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Anatomical characteristics of stem bark and wood of *Adenanthera pavonina* L. (Yway-gyi), *Caesalpinia sappan* (Tein-nyet), and *Pterocarpus santalinus* Lf. (Na-thani).



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Abstract

Specimens of *Caesalpinia sappan*) L. and *Pterocarpus santalinus* L.f**.** were collected from arboretum in the compound of Forest Research Institute, Yezin, and *Adenanthera pavonina* L. was taken from Pauk-Myaing village in Lewai Township. The specimens were studied and identified in Forest Research Institute. The anatomical characteristics of their bark, vascular cambium and wood of stems were described, discussed, and presented with their photographs and photomicrographs. Leaves of *Adenanthera pavonina* L. and *Caesalpinia sappan* L. were bipinnately compound and that of *Pterocarpus santalinus* L.f**.** was unipinnately compound. The flowers of *Adenanthera pavonina* L. was actinomorphic and those of the rest two were zygomorphic. The woods of the three species studied were diffuse-porous. Xylem rays were homogeneous in all species and xylem fibers were non-septate. Gum deposits were present in the wood of all species. In all of the three species, vascular cambium was found to be one layered with a few layers of immediate derivatives. Periderm forms in the stem of all three species. Large cells in groups were observed in the outer bark of *Caisalpinia sappan* L. and *Pterocarpus santalinus* L.f. but not found in *Adenanthera pavonina* L. In all of the three species, sieve tubes were with many sieve area on the lateral wall. Compound sieve plates were distinctly observed in the sieve tubes of *Adenanthera pavonina* L. but those were not found in the rest two species. The morphological and anatomical characteristics of these three species fulfilled the information on knowledge of the tree species. Moreover, these characteristics are useful in identification of the flowering tree species.

Keywords: actinomorphic, zygomorphic, diffuse-porous, homogeneous, large cells, compound sieve plates

ရွေးကြီး၊ တိန်းညက်၊ နံ့သာနီသစ်မျိုးတို့၏ ပြင်ပရုပ်သွင်နှင့် အပင်ခန္ဓာဗေဒလက္ခဏာများကို လေ့လာခြင်း

ကြည်ကြည်ခိုင်၊ သုတေသနလက်ထောက်-၂
အေးငြိမ်းချမ်း၊ သုတေသနလက်ထောက်-၃
သစ်တောသုတေသနဌာန၊ သစ်တောဦးစီးဌာန

စာတမ်းအကျဉ်း

သစ်တောသုတေသနဝင်း၊ သစ်ပင်ကြီးများဥယျာဉ်(Arboretum)မှ နံ့သာနီ၊ ရွေးကြီးနှင့် လယ်ဝေးမြို့နယ်၊ ပေါက်မြိုင်ကျေးရွာမှ တိန်းညက် မျိုးစိတ်(၃) မျိုးတို့ကိုစုဆောင်းပြီး ပြင်ပရုပ်သွင်ကို လေ့လာ၍ မျိုးမည်ဖော်ပါသည်။ ၎င်းတို့၏ အခေါက်၊ အစာရေကြော အသားတိုးလွှာ နှင့် သစ်သားတို့၏ အပင်ခန္ဓာဗေဒလက္ခဏာများကို ပုံများနှင့် တကွဆွေးနွေးတင်ပြထားပါသည်။ ရွေးကြီးနှင့်တိန်းညက်၏ အရွက်သည် နှစ်ကြိမ်ငှက်မွေးရွက်ပေါင်း၊ နံ့သာနီ အရွက်သည် တစ်ကြိမ် ငှက်မွေးရွက်ပေါင်းဖြစ်ပါသည်။ ရွေးကြီးပန်းပွင့်သည် လေးခြမ်းညီ၊ တိန်းညက်နှင့်နံ့သာနီ ပန်းပွင့်သည် နှစ်ခြမ်းညီဖြစ်သည်။ မျိုးစိတ်(၃)မျိုးစလုံး၏ သစ်သားတို့သည် diffuse-porous ဖြစ်၍ ကော်စေးများပါဝင်သည်။ ရေကြောရောင်ခြည်ဆဲလ်များ သည် homogeneous ဖြစ်၍ ရေကြောဖိုက်ဘာများသည် အကန့်နံရံမဲ့ဖြစ်သည်။ အခေါက်နှင့် သစ်သား အကြားတွင်ရှိသော အစာရေကြောအသားတိုးလွှာတွင် ဆဲလ်တစ်လွှာနှင့် ထပ်ကြပ်ဆင်းဆဲလ်အလွှာ အနည်းငယ်ရှိသည်။ မျိုးစိတ်(၃)မျိုးစလုံး၏ ပင်စည်တွင် periderm ဖြစ်ပေါ်သည်။ ကြီးသောဆဲလ်များကို တိန်းညက်ပင်နှင့်နံ့သာနီပင်တို့၏ အခေါက်အပြင် ပိုင်း တွင် အုပ်စုလိုက်တွေ့ရသည်။ ရွေးကြီးတွင် မတွေ့ရပါ။ ဆန်ကာပြွန်များ(sieve tubes) သည် ဘေးနံရံ၌ ဆန်ကာကွက်နေရာများပါသည်။ ရွေးကြီး၏ sieve tubes တွင် compound sieve plates များကို ထင်ရှားစွာတွေ့ရပြီး၊ ကျန်နှစ်ပင်တွင်သိပ်မထင်ရှားပါ။ ဤပြင်ပရုပ်သွင်လက္ခဏာများနှင့် အပင်ခန္ဓာဗေဒဝိသေသ လက္ခဏာများကို သိရခြင်းသည် သစ်ပင်မျိုးစိတ်တို့၏ အပင်ခန္ဓာဗေဒကိုသတင်းအချက်အလက် ထပ်ဖြည့်ပေးနိုင်သည်။ ထို့ပြင် ဤသစ်သားပိုင်းနှင့် အခေါက်တို့၏ ဝိသေသလက္ခဏာများကို သိရခြင်းသည် အပွင့်ဆောင် သစ်ပင်မျိုးစိတ်များကို မျိုးမည်ဖော်ရာ၌ အသုံးဝင်ပါသည်။

Anatomical characteristics of stem bark and wood of *Adenantherapavonina* L. (Yway-gyi), *Caesalpiniasappan* L. (Tein-nyet), and *Pterocarpussantalinus*L.f.

1. Introduction

Fabaceae (Leguminosae) was considered one of the most important families of flowering plants, comprising 727 genera and 19300 species distributed throughout the world **(**Mahmoud Mansour et al. 2020). Kress *et al*. (2003) recorded 732 species in Fabaceae growing in Myanmar. Fabaceae family was the second-largest family of medicinal plants (Gao et al. 2010). This family was divided into three subfamilies: Mimosoideae, Caesalpinioideae, and Papilionoideae (Souza et al. 2016).

Among the trees of the family Fabaceae, wood of some species are brownish red in colour and they are useful in traditional herbal medicine. *Adenanthera parvonina* L., *Caesalpinia sappan* L. and *Pterocarpus santalinus* L.f. belong to the Family Fabaceae and they are well known in Myanmar due to the medicinal uses of their wood in Myanmar traditional medicine. Their wood colour is brownish red and resembles each other.

Pterocarpus santalinus L.f. wood is famous for its medicinal uses especially in Myanmar and India Aryuvedic medicine. Its wood powder is red in colour and known as Na-thani in Myanmar.

Its wood powder is an ingredient of traditional skin care and used in body powder, soaps, and natural cosmetic (Penn Herb Co. Ltd. 1998-2020).

Pearson& Brown (1932) stated that the classification of Fabaceae timbers cannot be based on botanical relationships and affinities but must be purely artificial and arbitrary. In spite of the anatomical variations among the timbers of this family, certain well-marked anatomical types are recognizable.

In practice, some people usually used the wood of *Caesalpinia sappan* L. and *Adenanthera parvonina* L. falsely for that of *Pterocarpus santalinus* L.f. because of their morphological characters of the wood are very similar to each other. However, all of the three kinds of their wood practically seem to be used as Na-thani powder which is one of the components of traditional medicine.

Barks of trees are varied in appearance, however, some of them are slightly similar to each other, and their morphological characteristics are important in identification of the plants. In such case, not only external features but also anatomical characteristics of the barks can be mainly considered to identify the trees and anatomical characteristics of the wood can also support in identification.

The barks consisted of outer bark and inner bark. The outer bark is an older portion of the bark and it may consist of epidermis or ruptured epidermis, periderm which is protective layer of the inner tissue of the stem or root, cortex, primary phloem and older parts of secondary phloem which is nonconductive layer. The inner bark consisted of conductive secondary phloem tissue which can transport food materials throughout the whole plant body and usually found to be more fibrous compared to outer bark.

As the girth of stem or root becomes larger while the process of its growth formation because of the activity of its secondary meristem known as vascular cambium, the epidermal

cells might not be stretched or divided enough to form cells and some of the parenchymatous cells near the epidermis becomes meristematic. As a result, a covering layer forms around the epidermis completely or partially, in some cases many layers form to cover the inner tissue of stem or root. This layer functions as a protective layer and known as periderm.

Periderm is a protective tissue of secondary origin and replaces the epidermis in stems and roots that increase in thickness by secondary growth. Structurally the periderm consists of three parts: the phellogen, or cork cambium, the phellem, commonly called cork, and the phelloderm. The technical term for outer bark is rhytidome. The conducting phloem is the innermost part of the living bark (Evert 2006).

The external appearance of axes (stem or root) bearing periderm or rhytidome is highly variable. This variation depends partly on the characteristics and manner of growth of the periderm itself and partly on the amount and kind of tissue separated by the periderm from the axis. The characteristic external appearance of bark can provide valuable taxonomic information, especially in the identification of tropical trees (Evert 2006).

In this paper, one species from each of three sub-families of Fabaceae are selected and morphology and internal structures of their barks and wood are studied and described with the aims of providing knowledge of morphology and anatomy of bark and wood to support in identification of the trees which can be used intraditional medicine. The species studied are *Adenanthera parvonina* L. (Mimosoideae), *Caesalpinia sappan* L.(Caesalpinoideae), and *Pterocarpus santalinus* L.f. (Papilionoideae).

1.1 Literature review

Kress et al. (2003) recorded 732 species of the family Fabaceae growing in Myanmar. Among them, 1 species of the genus *Adenanthera*, 21 species of the genus *Caesalpinia* and 5 species of the genus *Pterocarpus* were included. Hundley and Chit KoKo (1987) listed 3 species of *Caesalpinia* found to be growing in Myanmar.

The important role of the tree of Fabaceae was to fix nitrogen and thus helped rejuvenate soils. (Benthall 1946; Clark and Thaman 1993). As an advantage of nitrogen fixation, the leguminous crops were utilized to increase nitrogen content of impoverished soil (Mu Mu Aung 2002).

A. pavonina was an important medicinal plant (Renilda et al. 2015, Ara et al. 2019). It was an essential representative of the subfamily Mimosoideae (Souza et al., 2016).

A. pavonina L. was fast growing tree of medium size with smooth bark of brown to greyish color, and many fissures (Rodrigues et al., 2009).Its uses included food and drink, traditional medicine, and timber. This tree was used for making soap and red dye could be obtained from the wood. The bark was rich in saponins and could be used as soap for washing clothes etc. (Ken Fern et al. 2019).

Common name of the tree was coral-wood, peacock flower fence, red bead tree, saga tree and red sandal wood. The bark and leaves were used as a remedy for diarrhea, gout, hematuria, hematemesis, and chronic rheumatism. The hard reddish wood was used in carpentry for making cabinets. Its wood was hard and had red-coloured heartwood and a light-grey sapwood making it useful for constructing decorative wood products (Orwa et al. 2009).

The barks of *A. pavonina* L. were used in traditional medicine for treating different diseases. The heartwood was resistant to dry wood termites. The wood was used for bridge and household construction, flooring, paving blocks and vehicle bodies. It might also be suitable for furniture and cabinet work and turnery (Orwa et al. 2009).

Caesalpinia sappan L. was a plant of Leguminosae family, commonly known as Brazil or sappan wood. ;Its dried heartwood was used as traditional ingredient of food or beverages. The heartwood was commonly used for the extraction of red dye and used in oriental folk medicine in Southeast Asia (Nirmal et al. 2015).

In the Caesalpinioideae, crystals were predominantly in chambered axial parenchyma, commonly in ray cells and occasionally in chambered fibres (Gasson et al.2003). Crystals are abundant in chambered axial parenchyma and ray cells in some papilionoid taxa. Prismatic crystals in ray cells were rarely found in the Mimosoideae. Crystals are most common in chambered fibers, and frequent in chambered axial parenchyma cells (Auther and year IAWA J. 2006).

Sappan wood was a one of natural dye that contained pigment brazilein ($C_{16}H_{14}O_5$). (Suarni Landuma et al. 2014).

C. sappan was a medicinal tree which could give income within a short period of 7 – 8 years (Mathew et al. 2007). The bark was used for tuberculosis, diarrhea, anthelmintic, antibacterial, dysentery, postpartum tonic (Ahmed. et al. 2010).

It was one of the versatile natural dye yielding trees that could be grown on a large scale in tropical areas (Mariappan et al. 2020).

The heart wood contained water soluble dyes such as brazilein, protosappanins, sappanchalcone and haematoxylin. In recent times the dye was used for natural colouring of food products, beverages, and pharmaceuticals. Brazilian on oxidation yield a red dye called brazilein, the most valuable dye used in colouring leather, silk, cotton, wool and fibres of different kinds, calico printing, batik, food products, pharmaceuticals and wines (Mariappan et al. 2020).

The wood was used in carpentry, the timber, which had straight grains, was of great value for making violin bows (Smartt 1990). The wood was orange red, hard, very heavy (Weight: 1,030 kg m^{-3}) straight grained with a fine and even texture. It was suitable for cabinet making, walking sticks and small ornamental turnery articles like dagger sheaths and hilts (Mariappan et al. 2020).

The wood of *C. sappan* L.was very heavy, interlocked-grained, orange-red, claret-purple, or purplish-black in colour; heavily impregnated with reddish-brown gum and contained a red dye (santalin) which was soluble in alcohol and ether but not in water; similar anatomically to the other Indian species of *Pterocarpus* but finer textured and with less pronounced ripple marks. It produced valuable timbers of the first class (Pearson and Brown 1932).

Pterocarpus santalinus L.f. possessed a red dye soluble in ether and alcohol, valuable durable timbers of the first class, interlocked-grained in narrow or broad bands and exhibiting a handsome ‘roe’ or ‘striated’ figure on the quarter section. Vessels were ringed rather scantily, usually independent of the narrow, wavy, numerous, regularly distributed bands of wood parenchyma (Pearson and Brown 1932**).**

Sapwood of *P. santalinus* was white; transition from sapwood to heartwood abrupt; heartwood orange-red when first exposed, turning to claret-purple with lighter and darker streaks, purplish-black, or almost black; decoctions of the wood exhibited fluorescence; dull, requiring care to bring to a smooth surface, without characteristic odour or taste, very heavy (sp. gr. approx. 0.99), interlocked-grained in narrow straight lines, medium fine-textured. Vessels were medium-sized to small or very small, generally united by narrow concentric wavy bands of parenchyma, reddish-brown gum or occasionally with white deposite, ripple marks present, rays storied (Pearson and Brown 1932**).**

A dye prepared from the heartwood of *P. santalinus* L.f. was used as a stain in light microscopy, as a coloring agent in pharmaceutical preparations, in food, leather and textile industries, and as a textile dye (Jaime et.al. 2018).

3. Materials and Methods

The specimens of vegetative and reproductive parts, bark, and stem wood of one species from Pauk-Myaing village in Lewai Township, and two species from Forest Research Institute Arboretum, Yezin, were collected in the year of 2020. Unfortunately reproductive parts of *Pterocarpus santalinus* L.f. were not obtained due to the young stages of the plants grown in Forest Research Institute Arboretum, Yezin. This plant was recently introduced to Myanmar and the plants were very young and no flowers were produced yet. Small portions of bark and wood of stem near at the breast height level were taken. The specimens were studied and identified in Forest Research Institute, Yezin by the available literature.

The specimens are killed and fixed in 50% ethyl alcohol for further study. The specimens killed and fixed were washed in the running water overnight and the specimens were dehydrated through a series of tertiary butyl alcohol solutions. Then the totally dehydrated specimens were infiltrated in a series of paraffin wax of which melting points were 49° C, 55° C and 60° C respectively. The specimens were then embedded in the 60° C paraffin wax and cut into 15 – 19 μm thick sections by using a rotary microtome, model AO 820.

These thin sections were mounted on a clean glass slide by Mayer's albumen and immersed in xylol solution to remove paraffin. Then they were double-stained in the combination of safranin and fast green solutions according to Johenson (1940). After staining, the sections were permanently mounted under a cover slip by using Canada balsam in xylol and kept dried for a few days on a slide tray in the room temperature. The killing and fixation, dehydration, infiltration, embedding, staining and mounting were made according to Johansen's (1940) Method.

Some of the stem blocks were boiled in water for 12 hours and cut into 25 – 30 μm thick sections at the transverse, tangential longitudinal and radial plane respectively by using a sliding microtome. These sections were stained haematoxilin and safranin combination according to Johansen (1940). After staining, the sections were dehydrated and permanently mounted under a cover slip with Canada balsam in xylol and kept dried for a few days on a slide tray. The sections were studied under Biological microscope (MT 4300H) attached to a laptop by a camera.

The parts of stem bark and stem wood were macerated separately by warming in a mixture of two parts of hydrogen peroxide solution and one part of glacial acetic acid solution according to Franklin's method (modified) (Berlyn and Mikshe 1976). The macerated elements were studied under Biological microscope (MT 4300H) and the vessel elements and fibers were measured and recorded.

Figure 3.1 Location map of collection site of three trees species.

4. Results

4.1 Morphology

4.1.1 *Adenanthera pavonina* L.

Synonym:.	*Adenanthera gersenii* Scheff
	Adenanthera polita Miq.
	Corallaria parvifolia Rumph.
Local name:	Ywegyi, mai-chek
English Name:	Red Sandalwood tree, Red bead tree
Subfamily:	Mimosoideae
Family :	Fabaceae
Locality:	Medicinal garden, Forest Research Institute, Yezin
Specimen examined:	Kyi Kyi Khaing & Aye Nyein Chan,30 - 3- 2020
Flowering period:	March to August.
Fruiting period:	May to September.

Taxonomic Description

A medium-sized to large deciduous tree, perennial, to 11 m high, to 14.5cm in diameter, with spreading crown, straight or fork. Outer bark grey to brown, inner bark pale yellowish, smooth.

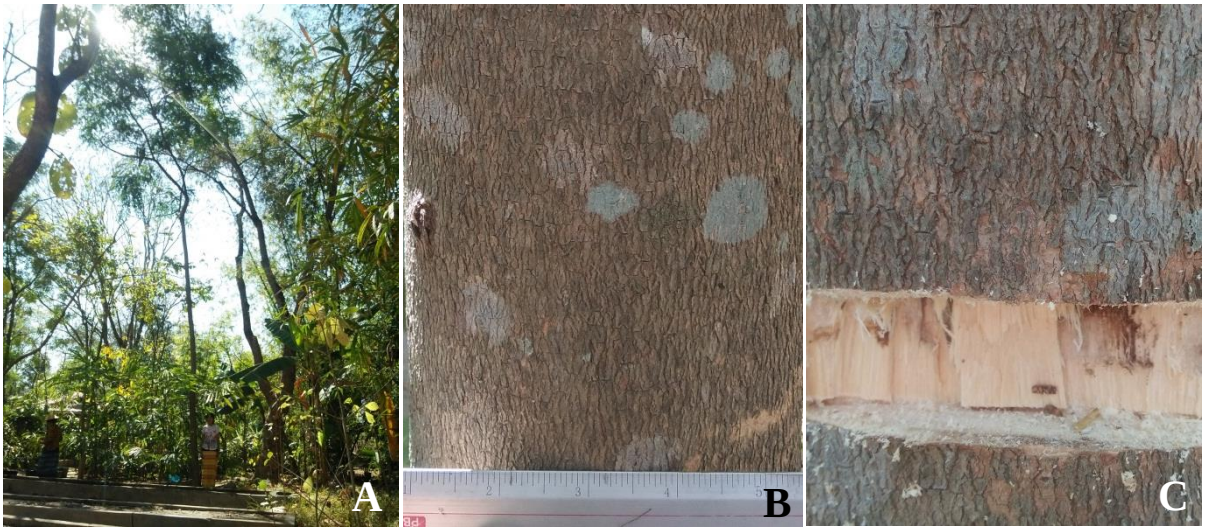
Leaves bipinnately compound, 21.0 – 48.0 cm long and 25.0 – 37.0 cm wide, alternate, petiolate with a large swollen pulvinate, 4.6 – 9.5 cm in length, cylindrical, glabrous, sparsely pubescent on both surface, minute gland on the upper surface of the leave; primary rachis 14.5 – 38.5 cm long, cylindrical, glabrous, tip pointed, 4 - 6 pairs (mostly 4) of secondary rechae per primary rachis; secondary rachis 6.5 – 24.3 cm long, sparely pubescent on the margin, with 9 – 13 pairs of leaflets; leaflets petiolulate; petiolule short, terete, glabrous, green, oblong, 1 – 3 mm long and 1 mm wide, tip oblong to ovate, margin entire, base oblong.

Inflorescence terminal and axillary, 9 – 17 in number per axil, yellow, pubescent, 8 – 21 cm length and 6 – 20 cm diameter; 99 – 204 flowers per inflorescence. Flower bisexual, yellow, clustered in axillary spiciform racemes, 5 – 8 mm across, pediclelate, ebractate, liner, ebracteolate, actinomorphic, pentamerous, hypogynous. Calyx tube campanulate, yellowish green, very small, 5 toothed, pubescent; petals 5, connate below, linear-lanceolate, 4 – 5 mm long, glabrous, minute gland.

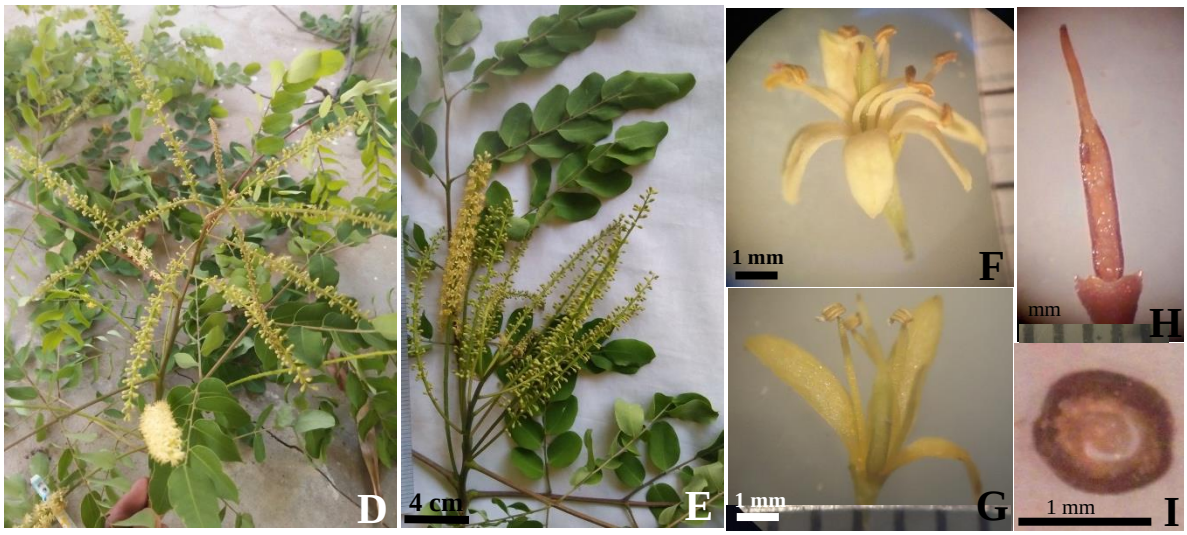
Androecium apostemonous, stamens 10, filaments filiform, about 3 - 4 mm long, glabrous, anther with dithecous gland, yellow, dehiscence longitudinal, pollens forming pollinia, dosifixed. Gynoecium monocarpellary, unilocular, placentation marginal. Ovary yellowish green, superior, flat, 3 mm long; style, filiform, glabrous, stigma simple, 2 mm long.

Pods or legumes 23.3 – 32.3 cm long and 1.3 – 1.5 cm wide, 8 – 13 seeded, yellowish green in colour while very young and turn green while older, then black while dry. Seeds discoid, germination epiginal.

Floral formula: ⊕ ♀ $\mathbf{K_{(5)}\ C_5\ A_{10}\ G_1}$



A. A plant fully bloomed in natural habit at Medicinal garden. **B.** Stem bark as seen. **C.** A portion of stem showing exposed wood**.**



D & E. Inflorescences. **F.** Flower as seen. **G.** L. S of a flower. **H.** L. S of ovary with many ovules in locule. I. T.S of ovary with ovule.

J , K & L Fruits and seeds as seen.

Figure 4.1 Habit of *Adenanthera pavonina* L**. .**

4.1.2 *Caesalpinia sappan* L.

Synonym:	*Biancaea sappan*
Local name:	Tein-nyet
Common name:	Sappan Wood, Brazil wood Red Sandalwood tree, Red bead tree
Subfamily:	Caesalpinioideae
Family:	Fabaceae
Locality:	Pauk Myaing village, Thawatti Village Tract, Lewei Township
Specimen examined:	Kyi Kyi Khaing & Aye Nyein Chan,15 - 8- 2020.
Flowering period:	August to September.
Fruiting period:	October to December

Taxonomic Description

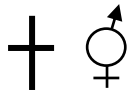
A small to medium sized, thorny tree, 8 m high and 15 – 25 cm in diameter with prickly branches; bark deep grey with irregular warty cracks and many prickles, lenticels wortlike, a few verticle long cracks present; branchlets grey, green while young, usually armed with stipular prickles.

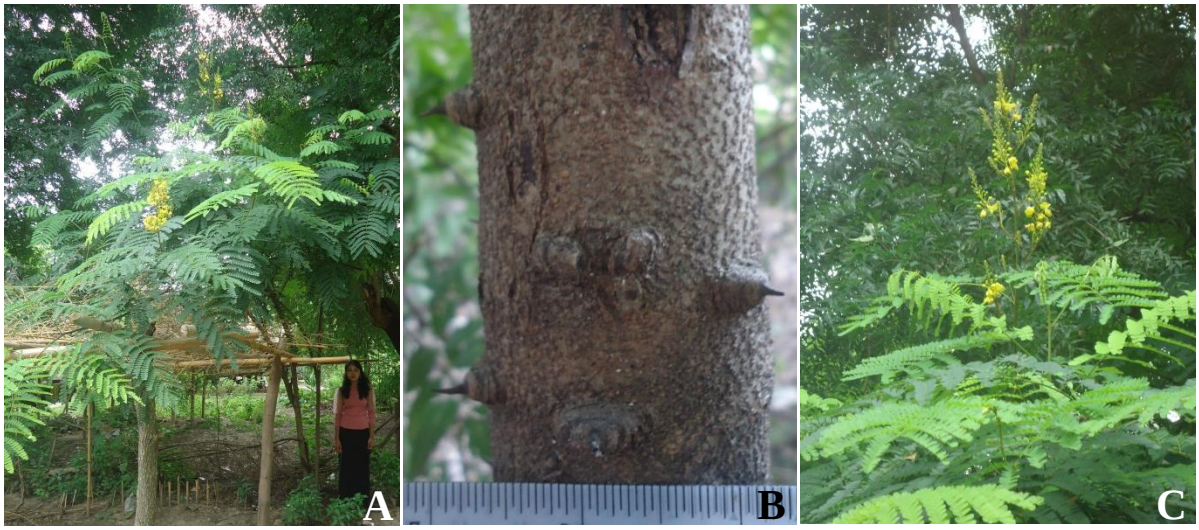
Leaves bipinnately compound, stipulate, alternate, 4 – 44 cm long 19.4 – 28.7 wide, petiole pulvinate, 4.5 – 18.0 cm long, bearing small prickles at the base, glabrous; primary rachis 23 – 38 cm long, with 8–12 pairs of pinnae, hairs pubescent; secondry rachis 9 – 13.5 cm long, 3 – 12 pairs of sessile leaflets on secondary rachae, hairs pubescent; leaflets oblong, 1.0 – 2.4 cm long and 0.7 – 1.1 cm wide, hairs glabrous, oblique at base, rounded to emarginate at apex.

Inflorescence an axillary or terminal paniculate raceme, up to 41 cm long; primary peduncle 3.5 – 6.0 cm long, hairs glabrous, 11 – 58 flowers in number per inflorescence; secondary peduncle 0.7 _4.5 cm long, hairs glabrous.

Flowers pediclelate, bracts lanceolate, 13 mm long, fragrant, zygomorphic, bisexual, 5-merous, 2.0 – 2.3 cm wide when open, yellow; calyx, 1+ 4, polysepalous, 11 mm long, leathery, glabrous; corolla 4+1, polypetalous, 2 cm across, petals orbicular, sub equal, yellow, the upper with a red spot at the base; stamens 10, unequal in length, with waxy-white hairs at the base, apostemonous, filaments woolly-hairy in the lower half, some recurved, anthers dithecous, longitudinal dehiscence, pollen granular; ovary monocarpellary, unilocular, stigma discoid, style slightly curved, white or pale green, pubescent, one row of ovules in the loculus, ovary superior, gynorphore present. Flowers cross-pollinated by bees, butterflies and insects.

Pods 5.0 – 7.4 cm long and 2.7 – 3.2 cm diameter, obliquely oblong, indehiscent, strongly flattened, shiny and glabrous with curved beak at apex, yellowish green when young, maturing to reddish brown, 3–5-seeded. Seeds ellipsoid, flattened, 15 – 16 mm and 8 –11 mm, yellowish - brown.

Floral formula:  $\mathbf{K_{1+4}\ C_{4+1}\ A_{10}\ \underline{G_1}}$



A. A plant fully bloomed in natural habit at Pauk Myaing Village. **B.** A portion of stem showing bark**.** **C.** Inflorescences on a tree.

D. Inflorescence. **E.** Terminal portion of an inflorescence showing floral buds. **F.** Developmental stages of flowers. **G.** Floral parts of a flower. **H.** pistil and stamens. **I.** L. S of a flower and ovary with basal portion of style showing four ovules in locule.

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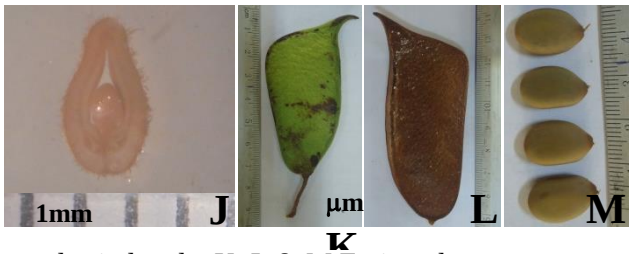


J. T. S of an ovary with ovules in locule. K, L & M Fruit and sees as seen.

Figure 4.2 Habit of *Caesalpinia sappan* L.

4.1.3 *Pterocarpus santalinus* L.f.

Pterocarpus santalinus L.f., Suppl. Pl. 318.1782; Hook.F., Fl. Brit. India 2: 239.1865; Gamble, Fl. Pres. Madras 384(271).1918.

Synonym:	*Lingoum santalinum* (L.f.) Kuntze
Local name:	Na-thani
Common name:	Burma padauk, Padauk, Red Sandalwood tree , Red bead tree
Subfamily:	Papilionoideae
Family:	Fabaceae
Locality:	Medicinal Garden, Forest Research Institute, Yezin
Specimen examined:	Kyi Kyi Khaing & Aye Nyein Chan,4 - 3- 2020
Flowering period:	September to November
Fruiting period:	December toJanuary

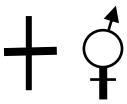
Taxonomic Description

A small to medium sized, deciduous tree growing to 4 m tall with a dense, rounded crown; bark blackish-gray, vertical cracks deep and large, yielding a deep red latex when cut.

Leaves unipinnately compound, imparipinnte, 13 – 29 cmlong and 8.5 – 20.0 cm width, petiole pulvinate, 2.5 – 4.5 cm long and 1 – 3 mm wide, number of leaflet usually 3, sometime 1 – 5, alternate, 4.8 – 12.6 cm long and 3.6 – 9.0 cm wide, lateral leaflets slightly opposite; leaflet broadly ovate, base obtuse, margin entire, tip slightly emarginated, lateral nerves distinct, lower surface pale and with fine grey hairs; petiolule 0.1 – 1.3 cm long, hairs.

Inflorescence raceme, flowers yellow, pedicles 0.5 mm long; calyx (5), 5 – 6 mm long, gamosepalous, teeth minute, (Sasidharan ver.2.0.), corolla 1+2+(2), polypetalous, papilionaceous, stamens 1+(9), pistil monocarpellayr, placentation marginal, one ovule in the locules in T.S., gynophore present.

Fruits (pods) obliquely orbicular, 3.8 – 5 cm diam including the wing,base narrow into a short stalk, concavely curved.Seeds 1-2, reddish brown, smooth, leathery, 1- 1.5 cm long (Sasidharan ver.2.0).

Floral formula:  $\mathbf{K_{(5)}\ C_{1+2+(2)}\ A_{1+(9)}\ \underline{G_1}}$

A. A cultivate tree in medicinal garden of FRI. **B.** A portion of stemshowing bark**. C., D. & E** Abranchlet.

F. & G. A branchlet. **H.** A branch with inflorescence (from internet.) I & J.Dry fruits (from internet.)

Figure 4.3 Habitof *Pterocarpus santalanus* L.f.

4.2 Anatomy

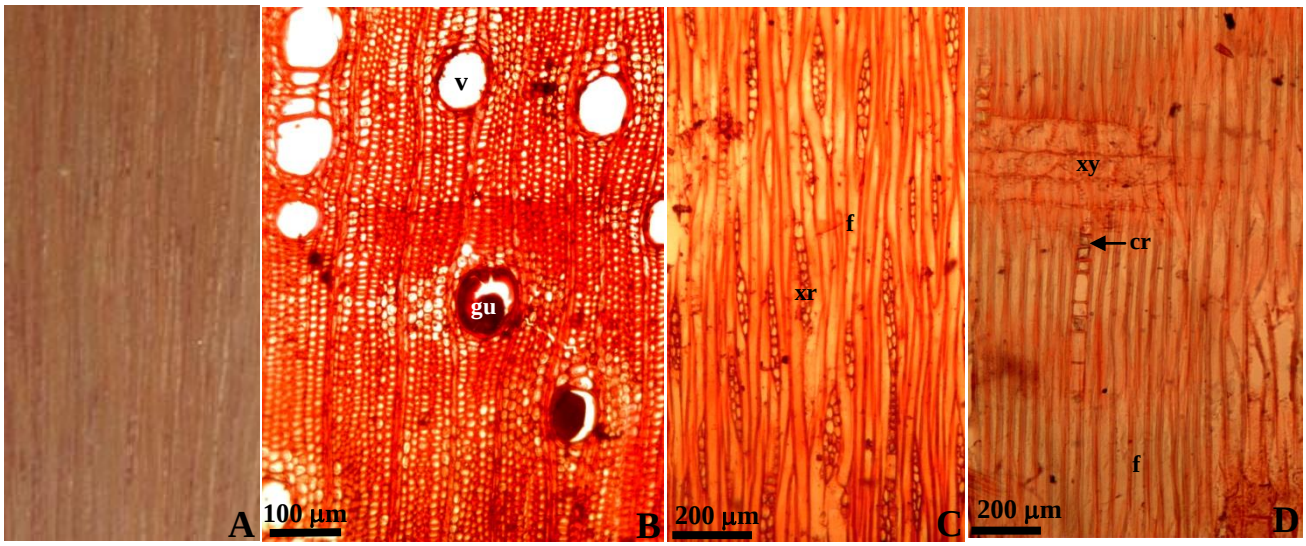
4.2.1 Wood of stem of *Adenanthera parvonina* L.

General characteristics and properties of the wood

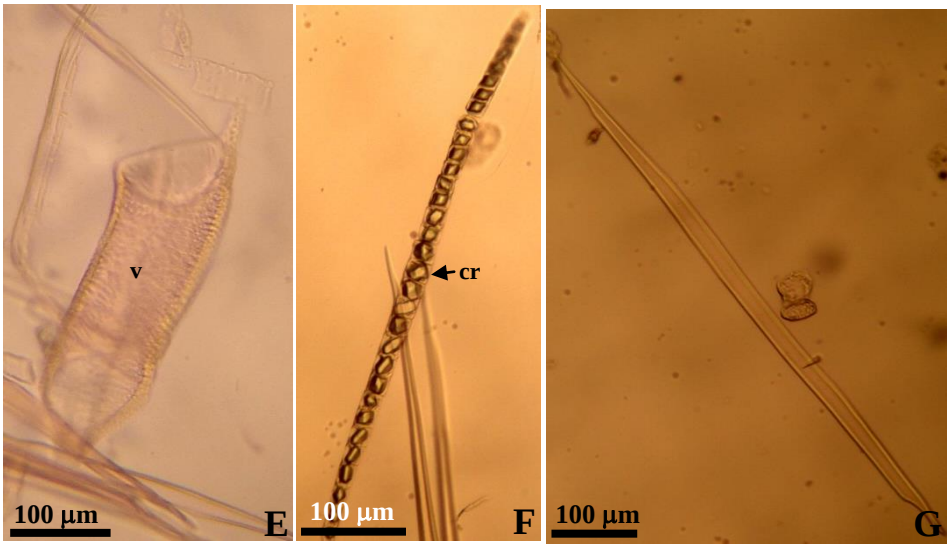
Sapwood of stem of *Adenanthera parvonina* L. studied is whitish and hardwood reddish brown; its odour and taste not distinct. It is hard wood, interlocked-grained and very fine-textured to medium textured. The wood is diffuse-porous and its growth ring is indistinct. Gum present in the vessel. Crystal chain present.

Microscopic characteristics

Vessel elements: Diffuse porous; pore very small to medium-sized, tangential diameter 30.0 – 190.0 μm (mean 123.0 μm), very fine-textured to medium textured; number per square mm



A. T.S of a portion of wood of stem as seen. **B.** T.S of a portion of wood of stem showing diffuse porous wood. **C.** T.L.S of a portion of wood of stem showing uniseriate, biseriate and multiseriate rays. **D.** R. L. S of stem wood showing homogenous ray cells with crystal change. (v – vessel, gu – gun, xr – xylem ray, f – fiber, cr – crystal.)



E. A vessel element with simple perforation plate. **F.** A fiber and parenchyma cells. **G.** A row of chambered prismatic crystals. (v – vessel element, f – fiber, pc – parenchyma cell, cr – crystal).

Figure 4.4 Internal structure and macerated elements of stem wood of *Adenanthera parvonina* L. .

few to moderately numerous (range 4 – 10); pore distribution solitary or as radial multiples or clusters, 1 – 11 (mostly solitary); pore circular in cross section; perforation plate simple; end walls oblique or transverse, tailed at one end or both ends; vessel element moderately short to medium-sized; 320 – 690 µm (mean 535.33 µm) long.

Fibres : Libriform, non-septate; very short to medium-sized, 630 – 1250µm (mean 947.0µm) long and 17.5– 35.0µm (mean 21.45 µm) wide, wall 5.0 – 22.5 µm (mean 8.6 µm) thick, thin or thick-walled, lumen 7.5 – 25.0 µm (mean 13.46 µm) thick, with tapering ends; chain of prismatic crystals present between the fiber cells.

Rays: Homogeneous, 1 – 3 seriate (mostly 2) cell wide; 5 – 11 per mm tangentially, moderately numerous to very numerous, uniseriate rays, 90.0 – 340.0 μm (mean 165.33 μm) in height, 18.0 – 20.0 μm (mean 19.3 μm) in width, 2 – 9 cells high, extremely fine to very fine; biseriate rays, 90.0 – 380.0 μm (mean 125.0μm) in height, 20.0 – 50.0 μm (mean 29.0μm) in width, 5 – 13 cells high, very fine to moderately fine.

Axial parenchyma : Paratracheal parenchyma aliform to confluent.

4.2.2 Bark of stem of *Adenanthera parvonina* L.

General characteristics and properties of the bark of stem

Bark of old stem of ***Adenanthera pavonina*** L. studied is gray with vertical shallow and long cracks, a few horizontal small cracks are present, very few patches of lichens may also found; 0.1 – 0.3 cm thick, 69 – 83 vertical lines per 5 cm square, forming ridges and shallow furrows, lenticel-like structures lying on the ridges; whitish yellow, fibrous, soft; odour and taste not distinct.

Microscopic characteristics

The older bark of the stem can be distinguished into protective layer, outer zone and inner conductive zone.

Protecive layer: It is outer-most zone of the stem. Epidermal cells damaged and no trace of cells left in old barks. Periderm formed around the stem at the outer part of cortex to protect the inner tissues, lenticels present, some lenticels closed and lying in the cortex.

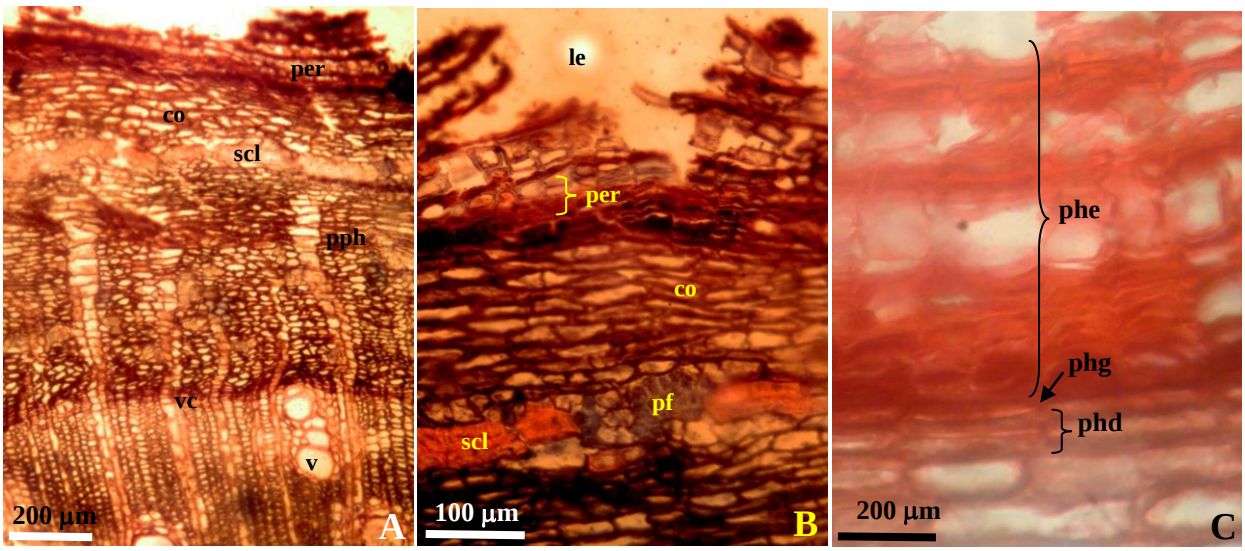
Periderm formed under a few layers of cortex at the outer part forming as a continuous ring around the cortex. Some lenticels formed beneath the periderm and closed. Periderm composed of phellogen or cork cambium, phellem or cork, and phelloderm (Fig. 4.5. B & C).

Phellogen lying between cork and phelloderm, one layered, parenchymatous, rectangular in shape, tangentially flattened, meristematic, usually with nucleus, gives rise to phellem or cork outside and gives rise to phelloderm inside; nucleus usually present, colourless.

Phellem or cork derived from phellogen or cork cambium, lying outside the phellogen, parenchymatous, slightly deep coloured, rectangular in shape, many layered, some cells forming sclereids.

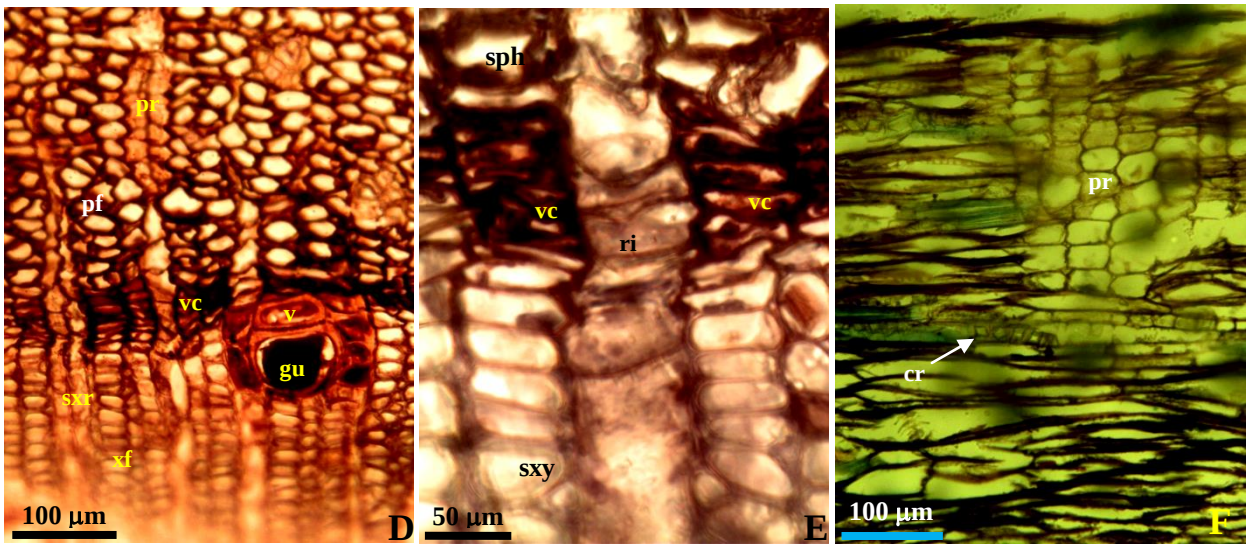
Phelloderm derived from phellogen or cork cambium, lying inside the phellogen, one or two layered, parenchymatous; rectangular, elongated, or polygonal in shape.

Outer zone of the bark: Composed of cortex, primary phloem and nonconductive phloem cells. Cortex lying outermost, parenchymatous, cells polygonal, tangentially elongated and irregular in shape,sclereids large cavity not found.



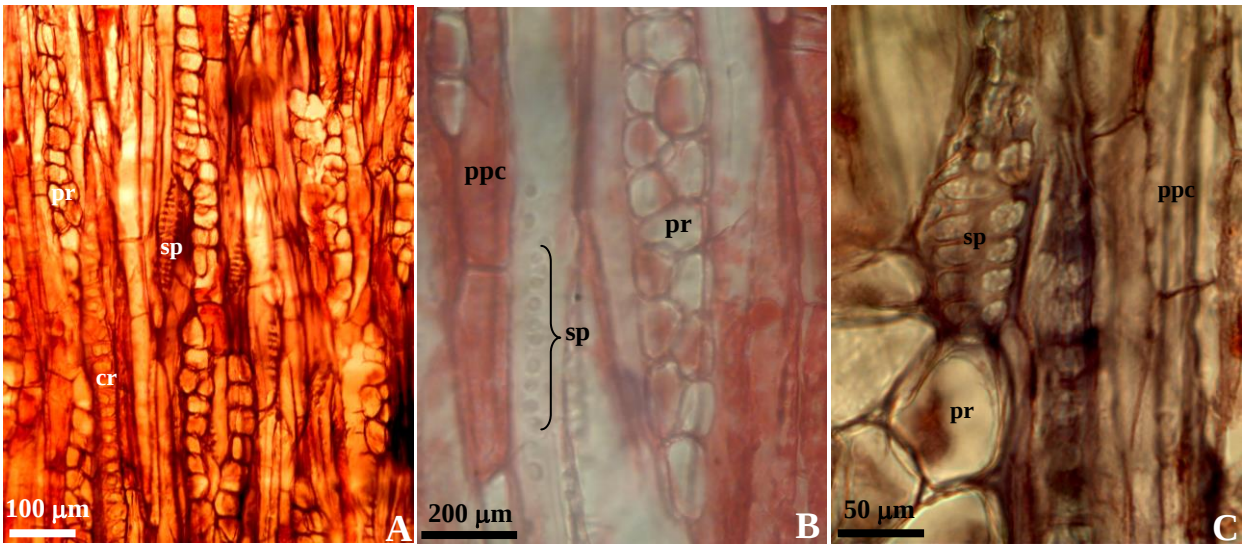
A. T.S of a portion of bark of stem showing phloem and xylem. **B.** T.S of a portion of outer bark of stem showing lenticel. **C.** T.S of a portion bark showing periderm.

(per – periderm, co –cortex, le – lenticel, pph – primary phloem, scl – sclereids, pf – phloem fiber, per – periderm, phg – phellogen, phe – phellem or cork, phd – phelloderm.)

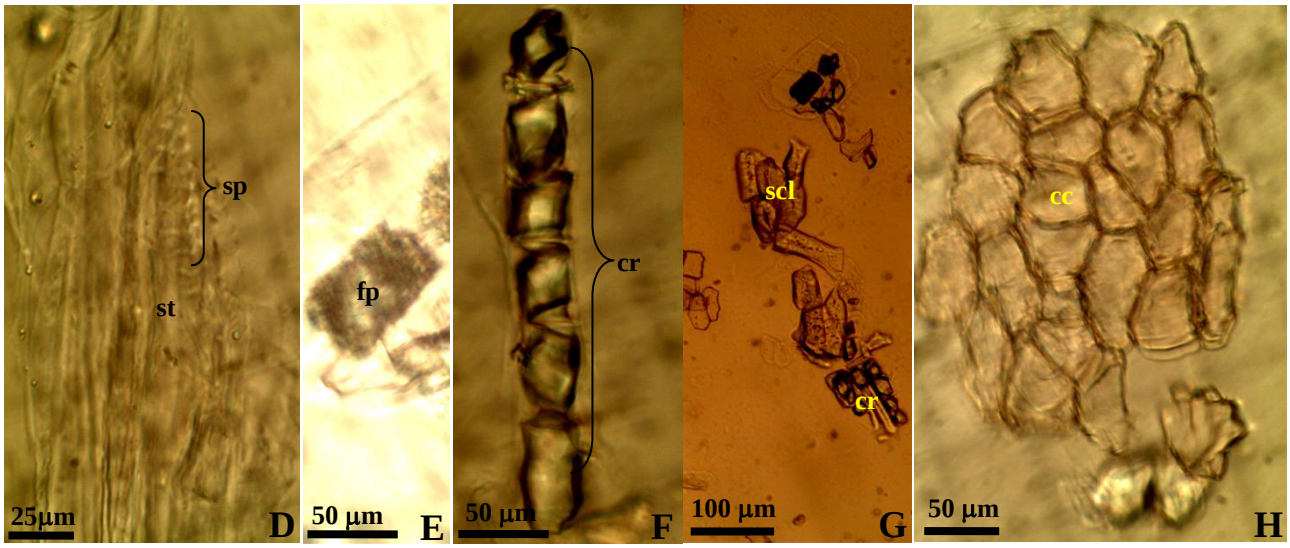


D. E. T.S of a portion of stem showing vascular cambial zone, secondary phloem and secondary xylem. **E.** T.S of a portion of stem showing vascular cambium and ray initial. F. R.L.S of bark of stem showing crystals and phloem rays.
(pf – phloem fiber, pr – phloem ray, gu – gum, vc – vascular cambial, ri – ray initial, sxr – secondary xylem ray, xf – xylem fiber, sxy – secondary xylem, cr – crystal, sph – secondary phloem.)

Figure 4.5 Internal structure of bark of stem of *Adenanthera parvonina* L. **.**



A. T.L.S of bark of stem showing phloem ray, sieve plate, and crystal chain. **B.** T.L.S of bark of stem showing phloem ray, phloem parenchyma, and border pit. **C.** T.L.S of bark of stem showing phloem ray, sieve plate sieve, and phloem parenchyma.
(pr – phloem ray, sp – sieve plate, cr – crystal, ppc – phloem parenchyma).



D. Terminal portion of a sieve tubeshowing compound sieve plates. **E.** Macerated element of bark of stem showing food particles. **F.** Macerated element of bark of stem showing crystals. G. Macerated element of bark of stem showing sclereids and crystals. H. Macerated element of bark of stem showing cork cells.
(dr – druses, scl – sclereids, cr – crystal, cc – cork cells, fp – food particles, sp – sieve plate, st – sieve tube.)

Figure 4.6 Internal structure and macerated elements of bark of stem of *Adenanthera parvonina* L.

Primary phloem cells lying inside the cortex, usually overlapped the cortex, mostly parenchymatous, cells rectangular, tangentially flattened, polygonal or irregular in shape, group of a few sclereids present, companion cell not distinct;sclereids forming discontinuous ring, phloem fibers in groups forming discontinuous ring, cells thick-walled, polygonal in shape, row of chambered crystals present, druses present.

Inner zone of the bark: composed of secondary phloem, outer layers of non-conductive secondary phloem, inner layers of conductive secondary phloem near vascular cambium, a few stretched sieve tubes present, companion cell not distinct; sieve tubes with many sieve areas at the lateral walls; phloem fibers forming many discontinuous rings, cells thick-walled, polygonal in shape; phloem parenchyma cells polygonal, elongated or irregular in shape, phloem ray cells uni- or biseriate.

Vascular cambium: Lying between phloem and xylem. Vascular cambium one-layered, parenchymatous, meristematic, tangentially flattened, rectangular, colourless, differentiated inti ray initial and fusiform initial; immediate derivatives a few layered; ray initial gives rise to phloem ray outside and to xylem ray inside; fusiform initial gives rise to secondary phloem outside and to secondary xylem inside.

Secondary phloem: Lyingoutside the vascular cambium, consisted of sieve tubes and companion cells, phloem parenchyma, ray parenchyma and phloem fibers. Sieve tubes near the cambium conductive, sieve tubes with compound sieve plates, sieve plates found at the lateral wall and end walls, compound sieve plates distinct, older sieve tubes non-conductive.

4.2.3 Wood of stem of *Caesalpinia sappan* L.

General characteristics and properties of the wood

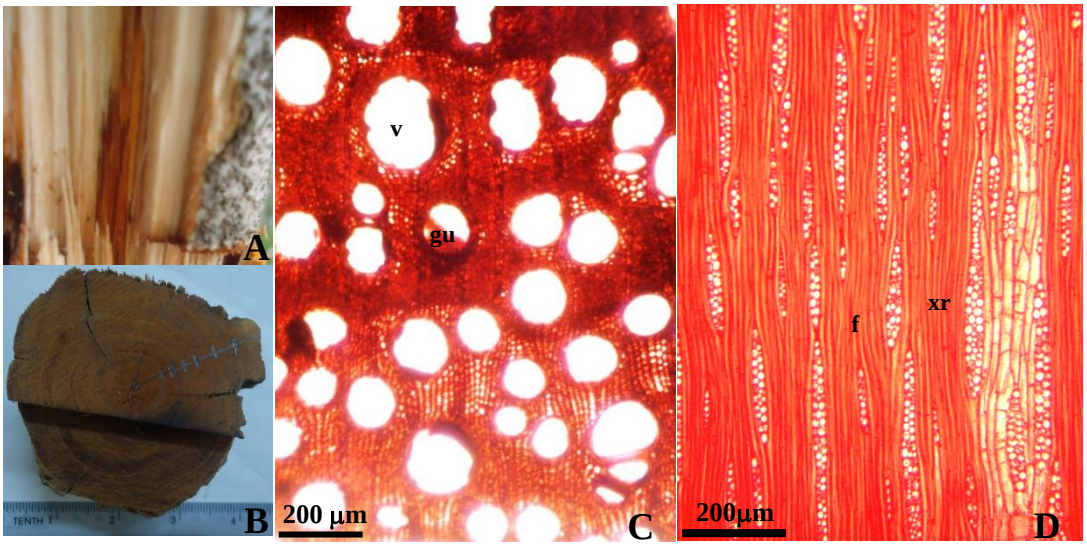
Sapwood of stem of ***Caesalpinia sappan*** L. studied is pale yellowish and hard wood orange when freshly cut, but quickly turned to red; odour and taste not distinct. Hard wood straight grained and very fine-textured to medium textured. The wood is diffuse porous and its growth ring distinct. Gum present in the vessel. Row of chambered crystals present.

Microscopic characteristics

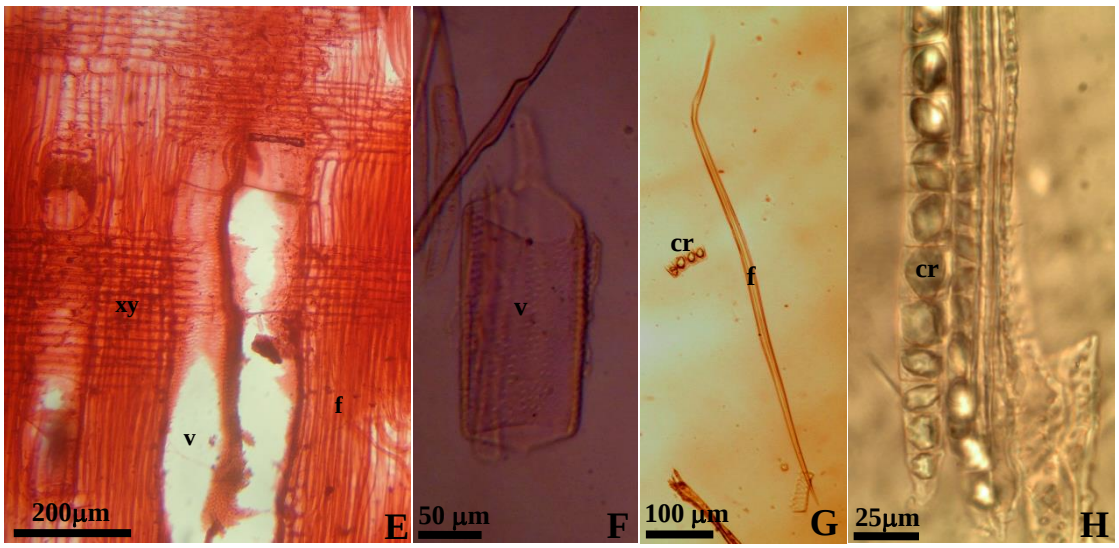
Vessel elements: Diffuse porous; pore very small to medium-sized, tangential diameter 30 – 200 μm (mean 100 μm), very fine-textured to medium textured; number per square mm very numerous (range 12 – 35); pores solitary or as radial multiples or clusters, 2 – 9 (mostly 2); pore circular in cross section ;perforation plate simple; end walls oblique or transverse; intervessel pits alternate, crowded, vessel element extremely short to medium-sized; 150 – 310 μm (mean 240.66 μm) long.

Fibres : Libriform, non-septate; very short to medium-sized, 540 – 1120 μm (mean 837.66 μm) long and 4 – 8 μm (mean 5.95 μm) wide, wall 2.0 – 5.5 μm (mean 3.9 μm) thick, thick-walled, lumen 2 – 6 μm (mean 1.98 μm),with tapering ends; chain of prismatic crystals present between the fiber cells.

Rays: Homogeneous, 1 – 5 seriate (mostly 3), 8 – 14 per mm tangentially, moderately few to moderately numerous; uniseriate rays 40 – 200 μm (mean 114 μm) in height, 2 – 14 cells high, moderately fine to moderately broad, 10 – 28 μm (mean 13.2 μm) in width; triseriate rays



A. L.S of a portion of sapwood of stem as seen. **B.** T.S of a portion of wood of stem as seen. C. T.S of a portion of stem showing diffuse porous wood. **D.** T.L.S of a portion of wood of stem showing uniseriate, biseriate and multiseriate rays. (v – vessel, gu – gum, xr – xylem ray, f – fiber.)



E. R.L.S of stem wood showing homogenous ray cells. F. A vessel element with simple perforation plate. **G.** Fibers. **H.** Prismatic crystal chain. (v – vessel element, f – fiber, cr – crystal.)

Figure 4.7 Internal structure and macerated elements of stem wood of *Caesalpinia sappan* L.

130 – 410 µm (mean 218.7 µm) in height, 5 – 22 cells high; fine to numerous, 10 – 30 µm (mean 29 µm) in width.

Axial parenchyma : Paratracheal parenchyma vasicentric, confluent and banded, irregularly storied.

4.2.4 Bark of stem of *Caesalpinia sappan* L.

General characteristics and properties of the bark of stem

Bark of old stem of ***Caesalpinia sappan*** L. studied is deep grey with irregular warty cracks and many prickles, lenticels wortlike, a few verticle long cracks present; branchlets grey, green while young, usually armed with stipular prickles. 0.3 – 0.35 cm thick, a few horizontal small cracks per 5 cm square, lenticels-like structures forming irregular ridges; brownish yellow, fibrous, soft; odour taste not distinct.

Microscopic characteristics

The older bark of the stem can be distinguished into protective layer, outer zone and inner conductive zone.

Protecive layer: It is outer-most zone of the stem. Epidermal cells damaged and no trace of cells left in old barks as the girth of stem grows. Periderm formed around the stem at the outer part of cortex to protect the inner tissues, lenticels present, some lenticels closed and lying in the cortex.

Periderm formed at the outer part of cortex forming as a continuous ring around the cortex. Some lenticels formed beneath the periderm and closed. Periderm composed of phellogen or cork cambium, phellem or cork, and phelloderm.

Phellogen lying between cork and phelloderm, one layered, parenchymatous, rectangular in shape, tangentially flattened, meristematic, usually with nucleus, gives rise to phellem or cork outside and gives rise to phelloderm inside, colourless.

Phellem or cork lying outside the phellogen, parenchymatous, rectangular in shape, a few layered.

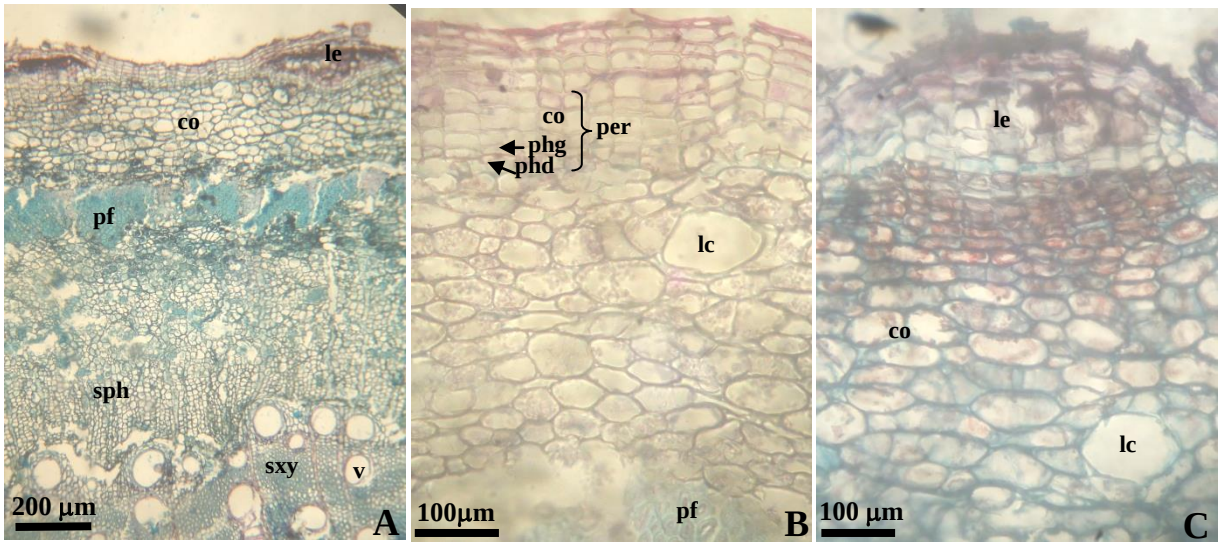
Phelloderm lying inside the phellogen, one layered, parenchymatous, rectangular or polygonal in shape.

Outer zone of the bark: Composed of cortex, primary phloem and nonconductive phloem cells. Cortex lying outermost, parenchymatous, cells polygonal, tangentially elongated and irregular in shape, rings of stretched sieve tube present, many large cavity present.

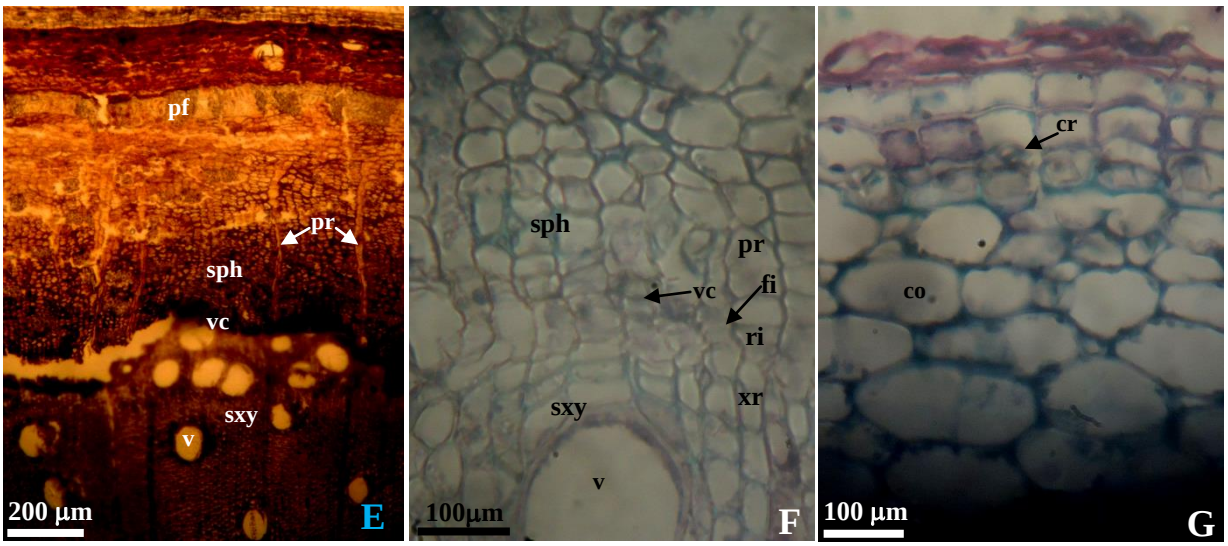
Primary phloem cells lying inside the cortex, usually overlapped the cortex, mostly parenchymatous, cells rectangular, polygonal or irregular in shape, tangentially flattened, group of a few sclereids present, a few stretched sieve tubes present, phloem fibers in groups forming discontinuous ring, cells thick-walled, polygonal in shape.

Inner zone of the bark: Composed of secondary phloem, outer layers of non-conductive secondary phloem, inner layers of conductive secondary phloem near vascular cambium, group of stretched sieve tubes forming like a ring, companion cell not distinct; sieve tubes with many sieve areas at the lateral walls; phloem fibers forming many discontinuous rings, cells thick-walled, polygonal in shape; phloem parenchyma cells polygonal, elongated or irregular in shape; phloem ray cells distinct, bi- to multi-seriate.

Vascular cambium: Lying between phloem and xylem. Vascular cambium one-layered, parenchymatous, meristematic, tangentially flattened, rectangular, colourless, differentiated



A. T.S of a portion of bark of stem showing secondary phloem and secondary xylem. **B.** T.S of a portion of outer bark of stem showing periderm, large cell, cortex and phloem fiber. **C.** T.S of a portion of outer bark showing lenticel.
(per – periderm, co –cortex, v – vessel, scl – sclereids, pf – phloem fiber, sph – secondary phloem, sxy – secondary xylem, phg – phellogen, phd – phelloderm, lc – large cell, le - lenticel.)

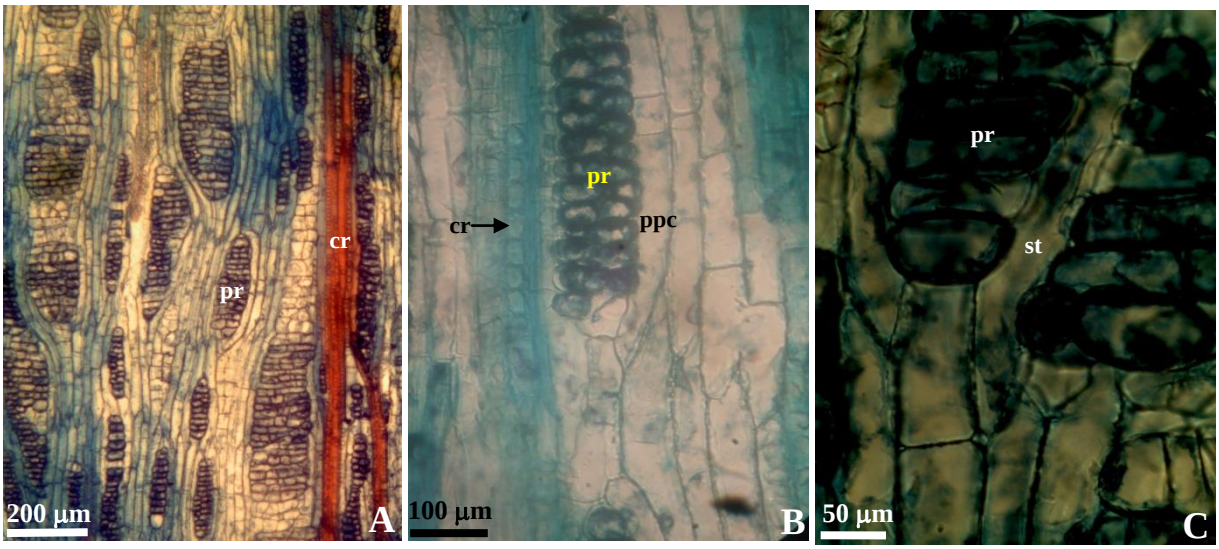


E. T.S of a portion of stem showing vascular cambial zone, secondary phloem and secondary xylem.**F.**T.S of a portion of stem showing vascular cambium, secondary phloem and secondary xylem. **G.**T.S of a portion of stem showing crystal chain and cortex.

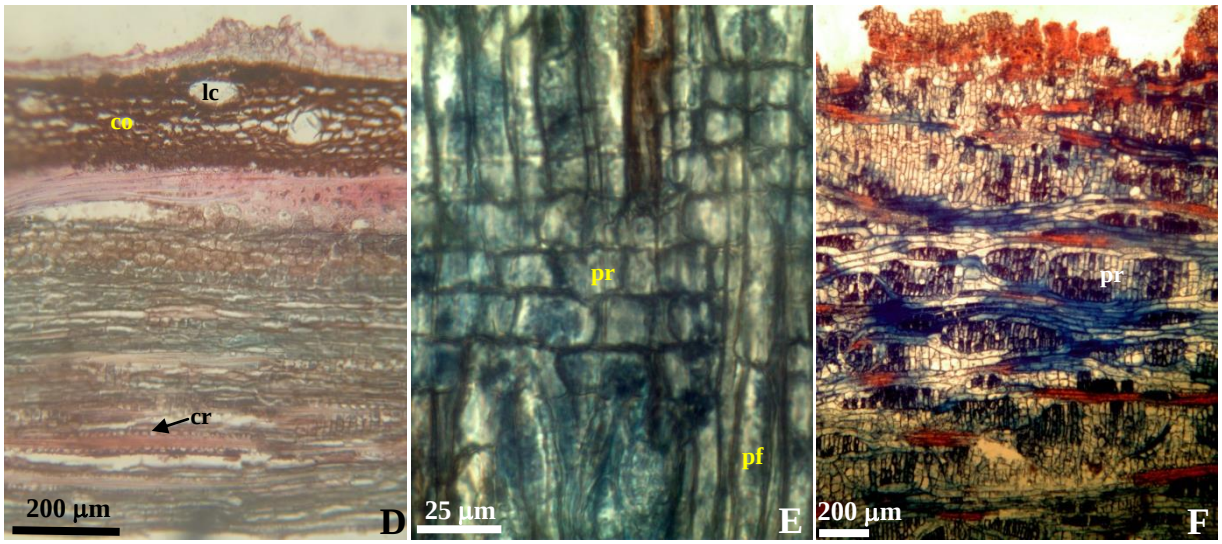
(pf – phloem fiber,pr – phloem ray,sph – secondary phloem, sxy – secondary xylem, v – vessel, vc – vascular cambium, fi – fusiform initial, ri – ray initial, cr – crystal, co – cortex)

Figure 4.8 Internal structure of bark of stem of *Caesalpinia sappan* L. **.**

inti ray initial and fusiform initial; ray initial gives rise to phloem ray outside and to xylem ray inside; fusiform initial gives rise to secondary phloem outside and to secondary xylem inside.



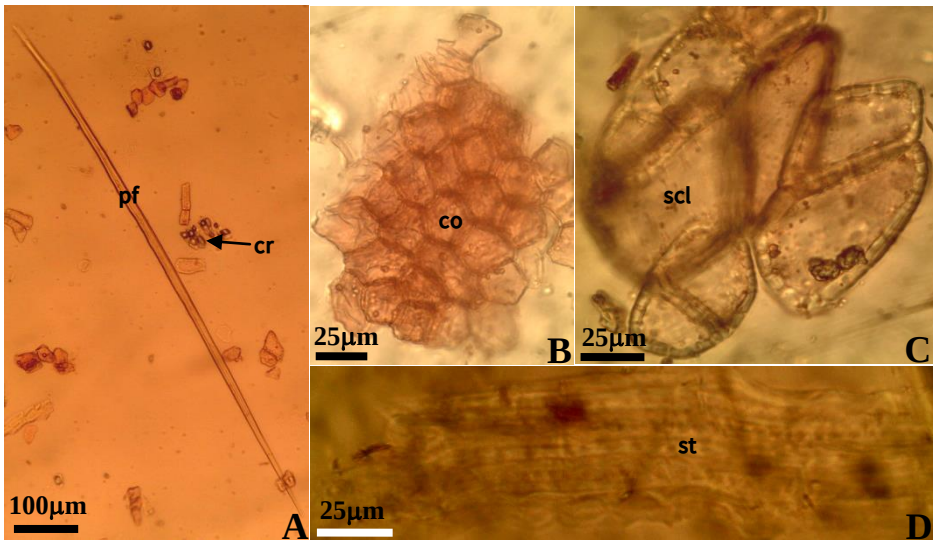
A. T.L.S of bark of stem showing phloem ray and crystal chain. **B.** T.L.S of bark of stem showing phloem ray, phloem parenchyma, and crystal chain. **C.** T.L.S of bark of stem showing phloem ray, sieve tube.
(pr – phloem ray, cr – crystal, ppc – phloem parenchyma, st – sieve tube, pt – border pit.)



D. R.L.Sof bark of stem showing crystals and phloem rays. **E.** R.L.S of of bark of stem showing phloem rays crystals and fiber. **F.** T.L.S of a portion of outer bark of stem showing cortex and phloem rays. (co –cortex, cr – crystal, lc – large cell, pr – phloem ray, pf – phloem fiber).

Figure 4.9 Internal structure of bark of stem of *Caesalpinia sappan* L.

Secondary phloem: Lying outside the vascular cambium, consisted of sieve tubes and companion cells, phloem parenchyma, ray parenchyma and phloem fibers. Sieve tubes near the cambium conductive.



A. Bark fiber and crystals. **B.** Cork cells. **C.**Sclereids. **D.** Macerated element of bark of stem showing sieve tube. (co –cortex, cr – crystal, st – sieve tube, pr – phloem ray, pf – phloem fiber.)

Figure 4.10 Macerated elements of bark of stem of *Caesalpinia sappan* L.

4.2.5 Wood of stem of *Pterocarpus santalinus* L.f.

General characteristics and properties of the wood

Sapwood of stem of *Pterocarpus santalanus* L.f. is bright yellowish-red; its odour and taste distinct. It is hard wood, interlocked-grained and very fine-textured to coarse textured. The wood is diffuse-porous and its growth ring is distinct.

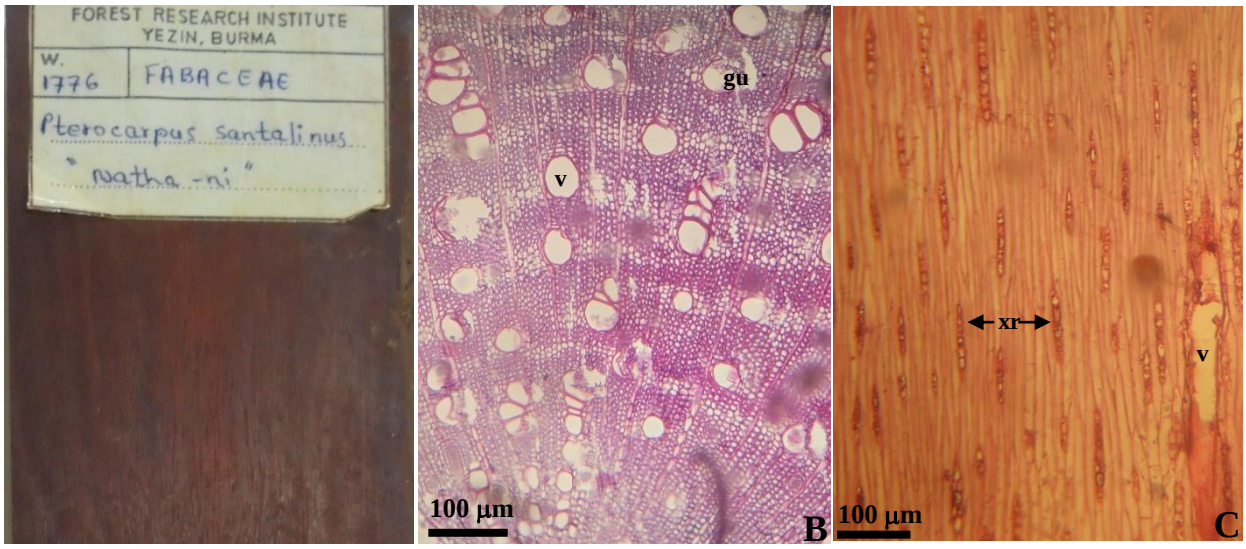
Microscopic characteristics

Vessel elements: Diffuse porous; pore very small to moderately large, tangential diameter 40 – 230 µm (mean 117.06 µm), very fine-textured to coarse textured; number per square mm few to moderately numerous (range 5 – 18); pore distribution solitary or as radial multiples or clusters, 2 –8 (mostly 2); pore circular in cross section; perforation plate simple; end walls oblique or transverse, tailed at one end or both ends or tailless; intervessel pits alternate, crowded, vessel element extremely short to moderately short; 120 – 290 µm (mean 189.5 µm) long.

Fibres : Libriform, non-septate; extremely short to medium-sized, 110 – 1210µm (mean 783.6µm) long and 5 – 11µm (mean 6.9µm) wide, wall 1.5 –5.0 µm (mean 3.17 µm) thick, thin or thick-walled, lumen 3.0 – 6.0 µm (mean 3.73 µm) thick, with tapering ends and fork; chain of prismatic crystals present between the fiber cells.

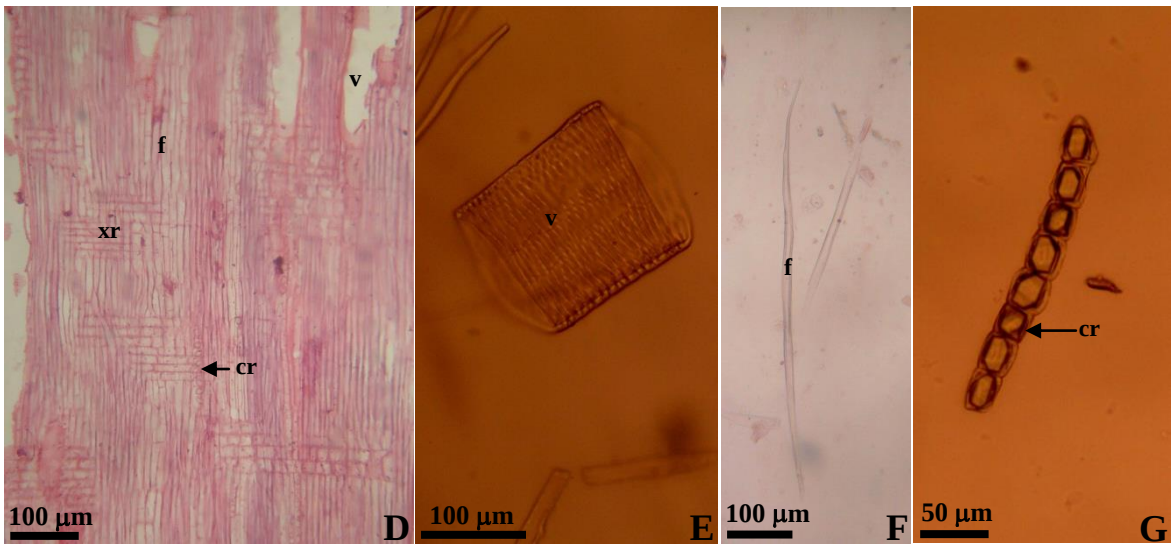
Rays: Homogeneous; uni- or bi-seriate one or two cells wide; 12 – 18 per mm tangentially, numerous to very numerous, uniseriate rays 60 – 250 µm (mean 146.66µm) in height, extremely fine to very fine, 10 – 20 µm (mean 18.33µm) in width; 3 – 10 cells high; biseriate ray 70 – 142 µm (mean 97.13µm) in height, extremely fine to very fine, 15 – 25µm (mean 18.73µm) in width; 3 – 7 cells high; pits between ray cells and other parenchyma cells few and size of pits small, gum deposits present.

Axial parenchyma : Paratracheal parenchyma vasicentric, aliform and confluent, banded.



A. Wood of stem as seen. **B.** T.S of a portion of wood of stem showing solitary, radial and multiple pores. **C.** T.L.S of a portion of wood of stem showing uniseriate and biseriate rays.

(v – vessel, gu– gum,xr – xylem ray, cr – crystal.)



D. R. L. S of stem wood showing homogenous ray cells with crystal change. **E.** A vessel element. **F.** Fibers. G. A row of chambered prismatic crystals.

(v – vessel element, xr – xylem ray f – fiber, cr – crystal.)

Figure 4.11 Internal structure and macerated elements of stem wood of *Pterocarpussantalin*

4.2.6 Bark of stem of *Pterocarpus santalinus* L.f.

General characteristics and properties of the bark of stem

Bark of old stem of *Pterocarpus santalinus* L. studied is bark blackish-gray, vertical cracks deep and large, forming deep furrows and ridges, horizontal short cracks present; 1.0 – 1.5 cm thick (Mohammad Azamthulla et al. 2014), 3 – 7 vertical ridges per 5 cm square; reddish brown, fibrous, soft; odour taste not distinct.

Microscopic characteristics

The older bark of the stem can be distinguished into protective layer, outer zone and inner conductive zone.

Protecive layer: It is outer-most zone of the stem. Epidermal cells damaged and no trace of cells observed. Periderm formed around the stem at the outer part of cortex to protect the inner tissues, lenticels present, some lenticels closed and lying in the cortex. Periderm formed at the outer part of cortex forming as a continuous ring around the cortex. Some lenticels formed beneath the periderm and closed. Periderm composed of phellogen or cork cambium, phellem or cork, and phelloderm (Fig.4.11 C).

Phellogen lying between cork and phelloderm, one layered, parenchymatous, rectangular in shape, tangentially flattened, meristematic, gives rise to phellem or cork outside and to phelloderm inside, colourless.

Phellem or cork lying outside the phellogen, parenchymatous, rectangular in shape, flattened, many layered, some cell formed sclereid.

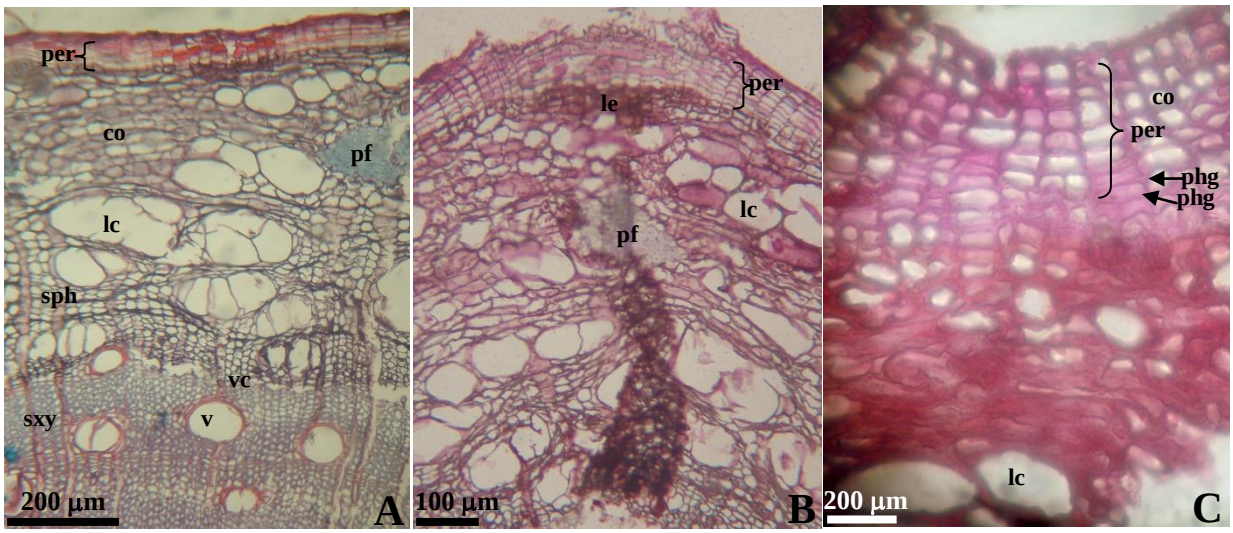
Phelloderm lying inside the phellogen, two or three layered, parenchymatous, rectangular or elongated.

Outer zone of the bark: Composed of cortex, primary phloem and nonconductive phloem cells. Cortex lying outermost, parenchymatous, cells polygonal, tangentially elongated and irregular in shape, rings of stretched sieve tube present, many groups of large cells present.

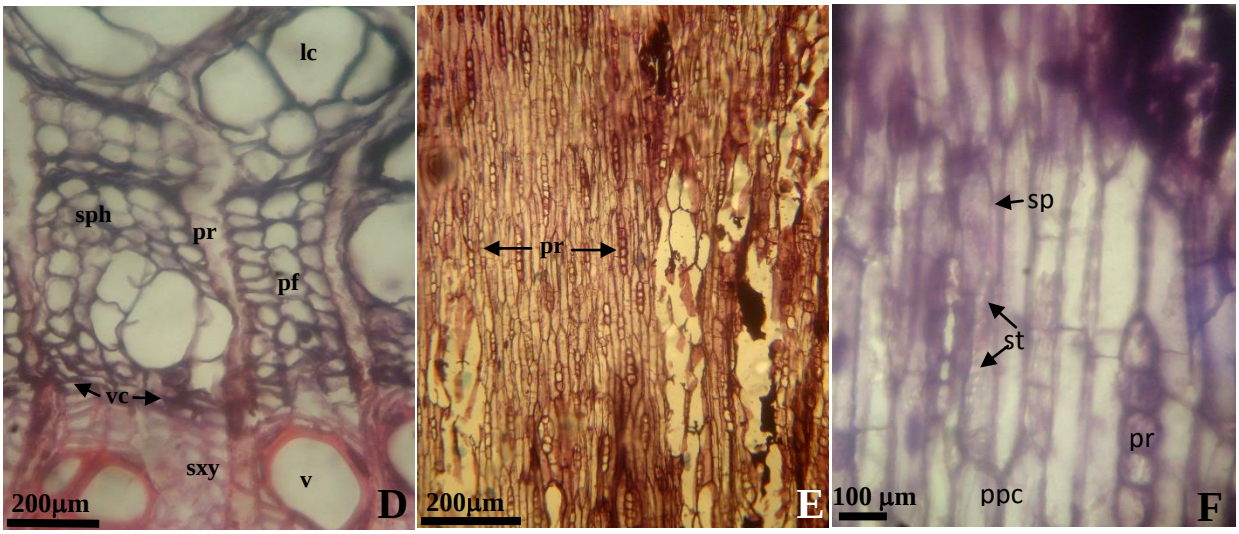
Primary phloem cells lying inside the cortex, usually overlapped the cortex, mostly parenchymatous, cells rectangular, polygonal or irregular in shape, tangentially flattened, group of a few sclereids present; a few stretched sieve tubes present, phloem fibers in groups present, cells thick-walled, polygonal in shape, phloem ray cells observed, many groups of large cells present.

Inner zone of the bark: composed of secondary phloem, outer layers of non-conductive secondary phloem, inner layers of conductive secondary phloem near vascular cambium, group of stretched sieve tubes present, companion cell not distinct; sieve tubes with many sieve areas at the lateral walls; phloem fibers in group, cells thick-walled, polygonal in shape; phloem parenchyma cells polygonal, elongated or irregular in shape; phloem ray cells distinct, uni- or bi-seriate, many groups of large cells observed.

Vascular cambium: Lying between phloem and xylem. Vascular cambium one-layered, parenchymatous, meristematic, tangentially flattened, rectangular, colourless, differentiated intiray initial and fusiform initial; ray initial gives rise to phloem ray outside and to xylem ray inside; fusiform initial gives rise to secondary phloem outside and to secondary xylem inside.



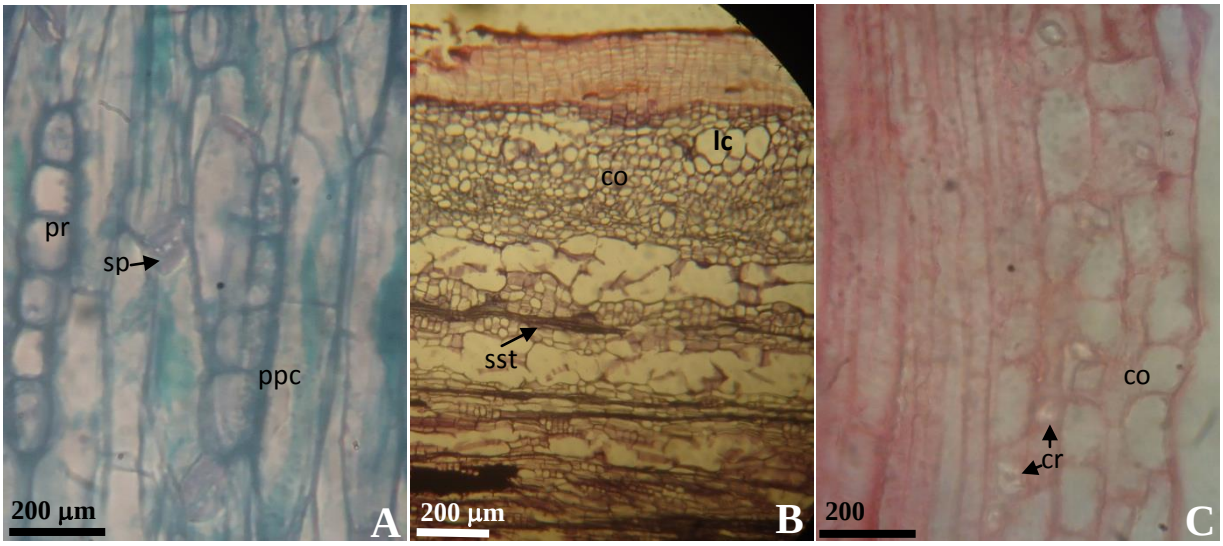
A. T.S of a portion of bark of stem showing phloem and xylem. A portion of stem showing bark**. B.** T.S of a portion of outer bark showing lenticel. **C.** T.S of a portion of outer bark of stem showing periderm.
(per – periderm, co –cortex, sph – secondary phloem, v – vessel, vc – vascular cambial , pf – phloem fiber, sxy – secondary xylem, phg – phellogen, phd – phelloderm, lc– large cell, le - lenticel.)



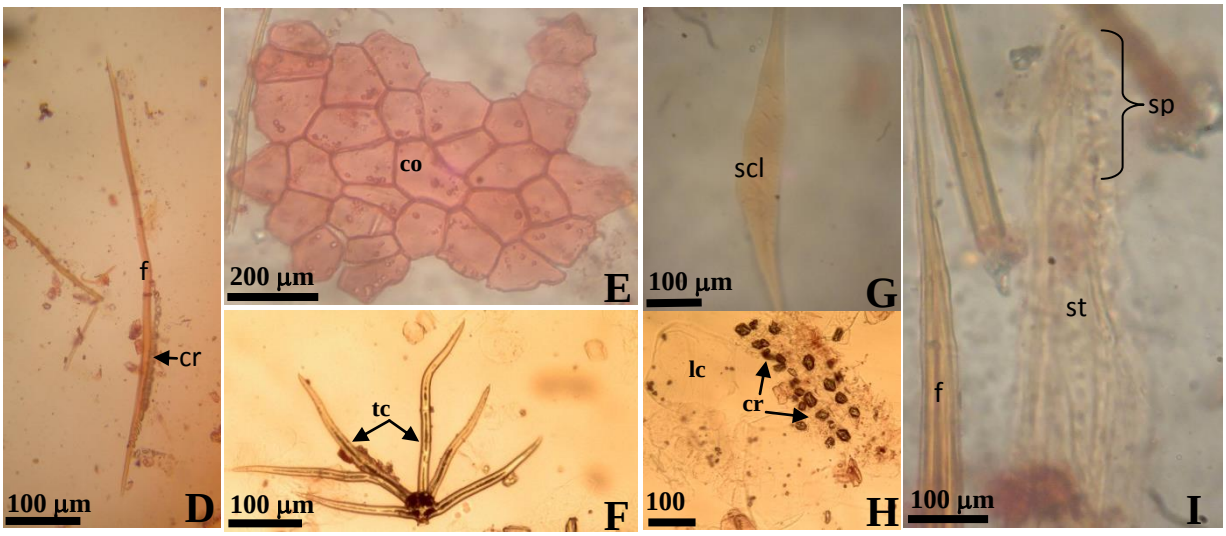
D. T.S of a portion of stem showing vascular cambial zone and phloem ray, secondary phloem, secondary xylem, phloem fiber and large cell. **E & F.** T.L.S of bark of stem showing phloem ray, phloem parenchyma, sieve tube and sieve plate.

(lc – large cell, pf – phloem fiber,pr – phloem ray,ppc – phellogen parenchyma,sph – secondary phloem, sxy – secondary xylem, v – vessel, vc – vascular cambial.)

Figure 4.11. Internal structure of bark of stem of *Pterocarpus santalinus* L.f .



A. T.L.S of bark of stem showing sieve plate, phloem ray and phloem parenchyma cell. **B.** T.L.S of bark of stem showing stretched sieve tubes and large cell. C. R.L.S of a portion of bark of stem showing cortex and crystal. (pr – phloem ray, ppc – phloem parenchyma cell, co – cortex, cr – crystal, lc – large cell, sst – stretched sieve tubes, sp –sieve plate).



D. Macerated element of bark of stem showing fiber. E. Macerated element of bark of stem showing cortex. F. Bark trichome. G. sclereids. H. large cell and crystals. I. Macerated element of bark of stem showing sieve tube and sieve plate.
(f – fiber, cr – crystal, co – cortex, tc – trichome, scl – sclereids, lc – large cell, st – sieve tubes, sp – sieve plate.)

Figure 4.13 Macerated elements of bark of stem of *Pterocarpus santalinus* L.

Secondary phloem: Lying outside the vascular cambium, consisted of sieve tubes and companion cells, phloem parenchyma, ray parenchyma and phloem fibers. Sieve tubes near the cambium conductive, many groups of large cells observed.

Table 4.1 Qualitative characteristics of wood structure of three species.

Sr. No.	Qualitative chracteristics	*Adenanthera pavonina*	*Caesalpinia sappan*	*Pterocarpus santalinus*
1	Growthrings	indistinct	distinct	distinct
2	Texture	very fine to medium	very fine to medium	very fine to coarse
3	Grain	interlocked-grain	straight	interlocked-grained
4	Odour & taste	Absent	Absent	Distinct
5	Porosity	Diffuse porous	Diffuse porous	Diffuse porous
6	Size of pores	very small to medium-sized	very small to medium-sized	very small to moderately large
7	Shape of pores	circular	circular	circular
8	Perforation plate	Simple	Simple	Simple
9	Axial parenchyma	aliform	vasicentric confluent	banded
10	Ray type	Homogeneous	Homogeneous	Homogeneous
11	Fiber septation	Non-septate	non-septate	non-septate
12	Fiber type	Libriform	Libriform	Libriform
13	Tyloses	Absent	Absent	Absent
14	Gum deposits	Gum deposits present in vessels	Gum deposits present in vessels	Gum deposits present in vessels
15	Crystals	Crystals present	Crystals present	Crystals present

Table 4.2 Quantitative characteristics of wood structure of three species**.**

Sr. No	Quantitative chracteristics	*Adenanthera pavonina*	*Caesalpinia sappan*	*Pterocarpus santalinus*
1	Pore frequency (per.sq mm) (µm)	4 – 10	12 – 35	5 – 18
2	Vessel diameter	30.0 – 190.0 (mean 123.0)	30.0 – 200.0 (mean 100.0)	40.0 – 230.0 (mean 117.06)
3	Vessel length	320 – 690 (mean 535.33)	150 – 310 (mean 240.66)	120 – 290 (mean 189.5)
4	Fiber length	630 – 1250 (mean 947.0)	540 – 1120 (mean 837.66)	470 – 1350 (mean 893.3)
5	Fiber width	7– 14 (mean 8.38)	4– 8 (mean 5.95)	5 – 11 (mean 6.9)
6	Fiber walled thickness	2.0 – 9.0 (mean 3.43)	2.0 – 5.5 (mean 3.9)	1.5 –5.0 (mean 3.17)
7	Uniseriate rays height	90.0 – 340.0 (mean 165.33)	40.0 – 200.0 (mean 114.0)	60 – 250 (mean 146.66)
8	Uniseriate rays width	18.0 – 20.0 (mean 19.3)	10.0 – 28.0 (mean 13.2)	10 – 20 (mean 18.33)
9	Biseriate rays height	90.0 – 380.0 (mean 125.0)	130.0 – 410.0 (Tri) (mean 218.7)	70 – 142 (mean 97.13)
10	Biseriate rays width	20.0 – 50.0 (mean 29.0)	10.0 – 30.0 (Tri) (mean 29.0)	15 – 25 (mean 18.73)

Table 4. 3 Size of ray of stem bark of three species studied**.**

No.	Characters	*Adenanthera pavonina*	Caesalpinia sappan	*Pterocarpus santalinus*
1	Ray/mm tgm	(4 – 9) Moderately numerous to numerous	(3 – 8) Few to numerous	(3 – 10) Few to numerous
2	Uni ray high	55.0 – 285.0 (mean 145.66)	62.0 – 216.0 (mean 133.26)	30.0 – 170.0 (mean 80.66)
3	Uni ray width	10.0 – 30.0(mean 17.2) Extremely fine to moderately fine	15.0 – 31.0(mean (21.56) Extremely fine to moderately fine	10.0 – 20.0(mean (13.4) Extremely fine to very fine
4	Uni ray height	(1 – 10)	(4 – 14)	(2 – 7)
5	Bi ray high	120 – 650(mean 300.83)	160 – 485(mean 282.36)	70 – 142 (mean 97.13μm)
6	Bi ray width	(15 – 40) mean (26.7) Extremely fine-derately	(21 – 51) mean (39.86) Very fine toMediumsized	15 – 25μm (mean 8.73μm) extremely fine to very fine
7	Bi ray height	(5 –21)	(9 – 38)	(3 – 7)

Table 4. 4 Size of fiber of stem bark of three species studied

Sr.No	Species Name	Fiber length (μm)	F-width	Lumen width	F-wall thickness
1	*Adenantherapavonina*	430 – 2600 (mean1221.8) Extremely short to very long	15 – 27.5 (mean 20.37)	5.0 – 17.5 (mean 9.04)	2.5 – 17.5 (mean 11.16)
2	Caesalpiniasappan	540 – 1390 (mean 910.0μm) Very short to medium sized	11.25- 27.5 (mean 15. 54)	2.5 – 15.0 (mean 9.08)	2.5 – 10.0 (mean 6.62)
3	*Pterocarpussantalinus*	400 – 1530 (mean 792.0) Extremely short to medium -sized	10.0- 22.5 (mean 13.45)	5.0 – 15.0 (mean 8.16)	2.5 – 15.0 (mean 5.29)

5. Discussion and conclusion

The two timber species, *Adenanthera pavonina* L. and *Pterocarpus santalinus* L.f., grown in arboretum of Forest Research Institute, Yezin, and one, *Caesalpinia sappan* L., from Pauk-Myaing village in Lewai Township were selected and their morphology and anatomical characteristics of wood and barks of their stem were studied, described and compared.

Among the three species, *Adenanthera pavonina* L. was known to be endamic to Southern China and India according to Renilda et al. (2015). However, *Adenanthera pavonina* L. was found cultivated in Myanmar.

Aronkumar and Joshi (2014) stated that *Pterocarpus santalinus* L.f. was endamic and endangered species of India. Zhang et al. (2018) also described that this species was endangered species and listed in CITES Appendix II. *P. santalinus* L.f. was not found in Myanmar as wild plant, and the species was introduced from foreign country and recently cultivated. This species studied was so young that flowers or fruits were not found on the trees. Although Kress et al. (2003) described that *P. santalinus* L.f. was found to be cultivated in Myanmar since 2003, the mature trees of this species were not unfortunately found in Myanmar yet.

Among the three species studied, *Adenanthera pavonina* L. are medium-sized to large deciduous tree whereas *Caesalpinia sappan* L. and *Pterocarpus santalinus* L.f. were small to medium sized tree.

The morphology of barks of the tree differs from each other. In *Adenanthera pavonina* L., the bark is deep gray with vertical shallow and long cracks, and a few horizontal small cracks are present. In *Caesalpinia sappan* L., the bark is grey with irregular warty cracks and many prickles, lenticels wortlike, and a few verticle long cracks present. In *Pterocarpus santalinus* L.f., the bark is blackish-gray with deep and large vertical cracks, forming deep furrows and ridges, and horizontal short cracks present.

In this study, the outer bark of *Adenanthera pavonina* L. was found to be deep gray with vertical shallow and long cracks and inner bark was whitish yellow and fibrous. Abdu et al. (2019) described that it was dark brown to greyish bark and inner bark was soft-pale brown, and Geronço et al. (2020) also described that the bark was smooth and brown to greyish in colour with many fissures.

In this paper, the bark of *Pterocarpus santalinus* L.f. is blackish-brown, yielding a deep red latex when cut, but Arunkumar et. al (2014) stated that the bark is typically dark brown in colour with rectangular plates and deeply fissured when matured.

In this paper, the leaves of *Adenanthera pavonina* L. were bipinnately compound with 9 – 13 pairs of leaflets. However Abdu1 et al. (2019) stated that its leaves were bi-pinnate in nature with 8 – 21 leaflets on short stalks.

In this paper, pods of *Caisalpinia sappan* L. was 5.0 – 7.4 cm long and 2.7 – 3.2 cm wide, maturing to reddish brown, 2 – 5-seeded. Mathew. et. al (2007) described that pods are 7.5 – 10 cm long and 3.8 – 8 cm in diameter, maturing to brown, indehiscent and 3 – 4 seeded.

In this study, heartwood of stem of *Pterocarpus santalinus* L.f. studied was found to be reddish brown, its odour and taste distinct. However, Pearson and Brown (1932**)**

mentioned that its heartwood was orange-red when first exposed, turning to scarlet-purple with lighter and darker streaks, purplish-black, or almost black**.** Donga (2017) stated that the stem was reddish brown, odour was fragrant and taste.

In this paper, the wood of *P. santalinus* was found to be diffuse-porous, growth ring is distinct, interlocked-grained but Donga (2017) stated that it was found to be semi-ringporous or diffuse porous, tightly interlocked and wavy grained.

The wood of *Caisalpinia sappan* L. was found to be straight grained, but those of *Adenanthera pavonina* L. and *Pterocarpus santalinus* L.f. were found to be interlocked-grained. The odour of wood of *Adenanthera pavonina* L. and *Caisalpinia sappan* L. were indistinct but that of *Pterocarpus santalinus* L.f. was found to be distinct. The wood of three species was tasteless.

In this study, heartwood of stem of *A. pavonina* L. was found to be reddish brown but Orwa et.al (2009) stated that the heartwood was bright yellow when fresh, turning red when old. In this paper, the wood is interlocked-grained and very fine-textured to medium textured. But, Abdu1 et al. (2019) described that the heartwood was closely and even grained, with a moderately fine to slightly coarse and even texture.

In this study, wood of *Caisalpinia sappan* L. was orange when freshly cut, but it quickly turned to red. Mathew. et. al (2007) mentioned that the wood was orange red.

In this study, its wood of *Caisalpinia sappan* L. is diffuse-porous and the growth ring is distinct. It is straight grained and very fine-textured to medium textured. But, Mathew. et. al (2007) stated that the wood was hard, very heavy, straight grained with a fine and even texture. Gasson et al, (2009) stated that the wood of *C. sappan* L. was semi-ringporous, growth ring distinct.

Among the three species studied, growth rings are distinct in the transverse section of the stem of *Caisalpinia sappan* L and *Pterocarpus santalinus* L.f., but that of *Adenanthera pavonina* L. is not distinct. The wood of *Pterocarpus santalinus* L.f. was found to be very fine to coarse textured while those of *Adenanthera pavonina* L. and *Caisalpinia sappan* L. were very fine to medium textured.

In all of the species, wood were diffuse porous. Size of pores of *Adenanthera pavonina* L. and *Caisalpinia sappan* L. was found to be in the range of very small to medium-sized and that of *Pterocarpus santalinus* L.f. was very small to moderately large. Perforation plates of vessel elements of all species studied were found to be simple.

Gum deposits and crystals chain were also present in the wood of all of the species. Fibers found in the wood of all species studied were non-septate. Xylem rays were homocellular in the wood of all of the species.

Tangential diameter of the vessel of the three species studied was in the range of 30 – 230 μm i.e., very small to moderately large. The lowest value was found in *Adenanthera pavonina* L. and the highest in *Pterocarpus santalinus* L.f..

Length of vessel elements of the three species studied was found to be in the range of 120 – 690 μm i.e., extremely short to medium-sized. The lowest value was found in *P. santalinus* L.f. and the highest was in *Adenanthera pavonina* L..

Xylem fibers was observed in the range of 110 – 1250 μm i.e., extremely short to medium-sized. The lowest value was found in *Pterocarpus santalinus* L.f. and the highest was in *Adenanthera pavonina* L..

In this paper, the rays of wood of the three species were found to be homogeneous. Uni-seriate to tri-seriate (mostly biseriate) rays were found in *Adenanthera pavonina* L. and uni- to penta-seriate (mostly triseriate) in *Caisalpinia sappan* L.. But uni-seriate or bi-seriate (mostly uniseriate) rays were observed in *Pterocarpus santalinus* L.f..

In this paper, the length of bark fibers of the three species studied were found in the range of 400 to 2600 μm i.e., extremely short to very long. The highest length was found in *Adenanthera pavonina* L. whereas the lowest was in *Pterocarpus santalinus* L.f.. The width of bark fibers was in the range of 10.0 to 27.5 μm.

Periderm formation occurred at the outer portion of the cortex in all species studied in this paper. The lenticels were found in the outer part of periderm. Some lenticels were observed beneath the outer periderm and closed.

In the three species studied, vascular cambium showed one layer of meristematic cell between xylem and phloem. Vasccular cambium was usually with a few layers of immediate derivatives.

The phloem rays of the bark of three species studied were in the range of uniseriate to pentaseriate. Uniseriate to triseriate phloem rays were found in the bark of *Adenanthera pavonina* L., uniseriate to pentaseriate rays were found in *Caisalpinia sappan* L. and uniseriate to biseriate phloem rays were found in *Pterocarpus macrocarpus* L.f..

Among the three species studied, secretory ducts were not found in the bark of *Adenanthera pavonina* L. but large cells in group were observed in the barks of *Caesalpinia sappan* L. and *Pterocarpus santalinus* L.f.. These large cells seemed to form secretary cells. They were much larger than neighbouring cells in size.

Prismatic crystals were present in the cortex and phloem of the bark of all species studied in this paper. Prismatic crystals might be singly or in rows of parenchymatous cells.

In the cortex and phloem of the bark of three species studied, sclereids were common as single cell or group of cells.

In the bark of three species studied, some sieve tubes were found to be as stretched structures in group due to aging. In transverse section, groups of stretched sieve tubes were forming ring-like structure in appearance. In tangential longitudinal section, sieve tubes could be seen with many sieve areas at the lateral wall and the end wall. Compound sieve plates were large and distinctly observed at the end wall of the sieve tube in the bark of *Adenanthera pavonina* L.

The morphological and anatomical characteristics of wood and barks found in this work are much important and provide the information on anatomy of the flowering plants. Moreover, these characteristics are useful in identification of the tree species.

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