ANTIOXIDANT AND ANTIFUNGAL ACTIVITIES OF SEVERAL MALAYSIAN WOOD EXTRACTS

NURUL ATIQAH BINTI SHAHARUDDIN

Universiti Sains Malaysia

2012

ANTIOXIDANT AND ANTIFUNGAL ACTIVITIES OF SEVERAL MALAYSIAN WOOD EXTRACTS

By

NURUL ATIQAH BINTI SHAHARUDDIN

Thesis submitted in fulfillment of the requirements
for the degree of
Master of Science
2012

ACKNOWLEDGEMENT

First and foremost, I am thankful to Allah S.W.T. for His blessing and allowed me to successfully complete my Master of Science study. I would like to express my sincere and heartfelt gratitude to my supervisor, Assoc. Prof. Dr. Rokiah Hashim for her guidance, support, and ideas throughout my research work and study. Special thanks to my co-supervisor, Dr. Fumio Kawamura, for his guidance, ideas, and sharing his knowledge with me and other students during our studies.

I also would like to express my sincere gratitude to other lecturers especially Prof. Dr.Othman Sulaiman and staffs of School Of Industrial Technology for their contribution. Grateful acknowledgement is also dedicated to Japan International Research Center for Agricultural Sciences (JIRCAS) for the collaboration research, Kedah Forestry Department for the wood identification and Guar sawmills for providing timber samples. A special gratitude is extended to Dr. Salmiah Ujang from Forest Research Institute Malaysia (FRIM) for generously providing the fungal strains.

Special thanks to my beloved colleagues partners, Sitti Fatimah Ramlee and Amalia Mahamud, who shared the precious moment and experience together with me. Finally, I would like to thank my dearest family, especially my parents, Dato' Shaharuddin Mohamad Ismail and Datin Zainon Timbong and my brother Muhammad Ariff Shaharuddin and sister Nurdiyana Shaharuddin for the unstoppable prayers, supports and sustained encouragements which gave me strength, motivation and courage to complete this study.

NURUL ATIQAH SHAHARUDDIN

School of Industrial Technology, USM

TABLE OF CONTENTS

LIST OF TABLES Page

LIST OF FIGURES Page

ABBREVIATIONS

$CH_3(CH_2)_3OH$	Butanol
CC	Column chromatography
$CDCl_3$	Deuterated chloroform
CD_3COCD_3	Deuterated acetone
COSY	Correlated spectroscopy
DEPT	Distortionless enhancement by polarization transfer
DPPH	1,1'-diphenyl-2-picrylhydrazyl
EC_{50}	half maximal effective concentration
EtOAc	Ethyl acetate
EtOH	Ethanol
g	Gram
H_2O_2	Hydrogen peroxide
HPLC	High performance liquid chromatography
MeOH	Methanol
Ml	Mililiter
mm	Milimeter
Na_2CO_3	Sodium bicarbonate
NMR	Nuclear magnetic resonance
TLC	Thin layer chromatography
UV	Ultra-violet
v/v	Volume over volume

AKTIVITI ANTIOKSIDAN DAN ANTIKULAT BAGI BEBERAPA EKSTRAK KAYU KAYAN MALAYSIA

ABSTRAK

Aktiviti antioksidan, antikulat dan sebatian fenol daripada 11 spesis kayu komersil Malaysia dipilih dan dikaji. Spesies terdiri daripada *Syzygium samarangense* (kelat jambu air), *Eugenia cerina* (kelat gelam), *Eugenia chorantha* (kelat merah), *Scorodocarpus borneensis* (kulim), *Myristica cinnamomea* (penarahan arang), *Artocarpus elasticus* (terap nasi), *Pometia pinnata* (kasai daun besar), *Palaquium hispidum* (nyatoh tembaga kuning), *Casuarina equisetifolia* (rhu), *Azadirachta indica* (neem) dan *Gonystylus bancanus* (ramin melawis). Ekstrak dari bahagian kulit kayu, kayu teras dan kayu gubal dari setiap spesies diuji dengan menggunakan 1,1-Difenil-2-pikrilhidrazil (DPPH) assay untuk penentuan aktiviti antioksidan, sedangkan sebatian fenol dinilai menggunakan kaedah Folin-Ciocalteu. Aktiviti antikulat diuji dengan *Gloephyllum trabeum*, sejenis kulat perang dan *Pycnoporus sanguineus* sejenis kulat putih. Bahagian kulit kelat gelam menunjukkkan aktiviti antioksida yang paling tinggi sedangkan kandungan fenol tertinggi ditemui pada bahagian kulit neem.

Metanol ekstrak kayu teras dari spesis neem menunjukkan aktiviti antikulat yang tinggi menentang *Gloephyllum trabeum*. Metanol ekstrak dari kayu gubal dan kayu teras neem dan kayu teras dari kulim menunjukkan aktiviti antikulat yang tinggi terhadap *Pycnoporus sanguineus* . Oleh sebab neem menunjukkan aktiviti antikulat yang kuat menentang kedua-dua kulat yang diuji, maka neem disisihkan dengan lebih lanjut menggunakan kaedah kromatografi TLC, CC, dan HPLC, disusuli dgn penentuan struktur menggunakan NMR. Berdasarkan kaedah tersebut, sebatian 1-Hydroxy-4-eudesmen-6-one diperolehi daripada *Azadirachta indica* (neem).

ANTIOXIDANT AND ANTIFUNGAL ACTIVITIES OF SEVERAL MALAYSIAN WOOD EXTRACTS

ABSTRACT

Antioxidant activities, antifungal properties and total phenolic compound of 11 selected commercial Malaysian timbers were studied. The species include *Syzygium samarangense* (kelat jambu air), *Eugenia cerina* (kelat gelam), *Eugenia chorantha* (kelat merah), *Scorodocarpus borneensis* (kulim), *Myristica cinnamomea* (penarahan arang), *Artocarpus elasticus* (terap nasi), *Pometia pinnata* (kasai daun besar), *Palaquium hispidum* (nyatoh tembaga kuning), *Casuarina equisetifolia* (rhu), *Azadirachta indica* (neem) and *Gonystylus bancanus* (ramin melawis). Extract from bark, sapwood and heartwood of each species were screened for antioxidant using 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay for antioxidant activities, whereas the total phenolic compound was evaluated using the Folin-Ciocalteu method. The antifungal activities were observed with *Gloephyllum trabeum* (brown-rot) and *Pycnoporus sanguineus,* which is white-rot. *Eugenia cerina* (Kelat gelam) bark showed the highest antioxidant activity while the highest total phenol content was found in *Azadirachta indica* (neem) bark.

The methanol extracts from the heartwood of *Azadirachta indica* (neem) showed the highest antifungal activity against *Gloephyllum trabeum*. The methanol extracts from the sapwood and the heartwood of *Azadirachta indica* (neem), and the heartwood of *Scorodocarpus borneensis* (kulim) showed the highest antifungal activity against *Pycnoporus sanguineus*. Since *Azadirachta indica* (neem) showed strong antifungal activities, it was continued for further separated, isolated and purified using thin layer chromatography (TLC), column chromatography (CC), high

performance liquid chromatography (HPLC) and analysed with nuclear magnetic resonance (NMR). The compound of 1-Hydroxy-4-eudesmen-6-one was obtained from *Azadirachta indica* (neem).

INTRODUCTION

1.1 General

Currently there are about 100 commercial timbers in Malaysia from the proof of over 2830 different tree species found in the tropical rainforest of Malaysia (Ng, 1999). These commercial timbers are converted to sawn timbers, plywood, veneer, moldings and furniture. In this regard, the chemical components of the timbers are also important and need to be exploited. In woody tree species, extracts from bark and heartwood have such strong biological activities such as antioxidant activities (Chang et al., 1999) and antifungal activities (Kishino et al., 1995).

A large variety of wood components, although usually representing a minor fraction, are soluble in neutral organic solvents or water. They are called extractives. The extractives can be regarded as nonstructural wood constituents, almost exclusively composed of extracellular and low-molecular-weight compounds. Phenolic extractives are present mainly in the heartwood and in bark (Sjöström, 1993). The content of extractives is higher in bark than in wood. It depends not only on the species but also on the solvents used. (Hergert, 1960: Dietrich, 1931). The aim of an extraction process should be, of course, to provide for the maximum yield of substances and of the highest quality (concentration of target compounds and antioxidant power of the extracts). Focusing on those authors who applied a single-stage solvent extraction, only a few literature works on antioxidant recovery from grape by-products were aimed to the optimization of some process parameters. The variables investigated up to now have been: pre-treatment of the sample (degreasing and size reduction), solvent/sample ratio, type of solvent, time and temperature of extraction (Spigno and De Faveri, 2007).

Since the past decade, there has been an increasing of interest among researchers for the quest of finding natural antioxidant as cure for various chronic diseases caused by oxidation and free radicals (Kinsella et al., 1993). Antioxidant is a substance that can delay or inhibit the oxidation of a substance. Antioxidants may act in various ways to delay the occurrence of auto oxidation by decreasing the oxygen concentration, intercepting singlet oxygen, preventing first chain initiation, scavenging free radicals, binding metal ion catalysts, decomposing primary products to non-radical compounds and chain-breaking to prevent the continuous hydrogen abstraction (Saha et al., 2004: Wang et al., 1996). The 1,1'-diphenyl-2-picrylhydrazyl (DPPH) is widely used analytical reagent for reducing substance and antioxidative activity of extract and compounds in the means of radical scavenging activity (Altarejos et al., 2005: Brand-Williams et al., 1995: Chen et al., 2006: Hu & Kitts, 2005: Saha et al., 2004).

Phenols is a group of compound including a wide range of plant substance that commonly contain an aromatic ring with one or more hydroxyl substituent (Harborne, 1998). Phenolic compound were utilized in taxonomy in early research (Ribereau-Gayon, 1972) but has gained attention from researches for its wide pharmacological activity especially as antioxidant in the past decades. Phenolic compound have been found to be an excellent antioxidant and synergist that is not mutagenic (Ishikawa et al., 1984). It is believed that these groups of compound are principally responsible for the antioxidant properties found in plant, fruit, and vegetables. Many methods have been suggested and developed for the estimation of total phenol in a sample. Folin-Ciocalteu method is the most widely used method in the determination of total phenolic in extracts (Cakir et al., 2003.: Cepaecka et al.,

2005; Miliauskas et al., 2004; Parejo et al., 2003; Singleton et al., 1965; Yoshki et al., 2004).

Wood, as a natural organic composite material, is widely used for construction materials and home furnishings, but the unprotected wood is susceptible to wood rotting fungi, resulting in reduction of mechanical strength. Traditional wood preservatives are highly effective against wood decay fungi, but they have been in restricted the use in recent years due to their toxicity and resulting in environmental hazards. It is also of grave concern in the agricultural practice where the use of traditional agrochemicals has caused seriously environmental pollution to our ecosystem. Consequently, developing environmental-friendly fungicides becomes undoubtedly needed (Yen et al., 2008). Plant pathogens consist of fungi, nematodes, bacteria and viruses which can cause diseases or damage in plants (Montesinos, 2003). They also cause yield losses in many economically important crops (Fletcher et al., 2006). Among these pathogens, fungi are the main pathogen causing many plant diseases.

Finding of a few methods have been identified to authorize isolation and structural determination of natural products. The past few decadess have witness development in particular applications of novel separation technologies and modern spectroscopic techniques for structural analysis (Snyder et al., 1989). Column chromatography (CC) is a method used to purify individual chemical compounds from mixtures of compounds (Pietrzyk et al., 1974). High-performance liquid chromatography (HPLC) method is better able to distinguish among different types of phenolics. Nuclear magnetic resonance (NMR) spectroscopy has developed since the introduction of the first commercial spectrometers in the early 1960s and it is always a dominant technique for use in structural analysis (Snyder et al., 1989).

1.2 Problem Statement

Numerous researches had been carried out to study the importance and properties of antioxidants from various natural sources. However, there were very little studies on Malaysian timbers (Molyneux, 2003; Cruz et al., 2005; Kitzberger et al., 2007). By the way, naturally occurring antioxidants from Malaysian timbers could contribute significantly in replacing the synthetic antioxidants mainly in foods, medicines and pharmaceutical products. More utilization of natural and safer antioxidants is desirable since synthetic antioxidant such as butylhydroxyanisole (BHA) have possible activity as promoters of carcinogenesis (Shimizu et al., 2002). At the same time, this study was intended to identify the capability of selected Malaysian commercial timbers to reduce the growth of a brown rot and white rot fungi as the primary steps on developing environmental-friendly fungicides. This research is expected to support other research in finding ways of replacing traditional agrochemicals which has caused environmental pollution to our ecosystem (Quiroga et al., 2003; Yen et al., 2007)

1.3 Objective

The objectives of this study are:

1. To purify and identify compounds from the most potential samples among the selected timbers

2. To evaluate methanol extract for antioxidant, antifungal activities and also total phenolic content from selected commercial Malaysian timbers.

3. To identify the antifungal properties of methanol extract from selected timbers.

2.0 LITERATURE REVIEW

2.1 Malaysian Timbers

Timbers in Malaysia are classified into four major groups. They are Heavy Hardwoods (HHW), Medium Hardwoods (MHW), Light Hardwoods (LHW) and Softwoods (SW) (MTC, 2002). The HHWs are heavy timber and having the density range from 800 to 1120 kg/m^3 at 15% moisture content. Besides, the timbers are naturally durable due to toxic substances that contained within their tissues. Therefore, they are mostly utilized as construction materials especially in the exposed conditions without undergoing any preservative treatment (Menon, 1993).

The MHWs are moderately heavy to heavy timbers and having the density range from 720 to 880 kg/m^3 at 15% moisture content. They are moderately durable and are mostly used for moderately heavy to heavy construction purposes. The LHWs are relatively light timbers and having the density range from 400 to 720 kg/m^3 at 15% moisture content. They are not naturally durable in tropical climate but are durable when used in temperature condition. There are only few softwood species of commercial significant in Malaysia. Softwood is timber that contains tracheids instead of vessels (pores) as in hardwoods. The density range from 385 to 735 kg/m^3 and they are mainly used as decorative plywood and paneling (Menon, 1993).

Most of the Malaysian timbers are hardwoods. Hardwoods have more strength capacity compared to softwoods. Therefore, hardwoods are suitable for both structural and non-structural construction purposes. Some species of timber possesses the characteristics that will affect its uses.

The wood has two main parts namely heartwood and sapwood. Heartwood is the older, harder central portion of a tree. It usually contains deposits of various materials that frequently give it a darker color than sapwood. Heartwood is generally darker than sapwood, and doesn't have the same expansion and contraction problems that beset some sapwood. It makes great wooden flooring because of its hardness and strength, and its resistance to many weather conditions. The hardness of heartwood, like sapwood, depends on the tree species and age of the tree. Figure 2.1 showed the part of wood.

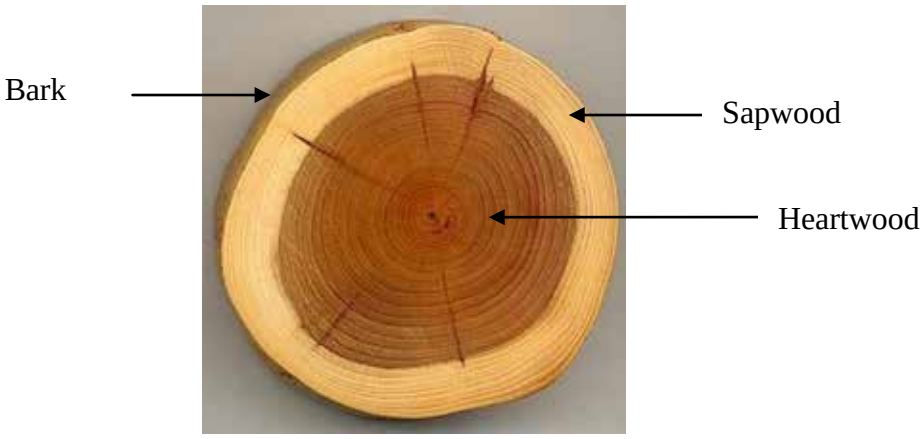


Figure 2.1. Heartwood, sapwood and bark (Source: Anonymous (a), 2008)

The sapwood is the younger, softer outer portion of a tree that lies between the heartwood and the cambium. As comparatively new wood, sapwood is less durable and more permeable than heartwood. While a floor purely of sapwood may be beautiful and smoother than heartwood, the softness and permeability of the sapwood makes it expand and contract easily, which can cause it to warp in certain conditions. This weakness also manifests differently in various tree species; some have sapwood that is strong and durable, others have weak, soft sapwood that is not

appropriate for wooden flooring. Coloration of sapwood ranges from white to light and yellow blonde tones.

2.2 Selected Malaysian timbers – species and family

In this study, eleven species from nine families randomly selected from Malaysian Timbers, which are *Artocarpus elasticus* (Moraceae), *Azadirachta indica* (Meliaceae), *Casuarina equisetifolia* (Casuarinaceae), *Gonystylus bancanus* (Thymelaeaceae), *Myristica cinnamomea* (Myristicaceae), *Palaquium hispidum* (Sapotaceae), *Pometia pinnata* (Sapindaceae), *Scorodocarpus borneensis* (Olacaceae), *Syzygium cerina*, *Syzygium chorantha* and *Syzygium samarangense* (Myrtaceae). The botanical name, commercial name, family name and species category are shown in Table 1.1.

2.2.1 Artocarpus elasticus (Moraceae)

Artocarpus consist of about 50 species and is distributed from Sri Lanka, India, Pakistan and Indo-China towards the Malaysian archipelago and the Solomon Island. The greatest diversity is in Malaysia. Vernacular names include *terap* (Peninsular Malaysia, Sabah and Sarawak) with various descriptions, *ara berteh* (Peninsular Malaysia), *miku* (Peninsular Malaysia), *paliu* (Sabah), *sukun* (Peninsular Malaysia), *timadang* (Sabah) and *timbangan* (Sabah). Major species include *Artocarpus altilis, A. elasticus, A. lowii, A. odoratissima, A. scortechinii, A. tamaran, A. teysmannii* (Lemmens et al., 1995).

Table 1.1 Eleven species of Malaysian timbers selected in the research work

No	Botanical Names	Commercial Name	Family	Category
1	*Artocarpus elasticus*	Terap nasi	Moraceae	Light
2	*Azadirachta indica*	Neem	Meliaceae	Light
3	*Casuarina equisetifolia*	Rhu	Casuarinaceae	Light
4	*Gonystylus bancanus*	Ramin melawis	Thymelaeaceae	Light
5	*Myristica cinnamomea*	Penarahan arang	Myristicaceae	Light
6	*Palaquium hispidum*	Nyatoh tembaga kuning	Sapotaceae	Light
7	*Pometia pinnata*	Kasai daun besar	Sapindaceae	Medium
8	*Scorodocarpus borneensis*	Kulim	Olacaceae	Medium
9	*Syzygium cerina*	Kelat gelam	Myrtaceae	Medium
10	*Syzygium chorantha*	Kelat merah	Myrtaceae	Medium
11	*Syzygium samarangense*	Kelat jambu air	Myrtaceae	Medium

Terap Nasi (*artocarpus elasticus*) is commonest and best known of wild species of Artocarpus and the species was used in this study. The trees is medium size tree rarely reaching 45 m tall and 210 cm diameter and the sapwood, except for some rare cases, is generally not differentiated from the heartwood, which is yellow to light yellow-brown. Occasionally, dark brown heartwood with an orange tinge is developed, in which case, the sapwood is distinct. The species are commonly deciduous in the northern part of the country and on the East Coast of Malaysia (Ng et al., 1978; Corner, 1997; Kochummen, 1997)

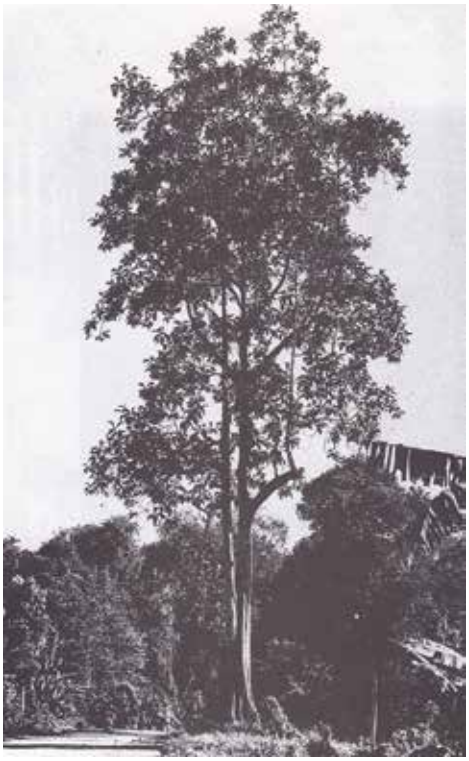
The bark is tough and strips readily in a big sheets. It is used as clothing by jungle-folk and by Malays for lining baskets and bins, for making house-walls and for string. The latex is most tenacious and is used for bird-lime. The fruit is edible but often has a bad taste and smell (Corner, 1997; Burkill, 1966; Lemmens et al., 1995)

Terap (*artocarpus elasticus*) is suitable for light construction, posts, beams, joists, rafters, flooring, plywood, packing boxes and crates, wooden pallets (expendable type), non-striking tool handles, pattern making, panelling, mouldings and furniture (Menon, 1986). In medicinal users, (Burkill, 1966) said that the leaves are given to consumptive patient, the latex for dysentery, inner bark serves for threat ulcers and also can prevents conception.

A

B

C



D

Figure 2.2. Artocarpus elasticus A& B. Leaf; C. bole; D. Tree (Source : Ng et al., 1978, Corner et al., 1997),

2.2.2 *Azadirachta* Indica (Meliaceae)

Meliaceae family consist of 45 genera with more than 1000 species of trees or shrubs, The Meliaceae is an important source of valuable commercial timbers because they have been known to be used in the furniture and cabinet trades for high-class joinery, paneling, and shop fittings, and sometimes as printers' blocks. (Desch (b), 1954). The word *Azadirachta* comes from the Persianised Indian, *azad-dirakht*, for the nim tree; *indica* means from India. The older generic name *Melia* has its origin in the Greek name for European ash, *Fraxinus*, as the shapes of the leaves are somewhat similar (Chin, 2003).

Azadirachta comprises 2 species; *A. excelsa* is native to Peninsular Malaysia, Sumatra, Borneo, Sulawesi, the Aru Island, New Guinea, and the Philippines. *A. indica* is thought to be native to the dry forest areas of the Indo-Pakistan. It is widely cultivated, also as a plantation tree and sometimes occurs naturalized throughout India, Pakistan, Sri Lanka, Thailand, and Indonesia (Lemmens et al., 1995).

Neem (*A.indica*) wood is appreciated for making carts, agricultural implements, doors, panels, window frames, poles, and other building materials, toys and idols. *A.indica* is of limited value for construction, as the logs are too short. However, it is considered suitable for the manufacture of plywood. *A.indica* seed and leaves, and apparently also the flowers and bark, yield azadirachtin which is used as insect and nematode repellent. The oil from the seed is used for the manufacture of soap, as fuel for lamps and as a lubricant for machinery. The oil extracted from the bark is industrially used in the manufacture of soap, toothpaste, and pharmaceutical and cosmetic products.

Various parts of *A.indica* have medicinal properties used against a wide variety of illness. *A.indica* oil has contraceptive properties and is used in local medicine against disease such as malaria, skin diseases, stomach ulcer, worms and rheumatism. The young leaves and young flowers are sometimes used as vegetable and the leaves and twigs are used as fodder for sheep and goats, and for mulching and fertilizing. *A.indica* cake, the residue left after extracting oil from the seed, is reportedly an excellent fertilizer and has potential as an insecticide. *A.indica* is regarded as a highly valuable multipurpose tree with great potential. *A.indica* is generally stronger and more durable than *A.excelsa* (sentang); it is more resistant to termite, powder-post beetle and fungal attacks and even durable under exposed condition.

The tree is held sacred by Hindus who used the leaves and fruits for religious rituals. In ancient times the leaves were used in India to exorcise the spirits of the dead. Bark from the roots and stem, as well as young fruits are used as tonic; and the oil, seeds and leaves as stimulant, insecticide and antiseptic. Dried leaves were once placed between the pages of old books in Indian libraries to deter damaging insects. Modern science has now found that the repellent is the limonoid, azadirachtin, which is also contained in the seeds. In the plains of Saudi Arabia, more than 50,000 trees have been planted to provide shade for the 2 million or more Muslim pilgrims camping there for their annual Hajj rites (Chin, 2003).

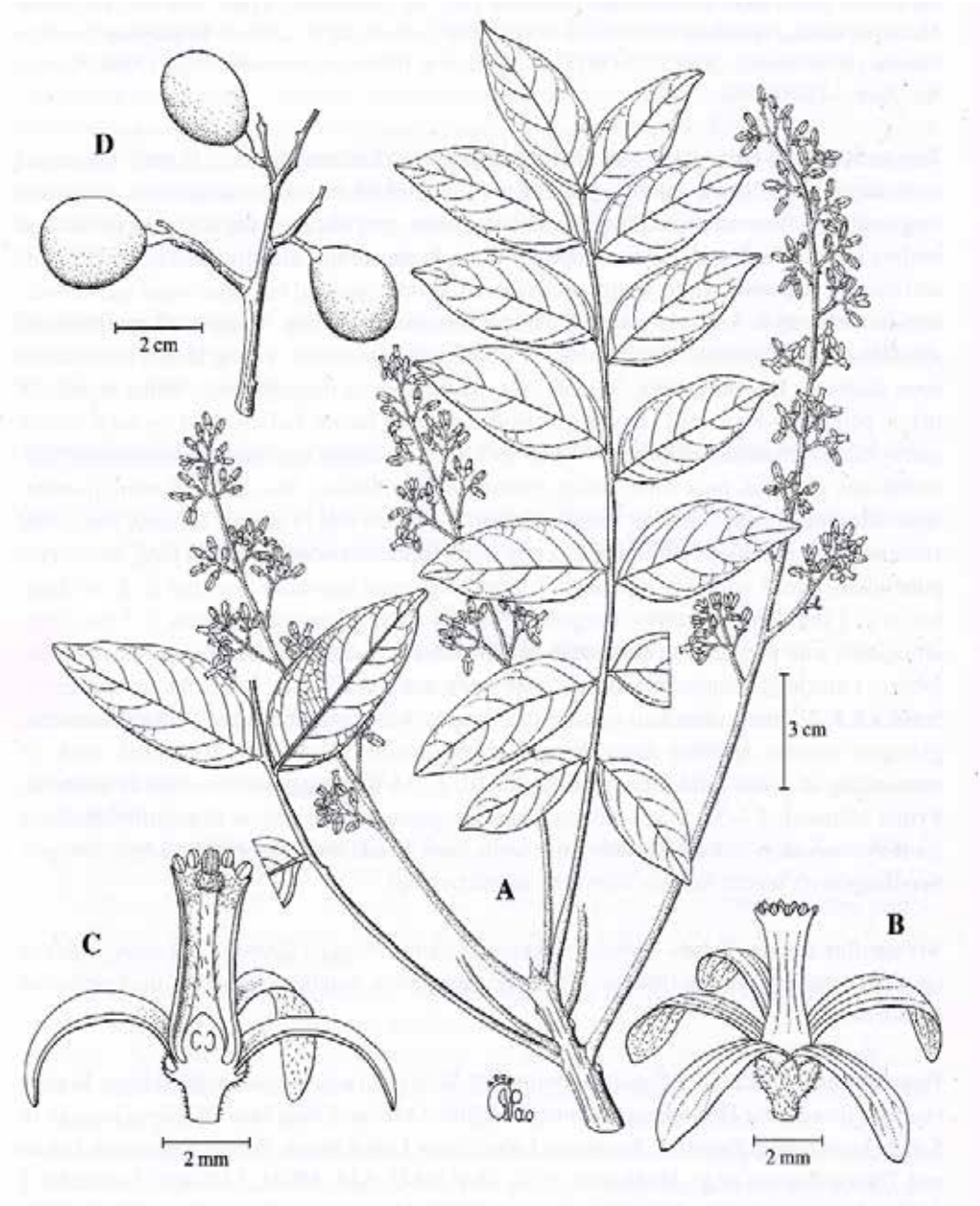


Figure 2.3. *Azadirachta indica,* A. flowering leafy twigs; B. flower; C. longitudinal section of flower; D. part of infructescence (Source : Soepadmo, 2007)

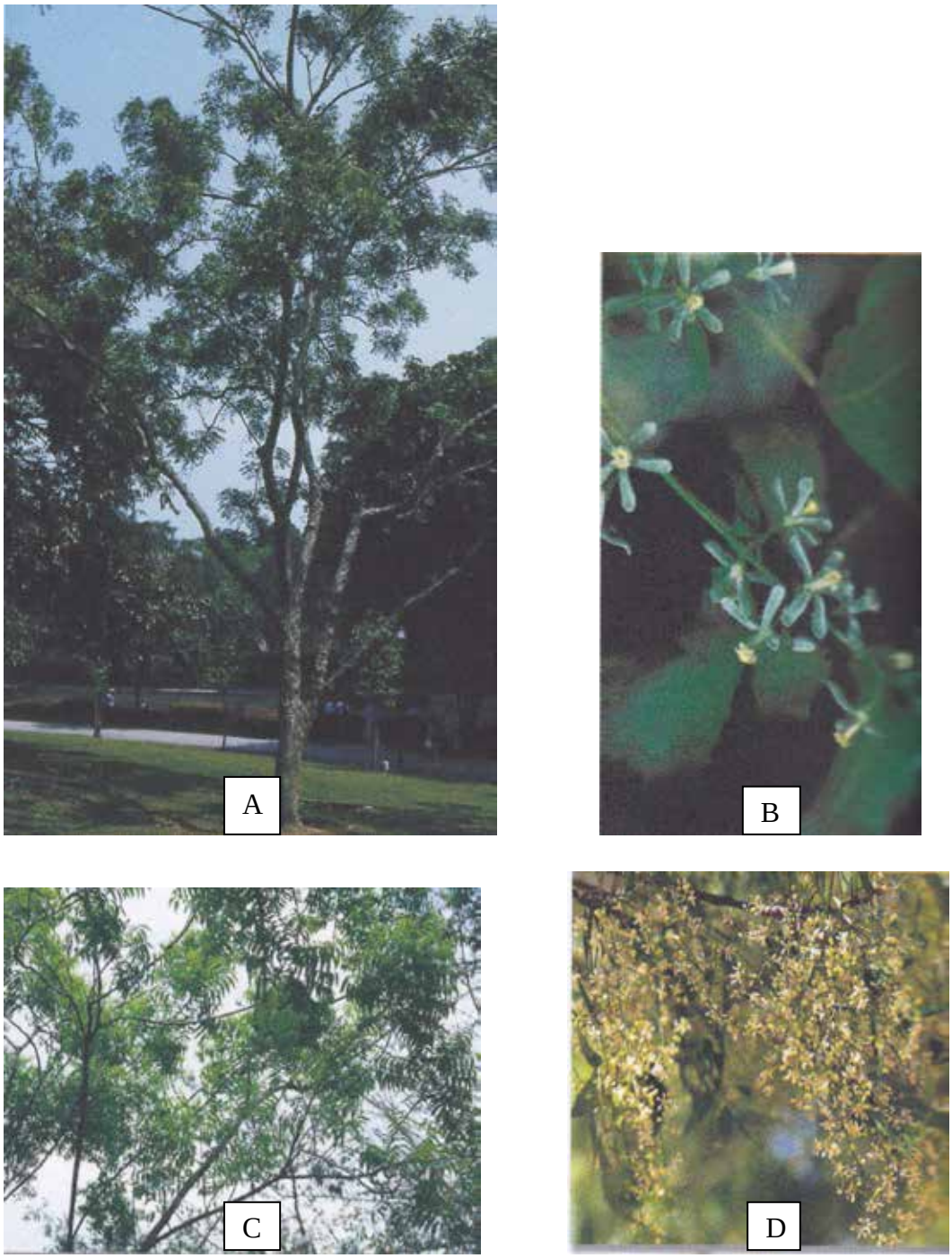


Figure 2.4 A. An evergreen tree with a bushy light green crown; B.Flowers are bisexual, white and fragrant; C. Leaves are simple pinnate compound and spirally arrange; D. Bunches of fragrant bisexual flowers. (Source : Chin, 2003)

2.2.3 *Casuarina equisetifolia* (Casuarinaceae)

Casuarina equisetifolia also known as Rhu or Aru is one of the species in Casuarinaceae family that have been used in this study. It is a very big tree around 50 m tall and 300 cm diameter. The bark is greyish brown, ridged, fissured and flaking into oblong pieces. About 17 species found in the Bay of Bengal to Malesia, Melanesia, Polynesia, New Caledonia and Australia but only *C.equisetifolia* is found in Borneo (Sabah, Sarawak, Brunei and Kalimantan) (Soepadmo et al. 1996). It is also found in Kedah (Langkawi), Penang (Muka Head), Perak (Teluk Batik), Selangor (Jugra FR), Negeri Sembilan (Port Dickson), Melaka (Pulau Besar), and is widespread on the East Coast from Terengganu to Johor (Kiew et al., 2010).

This species is found only along sandy beaches. It is grow naturally common in sandy soil near the sea but also grows well when planted far inland. Throughout its area of natural distribution the Rhu is a pioneer tree on sandy coasts. Its seeds sprout on the hot, open sand above the high-water mark and form a thicket of conical shaped trees that develop into a Casuarina-forest. *C.equisetifolia* will regenarate naturally and freely on the East Coast States but not on the West Coast (Ng et al., 1978). There is no evidence it natural occurrence in West Coast of Peninsular, though it is found in Port-Dickson, Morib and Penang. They are mainly planted, for instance, in the wild bays at Lumut and Pangkor where the virgin forest rises from the shore and the deep sandy beaches offer ideal condition (Corner, 1997).

The wood is suitable for light construction, piling and fuel. In Peninsular Malaysia, the Malays use a decoction of the twigs as a lotion which soothes swelling. The powdered bark is used to treat pimples (Soepadmo et al., 1996). The bark tannin is reported to be used to dyes fabric and also used for toughening fishing-lines. The bark is used as medicine to treat diarrhea and dysentery (Burkill, 1966). The timber is very heavy, very hard and makes excellent firewood and charcoal but is otherwise lowly regarded (Ng et al., 1978).

Mabberley (2008) reported that it is produces the ‘best firewood in the world’, being restively smokeless and provide good heat. A decoction of the twigs is used by the Malays as lotion for swellings while the powdered bark is prescribe for face pimples (Chin, 2003). In Peninsular Malaysia, it is commonly planted as an ornamental tree and is also used for hedges and topiary because it is easily pruned. Being a pioneer seashore tree, it is important as a windbreak for coastal resorts (Kiew et al., 2010). For this reason the species is protected in Sarawak for coastal erosion control.

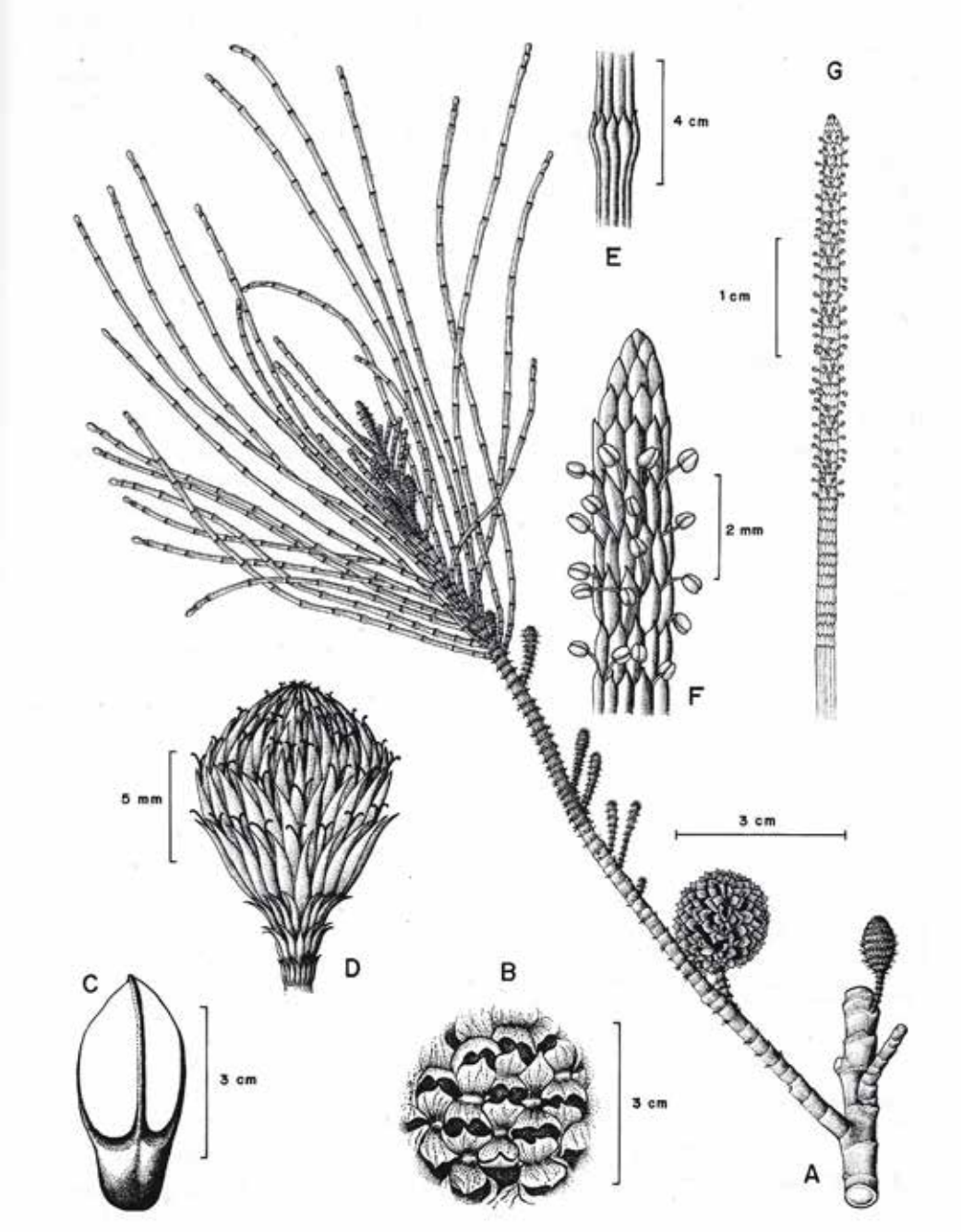


Figure 2.5. *Casuarina equisetifolia*, A.fruiting twig; B. detailed arrangement of bracts and bracteoles in fruit cone; C. samara of fruitlet; D. female inflorescence; E. nodal portion of needle-shaped twig; F-G. male inflorescence. (Source : Soepadmo et al., 1996)

2.2.4 *Gonystylus bancanus* (**Thymelaeaceae)**

Gonystylus, ramin, are the only big trees for the family of Thymelaeaceae. At present *Gonystylus* consist of about 30 species but this number will probably increase further because new species are regularly discovered. The species are distributed almost throughout the Malesian area. The huge majority of species is found on Borneo especially in Sarawak. Ramin is the common name of *Gonystylus*, but it also known as gaharu buaya (Sumatra, Kalimantan, and Sarawak), melawis (Peninsular Malaysia), *ramin* (Peninsular Malaysia, Sabah and Sarawak) with various epithets, *dara elok* (Peninsular Malaysia), *pinang baik* (Peninsular Malaysia) and *pinang muda* (Peninsular Malaysia) (Seopadmo et al., 2004; Soerianegara et al., 1994).

The sapwood is lighter in color and is poorly defined from the heartwood, which is white to creamy yellow. The tree is usually a medium tree about 25-50m tall and 30-100cm diameter (Whitmore et al., 1972). *Gonystylus bancanus* occurs gregariously in lowland freshwater swamps or peat-swamp forests outside the influence of tidal waters but often in broad belts along the coast. It occurs up to 100m altitude and is occasionally found in pure stands (e.g. Sarawak) (Soerianegara et al., 1994)

The logs, as well as freshly sawn boards are very susceptible to attacks by staining fungi and powder-post beetles. The dried timber is also liable to attacks by borers. Jackson (1965) recorded that nearly all the 30 pieces of test sticks of 50 mm x 50 mm x 600 mm tested with the standard graveyard test were destroyed after one year. The timber is therefore classified as non-durable.

The whitish timber of ramin is highly prized and popular as a decorative cabinet timber. More generally it is also suitable for furniture, interior decoration such as wall paneling, light flooring, toys, turnery, broom handle and other non-impact handle. Ramin is used for general light construction such as door and window frame, mouldings, skirting, ceilings, partitions, stair treads and counter tops. Ramin is very suitable for veneer, plywood and blockboard manufacture and can be made into a satisfactory quality of particle board. (Seopadmo et al., 2004; Soerianegara et al., 1994; Whitmore et al., 1972). The oil of this wood is used in incense, and the smoke is used for treating asthma (Burkill, 1966).

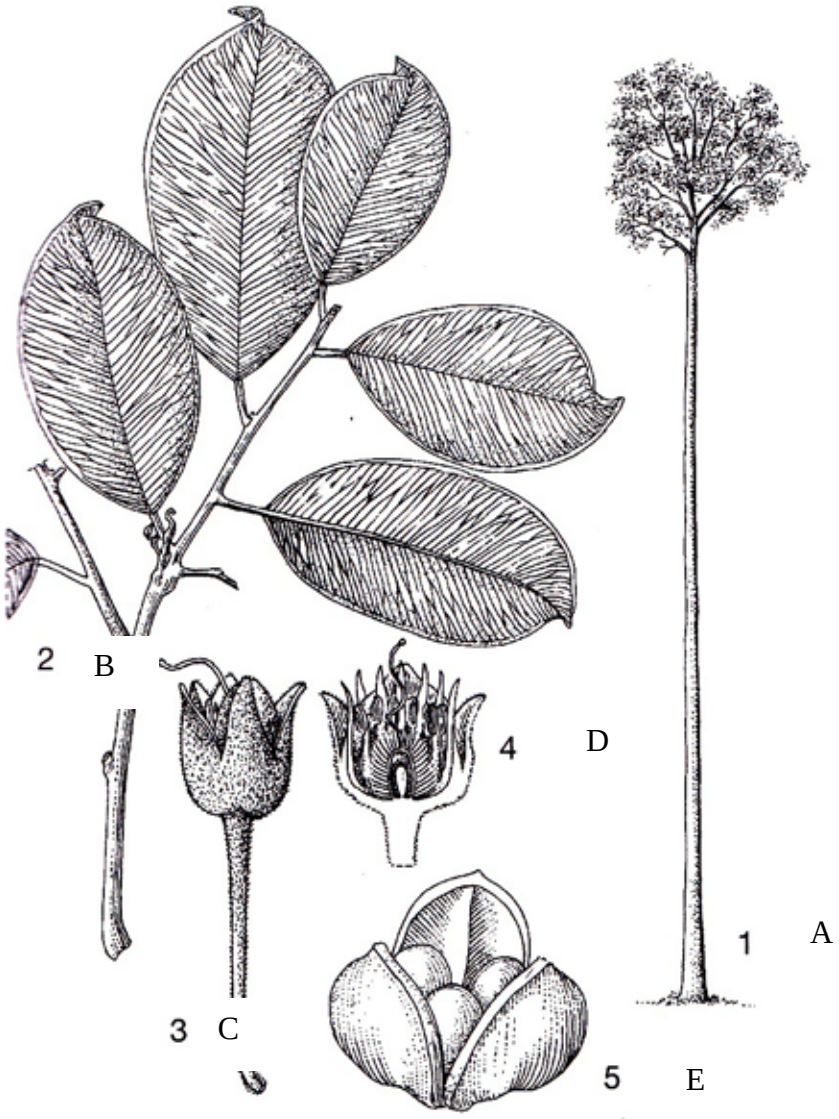


Figure 2.6. *Gonystylus bancanus;* A. tree habit; B. sterile twig; C. flower; D. section flower; E. dehisced fruit (Source : Soerianegara et al., 1994)

2.2.5 *Mytistica cinnamomea* (Myristicaceae)

The genus of *Myristica* includes more than 100 species and is distributed from southern India and Sri Lanka, through Burma, Thailand and the whole Malaysian area. The eastern Malaysian region comprises the largest species diversity for the genus. *Myristica* wood is lightwood to medium- weight tree. Penarahan timber represents the wood of all genera of the family Myristicaceae (Lemmens et al., 1995). Other common name of this genera include *darah-darah* (Sabah), *darah-darah kerantu* (Sabah), *dara kerbau* (Kelantan), *kumpang* (Sarawak), *lempoyang paya* (Sabah), *lunau* (Sabah), *mendarah* (Peninsular Malaysia), *pala* (Kedah) and *penarahan arang* (Peninsular Malaysia) (Midon, 1984).

The family Myristicaceae is homogeneous and clearly belongs (phytochemically) within the *Magnoliales.* Phylogenetic analysis of the genera revealed that the family is monophyletic, of African origin, and seemingly most related to the *Annonaceae*, mainly through the ruminate endosperm (De Wilde, 2000). *Myristica* is a very homogeneous genus which cannot satisfactorily be divided into section. The flowers are very uniform and variation in size of inflorescence, fruit and leaves.

The species of *Myristica* found in Peninsular Malaysia have rough, black, brittle, charcoal-like outer bark are known as penarahan arang. *Myristica cinnamomea* (penarahan arang) sapwood is lighter in color and is poorly defined from the heartwood, which is light yellow-brown, brown with occasional pink tinge and dark red-purple stripes. A blood-red core is found in some species (Kochummen, 1997; Whitmore et al., 1972). *Myristica cinnamomea* is characterized by the persistent inconspicuous hairs on the lower leaf surface, the short hairs on the leaf

bud and twig apices, the angular apex of flower buds, and the fruits with mealy indumentums (De Wilde, 2000).

The timber is thus classified as non-durable. If used in contact with the ground or exposed to the weather, the timber will perish fairly easily. It is very rapidly attacked by subterranean termites and is not particularly resistant to the development and growth of fungal decay. The timber is very liable to powder-post beetle and dry wood termite attacks indoors (Lemmens et al., 1995). The timber is suitable for pattern making, packing boxes and crates, plywood, light temporary construction, internal partitioning, flooring, match boxes and splints, furniture, posts, beams, joists, rafters, cooling tower (non-structural members), joinery and cabinet making (Menon, 1986).

Figure 2.7. A. Leaf; B. Tree of *Myristica cinnamomea* (Source: Chin et al., 2003)

2.2.6 *Palaquium hispidum* (Sapotaceae)

The genus *Palaquium* consists of about 110 species and is distributed from western India and Sri Lanka to Southern China. The centre of diversity is western Malesian and most species are found in the Philippines and Borneo with 32 species and 50 species respectively. In Sabah and Sarawak, 41 species are known. The most widely distributed species are *P. amboinense* and *P. obtusifolium* (western Indonesia to New Guinea), *P. ridleyi* (Indo-China to New Guinea) (Seopadmo et al., 2002; Soerianegara et al., 1994)

Excepting a few exotic shrubs, the members of this family are trees. Many are common in the Malayan forests, of which they are truly characteristic, and vary I size from 15 to 200 ft. as a group they are easily recognized from their latex spirally arranged leaves. To Malays, it is known as Nyatoh, less often as Betis, Belian, Taban, Semaram, and Sundek (Corner, 1997). *Palaquium hispidum* also known as mayang serikat (Indonesia), nyatoh tembaga kuning or nyatoh tembaga (Malaysia).

Palaquium is distinguished from other *Sapotaceae* genera by its flowers having most commonly 6 sepals and 12 stamens. The leaves show much variation between the different species in shape, size, indumentum and venation. Most *Palaquium* species growsin lowland forest. Only occasionally are species found at higher elevations, e.g. *P.Retina-montium* in Peninsular Malaysia and *P.Rioense* in Borneo. Usually the trees occur scattered in the forest. Nyatoh has become more important since 1985; trade and export of this timber have been increarasing. This is due to intensified logging operation and to the wood properties which are close to meranti (Soerianegara et al., 1994).