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COMPARATIVE MORPHOLOGY and WOOD ANATOMY of
Acacia catechu (Linn. f.) Willd., *A. modesta* Wall. and
A. sundra DC.

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Summary

A study on morphology and wood anatomy of the three species of the genus *Acacia* growing wild throughout central Myanmar has been made. Morphology of the vegetative and reproductive organs and anatomy of the sapwood of these species have been studied.

The species studied in this research are:

1. *Acacia catechu* (Linn. f.) Willd., (Sha),
2. *A. modesta* Wall., (Thinbaw-tanaung), and
3. *A. sundra* DC., (Sha).

The outstanding characteristics of the species, important botanical observation and their uses were described, compared and discussed.

ရှားပင်(၂)မျိုးနှင့်သင်္ဘောသနောင်းပင်တို့၏ပြင်ပရုပ်သွင်နှင့်သစ်အင်္ဂါပေစကို
နှိုင်းယှဉ်လေ့လာခြင်း

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ဦးစိုးမြင့် M.Sc (Rgn.)

ဒုတိယပါမောက္ခချုပ်၊ ပခုက္ကူတက္ကသိုလ်၊ ပခုက္ကူ။

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မြန်မာနိုင်ငံအလယ်ပိုင်းတွင် ပေါက်ရောက်သော ရှားပင်နှစ်မျိုး (*Acacia catechu* (Linn. f.) Willd. နှင့် *A. sundra* DC.) နှင့် သင်္ဘောသနောင်းပင် (*A. modesta* Wall.) တို့၏ပြင်ပရုပ်သွင်နှင့်ခန္ဓာပေစတို့ကိုလေ့လာတင်ပြထားပါသည်။ ၎င်းတို့၏ပင်ပိုင်းနှင့်မျိုးပွားပိုင်းတို့၏ ပြင်ပလက္ခဏာနှင့်သစ်အင်္ဂါပိုင်း၏ သစ်အင်္ဂါပေစတို့ကိုလေ့လာ၍ ထင်ရှားသောလက္ခဏာများနှင့် အရေးပါသော အချက်အလက်တို့ကို တင်ပြ နှိုင်းယှဉ်ဆွေးနွေးထားပါသည်။

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1. INTRODUCTION

Acacia, well known for its cutch or catechu which is the source of the most important brown dye, is one of the forty genera included in the sub-family Mimosoideae of Leguminosae (Lawrence, 1951).

The genus *Acacia* is of economical importance, not only for the timber of certain species, but also as an ornamental plant and as the source of tannins from bark, and gum arabic (Pearson and Brown, 1932).

Many of *Acacia* species widely grow wild in Myanmar, especially in the dry plains and lower hill forests of Upper and Lower Myanmar.

The amount of timber annually extracted from *Acacia catechu* (Linn. f.) Willd., had been estimated at over 50,000 tons from which about 5000 tons of cutch were manufactured in Myanmar (Pearson and Brown, 1932).

A review of the literature available revealed that many species of the genus *Acacia* are studied on morphology and taxonomy of their vegetative and reproductive parts, but a few research work on the anatomy was undertaken.

Some workers recently studied and described the morphology and heartwood anatomy of some Myanmar species of the genus *Acacia*.

However, the anatomy of sapwood of the stem had not been recorded yet so far. In this study the following three species of the genus *Acacia* of the spike inflorescence type, grown wild in central Myanmar are selected.

1. *Acacia catechu* (Linn. f.) Willd.; (Sha)
2. *A. modesta* Wall., (Thinbaw-tanaung), and
3. *A. sundra* DC.; (Sha).

Comparative study on their morphological characteristics of vegetative parts and reproductive organs and anatomical characteristics of sapwood of the stems has been made, described and discussed.

2. REVIEW OF THE LITERATURE

Lawrence (1951) stated that the family Leguminosae was divided into the sub-families Mimosoideae, Caesalpinioideae and Lotoideae, and these sub-families were treated as distinct families viz. Mimosaceae, Caesalpinaceae and Papilionaceae respectively by many botanists. He placed the genus *Acacia* (of about 350 species) under the Mimosoideae in which contained five tribes and about 40 genera.

According to Rendle (1967), the tribe Acacieae of the sub-family Mimosoideae, the smallest one of the three sub-families of Leguminosae, included a single large genus *Acacia*. He also placed Leguminosae, the second largest family of the seed plants, under the order Rosales of the grade Dialypetalae. He described that *Acacia* was one of the two largest genera of Mimosoideae and it contained about 500 species.

Brandis (1874) described *Acacia modesta* Wall. and *A. catechu* Willd. under a category which was characterized by trees or shrubs with stipules which were not spinescent, spines infra-stipular and flowers in spikes. He united *A. sundra* DC. with *A. catechu* Willd. and remarked that this species varied exceedingly chiefly in regard to the pubescence of calyx, petals and spike-rachis.

Kurz (1877) placed the two varieties viz. *catechu* proper and *sundra* (*A. sundra* DC.) under *A. catechu* Willd. He characterized var. *catechu* by young parts all of which were slightly appressed pubescent, soon glabrescent, the stipulary spines were usually recurved and blackish, the leaves when full grown glabrous or the leaflets ciliate, the rachis slightly glabrescent, the spikes shorter and thicker, along with the calyx and petals more or less appressed pubescent, the corolla about twice as long as the calyx.

The varieties *sundra* was characterized by the glabrous nature of the plant parts, except on young shoots which are slightly pubescent. The stipulary spines usually short, curved and blackish, the leaves and their rachis when full grown quite glabrous, the spikes elongate and slender, along with the calyx quite glabrous, the corolla glabrous, about longer than the calyx.

The genus *Acacia* was divided by Hooker (1879) into three series viz. Gummiferae globiferae, Gummiferae spicatae and Vulgares.

The characteristics of the series Gummiferae globiferae were erect shrubs or trees with long and straight spines, spinescent stipules and rounded head inflorescence. He described 7 species in this series viz. *A. farnesiana* Willd., *A. planifrons* W & A., *A. arabica* Willd., *A. eburnea* Willd., *A. jacquemontii* Benth., *A. tomentosa* Willd. and *A. leucophloea* Willd.

The series Gummiferae spicatae was characterized by erect trees with short and hooked spines except in *A. latronum* Willd., spinescent stipules and flowers in peduncled spikes in the axils of the leaves. He described 8 species in this series viz. *A. suma* Kurz., *A. catechu* Willd., *A. sundra* DC., *A. ferruginea* DC., *A. senegal* Willd., *A. modesta* Wall., *A. lenticularis* Ham. and *A. latronum* Willd..

The characteristics of the series Vulgares were climbers with copious scattered prickles and flowers in copiously paniced globose heads. He mentioned 3 species viz. *A. concinna* DC., *A. intsia* Willd., and *A. pennata* Willd. in this series.

He distinguished *A. sundra* DC. (syn. *A. chundra* Willd., *A. catechuoides* Wall., *A. catechu* Brand., *Mimosa sundra* Roxb.) by its short hooked spines in pair, 30 – 40 pinnae, leaflets 40 – 80 and small ligulate, glabrous rachis, corolla three times the glabrous calyx and strap-shaped and straight pods.

A. modesta (syn. *Mimosa dumosa* Roxb., *M. obovata* Roxb.) was also described by its distinct characters which were spines in pairs, short and hooked, pinnae 4 – 6, leaflets 6 – 8 and ovate, corolla twice the glabrous and campanulate calyx, and strap-shaped and straight pods.

Prain (1898) stated that *A. catechu* Willd. consisted of three varieties viz. *catechu* proper, *catechuoides* and *sundra*. In the variety *catechu* proper, calyx, petals and rachis were covered with spreading hairs and it was chiefly found in India and in

the Ayeyarwady valley of Bago and Upper Myanmar. In the variety *catechuoides*, calyx and petals were glabrous, rachis puberulous and it was chiefly found in the Sikkim and Assam, also in Upper Myanmar and in Mysore. In the variety *sundra*, calyx, petals and rachis were glabrous and chiefly found in the Western Peninsula and Upper Myanmar. He also remarked that these three varieties might differ in their mode of growth or other respects and the degree of pubescence varied to some extent (Brandis, 1906).

Gamble (1922) stated that *Acacia* was very important Indian species containing about 22 species in which 9 species were trees or shrubs and having straight spines and the flowers in rounded heads. Other 7 species had curved thorns and the flowers in elongated spikes viz. *A. suma*, *A. catechu* (including *A. catechu*, *A. catechuoides* and *A. sundra*), *A. ferruginea*, *A. senegal*, *A. modesta*, *A. lenticularis* and *A. latronum*. The rest six species were climbers.

Gamble (1922) also described the three varieties of *A. catechu* as had been decided by Prain (1898). According to Prain (1898), var. (1) *catechu* was found in India, but rare in Myanmar, and its calyx, petals and leaf-rachis were hairy. Var. (2) *catechuoides* was found in India and common in Myanmar, and its calyx and petals were glabrous but leaf-rachis puberulous. Var. (3) *sundra* was found in India and Upper Myanmar, and its calyx, petals and leaf-rachis were glabrous.

Nielsen (1992) stated that the family Mimosaceae was divided into seven tribes or collective genera, and 46 genera or sub-genera as had been mentioned by Benthams (1875).

Nielsen (1992) divided the sub-family Mimosoideae into four tribes viz. Acacieae, Ingeae, Mimoseae and Parkieae, and he placed the genus *Acacia* under the sub-family Mimosoideae of the family Leguminosae. He also placed the genus *Acacia* under the tribe Acacieae and this tribe was characterized by the calyx with valvate sepals in bud, joined or free stamens 15 to indefinite in number, the filaments free or very shortly connate at the base, the anthers gland-tipped or not.

Nielsen (1985, 1992) described that the genus *Acacia* could be divided into three sub-genera viz. *Aculeiferum*, *Acacia* and *Phyllodineae*, based mainly on the morphology of the stipules, the primary leaves, pollen and seeds as had been mentioned by Vassal (1972). The sub-genus *Aculeiferum* Vassal was described by the key characters of petiole and rachis with extra floral nectaries, bipinnate leaves, stipules not spinescent and prickles on the internodes and the plants spiny.

Nielsen (1985) characterized *A. catechu* (L.f) Willd. by its paired prickles just below the stipules. It was placed under the sub-genus *Aculeiferum*. Three forms (or formas) of *A. catechu* were (1) *catechu*, (2) *catechuoides* (Roxb.) Prain and (3) *sundra* (DC.) Prain. These forms were distinguished in hairy characters of calyx, petals and rachis of the spike. Calyces and petals of form *catechu* were puberulous to velutinous. In form *catechuoides* (Roxb.) Prain, the calyces and petals were glabrous and the rachis of the spike puberulous, but the spikes of form *sundra* (DC.) Prain were glabrous.

Nielsen (1992) stated that the glandular appendages of the anthers were found in most species of the sub-genus *Aculeiferum* and in several species of the sub-genus *Acacia*.

Morphological characteristics of *A. catechu* were recorded by Brandis (1874, 1906), Kurz (1877), Hooker (1879), Khin Maung Tin (1974), Hla Aye (1977), Hnin Hnin Mya (1977), Tin Tin Nwe (1977) and Myint Myint Lay (1991) in their floristic study; those of *A. sundra* were also described by Hooker (1879), Tin Tin Nwe (1977), Myint (1977) and Aung Naing Oo (1994); and those of *A. modesta* were stated by Brandis (1874, 1906), Hooker (1879), Hnin Hnin Mya (1977), Hla Aye (1977) and Myint Myint Lay (1991).

Hooker (1879) and Brandis (1906) stated that *A. catechu* was distributed in India and Burma. *A. sundra* was distributed in Western Peninsula of India, Ceylon and Burma (Hooker, 1879) and *A. modesta* in Western and Central Himalayas, and Afghanistan (Hooker, 1879).

Kurz (1877) stated that *A. catechu* Willd. var. *catechu* was common all over Ava and Prome, extending into the Irrawaddi zone of Pegu, especially in the dry forests, rather rare in the lower mixed and Savannah forests and var. *sundra* (*A. sundra* DC) apparently in Ava.

Morehead (1944) stated that thorn forest was characterized by a number of thorny species such as *A. catechu* and it was found where the annual rainfall was less than 40 inches.

The presence of calcium oxalate crystals in woody tissue, and their size, quantity and distribution may be used in wood anatomical identification and classification (Chattaway, 1937; Metcalfe and Chalk, 1950; and IAWA Committee, 1984).

Brandis (1874), Pearson and Brown (1932), Metcalfe and Chalk (1950), Myint Myint Lay (1991) and Aung Naing Oo (1994) studied wood anatomy of the genus *Acacia*.

The specific gravity of the wood of *Acacia* was 0.8 to 1.3 and hence they were heavy wood (Eames and Mac Daniels, 1947).

The sapwood of *A. acacia* was yellow (Talbot, 1902) and yellowish white (Watt, 1889; Gamble, 1922; and Pearson and Brown, 1932) and the heartwood was usually bright-red, smooth, extremely hard, weighed about 70 lbs. per cubic foot (Talbot, 1902), either dark or light red, extremely hard (Watt, 1889), either dark or light red (Gamble, 1922), light or dark-red, turning brownish-red with age (Pearson and Brown, 1932), and orange brown (Myint Myint Lay, 1991).

The sapwood of *A. modesta* was large and white, coarse-grained (Brandis, 1874), wide and white (Pearson and Brown, 1932), and yellowish white (Myint Myint Lay, 1991) and the heartwood was dark brown, nearly black, close-grained, compact and heavy (Brandis, 1874), light and russet with a faint greenish cast, ageing to dark brown, often with darker streaks (Pearson and Brown, 1932), and dark brown with darker streaks (Myint Myint Lay, 1991).

In *A. sundra*, the wood was dark red, close-grained and durable (Talbot, 1902); the sapwood was yellowish white and the heartwood light red to dark red and the wood was diffuse porous, growth rings not distinct (Aung Naing Oo, 1994).

Pearson and Brown (1932) described the microscopic key characters of *A. catechu* and *A. modesta*. A narrow sharp line of terminal parenchyma delimited growth rings in *A. modesta*, pores at least in part were united by more or less continuous tangential bands of parenchyma. The bands of parenchyma were not occupying more than half the space between the pores and rays.

In *A. catechu*, growth rings were delimited by a narrow sharp line of terminal parenchyma, pores were not united by parenchyma or, if so the bands broken. The heartwood was light to dark red, turning brownish red with age and the pores frequently with chalky deposits.

According to Kribs (1959), the wood colour of *A. catechu* was light to dark red turning reddish-brown. Odour and taste were not distinct. The wood was hard and heavy, and straight-grained.

3. MATERIALS AND METHODS

3.1 Collection, killing and fixation

The species studied were collected from central part of Myanmar during the flowering and fruiting periods of the year 1995, 1996 and 1997.

companion
- size of tree spec
- age

The vegetative and reproductive parts of the specimens were pressed, dried and preserved for morphological and taxonomic studies. A few numbers of small block of stem with bark attached for each species measured about 5 cm x 5 cm x 3 cm were taken at about four-foot height from the ground level for anatomical study.

The plant specimens were authenticated at the Department of Botany, Mandalay University. Some of the specimens were killed and fixed in 50% of ethyl alcohol solution.

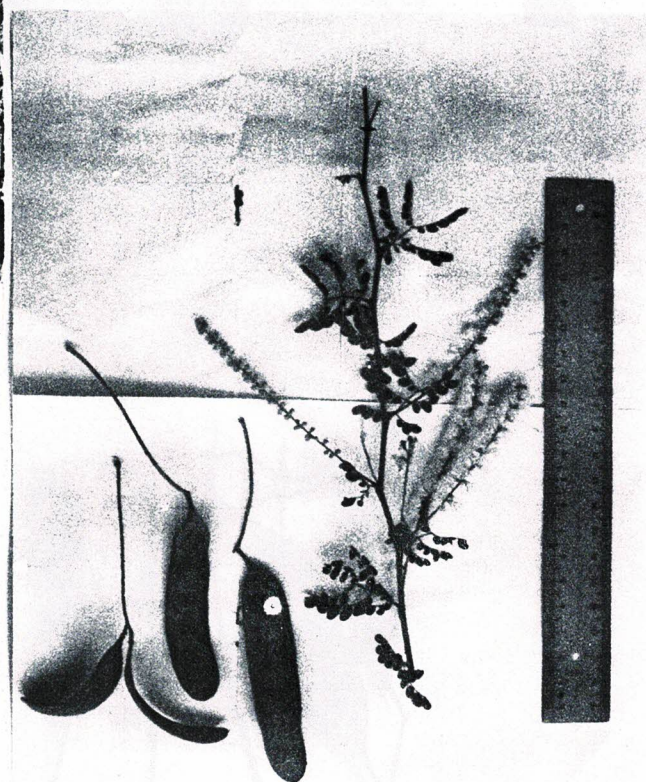
3.2 Microtoming, staining and mounting

For anatomical study, 1 cm x 1 cm x 2 cm blocks of the sapwood were cut and boiled in water about 24 hours to become soft for easy cutting. These blocks were cut by use of a sliding microtome at a thickness of 25 – 35 μ m. The thin sections obtained were stored in 50% ethyl alcohol-glycerine solution before staining.

These sections were washed in tap water and immersed in 3 % solution of ferric ammonium sulphate about three seconds. They were then washed in water three times and stained in a 0.5 % solution of haematoxylin about 30 seconds.

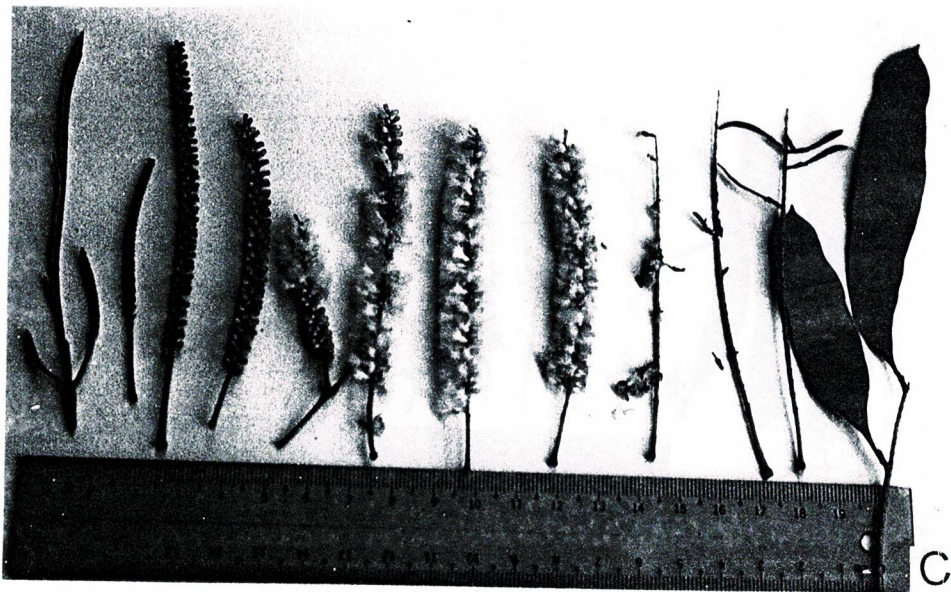
They were washed again in water twice and stained in dilute safranin solution overnight. Then the sections were destained and dehydrated by a series of 50%, 70%, 90% and absolute ethyl alcohol solution. The sections were then cleared with xylol and clove oil separately.

After clearing the sections, they were mounted in Canada balsam dissolved in xylol on the clean glass slides. The transverse, tangential and radial longitudinal sections of each species were mounted on the same slide and dried in the air for a week.



B

Acacia modesta Wall.; (Thinbaw-tanaung)
A. A flowering tree B. A flowering branchlet and young fruits



Acacia sundra DC.; (Sha)

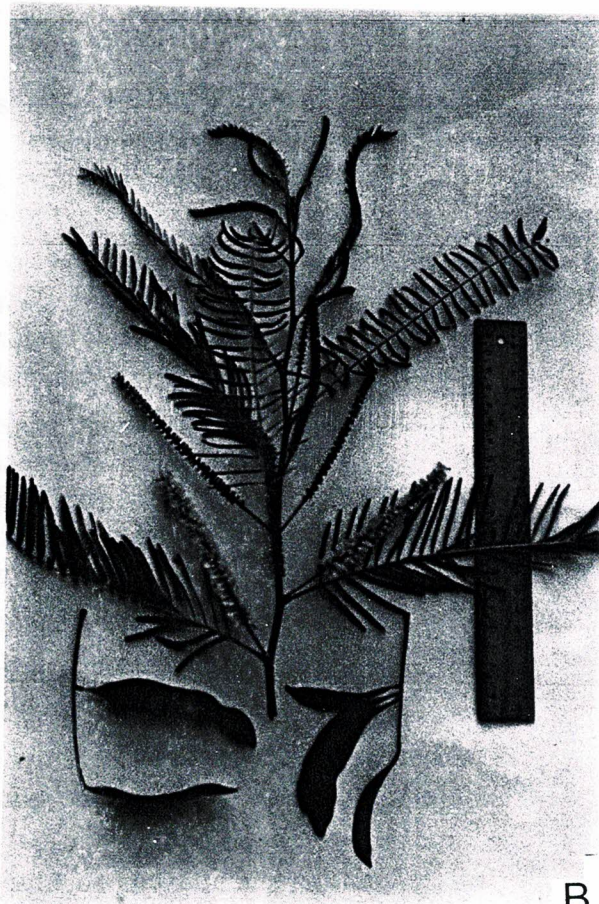
A. A flowering tree
inflorescences

B. A flowering branchlet and mature fruits

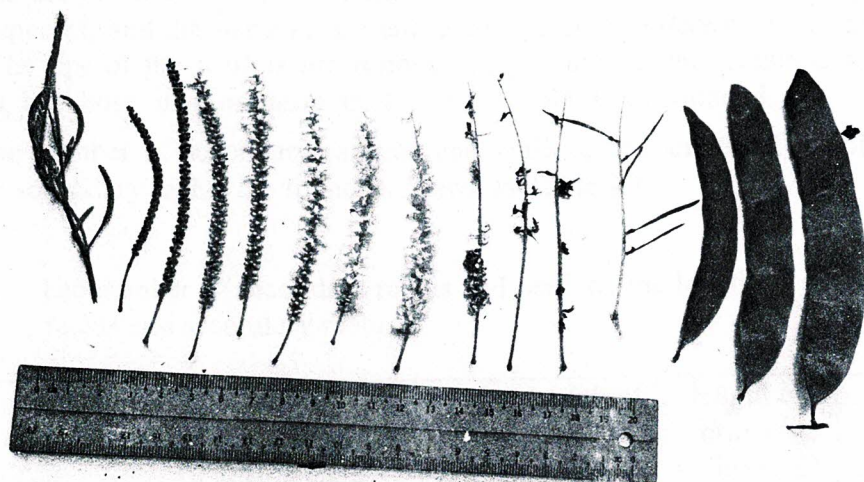
C. Developmental stages of



A



B



C

Acacia catechu (Linn. f.) Willd.; (Sha)

A. A flowering tree

B. A flowering branchlet and young fruits

C. Developmental stages of

inflorescences

4. OBSERVATIONS

4.1 Morphology

The three species of the genus *Acacia* studied in this research are usually deciduous, small to medium-sized armed trees. Among them, *A. modesta* is laxly umbelliform-crowned, and *A. catechu* has a trunk with laxly sub-cylindric crown. The crown of *A. sundra* is laxly sub-globose to globose or umbelliform.

The bark is found to be yellowish grey or grey, with longitudinal irregular fissures and few horizontal fissures in *A. modesta*, deep grey to reddish-grey or brownish-grey with deep and longitudinal fissures and irregular bark flecks in *A. sundra*, and grey with deep and longitudinal fissures and bark flecks in *A. catechu*.

The branchlets of *A. modesta* are green with minute tubercles and pubescent; those of *A. sundra* are green to dark brown, usually reddish-brown while young and green at maturity, sometimes reddish-brown at the upper surface, and glabrescent or pubescent, but those of *A. catechu* are tomentose in the terminal portion and pubescent or puberulous in the lower and usually brownish-green above and green below.

The stipules are paired and minute, in all the three species.

The paired hooked and glabrous spines are arisen just below the node and are found on the branches and branchlets of *A. modesta*.

The spines are also found on the branches and branchlets of *A. sundra*, and the spines are gradually appeared so that they are usually not found on the terminal portion of the branchlets.

But in *A. catechu*, the spines are not found on the terminal portion of the flowering branchlets. They may be present on the non-flowering branchlets and they are also paired and hooked.

The leaves are bipinnately compound and paripinnate in all of the three species. The leaflets are found to be linear-oblong in *A. catechu* and *A. sundra*, but those of *A. modesta* are obovate or ovate-oblong. The bases of the leaflets are oblique in all of the three species, and the margins are entire except in *A. catechu* in which they are ciliate. The tips of the leaflets are rounded in *A. catechu* and rounded to obtuse in *A. sundra*, but those of *A. modesta* are found to be obtuse or rounded.

The number of secondary rachaeae and leaflets, the length of petiole, primary rachis and secondary rachis are found as shown in Table 4.1.

Table 4.1 The number of secondary rachis and leaflets, the length of petiole, primary rachis and secondary rachis.

No.	species	no. of secondary rachis pairs	no. of leaflets pairs	length of petiole (cm)	length of primary rachis (cm)	length of secondary rachis (cm)
1	<i>Acacia catechu</i>	18 - 26	25 - 50	2.1 - 2.6	9.7 - 18.7	1.3 - 4.9
2	<i>A. sundra</i>	6 - 20	17 - 40	1.0 - 2.3	4.5 - 15.0	3.0 - 4.9
3	<i>A. modesta</i>	2 - 4	2 - 5	0.5 - 1.3	1.9 - 3.4	1.0 - 1.9

The minute cup-shaped glands are found on the petioles and terminal portion of the primary rachis as described in Table 4.2.

Table 4.2 The number, position and shape of basal glands and terminal glands.

No.	species	gland on the petiole		gland on the terminal portion of primary rachis	
		no.	shape	no.	shape
1	<i>A. catechu</i>	1	oval, cup-shaped	1 - 3	cup-shaped
2	<i>A. sundra</i>	1	oval, cup-shaped	1 - 3	1 - 3
3	<i>A. modesta</i>	1	oval, cup-shaped	-	-

The petioles are canaliculated on the adaxial surface with prominent glands and pulvini in all three species studied. They are tomentose in *A. catechu*, pubescent in *A. sundra* and *A. modesta*.

In *A. sundra*, the primary rachaeae are occasionally and minutely spinulose beneath and sparsely pubescent, and the secondary rachaeae are sparsely pubescent. In *A. catechu*, primary and secondary rachaeae are tomentose, but in *A. modesta* they are found to be pubescent.

The inflorescences are white cylindrical spikes and then they turn creamy white in age and are slightly fragrant in all the three species.

The stalks of inflorescences are glabrescent in *A. modesta*, tomentose in *A. catechu* and sparsely pubescent in *A. sundra*.

The flowers are numerous and borne on the peduncle, sessile or sub-sessile, white and creamy-white in age.

The calyces are campanulate in shape and 5-lobed, and the lobes are tomentose in *A. catechu*, glabrous in *A. sundra* and *A. modesta*, but those of *A. sundra* are sometimes found to be pubescent on their margin.

The corollas are tubular-campanulate in shape and 5-lobed. The lobes are glabrous in *A. sundra* and *A. modesta*, pubescent in *A. catechu*.

The stamens are numerous and inserted on the outer base of the cup-shaped disc, and they are exerted. The filaments are filiform, glabrous and white. The anther lobes are minute, ditheous, dorsifixed, faced upwards, pale yellow and dehiscent longitudinally and sometimes with stalked glands on the tip. The anthers are 4-lobed and consisted of four sacs which contained oval or rounded pollinia.

The pistils are monocarpellary and unilocular with many ovules. The ovules are anatropous and on two rows of marginal placentae. The ovaries are glabrous and shortly stalked. The styles are filiform and terminal and the stigmas are simple.

The gynophores are 1 - 3 mm long and pale green in *A. modesta*, about 1mm long and usually brown to deeply brown in *A. catechu*, and about 1mm long and pale green or brownish-green in *A. sundra*.

The developing young fruits are densely haired. The pods of these species are dehiscent, strap-shaped, compressed, stalked and beaked.

The colour of the fruits are green and turned pale brown when ripe in *A. modesta*. In *A. catechu*, the fruits are reddish brown on one side and paler on the other while young and become greenish brown when older, finally turn dark brown when ripe and dry. In *A. sundra*, the fruits are usually brownish green on one side and pale green on the other, then turn dark brown when ripe and dry.

In all of the three species the seeds are attached on each of the adjacent rows of placentae. Each seed on each row is alternate with that of the other. The seeds are oblongoid or rounded or oval, compressed, and they are shiny brown and glabrous.

4.2 Anatomy

4.2.1 Sapwood of the Stem

4.2.1.1 Key to the Species

1. Wood fine-textured; pores moderately small to medium-sized, mean tangential diameter 15 - 119 μm , number of pores per square mm few to moderately numerous; fibres extremely short to medium-sized, mean length 691 - 759 μm ; rays per mm tangentially moderately numerous to very numerous, mean width 17- 28 μm , mean height of uniseriate ray 77 - 81 μm , mean height of multiseriate ray 214 - 320 μm ; crystal frequently present in 1- to 29-chambered axial parenchyma.
 2. Sapwood yellowish-white, heartwood dark brown; growth ring distinct; average solitary pores 56%, vessel elements extremely short to very short, mean length 136 μm ; mean length of fibres 691 μm ; rays 6 - 37 per mm tangentially, extremely fine to moderately fine, mean width 17 μm , mean height of uniseriate ray 81 μm , mean height of multiseriate ray 214 μm , gum and crystal absent in ray cell *Acacia modesta*.
 2. Sapwood yellowish-brown, heartwood orange brown; growth ring not distinct; average solitary pores 75%, vessel elements extremely short to medium-sized, mean length 182 μm ; mean length of fibres 759 μm ; rays 6 - 13 per mm tangentially, extremely fine to medium-sized, mean width 28 μm , mean height of uniseriate ray 77 μm , mean height of multiseriate ray 320 μm , gum and crystal present in ray cell..... *Acacia catechu*
1. Wood medium-textured; pores very small to medium-sized, mean tangential diameter 162 μm , number of pores per square mm few to moderately few; fibres extremely short to moderately short, mean length 458 μm ; rays per mm tangentially moderately numerous to numerous, mean width 8 μm , mean height of uniseriate ray 49 μm , mean height of multiseriate ray 429 μm , crystal frequently present in 4- to 14-chambered axial parenchyma..... *Acacia sundra*.

4.2.1.2 Sapwood of *Acacia catechu* (Linn.f.) Willd.

General Characteristic and Properties of the Wood

The sapwood is yellowish-brown, heartwood orange-brown; odour and taste not distinct; moderately heavy to hard; straight-grained; fine-textured; diffuse porous; growth ring not distinct.

Microscopic Characteristics

Vessel elements: Diffuse porous, pores moderately small to medium-sized, mean tangential diameter 119 μm (range 82 - 174 μm); number per square mm few to moderately numerous (range 3 - 12); average solitary pores 75 % (range 25 - 100%); pore solitary or pore multiple of 2 - 3 or sometimes pore cluster; circular or oval in cross section; thin-walled; tyloses absent; perforation plate simple, truncate or tailed at one end or both ends; intervascular pitting alternate or opposite, crowded, oval or elliptic, mean tangential diameter of the chamber 5 μm (range 3 - 10 μm); vessel element extremely short to medium-sized, mean length 182 μm (range 72 - 533 μm).

Fibres : Libriform, extremely short to medium-sized, mean length 759 μm (range 369 - 923 μm); non-septate; interfibre pits simple, slit-like, minute.

Rays : Homocellular, uniseriate to multiseriate (2- to 6-seriate); 6 - 13 per mm tangentially, moderately numerous to very numerous, extremely fine to medium-sized, mean width 28 μm (range 3 - 65 μm); mean height of the uniseriate rays 77 μm (range 38 - 168 μm); 3 - 10 cells high, mean height of the multiseriate rays 320 μm (range 185 - 578 μm); 12 - 35 cells high; ray vessel pitting alternate to opposite, oval in shape, crowded, 3 - 8 μm in diameter; gum and crystal present.

Axial parenchyma: Abundant, paratracheal parenchyma, vasicentric, aliform, aliform confluent connecting 2 - 4 vessel pores; crystal frequently present in 5- to 29-chambered axial parenchyma.

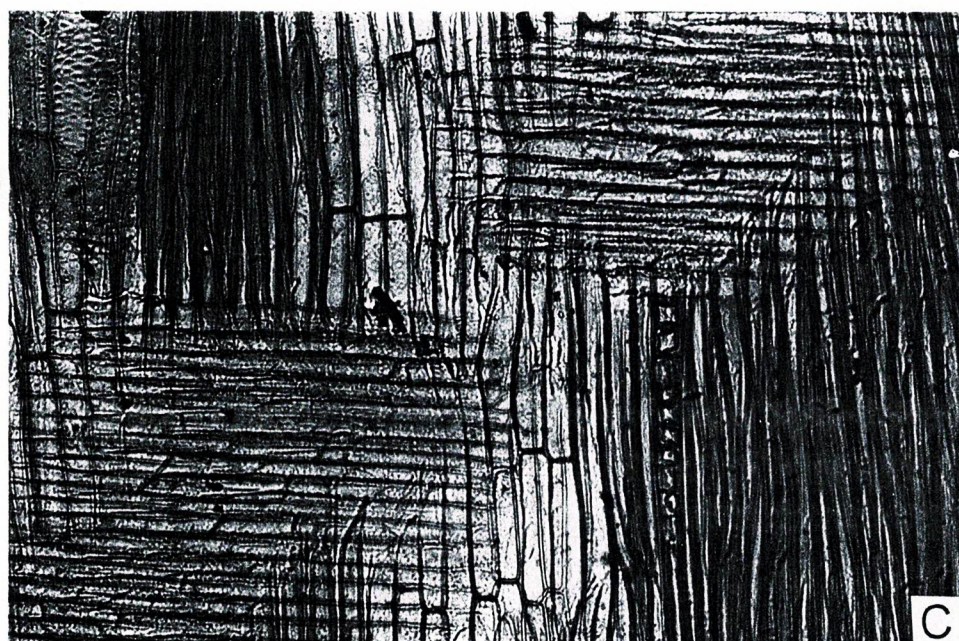
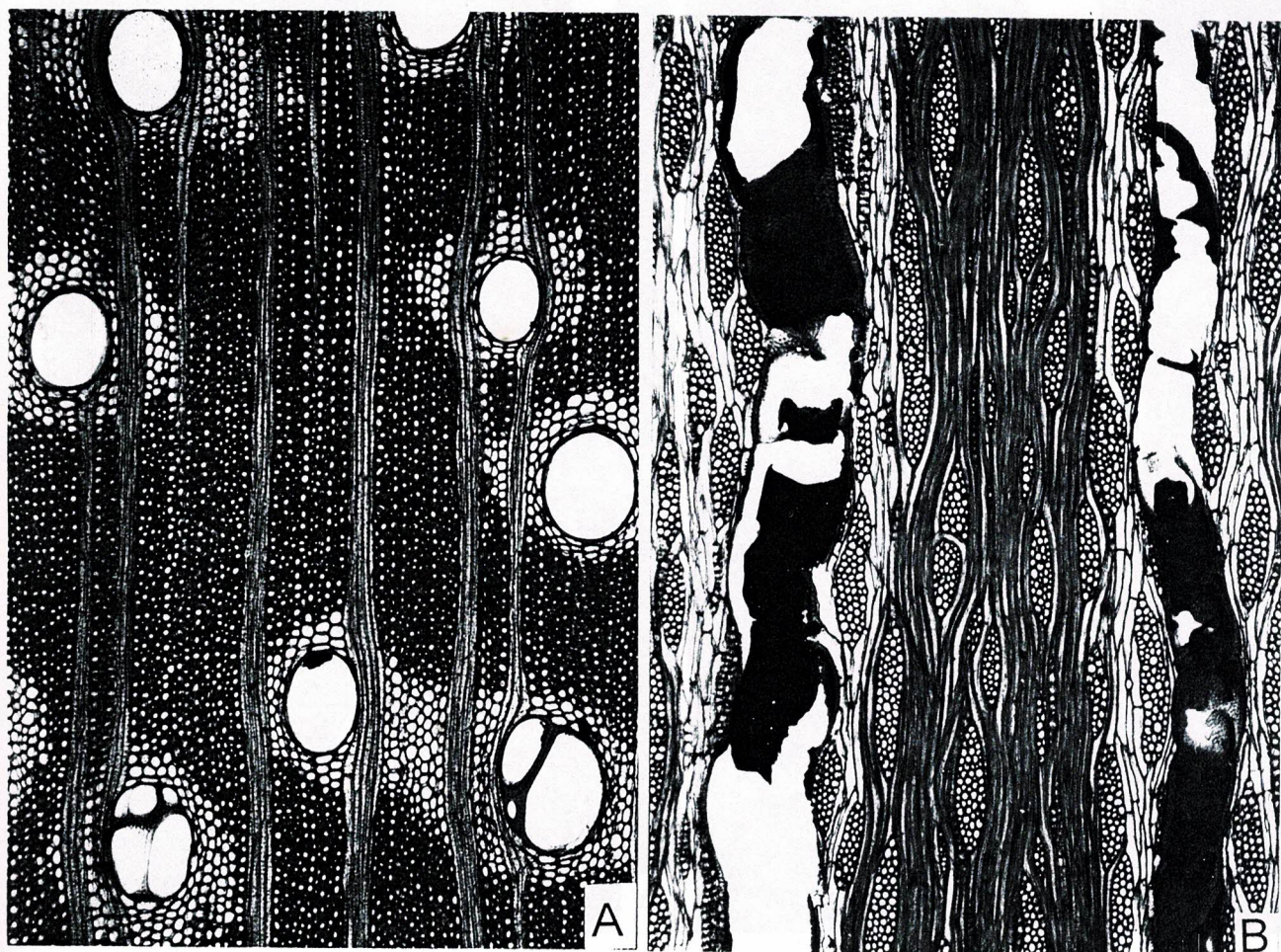
4.2.1.3 Sapwood of *Acacia modesta* Wall.

General Characteristic and Properties of the Wood

Sapwood is yellowish-white, heartwood dark brown; with darker streak; odour and taste not distinct; hard; straight-grained; fine-textured; diffuse porous; growth ring distinct.

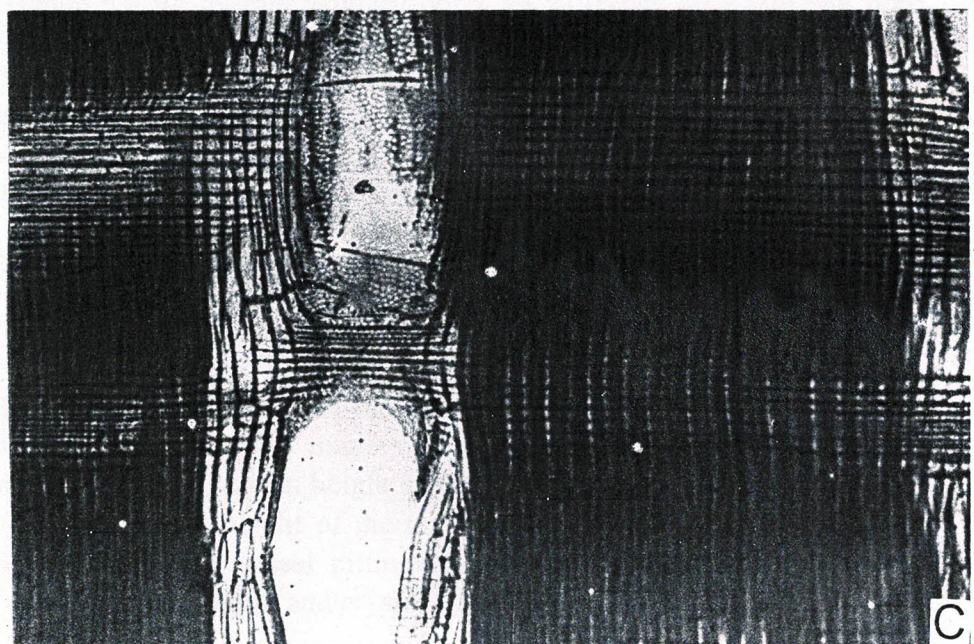
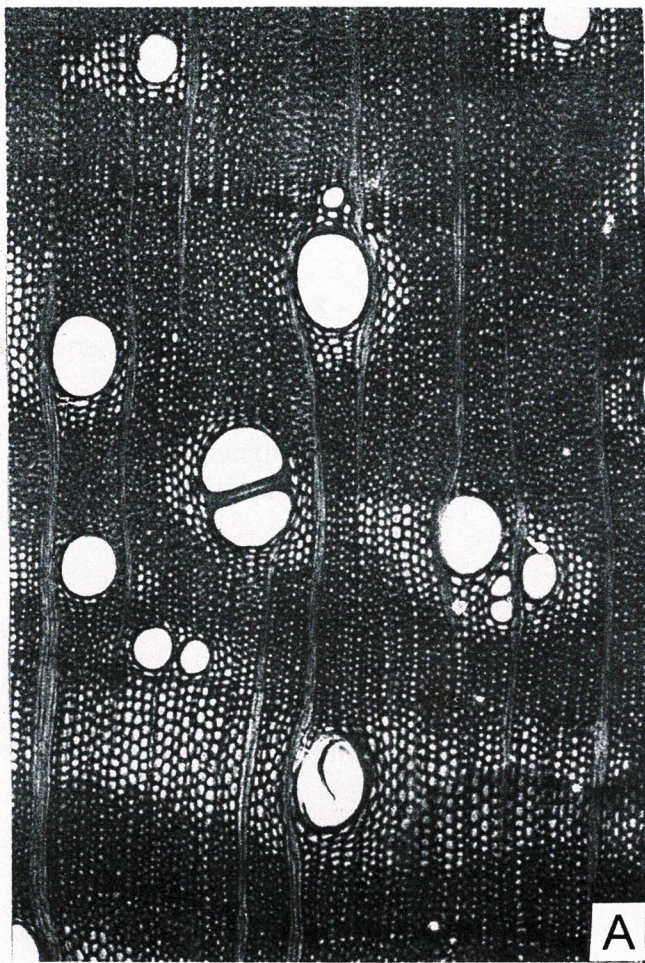
Microscopic Characteristics

Vessel elements: Diffuse porous, pores moderately small to medium-sized, mean tangential diameter 115 μm (range 51 - 164 μm); number per square mm moderately few to moderately numerous (range 6 - 12); average solitary pores 56 % (range 12 - 90 %); pore solitary or pore multiples of 2 - 4 or sometimes pore cluster; circular or oval in cross section; thin-walled; tyloses absent; perforation plate simple, truncate or tailed at one end or both ends; intervascular pitting alternate or opposite, crowded, oval, mean tangential diameter of the chamber 5 μm (rang 2 - 7 μm); vessel elements extremely short to very short, mean length 136 μm (range 71 - 215 μm).



Acacia catechu (Linn. f.) Willd.; (Sha)

- A. T.S of a portion of sapwood (x 80) B. T.L.S of a portion of sapwood (x 80)
C. R.L.S of a portion of sapwood (x 80)



Acacia modesta Wall.; (Thinbaw-tanaung)

A. T.S of a portion of sapwood (x 80) B. T.L.S of a portion of sapwood (x 80)

C. R.L.S of a portion of sapwood (x 80)

Fibres: Libriform, extremely short to medium-sized, mean length 691 μm (range 279 - 974 μm); non-septate; interfibre pits simple, slit-like, minute.

Rays: Homocellular, uniseriate to multiseriate (2- to 4-seriate); 6 - 37 per mm tangentially, moderately numerous to very numerous, extremely fine to moderately fine, mean width 17.2 μm (range 3 - 28 μm); mean height of the uniseriate rays 81 μm (range 41 - 144 μm); 2 - 9 cells high, mean height of the multiseriate rays 214 μm (range 62 - 369 μm); 8 - 37 cells high; ray vessel pitting alternate to opposite, oval in shape, crowded, 3 - 8 μm in diameter; gum and crystal absent.

Axial parenchyma: Abundant, paratracheal parenchyma, vasicentric, aliform, aliform confluent connecting 2 - 7 vessel pores; crystal frequently present in 1- to 26-chambered axial parenchyma.

4.2.1.4 Sapwood of *Acacia sundra* DC.

General Characteristics and Properties of the Wood

Sapwood is yellowish-white, heartwood light brown; odour and taste not distinct; very heavy and hard; straight-grained; medium-textured; diffuse porous; growth rings not distinct.

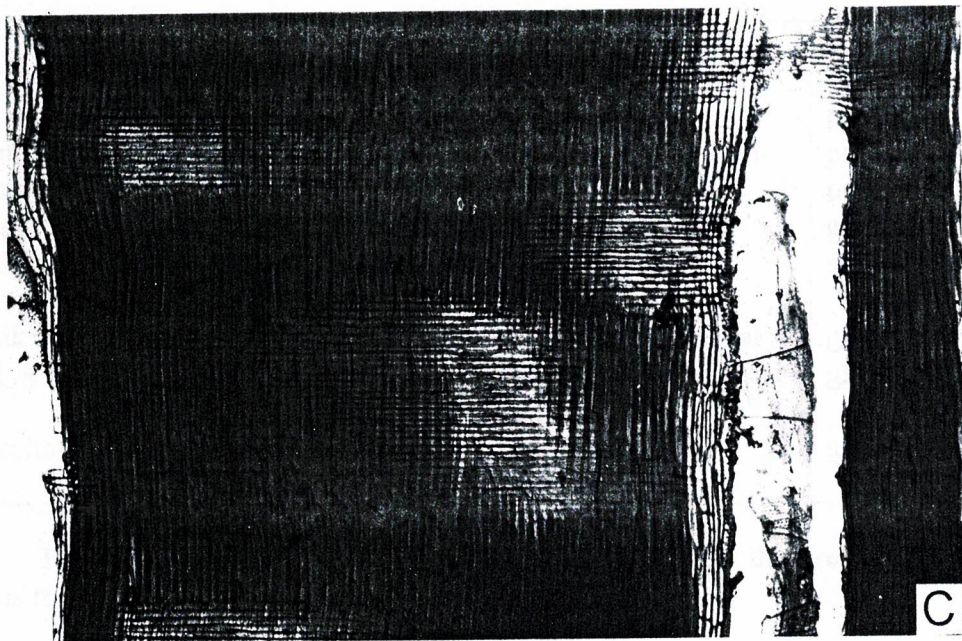
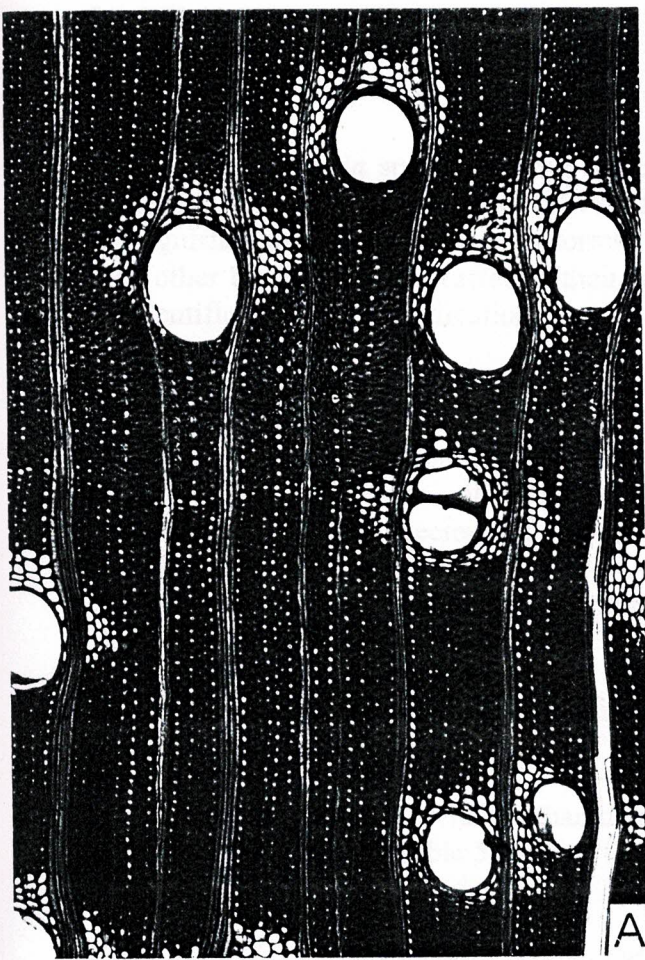
Microscopic Characteristics

Vessel elements: Diffuse porous, pores very small to medium-sized, mean tangential diameter 162 μm (range 41 - 174 μm); number per square mm few to moderately few (range 5 - 9); average solitary pores 73 % (range 40 - 100 %); pore solitary or pore multiples of 2 - 3 or sometimes pore cluster; circular or oval in cross section; thin-walled; tyloses absent; perforation plate simple, truncate or tailed at one end or both ends; intervacular pitting alternate or opposite, crowded, oval or elliptic, mean tangential diameter of the chamber 5 μm (range 3 - 8 μm); vessel elements extremely short to very short, mean length 155 μm (range 82 - 236 μm).

Fibres: Libriform, extremely short to moderately short, mean length 458 μm (range 215 - 718 μm); non-septate; interfibre pits simple, slit-like, minute, crystal present.

Rays: Homocellular, uniseriate to multiseriate (2- to 5-seriate); 5 - 9 per mm tangentially, moderately numerous to numerous, extremely fine to very fine, mean width 8.5 μm (range 3 - 18 μm); mean height of the uniseriate rays 49 μm (range 30 - 70 μm); 2 - 8 cells high, mean height of the multiseriate rays 429 μm (range 185 - 687 μm); 7 - 43 cells high; ray vessel pitting alternate to opposite, oval in shape, crowded, 3 - 10 μm in diameter; gum and crystal absent.

Axial parenchyma: Abundant, paratracheal parenchyma, vasicentric, aliform, aliform confluent connecting 2 - 5 vessel pores; crystal frequently present in 4- to 14-chambered axial parenchyma.



Acacia sundra DC.; (Sha)

- A. T.S of a portion of sapwood (x 80) B. T.L.S of a portion of sapwood (x 80)
C. R.L.S of a portion of sapwood (x 80)

5. DISCUSSION

5.1 Morphology

A few *Acacia* species having spike-inflorescence are growing wild in Central Myanmar. According to Prain (1898) and Nielsen (1992), *A. catechu* could be distinguished into three varieties or forms. These varieties or forms are differing from each other by the hairy character of their calyx, corolla and rachis which is significant for identification and classification.

According to Prain (1898), *A. catechu* var. *catechu* was rarely found in Myanmar. Khin Maung Tin (1974) and Myint Myint Lay (1991) described the morphology and distribution of *A. catechu* in their study, and stated that this species was found in Tet-the-inn of Mandalay and in the campus of Mandalay University respectively. But this species could not be found in Mandalay, Sagaing, Monywa, Myittha and their surrounding area since a few years ago. Fortunately, only one tree which could be identified as *A. catechu* was found in the estate of Forest Research Institute, Yezin, Pyinmana Township.

The comparison between morphological and anatomical characteristics of the species studied in this work and those of the previous workers are presented.

The comparison of hairy characters among the three species studied in this research is described in Table 5.1.

Table 5.1 Hairy characters of *Acacia catechu*, *A. sundra* and *A. modesta*

Species	<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>
Petiole	tomentose	pubescent	pubescent
Primary rachis	tomentose	sparsely pubescent	pubescent
Secondary rachis	tomentose	pubescent	pubescent
Leaflet	glabrous on upper surface, tomentose on the lower	glabrous on both surfaces	glabrous on both surfaces
Stalk of spike	tomentose	sparsely pubescent	glabrescent
Calyx	tomentose	glabrous, sometimes pubescent	glabrous
Corolla	pubescent on the margin	glabrous	glabrous

Hairy characters of the rachis and leaflets observed by the previous workers and in this research are also compared in Table 5.2, 5.3 and 5.4.

The number of secondary rachaeae (pinnae) and the number of leaflet per secondary rachis of *A. catechu*, *A. sundra* and *A. modesta* observed by the previous workers are compared with those of the results in this work in Table 5.5.

It is found that the hairy character of calyx, corolla and rachis of *A. catechu* is resemble that of the var. *catechu* of Prain (1898) and form *catechu* of Nielsen (1985).

The hairy character of calyx, corolla and rachis of *A. sundra* is also resemble that of the var. or form *sundra* and *catechuoides*.

Table 5.2 Comparison between the hairy characters of leaf rachis, rachis of spike, calyx and corolla of *A. catechu*, *A. catechu* var. *catechu* of Prain (1898) and *A. catechu* form *catechu* of Nielsen, 1985.

No.	species/ varieties/ form	leaf rachis	rachis of spike	calyx	corolla
1	<i>A. catechu</i>	tomentose	tomentose	tomentose	pubescent on the margin
2	<i>A. catechu</i> var. <i>catechu</i> of Prain (1898)	spreading hairs	-	spreading hairs	spreading hairs
3	<i>A. catechu</i> form <i>catechu</i> (Nielsen, 1985)	-	-	puberulous to velutinous	puberulous to velutinous

Table 5.3 Comparison between the hairy characters of leaf rachis, rachis of spike, calyx and corolla of *A. sundra*, *A. catechu* var. *sundra* of Prain (1898), *A. catechu* form *sundra* (DC.) Prain. of Nielsen, 1985, *A. catechu* var. *catechuoides* of Prain (1898) and *A. catechu* form *catechuoides* (Roxb.) Prain of Nielsen, 1985.

No.	species/ varieties/ form	leaf rachis	rachis of spike	calyx	corolla
1	<i>A. sundra</i>	sparsely pubescent, pubescent	sparsely pubescent	glabrous, sometimes pubescent	glabrous
2	<i>A. catechu</i> var. <i>sundra</i> of Prain (1898)	glabrous	-	glabrous	glabrous
3	<i>A. catechu</i> form <i>sundra</i> (DC.) Prain. (Nielsen, 1985)	glabrous	-	glabrous	glabrous
4	<i>A. catechu</i> var. <i>catechuoides</i> of Prain (1898)	puberulous	-	glabrous	glabrous
5	<i>A. catechu</i> form <i>catechuoides</i> (Roxb.) Prain (Nielsen, 1985)	-	puberulous,	glabrous	glabrous

The number of the secondary racheae and leaflets of *Acacia* species studied in this research can be matched with those described by many workers.

The colour of flowers or inflorescence of the *Acacia* species studied in this work is found to be white to creamy white. The flowers seem to be fertilized and become mature from the base to tip of the inflorescence. The ovaries become hairy when fertilized and began to develop.

The fruit size and colour of the three *Acacia* species observed by the previous workers and those found in this study are compared with each other in Table. 5.6.

In this study, the fruits of *A. modesta* are green while young and pale brown when ripe. In *A. sundra* studied, young fruits are usually brownish-green on one side and pale green on the other while young, but turn dark brown when ripe and dry. In the case of *A. catechu*, the young and developing fruits are reddish-brown on one side and paler on the other, and becoming greenish brown when older, dark brown when ripe and dry.

Table 5.4 Hairy characters of rachis and leaflets observed by previous workers and in this research.

No.	Author	Rachis			Leaflets		
		<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>	<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>
1.	Kurz (1877)	more or less pubescent, sometimes quite glabrous downy	quite glabrous	-	ciliate or quite glabrous	quite glabrous	-
2.	Hooker (1879)	-	glabrous	finely downy	-	pubescent	glabrous
3.	Brandis (1906)	-	-	-	glabrous or pubescent	-	-
4.	Khin Maung Tin (1974)	-	-	-	glabrous on both surfaces	-	-
5.	Myint Myint Lay (1991)	pubescent	-	pubescent	-	-	-
6.	Aung Naing Oo (1994)	-	sparsely pubescent	-	-	glabrous on both surfaces	-
7.	In this research	tomentose	pubescent	pubescent	margin ciliate	glabrous	glabrous

Table 5.5 The number of secondary rachaeae and the leaflets of *A. catechu*, *A. sundra* and *A. modesta* observed by previous workers and in this research

No	Author	Number of secondary rachaeae (pair)			Number of leaflets (pair)		
		<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>	<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>
1.	Kurz (1877)	10 - 20	-	-	20 - 40	-	-
2.	Hooker (1879)	20 - 40	15 - 20	2 - 3	30 - 50	20 - 40	3 - 4
3.	Watt (1889)	20 - 40	-	-	30 - 50	-	-
4.	Talbot (1902)	20-40	15-20	-	30-58	30-40	-
5.	Brandis (1906)	10-20	-	3	30-50	-	3-5
6.	Backer (1963)	20-40	15-20	-	30-50	20-40	-
7.	Khin Maung Tin (1974)	10-20	-	-	30-50	-	-
8.	Myint Myint Lay (1991)	10-42	-	2-3	31-48	-	6-8
9.	Aung Naing Oo (1994)	-	8-20	-	-	15-38	-
10.	In this research	18-26	6-20	2-4	25-50	17-40	2-5

Table 5.6 The size and colour of pods observed by previous authors and in this research

No	Author	Number of secondary rachae (pair)			Number of leaflets (pair)		
		<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>	<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>
1.	Kurz (1877)	2-3 inches long	-	-	black or brown	-	-
2.	Hooker (1879)	-	-	-	darker brown	-	-
3.	Watt (1889)	-	-	-	dark brown	-	-
4.	Brandis (1906)	2-3 inches long 0.5-0.75 inches broad	-	2-3 inches long 0.5 inches broad	brown	-	-
5.	Khin Maung Tin (1974)	4-8 cm long 1.5-2.3 cm wide	-	-	-	-	-
6.	Myint Myint Lay (1991)	7.5-12.5 cm long 1.5-2.0 cm wide	-	3.0-4.5 cm long 1.0-1.2 cm wide	brown to dark brown	-	light brown to yellowish-brown
7.	Aung Naing Oo (1994)	-	3.1-13.0 cm long 1.2-2.2 cm wide	-	-	shining brown	-
8.	In this research	9.1-12.0 cm long 1.6-2.0 cm wide	4.8-12.1 cm long 0.8-2.5 cm wide	7.1-11.5 cm long 1.2-1.7 cm wide	dark brown when ripe	dark brown when ripe	pale brown when ripe

5.2 Anatomy

In this research, the sapwood of three species of the genus *Acacia* are studied, described and compared with each other and with those of the other workers.

The microscopic characteristics of the sapwood studied in this work are shown in Table 5.7. The diameter of the vessels and the length of the fibres of three species of the genus *Acacia* observed by the previous workers and in this research are also described in Table 5.8. The heartwood is found to be orange-brown in *A. catechu*, light brown in *A. sundra* and dark brown in *A. modesta* in this work.

Table 5.7 The comparison of the physical characteristics of the sapwood of the three species of the genus *Acacia*

No	Species	Colour	Odour and taste	Grain	Texture	Pore distribution	Growth ring
1	<i>A. catechu</i>	yellowish-brown	not distinct	straight grained	fine	diffuse	not distinct
2	<i>A. sundra</i>	yellowish-white	not distinct	straight grained	medium	diffuse	not distinct
3	<i>A. modesta</i>	yellowish-white	not distinct	straight grained	fine	diffuse	not distinct

Table 5.8 The vessel diameter and fiber length of the wood of the three species of the genus *Acacia*

No	Author	Vessel diameter (μm)			Fiber length (μm)		
		<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>	<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>
1	Pearson and Brown (1932)	240 - 265	-	180 - 200	335 - 1500	-	320 - 1170
2	Myint Myint Lay (1991)	70 - 210	-	90 - 170	430 - 1250	-	800 - 1250
3	Aung Naing Oo (1994)	-	41 - 185	-	-	676 - 1035	-
4	In this research	82 - 174	41 - 174	51 - 164	369 - 923	215 - 718	279 - 974

The quantitative characteristics of the wood structure of the three species of the genus *Acacia* studied in this research are also described in Table 5.9.

Table 5.9 Quantitative characteristics of microscopic wood structure of the three species of the genus *Acacia*

No.	Species	<i>A. catechu</i>	<i>A. sundra</i>	<i>A. modesta</i>
	Characteristics			
1	Mean pores frequency (per sq.mm)	5.4	6.6	9.1
2	Mean vessel diameter (μm)	119.6	161.9	115.1
3	Mean vessel	181.7	154.8	135.9
4	Mean fibre diameter	10.5	12.5	11.3
5	Mean fibre length (μm)	759.2	457.9	690.5
6	Mean uniseriate ray height (cells)	6.4	19.8	4.8
7	Mean uniseriate ray height (μm)	77	49.2	81.3
8	Mean ray frequency (per mm)	7.9	7.1	14.9
9	Mean multiseriate ray height(cells)	20.0	19.9	16.3
10	Mean multiseriate ray height (μm)	320.5	428.8	213.5

In this research, the ray cells are found to be homogeneous in all of the three species of the genus *Acacia*. Pearson and Brown (1932) stated that the ray cells are homogeneous in *A. catechu* and *A. modesta*.

In this research, the ray cells are observed as 1- to 6-seriate in *A. catechu* as had been described by Pearson and Brown (1932) i.e. 1- to 6- (mostly 3 - 4) seriate. In *A. modesta* the rays are found to be 1- to 4-seriate, however Pearson and Brown (1932) stated that those are 1- to 5- (mostly 3 - 4) seriate. In this work, the rays are homogeneous, 1- to 5-seriate in *A. sundra*. but it was not described by Pearson and Brown (1932).

Among the three *Acacia* species, their wood texture, pore size, mean tangential diameter of pores, number of pores per square mm, length of fibres, number of rays per tangential mm, mean width of rays, mean height of uniseriate and multiseriate rays, crystals in axial parenchyma are very significant to form key characters of *A. sundra* distinguishing from those of *A. catechu* and *A. modesta*.

The sapwood and heartwood colour, percentage of average solitary pores, length of vessel elements and fibres, number of rays per tangential mm, width of ray, height of uniseriate and multiseriate rays, gum and crystals in ray cells are also important key characters to differentiate *A. modesta* from *A. catechu*.

In this research, the species of the genus could not be distinguished at the level of the variety or form because of the limitation of available literature. It is suggested to make further study to be able to classify the species at the level of variety or forms.

6. CONCLUSION

The morphological characteristics of both of the reproductive and vegetative organs and the anatomical characteristics of the sapwood of the stems of the three species of the genus *Acacia* collected from central Myanmar have been studied, described, compared and discussed.

Their distinct morphological characteristics are:

- (1) the medium-sized, deciduous armed trees.
- (2) bipinnately compound leaves which vary in the number of secondary rachae and leaflets.
- (3) the spines arisen just below the node, paired and hooked.
- (4) the presence of the basal gland on the petiole; and 1 - 3 terminal glands, one on each junction of the uppermost secondary rachis pairs.
- (5) the drooping or sub-pendulous and stalked cylindrical spikes bearing white to creamy white coloured flowers.
- (6) the sessile or sub-sessile, small, bisexual and hypogynous flowers with campanulate and 5-lobed calyx, tubular-campanulate and 5-lobed corolla, and numerous free exserted stamens.
- (7) the anthers 4-lobed and consisted of four sacs which contained oval or rounded pollinia.

- (8) the pistils monocarpellary, unilocular with two rows of alternating ovules on marginal adjacent placentae, with distinct gynophore.
- (9) the styles filiform and terminal and the stigmas simple.
- (10) the ovaries glabrous and shortly stalked.
- (11) the ovules anatropous.
- (12) the pods strap-shaped, dehiscent and pale to dark brown when dry.
- (13) the seeds oblongoid or rounded or oval, compressed, and shiny brown and glabrous.

The sapwood of the stems is diffuse porous and with tangential pore diameter very small to medium-sized and number per sq. mm few to moderately numerous; vessel pores solitary or multiples; perforation plate of the vessel elements simple; the fibre libriform, non-septate; the rays homocellular, uniseriate to multiseriate, number of the ray per mm. 5 - 37; axial parenchyma paratracheal, vasicentric, aliform, aliform confluent; gum and crystals present in fibres or parenchyma.

It is expected that the morphological and anatomical characteristics of these three Myanmar *Acacia* species will contribute useful information in identification, classification and their proper and effective utilization in the near future.

It is also suggested that further investigations on morphology and anatomy of the species of the genus *Acacia* are called for to gain more knowledge and to distinguish between the species at the level of variety or form.

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