In Investigation on Morphological and Anatomical Characteristics of Some Myanmar Fuelwood Timber Species

U Aung Naing Oo, B.Sc.(Hons.) (Mdy.), M.Sc.(Mdy),
Part Time Demonstrator,
U Soe Myint, B.Sc (Rgn.), M.Sc. (Rgn.)
Lecture
Botany Department, University of Mandalay
and
U Thein Kywe, M.Sc. (Rgn.), M.S. (SUNY, CESF)
Assistant Director
Forest Research Institute

January, 1995

Yezin
Acknowledgements

We would like to thank Professor Dr. Than Nyunt, Head of the Department of Botany, University of Mandalay and Daw Win Kyi and U Nyan Lwin, Professors, the former heads of the Department of Botany for permitting us to undertake this research.

Appreciation is also extended to U Saw Yan Aung C. Doo Rector, Institute of Forestry, the former Director of Forest Institute, Yezin, for allowing to use library and laboratory facilities and U Khin Maung Tin, Head of the Department of Botany, Yenangyaung College, for his invaluable advice and for reviewing the taxonomic description.

The assistance of Daw Yi Yi Han and U Kyaw Win Maung, Wood Anatomy Research Section, Forest Research Institute, Yezin is gratefully acknowledged.
Acacia arabica (Lam.) Willd.

Acacia leucoploea (Roxb.) Willd. (B.Sc. (Hons.) (Mdy.), M.Sc. (Mdy.))

Acacia sundra DC. (B.Sc. (Rgn.), M.Sc. (Rgn.))

Aubizzia lebbekoides (D.C) Benth. (M.Sc. (Rgn), M.Sc. (SUNY, CESE))

Albizzia procera (Roxb.) Benth. (M.Sc. (Rgn.), M.Sc. (SUNY, CESE))

Cassia siamea Lam. (M.Sc. (Rgn.), M.Sc. (SUNY, CESE))

Leucaena leucocephala (Lam.), de.Wit (M.Sc. (Rgn.), M.Sc. (SUNY, CESE))

Samanea saman (Jacq.) Merr.Tectona hamiltoniana Wall. (M.Sc. (Rgn.), M.Sc. (SUNY, CESE))

Terminalia oliveri Brandis.
In Investigation on Morphological and Anatomical Characteristics of Some Myanmar Fuelwood Timber Species

U Aung Naing Oo, B.Sc. (Hons.) (Mdy.), M.sc. (Mdy.),
Part Time Demonstrator,
U Soe Myint, B.Sc. (Rgn.) M.Sc.(Rgn.),
Lecturer,
Botany Department, University of Mandalay
and
U Thein Kywe, M.Sc.(Rgn.), M.S.( SUNY, CESF),
Assistant Director
Forest Research Institute

Abstract

A study on morphology and anatomy of fuelwood species especially growing in the tropical region of central Myanmar has been undertaken. The morphology of vegetative and reproductive parts and anatomy of woods of the ten species have been studied. The species observed in this research were Acacia arabica (Lam.) Willd., Acacia leucophloea (Roxb)., Willd., Acacia sundra DC., Albizia libbekoides (DC)., Benth., Albizia procera (Roxb). Benth., Cassia siamea Lam., Leucaena leucocephala (Lam).de wit., Samanea saman (Jacq)., Merr., Tectona hamiltoniana Wall. and Terminalia oliveri Brandis. The outstanding characteristics of the species and important botanical observations have been discussed.
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgement</td>
<td>i</td>
</tr>
<tr>
<td>သမာ၀င်ပြုပေးချက်များ</td>
<td>ii</td>
</tr>
<tr>
<td>Abstract</td>
<td>iii</td>
</tr>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. Review of the Literature</td>
<td>1</td>
</tr>
<tr>
<td>3. Material and Methods</td>
<td>6</td>
</tr>
<tr>
<td>4. Observations</td>
<td>6</td>
</tr>
<tr>
<td>4.1 Morphology</td>
<td>6</td>
</tr>
<tr>
<td>4.2 Anatomy</td>
<td>10</td>
</tr>
<tr>
<td>5. Discussion</td>
<td>32</td>
</tr>
<tr>
<td>6. References</td>
<td></td>
</tr>
</tbody>
</table>
1. Introduction

Wood, solid fuel including firewood and charcoal is the principal source of heat energy for domestic cooking and industrial uses (Winkelmann, 1995). However, fuelwood takes basic need for human welfare; the population and supply of fuelwood species have become more and more reduced in many regions of Union of Myanmar for its ever growing human population. The insufficiency of fuelwood is partly due to the deforestation caused by severe exploitation of wood as well as partly due to the reduction of forest land by extension of agricultural land (Sein Maung Wint, 1993). The volume of wood fallen annually for the fuelwood is estimated to be far greater than that of the timber extracted for export and local use (Sein Maung Wint, 1993).

If this subtle trend of acute fuelwood shortage will continue to the future, it will threaten the ecosystem of the environment and biodiversity, and consequently even upon the socioeconomy of the country.

The conservation and development of fuelwood resources may be critical at alarming rate especially in the tropical arid region where soil fertility and rainfall are bodily poor for plant growth. So that enforcement on massive plantation of fast-growing and multipurpose fuelwood species was significantly emerging in the field of development of wood energy resources. The choice of suitable species for particular condition is also important in efficient development of fuelwood resources.

In this research, the morphology and wood anatomy of ten fuelwood species especially growing in dry zone of Central Myanmar were studied. All the species in this study were useful not only as fuelwood but also other purposes such as fixation of atmospheric nitrogen, native medicine, animal fodder, furniture, construction materials, agricultural implements and industrial products such as gum arabic, Tanin, Cutch etc.

A review of literatures has revealed that very little work on wood anatomy of these species has been done so far in Myanmar, although their morphology was recorded to some extent in the taxonomic study of regional flora of Central Myanmar. Thus, this investigation will fulfill the need of wood structure and properties of these species.

Ten of fuelwood species taken in this research were Acacia arabica (Lam.) Willd. (Su byu), Acacia leucophloea (Roxb.) Willd. (Hta naung), Acacia sundra DC. (Sha), Albizia lebbekoides (DC.) Benth. (Pomeza), Albizia procera (Roxb.) Benth. (Slt), Cassia siamea Lam. (Mezali), Leucaena leucocephala (Lam.) de Wit. (Bawzagaing), Samanea saman (Jacq.) Merr. (Thinbaw-kokko), Tectona hamiltoniana Wall. (Dahat) and Terminalia oliveri Brandis. (Than).

2. Review of the Literature

Firewood and charcoal were principal sources of heat energy for domestic cooking. Hall (1952) mentioned that charcoal was not only used as valuable fuel but also used in medicine, in the iron and steel industry as reducing element, in the manufacture of chemicals, and for absorbing impurities and bad odour from both of water and atmosphere.

Ayensa (1980) described that more than one-third of the world’s population depends on wood for cooking and heating. 86 % of wood annually extracted was used for fuel and half of them is used for cooking. Eckholm (1975) mentioned that not less than one and a half billion people in developing countries derive at least 90 % of their energy required from the wood. Other billion people meet at least 50 % of their energy needs in this way.

Dry region of the world face more fuelwood problems than that of either the humid tropics or the tropical high lands.
In the Union of Myanmar, the firewood annually harvested is estimated to be as large as 45 times of the teak annually extracted and 17 times of the commercially extracted hardwood in volume (Soe Tint, 1984). He also mentioned that severe condition of climate and soil in dry zone induce the scarcity of fuelwood. To solve this extreme shortage of fuelwood, plantation of potentially adaptable firewood species with satisfactory characteristics in dry zone of adverse condition is essential.

As the classification of Hutchinson (1964) the genera *Acacia*, *Albizia*, *Leucaena* and *Samanea* belong to the family Mimosaceae, *Cassia* to the family Caesalpiniaceae. But Lawrence (1969) placed the genera *Acacia, Albizia, leucaena* and *Samanea* under the subfamily Mimosoideae, and the genus *Cassia* was also treated under subfamily Caesalpinoideae of the family Leguminosae. According to Hutchinson (1964) and Lawrence (1969) the genera *Tectona* and *Terminalia* were included the families Verbenaceae and Combretaceae respectively.

The relationship between anatomical structures and wood combustion was briefly accounted by Winkelmann (1955). He stated that combustible substances of wood consist of fixed carbon and volatile components, and it's combustion is also influenced by the structure of the wood, the number and size of the pores, the presence of resin and gum duct, and the direction of the fibres. Density of the wood is the most general gauge of a wood's burning quality. In addition, about 20% of the heat given off by combustion is due to the presence of the resin found as in the conifer and the oil and gum in the hardwood.

According to Hooker (1987) and Brandis (1874) *Acacia arabica* was distributed from Punjab to Behar, West Peninsula of India, in Ceylon, Arabia, Egypt, Tropical Africa, Natal, North-West of India and North-West of Himalaya.

As recorded in the Forest Inventory (1983-94) in Myanmar, the total number of *A. arabica* trees (over 2 feet in girth) found in reserve forest of Mandalay division was 4,12 and 14, 937 throughout the whole Myanmar. It was largely cultivated in the dry zone of Myanmar and drier parts of India as a road side tree (Pearson and Brown, 1932).

The morphological characteristics of *A.arabica* were described by Brandis (1874), Hooker (1874), Backer (1963), Khin Maung Tin (1974), Aung Kyaw (1976), Tin Tin Htay (1976), Aung Moe (1977), Myint (1977), Hnin Hnin Mya (1977), Tin Tin New (1977), and Ah-Mar Sein (1991).

Wood anatomy of the genus *Acacia* was mentioned by Metcalfe and Chalk (1950). General characteristics of the wood of *A. arabica* was noted by Gamble (1922), Brandis (1874), Pearson and Brown (1932). Gamble (1922) stated that the well-seasoned wood of *A. arabica* was very durable and extensively used for wheels, well-curbs, sugar and oil presses, rice pounders, agricultural implements, tool-handle, boat building and rafter. Pearson and Brown (1932) enumerated the present and prospective uses of *A.arabica*. According to them, it was one of the favorite timbers for native wheel wright work in India being used as felloes, spokes, naves, axles, bodies of carts, shafts and yokes. Maitland Kirwon mentioned that the timber was used as pit props in the coal mine. As observed by Gamble (1922) the wood of *A. arabica* was an excellent fuel by giving 0.86 lb of ash on complete burning of 100 lbs of wood.

*Acacia leucophloea* was distributed in some states of India, Ceylon and Java (Brandis, 1874 and Hooker, 1879).

Kurz (1877) described that it was commonly found in dry forests of Pyay and Inwa. Pearson and Brown (1932) also stated that it was grown in favorable localities of Myanmar.

According to the record of Forest Inventory (1983-84), the total number of *A. leucophloea* trees (over 2 feet in girth) distributed in reserve forest of Mandalay division was 23, 798 and 359,072 throughout the whole Myanmar.

General characteristics of wood *A. leucophloea* were stated by Brandis (1874), Gamble (1922) and Pearson and Brown (1932).

Pearson and Brown (1932) stated that the wood was commonly used for agricultural implements, especially for plough. A limited amount of timbers was also utilized for cart wheels. In Myanmar, as stated by Rodger (1951), it was used for posts and beams, carts, wheels, plough, and for turnery. The excellent purpose of these trees was as fuel (Gamble 1922, Pearson and Brown, 1932).

In the world, *Acacia sundra* was distributed from Indus eastward to Assam throughout the Peninsula, sub-Himalayan tract of India, Ceylon and Eastern Africa. (Brandis 1874; Hooker, 1978; Pearson and Brown, 1932).

According to Kurz (1877) and Pearson and Brown (1932), this species was apparently found around Inwa, dry plains and lower hill forests of upper and lower regions of Myanmar.

Kurz (1877), Hooker (1879), Myint (1977) and Tin Tin New (1977) mentioned the morphology of *A. sundra* and their distinguishable characteristics differed from *A. catechu*.

Kurz (1877), Gamble (1922), and Pearson and Brown (1932) described the anatomical characteristics of wood of *A. sundra*. The strong and durable heartwood of *A. sandra* was employed for posts and upright houses, for spear and sword handle, and bows (Kurz, 1877). The timber, not attacked by xylophages, was recommended for railway sleepers (Kurz, 1877; Gamble, 1922). Person and Brown (1932) mentioned that the timber of *A. sundra* was valuable and used as posts and construction, rice pestles, oil and sugar cane crusher, harrow teeth, boats wheel, bows, spear handles, plough, furnitures, combs, stocks and felloes of wheels, carts, bed post, legs, tool and rolling pins. According to Gamble (1922), the wood was the superior fuel and good charcoal, by giving 1.18 lb of ash in complete burning of 100 lbs of wood. In past it was largely used for the steamers of Ayeyarwaddy flotilla.

*Albizzia lebbekoides* was also scattered from northern Luzon to southern Mindanao (Brown, 1921; Brandis, 1906). It was distributed throughout the upper Myanmar (Kurz, 1988; Khin Than Htwe, 1991).

Morphological characteristics of *A. lebbekoides* was studies by Brown (1950), Backer (1963) and Khin Than Htwe (1991).

Anatomy of wood of the genus *Albizzia* was mentioned by Metcalfe and Chalk (1950). Anatomical characteristics of wood of *A. lebbekoides* was studied by Khin Than Htwe (1991).

The bark was used in tanning (Bor, 1953; Khin Than Htwe, 1991) and in the manufacture of fermented drink known as Basi (Brown, 1950).

*Albizzia procera* was distributed in central and eastern Himalayas, Western Peninsula of India, Myanmar, Malay Isles, China, Malay Archipelago and Philippines (Hooker, 1885; Cooker, 1903; Hirtikar and Basu, 1933).

Kurz (1877) noted that *A. procera* was distributed in the mixed and dry forest of Myanmar, especially around Pyay, Bago and Moattama down to Tanintharyi. They were also distributed in swampy lands all over Myanmar (Rodger, 1951).

As the record of Forest inventory of Myanmar (1983–84), the total number of *A. procera* trees (over 2 feet in girth) grew in the reserve forests of Mandalay division was 26, 321 and 497, 007 throughout the whole Myanmar.
Taxonomic description of *A. procera* was given by Brandis (1874), Kurz (1877), Hooker (1879), Backer (1963), Aung Kyaw (1976) and Tin Tin Htay (1976). Khin Than Htwe (1991) studied the anatomy and morphology of *Albizzia* species in Myanmar including *A. procera* and *A. lebbekoides.*

Wood anatomy of the genus *Albizzia* was mentioned by Metcalfe and Chalk (1950). General characteristics of wood of *A. procera* was noted by Kurz (1877), Talbot (1909), Gamble (1922), Pearson and Brown (1932) and Khin Than Htwe (1991).

Gamble (1991) stated that the wood was used for sugar cane crushers, rice pounders, wheels, agricultural implements, bridges, house posts and occasionally for tea box and charcoal. Kurz (1877) stated that the wood was good for house building and cabinet work. The timber took a beautiful polish and it was not being heavy, and would make a good furniture wood (Khin Than Htwe, 1991). The wood was also an excellent fuel (Gamble, 1922). The calorific value was experimented by Leather as 86.9 % compared to pure carbon 100.

*Cassia siamea* was native to South East Asia from Indonesia to Srilanka. It was been widely distributed in West Indies, Central America, Florida, East and West of Southern Africa, Western Peninsula, Ceylon, Peninsula, Siam and Malay isles (Hooker 1879; Anon, 1980).

As the record of Forest Inventory (1983-84), the total number of *C. siamea* trees (over 2 feet in girth) found in reserve forest of Mandalay division was 14,166 and 61, 604 throughout the whole Myanmar. Rodger (1951) stated it was grown in the forests of upper and lower Myanmar and commonly planted in Shan State.

Taxonomic characteristics of *C. siamea* was observed by Kurz (1877), Hooker (1879), Backer (1963), Khin Maung Tin (1974), Aung Kyaw (1976), Than Than Aye (1976), Aung Moe (1977), Hnin Hnin Mya (1977) and Myint (1977).

Wood anatomy of *Cassia* was mentioned by Metcalfe and Chalk (1950). The general characteristics of wood of *C. siamea* was noted by Kurz (1877) and Gamble (1922).

*Cassia siamea* was handsome and shady trees for road sides and in garden (Gamble, 1922). But its seeds and pods were toxic to pigs, Anon, (1980). Kurz (1877) said that the wood was used as halves, walking sticks and mallets in Myanmar. Gamble (1922) stated that it was required to be better known and more used in furniture, inlaying etc. In Ceylon it was chief fuel (Gamble, 1922) which had high calorific value and density (Anon, 1980).

*Leucaena leucocephala* was originated in midlands of Southern Mexico and introduced to the Pacific Islands, the Philippines, Indonesia, Papua New Guinea, Malaysia, East and West Africa and India (Brandis, 1874; Hooker 1879; Anon, 1980). As recorded in the Forest Inventory (1983-84), the total number of *L. leucocephala* trees (over 2 feet in girth) found in reserve forests Mandalay division was 882 and 8792 throughout the whole Myanmar.


Wood anatomy of *Leucaena* was mentioned by Metcalfe and Chalk (1950). General characteristics of wood of *L. leucocephala* was mentioned by Gamble (1922).

The wood was excellent fuel, and the charcoal with high calorific value for a fast growing tree. Potential use of *leucaena* leaf as manure for rice cultivation under South Indian condition was studied by Purushothaman, Jayaraman and Sudhakar (1988).

Ko Ko Gyi (1984) studied the spacing trial for cultivation of *leucaena* in correlation with fuelwood production.

Backer (1963) described that the native of *Samanea saman* was tropical America.
The data from Forest Inventory (1983-84) showed that the number trees (over 2 feet in girth) growing throughout the whole Myanmar was 2616. Morphological characteristics of *S. saman* were mentioned by Backer (1963), Khin Maung Tin (1974), Aung Moe (1977), Hnin Hnin Mya (1977).

Wood anatomy of *Samanea* was mentioned by Metcalfe and Chalk (1950). Rodger (1951) stated that the wood colour of *S. Saman* was brown.

Kurz (1877), Hooker (1879), Gamble (1922), Pearson and Brown (1932), and Rodger (1951) stated that *Tectona hamiltoniana* was distributed on rocky hills in the Dry Zone, up to 2000 feet, from Yamethin to Mandalay, around Pyay and dryer forests of upper Myanmar.

As mentioned in the record of Forest Inventory (1983-84), total number of *T. hamiltoniana* trees (over 2 feet in girth) grew in reserve forest of Mandalay division was estimated to be 1,013,219 and 10,108,863 throughout the whole Myanmar.

Kurz (1877), Hooker (1879), Aung Kyaw (1976), Myint (1977), Hnin Hnin Mya (1977), Tin Tin Nwe (1977) and Ah-Mar Sein (1991) enumerated the morphology of *T. hamiltoniana*.

The anatomy of wood of *Tectona* was described by Metcalfe and Chalk (1950). General characteristics of wood were noted by Kurz (1877), Gamble (1922), and Pearson and Brown (1932).

The wood was used for cart shafts, yokes and as fuel (Rodger, 1951). Rodger (1951) remarked that this was an interesting timber which deserved further investigation because of their provided supplies were reasonably large.

According to Forest Inventory record (1983-84), the total number of *Terminalia oliveri* trees (over 2 feet in girth) was 1,059,557 in reserve forest of Mandalay division and 6,723,963 throughout the whole Myanmar. Gamble (1922) noted that it was localized in dry regions of Ayeyawaddy valley, the lower part of the Chindwin and near the head water of Sittaung.

Taxonomic studies of *T. oliveri* were made by Myint (1977) and Hnin Hnin Mya (1977).

Anatomy of wood of the genus *Terminalia* was described by Metcalfe and Chalk (1950). The general characteristics were mentioned by Gamble (1922), and Pearson and Brown (1932).

Rodger (1951) stated that the wood was used for shaft, harrow teeth, and it was also good fuel. Robertson wrote that it was sometime used as house posts.

The outturn estimation among the firewood production of *Acacia catechu* (Sha), *Cassia siamea* (Mezali), *Eucalyptus camaldensis* and *Leucaena leucocephala* (Bawzagaling) was studied by Soe Tint (1984). From this study, he concluded that Bawzagaling standed first, Mezali second and Sha third. He also mentioned to make further studies of other dry zone fuelwood species such as Kokko, Htanaung, Dahat, Than, Tama and Subyu.

Ko Ko Gyi (1984) studied the spacing trial of *Leucaena* in correlation with fuelwood production. Species selection trial for fuelwood production was conducted by Ko Ko Gyi (1985) in dry zone area and vicinity of Yangon using 14 fuelwood species. They were *Acacia senegal* (1) Willd., *A. arabica* Willd., *A. catechu* Willd, *Albizia lebbeckoides* Benth., *Cassia siamea* Lam., *Dalbergia sissoo* Roxb., *Eucalyptus camaldulensis* Dehn., *Albizia procera* Benth., *Achinensis* (osbeck) Merr., *A. falcataria* (1) Fosberg., *Swietenia macrophylla* King.and *Leucaena leucocephala* (Lam.) de Wit. From this experiment, he concluded that grazing is one of the serious problems considered in the selection of fuelwood species especially in the dry zone environment.
3. Materials and Methods

The specimens of ten fuelwood species taken in this research were collected from Mandalay division, especially Mandalay and Patheingyi Township area during the flowering and fruiting periods of 1993, which occurred from April to December.

For morphological studies, both fresh and preserved specimens of the vegetative and reproductive parts were used.

For anatomical studies on wood, a portion of the stem with bark in tack, having a dimension of 8" x 6" x 1" was taken. The wood sample includes the bark, the sapwood and a portion of the heartwood.

For selection of representative samples the heartwood only was used for microscopic investigations.

In this work, the microscopic sections of the wood samples were prepared according to the methods as given by Jeffery (1917) with slight modification. The sectionings of wood samples were done using a sliding microtome.

Maceration of wood were prepared by heating them in equal volume of 30 % hydrogen peroxide and glacial acetic acid according to Franklian's method (1946).

The specimens were authenticated at the Department of Botany, University of Mandalay and at the wood anatomy research section, Forest Research Institute, Yezin. The photomicrographs were taken by using the Olympus Universal research Microscope, Vanox model.

For microscopic descriptions, the terminology used in this work was as given by Chattaway (1932), and Wheeler, Bass and Gassan (1989).

4. Observation

Morphology

Most of the species studied in this research are deciduous, but evergreen in Cassia siamea and Leucaena leucocephala, and unarmed trees with distinct umbelliform crown, but, Acacia arabica, Acacia sundra and Acacia leucophloea have long paired spines. The spines are straight except in Acacia sundra which are hooked. The stems of Acacia sundra, Albizia procera and Leucaena leucocephala are erect and the umbelliform crown are not distinct. All of the ten species usually reach a height of 8-25 meters.

The leaves of A. arabica, A. leucophloea, A. sundra, Albizia lebbekoides, A. procera, L. leucocephala and Samanea saman are bipinnately compound, pinnate, alternate, stipulate and petiolate. The racheae or primary racheae are usually angular but subterete in L. leucocephala and canaliculated at the adaxial sides. The lengths of racheae range from 2.2 to 16.5 cm. They are sparsely pubescent to tomentose. A gland is usually found at the apex of racheae of near the last pair of base of rachillae adaxially.

The rachillae or secondary racheae are usually angular and shallowly canaliculated at the adaxial sides. They vary from 2 to 8 pairs in A. arabica, 4 to 12 pairs in A. leucophloea, 8 to 20 pairs in A. sundra, 3 to 7 pairs in A. lebbekoides, 3 to 5 pairs in A. procera, 3 to 8 pairs in L. leucocephala and 2 to 6 pairs in S. saman. They are tomentose in A. leucophloea A. lebbekoides and S. saman, thinly pubescent in Acacia sundra, and puberulous in A. procera and A. leucocephala.

The leaflet pairs are opposite or may be nearly opposite, reticulate. They are linear-oblong, slightly falcate in sharp in A. arabica, A. leucophloea, A. sundra, A. lebbekoides and L. leucocephala, oval-oblong to ovate in A. procera, and oval-oblong to oblond-ovate in S. saman.
The petiolules are sessile in most species, but those of a *A. arabica* and *L. leucocephala* are subsessile and those of *A. procera* and *S. saman* are more than 1 mm long and pubescent.

The number of leaflet pairs varies from 4 to 26 in *A. arabica*, to 21 in *A. leucophloea*, 15 to 38 in *A. sundra*, 16 to 32 in *A. lebbekoides*, 5 to 11 in *A. procera*, 5 to 15 in *L. leucocephala*, and 2 to 10 in *S. saman*.

The tips of leaflets are acute in *A. leucophloea*, *A. lebbekoides* and *L. leucocephala*, rounded in *A. arabica*, *A. sundra* and *A. procera*, and obtuse in *S. saman*. The bases of the leaflets are obliquely rounded, but obliquely obtuse in *A. procera* and obliquely acute in *S. saman*. The margins are entire and ciliate and hairs are denser in *S. saman*.

The petioles are pulvinate, subterete and tomentose, but angular in *A. leucophloea*, *A. procera* and *S. saman*, sparsely pubescent in *A. sundra* and *A. procera*. A cupular gland is found near the apex of petioles adaxially, but it occurs at the middle of the petiole in *A. procera*. The length of petioles vary from 0.8 to 0.3 cm in *A. arabica*, 0.3 to 2.1 cm in *A. leucophloea*, 1.0 to 1.5 cm in *A. sundra*, 1.5 to 4.0 cm in *A. lebbekoides*, 4.2 to 10.5 cm in *A. procera*, 2.1 to 5.1 cm in *L. leucocephala*, and 3.1 to 10.5 cm in *S. saman*.

The leaves of *C. siamea* are unipinnately compound, paripinate, alternate, stipulate, and petiolate. The recheae are angular, shallowly canaliculated at adaxially and 6 to 23 cm long. Their leaflets are oval-oblong to oblong-elliptic and have a length of 2 to 6 cm. The bases of leaflets are rounded, the margin entire and the tips retuse. The petiolules are finely pubescent 1.5 to 5.0 mm long. The petioles are subterete, pulvinate and have a length of 1.5 to 7.0 cm.

The leaves of *Tectona hamiltoniana* and *Terminalia oliveri* are simple, opposite, exstipulate, and petiolate, but subopposite leaves are found in *T. oliveri*. The laminae of *T. hamiltoniana* are ovate to rhombic-ovate, panninerved, with 5 to 9 lateral veins, densely and stellately hairy and being 5.2 to 10.5 cm in length and 2.2 to 7.5 cm width. The laminae of *T. oliveri* are elliptic-oblong to ovate, panninerved, with 5 to 9 lateral veins, glabrous, and being 3.5 to 8.5 cm in length and 2.2 to 5.5 cm in width.

The leaftips are acute to acuminate and the margins are entire in *T. hamiltoniana* and acute in *T. oliveri*, but slightly lobed and densely hairy in *T. hamiltoniana*. The leafbases are cuneate to rounded in *T. hamiltoniana* and obtuse to rounded in *T. oliveri*. The petioles are terete and pubescent but slightly flattened and densely hairy in *T. hamiltoniana*.

The stipules are paired and found in various shapes, except *T. hamiltoniana* and *T. oliveri* which are exstipulate. The stipules of three of *Acacia* are modified into spines. The stipules are subulate in *A. lebbekoides* and *L. leucocephala*, filiform in *A. procera* and *C. siamea*, and lanceolate in *S. saman*.

In all of the species studied in this research, the inflorescences may be terminal or axillary. Inflorescences of *A. arabica*, *A. leucophloea*, *A. procera*, *L. leucocephala*, and *S. saman* are heads. Those of *A. sundra* are axillary spikes. The inflorescences are terminal axillary paniculate corymb in *C. siamea*, terminal and axillary paniculate dichasial cymes in *T. hamiltoniana*, and terminal and axillary dense paniculate spikes in *T. oliveri*.

The heads are usually fasciculated. They are borne directly from leaf-axils or from the primary or secondary peduncles. The axillary fascicles of heads are found in *A. arabica*, *L. leucocephala* and *S. saman*. The heads are combined into terminal simple panicle in *A. leucophloea*. The terminal and axillary paniculate fascicles of heads are also found in *A. lebbekoides* and *A. procera*. The number of heads in each fascicle are 1 to 8 in *A. arabica*, 2 to 5 in *A. lebbekoides*, 2 to 3 in *A. procera*, and 1 to 4 in *L. leucocephala* and *S. saman*. The heads are 30 to 40 flowered in *Acacia arabica*, 60 to 80 flowered in *A. leucophloea*, 15 to 20 flowered in *A. lebbekoides*, 20 to 28 flowered in *A. procera*, 150 to 180 flowered in *L. leucocephala*, and 20 to 25 flowered in *S. saman*. The heads may be more
or less globose in shape. The diameter of the heads are ranged from 1 to 2 cm in A. arabica, 0.8 to 1.1 cm in A. leucophloea, 3 to 4 cm in A. lebbekoides, 3.3 to 4.5 cm in A. procera, 1.5 to 3.2 cm in L. leucocephala, and 8 to 12 cm in S. saman.

The bracts are involucrate and situated at the middle portion of the stalks in A. arabica, A. leucophloea and L. leucocephala. But they are oblong in A. lebbekoides and A. procera, linear-spathulate in S. saman, linear-lanceolate in C. siamea and Terminalia oliveri, and linear in T. hamiltoniana.

The flowers are ebracteolate, but bracteolate in T. hamiltoniana, bisexual, actinomorphic, regular, but zygomorphic and irregular in C. siamea, complete, hypogynous, put apetalous and epigynous in T. oliveri. The flowers are pedicellate in C. siama, S. saman and T. hamiltoniana, and sessile in the rest of seven species. They are whitish yellow in A. arabica, greyish white in A. leucophloea, white in A. sundra, A. lebbekoides, A. procera, L. leucocephala and T. oliveri, pink in S. saman, yellow in C. siamea, and pale purple in T. hamiltoniana.

The bracteoles are absent in all of the species except T. hamiltoniana which has 2 minutes bracteoles beneath the calyx.

The calyces are synsepalous. They are rotate-shaped with 5 partites in C. siamea, tubular-campanulate in A. procera and S. saman, cupular in A. sundra and T. oliveri and campanulate in the rest of 5 species.

The calyces of almost all the species are caducous or subpersistent but the calyx of T. hamiltoniana is persistent and accrescently urceolate.

The corollas are synpetalous, but polypetalous in C. siamea, A. leucophloea, A. sundra, A. lebbekoides and A. procera, and rotate-funnel-shaped in T. hamiltoniana.

The gynoecium are monocarpellary, unilocular one row of ovules in the locule on the marginal placenta in A. arabica, A. leucophloea, A. sundra, A. lebbekoides, A. procera, C. siamea, L. leucocephala and S. saman, bicarpellary with basally axile placenation, tetrilocular, one ovule in each locule in T. hamiltoniana, and tri to hexacarpellary, unilocular, 1 to 2 pendulous ovules in A. oliveri.
The ovaries are superior, but inferior in *T. oliveri*. They are Oblongoid in *A. arabica*, *A. leucophloea*, *A. sundra*, *A. lebbekoides* and *A. procera*, linear-oblongoid in *L. leucocephala*, *C. siamea* and *S. saman*, narrow-oblongoid in *T. hamiltoniana*, and ellipsoid in *T. oliveri*.

The ovaries are shortly tomentose in *A. arbica*, *A. leucophloea*, *A. sundra*, glabrous in *A. sundra* and *T. oliveri*, pubescent in *A. lebbekoides*, *A. procera* and *S. saman*, woolly in *T. hamiltoniana*, and tomentose at the tip in *L. leucocephala*.

The styles are terminal and filiform in all of the species. The stigma are simple in *A. lebbekoides*, *A. procera*, *S. saman*, *C. siamea*, *T. oliveri*, slightly capitate in *A. arabica*, *A. leucophloea*, *A. sundra* and *L. leucocephala*, and bifid in *T. hamiltoniana*.

The gynophores are usually present except the ovaries of *T. hamiltoniana* and *T. oliveri*.

The fruits are legumes, dehiscent in *A. arabica*, *A. leucophloea*, *A. sundra*, *A. procera*, *C. siamea*, *L. leucocephala*, *S. saman*, but subdehiscent and lomentaceous in *A. arabica*, indehiscent, linear-oblongoid in *S. saman*, indehiscent drupaceous oblongoid in *T. hamiltoniana*, and indehiscent winged in *T. oliveri*.

The pods or fruits are 3-to 18-seeded in *A. arabica*, 3-to 15-seeded in *A. leucophloea*, 2- to 9-seeded in *A. sundra*, 3- to 11-seeded in *A. lebbekoides*, 6-to 13-seeded in *A. procera*, 12-to 24-seeded in *C. siamea*, 7- to 18-seeded in *S. saman*, 1- to 4-seeded in *T. hamiltoniana* and 1-to 2-seeded in *T. oliveri*.

The seeds are oblongoid in *A. leucophloea*, *S. saman*, obovoid in *A. arabica*, ovate in *A. sundra*, compressed ovoid in *A. lebbekoides* and *A. procera*, obovate in *C. siamea* and *L. leucocephala*, and ellipsoid in *T. hamiltoniana* and *T. oliveri*. They are reddish brown in *A. procera*, *L. leucocephala* and *S. Saman*, greenish brown in *A. sundra* and *A. lebbekoides*, dark brown in *A. arabica*, pale brown to brown in *A. leucophloea* and *C. siamea*, grey in *T. oliveri*, and whitish grey in *T. hamiltoniana*. The seed coats are smooth, hard and usually glabrous.
Anatomy

Key to the species

1. Wood fairly straight-grained, twisted or interlocked-grained; tyloses absent; rays uniseriate to multiseriate, homocellular... 2
   1. Wood straight-grained; tyloses present; rays predominantly uniseriate, heterocellular...
      2. Wood diffuse porous or semi-ring porous; fibers septate 3
      2. Wood diffuse porous; fibers nonseptate 4

2. Wood diffuse porous or semi-ring porous; fibers septate 3
2. Wood diffuse porous; fibers nonseptate 4

3. Wood medium or very coarsely textured; maximum vessel pores per sq. mm. less than 14; prismatic crystals present in parenchyma 5
3. Wood fine-textured; maximum vessel pores per sq. mm. more than 16; prismatic crystals absent in parenchyma 4

4. Wood straight-grained or interlocked-grained; paratracheal parenchyma vasicentric, aliform, and confluent connecting several pores forming tangential band.
4. Wood twisted-grained; paratracheal parenchyma vasicentric

5. Wood yellowish white to light brown, medium textured; pores scattered; intervessel pits not vestured 6
5. Wood light brown to dark brown, very coarse textured; pores arranged in oblique pattern, intervessel pits vestured 7

6. Wood fairly straight-grained, rays 1-4 cells wide (mostly 2-3), maximum height of multiseriate rays less than 799 um 7
6. Wood irregularly interlocked grained; rays 1-8 cells wide (mostly 3-5), maximum height of multiseriate rays more than 850 um.

7. Paratracheal parenchyma vasicentric, aliform and aliform confluent connecting 2 to 12 pores forming tangential bands; maximum pores diameter less than 45 µm. 8
7. Paratracheal parenchyma confluent connecting several pores forming long wavy tangential bands; maximum pores diameter more than 55 µm. 8

8. Wood moderately light or moderately heavy, yellowish white, dark brown to light brown, growth ring distinct 9
8. Wood heavy to very heavy, yellowish white to light red or dark red or growth ring not distinct 9

9. Rays 1-4 cells wide (mostly 3-4), elliptical, paratracheal parenchyma confluent connecting 2-7 pores forming 12-27 seriate tangential bands
9. Rays 1-3 cells wide (mostly 2), rounded, paratracheal parenchyma confluent connecting 2-4 pores forming 8-16 seriate tangential bands

Terminalia oliveri
Tectona hamiltonniana
Acacia arabica
Leucaena leucocephala
Albizia lebbekoides
Acacia leucophloea
Cassia siamea
Acacia sundra
Albizia procera
Samanea saman
Acacia arbica (Lam.) Willd.

General Characteristics and Properties of the Wood

Sapwood yellowish white, heartwood pinkish brown with blackish streaks; odor and taste not distinct; heavy; hard; coarse-textured; somewhat twisted-grained; diffuse porous; growth ring not distinct.

Microscopic Characteristics

Vessel elements: Diffuse porous; pores moderately small to moderately large; mean tangential diameter 125 m (range 51–215 m); number per sq. mm. few to moderately numerous (range 5–16); average solitary pore 58% (range 18–80 %), pores solitary arranged in oblique pattern or as radial pore multiples of 2–4 and sometimes as pore clusters; circular or oval in cross section; thin-walled; lumen with abundant orange-red gum deposits, tylose absent, perforation plate simple, end walls of elements oblique or transverse; intervacular pitting alternate, crowded, rounded or oval, vestured, chambers with mean diameter 7 m (range 5–9 m.); vessel elements extremely short to medium-sized, mean length 210 m (range 92–369 m.)

Fibers: Libriform, moderately short to medium-sized, mean length 1146 m (range 707–1394 m), F/V ratio 5.8 (range 3–12); fine to medium fine with mean tangential diameter 16.5 m (range 10–22.5 m); nonseptate, thin–to thick-walled, 2.5–7.5 m thick; interfibre pits minute, simple slit-like; crystals absent.

Rays: Homocellular, 1–6 cells wide, mostly triseriate and tetraseriate; 3–9 per mm tangentially, few to numerous, uniseriate rays extremely fine to very fine, mean width 11 m (range 5–20 m), mean height 87 m (range 30–153 m), 2–14 cells high; multiserate rays very fine to medium-sized, mean width 47 m (range 20–71 m), mean height 270 m (range 102–549 m.), 8–49 cells high; ray vessel pitting similar to intervacular pitting alternate, rounded or oval in shape, 2–4 m in diameter; gum deposits in rays cells; crystals absent.

Axial parenchyma: Moderately abundant, paratracheal vasicentric, sometimes radially extended; apotracheal parenchyma relatively abundant, scattered or diffuse in aggregate of 4–12 cells; prismatic crystals abundant, frequently in 2 to 12 chambed axial parenchyma; reddish brown gum deposits present.
**Acacia leucophloea** (Roxb.) Willd.

**General Characteristics and Properties of Wood**

Sapwood pale yellowish white, heart wood reddish brown; with darker streaks; odor and taste not distinct; moderately heavy; moderately hard; irregularly interlocked-grained; medium textured; diffuse porous; growth rings not distinct.

**Microscopic Characteristics**

Vessel elements: Diffuse porous; pores very small to moderately large, mean tangential diameter 136 μm (range 41-205 μm), numbers per sq. mm. very few to moderately numerous (range 2-14); average solitary pores 49% (range 30-80); pores solitary arranged in oblique pattern or as radial pore multiples of 2-5 and sometimes as pore clusters; circular or oval, in cross-section; thin-walled; lumen with abundant reddish-brown gum deposits, tyloses absent; perforation plate simple, end walls of elements oblique or transverse; intervascular pitting alternate, crowded, rounded or oval non-vestured, chambers with mean diameters 5 μm (range 4-6 μm); vessel elements extremely short to medium-sized, mean length 245 μm (range 82-369 μm).

Fibers: Libriform, medium-sized, mean length 1268 μm (range 994-1558 μm), F/V ratio 5.5 (range 3.2-8.8), fine to medium fine with mean tangential diameter 17 μm (range 7.5 - 22.5 μm); non-septate; thin-to thick-walled, 2.5-7.5 μm thick; interfibre pits minute, simple, slit-like; crystal absents.

Rays: Homocellular, 1-8 cells wide, mostly triseriate and tetraseriate, 4-12 per mm tangentially, few to very numerous; uniseriate ray extremely fine to very fine, mean width 12 μm (range 10-15 μm), mean height 363 μm (range 82-1463 μm), 5-105 cells high; ray vessel pitting similar to intervacular pitting, alternate, rounded to oval in shape 5-7.5 μm in diameter, gum deposits in ray cells.

Axial parenchyma: Abundant, typically paratracheal, vasicentric of confluent connecting 2 to 12 pores forming 4 to 18 seriate obliquely or tangential-board bands, occasionally as aliform; prismatic crystals abundant frequently in 3 to 16 chambered axial parenchyma.
Fig. 2. *Acacia leuacophloea*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).
Acacia sundra  D.C

General Characteristics and Properties of Wood

Sapwood yellowish white, heartwood light red to dark red; odor and taste not distinct; very heavy; hard; straight-grained; medium-textured; diffuse porous wood; growth rings not distinct.

Microscopic Characteristics

Vessel element: Diffuse porous; pores very small to medium-sized mean tangential diameter 123 μm (range 41-185 μm), number per sq. mm. few to moderately numerous (range 5-20); average solitary pores 40% (range 30-77), pores solitary or as radial pore multiples of 2-5 and occasionally as pore clusters; circular or oval in cross section, thin-walled; lumen with abundant reddish-brown gum deposits, tyloses absent; perforation plates simple, and walls of element oblique or transverse; intervessel pitting alternate, crowded, oval to elliptical, chambers with mean diameter 6 μm (range 4-8 μm); vessel extremely short to moderately short, mean length 230 μm (range 82-307 μm).

Fibers; Libriform, very short to medium sized, mean length 838 μm (range 676-1035 μm), F/V ratio 5 (range 2.3-9.6) extremely fine to medium fine with mean tangential diameter 13 μm (range 10-20 μm); nonseptate, thin-walled, 2.5-5 μm thick, interfiber pits minute, simple, slit-like; crystals absent.

Rays: Homocellular, uniseriate to tetraseriate, mostly triseriate to tetraseriate, 5-20 per mm, tangentially; moderately numerous to very numerous; uniseriate rays extremely fine, mean width 9 μm (range 5-10 μm), mean height 74 μm (range 25-133 μm), 1-9 cells high; multisieriate rays extremely fine medium-sized, mean width 32 μm (range 15-61 μm), mean height 222 μm (range 71-492 μm), 5-44 cells high; ray vessel pitting similar to intervessel pitting alternate, oval or elliptical in shape, (3-10 μm) in diameter, gum deposits in ray cells; crystal absent.

Axial parenchyma: Moderately abundant, typically paratracheal, usually aliform and aliform or confluent connecting 2-5 pores forming 4 to 10 (mostly 6) seriate tangential bands, large prismatic crystals frequently in 2 to 12 chambered axial parenchyma.
Fig. 3. *Acacia xundra*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).
Albizia lebbekoides (DC) Benth.

General Characteristics and Properties of the Wood

Sapwood light brown, heartwood darker brown; odor and taste not distinct; moderately hard; moderately heavy; fairly straight-grained; very coarse-textured; diffuse porous; growth rings not distinct.

Microscopic Characteristics

Vessel element: Diffuse porous; pores moderately small to moderately large, mean tangential diameter 173 μm (range 51-287 μm), number per sq. mm very few to moderately numerous (range 1-8); average solitary pores 71 % (range 20- 80), pores solitary arranged in oblique pattern or as radial pore multiples of 2-5 and sometimes as pores clusters; circular or oval in cross section; thin-walled; lumen with gum deposits, tylose absent; perforation plates simple, end walls of elements oblique transverse; intervessel pitting alternate, crowded, oval, vestured, chambers with mean diameter 8 μm (range 5010 μm); vessel element extremely short to medium-sized, mean length 273 μm (range 164-451 μm).

Fibres: Libriform, very short to medium sized, mean length 1100 μm (range 645-1353 μm), F/V ratio 4.3 (range 1.4-6.7), fine to medium fine with mean tangential diameter 19 μm (range 15-22.5 μm); septate, thin-walled, 2.5-5 μm thick; interfibre pits minute, simple, slit-like.

Rays: Homocellular, uniseriate to pentaseriate, mostly tetraseriate, 4–12 per mm, tangentially, few to very numerous; uniseriate rays extremely fine mean width 11 μm (range 10-15 μm); men height 83 μm (range 31-154 μm), 3-12 cells high; multiseriate rays extremely fine to moderately fine mean width 27 μm (range 15-41 μm), mean height 236 μm (range 92-461 μm), 5-36 cells high; ray vessel pitting similar to intervessel pitting alternate, rounded or oval in shape, 3-7.5 μm in diameter; gum deposits in ray cells.

Axial parenchyma: Abundant, typically paratracheal vasicentric, aliform or confluent forming 8- to 17- (mostly 12-) seriate obliquely tangential bands; prismatic crystals solitary or frequently in 2- to 12-chambered axial parenchyma.
Fig. 4. *A. lebbeckoides*. A. Plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).
Albizia procera (Roxb.) Benth.

General Characteristics and Properties of the Wood

Sapwood light brown, heartwood dark brown with light coloured bands; odor and taste not distinct; moderately heavy; hard; fairly straight-grained; medium-textured; diffuse porous; growth rings distinct.

Microscopic Characteristics

Vessel elements: Diffuse porous; pores very small to medium-sized, mean tangential diameter 111 \( \mu \text{m} \) (range 41–174 \( \mu \text{m} \)); number of pores per sq. mm. very few to moderately numerous (range 2–12), average solitary pores 50% (range 12–65); pores solitary or as radial pore multiples of 2–5 and sometimes as pore clusters; circular or oval in cross section; thin-walled; lumen with gum deposits, tylose absent; perforation plate simple; end walls of elements oblique or transverse; intervacular pitting alternate, crowded, oval elliptical, vestured, chambers with mean diameter 6 \( \mu \text{m} \) (range 5–8 \( \mu \text{m} \)); vessel elements extremely short to medium-sized, mean length 265 \( \mu \text{m} \) (range 112–410 \( \mu \text{m} \)).

Fibres: Non-libriform, very short to medium sized, mean length 815 \( \mu \text{m} \) (range 530–1107 \( \mu \text{m} \)); F/V ratio 3.5 (range 2.1–5.6), medium fine with mean tangential diameter \( \mu \text{m} \) (range 5–32 \( \mu \text{m} \)); nonseptate; thin-to thick walled 2-6 \( \mu \text{m} \) thick; interfibre pits minute, bordered rounded, gum deposits present; crystals absent.

Rays: Homocellular, uniseriate to tetraseriate, mostly triseriate and tetraseriate; 8-14 per mm. tangentially, numerous to very numerous; uniseriate rays extremely fine to very fine, mean width 10 \( \mu \text{m} \) (range 5–15 \( \mu \text{m} \)), mean height 93 \( \mu \text{m} \) (range 30–184 \( \mu \text{m} \)), 3-14 cells high; multiseriate rays extremely fine to medium-sized, mean width 39 \( \mu \text{m} \) (range 15–71 \( \mu \text{m} \)), mean height 249 \( \mu \text{m} \) (range 112–512 \( \mu \text{m} \)), 5-43 cells high; ray cells elliptical in shape, ray vessel pitting similar to intervacular pitting, alternate rounded, oval in shape, (2.5–7.5) in diameter; gum deposits in ray cells; crystal absent.

Axial parenchyma: moderately abundant, typically vasicentric paratracheal, usually aliform or confluent connecting 2-7 pores forming 12- to 24 (mostly 16-) seriate tangential bands, prismatic crystal frequently in 2 to 25 chambered axial parenchyma.

Cassia siamea Lamm.

General Characteristics and Properties of the Wood

Sapwood white, heartwood dark grey, with stripes of dark and light; odor and taste not distinct, moderately heavy; moderately hard; fairly straight-grained; medium-textured; diffuse porous; growth rings not distinct.

Microscopic Characteristics

Vessel element: Diffuse porous; pores moderately small to medium-sized mean tangential diameter 145 \( \mu \text{m} \) (range 92–190 \( \mu \text{m} \)); number per sq. mm. very few to numerous (range 2–8), average solitary pores 50% (range 16–75), pores solitary or as pore multiples of 2–5 and occasionally as pore clusters; circular or oval in cross section; thin-walled; lumen with abundant yellowish gum deposits, tyloses absent; perforation plates simple, end walls of elements oblique or transverse; intervacular pitting, alternate, crowded, oval chambers with mean diameter 6 \( \mu \text{m} \) (range 5–9 \( \mu \text{m} \)); vessel elements very short to moderately short, mean length 218 \( \mu \text{m} \) (range 153–307 \( \mu \text{m} \)).

Fibres: Libriform, extremely short to medium-sized, mean length 900 \( \mu \text{m} \) (range 538–116 \( \mu \text{m} \)); F/V ratio 4.5 (range 3.4–6.6), fine to medium fine with mean tangential diameter
12.5 μm (range 8-25 μm); nonseptate, thin-to thick-walled, 2.5-6 μm thick; interfibres pits minute, simple, slit-like; crystals absent.

Rays: Homocellulars, uniseriate to triseriate, mostly biseriate; 7-15 per mm. tangentially, moderately numerous to very numerous; uniseriate rays extremely fine, mean width 9 μm (range 5-12 μm), mean height 70 μm (range 30-143 μm), 2-11 cells high; multiseriate rays extremely fine to moderately fine, means width 24 μm (range 10-41 μm), mean height 153 μm (range 41-197 μm), 4-19 cells high; ray vessel pitting similar to intervacular pitting, alternate, oval or elliptic in shape, 5-9 μm in diameter; gum deposits in ray cells; crystal absent.

Axial parenchyma; Abundant, paratracheal, confluent connecting several pores forming long wavy tangential bands (6- to 17 seriate); prismatic crystals abundant, solitary and frequently in 2- to 25-chambered axial parenchyma.
Fig. 5. *Albizia procera*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).
**Cassia siamea** Lamm.

**General Characteristics and Properties of the Wood**

Sapwood white, heartwood dark grey, with stripes of dark and light; odor and taste not distinct, moderately heavy; moderately hard; fairly straight-grained; medium textured diffuse porous; growth rings not distinct.

**Microscopic Characteristics**

Vessel elements: Diffuse porous; pores moderately small to medium-sized, mean tangential diameter 145 µm (range 92-190 µm); number per sq. mm. very few to numerous (range 2-8), average solitary pores 50% (range 16-75), pores solitary or as radial pore multiples of 2-5 and occasionally as pore clusters; circular or oval in cross section; thin-walled lumen with abundant yellowish gum deposits, tyloses absent; perforation plates simple, end walls of elements oblique or transverse; intervessel pitting, alternate, crowded, oval, chambers with mean diameter 6 µm (range 5-9 µm); vessel elements very short to moderately short, mean length 218 µm (range 153-307 µm)

Fibres: Libriform, extremely short to medium-sized, mean length 900 µm (range 538-1168 µm); F/V ratio 4.5 (range 3.4–6.6), fine to medium fine with mean tangential diameter 12.5 µm (range 8-25 µm); nonseptate; thin-to thick-walled, 2.5 - 6 µm thick; interfibre pits minute simple, slit-like; crystals absent.

Rays: Homocellular, uniseriate to triseriate, mostly biseriate; 7-15 per mm. tangentially moderately numerous to very numerous; uniseriate rays extremely fine, mean width 9 µm (range 5-12 µm), mean height 70 µm (range 30-143 µm), 2-11 cells high multiseriate rays extremely fine to moderately fine, means width 24 µm (range 10-41 µm), mean height 153 µm (range 41-197 µm), 4-19 cells high; ray vessel pitting similar to intervessel pitting, alternate, oval or elliptic in shape, 5-9 µm in diameter; gum deposits in ray cells; crystal absent.

Axial parenchyma: Abundant, paratracheal, confluent connecting several pores forming long wavy tangential bands (6-17 seriate); prismatic crystals abundant, solitary and frequently in 2- to 25- chambered axial parenchyma.
Fig. 6. *Cassia siamica*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).
Leucaena leucocephala (lam.) de Wit.

General Characteristics and Properties of the Wood

Sapwood yellowish white, heartwood light brown; odor and taste not distinct; moderately heavy; hard; fairly straight-grained; medium-textured; diffuse porous wood; growth rings not distinct.

Microscopic Characteristics

Vessel elements: Diffuse porous; pores very small to medium-sized; mean tangential diameter 10 μm (range 41–164 μm); number per sq. mm few to moderately numerous (range 3–14), average solitary pores 58% (range 14–72); pores solitary scattered or as radial pore multiples of 2–5 and sometimes as pore clusters; circular or oval in cross section; thin-walled; lumen with gum deposits; tylose absent; perforation plates simple, end walls of elements oblique or transverse; intervessel pitting alternate, crowded, oval or elliptic, non-vestured, chambers with mean diameter 8 μm (range 5–9 μm); vessel elements extremely short to medium sized, mean length 339 μm (range 133–574 μm).

Fibers: Libriform, moderately short to medium-sized, mean length 1177 μm (range 785–1506 μm), F/V ratio 4.2 (range 2.1–9.2), fine to medium fine with mean tangential diameter 19 μm (range 12.5–25.0 μm), septate thin-to thick-walled, 2.5–10 μm thick; interfibre pits minute, simple, slit-like; crystals absent.

Rays: Homocellular, uniseriate to tetraseriate, mostly triseriate, 4–13 per mm. tangentially, few to very numerous; uniseriate rays very fine to extremely fine, mean width 10 μm (range 5–20 μm), mean high 99 μm (range 41–205 μm), 2–17 cells high; multiseriate rays extremely fine to moderately fine, mean width 27 μm (range 15–41 μm) mean height 218 μm (range 128–328 μm), 5–42 cells high; ray vessel pitting similar to intervessel pitting, alternate, oval or elliptic in shape, 2.5–6.0 μm in diameter; gum deposits in ray cells; crystals absent.

Axial parenchyma: Abundant, typically paratracheal vasicentric, occasionally unilateral or aliform and confluent connecting 2–3 pores forming 6– to 12– uniseriate tangential or obliquely tangential bands; prismatic crystals abundant in 4– to 21– chambered axial parenchyma.
Fig. 7. *Leucaena leucocephala*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).
Samanea saman  (Jacq.) Merr.

General Characteristics and Properties of the Wood

   Sapwood yellowish white, heart wood light brown; odor and taste not distinct; moderately light; moderately hard; fairly straight-grained; medium-textured; diffuse porous; growth rings obscurely distinct.

Microscopic Characteristics

   Vessel elements: Diffuse porous; pores very small to medium-sized, mean tangential diameter 110 \( \mu \text{m} \) (46-164 \( \mu \text{m} \)); number per sq. mm. very few to moderately numerous (1-10); average solitary pores 58 \% (range 14-70), pore solitary arranged in tangential rows or oblique pattern or as radial pores multiples of 2-4 and sometimes as pore clusters; circular or oval in cross section; thin-walled; lumen with reddish gum-deposits, tylose absent; perforation plate simple; end walls of elements oblique or transverse; intervessel pitting alternate, crowded, rounded or oval, nonvestured, chambers with mean diameter 8 \( \mu \text{m} \) (range 5-14 \( \mu \text{m} \)); vessel elements extremely short to moderately short, mean length 186 \( \mu \text{m} \) (range 82-307 \( \mu \text{m} \)).

   Fibers: Libriform, very short to medium-sized, mean length 701 \( \mu \text{m} \) (range 512-922 \( \mu \text{m} \)), F/V ratio 4.4 (range 1.6-8.2), fine to medium fine with mean tangential diameter 18 \( \mu \text{m} \) (range 12.5-25 \( \mu \text{m} \)), nonseptate; thick-walled, 1.5 to 5.0 \( \mu \text{m} \) thick; interfibre pits minute, simple, slit-like; crystals absent.

   Rays: Homocellular, uniseriate to triseriate, mostly biseriate, 7-16 per mm. tangentially, moderately numerous to very numerous; uniseriate rays extremely fine, mean width 10 \( \mu \text{m} \) (range 5-10 \( \mu \text{m} \)), mean height 71 \( \mu \text{m} \) (range 25-179 \( \mu \text{m} \)), 2-9 cells high; multiseriate rays extremely fine to moderately fine, mean width 29 \( \mu \text{m} \) (range 15-41 \( \mu \text{m} \)), mean height 240 \( \mu \text{m} \) (range 61-799 \( \mu \text{m} \)), 5-59 cells high; ray cells rounded, ray vessel pitting similar to intervessel pitting, alternate, rounded or oval in shape, 5.0 - 7.5 \( \mu \text{m} \) in diameter; gum deposits in ray cells; crystals absent.

   Axial parenchyma: Moderately abundant, typically vasicentric usually aliform and confluent connecting 2-4 pores forming 8- to 16- (mostly 12-) seriate tangential or bands; prismatic crystals frequently in 6- to 16-chambered axial parenchyma.
Fig. 8. *Samanea saman*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).
**Tectona hamiltoniana** Wall.

**General Characteristics and Properties of the Wood**

Sapwood brownish white, with faintly striated lines; heartwood light brown; odor and taste not distinct; moderately heavy; hard; straight-grained; fine textured; semi-ring porous; growth ring distinct.

**Microscopic Characteristics**

Vessel element: Semi-ring porous; pores very small to medium-sized, mean tangential diameter 77 µm (range 35-143 µm); number per sq. mm. moderately numerous to very numerous (range 16-45), average solitary pores 42 % (range 16-75); pores solitary arranged in oblique pattern or as radial pores multiples of 2-4 and frequently as pore clusters; circular or oval in cross section; thin-walled; lumen without gum deposits, tylose absent; perforation plate simple; end walls of elements oblique or transverse; intervacular pitting alternate, crowded, rounded or oval, vestured, chambers with mean tangential diameter 4 µm (range 3.5-5.0 µm); vessel elements extremely short to moderately short, mean length 225 µm (range 87-328 µm).

Fibers: Libriform, moderately short to moderately long, mean length 1233 µm (range 717-1619 µm), F/V ratio 5.6 (range 3.3-9.1), fine to medium fine with mean tangential diameter 19 µm (range 12.5-25 µm), septate; thin-to-thick-walled, 2.5-7.5 µm thick; interfibre pits minute, simple, slit-like; crystals absent.

Rays: Homocellular, uniseriate to tetrameriate, mostly biseriate and triseriate, 9-18 per mm. tangentially, numerous to very numerous; uniseriate rays extremely fine, mean width 12 µm (range 5-15 µm), mean height 76 µm (range 30-153 µm), 2-7 cells high; multiseriate rays extremely fine to medium fine, mean width 29 µm (range 15-46 µm), mean height 286 µm (range 82-1178 µm), 4-34 cells high; ray vessel pitting similar to intervacular pitting, alternate, crowded, rounded or oval in shape, 2.5 to 5.0 µm in diameter; gum deposits absent in ray cells; crystals absent.

Axial parenchyma: Scanty paratracheal, frequently confluent to 3- to 6-seriate tangential bands; in the inception of growth rings; apotracheal occasionally diffuse or diffuse in aggregate; crystals absent; gummy infiltration present.
Fig. 9. *Tectona hamiltoniana*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).
Terminalia oliveri  Brandis.

**General Characteristics and Properties of the Wood**

Sapwood pale yellowish white, heartwood dark purple; odor and taste not distinct; heavy; very hard; fairly straight-grained; very fine textured; diffuse porous; growth ring not distinct.

**Microscopic Characteristics**

Vessel elements: Diffuse porous; pores very small to moderately small, mean tangential diameter 63 μm (range 31-82 μm); number per sq. m.m. very numerous (range 66-153), average solitary pores 13 % (range 6-23); pores solitary or as radial pores multiples of 2-16 and occasionally as pore clusters; circular or oval in cross section; thick-walled; lumen with gum-deposits, or tylose; perforation plates simple; end walls of elements oblique or transverse; intervacular pitting alternate, crowded, or oval to elliptic, vestured, chamber with mean diameter 3 μm (range 2.5-5 μm); vessels extremely short to medium sized, mean length 338 μm (range 174-533 μm).

Fibers: Libriform, extremely short to moderate sized mean length 1060 μm (range 641-1466 μm), F/V ratio 3.4 (range 1.3-5.7), fine to medium fine with mean tangential diameter 15 μm (range 10-25 μm), nonseptate, thin-to thick-walled, 4-9 μm thick; interfibre pits minute, simple, slit-like.

Rays: Heterocellular, uniseriate, 4-24 per mm tangentially very numerous; extremely fine to moderately fine, mean width 19 μm (range 10-31 μm), mean, height 571 μm (range 82-1609 μm), 2-53 cells high; ray vessel pitting similar to intervacular pitting, alternate, rounded or to oval in shape, 3-5 μm in diameter; gum deposits in ray cells; large solitary crystals absent in ray cells.

Axial parenchyma: Scanty paratracheal, mostly restricted to tangential side of vessel, forming 1 or 2 seriate apotracheal, diffuse or diffuse in aggregate, 2-6 cells prismatic crystals absent.
Fig. 10. *Terminalia oliveri*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82"). E. Tangential and longitudinal section of wood (X 82").
5. Discussion

All the fuelwood timber species studied in this research are well adapted in dry zone of adverse conditions, and also recognized as versatile trees. Eight species of them namely Acacia arabica (Lam). Willd., A.leucophloea (Roxb.) Willd., A.sundar DC., Albizzia lebbekoides DC. Berth., A.procera (Roxb). Berth., Cassia siamean Lam., leucaena leucaena leucophloea (Lam). de Wirt. and Samanea saman (Jacq.) Merr. were belonged to the family leguminosae and the rest two, Tectona hamiltoniana Wall. and Terminalia oliveria Brandis to Verbenaceae and Combretaceae respectively (Lawrance, 1969). In this discussion, comparison has been made between some of the morphological and anatomical characteristics of ten species in this work and those of the other workers.

Morphology

The number of leaflets in Acacia arabica is 4 to 26 pairs in this study, instead of 10 to 20 pairs of leaflets per rachilla observed by previous workers (Brandis, 1874; Hooker, 1879; Backer, 1963; Khin Maung Tin, 1974; Hnin Hnin Mya, 1977; and Myint, 1977). Khin Maung Tin (1974) described that the ovary was thinly hairy, however Hnin Hnin Mya (1977) mentioned that it was glabrous. In the present study, the ovaries are covered with thin hairs at the outside in the present observation. Almost of all the previous workers described that the number of seeds in each was never more than 12 seeds. In the present work, the pods are found to be lomentosaceous and each pod contains 3 to 18 seeds.

Backer (1963) and Myint (1977) described that triplinate leaves were occasionally found in A.leucophloea but those are not observed in this present study. According to Hooker (1879) and Myint (1977), the number of leaflets in each pinna in A.sundar was found to 15 to 40 pairs. In this research, the number of leaflets per rachilla is 15 to 38 pairs.

The ovary of A.lebbekoides is elevated by short gynophore in this research. This character is in agreement with the observation of Khin Than Htwe (1991). However, Backer (1963) described that the ovary of A.lebbekoides was sessile. Aung Kyaw (1976) described that in A.procera the head contained a large medium flower. But, all the flowers in the head of A.procera studied in this research are found to be equal in size and shape. Hooker (1879), Backer(1963), Khin Maung Tin (1974) and Aung Kyaw (1976) described that the leaflets of C.siamea were terminating with emerginate apices. However, in this work, the tips of leaflets are found to be more or less retuse as been described by Kurz, 1877. But, the emerginate apices are found while the leaves are very young.

Most of the previous workers did not describe the stipules of L.leucocephala. In this study, stipules are found to be subulate and pairwise. However, Khin Maung Tin (1974) and Hnin Hnin Mya (1977) mentioned that the shape of stipules was triangular. The anther of L.leucocephala was considered as versatile by Brandis (1874), and basifixed by Aung Kyaw (1976) and Aung Moe (1977). However, the dorsifixed anthers are found in this study. Khin Maung Tin (1974) described that the pedicels of S.saman flower were absent or being about 1 mm. in length. Backer (1963) Myint (1977) and Hnin Hnin Mya (1977) also described that the length of pedicels was 1 to 3 mm. In this study the pedicels attain a length of 1.5 to 3.5 mm, but central flowers are absolutely sessile.

Aung Kyaw (1976) described that the blade of T.hamiltoniana has 9 to 11 pairs of lateral veins. In the present work, 5- to 9- pairs of lateral veins are observed in the leaf of T.hamiltoniana. Myint (1977) mentioned that the flowers of T.hamiltoniana were ebracteolate, but Aung Kyaw (1976) and Aung Moe (1977) pointed out that the two
bracteoles were found under the calyx. The two bracteoles are also observed beneath the calyx in this research.

The axile placentation of the ovary of *T. hamiltoniana* was described by Myint 1977, but basally axile placentation is found in the present study.

Myint (1977) mentioned that the arrangement of the leaves of *T. oliveri* was alternate. The subopposite arrangement of the leaves is observed in this species in this research. Hnin Hnin Mya (1977) described that the flowers of *T. oliveri* bloomed in axillary, dense, paniculate spike, but inflorescences of *T. oliveri* studied in this research are found to be terminal and axillary, dense, paniculate spikes, similar to the observation of Myint (1977).

**Anatomy**

All the general characteristics such as the colour, density, grain and texture of the species studied are found to be differed from each other. The relative differences in general characteristics of ten fuelwood species are revealed as shown in table 1.

As observed in present study, the colour of wood of *Acacia arabica* is yellowish white to pinkish brown with blackish streaks. However, according to Pearson and Brown (1932) it was whitish to pinkish white to light red generally mottled with darker streaks. Gamble (1922) also stated that it was whitish to reddish brown mottled with dark streaks, and Brandis (1874) stated that it was whitish to dark reddish brown with blackish streaks.

The sapwood of *Acacia leucophloea* is found to be yellowish white and the heartwood reddish brown with darker streaks which agree with Brandis (1874), Gamble (1922), and Pearson and Brown (1932).

The wood colour of *Acacia sundra* in this study is yellowish white to light or dark red which generally in accordance with the description of Kurz (1877), Gamble (1922) and Pearson and Brown (1932).

The wood of *Albizia lebbekoides* is light brown to dark brown which agrees with Gamble (1922) and Khin Than Htwe (1991).
<table>
<thead>
<tr>
<th>Species observed</th>
<th>colour</th>
<th>Odour and taste</th>
<th>Density</th>
<th>Grain</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acacia arabica</em></td>
<td>yellowish white to pinkish brown with blackish streaks</td>
<td>not distinct</td>
<td>heavy</td>
<td>somewhat twisted grained</td>
<td>coarse-textured</td>
</tr>
<tr>
<td><em>Acacia leucophloea</em></td>
<td>pale yellowish white to pale brown with darker streaks</td>
<td>not distinct</td>
<td>moderately heavy</td>
<td>irregularly interlocked grained</td>
<td>coarse-textured</td>
</tr>
<tr>
<td><em>Acacia sundra</em></td>
<td>yellowish white to light red to dark red</td>
<td>not distinct</td>
<td>very heavy</td>
<td>straight grained</td>
<td>medium-textured</td>
</tr>
<tr>
<td><em>Albizzia lebbekoides</em></td>
<td>light brown to dark brown</td>
<td>not distinct</td>
<td>moderately heavy</td>
<td>fairly straight</td>
<td>very coarse-textured</td>
</tr>
<tr>
<td><em>Albizzia procera</em></td>
<td>light brown to dark brown</td>
<td>not distinct</td>
<td>moderately heavy</td>
<td>fairly straight-grained</td>
<td>medium-textured</td>
</tr>
<tr>
<td><em>Cassia siamea</em></td>
<td>white to dark grey with stripes of dark and light</td>
<td>not distinct</td>
<td>moderately heavy</td>
<td>fairly straight-grained</td>
<td>medium-textured</td>
</tr>
<tr>
<td><em>Leucaena leucocephala</em></td>
<td>yellowish white to dark brown</td>
<td>not distinct</td>
<td>moderately heavy</td>
<td>fairly straight-grained</td>
<td>medium-textured</td>
</tr>
<tr>
<td><em>Samanea saman</em></td>
<td>yellowish white to light brown</td>
<td>not distinct</td>
<td>moderately light</td>
<td>fairly straight-grained</td>
<td>medium-textured</td>
</tr>
<tr>
<td><em>Tectona hamiltoniana</em></td>
<td>brownish white with faintly straited lines to light brown</td>
<td>not distinct</td>
<td>moderately heavy</td>
<td>straight-grained</td>
<td>fine-textured</td>
</tr>
<tr>
<td><em>Terminalia oliveri</em></td>
<td>pale yellowish white to dark purple</td>
<td>not distinct</td>
<td>heavy</td>
<td>fairly straight-grained</td>
<td>very fine-textured</td>
</tr>
</tbody>
</table>
The wood colour of *Albizia procera* is found to be light coloured bands, in general which agrees with observation of Khin Than Htwe (1991). However, Gamble (1922) and Talbot (1909) mentioned that it was yellowish white to dark brown with lighter and darker alternate bands, while Kurz (1877) also described as white or brownish to brown or blackish brown.

In this study, the colour of wood of *Cassia siamea* is white to dark-grey with stripes of dark and light, in general which agrees with Kurz (1877), Gamble (1922) and Rodger (1951).

The wood of *Leucaena leucocephala* studied in this work is yellowish white to light brown. However, Gamble (1922) mentioned that it is white. The wood of *Samanea saman* is also yellowish white to brown in this study which agrees with Rodger (1951).

The wood of *Tectona hamiltoniana* is brownish white with faintly striated lines to light brown in general which agrees with Kurz (1877) and Gamble (1922). But Pearson and Brown (1932) stated that the wood was light to dark brown with considerable darker marking.

The wood colour of *Terminalia oliveri* is yellowish white to dark to dark purple in this study. It generally agree with Pearson and Brown (1932) and Gamble (1922).

It is observed that in all the ten species the colour and taste is not distinct for identification.

In the present study, it is found that variation in weight of wood is significant. The weight of wood of *Acacia leucophloea*, *Albizia lebbekiodes*, *Albizia procera*, *Cassia siamea, Leucaena leucocephala*, and *Tectona hamiltoniana* are moderately heavy as described by Pearson and Brown (1932), Rodger (1951) and Khin Than Htwe (1991). The weight of wood of *Acacia arabica* and *Terminalia oliveri* is heavy and *Acacia sundra* is very heavy as mentioned by Pearson and Brown (1932). The *Samanea saman* wood studied in the present work is moderately light which agrees with Rodger (1951).

At the present work, the grains of wood of the species studied are fairly straight-grained, irregularly interlocked to twisted-grained.

The wood of *Acacia arabica* is somewhat twisted-grained, *Acacia leucophloea* irregularly interlocked and *Acacia sundra* straight-grained, and those are similar to observation of Pearson and Brown (1932). However, Brandis (1874) stated that the wood of *Acacia arabica* was coarsed-grained and *Acacia leucophloea* was close and fine-grained. According to Kurz (1877), the wood of *Acacia sundra* was closed-grained.

In the present work, the woods of *Albizia lebbekiodes* and *Albizia procera* are fairly straight-grained, which agree with Khin Than Htwe (1991). However, Pearson and Brown (1932) mentioned about the wood of *Albizia procera* as shallowly interlocked-grained.

In this study, the woods of *Cassia siamea, Leucaena leucocephala* and *Samanea saman* are also fairly straight-grained. However, Kurz (1877) noted that the wood of *Cassia siamea* was very close-grained.

The wood of *Tectona hamiltoniana* and *Terminalia oliveri* are straight and fairly straight-grained, and those are in agreement with Pearson and Brown (1932). However, Kurz (1877) and Rodger (1951) stated that the wood of *Tectona hamiltoniana* was close-grained.

At the present study, the woods of *Acacia arabica* and *Acacia leucophloea* are coarse-textured which agree with Pearson and Brown (1932). The *Albizia lebbekioides* is very coarse textured similar to the observation of Khin Than Htwe (1991).

The woods of *Acacia sundra, Albizia procera, Cassia siamea, Leucaena leucocephala* and *Samanea saman* are medium-textured. However, Pearson and Brown (1932) stated that *Acacia sundra* wood was medium to coarse-textured. The wood of
**Albizia procera** was very coarse-textured (Pearson and Brown, 1932 and Khin Than Htwe, 1991).

In the present study, the woods of *Tectona hamiltoniana* and *Terminalia oliveri* are fine and very fine-textured which agree with Pearson and Brown (1932).

The anatomical characteristics for the wood studied in the present research are in agreement with the description of the species given by some workers. Secondary xylem characteristics observed for all the species are shown in table 2. Growth rings are not distinct in all the species studied except *Albizzia procera*, *Samanea saman* and *Tectona hamiltoniana*.

All the species studied in this work have diffuse porous wood, except *Tectona hamiltoniana* which is semi-ring porous. The vessels are solitary as well as radial multiples and in clusters which are in agreement Pearson and Brown (1932).

The pores of *Acacia arabica* are found to be moderately small to moderately large. But, according Gamble (1922), Pearson and Brown (1932) they are very large to medium-sized.

The pores of *A. leucophloea* are observed as very small to moderately large. But, Gamble (1922) mentioned that they were moderate-sized and according to Pearson and Brown (1932) the pores were large to medium or small.

The pores of *A. sundra* in this work are very small to medium-sized, but Pearson and Brown stated that they were large to medium or small.

In *Albizia lebbekoides*, the pores are moderately small to moderately large, but Gamble (1922) revealed that it had large pores, and Khin Than Htwe (1991) described that the pores were very large.

In *A. procera*, the pores are very small to medium-sized, but Gamble (1922) described that the pores were moderate-sized and large. The other workers stated that pores were large or medium-sized (Talbot, 1909), extremely large to large or medium-sized (Pearson and Brown, 1932) and moderately small to very large (Khin Than Htwe, 1991).

The pores of *Cassia siamea* in this work moderately small to medium-sized but according to Gamble (1922) they were moderate-sized and large.

The pores of *Tectona hamiltoniana* studied in this work are very small to medium-sized, but according to Gamble (1922), they were small. Pearson and Brown (1932) stated that they were small to very small and extremely small.

The pores of *Terminalia oliveri* are small to moderately small but Gamble (1922) stated that they were very small to moderately small.

Vessel elements are found to be extremely short to medium-sized in all the species studied. Average length of vessel elements of these species range from 186 to 339 um, with the shortest occurring in *Samanea saman* and the longest in *Leucaena leucocephala* as shown in the tables 3. Tangential pore diameter exhibits the wide range among the species, however maximum diameter occurs in *Albizia lebbekoides* and the minimum in *Terminalia oliveri* as shown in the table 3.

Variation in wall thickness of vessel elements among the ten fuelwood species studied is not discernible. In all the species studied, perforation are simple, intervacular pittings are alternate, but only vestured in *Acacia arabica, Acacia lebbekoides, Albizia procera, Tectona hamiltoniana* and *Terminalia oliveri*. The intervacular pitting of all species are similar to ray - vessel pitting.

The number of pores per square millimeter is varied among the species, and their frequency and range are also presented in the table 4.
Table 2. Quantitative characteristics of microscopic wood structures for ten fuelwood timber species

<table>
<thead>
<tr>
<th>Species observed</th>
<th>Acacia arabica</th>
<th>Acacia leucophloea</th>
<th>Acacia senegal</th>
<th>Albizia lebbeckoides</th>
<th>Albizia procera</th>
<th>Cassia siamea</th>
<th>Leucaena leucocephala</th>
<th>Samanea saman</th>
<th>Tectona grandis</th>
<th>Terminalia oliveri</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean pores frequency (per sq.mm)</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>31</td>
<td>95</td>
</tr>
<tr>
<td>mean vessel diameter (μm)</td>
<td>125</td>
<td>136</td>
<td>123</td>
<td>173</td>
<td>111</td>
<td>145</td>
<td>101</td>
<td>110</td>
<td>77</td>
<td>63</td>
</tr>
<tr>
<td>mean vessel length (μm)</td>
<td>210</td>
<td>245</td>
<td>230</td>
<td>273</td>
<td>265</td>
<td>218</td>
<td>339</td>
<td>186</td>
<td>225</td>
<td>338</td>
</tr>
<tr>
<td>mean fibre diameter (μm)</td>
<td>17</td>
<td>17</td>
<td>13</td>
<td>19</td>
<td>22</td>
<td>13</td>
<td>19</td>
<td>18</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>mean fibre length (μm)</td>
<td>1146</td>
<td>1268</td>
<td>838</td>
<td>1100</td>
<td>815</td>
<td>900</td>
<td>1178</td>
<td>701</td>
<td>1233</td>
<td>1060</td>
</tr>
<tr>
<td>mean fibre thickness (μm)</td>
<td>4.4</td>
<td>4.5</td>
<td>4</td>
<td>4</td>
<td>3.7</td>
<td>4.2</td>
<td>5.4</td>
<td>3</td>
<td>4.9</td>
<td>5.5</td>
</tr>
<tr>
<td>mean uniseriate ray height (cells)</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>mean uniseriate ray height (μm)</td>
<td>87</td>
<td>81</td>
<td>74</td>
<td>83</td>
<td>93</td>
<td>70</td>
<td>99</td>
<td>71</td>
<td>76</td>
<td>571</td>
</tr>
<tr>
<td>mean multiseriate ray width (μm)</td>
<td>11</td>
<td>12</td>
<td>9</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>mean ray frequency (per mm)</td>
<td>6</td>
<td>7</td>
<td>12</td>
<td>8</td>
<td>10</td>
<td>11</td>
<td>8</td>
<td>11</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>mean multiseriate ray height (cells)</td>
<td>30</td>
<td>22</td>
<td>23</td>
<td>21</td>
<td>20</td>
<td>9</td>
<td>18</td>
<td>26</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>mean multiseriate ray height (μm)</td>
<td>270</td>
<td>363</td>
<td>222</td>
<td>236</td>
<td>249</td>
<td>153</td>
<td>218</td>
<td>240</td>
<td>386</td>
<td>-</td>
</tr>
<tr>
<td>mean multiseriate ray width (μm)</td>
<td>48</td>
<td>71</td>
<td>32</td>
<td>27</td>
<td>39</td>
<td>24</td>
<td>27</td>
<td>29</td>
<td>29</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 3. Comparison of vessel pores diameters among the ten fuelwood timber species.

<table>
<thead>
<tr>
<th>Species observed</th>
<th>mean</th>
<th>Pores diameter (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>minimum</td>
</tr>
<tr>
<td>Acacia arabica</td>
<td>125</td>
<td>51</td>
</tr>
<tr>
<td>Acacia leucophloea</td>
<td>136</td>
<td>41</td>
</tr>
<tr>
<td>Acacia sundar</td>
<td>123</td>
<td>41</td>
</tr>
<tr>
<td>Albizzia lebbekoides</td>
<td>173</td>
<td>51</td>
</tr>
<tr>
<td>Alibizzia procera</td>
<td>111</td>
<td>41</td>
</tr>
<tr>
<td>Cassia siamea</td>
<td>145</td>
<td>92</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>101</td>
<td>41</td>
</tr>
<tr>
<td>Samanea saman</td>
<td>110</td>
<td>46</td>
</tr>
<tr>
<td>Tectona hamiltoniana</td>
<td>77</td>
<td>35</td>
</tr>
<tr>
<td>Terminalia oliveri</td>
<td>63</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 4. Comparison of pores per square millimeter

<table>
<thead>
<tr>
<th>Species observed</th>
<th>Number of pores per sq. millimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
</tr>
<tr>
<td>Acacia arabica</td>
<td>10</td>
</tr>
<tr>
<td>Acacia leucophloea</td>
<td>7</td>
</tr>
<tr>
<td>Acacia sundar</td>
<td>10</td>
</tr>
<tr>
<td>Albizzia lebbekoides</td>
<td>4</td>
</tr>
<tr>
<td>Alibizzia procera</td>
<td>6</td>
</tr>
<tr>
<td>Cassia siamea</td>
<td>4</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>7</td>
</tr>
<tr>
<td>Samanea saman</td>
<td>5</td>
</tr>
<tr>
<td>Tectona hamiltoniana</td>
<td>31</td>
</tr>
<tr>
<td>Terminalia oliveri</td>
<td>95</td>
</tr>
</tbody>
</table>

In the present work, the fibers of all species are libriform, excepted in the case of Alibizzia procera which possesses nonlibriform fibers. Pearson and Brown (1932) mentioned that they were libriform to semilibriform, but are nonlibriform in A. procera. Interfiber pittings are inconspicuous, minute, simple slit-like which agree with Pearson and Brown (1932). In A. lebbekoides the fibers are found to be septate as had been described by Khin Than Htwe (1991). Macalfe and Chalk (1950) also found the septate fibers in the genus Leucaena. In this work the fibers are also found to be septate in Leucaena leucocephala. The fibers in the wood of Tectona hamiltoniana in this work are septate as had been mentioned by Pearson and Brown (1932). The fibers of Acacia arabica A.leucophloea, A.sandra, Alibizzia procera, Cassia siamea, Samanea saman and Terminalia oliveri in this work are nonseptate but Pearson and Brown (1932) stated that they had in part, septate fibers. The presence of crystals in the fibers are not found, which is in agreement with Pearson and Brown (1932).

In the present work, the length of vessel of fiber ratio are calculated and presented in the table 5. The highest is observed in Acacia arabica and the lowest in Terminalia oliveri.

Axial parenchyma as seen in cross section are variable and they are regarded as reliable diagnostic features for identification of species.

The paratracheal parenchyma of Acacia arabica are mostly vasicentric and those of Acacia leucophloea are vasicentric and confluent forming broad tangential bands. The
paratracheal parenchyma of *Acacia sundra* are vasicentric, aliform and aliform connecting 2-5 pores forming 4- to 10-seriate.

### Table 5. Expression of fiber length and vessel length ratio.

<table>
<thead>
<tr>
<th>Species observed</th>
<th>The ratio of length of vessel to fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
</tr>
<tr>
<td><em>Acacia arabica</em></td>
<td>5.8</td>
</tr>
<tr>
<td><em>Acacia leucophloea</em></td>
<td>5.5</td>
</tr>
<tr>
<td><em>Acacia sundra</em></td>
<td>5</td>
</tr>
<tr>
<td><em>Albizia lebbekoides</em></td>
<td>4.3</td>
</tr>
<tr>
<td><em>Alibizia procera</em></td>
<td>3.5</td>
</tr>
<tr>
<td><em>Cassia siamea</em></td>
<td>4.5</td>
</tr>
<tr>
<td><em>Leucaena leucocephala</em></td>
<td>4.2</td>
</tr>
<tr>
<td><em>Samanea saman</em></td>
<td>4.4</td>
</tr>
<tr>
<td><em>Tectona hamiltoniana</em></td>
<td>5.6</td>
</tr>
<tr>
<td><em>Terminalia oliveri</em></td>
<td>3.4</td>
</tr>
</tbody>
</table>

The parenchyma of *Albizia lebbekoides* are found to be abundant, typically paratracheal, aliform and aliform confluent forming 8- to 17 seriate obliquely tangential bands which agree with Khin Than Htwe (1991). Those of *Albizia procera* are moderately abundant, typically paratracheal, aliform and aliform confluent connecting 2-7 pores forming 12 to 14 seriate tangential bands but Khin Than Htwe (1991) stated that the paratracheal parenchyma of *Albizia procera* are confluent 2-4 pores.

The paratracheal parenchyma of *Cassia siamea* are confluent, connecting several pores forming long wavy tangential bands, which agree with Metcalfe and Chalk (1950).

The paratracheal parenchyma of *Leucaena leucocephala* are abundant, typically vasicentric, occasionally unilateral, aliform and confluent connecting 2-3 pores forming 6-12 seriate.

The paratracheal parenchyma of *Samanea saman* are moderately abundant, vasicentric, aliform and confluent connecting 2-4 pores forming 8-16 seriate.

The axial parenchyma of *Tectona hamiltoniana* and *Terminalia oliveri* are scanty paratracheal and apotracheal diffuse or diffuse in aggregate which agree with Pearson and Brown (1932).

Axial parenchyma cells are found with transverse septa resulting in multiple crystal chambers in all the species studied, except in *Tectona hamiltoniana* and *Terminalia oliveri*.

Rays vary from low to high and uniseriate to multiseriate, the minimum mean of rays millimeter tangentially occurs in *Acacia arabica* and maximum mean in *Terminalia oliveri*, and the variation within species studied are shown in the table 6.
Table 6. Comparison of ray number per millimeter for ten fluewood timber species.

<table>
<thead>
<tr>
<th>Species observed</th>
<th>ray per millimeter</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>minimum</td>
<td>maximum</td>
</tr>
<tr>
<td>Acacia arabica</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Acacia leucophloea</td>
<td>7</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Acacia sundra</td>
<td>12</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Albizia lebbekoides</td>
<td>8</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Alibizia procera</td>
<td>10</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Cassia siamea</td>
<td>11</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>8</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Samanea saman</td>
<td>11</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Tectona hamiltoniana</td>
<td>13</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Terminalia oliveri</td>
<td>21</td>
<td>16</td>
<td>24</td>
</tr>
</tbody>
</table>

Rays are commonly homocellular in all species studied, except the heterocellular rays are only found in *Terminalia oliveri*. The rays *Cassia siamea* and *Samanea saman* are uniseriate to triseriate (mostly biseriate) and those of *Acacia sundra*, *Albizzia procera*, *Leucaena leucocephala*, and *Tectona hamiltoniana* uniseriate to tetraseriate. The rays of *Albizzia lebbekoides* are uniseriate to pentaseriate, and those of *Acacia arabica* and *Acacia leucophloea* are uniseriate to multiseriate. The only *Terminalia oliveri* is predominantly uniseriate which is in accordance with Pearson and Brown (1932).

The presence of gum deposits are observed in the ray of all the species in the present study except in the case of *Tectona hamiltoniana*. However the solitary large crystals are found in the upright ray cells *Terminalia oliveri* as had been described by Pearson and Brown (1932), there are no crystals in the ray cells of the rest nine species.
References


