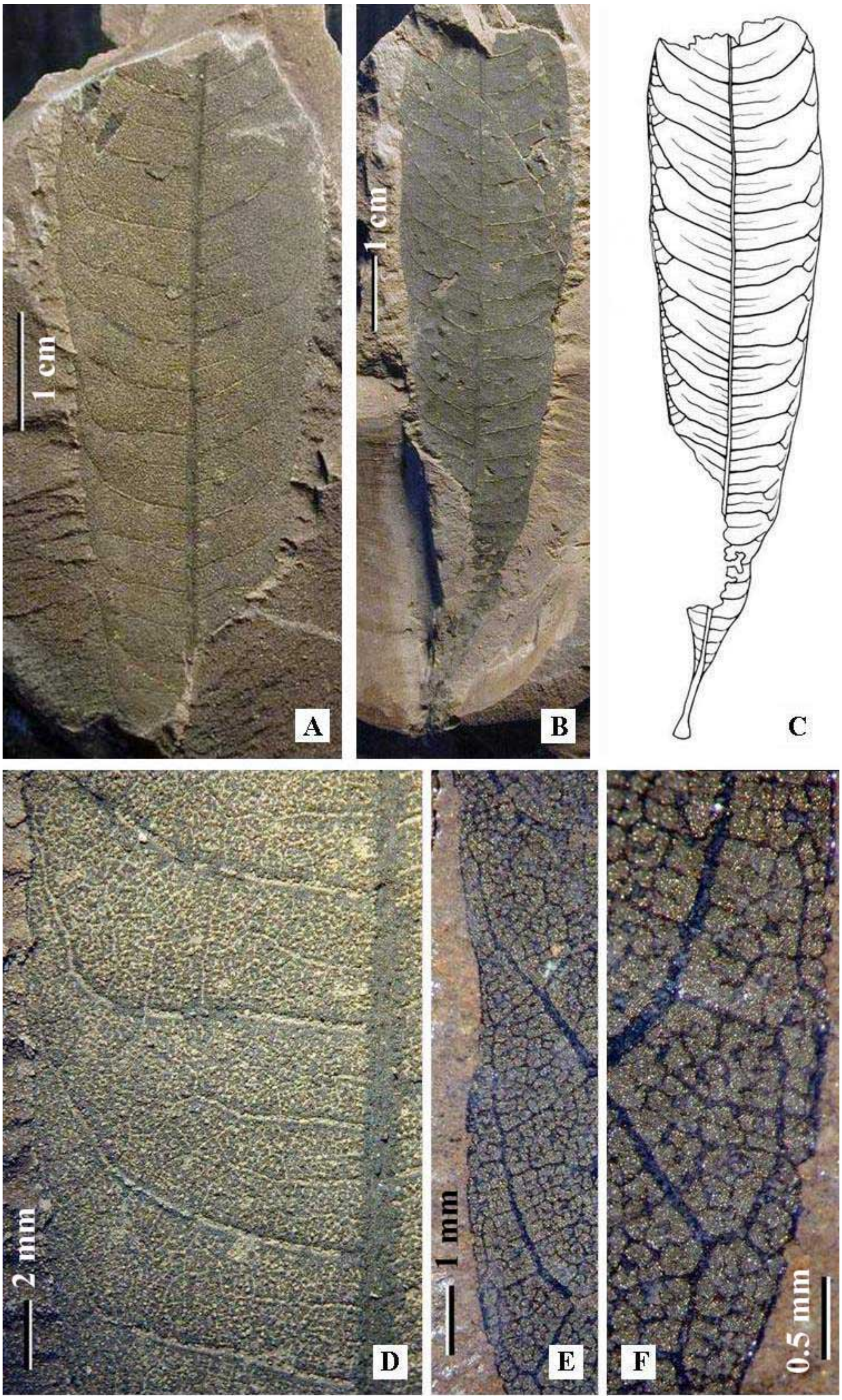


PLATE 40

Semecarpus paleomangiferoides sp. nov. Sawangchote, Grote, Dilcher



Appendix C

List of plates of leguminous fossil leaves

Codes of Specimen numbers are in parentheses. For explanations, see description of each species.

Plate 41 *Adenanthassia paleothailandica* gen. nov. & sp. nov. Sawangchote, Grote, Dilcher (Holotype; SUT 1149)

Plate 42 *Adenanthassia paleothailandica* gen. nov. & sp. nov. Sawangchote, Grote, Dilcher (Paratype; SUT 1018)

Plate 43 *Albizia paleoproceroides* sp. nov. Sawangchote, Grote, Dilcher (SUT 718)

Plate 44 *Antheroporum paleolamphunensis* sp. nov. Sawangchote, Grote, Dilcher (SUT 1341)

Plate 45 *Cassia paleosiamea* sp. nov. Sawangchote, Grote, Dilcher (Paratype; SUT 665)

Plate 46 *Cassia paleosiamea* sp. nov. Sawangchote, Grote, Dilcher (Holotype; SUT 706)

Plate 47 *Pithecellobium paleolampangensis* sp.nov. Sawangchote, Grote, Dilcher (Paratype; SUT 1023)

Plate 48 *Pithecellobium paleolampangensis* sp.nov. Sawangchote, Grote, Dilcher (Paratype; SUT 1028)

Plate 49 *Pithecellobium paleolampangensis* sp.nov. Sawangchote, Grote, Dilcher (Holotype; SUT 1051)

PLATE 41

Adenanthassia paleothailandica gen. nov. & sp. nov. Sawangchote, Grote, Dilcher

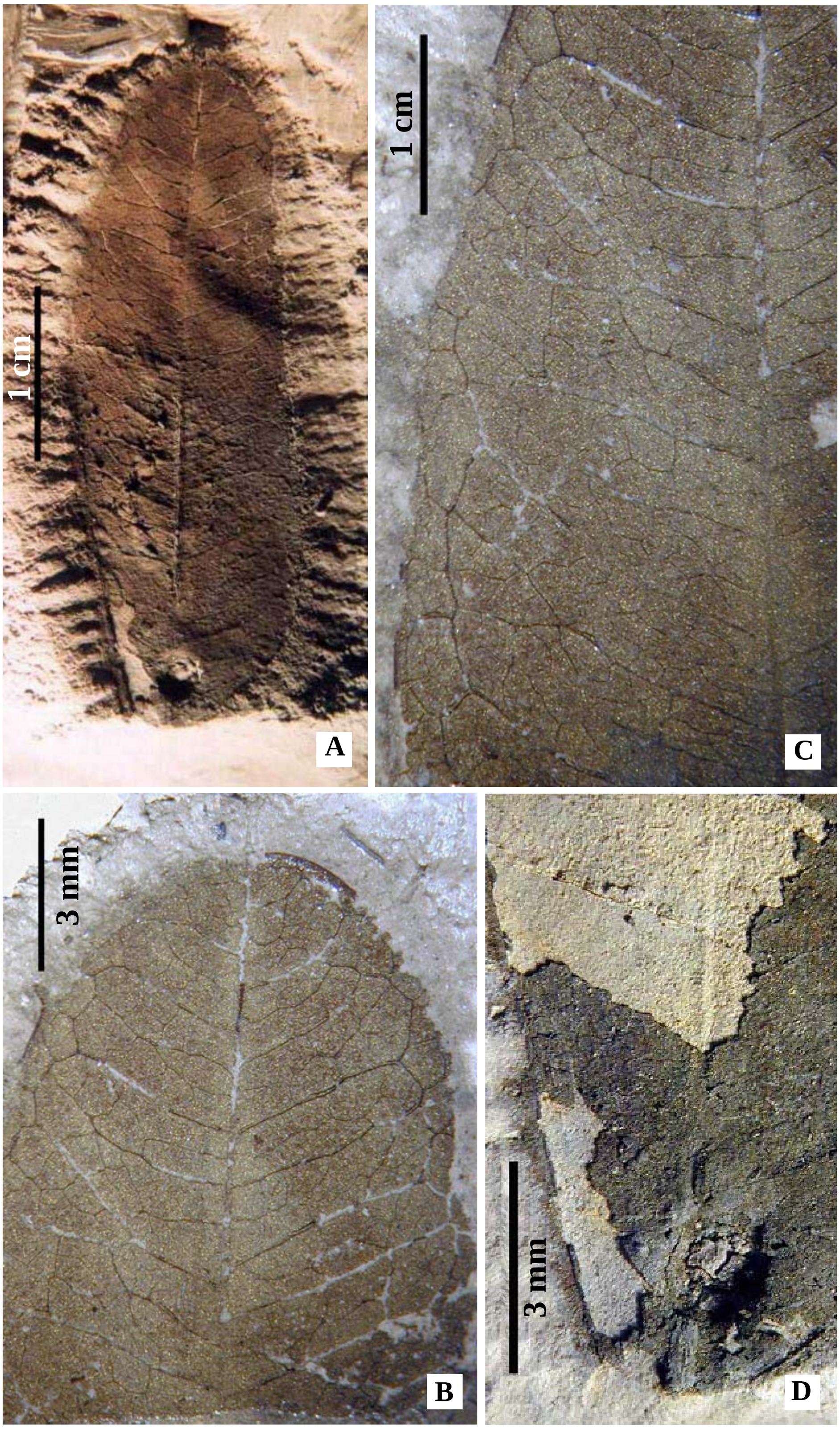


PLATE 42

Adenanthassia paleothailandica gen. nov. & sp. nov. Sawangchote, Grote, Dilcher

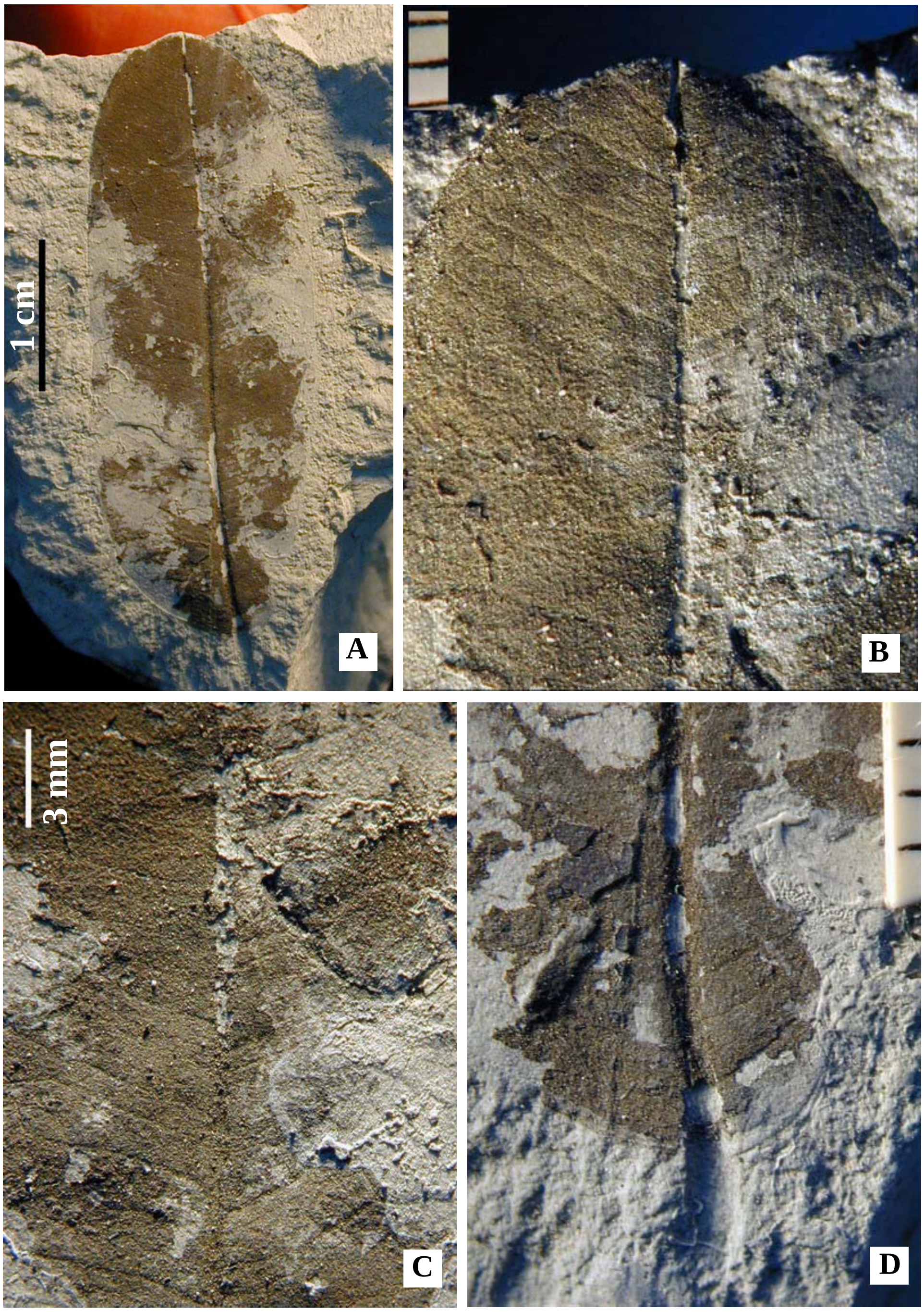


PLATE 43

Albizia paleoproceroides sp. nov. Sawangchote, Grote, Dilcher

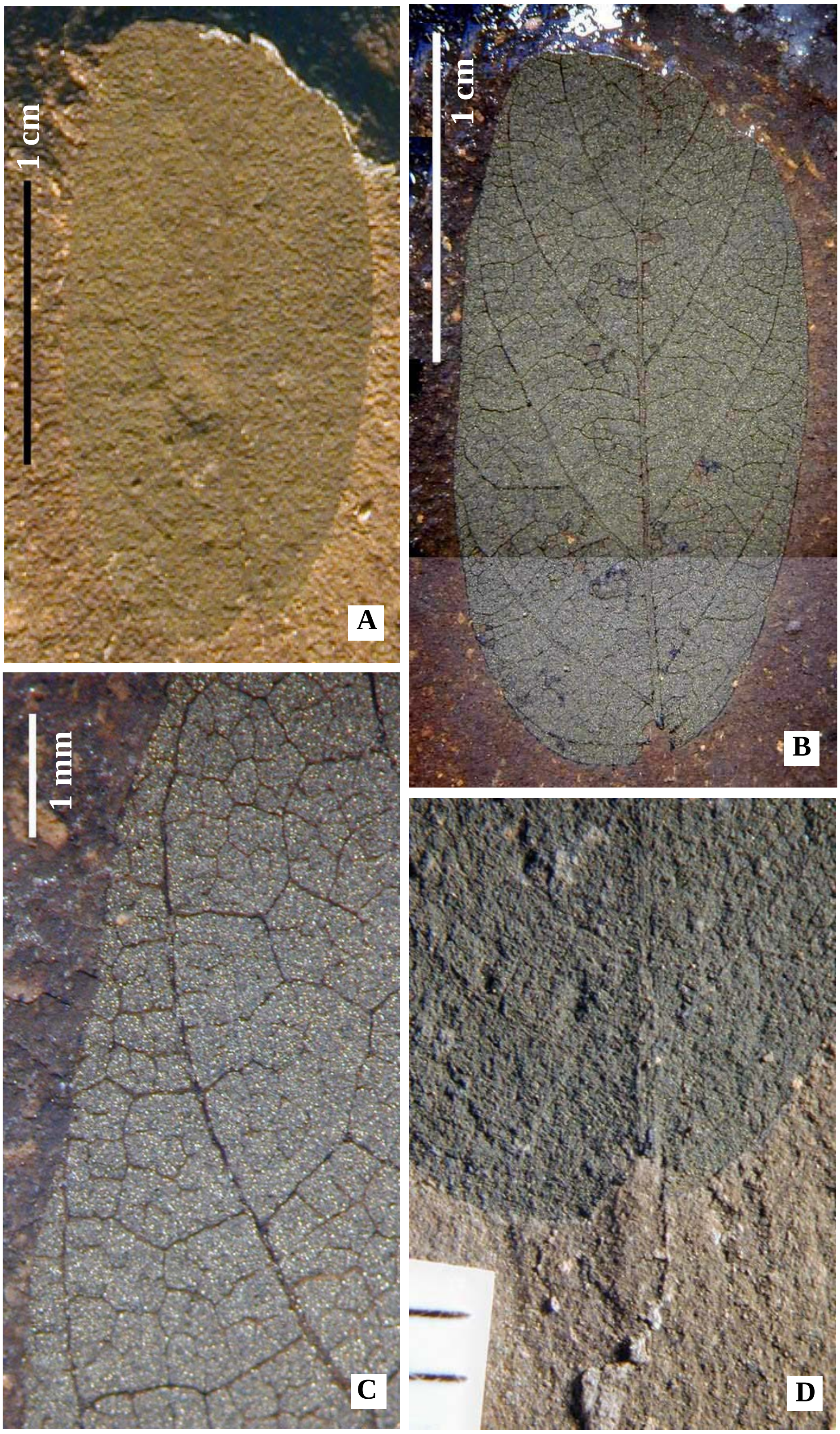


PLATE 44

Antheroporum paleolamphunensis sp. nov. Sawangchote, Grote, Dilcher

PLATE 45

Cassia paleosiamea sp. nov. Sawangchote, Grote, Dilcher

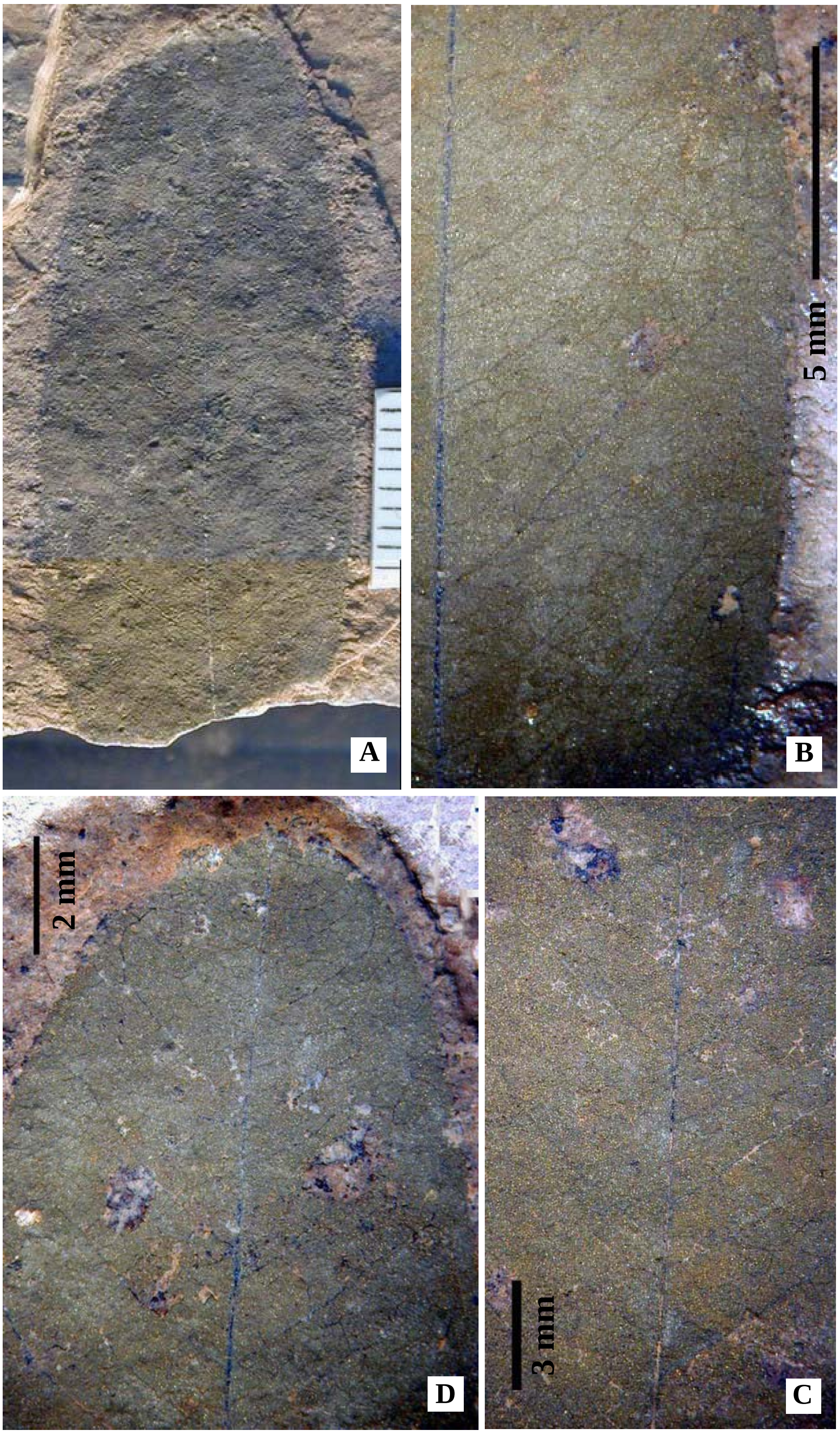


PLATE 46

Cassia paleosiamea sp. nov. Sawangchote, Grote, Dilcher

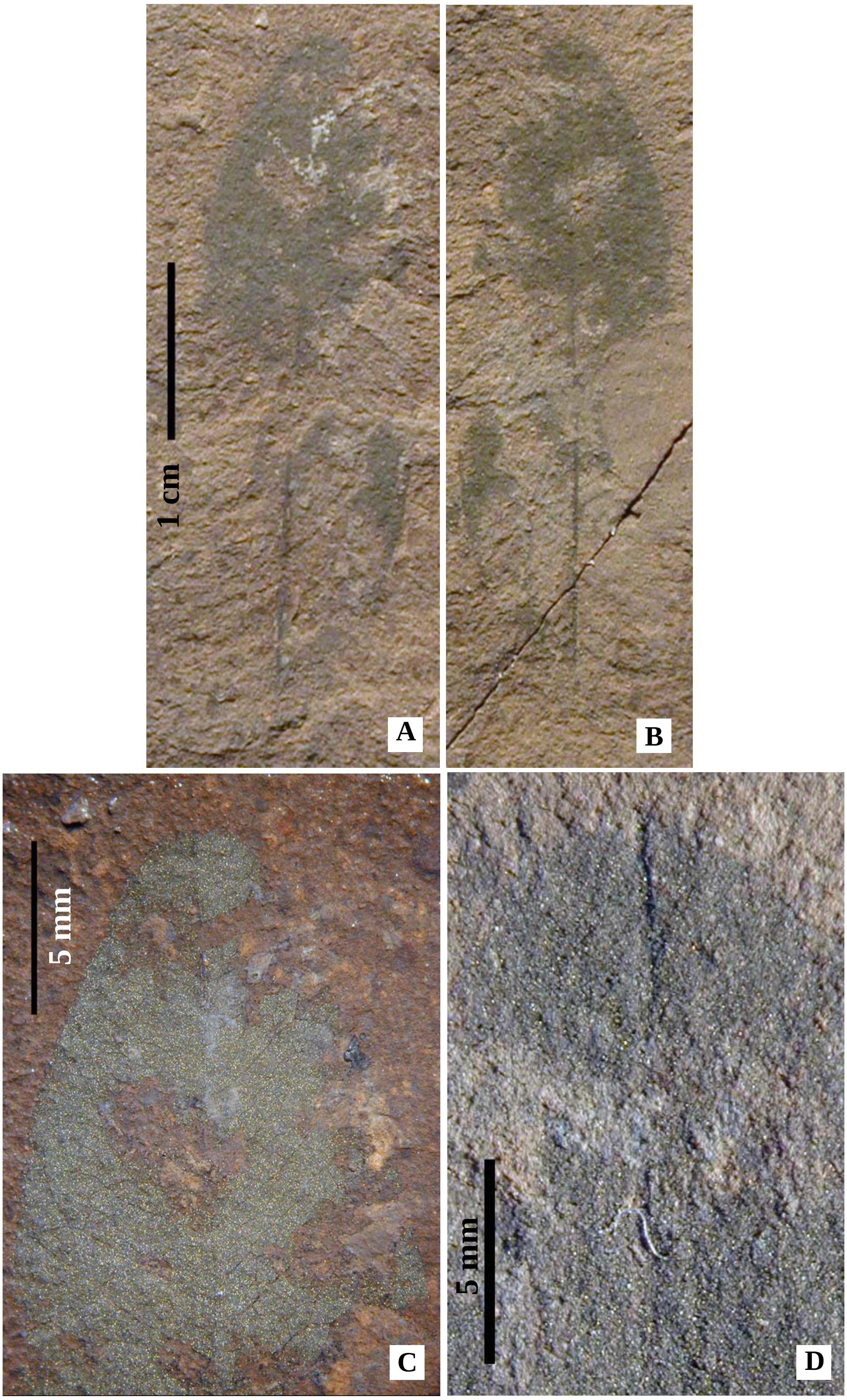


PLATE 47

Pithecellobium paleolampangensis sp.nov. Sawangchote, Grote, Dilcher

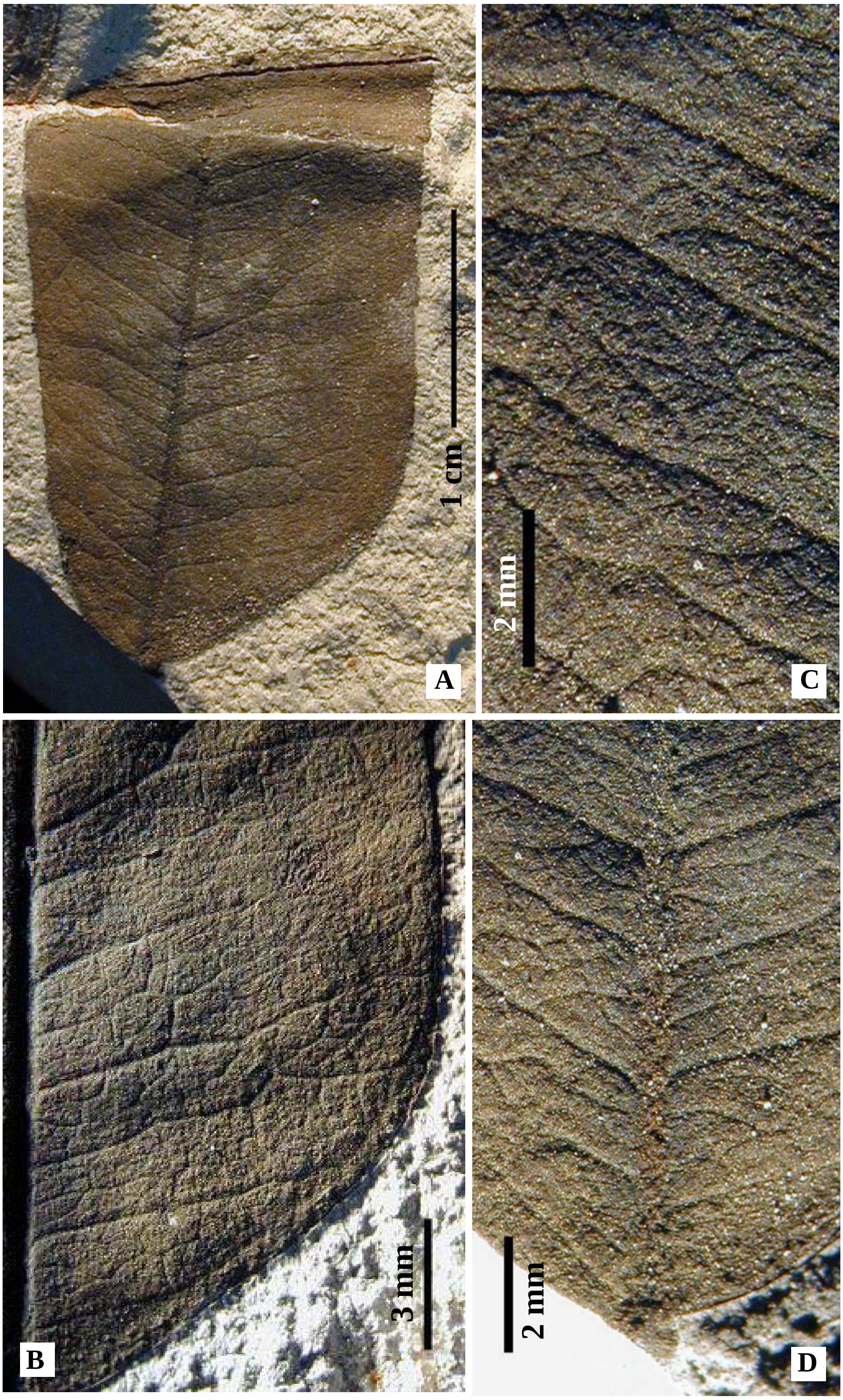


PLATE 48

Pithecellobium paleolampangensis sp.nov. Sawangchote, Grote, Dilcher

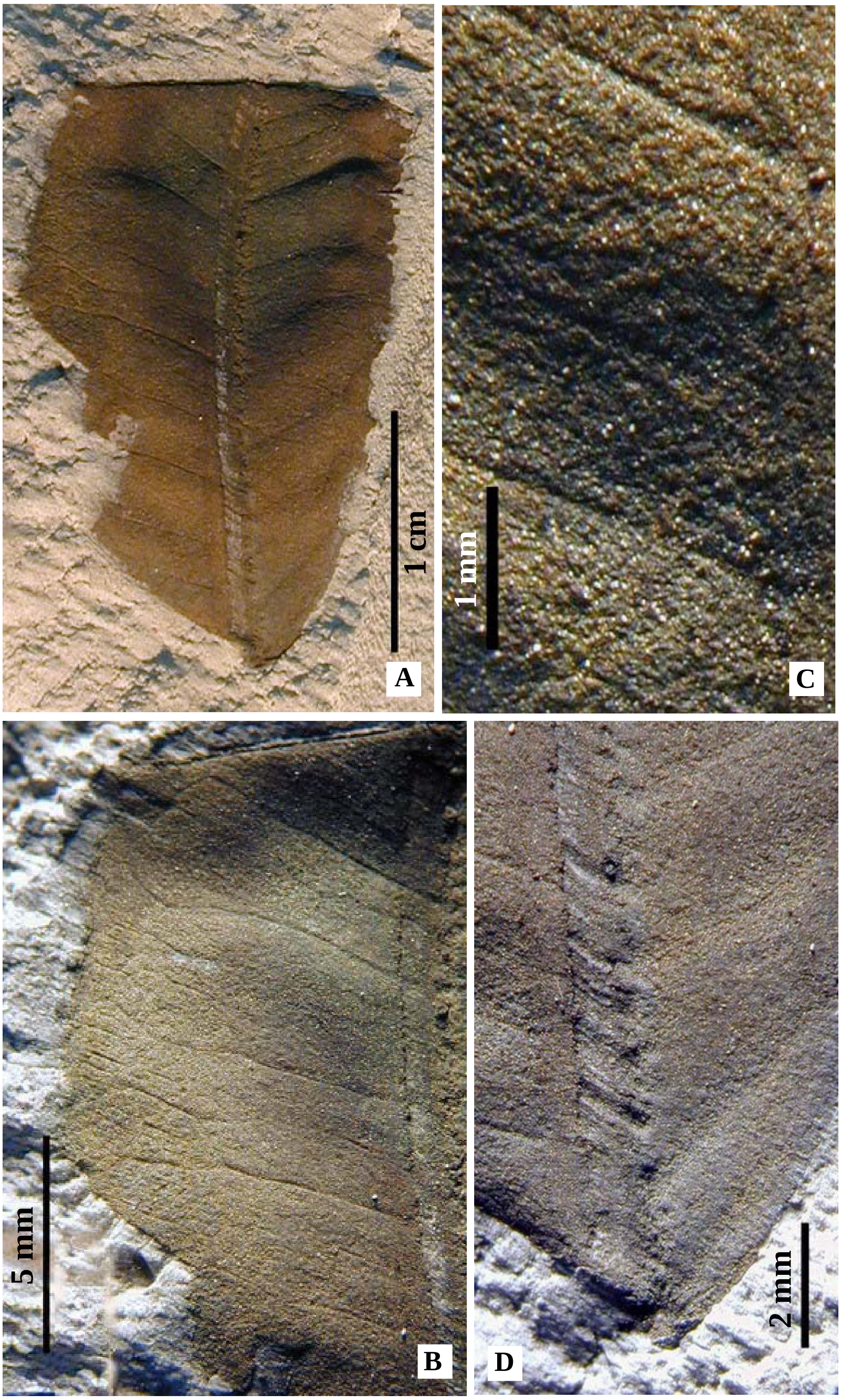
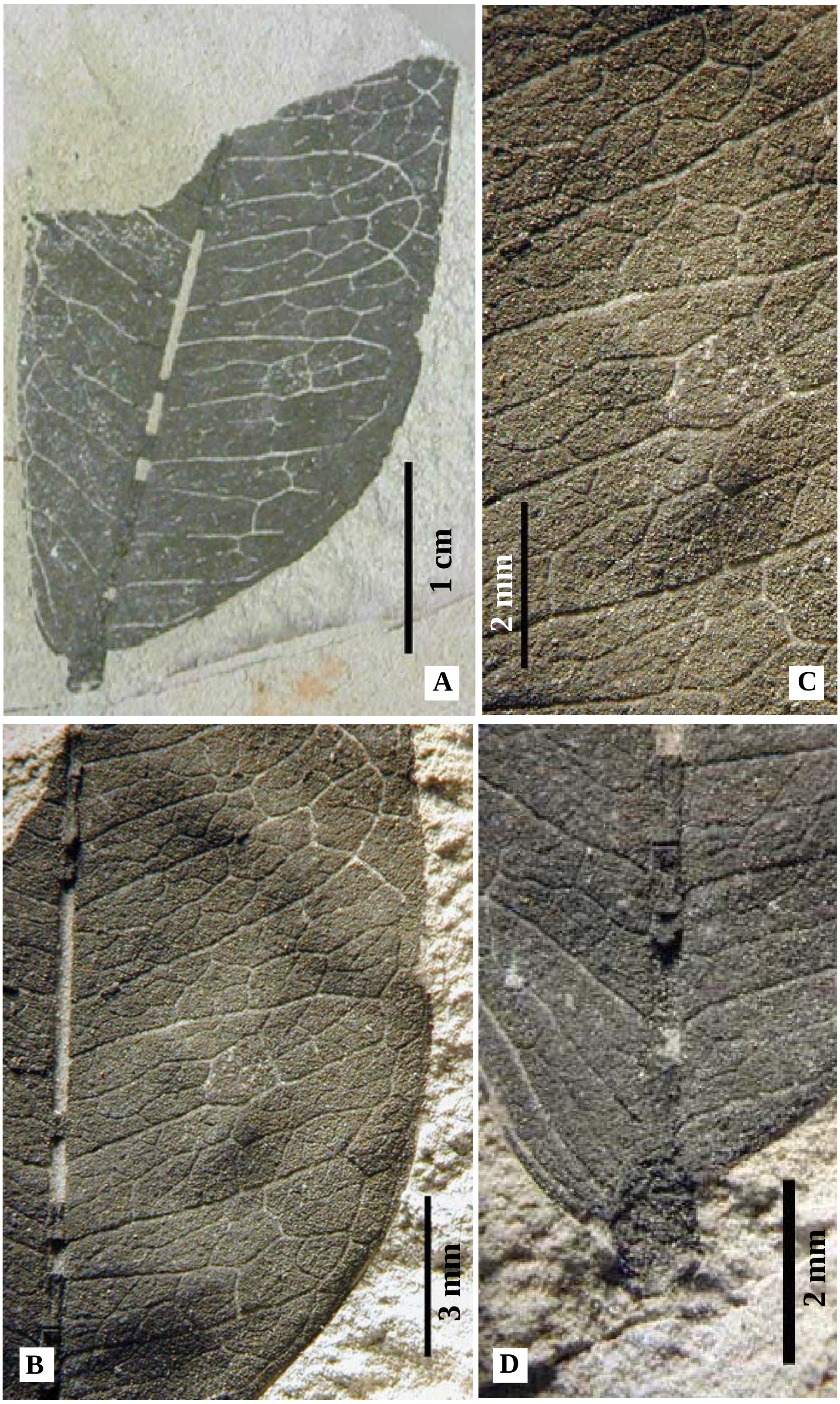


PLATE 49

Pithecellobium paleolampangensis sp.nov. Sawangchote, Grote, Dilcher



Appendix D

Species list of Anacardiaceae and other families examined. Tone-Proj.= Plant diversity project at Tone Nga Chang Wildlife Sanctuary, and the speciment were kept at PSUH, CLC = Cleared leaf collection, DC = Dilcher's collection, OE = Only examined, PS = Prakart Sawangchote, RA = Research assistant at SUT. For other abbreviations, see list of abbreviation in page XV-XVI. Photographs of all cleared leaves and herbarium specimens of most of the examined ones were stored in a CD. Those cleared leaves of Anacardiaceae with simple leaves are also in appendix A.

	Species	Family	Place of acquiring specimen/(number)	Cleared by
1	*Adenium* sp.	Apocynaceae	PSUH	OE
2	*Aganosma marginata* G. Don	Apocynaceae	PSUH	OE
3	*Aganosma wallichii* G. Don	Apocynaceae	PSUH	OE
4	*Allamanda cathartica* L.	Apocynaceae	PSUH	OE
5	*Allamanda violacea* Gardn.	Apocynaceae	PSUH	OE
6	*Allophyllus cobbe* (L.) Raeusch	Sapindaceae	Tone-Proj, F7, A911	OE
7	*Alstonia glaucescens* (K. Sch.) Mona.	Apocynaceae	PSUH	OE
8	*Alstonia macrophylla* Wall. ex G. Don	Apocynaceae	PSU campus (Khuan Mod Daeng)	PS
9	*Alstonia rostrata* C.E.C Fischer	Apocynaceae	PSUH	OE
10	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	SUT campus (Beside F2). Sawangchote002	PS
11	*Alstonia spatulata* Bl.	Apocynaceae	PSUH	OE
12	*Alyxia reinwardthiio* Bl.	Apocynaceae	PSUH	OE
13	*Amalocalyx microlobus* Pierre	Apocynaceae	PSUH	OE
14	*Anodendron paniculatum* (Wall.) Merr.	Apocynaceae	PSUH	OE
15	*Ardisia colorata* Roxb.	Myrsinaceae	PSU SN187000-1	OE
16	*Ardisia crenata* Sims.	Myrsinaceae	PSUH	OE
17	*Ardisia crispa* (Thunb.) A. DC. var. crispa	Myrsinaceae	PSUH	OE
18	*Ardisia lanceolata* Roxb.	Myrsinaceae	PSUH	OE
19	*Ardisia lenticellata* Fletcher	Myrsinaceae	PSUH	OE
20	*Ardisia littoralis* Andr	Myrsinaceae	PSUH	OE
21	*Ardisia maculosa* Mez.	Myrsinaceae	PSUH	OE
22	*Ardisia rigida* Kurz	Myrsinaceae	PSUH	OE
23	*Ardisia vestita* Wall. in Roxb.	Myrsinaceae	PSUH	OE
24	*Ardisia villosa* Roxb.	Myrsinaceae	PSUH	OE
25	*Ardisia virens* Kurz	Myrsinaceae	PSUH	OE
26	*Barringtonia macrostachya* (Jack.) Kurz.	Lecythidaceae	PSUH	PS
27	*Barringtonia pendura* (Griff.) Kurz.	Lecythidaceae	PSU SN185092	OE
28	*Beaumontia grandiflora* Wall.	Apocynaceae		OE
29	*Bertholletia exelsa* Humb. & Bonpl.	Lecythidaceae	PSU SN185093	OE
30	*Bouea macrophylla* Griff.	Anacardiaceae	BKF/SN 126886	PS
31	*Bouea macrophylla* Griff.	Anacardiaceae	PSU SN180485	OE
32	*Bouea oppositifolia* (Roxb.) Meisn.	Anacardiaceae	BKF 084983	PS
33	*Bouea oppositifolia* (Roxb.) Meisn.	Anacardiaceae	PSU SN180402	OE
34	*Bouea oppositifolia* (Roxb.) Meisn.	Anacardiaceae	Klangdong fruit market, Sawangchpte005	PS
35	*Buchanania arborescens* (Blume) Blume	Anacardiaceae	PSU SN180409	PS
36	*Buchanania lanzen* Elm.	Anacardiaceae	SUT campus. Sawangchote018	OE
37	*Buchanania lanzen* Elm.	Anacardiaceae	SUT CLC (190)	RA
38	*Buchanania sessifolia* Blume	Anacardiaceae	BKF/SN 002502	PS
39	*Buchanania sessifolia* Blume	Anacardiaceae	PSU/SN180409-180420	OE
40	*Buchanania siamensis* Miq.	Anacardiaceae	SUT CLC (190)	RA
41	*Buchanania siamensis* Miq.	Anacardiaceae	PSU SN180428	OE

	Species	Family	Place of acquiring specimen/(number)	Cleared by
42	*Carissa spinarum* L.	Apocynaceae		OE
43	*Catharanthus roseus* (L.) G. Don.	Apocynaceae		OE
44	*Cerbera manghas* L.	Apocynaceae		OE
45	*Cerbera odollam* Gaertn.	Apocynaceae		OE
46	cf *Madhuca* sp.	Sapotaceae	Klangdong fruit market. Sawangchote015	PS
47	*Chilocarpus costatus* Miq.	Apocynaceae		OE
48	*Dodonea viscosa* Jacq.		PSU SN189312	OE
49	*Dracontomelum dao* (Blanco) Merr.	Anacardiaceae	PSU SN180433	OE
50	*Drimycarpus luridus* (Hk.f.) Hou	Anacardiaceae	PSU SN 180435, 180434	PS
51	*Epigynum auritum* (CK Schneid.) Tsiang & PT Li	Apocynaceae		
52	*Epigynum* cf *cochinchinensis* (Pierre) DJ Middleton	Apocynaceae		OE
53	*Gluta coarctata* Hook.f.	Anacardiaceae	PSU SN180436	OE
54	*Gluta elegans* (Wall.) Hook.f.	Anacardiaceae	BKF 2071	PS
55	*Gluta elegans* (Wall.) Hook.f.	Anacardiaceae	PSU SN180438	OE
56	*Gluta renghas* L.	Anacardiaceae	BKF/SN 002628	PS
57	*Gluta tavoyana* Wall. ex Hook.f.	Anacardiaceae	PSU SN180439	OE
58	*Gluta usitata* (Wall.) Hou	Anacardiaceae	PSU SN180440	OE
59	*Gymnacranthera eugeniifolia* (A. DC.) Sincl.	Myristicaceae	PSU SN186937	OE
60	*Holarrhena curtisii* King & Gamb.	Apocynaceae	PSU SN180820	OE
61	*Horsfieldia irya* (Gaertn.) Warb.	Myristicaceae	PSU SN186942	OE
62	*Horsfieldia macrocoma* (Miq.) Warb.var. *canarioides* (King) J. Sin.	Myristicaceae	PSU SN186944	OE
63	*Horsfieldia tomentosa* Warb.	Myristicaceae	PSU SN186947	OE
64	*Hunteria zeylanica* (Retz.) Gardner ex Thwaites	Apocynaceae	PSHU	OE
65	*Ichnocarpus frutescens* (L.) WT.Aiton	Apocynaceae	PSHU	OE
66	*Knema curtisii* (King) Warb.	Myristicaceae	PSU SN186953	OE
67	*Knema furfuracea* (Hk. f. & Th.) Warb.	Myristicaceae	PSU SN186956	OE
68	*Knema globularia* (Lmk.) Warb.	Myristicaceae	PSU SN186965-6	OE
69	*Knema laurina* (Bl.) Warb.	Myristicaceae	PSUH	OE
70	*Kopsia alba* Ridl. ex Henderson	Apocynaceae	PSUH	
71	*Lepisanthes* cf *rubiginosa* (Roxb.) Leenh	Sapindaceae	TNC-Proj	OE
72	*Mangifera caesia* Jack	Anacardiaceae	Florida Museum of Natural History	DC
73	*Mangifera caloneura* Kurz	Anacardiaceae	BKF SN 038397	PS
74	*Mangifera camptosperma* Pierre	Anacardiaceae	BKF SN 002934	PS
75	*Mangifera chamaoensis*	Anacardiaceae	BKF 076791	PS
76	*Mangifera collina* Kosterm.	Anacardiaceae	BKF SN 088843	PS
77	*Mangifera duperreana* Pierre	Anacardiaceae	BKF 58080	PS
78	*Mangifera flava* Evrard	Anacardiaceae	BKF 62550	PS
79	*Mangifera foetida* Lour	Anacardiaceae	BKF 40462	PS
80	*Mangifera gedebe* Miq.	Anacardiaceae	BKF SN 105457	PS
81	*Mangifera griffithii* Hook. f.	Anacardiaceae	BKF 091440	PS

	Species	Family	Place of acquiring specimen/(number)	Cleared by
82	*Mangifera linearifolia*	Anacardiaceae	BKF SN 002938	PS
83	*Mangifera macrocarpa* Blume	Anacardiaceae	TNC-Proj,	OE
84	*Mangifera microphylla* Griff.	Anacardiaceae	BKF 26702	PS
85	*Mangifera odorata* Griff.	Anacardiaceae	TNC-Proj; SUT CLC	RA
86	*Mangifera pentandra* Hook.f.	Anacardiaceae	BKF 088210; PSU SN180447	PS
87	*Mangifera quadrifida* Jack var. *quadrifida*	Anacardiaceae	BKF 20027	PS
88	*Mangifera* sp. 2	Anacardiaceae	BKF 21739	OE
89	*Mangifera* sp.1	Anacardiaceae	BKF/SN 119969	OE
90	*Mangifera sylvatica* Roxb.	Anacardiaceae	BKF 29772	PS
91	*Melanochyla angustifolia* Hook.f.	Anacardiaceae	BKF SN 092806	PS
92	*Melanochyla bracteata* King	Anacardiaceae	BKF SN 105458	PS
93	*Melanochyla nitida* Ridl.	Anacardiaceae	BKF 082929	PS
94	*Melanorrhoea glaba* Wall. (q.v. Gluta)	Anacardiaceae	PSU SN180442	OE
95	*Melodinus cochinchinensis* (Lour.) Merr.	Apocynaceae	PSUH	OE
96	*Nephelium lappaceum* L.	Sapindaceae	Koksamrong, Lopburi. Sawangchote019	PS
97	*Nerium indicum* Mill.	Apocynaceae	PSUH	OE
98	*Ochrosia oppositifolia* (Lam.) K. Schumn.	Apocynaceae	PSUH	OE
99	*Parameria laevigata* (Juss.) Moldenke	Apocynaceae	PSUH	OE
100	*Parishia insignis* Hook. f.	Anacardiaceae	PSU SN180451	OE
101	*Parishia pubescens* Hook. f.	Anacardiaceae	PSU SN180453	OE
102	*Parsonia alboflavescens* (Dennst.) Mabb.	Apocynaceae	PSUH	OE
103	*Pentaspadon curtisii* (King) Corner	Anacardiaceae	PSU SN180454	OE
104	*Plumeria acutifolia* Poir.	Apocynaceae	PSUH	OE
105	*Pottsia laxiflora* (Blume) O. Kuntze	Apocynaceae	PSUH	OE
106	*Rhus* sp.	Anacardiaceae	PSU SN180456	OE
107	*Rhus wallichii* Hook. f.	Anacardiaceae	PSU SN180455	OE
108	*Semecarpus cochinchinensis* Engl.	Anacardiaceae	BKF SN 118520	PS
109	*Semecarpus curtisii* King	Anacardiaceae	BKF SN 126073	PS
110	*Semecarpus curtisii* King	Anacardiaceae	PSU SN180466	OE
111	*Semecarpus* sp.	Anacardiaceae	PSU SN180474	OE
112	*Semecarpus* sp.	Anacardiaceae	PSU SN180476	OE
113	*Semecarpus* sp.	Anacardiaceae	PSU SN180477	OE
114	*Semecarpus* sp.	Anacardiaceae	PSU SN180478	PS
115	*Spondias pinnata* (JG Konig ex Lf) Kurz.	Anacardiaceae	PSU SN180480	OE
116	*Swintonia floribunda* Griff.	Anacardiaceae	PSU SN180483; TNC-Proj	PS
117	*Swintonia schwenkii* (Teijsm. & Binn.) Teijsm. Binn.	Anacardiaceae	BKF 4476;	PS
118	*Swintonia schwenkii* (Teijsm. & Binn.) Teijsm. Binn.	Anacardiaceae	TNC-Proj	OE
119	*Willughbeia coriacea* Wall.	Apocynaceae	PSUH	OE

	Species	**Family**	**Place of acquiring specimen/(number)**	**Cleared by**
120	*Willughbeia grandiflora* Dyer ex Hook.f.	Apocynaceae	PSUH	OE
121	*Wrightia dubia* (Sims) Spreng.	Apocynaceae	PSUH	OE
122	*Wrightia laevis* Hook.f.	Apocynaceae	PSUH	OE

Appendix E

Species list of Leguminosae and other families examined. Tone-Proj.= Plant diversity project at Tone Nga Chang Wildlife Sanctuary, and the speciment were kept at PSUH, CLC = Cleared leaf collection, DC = Dilcher's collection, OE = Only examined, PS = Prakart Sawangchote, QBG = Queen Sirikit Botanical Garden, RA = Research assistant at SUT. For other abbreviations, see list of abbreviation in page XV-XVI. Photographs of all cleared leaves and most of the examined ones were stored in a CD.

	Species	Family	Place of acquiring specimen/(number)	Cleared by
1	*Abrus precalorius* L.	Fabaceae	Tone-Proj-outplot 069	PS
2	*Abrus precalorius* L.	Fabaceae	PSU: SN 185320	PS
3	*Acangelisia flava* (L.) Merr.	Fabaceae	PSU: SN186619	OE
4	*Acasia comosa* Gagnep.	Fabaceae	SUT 97-140	PS
5	*Acasia farnesiana* (L.) Willd.	Fabaceae	PSU: SN 185776	OE
6	*Acasia harmaniana* (Pierre) Gagnep.	Fabaceae	SUT campus	PS
7	*Acasia leucophloea* (Roxb.) Willd.	Fabaceae	SUT campus	OE
8	*Acasia pennata* (L.) Willd.	Fabaceae	PSU SN185778	OE
9	*Adenanthera klaineana*	Fabaceae	MO 2917772 UF 4281	DC
10	*Adenanthera pavonina* L.	Fabaceae	SUT 99-32, PSUH	PS
11	*Aeschynomene americana* L.	Fabaceae	PSU: SN185330	OE
12	*Aeschynomene aspera* L.	Fabaceae	PSU: SN185332	OE
13	*Aeschynomene indica* L.	Fabaceae	PSU: SN185334, SUT 157	OE
14	*Afzelia xylocarpa* (Kurz) Craib	Fabaceae	BKF	OE
15	*Agelaea trinervis* (Llanos) Merr.	Connaraceae	PSUH	OE
16	*Aglaia* cf *squamulosa* King	Meliaceae	Tone-Proj	OE
17	*Aglaia elaeagnoides* (A. Juss) Benth.	Meliaceae	Tone-Proj	OE
18	*Aglaia elliptica* Blume	Meliaceae	Tone-Proj	OE
19	*Aglaia kunstleri* King	Meliaceae	Tone-Proj	OE
20	*Aglaia odoratissima* Blume	Meliaceae	Tone-Proj	OE
21	*Aglaia palembanica* Miq var longifolia Craib	Meliaceae	Tone-Proj	OE
22	*Aglaia* sp.	Meliaceae	Tone-Proj	OE
23	*Albertisia* sp. nov.	Menispermaceae	SPU: SN186635	OE
24	*Albizia affopierense* (Pierre) I. Nielsen	Fabaceae	BKF: SN036775	OE
25	*Albizia bracteata* Dunn.	Fabaceae	NYBG	OE
26	*Albizia chinensis* (Osb.) Merr.	Fabaceae	BKF: SN118072	OE
27	*Albizia corniculata* (Lour.) Druce	Fabaceae	BKF: SN130452, 037427	OE
28	*Albizia crassirama* Lace	Fabaceae	BKF: SN109154	OE
29	*Albizia ferruginea* Benth.	Fabaceae	BKF: SN036795	OE
30	*Albizia garrettii* Niels.	Fabaceae	BKF: SN036796	OE
31	*Albizia julibrisia* Durazz	Fabaceae	BKF: SN036800	OE
32	*Albizia lebbeck* L. (Benth.)	Fabaceae	SUT campus	PS
33	*Albizia lebbeckoides* (DC.) Benth.	Fabaceae	SUT campus	PS
34	*Albizia lucida* Benth.	Fabaceae	BKF: SN106887	OE
35	*Albizia lucidior* (Stend.) I. Nielsen	Fabaceae	BKF: SN036835	OE
36	*Albizia millettii* Benth.	Fabaceae	BFK: SN036849	OE
37	*Albizia mollis* Benth.	Fabaceae	BKF: SN036850	OE
38	*Albizia myriophylla* Benth.	Fabaceae	BKF: SN127894; PSU: SN 185791,	OE
39	*Albizia odoratissima* (L.f.) Benth.	Fabaceae	SUT campus	OE
40	*Alibizia pachycarpa* Merr.	Fabaceae	NYBG	OE
41	*Albizia procera* (Roxb.) Benth.	Fabaceae	SUT campus	PS
42	*Albizia schimperiana* Oliv.	Fabaceae	BKF: SN037047	OE
43	*Albizia* sp.	Fabaceae	BKF: SN122807	OE
44	*Albizia* sp.	Fabaceae	BKF: SN037428	OE
45	*Albizia splendens* Miq.	Fabaceae	BKF: SN102165;	OE
46	*Albizia stipulata* Boid.	Fabaceae	BKF: SN037408	OE
47	*Albizia vernayana* Merr.	Fabaceae	NYBG	OE
48	*Albizia vialeana* Pierre	Fabaceae	BKF: SN037417	OE
49	*Allophylus cobbe* (L.) Raeusch	Sapindaceae	TNC-Proj	OE

	Species	Family	Place of acquiring specimen/(number)	Cleared by
50	*Alysicarpus* sp.	Fabaceae	SUT 166	PS
51	*Alysicarpus vaginalis* (L.) DC.	Fabaceae	PSU: SN185336, 185337	OE
52	*Antheroporum glaucum* Z. Wei	Fabaceae	BKF: SN043092	OE
53	*Antheroporum pierrei* Gagnep.	Fabaceae	BKF: SN089211 & PSU: SN 185338	OE
54	*Archidendron bulburinium* (Jack) Nielsen	Fabaceae	BKF: SN037439, 119063, PSUH	OE
55	*Archidendron clypearia* (Jack) Nielsen	Fabaceae	PSU:SN185802	PS
56	*Archidendron conspicum* (Craib) Nielsen	Fabaceae	BKF: SN109784, SN109785	OE
57	*Archidendron contortum* (Mart.) Nielsen	Fabaceae	PSU: SN 185801	PS
58	*Archidendron contortum* (Mart.) Nielsen	Fabaceae	BKF: SN037469	OE
59	*Archidendron ellipticum* (Blume) Nielsen	Fabaceae	BKF: SN122796, PSU:	OE
60	*Archidendron glomeriflorum* (Kurz.) Nielsen	Fabaceae	BKF: SN102349	OE
61	*Archidendron jiringa* Nielsen	Fabaceae	PSU: SN 185810	PS
62	*Archidendron jiringa* Nielsen	Fabaceae	BKF: SN037502	OE
63	*Archidendron kerrii* (Gagnep.) Niels.	Fabaceae	BKF: SN099385	OE
64	*Archidendron lucidum* (Benth.) Niels.	Fabaceae	BKF: SN036534	OE
65	*Archidendron poilanei* (Kosterm.) Niels.	Fabaceae	BKF: SN037505	OE
66	*Archidendron quocense* Pierre	Fabaceae	BKF: SN037510	OE
67	*Archidendron robinsonii* (Gagnep.) Niels.	Fabaceae	BKF: SN108798	OE
68	*Archidendron* sp.	Fabaceae	BKF: SN123359	OE
69	*Archidendron* ? sp. (Antheroporum pierrei?)	Fabaceae	From private orchard in Satoon	PS
70	*Averrhoa carambora* L.	Oxalidaceae	PSU: SN187643	OE
71	*Bauhinia acuminata* L.	Fabaceae	PSU: SN185113-4	OE
72	*Bauhinia aureifolia* K. & S.S. Larsen	Fabaceae	PSU: SN185177	OE
73	*Bauhinia bassacensis* Pierre ex Gagn.	Fabaceae	PSU: SN185118-9	OE
74	*Bauhinia bracteata* (Grah. ex Bth.) Bak.	Fabaceae	PSU: SN185112	OE
75	*Bauhinia* cf *integrifolia* Roxb.	Fabaceae	PSU: SN185120	OE
76	*Bauhinia curtisii* Prain	Fabaceae	PSU: SN185123	OE
77	*Bauhinia ferruginea* Roxb.	Fabaceae	PSU SN? (0008330)	OE
78	*Bauhinia glauca* (Wall. ex Bth.) Bth. ssp. Glauca	Fabaceae	PSU: SN185134	OE
79	*Bauhinia integrifolia* Roxb. ssp. Integrifolia	Fabaceae	PSU: SN185145	OE
80	*Bauhinia malabarica* Roxb.	Fabaceae	PSU: SN185152	OE
81	*Bauhinia ornata* Kurz. var. kerrii (Gagn.) K. & S. Lar.	Fabaceae	PSU: SN185153	OE
82	*Bauhinia pottsii* G. Don	Fabaceae	PSU: SN185162	OE
83	*Bauhinia purpurea* L.	Fabaceae	PSU: SN185163	OE
84	*Bauhinia tomentosa* L.	Fabaceae	PSU: SN185165	OE
85	*Bauhinia veridescens* Desv. var. viridescens	Fabaceae	PSU: SN185175	OE
86	*Bauhinia harmsiana* Hoss. Var. Harmsiana	Fabaceae	PSU: SN185136	OE
87	*Biophytum adiantoides* Wight.	Oxalidaceae	PSU: SN187645	OE
88	*Biophytum sensitivum* (L.) DC.	Oxalidaceae	PSU: SN187650	OE
89	*Breynia angustifolia* Hook. f.	Euphorbiaceae		PS
90	*Breynia discigera* Müll. Arg.	Euphorbiaceae	PSU: SN 183264	PS
91	*Breynia vitis-idaea* (Burm. f.) C.E.C. Fisch	Euphorbiaceae	PSU: SN 183270	PS

	Species	Family	Place of acquiring specimen/(number)	Cleared by
92	*Bridelia* sp.	Euphorbiaceae	PSU: SN183302	OE
93	*Brownea grandiceps* Jacq.	Fabaceae	PSU campus	OE
94	*Butea superba* Roxb.	Fabaceae	PSU: SN185344	OE
95	*Caesalpinia andamanica* (Prain) Hattink	Fabaceae	Tone-Proj-outplot 658, PSUH	PS
96	*Caesalpinia andamanica* (Prain) Hattink	Fabaceae	BKF: SN008234, SN008235	OE
97	*Caesalpinia bondac* (L.) Roxb.	Fabaceae	PSU: SN185188	PS
98	*Caesalpinia bondac* (L.) Roxb.	Fabaceae	BKF: SN008239	OE
99	*Caesalpinia coriaria* Willd.	Fabaceae	BKF: SN008250	OE
100	*Caesalpinia crista* Linn.	Fabaceae	BKF: SN008253	OE
101	*Caesalpinia cucullata* Roxb.	Fabaceae	BKF: SN008247	OE
102	*Caesalpinia cullata* Roxb.	Fabaceae	BKF: SN090916	OE
103	*Caesalpinia decapetala* (Roxb.) Alst.	Fabaceae	BKF: SN090385, SN008260	OE
104	*Caesalpinia digyna* Rottl.	Fabaceae	PSU: SN185195	PS
105	*Caesalpinia digyna* Rottl.	Fabaceae	BKF: SN008274, SN008279	OE
106	*Caesalpinia eneaphylla* Roxb.	Fabaceae	BKF: SN008283	OE
107	*Caesalpinia furfuracea* (Prain) Hattink	Fabaceae	BKF: SN090470	OE
108	*Caesalpinia globulorum* Bakf.f. & v.Royle	Fabaceae	BKF: SN127554	OE
109	*Caesalpinia godefroyana* Kuntze	Fabaceae	BKF: SN008288,	OE
110	*Caesalpinia hymenocarpa* (Prain.) Hattink	Fabaceae	BKF: SN008346, PSUH	OE
111	*Caesalpinia macra* Craib = C. parviflora Prain	Fabaceae	BKF: SN008316	OE
112	*Caesalpinia major* (Medik) Dandy & Exell	Fabaceae	Tone-Proj; BKF: SN008303	OE
113	*Caesalpinia mimosoides* Lmk.	Fabaceae	BKF: SN008482	OE
114	*Caesalpinia nuga* (L.) Aiton = C. crista	Fabaceae	BKF: SN008352	OE
115	*Caesalpinia pubescens* (Desf.) Hattink	Fabaceae	BKF: SN113549	OE
116	*Caesalpinia pulcherima* (L.) Swartz.	Fabaceae	BKF: SN008391	OE
117	*Caesalpinia rhombifolia* J.E. Vidal	Fabaceae	BKF: SN008353	OE
118	*Caesalpinia sappen* L.	Fabaceae	BKF: SN095180	OE
119	*Caesalpinia sinensis* (Hemsl.) J.E. Vidal	Fabaceae	BKF: SN008343	OE
120	*Caesalpinia* sp.	Fabaceae	PSU: SN185214	PS
121	*Caesalpinia tsoongii* Merr.	Fabaceae	BKF: SN008358	OE
122	*Cajanus cajan* (L.) Huth.	Fabaceae	PSU: SN185347	OE
123	*Cajanus scarabaeoides* (L.) Thouars	Fabaceae	PSU: SN185340	OE
124	*Cajanus volubilis* (Blanco) Gamb.	Fabaceae	PSU: SN185343	OE
125	*Callerya atropurpurea* (Wall) A.M. Schot	Fabaceae	See *Millettia atropurpurea*	OE
126	*Callerya* sp.	Fabaceae	PSU: SN185354	PS
127	*Callerya* sp. (Padbruggea)	Fabaceae	PSU: SN185353	PS
128	*Calliandra* sp.	Fabaceae	PSU: SN185818	OE
129	*Calopogonium mucunoides* Desv.	Fabaceae	PSUH	OE
130	*Canavalia catharthica* Thou.	Fabaceae	PSU: SN185357	OE
131	*Canavalia maritima* (Aubl.) Urb.	Fabaceae	PSU: SN185360	OE
132	*Cassia alata* L.	Fabaceae	PSU: SN185216	OE
133	*Cassia bakeriana* Craib	Fabaceae	PSU campus, PSU SN185223	OE
134	*Cassia fistula* L.	Fabaceae	PSU: SN185224	OE
135	*Cassia fruticosa* Mill.	Fabaceae	PSU: SN185226-8	OE

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136	*Cassia garrettiana* Craib	Fabaceae	SUT campus	OE
137	*Cassia grandis* L.f.	Fabaceae	SUT campus	PS
138	*Cassia grandis* L.f.	Fabaceae	PSU: SN185229	OE
139	*Cassia mimosoides* L.	Fabaceae	PSUH	OE
140	*Cassia moschata* Kunth	Fabaceae	US 2834700 IU 4884	DC
141	*Cassia occidentalis* L.	Fabaceae	SUT 7, PSU:	PS
142	*Cassia pumila* Lam.	Fabaceae	SUT: 185, PSUH	OE
143	*Cassia siamea* Lam.	Fabaceae	PSU: SN 185247, SUT campus	PS
144	*Cassia spectabilis* DC.	Fabaceae	PSU: SN185252	PS
145	*Cassia surattensis* Burm.f.	Fabaceae	SUT campus, PSU: SN185254	PS
146	*Cassia timoriensis* DC.	Fabaceae	PSU: SN185257	OE
147	*Cassia tora* L.	Fabaceae	PSU: SN185259	OE
148	*Centrosema pascuorum* Mart. ex Bth.	Fabaceae	PSU: SN185369	OE
149	*Centrosema pubescens* Bth.	Fabaceae	PSU: SN185365	OE
150	*Christia obcordata* (Poir.) Bakh.f.	Fabaceae	SUT CLC	RA
151	*Clitoria laurifolia* Poir.	Fabaceae	PSU: SN185370	OE
152	*Clitoria ternatea* L.	Fabaceae	PSU: SN185371	OE
153	*Cnestis palala* (Lor.) Merr.	Connaraceae	PSUH	OE
154	*Connarus monocarpus* L. ssp. malayanus Leenh.	Connaraceae	PSU: SN182026	OE
155	*Connarus semidecandrus* Jack	Connaraceae	PSU: SN182028	OE
156	*Coscinium bluemeanum* Hook. f. &	Menispermaceae	PSU: SN186620	OE
157	*Crotalaria acicularis* Benth.	Fabaceae	PSU: SN185380	OE
158	*Crotalaria alata* Buch.-Ham. ex D.Don	Fabaceae	PSU: SN185381	OE
159	*Crotalaria albida* Heyne ex Roth	Fabaceae	PSU: SN185382	OE
160	*Crotalaria anagyroides* Humb., Bonpl. & Kunth	Fabaceae	PSU: SN185384	OE
161	*Crotalaria bracteata* Roxb. ex DC.	Fabaceae	PSU: SN185387	OE
162	*Crotalaria ferruginea* Graham ex Benth.	Fabaceae	PSU: SN185388	OE
163	*Crotalaria incana* L.	Fabaceae	PSU: SN185389	OE
164	*Crotalaria juncea* L.	Fabaceae	PSU: SN185390	OE
165	*Crotalaria laburnifolia* L.	Fabaceae	PSU: SN185391	OE
166	*Crotalaria pallida* Aiton	Fabaceae	PSU: SN185396	OE
167	*Crotalaria quinquefolia* L.	Fabaceae	PSU: SN185411	OE
168	*Crotalaria uncinella* Lmk. ssp. Elliptica Roxb. Pohl.	Fabaceae	PSU: SN185413	PS
169	*Crotalaria verrucosa* L.	Fabaceae	PSU: SN185417	OE
170	*Cruddasia insignis* Prain.	Fabaceae	BKF: SN043698	OE
171	*Crudia caudata* Prain.	Fabaceae	BKF: SN105309	OE
172	*Crudia caudata* Prain.	Fabaceae	ToDaeng swamp forest	OE
173	*Crudia chrysantha* (Pierre) K. Schum.	Fabaceae	From Angthong, coll: Prakart	PS
174	*Crudia chrysantha* (Pierre) K. Schum.	Fabaceae	BKF: SN088650	OE
175	*Crudia curtisii* Prain.	Fabaceae	BKF: SN124468	OE
176	*Crudia evansii* Ridl.	Fabaceae	BKF: SN102673	OE
177	*Crudia gracilis* Prain.	Fabaceae	ToDaeng swamp forest	OE
178	*Crudia gracilis* Prain.	Fabaceae	BKF: SN105326	OE
179	*Crudia lanceolata* Ridl.	Fabaceae	BKF: SN008651,	OE
180	*Cyclea barbata* Miers	Menispermaceae	PSU: SN186622	OE

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181	*Cyclea laxiflora* Miers	Menispermaceae	PSU: SN186623	OE
182	*Cyclocarpa stellaris* Baker	Fabaceae?		OE
183	*Cylista* (=Paracalyx) *scariosa* (Roxb.) Ali	Fabaceae	PSU: SN 185423	PS
184	*Cynometra bijuga* Span. ex Miq.	Fabaceae	BKF: SN105308	OE
185	*Cynometra cauliflora* Linn.	Fabaceae	BKF: SN129782, PSU SN185272	OE
186	*Cynometra craibii* Gagnep.	Fabaceae	BKF: SN008673	OE
187	*Cynometra iripa* Kostel.	Fabaceae	BKF: SN008709	OE
188	*Cynometra malaccensis* Meeuwen	Fabaceae	BKF: SN008682, 008697, Tone-Proj	OE
189	*Cynometra ramiflora* L.	Fabaceae	BKF: Museum of natural history	PS
190	*Cynometra ramiflora* L.	Fabaceae	PSU: SN185273-4	OE
191	*Dalbergia assamica* Benth.	Fabaceae	BKF: SN130684	OE
192	*Dalbergia cana* Grah.	Fabaceae	BKF: SN109644	OE
193	*Dalbergia candenatensis* (Dennst.) Prain.	Fabaceae	PSU: SN185427	PS
194	*Dalbergia candenatensis* (Dennst.) Prain.	Fabaceae	BKF: SN043732	OE
195	*Dalbergia* cf *cultrata* Grah. ex. Benth.	Fabaceae	BKF: SN126287	OE
196	*Dalbergia cochinchinensis* Prain.	Fabaceae	SUT 98-70	PS
197	*Dalbergia cochinchinensis* Prain.	Fabaceae	BKF: SN043737	OE
198	*Dalbergia cultrata* Graham ex Benth	Fabaceae	PSU: SN185433	PS
199	*Dalbergia curtisii* Prain	Fabaceae	PSU: SN185435	PS
200	*Dalbergia darlacensis* P.h. & Niyomdham	Fabaceae	BKF: SN043792	OE
201	*Dalbergia discolor* Bl. ex. Miq.	Fabaceae	BKF: SN117474; PSU: SN185437	OE
202	*Dalbergia dongnaiensis* Pierre (=D.	Fabaceae	BKF: SN123280;	OE
203	*Dalbergia dyeriana* Prain.	Fabaceae	BKF: SN130204	OE
204	*Dalbergia entadioides* Pierre	Fabaceae	BKF: SN115379	OE
205	*Dalbergia foliacea* Wall. ex. Benth.	Fabaceae	BKF: SN043811	OE
206	*Dalbergia fusca* Pierre	Fabaceae	QBG, Chiangmai	PS
207	*Dalbergia fusca* Pierre	Fabaceae	BKF: SN117590	OE
208	*Dalbergia glomeriflora* Kurz.	Fabaceae	BKF: SN043818	OE
209	*Dalbergia hainanensis* Merr. & Chun	Fabaceae	BKF: SN130214	OE
210	*Dalbergia horida* (Denn.) Mabb. var. *glabescens* (Prain.) Thot. Nair	Fabaceae	BKF: SN131334	OE
211	*Dalbergia kerrii* Craib.	Fabaceae	BKF: SN095164	OE
212	*Dalbergia kerzii* Prain.	Fabaceae	BKF: SN103485; PSU: SN185440	OE
213	*Dalbergia kingiana* Prain.	Fabaceae	BKF: SN043820	OE
214	*Dalbergia lacei* Prain.	Fabaceae	BKF: SN118299	OE
215	*Dalbergia lanceolaria* L.f. var. *errans* (Craib.) Niyomdham	Fabaceae	BKF: SN117596	OE
216	*Dalbergia lanceolaria* L.f. var. *lakhonensis* (Gagnep.) Niyomdham	Fabaceae	BKF: SN043831	OE
217	*Dalbergia nigrescens* Kurz. var. *nigrescens*	Fabaceae	SUT campus	PS
218	*Dalbergia nigrescens* Kurz. var. *nigrescens*	Fabaceae	BKF: SN043838	OE
219	Dalbergia oliveri Gamble ex. Prain.	Fabaceae	BKF: SN043882	OE
220	*Dalbergia parniculata* Roxb. (= D. nigrescens)	Fabaceae	PSU: SN185442	OE

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221	*Dalbergia parviflora* Roxb.	Fabaceae	ToDaeng swamp forest	PS
222	*Dalbergia phyllanthoides* Blume ex Miq.	Fabaceae	PSU: SN 185443	PS
223	*Dalbergia pierriana*	Fabaceae	PSU: SN185444	OE
224	*Dalbergia pinnata* (Lour.) Prain.	Fabaceae	PSU: SN185445	OE
225	*Dalbergia rostrata* Hassk	Fabaceae	PSU: SN185448	PS
226	*Dalbergia* sp.	Fabaceae	SUTH	RA
227	*Dalbergia stipulacea* Roxb.	Fabaceae	PSU: SN185454	PS
228	*Dalbergia tamarindifolia* Roxb.	Fabaceae	PSU: SN185456	PS
229	*Dalbergia velutina* Bth.	Fabaceae	PSU: SN185459	OE
230	*Delonix regia* (Bojer ex Hook) Rafia	Fabaceae	SUT campus	PS
231	*Dendrolobium* cf *clouisii*	Fabaceae	PSU: SN191369	OE
232	*Dendrolobium rostratum* (Schindl.) Schindl.	Fabaceae	BKF: SN131615	OE
233	*Dendrolobium thorelii* (Gagnep.) Schindl.	Fabaceae	PSU: SN191370	OE
234	*Dendrolobium umbellatum* (L.) Benth.	Fabaceae	BKF: SN092288	OE
235	*Derris* aff. *tonkinensis* Gagnep.	Fabaceae	BKF: SN111389	OE
236	*Derris affinis* Benth.	Fabaceae	BKF: SN114944, PSU: SN185556	OE
237	*Derris allborubra* Hemsl. var. *allborubra*	Fabaceae	BKF: SN044199	OE
238	*Derris amoena* Benth.	Fabaceae	BKF: SN106341, 106342, PSUH	OE
239	*Derris elegans* Bth. Var. vestita Prain	Fabaceae	BKF: SN044125,	OE
240	*Derris elliptica* Benth.	Fabaceae	BKF: SN044126,	OE
241	*Derris furruginea* (Roxb.) Benth.	Fabaceae	BKF: SN044143	OE
242	*Derris heterophylla* (Willd.) Back.	Fabaceae	PSU: SN185567-8	OE
243	*Derris indica* Prain	Fabaceae	BKF: SN106339	OE
244	*Derris laotica* Gagnep.	Fabaceae	BKF: SN044176	OE
245	*Derris malaccensis* (Benth.) Prain	Fabaceae	BKF: SN044189, PSU;SN185572	OE
246	*Derris microphylla* (Miq.) Jacks.	Fabaceae	BKF: SN044222	OE
247	*Derris monticola* Prain	Fabaceae	BKF: SN103482	OE
248	*Derris robusta* Benth.	Fabaceae	BKF: SN124127, SN124126	OE
249	*Derris scandens* (Roxb.) Benth.	Fabaceae	SUT campus	RA, PS
250	*Derris scandens* (Roxb.) Benth.	Fabaceae	BKF: SN044162	OE
251	*Derris* sp	Fabaceae	PSU: SN185592	OE
252	*Derris* sp.	Fabaceae	BKF: SN044159	OE
253	*Derris* sp.	Fabaceae	BKF: SN099362, SN099363	OE
254	*Derris* sp.	Fabaceae	ToDaeng swamp forest	OE
255	*Derris thorelii* (Gagnep.) Craib	Fabaceae	BKF: SN044149	OE
256	*Derris thyrsiflora* Benth.	Fabaceae	BKF: SN125156,	OE
257	*Derris trifoliata* Lour.	Fabaceae	BKF: SN044183,	OE
258	*Derris wallichii*	Fabaceae	BKF: SN044161	OE
259	*Desmodium auricomum* Grah. ex Benth	Fabaceae	PSN: SN185470	OE
260	*Desmodium biarticulatum* var *articulatum* (L.) F. Muell.	Fabaceae	PSU: SN185472	OE
261	*Desmodium blandum* Meeuwen	Fabaceae	PSU: SN185473	OE
262	*Desmodium gangeticum* (L.) D.C.	Fabaceae	PSU: SN185474	OE
263	*Desmodium godefroyanum* O.K.	Fabaceae	PSU: SN185475	OE
264	*Desmodium gyroides* DC.	Fabaceae	PSU: SN185476	OE

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265	*Desmodium heterocarpon* (L.) DC. var *heterocarpon*	Fabaceae	PSU: SN185477	OE
266	*Desmodium heterocarpon* (L.) DC. var *strigosum*	Fabaceae	PSU: SN185487	OE
267	*Desmodium heterophyllum* (Willd.) DC.	Fabaceae	PSU: 185503	OE
268	*Desmodium lanceolatum* = *Dendrolobium lanceolatum* Schind.	Fabaceae	PSU: 185504	OE
269	*Desmodium lanceolatum* = *Dendrolobium lanceolatum* Schind.	Fabaceae	BKF: SN044368	OE
270	*Desmodium laxum* DC.	Fabaceae	PSU: SN185506	OE
271	*Desmodium longipes* Craib.	Fabaceae	PSU: SN185508	OE
272	*Desmodium megaphyllum* Zoll.	Fabaceae	PSU: SN185509	OE
273	*Desmodium obcordatum* (Miq.) Kurz.	Fabaceae	PSU: SN185511	OE
274	*Desmodium oblatum* Bak.	Fabaceae	PSU: SN185512	OE
275	*Desmodium oblongum* Wall. ex Benth.	Fabaceae	BKF: SN044596	OE
276	*Desmodium olivaceum* Prain	Fabaceae	BKF: SN123046	OE
277	*Desmodium pulchellum* (=*Phyllodium pulchellum* in this database)	Fabaceae	PSU: SN185516, 185518	OE
278	*Desmodium pulchellum* (=*Phyllodium pulchellum* in this list)	Fabaceae	Tone-Proj-outplot 682	OE
279	*Desmodium rugosum* Prain.	Fabaceae	BKF: SN044106	
280	*Desmodium* sp.	Fabaceae		RA
281	*Desmodium* sp.	Fabaceae	PSU: SN191377	OE
282	*Desmodium triangulare* (Retz.) Merr. = *Dendrobium troangulare* (Retz.) Schindl. ssp. Triangulare	Fabaceae	BKF: SN044080	OE
283	*Dialium* cf *cochinchinensis*	Fabaceae	Tone-Proj	OE
284	*Dialium cochinchinensis* Pierre	Fabaceae	BKF: SN008734	OE
285	*Dialium indum* L.	Fabaceae	BKF: SN008741	OE
286	*Dialium patens* Baker	Fabaceae	BKF: SN097129, SN097131, PSU: SN185280	OE
287	*Dialium platysepalum* Baker	Fabaceae	BKF: SN008740	OE
288	*Diplotropis duchei*	Fabaceae	US 1484843 IU 4845	DC
289	*Dodonea viscosa* Jack.	Sapindaceae	PSU: SN189312	OE
290	*Dolichos lablab* L.	Fabaceae	PSUH	OE
291	*Dolichos subcarnosus*	Fabaceae	PSUH	OE
292	*Dolichovigna pilosa* (Willd.) Niyomdham	Fabaceae	PSU: SN191379	OE
293	*Dunbaria longeracemosa* Craib.	Fabaceae	PSU: SN185598	OE
294	*Dunbaria scortechinii* Prain.	Fabaceae	PSUH	OE
295	*Ellipanthus tomentosus* Kurz.	Connaraceae	PSU: SN182046	OE
296	*Enicosanthum fuscum*	Annonaceae	TNC-Proj, D7, 2377	OE
297	*Entada* cf *pursaeta* (cf rheedii)	Fabaceae	Tone-Proj	OE
298	*Entada glandulosa* Pierre ex Gagnep.	Fabaceae	PSU: SN185819	OE
299	*Entada spiralis* Ridl.	Fabaceae	PSU: SN185822	OE
300	*Eriosema chinense* Vogel	Fabaceae	PSU: SN191381	OE
301	*Erycibe griffithii* Cl.	Convolvulaveae	PSU: SN182051	OE
302	*Erythrina fusca* Lour.	Fabaceae	PSU: SN185602	OE
303	*Erythrina orientaris* (L.) Murr.	Fabaceae	PSU: SN185604	OE
304	*Erythrina* sp	Fabaceae	PSU: SN185605	OE
305	*Erythrina* sp	Fabaceae	PSU: SN185606	OE
306	*Erythrophleum succirubrum* Gagnep.	Fabaceae	SUT campus	OE
307	*Fibraurea tinctoria* Lour.	Menispermaceae	PSU: SN186632	OE

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308	*Flemingia chappa* Han.	Fabaceae	PSU: SN191382	OE
309	*Flemingia macrophylla* (Willd.) Prain	Fabaceae	PSU: SN185281	OE
310	*Flemingia* sp.	Fabaceae	SUT 98-4, 98-3	OE
311	*Flemingia stricta* Roxb. ex Aiton.	Fabaceae	PSU: SN191385	OE
312	*Geissapsis cristata* W. & A.	Fabaceae	PSU: SN185608	OE
313	*Gilletiodendron mildbraedii* (Harms)Vermoesen	Fabaceae	MO 1701144 IU 4920	DC
314	*Gleditsia fera* (Lour.)Merr.	Fabaceae	BKF: SN?	OE
315	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Fabaceae	PSU: SN105609	OE
316	*Glochidion hypoleucum* (Miq.) Boerl	Euphorbiaceae	PSU: SN183500	PS
317	*Gymnocladus chinensis* Baillon	Fabaceae	F 477558 IU 4954	DC
318	*Hegnera obcordata* (Miq.) Schindl.	Fabaceae	PSU: SN191386	OE
319	*Indigofera hirsuta* L.	Fabaceae	PSUH	OE
320	*Indigofera oblongifolia* Forsskal	Fabaceae	PSUH	OE
321	*Indigofera* sp.	Fabaceae	SUT 102	OE
322	*Indigofera* sp.	Fabaceae	PSU: SN185624	PS
323	*Indigofera* sp.	Fabaceae	PSU: SN185623	PS
324	*Indigofera* sp.	Fabaceae	PSU: SN185625	OE
325	*Indigofera* sp.	Fabaceae	PSU: SN185626	OE
326	*Indigofera* sp.	Fabaceae	PSU: SN185627	OE
327	*Indigofera spicata* Forsskal	Fabaceae	PSU: SN191387	OE
328	*Indigofera wightii* Graham	Fabaceae	PSUH	OE
329	*Intsia bijuga* (Colebr.) O. Ktz.	Fabaceae	PSU: SN185282	OE
330	*Lablab purpureus* (L.) Sweet	Fabaceae	PSU: SN185628	OE
331	*Lansium domesticum* Corrêa	Meliaceae	TNC-Proj, G3, 1334	OE
332	*Lepisanthes* cf *rubiginosa* (Roxb.) Leenh.	Sapindaceae	TNC-Proj, out plot	OE
333	*Lespedeza* sp.	Fabaceae	PSU: SN185629	OE
334	*Leucaena leucocephala* (Lam.) de Wit	Fabaceae	SUT campus	PS
335	*Linostoma pauciflorum* Griff.	Thymelaeaceae	PSU: SN189953	PS
336	*Macroptilium atropurpureum* (DC.) Urb. cv. Siratro	Fabaceae	PSU: SN185630	OE
337	*Macrolobium gracile* Benth	Fabaceae	MO 2733360 UF 4568	DC
338	*Macroptilium lathyroides* (L.) Urb.	Fabaceae	PSU: SN 185631	OE
339	*Mecopus nidulans* Benn.	Fabaceae	PSU: SN191388	OE
340	*Millettia* aff *aurybotrya* Drake	Fabaceae	BKF: SN117689	OE
341	*Millettia atropurpurea* Benth.	Fabaceae	Tone-Proj	OE
342	*Millettia atropurpurea* Benth.	Fabaceae	BKF: SN045260	OE
343	*Millettia auriculata* Bth.ex Beker	Fabaceae	BKF: SN045321	OE
344	*Millettia brandisiana* Kurz.	Fabaceae	BKF: SN089734, SN045293	OE
345	*Millettia caerulea* Grah ex Bak.	Fabaceae	BKF: SN090847	OE
346	*Millettia* cf. *leucantha*	Fabaceae	SUT campus	OE
347	*Millettia cinerea* Bth.	Fabaceae	BKF: SN090694	OE
348	*Millettia dorwaldii*	Fabaceae	BKF: SN109636	OE
349	*Millettia erythrocalyx* Gagnep.	Fabaceae	BKF: SN045438	OE
350	*Millettia extensa* Bth.	Fabaceae	BKF: SN111175	OE
351	*Millettia follax* Craib.	Fabaceae	BKF: SN116869	OE
352	*Millettia glaucescens* Krz. var. *Siamensis* Craib.	Fabaceae	BKF: SN045323	OE
353	*Millettia hemsleyana* Craib.	Fabaceae	BKF: SN045328	OE
354	*Millettia kangensis* Craib.	Fabaceae	BKF: SN091021	OE
355	*Millettia laptobotrya* Dunn.	Fabaceae	BKF: SN094719	OE
356	*Millettia latifolia* Dunn.	Fabaceae	BKF: SN123629	OE

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357	*Millettia leucantha* Kurz.	Fabaceae	BKF: SN129809	OE
358	*Millettia macrostachya* Coll. et. Hemsl.	Fabaceae	BKF: SN122921	OE
359	*Millettia microphylla* Jacks.	Fabaceae	BKF: SN045361	OE
360	*Millettia ovalifolia* Kurz.	Fabaceae	BKF: SN045389	OE
361	*Millettia pachycarpa* Benth.	Fabaceae	BKF: SN045043	OE
362	*Millettia pachyloba* Drake	Fabaceae	BKF: SN045451	OE
363	*Millettia penduliformis* Gagnep.	Fabaceae	BKF: SN130578	OE
364	*Millettia pendura* Benth.	Fabaceae	BKF: SN045345	OE
365	*Millettia pinnata* (L.) Gees.	Fabaceae	PSU: SN185635	OE
366	*Millettia pubinervis* Kurz.	Fabaceae	BKF: SN045363	OE
367	*Millettia racemosa* = *Endosamara racemosa* (Roxb.)	Fabaceae	BKF-SN045370	OE
368	*Millettia sericea* (Wright. et. Arn.) Bth.	Fabaceae	BKF: SN045374, PSU: SN185636	OE
369	*Millettia* sp.	Fabaceae	SUT campus	PS
370	*Millettia* sp.	Fabaceae	BKF: SN091038	OE
371	*Millettia* sp.	Fabaceae	BKF: SN123998	OE
372	*Millettia* sp.	Fabaceae	BKF: SN094341	OE
373	*Millettia* sp.	Fabaceae	PSU: SN185642	OE
374	*Millettia* sp.	Fabaceae	PSU: SN185651,	OE
375	*Millettia* sp. (=*M. microphylla*?)	Fabaceae	PSU: SN185649	OE
376	*Millettia xylocarpa* Miq.	Fabaceae	BKF: SN045049	OE
377	*Mimosa invisa* Mart.	Fabaceae	SUT 98-5T	OE
378	*Mimosa priga* L.	Fabaceae	PSUH	OE
379	*Mimosa pusida* L.	Fabaceae	SUT 98-76T	OE
380	*Moghania macrophylla* (Willd.) O.K. = *Flemingia macrophylla* (Willd.) Prain	Fabaceae	PSUH	OE
381	*Moghania strobilifera* = *Flemingia strobilifera* (L.) W.T.Aiton	Fabaceae	PSUH	OE
382	*Mucana pruriens* (L.) DC.	Fabaceae	PSUH	OE
383	*Mucuna biplicata* Teysm. & Binn.	Fabaceae	PSUH	OE
384	*Mucuna gigantea* (Willd.) DC.	Fabaceae	PSUH	OE
385	*Murtonia kerrii* Craib.	Fabaceae	BKF: SN090342	OE
386	*Neptunia javanica* Miq.	Fabaceae	SUT 98-110	OE
387	*Neptunia oleracea* Lour.	Fabaceae	Korat market	PS
388	*Nogra grahamii* (Benth.) Merr.	Fabaceae	PSU: SN191390	OE
389	*Ophrestia* sp.	Fabaceae	PSU: SN191391	OE
390	*Ormosia sumatrana* Prain.	Fabaceae	PSU: SN185681	OE
391	*Oxalis barrelieri* L.	Oxalidaceae	PSU: SN187657	OE
392	*Oxymitra* (*Friesodielsia*) *affinis*	Annonaceae	TNC-Proj, 086	OE
393	*Parkia* cf *javanica* Merr.	Fabaceae	PSU: SN185835	OE
394	*Parkia speciosa* Hassk.	Fabaceae	PSU: SN185832	OE
395	*Peltophorum dasyrachis* (Miq.) Kurz.	Fabaceae	SUT campus	PS
396	*Peltophorum dasyrachis* (Miq.) Kurz.	Fabaceae	PSU: SN185288	OE
397	*Pericampyrus glaucus* (Lmk.) Merr.	Menispermaceae	PSU: SN186642	OE
398	*Phaseolus* (*Vigna*) *dalzellianus* O.K.	Fabaceae	PSUH	OE
399	*Phaseolus* (*Vigna*) *pubescens* Bl.	Fabaceae	PSUH	OE
400	*Phaseolus aureus* Roxb.	Fabaceae	PSUH	OE
401	*Phylacium majus* Coll. et. Hemsl.	Fabaceae	BKF: SN102003	OE
402	*Phyllanthus amarus* Schumach.&Thonn.	Euphorbiaceae	Bangkok	PS
403	*Phyllanthus carinatus* Beille	Euphorbiaceae	PSU: SN 183713	PS
404	*Phyllanthus columnaris* Müll.Arg.	Euphorbiaceae	PSU: SN183714	PS
405	*Phyllanthus elegans* Wall. ex Müll.Arg.	Euphorbiaceae	PSU: SN183719	PS

	Species	**Family**	**Place of acquiring specimen/(number)**	**Cleared by**
406	*Phyllanthus emblica* L.	Euphorbiaceae	PSU: SN183722, 183723	PS
407	*Phyllanthus gracilipes* (Miq.) Müll.Arg.	Euphorbiaceae	PSU: SN183724	PS
408	*Phyllanthus niruri*	Euphorbiaceae	PSU: SN183712	PS
409	*Phyllanthus oxyphyllus* Miq.	Euphorbiaceae	PSU: SN183726	PS
410	*Phyllanthus pulcher* Wall. ex Müll.Arg.	Euphorbiaceae	PSU: SN183730	PS
411	*Phyllanthus* sp.	Euphorbiaceae	PSU: SN183744	PS
412	*Phyllanthus* sp.	Euphorbiaceae	PSU: SN183742	OE
413	*Phyllanthus urinaria* L.	Euphorbiaceae	SUT 126	PS
414	*Phyllanthus virgatus* Forst. f.	Euphorbiaceae	SUT 123, PSU: SN 183739	PS
415	*Phyllocarpus septentrionalis* Denn. Smith	Fabaceae	PSU: SN185296	OE
416	*Phyllodium elegans* (Lour.) Desv.	Fabaceae	BKF: SN045642	OE
417	*Phyllodium insigne* (Prain.) Schindl.	Fabaceae	BKF: SN045598	OE
418	*Phyllodium kurzianum* (Prain.) Schindl.	Fabaceae	BKF: SN045605, 107079	OE
419	*Phyllodium longipes* (Craib.) Schindl.	Fabaceae	BKF: SN045612	OE
420	*Phyllodium pulchellum* (L.) Desv.	Fabaceae	SUT CLC	RA
421	*Phyllodium pulchellum* (L.) Desv.	Fabaceae	Tone-Proj-outplot 682	OE
422	*Phyllodium pulchellum* (L.) Desv.	Fabaceae	BKF: SN045633	OE
423	*Phyllodium* sp (Similar to P. vestitum)	Fabaceae	PSU: SN185685	OE
424	*Phyllodium vestitum* Benth.	Fabaceae	BKF: SN103841	OE
425	*Pithecellobium dulce* (Roxb.) Benth	Fabaceae	SUT campus	PS
426	*Pithecellobium leucocalyx*	Fabaceae	US 1635222 UF 4368	DC
427	*Pithecellobium lindsrefolium*	Fabaceae	US 2676898 US 4342	DC
428	*Pithecellobium macradenium*	Fabaceae	US 2795897 UF 4371	DC
429	*Pongamia (Derris) pinnata*	Fabaceae	PSUH	OE
430	*Psophocarpus tetragonolobus* (L.) DC.	Fabaceae	PSUH	OE
431	*Pterocarpus indicus* Willd.	Fabaceae	SUT campus, PSU: SN185695	OE
432	*Pterocarpus macrocarpus* Kurz	Fabaceae	SUT campus, PSU: SN185696	OE
433	*Pterolobium integrum* Craib.	Fabaceae	BKF: SN008899	OE
434	*Pterolobium macropterum* Kurz.	Fabaceae	BKF: SN008903, PSU: SN185299	OE
435	*Pterolobium micranthum* Gagnep.	Fabaceae	BKF: SN008621	OE
436	*Pterolobium microphyllum* Miq.	Fabaceae	BKF: SN121095,	OE
437	*Pueraria phaseoloides* (Roxb) Benth.	Fabaceae	PSU: SN191396	OE
438	*Pueraria triloba* (Lour.) Mak.	Fabaceae	PSUH	OE
439	*Pycnospora lutescens* (Poir.) Schindl.	Fabaceae	PSU: SN185707	OE
440	*Radermachera glandulosa* (Blume) Miq.	Bignoniaceae	TNC-Proj, out plot	OE
441	*Rourea mimosoides* (Vahl.) Pl.	Connaraceae	PSU: SN182054	OE
442	*Rourea* sp.	Connaraceae	PSU: SN182055	OE
443	*Samanea saman* Merr	Fabaceae	PSU campus	PS
444	*Saraca declinata* (Jack) Miq.	Fabaceae	PSU: SN185303	OE
445	*Saraca indica* L.	Fabaceae	Tone-Proj-outplot 330	OE
446	*Saraca thaipingensis* Cantley ex Prain	Fabaceae	PSU: SN185315	OE
447	*Sauropus quadrangularis* (Willd.) Müll. Arg.	Euphorbiaceae	PSU: SN 183784	PS
448	*Sauropus* sp.1	Euphorbiaceae	SUT: 98-174	PS, RA
449	*Sauropus* sp.2	Euphorbiaceae	SUT 130	PS, RA
450	*Sauropus* sp.3	Euphorbiaceae	SUT 77	PS, RA
451	*Sauropus* sp.4	Euphorbiaceae	SUT 97-1	PS, RA

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452	*Sesbania gigantea*	Fabaceae	PSU: SN 185715	OE
453	*Sesbania grandiflora* (L.) Desv.	Fabaceae	SUT campus	PS
454	*Sesbania javanica* Miq.	Fabaceae	Roadside, Wangnoi, Ayuthaya	PS
455	*Sindora echinocalyx* (Bentham) Prain	Fabaceae	Tone-Proj-outplot 587	OE
456	*Sindora siamensis* Teysm ex Miq. var. *Siamensis*	Fabaceae	SUT campus	OE
457	*Sophora tomentosa* L.	Fabaceae	PSU: SN185720	OE
458	*Spatholobus gyrocarpus* Bth.	Fabaceae	PSUH	OE
459	*Spatholobus harmandii* Gagn.	Fabaceae	PSU: SN 185726	OE
460	*Stephania* cf *corymbosa* (Bl.) Walp.	Menispermaceae	PSU: SN186651	OE
461	*Stephania hernandifolia* (Willd.) Walp.	Menispermaceae	PSU: SN186646	OE
462	*Stephania japonica* (Murr.) Miers.	Menispermaceae	PSU: SN186647	OE
463	*Stephania reticulata* Forman	Menispermaceae	PSU: SN186644	OE
464	*Stephania ? oblata* Craib.	Menispermaceae	PSU: SN186645	OE
465	*Stereospermum fimbliatum* (Wall. ex G.Don) A.DC.	Bignoniaceae	TNC-Proj, out plot 305	OE
466	*Stryphnodendron excelsum*	Fabaceae	MO 2128268	DC
467	*Stylosanthes fruticosa* Alst.	Fabaceae	PSUH	OE
468	*Stylosanthes gracilis = S. guianensis*	Fabaceae	SUT campus	OE
469	*Stylosanthes guianensis* C.V. Graham.	Fabaceae	PSUH	OE
470	*Stylosanthes sundaica* Taub.	Fabaceae	PSUH	OE
471	*Tadehagi godefroyanum* (Kuntze.) Ohashi	Fabaceae	PSU: SN191399	OE
472	*Tamarindus indica* L.	Fabaceae	PSU: SN185317	OE
473	*Tephrosia* cf *dichotoma* auct.	Fabaceae	SUT campus	PS
474	*Tephrosia noctiflora* Baker	Fabaceae	PSUH	OE
475	*Tephrosia purpurea* (L.) Pers.	Fabaceae	SUT CLC	RA
476	*Tephrosia siamensis*	Fabaceae	PSU: SN191400	OE
477	*Tephrosia vestita* Vogel	Fabaceae	SUT 99-155, PSUH	PS
478	*Tiliacora triandra* (Colebr.) Diels.	Menispermaceae	PSU: SN186634, 186654	OE
479	*Tinomiscium petiolare* Wall ex Miers.	Menispermaceae	PSU: SN186667	OE
480	*Tribulus cistoides* L.	Zygophyllaceae	SUT campus	PS
481	*Uraria campanulata* (Benth.) Gagnep.	Fabaceae	PSU: SN191405	OE
482	*Uraria crinita* (L.) Desv. Ex. DC.	Fabaceae	PSU: SN 185751, 185748	PS
483	*Uraria logopodioides* (L.) Desv.	Fabaceae	PSU: SN185752	OE
484	*Uraria logopodioides* (L.) Desv.	Fabaceae	SUT CLC; SUT campus	RA, PS
485	*Vigna vexillata* (L.) A. Richard	Fabaceae	PSU: SN191410	OE
486	*Xerospermum noronhianum*	Sapindaceae	TNC-Proj, F4, A843	OE
487	*Xylia xylocarpa* (Roxb.) Taubert	Fabaceae	SUT campus	OE
488	*Zornia diphylla* (L.) Pers.	Fabaceae	SUT CLC	RA
489	*Zornia diphylla* (L.) Pers.	Fabaceae	PSU: SN185758	OE