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

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မြန်မာ့ထင်းထွက်သစ်မျိုးများ၏ ပြင်ပရုပ်သွင်နှင့် သစ်အင်္ဂါဗေဒလက္ခဏာများ စူးစမ်းလေ့လာခြင်း။

ဦးအောင်နိုင်ဦး (B.Sc. (Hons.) (Mdy.), M.Sc. (Mdy.)
အချိန်ပိုင်းသရုပ်ပြဆရာ

ဦးစိုးမြင့် (B.Sc. (Rgn.), M.Sc. (Rgn.))
ကထိက၊ရုက္ခဗေဒဌာန၊မန္တလေးတက္ကသိုလ်
နှင့်

ဦးသိန်းကြွယ် (M.Sc. (Rgn), M.Sc. (SUNY, CESE))
လက်ထောက်ညွှန်ကြားရေးမှူး
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်းချုပ်

မြန်မာပြည်အပူပိုင်းဒေသတွင်၊ အထူးသဖြင့်ပေါက်ရောက်သော ထင်းထွက်သစ်မျိုးများပြင်ပရုပ်သွင်နှင့် သစ်အင်္ဂါဗေဒလက္ခဏာများကို လေ့လာတင်ပြထားပါသည်။ အပင်တိုင်း၏ ပင်ပိုင်းနှင့် မျိုးပွားပိုင်းတို့၏ ပြင်ပရုပ်သွင်များကိုလည်းကောင်း၊သစ်သားတို့၏ သစ်အင်္ဂါဗေဒလက္ခဏာများကိုလည်းကောင်း နှိုင်းယှဉ်ကာ တင်ပြထားပါသည်။ ဤသုတေသနစာတမ်းတွင် လေ့လာတင်ပြထားသော အပင်များမှာ ၊ *Acacia arabica* (Lam.) Willd. (ဆူးဖြူ) ၊ *Acacia leucoploea* (Roxb). Willd. (ထနောင်း) ၊ *Acacia sundra* DC. (ရှား) ၊ *Aubizzia lebbekoides* (D.C) Benth. (ပိုးမဲစာ) ၊ *Albizzia procera* (Roxb.) Benth. (စစ်) ၊ *Cassia siamea* Lam. (မယ်ဇလီ) ၊ *Leucaena leucocephala* (Lam.),de.Wit (ဘောစကိုင်း) ၊ *Samanea saman* (Jacq.) Merr.*Tectona hamiltoniana* Wall. (ဒဟတ်)၊ *Terminalia oliveri* Brandis. (သန်း) ၊ သစ်မျိုးတို့ဖြစ်ပါသည်။ မျိုးစိတ်တို့၏ ထင်ရှားသော လက္ခဏာများနှင့် မျိုးခွဲခြားရာတွင် အရေးကြီးသည့် ထူးခြားသော လေ့လာတွေ့ ရှိချက်များကို ဆွေးနွေးတင်ပြထားပါသည်။

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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., *Albizzia libbekoides* (DC)., Benth., *Albizzia 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

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 walfare, 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 bodly 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 fulfil 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), *Albizzia lebbekoides* (DC.) Benth. (Pomeza), *Albizzia procera* (Roxb.) Benth. (Sit), *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 demestic 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 valume (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* , *Albizzia, Leucaena* and *Samanea* belong to the family Mimosaceae, *Cassia* to the family Caesalpiniaceae. But lawrance (1969) placed the genera *Acacia, Albizzia, 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 Lawrance (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 Pujab 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.

Morphological studies of *A.leucophloea* were made by Brandis (1974), Kurz (1877), Hooker (1979), 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).

General characteristics of wood *A. leucophloea* was 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 Pearsoan 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 flottila.

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 hand-some and shady trees for road sides and in garden (Gamble, 1922). But it's 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.

Morphology of *L. leucocephala* was mentioned by Brandis (1974), Hooker (1879), Backer(1963), Khin Maung Tin (1974), Aung Meo (1977), Hnin Hnin Mya (1977).

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, Jayararaman and Sudhakar (1988).

Ko Ko Gyi (1984) studied the spacing trial for cultivation of *leuceana* 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 Mynamar.

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 outurn estimation among the firewood production of *Acacia catechu* (Sha), *Cassia siamea (Mezali), Eucalyptus camaldensis* and *Leucaena leucocephala* (Bawzagaing) was studied by Soe Tint (1984). From this study, he concluded that Bawzagaing 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, *Albizzia lebbekoides* Benth., *Cassia siamea* Lam., *Dalbergia sissoo* Roxb., *Eucalyptus camaldulensis* Dehnh., *Albizzia procera* Benth. *A.chinensis* (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 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 *Acaica sundra* which are hooked. The stems of *Acacia sundra, Albizzia 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, Albizzia lebbekoides, A.procera, L. leucocephala* and *Samanea saman* are bipinnately compound, paripinate, 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 to12 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 oblong-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 adaxilly, 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, actinmorphic, 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 palepurple 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 ary 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 outersurfaces of calyces are sparsely pubescent to pubescent, but stellately hairy in *T. hamiltoniana*, and glabrous in *A. sundra* and *T. oliveri*. In *T. oliveri*, the long hairs are found at the throat within the calyx.

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* and *L. leucocephala*, and apetalous in *T. oliveri*. The petals are 5 linear-spathulate in *L. leucocephala* and ovate with claw in *C.siamea*. The corollas are companulate with 5 minutes lobes in *A.arabica*, tubular companulate *A. leucoceaphala* and *A.sundra* infundibuliform in *A. lebbekoides* and *A. procera*, and rotate-funnel-shaped in *T. hamiltoniana*.

The outersurface of corollas are glabrous in *A. arabica* *A. sundra*, *C. siamea* and *T. hamiltoniana*, sparely pubescent in *A. leucophloea*, pubscent in *Albizzia lebbekoides* and *A. procera*. The innnersurfaces of corollas of *T. hamiltoniana* are woolly at the throat.

The petals of *C. siamea* are glabrous, but those of *L. leucocephala* are hairy at the tips.

The stamens are monadelphous and the staminal tubes are inserted, but exserted in central flower in *A. lebbekoides*, *A. procera* and *S. saman* and free portion of the filaments are usually exerted, but the stamens are free in the rest of seven species.

The number of stamen are numerous in *A. carabica*, *A. leucophloea*, *A. sundra*, 14 to 16 in *A. lebbekoides*, 10 in *A. procera*, *L. leucocephala*, *C. siamea* and *T.oliveri*, 20 to 25 in *S. saman*, and 15 in *T. hamiltoniana* . The filaments are filiform in all of the ten species. The length of the filaments are equal *C. siamea* and *T. oliveri*, the except.

All of the stamens are fertile but 4-staminodia are present in *C. siamea*.

The anthers are minute but large in *C. siamea*. They are dithecous, introrse, dorsifixed and longitudinally dehiscent but basifixed and apical porous-dehiscent in *C. siamea*.

The gynoecium are monocarpellary, unilocular one row of ovules in the locule on the marginal placentae in *A.arabica*, *A.leucophloea*, *A.sundra*, *A.lebbekoides*, *A. procera*, *C.siamea*, *L.leucocephala* and *S.saman*, bicarpellary with basally axile placentation, tetralocular, one ovule in each locule in *T.hamiltonikna*, 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,* pubscent 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-to15- 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 elliposid in *T. hamiltoniana* and *T. loiveri.* 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 predominently uniseriate, heterocellular…	*Terminalia oliveri*
2.	Wood diffuse porous or semi-ring porous; fibers septate	3
2.	Wood diffuse porous; fibers nonseptate	4
3.	Wood medium or very coarsetextured; 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	*Tectona hamiltonniana*
4.	Wood straight-grained or interlocked-grained; paratracheal parenchyma vasicentric, aliform, and confluent connecting several pores forming tangential band.	6
4.	Wood twisted-grained; paratracheal parenchyma vasicentric	*Acacia arabica*
5.	Wood yellowish white to light brown, medium textured; pores scattered; intervessel pits not vestured	*Leucaena leucocephala*
5.	Wood light brown to dark brown, very coarse textured; pores arranged in oblique pattern, intervessel pits vestured	*Albizzia lebbekoides*
6.	Wood fairly straight-grained, rays 1-4 cells wide (mostly 2-3), maximum height of multiseriate rays lees than 799 um	7
6.	Wood irrequlary interlocked grained; rays 1-8 cells wide (mostly 3-5), maximum height of multiseriate rays more than 850 µm.	*Acacia leucophloea*
7.	Paratracheal parenchyma vasicentric, aliform and aliform confluent connecting 2 to 12 pores forming tengential 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.	*Cassia siamea*
8.	Wood moderately light or moderately heavy, yellowish white, dark brown to light brown, growth ring distinct	
8.	Wood heavy to very heavy, yellowish white to light red or dark red or growth ring not distinct	*Acacia sundra*
9.	Rays 1-4 cells wide (mostly 3-4), elliptical, paratracheal parenchyma confluent connecting 2-7 pores forming 12-27 seriate tengential bands	*Albizzia procera*
9.	Rays 1-3 cells wide (mostly 2), rounded, paratracheal parenchyma confluent connecting 2-4 pores forming 8-16 seriate tangential bands	*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 µm (range 51–215 µm); 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; intervascular pitting alternate, crowded, rounded or oval, vestured, chambers with mean diameter 7 µm (range 5–9 µm.); vessel elements extremely short to medium-sized, mean length 210 µm. (range 92- 369 µm.).

Fibers: Libriform, moderately short to medium-sized, mean length 1146 µm (range 707- 1394 µm), F/V ratio 5.8 (range 3–12); fine to medium fine with mean tangential diameter 16.5 µm (range 10–22.5 µm); nonseptate, thin- to thick-walled, 2.5 -7.5µm 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 µm (range 5–20 µm), mean height 87 µm (range 30–153 µm), 2–14 cells high; multiserite rays very fine to medium-sized, mean width 47 µm (range 20–71 µm), mean height 270 µm (range 102–549 µm.), 8–49 cells high; ray vessel pitting similar to intervascular pitting alternate, rounded or oval in shape, 2–4 µm 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 .

Fig 1. *Acacia arabica*. 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 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 um (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 intervascular 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 leucophloea*. 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 multiplies 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; intervascular pitting alternate, crowded, oval to elliptical, chambers wit- 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 ration 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, interfibre pits minute, simple, slit-like; crystals absent.

Rays : Homocellular, uniserite to tetraseriate, mostly triseriate to tetraseriate, 5-20 per mm, tengentially; moderately numerous to very numerous; uniseriate rays extremely fine, mean width 9 um (range 5-10 µm), mean height 74 µm (range 25-133 µm), 1-9 cells high; multiseriate 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 intervascular 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.

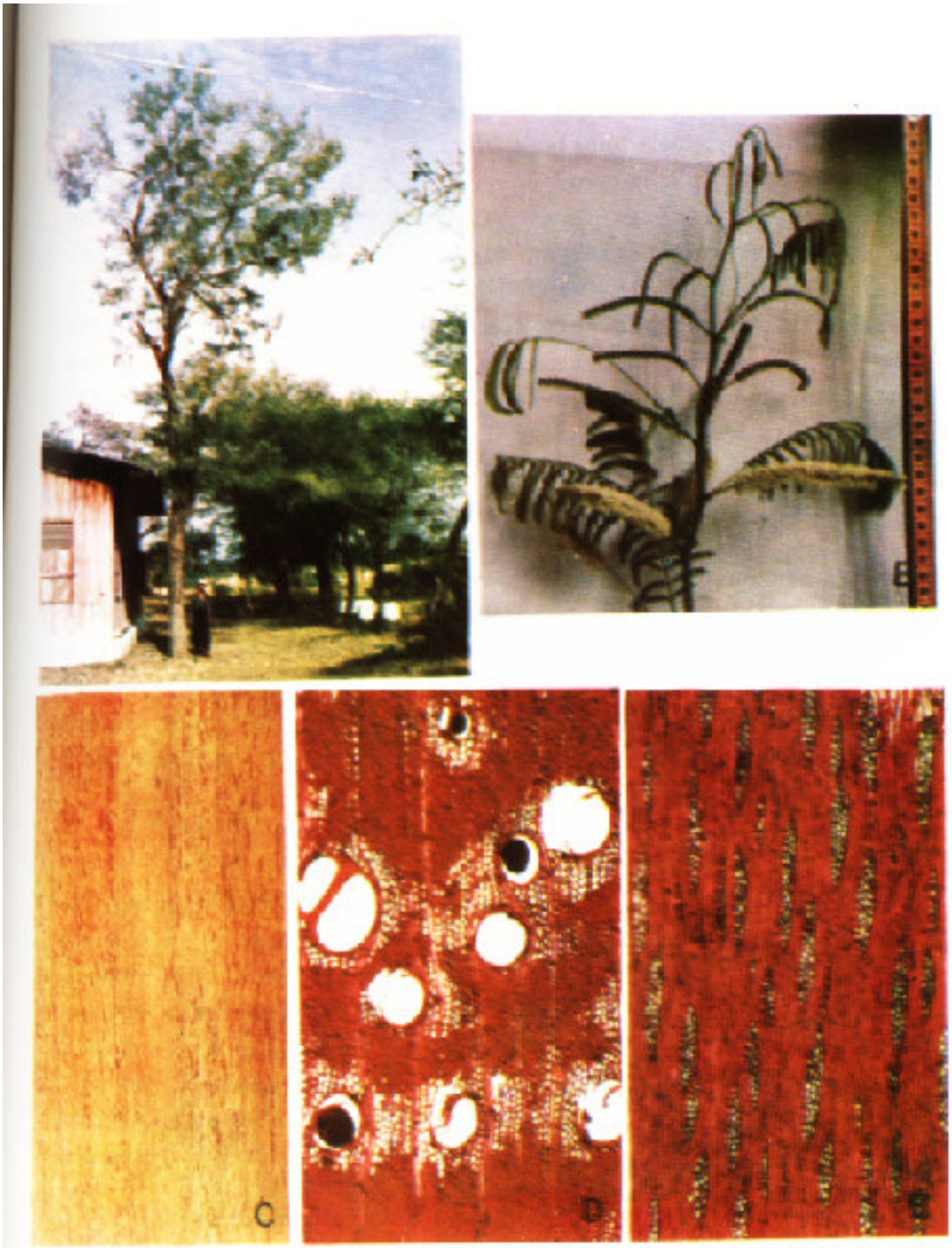

Fig. 3. *Acacia sundra*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).

Albizzia 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; intervascular 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 ration 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 15–41µm), mean height 236 µm (range 92–461 µm), 5–36 cells high; ray vessel pitting similar to intervascular 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. *Albizzia lebbekoides*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natura. colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).

Albizzia 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 um (range 41- 174 µm.); 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; intervascular pitting alternate, crowded, oval elliptical, vestured, chambers with mean diameter 6 µm (range 5-8 µm); vessel elements extremely short to medium-sized, mean length 265 µm (range 112-410 µm.).

Fibres: Non-libriform, very short to medium sized, mean length 815 µm (range 530-1107 µm); F/V ratio 3.5 (range 2.1-5.6), medium fine with mean tangential diameter um (range 5-32 µm); nonseptate; thin-to thick walled 2-6 µm 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 µm (range 5-15 µm), mean height 93 µm (range 30-184 µm), 3-14 cells high; multiseriate rays extremely fine to medium-sized, mean width 39 µm (range 15-71 µm), mean height 249 µm (range 112-512 µm), 5-43 cells high; ray cells elliptical in shape, ray vessel pitting similar to intervascular 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 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 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; intervascular 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 538-116 µm); F/V ration 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, unuiseriate 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 intervascular pitting, alternate, oval or elliptic in shape, 5–9µm 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.

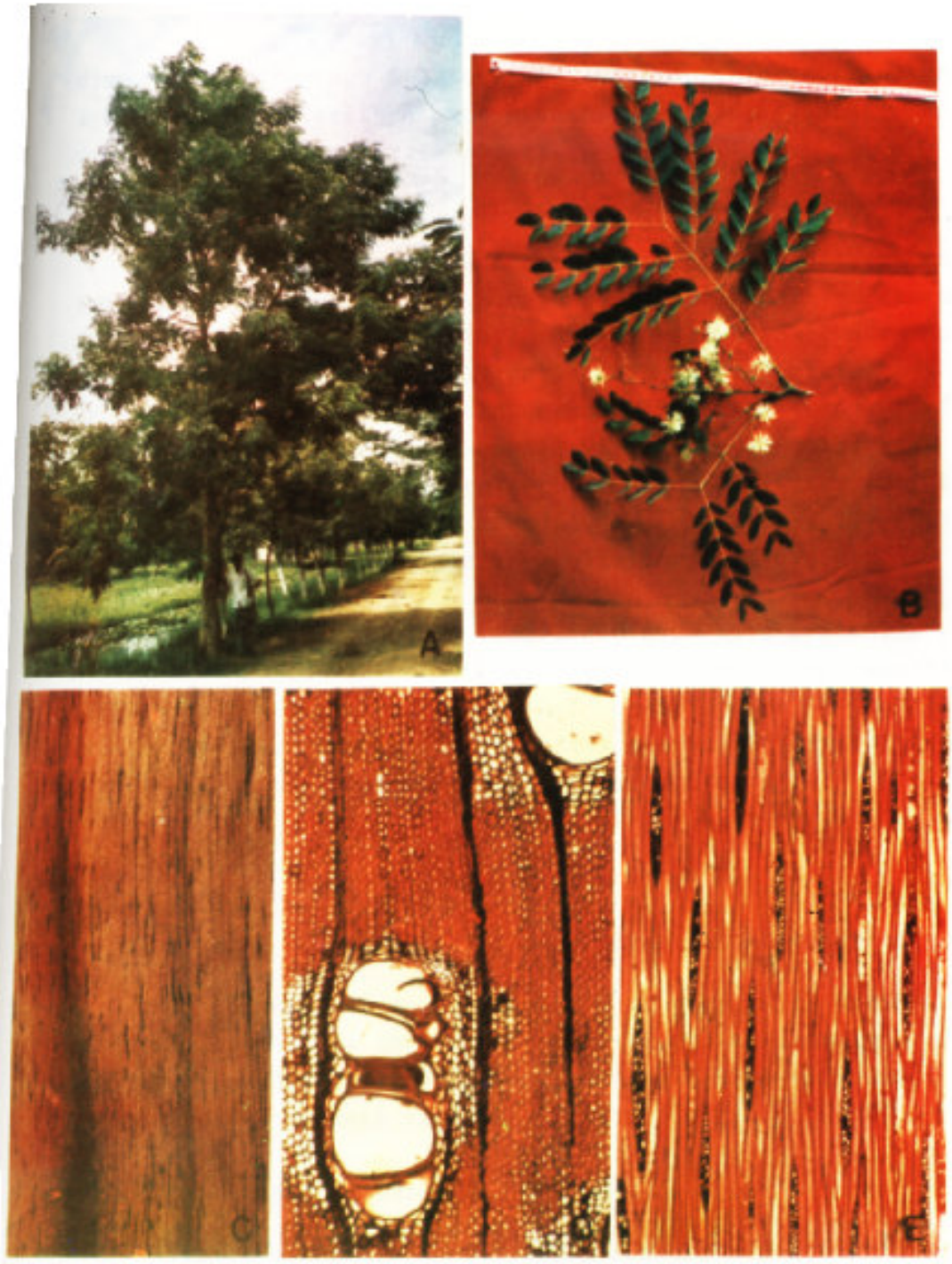

Fig. 5. *Albizzia procera.* A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).

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 145µm (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; intervascular 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: Librifon, extremely short to medium-sized, mean length 900µm (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 – 6µm 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 intervascular 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 siamea.* 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; intervascular 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 um (range 133-574 um).

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 intervascular 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

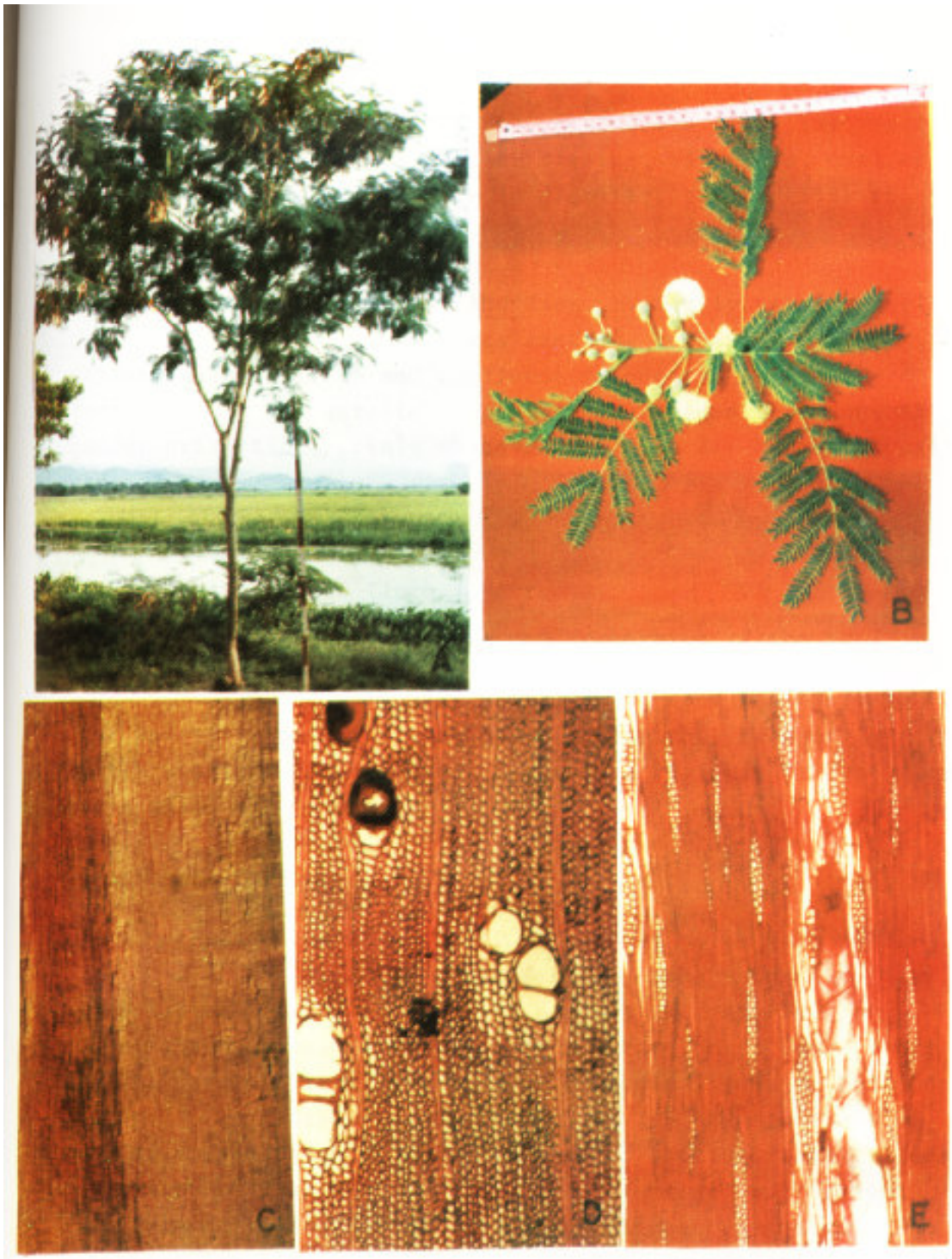

Fig. 7. *Leucaena leucocephala*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).

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 µm (46–164 µm); 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; intervascular pitting alternate, crowded, rounded or oval, nonvestured, chambers with mean diameter 8 µm (range 5–14 µm); vessel elements extremely short to moderately short, mean length 186 µm (range 82–307 µm).

Fibers: Libriform, very short to medium-sized, mean length 701 µm (range 512–922 µm), F/V ratio 4.4 (range 1.6–8.2), fine to medium fine with mean tangential diameter 18 µm (range 12.5–25 µm), nonseptate; thick-walled, 1.5 to 5.0 um 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 µm (range 5–10 µm), mean height 71 µm (range 25–179 µm), 2–9 cells high; multiseriate rays extremely fine to moderately fine, mean width 29 um (range 15–41 µm) ,mean height 240 um (range 61–799 µm), 5–59 cells high; ray cells rounded, ray vessel pitting similar to intervascular pitting, alternate, rounded or oval in shape, 5.0 – 7.5 µm 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.

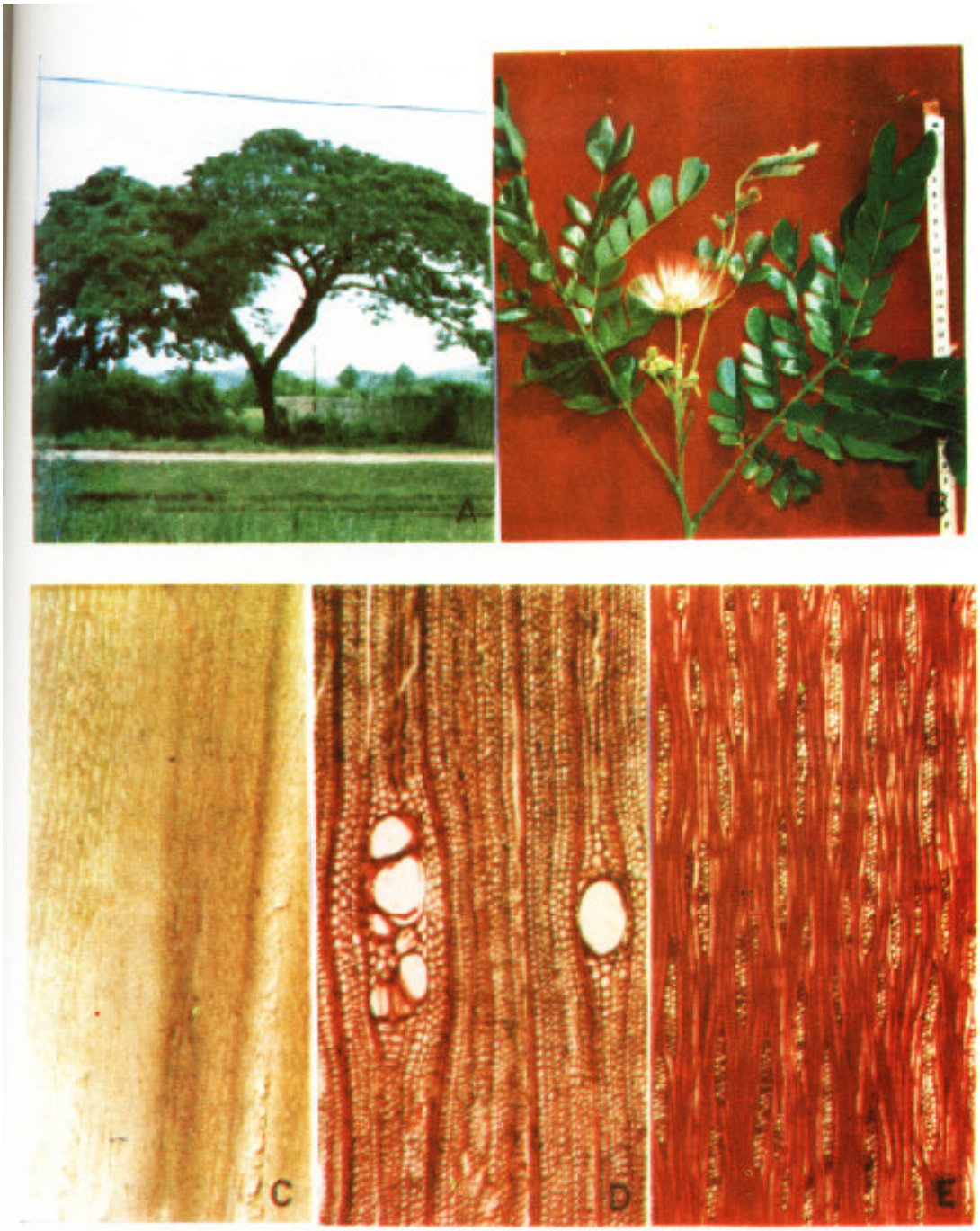

Fig. 8. *Samanea saman*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).

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; intervascular 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 tetraseriate, mostly biseriate and triseriate, 9–18 per mm. tangentially, numerous to very numerous; uniseriate rays extremely fine, mean width 12 um (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 intervascular 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 absents; gummy infiltration present.

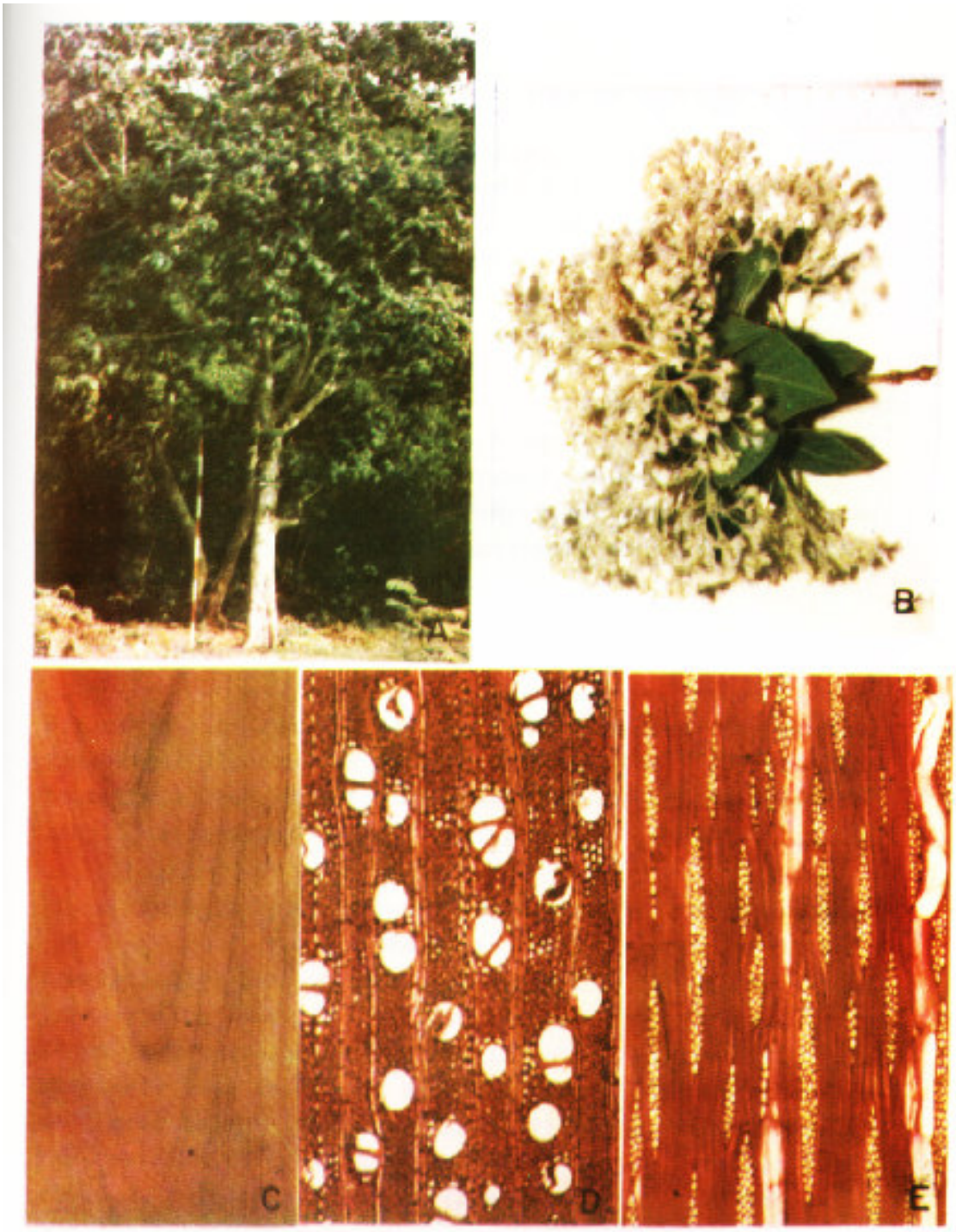

Fig. 9. *Tectona hamiltoniana*. A. A plant in natural habit. B. An inflorescence. C. Portion of a wood in natural colour. D. Transverse section of wood (X 82). E. Tangential and longitudinal section of wood (X 82).

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. mm. 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; intervascular pitting alternate, crowded, or oval to elliptic, vestered, chamber with mean diameter 3 µm (range 2.5–5 µm); vessels extremely short to medium sized, mean length 338 um (range 174–533 µm).

Fibers: Libriform, extremely short to medium 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 intervascular 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. *Terminalie 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). Wiied., *A.leucophloea* (Roxb.) Willd., *A.sundar* DC., *Albizzia lebbekoides* DC.) Benth., *A.procera* (Roxb).Benth., *Cassia siamean* Lam., *leucaena leucophloea* (Lam).de Wit. 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 often 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 lomentocaous and each pod contains 3 to 18 seeds.

Backer (1963) and Myint (1977) described that tripinnate leaves were occasionally found in *A.leucopholoea* 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 *Albizzia lebbekoides* is light brown to dark brown which agrees with Gamble (1922) and Khin Than Htwe (1991).

Table 1. Comparison of macroscopic characteristics of wood for ten fuelwood timber species

Species observed	colour	Odour and taste	Density	Grain	Texture
Acacia arabica	yellowish white to pinkish brown with blackish streaks	not distinct	heavy	somewhat twisted grained	coarse-textured
Acacia leucophloea	pale yellowish white to pale brown with darker streaks	not distinct	moderately heavy	irregularly interlocked grained	coarse-textured
Acacia sundra	yellowish white to light red to dark red	not distinct	very heavy	straight grained	medium- textured
Albizzia lebbekoides	light brown to dark brown	not distinct	moderately heavy	fairly straight	very coarse textured
Albizzia procera	light brown to dark brown	not distinct	moderately heavy	fairly straight-grained	medium-textured
Cassia siamea	white to dark grey with stripes of dark and light	not distinct	moderately heavy	fairly straight-grained	medium-textured
Leucaena leucocephala	yellowish white to dark brown	not distinct	moderately heavy	fairly straight-grained	medium-textured
Samanea saman	yellowish white to light brown	not distinct	moderately light	fairly straight-grained	medium-textured
Tectona hamiltoniana	brownish white with faintly straited lines to light brown	not distinct	moderately heavy	straight-grained	fine-textured
Terminalia oliveri	pale yellowish white to dark purple	not distinct	heavy	fairly straight-grained	very fine-textured

The wood colour of *Albizzia 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 odour 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, Albizzia lebbekoides, Albizzia 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 *Albizzia lebbekiodes* and *Albizzia procera* are fairly straight- grained, which agree with Khin Than Htwe (1991). However, Pearson and Brown (1932) mentioned about the wood of *Albizzia 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 *Albizzia lebbekoides* is very coarse textured, similar to the observation of Khin Than Htwe (1991).

The woods of *Acacia sundra, Albizzia 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

Albizzia 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 district in all the species studied except *Albbizzia 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 *Albizzia 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 ovliveri* 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 occuring 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 *Albizzia 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, intervascular pittings are alternate, but only vestured in *Acacia arabica, Acacia lebbekoides, Albizzia procera, Tectona hamiltoniana* and *Terminalia oliveri*. The intervascular 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

Species observed	*Acacia arabica*	*Acacia leucophloea*	*Acacia sundra*	*Albizzia lebbekoides*	*Albizzia procera*	*Cassia siamea*	*Leucaena leucocephala*	*Samanea saman*	*Teatona hamiltoniana*	*Terminalia oliveri*	
mean pores frequency (per sq.mm)	10	7	10	4	6	4	7	5	31	95	
mean vessel diameter (µm)	125	136	123	173	111	145	101	110	77	63	
mean vessel length (µm)	210	245	230	273	265	218	339	186	225	338	
mean fibre diameter (µm)	17	17	13	19	22	13	19	18	19	15	
mean fibre length (µm)	1146	1268	838	1100	815	900	1178	701	1233	1060	
mean fibre thickness (µm)	4.4	4.5	4	4	3.7	4.2	5.4	3	4.9	5.5	
mean uniseriate ray height (cells)	6	5	6	6	6	6	6	5	3	19	
mean uniseriate ray height (µm)	87	81	74	83	93	70	99	71	76	571	
mean nuiseriate ray width (µm)	11	12	9	11	10	9	10	10	12	19	
mean ray frequency (per mm)	6	7	12	8	10	11	8	11	13	21	
mean multiseriate ray height (cells)	30	22	23	21	20	9	18	26	20	-	
mean multiseriate ray height (µm)	270	363	222	236	249	153	218	240	386	-	
mean multiseriate ray width (µm)	48	71	32	27	39	24	27	29	29	-	

Table 3. Comparison of vessel pores diameters among the ten fuelwood timber species.

Species observed	Pores diameter (μm)		
	mean	minimum	maximum
Acacia arabica	125	51	215
Acacia leucophloea	136	41	205
Acacia sundar	123	41	186
Albizzia lebbekoides	173	51	287
Alibizzia procera	111	41	174
Cassia siamea	145	92	190
Leucaena leucocephala	101	41	164
Samanea saman	110	46	164
Tectona hamiltoniana	77	35	143
Terminalia oliveri	63	30	82

Table 4. Comparison of pores per square millimeter

Species observed	Number of pores per sq. millimeter		
	mean	minimum	maximum
Acacia arabica	10	5	16
Acacia leucophloea	7	2	14
Acacia sundra	10	5	20
Albizzia lebbekoides	4	1	8
Alibizzia procera	6	2	12
Cassia siamea	4	2	8
Leucaena leucocephala	7	3	14
Samanea saman	5	1	10
Tectona hamiltoniana	31	16	45
Terminalia oliveri	95	66	153

In the present work, the fibers of all species are libriform, excepted in the case of *Alibizzia procera* which possesses nonlibrifrom fibers. Pearson and Brown (1932). mentioned that they were librifrom to semilibrifrom, but are nonlibrifrom 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, Allbizzia 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 in dentification 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.

Species observed	The ratio of length of vessel to fiber		
	mean	minimum	maximum
Acacia arabica	5.8	3	12
Acacia leucophloea	5.5	3	9
Acacia sundra	5	2	10
Albizzia lebbekoides	4.3	3	7
Alibizzia procera	3.5	2	7
Cassia siamea	4.5	3	7
Leucaena leucocephala	4.2	2	9
Samanea saman	4.4	2	8
Tectona hamiltoniana	5.6	3	9
Terminalia oliveri	3.4	1	6

The parenchyma of *Albizzia 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 *Albizzia 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 *Albizzia 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 vascentric, 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 very 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.

Species observed	ray per millimeter		
	mean	minimum	maximum
Acacia arabica	6	3	9
Acacia leucophloea	7	4	12
Acacia sundra	12	5	20
Albizzia lebbekoides	8	4	12
Alibizzia procera	10	8	14
Cassia siamea	11	7	15
Leucaena leucocephala	8	4	13
Samanea saman	11	7	16
Tectona hamiltoniana	13	9	18
Terminalia oliveri	21	16	24

Rays are commonly homocellular in all species studied, except the heterocellualr 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 predomeninently 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.

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