Taxonomic Revision of the Family Dilleniaceae in Thailand

Sarayut Rak-archa

A Thesis Submitted in Partial Fulfillment of Requirements for
degree of Doctor of Philosophy in Biology
November 2018

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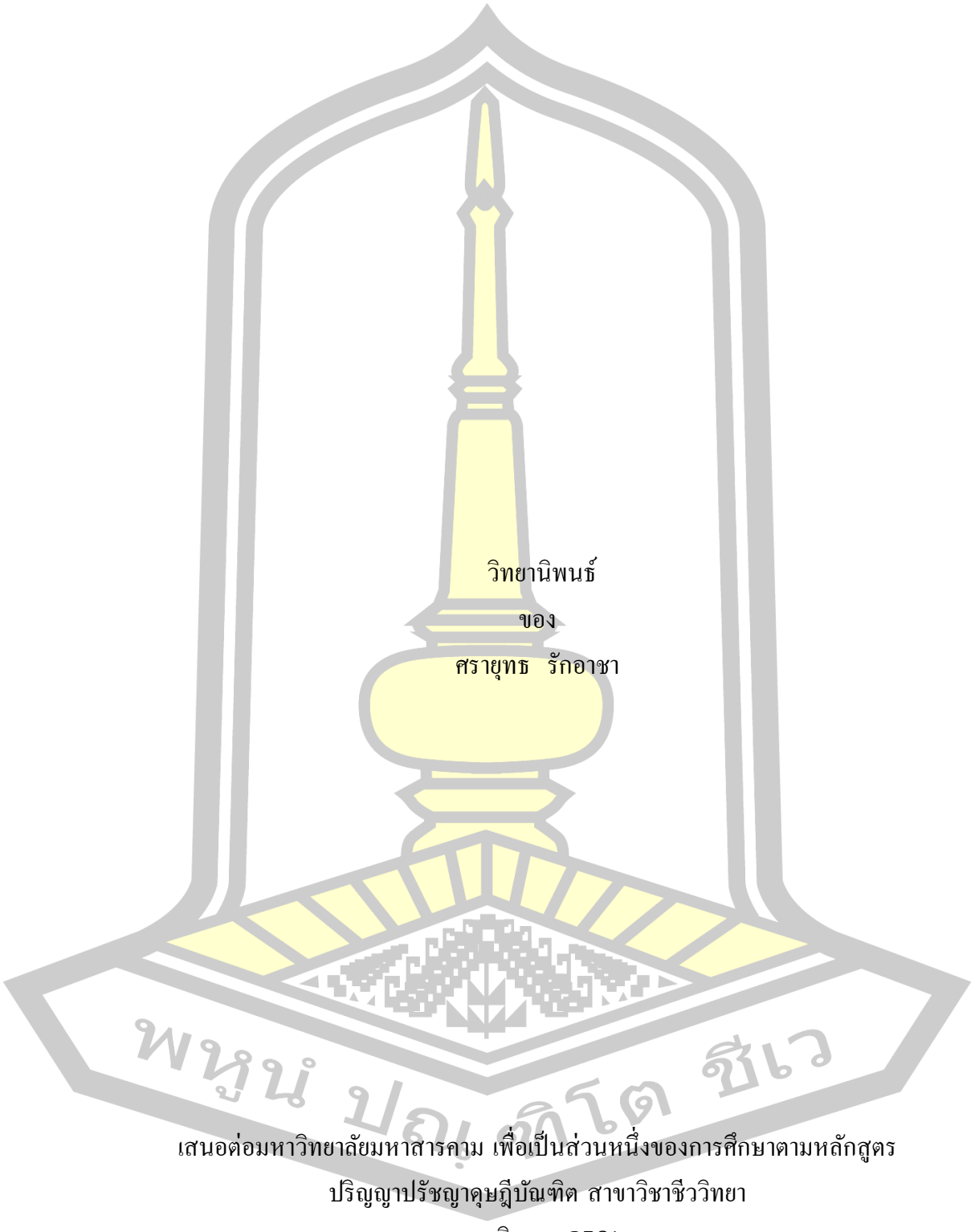

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for Doctor of Philosophy (Biology)

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The examining committee has unanimously approved this Thesis, submitted by Mr. Sarayut Rak-archa , as a partial fulfillment of the requirements for the Doctor of Philosophy Biology at Mahasarakham University

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TITLE Taxonomic Revision of the Family Dilleniaceae in Thailand

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ABSTRACT

A taxonomic revision of Dilleniaceae in Thailand is presented. Twenty species, three genera from two subfamilies were reported in Thailand. Subfamily Delimoideae consist 5 species of *Tetracera*. Subfamily Dillenioideae consist 14 species of *Dillenia* and 1 species of *Acrotrema*. Two species are ornamental plants in many places, including *Dillenia philippinensis* and *D. suffruticosa*. *Tetracera akara* is a new record for Thailand. *Dillenia philippinensis*, *D. puchella* and *D. reticulata* were descripted for the first time base on Thai specimen. *D. grandifolia* and *D. reticulata* may be are a single species by *D. reticulata* may be a synonym of *D. grandifolia*. In addition, key to species, description, ecological information, vernacular name and data of distribution are provided in this report.

Pollen morphology of Dilleniaceae are monad, radially symmetrical, and isopolar. Most of the species of Thai Dilleniaceae are triaperture while *Dillenia philippinensis* and *D. ovata* are triaperture or occasionally tetraaperture. The elongated aperture covered with large irregular flecks. Most of the studied species have small sized except *D. aurea* and *D. philippinensis* that have medium sized. The exine sculpturing are punctate, reticulate, regulate, and reticulate-verrucose. In addition, this study reported characters of pollen morphology for the first time as follow: distance between the apices of two ectocolpi, colpus length, colpus width, porus length and porus width.

The anatomy of leaves were observed by epidermal peeling and transverse section. The present study suggests that detailed analysis of anatomy of leaf surface, leaf lamina, leaf margin, midrib and petiole. The data is extremely important for understanding the taxa. The characters of leaf anatomy are basic characteristic in the Dilleniaceae as follows: 1) the one layer epidermal cells and thin cuticle on both surfaces; 2) the hypostomatic leaves with anisocytic, anomocytic and paracytic stomata; 3) the presence of stomata on abaxial surface; 4) the present of simple unicellular trichomes; 5) the bundle sheath extensions which extends to both epidermises; 6) the mesophyll is dorsiventral; 7) the presence of raphides crystals; 8) leaf margin are round in outline and 9) The vascular bundles are collateral bundle. The result show that the type and distribution of trichomes, type of stomata, shape of

epidermal cells, vascular tissue systems, shape of petioles and shape of midrib can be used for identified to species of Thai Dilleniaceae.

In numerical analysis base on pollen morphology and leaf anatomy data support classification and relationship of infrafamilial. The results show that genera *Dillenia* and *Acrotrema* were placed in the same group (Dillenioideae) and classified the genus *Tetracera* in another group (Delimoideae) follow as classification system of Horn in 2005.

Keyword : Anatomy, Dilleniaceae, Pollen morphology, Taxonomy

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CHAPTER 1
INTRODUCTION

1.1 Background

Dilleniaceae comprised of 11 genera and approximately 500 species (Horn, 2005). They have characteristics of trees, woody climber, shrubs and rhizomatous herbs. Leaves are simple, spirally arranged, length 1 mm to 1 m and many other important characteristics are apocarpous gynoecium, numerous stamen, centrifugal androecium, superior gynoecium, seeds surrounded by an aril and small embryo with abundant endosperm and primitive structure. Dilleniaceae comprises 11 genera and distribution in several zones, as follows: *Tetracera* distribution in the pantropical zone and is the only genus of the family present on continental Africa. *Curatella*, *Davilla*, *Pinzona*, *Doliocarpus* and *Neodillenia* are endemic to the neotropics, with a center of diversity in Brazil. *Hibbertia* (included *Pachynema*) are mostly endemic in Australia. *Acrotrema* endemic in Sri Lanka, one species in the Western Ghatts of India and another ranging from southern Thailand and Myanmar to northern Sumatra. *Schumacheria* is endemic in Sri Lanka. *Didesmandra* is known from only a few populations in Sarawak, Borneo. *Dillenia* distribution from Madagascar and the Seychelles to Fiji (Hoogland, 1952; Eames, 1961; Sastri, 1958; Horn, 2005). In previous systems of angiosperm classification, Dilleniaceae was placed in several orders such as Ranales (De Candolle, 1824; Lindley, 1830; Bentham and Hooker, 1862), Parietales (Pollard, 1872; Gilg and Werdermann, 1925; Lawrence, 1951), Dilleniales (The Angiosperm Phylogeny Group, 2016) and other. Infraorder relationship of Dilleniaceae is not clear. It changes based on the information available. Infrafamilial relationships of Dilleniaceae is not exactly position. Infrafamilial relationships changes based on classification system and data. If this study succeeds, it may be useful to support the classification system.

Thailand is located in the tropical zone and has a high biodiversity. In current, natural forest area of the country is remaining approximately 25% because it is mostly damaged or degraded forests. The forest contains a wide variety of plant resources that can be a basis for sustainable national development. The forests of Thailand have more than 10,000 vascular plant species, from about 275 family of seed plants (spermatophytes) and about 36 families of pteridophytes (Santisuk, 2006). In 1970, the first volume of Thai plant was published in Flora of Thailand and has

published continuously until. The current is volume 13 part 4. In the present, many flowering plants of Thailand should have revised of taxonomy because the classification system is constantly being updated, allowing some species to change their taxonomic status. In 1972, the morphology, distribution, ecology, vernacular name and artificial key of Thai Dilleniaceae are reported by Hoogland in the Flora Thailand. It has 10 species of *Dillenia*, one species of *Acrotrema* and four species of *Tetracera*. The study in Thailand has been performed for over 40 years. In current, dry specimen of Thai Dilleniaceae were added in all Thai herbarium and the classification of Dilleniaceae changed base on classification systems. Therefore, Thai Dilleniaceae will be need to revise for the purpose of identify and confirm the number of species, correct scientific name including information of the distribution and ecology of Thai Dilleniaceae.

The study of pollen morphology can be used in the study of plant taxonomy and can be compared to the relationship between closely species because pollen grains have variety of characteristic, i.e., size, shape, symmetry, aperture, exine structure and exine sculpturing. In addition, the pollen morphology can be applied in geology, ecology, or archeology and others. However, the pollen morphology of Dilleniaceae briefly described at the species level. The palynological data of the family Dilleniaceae have never been described in detail for some of the characteristics, e.g., exine thickness, distance between apices of two ectocolpi, colpus length, colpus width, porus length, porus width and apocolpium index. Additionally, only a few of the species have been studied by researchers. Therefore, this study will provide new data for the first time about this topic and information that could be used to the classification of this family more complete and accurate.

The current, classification of Dilleniaceae is based on the flower structure and a shorter period of flowering and fruit. The structure of the flower is often caducous and this is a problem of identifying species. The data of leaf anatomy is used in plant taxonomy studies because leaf anatomy have a variety of characteristics. From the literature review, the leaf anatomy of Dilleniaceae published data for only some species and many species lack of data. Characteristics of midrib and petiole anatomy were reported very incomplete. A study of the plant anatomy is important for taxonomy and

applications in other fields, such as paleobotany and ecology. Therefore, the study of leaf anatomy in this study is required.

1.2 Objectives of Study

1.2.1 To revise a taxonomy of family Dilleniaceae in Thailand.

1.2.2 To study anatomy of family Dilleniaceae in Thailand.

1.2.3 To study pollen morphology of family Dilleniaceae in Thailand.

1.3 Scope of study

1.3.1 Taxonomy

A taxonomic revision of Dilleniaceae in Thailand was conducted using standard taxonomical procedures with studies of the morphology, distribution and ecology of the species. This revision was based on a field survey and collection of Dilleniaceae species throughout many parts of Thailand. Specimens were collected with six duplicates with twigs, leaves, flowers and fruits and the recorded data in the field survey, which consists of local names and uses, ecology, distributions, preliminary characteristic and photographs of the taxa. Previous specimens of herbarium material from herbaria both in Thailand and abroad were investigated. Descriptions and identifications are provided based on the surveyed data and literature.

1.3.2 Anatomy

Comparative leaf anatomy is obtained from free-hand sections and paraffin method and examined under a light microscope. Leaf surfaces are studied by the peeling method and clearing method. Transverse leaves are studied by paraffin method.

1.3.3 Pollen morphology

The flowers were collected from field trip in Thailand and the samples were preserved in 70% alcohol. The anthers were removed from the flowers and the samples were dehydrate using alcohol series. The pollen morphological characteristics were studied under light microscope (LM) and scanning electron microscope (SEM). Then measure the size of about 30 pollen/specimen by LM. The pollen types were measured to determine the polar axis (P), equatorial axis (E), size of aperture and exine thickness using LM (Axio LabA1). The micrographs were taken using a SEM (JEOL: JSM 6460 LV) to determine the details of the exine sculpturing and aperture structure.

1.3.4 Data analysis

The pollen morphology and leaf anatomy of 18 species, 3 genera of Dilleniaceae within Thailand were analysis by numerical taxonomic. In total of quantitative and qualitative characters of the pollen morphology and leaf anatomy were studied and selected for multivariate analyses. A statistic was used to perform a Factor analysis (FA) and cluster analysis (CA) were performed to determine the pattern of grouping of the collected specimens (OTUs). The procedures are available in SPSS for windows.

1.4 Anticipated benefits

The achievements gained through a biology and taxonomic revision study of the Dilleniaceae in Thailand will provide information as follows.

1.4.1 The number of genera and species with the correct botanical names of Dilleniaceae in Thailand, including data on morphology, taxonomy, ecology and distribution include artificial key to the genera and key to species.

1.4.2 The data on the characteristic of anatomy of family Dilleniaceae in Thailand.

1.4.3 The data on the characteristic of pollen morphology of family Dilleniaceae in Thailand.

1.5 Study location

1.5.1 Department of Biology, Faculty of Science, Mahasarakham University.

1.5.2 Walai Rukhavej Botanical Research Institute, Mahasarakham University.

1.5.3 Abroad and domestic herbarium: Herbarium and Nature Reserve, Singapore (SING), Domestic herbaria: Bangkok Herbarium (BK), Forest Herbarium, Bangkok (BKF), Chiang Mai University Herbarium (CMU), Prince of Songkla University Herbarium (PSU) and Queen Sirikit Botanic Garden Herbarium, Chiang Mai (QBG).

1.5.4 Field trips to throughout Thailand.

1.6 Plans (Table 1)

1.6.1 Literature review and study preliminary data from specimens in herbarium as guidelines for field survey.

1.6.2 Field survey and collection of Dilleniaceae, prepare dried specimens and preserved specimens.

1.6.3 Descriptions morphological and identification based on principles of taxonomy and.

1.6.4 Study leaf anatomy by epidermal peeling methods, clearing methods and paraffin methods.

1.6.5 Study pollen morphology.

1.6.6 Artificial key for identification of Thai Dilleniaceae from characteristic of morphology, anatomy and palynology.

1.6.7 Report writing.

Table 1 Plans for study taxonomic revision of the family Dilleniaceae in Thailand.

Content	2013	2014	2015	2016	2017	2018
Study preliminary data	←	→				
Field survey and collection specimens	←	—	—	→		
Taxonomy		←	—	—	→	
Leaf anatomy and pollen morphology		←	—	—	→	
Pollen morphology				←	→	
Key artificial				←	→	
Report writing				←	→	

CHAPTER 2
TAXONOMY OF FAMILY DILLENIACEAE IN THAILAND

2.1 Introduction

Many years ago, Thai and abroad plant taxonomists studied and revised taxonomy of angiosperms for Flora of Thailand Project. At the present, they are on going this project. The Flora of Thailand Project was initiated in 1963 under Thai–Danish collaboration and formally launched in 1967. In 1970, the first part was published in Flora of Thailand (Volume 2, part 1) and has published continuously until. The current is volume 13 part 4 (Dipterocarpaceae). Flowering plants that have been published, about 10,000-12,500 species (60%). In 1972, Thai Dilleniaceae published in flora of Thailand Volume 2 part 2 by Hoogland, this study was more than 40 years ago. The description of Thai Dilleniaceae is incomplete, so it affects to truly understand of Thai Dilleniaceae species. In the present, many flowering plants of Thailand should have revised of taxonomy because the classification system is constantly being updated, allowing some species to change their taxonomic status.

The family Dilleniaceae is comprised of 11 genera with approximately 500 species, distributed in the tropical zone (Horn, 2005). In Thailand there are 15 species belonging three genera: namely *Dillenia* L. (10 species), *Acrotrema* Jack. (*A. costatum*) and *Tetracera* L. (3 species) (Hoogland, 1972). Many botanists are studied taxonomy of Dilleniaceae such as *Dillenia* was established in 1753 by Linnaeus and *D. indica* was selected type specimen for nomenclature. In 1872, Hooker and Thomson studied Dilleniaceae for Flora of British India. Hoogland (1951) reported family Dilleniaceae in Flora Malesiana, 41 species, 5 genera. Hoogland (1952) revised of 55 species of genus *Dillenia*. In 2001, *D. scabrella* (D. Don) Wall. was found, as a new record for Thailand from Khun Korn waterfall forest park, Chiang Rai province by Busban Na Songkhla and Chirayupin Chandraprasong. Choudhary *et al*. (2012) found *Dillenia tetrapetala*, new species in Vietnam. Hoogland (1972) published Dilleniaceae for Flora of Thailand but not cleared in description and key of many species such as *Dillenia aurea* and *D. obovata* shown below:

Key to the species

Adult leaves obovate-oblong, petiole long 3-6.5 cm, pedicel 5-12 cm **D. aurea**

Adult leaves obovate, petiole long 1.5-4 cm, pedicel 4-5 cm **D. obovata**

It is difficult to use the key to species. Moreover, Hoogland reported that "*D. obovata* and *D. aurea* grow closely together they may occupy distinct niches, but further field observation are required". In current, dry specimen of Thai Dilleniaceae were added in all Thai herbarium and the nomenclature of Dilleniaceae changed base on classification systems. Therefore, there should be a revision of the taxonomy of Dilleniaceae for the purpose of identify and confirm the number of species, correct scientific name including information on the distribution and ecology of Thai Dilleniaceae. The results of this study will be use as input for planning for genetic conservation and for more information support the Flora of Thailand.

2.2 Literature review

2.2.1 Number of genera in family Dilleniaceae

In current, classification of Dilleniaceae by Horn (2007) classified Dilleniaceae into 4 subfamilies: Dillenioideae, Hibbertioideae Delimoideae and Doliocaepoideae. Dillenioideae contains 4 genera: *Schumacheria* (three species) endemic to Sri Lanka, *Didesmandra* (one species, *D. aspera* Stapf.) endemic to Sarawak, Borneo, *Acrotrema* (about 10 species) c. 8 species in Sri Lanka, 1 species in the Western Ghats of India and 1 Species in southern Myanmar, Southern Thailand, Maley Peninsula and Northern Sumatra, *Dillenia* (about 110 species) from pentopical. Hibbertioideae contains 1 genus: *Hibbertia* c. 200 species in Australia include Tasmania, 24 species in New Caledonia, 2 species in New Guinea. In this classification, species previously placed in genus *Pachynema*, *Hemistema* and *Adrastaea* recently transferred as subgenus of genus *Hibbertia* base on both molecular and morphological data. Delimoideae contains 1 genus: *Tetracera* (about 50 species) southern Maxico to Paraguay, Antilles, equatorial Africa, Madagascar, Sri Lanka ans Southern India, Southeast Asia to Northeastern Australia, New Caledonia; Most speciose in Brazil. Doliocaepoideae contains 5 genera: *Davilla* (about 25 species), from southern Mexico to southern Brazil, Bolivia and Paraguay; *Curatella* (one species, *C. americana*) from

southern Mexico to southern Brazil and Bolivia; *Pinzona* (one species, *P. coriacea*) from Central and South America to northeastern Brazil; *Doliocarpus* (about 45 species) from southern Mexico to southern Brazil and Paraguay, with the center of species diversity in Brazil; Neodillenia (three species) in the Amazonian region of Colombia, Ecuador, Peru and Venezuela.

2.2.2 General morphological characteristic of Dilleniaceae

The morphology of the family is described based on Aymard (1997); Corner (1978); Dickison (1969); Hoogland (1951, 1952, 1953, 1959, 1972); Horn (2005, 2007); Kubitzki (1970); Rury and Dickison (1977)

1. Habit

Dilleniaceae is trees (*Dillenia* spp. and *Curatella*); stilt roots present in several *Dillenia* spp.; small to medium-sized rosette trees (*Hibbertia* spp.); small trees or large shrubs (*Didesmandra*, *Dillenia* spp., *Hibbertia* spp. and *Schumacheria*); shrubs (*Hibbertia*; some species of *Davilla*, *Doliocarpus* and *Tetracera*); lianas (*Davilla*, *Doliocarpus*, *Hibbertia* spp., *Neodillenia*, *Pinzona* and *Tetracera*); subshurbs with phyllocladous (*Hibbertia* subg. *Pachynema*) and subshrubs, sometimes rhizomatous and perennial herbs with a woody rhizome (*Acrotrema*). The bark is red or orange-brown color; younger bark is brown color; outer bark is gray color; and the breakage of the outer bark is plates, flakes, or strips.

2. Leaves

Leaves are simple, evergreen except in some *Dillenia* spp. in Southeast Asia are deciduous. Leaves pinnate found in some species of *Acrotrema* spp. Young leaves are often conduplicate and plicate-conduplicate. Leaves have a spiral arranged or vary rarely opposite arranged (*Doliocarpus pruskii* and *Hibbertia coriacea*). Leaves are mostly distinctly petiolate, adaxial groove. In some *Hibbertia* species, leaf laminae are sessile and are rarely amplexicaul. Petiolar wings are present in *Acrotrema*, *Davilla* spp., *Didesmandra*, *Dillenia* spp. and *Schumacheria*. Caducous amplexicaul wings in *Acrotrema* and *Dillenia* spp. The base of petiolar wings of *Acrotrema*, *Davilla alata and* allied species, *Didesmandra*, *Dillenia* spp. and *Schumacheria* completely ensheath

the stem. The petiolar wings may be caducous or persistent and are not stipules but function similarly to them by enclosing the developing terminal bud. Leaf margins are denate, serrate and entire; with or without toothed. Leaf venation is pinnate.

3. Inflorescence structure

Thrysoids or doublethyrsoids inflorescences with either dichasial or cincinate partial inflorescences of *Tetracera* are occured at terminal and often also axillary. Panicles, botyoids, or dichasia are found in few species.

Within *Davilla*, paniculate inflorescences are presented at terminal and axillary with ultimate paraclades of triads or monades, never raflorous. In *Curatella*, *Doliocarpus*, *Neodillenia* and *Pizona*, the inflorescence are exclusively axillary and are mostly ramiflorous. In *Curatella* and *Pinzona* are panicle inflorescences. In *Doliocarpus* inflorescences are panicle, to a botryoid, to uncommonly a monad. Inflorescence axillary of *Neodillenia* consist a solitary or botryoid, or terminal and consisting of a solitary flower or impoverished panicle.

Thyrsoids with cincinnate partial inflorescences of *Didesmandra* are occurred at terminal and axillary. In *Schumacheria* spp. found both terminal and axillary thyrsoid. Most *Dillenia* spp. have terminal inflorescences, cincinni inflorescences (*D. ferruginea* and *D. triquetra*) and thyrsoids inflorescences (*D. albiflos* and *D. suffruticosa*); several species have few-flowered cymose inflorescences. Solitary flowered with large flowers occured at terminal in several species of genus *Dillenia*. Inflorescences of *Acrotrema* are terminal raceme inflorescences.

Inflorescences of *Hibbertia* found varies from; most species are terminal solitary flower; panicle or thysoid inflorescences (*Hibbertia* subg. *Pachynema*); terminal cincinni and thysoids (*Hibbertia* subg. *Hemistema*).

4. Flowers

Flowers are small to vary large size and actinomorphic. Calyx is persistent and enclosing fruit after post-anthesis. Sepals of *Curatella*, *Pinzona*, *Tetracera* and some *Doliocarpus* spp. reflex immediately post-anthesis. Calyx found a number of different sepals: 3-15 (*Tetracera*), 5 (*Davilla*, *Hibbertia*, *Schumacheria*, *Didesmandra*,

Acrotrema), 3-5 (*Curatella*), 3-4 (*Pinzona*), 3-6 (*Doliocarpus*, *Neodillenia*), 4-18 (*Dillenia*, *D. pteropoda* (c. 18) and *D. reifferscheidia* (11-17)). Sepals are equal to unequal, free and persistent. Corolla composed 2-7 free petals, very showy, white or yellow, often emarginate and typically caducous. The absence of petals in a few *Dillenia* spp. Androecium is characteristically composed of 1-900 members of stamens. Some species of *Hibbertia* spp. found 1-5 stamens and 900 stamens in *Dillenia ovalifolia*. Staminodes was found in many species of *Dillenia* spp. and *Hibbertia* spp. (except subgenus *Adrastaea*). In Dilleniaceae, anthers separate filaments. Anthers are basifixed, dithecal and tetrasporangiate. Dehiscent of anthers are longitudinal slits, apical clefts or apical pores. Gynoecium is apocarpous comprising 1-20 carpels. Carpels are arranged in a single whorl and adnate to the conical or flat receptacle. Placentation is submarginal.

5. Fruit and seed

Fruits of Dilleniaceae are presented as follicle or aggregate of follicles types. In *Davilla*, the fruits dehiscent enclosed by two innermost sepals and prominently accrescent sepals. Baccate or leathery capsular fruits occur in *Curatella* and *Pinzona*. The fruits of *Doliocarpus* are also found as baccate and are either baccate follicles that are dehiscent along both the dorsal and ventral portions of the carpel, or indehiscent and berry-like. In dehiscent fruits of *Dillenia* spp. and *Acrotrema*, the fruits may be considered capsules. In several species of *Dillenia* spp. are pseudocarps (indehiscent) enclosed by accrescent sepals. In many species of *Acrotrema*, *Dillenia*, *Hibbertia* and *Tetracera* several seeds per carpel reach maturity, whereas in most other genera, carpels comprised of 1-2 seed. Arils are presented on the seeds of all genera and are of funicular origin. Aril of many *Dillenia* spp. with indehiscent fruits, the aril is presented only by a slight annular thickening on the funiculus. All *Dillenia* spp. with dehiscent fruits and a few with indehiscent fruits have arillate seeds. Red, white, or (rarely) orange, fleshy and typically oily or waxy arils of most Dilleniaceae are investigated. While, arils of *Hibbertia* spp. are presented as scarious, beige and waxy. The margin of the aril varies from as bellow: evenly fimbriate or laciniate (most species of *Tetracera*); shallowly incised (many species of *Dillenia*, *Hibbertia cuneiformis* and *H. scandens*); subentire to undivided in all other genera, sometimes asymmetrical.

Seeds are presented spheroidal to reniform shape and colour of seeds are occurred as a lustrous black or dark brown color, owing to the presence of pigments and tannins in the exotesta. Endosperm is nuclear, abundant, fleshy and oily, or in *Hibbertia* also with starch granules. The embryo of mature seeds are presented as straight, often very minute and not fully differentiated. Germination is phanerocotylar.

2.2.3 Distribution of Dilleniaceae

The distribution of the family is described based on Aymard (1997); Dickison (1966); Hoogland (1951, 1952, 1953); Horn (2005, 2009).

Dilleniaceae is distributed in a pantropical zone, but a large number of species also occur in subtropical and temperate Australia. Comparatively, this family is rare in Africa, where it is represented only by members of the pantropical genus *Tetracera*. The *Curatella*, *Davilla*, *Pinzona*, *Doliocarpusand* and *Neodillenia* are endemic to the Neotropics, with a center of diversity in Brazil (Figure 1A). *Hibbertia* are mostly endemic in Australia and are the largest genus in Dilleniaceae (Figure 1B). The genera *Schumacheria*, *Didesmandra*, *Acrotremaand* and *Dillenia* have a distribution from Madagascar and the Seychelles, to Sri Lanka and southern and eastern India, to Southeast Asia and the Pacific (north Australia and Fiji) (Figure 1B). *Schumacheria* is endemic to Sri Lanka. *Didesmandra* is known from only a few populations in Sarawak, Borneo. *Acrotrema* is endemic to Sri Lanka, one species in the Western Ghatts of India and another ranging from southern Thailand and Myanmar to northern Sumatra.

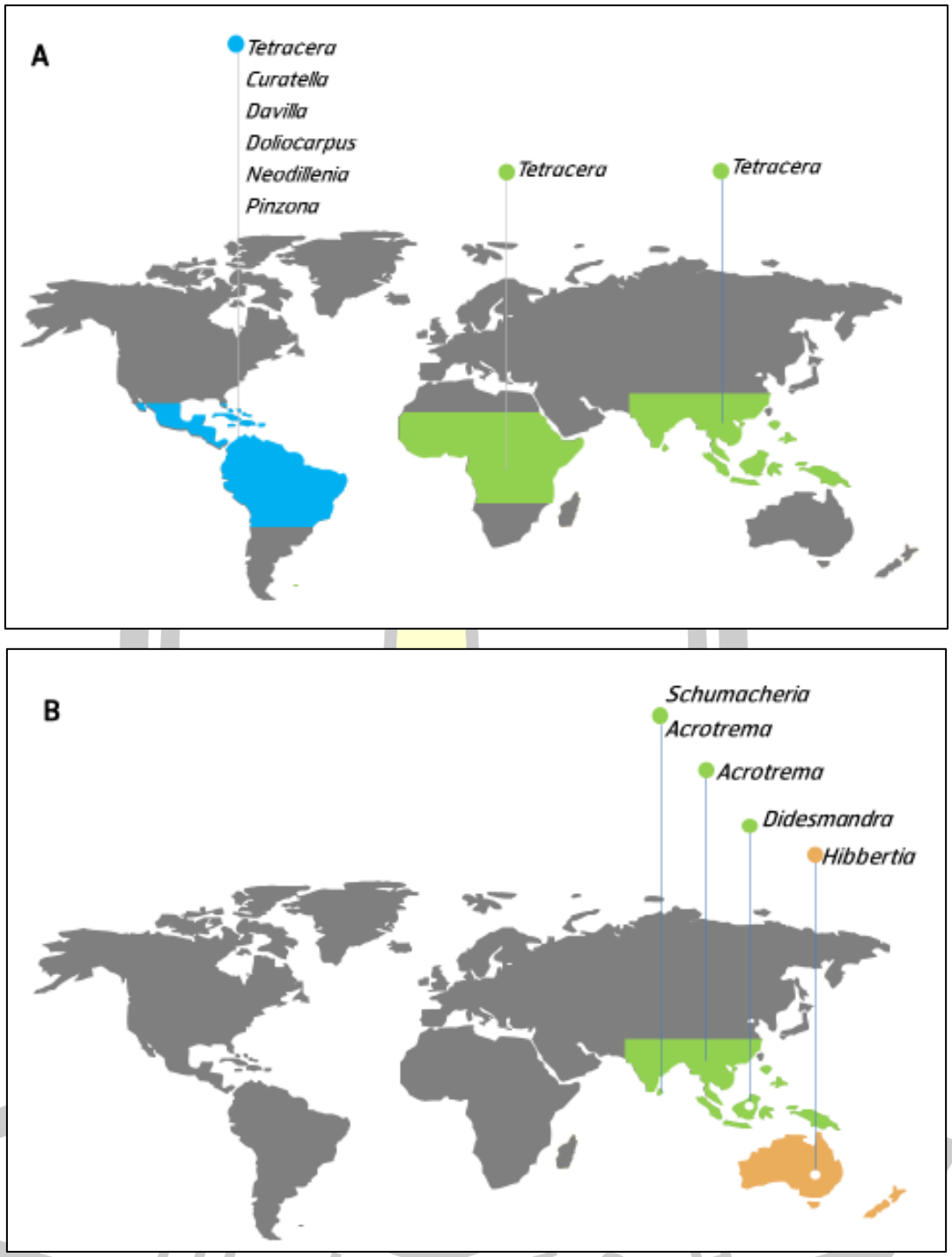


Figure 1 Distribution of Dilleniaceae (modified from study of Horn (2009)).

(A) Distribution of *Tetracera* (across whole shaded area) and the *Curatella, Davilla, Doliocarpus, Neodillenia* and *Pinzona* (across whole shaded blue area). (B) Distribution of *Hibbertia* (across whole shaded orange area) and distribution of *Schumacheria, Acrotrema* and *Didesmandra*. *Dillenia* occurs within the whole shaded green area; distributions of other genera within the clade are as shown.

2.2.4 Taxonomic history of family Dilleniaceae (Figure 2)

The type specimens of genus *Dillenia* and *D. indica* was established by Linnaeus and published in Species Plantarum (1753). Then the following genera were described for this family: *Tetracera* L. (1753), *Doliocarpus* Roland (1756), *Curatella* Loefl. (1758), *Davilla* Vandelli (1788), *Hibbertia* Andr. (1800), *Schumacheria* Vahl (1810), *Acrotrema* Jack (1820), *Pinzona* Mart. & Zucc. (1832), *Didesmandra* Stapf (1900) and *Neodillenia* Aymard (1997).

Hooker and Thomson (1872) described the morphology of the Dilleniaceae in the Flora of British India. They divided the Dilleniaceae into two tribes based on the form of the stamens: Tribe I- Delimeae comprising two genera; *Delima* has a solitary carpel and *Tetracera* has 2-5 carpels. Tribe II- Dillenieae comprising of four genera: namely *Acrotrema* have morphological characteristics of three carpels, stem less herbs and leaves all radical large; *Schumacheria* is morphological characteristics of three carpels and trees or shrubs; *Wormia* is morphological characteristics of 5-10 carpels and seeds arillate; *Dillenia* is morphological characteristics of 5-20 carpels and seeds not arillate. Brief descriptions of the morphological characteristics of Dilleniaceae for a total of 34 species.

Hoogland (1951) revised of the Dilleniaceae in the Flora Malesiana. He described the morphology and distribution of five genera consisting of the following: 13 species of *Tetracera*, two species of *Hibbertia*, one species of *Acrotrema*, one species of *Didesmandra* and 38 species of *Dillenia*. Descriptions of six new species*: Dillenia borneensis* sp. nov., *D. diantha* sp. nov., *D. talaudensis* sp. nov., *D. marsupialis* sp. nov., *D. fagifolia* sp. nov. and *D. celebica* sp. nov., with his new nomenclature correctly according to ICN: *Dillenia pteropoda* comb. nov., *D. albiflos* comb. nov., *D. quercifolia* comb. nov. and *D. obovata* comb. nov.

Hoogland (1952) revised the genus *Dillenia*, an extension of his revision of the Malaysian species of the genus *Dillenia* L. (*wormia* Rottb. included) inserted in the revision of the Dilleniaceae in the Flora Malesiana ser. I, vol. 4, part 3, pp. 141-174, published in December 1951. This described the morphology of 55 species of genus *Dillenia*, with descriptions of new species: *D. parkinsonii* sp. nov., *D. borneensis* sp. nov., *D. marsupialis* sp. nov., *D. ovalifolia* sp. nov. and *D. celebica* sp. nov., with his new nomenclature correctly according to ICN: *D. mansoni* comb. nov., *D. insignis*

comb. nov., *D. solomonensis* comb. nov. and *D. crenata* comb. nov. His present history of the genus *Dillenia* was founded by Linnaeus in 1753 is *D. indica*, which therefore is the nomenclature type. A pre-Linnean publication is that of Rheede (1683 in reference of Hoogland (1952)) who described "*Syalita*" from Malabar, on whose figure and description *D. indica* L. is practically wholly based. The genus *Wormia* was founded by Rottboell (1783 in reference of Hoogland (1952)) on a specimen from Ceylon; he did not compare his new genus with *Dillenia*. Vahl (1810 in reference of Hoogland (1952)) was the first to reduce *Wormia* to *Dillenia*. Gilg (1895), in the first edition of the "Naturliche Pflanzenfamilien", also reducing *Wormia* to *Dillenia* and publishing some new combinations. In the second edition, however, Gilg and Werdermann (1925) reestablished the genus *Wormia* on account of the presence of an aril. The later is synonyms.

Hoogland (1953) revised genus *Tetracera*, 15 species, an extension of his revision of Flora malesiana (I 4:141-149. 1951) and the revision now covers, besides Malaysia, continental Asia (Ceylon and Hainan included), Australia and New Caledonia.

Hoogland (1959) reported additional information of Dilleniaceae. He found the following additional information: the first, he described morphological characters of *Dillenia pteropoda*, *D. papyracea*, *D. ovalifolia*, *D. montana* and *D. quercifolia*; the second, he described three new species: *D. nalagi* sp. nov., *D. insularum* sp. nov. and *D. cyclopensis* sp. nov. and the last, he points out that *Tetracera asiatica* (Lour.) Hoogl. for Flora Malesiana is synonyms of *Tetracera sarmentosa* (L.) Yahl.

Hoogland (1972) reported description of the morphology, distribution, ecology, vernacular name and artificial key of Dilleniaceae in the Flora of Thailand as follow: 10 species of *Dillenia*, one species of *Acrotrema* and four species of *Tetracera*.

Stanley and Ross (1983) reported description of the morphology, distribution, ecology and artificial key of Dilleniaceae in the Flora of south-eastern Queensland of Australia. 17 species of genus *Hibbertia* were reported in south-eastern Queensland.

Wadhwa (1966) revised Dilleniaceae in Flora of Ceylon Vol. 10. Ceylon (Sri Lanka) found four genera and 16 species and artificial key as follow: 4 species of *Dillenia*, 7 species of *Acrotrema*, 3 species of *Schumacheria* and 2 species of *Tetracera*.

Na Songkhla and Chandraprasong (2001) found *Dillenia scabrella* (D. Don) Wall., a new record for Thailand, from Khun Korn Waterfall Forest Park, Chiang Rai province. The morphology has at least part of the pedicels with 1-3 caduceus bracteoles, inflorescences have 5-8 flowers, 4.5-5 cm across and stamens in two distinct groups: outer ones (numerous) and inner ones (11-14), carpels 4-5, seed without aril.

Hernández (2004) reported Dilleniaceae and artificial key to species of *Curatella* (*C. americana*), *Tetracera* (*T. volubilis* Subsp. *volubilis*), *Doliocarpus* (*D. dentatus*) and *Davilla* (*D. kunthii* and *D. nitida*) in Flora de Veracruz of Maxico.

Zhixiang and Kubitzki (2007) recognized the morphology, distribution, ecology, vernacular and identification of Dilleniaceae in the Flora of China consisting of two species of *Dillenia* and three species of *Tetracera*.

Kerrigan *et al.* (2011) reported Dilleniaceae and artificial key to two genera (*Dillenia* and *Hibbertia*), 20 species in Darwin region of capital city of the Northern Territory of Australia. In this classification, species previously placed in *Pachynema* recently transferred to *Hibbertia*.

Todzia and Aymard (2011) reported Dilleniaceae and artificial key to six genera of the Flora Mesoamericana viz *Curatella* (*C. americana*), *Davilla* (*D. kunthii* and *D. nitida*), *Dillenia* (*D. indica* and *D. suffruticosa*), *Doliocarpus* (*D. dressleri*, *D. brevipedicellatus*, *D. dentatus*, *D. major*, *D. multiflorus* and *D. olivaceus*), Pinzona (*P. coriacea*) and *Tetracera* (*T. macphersonii*, *T. hydrophila*, *T. portobellensis*, *T. volubilis* and *T. willdenowiana*).

Choudhary *et al.* (2012) found *Dillenia tetrapetala* from HonBa Nature Reserve, Vietnam. They compared the detailed illustrations and taxonomic comments to similar taxa. Phylogenetic analyses using the nrITS region of ribosomal DNA and *psb*A–*trn*H intergenic spacer region of chloroplast DNA sequences were also performed and they supported the status of *D. tetrapetala* as a distinct species. The morphology has inflorescences terminal, usually two, rarely one or three, flowered racemes; pedicels without bracteoles; sepals four, glabrous inside and sparsely hirsute outside; and petals four, yellow. Stamens pink-purple, in two distinct groups: outer ones and inner ones. Carpels 5–7, pink-purple, arranged around narrow conical receptacle. In Vietnam, the genus is represented by eight species viz *D. hokerri*, *D. tetrapetala*,

D. blanchardii, *D. indica*, *D. turbinate*, *D. ovata*, *D. obovata*, *D. pentagyna* and *D. scabrella*.

Aymard and Kelloff (2016) reported Dilleniaceae and artificial key to six genera of the Flora of the Guianas in south America viz *Curatella*, *Davilla*, *Doliocarpus*, *Neodillenia*, *Tetracera* and *Pinzona*.

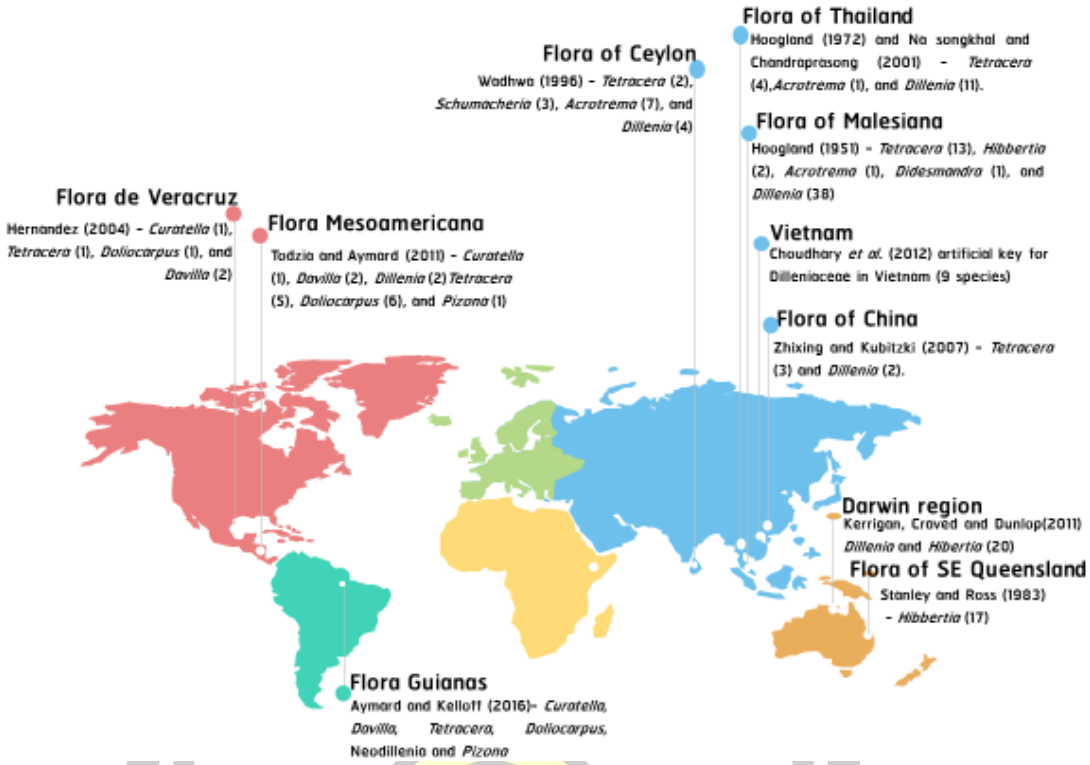


Figure 2 Taxonomic study of family Dilleniaceae in worldwide.

2.2.5 Relationship of Dilleniaceae to other Angiosperms (Table 2 and Figure 3)

Relationship of Dilleniaceae to other angiosperms is explained further from the study of Dickison (1966) in Table 2. Initially, the Dilleniaceae was in relationship with the Ranunculaceae and Magnoliaceae in Ranales, based on polypetalous corolla, apocarpous gynoecium and numerous stamens. Pollard (1872) classified Dilleniaceae under the order Parietales on account of the fact that the ovule-bearing surfaces (placentae) were attached to the walls of the ovary and numerous stamens, so should be placed near Eucryphiaceae. Gilg (1895) classified Dilleniaceae in the order Parietales

by being placed between Sterculiaceae and Eucryphiaceae based on parietal placentation; later, Lawrence (1951) placed Dilleniaceae in the order coincide. Gilg formed three sub-families to accommodate the genera *Actinidia* and *Saurauia*. Gilg and Werdermann (1925) removed the two above-mentioned genera to form a separate family Actinidiaceae. Hallier (1905) included the Dilleniaceae in his Rosalas. Hutchinson (1926) was the first to raise the family to ordinal rank, within his Dilleniales, which comprised Dilleniaceae and Crossosomataceae based on follicular free carpels, strongly arillate seeds and the absence of stipule. In 1959 Connaraceae and Brunelliaceae entered the order Dilleniales by Hutchinson based on the same treatment.

Metcalfe and Chalk (1950) pointed out in *Crossosoma* the absence of raphides but the presence in *Dillenia* is a clear indication that the genus is not closely related to the Dilleniaceae.

Corner (1946) placed the Paeoniaceae in affinity with Dilleniaceae by evidence from Zamora (1965). The perforation plate in the protoxylem-metaxylem elements of *Paeonia* is similar to those of *Dillenia* and *Tetracera*, but in *Crossosoma* the primary xylem differs from the Paeoniaceae and Dilleniaceae. Boivin (1956) included the Paeoniaceae and Crossosomataceae under his Dilleniales as did Cronquist (1957), but the sequence of stamen development was the only essential character by which the Dilleniales differed from the Ranales.

Copeland (1957) returned the Dilleniaceae to the Guttiferae based on the wood anatomy.

Thorne (1992) update phylogenetic classification of the flowering plants, or Angiospermae, is based upon about 800 pertinent books, monographs and other botanical papers. Dilleniaceae was placed in class Angiospermae (Annonopsida), subclass Dicotyledoneae (Annonidae), superoder Theanea, order Theales. Dilleniacea closely rerationships with suborder Theineae (Actinidiaceae, Paracryphiaceae, Stachyuraceae, Theaceae, Asteropeiaceae, Tetrameristaceae, Pellicieraceae, Chrysobalanaceae, Symploacaceae and Marcgraviaceae).

The Angiosperm Phylogeny Group (1998) classified angiosperm based on phylogenetic principle of arranging taxa on the basis of established monophyly. It relied on the synthesis of information from the disciplines of morphology, anatomy, embryology, phytochemistry and more strongly on molecular studies with reference to

DNA sequences of two chloroplast genes (*cp*DNA; *atpB* and *rbcL*) and one gene coding for ribosomes (nuclear ribosomal 18s DNA). In addition, APG included Dilleniaceae in core eudicots but not assigned to order in the classification. Dilleniaceae are included in the core eudicot. Dilleniaceae are not closely related or assigned to particular order.

Savolainen *et al.* (2000a) study phylogeny of flowering plant based on combined analysis of plastid *atpB* and *rbcL* gene sequences. Dilleniaceae are together sister to Santalales.

Savolainen *et al*. (2000b) used 589 plastid *rbcL* gene sequences representing nearly all eudicot families. Dilleniaceae and Vitaceae (including *Leea*) are together and sister to Caryophyllales.

Soltis *et al.* (2000) suggest the closely relationship between Dilleniaceae and Caryophyllales. Three-gene analysis (18s rDNA, *rbcL* and *atpB*) can be divided core eudicots into 6 subclades: (1) Berberidopsidales; (2) Gunnerales; (3) Saxifragales/Vitaceae (including *Leea*); (4) Santalales; (5) Dilleniaceae/Caryophyllales and (6) asterid clade.

The Angiosperm Phylogeny Group (2003) Dilleniaceae were consistently placed as sister to Caryophyllales in the three-gene analysis but with jackknife support of only 60% and on this basis, they refrain from adding them to Caryophyllales. Dilleniaceae unplaced as to order, assigned to the clade core eudicots.

Hilu *et al.* (2003) analyzed angiosperm phylogeny based on plastid *matK* gene sequences for 374 genera representing all angiosperm orders and 12 genera of gymnosperms. Dilleniaceae is sister to Vitaceae, although support for this relationship varies with the method applied (weak using MP, but 1.0 PP in BI).

Soltis *et al.* (2003) used four individual genes (26S rDNA, 18S rDNA, *atpB*, *rbcL*) for analysis. The addition of 26S rDNA sequences also increased support sister-group relationship of *Dillenia* with Caryophyllales increased from 72% with three genes to 83% with four genes. Four genes can be divided core eudicots into 6 subclades: (1) Gunnerales; (2) asterid clade; (3) Santalales; (4) *Dillenia*/Caryophyllales; (5) Saxifragales/Vitaceae; (6) Rosids clade

Horn (2005) hypothesized that the Dilleniaceae closely relationship to Caryophyllales or Vitaceae. Molecular phylogenetic data shows families within the Theales such as Actinidiaceae, Crossosomataceae, Paeoniaceae and others, which are

distantly related to Dilleniaceae. He compares data collected for Dilleniaceae with Vitaceae and Caryophyllales (emphasizing Rhabdodendraceae). Vitaceae is closely related with Dilleniaceae in most *rbcL* phylogenies; this relationship is supported with 100% Bayesian posterior probability in a recent *matK* angiosperm phylogeny. Nandi *et al.* (1998) pointed out that both families have calcium oxalate raphides and seeds with an endotestal layer of radially elongated cells and a tracheidal exotegmen. Dilleniaceae and Caryophyllales families have the characteristics of leaf mesophyll containing silica bodies, a broad petiole with at least a somewhat sheathing insertion, anthers with a persistent, tanniferous epidermis and a seed coat with a tanniferous exotesta and a layer or layers of cells developing spiral thickenings.

Thorne and Reveal (2007) in an Updated Classification of the Class Magnoliopsida ("Angiospermae") divided them into 12 subclasses, 35 superorders, 87 orders, 40 suborders, 472 families and 400 subfamilies and classified Dilleniaceae under superorder Dillenianae, that has only the order Dilleniales. Placed Dillenianae between Caryophyllanae and Santalanae and all of the above classified under Subclass Caryophyllidae as well as the Berberidopsidanae and Balanopnoranae. This subclass was placed closer to the Rosidae and Hamamelididae.

Kubitzki (2007) pointed out that Dilleniaceae is not assigned to an order because it has not been confirmed by recent phylogenetic studies. Dilleniaceae has not had molecular studies to confirm their closest relative, but it seems that they have some affinity with Caryophyllales. Horn (2005) described several important characters uniting Dilleniaceae and (woody) Caryophyllales such as Rhabdodendraceae.

Takhtajan (2009) classified Dilleniaceae under the superorder Dillenianae, which has only order Dilleniales. He placed Dillenianae near Ericanae, all of the above classified under subclass Dilleniidae as well as the Primulanae, Violanae, Capparanae, Malvanae and Euphorbianae. This subclass can be placed closer to the Rosidae and Hamamelididae. This subclass has flowers usually with double perianth, mostly bisexual, spiral, spirocyclic or cyclic. Petals free or less often corolla sympetalous. Pollen grains 2-celled or seldom 3-celled, 3-colpate or tricolpate-derived type. Gynoecium apocarpous, ovules mostly bitegmic, endosperm nuclear or less often cellular.

The Angiosperm Phylogeny Group (2009) is the third version of a modern, mostly molecular-based. Updated classification of the orders and families of flowering plants was compiled by the Angiosperm Phylogeny Group. Dilleniaceae was placed under core eudicots but Dilleniaceae position within the core eudicots was uncertain. The ordinal name, Dilleniales DC. Ex Bercht. & J. Presl, is available.

Moore *et al.* (2010), phylogenetic analyses of 83 protein-coding and rRNA genes from the plastid genome. Pentapetalae diverged into three clades: (1) a superrosid clade of Saxifragales, Vitaceae, Rosidae; (2) a superasterid clade of Berberidopsidales, Santalales, Caryophyllales and Asteridae and (3) Dilleniaceae. In study support the position of Dilleniaceae as sister to Superrosidae, but topology tests did not reject alternative positions of Dilleniaceae as sister to Asteridae or Pentapetalae.

Soltis *et al*. (2011) used 17 individual genes for analysis. Dilleniaceae were recovered as sister to the remaining Superasteridae (BS = 97%). Dilleniaceae are strongly placed as sister to a clade comprising Santalales, Caryophyllales, Berberidopsidales and Asteridae

The Angiosperm Phylogeny Group (2016) by Angiosperm Phylogeny Group botanical classification system reinstated the Dilleniaceae in order Dilleniales of the core eudicots. The Dilleniales contains the single family Dilleniaceae. Dilleniales is new orders, after APG III point out that Dilleniaceae has no stable position as yet.

Table 2 Comparison of relationships of Dilleniaceae to other angiosperms.

Authors	Placement
De Candolle (1824)	Ranales; between Ranunculaceae and Magnoliaceae
Lindley (1830)	Ranales; between Magnoliaceae and Winteraceae
Bentham and Hooker (1862)	Ranales; between Ranunculaceae and Calycanthaceae
Baillon (1871)	between Ranunculaceae and Magnoliaceae
Pollard (1872)	Parietales; near Eucryphiaceae
Le Maout and Decaisne (1873)	Ranales; between Ranunculaceae and Calycanthaceae
Kuntze (1891)	between Ranunculaceae and Calycanthaceae
Gilg (1895)	Parietales; between Sterculiaceae and Eucryphiaceae

Table 2 Comparison of relationships of Dilleniaceae to other angiosperms (cont.).

Authors	Placement
Hallier (1905)	Rosales; near Brunelliaceae
Warming (1911)	Cistiflorae; near Bixaceae
Bessey (1915)	Ranales; between Ceratophyllaceae and Canellaceae
Gilg and Werdermann (1925)	Parietales; near Actinidiaceae
Rendle (1925)	Guttiferales; near Ochnaceae
Hutchinson (1926)	Dilleniales; near Connaraceae
Wettstein (1935)	Guttiferales; near Actinidiaceae
Corner (1946)	near Paeoniaceae
Gundersen (1950)	Theales; near Actinidiaceae
Lawrence (1951)	Parietales; near Actinidiaceae
Boivin (1956)	Dilleniales; near Crossosomataceae
Benson (1957)	Ranales; between Annonaceae and Cercidiphyllaceae
Copeland (1957)	Guttiferales; near Theaceae
Cronquist (1957)	Dilleniales; near Crossosomataceae
Chadefaud and Emberger (1960)	Parietales; near Actinidiaceae
Eames (1961)	Dilleniales; near Paeoniaceae
Melchior (1964)	Guttiferales; near Paeoniaceae
Croquist (1988)	Dilleniales; near Paeoniaceae
APG I (1998)	Dilleniaceae; eudicots
Savolainen *et al.* (2000a)	Dilleniaceae; near Santalales
Savolainen *et al.* (2000b)	Dilleniaceae; near Vitaceae
Soltis *et al.* (2000)	Dilleniaceae; near Caryophyllales
APG II (2003)	Dilleniaceae; near Caryophyllales
Hilu *et al.* (2003)	Dilleniaceae; near Vitaceae
Soltis *et al.* (2003)	Dilleniaceae; near Caryophyllales
Thorne and Reveal (2007)	Dillenianae; between Caryophyllanae and Santalanae
APG III (2009)	Dilleniaceae; between Asterids and Rosids clade
Moore *et al.* (2010)	Dilleniaceae; near Superrosidae
Soltis *et al.* (2011)	Dilleniaceae; Superasteridae
APG IV (2016)	Dilleniales; between Superasterids ans Superrosids Clade

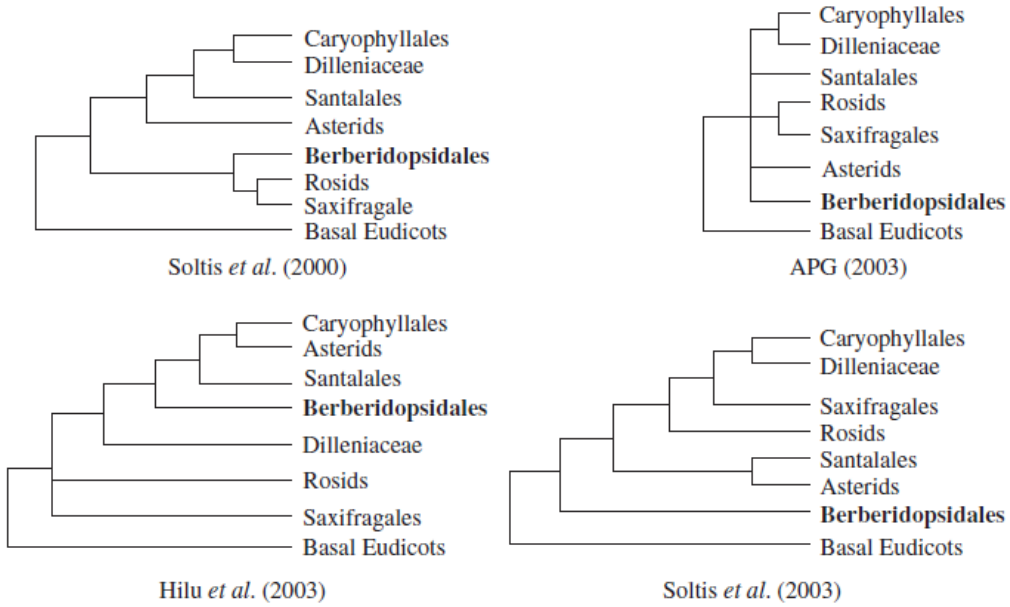


Figure 3 The position of Dilleniaceae relative to other core eudicots based on recent molecular studies (modified from study of De Craene (2004)).

2.2.6 Comparison relationships within the family

Dilleniaceae contains 11 genera with approximately 500 species that are *Acrotrema* (about 10 species), *Curatella* (one species), *Davilla* (25 species), *Didesmandra* (one species), *Dillenia* (about 110 species), *Doliocarpus* (about 45 species), *Hibbertia* (about 225 species), *Neodillenia* (three species), *Pinzona* (one species), *Schumacheria* (three species) and *Tetracera* (about 50 species) and a change occurs within the family by morphological characters support. Characters used for earlier subdivisions of Dilleniaceae include anther structure (linear vs. globose), leaf architecture (lateral nerves well-developed and often parallel vs. small, sometimes 1-nerved leaves), anther dehiscence (longitudinal slits vs. apical pores) and degree of carpel fusion (carpels entirely free vs. +/- synovarious) (Horn, 2005) in Table 3.

Table 3 Comparison of intrafamilial relationships by morphological characters.

Author	Placement
De Candolle (1824)	Tribe - Delimeae Tribe - Dillenieae
Bentham and Hooker (1862)	Tribe - Delimeae Tribe - Dillenieae Tribe - Hibertieae
Hooker and Thomson (1872)	Tribe - Delimeae Tribe - Dillenieae
Gilg (1895)	Subfamily - Dillenioideae Tribe - Tetracereae Tribe - Hibbertieae Tribe - Acrotremeae Tribe - Dillenieae Subfamily - Actinioideae Tribe - Actinidieae Subfamily Saurauioideae Tribe - Saurauieae
Gilg and Werdermann (1925)	Tribe - Dillenieae Tribe - Hibbertieae Tribe - Acrotremeae Tribe - Tetracereae
Hoogland (1952)	Subfamily - Tetraceroideae Subfamily - Dillenioideae
Hutchinson (1964)	Tribe - Dillenieae Tribe - Hibbertieae Tribe - Tetracereae
Thorne (1992)	Subfamily-Dillenioideae Subfamily-Tetraceroideae
Thorne (2000)	Subfamily- Dillenioideae Subfamily- Delimoideae

Table 3 Comparison of intrafamilial relationships by morphological characters (cont.).

Author	Placement
Horn (2005)	Subfamily- Dillenioideae Subfamily- Hibbertoideae Subfamily- Doliocarpoideae Subfamily- Delimoideae
Horn (2007)	Subfamily- Dillenioideae Subfamily- Hibbertoideae Subfamily- Doliocarpoideae Subfamily- Delimoideae
Thorne and Reveal (2007)	Subfamily- Dillenioideae Subfamily- Delimoideae
Takhtajan (2009)	Subfamily - Dillenioideae Tribe - Dillenieae Tribe - Hibbertieae Subfamily - Delimoideae (Tetraceroideae)

In current, APG IV (2016), Dilleniaceae treated as order Dilleniales of the core eudicots and contained within the mono familia Dilleniales. Within the family classification by Horn (2005, 2007, 2009) is completed system for the infrafamilial relationships (Figure 4). Therefore, classification of Dilleniaceae is as follows:

Kingdom Plantae – Plants

Division Magnoliophyta – Flowering plants

Class Magnoliopsida – Dicotyledons

Order Dilleniales

Family Dilleniaceae

Horn (2005) studies comparison of interfamilial relationships by molecular data divided follow as.

Dilleniaceae Salisb., Parad. Lond. 2(1): ad t. 73 (1807), nom. cons. ('Dilleneae')

Soramiaceae Martinov (1820)

Hibbertiaceae J. Agardh (1858)

Subfamily Delimoideae Burnett, Outl. Bot.: 836. (1835) (‘Delimidae’)

Tribe Delimeae DC.,

Tetracera L.

Subfamily Doliocarpoideae J.W. Horn, subfam. nov.

Tribe Davilleae J.W. Horn, trubus nov.

Davilla Vand.

Tribe Doliocarpeae Rchb.

Curatella Loefl.

Pinzona Mart. & Zucc.

Doliocarpus Rol.

Neodillenia Aymard

Subfamily Hibbertioideae J.W. Horn, subfam. nov.

Tribe Hibbertieae Spach

Hibbertia Andrews

Subgenus *Pachynema* (R. Br. ex DC.) J.W. Horn, comb et stat. nov.

Subgenus *Hemistema* (Thouars) J.W. Horn

Subgenus *Adrastaea* (R. Br. ex DC.) J.W. Horn, comb, et stat. nov.

Subgenus *Hibbertia* (Andrews) J.W. Horn

Subfamily Dillenioideae Burnett, Outl. Bot.: 836 (1835) (‘Dillenidae’)

Tribe Schumachereae J.W. Horn, tribus nov.

Schumacheria Vahl

Didesmandra Stapf (provisional placement)

Tribe Dillenieae DC.

Acrotrema Jack

Dillenia L.

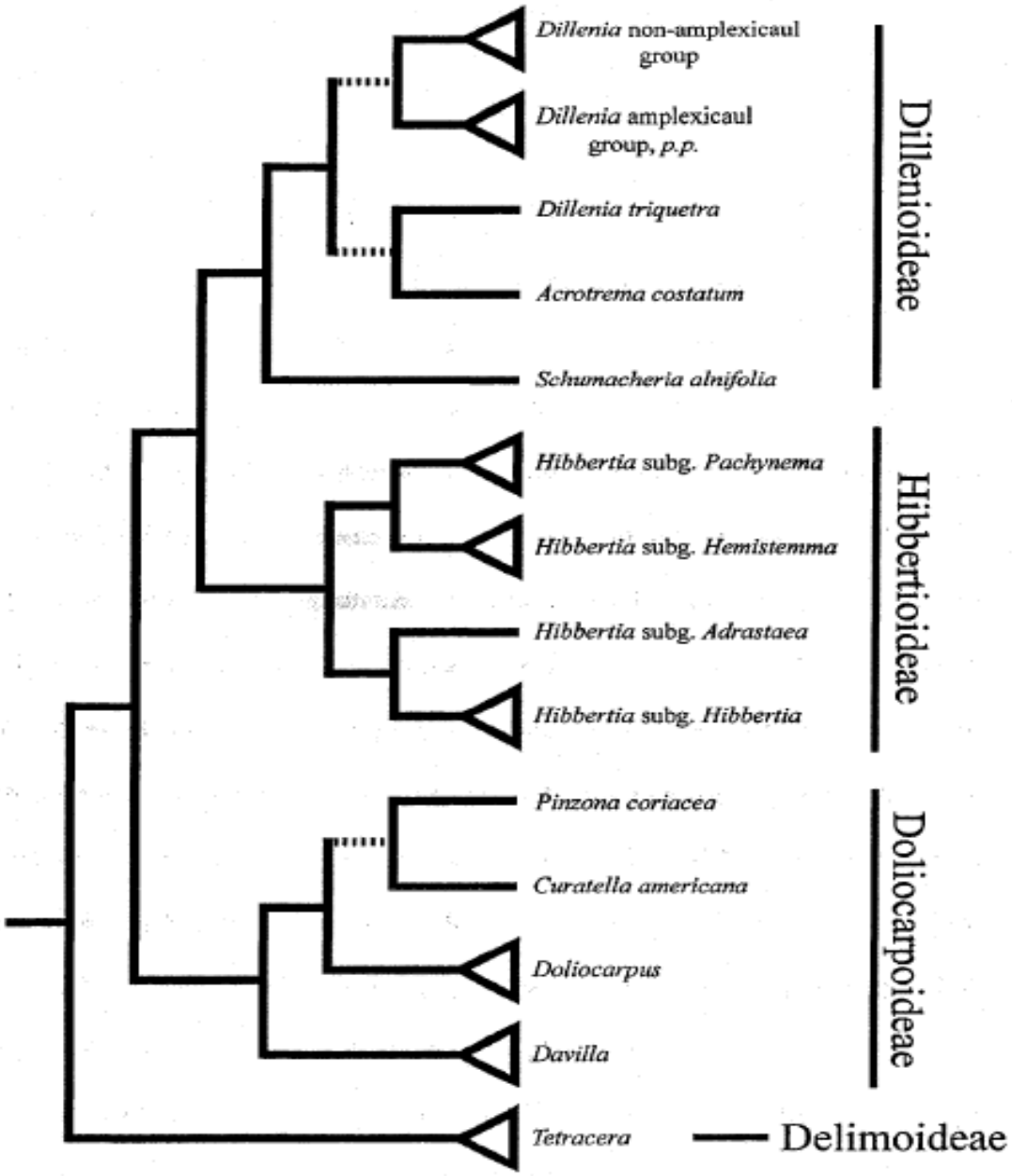


Figure 4 Summary tree of intrafamilial ralationships of Dilleniaceae base on molecular data (Horn, 2005).

2.3. Materials and methods

2.3.1 Review literature and plant specimen collection

1. Literatures of Dilleniaceae were consulted such as journals, flora and monographs. The documents guide to the study and identification.

2. Herbarium specimens from aboard herbaria were studied for preliminary data, such as date of collection, location of collection and other. Previous specimens from the following herbaria were investigated:

- Herbarium and Nature Reserve, Singapore (SING)
- Bangkok Herbarium (BK)
- Forest Herbarium, Bangkok (BKF)
- Prince of Songkla University Herbarium (PSU)
- Chiang Mai University Herbarium (CMU)
- Queen Sirikit Botanic Garden Herbarium, Chiang Mai (QBG)

3. Field survey and collection of Dilleniaceae species throughout Thailand were collected with six duplicates with twigs, leaves, flowers and fruits and record data in the field survey, which consists of vernacular names and uses, ecology, location, phonological, characteristic preliminary and photograph of the taxa were included.

4. Dried plant specimens were stitched on herbarium sheets and labeled. The plant specimens were deposited in Department of Biology, Faculty of Science, Mahasarakham University for further taxonomic reference and morphological studies.

5. Mature leaves and flowers were fixed in 70% ethanol alcohol for anatomical studies and palynological studies.

2.3.2 Morphological descriptions

Descriptions of morphological, ecological and geographical distribution data from field investigations and herbarium specimens of Dilleniaceae in Thailand are studied. The morphological characteristic for descriptions that describe several organs, as follow:

1. Habit is the characteristics of the mature plant by interpretation from several characters such as presence or absence of wood, the branches and the balancing of the plant. This consists of trees, shrubs, herbs and climbers.

2. Stems mean the part growing above ground level that supports the leaves, flowers and buds. The high is measured from base to top of trees. Bark, the outer bark is observed for color and the cracking of the bark.

3. Leaf blade measure length of leaf blade from leaf base to leaf apex. The width is measured at the middle part of the lamina. Nerved, count the number of lateral veins. Finally, observe other noticeable features include leaf shape, leaf apices, leaf base, leaf margins and leaf surfaces. Petioles observe the character and measure length of petiole.

4. Flowers, the data of flowers is measured at least from 10 mature flowers.

- Types of flower
- Quantity of flowers, if a group or inflorescence of flowers
- Length of pedicel
- Presence and absence of hair at peduncle
- Position of bracts
- Diameter of flower, measured from sepal to sepal in the opposite direction
- Length of sepal, measured from base at joint with pedicel to apex of sepal
- Width of sepal, the width is measured at the middle part of sepal
- Position of hairs base on sepal surface
- Quantity of petals
- Color of petals
- Length of petals
- Width of petals, the width is measured at the middle part of petals
- Quantity of stamens
- Length of stamens, measured from base at joint with receptacle to apex of stamen
- Color of stamen
- Quantity of carpel
- Length of styles

5. Fruits and seeds, the data of the at least 10 mature fruits were measured.

- Fruit size, type
- Seeds per carpels, presence and absence of aril, color of aril

2.3.3 Identification

1. Morphological characters of each specimen were described in morphological studies.

2. The collected specimens and specimens in herbarium were identified with relevant taxonomic literature.

3. The nomenclature of each species was investigated, following the International Code of Nomenclature for algae, fungi and plants (ICN).

2.3.4 Descriptions

1. Descriptions of the species were made.

2. Taxonomic literature was quoted following the literature review.

3. Vernacular names and uses were received based on the field observations and supplemented with information from the literature.

4. Ecological, distribution and phenological information for each species was added from field observations and literature. Distribution of Thai Dilleniaceae was consulted the map of floristic regions in Figures 5-6.

5. Photographs of the taxa were taken to illustrate the species.

6. Key and description of the species including vernacular names and their uses were made and supplemented with line drawings of identifications for all taxa.

Figure 5 The floristic regions and provinces of Thailand (Santisuk and Larsen, 2017).

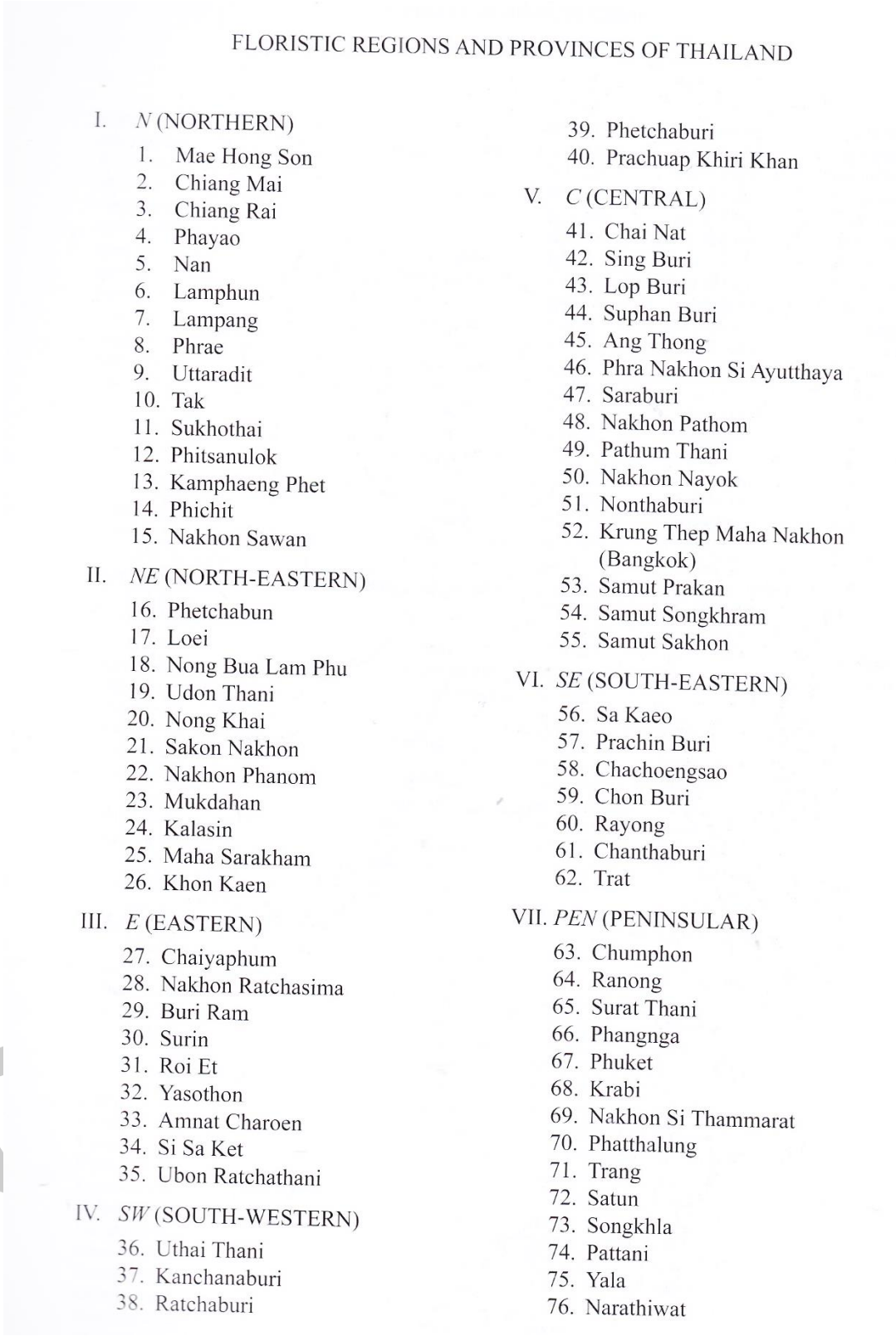


Figure 6 The floristic regions and provinces of Thailand (Santisuk and Larsen, 2017).

2.4 Results

2.4.1 Classification of Dilleniaceae

APG IV (2016) classified family Dilleniacea to order Dilleniales. Current Dilleniaceae ranking is shown below.

Kingdom Plantae – Plants

Division Magnoliophyta – Flowering plants

Class Magnoliopsida – Dicotyledons

Order Dilleniales

Family Dilleniaceae

The number and infrafamilial classification of Dilleniaceae and synonyms of each genus follow as Horn system base on molecular data and morphological data show in Table 4.

Table 4 Infrafamilial classification of Dilleniaceae and synonyms of each genus.

Infrafamilial relationships	**Genus**	**Synonym of each genus**
Subfamily Delimoideae Burnett		
	Tetracera L.	*Delima* L. (1753), *Tigarea* Aubl. (1775), *Assa* Houtt. (1775), *Empedoclea* A. St.-Hil. (1824)
Subfamily Doliocarpoideae J.W. Horn		
	Davilla Vand.	*Hieronia* Veil. (1829)
	Curatella Loefl.	-
	Pinzona Mart. & Zucc.	-
	Doliocarpus Rol.	*Soramia* Aubl. (1775), *Calinea* Aubl. (1775), *Ricaurtea* Triana (1858)
	Neodillenia Aymard	-

Table 4 Infrafamilial classification of Dilleniaceae and synonyms of each genus (cont.).

Infrafamilial relationships	**Genus**	**Synonym of each genus**
Subfamily Hibbertioideae J.W. Horn		
	Hibbertia Andrews	*Hemistema* Thouars (1804), *Pleurandra* Labill. (1806), *Candollea* Labill. (1806), *Adrastaea* DC. (1817), *Pachynema* R. Br. ex DC. (1817), *Trisema* Hook. f. (1857)
Subfamily Dillenioideae Burnett		
	Schumacheria Vahl	-
	Didesmandra Stapf	-
	Acrotrema Jack	-
	Dillenia L.	*Wormia* Rottb. (1783), *Colbertia* Salisb. (1807), *Reijferscheidia* C. Presl (1835), *Neowormia* Hutch. & Summerh. (1928)

2.4.2 Taxonomy of Dilleniaceae in Thailand

The results of the study found twenty species, three genera from two subfamilies of the family Dilleniaceae in Thailand were reported from around Thailand. Subfamily Delimoideae found only the genus *Tetracera*, 5 species. Subfamily Dillenioideae found 14 species of genus *Dillenia* and 1 species of genus *Acrotrema*. *Tetracera akara* is new records for Thailand. *Dillenia suffruticosa* and *D. philippinensis* are cultivated as ornamental plant. In this study, *Dillenia pulchella* and *D. reticulata* was described for the first time base on Thai specimens. *Dillenia grandifolia* was classified to synonym of *Dillenia ovata* by The Plant List (2018).

General Characters of Dilleniaceae in Thailand

Habitate tree, shrubs, woody climbers, or perennial herbs, evergreen or deciduous. **Leaves** simple, spirally arranged, simple, exstipule, in *Acrotrema* and some species of *Dillenia*. **Petiole** with wing-like and adnate to the petiole, mostly deciduous. **Inflorescence** terminal or axillary, racemose or panicle or solitary (Table 6). **Flower** bisexual, usually actinomorphic, hypogynous, mostly yellow or sparse white. **Sepals** 4-5, persistent into fruit, mush imbricate. **Petals** (2-) 3-5 (-7), yellow or white or red, menbranaceous, caducous, rounded or emarginate at apex. **Stamen** numerous, free; anther basifixed, anther opening by longitudinal slits or by apical pore. **Carpels** 1-20, superior, free, with free styles; ovules 1 to numerous. **Fruit** follicle, capsule, indehiscent or dehiscent, enclosed by the persistent fleshy sepals. **Seed** 1 to numerous; abundant endosperm and embryo vary small, with aril or without aril.

Distribution: 3 genera and about 20 species are distributed in Thailand.

Table 5 Comparison dominant characteristics of three genera in family Dilleniaceae in Thailand.

Characters	***Acrotrema***	***Tetracera***	***Dillenia***
Habit	Small perennial herb	Woody climber	Shrubs or trees
Inflorescence	Racemes	Panicle	Solitary, racemes or fascicled
Anther	Thecae linear	Anther divergent towards the base	Thecae linear
Anther opening	opening with pore near apex	Longitudinal slit	Longitudinal lateral or opening with pore near apex
Ovary	Conical receptacle	Flat receptacle	Flat receptacle

Key to genera of Dilleniaceae in Thailand (modified from Hoogland (1972) in Flora of Thailand Vol. 2 Part 2)

1. Shrubs or trees with large leaves and large flowers with few-flowered; sepals fleshy, enlarged when fruiting; carpels adnate to conical receptacle **1. Dillenia**

1. Small perennial herb, or woody climber with smaller leaves and flowers with many flowered; sepals not noticeably enlarged with fruiting; carpels adnate to flat receptacle **2**

2. Small perennial herb, yellow flowers in racemes inflorescence, anther thecae long (linear) and parallel **2. Acrotrema**

2. Woody climber, white or reddish white flower in panicle inflorescence, anther thecae short, diverging towards the base **3. Tetracera**

Dominant characters for key to genera of family Dilleniaceae in Thailand show in Tables 5 and 6 and Figures 14-19. Distribution of Thai Dilleniaceae conclusion in Table 7. Distribution of all species of genus *Dillenia* show in Figures 7-10, genus *Acrotrema* in Figure 11 and genus *Tetracera* in Figures 12-13.

Table 6 Type of inflorescences of Thai Dilleniaceae.

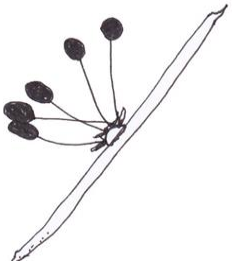
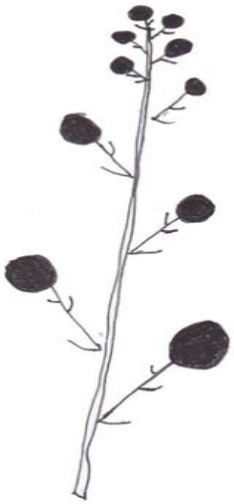
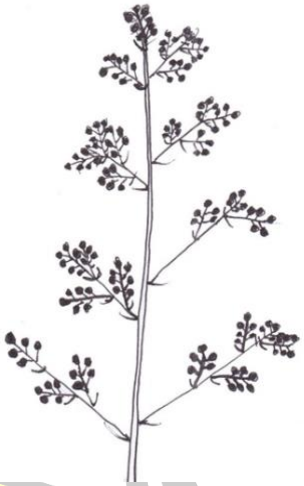
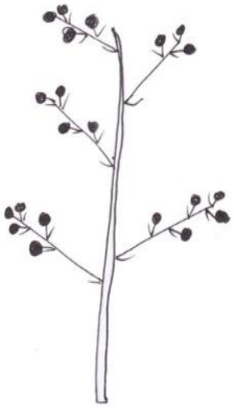
Numbers	Characters	Illustration
1	Solitary flowers	
2	Fascicled flowers or clustered inflorescences	

Table 6 Type of inflorescences of Thai Dilleniaceae (cont).

Numbers	Characters	Illustration
3	Raceme inflorescence	
4	Thyrse	
5.	Panicle	

Dillenia

L., Sp. Pl.: 535. 1753; Gen. Pl. ed. 5:239. 1754; Trimen, Handb. in Fl. Ceylon 1:12. 1893; Hoogl. in Fl. Mal. I.4:154. 1951; Blumea 7:1. 1952.; Hoogl. in Fl. Thailand 2(2):95. 1972.; Wadhwa. in Fl. Ceylon 10:110. 1996.; Shu. in Fl. China 12:332. 2007.; Kerrigan, Craven & Dunlop. in Fl. The Darwin Region 1:1. 2011.; Type species: *Dillenia indica* L. — *Wormia* Rottb., Nye Sml. Kongel. Danske Vidensk. Selsk. Skr. 2: 531. 1783; Hook. f. & Thoms., Fl. Ind. 1:56. 1855; Trimen, Handb. Fl. Ceylon 1:11. 1893. Type species: Wormia triquetra Roottb. = *Dillenia triquetra* (Rottb.) Gilg. — *Colbertia* Salisd., Parad. Londin. 2(1): sub t. 73. 1807.

Usually tree, some species small shrubs, evergreen or deciduous; Stilt-roots usually absent, **Bark** usually about reddish brown or gray, peeling off in thin, often papery flakes. Branches sympodial, branching from axil of uppermost leaf below inflorescence or solitary flower. **Leaf-scars** either completely amplexicaul or clasping up to ca 3/4 of branches. **Leaves** simple, spiral arranged, entire, undulate or dentate at margin, smaller teeth at margin, pinnately nerved; midrib, nerves and veins usually prominent on both sides, most so below. **Petiole** grooved above, in some species with amplexicaul wings in young leaf enclosing terminal bud. **Inflorescences** solitary or in few flowered racemose, solitary or in few-(up to 10)-flowered cluster inflorescences on the branches with few to many bracts. **Bracts** small, caducous, usually densely hairs. **Bracteoles** usually inconspicuous or absent. **Flowers** actinomorphic. **Sepals** usually 5, fleshy, free, imbricate, persistent in fruit. **Petals** usually 5, much larger than sepals, yellow or white, deciduous, usually rounded at apex. **Stamen** numerous (up to 500), all of the same length or the innermost distinctly longer; anthers linear, opening by longitudinal slits or pore near apex. **Ovary** superior; carpels 4-20, connate along central part of receptacle; ovules 4 to numerous attached to marginal adaxial placentae; styles filamentous or linear, curved outward, spreading. **Fruit** either dehiscent or indehiscent, consisting of gynoecium and persistent sepals, enclosed by the persistent sepals. **Seed** 1-numerous, dark brown to black, glabrous, arillate or exarillate.

Distribution: This genus is found about 65 species from Madagascar and the Seychelles, to Sri Lanka and southern and eastern India, to Southeast Asia and the Pacific (north Australia and Fiji).

Key to Genus *Dillenia* in Thailand (modified from Hoogland (1972) in Flora of Thailand Vol. 2 Part 2)

1. Petiole with broad wings, in young leaf completely amplexicaul and enclosing terminal bud **2**
   2. Petiolar wings not constricted at leaf base, wing continuous from the base of leaf; inflorescence racemose, 4-8 flowered, petal yellow, fruit dehiscent **D. suffruticosa**
   2. Petiolar wings more or less constricted at leaf base, wing separated or independent from the base of leaf; inflorescence solitary or racemose, 1-2 flowered, petal white; fruit indehiscent **D. philippinensis**
1. Petiole without amplexicaul wings or not completely amplexicaul **3**
   3. Deciduous tree with solitary flowers or in few-flowered fasciculate inflorescence with few-several bract, flower appearing before or with new leaf **4**
      4. Flower small (ca. 2-5 cm diam.), fascicled inflorescences comprising 4-8 flower, fruit (include sepals) ca. 1-2 cm diam **5**
         5. Sepals densely sericeous outside **D. parviflora**
         5. Sepals glabrous on both side **6**
            6. Pedicels without bracteoles **D. pentagyna**
            6. Pedicel with caducous bracteoles **D. scabrella**
      4. Flowers larger (ca. 10-20 cm diam.), solitary flower or 1-3 flowered on same pedicels (inflorescence); fruit (Include sepals) ca. 4-10 cm diam **7**
         7. Bark rather smooth, flaky, yellowish to reddish gray, heartwood lightly red or red; petiole 1.5-4 long; pedicel 4-5 cm long; occurrence in southerly Thailand **D. obovata**
         7. Bark thick scales, rough, reddish, heartwood reddish brown or gray; petiole 3.6.5 cm long; pedicel 5-12 cm long, rarely shorter, occurrence in northerly Thailand **D. aurea**
   3. Evergreen tree with solitary flowers or racemose inflorescences terminal **8**
      8. Evergreen tree with stilt root; raceme inflorescence **9**
         9. Without petals **D. grandifolia**
         9. With 5 petals, whitish yellow **D. reticulata**

8. Evergreen tree without stilt root; solitary or raceme inflorescence amongst fully developed leaves **10**

10. Stamen all of approximately the same length; pedicel with 3 large verticillate bracteoles; leaves densely velvety tomentose below **D. hookeri**

10. Stamen in 2 sharply separated group of difference length; no such bracteoles; leaves not densely velvety tomentose below **11**

11. Solitary flower, axillary, occasionally 2-3 serially arranged **D. pulchella**

11. Solitary flower or racemose inflorescence terminal **12**

12. Recemose inflorescence with 3-12 flowered; fruits dehiscent **D. excelsa**

12. Flower solitary or occasionally in 2 flowered inflorescence; fruits indehiscent **13**

13. Petal yellow; carpels 10-12, Leaves tomentose-hirsute below **D. ovata**

13. Petal white; carpels 14-20, leaves stigose below **D. indica**

Dominant characteristics for key to species of genus *Dillenia* showed in Figures 20-30.

1. Dillenia aurea Sm., Exot. Bot. 2:65. t. 92, 93. 1860; Hook. f. & Thoms. in Hook.f., Fl. Br. Ind. 1:37. 1872; Parkins., Indian Forester 61:450. t. 28. f. 2. 1935; Hoogl., Blumea 7: 128. 1952; Dansk bot. Ark. 20:185. 1962.; Hoogl. in Fl. Thailand 2(2):95. 1972. — *D. pulcherrima* Kurz, J. Asiat. Soc. Beng. 40(2):46. 1871; Fl. Burm. 1. 19. 1877; Craib, Fl. Siam. En. 1:24. 1925. — *Dillenia aurea* var. *trichocarpella* Hoogland, Blumea 7:130. 1952. — *Dillenia indica* var. *aurea* (Sm.) Kuntze, Revis. Gen. Pl. 1:44 1891.

Deciduous trees up to 20 m, with usually rather crooked bole. Bark reddish. Young part densely hairy, glabrescent. **Leaf-scars** clasping about 10-20 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina chartaceous, oblong-

elliptic, 20-45 x 10-25 cm, rounded to truncate at apex, acute or cuneate at base, margin entire to undulate-dentate, later vein 25-50 on either side, ending in apex of teeth in margin; upper surface glabrescent; lower surface hirsute on midrib. **Petioles** 3-10 cm, glabrous above, rather densely hair on below. **Inflorescence** solitary or sometime 2 together on same branch, terminal or axillary, with bracts 3-6 at base broad attached pedicel; bracts lanceolate, 1.5-5 by 0.5-1.5 cm, obtuse to acute at apex, broad attached pedicel at base, margin ciliate, densely hirsute on both sides; flowering slightly before and with new leaves. **Flowers** 10-17 cm across; pedicel 2-10 cm, densely hirsute, without or with 1-2 bracteoles; bracteoles similar to bracts at base of pedicel. **Sepals** 5; free, ovate 20-30 x 15-20 cm; 2 outermost, densely hirsute at apical part, further glabrous, ciliate at margin; 3 innermost, glabrous insides, densely hirsute outside except glabrous margin, ciliate at margin. **Petals** 5, free, yellow, obovate, 3-8 x 3-5 cm, rounded at apex, narrowed toward base, glabrous. **Stamens** in 2 distinct group: outer group 100-180, curved, 7-15 mm long, filament 2-5 mm long; inner group 30-60, reflexed at apex, 10-25 mm long, filament 9-15 mm long; anther thecae linear, opening with pore near apex, basifixed. **Carpels** 10-14, ovate, glabrous or densely hirsute, each carpel with 20-30 ovules; style recurved, 10-20 mm long, flattened. **Fruit** indehiscent, globular, 2-4 cm diam. enclosed by the persistent sepals. **Seeds** obovate, dark brown, without aril.

Thailand.— Northern: Chiang Mai, Mae Hong Son; North-Eastern: Kalasin, Loei, Maha Sarakham, Nong Khai; Eastern: Chaiyaphum, Nakhon Ratchasima, Roi Et, Ubon Ratchathani.

Distribution.— N. India (Type locality), Southeast Asia, Burma, Thailand.

Ecology.— In deciduous forest, dry dipterocarp forest and hill evergreen forests (250-1300 m).

Vernacular.— Pang Dao (ปังดาว) (Lawa-Chiang Mai); Ma San (มะส้าน) (Loei, Nakhon Ratchasima); Ma San Luang (มะส้านหลวง) (Chiang Mai); Ma San Hing (มะส้านหิ่ง) (Chiang Mai) San (ส้าน) (General); San Wae (ส้านแว้) (Chiang Mai).

Material studied.— *Pooma, R; Phattarahirankanok, K; Sirimongkol, S; Poopath, M* 4950 (BKF); *Phengklai c. et al.* 13660 (BKF); *เต็ม ประเสิญ* s.n. (BKF); *T. Smitinand* 3310 (BKF); *เชิญ พิจวิเศษ* 53/2474 (BKF); *T. Santisuk* 231 (BKF); *J. F. Maxwell* 98-388

(BKF); *T. Santisuk* 961 (BKF); *Siriporn Kopaohon* 25 (BKF); *Siriporn Kopaohon* 25 (BKF); *T. Santisuk* 234 (BKF); *J.F. Maxwell* 88-77 (BKF); *T. Santisuk* 229 (BKF); *J. F. Maxwell* 94-564 (BKF); *C. Maknoi & P. Srisanga* 2154 (BKF); *T. Santisuk* 232 (BKF); *Sakol Sulthusorn* 2325 (BK); *J.F. Maxwell* 72-127 (BK); *J.F. Maxwell* 98-388 (CMU); *J.F. Maxwell* 94-664 (CMU); *C. Maknoi* 1351 (QBG); *Kanchana & Pattaraporn* 3 (QBG); *C. Maknoi & P. Srisanga* 2154 (QBG); *W. Nanakorn et al.* 9085 (QBG); *W. Boonprakop* 0205; *P. Wessumritt* 118 (QBG); *C. Glamwaewwong* 939 (QBG); *S. Rakarcha* 60 (Mahasarakham University Herbarium).

2. Dillenia excelsa (Jack) Gilg in Pflanzenfam. 3. 6:123. 1893; Hoogl. in Fl. Mal. I. 4: 169. 1951; Blumea 7:86. 1952.; Hoogl. in Fl. Thailand 2(2):101. 1972. — *Wormia excelsa* Jack, Mal. Misc. 2 (7):69. 1922; Corn., Gdns' Bull. Straits Settl. 10:5. 1939; Wayside Trees Malaya: 206. 1940. Type: Sumatra, *de Voogd* 503 (neotype L!, BO). — *Wormia oblonga* Wall. [Cat. No. 951. 1829, nom. nud.] ex Hook. f. & Thoms., Fl. Ind. 1:67. 1855; in Hook. f., Fl. Br. Ind. 1: 35. 1872; Ridi., Fl. Mal. Pen. 1:9. 1922; Craib, Fl. Siam. En. 1: 21. 1925. Type specimens: *Wallich* 9518 (lectotype K). — *Dillenia magnoliifolia* Martelli Malesia 3:155. 1886. — *Dillenia glabra* Martelli, Malesia 3: 157. 1886. — *Dillenia tomentella* Martelli, Malesia 3:159. 1886. — *Dillenia mattadensis* Martelli, Malesia 3:160. 1886. — *Dillenia oblonga* (Wall. ex Hook.f. & Thomson) Martelli, Malesia 3:163. 1887. — *Dillenia pauciflora* (Zoll. & Moritzi) Gilg, Nat. Pflanzenfam. 3(6):123. 1893. — *Dillenia secunda* Hunter ex Ridl., J. Straits Branch Roy. Asiat. Soc. 53:98. 1909.

Evergreen tree up to 30 m high, with usually rather slender bole, without buttress or with small buttress; young part glabrous to sparsely hirsute or densely hirsute, glabrescent. Bark grey to brown, scurfy with reddish scales. **Leaf-scars** clasping about 10-15 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina coriaceous, elliptic to oblong, 10-30 x 5-10 cm, rounded to acute, sometimes slightly acuminate at apex, acute at base, margin undulate or dentate; later vein 10-15 on either side, ending in apex of teeth in margin or otherwise in margin; upper surface glabrous, glossy; lower surface glabrous or sparsely hirsute on nerves. **Petioles** 2-5 cm long, glabrous above. **Inflorescences** terminal branchlets, about 4-10

flowered of simple or composed racemes, ca. 15 cm long, with caducous bract; bracts oblong-triangular, 10-15 x 2-5 mm, axis glabrous to slightly hirsute. **Flower** 7-10 cm across; pedicels 2-10 cm long, glabrous to slightly hirsute, without bracteoles. **Sepals** 5, free, often reddish, ovate to elliptic, 20-25 x 10-55 mm, rounded at apex, narrowed towards base, 2 outermost slightly smaller than 3 innermost, glabrous insides, glabrous to rather densely tomentose outside, not ciliate at margin. **Petals** 5, free, yellow, obovate, 4-5 x 2-4 cm, membranaceous, glabrous, rounded at apex, narrowed towards base. **Stamen** in 2 distinct group; outer group 300-350, curved, 10-15 mm long, filament 2-10 mm long, yellow, flattened; inner group 20-40, reflexed outward at apex part, 16-20 mm long, filament 5-12 mm long, yellow, flattened; anther reddish to purplish, thecae linear, opening with pore near apex, basifixed. **Carpels** 5-10, lanceolate, 10-20 mm long, glabrous, each carpel with 20-30 ovules; style recurved, spreading, pink, 15-20 mm long. **Fruit** dehiscent, globular, 5-10 cm diam. enclosed by the persistent sepals. **Seeds** obovate, glabrous, dark brown, with red aril.

Thailand.— Peninsular: Nakhon Si Thammarat, Narathiwat, Pattani, Satun, Songkhla, Trang.

Distribution.— Malay Peninsular, Sumatra (Type locality), W. Java, Borneo.

Ecology.— In rain forest at low atitudes, undulate swampy lowland or nearby water resources.

Vernacular.— Si Po Yae Kae (ซีโปแยแกะ) (Malay-Narathiwat); San Dam (ส้านดำ) (Peninsular); San Tit (ส้านติด) (Narathiwat); Saen (แส้น) (Songkhla).

Material studied.— *T. Shimizu, N. Fukuoka & A. Nalampooh* 18174 (BKF); *C. Phengklai & N. Fukuoka* 10004 (BKF); *C. Niyomdham et al.* 1168 (BKF); *C. Niyomdnam, P. Phudjaa & S. Cbukunjana* 5926 (BKF); *C. Niyomdnam, P. Phudjaa & S. Cbukunjana* 5926 (BKF); *S. Gardner & P. Sidisunthorn* s.n. (BKF); *C. Niyomdham et al.* 1168 (BKF); *Th. Wongprasert* 9912-59 (BKF); *T. Suntisuk* 11937 (BKF); *A.F.G. Kerr* 7133 (BK); *Rabil* 173 (BK); *N. muipao* 09 (PSU); *Chodchai Khogkhao* 5 (PSU); *J.F. Maxwell* 86-602 (PSU); *J.F. Maxwell* 86-634 (PSU); *S. Gardner & P. Sidisunthorn* ST0611a (QBG); *P. Sidisunthorn* ST1616 (QBG); *S. Rakarcha* 83 (Mahasarakham university).

3. Dillenia grandifolia Wall. [Cat. no. 946. 1829, nom. nud.] ex Hooker. f. & Thoms., Fl. Ind. 1:71. 1855; in Hook. f., Fl. Br. Ind. 1:38. 1872; Ridl., Fl. Mal. Pen. 1:11. 1922; Craib, Fl. Siam. En. 1:22. 1925; Corn., Wayside Trees Malaya, 2.3. 1940; Hoogl., in Fl. Mal. I.4:174. 1951; Blumea 7:134, 1952; Kochummen & Khitmore; Gdns. Bull., Singapore 24:3. 1969. Hoogl., in Fl. Thailand 2(2):100. 1972. Type specimen: Convalescent Hill, Penang, *Wallich* 946 (holotype K!, isotypes CAL, CGE, P!).

Deciduous tree up to 40 m high, with usually rather slender bole, with conspicuous steep buttress, Branches sympodial, young part densely hairy, glabrescent. Bark brown. **Leaf-scars** clasping about 10-15 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina chartaceous, elliptic or obovate, 10-30 x 8-16 cm, rounded to obtuse at apex, obtuse to rounded or cordate at base, margin entire to undulate-dentate; later vein 15-30 on either side, ending in apex of teeth in margin; upper surface sparsely tomentose-hirsute on intervenium, densely hirsute on nerves and midrib, more or less glabrescent; lower surface densely hirsute on intervenium, midrib and nerves. **Petioles** 5-10 cm long, densely hirsute below. **Inflorescences** terminal, 5-10 flowered composed raceme, forming a loose cluster, densely shortly tomentose; bracts caducous, triangular, up to 7-10 X 4-7 mm. **Flower** 6-12 cm across. **Pedicels** 2-5 cm long, densely tomentose, without bracteoles. **Sepals** 5, free, whitish green, ovate, 18-30 x 15-24 mm, rounded at apex, narrowed towards base, glabrous insides except densely hirsute margin, densely hirsute outside, ciliate at margin. **Petals** (not found petal in specimen). **Stamen** not in 2 conspicuous rings, 400-450, curved, 10-15 mm long, filament 4-12 mm long, flattened, the size gradually increasing towards the center; anther thecae linear, opening with pore near apex, basifixed. **Carpels** 9-10, lanceolate, 6-10 cm long, densely hirsute in apical part or glabrous, each carpel with 40-70 ovules; style recurved, spreading, 5-6 mm long. **Fruit** indehiscent, globular, 3-8 cm diam enclosed by the persistent sepals. **Seeds** ovate, glabrous, glossy black, with aril.

Thailand.— Peninsular: Phatthalung, Songkhla, Trang.

Distribution.— Sumatra, Malay Peninsular, Singapore, Borneo.

Ecology.— Lowland forest (up to 500 m).

Vernacular.— San (ส้าน) (General)**.**

Material studied.— *C.Niyomdham & W. Ueachirakan* 1807 (BKF); *C. Niyomdham et al.* 1167 (BKF); *K. Larsen, S.S. Larsen, C. Niyomdham, W. Ueachirakan & P. Sirirugsa* 42461 (BKF); *P. Sidisunthorn* ST1616 (BKF, QBG); *S. Gardner & P. Sidisunthorn* ST0582 (QBG); *S. Rakarcha* 90 (Mahasarakham University Herbarium).

Note: Type specimens of *Dillenia grandifolia* is based on leaves only, which were taken from a sapling or young-tree and may belong either to *D. ovata* or to *D. reticulata*. After I Checked carefully and found that *D. grandifolia* was nomenclated from the specimens in *Wall.* 946, are very imperfect (holotype in K!, isotypes in CAL, CGE, P!). Type specimens were collected from Penang, Malaysia Peninsular in August 1822. In currently, The Plant list refers to specimens of *D. ovata*. In Flora of Malaysiana ser.1 vol.4 and A revision of the genus *Dillenia* by Hoogland (1951, 1952) refer to *D. reticulata*. In 1972, Hoogland will have to be renamed *D. grandifolia* Wall. ex Hook.f. & Thorns in Flora of Thailand. The identity of the species can only be ascertained by comparison with specimens of which the identity by means of dditional characters (flowers, normal leaves) is certain. In study of *D. grandifolia* and *D. reticulata* may be as a single species because holotype of *D. grandifolia* very similar to holotype of *D. reticulata*. The reason showed in conclusion and discussion as below.

4. Dillenia hookeri Pierre, FI. For. Cochinch. 1: t. 5. 1880; Fin. & Gagnep., Bull. Soc. Bot. Fr. Mem. 4:9. 1906; in Fl. Gen. I.-C. 1:20. 1907; Craib, in Fl. Siam. En. 1:22. 1925; Gagnep., in Fl. Gen. I.-C. Suppl. 1:21. 1938; Hoog. in Fl. Mal. I. 4:168. 1951; Blumea 7:85. 1952; Dansk bot. Ark. 20:185. 1962.; Hoogl., in Fl. Thailand 2(2):102. 1972. Type specimen: Cambodia, *Pierre* 663 (Isotype K!).

Evergreen tree or shrubs 1-2 m high, young part densely hairy, glabrescent. Bark reddish or brown. **Leaf-scars** clasping about 10-20 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina chartaceous, oblong to oblanceolate, 10-30 x 5-15 cm, acute or obtuse, sometime slightly rounded or slightly acuminate at apex, rounded to acute at base, decurrent; margin serrate; later vein 30-40 on either side, ending in apex of teeth in margin or otherwise in margin; upper surface densely tomentose. most densely on nerves, glabrescent; lower surface not glabrescent. **Petioles** 1-4 cm long, densely sericeous. **Flower** solitary, sometime 2 together,

terminal, 4-5 cm across. **Pedicels** 1-4 cm long, densely sericeous, with 3 bracteoles; bracteoles persistent, lanceolate, 2-5 x 0.5-1 mm, acute or truncate at apex, densely hairy on both sides, ciliate at margin. **Sepals** 5, free, green, ovate to elliptic, 5-15 x 10-15 mm, rounded at apex, narrowed towards base, glabrous inside, densely sericeous outside, ciliate at margin. **Petals** 5, free, yellow, obovate, 1-3 x 0.5-2 cm, membranaceous, glabrous, rounded at apex, narrowed towards base. **Stamen** 200-250, slightly curved, 8-10 mm long; filament 3-5 mm long, flattened; anther thecae linear, opening with pore near apex, basifixed. **Carpels** 6-7, oblong, 2-5 cm long, glabrous, each carpel with 10-20 ovules; style recurved, spreading, 10-15 mm long, cylindrical. **Fruit** indehiscent, globular, 2-5 cm diam. enclosed by the persistent sepals. **Seeds** obovate, glabrous, without aril, dark brown or black.

Thailand.— Northern: Phitsanulok; North-Eastern: Loei, Nong Khai, Nakhon Phanom; Eastern: Nakhon Rachasima, Si Sa Krt, Surin, Ubon Ratchathani; South-Western: Kanchanaburi; South-Eastern: Chanthaburi, Trat; Penisular: Satun, Songkhla, Surat Thani.

Distribution.— Indo-China (Type locality), Thailand, Malay Peninsula.

Ecology. — Open area, Dry deciduous forest, dry dipterocarp forests or evergreen forest, commonly found on flatland thickets (up to 300 m).

Vernacular.— Ka Plao (กะเปล่า) (Mon-Kanchanaburi); Kong Thi (โก้งที่) (Karen-Kanchanaburi); Phlu Sa Bat (พลูสะบาด) (Khmer-Surin); San Din (ส้านดิน) (Central); San Tao (ส้านเต่า) (Surat Thani); San Tia (ส้านเตี้ย) (Prachin Buri, Trat); San Thung (ส้านทุ่ง) (Surat Thani); San Noi (ส้านน้อย) (Phitsanulok); San Bat (ส้านบาด) (Nakhon Ratchasima).

Material studied.— *A.S. Barfod & T. Burholt* 43847 (BKF); *K. Larsen, T. Smitinand & E. Warck* 1443 (BKF); *Winit* 316 (BKF); *R. Pooma, N. Koonkunthod, P. Chantaboon* 3256 (BKF); *C. Niyomdham, T. Jonganurak, N. Hemrath & J. Rithipheth* 1595 (BKF); *T. Boojaras* 26 (BKF); *K. & S.S. larsen, Christian tange, Robbin Moran, T. Niyomdham &P. Puudjaa* 54833 (BKF); *K. Laesen* 10025 (BKF); *R. Pooma* 1600 (BKF); *C. Phengklai et al.* 3576 (BKF); *A. Mauric* s.n. (BKF); *T. smitinand* s.n. (BKF); *J.F. Maxwell* 84-111 (BKF); *T*- 2904 (BKF); *D.P. Hurburt* 2 (BKF); *K. larsen, Supee S. Larsen, L. Nielsen & T. smitinand* 32124 (BKF); *Sakol Suthusorn* 3212 (BK); *A. F. G. Kerr* s.n. (BK); *Y. Paisooksantivatana & P. Sangkhachand* 2100-87 (BK); *M.G.*

Lakshnakara 912 (BK); *Peaclit* 689 (BK); *Sakol* 138 (BK); *Sakol* 317 (BK); *A. F. G. Kerr* 13695 (BK); *Yingyong Paisooksantivatan & Sakol Sutheesorn* 975-82 (BK); *Yingyong Paisooksantivatan* 1500-84 (BK); *W* 13077 (BK); *J.F. Maxwell* 01-207 (CMU); *J.F. Maxwell* 98-98 (CMU); *J.F. Maxwell* 07-495 (CMU); *C. Phengklai et al.*. 3576 (PSU); *P. Pattarakulpisutti and K. Sridith* 357-2 (PSU); *L. taing, V.B. Truong, Lal, J. wai, S. Kitichate* 2 (PSU); *K. Maneenoon* 7 (PSU); *J.F. Maxwell* 84-111 (PSU); *Supatra* 10 (PSU); *Ampai Tongseedam* 30 (PSU); *K. Kertsawang* 484 (QBG); *M. Norsaengsri* 4926 (QBG); *C. Maknoi* 5875 (QBG); *P. Wessumritt & S. Sawangsawat* 106 (QBG); *S. Watthana & W. La-ongsri* 3981 (QBG); *M. Norsaengsri* 4527 (QBG); *N. Turreira Garcia* 87 (QBG); *N. Turreira-Garcia* 381PR (QBG); *W. Nanakorn et al.*. 7588 (QBG); *S. Rakarcha* 12 (Mahasarakham University Herbarium).

5. Dillenia indica L., Sp. Pl.: 535. 1753; Hook. f. & Thoms. in Hook. f., Fl. Br. Ind. 1:36. 1872; Kurz, Fl. Burm. 1:19. 1877; Fin. & Gagnep., Bull. Soc. Bot. Fr. Mem. 4: 9. 1906; in Fl. Gen. I.-C. 1:21. 1907; Ridl., Fl. Mal. Pen. 1:10. 1922; Craib, Fl. Siam. En. 1:22. 1925; Hoogl. in Fl. Mal. I. 4:171. 1951; Blumea 7:108. 1952.; Wadhwa. in Fl. Ceylon 10:110. 1996.; Hoogl., in Fl. Thailand 2(2):101. 1972. Type: India, as for *Dillenia indica* L. — *D. speciosa* Thunb., Trans. L. Soc. Lond. 1:200. 1791; Sm., Exot. Bot. 1:3. T. 2, 3. 1804; Hook. f., Curtis's bot. Mag. 83: t. 5016. 1857. — *Dillenia elongata* Miq., Fl. Ned. Ind. 1(2):12. 1858.

Evergreen tree up to 30 m high, with usually rather crooked bole, without buttress or with small buttress, young part densely hairy, glabrescent. Bark smooth, orange brown to dark orange, peeling off in small, thin scales. **Leaf-scars** clasping about 10-20 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina chartaceous, oblong, 10-40 x 5-15 cm, acute or obtuse, sometime slightly acuminate at apex, rounded to acute at base, decurrent; margin serrate; later vein 20-70 on either side, ending in apex of teeth in margin; upper surface glabrous on intervenium and nerves, sparsely hirsute on midrib; lower surface glabrous to sparsely strigose on intervenium, sparsely to rather densely strigose on nerves and midrib. **Petioles** 4-10 cm long, glabrous above, hirsute below. **Flower** solitary, terminal, 15-20 cm across. **Pedicels** 4-10 cm long, hairy, sometimes with single bracteole; bracteole caducous,

linear-lanceolate, 2-8 x 1-5 mm, glabrous above, densely hirsute below, ciliate at margin. **Sepals** 5, free, 2 outermost, 3 innermost, yellowish green, ovate to elliptic, 40-60 x 30-50 mm, rounded at apex, narrowed towards base, glabrous on both sides, not ciliate at margin, **Petals** 5, free, white with green veins, obovate, 7-9 x 5-7 cm, membranaceous, glabrous, rounded or obtuse at apex, narrowed towards base. **Stamen** in 2 distinct group; outer group 400-500, curved, 10-15 mm long, filament 5-10 mm long, flattened; inner group 20-25, reflexed outward at apex part, 20-30 mm long, filament 10-15 mm long; anther thecae linear, opening with pore near apex, basifixed. **Carpels** 10-20, ovate, 1-2 cm long, glabrous each carpel with 40-100 ovules; style recurved, spreading, 20-25 mm long, flattened, acute at apex. **Fruit** indehiscent, globular, 5-15 cm diam. enclosed by the persistent sepals. **Seeds** reniform, glabrous, without aril, dark brown or black.

Thailand.— Northern: Chiang Mai, Chiang Rai, Mae Hong Son, Sukhothai, Tak; North-Eastern: Loei, Phetchabun; Central: Pathum Thani; South-Westren: Kanchanaburi; Peninsular: Nakhon Si Thammarat, Phangnga, Surat Thani, Trang.

Distribution.— India (Type locality), Ceylon, Burma, S. China, Indo-china, Sumatra, Malay Peninsula, Indonesia, Thailand.

Ecology.— Evergreen forest or tropical rain forest, commonly found nearby river, also sometime planted in gardens (up to 1100 m).

Vernacular.— Ma Tat (มะตาด) (Central); Som Pru (ส้มปรุ) (Surat Thani); San Kwang (ส้านกว้าง) (Surat Thani); San Tha (ส้านท่า) (Surat Thani); San Pao (ส้านป้าว) (Chiang Mai); San Yai (ส้านใหญ่) (Surat Thani); Saen (แส้น) (Nakhon Si Thammarat, Trang).

Material studied.— *P. Puudjaa* 315 (BKF); *K. larsen, Supee S. Larsen, L. Nielsen & T. smitinand* 30918 (BKF); *J.F. Maxwell* 89-152 (BKF); *K. larsen* 8658 (BKF); R. Pooma 287 (BKF); *T. Santisuk* 1193 (BKF); *T. Santisuk et al.* 413 (BKF); *K. larsen, T. Santisuk & E. Warncke* 3057 (BKF); *V. Chamchumroon* 2154 (BKF); *T. Smitinand* 10528 (BKF); *C. Phengklai, T. Smitinand & C. Phengklai* 6087 (BKF); *D.J. Middleton, S. Sudee & C. Hemrat* 1600 (BKF); *J.F. maxwell* 71-478 (BK); *J.F. maxwell* 75-853 (BK); *Yingyong P. & Pranai* 1329-83 (BK); *J.F. Maxwell* 95-488 (CMU); *S. Chongko & A. Boonkongchart* 391 (CMU); *David J. Middleton, S. Sudee & C. Hemrat* 1600 (CMU); *J.F. Maxwell* 94-713 (CMU); *Twat* 16 (PSU); *V. Chamchumroon* 2154 (PSU);

Hatthaya s.n. (PSU); *W. Ramari* 90 (PSU); *C. Maknoi, N. Muangyen, P. Yadee, P. Ngaosumart* L8-263 (QBG); *C. Maknoi* 7121 (QBG); *M. Norsaengsri* 11540 (QBG); *W. Nanakorn et al.*. 28909 (QBG); *W. Pongamornkul* 04129 (QBG); *M. Norsaengsri & N. Tathana* 9020 (QBG); *M. Norsaengsri & N. Tathana* 9792 (QBG); *N. Turreira-Garcia* 411 (QBG); *C. Lakoet* 0392 (QBG); *Nobuyuki Tanaka, Hidetoshi Nagamasu, Akiyo Naiki, Sachiko Hishida, Prachaya Srisanga and Santi Watthana* HN8450 (QBG); *W. Nanakorn et al.* 261 (QBG); *C. Maknoi* 3377 (QBG); *C. Maknoi* 7940 (QBG); *C. Glamwaewwong* 108/58 (QBG); *C. Maknoi* 8100 (QBG); *S. Rakarcha* 92 (Mahasarakham University Herbarium).

6. Dillenia obovata (Blume) Hoogland, in Fl. Mal. I.4: 173. f. 13. 1951; Blumea 7: 130. 1952. in Fl. Thailand 2(2):99. 1972. — *Colbertia obovata* Blume, Bijdr. 1:6. 1825. Type specimens: Java, *Blume* 1519 (holotype L!). — *Wormia obovata* (Blume) Sprang., Syst. 4, Our. Post., 1827, 213. — *D. ornata* Wall., Pl. As. Rar. 1:21. t. 23. 1830; Parkins., Indian Forester 61:451. t. 28. F. 1. 1935. Type specimen: *Wallich* 947 (holotype K). — *D. aurea* auct. Non Sm.: Hook. f. & Thoms. in Hook. f., Fl Br. Ind. 1: 37 p.p. 1872; Fin. & Gagnep., Bull. Soc. bot. Fr. Mem. 4:9. 1906; in Fl. Gen. I.-C. 1: 21. 1907; Ridl., Fl. Mal. Pen. 1:11. 1922; Craib, Fl. Siam. En. 1:21. 1925. — *Dillenia aurea* var. blumei Pierre, Fl. Forest. Cochinch. t. 12. 1880. — *Dillenia aurea* var. *harmandii* Pierre, Fl. Forest. Cochinch. t. 12. 1880. — *Dillenia aurea* var. *kurzii* Pierre, Fl. Forest. Cochinch. t. 12. 1880. — *Dillenia harmandii* Gagnep., Notul. Syst. (Paris) 6:39. 1937.

Deciduous trees up to 30 m, with usually rather crooked bole, without buttress or with small buttress; young part glabrous, smooth; flowering slightly before and with new leaves. **Leaf-scars** clasping about 10-20 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina chartaceous, obovate, 20-50 x 10-25 cm, rounded at apex, acute at base, margin entire to slightly dentate, later vein 30-50 on either side, ending in apex of teeth in margin; upper surface glabrescent; lower surface midrib and veinlets hirsute. **Petioles** 1-5 cm, rather glabrous above, rather densely hair on below. **Flowers** solitary or sometime 2 together on same branch, terminal or axillary, bracts 3-6 at base broad attached pedicel; bracts lanceolate, 1.5-5 x 0.5-1 cm, acute at

apex, base broad attached pedicel, margin ciliate, densely hirsute on both sides except glabrous in basal part above. **Flowers** 14-16 cm across. **Pedicel** 2-5 cm, slightly hirsute, without or with 3 bracteoles; bracteoles like bracts at base pedicel. **Sepals** 5, free, ovate, 30-40 x 20-30 mm; 2 outermost, densely hirsute at apical part, further glabrous, ciliate at margin; 3 innermost, glabrous inside, densely hirsute outside, ciliate at margin. **Petals** 5, free, yellow, obovate, 6-8 x 3-6 cm, rounded at apex, narrowed toward base, glabrous. **Stamens** in 2 distinct group: outer group 200-250, curved, 10-13 mm long, filament 3-8 mm long; inner group 30-60, reflexed at apex, 20-25 mm long, filament 10-15 mm long; anther thecae linear, opening with pore near apex, basifixed. **Carpels** 10-14, lanceolate, glabrous, each carpel with 20-40 ovules; style recurved, 10-20 mm long, flattened. **Fruit** indehiscent, globular, 2-4 cm diam. enclosed by the persistent sepals. **Seeds** ovate, dark brown or reddish, without aril.

Thailand.— South-Eastern: Chanthaburi, Chon Buri, Trat; South-Western: Kanchanaburi, Prachuap Khiri Khan; Peninsular: Chumphon, Narathiwat, Pattani, Phangnga, Phuket, Ranong, Satun, Songkhla, Surat Thani, Trang.

Distribution.— Lower Burma, Indo-China, Northern part of the Malay Peninsula, S. Sumatra and W. Java (Type locality).

Ecology.— Open lowland forest, deciduous or evergreen (up to 300 m).

Vernacular.— Cha Wing (ชะวิง) (Chong-Chanthaburi); Si Po Don Poe Sa (ซีโปดอนเปอซา) (Malay-Narathiwat); San (ส้าน) (Peninsular); San Khaeng (ส้านแข็ง) (Chiang Mai); San Tong (ส้านต้อง) (Peninsular); San Yai (ส้านใหญ่) (Surat Thani).

Material studied.— *S. Gardner, S. Sidisunthorn & P. Tippayasri* ST1546 (BKF); *S. Gardner* ST0382 (BKF); *Siam* 867 (BKF); *C.F. van Beusekom, T. Santisuk Sirimongkol, S.; Chamchumroon V.; Strijk J.S. & M. Poopath* 616 (BKF); *C. Phengklai et al.* 14214 (BKF); *C. Phengklai et al.* 14214 (BKF); *J.F. Maxwell* 85-349 (BKF); *E.C. Abbe, T. Smitinand & B. Rollet* 9667 (BKF); *Phengklai C. et al.* 13335 (BKF); *C. Phengklai et al.* 13335 (BKF); *C. Phengklai et al.* 14935 (BKF); *R. Gessink & T. Santisuk* 4953 (BKF); *J.F. Maxwell* 87-340 (BKF); *K. & S.S. Larsen* 33467 (BKF); *Phengklai C. et al.* 13737 (BKF); *J.F. Maxwell* 85-241 (BKF); *J.F. Maxwell* 85-241 (BKF); *C. Phengklai et al.* 1167 (BKF); *T. Santisuk* 840 (BKF); *M.* 1184 (BKF); *A.F.G. Kerr* 6929 (BK); *A.F.G. Kerr* 16529 (BK); *A.F.G. Kerr* 10499 (BK); *A.F.G. Kerr* 13625

(BK); *Nr* 374 (BK); *Nvacharee* 632 (BK); *A.F.G. Kerr* 14020 (BK); *A.F.G. kerr* 19352 (BK); *M.O. Lakshnakara* 650 (BK); *Sakol Sutheesorn* 3665 (BK); *A.F.G. kerr* 13811 (BK); *A.F.G. Kerr* 14798 (BK); *A.F.G. Kerr* 11440 (BK); L. 6 (BK); *C. Niyomdnam & P. Puudjaa* 4227 (BK); *C. Niyomdnam & P. Puudjaa* 4227 (BK); *C. Phengkhlai* 1290 (BK); *L.B.&E.C. Abbe, Tem Smitinand, B. Rollet* 9667 (BK); *Phengklai C. et al.* 13335 (BK); *Phengklai C. et al.* 13335 (BK); *C. Phengklai et al.* 14935 (BK); *R. Gessink & T. Santisuk* 4953 (BK); *J.F. Maxwell* 87-340 (BK); *K. & S.S. Larsen* 33467 (BK); *C. Phengklai et al.* 13737 (BK); *J.F. Maxwell* 85-241 (BK*); J.F. Maxwell* 85-241 (BK); *C. Phengklai et al.* 1167 (BK); *T. Santisuk* 840 (BK); *M.* 1184 (BK); *C. Niyomdnam & P. Puudjaa* 4227 (BK); *C. Niyomdnam & P. Puudjaa* 4227 (BK); *C. Phengkhlai* 1290 (BK); *J.F.Maxwell* 06-185 (CMU); *HLC* 313 (PSU); *J.F. Maxwell* 85-241 (PSU); *J.F. Maxwell* 87-340 (PSU); *J.F. Maxwell* 85-349 (PSU), *J.F. Maxwell* 06-185 (QBG); *S. Gardner & P. Sidisunthorn* ST0001 (QBG); *S. Gardner* ST0382 (QBG); *S. Gardner, S. Sidisunthorn& P. Tippayasri* ST1546 (QBG); *BGO Staff* 13 (QBG); *S. Rakarcha* 89 (Mahasarakham University Harbarium).

7. Dillenia ovata Wall. [Cat. no. 945. 1829, nom. nud.] ex Hook. f. & Thoms., Fl. Ind. 1:70. 1855; in Hook. f., Fl. Br. Ind. 1:36. 1872; Pierre, Fl. For. Cochinch. 1: t. 10. 1879; Fin. & Gagnep., Bull. Soc. Bot. Fr. Mem. 4:10. 1906; in Fl. Gen. I.-C. 1:22. 1907; Ridl., Fl. Mal. Pen. 1: 11. 1922; Craid, Fl. Siam. En. 1: 23. 1925; Gagnep. in Fl. Gen. I.-C. Suppl. 1:23. 1938; Hoogl. in Fl. Mal. I. 4:170. 1951; Blumea. 7:105. 1952; Dansk bot. Ark. 20:185. 1962.; Hoogl. in Fl. Thailand 2(2):99. 1972. Type specimen: Penang, Malaysia, *Wallich* 945 (holotype K!). — *D. aurea* auct. Non Sm.: J. Schmidt, Bot. Tidsskr. 32:334. 1916. — *D. meliosmifolia* auct. Non Hook. f. & Thoms.: Craib, Fl. Siam. En. 1: 23. 1925.

Evergreen tree up to 30 m high, with usually rather slender bole, with small buttress, young part densely hairy, glabrescent. Bark reddish or brown, peeling off in small, flaky scales. **Leaf-scars** clasping about 10-20 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina chartaceous, ovate or elliptic, 10-30 x 5-15 cm, acute or obtuse, sometime slightly acute to obtuse at apex, acute at base, margin entire to obscurely dentate; later vein 15-30 on either side, ending in apex of

teeth in margin; upper surface sparsely hirsute on intervenium, densely hirsute on midrib; lower surface densely hirsute on midrib and nerves. **Petioles** 2-5 cm long, densely hirsute. **Flower** solitary, terminal, 10-25 cm across; pedicels 2-5 cm long, densely hirsute, with 1-2 bracteole; bracteole caducous, linear-lanceolate, 5-10 x 2-5 mm, densely hirsute, ciliate at margin. **Sepals** 5, free, 2 outermost, 3 innermost, whitish green, ovate, 25-30 x 15-25 mm, rounded at apex, narrowed towards base, glabrous insides, densely hirsute outside, ciliate at margin. **Petals** 5, free, yellow, obovate, 5-10 x 5-7 cm, membranaceous, glabrous, rounded at apex, narrowed towards base. **Stamen** in 2 distinct group; outer group 450-500, curved, 15-20 mm long, filament 5-12 mm long, flattened; inner group 20-30, reflexed outward at apex part, 20-30 mm long, filament 10-15 mm long; anther thecae linear, opening with pore near apex, basifixed. **Carpels** 6-10, lanceolate, 6-10 cm long, glabrous each carpel with 40-100 ovules; style recurved, spreading, 20-25 mm long, flattened. **Fruit** indehiscent, globular, 5-15 cm diam. enclosed by the persistent sepals. **Seeds** obovate, glabrous, dark brown or black, without aril.

Thailand.— Northern: Chiang Mai, Mae Hong Son, Phitsanulok; North-Eastern: Loei, Nakhon Phanom, Phetchabun, Sakon Nakhon; Eastern: Nakhon Ratchasima, Surin, Ubon Rachathani; Central: Nakhon Nayok, Pathum Thani; South-Eastern: Chon Buri, Chachoengsao, Chanthaburi, Prachin Buri, Rayong, Trat; South-Westren: Phetchaburi; Peninsular: Chumphon, Phatthalung, Satun, Surat Thani, Trang.

Distribution.— Indo-china, Sumatra, Malay Peninsula, Thailand.

Ecology.— Dry deciduous forest, evergreen forest, commonly found on flatland thickets (up to 1200 m).

Vernacular.— Khai Nao Dong (ไข่เน่าดง) (Loei); Ta Nok Kot (ตานกกด) (Loei); Plo (ปล้อ) (Suai-Surin); Ma Ton (มะโตน) (Chon Buri); San Kwang (ส้านกวาง) (Peninsular); San Doi De (ส้านโดยเด) (Nakhon Phanom); San Bai Lek (ส้านใบเล็ก) (Pattani); Saen (แส้น) (Trang).

Material studied.— *Charan Boonnad* 309 (BKF); *Phengklai C. et al.* 11230 (BKF); *T. Boonjaras* 230 (BKF); *J.F. Maxwell* 74-139 (BKF); *T. Santisuk* 238 (BKF); *S. Phusomsaeng* 36500 (BKF); *Choung* 15 (BKF); *C. Niomdham* 47 (BKF); *M. Ramsri* 22 (BKF); *Gen Murata, Nobuyuki Fukuoka & Chamlong Phengklai* T-17584 (BKF); *Pooma R.; Phattarhirankanok, K. Sirimongkol, S.* 4719 (BKF); *Phengklai C. et al.*

15758 (BKF); *Newman, M.F.; Thomas, P., Armstrong, K. E.; Sengdala, K.& Lamxay, V.* LAO1132 (BKF); *S. Gardner & S. Setsin* s.n. (BKF); *Phengklai C. et al.* 13432 (BKF); *W. McClatchey, P. Mokkamul & C. Hobbs* WCM3570 (BKF); *T. Santisuk* 239 (BKF); *Phengklai C. et al.* 359 (BKF); *S. Gardner & P. Sidisunthorn* ST0352 (BKF); *W. Mclatchey, P. Mokkamul & C.Hobbs* WCM3570 (BKF); *Suen Suksakorn* 935 (BKF); *Chaulag* 1146 (BKF); *B. Sangkhachand, B. Nimanong* 1286 (BKF); *P. Chantaranothai, J. Parnell; D. Middleton & D. Simpson* 1077 (BKF); *D.J. Collins* 858 (BK); *D.J. Collins* 812 (BK); *L* 5803 (BK); *A.F.G. Kerr* 20081 (BK); *L* 8272 (BK); *L* 5869 (BK); *A.F.G. Kerr* 9519 (BK); *J.F. Maxwell* 75-338 (BK); *Sakol* 3055 (BK); *Prayad* 466 (BK); *Prayad* 188 (BK); *J.F. Maxwell* 70-151 (BK); *J.F. Maxwell* 72-150 (BK); *Rabil* 22 (BK); *M.C. Lakshnakara* 1377 (BK); *Put* 649 (BK); *A.F.G. Kerr* 15330 (BK); *L* 8847 (BK); *Meng Monyrak, Khou Eanghourt et al.* 745 (CMU); *J.F. Maxwell* 98-417 (CMU); *Chhang Phourin* Pl05 (CMU); *W. Ramsri* 22 (PSU); *Romklao Botanical Garden* 0240/2554 (QBG); *C. Maknoi* 5865 (QBG); *S. Gardner & P. Sidisunthorn* ST0352 (QBG); *W. Nanakorn et al.*. 3769 (QBG); *C. Maknoi* 3140 (QBG); *M. Pinyosak & P. Wessumritt* 122 (QBG); *W. Nanakorn et al.* 6045 (QBG); *M. Tanaros* 527 (QBG); *W. Nanakorn et al.* 6311 (QBG); *C. Maknoi* 1446 (QBG); *S. Gardner & S. Setsin* ST0622 (QBG); *W. Nanakorn et al.* 8803 (QBG); *C. Maknoi* 230 (QBG); *C. Maknoi* 7828 (QBG); *P. Wessumritt* 215 (QBG); *K. Kertsawang* 170 (QBG); *W. Pongamornkul* 04213 (QBG); *C. Maknoi* 6759 (QBG); *S. Rakarcha* 11 (Mahasarakham University Herbarium).

8. Dillenia parviflora Griff., Not. Pl. AS. 4:704. 1854; Hook. f. & Thoms. in Hook. f., Fl. Br. Ind. 1:38. 1875; Kurz, Fl. Burm. 1:21. 1877; Hoogl., Blumea 7:125. 1952; Hoogl. in Fl. Thailand 2(2):98. 1972. Type specimens: Mergui, Burma, *Griffith* 50 (holotype K!). — *D. kerrii* Craib, Bull. Misc. Inf. R. bot. Gdns Kew 8. 1911; Fl. Siam. En 1:23. 1952. Type specimens: Thailand, Kerr 1040 (holotype K!, isotype BM). — *D. elata* autc. Non Pierre: Craib, Fl. Siam. En. 1:22. 1925. — *Dillenia parviflora* var. *kerrii* (Craib) Hoogl., Blumea 7:126. 1952.

Deciduous tree up to 30 m high, more less densely hirsute, glabrescent. **Leaf-scars** clasping about 10-20 leaf traces form terminal, subfalcate, flowering with or

before new leaves. **Leaves** simple, spirally arranged; lamina chartaceous, obovata to elliptic-oblong, 10-30 x 8-20 cm, glabrescent above; rounded to obtuse at apex; acute at base; margin dentate; later vein 20-35 on either side, ending in apex of teeth in margin, veinlets rather straight to slightly curving upward; lamina slightly scabrid, hirsute on both surface. **Petioles** 1-5 cm long, densely hirsute. **Inflorescence** fascicled, comprising 4-8 flowers together with several caducous bract on reduced branchlets along the branch; bracts up to 10-15 x 4-7 mm, densely hirsute on both sides. **Flower** 4-10 cm across. Pedicels 5-40 mm long, densely hirsute, without or with 1 or 2 bracteoles; bracteoles caducous, linear-lanceolate, 2-10 x 1-5 mm, densely hirsute. **Sepals** 5, free, green, ovate, 10-20 x 5-10 mm; obtuse to rounded at apex, narrowed towards base, inside glabrous except shortly hirsute part at apex; outside densely sericeously hirsute, ciliate at margin. **Petals** 5, free, yellow, obovate to oblong, 20-30 x 10-15 mm, membranaceous, glabrous, rounded at apex, narrowed towards base. **Stamen** in 2 distinct group; outer group 120-200, curved, 5-10 mm long, filament 1-5 mm long, flattened; inner group 10-15, reflexed outward at apex part, 12-20 mm long, filament 5-10 mm long, flattened; Anther thecae linear, opening with longitudinal lateral slits, basifixed. **Carpels** 5-10, ovate to lanceolate, 1-2 cm long, glabrous each carpel with ca. 20 ovules; style recurved, 5-15 mm long, flattened. **Fruit** indehiscent, globular, 10-20 mm diam. enclosed by the persistent sepals. **Seeds** obovate, without aril, dark brown.

Thailand.— Northern: Chiang Mai, Lampang, Nan, Phrae; North-Eastern: Loie; South-western: Kanchanaburi.

Distribution.— Thailand**,** Myanmar**.**

Ecology.— In deciduous forest, dry dipterocarp forest, hill evergreen forest (250-1100 m).

Vernacular.— Khwong Pa Du (ควองปะดุ) (Karen-Kanchanaburi); Ma San Khwaeng (มะส้านแคว้ง) (Chiang Mai); Ma San Hin (มะส้านหิง) (Chiang Mai); Lawe (ละเว) (Central); San Cha (ส้านจา) (Lampang); San Hing (ส้านหิ่ง) (Loei); San Hin (ส้านหิน) (Lampang).

Material studied.— *C. Niyomdham* 47 (BKF); *J.F. Maxwell* 94-186 (BKF); *T. Smitinand et al.* 10222 (BKF); *J.F. Maxwell* 89-296 (BKF); *T. Santisuk* 224 (BKF); *Phengklai C. et al.* 6961 (BKF); *T. Smitinand* 8699 (BKF); *C. Niyomdham & R. Phuma*

4969 (BKF); *Winit* 1958 (BKF); *Pooma R; Pattharahirantricin N; Sirimongkol, S; Saelao F* 7656 (BKF); *J.F. Maxwell* 98-356 (BKF); *J.F. Maxwell* 94-310 (BKF); *R. Pooma* 803 (BKF); *J.F. Maxwell* 89-342 (BKF); *J.F. Maxwell* 96-358 (BKF); *J.F. Maxwell* 93-610 (BKF); *J.F. Maxwell* 88-792 (BKF); *J.F. Maxwell* 89-404 (BKF); *T. Smitinand* 8899 (BK); *Nr* 264 (BK); *T. Smitinand* 10222 (BK); *A.F.G. Kerr* 5235 (BK); *A.F.G. Kerr* 10493 (BK); *J.F. Maxwell* 98-340 (BK); *Drawit Jittamma* 267 (CMU); *J.F. Maxwell* 96-358 (CMU); *S. Gardner* 1021 (CMU); *Siriporn Kopachon* 23 (CMU); *J.F. Maxwell* 93-322 (CMU); *J.F. Maxwell* 06-290 (CMU); *J.F. Maxwell* 97-335 (CMU); *J.F. Maxwell* 96-330 (CMU); *J.F. Maxwell* 94-310 (CMU); *J.F.Maxwell* 98-340 (CMU); *J.F. Maxwell* 98-356 (CMU); *P. Sidisunthorn & S. Gardner* 2650 (CMU); *J.F. Maxwell* 94-186 (CMU); *J.F. Maxwell* 94-345 (CMU); *Pranee Palee* 1259 (CMU); *Sawat Sanitjan* 59 (CMU); *J.F. Maxwell* 00-259 (CMU); *Pavlos Georgiadis* 476 (CMU); *Pavlos Georgiadis* 568 (CMU); *Pavlos Georgiadis* 533 (CMU); *J.F. Maxwell* 06-290 (QBG); *P. Srisanga, S. Watthana & W. La-ongsri* 841 (QBG); *W. Nanakorn* 434 (QBG); *C. Glamwaewwong* 1366 (QBG); *BGO. Staff* 6082 (QBG); *S. Rakarcha* 71 (Mahasarakham University Herbarium).

9. Dillenia pentagyna Roxb., PI. Corom. 1:21. t. 20. 1795; Hook. f. & Thoms. in Hook. f., FI. Br. Ind. 1:38. 1872; Kurz, Fl. Burm. 1:21. 1877; Pierre, Fl. For. Cochinch. 1: t. 6-8. 1879; Fin. & Gagnep., Bull. Soc. Bot. Fr. Mem. 4:8. 1906; in Fl. Gen. I.-C. I: 19. 1907; Hoogl. in Fl. Mal. I. 4: 172. f. 12 (map). 1951; Blumea 7:117. 1952; Dansk bot. Ark. 20:185. 1962.; Hoogl. in Fl. Thailand 2(2):97. 1972. Type specimen: Coromandel, *Roxburgh* s.n. (holotype BM). — *Colbertia coromandelina* DC., Syst. Nat. 1:435. 1817. — *Colbertia floribunda* Wall., Numer. List 1:950. 1829. — *Colbertia augusta* Wall. ex G.Don, Gen. Hist. 1:77. 1831. — *Dillenia augusta* Roxb. Fl. Ind. 2:652. 1832. — *Dillenia floribunda* Hook.f. & Thomson, Fl. Ind. 1:71. 1855. — *D. baillonii* Pierre in Laness., Pl. Util. Col. Frang.: 281, 702. 1886; Fin. & Gagnep., Bull. Soc. bot. Fr. Mem. 4: 8. 1906: in Fl. Gen. I.-C. 1:19. 1907; Craib, Fl. Siam. En. 1:22. 1925; Gagnep. in Fl. Gen. I.-C. Suppl. 1:21. 1938. Type specimen: Samrongtong, Cambodia, *Pierre* 661 (lectotype P!; isotypes A, K). — *Dillenia minor* (Zoll. & Moritzi) Gilg, Nat. Pflanzenfam. 3(6a):125. 1893. — *Dillenia hainanensis* Merr., Lingnan Sci. J. 13:64. 1934.

Deciduous tree up to 30 m high, with usually rather crooked bole, branch glabrous. Bark smooth, greyish, peeling off in thin scales. **Leaf-scars** clasping about 10-20 leaf traces from terminal, subfacate, flowering with or before new leaves. **Leaves** simple, spirally arranged; lamina chartaceous, oblong to obovate-oblong, 20-60 x 10-30 cm, glabrescent above; obtuse, rounded or acute, decurrent at base; obtuse to acute at apex; margin dentate; later vein 20-50 on either side, ending in apex of teeth in margin, veinlets rather straight to slightly curving upward; upper surface glabrescent; lower surface hirsute on nerves and midrib, less densely on intervenium. **Petioles** 1-5 cm long, glabrous above, hirsute below, slightly winged with non-amplexicaul wings, wings narrowed towards near base of blade. **Inflorescence** fascicled, comprising 2-8 flowers together with several caducous bract on reduced branchlets along the branch; bracts up to 5-15 x 5-10 mm, densely hirsute on both sides. **Flower** 2-10 cm across. Pedicels 5-60 mm long, glabrous, without bracteoles. **Sepals** 5, free, green, ovate, 10-20 x 5-10 mm, obtuse to rounded at apex, narrowed towards base, glabrous on both sides, ciliate at margin. **Petals** 5, free, yellow, obovate to oblong, 10-30 x 5-15 mm, membranaceous, glabrous, rounded at apex, narrowed towards base. **Stamen** in 2 distinct group; outer group 50-150, curved, 3-8 mm long, filament 1-5 mm long, flattened; inner group 8-15, reflexed outward at apex part, 5-15 mm long, filament 3-10 mm long; anther thecae linear, opening with longitudinal lateral slits, basifixed. **Carpels** 5-8, ovate to lanceolate, 1-2 cm long, glabrous each carpel with ca. 20 ovules; style recurved, spreading, cylindric, 5-10 mm long, flattened. **Fruit** indehiscent, globular, 10-20 mm diam, enclosed by the persistent sepals. **Seeds** obovate, without aril, dark brown or black.

Thailand.— Northern: Chiang Mai, Chiang Rai, Lampang, Mae Hong Son, Phayao, Phisanulok, Sukhothai, Tak; North-Eastern: Loei, Nakhon Phanom, Phetchabun; South-Eastern: Chantha Buri, Prachin Buri; South-Westren: Kanchanaburi.

Distribution.— India (Type locality), Burma, Andaman Island, China (Yunnan, Hainan), Indo-China, Southeast Asia.

Ecology.— In deciduous forests and dry dipterocarp forests, hill evergreen forest (up to 1100 m).

Vernacular.— Phaeng (แพ่ง) (Loei, Nakhon Phanom); Ma San Khaeng (มะส้านแข็ง) (Central); San Chang (ส้านช้าง) (Central); San Nok Plao (ส้านนกเปล้า) (Northern);San Na (ส้านนา) (Central, Northern); San Wae (ส้านแว้) (Northern).

Material studied.— *P. Chantaranothai, J. parnell, D. Middleton & D. Simpson* 1008 (BKF); *Winit* 1640 (BKF); *J.F. Maxwell* 96-491 *C.F. Van Beusekom, T. Santisuk* 2840 (BKF); *J.F. Maxwell* 03-123 (BKF); *T. Santisuk* 236 *J.F. Maxwell* 8353 (BKF); *Cp, BN, SS* 3122 (BKF); *K. Larsen, T. Santisuk & E. Warncke* 2259 (BKF); *B. Nimanong, S. Phusomsaeng C. Phengklai* 1792 (BKF); *J.F. Maxwell* 93-588 (BKF); *J. F. Maxwell* 89-298 (BKF); *A. Phenphaibunsathien* s.n. (BKF); *T. Santisuk* 233 (BKF); *R. Greesink, D. Phanichapol & T. Santisuk* 5812 (BKF); *C.C.* 309 (BKF); *J.F. Maxwell* 75-112 (BK); *J.F. Maxwell* 75-27 (BK); *J.F. Maxwell* 75-127 (BK); *Nr.* 88 (BK); *Nr* 505 (BK); *Winit* 1640 (BK); *Vacharapong* 334 (BK); *A.F.G. Kerr* 20039 (BK); *L.* 8746 (BK); *A.F.G. Kerr* 10556 (BK); *J.F. Maxwell* 98-470 (CMU); *J.F. Maxwell* 98-1021 (CMU); *Meng Monyrak, Khou Eanghourt et al.* 750 (CMU); *J.F. Maxwell* 93-610 (CMU); *J.F. Maxwell* 03-123 (CMU); *J.F. Maxwell* 07-301 (CMU); *J.F. Maxwell* 07-72 (CMU); *Pavlos Georgiadis* 475 (CMU); *J.F. Maxwell* 93-588 (CMU); *J.F. maxwell* 96-491 (CMU); *B. nimanong and S. phusomsaeng* 1072 (PSU); *C. Glamwaewwong* 1364 (QBG); *Romklao Botanical Garden* 0237/2554 (QBG); *S. Watthana* 1730 (QBG); *W. Pongamornkul* 1858 (QBG); *BGO. Staff* 8891 (QBG); *S. Rakarcha* 37 (Mahasarakham University Herbarium).

10. Dillenia philippinensis Rolff, J. L. Soc. Bot. 21:107, 1884; Vidal, Rev. PI. Vase. filip 37. 1886; Merr., Fl. Manila. 331. 1912; Wester, Philip., Agric. Rev. 8:104. 1915; Hoogl., Fl. Mal. I. 4: 164. 1951; Blumea 7:62. 1952. Type specimen: panay island, *Vidal* 4 (holotype K!, isotypes Fl, L). — *Dillenia catmon* Elmer, Leafl. Philipp. Bot. 7:2610. 1915. — *Dillenia philippinensis* var. *pubifolia* Merr., Enum. Philipp. Fl. Pl. 3:61. 1923.

Evergreen tree up to 15 m high; young part glabrous to sparsely hirsute or densely hirsute, glabrescent. Bark reddish brown, peeling off in thin irregular plates. **Leaf-scars** clasping about 7-10 leaf traces from terminal, subfacate. **Leaves** simple,

spirally arranged; lamina chartaceous, elliptic or ovate, 10-20 x 5-15 cm, rounded to obtuse, sometimes slightly acuminate at apex, rounded to obtuse at base, margin undulate or dentate; later vein 10-15 on either side, ending in apex of teeth in margin or otherwise in margin; upper surface glabrous or sparsely hirsute on midrib; lower surface dull, glabrous or sparsely hirsute on intervenium, sparsely hirsute on nerves and midrib. **Petioles** 2-5 cm long, glabrous above, glabrous to hirsute below, with amplexicaul wings; wings elliptic, caducous, 2-5 mm across, rounded apex, entire margin, glabrous or shortly hirsute. **Inflorescences** terminal branchlets, about 1-2 flowered of racemes, ca. 15 cm long, without bract, axis glabrous to slightly hirsute. **Flower** 10-15 cm across; pedicels 0.5-5 cm long, glabrous to slightly hirsute, without bracteoles or with small bracteoles; bracteoles 8-10 x 4-5 mm, acute apex, slightly hirsute. **Sepals** 5, free, ovate to elliptic, 15-25 x 10-20 mm, 2 outermost slightly smaller than 3 innermost, often reddish, rounded at apex, narrowed towards base, glabrous insides, glabrous to rather densely hirsute outside, ciliate at margin. **Petals** 5, free, white, obovate, 4-10 x 2-5 cm, membranaceous, glabrous, rounded at apex, narrowed towards base. **Stamen** in 2 distinct group; outer group 200-300, yellowish white, curved, 10-15 mm long, filament 5-10 mm long, flattened; inner group 20-40, reflexed outward at apex part, purplish, 16-25 mm long, filament 8-12 mm long, flattened; Anther reddish to purplish, thecae linear, opening with pore, basifixed. **Carpels** 10-12, lanceolate, 10-12 mm long, glabrous, each carpel with 10-15 ovules; style recurved, spreading, purplish, 15-20 mm long. **Fruit** dehiscent, globular, 5-10 cm diam. enclosed by the persistent sepals. **Seeds** obovate, glabrous, black, with aril.

Thailand.— Cultivation in all part of Thailand.

Distribution.— Philippines.

Ecology.— Common in forests at low and medium altitudes, found planted in gardens (up to 500 m).

Vernacular.— San Dok Khao (ส้านดอกขาว) (Bangkok), San Jawa (ส้านชวา) (General).

Material studied.— *S. Rakarcha* 94 (Mahasarakham University Herbarium).

11. Dillenia pulchella (Jack) Gilg, in Engl. & Prantl, Nat. Pfl. Fam. 3 (6):123. 1893; Merr., Bibl. En. Born. PL: 383. 1921; Beyno, Nutt. PI. Indon., 1072. 1950; Hoogl., Fl. Mal. I 4:171. 1951. Hoogl., in Fl. Thailand 2(2): 96. 1972. — *Wormia pulchella* Jack,

Mal. Misc. 2 (7):70. 1822; Hook.f. & Thoms., in Fl. Ind. 1:68. 1855; Miq., in Fl. Ind. Bat. 1(2):11. 1559; Hook. f. & Thoms. in Fl. Br. Ind. 1:36. 1872; King, J. As. Soc. Bong. 58(2):365. 1889; Ridl., J. Str. Br. R. A. S. 33:37. 1900; Gage & Burk., J. Str. Br. It. A. S. 73:243. 1916; Ridl., Fl. Mal. Pen. 1:9. 1922; Burk., Diet. Econ. Prod. Mal. Pen., 2265. 1935; Corn., Wayside Trees Malaya: 206. 1940. Type specimen: Natal, Sumatra, *Jack* (probably lost); Singapore, *Ridley* 3965 (holotype L!, isotypes BM, MEL, SING!). — *Dillenia parvifolia* Martclli in Boec., Malesia 3:158. 1886; Merr., Bibl. En. Bom. PI., 383. 1921. Type specimen: Sarawak, *Beccari* PB 3177 (lectotype Fl, isotype K). — *Dillenia micrantha* Martclli in Boec., Malesia 3:156. 1887; Merr., Bibl. En. Born. PI., 383. 1921. Type specimen: Sarawak, *Beccari* PB514 (holotype Fl).

Evergreen tree up to 40 m high, without buttress; young part glabrous. Bark reddish. Leaf-scars clasping about 5-10 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina coriaceous, elliptic to obovate, 5-15 x 3-10 cm, rounded to obtuse at apex, acute at base, margin entire; later vein 4-8 on either side, ending about 1 mm from margin; upper surface glabrous, glossy; lower surface dull, glabrous below. **Petioles** 1-4 cm long, glabrous. **Inflorescences** axillary, solitary or 2 (-3), occasionally terminal raceme about 4-6 flowered. Sparsely to densely pubescent. **Flower** 3-5 cm across; pedicels 2-10 cm long, glabrous to slightly hirsute, without bracteoles or with 1-2 small bracteoles. **Sepals** 5, free, one outermost slightly smaller than 4 innermost, often reddish, ovate to elliptic, 5-15 x 7-10 mm, rounded at apex, narrowed towards base; glabrous insides; glabrous to rather sparsely tomentose outside; ciliate at margin. **Petals** 5, free, yellow, oblong, 4-5 x 2-4 cm, membranaceous, glabrous, rounded at apex, narrowed towards base. **Stamen** in 2 distinct group; outer group 100-120, curved, 4-8 mm long, filament 2-4 mm long, yellow, flattened; inner group 10-15, reflexed outward at apex part, 10-15 mm long, filament 5-8 mm long, flattened; anther thecae linear, with lateral longitudinal slits. **Carpels** 5 (-6), lanceolate to oblong, 5-7 mm long, glabrous, each carpel with 7-10 ovules; style recurved, spreading, pink, 5-10 mm long. **Fruit** dehiscent, globular, 2-8 cm diam, enclosed by the persistent sepals. **Seeds** obovate, glabrous, dark brown, with red aril.

Thailand.— Peninsular: Narathiwat.

Distribution.— Malay Peninsular, Sumatra, Borneo, Thailand Peninsular.

Ecology.— In rain forest at low atitudes (300 m).

Vernacular.— Se Po Pue La (ซีโปปือละ) (Malay-Narathiwat); San Nam (ส้านน้ำ) (Narathiwat)

Material studied.— *C. Niyomdham et al.* 1152 (BKF); *C. Niyomdham & W. Ueachirakan.* 1829 (BKF); *C. Niyomdham* 1171 (BKF); *C. Niyomdham* 840 (BKF); *Sakol* 1353 (BK).

12. Dillenia reticulata King, J. As. Soc. Beng. 58(2):367. 1889; Ridl., PI. Mal. Pen. 1:11. 1922; Craib, FI. Siam. En. 1:25. 1925; Burk., Diet. Econ. Prod. Mal. Pen., 810. 1935; Hoogl., Fl. Mal. 1(4):168. Fig. 11. 1951; in Fl. Thailand 2(2):96. 1972. Type Specimen: Dipong, *Scortechini* 1844 (holotype CAL, isotype K!). — *Wormia mollissima* Boerl., Cat. Hort. Bogor., 5. 1899., Lampong Distr., Sumatra, IV-G-23 (holotype BO, isotype BO, FI, L, US).

Deciduous tree up to 40 m high, with usually rather slender bole, with conspicuous steep buttress, commonly found with stilt root in swampy area, young part densely hairy, glabrescent. Bark brown. **Leaf-scars** clasping about 10-15 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged, chartaceous, elliptic or obovate, 10-30 x 10-20 cm, rounded to slightly emarginate at apex, obtuse to rounded or cordate at base, margin entire to undulate-dentate; later vein 20-35 on either side, ending in apex of teeth in margin; upper surface sparsely hirsute on intervenium, densely hirsute on midrib, more or less glabrescent; lower surface densely hirsute on intervenium, midrib and nerves. **Petioles** 5-10 cm long, densely hirsute below. **Inflorescences** terminal, 5-10 flowered composed raceme, forming a loose cluster, moderately to densely pubescent; bracts caducous, triangular, up to 5-10 x 3-6 mm. **Flower** 5-12 cm across; pedicels 2-5 cm long, densely tomentose, without bracteoles. **Sepals** 5, free, whitish green, ovate, 20-30 x 15-25 mm, rounded at apex, narrowed towards base, glabrous insides except densely hirsute margin, densely hirsute outside, ciliate at margin. **Petals** 5, free, yellow, obovate, 3-10 x 1-5 cm, membranaceous, glabrous, rounded at apex, narrowed towards base. **Stamen** 400-450, curved, 10-15 mm long, filament 8-10 mm long, flattened, the size gradually increasing towards the center; anther thecae linear, opening with pore, basifixed. **Carpels** 9-10, lanceolate, 6-10 cm

long, densely hirsute in apical part or glabrous, each carpel with 40-70 ovules; style recurved, spreading, 5-6 mm long. **Fruit** indehiscent, globular, 3-8 cm diam, enclosed by the persistent sepals. **Seeds** ovate, glabrous, glossy black, with aril.

Thailand.— Peninsular: Narathiwat, Sonkkhla, Trang.

Distribution.— Sumatra, Malay Peninsula, Borneo and Thailand Peninsular.

Ecology.— Lowland forest, on wet to rather dry soil (up to 500 m).

Vernacular.— San Malayu (ส้านมลายู) (General).

Material studied.— *C. Niyomdham* 456 (BKF); *Poopath, M.* 209 (BKF); *C. Niyomdham, P. Phudjaa, S. Chonkunjana* 6321 (BKF); *S.* 16655 (BKF); *S. Rakarcha* 91 (Mahasarakham University Herbarium).

13. Dillenia scabrella (D.Don) Roxb. ex Wall. Pl. Asiat. Rar. 1:20. 1830; Roxb., Fl. Ind. ed. Carey 2:653. 1832; Hook.f. & Thoms., Fl. Ind. 1:70. 1855; Drury, Handb. Ind. Fl. 1:10. 1864; Hook.f. & Thorns., Fl. Br. Ind. 1:38. 1872; Kurz, For. Fl. Br. Burma 1:21. 1877; Brandis, Ind. Forester 26:430. 1900; Fin. & Gagnep., Fl. Gen. Ind.-Ch. 1:18. 1907; Kanjilal, Kanjilal, & Das, Fl. Assam 1:11 1934. Hoogl., Blumea 7(1):123. 1952. Hoogl. in Fl. Thailand 2(2):96. 1972. — *Colbertia scabrella* D.Don, Prodr. Fl. Nepal. 226. 1825. Type specimens: India, *Wallich* 944 (holotype K!, isotype BM, BR, CAL, G, NY, P!). — *Wormia scabrella* (D. Don) Sprung., Syst. 4, Cur. Post., 213. 1827. — *Dillenia elata* Pierre, Fl. Forest. Cochinch. t. 9 1880. — *Dillenia pilosa* Roxb. ex Buch.-Ham, Trans. L. Soc. London 15:102. 1827.

Deciduous tree up to 20-25 m high, young part densely hairy, glabrescent. Bark smooth, greyish, red, or brown. **Leaf-scars** clasping about 10-20 leaf traces from terminal, subfacate, flowering with or before new leaves. **Leaves** simple, spirally arranged, chartaceous, obovate to oblong-elliptic, 20-30 x 10-15 cm, obtuse to acute at apex and base; margin dentate; later vein 35-45 on either side, ending in apex of teeth in margin, veinlets rather straight to slightly curving upward; upper surface glabrescent, often more or less scabrid; lower surface rather densely softly strigose-hirsute, mainly on midrib, nerves and veins, usually less scabrid. **Petioles** 1-5 cm long, glabrous above, hirsute below, slightly winged with non-amplexicaul wings. **Inflorescence** fascicled, comprising 5-8 flowers together with several caducous bract on reduced branchlets

along the branch; bracts up to 2-8 x 2-5 mm, densely hirsute. **Flower** 4.5-5 cm across. Pedicels 10-60 mm long, glabrous, with 1-3 bracteoles at the same or slightly different level near the middle; bracteoles caducous, linear-lanceolate, 2-10 x 1-5 mm, glabrous above, densely hirsute below, ciliate at margin. **Sepals** 5, free, reddish-green, ovate, 5-20 x 5-10 mm, obtuse to rounded at apex, narrowed towards base, glabrous on both sides, ciliate at margin. **Petals** 5, yellow, obovate, free, 10-25 x 5-15 mm, membranaceous, glabrous, rounded or obtuse at apex, narrowed towards base. **Stamen** in 2 distinct group; outer group 100-150, curved, 4-5 mm long, filament 1-2 mm long, flattened; inner group 10-20, reflexed outward at apex part, 10-15 mm long, filament 5-8 mm long; anther thecae linear, opening with longitudinal lateral slits, basifixed. **Carpels** 4-7, ovate -oblong, 1-2 cm long, glabrous each carpel with ca. 10 ovules; style recurved, spreading, 8-10 mm long, flattened. **Fruit** indehiscent, globular, 10-25 mm diam. enclosed by the persistent sepals. Seeds obovate, glabrous, without aril, dark brown or black.

Thailand.— Northern: Chiang Mai, Chiang Rai**,** Nan, Phisanulok; North-Eastern: Loei**.**

Distribution.— India (Bengal and Assam), Myanmar and Indo-china, Southeast Asia, possibly also Nepal.

Ecology.— In deciduous forests and dry dipterocarp forests, hill evergreen forest (800-1300 m).

Vernacular.— San (ส้าน) (Chiang Mai).

Material studied.— *BGO. Staff* 66 (QBG); *W. Nanakorn et al.* 8802 (QBG); *C. Maknoi* 2081 (QBG); *W. Nanakorn et al.* 8865 (QBG); *S. Rakarcha* 69 (Mahasarakham University Heraium).

14. Dillenia suffruticosa (Griff.) Martelli, in Becc., Malesia 3:163. 1886; Hoogl. in Fl. Mal. I. 4:162. f. 10. 1951; Blumea 7:70. 1952. Hoogl. in Fl. Thailand 2(2):101. 1972; B.M. Wadhwa. in Fl. Ceylon 10:112. 1996.— *Wormia suffruticosa* Griff., Not. Pl As. 4:706. 1854; Ic. Pl. As.: t. 649. 1854; Ridi., Fl. Mal. Pen. 1:8. 1922; Corn., Wayside Trees Malaya: 207. t. 53. 1940. Type specimen: Malacca, *Kew Distr*. 55 (holotype K!, isotypes C, FI, GH, K, L, M, NY, P!). — *Wormia burbidgei* Hook. f. in Curtis's bot. Mag. 106: t. 6531. 1880. Type specimen: Borneo, *Burbidge* s.n. (holotype K).

— *Dillenia burbidgei* (Hook.f.) Martelli, Malesia 3:163. 1887. — *Dillenia suffruticosa* var. *borneensis* (Ridl.) Ridl., Sarawak Mus. J. 1:71. 1913.

Large shrubs to appreciable height trees ca. 5 m, evergreen, branchlets terete, dark greyish brown, sparsely hairy to glabrous, glabrescent. **Leaf-scars** clasping about 15-20 leaf traces from terminal, subfacate. **Leaves** simple, spirally arranged; lamina coriaceous, ovate to elliptic, 10-40 x 5-25 cm, rounded to obtuse at apex, obtuse at base, decurrent; margin serrate; later vein 10-20 on either side, ending in apex of teeth in margin; glabrous, upper surface rarely slightly villose on intervenium in younger leaves; slightly to densely villose on nerves, on both sides along midrib, highly raised below. **Petioles** 2-10 cm long, glabrous, with amplexicaul wings; wings usually persistent. **Inflorescences** terminal branchlets, about 4-18 flowered of simple or composed racemes, ca. 20 cm long, with caducous bract; bracts triangular, 2-10 x 2-5 mm. **Flower** 5-15 cm across; pedicels 1-3 cm long, green, bearing scattered hairy to glabrous, without bracteoles. **Sepals** 5, free, ovate to oblanceolate, green with marginal pink, 15-35 x 8-15 mm, rounded at apex, narrowed towards base, glabrous inside, glabrous to rather densely hairy outside. **Petals** 5, free, yellow, obovate, 4-5 x 2-3 cm, membranaceous, glabrous, rounded or obtuse at apex, narrowed towards base. **Stamens** ca 200, outermost slightly curved, 8-10 mm long, filament 5-7 mm long; innermost with apical part reflexed outward, 10-15 mm long, filament 5-10 mm long; Anther thecae linear, opening with pore near apex, basifixed. **Carpels** ca 7, ovate to elliptic, 1-2 cm long, glabrous, each carpel with 7-10 ovules; style recurved, spreading, ca 10 mm long, flattened. **Fruit** dehiscent, globular to elliptic, ca 1-5 cm diam. enclosed by the persistent sepals. **Seeds** obovate, glabrous, dark brown or black, with aril.

Thailand.— Cultivation in Central and Peninsular**.**

Distribution.— Malay Peninsula, Native to Sumatra, Borneo, Indonesia; widely cultivated in tropical countries.

Ecology.— wasteland or in swampy area, also sometime planted in gardens (up to 500 m).

Vernacular.— San Chawa (ส้านชวา) (Bangkok); San Yawa (ส้านยะวา) (Bangkok).

Material studied.— *E.J.H. Corner* 32984 (BKF); *T. santisuk* 497 (BKF); *S. Gardner* ST0159 (BKF); *F. Fleury* 30126 (BKF); *PS.* 244 (PSU); *S. Gardner* ST0159 (QBG); *S. Rakarcha* 26 (Mahasarakham University Herbarium).

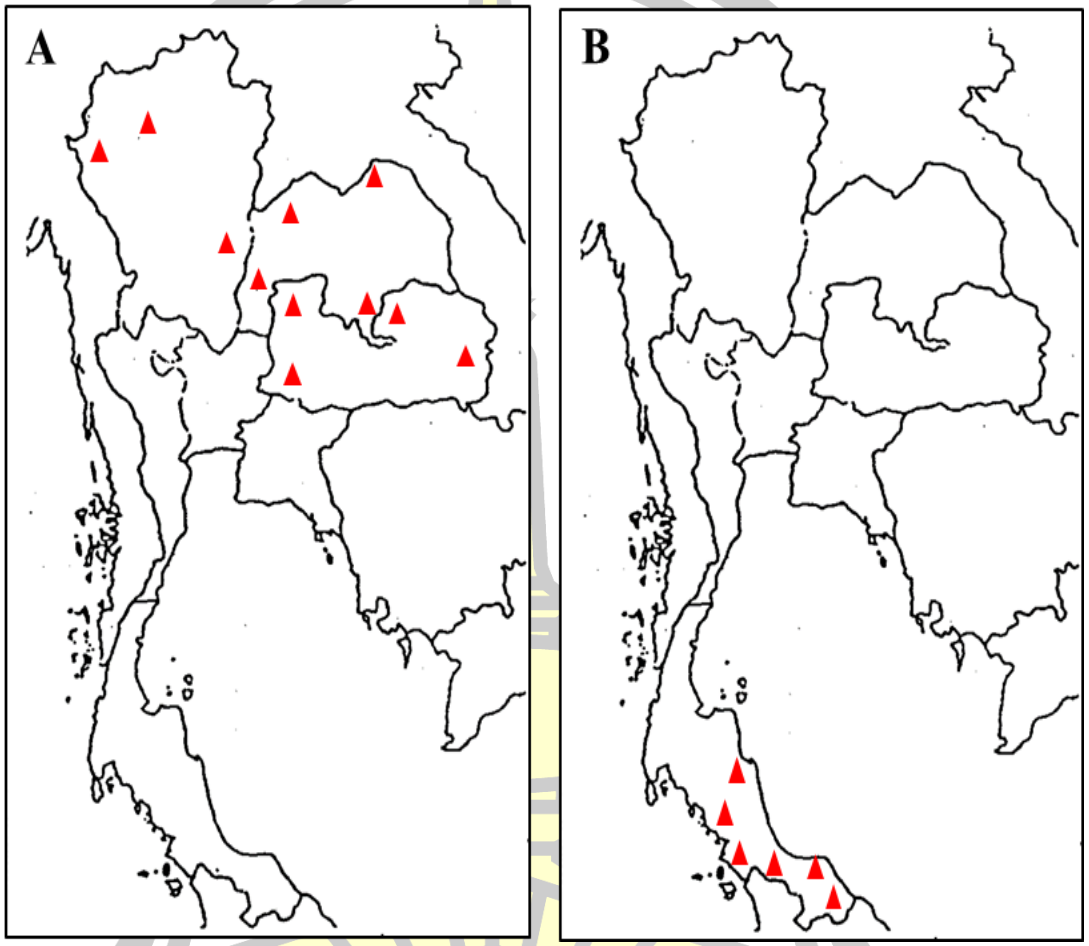


Figure 7 Distribution of genus *Dillenia* in Thailand.
(A) *D. aurea* and (B) *D. excelsa*.

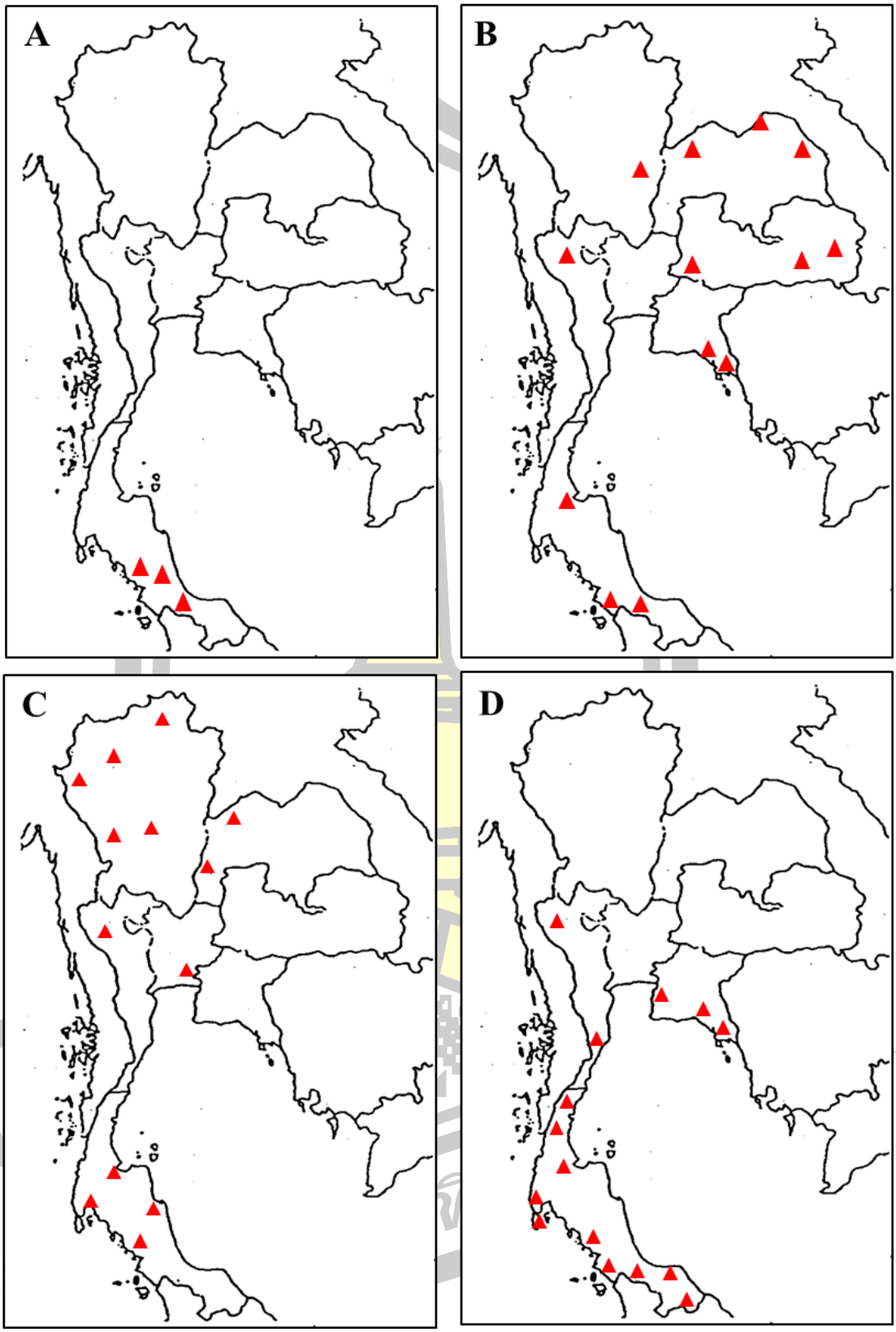


Figure 8 Distribution of genus *Dillenia* in Thailand.

(A) *D. grandifolia*, (B) *D. hookeri*, (C) *D. indica*, (D) *D. obovata*.

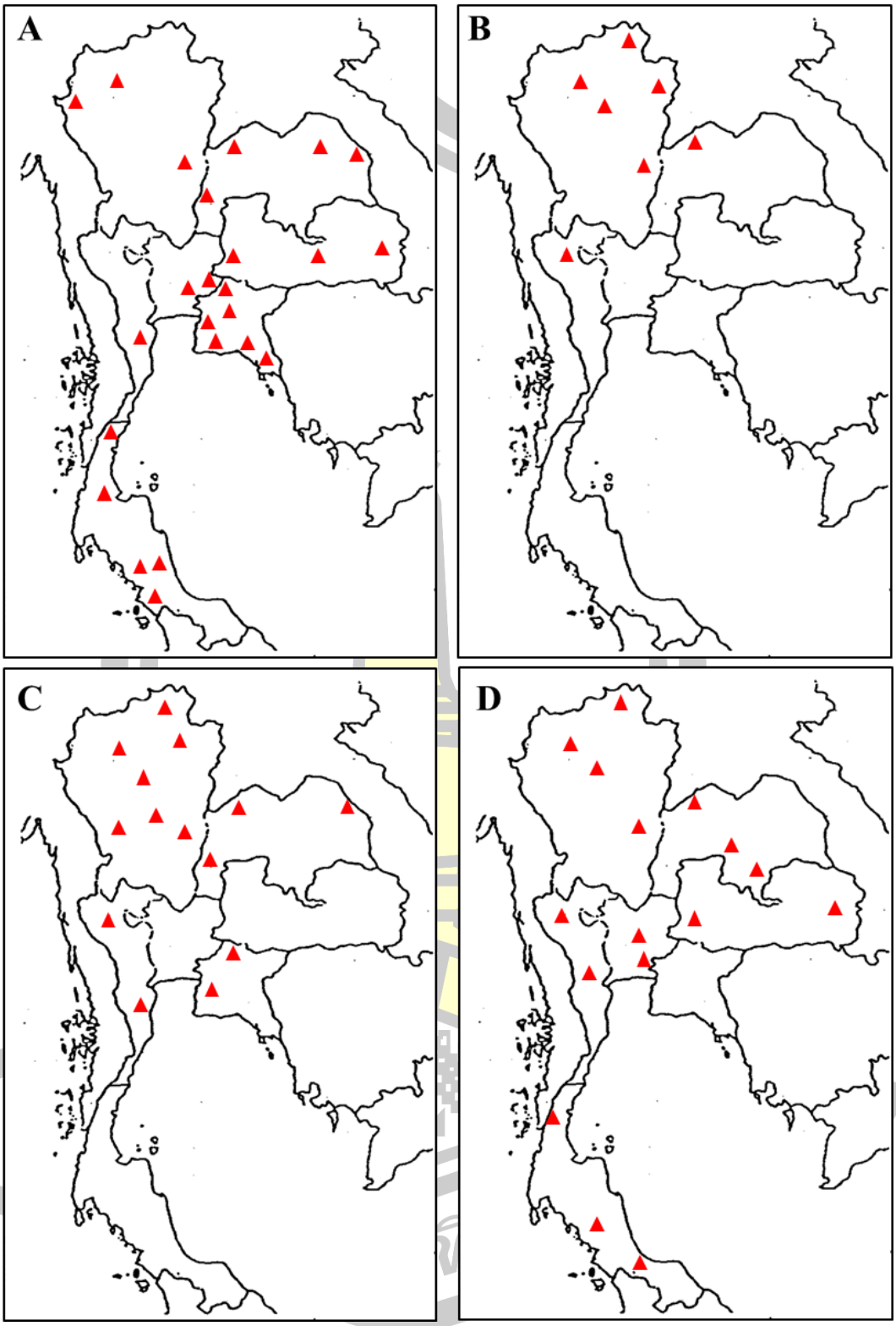


Figure 9 Distribution of genus *Dillenia* in Thailand.

(A) *D. ovata*, (B) *D. parviflora*, (C) *D. pentagyna*, (D) *D. philippinensis* (Cultivated plant in Thailand).

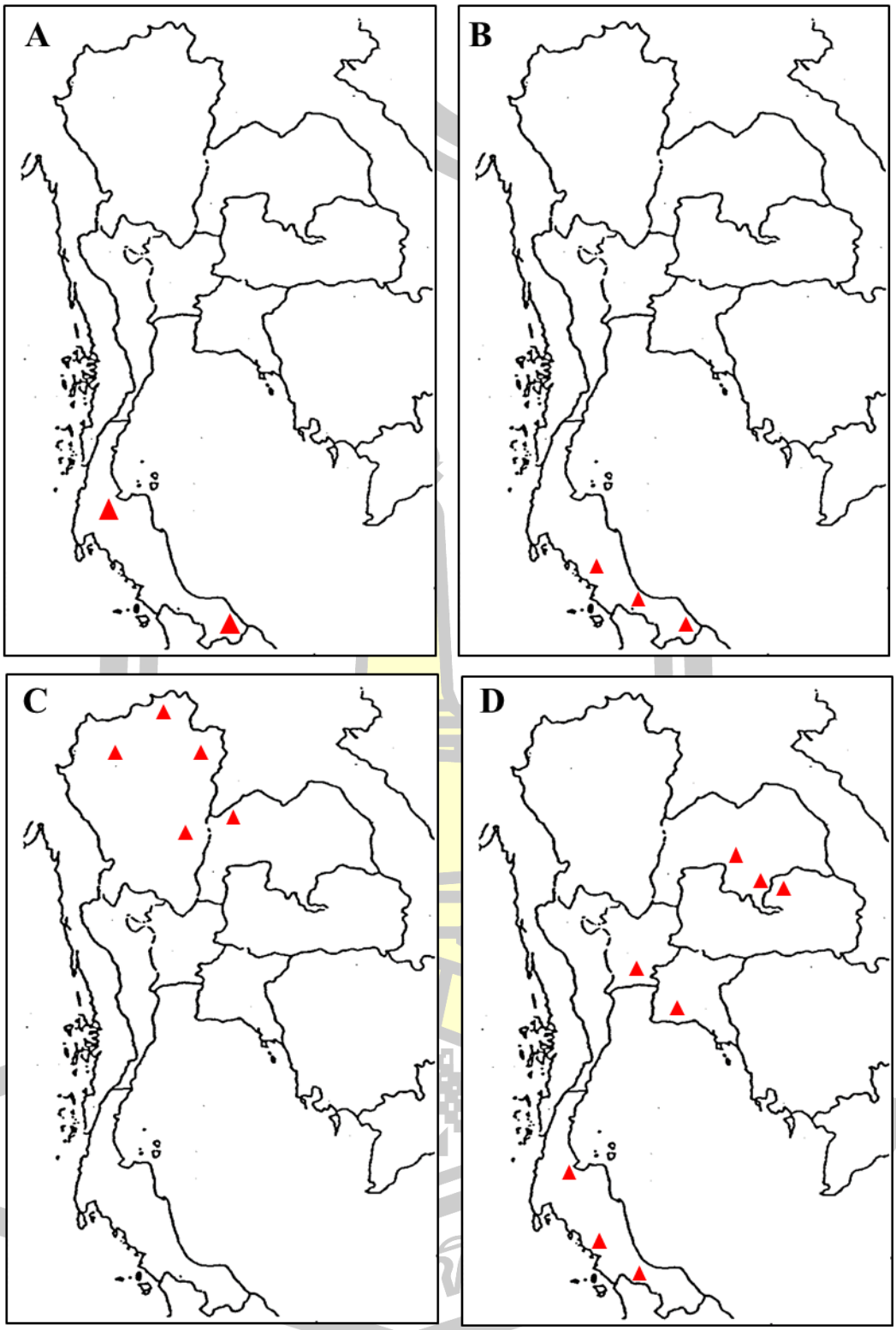


Figure 10 Distribution of genus *Dillenia* in Thailand.

(A) *D. puchella*, (B) *D. reticulata*, (C) *D. scabrella*, (D) *D. suffruticosa* (Cultivated plant in Thailand).

Acrotrema

Jack, Mal. Misc. 1(5):36. 1820; Hook. f. & Thoms. in Hook. f., Fl. Br. Ind. 1:32. 1872; Trim., Fl. Ceyl. 1:6. 1893. Hoogl. in Fl. Thailand 2(2):104. 1972; Wadhwa. in Fl. Ceylon 10:119. 1996. Type Species: *A. costatum* Jack.

Small perennial herbs with a horizontal woody rhizome; **Stem** short, erect, simple. **Leaves** all radical or on a short stem, spirally arranged, dentate margin, smaller teeth at margin, pinnately nerved. **Petiole** with broadly winged, membranous, caducous. **Inflorescences** racemose terminal, with membranaceous. **Flower** 5-nerous, yellow. **Sepals** 5, free. **Petals** 5, free, yellow, rounded or emarginate margin. **Stamen** 15-many, yellow; anther linear, opening with pore near apex, basifixed. **Carpels** usually 3, free, recurred styles, with 2-6 or 10-20 ovule. **Fruits** follicles or capsule enclosed by the persistent sepals. **Seeds** ovate, born with white aril.

Distribution: The genus is found about 10 species, two in India (southern Western Ghats), one in lower Burma, Peninsular Thailand and Malay Peninsular and 7 in Sri Lanka.

Acrotrema costatum Jack, Mal. Misc 1(5):36. 1820; Hook. f. & Thoms. in Hook. f., Fl. Br. Ind. 1:32. 1872; Ridl., Fl. Mal. Pen. 1:7. 1922; Hoogl. in Fl. Mal. I. 4:151. f. 6. 1951. Hoogl. in Fl. Thailand 2(2):104. 1972. — *Acrotrema wightianum* Wall., Numer. List 3669. 1831.

Small perennial herbs with a horizontal woody rhizome; Stem short, erect, simple. **Leaves** simple, spirally arranged; lamina chartaceous, obovate, 5-30 x 3-20 cm, rounded to acuminate at apex, auriculate at base, margin crenate-dentate, lateral vein 10-20 pairs, ending in apex of teeth in margin; hirsute above and below, usually with a whiting or grayish area along the midrib; leaves emerging reddish or red-yellow, older ones green light or coppery. **Petioles** 5-10 mm long, broadly winged. **Inflorescences** recemose terminal, about 8-15 flowered, 8-15 cm long, hirsute peduncles. **Flower** 1-3 cm across; pedicles 5-15 mm long densely tomentose, without or with 1-2 bracteoles; bracteoles persistent, lanceolate, 3-10 x 0.5-3 mm, acute at apex, tomentose both

surface. **Sepals** 5, free, ovate-lenceolate, 6-14 x 3-8 mm, acute at apex, glabrous inside, hairy outside. **Petals** 5, free, yellow, ovate, 8-16 x 5-9 mm, glabrous. **Stamen** 20-40; filaments 1-3 mm long; yellow, glabrous; anther thecae linear, opening with pore near apex, basifixed. **Carpels** 3, free, ovate, 4-10 mm long, glabrous; ovules 2-6, basal placentation. **Fruits** capsule enclosed by the persistent sepals, 3 loculed. **Seeds** ovate, 2-4 mm long, born with white aril.

Thailand.— Peninsular: Chumphon, Nakhon Si Thammarat, Phangnga, Pattani, Phuket, Ranong, Satun, Songkhla, Trang.

Distribution.— Lower Burma, Malay Peninsular (Type locality), Sumatra, Peninsular Thailand**.**

Ecology.— Under shade in wet zone lowland (up to 400 m).

Vernacular.— Pot Khon (ปดขน) (Nakhon Si Thammarat); Pot Din (ปดดิน) (Trang); Maha Prap (มหาปราบ) (Trang); Wan Chai (ว่านชัย) (Chumphon, Trang); Wan Chai Maha Prap (ว่านชัยมหาปราบ) (Peninsular); San Tao (ส้านเต่า) (Chumphon, Trang).

Material studied.- *David J. Middleton, S. Suddee, C. Hemrat* 1379 (BKF); *Rafidan, AR.* 51745 (BKF); *Suddee, s; Trisarasri, P.; Tepkaew, W; Subnugra, S; Chaiyaporn, S.* 331 (BKF); *Elored* 66 (BKF); *Larsen* 33134 (BKF); *K. Larsen, Supee S. Larsen, L. Nielsen, T. Santisuk* 30804 (BKF); *Weerachai Nanakorn* 651 (BKF); *David Middleton, T. Boonthavikoon, S. J. Davies, C. Hemarat, M. F. Newman* 398 (BKF); *J. F.Maxwell* 84-23 (BKF); *Th. W. et al.* 196 (BKF); *S.N.* 331 (BKF); *Nobuyuki Fukuoka, Thawachai Santisuk, Weerachai Na Nakhon* 35974 (BKF); *W. N.* 651 (BKF); *R. Geesink, T. Haltink, C. C. Charoenphol* 7240 (BKF); *Kamarui Hisham, M. FRI* 52022 (BKF); *C. Phengklai* 14939 (BKF); *C. Niyomdham et al.* 310 (BKF); *Hamiltonand Congdon* 21 (BKF); *C. Niyomdham and P. Phudjua* 3080 (BKF); *Thitinan* 29999 (BKF); *R. Geesink, T. Santisuk* 4863 (BKF); *T. Muadsub* 92 (BKF); *Kyle Williams, Rachun Pooma, Manop Poopath* 2043 (BKF); *R. Pooma, V. Chamchumroon, K. Phattarahirankanok* 1993 (BKF); *R. Pooma* 28 (BKF); *Sakol Sutheesorn* 2444 (BK); *Chirayupin* 66 (BK); *Puayad* 386 (BK); *Umpai* 208(BK); *T.* 120 (BK); *Sakol Sutheesorn* 3369 (BK); *Tuppan* 203 (BK); *C.X. Futado* s.n. (BK); *A.F.G. Kerr* 13668 (BK); *A.F.G. Kerr* 7437 (BK); *Rabil* 350 (BK); R. *Inyod* 13 (PSU); *T. Muadsub* 92 (PSU); *Siwat Salinrat* 3 (PSU); *Supattra* 17 (PSU); *F. Lengkol* 03 (PSU); *DL* 6 (PSU);

J.F. Maxwell 84-23 (PSU); *Paninee Thapnu* 12 (PSU); *Congdon & Hamilton* 21 (PSU); *Kwan Nualcharoen* (PSU); *Siriwarin Thibod* 4 (PSU); *Morut Pitahornnop* 4 (PSU); *Hattaya Memuang* 4 (PSU); *Khamga Khonpat* 6 (PSU); *Hodyot* 1 (PSU); *Siriwarin thibod* 4 (PSU); *Siriwarin Thibool* 4 (QBG); *J.F. Maxwell* 07-610 (QBG); *C. Maknoi* 1554 (QBG); *W. Nanakron et al.* 7302 (QBG); *W. Nanakorn et al.* 7256 (QBG); *S. Gardner & P. Sidisunthon* 43637 (QBG); *S. Rakarcha* 88 (Mahasarakham University Herbarium).

Figure 11 Distribution of *Acrotrema costatum* in Thailand.

Tetracera

L., Sp. Pl.: 533. 1753; Gen. Pl. ed. 5:237. 1754; Hoogl. in Fl. Mal. I. 4:141. 1951; Reinwardtia 2:185. 1953; Kubitzki, Mitt. Bot. Staatssamml. Münch. 8:1. 1970; Hoogl. in Fl. Thailand 2(2):105. 1972.; Wadhwa. in Fl. Ceylon 10:116. 1996.; Shu. in Fl. China 12:331. 2007. Type species: *Tetracera volubilis* L.— *Delima* L., Gen. Pl. ed. 5:231. 1754. Hook. f. & Thoms., Fl. Ind. 1:61. 1855; Thw., Enum. Pl. Zeyl. 2. 1858; Hooh. F. & Thoms. in Hook. f., Fl. Br. Ind. 1:31. 1872; Trimen. Fl. Ceylon 1:5. 1893. Type species: *D. sarmentasa* L. (= *Tetracera sarmentosa* (L.) Vahl). — *Assa* Houtt., Nat. Hist. 5:275. 1776. Christm. & Panz., PflSyst. 1: 40. 1779. Type species: *A. indica* Houtt. ex Christm. & Panz. (= *Tetracera indica* (Houtt. ex Christm. & Panz.) Merr.).

Small shrub with flexuous branchlets or woody clambering, evergreen, clambering upwards over other plants. **Leaves** simple, spirally arranged, without stipules, entire or with serrate margin, often scabrid on one or both side. **Petiole** short, sparsely to densely strigose, upper side concave. **Inflorescences** terminal or axillary, few-many (4-over 100) flowered of panicles, bisexual. **Flowers** actinomorphic. **Sepals** 4-5, imbricate, persistent, not enlarged and often reflexed in fruit. **Petals** 3-5, caducous, much larger than sepals, white or slightly reddish, deciduous, usually rounded or emarginate at apex. **Stamen** few-numerous, long filaments with broadened connective; anther divergent towards the base, opening with longitudinal slit. **Ovary** superior; carpels 1-4 with a short style; connate along central part of receptacle; ovules 4-20 each loculus attached to 2 marginal adaxial placentae. **Fruits** follicles or capsule, opening with longitudinal slit, ovate with a short rostrate, enclosed by the persistent sepals. **Seed** glossy dark brown, with fleshy aril fimbriate at margin; aril fleshy, reddish or purplish.

Distribution: The genus is found 40 species of a pantropical genus (Asia, Africa, America), with most species in tropical America.

Key to species of genus *Tetracera* of Dilleniaceae in Thailand (applied from Hoogland (1972) in Flora of Thailand Vol. 2 Part 2 and Hoogland (1953)

1. Carpels in most flowers solitary, but often in some flowers of the same plant two Carpels (more less 10% on same inflorescence) **2**
    2. Carpels and capsules densely hirsute **T. scandens**
    2. Carpals and capsules glabrous **T. sarmentosa**
1. Carpels in all flowers 2-4 **3**
    3. Sepals 4; inflorescences few- (up to 12) flowered, terminal or axillary, without leaves in the basal part; flowers about 2.5-3 cm across **4**
        4. Sepals glabrous both surface **T. indica**
        4. Sepals densely whitish or yellowish sericeous inside and glabrous outside **T. akara**
    3. Sepals 5-6; inflorescences many- (30-200) flowered, terminal, often with small leaves in basal part, sometimes on short axillary few-leaved branch; flowers about 0.8-2.5 cm across **T. loureiri**

Characters used for identification to species of genus *Tetracera* showed in Figure 31-32.

1. Tetracera akara (Burm.f.) Merr., Philipp. J. Sci. 19:366. 1921; Alston in Trimen, Handb. Fl. Ceylon 6:3. 1931; Hoogl. in Fl. mal. I 4:146. 1951; Reinwardtia 2:208. 1953. Wadhwa. in Fl. Ceylon 10:118. 1996. — *Calophyllum akara* Burm.f., Fl. Ind. 121. 1768. Type specimens: India, Malabar, Akara Patsjoti Rheede, Hort. Malabar. 5:15 t.8. 1685. — *Tetracera rkeedii* DC, Syst. 1:402. 1818; Prod. 1:68. 1824; Wight & Am., Prod. PI. Pen. Ind. or. 1:5. 1834; Wight, Ic. PI. Ind. or. 1: t. 70. 1838; Drury, Hanilb. Ind. PI. 1: 9. 1864. — *Tetracera laevis* Auet. (noil Vahl); DC, Syat. 1:401. 1818; Prod. 1:68. 1824; Hook. f. &. Thorns., Fl. ind. 1:62. 1855; Hook. f. & Thorns, in Fl. Br. Ind. 1:31. 1872; Trim., Handb. Fl. Ceyl. 1:6. 1893; Gamble, Fl. Pres. Madras 1:7. 1915; Back., Beta. Fl. Java (Nooduitg.) 4 (Fam. 80):2. 1942.

Small shrub with flexuous branchlets or woody clamber, clambering upwards over other plants; branches and branchlets strigose, glabrescent when mature; younger branches strigose; older ones bright brown to whitish bark, with flaky, longitudinally fissured bark. **Leaves** spirally arranged, without stipules; lamina obovate to oblong or lanceolate, 4–15 x 2–8 cm, obtuse or acuminate at apex, acute at base, margin dentate; lateral vein 5-15 on either side, ending in apex of teeth in margin, tertiary venation reticulate; upper surface slightly glossy, glabrous on intervenium, sparsely pubescent on nerves; lower surface dull, glabrous on intervenium, strigose on nerves; smooth or sometime scabrid on both sides. **Petiole** 5-15 mm long, sparsely strigose on below, upper side slightly concave. **Inflorescences** terminal or axillary, 5-10 cm long, about ca 8 flowered of double panicles, rachis glabrous to sparsely hirsute; bract lanceolate, caducous, greenlight, 1-2 x 0.5-1 mm, acute at apex, margin ciliate, glabrous to sparsely hirsute above, hirsute below. **Flowers** 5-25 mm across; pedicel 10-15 mm long, glabrous to sparsely hirsute, without or with 1-2 bracteoles; bracteoles lanceolate, 1-3 x 0.5-1.5 mm, acute at apex, margin ciliate. **Sepals** 4, ovate to orbicular, persistent, green or reddish green, 5-10 x 5-8 mm, glabrous outside, densely whitish or yellowish sericeous inside, margin ciliate. **Petals** 3-4, caducous, obovate, white or greenish white, 10-15 x 2-10 mm, rounded to retuse at apex, narrowed toward base, glabrous. **Stamens** ca 250, filaments 5-10 mm long, yellowish white, glabrous, with broadened connective, anther divergent towards the base, opening with longitudinal slit. **Carpels** 3 (-4), ovate, glabrous with rigid, style 2-3 mm long; placentae marginal, each with 6-10 ovules. **Fruits** capsule, ovate, glabrous, glossy, ca 5 mm long, rostrate acute with 1-3 mm long, opening with longitudinal slit. **Seed** ovate, glossy dark brown, with fleshy aril fimbriate at margin.

Thailand.— Penisular: Narathiwat.

Distribution.— India, Ceylon, Indo-China, Malay Peninsular, Sumatra, Borneo.

Ecology.— In lowland of the wet zone (up to 700 m).

Material studied.— *Soepadmo* 149 (BKF); *C. Niyomdham and P. Puudjaa* 7393 (BKF); *C. Niyomdham and P. Puudjaa* 7414 (BKF).

2. Tetracera indica (Christm. & Panz.) Merr., Interpr. Herb. Amboin. 367. 1917; Heyne, Nutt. PL Ned. Ind., 2nd Ed., 1070. 1927; Burk., Dict. Econ. Prod. Mal. Pen. 2143. 1935; Hoogl. in Fl. Mal. Mal. I. 4: 146. f. 1. 1951; Reinwardtia 2:205. F. 4 (map). 1953. Hoogl. in Fl. Thailand 2(2):108. 1972. — *Assa indica* Christm. & Panz., Vollst. Pflanzensyst. 4:40. 1779. Type Specimens: Java, *Houttuyn* s.n., (holotype L). — *T. assa* DC., Syst. 1:402. 1817; Hook. f. & Thoms. in Hook. f., Fl. Br. Ind. 1:31. 1872; Kurz, Fl. Burm. 1:22. 1877; Fin. & Gagnep., Bull. Soc. bot. Fr. Mem. 4:3. 1906; in Fl. Gen. I.-C. 1:14. 1907; Ridl., Fl. Mal. Pen. 1:5. 1992; Craib, Fl. Siam. En. 1:19. 1925; Gagnep. in Fl. Gen. I.-C. Suppl. 1:18. 1938.

Small shrub with flexuous branchlets or woody clamber, clambering upwards over other plants; branches and branchlets glabrous when mature; younger branches strigose, reddish green; older ones glabrous with greyish brown bark, with flaky, longitudinally fissured bark. **Leaves** spirally arranged, without stipules; lamina obovate to oblong or elliptic, 4–12 x 3–8 cm, obtuse or acute at apex, acute at base, margin entire to less dentate; lateral vein 8-12 on either side, ending in apex of teeth in margin, tertiary venation reticulate; upper surface slightly glossy, glabrous; lower surface dull, glabrous or very sparsely strigose on midrib and nerves; smooth on both sides. **Petiole** 5-15 mm long, strigose on below, upper side slightly concave. **Inflorescences** terminal, 5-10 cm long, about 5-8 flowered of double panicles, rachis strigose; bract lanceolate, caducous, greenlight, 2-10 x 0.5-5 mm, acute at apex, margin ciliate, glabrous above, hirsute below. **Flowers** 2-5 cm across; pedicel 10-15 mm long, glabrous to sparsely hirsute, without or with 1-3 bracteoles; bracteoles lanceolate, 1-3 x 0.5-1.5 mm, acute at apex, margin ciliate. **Sepals** 4, ovate, persistent, green or reddish green, 5-12 x 4-8 mm, glabrous on both sides. **Petals** 4, sometime 5 on same flower, caducous, obovate, reddish white, 10-16 x 5-10 mm, rounded to retuse at apex, narrowed toward base, glabrous. **Stamens** 100-250, filaments 5-10 mm long, red, white at base, glabrous, with broadened connective, anther divergent towards the base, opening with longitudinal slit. **Carpels** 3-4, ovate, mostly glabrous or less sparsely hirsute; style 2-5 mm long; placentae marginal, each with 8-15 ovules. **Fruits** capsule, ovate, red or reddish brown, glabrous, glossy, 5-10 mm long, rostrate acute with 1-3 mm long, opening with longitudinal slit. **Seed** ovate, glossy dark brown, with fleshy red aril fimbriate at margin.

Thailand.— Central: Bangkok; Peninsular: Chumphon, Krabi, Nakhon Si Thammarat, Narathiwat, Phatthalung, Satun, Surat Thani, Songkhla, Trang.

Distribution.— India (Assam, Bengal), Burma, Malay Peninsular, Sumatra, Java, Indo-China.

Ecology.— Open forest and lowland of the wet zone (up to 100 m).

Vernacular.— Khruea Pot (เครือปด) (Chumphon); Thao Ora Khon (เถาอรคนธ์) (Central); Pot Luen (ปดลื่น) (Pattani, Yala); Yan Pot (ย่านปด) (Peninsular); Yan Plao (ย่านเปล้า) (Trang); Rotsukhon Daeng (รสสุคนธ์แดง) (Bangkok); Ora Khon (อรคนธ์) (Bangkok); U Be Sa Pan La Me Yo (อุเบ๊ะสะปัลละเมเยาะ) (Malay-Narathiwat).

Material studied.— *Th. Wongprasert* 075-15 (BKF); *K. Larsen, Supee S. Larsen, Li Nielsen & T. Santisuk* 30791 (BKF); *K. Larsen, S.S. Larsen, S.. Renner, C. Niyomdham, W. Ueachirakan & P. Sirirugsa* 42894 (BKF); *Vaupruk* 764; *C. Niyomdham, B. Sangkachand, M. Suangto, O. Vijitranded* 197; *T. Smitinand* no number (BKF); *R. Geesink & T. Santisuk* 5215; *Weerachai Nanakorn* 618; *K. Larsen, Supee S. Larsen, Li Nielsen & T. Santisuk* 30634 (BKF); *K. Larsen, Supee S. Larsen* 33448 (BKF); *C. Niyomdham* 3460 (BKF); *หลวงสมานกิจ* 91 (BKF); *T* 29266 (BKF); *Th. S. et al.* s.n. (BKF); *Phengklai, C. et al.* 15809 (BKF); *Phengklai, C. et al.* 15632 (BKF); *WN.* 618 (BKF); *Subbee, S., Trisarasri, P., Tepkaew, W, Subnugarn, S.* 3151 (BKF); *Cho*, 1150 (BKF); *WN* 517 (BKF); *C. Phengklai et al.* 14938 (BKF); *T* 35894 (BKF); *T* 2902 (BKF); *V. Chamchumroon et al.* s.n. (BKF); *David J. Middleton, C. Hemrat, Stuart Lindsay, Samran Suddee & Suwat Suwanachat* 3845 (BKF); *C. Niyomdham* 7397 (BKF); *Praust* 446 (BK); *A.* 21753 (BK); *A. F. G. Kerr* 18896 (BK); *A.F.G. Kerr* 14698 (BK); *M.C. Lakshnakara* 575 (BK); *Sakol Suthusorn* 2422 (BK); *J.F. Maxwell* 01-382 (CMU); *U. Martmoon* 8 (CMU); *S. Chongko & A. Boonkongchart* 195 (CMU); *PK* 43 (PSU); *Yariha matahea* 1 (PSU); *Hic* 384 (PSU); *G. Congdon* 533 (PSU); *A* 13 (PSU); *Paungpen Siriruqua* s.n. (PSU); *W. Nanakorn et al.* 7573 (QBG); *W. Nanakorn et al.* 3396 (QBG); *M. Tanaros* 511 (QBG); *M. Tanaros* 510 (QBG); *C. Glamwaewwong* 1013 (QBG); *BGO Staff* 3413 (QBG); *S. Rakarcha* 87 (Mahasarakham University Herbarium).

3. Tetracera loureiri (Finet & Gagnep.) Pierre ex W. G. Craib, Kew Bull. (5):165. 1922; Craib, Fl. Saim. En. 1:20. 1925; Gagnep. in Fl. Gen. I.-C. Suppl. 1:28. 1938; Hoogl. in Fl. Mal. I. 4:147. 1951; Reinwardtia 2:210. f. 6 (map). 1953; Dansk bot. Ark. 20:185. 1962. Hoogl. in Fl. Thailand 2(2):107. 1972. — *Tetracera assa* var. *loureiri* Fin. & Gagnep. in Bull. Soc. hot. Fr., Mem. 4:3. 1906. Type Specimen: Bangkok, *Zimmermann* 74 (holotype P!, isotypes BM, BO, BR, G, K!, L, U). — *T. sarmentosa* var. *loureiri* (Fin. & Gagnep.) Fin. & Gagnep. in Fl. Gen. I.-C. 1:16. 1907; Craib, Bull. Misc. Inf. R. bot. Gdns Kew 8. 1911; Aberd. Univ. Stud. 57:4. 1912.

Woody clamber, clambering upwards over other plants, branching; younger branches green, slightly strigose; older ones greyish brown bark. **Leaves** spirally arranged, without stipules; lamina elliptic to oblong, 6-14 x 3-6 cm, rounded to obtuse or acute at apex, obtuse to acute at base; margin dentate; lateral vein 8-10 pairs, ending in apex of teeth, tertiary venation reticulate; upper surface glossy, glabrous to sparsely strigose, glabrous to scabrid; lower surface dull, glabrous on intervenium, glabrous to sparsely strigose on nerves; many circular spots, glabrous to scabrid. **Petiole** 5-13 mm long, glabrous to sparsely strigose on both side, upper side concave. **Inflorescences** terminal or axillary, about 40-90 flowered of double thyrsoids, with 1-3 leaves arranged from basal part to upward, branch strigose, scabrid; bract lanceolate, greenlight, acute at apex, margin ciliate, upper surface glabrous, lower surface glabrous except the strigose distributed at midrib and basal. **Flowers** 6-12 mm across; pedicel 3-8 mm long, strigose, with 1-3 bracteoles; bracteoles lanceolate, greenlight, 1-3 x 0.5-1.5 mm, acute at apex, upper surface glabrous, lower surface strigose, margin ciliate. **Sepals** 5, persistent, not enlarged in fruit, 3-8 x 2-5 cm, glabrous on both side, margin ciliate. **Petals** 3, caducous, obovate, white, 5-7 x 2-5 mm, rounded to retuse at apex, narrowed toward base, glabrous. **Stamens** 120-160, filaments 4-6 mm long, white, with broadened connective, anther divergent towards the base, opening with longitudinal slit. **Carpels** (2-) 3, free, glabrous, style long 2-3 mm; placentae marginal, each with 6-10 ovules. **Fruits** capsule, opening with longitudinal slit. **Seed** globular, glossy dark brown, with fleshy aril fimbriate at margin.

Thailand.— NORTHERN: Chiang Mai, Chiang Rai, Lampang, Phrea; EASTERN: Chaiyaphum, Nakhon Ratchasima, Roi Et, Surin, Ubon Ratchathani; CENTRAL:

Bangkok (Type locality), Nakhon Nayok; SOUTH-EASTERN: Chanthaburi, Prachin Buri, Trat; SOUTH-WESTERN: Prachuap Khiri Khan; PENINSULAR: Narathiwat, Nakhon Si Thammarat, Pattani, Phatthalung, Phuket, Ranong, Satun, Songkhla, Surat Thani.

Distribution.— Malay Peninsular, Cambodia, Thailand, Vietnam.

Ecology.— In open deciduous or evergreen forest and in thickets in the lowland (up to 400 m).

Vernacular.— Lin raet (ลินแรด) (Eastern); Rot Sukhon (รสสุคนธ์), Sukhontharot (สุคนธรส), Matrat Khua (มะตาดเครือ) (Central); Norakhon (นรคนธ์), Borakhon (บอระคน), Orakhon (อรคนธ์), Saowakhon (เสาวคนธ์) (South-eastern); Kapot Bai Luam (กะปดใบเหลื่อม) (South-western); Pot Namman (ปดน้ำมัน), Pot Lun (ปดลื่น), Pot Khai (ปดคลาย), Kan Pot (ย่านปด) (Penisular).

Material studied. — *J.F. Maxwell* 85-207 (BKF); *T.* 17672 (BKF); *L. thilirand* 2943 (BKF); *R. Geesink* 6342 (BKF); *K. Larsen* 10040 (BKF); *T. Smitinand* 2870 (BKF); *Tem* 230 (BKF); *R. Geesink, T. Hattink, C. Pheng* 6993 (BKF); *B. Sangkhachand* 435 (BKF); *T. Smitinad* 2288 (BKF); *C. Phengklai et al.* 3821 (BKF); *Th. Wongprasat* (BKF); *Suen Suksakorn* 902 (BKF); *R. Pooma, K. Phattarahirankanok, S. Sirimongkol* 4686 (BKF); *C. Niyomdham* 3461 (BKF); *R. Geesink, T. Hattink, C. Pheng* 6866 (BKF); *Runnok* 435; *T. Smitinand, E. Warncke* 90 (BKF); *C. Niyomdham* 739 (BKF); *K. Larsen, S.S. Larsen, A.S. Barfod, W. NanaKorn, W. Ueachirakan, P. Sirirugsa* 41230 (BKF); *J. F. Maxwell* 01-362 (BKF); *K. Chayamarit* 897 (BKF); *B. Sangkhachand* 261 (BKF); *T.* 17728 (BKF); *Th. Sorensen, K. Larsen, Bertel Hansen* 558 (BKF); *K. Chayamarit* 330 (BKF); *K. Larsen, T. Smitinand, E. Warncke* 1328 (BKF); *C. Phengklai et al.* 14550 *A. Virapongse* 44 (BKF); *T.* 61946 (BKF); *C. Phengklai et al.* 11226 (BKF); *C. Phengklai et al.* 3775 (BKF); *LAO* 820 (BKF); *M.C. Lakohuakeu* 107 (BK); *V.* 13100 (BK); *Sakol* 1043 (BK); *C. B* 25 (BK); *J.F. Maxwell* 74-620 (BK); *Juany* 3 (BK); *A.F.G. Kerr* 12644 (BK); *A.F.G. Kerr* 10743 (BK); *J.F. Maxwell* 01-362 (CMU); *J.F. Maxwell* 04-458 (CMU); *J.F. Maxwell* 98-458 (CMU); *J.F. Maxwell* 07-172 (CMU); *Pranee palee* 1146 (CMU); *Pisan sungtthisawasdi* 178 (CMU); *Duangpon peawan* 5 (CMU); *Pranee Palee* 25 (CMU); *Niyom 356* (CMU); *S. Korkaew* 55 (CMU); *M. Pinyosak & P. Vessumritt* 113 (QBG); *Kannikan* 24 (QBG);

W. Nanakorn et al. (QBG); *L. Kamkom* 07018 (QBG); *K. Warintorn* 08-323 (QBG); *S. Rakarcha* 51 (Mahasarakham University Herbarium).

4. Tetracera sarmentosa (L.) Vahl, Symb. Bot. 3:70. 1794; Fin. & Gagnep., Bull. Soc. Bot. Fr. Mem. 4:3. 1906; in Fl. Gen. I.-C. 1:15. 1907; Gagnep. in Fl. Gen. I.-C. Suppl. 1:20. 1938; Hoogl., Blumea 9:588. 1959; in Fl. Thailand 2(2):106. 1972.; Wadhwa. in Fl. Ceylon 10:117. 1996.; Shu. in Fl. China 12:331. 2007. — *Delima sarmentosa* L., Herb. Amb. 18. 1754; Hook. f. & Thoms., Fl. Ind. 1:61. 1855; Thw., Enum. Pl. Zeyl. 2. 1858; Hook. f. & Thoms. In Hook. f., Fl. Br. Ind. 1:31. 1872; Kurz, Fl. Burm. 1:22. 1877. Trimen, Handb. Fl. Ceylon 1:5. 1893. Type Specimen: Sri Lanka, *Hermann* 205 (holotype BM). — *Seguireria asiatica* Lour., Fl. Cochinch. 1:341. 1790. — *Tetracera levinei* Merr., Philipp. J. Sci. 13(3):147. 1918. — *Delima sarmentosa* var. *glabra* Hook. f. & Thoms., Fl. Ind. 1:61. 1855; in Hook. f., Fl. Br. Ind. 1:31. 1872. — *T asiatica* (Lour) Hoogl., Fl. Males. Bull. 1(4):143. 1951.; Reinwardtia 2:193. f. 2 (map). 1953.

Small shrub with flexuous branchlets or woody clamber, clambering upwards over other plants; branches and branchlets strigose, glabrescent when mature; younger branches strigose; older ones bright brown to reddish brown, with flaky, longitudinally fissured bark. **Leaves** spirally arranged, without stipules; lamina obovate to oblong, 4–12 x 2–5 cm, obtuse or rounded at apex, cuneate or acute at base, margin dentate; lateral vein 10-15 on either side, ending in apex of teeth in margin, tertiary venation reticulate; upper surface slightly glossy, sparsely strigose or hairs on intervenium, sparsely hirsute or hairs on nerves and midrib; lower surface dull, light green, glabrous to sparsely hirsute or hairs on intervenium, strigose or hairs on nerves and midrib; scabrid on both sides. **Petiole** 5-15 mm long, sparsely strigose or hairs on below, upper side slightly concave. **Inflorescences** terminal, ca 20 cm long, about 50-180 flowered of panicles, rachis strigose with hairs, scabrid; with 1-5 small leaves arranged from basal part to upward; bract lanceolate, caducous, greenlight, 1-3 x 0.5-1 mm, acuminate at apex, margin ciliate. **Flowers** 6–8 mm across; pedicel 2-10 mm long, strigose with hairs, without or with 1-2 bracteoles; bracteoles lanceolate, 1-3 x 0.5-1.5 mm, acute at apex, margin ciliate. **Sepals** 5, unequal, ovate, persistent, 2 outermost small than 3 innermost,

2-6 x 1-5 mm, sparsely hirsute outside, glabrous inside, margin ciliate. **Petals** 3, caducous, obovate, white or greenish white, 3-8 x 2-5 mm, rounded to retuse at apex, narrowed toward base, glabrous. **Stamens** 100-150, filaments 3-8 mm long, yellowish white, glabrous, with broadened connective, anther divergent towards the base, opening with longitudinal slit. **Carpels** 1 (-2), ovate, glabrous, style long 0.5-2 mm; placentae marginal, each with 10-12 ovules. **Fruits** follicles, ovate, glabrous, glossy, ca 8 mm long, rostrate acute with 1-3 mm long, opening with longitudinal slit. **Seed** ovate, glossy dark brown, with fleshy aril fimbriate at margin.

Thailand.— South-Eastern: Trat; South-Western: Prachuap Khiri Khan; Peninsular: Trang.

Distribution.— Indo-China, Ceylon, South China (Hainan, Yunnan), Andaman Island, Malay Peninsular. and South Sumatra.

Ecology.— Open forest and evergreen forest (up to 500 m).

Vernacular.— Pot Khon Khaeng (ปดขนแข็ง) (Surat Thani, Southwestern); Rotsukhon (รสสุคนธ์) (General).

Material studied.— *C. Niyomdham et al.* 300 (BKF); *T*-23308 (BKF); *Lao* 820 (BKF); *Sidek & ali* 596 (BKF); *A.F.G. kerr* 19149 (BK); *Tsiang Ying* 0279 (BK), *S. Rakarcha* 94 (Mahasarakham University Herbarium).

5. Tetracera scandens (L.) Merr., Int. Rumph.: 365. 1917; Hoogl. in Fl. Mal. I. 4:143. 1951; Reinwardtia 2:190. f. 1 (map). 1953; in Fl. Thailand 2(2):105. 1972.; Shu. in Fl. China 12:331. 2007. — *Tragia scandens* L. in Stickm., Herb. Amb. 18. 1754. — *Delima hebecarpa* DC., Syst. 1:407. 1817. — *Delima sarmentosa* var. *hebecarpa* (DC.) Hook. f. & Thoms., Fl. Ind. 1:61. 1855; in Hook. f., Fl. Br. Ind. 1:31. 1872. — *Tetracera sarmentosa* var. *hebecarpa* (DC.) Martelli in Becc., Malesia 3:150. 1886; Fin. & Gagnep., Bull. Soc. Bot. Fr. Mem. 4:4. 1906; in Fl. Gen. I.-C. 1:16. 1907. — *Tetracera hebecarpa* (DC.) Boerl., Cat. Hort. Bog.: 3. 1899; Craib, Fl. Siam En. 1:19. 1925. —*Delima scandens* (L.) Burk., Dict. 1:776. 1935. —*Delima sermentosa* auct. Non L.: Ridl., Fl. Mal. Pen. 1:3. 1922.

Small shrub with flexuous branchlets or woody clambering, clambering upwards over other plants; branches and branchlets strigose, glabrescent when mature; younger branches light brown, slightly strigose; older ones grey bark, with flaky, longitudinally fissured bark. **Leaves** spirally arranged, without stipules; lamina obovate to oblong or oblanceolate , 1.5–15 x 1–8 cm, rounded to obtuse or acute at apex, obtuse at base, margin dentate; lateral vein 10-15 on either side, ending in apex of teeth in margin, tertiary venation reticulate; upper surface slightly glossy, glabrous to sparsely strigose on intervenium, sparsely pubescent on midrib; lower surface dull, glabrous to pubescent on intervenium, strigose on nerves and midrib; scabrid on both sides. **Petiole** 5-15 mm long, sparsely strigose on lower, upper side concave. **Inflorescences** terminal, ca 50 cm long, about ca 150 flowered of double thyrsoids, with 1-5 small leaves arranged from basal part to upward, rachis strigose, scabrid; bract lanceolate, caducous, greenlight, 1-2 x 0.5-1 mm, acute at apex, glabrous above, strigose below, margin ciliate. **Flowers** 6-10 mm across; pedicel 2-8 mm long, strigose, without or with 1-2 bracteoles; bracteoles lanceolate, 1-3 x 0.5-1.5 mm, acute at apex, margin ciliate. **Sepals** 4, may be 5 on same inflorescent, ovate to orbicular, persistent, 3-10 x 2-5 mm, slightly strigose on outside, glabrous inside, margin ciliate. **Petals** 3, caducous, obovate, white, yellowish white, or reddish white, 3-7 x 2-5 mm, rounded to retuse at apex, narrowed toward base, glabrous. **Stamens** ca 100, filaments 3-5 mm long, white, glabrous, with broadened connective, anther divergent towards the base, opening with longitudinal slit. **Carpel** 1 (-2), ovate, densely hairy with rigid, style long 2-3 mm; placentae marginal, each with 6-10 ovules. **Fruits** follicles, ovate, reddish brown, glossy, ca 10 mm long, rostrate acute with 1-3 mm long, opening with longitudinal slit. **Seed** ovate, glossy dark brown, with fleshy aril fimbriate at margin.

Thailand.— North-Eastern: Sakon Nakhon; Eastern: Chaiyaphum: South-Western: Phetchaburi, Prachuap Khiri Khan; Peninsular: Surat Thani, Phangnga, Krabi, Phuket, Nakhon Si Thammarat, Trang, Phatthalung, Songkhla, Narathiwat, Pattani.

Distribution.— South-Eastern Asia, Southern China (Yunnan), Burma, Sumatra, Malay Peninsula, Banka, Java, Borneo, Philippine, Andaman Island, Indo-China.

Ecology.— In open deciduous or evergreen forest and in thickets in the lowland (up to 600 m).

Vernacular.— kapot (กะปด) (Peninsular); pot khon (ปดขน) (Nakhon Si Thammarat); pot khai (ปดคาย) (Peninsular); pot lueam (ปดเลื่อม) (Songkhla); pa-la-lue-laeng (ปะล่ะลือแล็ง) (Malay-Pattani); lin raet (ลิ้นแรด) (Nakhon Ratchasima); sap-pla (สับปละ) (Malay-Narathiwat).

Material studied.— *Gordon H.Spare* 34554 (BKF); *Mohd. Shah & Ahmad Shukor MS* 2470 (BKF); *H.M. Burkill & Kiah* 661 (BKF); *Phengklai C. et al.* 13701 (BKF); C. *Phengklai et al.* 14937 (BKF); *BS.* 898 (BKF); *M.F. Newman, T. Boonthavikoon, C. Hemrat & D.J. Middleton* 1053 (BKF); *Phengklai C. et al.* 13601 (BKF); *T. Shimizu, N. Fukuoka & A. Nalampoon* 8156 (BKF); *Kyle Williams; Rachun Pooma, Manop Poopath, Varadol Chumchamroon* 1452 (BKF); *C. Niyomdham, B. Sangkachand, M. Suangto, O. Vijitranand* 179 (BKF); *T. smitinand* 8909 (BKF); *Charan Bunnab* 491 (BKF); *C. Niyomdham, P. Phudjaa, S. Chonkunjana* 6153 (BKF); Snan 279 (BKF); *TH. Santisuk et al.* s.n. (BKF); *R. Pooma* P75 (BKF); *Hamilton & Congdon* 140 (BKF); *Th. Nangpraset* s.n. (BKF); *T. Smitinanad* 11956 (BKF); *C. phengklai et al.* 15393; *Newman, M.F, Thomas, P.L., Aimstrong K.A., Sengdala, K. Lamxay, V.* (LAO 974) (BKF); *V. Chamchumroon, C. Puff, N. Koonkhunthud* 1375 (BKF); *R. Pooma, V. Chamchumroon, K. Phattarahirankanok* 2075 (BKF); *Kyle Williams, Rachun Pooma, Manop Poopath* 1655 (BKF); *A.F.G. Kerr* 15304 (BK); *Laray* 24 (BK); *C. chemri. & T. Smitinand* 2104 (BK); *Prayad Sangkhaehand* 1615 (BK); *J. & M.S. Clemens* 3171 (BK); *G. Lopez* 2-107 (BK); *M.O. Lakshnakara* 834 (BK); *A.F.G.* 16086 (BK); *S.* 536 (BK); *A.F.G. Kerr* 15819 (BK); *A.F.G. Kerr* 10778; *A.F.G. Kerr* 17238; *A.F.G. Kerr* 21655; *A.F.G. Kerr* 18631;); *H & C* 140 (PSU); *Somsrin Sakol* 75 (PSU); *P. Luengluetham* 5 (PSU); *Hattaya Memuang* 10 (PSU); *C. Maknoi* 3148 (QBG); *S. Rakarcha* 85 (Mahasarakham University Herbarium).

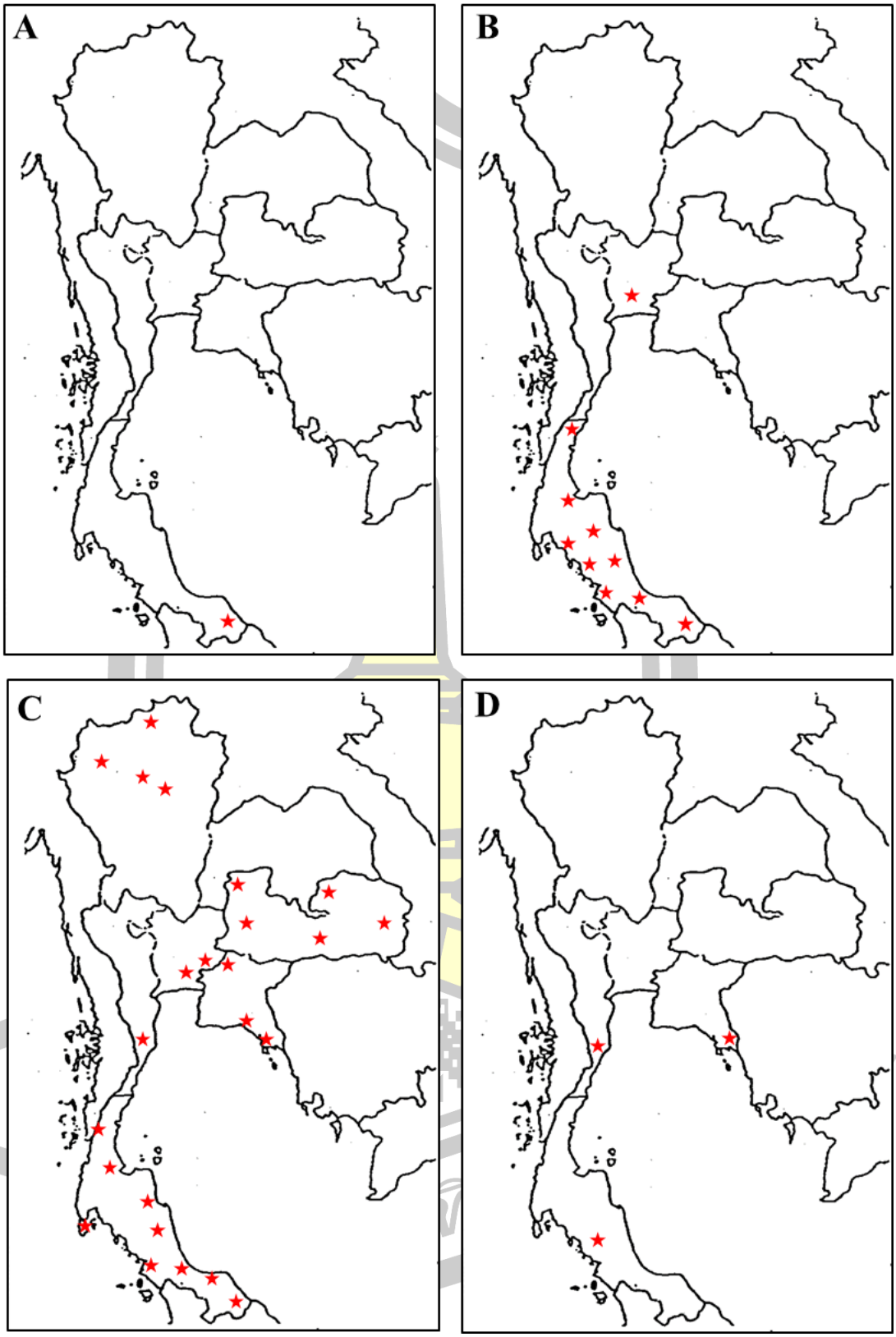


Figure 12 Distribution of genus *Tetracera* in Thailand.

(A) *T. akara*, (B) *T. indica*, (C) *T. loureiri*, (D) *T. sarmentosa*.

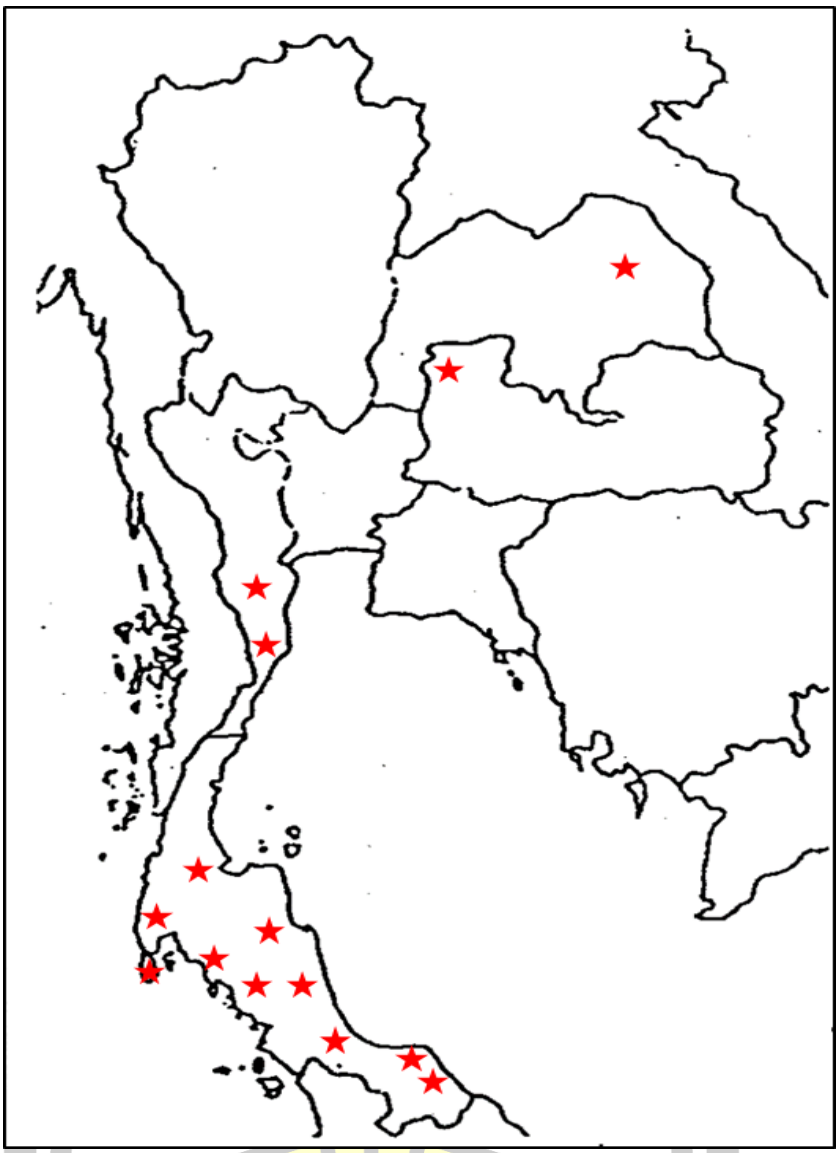


Figure 13 Distribution of *Tetracera scandens* in Thailand.

2.5 Discussion

The classification of Dilleniaceae by The Angiosperm Phylogeny Group (2016), it was classified in order Dilleniales of core eudicots. The Dilleniales are an order of flowering plants, potentially containing one family, Dilleniaceae. Within the family classification used Horn system (2005, 2007, 2009). In this study, twenty species, three genera from two subfamilies of the family Dilleniaceae in Thailand were reported from around Thailand. Subfamily Delimoideae found only the genus *Tetracera*, 5 species. Subfamily Dillenioideae found 14 species of genus *Dillenia* and 1 species of genus *Acrotrema*. While, Hoogland (1972) reported 15 species from three

genera (10 species of *Dillenia*, 4 species of *Tetracera* and one species of *Acrotrema*). In the present study, the result shows additional data for Thai Dilleniaceae as follow: *Tetracera akara* is a new record for Thailand; *Dillenia philippinensis*, *D. reticulata* and *D. puchella* was described for the first time base on Thai specimen; *D. grandifolia* and *D. reticulata* may be a single species.

Hoogland (1972) reported 15 species from three genera of Dilleniaceae in flora of Thailand. *Dillenia scabrella* was reported by Busaban Na Songkhla and Chirayupin Chandraprasong in 2001 form Khun Korn Waterfall Forest Park, Chiang Rai Province. Hoogland (1972) reported *D. suffruticosa* is cultivated plant, which consistent with this study because the study in the fieldwork and dry specimen in herbarium not found specimen in natural but found it in the gardens in around countries. In addition, the fieldwork found *D. philippinensis* is cultivated plant in many places such as hotel, cafe, government office and other.

Dillenia reticulata was reported from only Phuket Island by Hoogland (1972, refer to Ridley in flora of Malaysia Penninsular,1922). Hoogland (1972) has not found any specimen in Thailand, so he did not describe this species in Thailand. After I carefully checked and found that *Dillenia reticulata* distributed in peninsular of Thailand, especially, a complete dry specimen was found at Narathiwat Province.

Dillenia puchella was found in Thailand in long time. Hoogland (1972) reported that *D. puchella* not found in Thailand. After Hoogland reported Dilleniacae in Flora of Thailand in 1972. He determined *D. puchella* in dry specimen (collect by Sakol 1353) in Bangkok Herbarium in May 1975. In current, *D. puchella* not decried based on the Thai specimens. In This study provided description of *D. puchella* to benefit in other study.

The Plant List (2018) data base reported *Dillenia grandifolia* as a synonym of *D. ovata*. After I carefully checked and found that *D. grandifolia* was nomenclated from the specimens very imperfect (holotype K!, isotypes CAL, CGE, P!). Type specimens were collected from Penang, Malaysia Peninsular in August 1822 from a sapling or young-tree. Wallich reported the *Dillenia grandifolia* base on incomplete specimen (no. 946) but he did not descried morphology charecteristic (nomen nudum). The latter, Hooker and Thomson (1855) described morphological of *Dillenia grandifolia* in Flora Indica (Vol. 1(2), p. 71). In current, most of the later literature refers to specimens of

D. ovata. In some literature refers to specimens of *D. reticulata*. In Flora of Malaysiana ser.1 vol.4 and a revision of the genus *Dillenia* by Hoogland (1951, 1952) refer to *D. reticulata*. In this study, I expect *D. grandifolia* and *D. reticulata* are a single species because I follow from holotype and literature review of *D. grandifolia* very similar to *D. reticulata*. In this study, *D. reticulata* will be disbanded as the synonym of *D. grandifolia* because nomenclature of *D. grandifolia* (1855) was set before *D. reticulata* (1889).

Dilleniaceae is distributed in all part of Thailand, but a large number of species also occurs in peninsular. Therefore, peninsular is the center diversity of this family. The genus *Acrotrema* is found only in peninsular. The genus *Tetracera* is distributed in peninsular, except *T. loureiri* found in several parts of Thailand. In *Dillenia*, deciduous plants usually found N, NE, E and SW. While, evergreen plant usually found SE and PEN. *D. hookeri*, *D. ovata* and *D. indica* can be found in all parts of Thailand (Table 7).

2.6 Conclusion

Dilleniaceae was classified to order Dilleniales of core eudicots. The Dilleniales is an order of flowering plants, potentially containing one family, Dilleniaceae. In this study, twenty species for three genera from two subfamilies of the family Dilleniaceae were reported from around Thailand. Subfamily Delimoideae found only the genus *Tetracera*, 5 species. Subfamily Dillenioideae found 14 species of genus *Dillenia* and 1 species of genus *Acrotrema*. In the present study, the result shows additional data for Thai Dilleniaceae as follow: *Tetracera akara* is a new record for Thailand; *Dillenia philippinensis*, *D. reticulata* and *D. puchella* were described for the first time base on Thai specimen; *Dillenia grandifolia* and *D. reticulata* may be are a single species.

Table 7 Distribution of Thai Dilleniaceae.

Species	N	NE	E	SW	C	SE	PEN
Acrotrema costatum							✓
Dillenia aurea	✓	✓	✓				
D. excelsa							✓
D. grandifolia							✓
D. hookeri	✓	✓	✓	✓		✓	✓
D. indica	✓	✓			✓	✓	✓
D. obovata				✓		✓	✓
D. ovata	✓	✓	✓	✓	✓	✓	✓
D. parviflora	✓	✓		✓			
D. pentagyna	✓	✓		✓		✓	
D. philippinensis	✓	✓	✓	✓	✓	✓	✓
D. phucella							✓
D. reticulata							✓
D. scabrella	✓	✓					
D. suffruticosa		✓	✓		✓	✓	✓
Tetracera akara							✓
Tetracera indica					✓		✓
T. loureiri	✓		✓	✓	✓	✓	✓
T. sarmentosa						✓	✓
T. scandens		✓		✓			✓

Key to abbreviations: N = Northern, NE = North Eastern, E = Eastern, SW = South Western, C = Central, SE = South Eastern, PEN = Peninsular.

Characters used for key to genera of Thai Dilleniceae

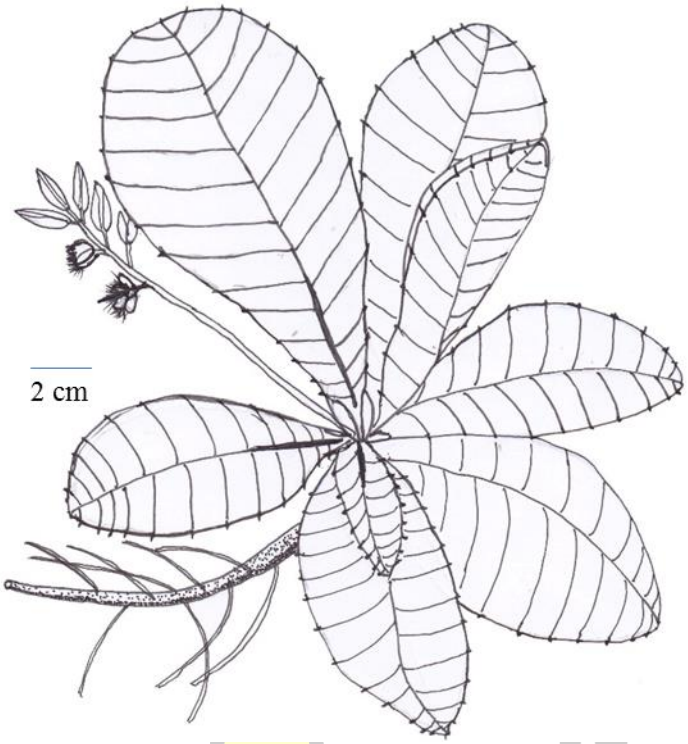


Figure 14 Small perennial herb and racemes inflorescence of *Acrotrema costatum*.

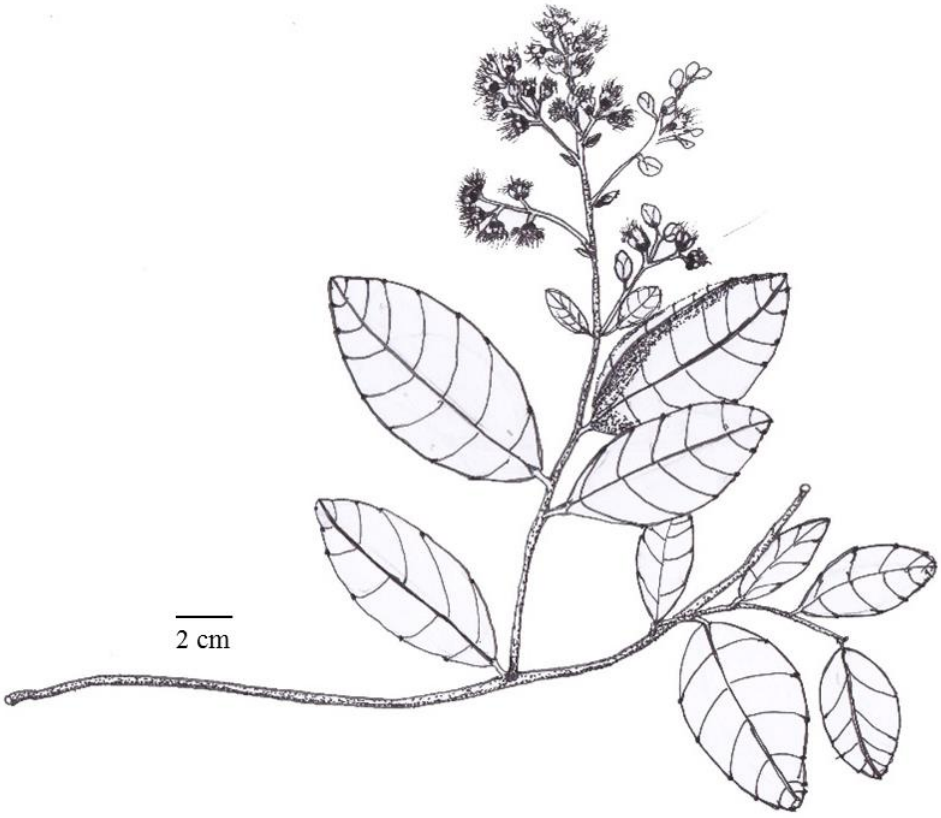


Figure 15 Woody climber and panicle inflorescence of *Tetracera loureiri*.

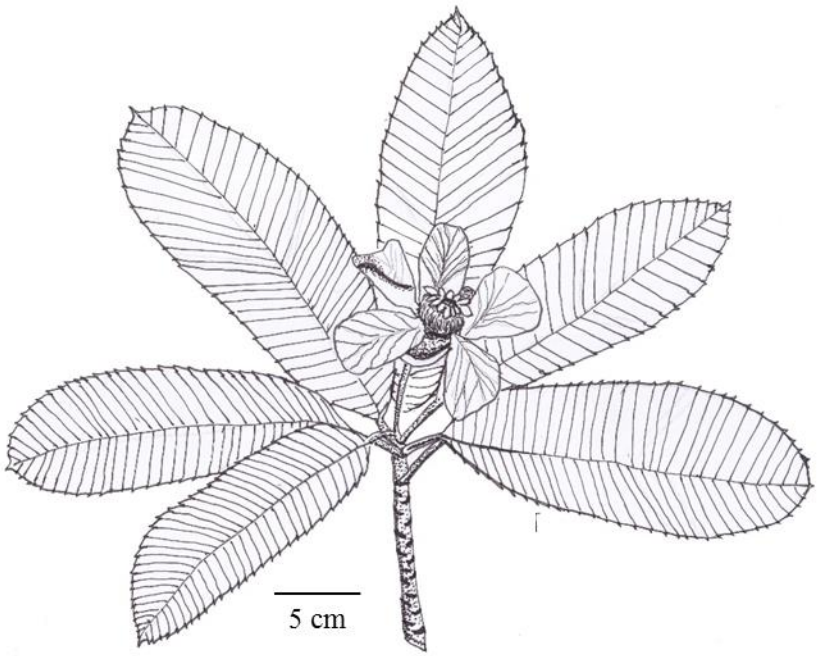


Figure 16 Tree and solitary flower of *Dillenia indica*.

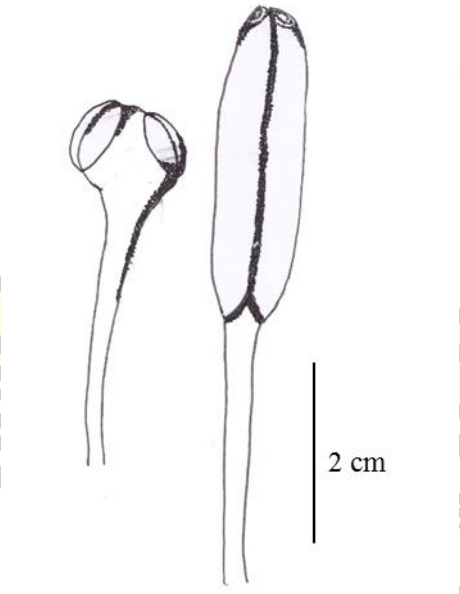


Figure 17 Anther divergent towards the base, opening with longitudinal slit found in genus *Tetracera* (left) and Thecae linear, opening with pore near apex of genus *Acrotrema* and *Dillenia* (right).

Figure 18 Carpels around rather narrow conical receptacle found only in *Dillenia*.

Figure 19 Carpels around flat receptacle found in species of genus *Tetracera* and genus *Acrotrema*.

Dominant characteristics of key to species of Dilleniceae in Thailand.

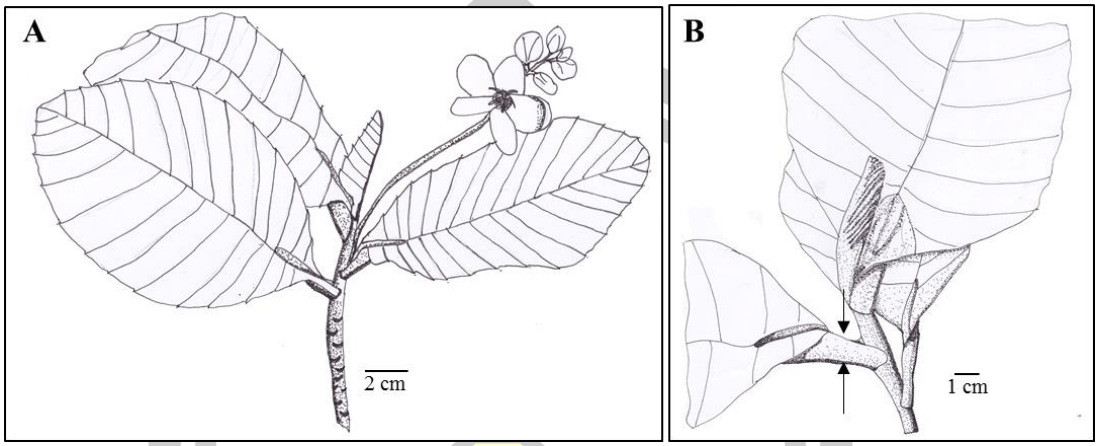


Figure 20 Morphology of flower and petiole of *Dillenia suffruticosa*.

(A) Racemose inflorescence, (B) Petiolar wings not constricted at leaf base (arrows), wing continuous from the base of leaf.

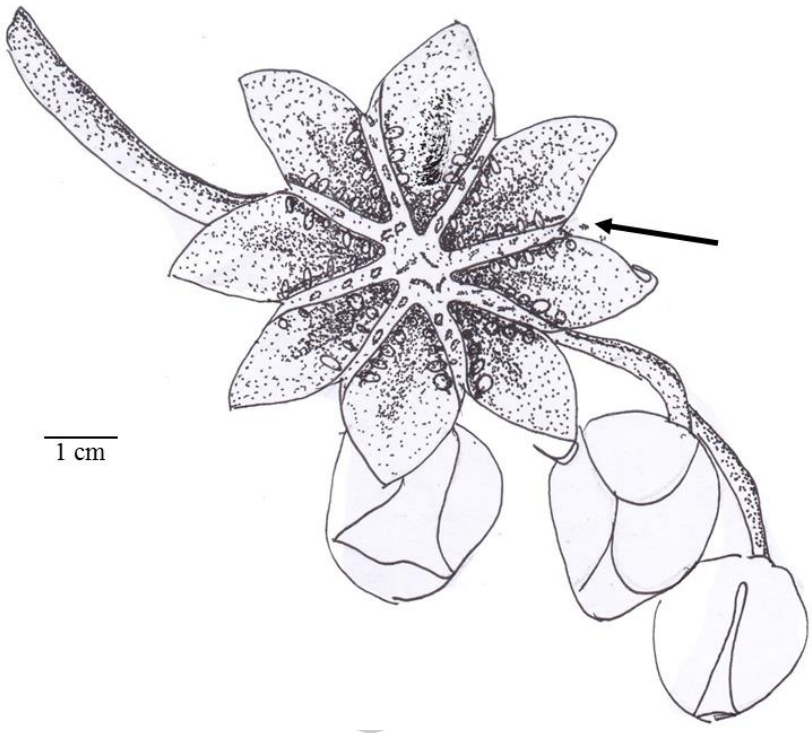


Figure 21 Dehiscent fruit of *Dillenia suffruticosa* (arrow).

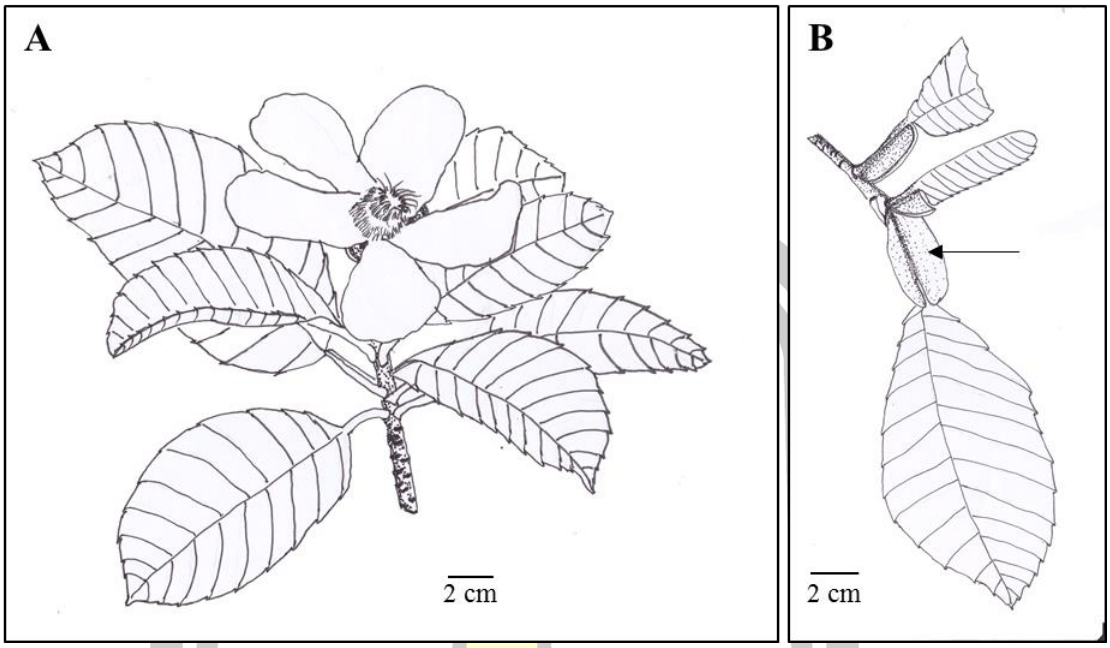


Figure 22 Morphology of flower and petiole of *Dillenia philippinensis*

(A) Solitary flower, (B) Petiolar wings more or less constricted at leaf base, wing separated or independent from the base of leaf (arrow).

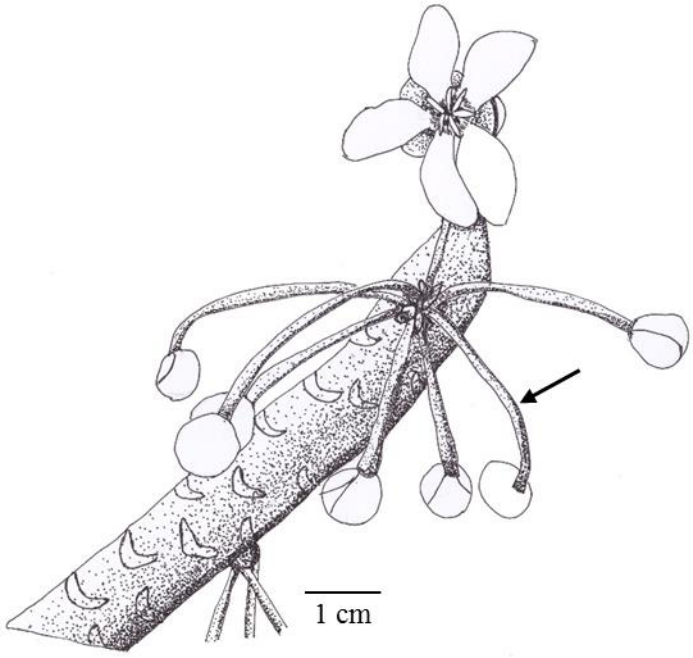


Figure 23 Flower small (ca. 2-5 cm diam.), fascicled inflorescences comprising 4-8 flower, pedicels without bracteoles (arrow) and Sepals glabrous on both side of *Dillenia pentagyna*.

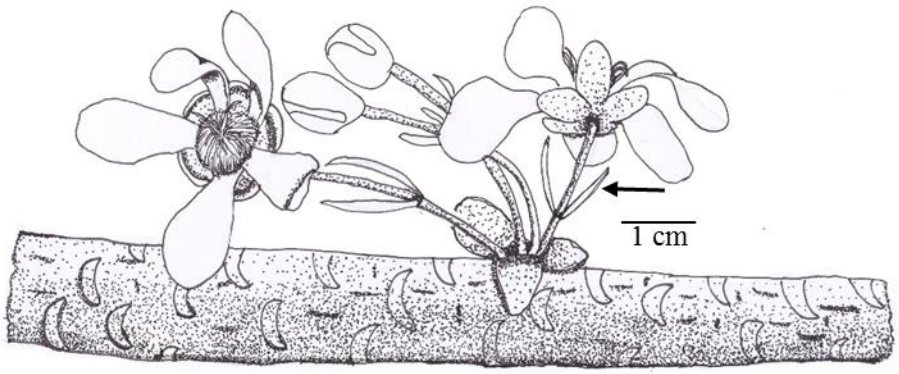


Figure 24 Fasciculate inflorescence with few-several bract, pedicel with caducous bracteoles (arrow) and Sepals glabrous on both side of *Dillenia scabrella*.

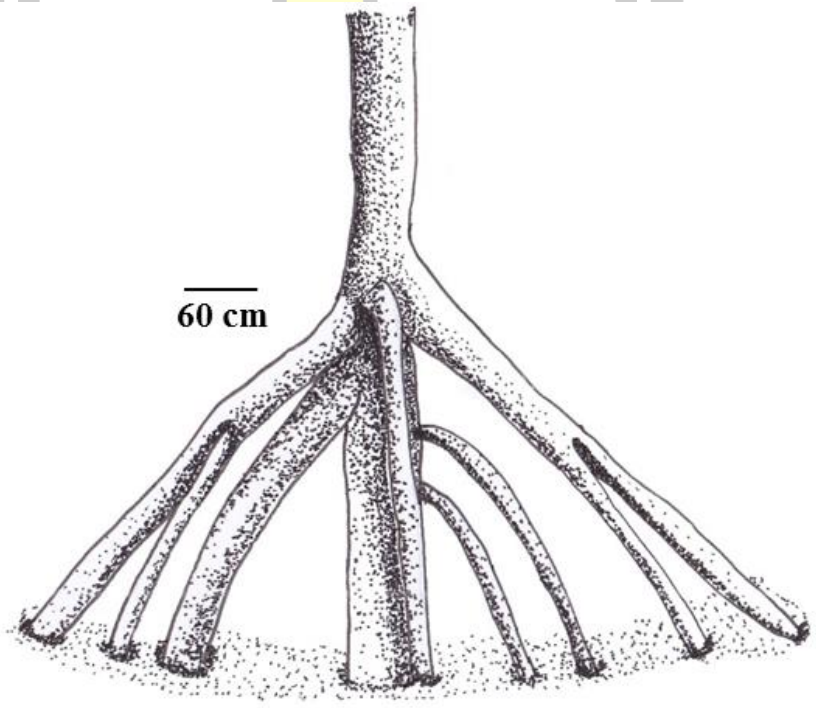


Figure 25 Stilt root of *Dillenia reticulata*.

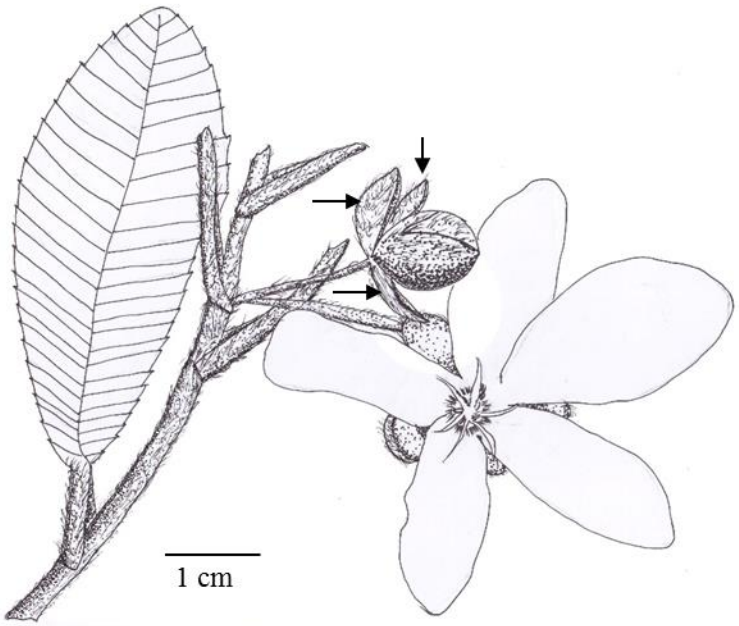


Figure 26 Pedicel with 3 large verticillate bracteoles (arrows) and allpart densely velvety tomentose of *Dillenia hookeri*.

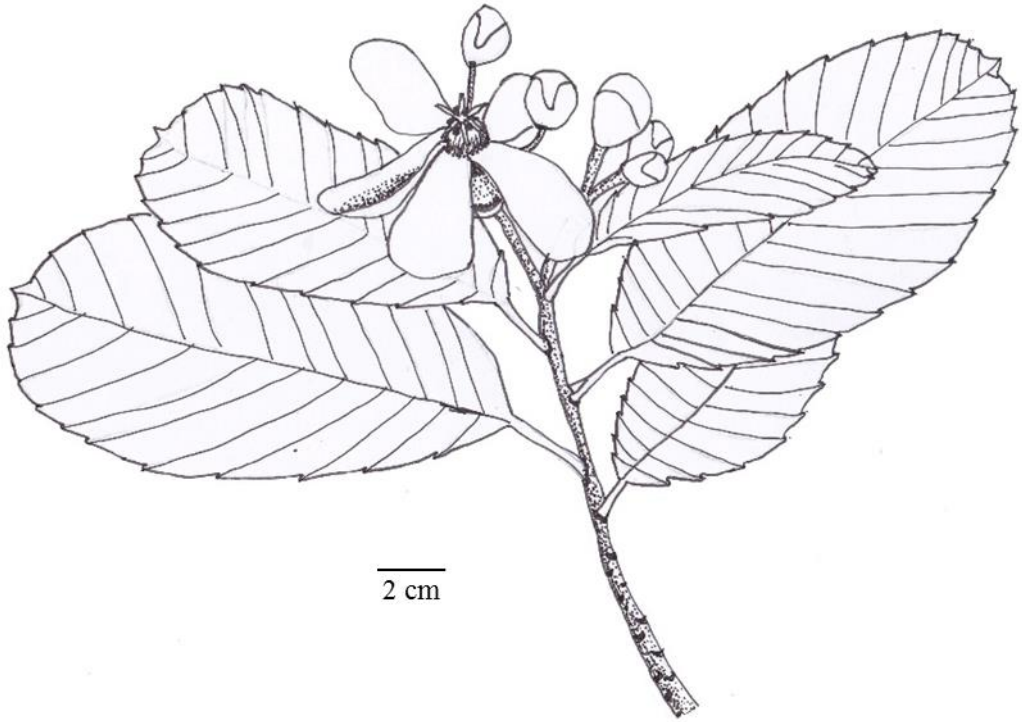


Figure 27 Recemose inflorescence, stamen in 2 sharply separated group of difference length of *Dillenia excelsa*.

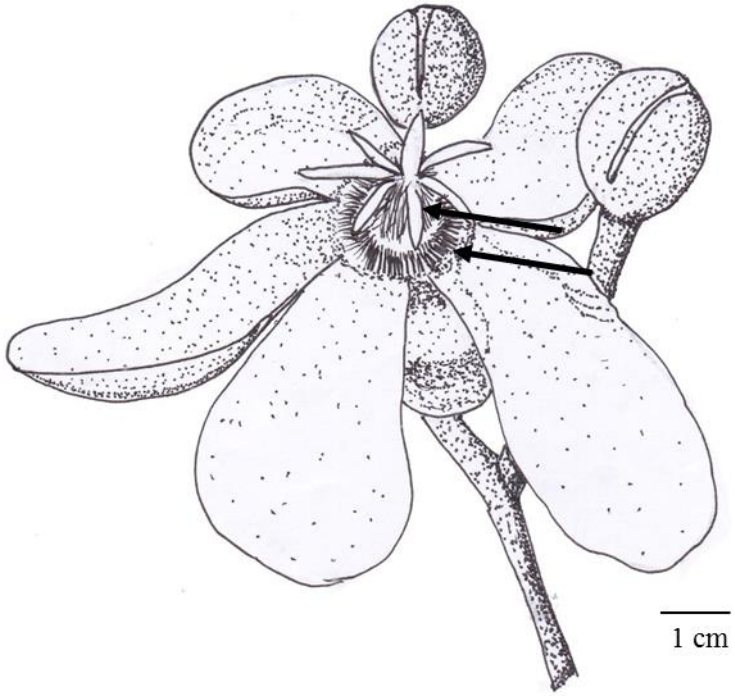


Figure 28 Stamen in 2 sharply separated group of difference length of *Dillenia excelsa* (arrows).

Figure 29 Bark rather smooth, flaky, yellowish to reddish gray of *Dillenia obovata*.

Figure 30 Bark thick scales, rough, reddish of *Dillenia aurea*.

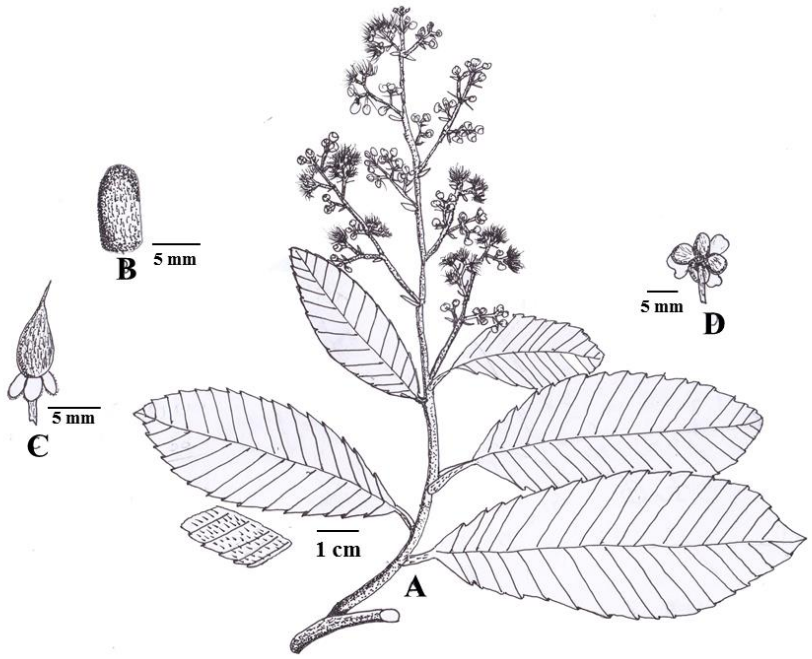


Figure 31 Morphology of *Tetracera scandens*.

(A) Thyrsoids inflorescence, (B) Sepals slightly stigose on outside, (C) Sigle carpel with densely hairy, (D) Flower.

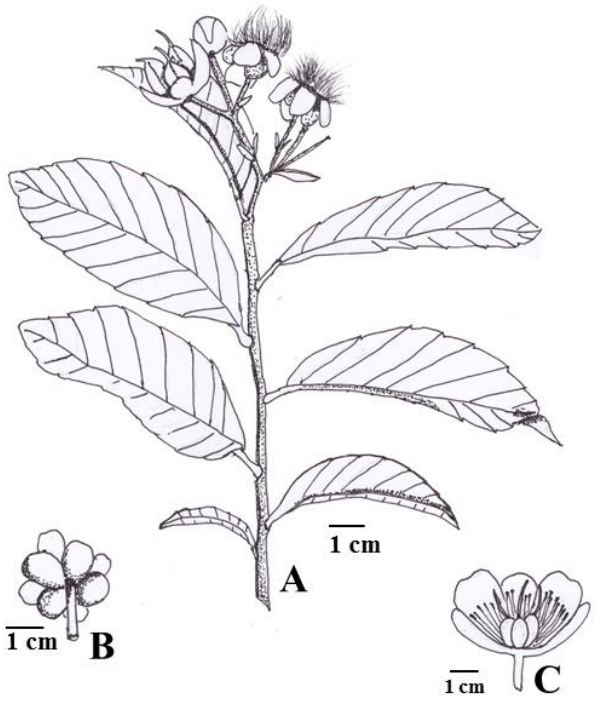


Figure 32 Morphology of *Tetracera indica*.

(A) Double panicles inflorescence, (B) Flower with sepals glabrous on both sides, (C) Three carpels and glabrous.

CHAPTER 3
POLLEN MORPHOLOGY OF DILLENIACEAE IN THAILAND

3.1 Introduction

The study of plant taxonomy used the many morphological characteristics in conjunction with other knowledge such as molecular biology, anatomy, chromosome, embryology and pollen morphology to identify, describe and classify species of plant. The study of pollen morphology can be used in plant taxonomy studies because the pollen grains have a variety of characteristic, i.e. size, shape, symmetry, aperture, exine structure and exine sculpturing (Erdtman, 1952; Moore *et al.*, 1991; Rashid *et al.*, 2017; Saensouk *et al.*, 2015). In addition, the pollen morphology can be valuable to other knowledge such as the study of plant evolution used pollen analysis on the surface of the earth to find the history of the plant community. The archaeology can be used pollen morphology to determine the age of antiques and ancient humans and useful in many other aspects (geology, ecology, archeology, or medical research) (Erdtman, 1952; Moore *et al.*, 1991; Nairs, 1971; Ruksat, 1996).

The study of pollen morphology of Dilleniaceae was briefly described at the species level by Erdtman (1952), Barth (1962) and Dickison (1967b). The study of Dickison *et al.* (1982) completely described the pollen morphology of 38 species of Dilleniaceae using light microscopy, scanning electron microscopy and transition electron microscopy. Other studies report of Erdtman (1952), Barth (1962) and Dickison (1967b) are incomplete because no attempt was made to collect the numerical data statistically and data incomplete of details about the pollen morphology in species levels. In particular, characteristics of exine sculpturing that requires a microscope with high magnification but pollen morphology were descried under oil immersion (X1000). The palynological data of the family Dilleniaceae have never been described in detail for some of the characteristics, e.g., exine thickness, distance between apices of two ectocolpi, colpus length, colpus width, porus length, porus width and apocolpium index. Additionally, only a few of the species have been studied by researchers. Therefore, this study was designed to describe the pollen morphology of the Dilleniaceae from Thailand and to compare the pollen morphological data with the species relationship among the genera *Acrotrema*, *Dillenia* and *Tetracera* of the Dilleniaceae in Thailand.

3.2 Literature review

Erdtman (1952) described pollen morphology of seven species of five genera of Dilleniaceae. The result showed that the shape of the pollens is oblate spheroidal and subprolate. The size of the pollen grains varies from 17-26 µm in polar axis and 16.5-27 µm in the equatorial axis. The apertures are tricolpate, tricolporate and tetracolpate. The exine is reticulate.

Barth (1962) described pollen morphology of four species of Dilleinaceae as a follow: *Davilla angustifolia* St. Hil., *D. rugosa* Poir., *Doliocarpus lasiogyne* R. Benoist and *Tetracera oblongata* D.C.. The Dilleniaceae were divided into two groups: *Davilla angustifolia, Doliocarpus lasiogyne* and *Tetracera oblongata* with tricolporate aperture, while *Davilla rugosa* is tetraporate apertures. The important feature is the shape of pollen subprolate and prolate, size 23.5-33 µm in P x 16.5-29.6 µm in E.

Dickison (1967b) studied pollen morphology in 10 genera and 55 species of Dilleniaceae consist of one species of *Acrotrema* Jack, one species of *Curatella* Loefi., five species of *Davilla* Vandelli, one species of *Didesmandra* Stapf, 12 species of *Dillenia* L., five species of *Doliocarpus* Roland., 12 species of *Hibbertia* Andr., two species of *Pachynema* R. Br., one species of *Schumacheria* Vahl and 15 species of *Tetracera* L.. No effort was made to treat the numerical data statistically. All measurements and descriptions were made under oil immersion (x1000). The shape of pollens are oblate, spheroidal, or prolate, size 15-34 µm in P x 16.5-32.2 µm in E, the smallest pollen was found in *Schumacheria castaneifolia* Vahl. (15 x 16.5 µm), while the largest found in *Hibbertia stricta* (DC) R. Br. ex F. Muell. (34 x 32.2 µm). The apertures are tricolporate, tricolpate, triporate and tetracolpate, pollen was exclusively tectate or rarely semitectate, with no significant difference in thickness between endexine and ektexine. Sculpturing was predominantly reticulate or a modification of reticulate.

Dickison *et al.* (1982) studied the pollen morphology of the Dilleniaceae and Actinidiaceae with a light microscopy, scanning electron microscopy and a selected group in a transmission electron microscopy. The result showed that the pollen morphology of 38 species of Dilleniaceae was monads, the shape of the pollen was spheroidal sometimes suboblate or subprolate, size 15-32 µm P x 17-32 µm E, the

apertures tricolporate, tricolpate, tetracolpate and incipiently inaperturate; the tectum incomplete, finely punctate to coarsely reticulate. In the Actinidiaceae, the pollen morphology of 15 species are usually monads, the shape of the pollen was oblate-spheroidal to prolate, size 13-26 µm P x 13-18 µm E, the apertures tricolporate, the colpi usually long, the endoaperture circular or ovoid, frequently covered by an ektexine bridge consisting of lateral extensions of the colpus margin, the tectum complete and psilate or granular. Pollen morphology data does not support a close relationship of the Dilleniaceae and Actinidiaceae. Tectum characteristic of Actinidiaceae there is the tectum complete, psilate or granular but in Dilleniaceae the tectum is incomplete, reticulate to punctate. Equatorial bridge of ektexine over the endoaperture is usually present in Actinidiaceae but absent in Dilleniaceae. Columella reduced in Actinidiaceae but usually well-developed in Dilleniaceae.

3.3 Materials and methods

3.3.1 Pollen morphology

The flowers were collected from field trip in Thailand and the samples were preserved in 70% alcohol. The anthers were removed from the flowers and the samples were dehydrate using alcohol series as follow: 70%, 90%, 95% and 100%. Then, the samples were divided into two parts; the first part were examined by using Light Microscopy (LM), pollen grains were mounted in silicone oil and sealed with paraffin. At 30 pollen grains of each specimen were measurement of polar exis (P), equatorial diameter (E), size of aperture and axine thickness. The photographed using LM (Axio Lab A1). The second part were examined by using Scanning Electron Microscopy (SEM), pollen grains were suspended in absolute alcohol. Then pollen grains were dried and attached to aluminum stubs with double-sided cellophane tape and coated with gold. The micrographs were taken using a SEM (JEOL: JSM 6460 LV) to determine the details of the exine sculpturing and aperture structure. The terminology classes follow Punt *et al.* (2007). Pollen shape classification follows Erdtman (1952) as based on the P/E ratio. Pollen size classes follow Erdtman (1952) as based on the length of the pollen grains longest axis. Voucher specimens and slides of all samples were deposited at the Department of Biology, Faculty of Science, Mahasarakham University, Mahasarakham, Thailand.

3.3.2 Data analysis

The pollen morphology characters of each species were evaluated for morphometric analysis, comprising 13 quantitative and five qualitative characters (Table 9). The morphometric analysis was performed by factor analysis and cluster analysis. The analysis was conducted using Statistical Package for the Social Science (SPSS version 25 for Windows). Factor analysis was undertaken using the principal component analysis method (PCA). PCA was used to reduce the variables from a larger set into a smaller set. The result of the PCA is usually discussed in terms of the factor loading. Factor loading score could be obtained from the output. The factor analysis was performed, it could be divided into new factor. Each factor contained parameters with eigen values higher than 1.0. The highest loadings are placed with the same factor and the PCA scatterplot can be developed from principal component I (factor I) and principal component II (factor II). Cluster analysis (CA) with the taxonomic distance was performed using the Euclidean distance and a phenogram was developed with the unweighted pair-group method using arithmetic average (UPGMA).

Table 8 List of Dilleniaceae species in Thailand investigated in present study.

Taxa	Location	Collection number	Remark
Acrotrema costatum Jack	Songkhla Province	S. Rakarcha 88	-
Dillenia aurea Sm.	Chaiyaphum Province	S. Rakarcha 60	-
D. excelsa (Jack) Martelli ex Gilg.	Trang Province	S. Rakarcha 83	-
D. grandifolia Wall. ex Hook. f. & Thomson	Trang Province	S. Rakarcha 90	-
D. hookeri Pierre	Ubon Ratchathani Province	S. Rakarcha 12	-
D. indica L.	Tak Province	S. Rakarcha 92	-
D. obovata (Blume) Hoogland	Trang Province	S. Rakarcha 89	-
D. ovata Wall. ex Hook.f. & Thomson	Yasothon Province	S. Rakarcha 11	-
D. parviflora Griff.	Chiang Rai Province	S. Rakarcha 71	-
D. pentagyna Roxd.	Chaiyaphum Province	S. Rakarcha 37	-
D. philippinensis Rolfe	Mahasarakham Province	S. Rakarcha 94	cultivated
D. reticulata King	Songkhla Province	S. Rakarcha 91	-
D. scabrella (D. Don) Roxb. ex Wall.	Loei Province	S. Rakarcha 69	-
D. suffruticosa (Griff.) Martelli	Bangkok Province	S. Rakarcha 26	cultivated
Tetracera indica (Christm.& Panz.) Merr.	Phatthalung Province	S. Rakarcha 87	-
T. loureiri (Finet & Gagnep.) Pierre ex W. G. Craib	Ubon Ratchathani Province	S. Rakarcha 51	-
T. sarmentosa (L.) Vahl	Trang Province	S. Rakarcha 94	-
T. scandens (L.) Merr.	Songkhla Province	S. Rakarcha 85	-

Table 9 Pollen morphological characters and character states used in numerical analysis of 18 species of Dilleniaceae in Thailand.

No.	Characters	Character status
1	Polar axis (P)	Scale
2	Equatorial axis (E)	Scale
3	Polar axis/Equatorial axis ratio (P/E)	Scale
4	Exine thickness (Et)	Scale
5	Distance between apices of two ectocolpi (d)	Scale
6	Apocolpium index (d/D)	Scale
7	Colpus length (Clg)	Scale
8	Colpus width (Clt)	Scale
9	Colpus length/Colpus width (Clg/Clt)	Scale
10	Colpus length/Polar axis (Clg/P)	Scale
11	Porus lenght (Prg)	Scale
12	Porus width (Prt)	Scale
13	Porus lenght/Porus width (Prg/Prt)	Scale
14	Pollen shape (Ps)	Suboblate (0)
		Oblate spheroidal (1)
		Prolate-spheroidal (2)
		Subprolate (3)
15	Size (S)	Small (0)
		Medium (1)
16	Exine sculpturing types (Es)	Punctate (0)
		Reticulate (1)
		Regulate (2)
		Reticulate-verrucose (3)
17	Aperture type (A)	Tricolporate (0)
		Tricolpate (1)
		Tricolpate and tetracolpate (2)
18	P/E ratio	P/E ratio less than 1 (0)
		P/E ratio more than 1 (1)

3.4 Results

The pollen morphologies of the family Dilleniaceae in Thailand were observed and analyzed under LM and SEM. The results are summarized in Tables 10-11. The general characteristic of pollen is monad, radially symmetrical and isopolar. The information of the taxa are described as follows.

Table 10 Pollen morphological characteristic of Dilleniaceae in Thailand.

Species	**Shape**	**Size**	**Aperture**	**Exine sculpturing**
Acrotrema costatum	Oblate spheroidal	Small	Tricolpate	Punctate
Dillenia aurea	Oblate spheroidal	Medium	Tricolpate	Reticulate
D. excelsa	Oblate spheroidal	Small	Tricolpate	Reticulate
D. grandifolia	Oblate spheroidal	Small	Tricolpate	Reticulate
D. hookeri	Suboblate	Small	Tricolpate	Reticulate
D. indica	Suboblate	Small	Tricolpate	Punctate
D. obovata	Oblate spheroidal	Small	Tricolpate	Rugulate
D. ovata	Oblate spheroidal	Small	Tricolpate, Tetracolpate	Reticulate
D. parviflora	Oblate spheroidal	Small	Tricolpate	Punctate
D. pentagyna	Oblate spheroidal	Small	Tricolpate	Reticulate-verrucose
D. philippinensis	Oblate spheroidal	Medium	Tricolpate, Tetracolpate	Punctate
D. reticulata	Suboblate	Small	Tricolpate	Reticulate
D. scabrella	Oblate spheroidal	Small	Tricolpate	Reticulate-verrucose
D. suffruticosa	Suboblate	Small	Tricolpate	Punctate
Tetracera indica	Subprolate	Small	Tricolporate	Punctate
T. loureiri	Prolate-spheroidal	Small	Tricolporate	Punctate
T. sarmentosa	Prolate-spheroidal	Small	Tricolporate	Punctate
T. scandens	Prolate-spheroidal	Small	Tricolporate	Punctate

Table 11 Pollen morphometric characteristics and measurements of Dilleniaceae in Thailand. numbers refer to minimum-maximum (mean ± standard deviation), polar axis (P), equatorial axis (E), polar axis/equatorial axis (P/E) ratio, exine thickness (Et), distance between the apices of two ectocolpi (d), apocolpium index (d/D), colpus length (Clg), colpus width (Clt), colpus length/colpus width (Clg/Clt), colpus length/polar axis (Cl/P), porus length (Prg), porus width (Prt), porus length/porus width (Prg/Prt) and not found this characteristic (-).

Species	**P (µm) (Mean ± S.D.)**	**E=D (µm) (Mean ± S.D.)**	**P/E ratio**	**Et (µm) (Mean ± S.D.)**	**d**	**d/D**
Acrotrema costatum	18.21-24.34 (20.77±1.63)	20.65-26.61 (23.28±1.26)	0.892	0.72-1.39 (1.01±0.19)	12.42-17.27 (15.81±0.99)	0.68
Dillenia aurea	19.84-26.68 (22.85±1.72)	23.18-28.98 (25.93±1.63)	0.881	0.80-1.87 (1.40±0.31)	9.47-14.69 (11.75±1.64)	0.45
D. excelsa	14.93-19.54 (16.78±1.06)	17.19-20.82 (18.79±1.04)	0.893	0.68-1.24 (0.91±0.13)	7.10-12.01 (9.67±1.76)	0.51
D. grandifolia	14.16-19.49 (15.98±1.03)	14.92-21.24 (17.45±1.43)	0.916	0.70-1.28 (0.99±0.13)	9.02-10.92 (10.13±0.57)	0.58
D. hookeri	15.18-20.38 (17.30±1.43)	18.49-24.79 (20.86±1.41)	0.829	0.69-1.39 (0.98±0.17)	7.50-16.02 (11.12±2.68)	0.53
D. indica	16.84-20.21 (18.21±0.73)	19.59-23.74 (21.26±0.94)	0.857	0.69-1.39 (0.98±0.18)	10.19-13.8 (11.79±0.92)	0.55
D. obovata	17.62-22.16 (19.38±1.08)	18.83-24.66 (21.05±1.35)	0.921	0.66-1.33 (1.01±0.18)	9.21-14.10 (11.79±1.37)	0.56
D. ovata	18.08-21.43 (19.26±0.83)	19.24-21.95 (20.43±0.74)	0.943	0.66-1.17 (0.85±0.12)	8.33-13.12 (9.50±1.22)	0.47
D. parviflora	13.01-15.89 (14.48±0.83)	14.59-17.64 (15.61±0.72)	0.928	0.74-1.66 (1.17±0.24)	6.20-12.45 (8.21±2.01)	0.53
D. pentagyna	13.88-23.65 (17.63±2.24)	15.29-23.77 (18.00±1.92)	0.979	0.68-1.46 (1.04±0.23)	5.26-12.24 (9.53±2.03)	0.53
D. philippinensis	29.54-33.50 (31.39±1.22)	31.64-36.74 (34.51±1.45)	0.909	0.94-1.64 (1.26±0.20)	12.61-15.21 (13.61±1.05)	0.39
D. reticulata	12.57-15.25 (13.66±0.67)	13.99-17.38 (15.64±0.86)	0.873	0.70-1.36 (0.95±0.19)	6.84-10.80 (9.31±1.01)	0.59
D. scabrella	17.51-21.42 (18.87±0.96)	18.14-22.02 (20.05±0.98)	0.941	1.04-2.32 (1.58±0.25)	6.93-8.68 (7.64±0.65)	0.38
D. suffruticosa	17.60-20.79 (19.19±0.72)	20.04-25.01 (23.36±0.99)	0.821	0.66-1.53 (1.00±0.18)	8.33-12.17 (10.65±1.57)	0.46
Tetracera indica	16.96-20.90 (19.17±0.80)	11.86-17.96 (16.06±1.43)	1.194	0.51-1.29 (0.91±0.17)	3.33-5.52 (4.58±0.65)	0.23
T. loureiri	16.42-19.42 (18.09±0.57)	15.08-17.85 (16.79±0.58)	1.077	0.74-1.23 (1.03±0.11)	4.47-6.40 (5.18±0.50)	0.29
T. sarmentosa	15.11-17.66 (16.41±0.52)	14.53-17.34 (15.89±0.53)	1.033	0.49-1.41 (0.92±0.17)	3.29-5.26 (4.52±0.52)	0.28
T. scandens	14.68-19.28 (16.97±0.98)	13.77-18.18 (16.04±0.83)	1.058	0.71-1.33 (0.94±0.71)	4.11-6.23 (4.97±0.69)	0.30

Table 11 (continued)

Species	Clg (µm)	Clt (µm)	Clg/Clt	Clg/P	Prg	Prt	Prg/Prt
Acrotrema costatum	3.60-5.60 (4.60±0.65)	1.88-3.67 (2.68±0.67)	1.72	0.22	-	-	-
Dillenia aurea	7.00-11.16 (9.14±1.65)	2.33-3.75 (3.04-0.46)	3.01	0.40	-	-	-
D. excelsa	5.94-11.30 (8.37±1.54)	1.31-3.21 (1.98±0.54)	4.23	0.49	-	-	-
D. grandifolia	3.94-7.12 (5.81±1.29)	1.78-2.37 (2.02±0.21)	2.87	0.36	-	-	-
D. hookeri	10.26-12.35 (11.49±0.78)	2.50-3.33 (2.84±0.29)	4.05	0.66	-	-	-
D. indica	5.79-8.26 (6.95±0.82)	2.50-3.97 (2.89±0.46)	2.40	0.38	-	-	-
D. obovata	7.68-12.56 (9.79±1.65)	1.46-2.08 (1.79±0.20)	5.46	0.51	-	-	-
D. ovata	8.02-10.66 (9.40±0.96)	1.18-2.67 (2.21±0.46)	4.25	0.49	-	-	-
D. parviflora	7.18-11.00 (9.35±1.23)	1.65-2.10 (1.92±0.13)	4.87	0.65	-	-	-
D. pentagyna	8.20-14.21 (10.01±2.21)	1.74-2.75 (2.17±0.33)	4.61	0.57	-	-	-
D. philippinensis	7.75-12.87 (10.27±1.92)	2.84-4.24 (3.26±0.47)	3.15	0.32	-	-	-
D. reticulata	3.36-6.25 (5.31±0.84)	1.55-2.01 (1.82±0.16)	2.92	0.39	-	-	-
D. scabrella	6.07-9.47 (7.87±1.26)	1.56-2.23 (1.82±0.24)	4.32	0.41	-	-	-
D. suffruticosa	8.98-11.48 (10.56±0.75)	1.65-3.67 (2.39±0.67)	4.42	0.55	-	-	-
Tetracera indica	12.03-15.29 (13.73±1.24)	1.33-1.98 (1.72±0.19)	7.98	0.71	2.25-2.89 (2.55±0.31)	1.32-1.87 (1.60±0.19)	1.59
T. loureiri	10.50-14.07 (12.53±1.20)	1.45-1.95 (1.74±0.16)	7.20	0.74	2.55-2.95 (2.79±0.16)	1.45-1.78 (1.57±0.13)	1.78
T. sarmentosa	11.27-15.13 (13.25±1.20)	1.45-2.20 (1.74±0.26)	7.61	0.81	1.85-2.87 (2.41±0.40)	1.45-1.85 (1.67±0.14)	1.44
T. scandens	10.77-13.74 (12.30±0.91)	1.65-2.44 (1.98±0.33)	6.21	0.72	1.95-2.78 (2.54±0.34)	1.45-2.20 (1.45±2.20)	1.75

3.4.1 Description of pollen morphology

1. *Acrotrema costatum* (Figure 33)

The pollens are monad, small size, radial symmetry, oblate spheroidal shape, tricolpate aperture and punctate in exine sculpturing. The polar axis (P) ranged from 18.21-24.34 (20.77±1.63) µm. The equatorial diameter (E) ranged from 20.65-26.61 (23.28±1.26) µm. The exine thickness of the pollen ranged from 0.72-1.39 (1.01±0.19) µm. The distance between apices of two ectocolpi (d) ranged from 12.42-17.27 (15.81±0.99) µm. The colpus length ranged from 3.60-5.60 (4.60±0.65) µm and the colpus width ranged from 1.88-3.67 (2.68±0.67) µm (Tables 10-11).

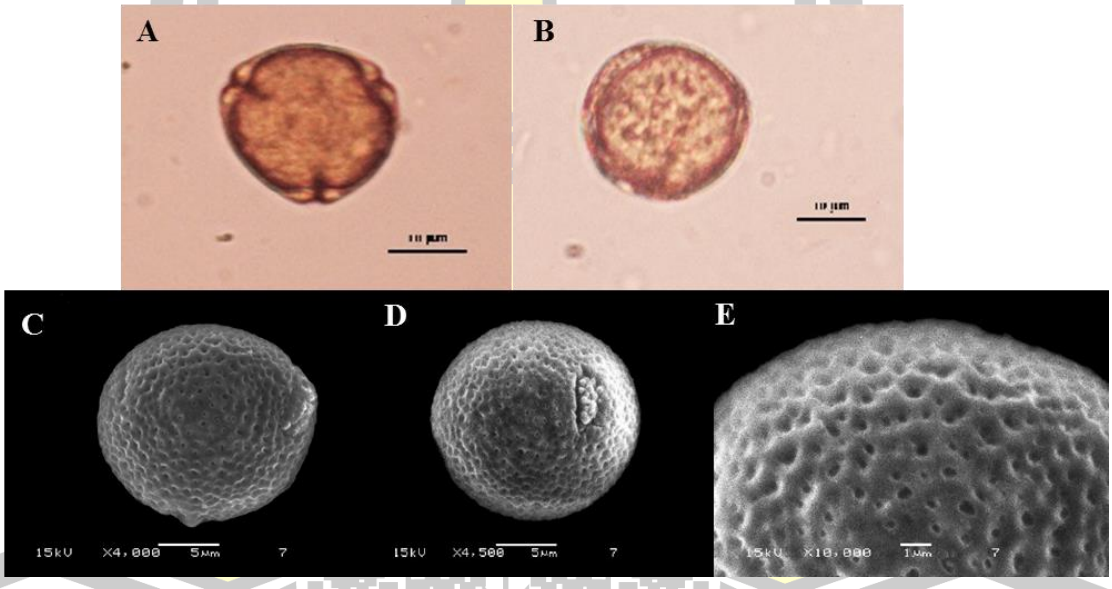


Figure 33 Pollen morphology of *Acrotema costatum*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

2. *Dillenia aurea* (Figure 34)

The pollens are monad, small size, radial symmetry, tricolplate aperture, oblate spheroidal shape, tricolpate aperture and reticulate in exine sculpturing. The polar axis ranged from 19.84-26.68 (22.85±1.72) µm. The equatorial diameter ranged from 23.18-28.98 (25.93±1.63) µm. The exine thickness of the pollen ranged from 0.80-1.87 (1.40±0.31) µm. The distance between apices of two ectocolpi ranged from 9.47-14.69 (11.75±1.64) µm. The colpus length ranged from 7.00-11.16 (9.14±1.65) µm and the colpus width ranged from 2.33-3.75 (3.04±0.46) µm (Tables 10-11).

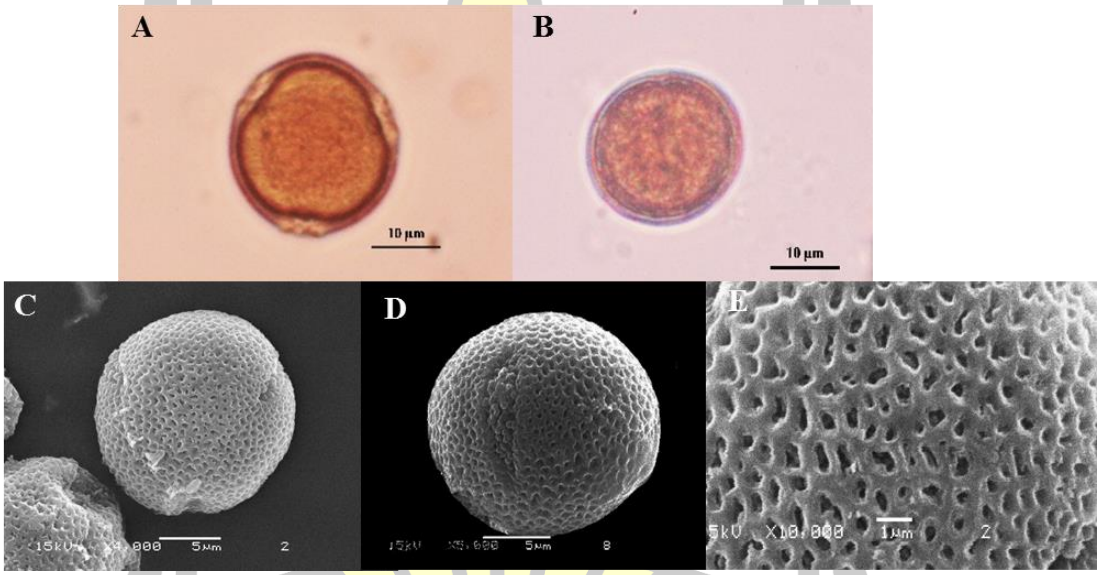


Figure 34 Pollen morphology of *Dillenia aurea*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

3. *Dillenia excelsa* (Figure 35)

The pollens are monad, small size, radial symmetry, oblate spheroidal shape, tricolpate aperture and reticulate in exine sculpturing. The polar axis ranged from 19.93-19.54 (16.78±1.06) µm. The equatorial diameter ranged from 17.19-20.82 (18.79±1.04) µm. The exine thickness of the pollen ranged from 0.68-1.24 (0.91±0.13) µm. The distance between apices of two ectocolpi ranged from 7.01-12.01 (9.67±1.76) µm. The colpus length ranged from 5.94-11.30 (8.37±1.54) µm and the colpus width ranged from 1.31-3.21 (1.98±0.54) µm (Tables 10-11).

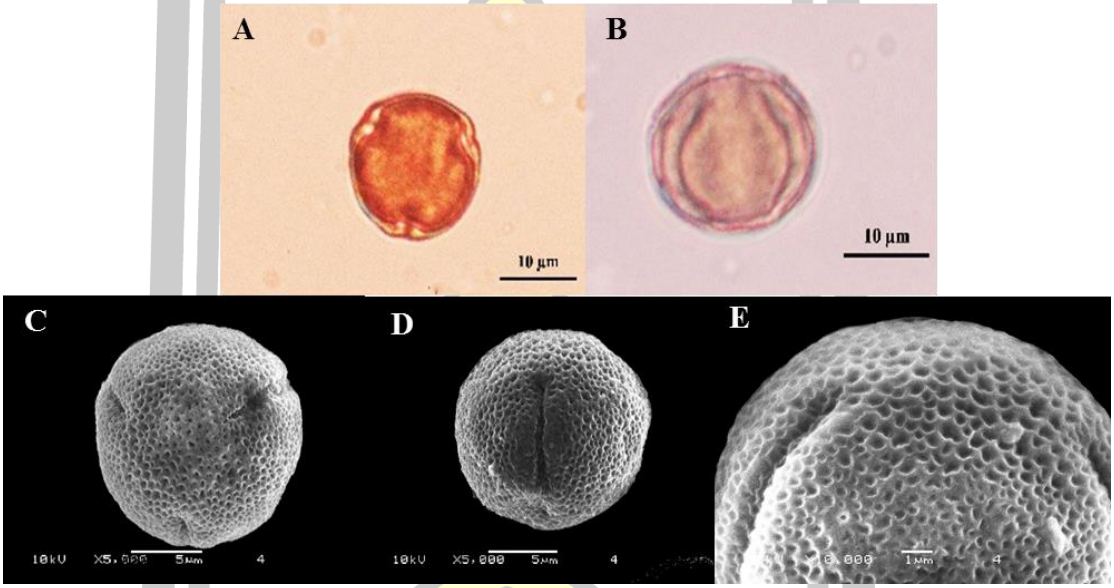


Figure 35 Pollen morphology of *Dillenia excelsa*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

4. *Dillenia grandifolia* (Figure 36)

The pollens are monad, small size, radial symmetry, oblate spheroidal shape, tricolpate aperture and reticulate in exine sculpturing. The polar axis ranged from 14.16-19.49 (15.98±1.03) µm. The equatorial diameter ranged from 14.92-21.24 (17.45±1.43) µm. The exine thickness of the pollen ranged from 0.70-1.28 (0.99±0.13) µm. The distance between apices of two ectocolpi ranged from 9.02-10.92 (10.13±0.57) µm. The colpus length ranged from 3.94-7.12 (5.81±1.29) µm and the colpus width ranged from 1.78-2.37 (2.02±0.21) µm (Tables 10-11).

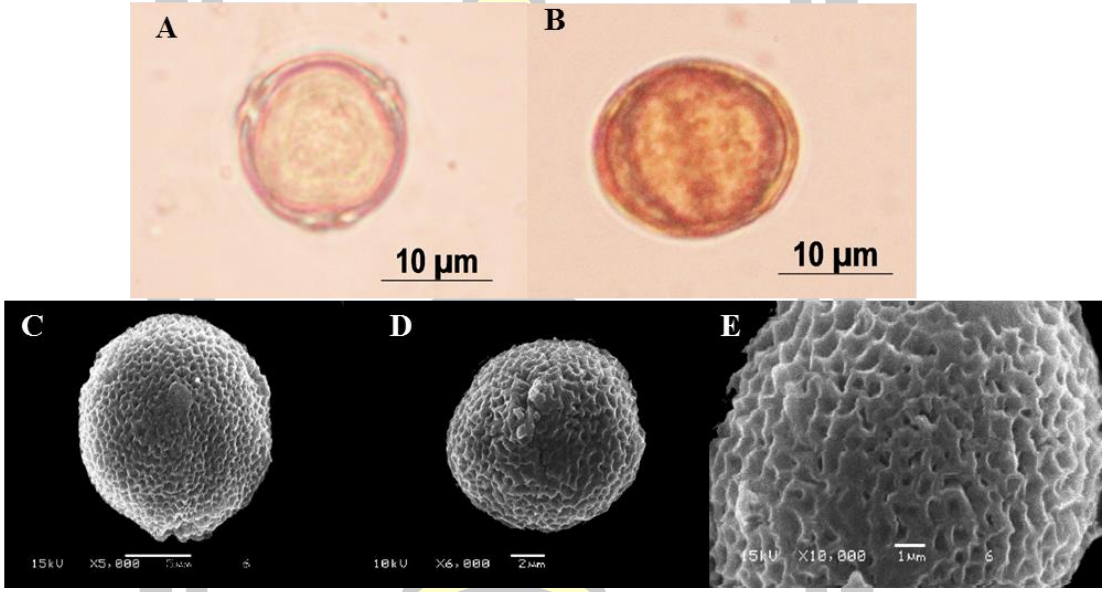


Figure 36 Pollen morphology of *Dillenia grandifolia*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm; C, D = 5 µm; E = 1 µm.

5. *Dillenia hookeri* (Figure 37)

The pollens are monad, small size, radial symmetry, subobolate shape, tricolpate aperture and reticulate in exine sculpturing. The polar axis ranged from 15.18-20.38 (17.30±1.43) µm. The equatorial diameter ranged from 18.49-24.79 (20.86±1.41) µm. The exine thickness of the pollen ranged from 0.69-1.39 (0.98±0.17) µm. The distance between apices of two ectocolpi ranged from 7.50-16.02 (11.12±2.68) µm. The colpus length ranged from 10.26-12.35 (11.49±0.78) µm and the colpus width ranged from 2.50-3.33 (2.84±0.29) µm (Tables 10-11).

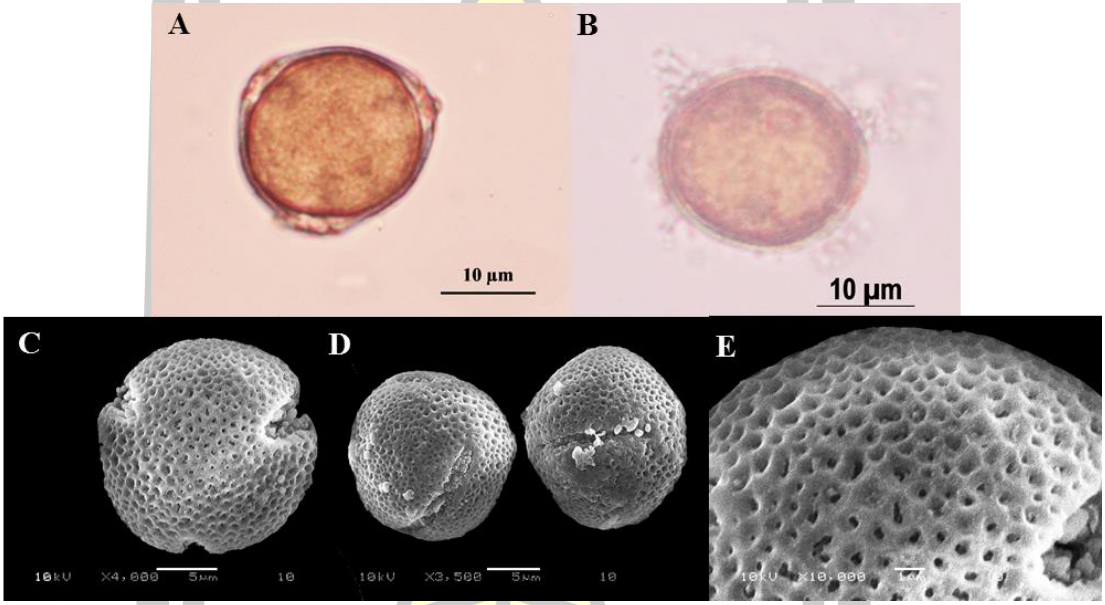


Figure 37 Pollen morphology of *Dillenia hookeri*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

6. *Dillenia indica* (Figure 38)

The pollens are monad, small size, radial symmetry, subobolate shape, tricolpate aperture and punctate in exine sculpturing. The polar axis ranged from 16.84-20.21 (18.21±0.73) µm. The equatorial diameter ranged from 19.59-23.74 (21.26±0.94) µm. The exine thickness of the pollen ranged from 0.69-1.39 (0.98±0.18) µm. The distance between apices of two ectocolpi ranged from 10.19-13.80 (11.79±0.29) µm. The colpus length ranged from 5.79-8.26 (6.95±0.82) µm and the colpus width ranged from 2.50-3.97 (2.89±0.46) µm (Tables 10-11).

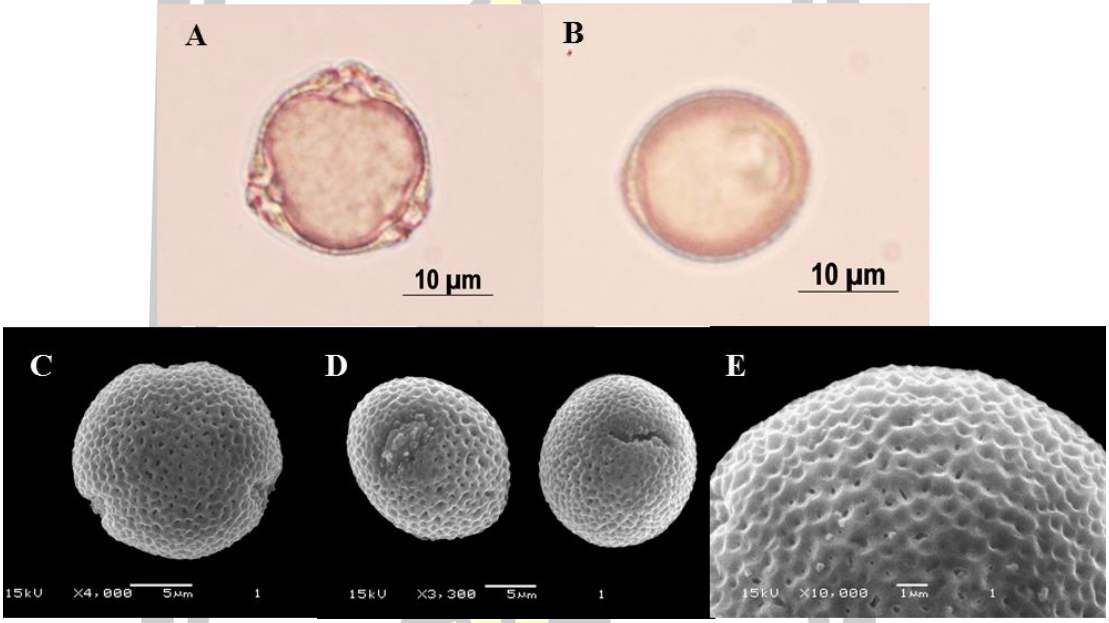


Figure 38 Pollen morphology of *Dillenia indica*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

7. *Dillenia obovata* (Figure 39)

The pollens are monad, small size, radial symmetry, obolate spheroidal shape, tricolpate aperture and regulate in exine sculpturing. The polar axis ranged from 17.62-22.16 (19.38±1.08) µm. The equatorial diameter ranged from 18.83-24.66 (21.05±1.35) µm. The exine thickness of the pollen ranged from 0.69-1.33 (1.01±0.18) µm. The distance between apices of two ectocolpi ranged from 9.21-14.10 (11.79±1.37) µm. The colpus length ranged from 7.68-12.56 (6.95±0.82) µm and the colpus width ranged from 1.46-2.08 (1.79±0.20) µm (Tables 10-11).

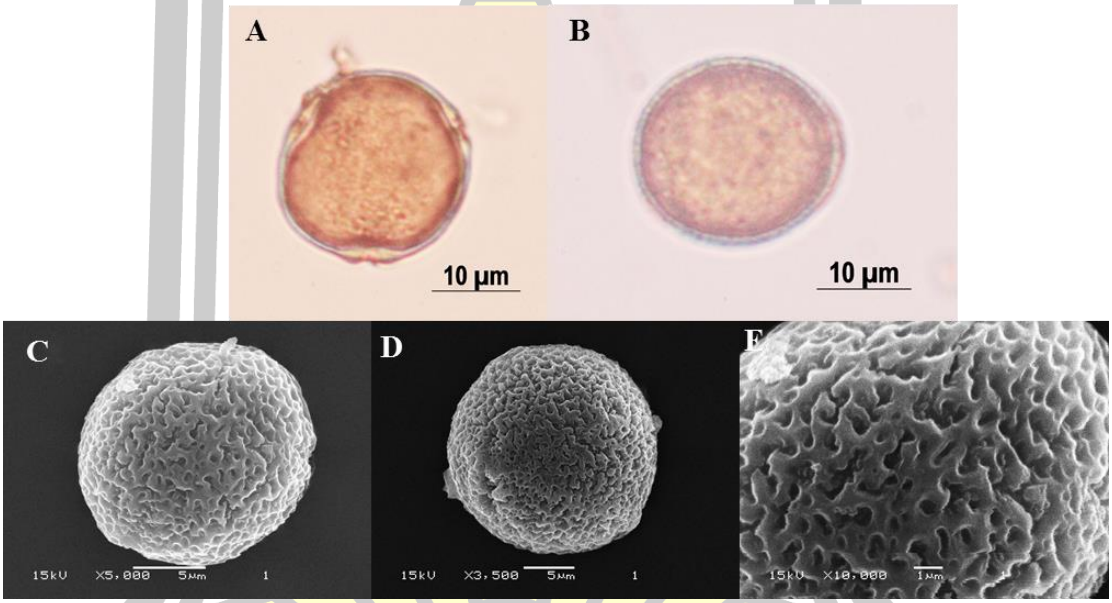


Figure 39 Pollen morphology of *Dillenia obovata*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm; C, D = 5 µm; E = 1 µm.

8. *Dillenia ovata* (Figure 40)

The pollens are monad, small size, radial symmetry, obolate spheroidal shape, tricolpate and tetracolpate aperture and reticulate in exine sculpturing. The polar axis ranged from 18.08-21.43 (19.26±0.83) µm. The equatorial diameter ranged from 19.24-21.95 (20.43±0.74) µm. The exine thickness of the pollen ranged from 0.66-1.17 (0.85±0.12) µm. The distance between apices of two ectocolpi ranged from 8.33-13.12 (9.50±1.22) µm. The colpus length ranged from 8.02-10.66 (9.40±0.96) µm and the colpus width ranged from 1.18-2.67 (2.21±0.46) µm (Tables 10-11).

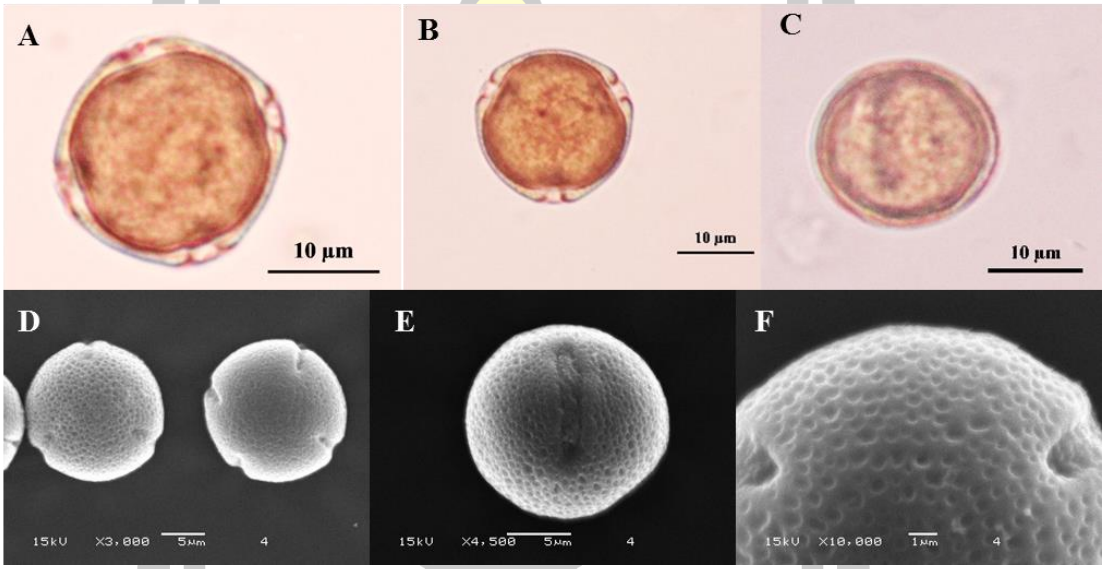


Figure 40 Pollen morphology of *Dillenia ovata*.

(A-C) LM micrographs: (A) polar view of tetracolpate aperture, (B) polar view of tricolpate aperture, (C) equatorial view. (D-F) SEM micrographs: (D) polar view, (E) equatorial view, (F) exine sculpturing. Scale bar A, B, C = 10 µm, D, E = 5 µm, F = 1 µm.

9. *Dillenia parviflora* (Figure 41)

The pollens are monad, small size, radial symmetry, obolate spheroidal shape, tricolpate aperture and punctate in exine sculpturing. The polar axis ranged from 13.01-15.89 (14.48±0.83) µm. The equatorial diameter ranged from 14.59-17.64 (15.61±0.72) µm. The exine thickness of the pollen ranged from 0.74-1.66 (1.17±0.24) µm. The distance between apices of two ectocolpi ranged from 6.20-12.45 (8.21±2.01) µm. The colpus length ranged from 7.18-11.00 (9.35±1.23) µm and the colpus width ranged from 1.65-2.10 (1.92±0.13) µm (Tables 10-11).

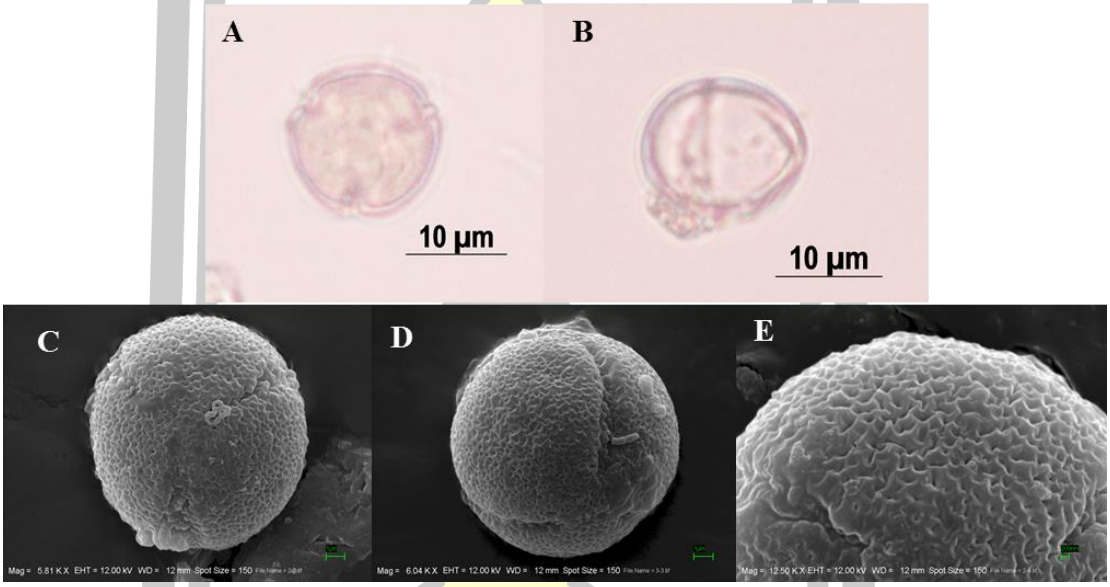


Figure 41 Pollen morphology of *Dillenia parviflora*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 1 µm, E = 0.2 µm.

10. *Dillenia pentagyna* (Figure 42)

The pollens are monad, small size, radial symmetry, oblate spheroidal shape, tricolpate aperture and reticulate-verrucose in exine sculpturing. The polar axis ranged from 13.88-23.65 (17.63±2.24) µm. The equatorial diameter ranged from 15.29-23.77 (18.00±1.92) µm. The exine thickness of the pollen ranged from 0.68-1.46 (1.04±0.23) µm. The distance between apices of two ectocolpi ranged from 5.26-12.24 (9.53±2.03) µm. The colpus length ranged from 8.20-14.21 (10.01±2.21) µm and the colpus width ranged from 1.74-2.75 (2.17±0.33) µm (Tables 10-11).

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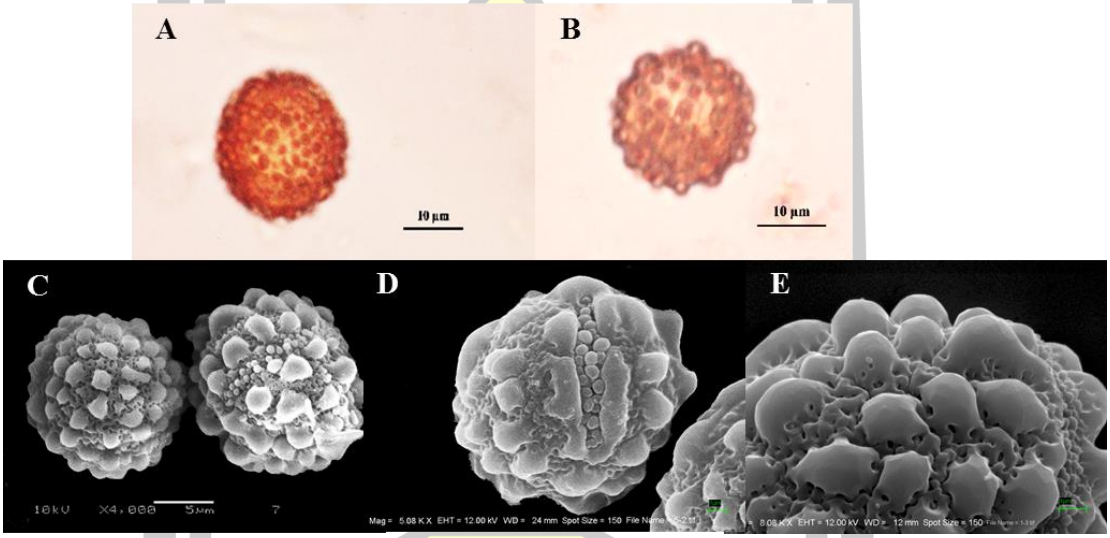

Figure 42 Pollen morphology of *Dillenia pentagyna*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C = 5 µm, D = 2 µm, E = 1 µm.

11. *Dillenia philippinensis* (Figure 43)

The pollens are monad, medium size, radial symmetry, obolate spheroidal shape, tricolpate and tetracolpate aperture and punctate in exine sculpturing. The polar axis ranged from 29.54-33.50 (31.39±1.22) µm. The equatorial diameter ranged from 31.64-36.74 (34.51±1.45) µm. The exine thickness of the pollen ranged from 0.94-1.64 (1.26±0.20) µm. The distance between apices of two ectocolpi ranged from 12.61-15.21 (13.61±1.05) µm. The colpus length ranged from 7.75-12.87 (10.27±1.92) µm and the colpus width ranged from 2.84-4.24 (3.26±0.47) µm (Tables 10-11).

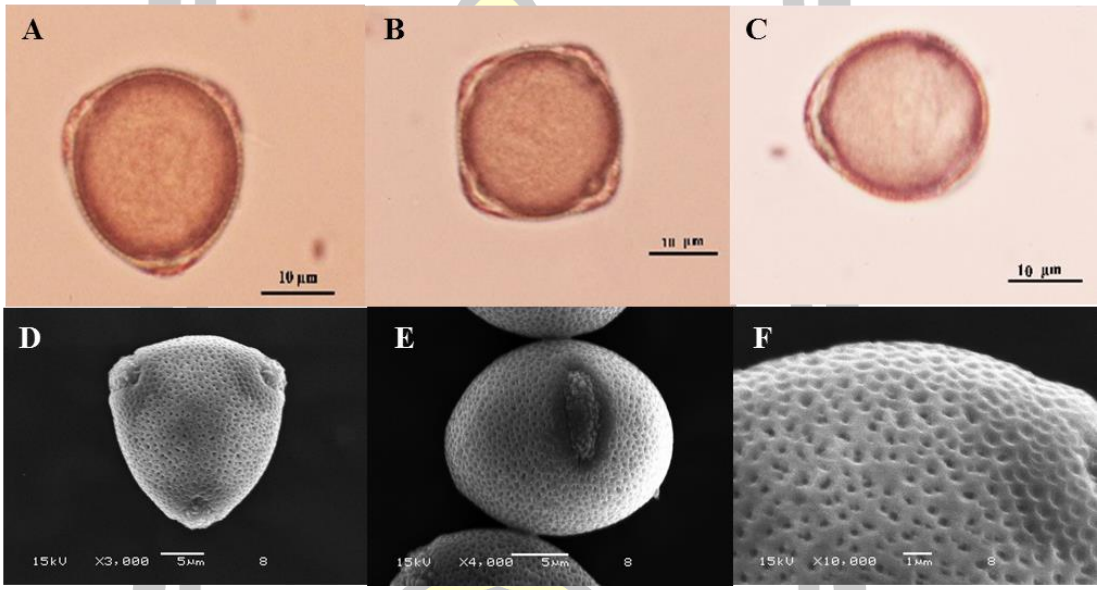

Figure 43 Pollen morphology of *Dillenia philippinensis*.

(A-C) LM micrographs: (A) Polar view of tetracolpate aperture, (B) Polar view of tricolpate aperture, (C) Equatorial view. (D-F) SEM micrographs: (D) Polar view, (E) Equatorial view, (F) Exine sculpturing. Scale bar: A, B, C = 10 µm, D, E = 5 µm, F = 1 µm.

12. *Dillenia reticulata* (Figure 44)

The pollens are monad, small size, radial symmetry, suboblate shape, tricolpate aperture and reticulate in exine sculpturing. The polar axis ranged from 12.57-15.25 (13.66±0.67) µm. The equatorial diameter ranged from 13.99-17.38 (15.64±0.86) µm. The exine thickness of the pollen ranged from 0.70-1.36 (0.95±0.19) µm. The distance between apices of two ectocolpi ranged from 6.84-10.80 (9.31±1.01) µm. The colpus length ranged from 3.36-6.25 (5.31±0.84) µm and the colpus width ranged from 1.55-2.01 (1.82±0.16) µm (Tables 10-11).

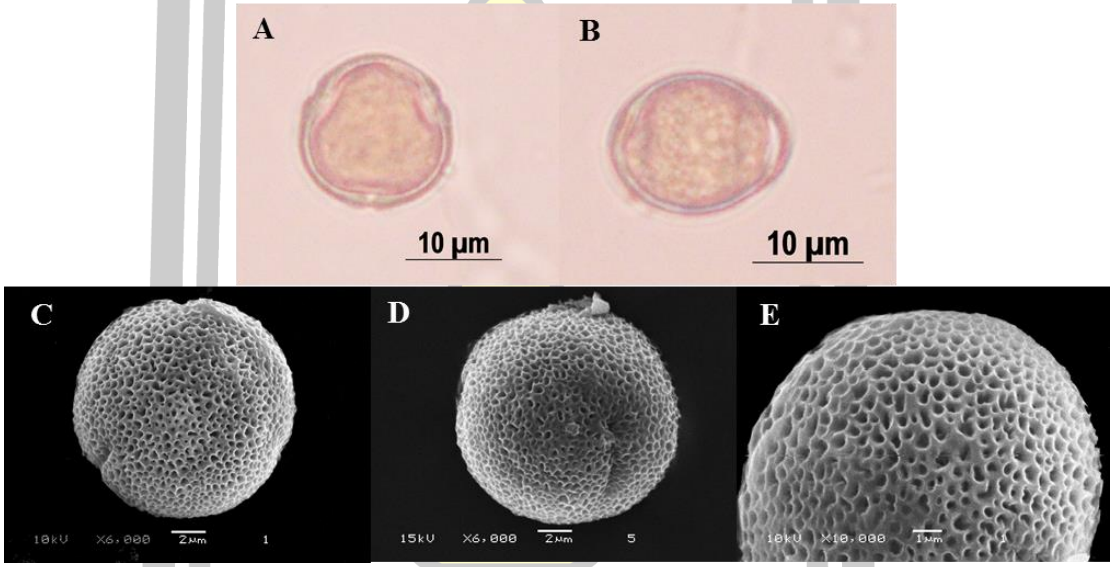

Figure 44 Pollen morphology of *Dillenia pentagyna*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 2 µm, E = 1 µm.

13. *Dillenia scabrella* (Figure 45)

The pollens are monad, small size, radial symmetry, oblate spheroidal shape, tricolpate aperture and reticulate-verrucose in exine sculpturing. The polar axis ranged from 17.51-21.42 (18.87±0.96) µm. The equatorial diameter ranged from 18.14-22.02 (20.05±0.98) µm. The exine thickness of the pollen ranged from 1.04-2.32 (1.58±0.25) µm. The distance between apices of two ectocolpi ranged from 6.93-8.68 (7.64±0.65) µm. The colpus length ranged from 6.07-9.47 (7.87±1.26) µm and the colpus width ranged from 1.56-2.23 (1.82±0.24) µm (Tables 10-11).

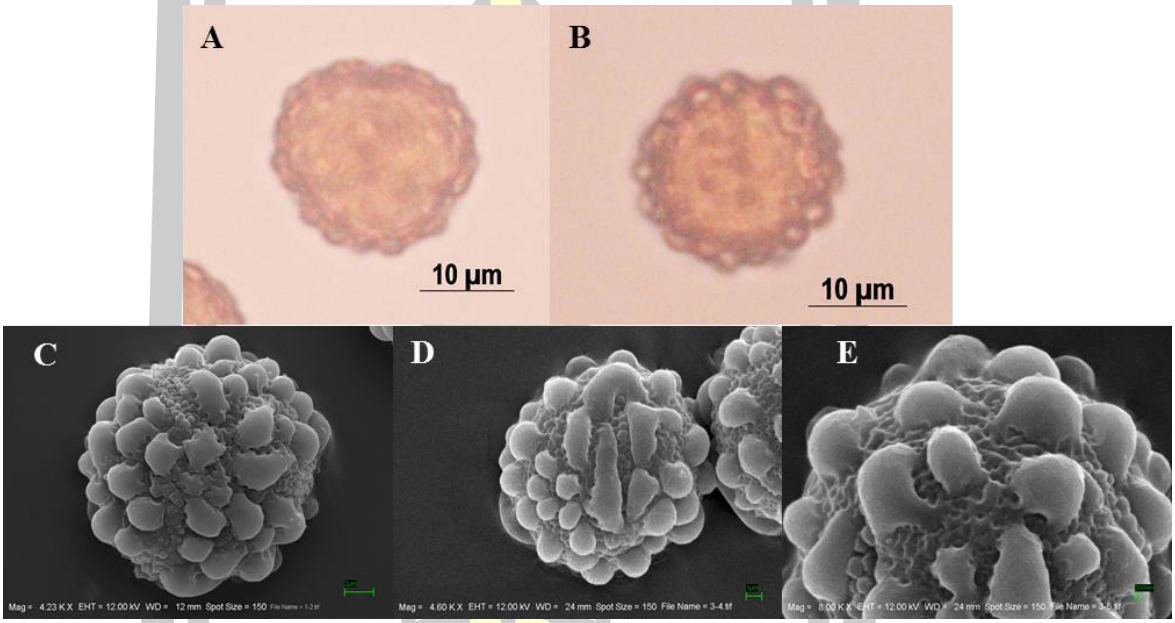

Figure 45 Pollen morphology of *Dillenia scabrella*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 2 µm, E = 0.2 µm.

14. *Dillenia suffruticosa* (Figure 46)

The pollens are monad, small size, radial symmetry, suboblate shape, tricolpate aperture and punctate in exine sculpturing. The polar axis ranged from 17.60-20.79 (19.19±0.72) µm. The equatorial diameter ranged from 20.04-25.01 (23.36±0.99) µm. The exine thickness of the pollen ranged from 0.66-1.53 (1.00±0.18) µm. The distance between apices of two ectocolpi ranged from 8.33-12.17 (10.65±1.57) µm. The colpus length ranged from 8.98-11.48 (10.56±0.75) µm and the colpus width ranged from 1.65-3.67 (2.39±0.67) µm (Tables 10-11).

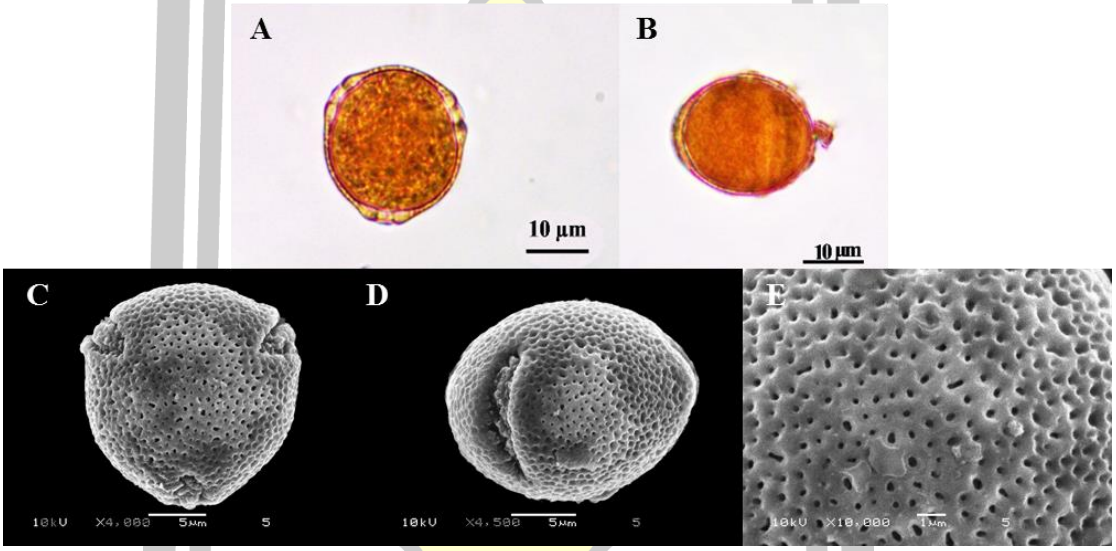

Figure 46 Pollen morphology of *Dillenia suffruticosa*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

15. *Tetracera indica* (Figure 47)

The pollens are monad, small size, radial symmetry, subprolate shape, tricolporate aperture and punctate in exine sculpturing. The polar axis ranged from 16.96-20.90 (19.17±0.80) µm. The equatorial diameter ranged from 11.86-17.96 (16.06±1.43) µm. The exine thickness of the pollen ranged from 0.51-1.29 (0.91±0.17) µm. The distance between apices of two ectocolpi ranged from 3.33-5.52 (4.58±0.65) µm. The colpus length ranged from 12.03-15.29 (13.73±1.24) µm and the colpus width ranged from 1.33-1.98 (1.72±0.19) µm. The porus length ranged from 2.25-2.89 (2.55±0.31) µm. The porus width ranged from 1.32-1.87 (1.60±0.19) µm (Tables 10-11).

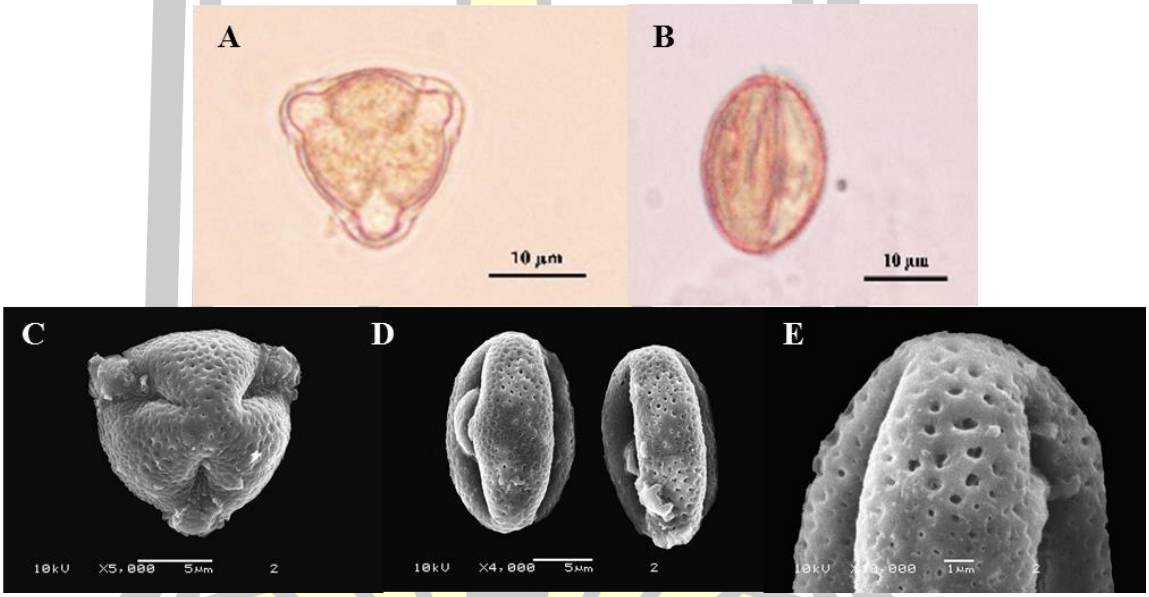

Figure 47 Pollen morphology of *Tetracera indica*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

16. *Tetracera loureiri* (Figure 48)

The pollens are monad, small size, radial symmetry, prolate-spheroidal shape, tricolporate aperture and punctate in exine sculpturing. The polar axis ranged from 16.42-19.42 (18.09±0.57) µm. The equatorial diameter ranged from 15.08-17.85 (16.79±0.58) µm. The exine thickness of the pollen ranged from 0.74-1.23 (1.03±0.11) µm. The distance between apices of two ectocolpi ranged from 4.47-6.40 (5.18±0.50) µm. The colpus length ranged from 10.50-14.07 (12.53±1.20) µm and the colpus width ranged from 1.45-1.95 (1.74±0.16) µm. The porus length ranged from 2.55-2.95 (2.79±0.16) µm. The porus width ranged from 1.45-1.78 (1.57±0.13) µm (Tables 10-11).

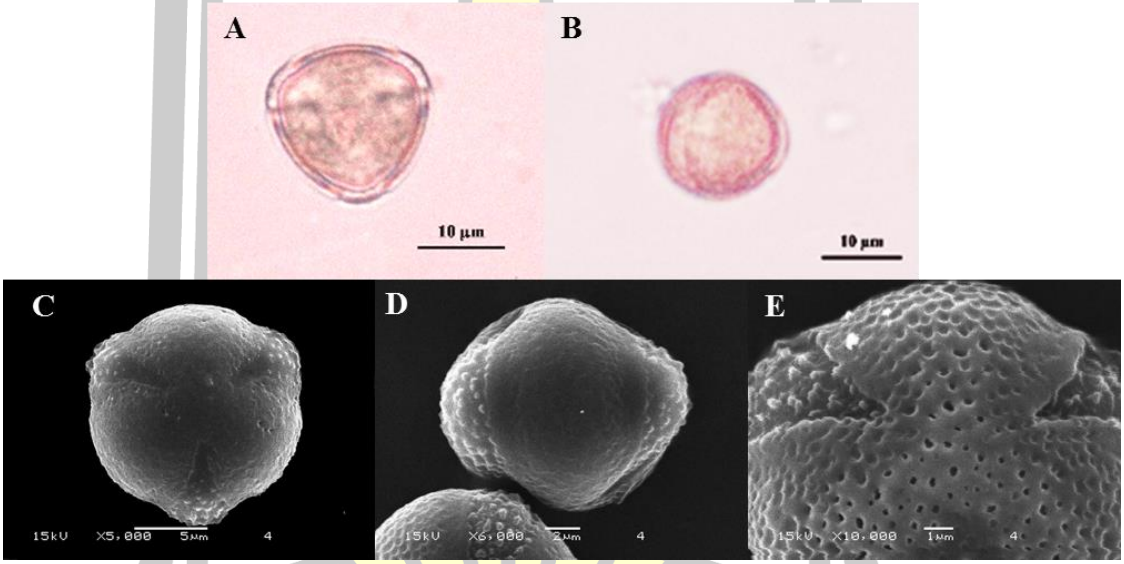

Figure 48 Pollen morphology of *Tetracera loureiri*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

17. *Tetracera sarmentosa* (Figure 49)

The pollens are monad, small size, radial symmetry, prolate-spheroidal shape, tricolporate aperture and punctate in exine sculpturing. The polar axis ranged from 15.11-17.66 (16.41±0.52) µm. The equatorial diameter ranged from 14.53-17.34 (15.89±0.53) µm. The exine thickness of the pollen ranged from 0.49-1.41 (0.92±0.17) µm. The distance between apices of two ectocolpi ranged from 3.29-5.26 (4.52±0.52) µm. The colpus length ranged from 11.27-15.13 (13.25±1.20) µm and the colpus width ranged from 1.45-2.20 (1.74±0.26) µm. The porus length ranged from 1.85-2.87 (2.41±0.40) µm. The porus width ranged from 1.45-1.85 (1.67±0.14) µm (Tables 10-11).

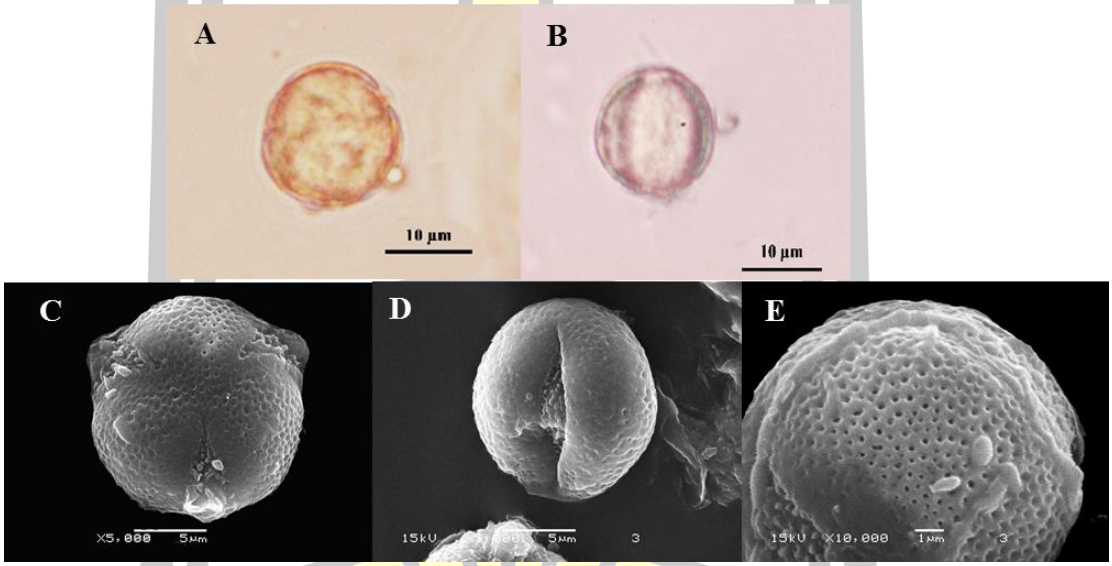

Figure 49 Pollen morphology of *Tetracera sarmentosa*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm, C, D = 5 µm, E = 1 µm.

18. *Tetracera scandens* (Figure 50)

The pollens are monad, small size, radial symmetry, prolate-spheroidal shape, tricolporate aperture and punctate in exine sculpturing. The polar axis ranged from 14.68-19.28 (16.97±0.98) µm. The equatorial diameter ranged from 13.77-18.18 (16.04±0.83) µm. The exine thickness of the pollen ranged from 0.71-1.33 (0.94±0.71) µm. The distance between apices of two ectocolpi ranged from 4.11-6.23 (4.97±0.69) µm. The colpus length ranged from 10.77-13.74 (12.30±0.91) µm and the colpus width ranged from 1.65-2.44 (1.98±0.33) µm. The porus length ranged from 1.95-2.78 (2.54±0.34) µm. The porus width ranged from 1.45-2.20 (1.45±2.20) µm (Tables 10-11).

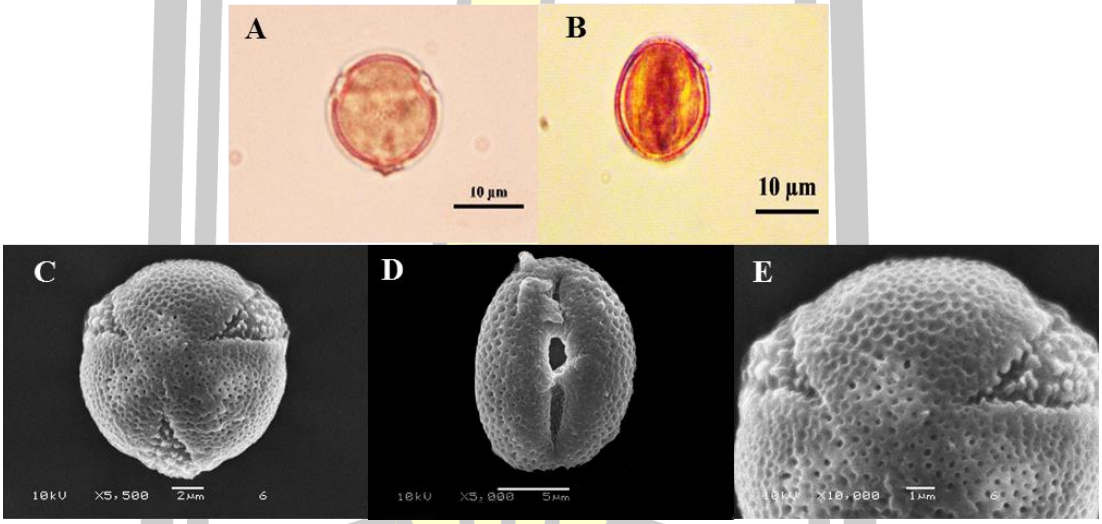

Figure 50 Pollen morphology of *Tetracera scandens*.

(A-B) LM micrographs: (A) Polar view, (B) Equatorial view. (C-E) SEM micrographs: (C) Polar view, (D) Equatorial view, (E) Exine sculpturing. Scale bar: A, B = 10 µm; C, D = 5 µm; E = 1 µm.

3.4.2 Principal component analysis (PCA)

The morphometric of all parameter was analyzed by principal component analysis method of factor analysis. PCA analysis method was done based on 18 characters states of 18 species that became evident during palynological investigation. Eigen analysis results and factor loading scores based on pollen morphology characteristic could be obtained from the output in Tables 12 and 13. After the factor analysis was performed, it could be divided into three new factors or component. Each factor contained parameters with eigen values higher than 1.0. The three components describe 87.39% of the total variance in the pollen morphological character between 18 species, in which maximum variability was contributed by the first component (60.51%), followed by the second component (18.75%) and third component (8.13%). The first principle component was most highly influenced by the apocolpium index (d/D), porus width (Prt), aperture type (A), polar axis/equatorial axis (P/E) ratio, porus length (Prg), porus length/porus width (Prg/Prt), colpus length/colpus width (Clg/Clt), polar axis/equatorial axis (P/E), pollen shape (Ps), colpus length (Clg), distance between the apices of two ectocolpi (d) and colpus length/polar axis (Clg/P). The second principle component scoring system is dominated by polar axis (P), equatorial axis (E), size (S) and colpus length (Clt). The third principle component scoring system is dominated by exine sculpturing types (Es) and exine thickness (Et).

The PCA scatter plot is created by factor score 1 (principle component 1) at X-axis and factor score 2 (principle component 2) at Y-axis. Thai Dilleniaceae species are grouped into three groups as shown in Figure 51. *D. philippinensis* is grouped in the first group. The second group comprises 13 species: *A. costatum*, *D. aurea*, *D. excelsa*, *D. grandifolia*, *D. hookeri*, *D. indica*, *D. obovata*, *D. ovata*, *D. parviflora*, *D. pentagyna*, *D. reticulata*, *D. scabrella* and *D. suffruticosa*. The third group consists of species of genera *Tetracera*: *T. indica*, *T. loureiri*, *T. sarmentosa* and *T. scandens*.

3.4.3 Cluster analysis (CA)

The UPGMA dendrogram were constructed by using Between-groups linkage method of cluster analysis on squared Euclidian distances. The cluster analysis is shown in Figure 52. The dendrogram grouped 18 species into three major clusters based on 18 characters states of 18 species that became evident during palynological investigation.

The first cluster consists of *D. philippinensis*. The second cluster consists of *A. costatum*, *D. aurea*, *D. excelsa*, *D. grandifolia*, *D. hookeri*, *D. indica*, *D. obovata*, *D. ovata*, *D. parviflora*, *D. pentagyna*, *D. reticulata*, *D. scabrella* and *D. suffruticosa*. The third cluster includes four species of genus *Tetracera*: *T. indica*, *T. loureiri*, *T. sarmentosa* and *T. scandens*.

Table 12 Factor loadings explaining relationships of variables and showing the most intrinsic characters for separation of studied Dilleniaceae species.

Variable	Factor loadings		
	Principal components		
	1	2	3
d/D	-0.94	-0.15	
Prt	0.93	-0.16	0.26
A	0.93	-0.16	0.27
P/E retio	0.93	-0.16	0.27
Prg	0.93	-0.16	0.26
Prg/Prt	0.93	-0.16	0.27
Clg/Clt	0.90	-0.29	
P/E	0.90	-0.18	
Ps	0.88		
Clg	0.83		
d	-0.83	0.45	0.10
Clg/P	0.75	-0.39	0.14
P		0.95	
E	-0.31	0.92	
S		0.91	-0.15
Clt	-0.44	0.78	0.24
Es	-0.29	-0.24	-0.83
Et		0.49	-0.72

Key to abbreviations: apocolpium index (d/D), porus width (Prt), aperture type (A), polar axis/equatorial axis (P/E) ratio, porus length (Prg), porus length/porus width (Prg/Prt), colpus length/colpus width (Clg/Clt), pollen shape (Ps), colpus length (Clg), distance between the apices of two ectocolpi (d), colpus length/polar axis (Clg/P), polar axis (P), equatorial axis (E), size (S), colpus length (Clt), exine sculpturing types (Es) and exine thickness (Et).

Table 13 Eigen analysis of correlation matrix.

Component	Eigenvalues		
	Total	% of Variance	Cumulative %
1	10.89	60.51	60.51
2	3.38	18.75	79.26
3	1.46	8.13	87.39

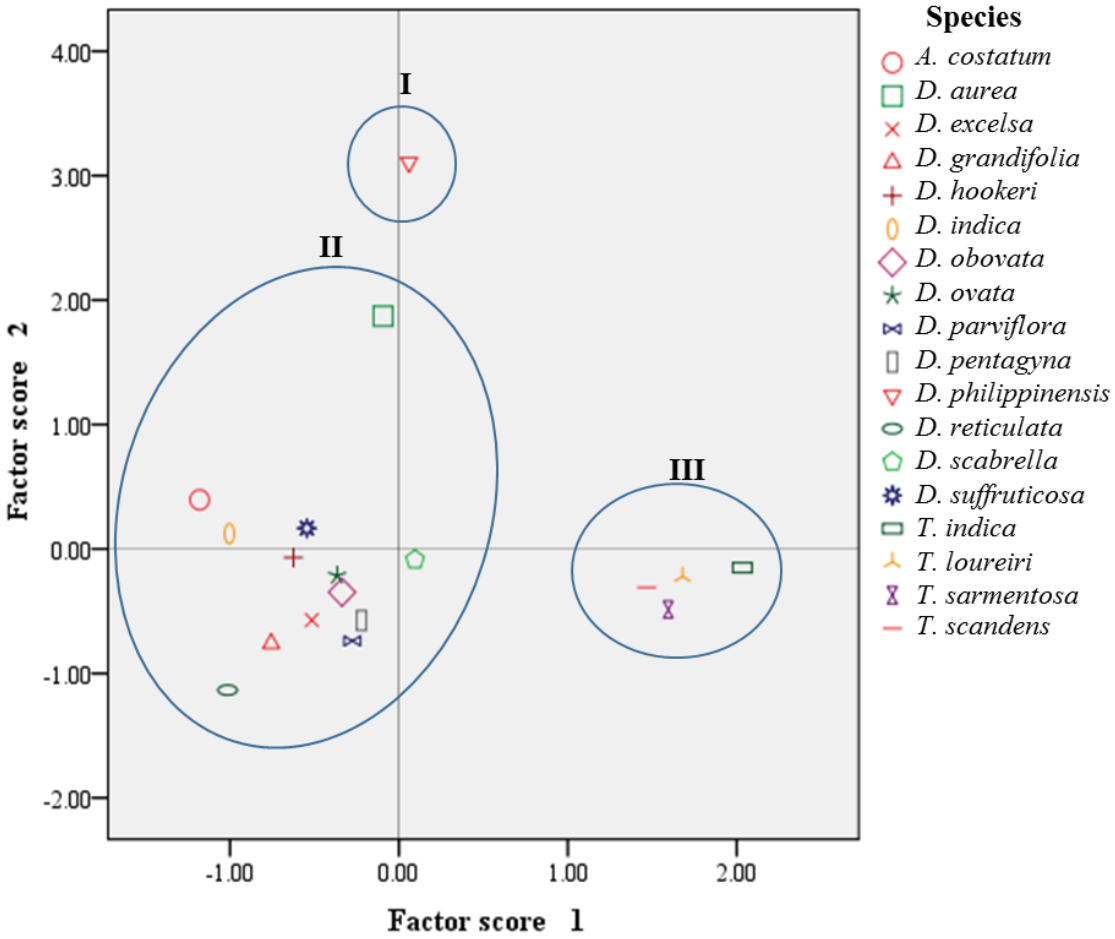

Figure 51 PCA scatterplot of Dilleniaceae species in Thailand based on pollen morphological characters.

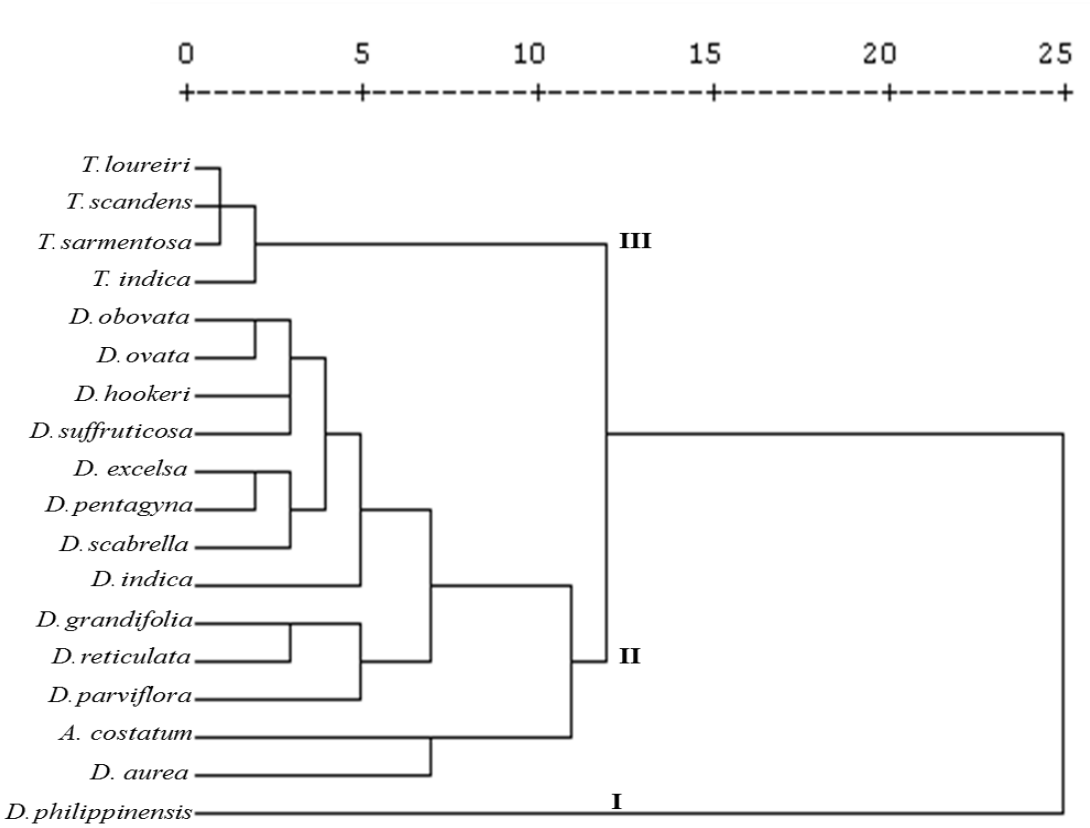

Figure 52 UPGMA clustering of 18 species based on Euclidean distance matrix calculated between means of 13 quantitative and five qualitative pollen morphological characters of Dilleniaceae in Thailand.

3.5 Discussion

3.5.1 Pollen size

This study reveals the pollen morphological characteristics of family Dilleniaceae in Thailand by observation under light microscopy and scanning electron microscope. They include details of the size, shape, aperture and exine wall. For pollen size, pollens are small to medium size. Most of the species have small size. The small sizes are observed in 16 species of Thai Dilleniaceae species. The polar axis ranges from 13.66 µm in *D. reticulata* to 20.77 µm in *A. costatum*. The equatorial axis ranges from 15.61 µm in *D. parviflora* to 23.36 µm in *D. suffruticosa*. The medium size is recorded in *D. aurea* (22.85 µm of polar axis and 25.93 µm of equatorial axis) and *D. philippinensis* (31.39 µm of polar axis and 34.51 µm of equatorial axis). These pollen morphological data are in agreement with previous studies on some species by

Erdtman (1952), Barth (1962), Dickison (1967b) and Dickison *et al.* (1982). Present observation, it is quite clear that the small and medium sizes represents the basic condition in this family. The pollen size can be used to separate some species, especially *D. philippinensis* for the largest (polar axis ranged 29.54-33.50 µm) and *D. parviflora* for the smallest pollen size (polar axis ranged 13.01-15.89 µm).

3.5.2 Pollena shape

The pollen grains vary in shape from suboblate (100 x P/E ratio = 75.10-88), oblate spheroidal (100 x P/E ratio = 88.10-100), prolate spheroidal (100 x P/E ratio = 100.10-114), to subprolate (100 x P/E ratio=114.10-133). The result agree with some species from the studies of Dickison (1967b) and Dickison *et al.* (1982), in which they reported that the pollen shapes of the genera *Acrotrema*, *Dillenia* and *Tetracera* are varied, as follows: the genus *Acrotrema* are oblate spheroidal; genus *Dillenia* are oblate, oblate spheroidal, or spheroidal and genus *Tetracera* are spheroidal, prolate spheroidal or prolate. Barth (1962) indicated that the pollen shape of the genus *Tetracera* is subprolate. Erdtman (1952) reported the pollen shapes of *D. ovata* and *T. scandens* as being oblate spheroidal and prolate spheroidal, respectively and these data are consistent with the present study. In addition, the present study reports an additional pollen shape of suboblate as found in several species of the genus *Dillenia*. The shape of pollen cannot confirm status of species in classification because in same genus have variation of pollen shape. Comparison of pollen characteristics in various studies as shown in the Table 15.

3.5.3 Pollen aperture

The difference in aperture type is essential for taxonomic at the infrageneric level. The findings of the current study show that two different pollen morphological group; Pollen group I is distinguished by being compound aperture (tricolporate) with genus *Tetracera* and group II tricolpate with elongated apertures representing *A. costatum* and the genus *Dillenia*. This study and the study of Dickison *et al.* (1982) confirm that tricolporate pollen represents the basic condition of *Tetracera*, while tricolpate pollen are the basic condition of *Acrotrema* and *Dillenia*. Dickison *et al.* (1982) and Barth (1962) indicated that tricolporate were found in genus *Curatella*,

Davilla, *Doliocarpus* and *Pinzona*. Previously, Dickison (1967b) first reported that in some species of the genus *Dillenia*, the aperture is tricolplate with rare or occasional tetracolpate within single species. In the present study confirms that the tetracolpate form can be found occasionally with the tricolpate form in some species of the genus *Dillenia*. Pollen aperture variation similar to that in Dilleniaceae can be found in other dicotyledon such as genus *Alchemilla* L. (Rosaceae) (Faghir *et al.*, 2014). Dickison (1967b) studied pollen morphological characteristic of Dilleniaceae under the light microscopy. The results show that the length of the colpus of *D. indica* and *D. philippinensis* as very short, which are classified as porate. The present study and a previous study by Dickison *et al.* (1982) confirm that the apertures of *D. indica* and *D. philippinensis* are colpate based on SEM photographs because the length of aperture longer than the width of aperture (colpus length/colpus width ratio more than 1.0). In this study concluded that in study of Erdtman (1952), Barth (1962) and Dickison (1967b) seem to have little value for taxonomic study because pollen morphological characteristic observed under the light microscopy provides a little information on the details of the aperture but investigation of aperture under SEM provides a better result for dividing the pollen morphological into groups. Comparison of pollen characteristics in various studies as shown in the Table 14.

3.5.4 Exine sculpturing

The present observation of the exine sculpturing classified it as punctate, reticulate, regulate and reticulate-verrucose. The exine thickness of all the sample varies from a minimun of 0.85 µm in *D. ovata* to a maximum of 1.58 µm in *D. scabrella*. The result from the present study and the study of Dickison *et al.* (1982) differs from the study of Barth (1962), Erdtman (1952) and Dickison (1967b) who reported that in all cases the genus *Tetracera* had exine sculpturing that is reticulate, but the present study and the study of Dickison *et al.* (1982) from SEM observations point out that the exine sculpturing of the genus *Tetracera* is punctate. Dickison *et al.* (1982) pointed out that in some species of the genus *Dillenia*, such as *D. pentagyna*, the tactum consists of granules on the surface of the exine and exine sculpturing, which is classified as punctate-striate. In the present study, the exine sculpturing of *D. pentagyna* is classified as reticulate-verrucose as the outer wall of the lumina is wider than 1 µm and combined

with a wart-like surface. In addition, those characteristics are found in *D. scabella*. Punt *et al.* (2007) point out that the differentiation of the striate and verrucose by striate is the sculpturing elements that are parallel and separated by grooves, while, for verrucose it is sexine elements that contain wart-like structures, more than 1 µm and where the base is wider than the height. Dickison (1967b), Dickison *et al.* (1982) and this study point out that exine pattern in Dilleniaceae have variation of among species of same genus. These variation effect to overlap of exine pattern between genus. Exine sculpturing cannot be utilized in classifying the Dilleniaceae into tribes or subfamilies because of an overlap between genera. Comparison of pollen characteristics in various studies as shown in the Table 16.

3.5.5 Data analysis

The PCA scatter plot and UPGMA clustering analysis based on the pollen morphological characteristics support as belonging to three groups. The present observations show that pollen morphological characteristics, such as shape, aperture, distance between apices of two ectocopi, d/D ratio, P/E ratio, Clg/Clt ratio and Clg/P ratio support a relationship between the genera *Acrotrema*, *Dillenia* and *Tetracera*. The species of genus *Dillenia* and *Acrotema* were classified to group one and two, while species of the genus *Tetracera* in Thailand are placed in group three, which is separated from the other groups. The evidence from pollen morphology supports a closely infrafamilial relationship between *Acrotrema* and *Dillenia*, while *Tetracera* is placed elsewhere (Table 17, Figure 53). The relationship of *Acrotrema*, *Dillenia* and *Tetracera* is supported by the studies of Hoogland (1952, 1953), Takhtajan (2009) and Horn (2005, 2007), who arranged *Dillenia* and *Acrotrema* in the subfamily Dillenioideae based on the morphological characteristic and wood anatomy as follows: anthers linear or oblong, loculi very rarely slightly divergent and lateral pitting scalariform-transitional; while, the genus *Tetracera* was classified into subfamily Delimoideae based on the morphological characteristic and anatomy as follows: anthers short, loculi divergent, separated at the base by the thickened connective and lateral pitting opposite-transitional. While, Horn (2009) arranged the genera *Dillenia* and *Acrotrema* in the subfamily Dillenioideae and classified the genus *Tetracera* in subfamily Delimoideae based on molecular data.

3.6 Conclusion

This study provides detailed analysis of the pollen morphology is extremely important for understanding the taxa and definite clue to the relationships of the *Acrotrema*, *Dillenia* and *Tetracera*. The pollen morphology data cannot be used for species identification due to the variation within and overlap between species. The elongated aperture covered with large irregular flecks, small or medium size and tri-aperture represents the basic characteristic in the Dilleniaceae. In the present work, the result shows addition characteristics for the first time for the Dilleniaceae as follows: exine thickness, colpus length, colpus width, ratio between colpus length and polar axis, ratio between colpus length and colpus width, porus length, porus width, ratio between porus length and porus width, distance between apices of two ectocolpi and apocolpium index. The above characteristics of the pollen are very important for grouping the Dilleniaceae in Thailand, such as the apocolpium index of the genus *Tetracera* ranged from 0.20-0.30, while for the genera *Acrotrema* and *Dillenia* ranged from 0.40-0.70.

The factor and cluster analyses of pollen morphology of Dilleniceae in Thailand can be classified and clustered. The pollen morphology can be classified *Acrotrema* and *Dillenia* in the same group, while the genus *Tetracera* was classified into other group.

Moreover, using the pollen morphological characteristic in combination with other characters, such as anatomy and morphology, may help in the identification of species and problematic taxa.

Table 14 Pollen aperture of Dilleniaceae in this study and the data reported by other authors.

Genera	**Erdtman (1952)**	**Barth (1962)**	**Dickison (1967)**	**Dickison *et al.* (1982)**	**This study**
Acrotrema	No data	No data	Tricolplate	Tricolpate	Tricolpate
Dillenia	Tricolplate Tetracolpate	No data	Tricolplate Tetracolpate Tripolate	Tricolplate Tetracolpate	Tricolplate Tetracolpate
Tetracera	Tricolpate Tricolporate	Tricolporate	Tricolporate	Tricolporate	Tricolporate

Table 15 Pollen shape of Dilleniaceae in this study and the data reported by other authors.

Genera	Erdtman (1952)	Barth (1962)	Dickison (1967)	Dickison *et al.* (1982)	This study
Acrotrema	No data	No data	Oblate spheroidal	Oblate spheroidal	Oblate spheroidal
Dillenia	Oblate spheroidal	No data	Oblate, Oblate spheroidal, Spheroidal	Oblate, Oblate spheroidal, Spheroidal	Oblate spheroidal, Suboblate
Tetracera	Prolate spheroidal, Subprolate	Subprolate	Spheroidal, Prolate spheroidal, Prolate	Spheroidal, Prolate spheroidal, Prolate	Subprolate, Prolate spheroidal

Table 16 Pollen exine sculpturing of Dilleniaceae in this study and the data reported by other authors.

Genera	Erdtman (1952)	Barth (1962)	Dickison (1967)	Dickison *et al.* (1982)	This study
Acrotrema	No data	No data	Reticulate	Punctate	Punctate
Dillenia	Reticulate	No data	Scabrate, Reticulate-rugulate, Reticulate	*D. pentagyna* (punctate-striate)	*D. pentagyna* (reticulate-verrucose)
Tetracera	Reticulate	Reticulate	Punctate	Punctate	Punctate

Table 17 Pollen morphological characters supported relationship of Thai Dilleniaceae.

Characters	***Acrotrema***	***Dillenia***	***Tetracera***
Aperture	Tricolpate	Tricolpate	Tricolporate
d/D ratio	More than 0.3	More than 0.3	0.2-0.3
P/E	Less than 1	Less than 1	More than 1
Clg/Clt	Less than 6	Less than 6	More than 6
Clg/P	Less than 0.7	Less than 0.7	More than 0.7
Shape	Oblate spheroidal, suboblate	Oblate spheroidal, suboblate	Prolate-spheroidal, Subprolate

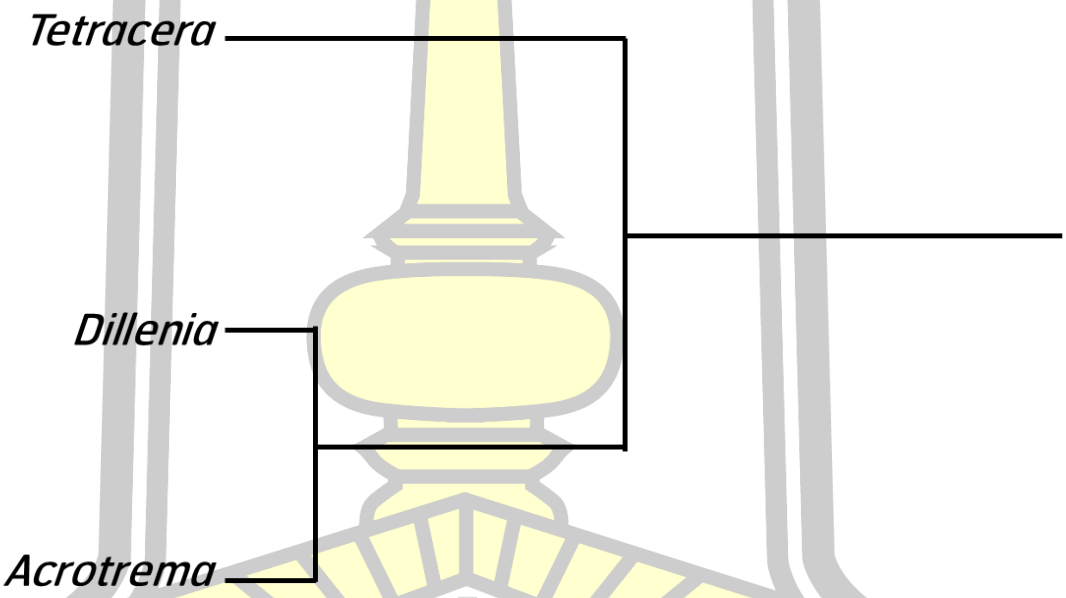

Figure 53 Relationship of Thai Dilleniaceae base on pollen morphological characters

CHAPTER 4
ANATOMY OF DILLENIACEAE IN THAILAND

4.1 Introduction

Studies of plant taxonomy using morphology as the basis as well as data from cytology, molecular biology, palynology and anatomy to support the classification of plants have been performed. Morphology is important to identify the species of Dilleniaceae from the flowers and fruits, but the plants in this family have the flowering and fruits in a short time, which causes problems in identifying the species. The data of leaf anatomy is used in plant taxonomy studies because leaf anatomy have a variety of characteristics, i.e., type of trichomes, type of stomata, characters of epidermal on leaf surface and the outline of midrib and petiole. The cells and tissues with the qualitative characteristics are fixed and often influences environmental changes are minimal. Therefore, the study of the anatomy is another method that can be used to help solve the problem of identification and classification of plants (Stace, 1980). A study of the anatomy of plants is the basis of the taxonomy, the data can also be applied in other fields as well, such as applied when using a plant in small pieces as a mixture in traditional medicine and analysis of plant cells that accumulate in the soil of the archaeological and paleobotany sites (Moore *et al.*, 1991). In addition, the application in the field of agriculture and forestry by confirming the species and applications of forensic science by histological methods (Metcalfe and Chalk, 1979), even comparing the relationship between plants as well.

The morphology of *Dillenia aurea* is similar to that of *D. obovata* because *D. aurea* and *D. obovata* are the closely related species, the first with a northerly and the second with a more southerly distribution, with a dividing line at 14 ^{0}N. latitude in Thailand and Burma (Hoogland, 1972). This is first factor for identifying the two species and the easiest characteristic to identify them from each other is the pedicle that in *D. aurea* (5-12 cm) is longer than in *D. obovate* (1.5-4 cm). Also found in many plant species, such as *D. pentagyna*, *D. scabrella* and *D. parviflora*, where it cannot identify the species clearly because the characteristics of asexual characters are similar. Identification requires the character of the flowers using sepals and bracts. However, botanists published anatomical data of this family for only some species and many

species lack of data. Therefore, the study in the past are either incomplete, or else were produced in last century, thus, the revision of this study is required. The aim of the study was designed to describe leaf anatomy of the family Dilleniaceae in Thailand and to compare the anatomy of leaves consisting of petiole, midrib, lamina and leaf margin by epidermal peeling and paraffin method. As a result, the classification and identification of plants in the family Dilleniaceae are complete and accurate and to provide additional leaf anatomy information.

4.2 Literature review

4.2.1 Leaf anatomy

Metcalfe and Chalk (1950) reported anatomical characteristics of plants in the family Dilleniaceae. The trichomes of Dilleniaceae were reported as three types consisting of simple unicellular, stellate, or peltate hairs. The mesophyll has palisade tissue with 1-4 layers. The stomata are anomocytic and paracytic. Hypoderm were found in some species of genus *Dillenia*. The midrib of genus *Curatella*, *Davilla*, *Doliocarpus* and *Tetracera* containing sheaths round encloses vascular bundles. Petiole of *Dillenia indica* in part of cylindrical vascular strand accompanied by subsidiary bundles in the wing. Vascular bundles of *Hibbertia volubilis* is crescent-shaped strand with a smaller dorsal one between the arms of leaf in transverse sections. Calcium oxalate found in form of raphides and crystal sand. The distribution of calcium oxalate present in the mesophyll and in the phloem of the veins.

Dickison (1969) studied anatomy of the node and vascularization of the leaf. The mature nodes of the family Dilleniaceae are unilacunar, trilacunar and multilacunar. The number of traces in genus *Schumacheria* and genus *Didesmanda* are nine and seventeen respectively. The number in genus *Dillenia* varies from 7-27 traces. The genus *Acrotrema* are trilacunar. The New World genera *Curatella*, *Davilla* and *Doliocarpus* are mostly pentalacunar or fire trace nodes. The genus *Tetracera* are trilacunar. Unilacunar and trilacunar were found in genus *Hibbertia*. The genus *Pachynema* are mostly a single prominent trace. The cotyledonary node of *Dillenia indica*, *Tetracera indica*, *Hibbertia dentata* and *H. scandens* are unilacunar.

The petiole anatomy of Dilleniaceae is diverse both between and within genera. The diversity of petiole anatomy at the species level indicates that the petiole

anatomy may be of taxonomic significance in the family. Petiolar anatomy were classified to three major patterns following:

1. Unilacunar nodes is present in many species of genus *Hibbertia*.

2. Trilacunar nodes found in some species of genus *Hibbertia, Doliocarpus, Tetracera* and *Acrotrema*. Trilacunar was classified into six subtypes using character of traces.

3. Multilacunar nodes (five to many traces from an equal number of gaps) is present in the petiole of some species of genus *Acrotrema, Didesmandra, Dillenia, Davilla* and *Doliocarpus*. Multilacunar nodes was classified into four subtypes using character of traces.

The prevailing type of the secondary veins (major venation) is pinnate and conducting to the margin of the blade. Bundle sheath cells are parenchymatous or sclerenchymatous and may enclose the terminal tracheids. Parenchymatous sheath cells surround both the major veins and terminal veinlets. This sheath was observed in some species of genus *Curatella* and *Dillenia*. Sclerenchymatous sheath cells create massive sheaths by the presence of lignified and extensively pitted over the vein and veinlets as in genus *Hibbertia*, *Tetracera* and some species of *Diliocarpus*. Slender venation patterns are weak bundle sheathing or lacking bundle sheathing. Very slender venation was observed in genus *Acrotrema*, *Didesmandra*, *Schumacheria* and some species of *Hibbertia*. The presence of specialized terminal cells in the leaves of few species of genus *Hibbertia* is a tracheoidal element.

Dickison (1970) studied leaf anatomy of 10 genera in Dilleniaceae. General anatomical characters of Dilleniaceae. He classified idioblasts according to Foster (1946) into three major categories as follows: excretory, tracheoid and sclerenchymatous.

1. Excretory idioblasts, four types of excretory idioblast of Dilleniaceae were recorded in leaf anatomy: (1) raphides, which were present in all genera studied, except *Schumacheria*; (2) crystal of the family also includes cuboidal shape and nearly prismatic shape; (3) crystal sand are prevalent in some members of the Dilleniaceae; (4) silica deposit in the parenchymatous regions for some time of the leaf mesophyll and epidermis in *Curatella, Davilla, Doliocarpus, Hibbertia* and *Tetracera*.

2. Tracheoid idioblasts, leaves of genus *Hibbertia* revealed tracheoid type, which closely resemble the typical tracheids in their general characteristic but are found completely isolated from other venation.

3. Sclerenchymatous idioblasts presented in the leaves of Dilleniaceae. Folia sclereid have a high diversity of morphology and distribution. Sclerenchymatous idioblasts distinguish to four types base on their distribution: (1) sclereids diffuse in the mesophyll (and pith and cortex of petiole). This type are present clusters of unbranched brechysclereids (stone cells) in genus *Davilla*, *Doliocarpus*, *Hibbertia* and *Schumacheria*. In addition, irregularly branched, oateosclereids and stellate sclereid (astrosclereids) can be found in the leaves of genus *Hibbertia*. (2) sclereids terminal at vein endings, this sclerenchyma is encountered encloses the terminal tracheids in the form of perivascular fibers. (3) epidermal sclereids is present in genus *Hibbertia*. (4) sclereids subtending trichomes is present the leaves of genus *Tetracera*. This condition is those which subtend the spiny hair.

Trichomes was described to four types as consisting of simple unicellular trichomes, stellate trichomes, papillate trichomes and glandular trichomes. Simple unicellular trichomes are the common characteristics of Dilleniaceae, being present in all genera. Stellate trichomes are present in the leaves of genus *Curatella* and genus *Hibbertia*. Stellate trichomes in genus *Curatella*, *Didesmandra* and *Tetracera*; the rays are reduced to spines. Papillate trichomes are prevalent in many species of genus *Dillenia*. He also reported glandular trichomes for the first time in the family.

This observation found that the stomata were only on the abaxial leaf surface and generally level with the surface of the leaf. In many species of *Hibbertia*, stoma are located in stomatal crypts or stomatal grooves. A specific area of stomatal crypts or stomatal grooves is different in shape and distribution of hair. The stomata are paracytic type in *Didesmandra* and *Tetracera*, except *Curatella*, *Davilla*, *Dillenia* and *Hibbertia* are the anomocytic type. Guard cells length from 16 to 36 µm. *Hibbertia tetrandra* guard cells surrounded by 2-4 subsidiary cells that differ from ordinary epidermal cells in narrower cell shape and in their reaction to chemical reagents, it classified as “gordoniaceous”.

The number of palisade layers are different at both species and genera, ranging from 1 to 3 (4) layers. Hypodermis is found in some species of *Dillenia* and *Hibbertia*.

In addition, the presence or absent of intercellular spaces and specialized idioblasts exploited for taxonomic purposes.

4.2.2 Wood anatomy

Metcalfe and Chalk (1950) studied wood anatomy of Dilleniaceae. The result show that vessels mostly solitary, perforation plates typically scalariform or simple perforation and intervascular pitting opposite to scalariform. Parenchyma predominantly apotracheal, diffuse or in uniseriate lines, sometimes containing raphides. Rays are multiseriate rays consisting 8-10 cells wide and up to 20 cells wide in *Curatella* and *Davilla*. Raphides were found in enlarged mucilage cell in many species. Scleroid cells were found in genus *Davilla*. Fibers with distinctly bordered pits, moderately to very long, mean length 1.8-3 mm.

Dickison (1967a) compared morphological studies of forty species in all 10 genera of Dilleniaceae and examined the wood anatomy. Wood without growth rings is diffuse-porous in all genera except that growth rings are present in some species of genus *Tetracera* and *Hibbertia*. Vessels mostly solitary or occasionally in small clusters in many species of genus *Dillenia*, *Curatella* and *Hibbertia*, vessels density 1-65/mm^2, vessel elements are circular to less commonly angular, very small to very large (11-450 µm X 80-374 µm). Tyloses found only in vessel elements of some species of genus *Dillenia*. Intervascular pitting opposite to transitional, pits are circular to elongate, without vestures. In *Acrotrema*, *Pachynema*, *Didesmandra*, *Dillenia*, *Hibbertia* and *Schumacheria* have perforation plates are scalariform (5-160 bars), completely bordered, sometimes branched, in *Curatella*, *Doliocarpus*, *Davilla* and *Tetracera* perforation plates mostly simple, scalariform (1-20 bars) in the smaller vessels. Imperforate tracheary elements of the tracheid and fiber tracheid type, thin to thick walled; fiber tracheids with distinctly bordered pits. The axial parenchyma is mostly apotracheal diffuse.

Dickison *et al.* (1978) studied the wood of 27 species of genus *Hibbertia*. Growth rings present, vessels mostly solitary, sometimes occasionally small clusters and the shape of the pores varies from slightly angular to circular. Vessel walls are often of medium thickness. Mean of vessel diameters range from very small (13 µm in *H. drummondii*, *H. huegelii* and *H. uncinate*) to medium sized (95 µm in *H. ngoyensis*).

Mean of vessel element length ranges from medium sized (430 µm in *H. exutiacies*) to moderately long (1199 µm in *H. saligna*). Intervessel pitting is sparse, but where present is opposite to transitional to scalariform in distribution. Pits are circular to scalariform in outline and range in size from minute to very large. Ray-vessel pitting is half bordered. Perforation plates are exclusively scalariform, number of bars per perforation from a low of two in *H. drummondii* to a high of 42 in *H. lucens*. Imperforate tracheary elements are fiber-tracheids, the mean length of the fiber tracheids ranges within 517-1804 µm. The walls of fiber tracheids are thick, with bordered pits. Rays are heterogeneous and in plants with abundant xylem both multiseriate and uniseriate rays are present. Axial parenchyma is diffuse and scant in distribution, although it becomes increasingly scarce in more xeric species.

Dickison (1979) studied anatomy of 31 species of *Dillenia* as described and discussed with reference to environmental factors. The dry habitats found lowest bar number on scalariform perforation plates. Vessel solitary, perforation plates are scalariform (8-77 bars/perforation), small, sparse and predominantly opposite intervascular pitting. Pore number ranges between mostly 3-17/mm^2, vessel diameter ranges from 53 µm of *D. auriculata* to 259 µm of *D. papuana*, vessel element length ranges from 944 µm of *D. aurea* to 2105 µm of *D. triquetra* and fiber length varies from 1596 µm of *D. diantra* to 3289 µm of *D. schlechteri*. Rays are heterogeneous. Multiseriate rays are wide (up to 12 cells) and very long (up to and exceeding 8 mm) with prominent uniseriate wing extensions. Wood parenchyma is diffuse, diffuse-in-aggregates and scanty. Raphides are numerous in the ray parenchyma.

4.2.3 Carpels anatomy

Dickison (1968) studies comparative morphological of 10 genera in family Dilleniaceae examined part of the carpels. Carpels of representatives of all 10 genera in Dilleniaceae were examined, as follows: *Acrotrema*, *Curatella*, *Davilla*, *Didesmandra*, *Dillenia*, *Doliocarpus*, *Hibbertia*, *Pachynema*, *Schumacheria* and *Tetracera*. The several species of Dilleniaceae that were investigated can summarized as follows: (1) complete or nearly complete apocarpy; (2) visible conduplicate folding; (3) open ventral sutures; and (4) large numbers of ovules.

4.3 Material and methods

All specimens used in this study were collected from the field in Thailand during 2013-2016 (Table 18). Voucher specimens were deposited in the herbarium at the Department of Biology, Faculty of Science, Mahasarakham University, Thailand. The leaf anatomical characters of all species of the family Dilleniaceae in Thailand were investigated by leaf epidermal clearing and transverse sectioning of the lamina and petiole.

Table 18 List of Dilleniaceae species in Thailand investigated in present study.

Taxa	Location	Collection number	Remark
Acrotrema costatum Jack	Songkhla Province	S. Rakarcha 88	-
Dillenia aurea Sm.	Chaiyaphum Province	S. Rakarcha 60	-
D. excelsa (Jack) Martelli ex Gilg.	Trang Province	S. Rakarcha 83	-
D. grandifolia Wall. ex Hook.f. & Thomson	Trang Province	S. Rakarcha 90	-
D. hookeri Pierre	Ubon Ratchathani Province	S. Rakarcha 12	-
D. indica L.	Tak Province	S. Rakarcha 92	-
D. obovata (Blume) Hoogland	Trang Province	S. Rakarcha 89	-
D. ovata Wall. ex Hook.f. & Thomson	Yasothon Province	S. Rakarcha 11	-
D. parviflora Griff.	Chiang Rai Province	S. Rakarcha 71	-
D. pentagyna Roxd.	Chaiyaphum Province	S. Rakarcha 37	-
D. philippinensis Rolfe	Mahasarakham Province	S. Rakarcha 94	cultivated
D. reticulata King	Songkhla Province	S. Rakarcha 91	-
D. scabrella (D. Don) Roxb. ex Wall.	Loei Province	S. Rakarcha 69	-
D. suffruticosa (Griff.) Martelli	Bangkok Province	S. Rakarcha 26	cultivated
Tetracera indica (Christm. & Panz.) Merr.	Phatthalung Province	S. Rakarcha 87	-
T. loureiri (Finet & Gagnep.) Pierre ex W. G. Craib	Ubon Ratchathani Province	S. Rakarcha 51	-
T. sarmentosa (L.) Vahl	Trang Province	S. Rakarcha 94	-
T. scandens (L.) Merr.	Songkhla Province	S. Rakarcha 85	-

4. 3. 1 Epidermal peeling methods (applied from Lersten and Curtis (2001))

The mature leaf specimens were selected from midway between the apex and the base. The leaf specimens were peeled by razor blade. The pieces of sample that combine upper and lower epidermis were cleared in 5% (W/V) KOH. The pieces of epidermis surface should be immersed in water for five minutes, repeatedly three times and stained with 1% safranin in water for 30 minutes. The excess safranin was washed by distilled water. The samples were dehydrated in an ethanol alcohol series (15%, 30%, 50%, 70%, 95% and 100% (V/V)), transfer sample in immersion in mixed solution of absolute alcohol and xylene (1:1) and pure xylene, each step 5-15 minutes. Permanent slides of samples were mounted with DePeX mounting media. The observation patterns are examined and photographed under a light microscope (LM). Photographs were taken under Axio Lab A1 microscope with a digital photomicrograph system. All specimen examination and slide collections are kept at the Department of Biology, Faculty of Science, Mahasarakham University.

4.3.2 transverse sectioning (applied from Thammathaworn (1996))

Paraffin methods were used for studies leaf anatomy by transverse section. Transverse sections were made from the leaf blades between the midrib and margin of lamina, margins, midribs and petioles. The process of Paraffin methods in this study have follows:

1. The mature leaf specimens were washed with water and selected from midway between the apex and the base.

2. The specimens sectioned into pieces (5x10 mm). The pieces of sample were transferred in the vial and label a vial on labeling tape with tissue type, date and important information.

3. The sample in the vial were fixed in 70% FAA (formalin acetic alcohol) for 24 hours at room temperature. The FAA have components as follows:

Formalin	5 parts by volume
Glacial acetic acid	5 parts by volume
70% Ethyl alcohol	90 parts by volume

4. Suction, vial containing pieces of sample in fixative were removal of air in order to force fluid into a vacant space by suction pump at 25 Hg Vac for 30 minutes, then turn off the suction pump for 30 minutes and repeat three continuous times, store the vial for at 24 hours.

5. Fixing agents were washed with 50% alcohol, repeatedly two times, for at least 24 hours/time.

6. Dehydration, the pieces of the sample were dehydrated by tertiary butyl alcohol (TBA). The dehydration is carried out by passing the tissue of samples through a series of solutions of increasing TBA concentration (Table 19). The TBA grades (grades 1, 2, 3, 4 and 5) are changed every 24 hours per grade, then TBA grade 5 was replaced by pure TBA.

7. Infiltration, the pure TBA were discarded from the last dehydration step and fill in the vial about 3/4 full using pure TBA and liquid paraffin ratio 1:1 for 24 hours.

8. Pure paraffin was melted at a temperature of 60 ^{0}C in an oven and fill in the vial about 3/4 full after discarding pure TBA and liquid paraffin ratio 1:1, repeat previous step using fresh melted paraffin. The samples to equilibrate in an oven set at 60 ^{0}C for 24 hours per time.

Table 19 Grades of tertiary butyl alcohol (TBA) used for dehydration.

	Volume (ml) in TBA grade				
	GRADE				
	1	**2**	**3**	**4**	**5**
Distilled water	50	30	15	0	0
Ethyl alcohol	40	50	50	40	0
Tertiary butyl alcohol	10	20	35	55	75
Ethyl alcohol 100%	0	0	0	0	25
Total percentage of alcohol	50	70	85	95	100

9. Embeding, decant the melted paraffin into paraffin blocks. Working quickly but carefully, use forceps to transfer the tissue of samples from vial in step 9 to paraffin blocks and label a paraffin blocks with tissue type, date and important

information. Allow the paraffin to solidify at room temperature. When the paraffin solidifies, then the paraffin surrounding the tissue block must be trimming.

10 The samples from step 10 were mounted on plastic blocks and labeled plastic blocks.

11. Sectioning of sample is carried out using a rotary microtome 15-25 µm. The objective is to produce a continuous "ribbon" of sections adhering to one another by their leading and trailing edges.

12. Carefully transfer the ribbon to a solution of gelatin at 45 ^{0}C in water bath. Within a few seconds, the ribbon flattens and the wrinkles disappear. Dip a microscope slide into the gelatin solution and slowly pull it upward, allowing ribbon to adhere to the surface of microscope slide. Make sure that the slide is oriented with the label facing upward. Allow the slides to dry overnight on a slide warmer at 45 ^{0}C.

13. Prestaining, before a sample can be stained the paraffin must be removed by dissolves the paraffin with xylene, transfer to mixture of xylene and absolute alcohol (1:1), mixture of absolute alcohol and ether (1:1), absolute alcohol, ethanol 95% and 70% for five minutes in each step.

14. Staining, stain samples slides with the following schedule of solutions held in jars:

1.	1% safranin O	2 hours
2.	Tap water 1	2 minutes
3.	Tap water 2	2 minutes
4.	95% ethanol 1	5 minutes
5.	95% ethanol 2	5 minutes
6.	Fast green	10 seconds
7.	Clove oil: absolute alcohol: xylene (1:2:1)	10 minutes
8.	Absolute alcohol: xylene (1:1)	10 minutes
9.	Pure xylene	15 minutes

15. The final step is permanently mount the samples under a coverslip. Place 3-4 drops of DePeX mounting media over the samples. Place the coverslip on the slide slowly from one side of the droplet. Using a pencil label slides on labeling tape at one end with your name, date, tissue type and numbered sequentially from 1 – 5; five

slides will be used for the samples (blades, margins, midribs and petioles). Allow the mounting media to solidify at room temperature. Excess medium can be cut from edges of cover slip with a razor blade.

16. Photographs were taken under Axio Lab A1 microscope.

4.3.3 Data analysis

The pollen morphology characters of each species were evaluated for morphometric analysis, comprising 34 characters (Table 20). The morphometric analysis was performed by factor analysis and cluster analysis. The analysis was conducted using Statistical Package for the Social Science (SPSS version 25 for Windows). Factor analysis was undertaken using the principal component analysis method (PCA). PCA was used to reduce the variables from a larger set into a smaller set. The result of the PCA is usually discussed in terms of the factor loading. Factor loading score could be obtained from the output. The factor analysis was performed, it could be divided into new factor. Each factor contained parameters with eigen values higher than 1.0. The highest loadings are placed with the same factor and the PCA scatterplot can be developed from principal component I (factor I) and principal component II (factor II). Cluster analysis (CA) with the taxonomic distance was performed using the Euclidean distance and a phenogram was developed with the unweighted pair-group method using arithmetic average (UPGMA).

Table 20 Leaf anatomy characters and character states used in numerical analysis of 18 species of Dilleniaceae in Thailand.

No.	Characters	Character status
1	Number of palisade mesophyll (NP)	1 layer (0)
		2 layers (1)
		3 layers (2)
2	Bundle sheath extension in transverse section of leaf blade (BSE)	Absent (0)
		Present (1)
3	Hypodermis (HY)	Absent (0)
		Present (1)
4	Secretory cavities in leaf blade (SE)	Absent (0)
		Present (1)
5	Petiole diameter by transverse section (PD)	Small (less than 5 mm, 0)
		Lage (more than 5 mm, 1)
6	Midrib diameter by transverse section (MD)	Small (less than 5 mm, 0)
		Lage (more than 5 mm, 1)
7	Thickness of leaf blade by transverse section (TOB)	100-200 µm (0)
		201-300 µm (1)
		301-400 µm (2)
8	Unicellular hair on adaxial surface of leaf blade (UHDB)	Absent (0)
		Present (1)
9	Glandular trichomes on adaxial surface of leaf blade (GTDB)	Absent (0)
		Present (1)
10	Spiny hair on adaxial surface of leaf blade (SHDB)	Absent (0)
		Present (1)
11	Unicellular hair on abaxial surface of leaf blade (UHBB)	Absent (0)
		Present (1)
12	Glandular trichomes on abaxial surface of leaf blade (GTBB)	Absent (0)
		Present (1)
13	Spiny hair on abaxial surface of leaf blade (SHBB)	Absent (0)
		Present (1)
14	Shape of epidermis cells on adaxial surface (SCD)	PSI (0)
		JC (1)
15	Shape of epidermis cells on abaxial surface (SCB)	PSI (0)
		JC (1)

Table 20 Leaf anatomy characters and character states used in numerical analysis of 18 species of Dilleniaceae in Thailand (cont.).

No.	Characters	Character status
16	Type of stomata on abaxial surface (TS)	Paracytic (0)
		Anomocytic (1)
		Anisocytic (2)
17	Shape on adaxial surface of midrib by transverse section (SDM)	Convex (0)
		Concave (1)
18	Shape on abaxial surface of midrib by transverse section (SBM)	U-Shaped (0)
		V-Shaped (1)
19	Unicellular hairs on adaxial surface of midrib (UHDM)	Absent (0)
		Present (1)
20	Glandular trichomes on adaxial surface of midrib (GTDM)	Absent (0)
		Present (1)
21	Spiny hairs on adaxial surface of midrib (SHDM)	Absent (0)
		Present (1)
22	Unicellular hair on abaxial surface of midrib (UHBM)	Absent (0)
		Present (1)
23	Glandular trichomes on abaxial surface of midrib (GTBM)	Absent (0)
		Present (1)
24	Spiny hair on abaxial surface of midrib (SHBM)	Absent (0)
		Present (1)
25	Type of cell at surround vascular bundle of midrib (TCSM)	Collenchyma (0)
		Sclerenchyma (1)
26	Shape of margin (SOM)	Curving downwards (0)
		Straight (1)
27	Shape on adaxial of petiole by transverse section (SBP)	Straight
		V-Shaped (1)
		Concave (2)
		U-Shaped (3)
28	Shape on abaxial of petiole by transverse section (SDP)	U-Shaped (0)
		V-Shaped (1)
29	Unicellular hair on adaxial of petiole (UHDP)	Absent (0)
		Present (1)
30	Spiny hairs on adaxial of petiole (SHDP)	Absent (0)
		Present (1)

Table 20 Leaf anatomy characters and character states used in numerical analysis of 18 species of Dilleniaceae in Thailand (cont.).

No.	Characters	Character status
31	Unicellular hairs on abaxial of petiole (UHBP)	Absent (0)
		Present (1)
32	Glandular trichomes on abaxial of petiole (GTBP)	Absent (0)
		Present (1)
33	Spiny hair on abaxial of petiole (SHBP)	Absent (0)
		Present (1)
34	Type of cell at surround vascular bundle of petiole (TCSP)	Collenchyma (0)
		Sclerenchyma (1)

Key to abbreviations: JC = The shape of epidermal cells are jigsaw-like, PSI = The shape of epidermal cells are polygonal and cell wall are sinuate.

4.4 Results

4.4.1 Specific Characteristics

The leaf anatomy of the family Dilleniaceae in Thailand was observed and analyzed under light microscope. The results are summarized in Tables 21-25. Detailed information of the taxa are described as follows:

1. *Acrotema costatum* (Figures 54-57)

1.1 Leaf surface anatomy from the epidermal peeling methods (Figure 54)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall. Simple unicellular hairs were divided into two types by using length of hair; short simple unicellular hair (length less than 100 µm) and long simple unicellular hair (length more than 100 µm). The average length of short and long unicellular hairs are 82.19 and 1,299.77 µm respectively. The average densities of short and long hairs are 16.69 and 0.72 mm^{-2} respectively. (Table 21) Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anisocytic stomatal complexes. The three subsidiary cells are distinguishable from the surrounding epidermal cells by their shape. The average densities of stomata are 125.00 mm^{-2}. The average lengths of guard cells are 23.39 µm. Short unicellular hairs are observed on abaxial surface. The average length

of short unicellular hairs are 83.58 µm. The average densities of short hair are 45.89 mm^{-2} (Table 22).

1.2 Transverse section of leaf lamina (Figure 55A)

The average thickness of leaf blade is 154.87 µm. Short unicellular hairs are present on both surfaces. Long unicellular hair present on adaxial surface. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side or semicircular in shape and straight or slightly curved anticlinal walls. The adaxial epidermis is slightly thicker than the abaxial epidermis. Thin cuticle is presented on both surfaces. The outline of adaxial and abaxial epidermis layers are rather straight. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one cell layer of palisade parenchyma. The spongy cell is composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells (Table 23).

1.3 Transverse section of leaf margin (Figure 55B)

The outline of the leaf margin in transverse section is curved down (Figure 52B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

1.4 Transverse section of midrib (Figure 56)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 56A). Short unicellular hairs are present on both surfaces. Long unicellular hairs are present on adaxial surface. The epidermis cells in transverse section of adaxial surface are four to six side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Under the epidermis is a zone of two to four layer of collenchyma. Parenchyma predominates in ground tissue. Parenchyma cells predominates in ground tissue. Under the epidermis layer is a zone of two to four layers of collenchyma. The vascular bundles are collateral bundle (opened type)

consisting 3-10 separate bundles. The vascular bundle is surrounded by collenchyma cells. Raphides crystals were found in parenchyma cells of ground tissue (Table 24).

1.5 Transverse section of petiole (Figure 57)

The outline of the petioles shape in transverse section at the adaxial surface is V-shaped, while the abaxial surface is U-shape. The two adaxial wings curved toward the core. Short unicellular hairs and long unicellular hairs are presented on both surfaces. The epidermis cells in transverse section of both surfaces are four side to circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surface. Epidermis cells are usually smaller than cells in the ground tissue. Under the epidermis layer is a zone of 2-5 layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 6-15 separate bundles. The vascular system is composed of a central region of xylem with collateral phloem. Collenchyma cells from a continuous ring around each vascular bundle. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

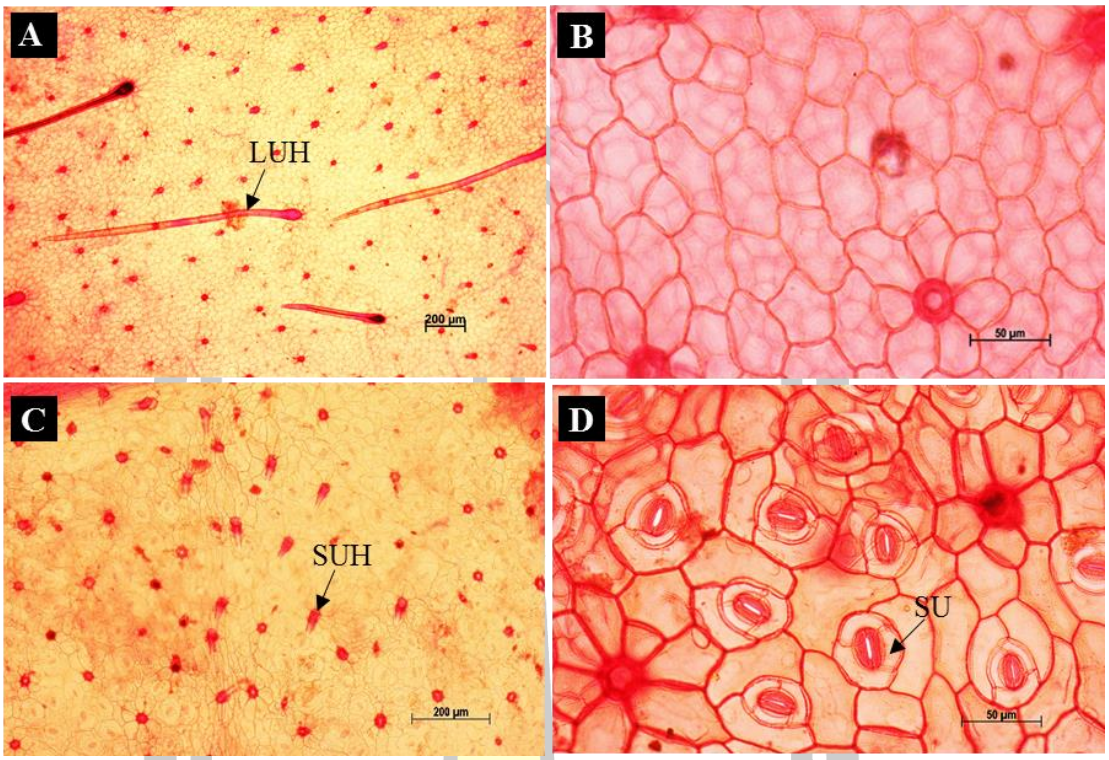

Figure 54 The leaf epidermis of *Acrotrema costatum*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A, C = 200 µm; B, D = 50 µm. Key to abbreviations: LUH = long unicellular hair, SU = subsidiary cell, SUH = short unicellular hair.

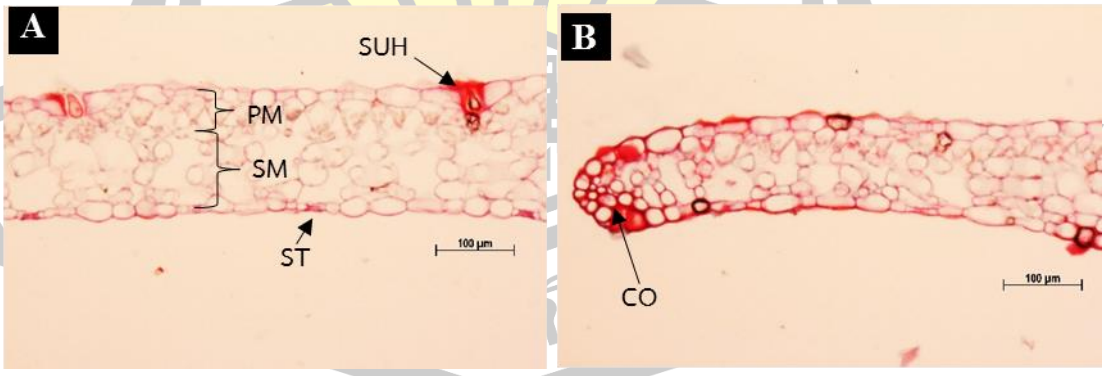

Figure 55 Transverse sections leaf of *Acrotrema costatum*.

(A) Lamina and (B) Leaf margin. Scale bar: A and B = 100 µm. Key to abbreviations: CO = collenchyma cells, PM = palisade mesophyll, SM = spongy mesophyll, ST = stomata, SUH = short unicellular hair.

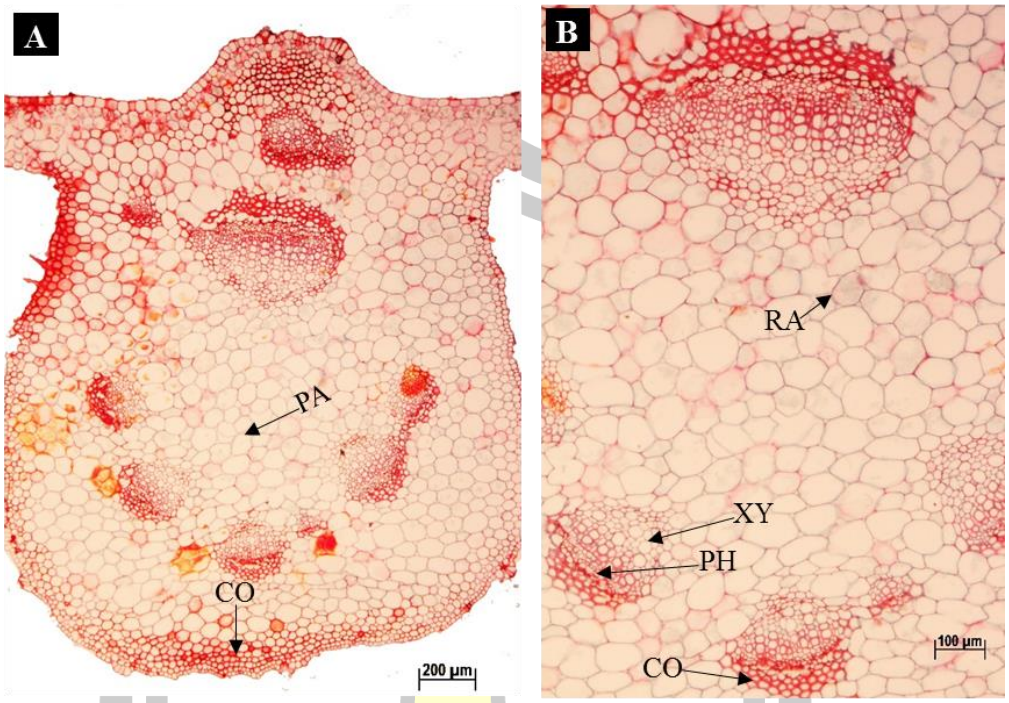

Figure 56 Transverse section of midribs of *Acrotrema costatum*.

(A) The outline of midribs. (B) Vascular bundle is collateral surrounding by collenchyma cells. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA = raphides crystals, XY = xylem.

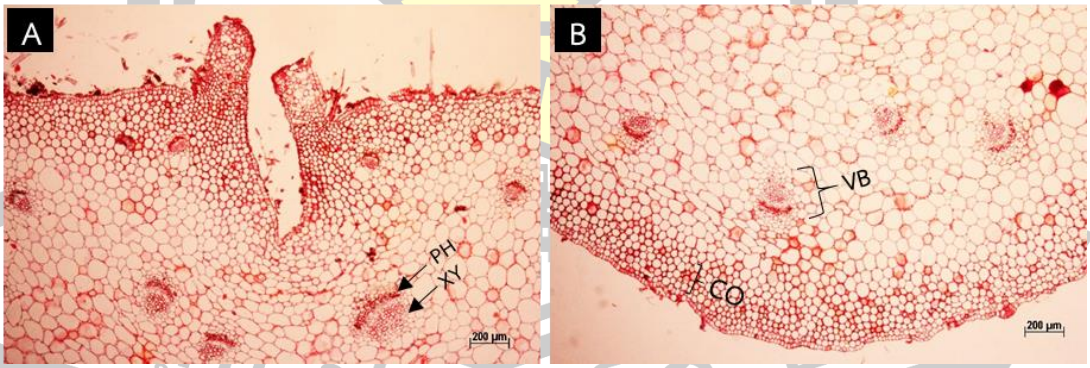

Figure 57 Transverse section of petiole of *Acrotrema costatum*.

(A) The outline of petiole on adaxial surface. (B) The outline of petiole on abaxial surface. Scale bar: A and B = 200 µm. Key to abbreviations: CO = collenchyma, PH = phloem, VB = vascular bundles, XY = xylem.

2. *Dillenia aurea* (Figures 58-61)

2.1 Leaf surface anatomy from the epidermal peeling methods (Figure 58)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 300.00 mm^{-2}. The average length of guard cells is 24.88 µm. Long unicellular hairs are observed on abaxial surface. The average length of long unicellular hairs is 406.33 µm. The average densities of unicellular hairs are 9.80 mm^{-2} (Table 22).

2.2 Transverse section of leaf lamina (Figure 59A)

The average thickness of leaf blade is 410.65 µm. Long unicellular hairs are found on abaxial surface. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermis layers are rather straight. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two to three palisade parenchyma and secretory cavities are located in palisade layers. The spongy cell is composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by sclerenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are present in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

2.3 Transverse section of leaf margin (Figure 59B)

The outline of the leaf margin in transverse section is curved down (Figure 59B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis layer of lamina. Hypodermis were found in only leaf margin at adaxial (Table 24).

2.4 Transverse section of midrib (Figure 60)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 60B). Simple unicellular hairs are presented on both surfaces. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Under the epidermis is a zone of two to four layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 3-10 separate bundles. The vascular bundles are surrounded by sclerenchyma cell. Raphides crystals were found in parenchyma cells of ground tissue (Table 24).

2.5 Transverse section of petiole (Figure 61)

The outline of the petioles in transverse section at the adaxial surface is concave, while the abaxial surface is U-shaped. The two adaxial wings bent out of the core. Long unicellular hairs were found on both surfaces. The epidermis cells in transverse section of both surfaces are four side to semicircular. Epidermis cells are usually smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 61A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

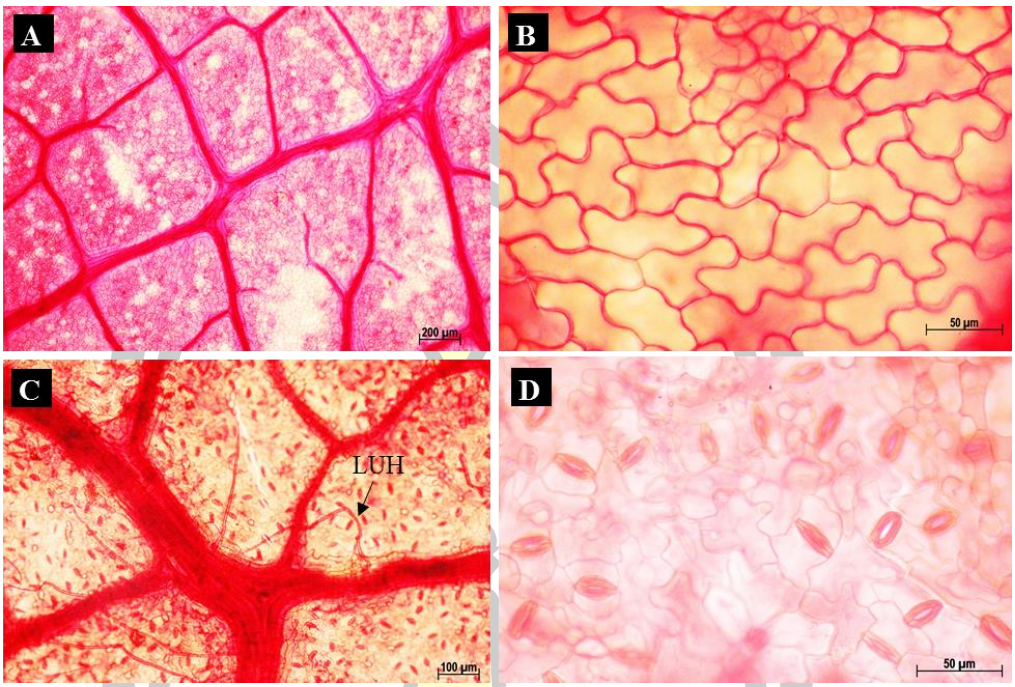

Figure 58 The leaf epidermis of *Dillenia aurea*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on adaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A = 200 µm, B, D = 50 µm, C = 100 µm. Key to abbreviations: LUH = long unicellular hairs.

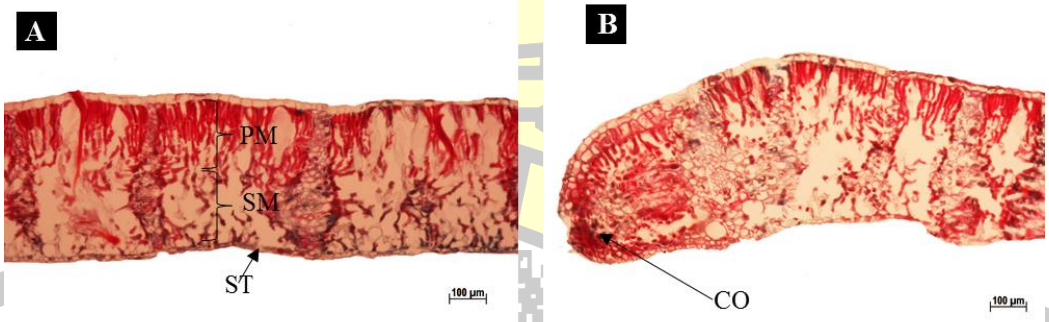

Figure 59 Transverse sections leaf of *Dillenia aurea*.

(A) Lamina and (B) Leaf margin. Scale bar: A and B = 100 µm. Key to abbreviations: CO = collenchyma cells, PM = palisade mesophyll, SM = spongy mesophyll, ST = stomata.

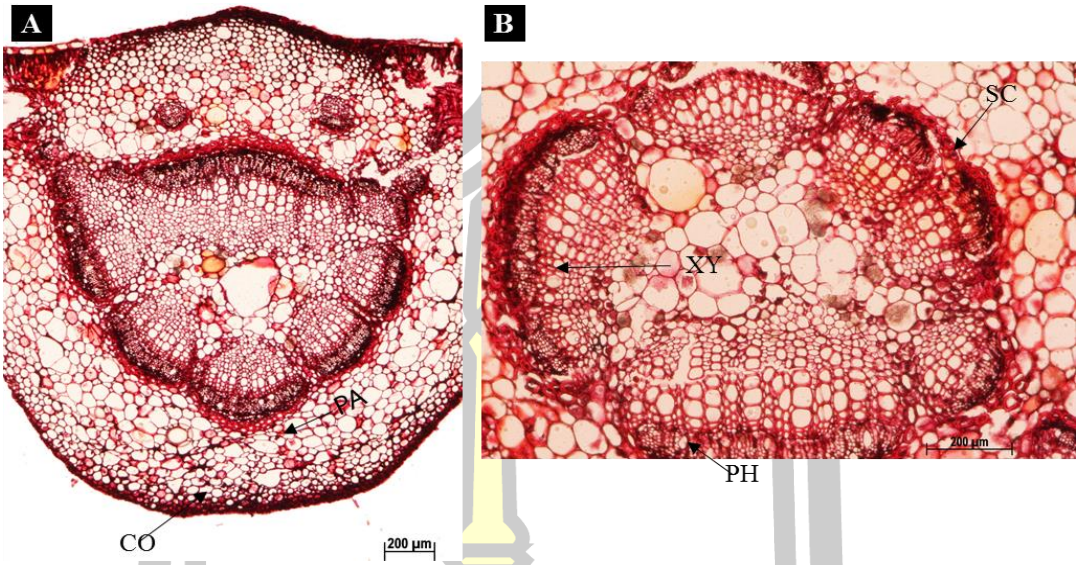

Figure 60 Transverse section of midribs of *Dillenia aurea*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A and B = 200 µm. Key to abbreviations: CO = collenchyma, PA = parenchyma, PH = phloem, RA = raphides crystal, SC = sclerenchyma cells, XY = xylem.

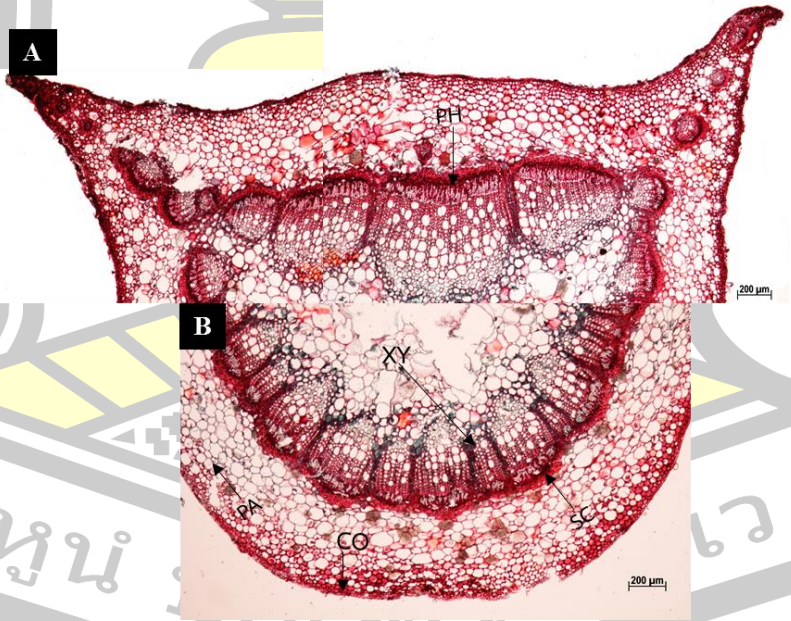

Figure 61 Transverse section of petiole of *Dillenia aurea*.

(A) The outline of petiole on adaxial surface. (B) The outline of petiole on abaxial surface. Scale bar: A, B = 200 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma, PH = phloem, RA = raphides crytals, SC= sclerenchyma cells, XY = xylem.

3. *Dillenia excelsa* (Figures 62-65)

3.1 Leaf surface anatomy from the epidermal peeling methods (Figure 62)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anisocytic stomatal complexes. The three subsidiary cells are distinguishable from the surrounding epidermal cells by their shape. The average densities of stomata are 217.50 mm^{-2}. The average lengths of guard cells are 26.27 mm^{-2} (Table 22).

3.2 Transverse section of leaf lamina (Figure 63A)

The average thickness of leaf blade is 191.17 µm. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal walls. The adaxial epidermis is slightly thicker than the abaxial epidermis. Thin cuticle is presented on both surfaces. The hypodermis was found below epidermis layer. The hypodermis is composed a single layer of large and circular or semicircular cells. The outline of abaxial and adaxial epidermis layers are rather straight. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two layers of palisade parenchyma and secretory cavities are located palisade layers. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by sclerenchyma cells (Table 23).

3.3 Transverse section of leaf margin (Figure 63B)

The outline of the leaf margin in transverse section is curved down (Figure 63B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina. Secretory cavities occupies the half of the margin in cross section (Table 24).

3.4 Transverse section of midrib (Figure 64)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is V-shaped (Figure 64A). The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surface are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surface. Under the epidermis is a zone of two to four layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 6-10 separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by sclerenchyma cell. Raphides crystals were found in parenchyma cells of ground tissue (Table 24).

3.5 Transverse section of petiole (Figure 65)

The outline of the petioles in transverse section at the adaxial surface and abaxial surface are U-shaped. The two adaxial wing curved toward the core. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cell of abaxial surface are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surface. Epidermis cells are usually smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 65A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

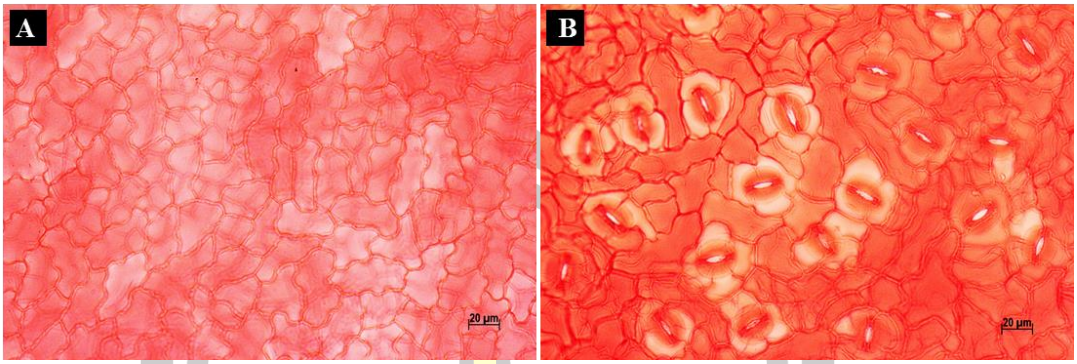

Figure 62 The leaf epidermis of *Dillenia excelsa*.

(A) Characteristics of epidermal shaped on adaxial surface. (B) Stomata on abaxial surface. Scale bar: A and B = 20 µm.

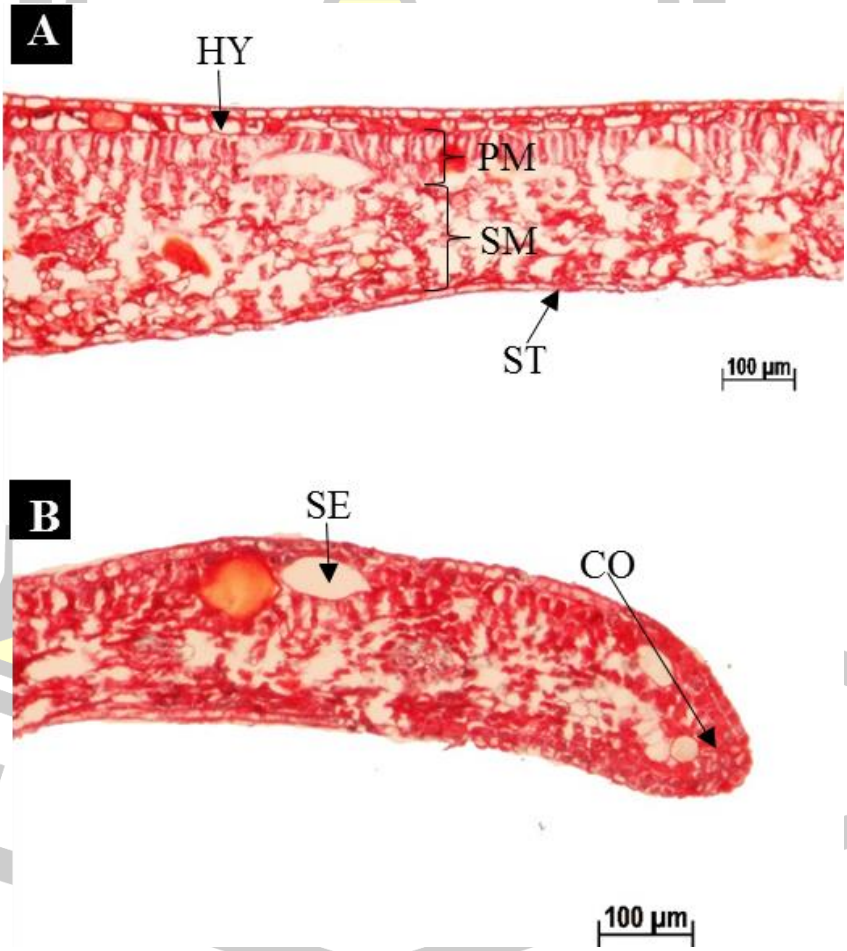

Figure 63 Transverse sections leaf of *Dillenia excelsa*.

(A) Lamina and (B) Leaf margin. Scale bar: A and B = 100 µm. Key to abbreviations: CO = collenchyma, HY= hypodermis, PM = palisade mesophyll, SM = spongy mesophyll, SE = secretory cavities, ST = stomata.

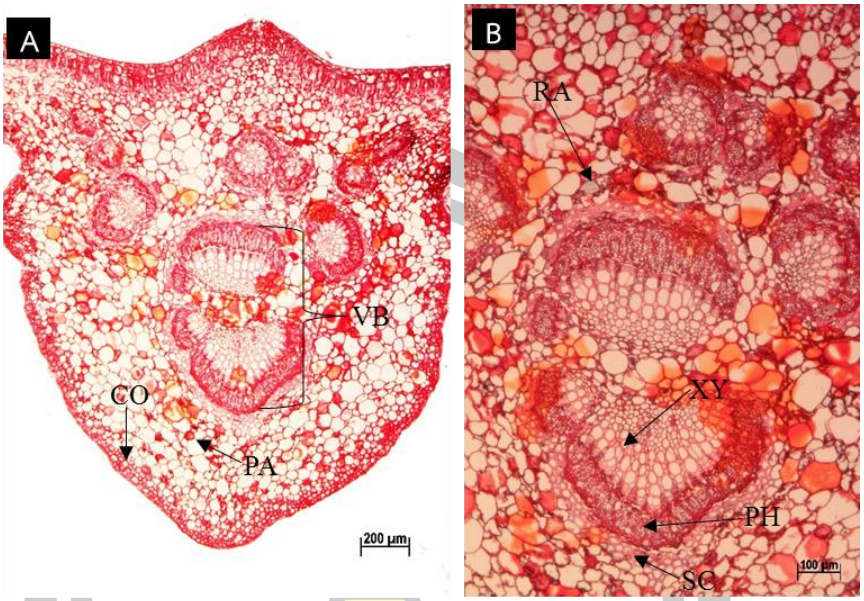

Figure 64 Transverse section of midribs of *Dillenia excelsa*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, SC= sclerenchyma cells, VB = vascular bundle, XY = xylem.

Figure 65 Transverse section of petiole of *Dillenia excelsa*.

(A) The overview of petiole. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: CO = collenchyma cells, PH = phloem, RA = raphides crystal, SC = sclerenchyma cells, VB = vascular bundles, XY = xylem.

4. *Dillenia grandifolia* (Figures 66-69)

4.1 Leaf surface anatomy from the epidermal peeling methods (Figure 66)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall. Long unicellular hairs are observed on adaxial surface. The average length of long hairs is 180.12 µm. The average densities of long hairs are 10.61 mm^{-2} (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 123.94 mm^{-2}. The average lengths of guard cells are 15.38 µm. Long and short unicellular hairs are observed on abaxial surface. The average length of long and short unicellular hairs is 192.90 and 73.53 µm respectively. The average densities of long and short unicellular hairs are 158.50 and 111.97 mm^{-2} respectively (Table 22).

4.2 Transverse section of leaf lamina (Figure 67A)

The average thickness of leaf blade is 171.73 µm. Long unicellular hairs are presented on both surfaces. Short unicellular hairs are present on abaxial surface. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal walls. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are slightly sinuate. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one layer of palisade parenchyma. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by sclerenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are present in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

4.3 Transverse section of leaf margin (67B)

The outline of the leaf margin in transverse section is curved down (Figure 67B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf

margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

4.4 Transverse section of midrib (Figure 68)

The outline of midrib in transverse section at the adaxial surface is convex while the abaxial surface is U-shaped (Figure 68A). Long unicellular hairs are present on both surfaces. The epidermis cells in transverse section of both surfaces are circular or semicircular and cell are smaller than cells in the group tissue. Under the epidermis is a zone of two to four layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting one to three separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by collenchyma cells. Two main type of crystals were found, namely raphides and crystal sand. Crystals were found in parenchyma cells of ground tissue (Table 24).

4.5 Transverse section of petiole (Figure 69)

The outline of the petioles in transverse section at the adaxial is U-shaped, while the adaxial surface is U-shaped. The two adaxial wings curved toward of the core. Long unicellular hairs are present on both surfaces. Short unicellular hairs are present on abaxial surface. The epidermis cells in transverse section of both surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surface. Epidermis cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which two to three smaller vascular bundle distributed into lateral adaxial wings. The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides and crystals sand were found in parenchyma cells of ground tissue (Table 25).

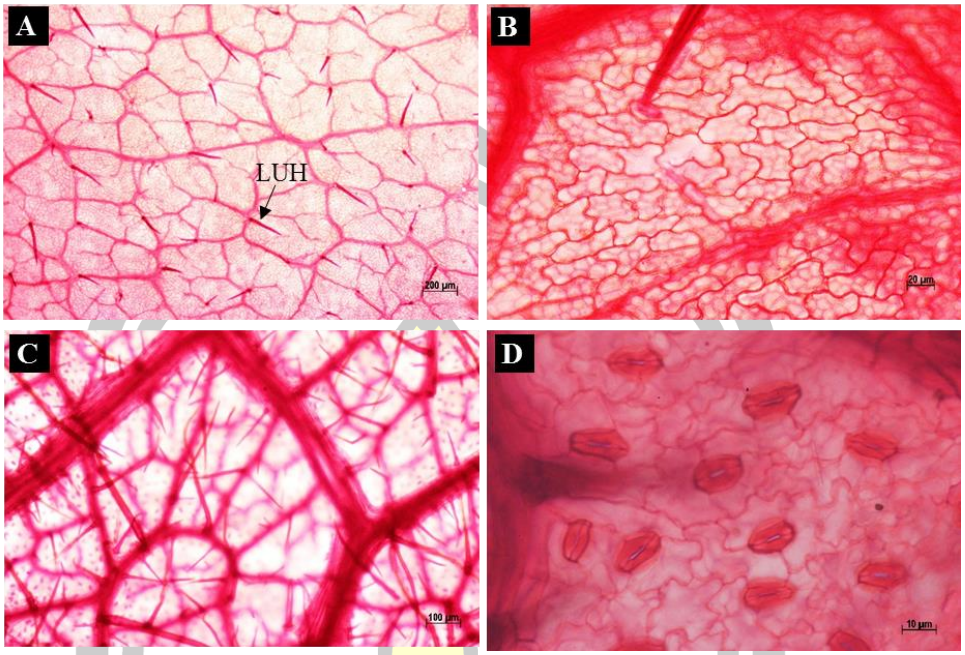

Figure 66 The leaf epidermis of *Dillenia grandiforia*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of leaf surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A = 200 µm, B = 20 µm, C= 100 µm, D = 10 µm. Key to abbreviations: LUH = long unicellular hairs.

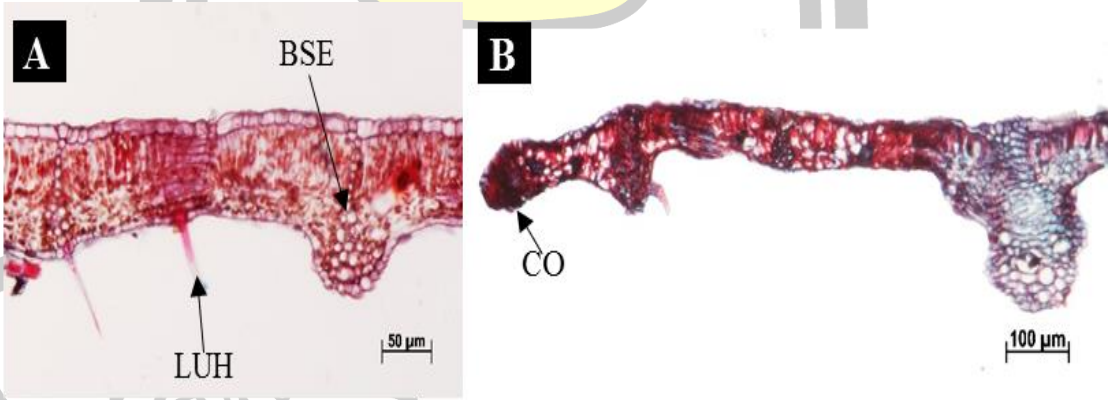

Figure 67 Transverse sections leaf of *Dillenia grandiforia*.

(A) Lamina and (B) Leaf margin. Scale bar: A = 50 µm, B and C = 100 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma, LUH = long unicellular hair, PM = palisade mesophyll, SM = spongy mesophyll.

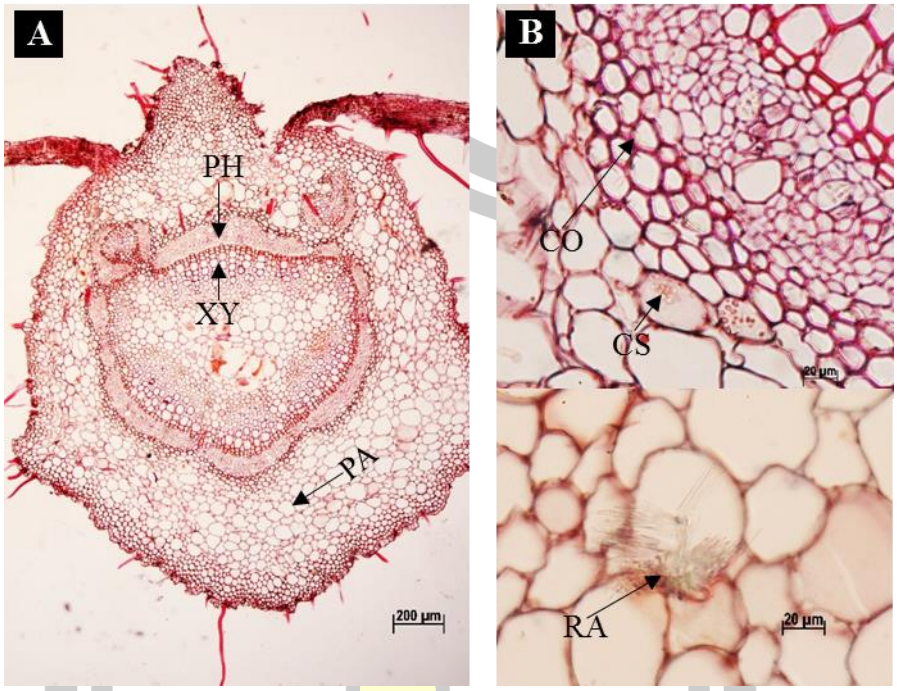

Figure 68 Transverse section of midribs of *Dillenia grandiforia*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by collenchyma cells. Scale bar: A = 200 µm, B= 20 µm. Key to abbreviations: CO = collenchyma cells, CS = crystals sand, PA = parenchyma cells, PH = phloem, RA= raphides crystals, XY = xylem.

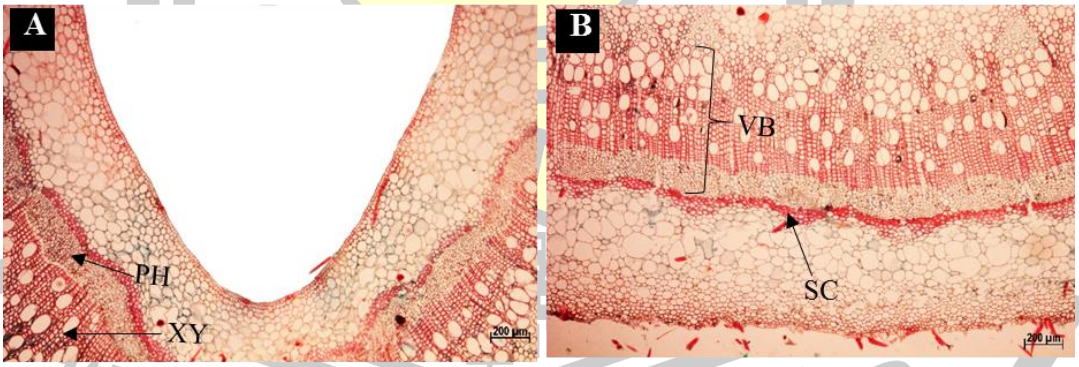

Figure 69 Transverse section of petiole of *Dillenia grandiforia*.

(A) The overview of petiole on adaxial surface. (B) The overview of petiole on abaxial surface and vascular bundle of petiole. Scale bar: A and B = 200 µm. Key to abbreviations: PH = phloem, SC = sclerenchyma cells, VB = vascular bundles, XY = xylem.

5. *Dillenia hookeri* (Figures 70-73)

5.1 Leaf surface anatomy from the epidermal peeling methods (Figure 70)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall. Long unicellular hairs are observed on adaxial surface. The average length of long hairs is 361.50 µm. The average densities of long hairs are 34.27 mm^{-2} (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 398.19 mm^{-2}. The average lengths of guard cells are 21.45 µm. Long unicellular hairs are observed on abaxial surface. The average length of long unicellular hairs is 539.50 µm. The average densities of long unicellular hairs are 610.24 mm^{-2} (Table 22).

5.2 Transverse section of leaf lamina (Figure 71A)

The average thickness of leaf blade is 167.28 µm. Long unicellular hairs are presented on both surfaces. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side and straight or slightly curved anticlinal walls. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial epidermal layers are straight. The shape of abaxial epidermal layers are deep sinuate. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one layer of palisade parenchyma. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by sclerenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

5.3 Transverse section of leaf margin (Figure 71B)

The outline of the leaf margin in transverse section is curved down (Figure 71B). Collenchyma and sclerenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

5.4 Transverse section of midrib (Figure 72)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 72A). Long unicellular hairs are present on both surfaces. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the group tissue. Under the epidermis is a zone of two to four layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting one to five separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by sclerenchyma cells. Raphides crystals were found in parenchyma cells of ground tissue (Table 24).

5.5 Transverse section of petiole (Figure 73)

The outline of the petioles shape in transverse section at the adaxial surface is concave, while the abaxial surface is U-shaped. The two adaxial wings bent out of the core. Long unicellular hairs were found on both surfaces. The epidermis cells in transverse section are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 73). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

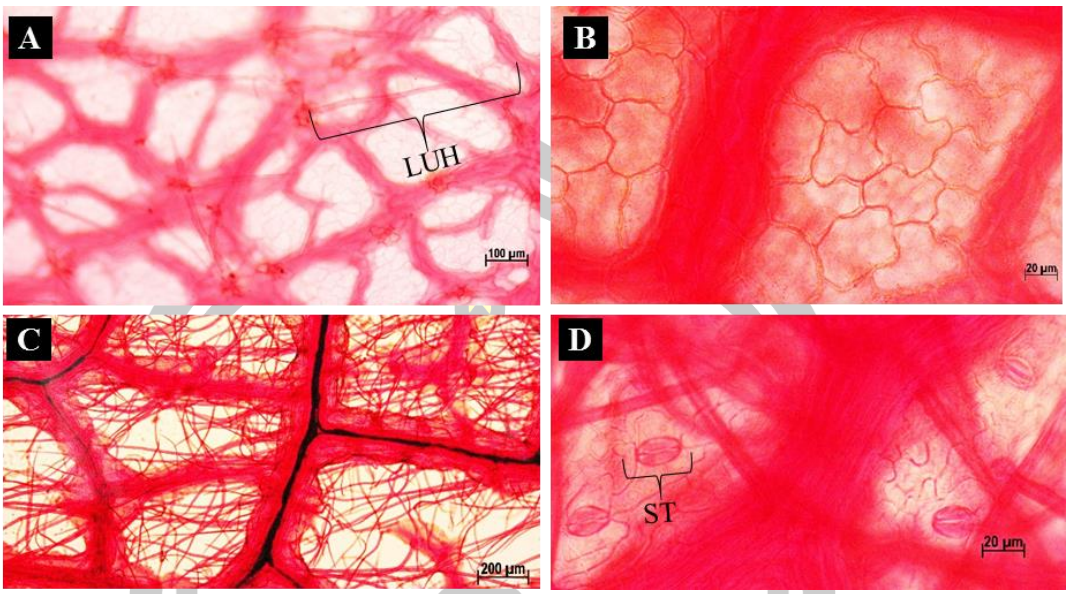

Figure 70 The leaf epidermis of *Dillenia hookeri*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on adaxial surface: (C) Epidermis surface and long unicellular hair, (D) Stomata. Scale bar: A = 100 µm, B, D = 20 µm C = 200 µm. Key to abbreviations: LUH = long unicellular hair, ST = stomata.

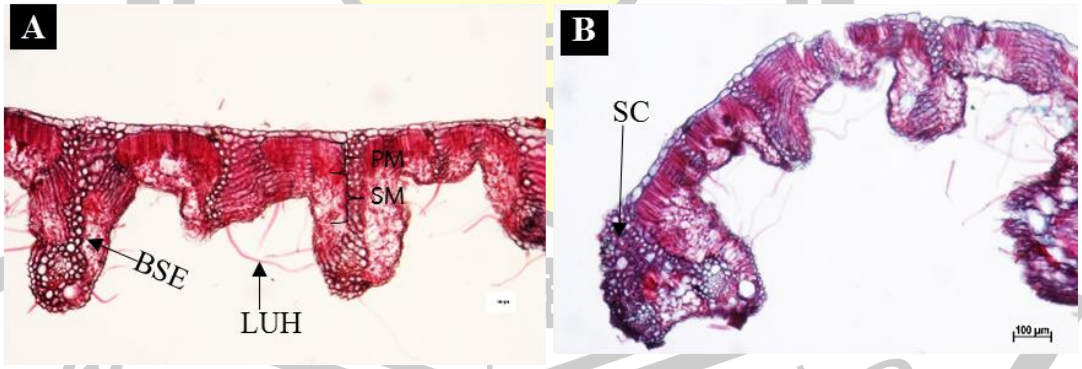

Figure 71 Transverse sections leaf of *Dillenia hookeri*.

(A) Lamina and (B) Leaf margin. Scale bar: A = 50 µm, B = 100 µm. Key to abbreviations: BSE = bundle sheet extension, PM = palisade mesophyll, SM = spongy mesophyll, SC = sclerenchyma, LUH = long unicellular hair.

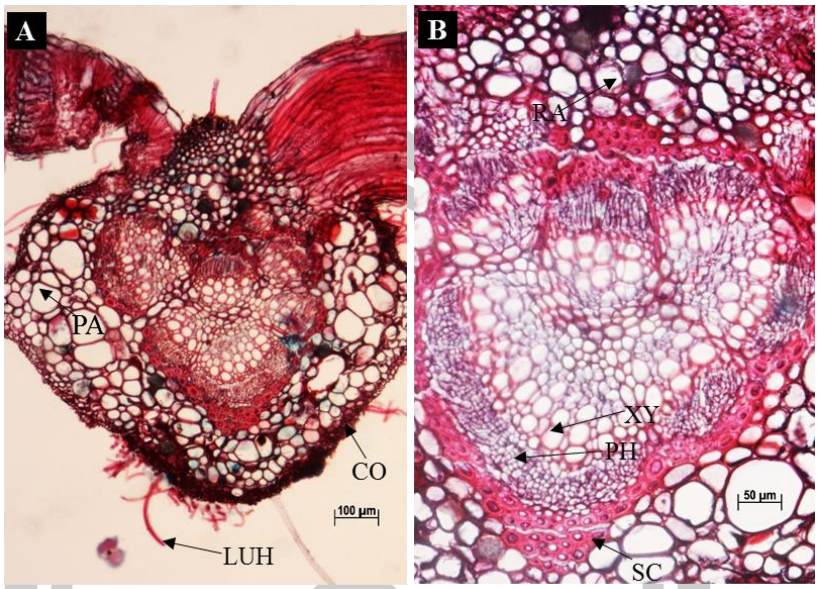

Figure 72 Transverse section of midribs of *Dillenia hookeri*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A = 100 µm, B= 50 µm. Key to abbreviations: CO = collenchyma, LUH = long unicellular hair, PA = parenchyma, PH = phloem, RA = raphides crystals, SC= sclerenchyma, XY = xylem.

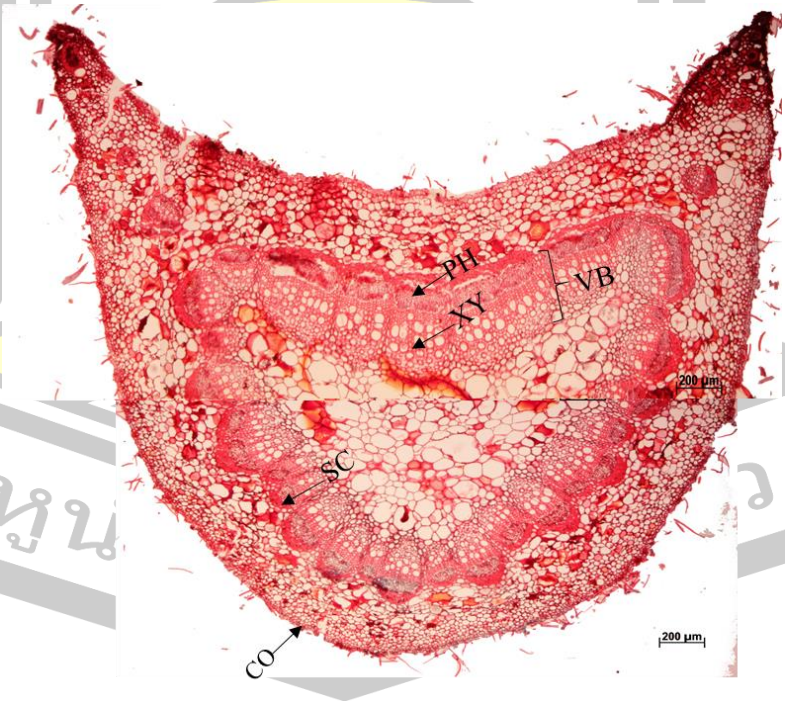

Figure 73 Transverse section of petiole of *Dillenia hookeri*.

Scale bar: A, B = 200 µm. Key to abbreviations: CO = collenchyma, PH = phloem, SC= sclerenchyma, VB = vascular bundles, XY = xylem.

6. *Dillenia indica* (Figures 74-76)

6.1 Leaf surface anatomy from the epidermal peeling methods (Figure 74)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall. Long unicellular hairs are observed on adaxial surface. The average length of long hairs is 173.92 µm. The average densities of long unicellular hairs are 1.64 mm^{-2} (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 157.50 mm^{-2}. The average lengths of guard cells are 24.35 µm. Long unicellular hairs are observed on abaxial surface. The average length of long simple unicellular hairs is 134.73 µm. The average densities of long unicellular hairs are 2.96 mm^{-2} (Table 22).

6.2 Transverse section of leaf lamina (Figure 75A)

The average thickness of leaf blade is 125.22 µm. Long unicellular hairs are present on both surfaces. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal walls. The adaxial epidermis is slightly thicker than abaxial epidermis. The hypodermis was found below epidermis layer. The hypodermis is composed a single layer of large and circular or semicircular cells. The outline of adaxial and abaxial epidermal layers are straight. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two layer of palisade parenchyma and secretory cavities are located in palisade layers. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by sclerenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

6.3 Transverse section of leaf margin (Figure 75B)

The outline of the leaf margin in transverse section is curved down (Figure 75B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

6.4 Transverse section of midrib (Figure 76)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 76A). Long unicellular hairs are presented on both surfaces. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 2 to 8 separate bundles. The main large vascular bundles occupies below small vascular bundles. The vascular bundles are surrounded by chlorenchyma cells. Raphides crystals were found in parenchyma cells of ground tissue (Table 24).

6.5 Transverse section of petiole (Figure 77)

The outline of the petioles shape in transverse section at the adaxial surface and abaxial surface is U-shaped. The two adaxial wings curved toward the core. Long unicellular hairs are present on abaxial surface. The epidermis cells in transverse section are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 77A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

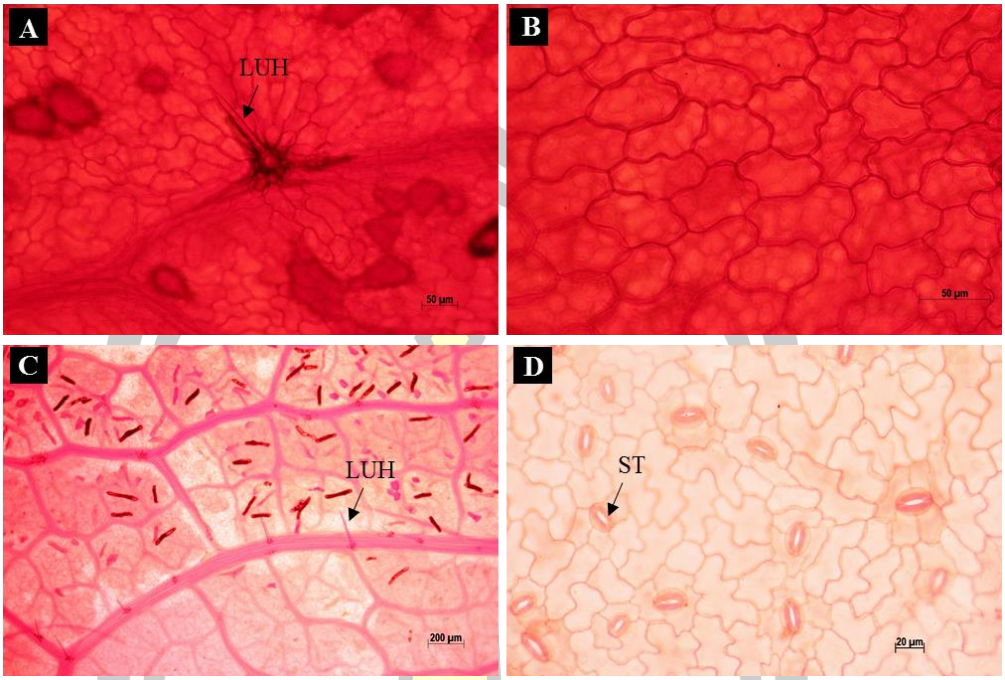

Figure 74 The leaf epidermis of *Dillenia indica*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on adaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A, B = 50 µm, C = 200 µm, D = 20 µm. Key to abbreviations: LUH = long unicellular hair, ST = stomata.

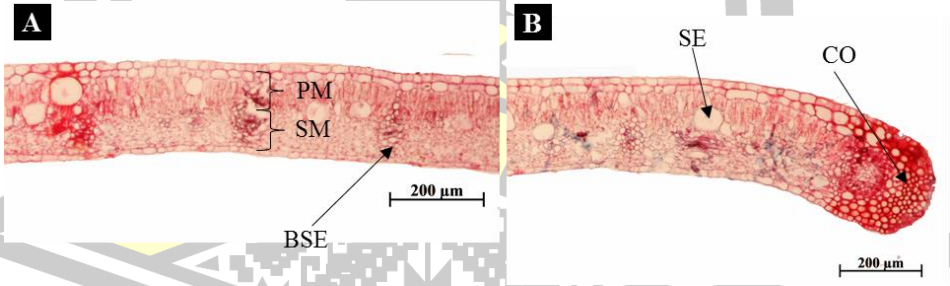

Figure 75 Transverse sections leaf of *Dillenia indica*.

(A) Lamina and (B) Leaf margin. Scale bar: A, B = 200 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma cells, PM = palisade mesophyll, SM = spongy mesophyll, SE = secretory cavities.

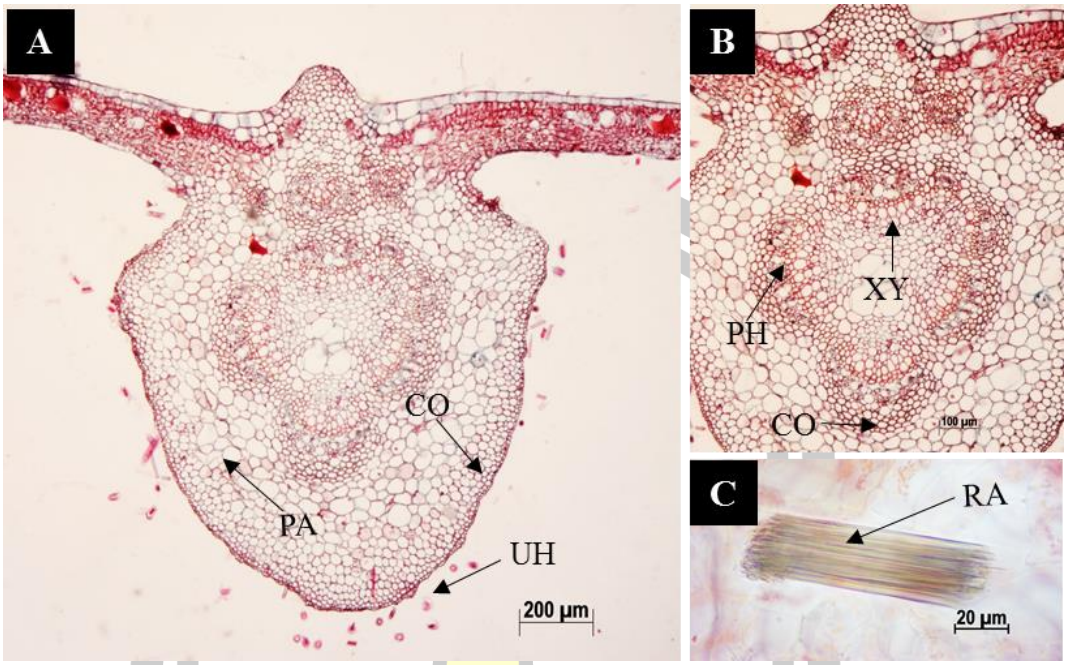

Figure 76 Transverse section of midribs of *Dillenia indica*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by collenchyma cells. (C) Raphide crystals. Scale bar: A = 200 µm, B = 100 µm C = 20 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA = raphide crystals, UH = unicellular hair, XY = xylem.

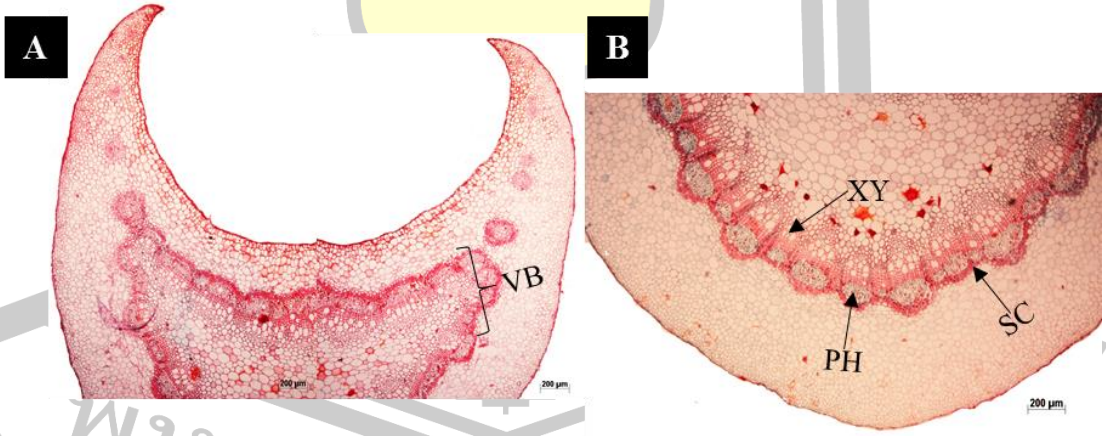

Figure 77 Transverse section of petiole of *Dillenia indica*.

(A) The outline of petiole on adaxial surface. (B) The outline of petiole on abaxial surface. Scale bar: A, B = 200 µm. Key to abbreviations: PH = phloem, SC = sclerenchyma cells, VB = vascular bundle, XY = xylem.

7. *Dillenia obovata* (Figures 78-81)

7.1 Leaf surface anatomy from the epidermal peeling methods (Figure 78)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall (Table 21). Abaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 455.00 mm^{-2}. The average lengths of guard cells are 19.60 µm. Short and long unicellular hair are observed on abaxial surface. The average length of short and long unicellular hairs are 69.10 and 140.32 µm respectively. The average densities of short and long unicellular hair are 3.10 and 13.93 mm^{-2} respectively (Table 22).

7.2 Transverse section of leaf lamina (Figure 79A)

The average thickness of leaf blade is 213.12 µm. Short unicellular hairs and Long unicellular hairs are present on abaxial surfaces. The epidermis on both surfaces are one layer with epidermis cell in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are rather straight. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two to three layer of palisade parenchyma and secretory cavities are located in palisade layers. The spongy cell is composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

7.3 Transverse section of leaf margin (Figure 79B)

The outline of the leaf margin in transverse section is straight (Figure 79B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin

in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

7.4 Transverse section of midrib (Figure 80)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 80A). Long unicellular hairs are present on both surface. Short unicellular hairs are present on abaxial surface. The epidermis cells in transverse section of both surfaces are circular or semicircular. Under the epidermis is a zone of two to four layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting two to ten separate bundles. The large main vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by chlorenchyma cells. Two main type of crystals were found, namely raphides and crystal sand. Crystals were found in parenchyma cells of ground tissue (Table 24).

7.5 Transverse section of petiole (Figure 81)

The outline of the petioles shape in transverse section at the adaxial surface and abaxial surface are U-shaped. The two adaxial wings bent out of the core. Short unicellular hairs and long unicellular hairs are present on abaxial surface. The epidermis cells in transverse section are four side to semicircular shape and cells are smaller than cells in the ground tissue. The adaxial epidermis is slightly thicker than the abaxial epidermis. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 81A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides and crystals sand were found in parenchyma cells of ground tissue (Table 25).

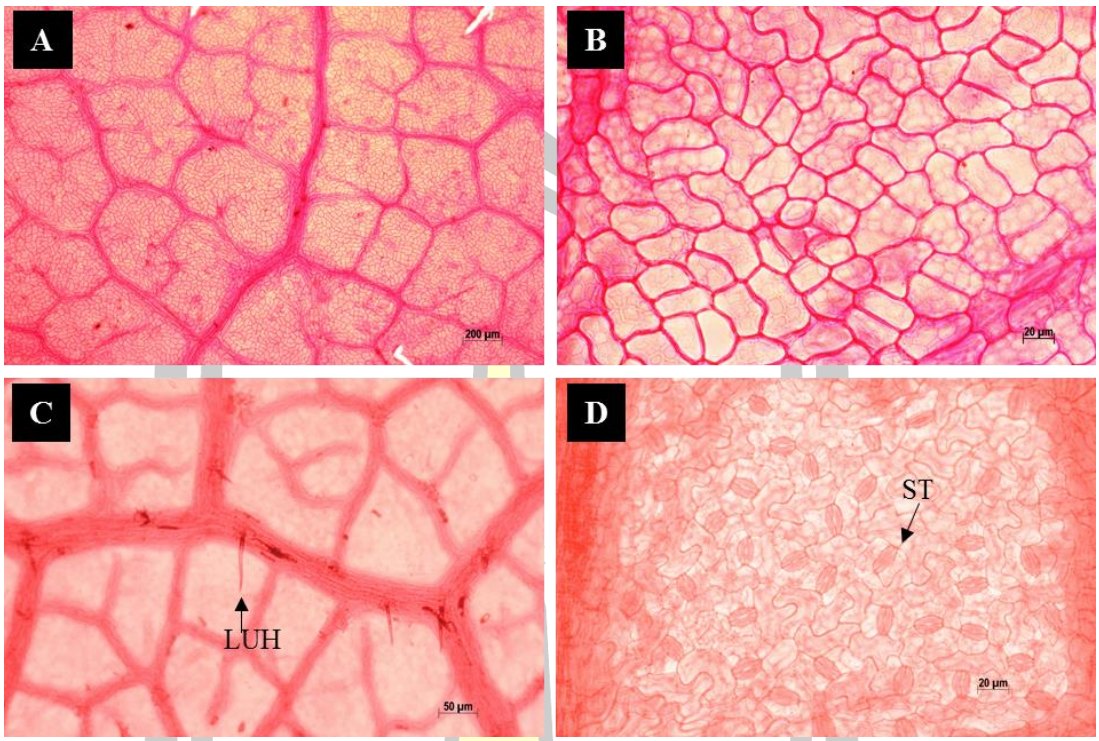

Figure 78 The leaf epidermis of *Dillenia obovata*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on adaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A = 200 µm; B, D = 20 µm; C = 50 µm. Key to abbreviations: LUH = long unicellular hair, ST = stomata.

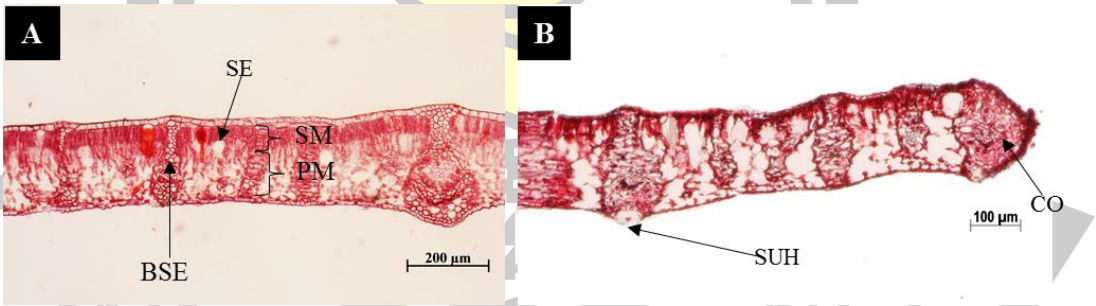

Figure 79 Transverse sections leaf of *Dillenia obovata*.

(A) Lamina and (B) Leaf margin. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma, PM = palisade mesophyll, SE = secretory cavities, SM = spongy mesophyll, SUH = short unicellular hair.

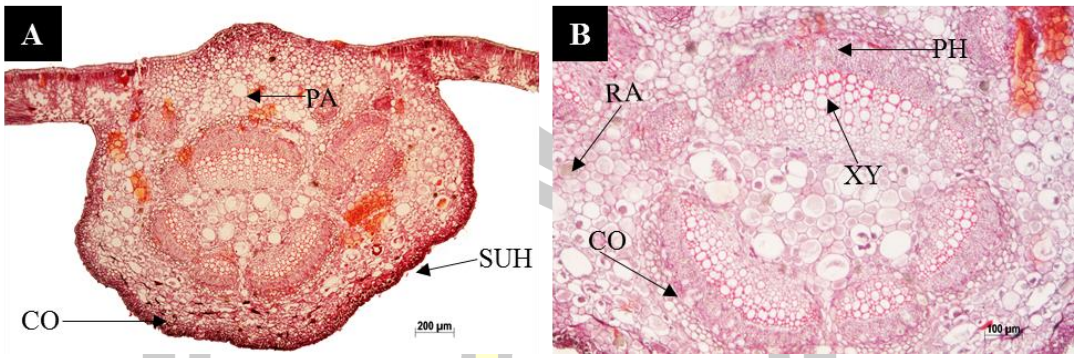

Figure 80 Transverse section of midribs of *Dillenia obovata*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by collenchyma cells. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: RA = raphide crystal, CO = collenchyma, PA = parenchyma, PH = phloem, SUH = short unicellular hair, XY = xylem.

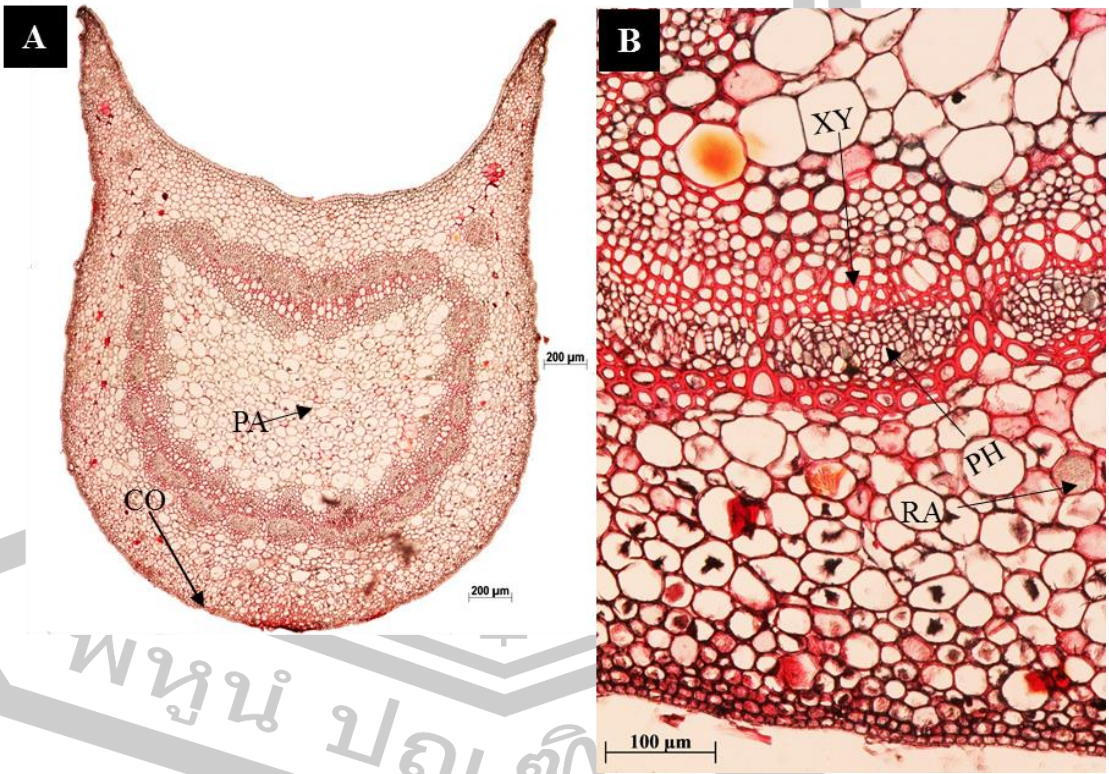

Figure 81 Transverse section of petiole of *Dillenia obovata*.

(A) The outline of petiole. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: CO = collenchyma, PA = parenchyma, PH = phloem, RA = raphides crystals, XY = xylem.

8. *Dillenia ovata* (Figures 82-85)

8.1 Leaf surface anatomy from the epidermal peeling methods (Figure 82)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall. Long unicellular hairs are observed on adaxial surface. The average length of long hairs is 233.33 µm. The average densities of long hairs are 3.06 mm^{-2} (Table 21). Abaxial surface: The shapes of epidermal cells are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 624.84 mm^{-2}. The average length of guard cells is 18.90 µm. Long unicellular hairs are observed on abaxial surface. The average length of long unicellular hairs is 262.60 µm. The average densities of long unicellular hairs are 40.55 mm^{-2} (Table 22).

8.2 Transverse section of leaf lamina (Figure 83A)

The average thickness of leaf blade is 250.07 µm. Long unicellular hairs are present on both surfaces. The epidermis on both surfaces are one layer with epidermis cell in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. Thin cuticle is presented on both surfaces. The outline of adaxial epidermal layers are rather straight. The outline of abaxial epidermal layers are sinuate. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two to three layer of palisade parenchyma and secretory cavities are located in palisade layers. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

8.3 Transverse section of leaf margin (Figure 83B)

The outline of the leaf margin in transverse section is curved down (Figure 83B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

8.4 Transverse section of midrib (Figure 84)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 84A). Long unicellular hairs are present on both surfaces. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 2 to 10 separate bundles. The large main vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by sclerenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

8.5 Transverse section of petiole (Figure 85)

The outline of the petioles shape in transverse section at the adaxial surface and abaxial surface are U-shaped. The two adaxial wings rolls toward the core. Long unicellular hairs are presented on both surfaces. The epidermis cells in transverse section are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 85A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

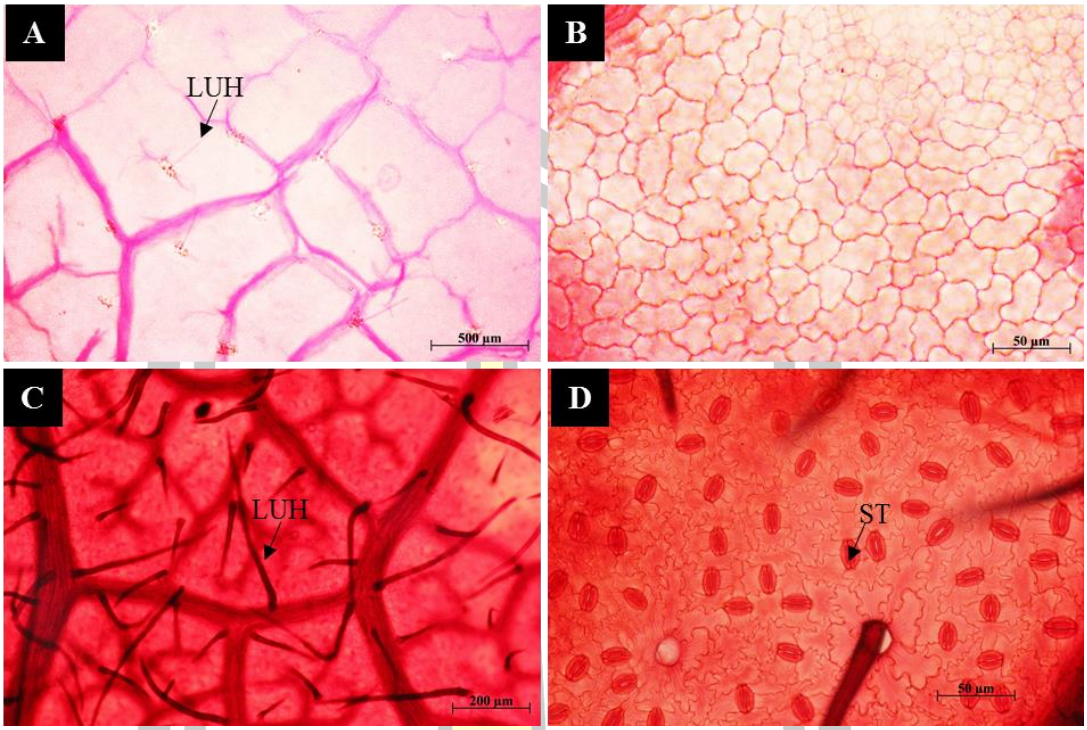

Figure 82 The leaf epidermis of *Dillenia ovata*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A = 500 µm, B, D = 50 µm, C = 200 µm. Key to abbreviations: LUH = long unicellular hair, ST = stomata

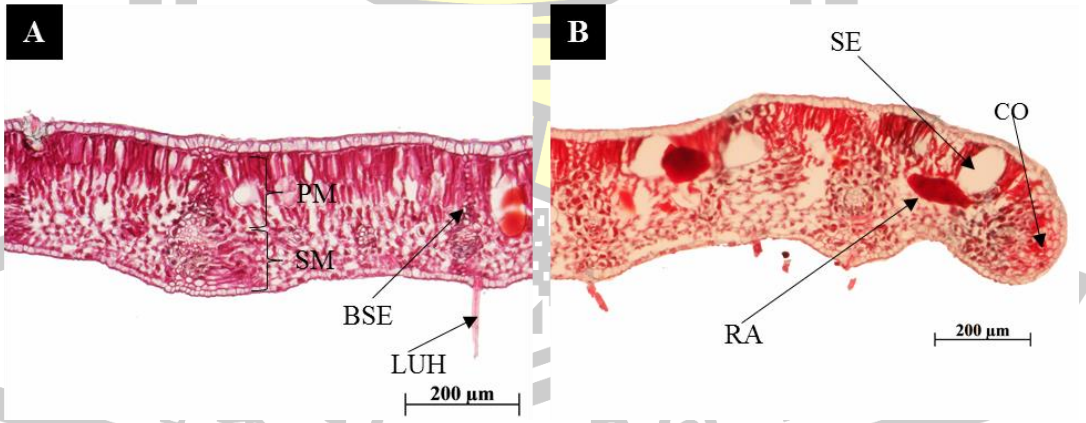

Figure 83 Transverse sections leaf of *Dillenia ovata*.

(A) Lamina and (B) Leaf margin. Scale bar: A, B = 200 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma, LUH = long unicellular hair, PM = palisade mesophyll, RA = raphide crystals, SE = secretory cavities, SM = spongy mesophyll.

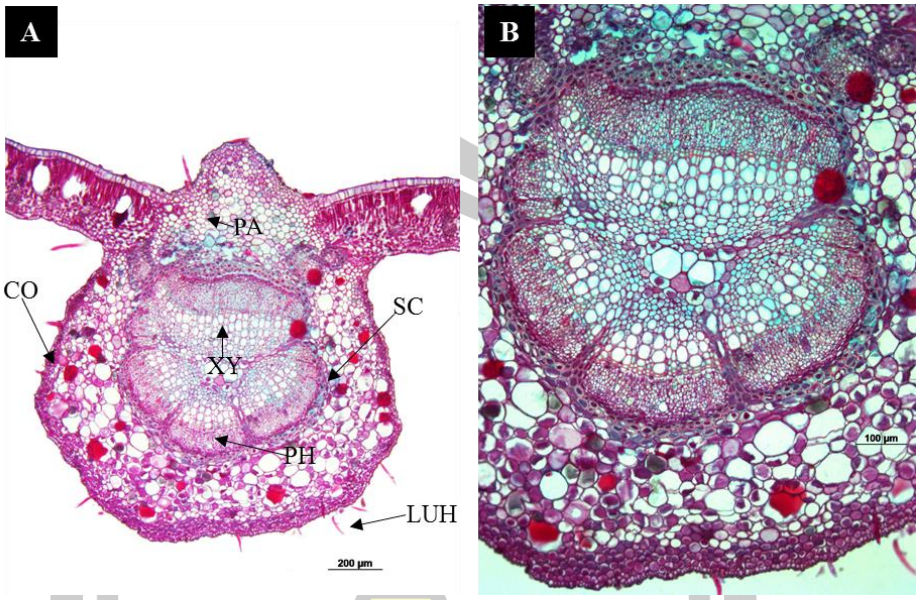

Figure 84 Transverse section of midribs of *Dillenia ovata*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: CO = collenchyma, LUH = long unicellular hair, PA = parenchyma, PH = phloem, SC = sclerenchyma cells, XY = xylem.

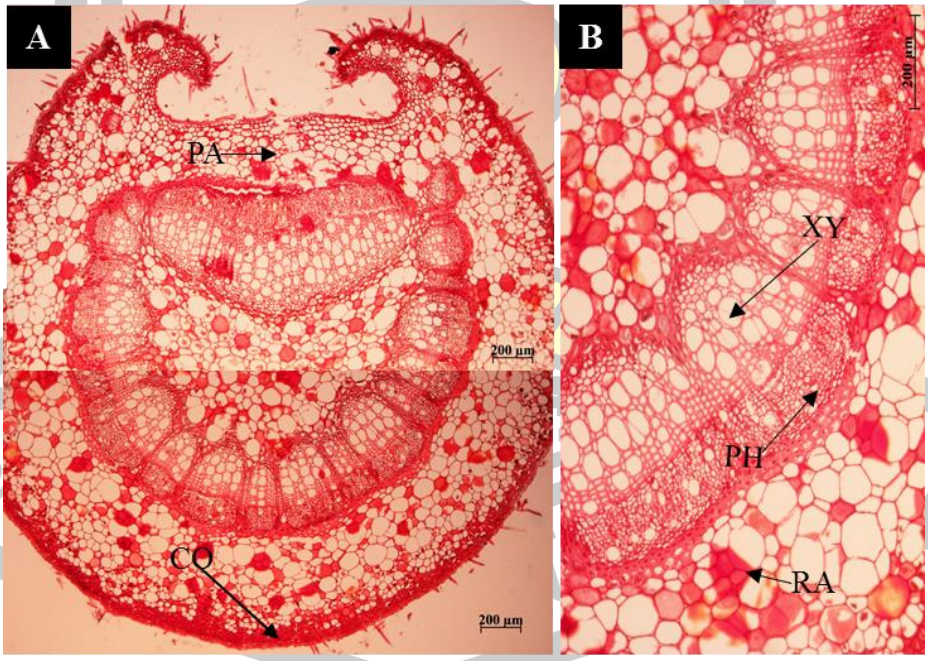

Figure 85 Transverse section of petiole of *Dillenia ovata*.

(A) The outline of petiole. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A, B, C = 200 µm. Key to abbreviations: CO = collenchyma, PA = parenchyma, PH = phloem, RA = raphides crytals, XY = xylem.

9. *Dillenia parviflora* (Figures 86-89)

9.1 Leaf surface anatomy from the epidermal peeling methods (Figure 86)

Adaxial surface: The shapes of epidermal cells are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall. Short and long unicellular hairs are observed on adaxial surface. The average length of short and long trichomes are 85.12 and 357.61 µm respectively. The average densities of short and long trichomes are 0.92 and 3.25 mm^{-2} respectively (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 120.00 mm^{-2}. The average lengths of guard cells are 21.88 µm. Short and long unicellular hairs are observed on abaxial surface. The average length of short and long trichomes are 82.13 and 211.53 µm respectively. The average densities of short and long trichomes are 0.85 and 25.28 mm^{-2} respectively (Table 22).

9.2 Transverse section of leaf lamina (Figure 87A)

The average thickness of leaf blade is 104.87 µm. Short and long unicellular hairs are presented on both surfaces. The epidermis on both surfaces are one layer with epidermis cell in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are rather straight. Thin cuticle is present on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one layer of palisade parenchyma. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

9.3 Transverse section of leaf margin (Figure 87B)

The outline of the leaf margin in transverse section is curved down (Figure 87B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

9.4 Transverse section of midrib (Figure 88)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 88A). Short unicellular hairs and long unicellular hair are present on both surfaces. The epidermis cells in transverse section of both surfaces are four side to semicircular and cells are smaller than cells in group tissue. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting four to six separate bundles. The large main vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by sclerenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

9.5 Transverse section of petiole (Figure 89)

The outline of the petioles shape in transverse section at the adaxial surface is concave, while the abaxial surface is U-shaped. The two adaxial wings curved toward the core. Short unicellular hairs and long unicellular hair are present on both surfaces. The epidermis cells in transverse section are four side to circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 89A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

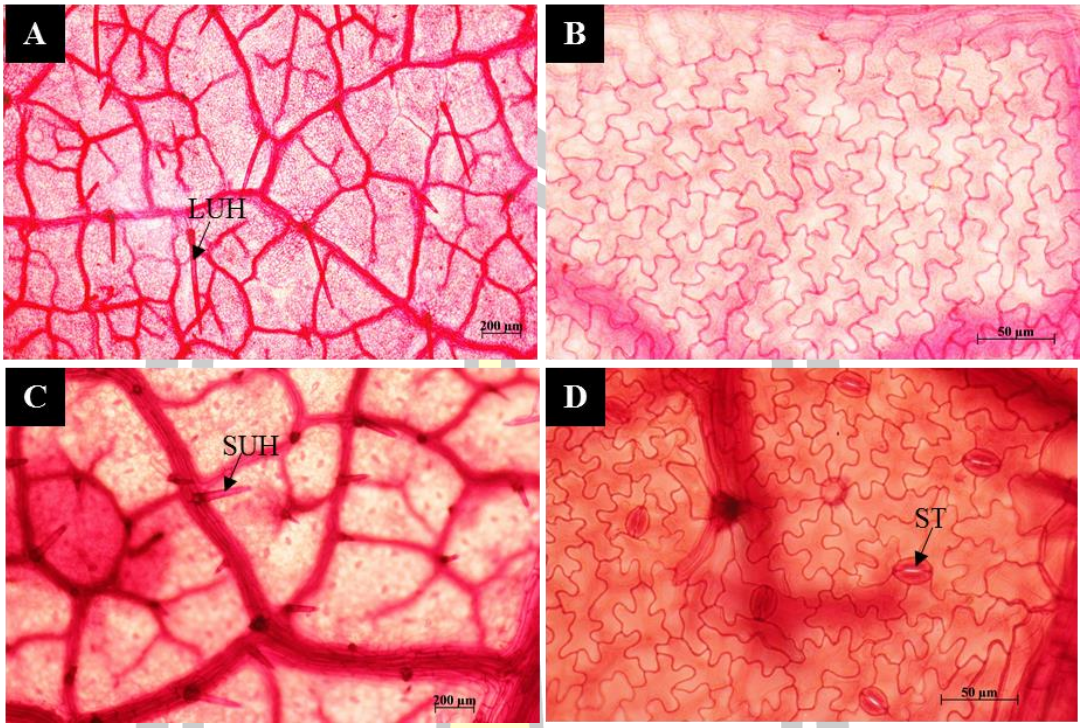

Figure 86 The leaf epidermis of *Dillenia parviflora*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A = 500 µm; B, D = 50 µm; C = 200 µm. Key to abbreviations: LUH = long unicellular hair, ST = stomata, SUT = short unicellular hair.

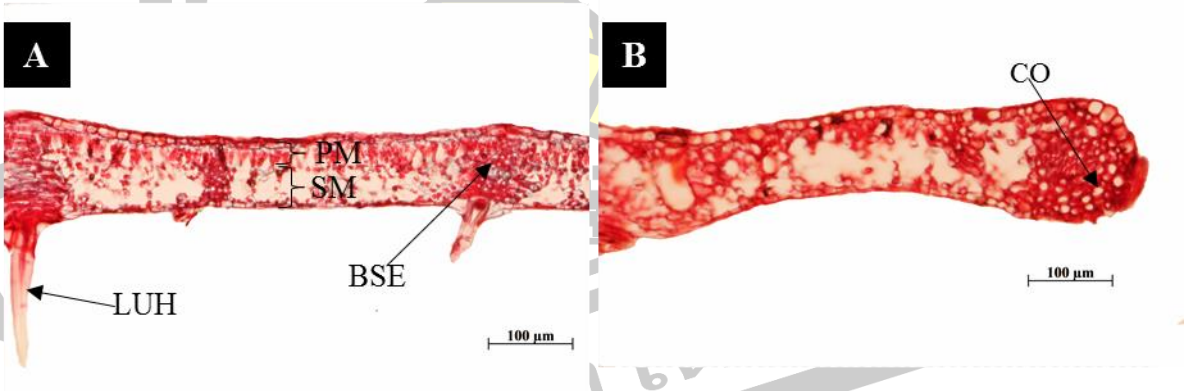

Figure 87 Transverse sections leaf of *Dillenia parviflora*.

(A) Lamina and (B) Leaf margin. Scale bar: A, B = 100 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma cells, LUH = long unicellular hair, PM = palisade mesophyll, SM = spongy mesophyll.

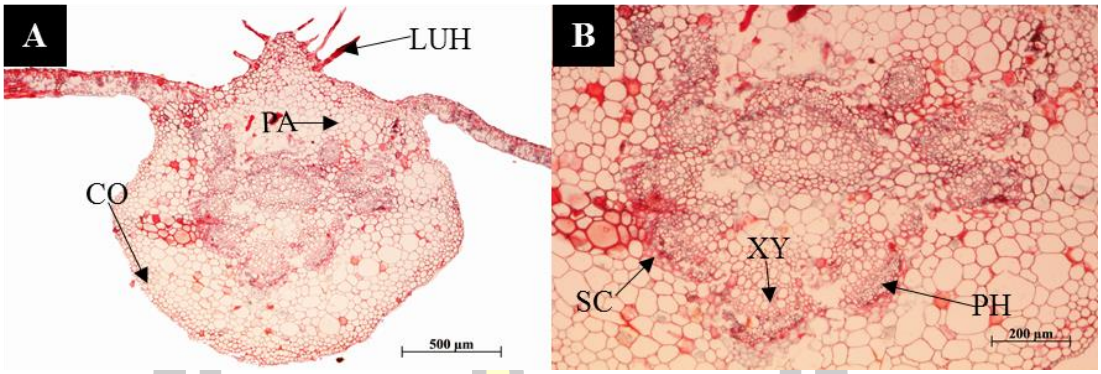

Figure 88 Transverse section of midribs of *Dillenia parviflora*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A = 500 µm, B = 200 µm. Key to abbreviations: CO = collenchyma, PA = parenchyma, PH = phloem, SC = sclerenchyma cells, UH = unicellular hair, XY = xylem.

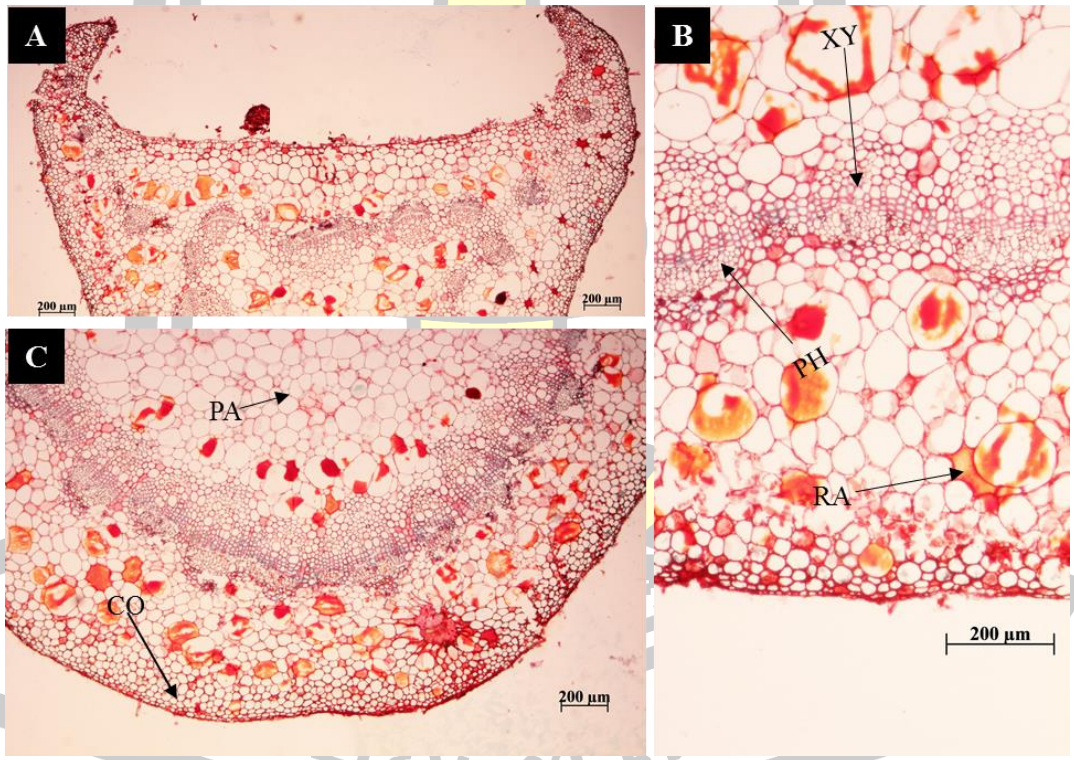

Figure 89 Transverse section of petiole of *Dillenia parviflora*.

(A) The outline of petiole on adaxial surface. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. (C) The outline of petiole on abaxial surface. Scale bar: A, B, C = 200 µm. Key to abbreviations: CO = collenchyma, PA = parenchyma, PH = phloem, RA = raphides crytals, XY = xylem.

10. *Dillenia pentagyna* (Figures 90-93)

10.1 Leaf surface anatomy from the epidermal peeling methods (Figure 90)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall. Long unicellular hairs are observed on adaxial surface. The average length of long hairs is 369.24 µm. The average densities of long hairs are 1.40 mm^{-2} (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 347.50 mm^{-2}. The average lengths of guard cells are 26.24 µm. Long unicellular hairs are observed on abaxial surface. The average length of long trichomes are 352.48 µm. The average densities of long trichomes are 2.88 mm^{-2} (Table 22).

10.2 Transverse section of leaf lamina (Figure 91A)

The average thickness of leaf blade is 207.95 µm. Long unicellular hairs are presented on both surfaces. The epidermis on both surfaces are one layer with epidermis cell in transverse section of adaxial surfaces are four side, while epidermis cells of abaxial surfaces are circular or semicircular with straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are rather straight. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two layer of palisade parenchyma and secretory cavities are located in palisade layers. The spongy cell is composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

10.3 Transverse section of leaf margin (Figure 91B)

The outline of the leaf margin in transverse section is curved down (Figure 91B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than

cells in the epidermis of lamina. Air space occupies the half of the margin in cross section (Table 24).

10.4 Transverse section of midrib (Figure 92)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 92A). Long unicellular hairs are presented on both surfaces. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 2 to 10 separate bundles. The large main vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by sclerenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

10.5 Transverse section of petiole (Figure 93)

The outline of the petioles shape in transverse section at the adaxial surface and abaxial surface are U-shaped. The two adaxial wings curved toward the core. Long unicellular hair present on abaxial surface. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The large main vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 93A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

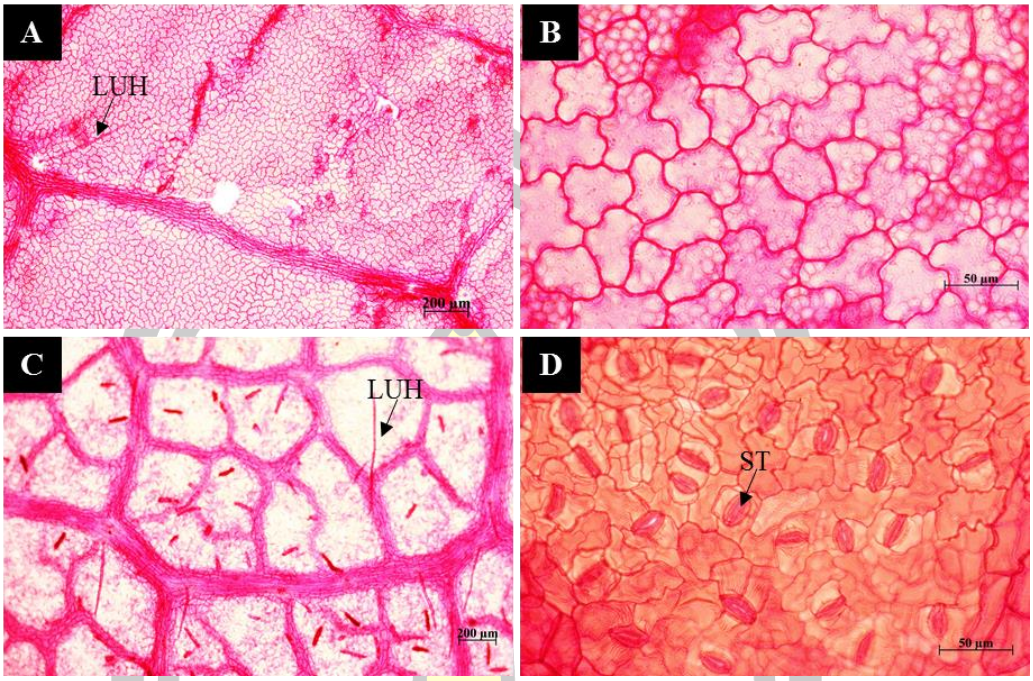

Figure 90 The leaf epidermis of *Dillenia pentagyna*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A = 200 µm; B, D = 50 µm; C = 200 µm. Key to abbreviations: LUH = long unicellular hair, ST = stomata.

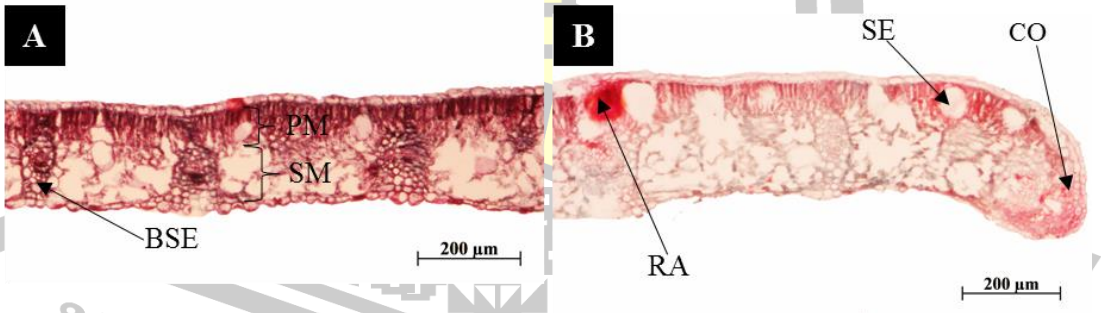

Figure 91 Transverse sections leaf of *Dillenia pentagyna*.

(A) Lamina and (B) Leaf margin. Scale bar: A, B = 200 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma cells, PM = palisade mesophyll, RA = raphide crytals, SE = secretory cavities, SM = spongy mesophyll.

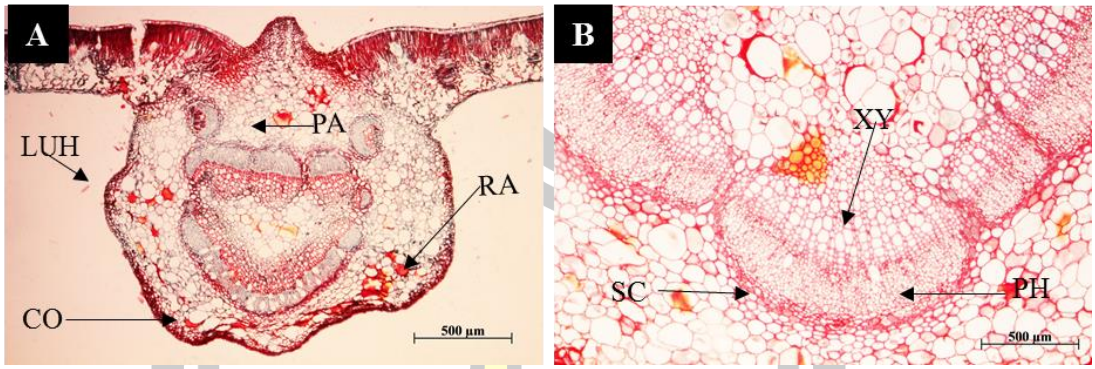

Figure 92 Transverse section of midribs of *Dillenia pentagyna*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A, B = 500 µm. Key to abbreviations: LUH = long unicellular hair, PA = parenchyma cells, PH = phloem, RA = raphide crystal, SC = sclerenchyma cells, XY = xylem.

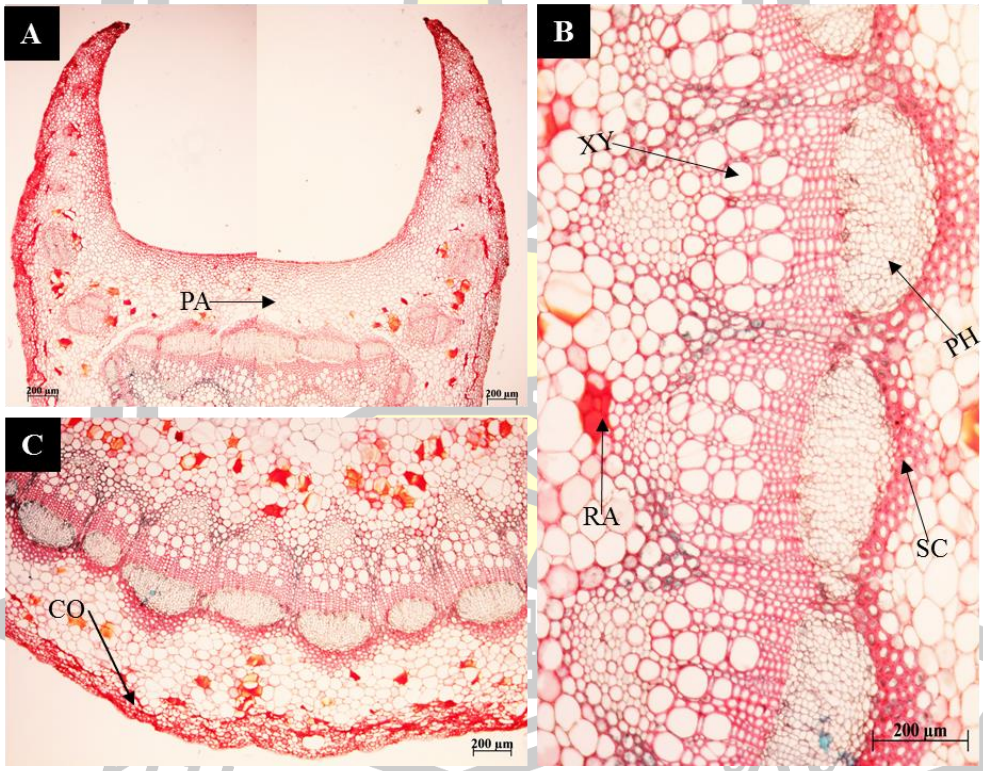

Figure 93 Transverse section of petiole of *Dillenia pentagyna*.

(A) The outline of petiole on adaxial surface. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. (C) The outline of petiole on abaxial surface. Scale bar: A, B, C = 200 µm. Key to abbreviations: CO = collenchyma, PA = parenchyma cells, PH = phloem, RA = raphides crytals, SC= sclerenchyma cells, XY = xylem.

11. *Dillenia philippinensis* (Figures 94-97)

11.1 Leaf surface anatomy from the epidermal peeling methods (Figure 94)

Adaxial surface: The shapes of epidermal cells are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall. Two to five cells (per one group) of epidermal sclereids are massive, thick-walled and these is very little space in cells. The striking nature of these isolated may be seen in surface view in Figure 94A. Multiple glandular trichomes are observed on adaxial surface. The average diameter of glandular trichomes is 23.45 µm. The average densities of glandular trichomes is 4.47 mm^{-2} (Table 21). Abaxial surface: The shapes and group of epidermal sclereids cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 227.50 mm^{-2}. The average lengths of guard cells are 21.61 µm. Multiple glandular trichomes are observed on abaxial surface. The average diameter of multiple glandular trichomes is 21.98 µm. The average densities of multiple glandular trichomes is 13.59 mm^{-2} (Table 22).

11.2 Transverse section of leaf lamina (Figure 95A)

The average thickness of leaf blade is 317.14 µm. Multiple glandular trichome are present on both surfaces. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The hypodermis was found below epidermis layer. The hypodermis is composed a single layer of large and circular or semicircular cells. In sectioning of epidermal sclereids cells are usually different from epidermal cells. The epidermal sclereids cells smaller than epidermal cells and cell walls thicker than epidermal cells. The outline of adaxial and abaxial epidermal layers are straight. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two layer of palisade parenchyma. The spongy cell is composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

11.3 Transverse section of leaf margin (Figure 95B)

The outline of the leaf margin in transverse section is straight (Figure 95B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina. Secretory cavities occupies the half of the margin in cross-section (Table 24).

11.4 Transverse section of midrib (Figure 96)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is V-shaped (Figure 96A). Multiple glandular trichomes are presented on both surfaces. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 9 to 11 separate bundles. The vascular bundles are surrounded by collenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

11.5 Transverse section of petiole (Figure 97)

The outline of the petioles shape in transverse section at the adaxial surface is concave, while abaxial surface is U-shaped. The two adaxial wings bent out of the core. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which three to four smaller vascular bundle distributed into lateral adaxial wings (Figure 97A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

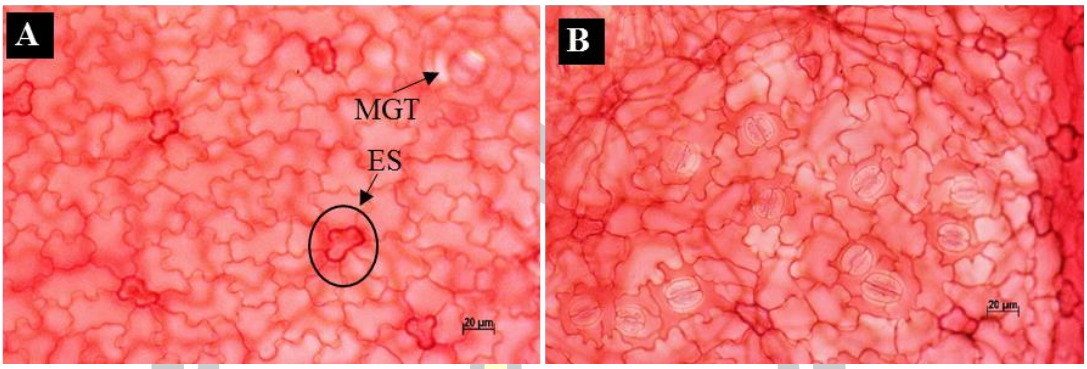

Figure 94 The leaf epidermis of *Dillenia philippinensis*.

(A) Characteristics of epidermal sclereids and multiple glandular trichomes on adaxial surface. (B) The stomata are hypostomatic with anomocytic stomatal complexes on abaxial surface. Scale bar: A and B = 20 µm. Key to abbreviations: ES = epidermal sclereids, MGT = multiple glandular trichomes.

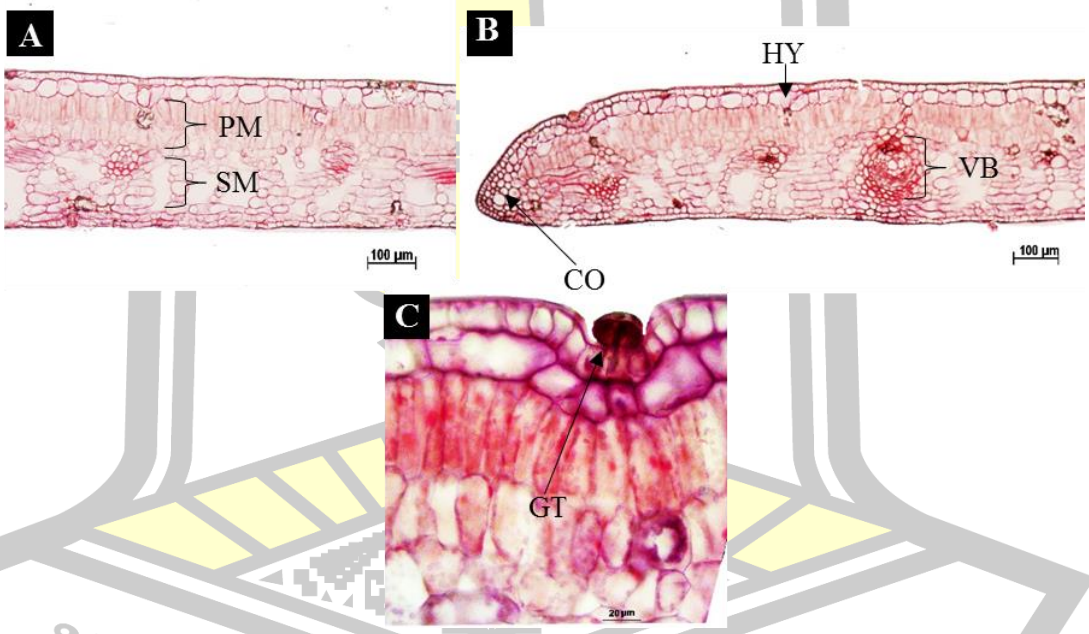

Figure 95 Transverse sections leaf of *Dillenia philippinensis*.

(A) Lamina, (B) Leaf margin and (C) Glandular trichomes. Scale bar: A and B = 100 µm, C = 20 µm. Key to abbreviations: CO = collenchyma cells, GT = glandular trichomes, HY= hypodermis, PM = palisade mesophyll, SM = spongy mesophyll, VB = vascular bundle.

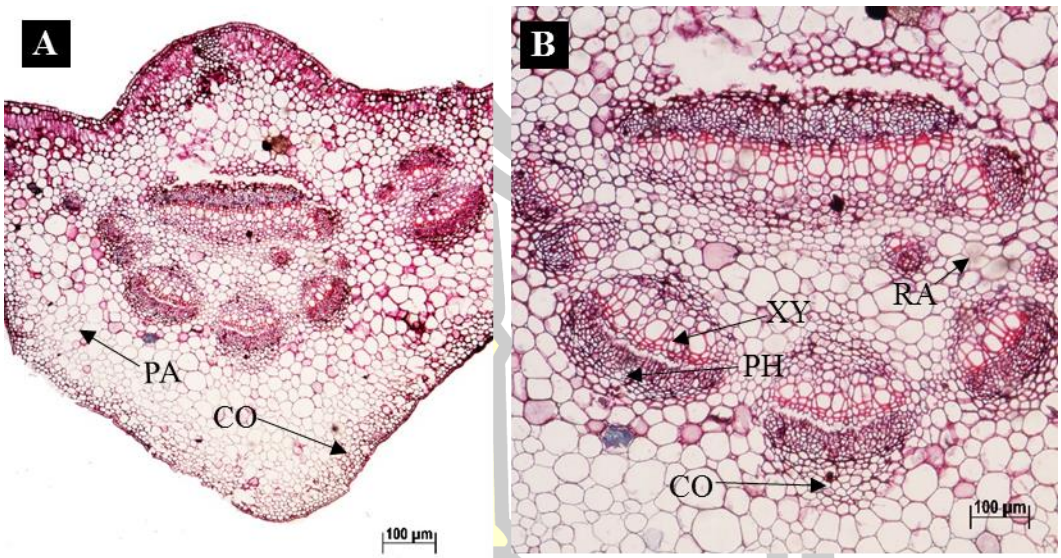

Figure 96 Transverse section of midribs of *Dillenia philippinensis*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by collenchyma cells. Scale bar: A and B = 100 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma, PH = phloem, RA= raphides crystals, XY = xylem.

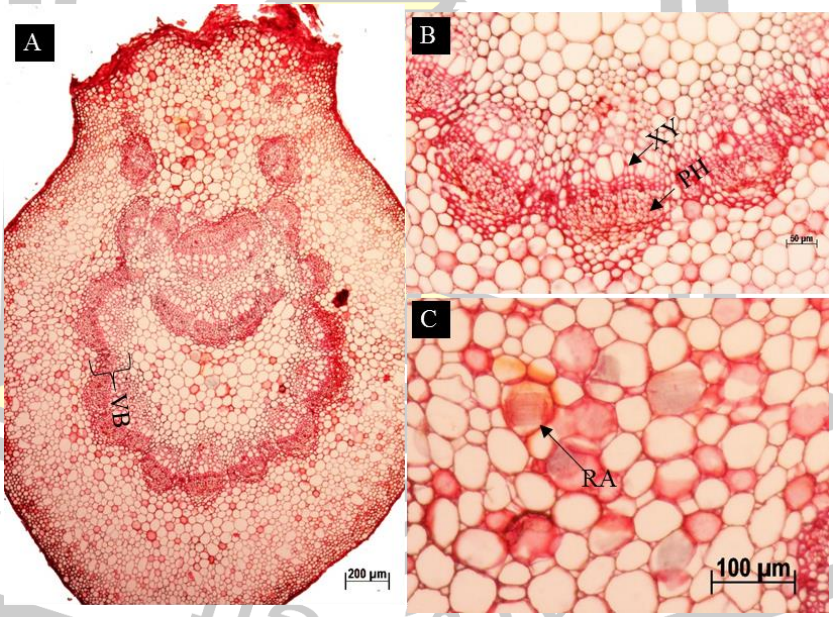

Figure 97 Transverse section of petiole of *Dillenia philippinensis*.

(A) The overview of petiole. (B) Vascular bundle of petiole. (C) Raphides crystal. Scale bar: A = 200 µm, B = 50 µm, C = 100 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA = raphides crystal, VB = vascular bundles, XY = xylem.

12. *Dillenia reticulata* (Figures 98-101)

12.1 Leaf surface anatomy from the epidermal peeling methods (Figure 98)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with slightly sinuous anticlinal wall. Long unicellular hairs are observed on adaxial surface. The average length of long hairs is 190.92 µm. The average densities of long hairs are 11.69 mm^{-2} (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 813.90 mm^{-2}. The average length of guard cells is 16.85 µm. Short and long unicellular hairs are observed on abaxial surface. The average length of short and long trichomes are 80.27 and 221.69 µm respectively. The average densities of short and long trichomes are 116.88 and 200.33 mm^{-2} respectively (Table 22).

12.2 Transverse section of leaf lamina (Figure 99A)

The average thickness of leaf blade is 212.21 µm. Long unicellular hairs are present on both surfaces. Short unicellular hairs are present on abaxial surfaces. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial epidermal layers are rather straight. The shape of abaxial epidermal layers are sinuate. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one layer of palisade parenchyma. The spongy cell is composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

12.3 Transverse section of leaf margin (Figure 99B)

The outline of the leaf margin in transverse section is straight (Figure 99B). Collenchyma cells are observed in the leaf margins. The size of Leaf margin is enlarged

to larger than leaf lamina. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

12.4 Transverse section of midrib (Figure 100)

The outline of midrib in transverse section at the adaxial surface is convex while the abaxial surface is U-shaped (Figure 100A). Long unicellular hairs and short unicellular hair are present on both surfaces. Short unicellular hairs are present on abaxial surface. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 4 to 10 separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by collenchyma cells. Raphide crystals and crystals sand were found in parenchyma cells of ground tissue (Table 24).

12.5 Transverse section of petiole (Figure 101)

The outline of the petioles shape in transverse section at adaxial surface and abaxial surface are U-shaped. The two adaxial wings rolls toward the core. Short unicellular hairs and long unicellular hairs are present on abaxial surface. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 101A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals and crystals sand were found in parenchyma cells of ground tissue (Table 25).

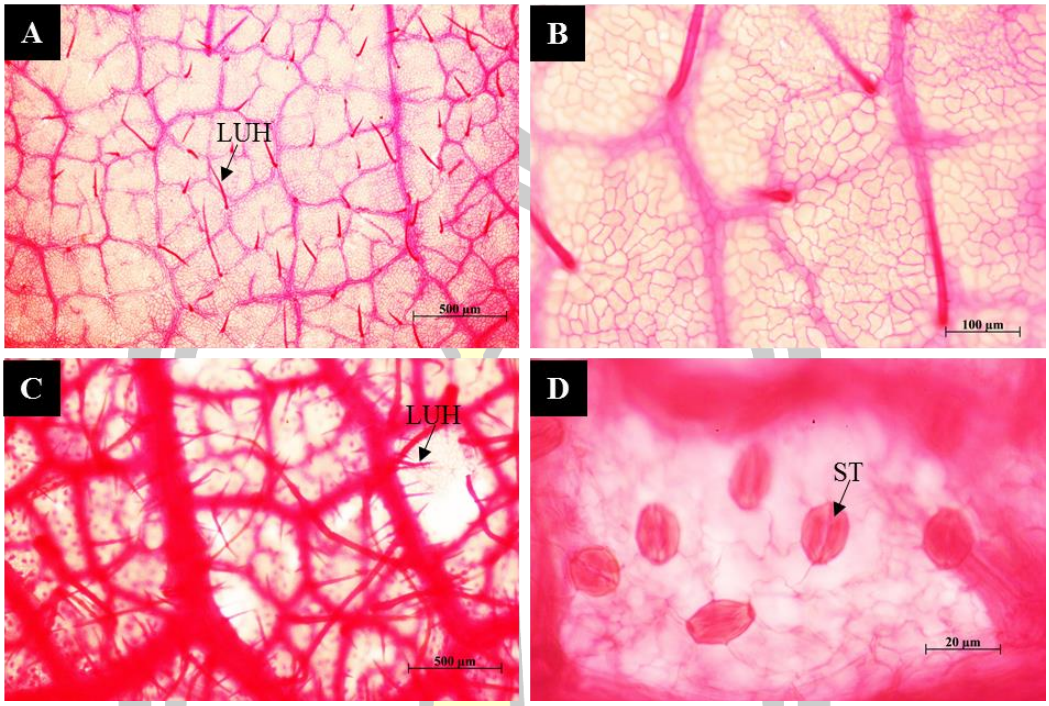

Figure 98 The leaf epidermis of *Dillenia reticulata*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A, C = 500 µm; B = 100 µm; D = 20 µm. Key to abbreviations: LUH = long unicellular hair, ST = stomata.

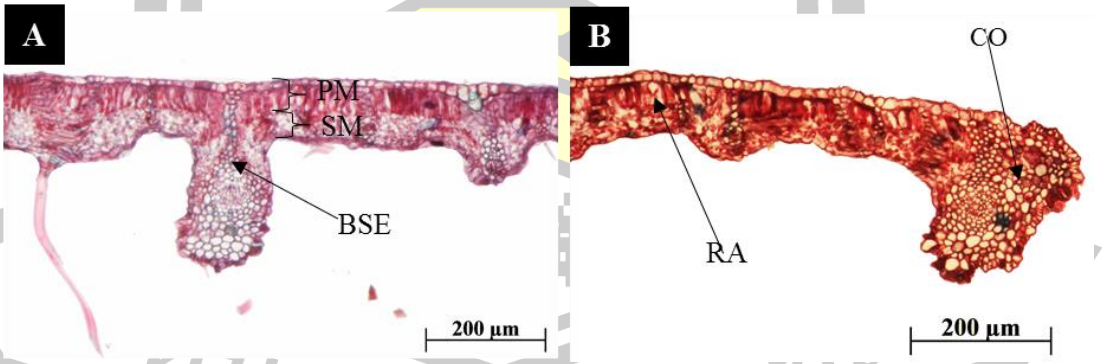

Figure 99 Transverse sections leaf of *Dillenia reticulata*.

(A) Lamina and (B) Leaf margin. Scale bar: A, B = 200 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma cells, PM = palisade mesophyll, RA = raphide crytals, SM = spongy mesophyll.

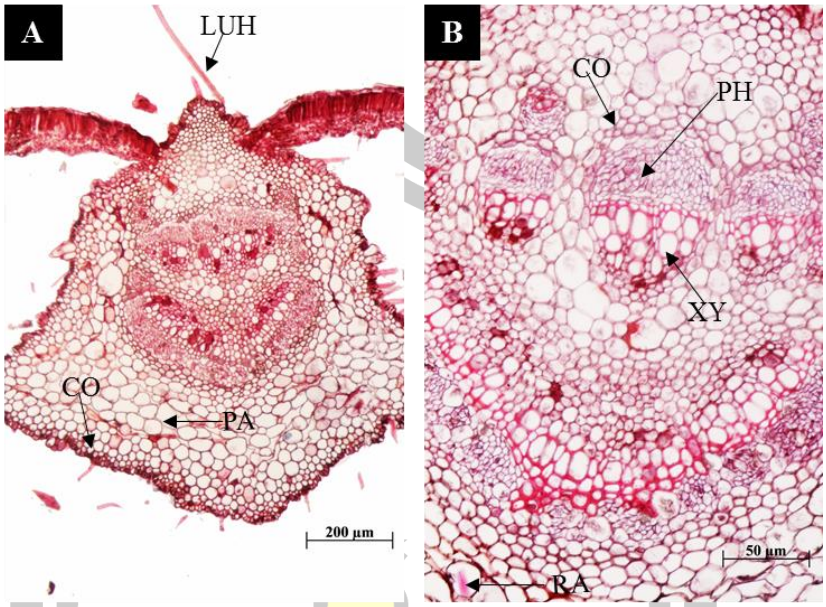

Figure 100 Transverse section of midribs of *Dillenia reticulata*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by collenchyma cells. Scale bar: A = 200 µm, B = 50 µm. Key to abbreviations: CO = collenchyma cells, LUH = long unicellular hair, PA = parenchyma cells, PH = phloem, RA = raphide crystal, XY = xylem.

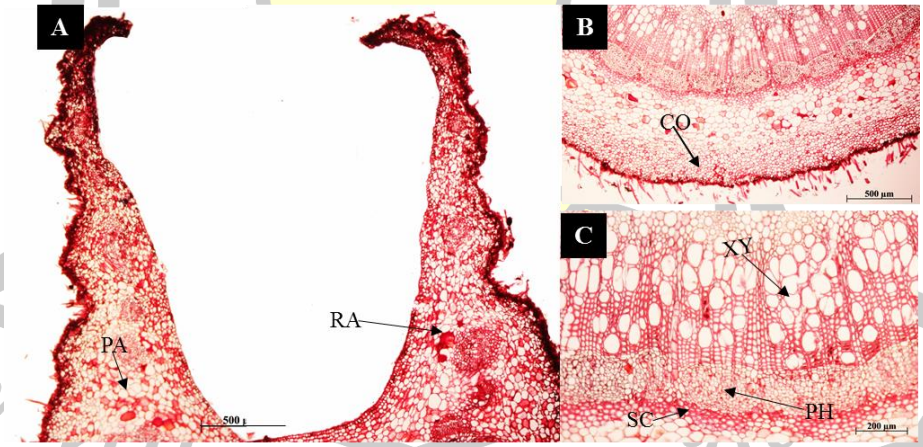

Figure 101 Transverse section of petiole of *Dillenia reticulata*.

(A) The outline of petiole on adaxial surface. (B) The outline of petiole on abaxial surface. (C) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A, B = 500 µm; C = 200 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA = raphides crytals, SC = sclerenchyma cells, XY = xylem.

13. *Dillenia scabrella* (Figures 102-105)

13.1 Leaf surface anatomy from the epidermal peeling methods (Figure 102)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with straight or slightly curved anticlinal walls. Long unicellular hairs are observed on adaxial surface. The average length of long hairs is 295.31 µm. The average densities of long hairs are 14.47 mm^{-2} (Table 21). Abaxial surface: The shapes of epidermal cells are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 363.01 mm^{-2}. The average lengths of guard cells are 23.58 µm. Short and long unicellular hairs are observed on adaxial surface. The average length of short and long trichomes are 66.66 and 246.66 µm respectively. The average densities of short and long trichomes are 41.48 and 15.01 mm^{-2} respectively (Table 22).

13.2 Transverse section of leaf lamina (Figure 103A)

The average thickness of leaf blade is 202.46 µm. Long unicellular hairs are present on both surfaces. Short unicellular hairs are present on abaxial surfaces. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are slightly sinuate. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two layers of palisade parenchyma. The spongy cell is composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by sclerenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are present in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

13.3 Transverse section of leaf margin (Figure 103B)

The outline of the leaf margin in transverse section is straight (Figure 103B). Sclerenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

13.4 Transverse section of midrib (Figure 104)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped (Figure 104A). Long unicellular hairs are present on both surfaces. Short unicellular are present on abaxial surface. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting 2 to 10 separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by sclerenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

13.5 Transverse section of petiole (Figure 105)

The outline of the petioles shape in transverse section at the adaxial surface and abaxial surface are U-shaped. The two adaxial wings curved toward the core. Long unicellular hairs are present on both surfaces. Short unicellular are present on abaxial surface. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which four to five smaller vascular bundle distributed into lateral adaxial wings (Figure 105A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

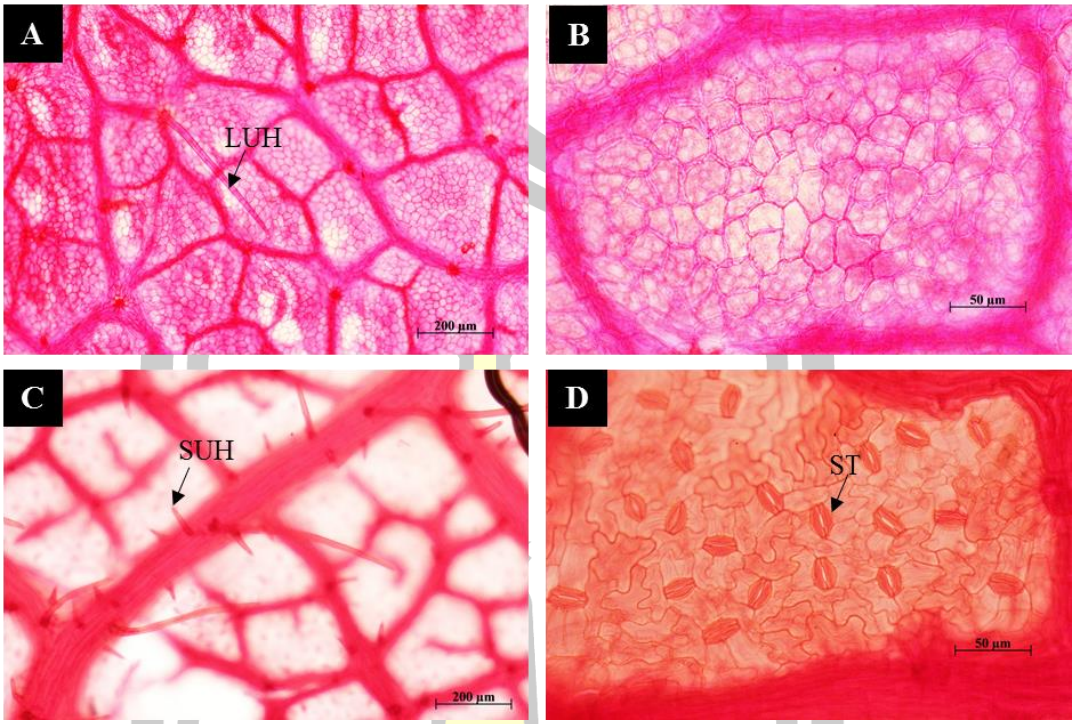

Figure 102 The leaf epidermis of *Dillenia scabrella*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A, C = 200 µm; B, D = 50 µm. Key to abbreviations: LUH = long unicellular hair, ST = stomata, SUH = short unicellular hair.

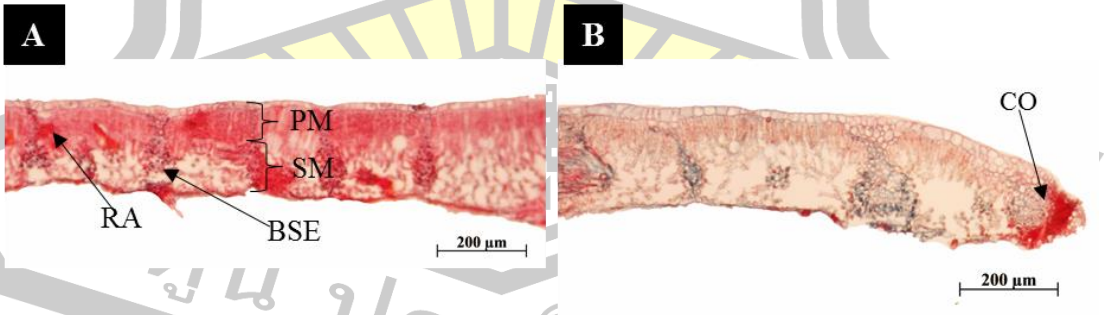

Figure 103 Transverse sections leaf of *Dillenia scabrella*.

(A) Lamina and (B) Leaf margin. Scale bar: A, B = 200 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma cells, PM = palisade mesophyll, RA = raphide crytals, SM = spongy mesophyll.

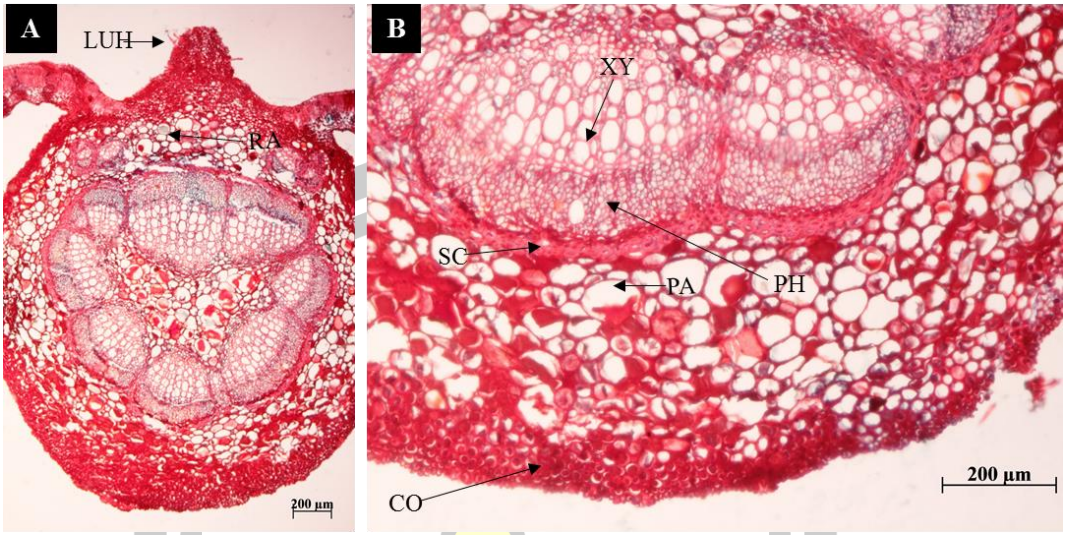

Figure 104 Transverse section of midribs of *Dillenia scabrella*.

The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A, B = 200 µm. Key to abbreviations: RA = raphide crystal, PA = parenchyma cells, PH = phloem, SC = sclerenchyma cells, UH = unicellular hair, XY = xylem.

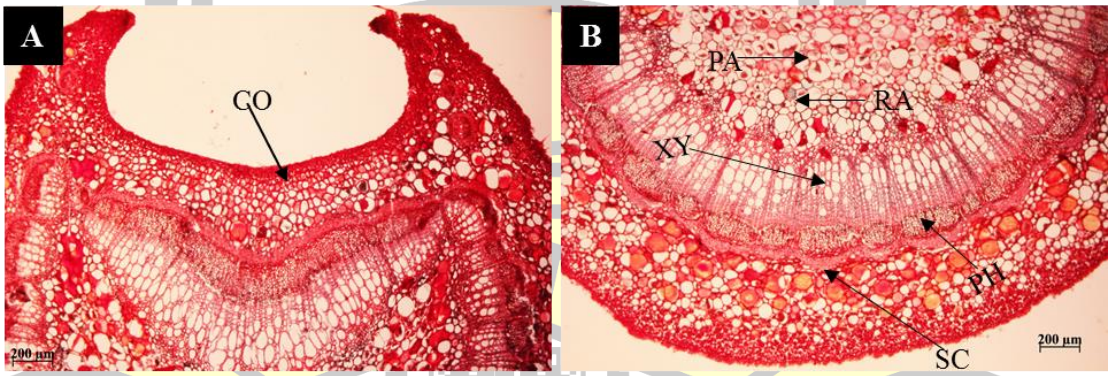

Figure 105 Transverse section of petiole of *Dillenia scabrella*.

(A) The outline of petiole on adaxial surface. (B) The outline of petiole on abaxial surface and vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A, B = 200 µm. Key to abbreviations: CO = collenchyma, PA = parenchyma, PH = phloem, RA = raphides crystals, SC= sclerenchyma cells, XY = xylem.

14. *Dillenia suffruticosa* (Figures 106-109)

14.1 Leaf surface anatomy from the epidermal peeling methods (Figure 106)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with straight or slightly curved anticlinal walls. Single glandular trichomes are observed on adaxial surface. The average diameter of glandular trichomes is 25.71 µm. The average densities of glandular trichomes is 72.71 mm^{-2} (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with anomocytic stomatal complexes. The average densities of stomata are 517.50 mm^{-2}. The average lengths of guard cells are 21.31 µm. Single and multiple glandular trichomes are observed on adaxial surface. The average length of single and multiple glandular trichomes are 25.71 and 29.11 µm respectively. The average densities of single and multiple glandular trichomes are 121.49 and 12.58 mm^{-2} respectively (Table 22).

14.2 Transverse section of leaf lamina (Figure 107A)

The average thickness of leaf blade is 294.17 µm. Single glandular trichomes are observed on both surfaces. Multiglandular trichomes are present on abaxial surface. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are straight. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with two to three layer of palisade parenchyma. The spongy cell is composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

14.3 Transverse section of leaf margin (Figure 107B)

The outline of the leaf margin in transverse section is slightly curved down (Figure 107B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

14.4 Transverse section of midrib (Figure 108)

The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is V-shaped (Figure 108A). Single glandular trichomes and multiglandular trichomes are present on abaxial surface. The epidermis cells in transverse section of both surfaces are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting two to four separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by collenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

14.5 Transverse section of petiole (Figure 109)

The outline of the petioles shape in transverse section at adaxial surface and abaxial surface are V-shape. The two adaxial wings bent out of the core. Simple glandular trichomes and multiglandular trichomes are present on abaxial. The epidermis cells in transverse section are circular or semicircular and cells are smaller than cells in the ground tissue. Under the epidermis is a zone of two to four layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which three to four smaller vascular bundle distributed into lateral adaxial wings (Figure 109A). The vascular system is composed of a central region of xylem with collateral phloem. Sclerenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

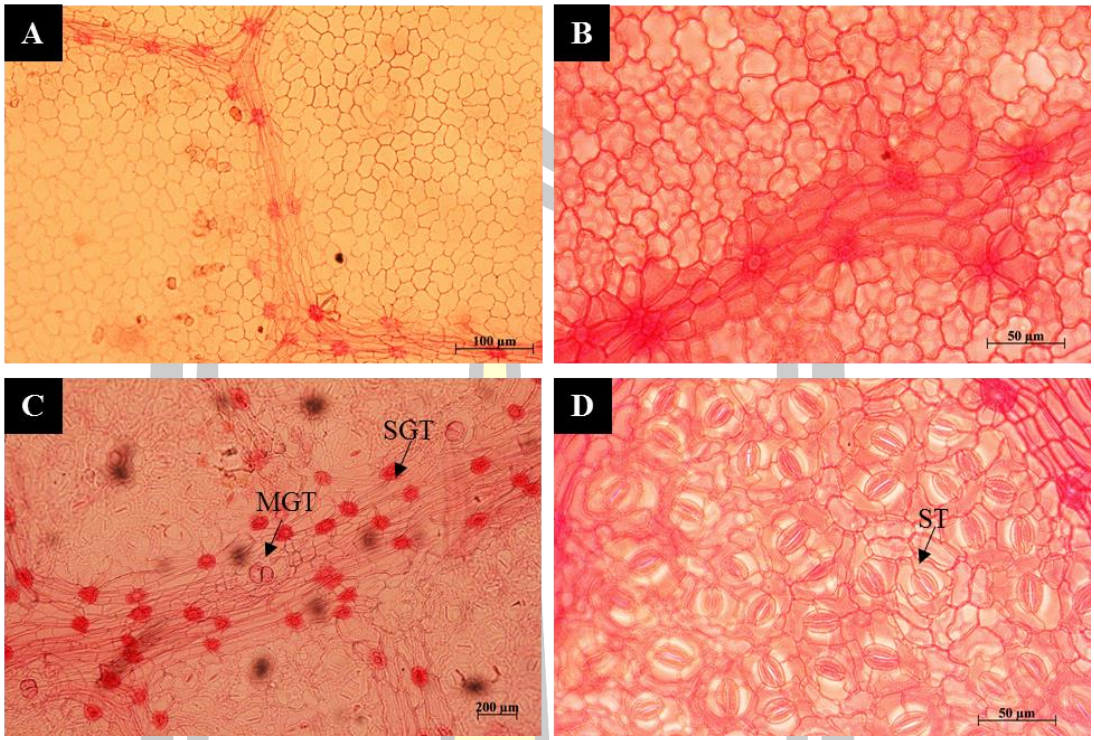

Figure 106 The leaf epidermis of *Dillenia suffruticosa*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A = 100 µm; B, D = 50 µm, C = 200 µm. Key to abbreviations: MGT = multiple glandular trichomes, SGT = single glandular trichomes, ST = stomata.

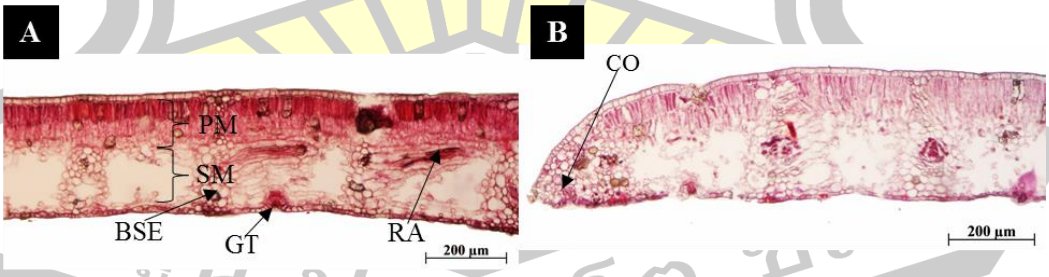

Figure 107 Transverse sections leaf of *Dillenia suffruticosa*.

(A) Lamina and (B) Leaf margin. Scale bar: A, B = 200 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma cells, GT = glandular trichomes, PM = palisade mesophyll, RA = raphide crystals, SM = spongy mesophyll.

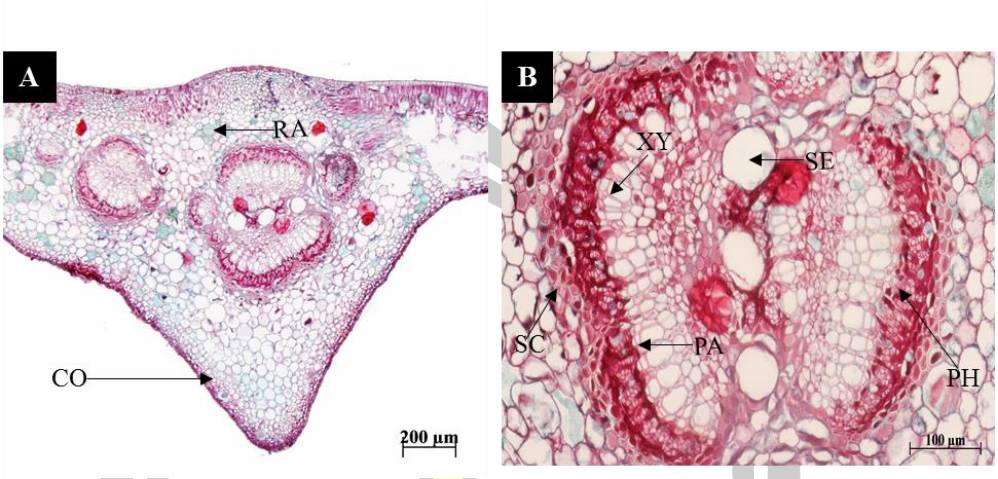

Figure 108 Transverse section of midribs of *Dillenia suffruticosa*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A= 200 µm; B = 100 µm. Key to abbreviations: RA = raphide crystal, PA = parenchyma cells, PH = phloem, SC = sclerenchyma cells, SE = secretory cavities, XY = xylem.

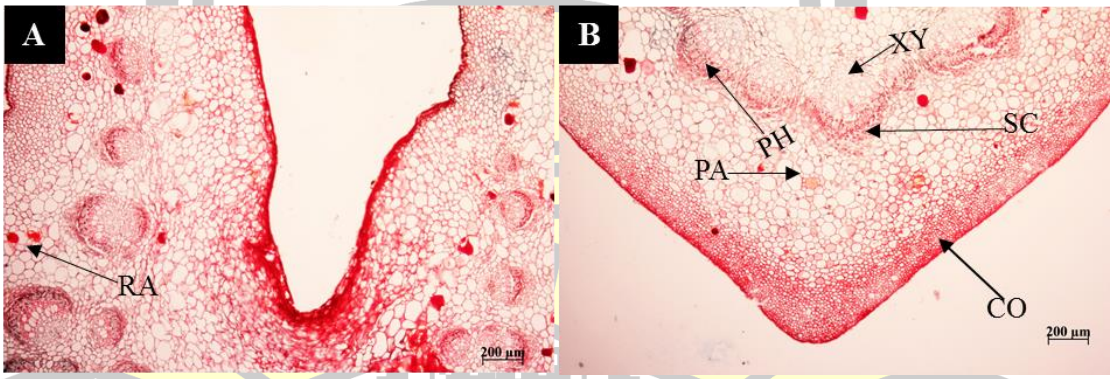

Figure 109 Transverse section of petiole of *Dillenia suffruticosa*.

(A) The outline of petiole on adaxial surface. (B) The outline of petiole on abaxial surface and vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A, B = 200 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA = raphides crystals, SC = sclerenchyma cells, XY = xylem.

15. *Tetracera indica* (Figures 110-113)

15.1 Leaf surface anatomy from the epidermal peeling methods (Figure 110)

Adaxial surface: The shapes of epidermal cells are polygonal and cells wall are sinuate with sinuous anticlinal wall (Table 21). Abaxial surface: The shapes of epidermal cells are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall. The stomata are hypostomatic with paracytic stomatal complexes. The two parallel subsidiary cells are distinguishable from the surrounding epidermal cells by their shape. The average densities of stomata are 140.00 mm^{-2}. The average lengths of guard cells are 31.38 µm (Table 22).

15.2 Transverse section of leaf lamina (Figure 111A)

The average thickness of leaf blade is 127.31 µm. The epidermis on both surfaces are one layer with epidermis cells in transverse section of both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are straight. Thin cuticle are presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one layer of palisade parenchyma. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises and these are frequently present on the largest vein whilst absent on the small veins. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

15.3 Transverse section of leaf margin (Figure 111B)

The outline of the leaf margin in transverse section is straight (Figure 111B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

15.4 Transverse section of midrib (Figure 112)

The outline of midrib in transverse section at the adaxial surface is concave, while the abaxial surface is U-shaped (Figure 112A). Spiny hairs are presented on abaxial surface. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting two to four separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by sclerenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

15.5 Transverse section of petiole (Figure 113)

The outline of the petioles shape in transverse section at the adaxial surface is straight, while the abaxial surface is U-shaped. The two adaxial small wings bent out of the core. Spiny hairs are present on abaxial surface. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Epidermis cells are usually smaller than cell in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which two to four smaller vascular bundles distributed into atero-adaxial small wings (Figure 113A). The vascular system is composed of a central region of xylem with collateral phloem. Collenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

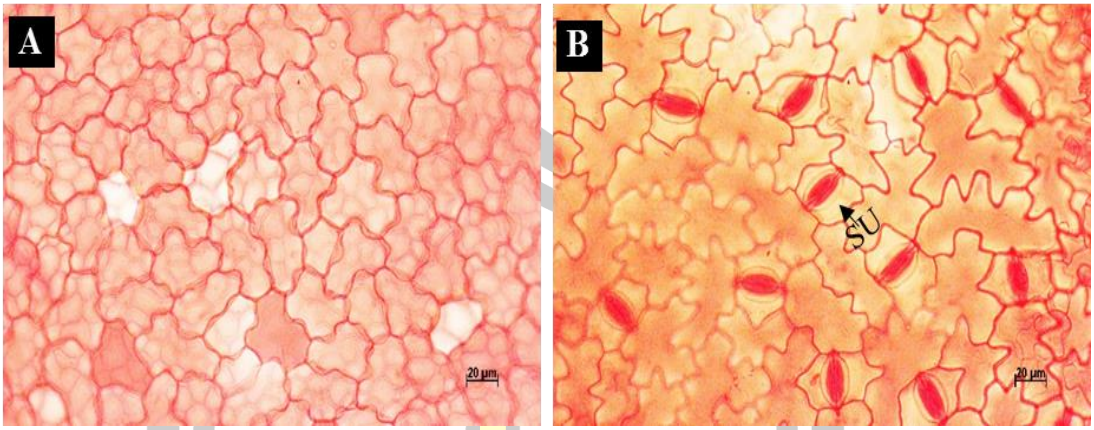

Figure 110 The leaf epidermis of *Tetracera indica*.

(A) Characteristics of epidermal shaped on adaxial surface. (B) The stomata are hypostomatic with paracytic stomatal complexes on abaxial surface. Scale bar: A, B = 20 µm. Key to abbreviations: SU = subsidiary cell.

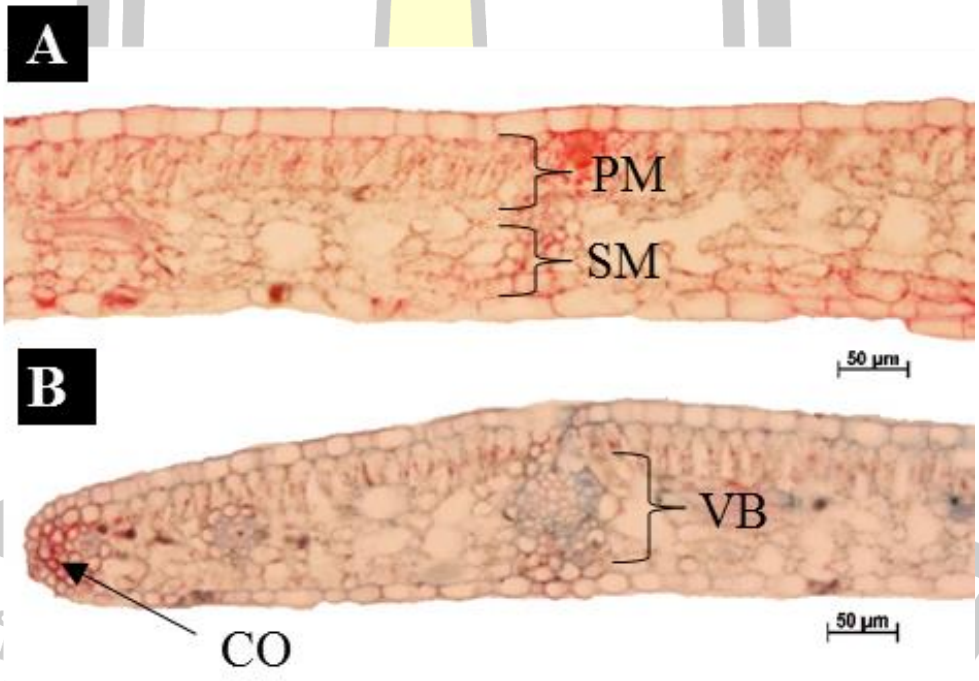

Figure 111 Transverse sections leaf of *Tetracera indica*.

(A) Lamina and (B) Leaf margin. Scale bar: A and B = 50 µm. Key to abbreviations: CO = collenchyma cell, PM = palisade mesophyll, SM = spongy mesophyll, VB = vascular bundles.

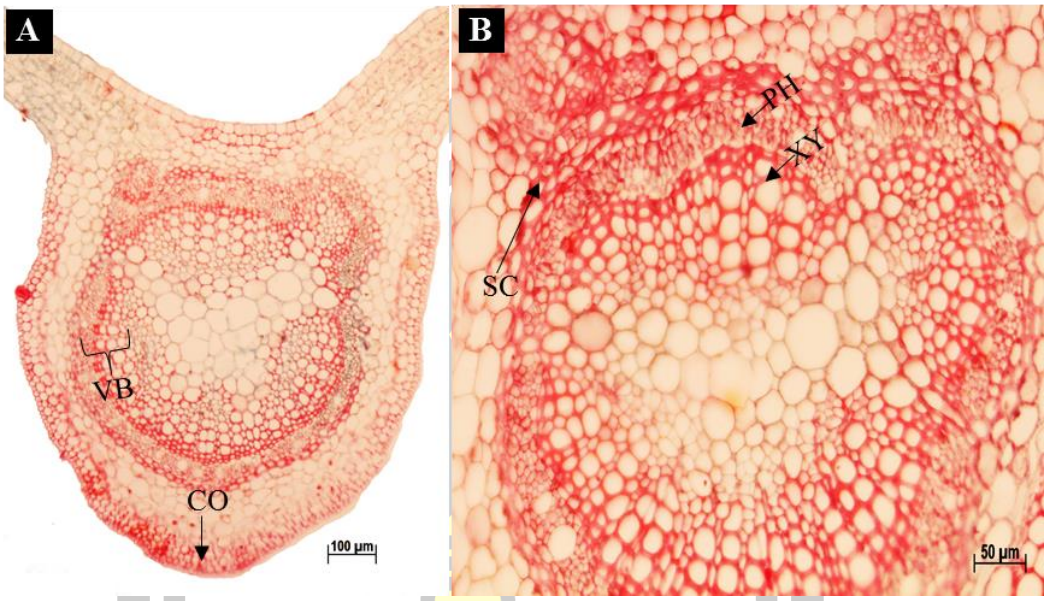

Figure 112 Transverse section of midribs of *Tetracera indica*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A = 100 µm, B = 50 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA= raphides crystals, VB = vascular bundle, XY = xylem.

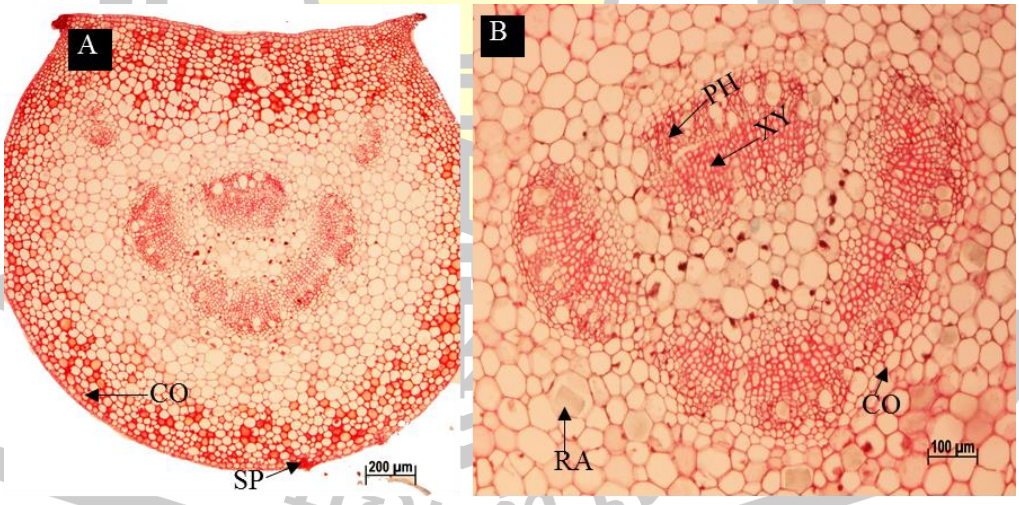

Figure 113 Transverse section of petiole of *Tetracera indica*.

(A) The outline of petiole. (B) The vascular bundle is collateral surrounding by collenchyma cells. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: CO = collenchyma cell, PA = parenchyma, PH = phloem, RA = Raphides, SH = Spiny hair, XY = xylem.

16. *Tetracera loureiri* (Figures 114-117)

16.1 Leaf surface anatomy from the epidermal peeling methods (Figure 114)

Adaxial surface: The shapes of epidermal cells are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall. Multiple glandular trichomes and spiny hair are observed on adaxial surface. The average dimeter of glandular trichomes and spiny hair are 28.66 and 124.66 µm respectively. The average densities of glandular trichomes and spiny hair are 1.02 and 7.91 mm^{-2} respectively (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with paracytic stomatal complexes. The two parallel subsidiary cells are distinguishable from the surrounding epidermal cells by their shape. The average densities of stomata are 160.00 mm^{-2}. The average lengths of guard cells are 31.12 µm. Multiple glandular trichomes and spiny hair are observed on abaxial surface. The average dimeter of glandular trichomes and spiny hair are 29.95 and 113.44 µm respectively. The average densities of glandular trichomes and spiny hair are 1.14 and 14.32 mm^{-2} respectively (Table 22).

16.2 Transverse section of leaf lamina (Figure 115A)

The average thickness of leaf blade is 164.62 µm. Multiple glandular trichomes and spiny hair are observed on both surfaces. The epidermis on both surfaces are one layer with epidermis cells on both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are straight. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one layer of palisade parenchyma. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises and these are frequently present on the largest vein whilst absent on the small veins. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

16.3 Transverse section of leaf margin (Figure 115B)

The outline of the leaf margin in transverse section is straight (Figure 115B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina. Air space occupies the half of the Leaf margin in cross-section (Table 24).

16.4 Transverse section of midrib (Figure 116)

The outline of midrib in transverse section at the adaxial surface is concave, while the abaxial surface is U-shaped (Figure 116A). Spiny hairs are present on both surfaces. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting two to four separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by collenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

16.5 Transverse section of petiole (Figure 117)

The outline of the petioles shape in transverse section at the adaxial surface is straight, while the abaxial surface is U-shaped. The two adaxial small wings bent out of the core. Spiny hairs are present on abaxial surface. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Epidermis cells are usually smaller than cell in the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which two to four smaller vascular bundle distributed into atero-adaxial small wings (Figure 117A). The vascular system is composed of a central region of xylem with collateral phloem. Collenchyma cells from a continuous ring

around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

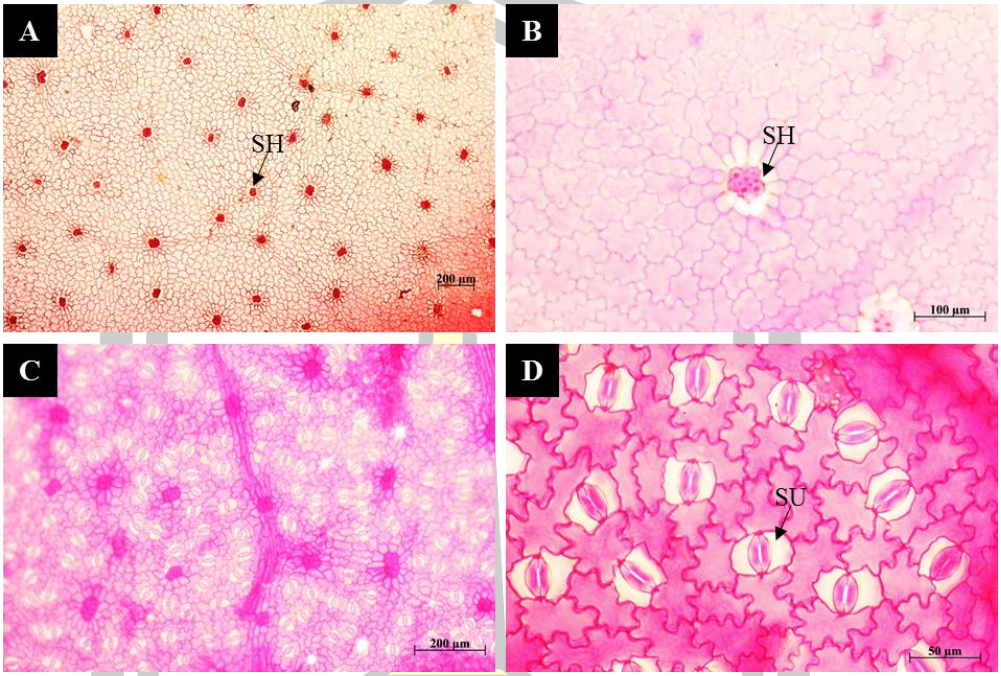

Figure 114 The leaf epidermis of *Tetracera loureiri*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A, C = 200 µm, B = 100 µm, D = 50 µm. Key to abbreviations: SH = spiny hair, SU = subsidiary cells.

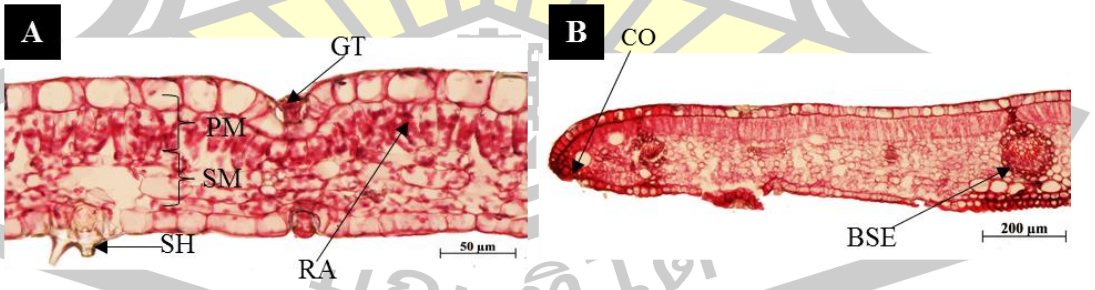

Figure 115 Transverse sections leaf of *Tetracera loureiri*.

(A) Lamina and (B) Leaf margin. Scale bar: A =100 µm, B = 200 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma cells, GT = glandular trichomes, PM = palisade mesophyll, RA = raphide crystals, SH = spiny hairs, SM = spongy mesophyll.

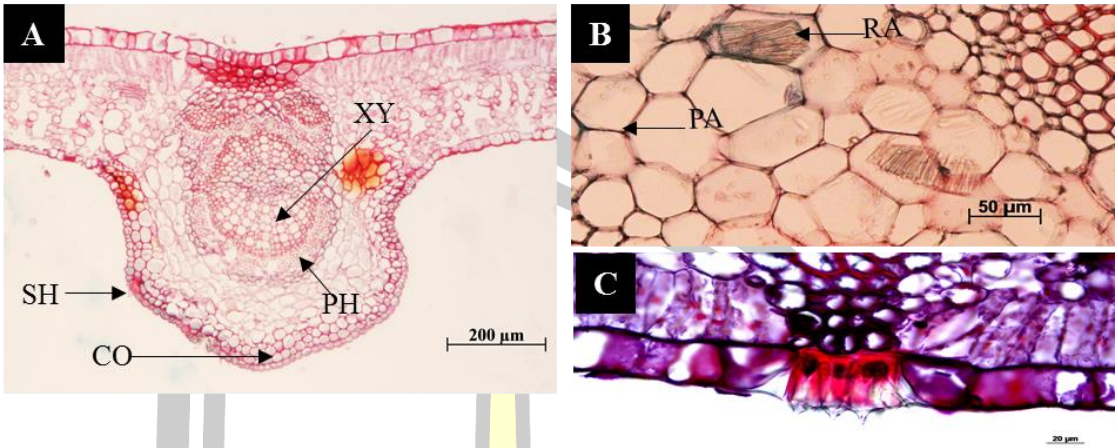

Figure 116 Transverse section of midribs of *Tetracera loureiri*.

(A) The outline of midribs. (B) Raphide crystals. (C) Spiny hair. Scale bar: A= 200 µm; B, C = 50 µm. Key to abbreviations: RA = raphide crystal, PA = parenchyma cell, PH = phloem, SH = spiny hair, XY = xylem.

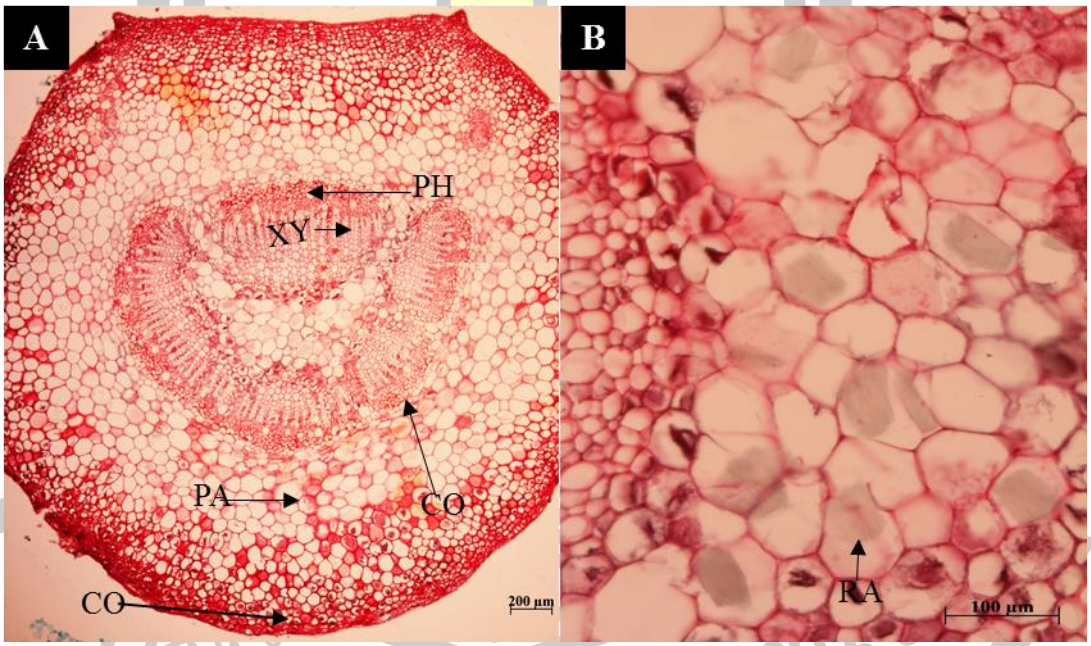

Figure 117 Transverse section of petiole of *Tetracera loureiri*.

(A) The outline of petiole. (B) Rephide crystals. Scale bar: A, C = 200 µm; B = 100 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA = raphides crystals, XY = xylem.

17. *Tetracera sarmentosa* (Figures 118-121)

17.1 Leaf surface anatomy from the epidermal peeling methods (Figure 118)

Adaxial surface: The shapes of epidermal cells are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall. Long unicellular hair, multiple glandular trichomes and spiny hair are observed on adaxial surface. The average length of long unicellular hairs is 178.53 µm. The average dimeter of multiple glandular trichomes and spiny hair are 19.85 and 135.05 µm respectively. The average densities of long unicellular hair, multiple glandular trichomes and spiny hair are 0.47, 0.99 and 8.32 mm^{-2} respectively (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with paracytic stomatal complexes. The two parallel subsidiary cells are distinguishable from the surrounding epidermal cells by their shape. The average densities of stomata are 209.94 mm^{-2}. The average lengths of guard cells are 34.28 µm. Multiple glandular trichomes and spiny hair are observed on abaxial surface. The average dimeter of multiple glandular trichomes and spiny hair are 18.88 and 132.05 µm respectively. The average densities of multiple glandular trichomes and spiny hair are 1.78 and 26.08 mm^{-2} respectively (Table 22).

17.2 Transverse section of leaf lamina (Figure 119A)

The average thickness of leaf blade is 117.76 µm. Long unicellular hairs are present on adaxial. Multiple glandular trichomes and spiny hair are observed on both surfaces. The epidermis on both surfaces are one layer with epidermis cells on both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. The outline of adaxial and abaxial epidermal layers are straight. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one layer of palisade parenchyma. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises and these are frequently present on the largest vein whilst absent on the small veins. Raphides crystals are

presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

17.3 Transverse section of leaf margin (Figure 119B)

The outline of the leaf margin in transverse section is curved down (Figure 119B). Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

17.4 Transverse section of midrib (Figure 120)

The outline of midrib in transverse section at the adaxial surface is concave, while the abaxial surface is U-shaped (Figure 120A). Spiny hairs are present on both surfaces. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Under the epidermis is a zone of two to three layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting two to four separate bundles. The vascular bundles are surrounded by sclerenchyma cells. Raphide crystals were found in parenchyma cells of ground tissue (Table 24).

17.5 Transverse section of petiole (Figure 121)

The outline of the petioles shape in transverse section at the adaxial surface is straight while the abaxial surface is U-shaped. The two adaxial wings bent out of the core. Spiny hairs are presented on both surfaces. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Epidermis cells on abaxial surface are usually smaller than cells on the ground tissue. Under the epidermis is a zone of two to three layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which two to four smaller bundle distributed into lateral adaxial small wings (Figure 121A). The vascular system

is composed of a central region of xylem with collateral phloem. Collenchyma cells from a continuous ring around the vascular bundles. Raphides crystals were found in parenchyma cells of ground tissue (Table 25).

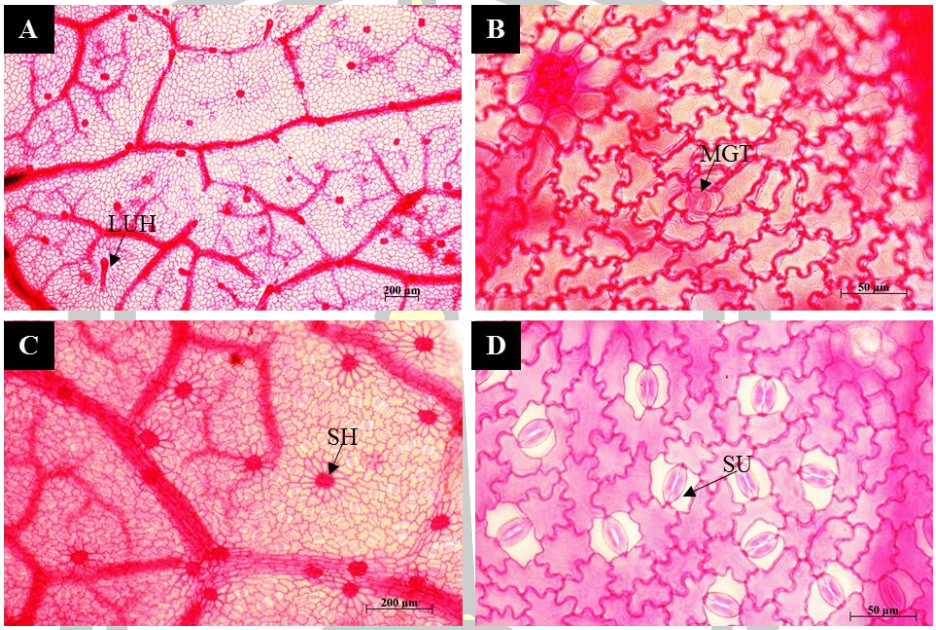

Figure 118 The leaf epidermis of *Tetracera sarmentosa*.

(A-B) Characteristics of epidermis on adaxial surface: (A) overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on abaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A, C = 200 µm; B, D = 50 µm. Key to abbreviations: LUH = long unicellular hair, MGT = multiple glandular trichomes, SH = spiny hair, SU = subsidiary cells.

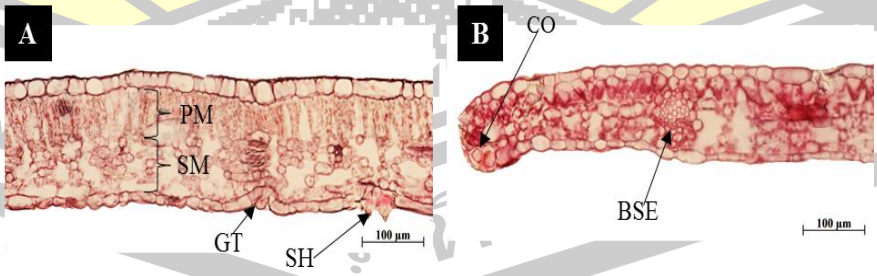

Figure 119 Transverse sections leaf of *Tetracera sarmentosa*.

(A) Lamina and (B) Leaf margin. Scale bar: A, B = 100 µm. Key to abbreviations: BSE = bundle sheet extension, CO = collenchyma cells, GT = glandular trichomes, PM = palisade mesophyll, SH = spiny hair, SM = spongy mesophyll.

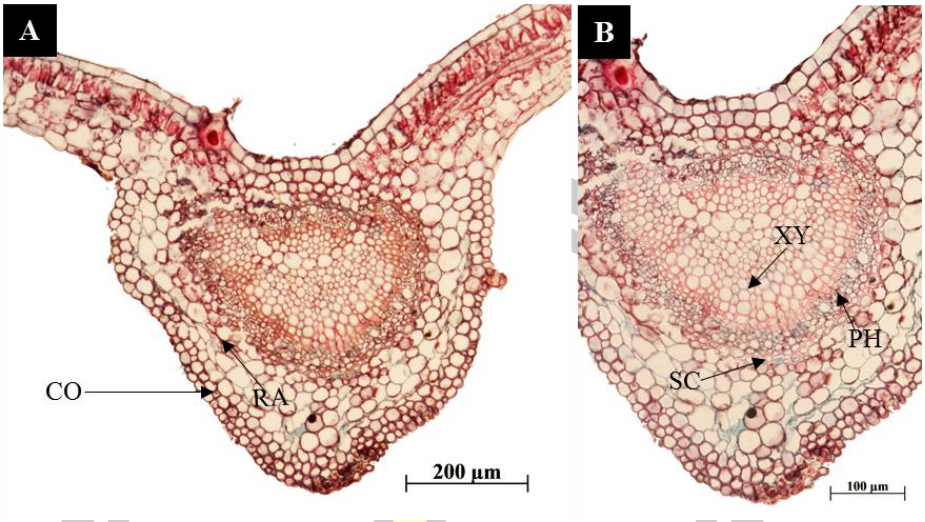

Figure 120 Transverse section of midribs of *Tetracera sarmentosa*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by sclerenchyma cells. Scale bar: A = 200 µm, B = 100 µm. Key to abbreviations: CO = collenchyma cells, RA = raphide crystals, PA = parenchyma cells, PH = phloem, SC = sclerenchyma cells, XY = xylem.

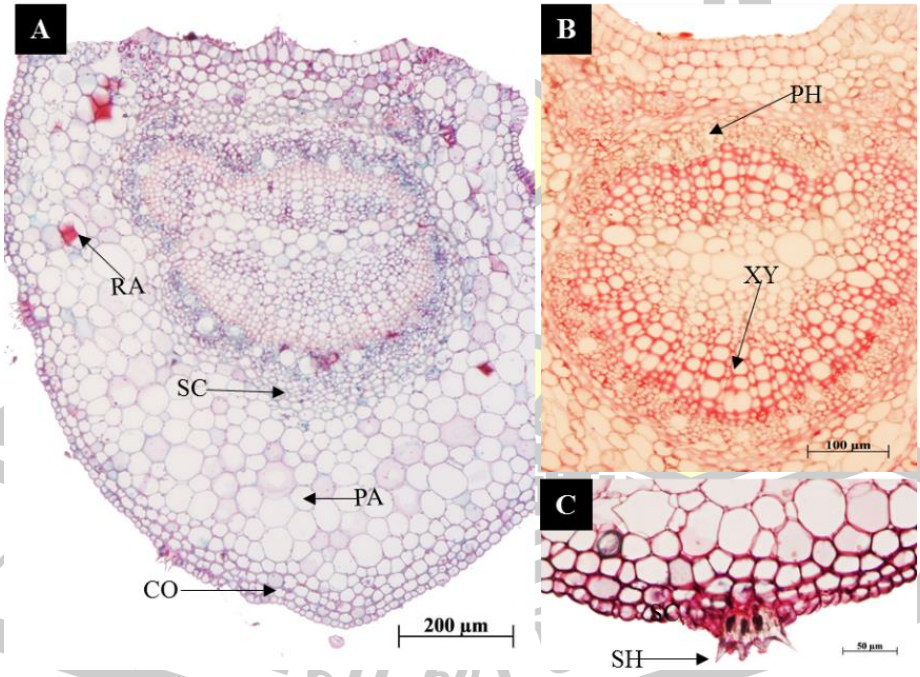

Figure 121 Transverse section of petiole of *Tetracera sarmentosa*.

(A) The outline of petiole. (B) The vascular bundle is collateral surrounding by collenchyma cells. (C) Spiny hair. Scale bar: A = 200 µm; B = 100 µm; C = 50 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA = raphides crystals, SC= sclerenchyma cells, SH = spiny hair, XY = xylem.

18. *Tetracera scandens* (Figures 122-125)

18.1 Leaf surface anatomy from the epidermal peeling methods (Figure 122)

Adaxial surface: The shapes of epidermal cells are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall. Short and long unicellular hair and spiny hair are observed on adaxial surface. The average length of short and long unicellular hairs are 82.43 µm and 504.94 µm respectively. The average diameter of spiny hairs is 117.32 µm. The average densities of short and long unicellular hairs and spiny hairs are 1.03, 1.84 and 5.23 mm^{-2} respectively (Table 21). Abaxial surface: The shapes of epidermal cells are similar to adaxial surface. The stomata are hypostomatic with paracytic stomatal complexes. The two parallel subsidiary cells are distinguishable from the surrounding epidermal cells by their shape. The average lengths of guard cells are 29.18 µm. The average densities of stomata are 155.00 mm^{-2}. Spiny hairs are observed on abaxial surface. The average dimeter of spiny hairs is 105.83 µm. The average densities of spiny hairs are 14.71 mm^{-2} (Table 22).

18.2 Transverse section of leaf lamina (Figure 123A)

The average thickness of leaf blade is 110.60 µm. Short unicellular hairs and Long unicellular hairs are present on adaxial. Spiny hairs are observed on both surfaces. The epidermis on both surfaces are one layer with epidermis cells on both surfaces are four side in shape and straight or slightly curved anticlinal wall. The adaxial epidermis is slightly thicker than the abaxial epidermis. Thin cuticle is presented on both surfaces. The stomata are typical type. Guard cells occur at the same general level as surrounding epidermal cells on abaxial surface. The mesophyll is dorsiventral with one layer of palisade parenchyma. The spongy cells are composed of large, irregularly shaped and multilayer cells. The vascular bundle is collateral surrounding by collenchyma cells. The bundle sheath extensions spread to both epidermises and these are frequently present on the largest vein whilst absent on the small veins. Raphides crystals are presented in palisade mesophyll. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage (Table 23).

18.3 Transverse section of leaf margin (Figure 123B)

The outline of the leaf margin in transverse section is curved down. Collenchyma cells are observed in the leaf margins. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina (Table 24).

18.4 Transverse section of midrib (Figure 124)

The outline of midrib in transverse section at the adaxial surface is concave while the abaxial surface is U-shaped (Figure 124A). Short unicellular hairs and long unicellular hair are present on adaxial surface. Spiny hairs are present on abaxial surface. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Under the epidermis is a zone of two to four layers of collenchyma. Parenchyma predominates in ground tissue. The vascular bundles are collateral bundle (opened type) consisting two to four separate bundles. The main large vascular bundles occupies below smaller vascular bundles. The vascular bundles are surrounded by collenchyma cells. Raphide and crystals sand were found in parenchyma cells of ground tissue (Table 24).

18.5 Transverse section of petiole (Figure 125)

The outline of the petioles shape in transverse section at the adaxial surface is concave, while the abaxial surface is U-shaped. The two adaxial wings bent out of the core. Spiny hairs are presented on both surfaces. The epidermis cells in transverse section of adaxial surface are four side, while epidermis cells of abaxial surfaces are circular or semicircular. Epidermis cells on abaxial surface are usually smaller than cells on adaxial surfaces. Under the epidermis is a zone of two to three layers of collenchyma. Ground tissue: the parenchyma cells were mainly present in ground tissue. The vascular bundles are collateral bundle (opened type). The main large vascular bundles occupies below smaller vascular bundles which three to four smaller vascular bundle distributed into lateral adaxial wings (Figure 125A). The vascular system is composed of a central region of xylem with collateral phloem. Collenchyma

cells from a continuous ring around the vascular bundles. Raphides and crystals sand were found in parenchyma cells of ground tissue (Table 25).

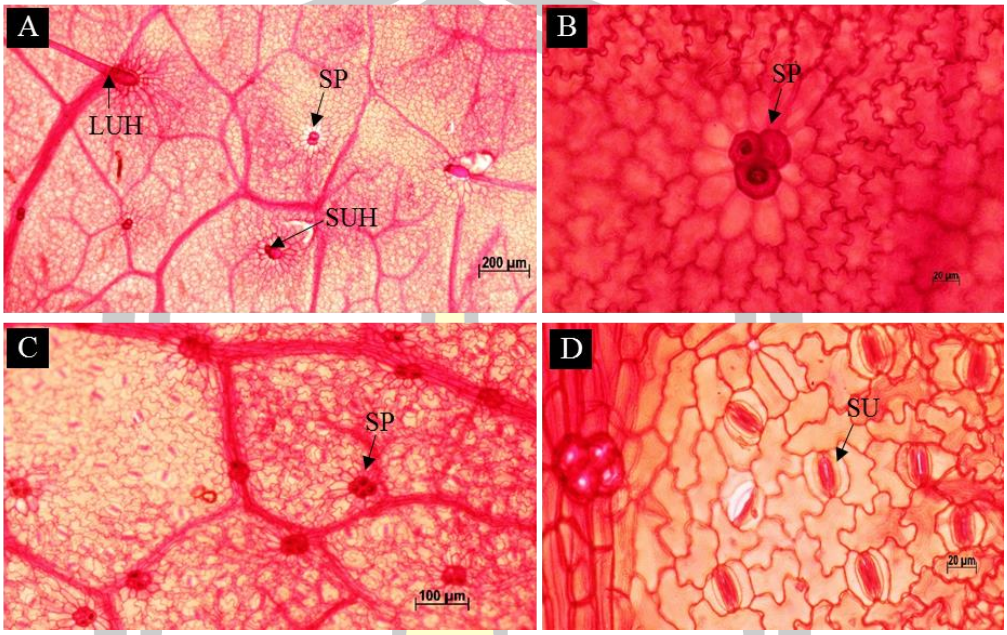

Figure 122 The leaf epidermis of *Tetracera scandens*.

(A-B) Characteristics of epidermis on adaxial surface: (A) Overview of adaxial surface, (B) The shapes of epidermal cells. (C-D) Characteristics of epidermis on adaxial surface: (C) Epidermis surface, (D) Stomata. Scale bar: A = 200 µm; B, D = 20 µm; C = 100 µm. Key to abbreviations: LUH = long unicellular hair, SU = subsidiary cell, SP = spiny hair, SUH = short unicellular hairs.

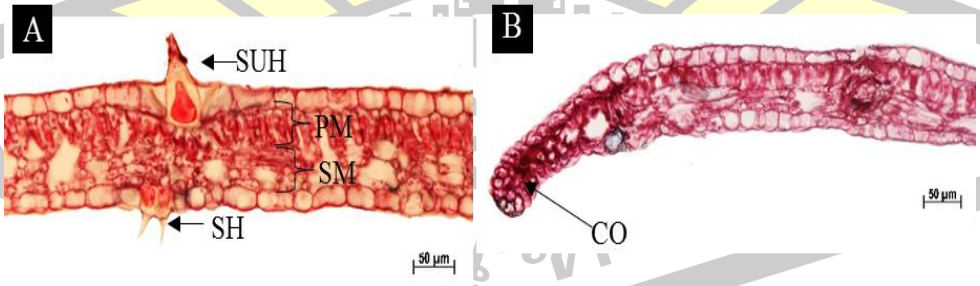

Figure 123 Transverse sections leaf of *Tetracera scandens*.

(A) Lamina and (B) Leaf margin. Scale bar: A and B = 50 µm. Key to abbreviations: CO = collenchyma cells, PM = palisade mesophyll, SM = spongy mesophyll, SH = spiny hair, SUH = short unicellular hair.

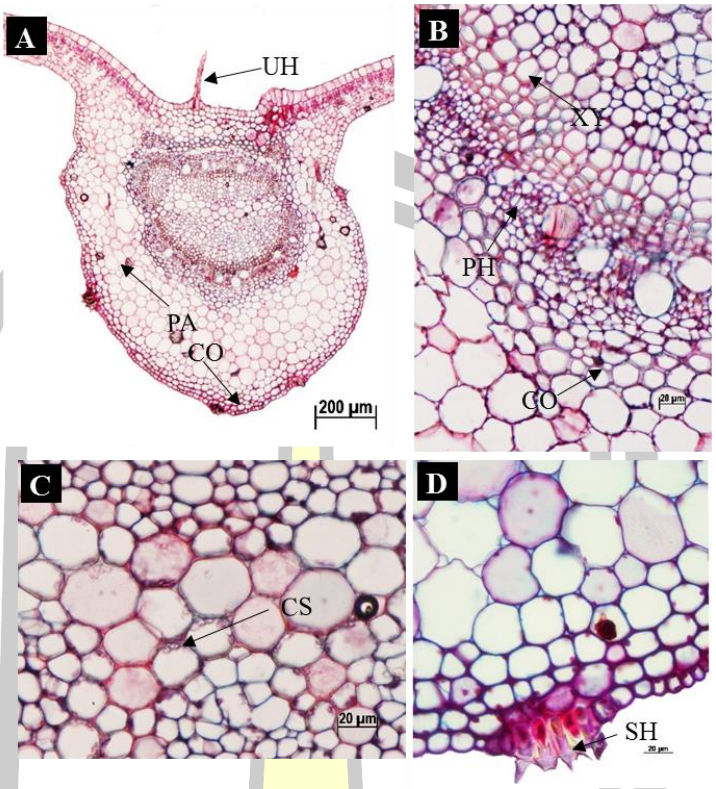

Figure 124 Transverse section of midribs of *Tetracera scandens*.

(A) The outline of midribs. (B) The vascular bundle is collateral surrounding by collenchyma cells. (C) Crystal sand. (D) Spiny hair. Scale bar: A and B = 200 µm, C and D = 20 µm. Key to abbreviations: CS = crystal sand, CO = collenchyma cells, PA = parenchyma cells, PH = phloem, SH = spiny hair, UH = unicellular hair, XY = xylem.

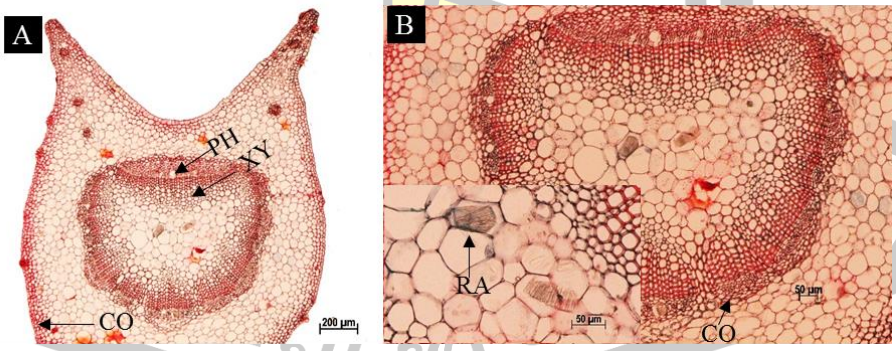

Figure 125 Transverse section of petiole of *Tetracera scandens*.

(A) The outline of petiole. (B) The vascular bundle is collateral surrounding by collenchyma cells. Scale bar: A = 200 µm, B = 50 µm. Key to abbreviations: CO = collenchyma cells, PA = parenchyma cells, PH = phloem, RA = raphides crytals, XY = xylem.

Key to Thai species of Dilleniaceae based on anatomy of lamina and petiole

Key to Genus of Dilleniaceae

1. Stomata on abaxial surface are paracytic **Tetracera**

1. Stomata on abaxial surface are anisocytic or anomocytic **2**

2. Anisocytic stomata on abaxial surface in conjunction with unicellular hair present on abaxial surface **Acrotrema (A. costatum)**

2. Anisocytic stomatal on abaxia surface in conjunction with unicellular hair absent on abaxial surface or anomocytic stomata on abaxial surface **Dillenia**

Key to species of genus *Tetracera*

1. Trichomes absent on both surfaces of lamina **T. indica**

1. Trichomes present (simple unicellular hair or glandular trichomes or spiny hair) on surface of lamina **2**

2. Vascular bundle of petiole anatomy is composed of a continuous cylinder of vascular tissue, glandular hair absents on both surfaces of lamina **T. scandens**

2. Vascular bundle of petiole anatomy is composed of a multivascular bundle forming a ring of widely dissected collateral bundles **3**

3. Unicellular hair present on abaxial surface of lamina **T. sarmantosa**

3. Unicellular hair absent on abaxial surface of lamina **T. loureiri**

Key to species of genus *Dillenia*

1. Anisocytic stomata on abaxial surface **D. excelsa**

1. Anomocytic stomata on abaxial surface **2**

2. Hypodermis present on adaxial surface of lamina in conjunction with glandular trichomes present on leaf lamina **D. philippinensis**

2. Hypodermis absent or hypodermis present on adaxial surface of lamina in conjunction with unicellular hair **3**

3. Hypodermis present on adaxial surface of lamina with unicellular hair **D. indica**

3. Hypodermis absent on lamina **4**

4. Single glandular trichomes present on lamina **D. suffruticosa**

4. Single glandular trichomes absent on lamina **5**

5. The shapes of epidermal cells on both surfaces are similar to jigsaw and cells wall are deep sinuate with sinuous anticlinal wall **D. parviflora**

5. The shapes of epidermal cells on both surfaces are other type **6**

6. Simple unicellular hair present only on abaxial surface of petiole in conjunction with secretory cavities absent in palisade parenchyma **D. reticulata**

6. Simple unicellular hair present only on abaxial surface of petiole in conjunction with secretory cavities in palisade mesophyll or simple unicellular present on both surfaces of petiole **7**

7. Simple unicellular hair present only on abaxial surface of lamina and simple unicellular hair present on both surfaces of petiole **D. aurea**

7. Simple unicellular hair present only on abaxial surface of lamina in conjunction with simple unicellular hair absents on abaxial surface of petiole or simple unicellular hair present on both surfaces of lamina **8**

8. Simple unicellular hair present only on abaxial surface of lamina in conjunction with simple unicellular hair presents only abaxial surface of petiole **D. obovata**

8. Simple unicellular hair present on both surfaces of lamina **9**

9. The mesophyll is dorsiventral with one layer of palisade parenchyma in conjunction with collenchyma surround vascular bundle of petiole **D. grandifolia**

9. The mesophyll is dorsiventral with one layer of palisade parenchyma in conjunction with sclerenchyma surround vascular bundle of petiole or the mesophyll is dorsiventral with of two to three layers of palisade parenchyma **10**

10. The mesophyll is dorsiventral with one layer of palisade parenchyma in conjunction with sclerenchyma surround vascular bundle of petiole **D. hookeri**

10. the mesophyll is dorsiventral with of two to three layers of palisade parenchyma **11**

11. Secretory cavities on palisade mesophyll in conjunction with simple unicellular hair on adaxial surface **D. ovata**

11. Secretory cavities on palisade mesophyll in conjunction with simple unicellular hair absent on adaxial surface or secretory cavities absent on palisade mesophyll **12**

12. Secretory cavities present on palisade mesophyll in conjunction with simple unicellular hair absent on adaxial surface **D. pentagyna**

12. Secretory cavities absent on palisade mesophyll **D. scabrella**

Dominate characteristic for key to species of Thai Dilleniaceae (Figure 126-144)

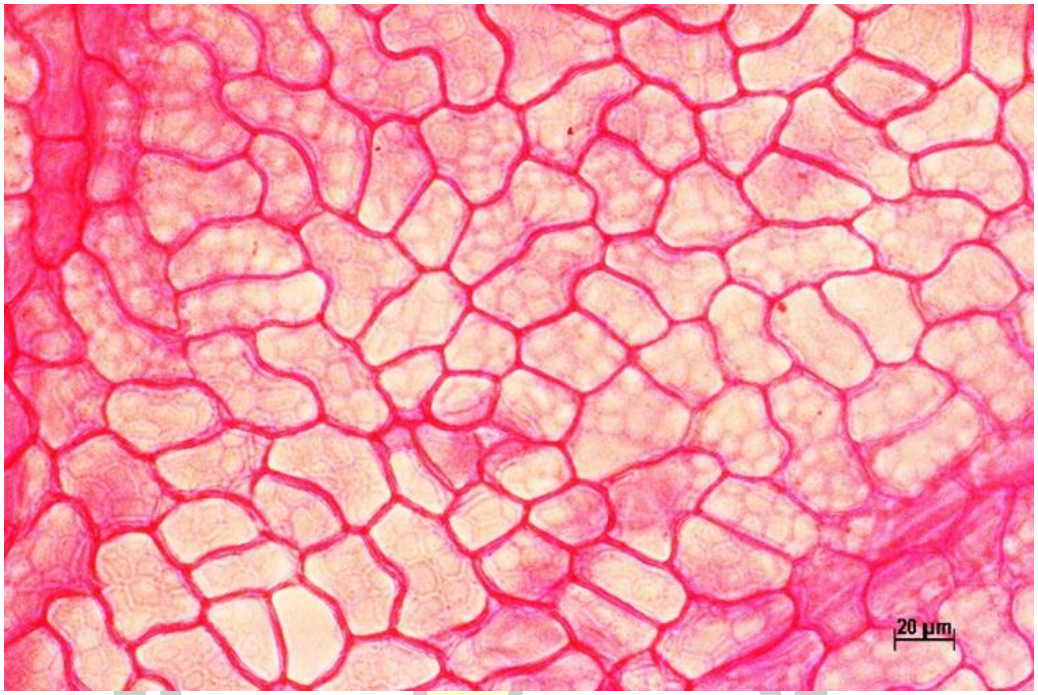

Figure 126 The shape of epidermal cells are polygonal and cell walls are sinuate of *Dillenia obovata*.

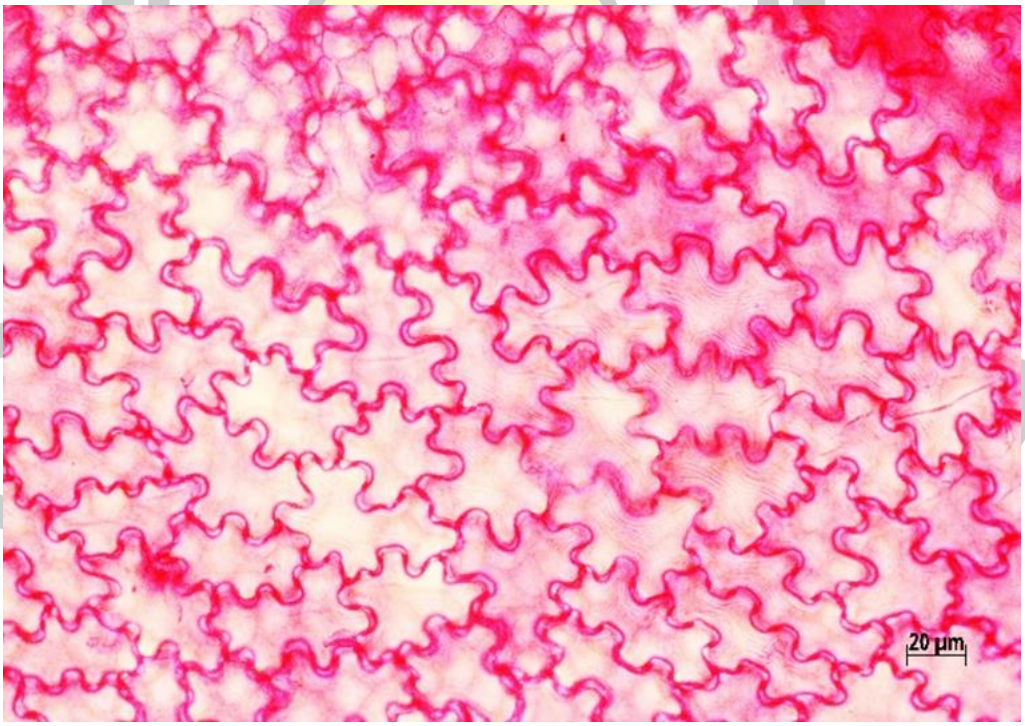

Figure 127 The shape of epidermal cells are jigsaw-like and cell wall are cleft of *Tetracera scandens*.

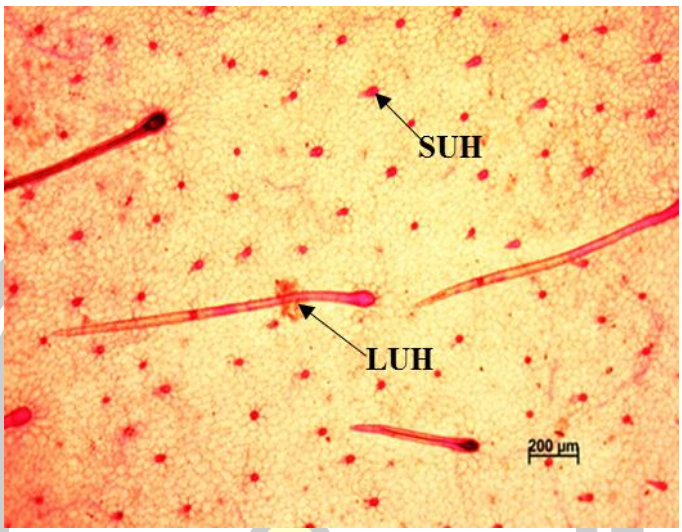

Figure 128 Simple unicellular trichomes of *Acrotrema costatum*.

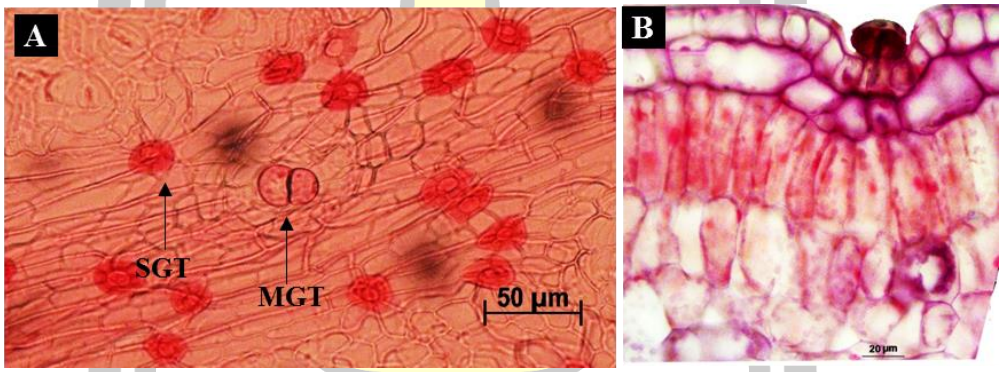

Figure 129 Glandular trichomes of *Dillenia philippinensis*.

(A) Leaf surface and (B) Transverse of glandular trichomes.

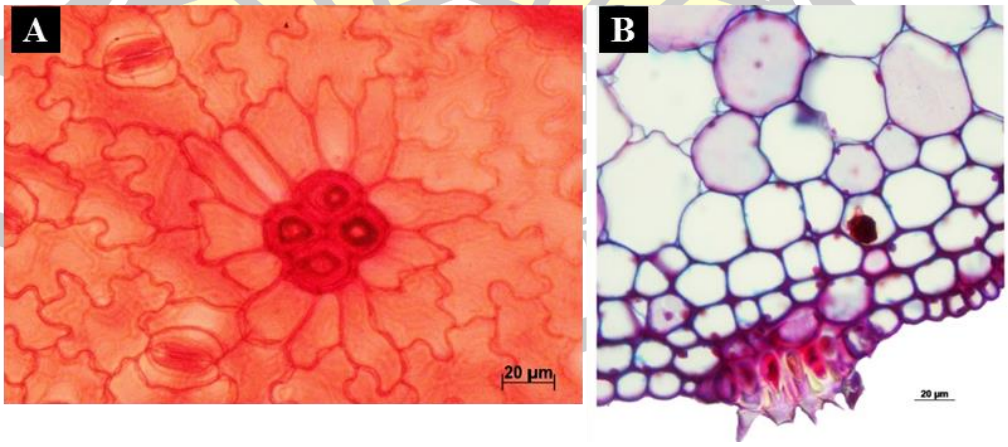

Figure 130 Spiny hair of *Tetracera loureiri*.

(A) Leaf surface and (B) Transverse of spiny hairs.

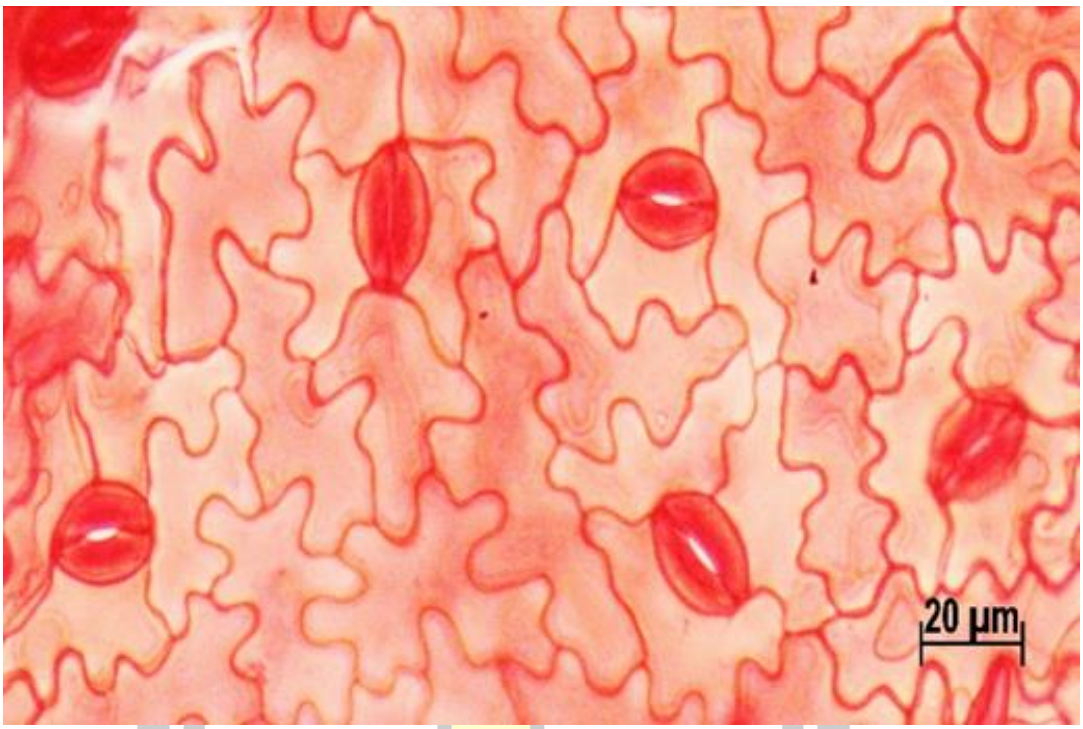

Figure 131 Anomocytic stomata of *Dillenia reticulata.*

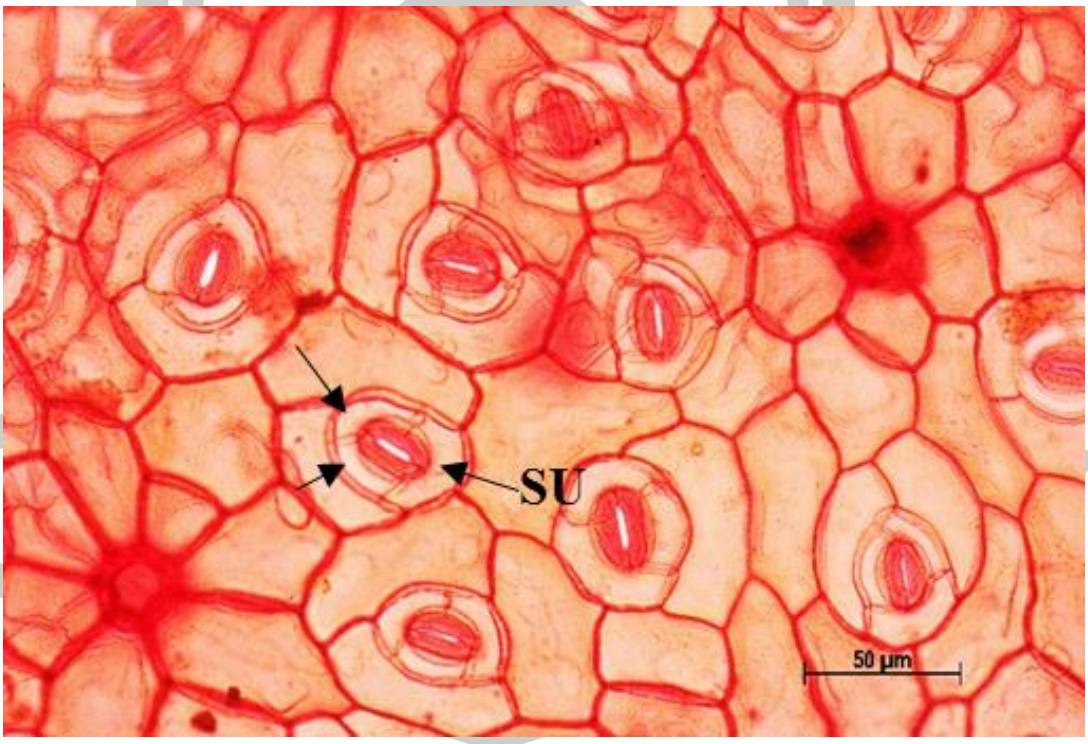

Figure 132 Anisocytic stomata of *Acrotrema costatum*.

Key to abbreviation: SU = subsidiary cells

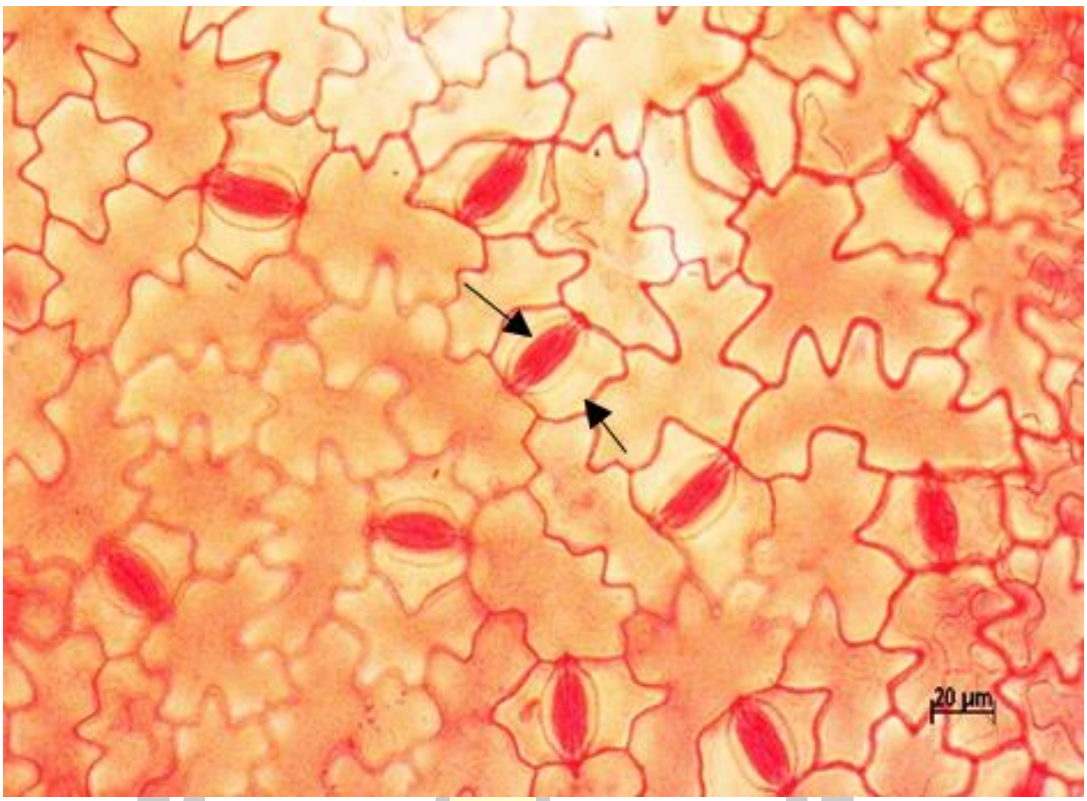

Figure 133 Paracytic stomata of *Tetracera scandens*.

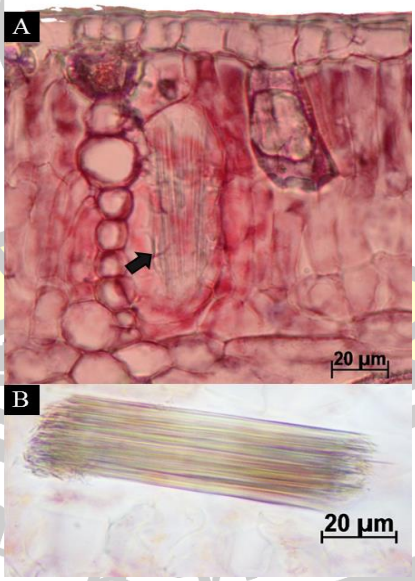

Figure 134 Raphides crystals in palisade mesophyll of *Dillenia suffruticosa*.

(A) Raphides crystals in cross section of leaf blade. (B) Raphides crystals in surface view.

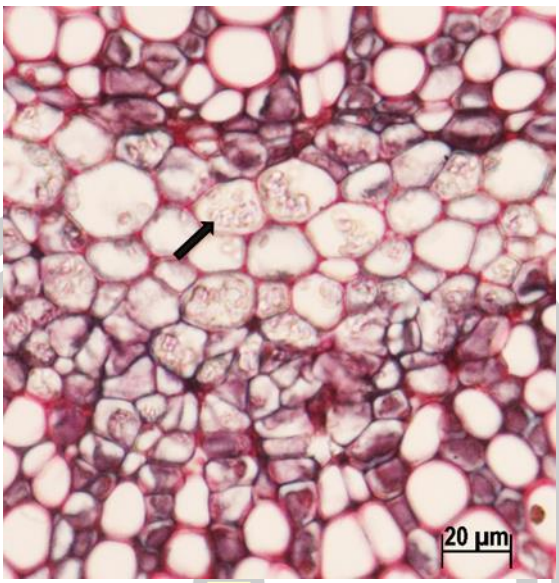

Figure 135 Crystals sand in palisade mesophyll of *Dillenia obovata*.

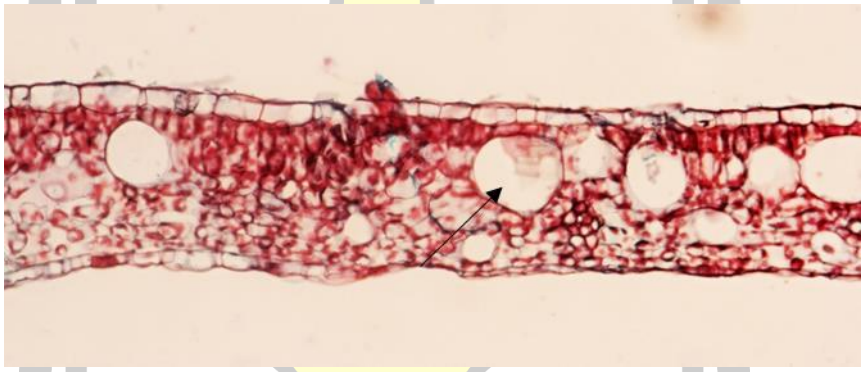

Figure 136 Secretory cavities in palisade mesophyll of *Dillenia indica*.

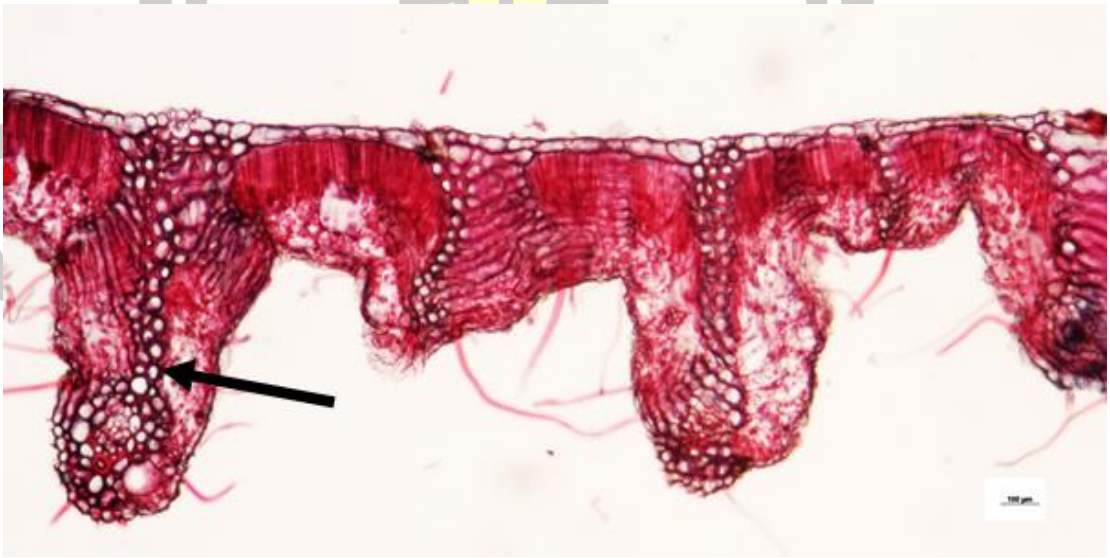

Figure 137 Bundle sheath extension of *Dillenia hookeri*.

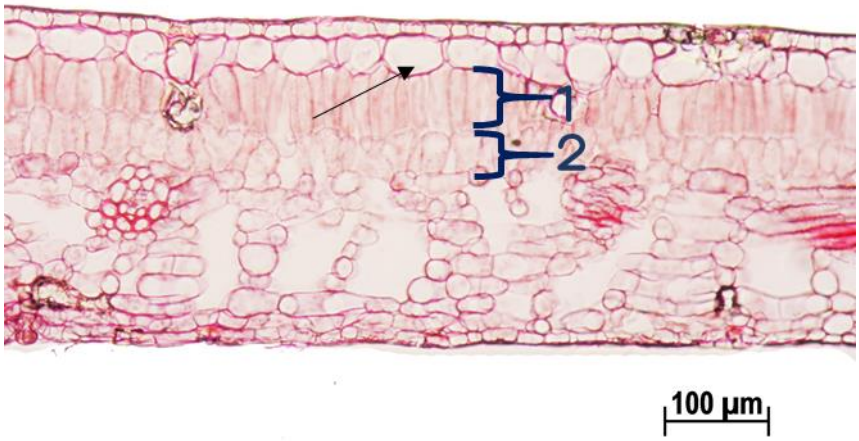

Figure 138 Hypodermis and two layers of palisade of *Dillenia philippinensis*.

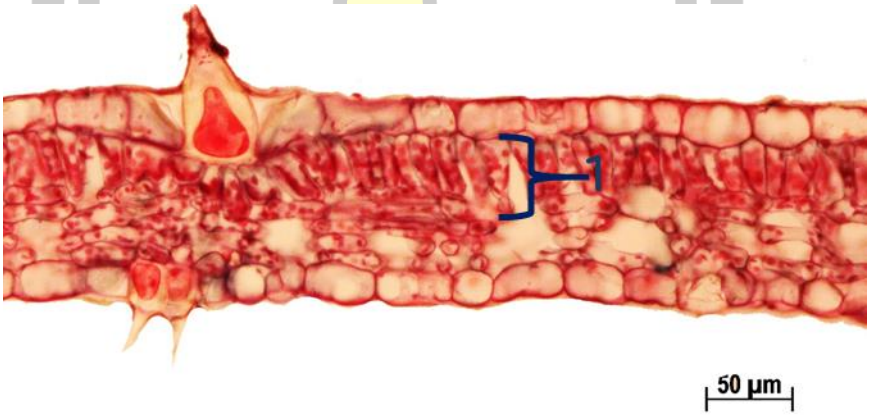

Figure 139 One layers of palisade of *Tetracera scandens*.

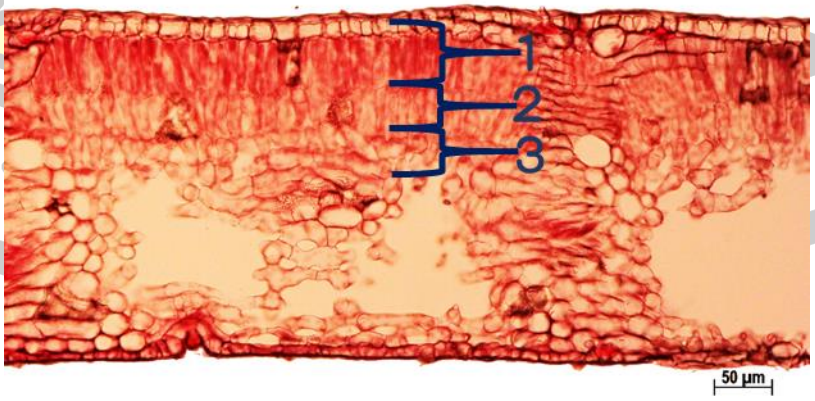

Figure 140 Three layers of palisade of *Dillenia suffruticosa*.

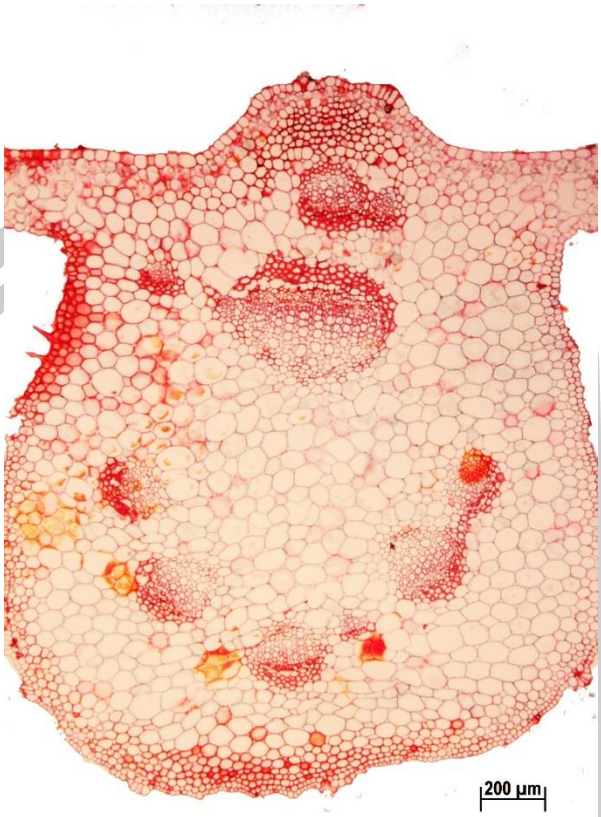

Figure 141 The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is U-shaped of *Acrotrema costatum*.

Figure 142 The outline of midrib in transverse section at the adaxial surface is convex, while the abaxial surface is V-shaped of *Dillenia philippinensis*.

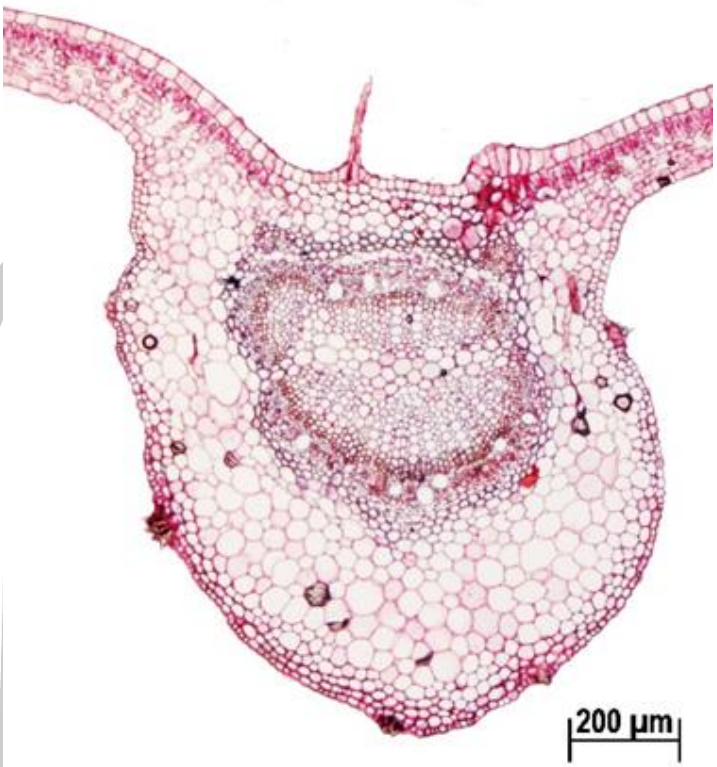

Figure 143 The outline of midrib in transverse section at the adaxial surface is concave, while the abaxial surface is U-shaped of *Tetracera scandens*.

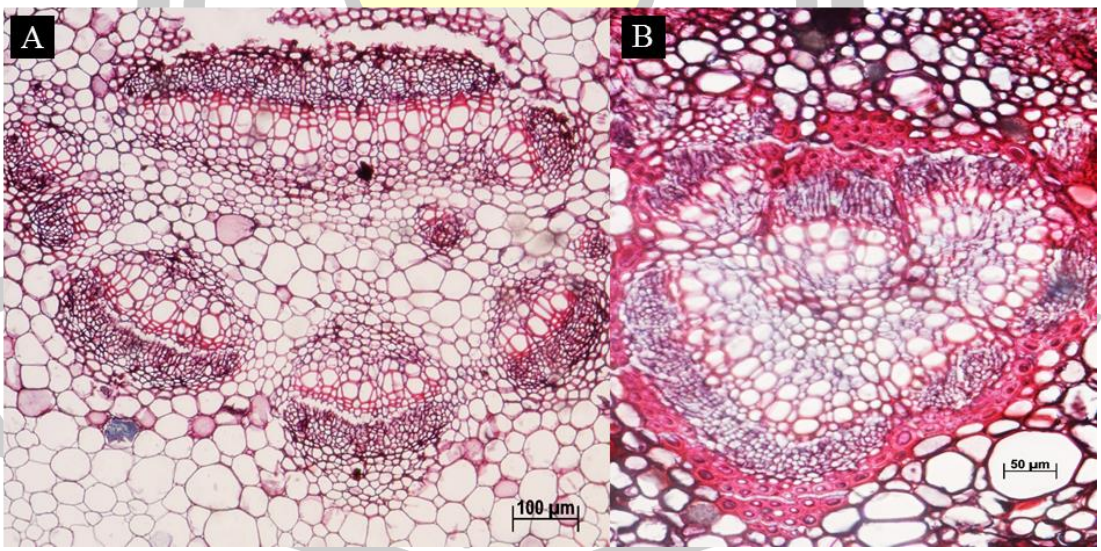

Figure 144 Type of cell at surround vascular bundle.

(A) colerenchyma in *Dillenia philippinensis* and (B) Sclerenchyma in *Dillenia hookeri*.

Table 21 Comparisons of leaf epidermal on adaxial surface of the family Dilleniaceae in Thailand.

Species	SC	Type of trichomes					Density of trichomes				
		SUH (µm) (M±SD)	LUH (µm) (M±SD)	SGT (µm) (M±SD)	MGT (µm) (M±SD)	SH (µm) (M±SD)	SUH (mm^{-2}) (M±SD)	LUH (mm^{-2}) (M±SD)	SGT (mm^{-2}) (M±SD)	MGT(mm^{-2}) (M±SD)	SH (mm^{-2}) (M±SD)
1	PSI	65.55-93.38 (82.19±9.78)	960.65-1674.25 (1299.77±119.04)	-	-	-	1.29-20.89 (16.69±5.68)	0.59-0.99 (0.72±0.13)	-	-	-
2	PSI	-	-	-	-	-	-	-	-	-	-
3	PSI	-	-	-	-	-	-	-	-	-	-
4	PSI	-	115.85-280.96 (180.12±46.21)	-	-	-	-	9.31-11.64 (10.61±0.80)	-	-	-
5	PSI	-	330.44-497.60 (361.50±37.35)	-	-	-	-	24.92-43.62 (34.27±8.81)	-	-	-
6	PSI	-	133.21-238.05 (173.92±27.78)	-	-	-	-	0.99-1.97 (1.64±0.35)	-	-	-
7	PSI	-	-	-	-	-	-	-	-	-	-
8	PSI	-	137.96-498.29 (233.33±83.30)	-	-	-	-	2.56-4.34 (3.06±0.52)	-	-	-
9	JC	77.32-88.78 (85.12±3.85)	224.30-540.46 (357.61±63.40)	-	-	-	0.59-1.18 (0.92±0.20)	2.76-3.35 (3.25±0.27)	-	-	-
10	PSI	-	275.95-1026.49 (369.24±178.14)	-	-	-	-	0.99-1.77 (1.40±0.29)	-	-	-
11	JC	-	-	-	18.26-28.79 (23.45±2.99)	-	-	-	-	3.10-6.69 (4.47±1.27)	-

Table 21 Comparisons of leaf epidermal on adaxial surface of the family Dilleniaceae in Thailand. (Cont.)

Species	SC	Type of trichomes					Density of trichomes				
		SUH (µm) (M±SD)	LUH (µm) (M±SD)	SGT (µm) (M±SD)	MGT (µm) (M±SD)	SH (µm) (M±SD)	SUH (mm^{-2}) (M±SD)	LUH (mm^{-2}) (M±SD)	SGT (mm^{-2}) (M±SD)	MGT(mm^{-2}) (M±SD)	SH (mm^{-2}) (M±SD)
12	PSI	-	141.03-374.64 (190.92±54.41)	-	-	-	-	6.69-23.22 (11.69±5.09)	-	-	-
13	PSI	-	182.38-459.88 (295.31±65.41)	-	-	-	-	11.61-18.57 (14.47±2.10)	-	-	-
14	PSI	-	-	22.04-29.66 (25.71±2.33)	-	-	-	-	49.08-110.44 (72.71±19.02)	-	-
15	PSI	-	-	-	-	-	-	-	-	-	-
16	JC	-	-	-	23.33-34.58 (28.66±3.22)	94.50-149.65 (124.66±14.76)	-	-	-	0.59-1.57 (1.02±0.34)	6.47-9.03 (7.91±0.96)
17	JC	-	(106.94-273.76 (178.53±47.53)	-	10.85-33.43 (19.85±5.88)	101.42-190.98 (135.05±23.83)	-	0.20-0.79 (0.47±0.21)	-	0.59-1.38 (0.99±0.24)	6.90-10.45 (8.32±1.02)
18	JC	74.42-97.23 (82.43±6.49)	234.49-925.38 (504.94±204.95)	-	-	93.68-154.22 (117.32±16.45)	0.59-1.38 (1.03±0.24)	0.79-3.35 (1.84±0.94)	-	-	2.71-10.65 (5.23±2.75)

Key to abbreviations: species; 1 = *Acrotrema costatum*, 2 = *Dillenia aurea*, 3 = *D. excelsa*, 4 = *D. grandifolia*, 5 = *D. hookeri*, 6 = *D. indica*, 7 = *D. obovata*, 8 = *D. ovata*, 9 = *D. parviflora*, 10 = *D. pentagyna*, 11 = *D. philippinensis*, 12 = *D. reticulata*, 13 = *D. scabrella*, 14 = *D. suffruticosa*, 15 = *Tetracera indica*, 16 = *T. loureiri*, 17 = *T. sarmentosa*, 18 = *T. scandens*; JC = the shape of epidermal cell are jigsaw-like, LUH = long unicellular hair, MUT = multiglandular trichomes, PSI = the shapes of epidermal cells are polygonal and cells wall are sinuate, SC = shape of epidermis, SGT = single glandular trichomes, SH = spiny hair, SUH = short unicellular hairs, - = absent

Table 22 Comparisons of leaf epidermal on abaxial surface of the family Dilleniaceae in Thailand.

SP	SC	TS	DT (mm^{-2}) M±SD	LG (µm) M±SD	Type of trichomes					Density of trichomes				
					SUH (µm) (M±SD)	LUH (µm) (M±SD)	SGT (µm) (M±SD)	MGT(µm) (M±SD)	SH (µm) (M±SD)	SUH (mm^{-2}) (M±SD)	LUH (mm^{-2}) (M±SD)	SGT (mm^{-2}) (M±SD)	MGT(mm^{-2}) (M±SD)	SH (mm^{-2}) (M±SD)
1	PSI	Ani	112.50-137.50 (125.00±12.5)	19.32-26.38 (23.39±1.76)	67.58-98.74 (23.58±9.04)	-	-	-	-	40.24-61.13 (45.89±6.78)	-	-	-	-
2	PSI	Ano	275.00-337.50 (300.00±27.64)	22.25-29.08 (24.88±1.65)	-	266.06-621.47 (406.33±111.26)	-	-	-	-	7.74-10.83 (9.80±1.17)	-	-	-
3	PSI	Ani	175.00-237.50 (217.50±25.92)	23.12-29.27 (26.27±1.70)	-	-	-	-	-	-	-	-	-	-
4	PSI	Ano	945.18-1102.71 (1023.94±55.70)	12.90-18.47 (15.38±1.26)	53.45-98.75 (73.53±18.32)	109.70-319.09 (192.90±63.62)	-	-	-	92.03-138.05 (111.97±17.43)	122.71-184.07 (158.50±26.22)	-	-	-
5	PSI	Ano	317.46-460.65 (398.19±63.37)	20.20-23.42 (21.45±1.00)	-	192.97-789.71 (539.50±177.32)	-	-	-	-	496.52-714.27 (610.24±86.68)	-	-	-
6	PSI	Ano	137.50-187.50 (157.50±18.96)	21.10-28.40 (24.35±2.27)	-	107.07-162.25 (134.73±17.88)	-	-	-	-	2.37-4.34 (2.96±0.75)	-	-	-
7	PSI	Ano	437.50-475.00 (455.00±14.25)	17.22-22.42 (19.60±1.55)	58.66-75.08 (69.10±6.41)	109.91-202.80 (140.32±28.38)	-	-	-	2.32-3.87 (3.10±0.69)	8.51-17.80 (13.93±3.21)	-	-	-
8	JC	Ano	546.58-708.07 (624.84±50.75)	16.22-21.49 (18.90±1.30)	-	121.83-537.75 (262.60±115.29)	-	-	-	-	30.18-47.98 (40.55±5.62)	-	-	-
9	JC	Ano	112.50±137.50 (120.00±11.18)	19.22-25.19 (21.88±1.85)	65.01-95.94 (82.13±9.03)	138.18-323.05 (211.53±49.93)	-	-	-	0.59-0.99 (0.85±0.16)	28.99-27.08 (25.28±1.26)	-	-	-
10	PSI	Ano	312.50-387.50 (347.50±29.84)	22.73-32.19 (26.24±2.10)	-	198.82-471.02 (352.48±65.64)	-	-	-	-	2.37-3.35 (2.88±0.36)	-	-	-
11	JC	Ano	200.00-250.00 (227.50±22.36)	17.93-24.73 (21.61±1.59)	-	-	-	17.28-28.36 (21.98±2.60)	-	-	-	-	9.20-18.41 (13.59±3.90)	-
12	PSI	Ano	787.65-866.41 (813.90±40.67)	14.23-20.55 (16.85±1.69)	57.50-98.88 (80.27±13.37)	122.43-455.85 (221.69±121.39)	-	-	-	98.17-147.25 (116.88±19.10)	150.32-266.90 (200.33±42.09)	-	-	-

Table 22 Comparisons of leaf epidermal on abaxial surface of the family Dilleniaceae in Thailand (Cont.).

SP	SC	TS	DT (mm^{-2}) M±SD	LG (µm) M±SD	Type of trichomes					Density of trichomes				
					SUH (µm) (M±SD)	LUH (µm) (M±SD)	SGT (µm) (M±SD)	MGT(µm) (M±SD)	SH (µm) (M±SD)	SUH (mm^{-2}) (M±SD)	LUH (mm^{-2}) (M±SD)	SGT (mm^{-2}) (M±SD)	MGT(mm^{-2}) (M±SD)	SH (mm^{-2}) (M±SD)
13	JC	Ano	298.85-428.57 (363.01±49.20)	19.89-26.09 (23.58±1.54)	46.65-98.06 (66.66±15.82)	107.47-516.16 (246.66±98.90)	-	-	-	29.41-49.53 (41.48±7.23)	10.06-21.67 (15.01±3.92)	-	-	-
14	PSI	Ano	475.00-537.50 (517.50±42.94)	18.79-24.89 (21.31±1.68)	-	-	21.74-30.81 (25.71±2.44)	22.08-35.47 (29.11±3.68)	-	-	-	98.17-150.32 (121.49±15.99)	6.41-18.41 (12.58±4.45)	-
15	JC	Pa	112.50-162.50 (140.00±20.54)	28.35-34.91 (31.38±1.81)	-	-	-	-	-	-	-	-	-	-
16	JC	Pa	150.00-162.50 (160.00±5.59)	29.13-33.24 (31.12±1.24)	-	-	-	22.34-35.13 (29.95±3.72)	81.42-135.45 (113.34±14.20)	-	-	-	0.39-1.97 (1.14±0.52)	12.38-18.57 (14.32±1.97)
17	JC	Pa	149.07-298.14 (209.94±40.76)	30.68-40.85 (34.28±2.31)	-	-	-	12.80-24.80 (18.88±3.92)	94.58-162.78 (132.05±18.48)	-	-	-	0.77-3.10 (1.78±0.90)	14.70-36.37 (26.08±8.02)
18	JC	Pa	137.50-162.50 (155.00±14.29)	26.69-30.67 (29.18±1.19)	-	-	-	-	77.98-127.96 (105.83±12.48)	-	-	-	-	12.42-16.76 (14.71±1.54)

Key to abbreviations: species; 1 = *Acrotrema costatum*, 2 = *Dillenia aurea*, 3 = *D. excelsa*, 4 = *D. grandifolia*, 5 = *D. hookeri*, 6 = *D. indica*, 7 = *D. obovata*, 8 = *D. ovata*, 9 = *D. parviflora*, 10 = *D. pentagyna*, 11 = *D. philippinensis*, 12 = *D. reticulata*, 13 = *D. scabrella*, 14 = *D. suffruticosa*, 15 = *Tetracera indica*, 16 = *T. loureiri*, 17 = *T. sarmentosa*, 18 = *T. scandens*; Ani = anisocytic stomata, Ano = anomocytic stomata, DT = density of stomata, JC = the shape of epidermal cell are jigsaw-like, LG = length of guard cells, LUH = long unicellular hair, MGT = multiglandular trichomes, Pa = paracytic stomata, SC = shape of epidermis cells, SGT = single glandular trichomes, SH = spiny hair, SP = species, SUH = short unicellular hairs, TS = type of stomata, - = absent.

Table 23 Comparison of cross-sectional anatomy leaf blade of Dilleniaceae in Thailand.

Species	Thickness (µm)	Mesophyll		Type of trichomes		Bundle sheath extension	Type of crystal	Hypodermis	Secretory cavities
		NP	NS	Adaxial	Abaxial				
Acrotrema costatum	154.87±18.27	1 layer	multilayer	SUH, LUH	SUH	-	-	-	-
Dillenia aurea	410.65±18.83	2-3 layers	multilayer	-	LUH	✓	Raphide	-	✓
D. excelsa	191.17±16.26	2 layers	multilayer	-	-	-	-	✓	✓
D. grandifolia	171.73±16.52	1 layer	multilayer	LUH	LUH	✓	Raphide	-	-
D. hookeri	167.28±15.00	1 layer	multilayer	LUH	LUH	✓	Raphide	-	-
D. indica	125.22±8.81	2 layers	multilayer	LUH	LUH	✓	Raphide	✓	✓
D. obovata	213.12±9.14	2-3 layers	multilayer	-	SUH, LUH	✓	Raphide	-	✓
D. ovata	250.07±16.21	2-3 layers	multilayer	LUH	LUH	✓	Raphide	-	✓
D. parviflora	104.87±10.11	1 layer	multilayer	SUH, LUH	SUH, LUH	✓	Raphide	-	-
D. pentagyna	207.95±10.34	2 layers	multilayer	LUH	LUH	✓	Raphide	-	✓
D. philippinensis	317.14±12.89	2 layers	multilayer	MGT	MGT	-	Raphide	✓	-
D. reticulata	212.21±13.91	1 layer	multilayer	LUH	SUH, LUH	✓	Raphide	-	-
D. scabrella	202.46±10.20	2 layers	multilayer	LUH	SUH, LUH	✓	Raphide	-	-
D. suffruticosa	294.17±13.56	2-3 layers	multilayer	SGT	SGT, MGT	✓	Raphide	-	-
Tetracera indica	127.31±6.18	1 layer	multilayer	-	-	✓	Raphide	-	-
T. loureiri	164.62±26.80	1 layer	multilayer	SH, MGT	SH, MGT	✓	Raphide	-	-
T. sarmentosa	117.76±11.82	1 layer	multilayer	LUH, MGT, SH	SH, MGT	✓	Raphide	-	-
T. scandens	110.60±9.24	1 layer	multilayer	SUH, LUH, SH	SH	✓	Raphide	-	-

Key to abbreviations: GT = glandular trichomes, LUH = long unicellular hairs, MGT = multiglandular trichomes, NP = number of palisade, NS = number of spongy, SGT = single glandular trichomes, SH = spiny hair, SUH = short unicellular hair, - = absent, ✓ = present.

Table 24 Comparison of cross-sectional anatomy leaf margin and midrib of Dilleniaceae in Thailand.

Species	Leaf margin	Midrib					
	Shape of leaf margin	Shape of midrib		Type of trichomes		Type of cells at surround vascular bundle	Type of crystals
		Adaxial	Abaxial	Adaxial	Abaxial		
A. costatum	Curving downwards	Convex	U	SUH, LUH	SUH	Collenchyma	Raphide
Dillenia aurea	Curving downwards	Convex	U	LUH	LUH	Sclerenchyma	Raphide
D. excelsa	Curving downwards	Convex	V	-	-	Sclerenchyma	Raphide
D. grandifolia	Curving downwards	Convex	U	LUH	LUH	Collenchyma	Raphide, Crystal sand
D. hookeri	Curving downwards	Convex	U	LUH	LUH	Sclerenchyma	Raphide
D. indica	Curving downwards	Convex	U	-	LUH	Collenchyma	Raphide
D. obovata	Straight	Convex	U	LUH	SUH, LUH	Collenchyma	Raphide, Crytals sand
D. ovata	Curving downwards	Convex	U	LUH	LUH	Sclerenchyma	Raphide
D. parviflora	Curving downwards	Convex	U	SUH, LUH	SUH, LUH	Sclerenchyma	Raphide
D. pentagyna	Curving downwards	Convex	U	LUH	LUH	Sclerenchyma	Raphide
D. philippinensis	Straight	Convex	V	MGT	MGT	Collenchyma	Raphide
D. reticulata	Straight	Convex	U	LUH	SUH, LUH	Collenchyma	Raphide Crystal sand
D. scabrella	Straight	Convex	U	LUH	SUH, LUH	Sclerenchyma	Raphide
D. suffruticosa	Curving downwards	Convex	V	-	SGT, MGT	Sclerenchyma	Raphide
Tetracera indica	Straight	Concave	U	-	SH	Sclerenchyma	Raphide
T. loureiri	Straight	Concave	U	SH	SH	Collenchyma	Raphide
T. sarmentosa	Curving downwards	Concave	U	SH	SH	Sclerenchyma	Raphide
T. scandens	Curving downwards	Concave	U	SUH, LUH	SH	Collenchyma	Raphide, Crystal sand

Key to abbreviations: LUH = long unicellular hair, MGT = multiglandular trichomes, SGT = single glandular trichomes, SH = spiny hair, SUH = short unicellular hairs, U = U-shaped, V = V-shaped, - = absent.

Table 25 Comparison of cross-sectional anatomy petiole of Dilleniaceae in Thailand.

Species	Shape of midrib		Type of trichomes		Type of cells at surround vascular bundle	Type of crystal
	Adaxial	Abaxial	Adaxial	Abaxial		
A. costatum	V	U	SUH, LUH	SUH, LUH	Collenchyma	Raphide
Dillenia aurea	Concave	U	LUH	LUH	Sclerenchyma	Raphide
D. excelsa	U	U	-	-	Sclerenchyma	Raphide
D. grandifolia	U	U	LUH	LUH	Sclerenchyma	Raphide Crystal sand
D. hookeri	Concave	U	LUH	LUH	Sclerenchyma	Raphide
D. indica	U	U	-	LUH	Sclerenchyma	Raphide
D. obovata	U	U	-	SUH, LUH	Sclerenchyma	Raphide, Crystal sand
D. ovata	U	U	LUH	LUH	Sclerenchyma	Raphide
D. parviflora	Concave	U	SUH, LUH	SUH, LUH	Sclerenchyma	Raphide
D. pentagyna	U	U	-	LUH	Sclerenchyma	Raphide
D. philippinensis	Concave	U	-	-	Sclerenchyma	Raphide
D. reticulata	U	U	-	UH	Sclerenchyma	Raphide Crystal sand
D. scabrella	U	U	LUH	SUH, LUH	Sclerenchyma	Raphide
D. suffruticosa	V	V	-	SGT, MGT	Sclerenchyma	Raphide
Tetracera indica	Straight	U	SH	SH	Collenchyma	Raphide
T. loureiri	Straight	U	-	SH	Collenchyma	Raphide
T. sarmentosa	Straight	U	SH	SH	Collenchyma	Raphide
T. scandens	Concave	U	SH	SH	Collenchyma	Raphide Crystal sand

Key to abbreviations: LUH = long unicellular hair, MGT = multiglandular trichomes, SGT = single glandular trichomes, SH = spiny hair, SUH = short unicellular hairs, U = U-shaped, UH = simple unicellular hair, V = V-shaped, - = absent.

4.4.2 Principal component analysis (PCA)

The morphometric of all parameter was analyzed by principal component analysis method (PCA) of factor analysis. PCA analysis method was done base on 34 characters states of 18 species (Table 20) that became evident during leaf anatomy investigation. Eigen analysis results and factor loading scores base on leaf anatomy characteristic could be obtained from the output in Table 26 and 27. After the factor analysis was performed, it could be divided into 7 new factors or component. Each factor contained parameters with eigen values higher than 1.0. The seven components descried 90.08% of the total variance in the leaf anatomical character between 18 species, in which maximum variability was contributed by the first component (42.37%) and minimum variability was contributed by the seventh component (3.96%). The first principle component was most highly influenced by the MD, SDM, SHBP, PD, SHDP, SHBM, TCSP, SHBB, SHDB, TS, SBP, UHBM, UHBP, UHBB, SHDM SCB and UHDP. The second principle component scoring system is dominated by SDP, GTBP, GTBM, GTDB and GTBB. The third principle component scoring system is dominated by SMB, BSE, HY, GTDM and UHDM. The fourth principle component scoring system is dominated by SCD. The fifth principle component scoring system is dominated by SE and NP. The sixth principle component scoring system is dominated by SOM, TOB and UHDB. The seventh principle component scoring system is dominated by TCSM.

The PCA scatter plot is generated by factor score 1 (principle component 1) at X-axis and factor score 2 (principle component 2) at Y-axis. Thai Dilleniaceae species are grouped into three group as shown in Figure 145. The first group consists of species of genera *Tetracera*: *T. indica*, *T. loureiri*, *T. sarmentosa* and *T. scandens*. The third group comprises 13 species: *A. costatum*, *D. aurea*, *D. excelsa*, *D. grandifolia*, *D. hookeri*, *D. indica*, *D. obovata*, *D. ovata*, *D. parviflora*, *D. pentagyna*, *D. philippinensis*, *D. reticulata* and *D. scabrella*, while *D. suffruticosa* is grouped in the second group.

4.4.3 Cluster analysis (CA)

The UPGMA dendrogram were constructed by using Between-groups linkage method of cluster analysis on squared Euclidian distances. The cluster analysis is shown in Figure 146. The dendrogram grouped 18 species into three major clusters based on 34 characters states of 18 species that became evident during palynological investigation. The first cluster includes four species of genus *Tetracera*: *T. indica*, *T. loureiri*, *T. sarmentosa* and *T. scandens*. The second cluster consists of *A. costatum*, *D. aurea*, *D. excelsa*, *D. grandifolia*, *D. hookeri*, *D. indica*, *D. obovata*, *D. ovata*, *D. parviflora*, *D. pentagyna*, *D. reticulata*, *D. scabrella* and *D. suffruticosa*. The second cluster consists of *D. philippinensis*.

Table 26 Eigen Analysis of correlation matrix.

Component	**Initial Eigenvalues**		
	Total	**% of Variance**	**Cumulative %**
1	14.41	42.37	42.37
2	6.57	19.31	61.68
3	3.22	9.48	71.16
4	2.08	6.10	77.26
5	1.94	5.70	82.96
6	1.42	4.17	87.12
7	1.35	3.96	91.08

Table 27 Factor loadings explaining relationships of variables and showing the most intrinsic characters for separation of studied Dilleniaceae species.

Variable	Factor loadings						
	Principal components						
	1	**2**	**3**	**4**	**5**	**6**	**7**
MD	0.987						
SDM	-0.987						
SHBP	-0.987						
PD	0.987						
SHDP	-0.987						
SHBM	-0.987						
TCSP	0.840				0.329		
SHBB	-0.822			0.438			
SHDB	-0.822			0.438			
TS	0.783		-0.372	-0.252		-0.284	
SBP	0.783	-0.334			0.331		
UHBM	0.714	-0.444	0.501				
UHBP	0.714	-0.444	0.501				
UHBB	0.714	-0.444	0.501				
SHDM	-0.673			0.501			
SCB	-0.538			0.439	-0.223	0.331	0.411
UHDP	0.492	-0.301	0.311		-0.372		0.445
SDP		0.964					
GTBP		0.964					
GTBM	0.201	0.767	-0.366	0.283		0.309	
GTDB	-0.357	0.629	-0.221	0.592			
GTBB	-0.357	0.629	-0.221	0.592			
SBM			-0.952				
BSE			0.869		0.211		
HY			-0.823		0.251		
GTDM			-0.618	0.458		0.514	
UHDM	0.536	-0.523	0.543				
SCD	-0.521			0.697	-0.222		
SE	0.295	-0.247			0.864		
NP	0.434	0.319			0.718		0.200

Table 27 Factor loadings explaining relationships of variables and showing the most intrinsic characters for separation of studied Dilleniaceae species (Cont.).

Variable	Factor loadings						
	Principal components						
	1	2	3	4	5	6	7
SOM						0.863	-0.233
TOB	0.461			0.270	0.362	0.592	
UHDB		-0.438	0.400		-0.362	-0.450	
TCSM							0.884

Key to abbreviations: Number of palisade mesophyll (NP), Bundle sheath extension in transverse section of leaf blade (BSE), Hypodermis (HY), Secretory cavities in leaf blade (SE), Petiole diameter by transverse section (PD), Midrib diameter by transverse section (MD), Thickness of leaf blade by transverse section (TOB), Unicellular hair on adaxial surface of leaf blade (UHDB), Glandular trichomes on adaxial surface of leaf blade (GTDB), Spiny hair on adaxial surface of leaf blade (SHDB), Unicellular hair on abaxial surface of leaf blade (UHBB), Glandular trichomes on abaxial surface of leaf blade (GTBB), Spiny hair on abaxial surface of leaf blade (SHBB), Shape of epidermis cells on adaxial surface (SCD), Shape of epidermis cells on abaxial surface (SCB), Type of stomata on abaxial surface (TS), Shape on adaxial surface of midrib by transverse section (SDM), Shape on abaxial surface of midrib by transverse section (SBM), Unicellular hairs on adaxial surface of midrib (UHDM), Glandular trichomes on adaxial surface of midrib (GTDM), Spiny hairs on adaxial surface of midrib (SHDM), Unicellular hair on abaxial surface of midrib (UHBM), Glandular trichomes on abaxial surface of midrib (GTBM), Spiny hair on abaxial surface of midrib (SHBM), Type of cell at surround vascular bundle of midrib (TCSM), Shape of Leaf margin (SOM), Shape on adaxial of petiole by transverse section (SBP), Shape on abaxial of petiole by transverse section (SDP), Unicellular hair on adaxial of petiole (UHDP), Spiny hairs on adaxial of petiole (SHDP), Unicellular hairs on abaxial of petiole (UHBP), Glandular trichomes on abaxial of petiole (GTBP), Spiny hair on abaxial of petiole (SHBP) and Type of cell at surround vascular bundle of petiole (TCSP).

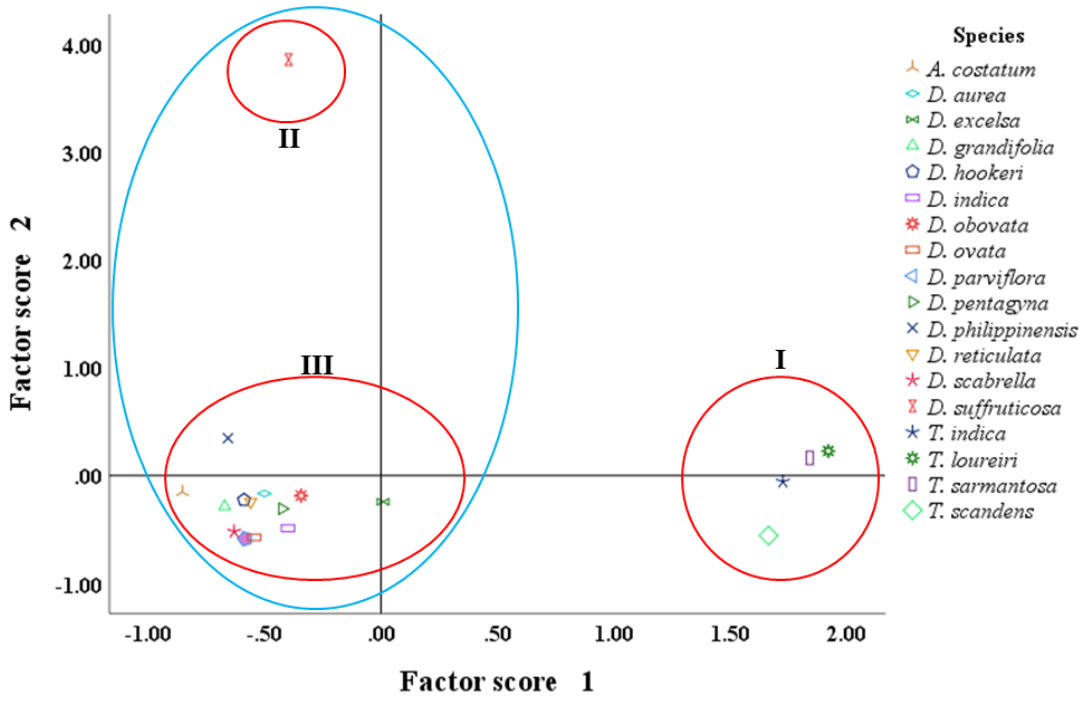

Figure 145 PCA scatterplot of Dilleniaceae species in Thailand based on leaf anatomical characters.

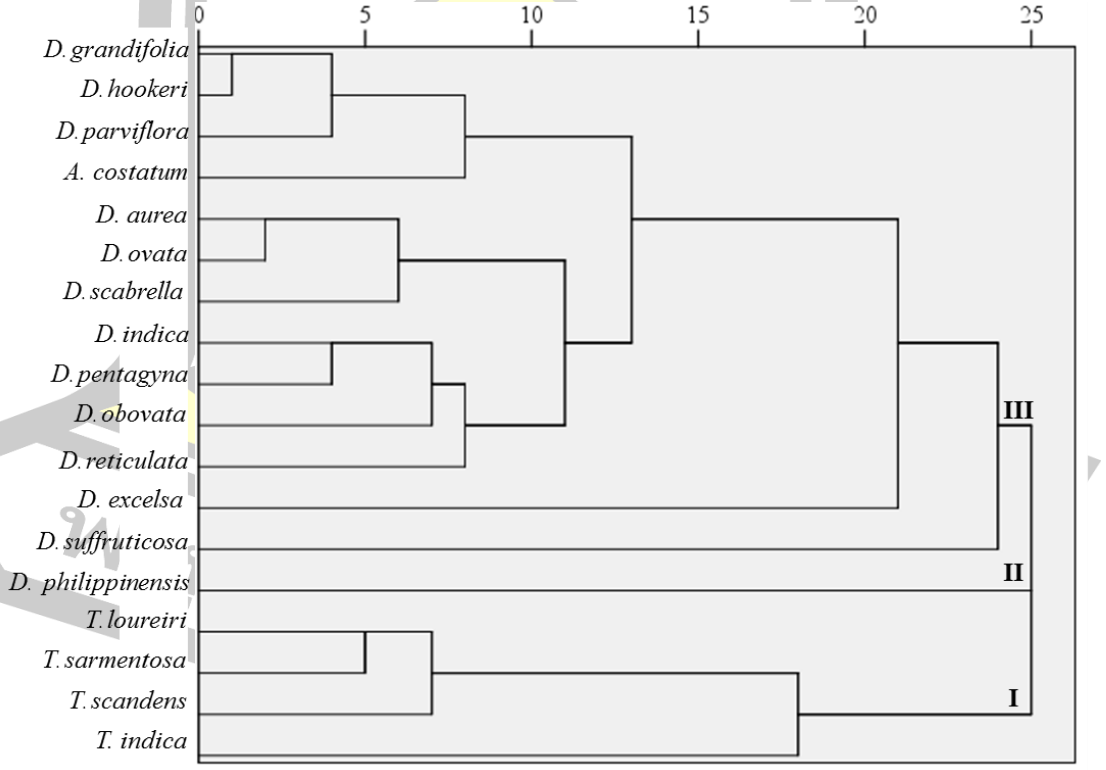

Figure 146 UPGMA clustering of 18 species based on Euclidean distance matrix calculated between means of Dilleniaceae in Thailand.

4.5 Discussion

The present study suggests that detailed analysis of anatomy of leaf surface, leaf lamina, leaf margin, midrib and petiole is extremely important for understanding the taxa. Summaries of the anatomical characters of the lamina and petiole of Thai Dilleniaceae are shown in tables 21-25. The anatomy of leaf surface, leaf lamina, leaf margin, midrib and petiole can be used for species identification and this study provided new characteristics on the anatomy of family Dilleniaceae, which can be useful for classification. The anatomical character of the family Dilleniaceae in Thailand are constant in genus, while some characters are different and distinguishing between species.

4.5.1 Leaf surface (Tables 28-29)

The epidermal cells on both surfaces are polygonal to irregular in shape with straight to slightly undulate anticlinal walls and some species deep sinuate. The stomata are restricted on the abaxial surface. Three stomata types are observed in this Dilleniaceae: 1) anisocytic; 2) anomocytic and 3) paracytic. This is in contrast to previous study of Metcalfe and Chalk (1950), which only reported the anomocytic and paracytic in Dilleniaceae, whilst Dickison (1970) recorded three stomatal types in Dilleniaceae: 1) paracytic type in genus *Didesmandra* and *Tetracera*; 2) anomocytic type in genus *Curatella*, *Davilla*, *Dillenia* and *Hibbertia* and 3) compound type by guard cells surrounded 2-4 subsidiary cells in some species of *Hibbertia*. Therefore, the anisocytic type in *Acrotrema costatum* and *Dillenia excelsa* are reported here for the first time in the family Dilleniaceae.

The trichomes are usually present on both sides except in some species, which the leaves are glabrous. Three main type of trichomes, i.e., simple unicellular, glandular and spiny hair are observed in Thai Dilleniaceae. This is in contrast to the work of Metcalfe and Chalk (1950) which reported the simple unicellular, stellate hair, spiny hair and peltate hairs in Dilleniaceae, whilst Dickison (1970) recorded simple unicellular, stellate, papillate and glandular trichomes. Simple unicellular trichomes are the common characteristic of Dilleniaceae. In this study report spiny hair are the common characteristic of Thai *Tetracera*.

4.5.2 Transverse section of the leaf lamina (Tables 30-31)

The lamina anatomical features in Dilleniaceae by Dickison (1970) and this study, the common structures of leaf anatomy of most Dilleniaceae include the present of one layer of both sides with epidermis cells in transverse section of both surfaces are four side or semicircular in shape except in some species where the leaves present of hypodermis on adaxial surface. The hypodermis is formed by a single layer of conspicuously large cells lying next to the adaxial epidermis. In this study can be found hypodermis in some species of genus *Dillenia*, which this data is consistent with the study of Metcalfe and Chalk (1950) and Dickison (1970).

The mesophyll has a well differentiated palisade and spongy region. The palisade mesophyll consists 1-4 layers. The findings are consistent with the studies of Metcalfe and Chalk (1950) and Dickison (1970). The secretory cavities are distinguished in some species and are present in the palisade mesophyll. These secretory cavities are in contract to study of Dickison (1970) which reported that intercellular space. Raphides have been observed in the leaves of Dilleniaceae in palisade layers. The raphides are often produced in enlarged, thin cell wall containing an abundance of mucilage.

4.5.3 Transverse section of the leaf margin

This study reports an additional transverse section of the leaf margin for the first time in Dilleniaceae. The outline of the leaf margin in transverse section in most species are curving downwards except *Dillenia obovata*, *D. philippinensis*, *D. retaculata* and *D. scabrella* are straight margin. The epidermis cells of leaf margin in transverse section is circular or semicircular and cells are usually smaller than cells in the epidermis of lamina.

4.5.4 Transverse section of the leaf midrib (Table 32)

This study reports an additional transverse section of the leaf midrib for the first time in Dilleniaceae. In study of Dickison (1970) was briefly described at the species level and incomplete data for leaf midrib anatomy. The current study of Thai Dilleniaceae report types of the outline of adaxial and abaxial surface of midrib, i.e., U-shape, V-shape, convex and concave. In adaxial surface, convex shape are the

common characteristic of Thai *Dillenia*, whilst concave shape is the common characteristic of Thai *Tetracera*. In abaxial surface, U-shape are the common characteristic of Thai Dilleniaceae except *Dillenia excelsa*, *D. philippinensis* and *D. suffruticosa*.

Midrib vascular bundle of Dilleniaceae is divers both between and within genera. Midrib vascular bundle in transverse section were observed by present study for the first time. An attempt to define the rang of variability in petiolar anatomy of Thai Dilleniaceae reported the following patterns: 1) vascular bundles form a cylindrical ring in genus *Tetracera*; 2) multivascular bundles (three to many trace), vascular bundle free forming a ring of widely dissected collateral bundles in genus *Acrotema* and *Dillenia*. The vascular bundles are surrounded by collenchyma cells and sclerenchyma cells, this is in agreement with the studies by Dickison (1969) and Dickison (1970).

4.5.5 Transverse section of the leaf petiole (Table 33)

The adaxial outline of the petiole i.e. V-shape, U-shape, Straight and Concave, while U-shape and V-shape was found on the abaxial side. The outline of petiole in Thai Dilleniaceae can be used for species identification such as in abaxial surface of *Dillenia suffruticosa* are V-shape, while most species of Dilleniaceae are U-shape.

The vascular systems in petiole of Thai Dilleniaceae are similar to the midrib in some characters. An attempt to define the rang of variability in petiolar anatomy of Thai Dilleniaceae reported the following patterns: 1) vascular bundles form a cylindrical ring in *D. granifolia*, *D. suffruticosa* and *D. scabrella* and *Tetracera scanden*; 2) multivascular bundles (three to many trace), vascular bundle free forming a ring of widely dissected colleteral bundles in most species of Thai Dilleniaceae. The vascular bundles are surrounded by collenchyma cells and sclerenchyma cells, this is in agreement with the studies by Dickison (1969) and Dickison (1970). Dickison (1969) reported that vascular bundle type of nodal anatomy is not compatible with petiole anatomy in some species of Dilleniaceae. In this study found character of vascular bundle type is not compatible between petiole with midrib such as vascular bundles on midrib anatomy of *Tetracera indica* form a cylindrical ring, while vascular bundles on petiole anatomy are multivascular bundles.

4.5.6 Data analysis

The PCA scatter plot and UPGMA clustering analysis base on leaf anatomical characters support as belonging to three groups. The present observations show that leaf anatomical characteristics, such as type of trichomes, position of trichomes, number of palisade mesophyll, present or absent of secretory cavities in leaf blade and other support a relationship between the genera *Acrotrema*, *Dillenia* and *Tetracera*. The species of genus *Dillenia* and *Acrotema* were classified to group two and three, while species of the genus *Tetracera* in Thailand are placed in group one, which is separated from the other groups. The evidence from leaf anatomical characters supports a closely relationship between *Acrotrema* and *Dillenia*, while *Tetracera* is placed elsewhere. The prominent leaf anatomical character of the genus *Tetracera* as follow: spiny hair on leaf surface or petiole, paracytic stomata, epidermal cells of leaf surface are jigsaw-like, thin of leaf blade in transverse section (100-160 µm), shape of midrib concave on adaxial surface. The remain group consisted of the genera *Dillenia* and *Acrotrema*, in which all group had absent spiny hairs, anomocytic or anisocytic stomata, thick of leaf blade in transverse section 120-410 µm), shape of midrib convex on adaxial surface. The relationship of *Acrotrema*, *Dillenia* and *Tetracera* is supported by the studies of Hoogland (1952, 1953), Takhtajan (2009) and Horn (2005, 2007), who arranged *Dillenia* and *Acrotrema* in the subfamily Dillenioideae based on the morphological characteristic and wood anatomy as follows: anthers linear or oblong, loculi very rarely slightly divergent and lateral pitting scalariform-transitional; while, the genus *Tetracera* was classified into subfamily Delimoideae based on the morphological characteristic and anatomy as follows: anthers short, loculi divergent, separated at the base by the thickened connective and lateral pitting opposite-transitional. While Horn (2009) arranged the genera *Dillenia* and *Acrotrema* in the subfamily Dillenioideae and classified the genus *Tetracera* in subfamily Delimoideae based on molecular data. Anatomy character is consistent with the pollen morphology in classification in two subfamilies. In second group of PCA scatterplot inconsistent with UPGMA clusters because in PCA scatterplot was generated from 22 characters of factor 1 (X-axil) and factor 2 (Y-axil), which it can be descried 61.68% of the total variance in 18 species. If in analysis use total character can be descried 91.08% of the total variance in 18 species.

In UPGMA clusters use all characters in analysis, therefor the results may be different, but overall the results are the same.

4.5.7 Overview of leaf anatomy

Character of leaf anatomy may be slightly different to leaf morphology in description on taxonomy chapter of some species such as petiole anatomy in adaxial surface of *Dillenia aurea* found smooth long unicellular hairs but in plant taxonomy described glabrous above. This is due to the sparsely distribution of the hairs, when the plants bring to the descried to find the surface smooth or glabrous in taxonomy chapter. In each phase, leaf is a difference in morphology characteristics such as *Dillenia obovata* in young leaves often more or less purplish, hirsute when young, later on glabrescent in mature leaf above. Therefore, the selection of leaves in each stage also influenced the study results. This study uses the leaves of the mature plant to study, so the leaf blade anatomy of *Dillenia obovata* is glabrous. The position of study also influenced the study results such as *D. indica* leaf morphology is glabrous on intervenium, sparsely hirsute on midrib and nerves above. Therefore, if observation on intervenium, it looks like smooth leaves. The study of anatomy will result in a more noticeable appearance. In case of spiny hair, if observe under stereo microscopy will look like a unicellular hair. It will affect the morphological descriptions such as *Tetracera* spp. were decried that strigose on surface because strigose is unicellular hair with stiff bristles.

Dillenia grandifolia and *D. reticulata* may be are single species. After I Checked carefully and found that *D. grandifolia* was nomenclated from the specimens in *Wall.* 946, are very imperfect (holotype in K!, isotypes in CAL, CGE, P!). Type specimens were collected from Penang, Malaysia Peninsular in August 1822. In currently, The Plant list refers to specimens of *D. ovata*. In Flora of Malaysiana ser.1 vol.4 and A revision of the genus *Dillenia* by Hoogland (1951, 1952) refer to *D. reticulata*. In 1972, Hoogland will have to be renamed *D. grandifolia* Wall. ex Hook.f. & Thorns in Flora of Thailand. Key to species of The Flora of Thailand *D. glandifloria* close relationship with *D. reticulata*. *D. reticulata* and *D. grandifolia* are deciduous stilt-rooted tree with flower in fasciculately breached inflorescence. Key to species used petals and carpels by *D. grandifolia* absent patulous, while *D. reticulata*

present patulous. In anatomy study *D. grandifolia* vary similar to *D. reticulata*. *D. grandifolia* have unicellular hair on both surfaces of petiole, while *D. reticulata* have unicellular hair present only on abaxial surface of petiole. This study, *D. grandifolia* is likely to have duplicate of *D. reticulata*, because of the taxonomy used key to species of The Flora of Thailand, Flora of Malay Peninsular and Revision of genus *Dillenia*. Key to species classified *D. grandifolia* to duplicate of *D. reticulata*.

4.6 Conclusion

The present study has apparently valuable for solving the species delimitation problem and useful for the identification and classification. Leaf anatomy of Thai Dilleniaceae can be used for the identification of morphologically closely related species. Those feature which are generally found in all members of Dilleniaceae investigated are as follows: 1) the one layer epidermal cells and thin cuticle on both surfaces; 2) the hypostomatic leaves with anisocytic, anomocytic and paracytic stomata; 3) the presence of stomata on abaxial surface; 4) the present of simple unicellular trichomes; 5) the bundle sheath extensions which extends to both epidermises; 6) the mesophyll is dorsiventral; 7) the presence of raphides crystals; 8) leaf margin are round in outline and 9) The vascular bundles are collateral bundle.

Dillenia aurea and *D. obovata* have similar morphological characters because *D. aurea* and *D. obovata* are closely related vicariant species, the first with a northerly and the second with a more southerly distribution, with a dividing line at 14 ^{0}N latitude in Thailand and Burma. Current, in Flora of Thailand identified between them base on the petiole and pedicle. Here the leaf anatomical characters, such as type of cell at surround vascular bundle, position of trichomes in petiole and midrib anatomy. The anatomy of leaf supported the differentiation between these two species.

The factor and cluster analyses of leaf anatomy can be classified *Acrotrema* and *Dillenia* in the same group while the genus *Tetracera* was classified into other group (Table 34, Figure 147).

Key to species by leaf anatomy cannot vouch for correct 100% because in character of leaf appearance depends on many things such as developmental stage, weather, topography and other. Therefore, the key to species from the taxonomy chapter is optimum.

Table 28 Stomata types of Dilleniaceae in this study and the data reported by other authors.

Genera	Stomata		
	Metcalfe and Chalk (1950)	**Dickison (1970)**	**This study**
Acrotrema	Anomocytic	No data	Anisocytic
Dillenia	Anomocytic	Anomocytic	Anisocytic Anomocytic
Tetracera	Paracytic	Paracytic	Paracytic

Table 29 Trichomes of leaf surface of Dilleniaceae in this study and the data reported by other authors.

Genera	Trichomes		
	Metcalfe and Chalk (1950)	**Dickison (1970)**	**This study**
Acrotrema	Unicellular hair	Unicellular hair	Unicellular hair
Dillenia	Unicellular hair	Unicellular hair Papillate trichomes Glandular trichomes (*D. philippinensis*)	Unicellular hair Glandular trichomes
Tetracera	Spiny hair	Unicellular hair Spiny hair	Unicellular hair Glandular trichomes Spiny hair

Table 30 Hypodermis layers in cross section of leaf blade in this study and the data reported by other authors.

Genera	**Hypodermis layers**		
	Metcalfe and Chalk (1950)	**Dickison (1970)**	**This study**
Acrotrema	Absent	No data	Absent
Dillenia	Present (*D. indica*)	Present (*D. excelsa*, *D. philippinensis*)	Present (*D. excelsa*, *D. indica*, *D. philippinensis*)
Tetracera	Absent	Absent	Absent

Table 31 Mesophyll in cross section of leaf blade in this study and the data reported by other authors.

Genera	**Mesophyll**		
	Metcalfe and Chalk (1950)	**Dickison (1970)**	**This study**
Acrotrema	1-4 layer in all genera	No study	1 layers
Dillenia	1-4 layer in all genera	1-3 layers	1-3 layers
Tetracera	1-4 layer in all genera	1 layer (*T. indica*) 3 layers (*T. scandens*)	1 layers

Table 32 Vascular bundles of mridrib by cross section in this study and the data reported by other authors.

	Acrotrema	***Dillenia***	***Tetracera***
Metcalfe and Chalk (1950)	2-7 or more concentric bundles	2-7 or more concentric bundles	Closed ring
Dickison (1970)	No data	No data	No data
This study	2 or more concentric bundles	2 or more concentric bundles	Closed ring

Table 33 Vascular bundles of petiole by cross section in this study and the data reported by other authors.

	Acrotrema	***Dillenia***	***Tetracera***
Metcalfe and Chalk (1950)	No data	Closed, cylindrical vascular strand accompanied by subsidiary bundles in the wings (*D. indica*)	No data
Dickison (1969)	Multivascular bundles or dissected collateral bundles	Multivascular bundles	Vascular fuse and form cylindrical ring or slightly dissected
This study	Multivascular bundles	-Multivascular bundles - cylindrical vascular strand accompanied by subsidiary bundles in the wings	Vascular fuse and form cylindrical ring or slightly dissected

Table 34 Leaf anatomical characters supported relationship of Thai Dilleniaceae.

Characters	***Acrotrema***	***Dillenia***	***Tetracera***
Stomata	Anisocytic	Anomocytic Anisocytic	Paracytic
Spiny hairs	Absent	Absent	Present
Shape of midrib on adaxial surface	Convex	Convex	concave
Thickness of leaf blade	Thick (120-410 µm)	Thick (120-410 µm)	Thin (100-160 µm)

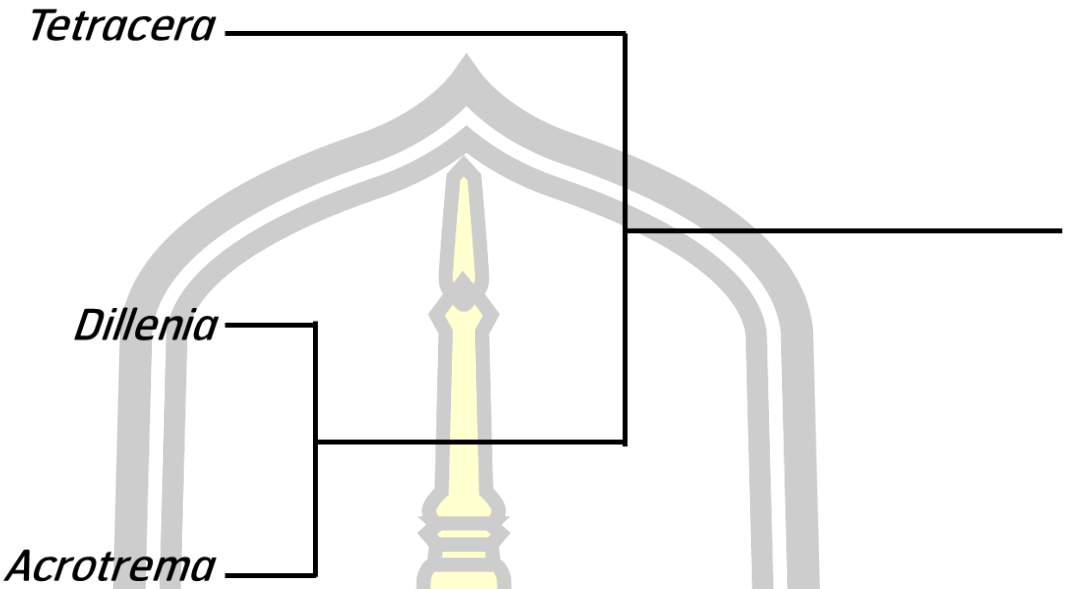

Figure 147 Relationship of Thai Dilleniaceae base on leaf anatomical characters.

CHAPTER 5
SUMMARY

This present study is based on taxonomy, palynology and anatomy of the family Dilleniaceae in Thailand. The study was carried out between 2013-2018. The summary of this study follows as below:

For the taxonomic studies, 20 species, three genera from two subfamily of the family Dilleniaceae are recognized in Thailand. Subfamily Delimoideae found 5 species of genus *Tetracera*. Subfamily Dillenioideae found 14 species of genus *Dillenia* and 1 species of genus *Acrotrema*. *Tetracera akara* is new record for Thailand. *Dillenia philippinensis*, *D. reticulata* and *D. puchella* was descripted for the first time base on Thai specimen. *Dillenia grandifolia* and *D. reticulata* may be are a single species by *D. reticulata* should be a synonym of *D. grandifolia*. *D. suffruticosa* and *D. philippinensis* are cultivated plant in several zones of Thailand.

For the palynology studies provides a definite clue to the relationships of the *Acrotrema*, *Dillenia* and *Tetracera*. The elongated aperture covered with large irregular flecks, monad, radially symmetrical, isopolar and tri-aperture represents the basic characteristic in the Dilleniaceae. The pollen morphology data cannot be used for species identification due to the variation within and overlap between species.

The data of leaf anatomy could be used for identification to species of Thai Dilleniaceae. The characters of leaf anatomy are basic characteristic in the Dilleniaceae as follows: 1) the one layer epidermal cells and thin cuticle on both surfaces; 2) the hypostomatic leaves with anisocytic, anomocytic and paracytic stomata; 3) the presence of stomata on abaxial surface; 4) the present of simple unicellular trichomes; 5) the bundle sheath extensions which extends to both epidermises; 6) the mesophyll is dorsiventral; 7) the presence of raphides crystals; 8) leaf margin are round in outline and 9) The vascular bundles are collateral bundle. The leaf anatomical data of 18 species can be divided into two group base on the type of anatomy, *Acrotrema* and *Dillenia* in the same group while the genus *Tetracera* was classified into other group. Leaf anatomy of Thai Dilleniaceae can be used for the identification of morphologically closely related species of *Dillenia aurea* and *D. obovata*.

In factor analysis and cluster analysis of pollen morphology and leaf anatomy data support classification of infrafamilial. In this study arranged the genera *Dillenia* and *Acrotrema* in the same group (Dillenioideae) and classified the genus *Tetracera* in another group (Delimoideae). The pollen morphology supports a classification of genera *Acrotrema*, *Dillenia* and *Tetracera* as follow: shape, aperture, distance between apices of two ectocopi, d/D ratio, P/E ratio, Clg/Clt ratio and Clg/P ratio. The leaf anatomy support a classification of genera *Acrotrema*, *Dillenia* and *Tetracera* as follow: type and position of trichome, type of stomata, shape of epidermal cells, thickness of leaf blade in transverse section and shape of midrib in transverse section.

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