BARK ANATOMY OF CERTAIN MEMBERS OF LEGUMINOSAE

THESIS SUBMITTED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY IN BOTANY
OF
BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE
PILANI
1969

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By

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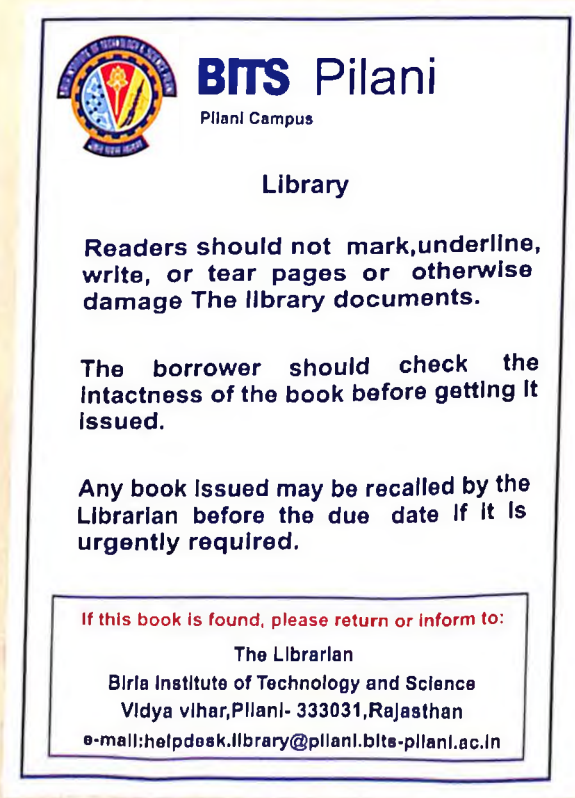

CONTENTS

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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE,PILANI.

DEPARTMENT OF BOTANY

The thesis entitled "Bark Anatomy of certain members of Leguminosae" submitted by Shri Ashok Kumar, M.Sc., for the Degree of Doctor of Philosophy embodies the results of investigations done under our supervision, and we certify that the work is original.

June 6, 1969

M.C. JOSHI

B.D. DESHPANDE

ACKNOWLEDGEMENTS

I take this opportunity to express my gratitude to my supervisors Dr.M.C. Joshi and Dr. B.D.Deshpande for guidance, generous help and keen interest in this work.

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Kumar

(ASHOK KUMAR)

INTRODUCTION

Bark is the outer part of the stem encircling the wood and includes all the tissue outside the vascular cambium. Although the tissues outside the vascular cambium vary anatomically in different species, they are fundamentally similar in structure and function. It was also referred to as " Bast " by earlier workers.

Though bark gained its importance in paper industry since 105 A.D., its structure was not known except for those of a few families, viz., Moraceae, Thymeliaceae and Tiliaceae. Importance of bark utilization attracted the attention of many wood anatomists and industrialists. Its importance has also been emphasied in various fields of botany and Pharmacognosy. Barks have additional importance since many yield gums, resins, mucilage, tannins, alkaloids, aldehydes and essential oils. Studies on bark have academic importance because of it protective function and role in physiology.

Perredes (1903) studied the anatomy of Salicaceae barks. Hart (1922) investigated the histology of Vilca bark. Welch et al (1923) has written notes on wattle barks. Youngken (1923) studied the bark of Myrica cerifera. Anderson (1934) investigated the structure of slippery elm bark and Isenberg (1943) studied the anatomy of red wood bark.

Guttenberg (1951) has written an article "Listen to barks" and Huber (1949) has discussed the phylogeny of annual rings of barks.

Extensive studies on the anatomy of bark have also been made in the last decade by many workers, viz., Chang (1951, 1954) of Rubiaceae and conifers; Chattaway (1953a, b, 1955a, b, c, 1959) of Eucalyptus species and Eugenia; Sidey (1953) of Acacia mollissima; Harada (1954) in Ligustrum japonicum; Eckbald (1953) of Ulmus glabra and Pinus sylvestris; Schneider (1955) on the anatomy of lemon tree bark; Bamber (1959) of Callitris and Lovota (1959) of tall and short apple trees.

Work on the bark in the present decade includes those of Shah & Bhattacharyya (1960) on Albizzia lebbeck, Prasad et al (1960, 1961) on Erythrina and Ashoka tree; Whitmore (1960, 1962, a, b, c, 1959) on Dipterocarpaceae, beech, oak and sweet chest-nut; Ghosh & Purkayastha (1962) of Acacia senegal and Chaudhuri (1961, 1966a, b) on Soymida fibrifuga, Ficus and Sesbania. Esau (1964) has given an account of the structure and development of bark in dicotyledons.

Work on the periderm, an important component of the bark is very scanty. However, some of the workers have attempted to work out the structure of the periderm (Douliot, 1889; Kaufert, 1937; Lier, 1949, 1952a, b, 1955 & 1959; Kwaitkowska, 1957 and Belostokow, 1963).

Eames and Mac Daniels (1947), Metcalfe & Chalk (1950)

and Esau (1965) have described the structure of bark, phloem and periderm.

It is evident from the literature that only little work has been done on the barks of Leguminosae which include most of the economically important plants.

Keeping in view the scanty information on barks, the present problem was undertaken to study the external morphology, structure of young as well as mature bark of some selected species of Leguminosae. Attempt has also been made to investigate the tissues involved in the outer and inner bark, and to identify these barks based on their structure and formulate an artificial key for their identification.

MATERIALS AND METHODS

The following plants were selected for investigation:

Sl.No.	Name of the plant	Place of collection
1.	PAPILIONATAE	
1.	*Erythrina indica* Lamk.	Bot. Garden, Pilani
2.	*Butea frondosa* Roxb.	"
3.	*Dalbergia sisso* Roxb.	Vidya Vihar, Pilani
	CAESALPINEAE:	
4.	*Caesalpinia pulcherrima* Swartz.	"
5.	*Delonix regia* (Boj.) Raf.	"
6.	*Cassia auriculata* L.	"
7.	*C. fistula* L.	"
8.	*C. siamea* Lamk.	"
9.	*Tamarindus indica* L.	"
10.	*Bauhinia vairegata* L.	Bot. Garden, Pilani.
	MIMOSEAE:	
11.	*Prosopis spicigera* L.	Vidya Vihar, Pilani
12.	*P. juliflora* DC.	"
13.	*Acacia nilotica* Willd.	"
14.	*A. aneura* F. Muell	CAZRI, Jodhpur.

15.	A. benthamii Meissn.	CAZRI, Jodhpur
16.	A. salicina Lindl.	"
17.	A. cyanophylla Lindl.	"
18.	A. drepanolobium Harms ex Sjostedt.	"
19.	A. hockii De Wild.	"
20.	A. ligulata Ait. ex Steud.	"
21.	A. senegal Willd.	Vidya Vihar, Pilani
22.	A. sieberiana DC.	CAZRI, Jodhpur
23.	A. spirocarpa Hochst. ex A.Rich.	"
24.	A. victoriae Benth.	"
25.	Albizzia lebbeck Benth.	Vidya Vihar, Pilani.

Young branches were collected to investigate the structure of epidermis and initiation of the first phellogen. Comparatively older branches were collected to study the mode of pericyclic expansion. Bole bark was collected to investigate its structure, position of additional layers of periderm, formation of rhytidome, ray expansion, phloem proliferation and sclerosis. The materials were cut into suitable pieces and preserved in the formaline-acetic-alcohol. Some material was preserved in four percent formaline.

In plants where the bark was hard, small pieces were softened in 50% hydrofluoric acid for three to five days. These pieces were thoroughly washed in running water so as to remove completely traces of hydrofluoric acid. Softened

material was stored in a mixture of glycerine and 90% alcohol.

Small pieces of the materials were embedded in celloiden following the schedule given by Johansen (1940).

Materials with and without embedding were sectioned on a sliding microtome. Fresh and preserved materials of locally available plants were also sectioned. Sections were cut at 30 to 40 microns in transverse, tangential longitudinal and radial longitudinal planes. A piece of thin paper moistened with water was kept at the surface of the material before each stroke so as to avoid curving of the section and were allowed to rest at the knife before removing. Paraffin embedded material of Acacia nilotica was also cut on a rotary microtome. Free-hand sections of the younger branches were cut.

Sections were stained with safranin-light green and safranin haematoxyline combinations. In addition, Bismark brown and safranin combination was also tried. However, the results were not satisfactory. To detect slime and callose in the mature sieve tubes sections were stained with aqueous solution of aniline blue and very dilute aqueous resorcin blue and potassium iodide and aniline blue respectively. Temporary preparations were made. Others were made permanent following ethyl alcohol series for dehydration.

Measurements of fiber bands were taken from transverse sections of the mature bark while fiber length was measured from the macerated preparations. Length and width of

the sieve tubes and height and width of the phloem rays were measured from tangential longitudinal sections. Number of rays per square mm. was also counted from the tangential longitudinal sections and percentage of uni-, bi- and multiseriate rays was calculated from the readings of the number of rays per square mm.

Observations were recorded under the following heads: external morphology, structure of young twigs and structure of mature bark.

Structure of mature bark has been described under the headings of secondary phloem, periderm and sclerosis.

In the secondary phloem, occurrence and arrangement of fiber bands, structure, distribution and arrangement of sieve tubes, companion cells and phloem parenchyma have been described under the phloem blocks and phloem rays in the horizontal system. Observations on measurements of various elements have been classified into various frequency classes, their percentage have been calculated and represented graphically. The frequency classes are as follows:

Fiber bands, Tangential and radial extent:

Up to 25 microns, 25 to 50 microns, 50 to 75 microns, 75 to 100 microns, 100 to 150 microns, 150 to 200 microns, 200 to 300 microns, 300 to 400 microns, 400 to 500 microns and 500 to 600 microns.

Length of phloem fibers:

Up to 300 microns, 300 to 600 microns, 600 to 900 microns, 900 to 1200 microns, 1200 to 1500 microns, 1500 to 1800 microns, 1800 to 2100 microns, 2100 to 2400 microns, 2400 to 2700 microns, 2700 to 3000 microns and 3000 to 3300 microns. These frequency classes are similar to those given for wood fibers by Metcalfe & Chalk (1950).

Length of the sieve tubes:

Up to 100 microns, 100 to 200 microns, 200 to 300 microns, 300 to 400 microns, 400 to 500 microns and 500 to 600 microns.

Width of sieve tubes:

Up to 25 microns, 25 to 50 microns and 50 to 100 microns.

These frequency classes have been made following those for vessel sizes given by Dadswell & Eckerseley (1935) and Chalk (1938).

Height and width of the phloem rays:

Up to 15 microns, 15 to 25 microns, 25 to 50 microns, 50 to 100 microns, 100 to 200 microns, 200 to 400 microns, 400 to 600 microns, 600 to 800 microns, 800 to 1000 microns, 1000 to 1200 microns, 1200 to 1400 microns, 1400 to 1600 microns, 1600 to 1800 microns, 1800 to 2000 microns, 2000 to 2200 microns, 2200 to 2400 microns, 2400 to 2600 microns, 2600 to 2800 microns, 2800 to 3000 microns.

Number of rays per square mm:

Up to 10, 11 to 20, 21 to 30, 31 to 40, 41 to 50, 51 to 60, 61 to 70, 71 to 80, 81 to 90, 91 to 100, 101 to 110, 111 to 120, 121 to 130, 131 to 140, 141 to 150, 151 to 160, 161 to 170, 171 to 180, 181 to 190, 191 to 200, 201 to 210, 211 to 220, 221 to 230, 231 to 240, 241 to 250.

Mode of cortical, pericyclic and rays expansion has been described under expansion and expansion in the phloem parenchyma under phloem proliferation. General observations on the sclerosis have also been made.

In the periderm, observations have been recorded for the first as well as subsequent periderm layers.

OBSERVATION INDEX

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ERYTHRINA INDICA

EXTERNAL MORPHOLOGY:

In the young branches bark is smooth, green, turning to grey, while in the older branches and bole it is smooth with whitish longitudinal lines formed by the shallow furrows in the periderm (Photo. 1) and soft in texture. Black spines with broad bases are found sparsely distributed on the bark surface of the bole region and young branches. Thickness of the bark (from cambium to periphery) in the bole region is 4.0 to 5.0 mm.

STRUCTURE OF THE YOUNG TWIG:

Young twigs show wide pith of thin walled, angular cells without interecellular spaces and contain starch. Pericycle consists of alternate patches of sclerenchyma and parenchyma. Cortical cells are large, oval to oblong or round and contain chloroplast. Epidermal cells are radially elongated with thick cuticle (Fig. 1).

STRUCTURE OF MATURE BARK:

The two major components of the bark are the secondary phloem and periderm. In addition expansion and proliferation are also common in the bark tissue.

Secondary phloem:

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STRUCTURE OF MATURE BARK:

The two major components of the bark are the secondary phloem and periderm. In addition expansion and proliferation are also common in the bark tissue.

Secondary phloem:

The secondary phloem is characterised by the presence

of definite phloem blocks constituting the axial system alternating with the phloem rays which constitute the horizontal system. The phloem blocks gradually become narrow towards the periphery (Fig. 6; Photomicro. 2). In each phloem block there are tangential fiber bands which alternate with the soft tissue consisting of sieve tubes, companion cells and phloem parenchyma (Photomicro. 2). The fiber bands vary in size and shape; may or may not touch the rays laterally and show almost irregular distribution (Fig. 6, Photomicro. 2). A single layer of crystalliferous cells is present only on inner side of the fiber band. Two to three layers of parenchymatous cells occur on abaxial and adaxial side of each fiber band. Tangential extent of the fiber bands ranges from 67.83 to 445.74 microns and the radial extent from 38.76 to 135.66 microns. Average tangential and radial extent is 202.14 and 84.50 microns respectively. Percentage of the fiber bands in different frequency classes of tangential and radial extent is shown in Text-figure 1.

Fibers are broad at the middle and tapering to the ends (Fig. 2). Length ranges from 722.50 to 3017.50 microns with an average of 1906.38 microns. Percentage of fibers in different frequency classes of length is shown in text-figure 2.

Sieve tubes are angular in transverse section. In longitudinal section they are short, tubular and arranged in a storied fashion (Photomicro. 3). Only one sieve area occurs on the end walls forming a simple sieve plate (Fig. 3, Photomicro. 3,4). The sieve plates are almost transverse or slightly inclined and are oriented at an angle ranging from 60.0 to 90.

degrees with an average of 80.8 degrees. At maturity sieve tubes are enucleate and vacuolated. Cytoplasm is parietal. Slime occurs near the sieve plates in the form of plugs, only on one side and rarely on both (Fig. 3, Photomicro. 3). Length of the sieve tubes ranges from 155.04 to 261.63 microns and width from 23.26 to 46.51 microns. Average length and width is 210.27 and 32.98 microns respectively. Percentage of sieve tubes in different frequency classes of length and width is shown in text-figure 3.

Obliteration of the sieve tubes in the nonfunctional phloem is very common and probably takes place due to the pressure exerted on them by the increase in girth. The sieve tubes are compressed tangentially; their lumen becomes reduced and walls comparatively thick. Ultimately the lumen collapses completely forming irregular bands of crushed tissue in the peripheral part of the bark. These bands of crushed tissue occur in between the fiber bands with parenchyma on both the sides (Photomicro. 2).

Each sieve tube is associated with one or two companion cells in transverse section and three to four along the length. These cells have distinct nuclei and dense cytoplasm.

Phloem parenchyma cells are hexagonal and are present below and above the fiber bands. Some of the cells become partitioned further and contain rhomboidal crystals.

Phloem rays are of two categories: (1) those running from the cambium to the periphery and (2) those running only for

a short distance or ending blindly. In transverse section these are one to many cells wide. Cells are rectangular to hexagonal. They are homogeneous and uni-, bi- and multiseriate.

Uniseriate rays have large, either conical or dome shaped and cells (Figs. 4). Height ranges from 29.07 to 271.32 microns and width from 17.44 to 50.79 microns. Average height and width is 133.18 and 32.29 microns respectively. Percentage of uniseriate rays in different frequency classes of height and width is shown in text-figures 4 and 5 respectively.

Biseriate rays have short uniseriate ends. However, some show uniseriate unequal or equal extensions (Figs. 5A-B). Height ranges from 106.59 to 310.08 microns and width from 20.07 to 87.21 microns. Average height and width is 177.52 and 45.97 microns respectively. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 4 and 5 respectively.

Multiseriate rays are three to many cells wide (Photomicro. 3). Ends are uniseriate and short. Height ranges from 255.00 to 2890.00 microns and width from 59.50 to 382.50 microns. Average height and width are 1157.87 and 184.28 microns respectively. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 4 and 5 respectively.

Number of rays per square mm. is half or rarely one, hence readings were not taken. Multiseriate rays are however, predominant.

Expansion: Bark shows cortical, pericyclic and ray

expansion.

Cortical expansion: Secondary growth in the young branches is followed by the expansion in the cortex. The cells of the cortex are stretched tangentially followed by anticlinal divisions. Each cell may divide once or more. As a result of these changes the circumference of the cortex increases to some extent. This expansion gradually increases with the increase in diameter.

Pericyclic expansion: with the increase in the diameter of the branch, expansion in the pericycle has also been observed. The cells of the parenchymatous region of the pericycle opposite the primary phloem rays undergo tangential stretching. This is followed by anticlinal divisions resulting in the increase in the circumference of the pericycle. The sclerenchymatous patches of the pericycle are thus separated by wide regions of the parenchymatous tissue (Pericyclic expansion) (Fig. 6).

Ray expansion: Almost all the primary and secondary rays have been observed to expand. The ray cells show tangential stretching which gradually increases towards the periphery. Tangential stretching is followed by anticlinal divisions in the ray cells. The frequency of anticlinal divisions gradually increases towards the periphery. These changes result in the dilation of rays forming wedges of parenchymatous tissue, the ray expansion tissue which can be seen as pale coloured patches on the clean cut transverse surface of a bark piece. Occasionally the expanded rays end blindly in a phloem block coming in between

the dilated rays to form a close type of expansion (Fig. 6). The cortical and ray expansion become connected through the pericyclic expansion (Fig. 6).

Periderm:

The phellogen is superficial. It is initiated in the localized patches in the sub-spidermal layer. Cells of this layer divide by periclinal division forming two daughter layers (Fig. 1. Photomicro. 5). The outer layer matures first and forms cork and the cells of the inner layer by one more periclinal division gives rise to phellogen abaxially and phelloderm adaxially. Thus a zone of three layers with phellogen in the middle is formed (Fig. 1). Due to the activity of this phellogen cork layers are formed outside and phelloderm inside (Fig. 7, Photomicro. 6). In transverse section the cork cells are rectangular, thin called, light green to yellow in colour and vaculated. These cells are arranged regularly and compressed later and become tangentially flattened (Photomicro. 8). In surface view the cork cells are angular with distinct middle lamella (Fig. 8). Phelloderm cells are thin-walled, regularly arranged and have dense protoplasm. Cork and phelloderm are almost equal in extent (Photomicro. 6).

Additional phellogen layers are not formed and the first phellogen remains functional throughout. Cork layers are regularly peeled off in the form of thin papery scales of small size and are eight to ten layers in thickness.

Sclerosis: Irregular patches of cells in the cortical

region and expansion tissue become thick walled and posses crystals. Some of the cells show striated thickenings without pit canals (Figs. 9A-D).

Text-figures 1 to 5. *Erythrina indica*.

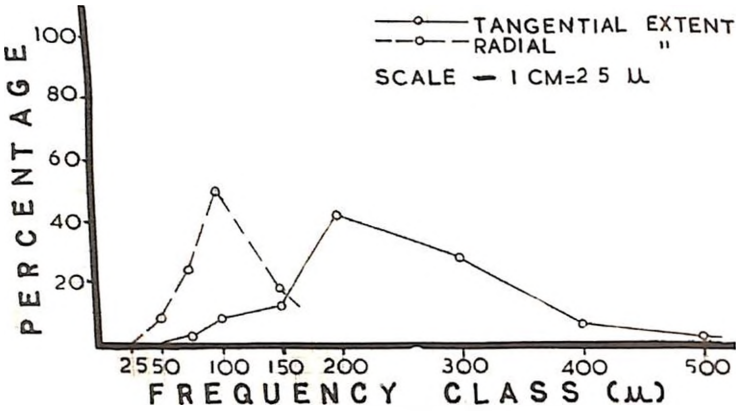
Text-figure 1. Percentage of fiber bands in different frequency classes of tangential and radial extent.

Text-figure 2. Percentage of fibers in different frequency classes of length.

Text-figure 3. Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 4. Percentage of uni-, bi- and multiseriate rays in different frequency classes of height.

Text-figure 5. Percentage of uni-, bi- and multiseriate rays in different frequency classes of width.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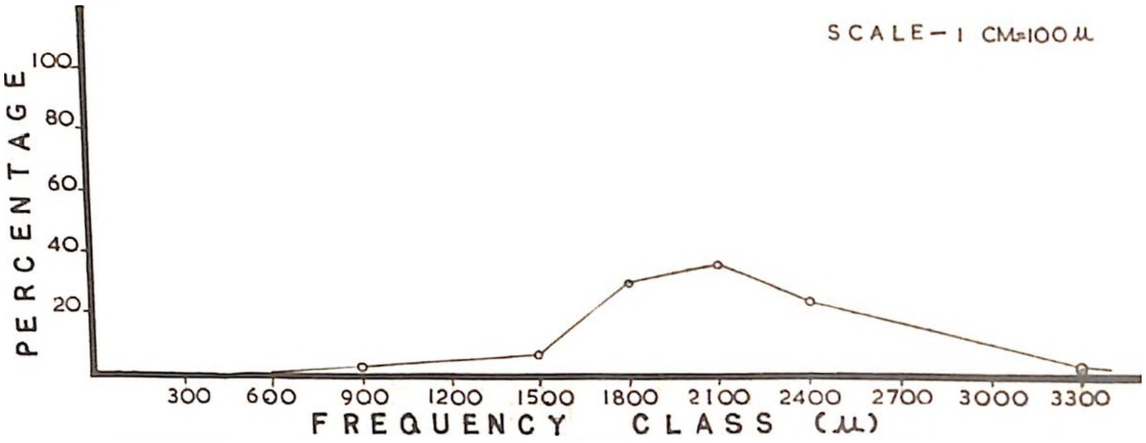
1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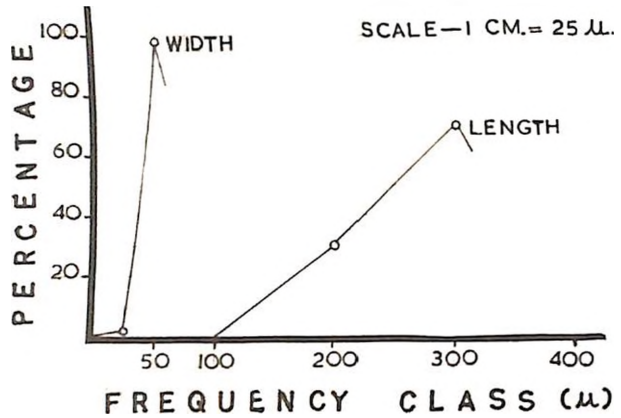
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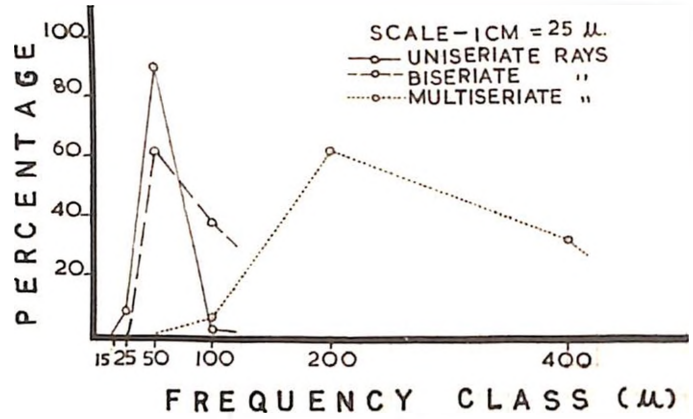
SCALE — 1 CM = 25 μ.
UNISERIATE RAYS
BISERIATE "
MULTISERIATE "
PERCENTAGE
100
80
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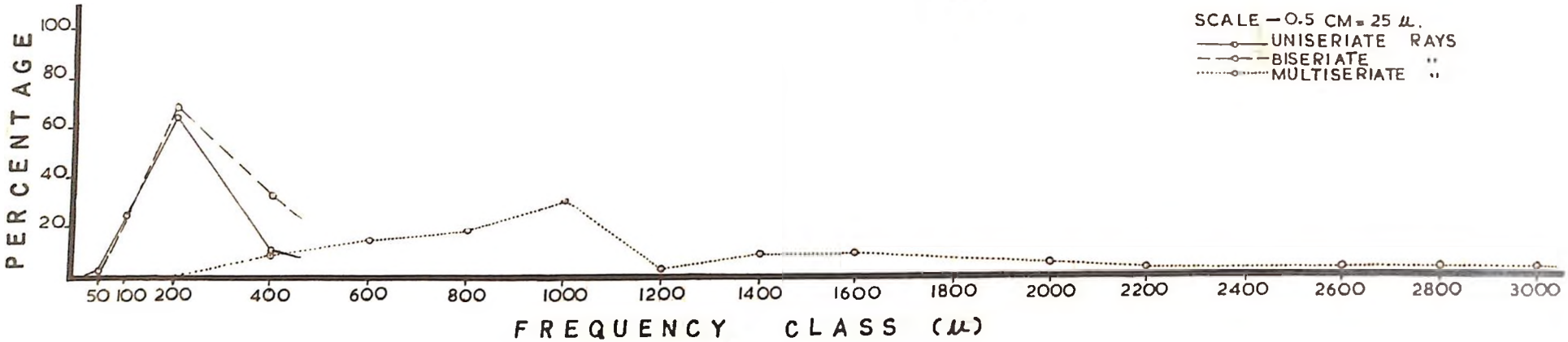
15 25 50 100 200 400
FREQUENCY CLASS (μ)

5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UNISERIATE RAYS
BISERIATE "
MULTISERIATE "
PERCENTAGE
100
80
60
40
20
50 100 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000
FREQUENCY CLASS (μ)

4

BUTEA FRONDOSA

EXTERNAL MORPHOLOGY:

In young branches bark is green and smooth and turns light brown to grey later. Bole bark is rough, scaly, shallow fissured (Photo. 7) and dull brown in colour. Thickness of the bole bark is 3.0 to 4.0 mm.

STRUCTURE OF YOUNG BRANCH:

Pith cells are large, circular with intercellular spaces in the centre and small round in the periphery. Pericycle is wide and sclerenchymatous. Outer few layers of the pericycle are comparatively thick walled. The cells in the pericyclic grooves are also thick walled (Photomicro. 8). Cells of the cortical layer immediately outside the pericycle contain rhomboidal crystals. The cortex consists of angular to circular cells without intercellular spaces. Cells are compactly arranged in the peripheral part of the cortex. Epidermal cells are papillate with conical to triangular outer tangential walls. Cuticle is thick and striated (Fig. 10; Photomicro. 8).

STRUCTURE OF MATURE BARK:

Secondary phloem:

Secondary phloem is characterised by the presence of narrow phloem blocks alternating with phloem rays as in Erythrina

the deposition of the callose which gets desolved later rendering the pores open. However, connecting strands do not reappear which points out the inactive nature of the sieve plates (Fig. 15 B). The sieve plates are oriented at an angle ranging from 50 to 90 degrees with an average of 81.60 degrees.

Slime occurs in the form of darkly stained plug on one side of the sieve plate (Figs. 14 A-C; Photomicro. 11). In some, slime plug occurs a little away from the sieve plate and is connected with it by cytoplasmic strands (Fig. 14 C).

Sieve tubes are 77.52 to 193.80 microns in length and 19.38 to 34.88 microns in width. Average length and width is 160.16 and 23.80 microns respectively. Percentage of sieve tubes in different frequency classes of length and width is shown in text-figure 8.

Each sieve tube is associated with one or two companion cells which are triangular or squarish in transverse section (Fig. 12). However, the number of companion cells associated along the length is either one or three to five (Figs. 14 A-C). In case, one companion cell is associated with the sieve tube it may run along the whole length or a part of it (Fig. 14 B).

Phloem parenchyma cells are rectangular and form definite bands or may be interspersed (when seen in transverse section). Some of the parenchyma cells are enlarged and contain darkly stained material or rhomboidal crystals (Fig. 12).

Similar to Erythrina indica, the phloem rays are of the first as well as second categories (Fig. 11). In transverse section the rays are many cells wide and become still wider towards the periphery. In radial longitudinal section, the rays are homogeneous, while in tangential longitudinal section they are uni-, bi- and multiseriate.

Uniseriate rays are three to many cells high with conical, round or dome shaped end cells (Figs. 16 A,B). Height ranges from 32.95 to 368.22 microns and width from 13.57 to 38.76 microns. Average height and width is 197.06 and 28.37 microns respectively. Percentage of uniseriate rays in different frequency classes of height and width is shown in text-figures 9 and 10 respectively.

Biseriate rays have either short ends or equal or unequal uniseriate extensions (Figs. 17 A,B). Height ranges from 87.21 to 339.15 microns and width from 19.39 to 77.52 microns. Average height and width is 154.23 and 46.86 microns respectively. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 9 and 10 respectively.

Multiseriate rays are three to many cells wide. The cells are angular or round in shape. Ends are short and uniseriate (Photomicro. 11). Height ranges from 144.50 to 1700.00 microns and width from 68.00 to 297.50 microns. Average height and width is 722.80 and 247.86 microns respectively. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 9 and 10 respectively.

Number of rays per square mm. ranges from 5 to 17 with an average number being 11.4 per square mm. Percentage readings in different frequency classes of ray number per square mm. are shown in text-figure 11.

Percentage occurrence of uni-, bi- and multiseriate rays in the secondary phloem is 4.00, 3.83 and 92.17 respectively.

Expansion growth:

All the three types of expansions (Cortical, pericyclic and ray expansions) occur in this plant also and take place in a fashion similar to that in Erythrina indica. The cells in the region of the pericyclic expansion show slight wall thickenings but sclereids are not formed. Ray expansion takes place in almost all the rays resulting in the wedges of parenchymatous ray expansion tissue (Fig. 11; Photomicro. 9). Some of the rays show closed type of expansion (Fig. 11).

Periderm:

The initiation, position and activity of the phellogen is similar to Erythrina indica (Fig. 18; Photomicro. 12). The extent of the cork cut off is more than the that of phelloderm. Cork cells in transverse section are rectangular and get crushed. Cork layers are light grey in colour. In surface view, the cork cells are angular (Fig. 19), phelloderm cells are thin walled and contain rhomboidal crystals.

Additional phellogen layers do not arise in this case also. Exfoliation takes place in the form of small scales which are approximately 0.50 mm. in thickness.

Text-figures 6 to 11. *Butea frondosa*.

Text-figure 6. Percentage of fiber bands in different frequency classes of tangential and radial extent.

Text-figure 7. Percentage of fibers in different frequency classes of length.

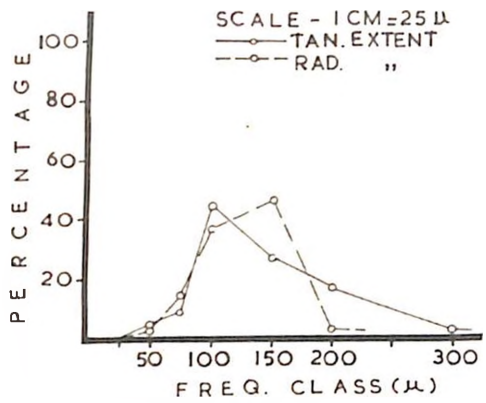
Text-figure 8. Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 9. Percentage of uni-, bi- and multiseriate rays in different frequency classes of height.

Text-figure 10. Percentage of uni-, bi- and multiseriate rays in different frequency classes of width.

Text-figure 11. Percentage readings in different frequency classes of number of rays per sq.mm.

TAN. EXTENT - Tangential extent,
RAD. EXTENT - Radial extent.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RAD. ,,
PERCENTAGE
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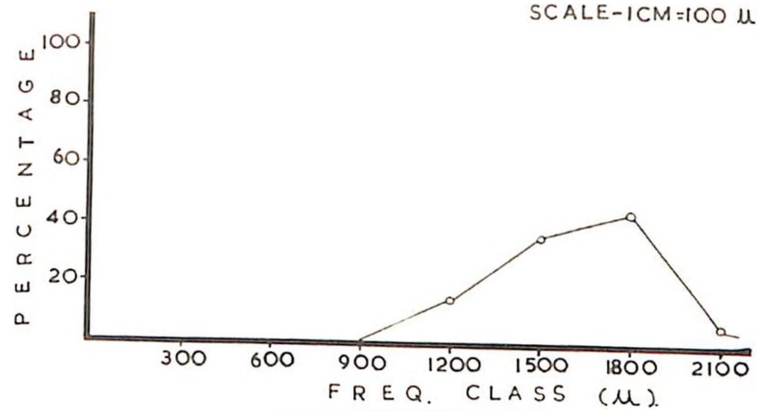
60
40
20
50 100 150 200 300
FREQ. CLASS (μ)

6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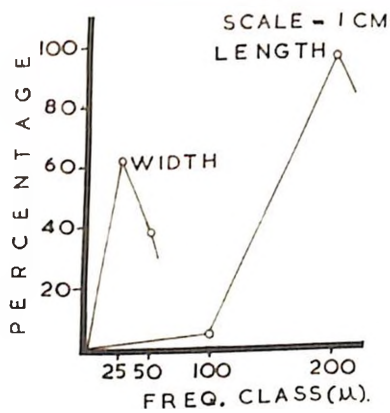
FREQ. CLASS (μ).

7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WIDTH
PERCENTAGE
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40
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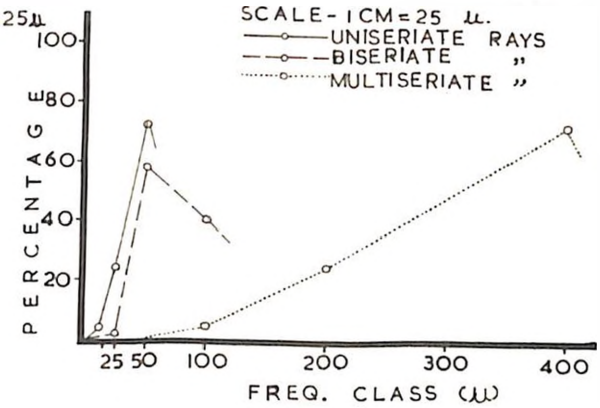
FREQ. CLASS (μ).

8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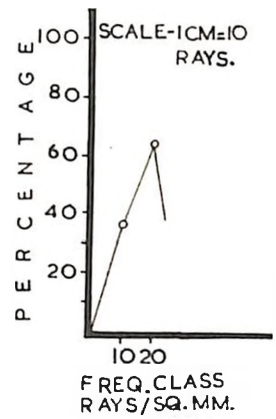
UNISERIATE RAYS
BISERIATE ,,
MULTISERIATE ,,
PERCENTAGE
100
80
60
40
20
25 50 100 200 300 400
FREQ. CLASS (μ)

10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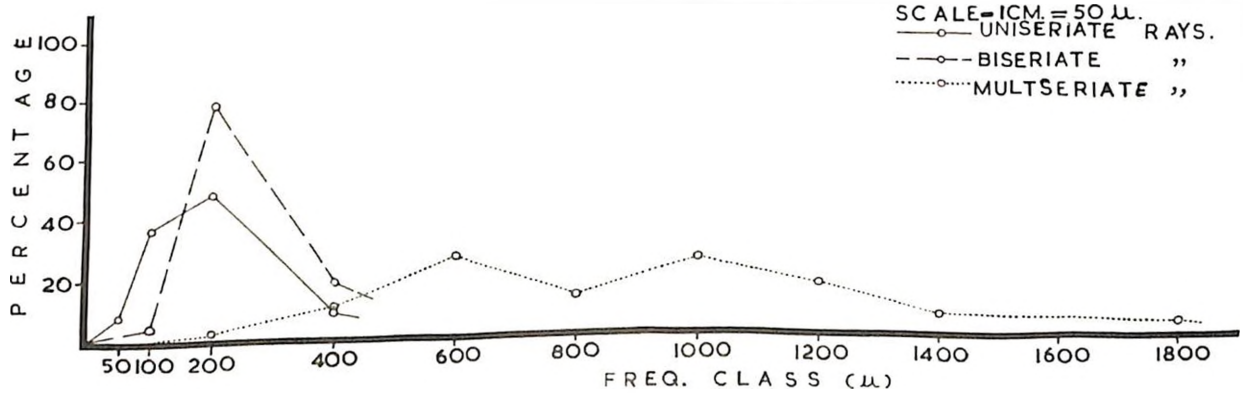
RAYS.
PERCENTAGE
100
80
60
40
20
10 20
FREQ. CLASS
RAYS/SQ.MM.

11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UNISERIATE RAYS.
BISERIATE ,,
MULTSERIATE ,,
PERCENTAGE
100
80
60
40
20
50 100 200 400 600 800 1000 1200 1400 1600 1800
FREQ. CLASS (μ)

9

DALBERGIA SISSO

EXTERNAL MORPHOLOGY:

In young branches bark is green which turns whitish grey soon. In comparatively older branches bark is smooth and downy (whitish). Bole bark is rough, scaly, deeply fissured (Photo. 13), and yellowish grey in colour. Thickness of the bole bark is about 25.0 mm. Inner bark is yellow in colour.

STRUCTURE OF YOUNG TWIG:

Pith is wide consisting of large thin walled hexagonal cells with intercellular spaces in the centre and small, thick walled cells in the peripheral region (Photomicro. 14). Pericycle is wide consisting of large sclerenchymatous patches alternating with narrow patches of parenchyma (Fig. 20; Photomicro. 15). Cortex consists of tangentially elongated circular or hexagonal cells. Cortical layer immediately outside the pericycle contains rhomboidal crystals (Fig. 20). Epidermal cells are small with thick striated cuticle (Fig. 20; Photomicro. 15).

STRUCTURE OF MATURE BARK:

Secondary phloem:

It is characterised by the presence of phloem blocks which alternate with the phloem rays (Figs. 21, 22; Photomicro. 16, 17). The phloem blocks become narrow towards the periphery

of the bark due to ray expansion and phloem proliferation. Each phloem block is charaterised by the presence of tangential rows of fiber bands alternated by soft tissue as in Erythrina indica. In transverse section fiber bands are variable in shape (Fig. 21, 22). These fiber bands are scattered in the inner part but are in regular tangential rows in the peripheral region (Photomicro. 16). On the abaxial and adaxial side of each fiber band there is a single or at places two rows of crystalliferous cells having rhomboidal crystals. However, the crystalliferous cells are even mixed up in the fibers (Fig. 22). Crystalliferous layer is followed by a few parenchymatous layers on both the sides of each fiber band (Fig. 22). Tangential extent of the fiber bands ranges from 38.76 to 193.80 microns and the radial extent from 38.76 to 232.56 microns. Average tangential and radial extent is 101.83 and 92.52 microns respectively. Percentage of fiber bands in different frequency classes of tangential and radial extent is shown in text-figure 12.

Macerated preparations show mainly two types of fibers: (1) with broad middle portion and gradually tapering conical ends and (2) with broader middle portions and sharply tapering ends. Length ranges from 765.00 to 1487.50 microns. Average fiber length is 1173.13 microns. Percentage of the fibers in different frequency classes of length is shown in text-figure 13.

Sieve tubes are distributed in the soft tissue in between the parenchymatous layers. They are thin walled, large, almost angular to circular in transection and are arranged in aggregates (Fig. 22). In tangential longitudinal sections sieve

tubes are almost hexagonal (Photomicro. 18, 19). End walls are more or less transverse and are perforated to form sieve plates which are similar to that in Erythrina indica and Butea frondosa (Figs. 23 A,B,C; Photomicro. 18,19). Some of the sieve plates are concavo-convex (Fig. 23C). Through each of the sieve pores passes a connecting strand enclosed in a callose cylinder (Figs. 23D, 24). Sieve plates are oriented at an angle ranging from 40.0 to 90.0 degrees with an average of 85.19 degrees. Slime occurs in the form of plugs of variable shapes (Figs. 23A-C; Photomicro. 18,19). The slime plugs are present on one or both sides of the sieve plates. In case these are present on both the sides they are connected with each other by connecting strands which pass through the sieve pores (Fig. 23B). In some, slime plug occurs a little away from the sieve plate and is attached with it by the connecting strands (Figs. 23A,C). In still others slime occurs in the middle of the sieve tube and has small connecting strands on one or both sides, which probably represent incompletely dispersed slime strands (Fig. 23A; Photomicro. 19).

Sieve tubes are 116.28 to 203.19 microns in length and 15.50 to 32.95 microns in width. Average length and width is 128.80 and 23.39 microns respectively. Percentage of sieve tubes in different frequency classes of length and width is shown in text-figure 14.

In transection, one or two companion cells of varying shape are associated with each sieve tube (Fig. 22). Along the length one or more companion cells are associated with each sieve tube. In case one companion cell is associated with the

sieve tube it occupies only a part of it (Fig. 23B). However, if more companion cells are associated with the sieve tube, they run along the whole length.

Phloem parenchyma forms a zone on both sides of the fiber bands. In addition, groups of small, rectangular parenchymatous cells also occur in between the sieve tubes or their groups (Fig. 22). The parenchyma cells are thin walled. However, the walls of the parenchymatous cells which occur in between the sieve tubes of their groups are comparatively thick (Fig. 22).

In the nonfuctional phloem the sieve tubes are obliterated forming irregular bands in between the fiber bands (Figs. 21, 22).

Similar to the plants described earlier, the phloem rays in transverse section are of the first as well as second categories (Photomicro. 16,17). Twisting of the rays in the peripheral part is prominent. They are one to three cells wide, and the cells are small, squarish or rectangular (Fig. 22). In radial longitudinal section, the rays are homogeneous consisting of only procumbent cells while tangential longitudinal section shows uni-, bi- amd multiseriate rays (Photomicro. 18,19). Ray cells are circular or angular.

Uniseriate rays are three to eight cells heigh. End cells are conical (Photomicro. 18). Height ranges from 32.95 to 155.04 microns and width from 11.63 to 25.19 microns. Average height and width is 86.27 and 18.45 microns respectively. Percentage of uniseriate rays in different frequency classes of height

and width is shown in text-figures 15 and 16 respectively.

Biseriate rays usually have uniseriate equal ends. In a few, one end is short while the other is long (Fig. 25A). Some of the rays show one end uniseriate and the other biseriate (Fig. 25 B) and still others show alternate uniseriate and biseriate portions (Fig. 25 C). Height ranges from 52.33 to 248.06 microns and width from 19.38 to 38.76 microns. Average height and width is 118.95 and 31.32 microns respectively. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 15 and 16 respectively.

Multiseriate rays have equal or unequal uniseriate ends (Figs. 26 A-C, Photomicro. 18,19). Some of the multiseriate rays have either one or both ends biseriate (Figs. 26 C,D). A few of the multiseriate rays are with distal multiseriate and middle biseriate portion (Fig. 26 B). In still others, rays include uni- and biseriate portions (Fig. 26 A). Height ranges from 87.21 to 872.10 microns and width from 32.95 to 62.02 microns. Average height and width is 271.68 and 44.38 microns respectively. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 15 and 16 respectively.

Number of rays per square mm. ranges from 62 to 87 with an average of 73.9. Percentage readings in different frequency classes of ray number per square mm. are shown in text-figure 17.

Percentage of uni-, bi- and multiseriate rays is 12.35, 42.39 and 45.26 respectively.

Expansion: As in Erythrina and Butea, the bark shows cortical, pericyclic and ray expansion.

Cortical expasion: The cells of the cortex against the parenchymatous portions of the pericycle show more expansion growth (Fig. 27). The mode of expansion is similar to that described earlier.

Pericyclic expansion: It is similar to Erythrina and Butea. However, interpolation of parenchyma in between the sclerenchyma does not occur and the parenchyma already present helps in pericyclic expansion (Fig. 27). The cells in the region of pericyclic expansion are not sclerosed.

Ray expansion: It starts in the rays against the parenchymatous pericyclic portion and is similar to that in other plants described earlier. Ray expansion is not pronounced in comparison to Erythrina and Butea. In most of the rays the frequency of tangential stretching and anticlinal division is more on one side of the ray than on the other. Sometimes the cells only on one side divide. This partial expansion results in the twisting of the rays (Figs. 21,28). The wedges of expansion tissue thus formed, are narrow.

Phloem proliferation: It takes place in the axial parenchyma and results in the formation of parenchymatous patches similar to that of ray expansion tissue (Figs. 21,28).

Periderm:

The first phellogen is superficial and resembles

Erythrina and Butea in its origin, initiation and activity. However, this phellogen is short lived. The cork cells are radially elongated, thick-walled, squarish to rectangular and compactly arranged in transverse section (Figs. 20,29; Photomicro. 15). Phelloderm cells are narrow and thin walled (Fig. 29). Cork cells are angular in surface view (Fig. 30). The epidermis remains intact even though one or two cork layers are formed below it. However, it gets peeled off later.

Due to less expansion and proliferation, the bark cracks In response to these cracks successive phellogen arise in the deeper layers of secondary phloem forming periderm of a few layers which separate blocks of secondary phloem from the living inner portion of the bark. The blocks of secondary phloem thus isolated along with periderm form rhytidome layers (Photomicro. 16). Many rhytidome layers are coherent with one another forming scales The scales hang loosely and colour changes from yellowish to dull gray before exfoliation.

Text-figures 12 to 17. *Dalbergia sisso*

Text-figure 12 — Percentage of fiber bands in different frequency classes of tangential and radial extent.

Text-figure 13 — Percentage of fibers in different frequency classes of length.

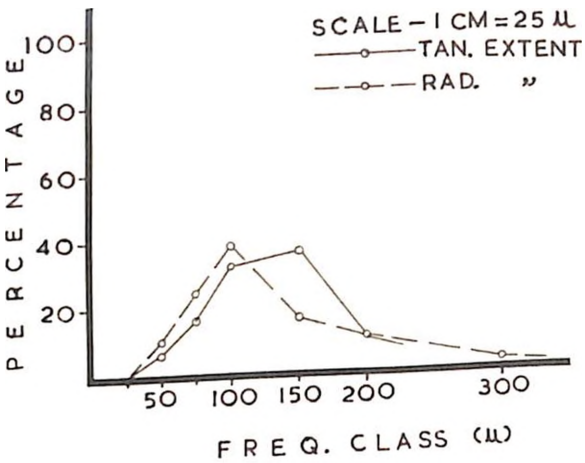
Text-figure 14 — Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 15 — Percentage of uni-,bi-, and multiseriate rays in different classes of height.

Text-figure 16 — Percentage of uni-, bi- and multiseriate rays in different frequency classes of width.

Text-figure 17 — Percentage readings in different frequency classes of number of rays per sq.mm.

TAN. EXTENT - tangential extent, RAD. EXTENT - Radial extent, UNI. RAYS - uniseriate rays, BI. RAYS - biseriate rays, MULTI. RAYS - multiseriate rays.



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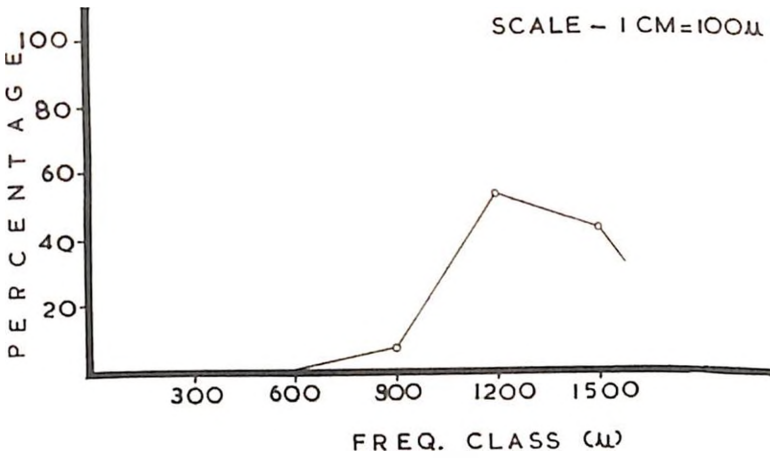

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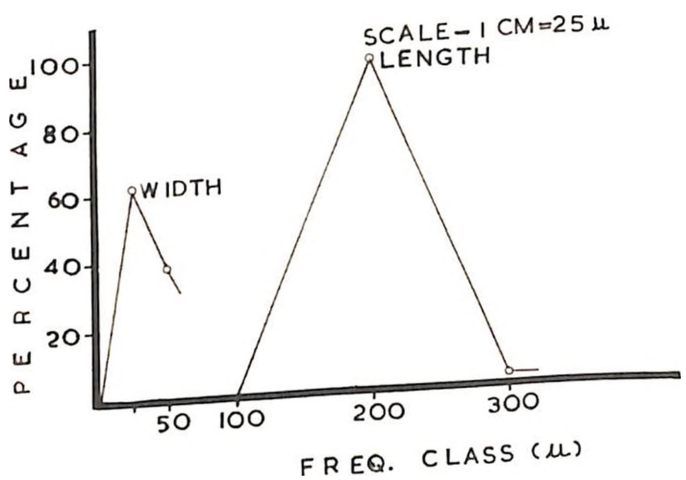

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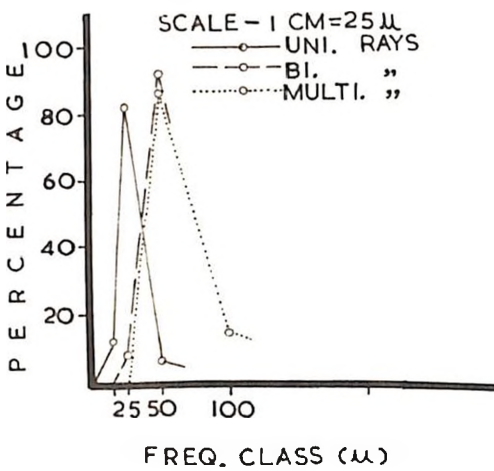

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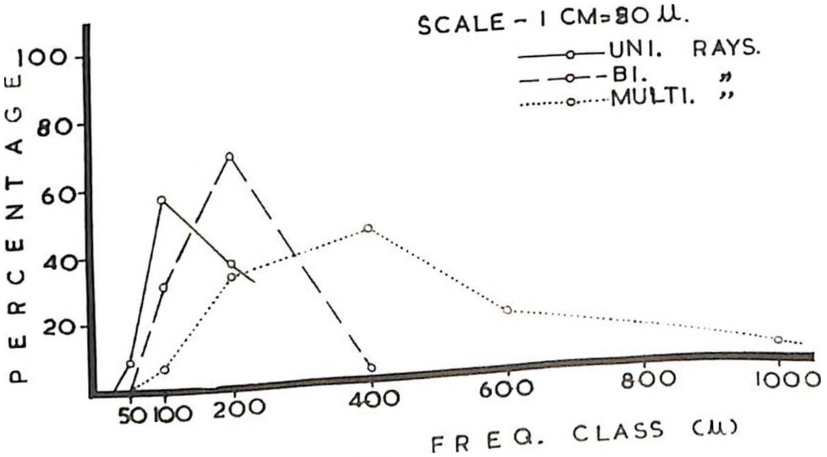

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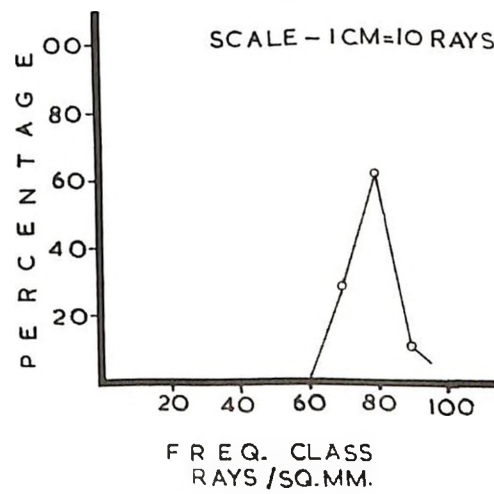


17

CAESALPINIA PULCHERRIMA

EXTERNAL MORPHOLOGY:

Bark in the young branches is green with distinct lenticels, while in the older branches and bole it is smooth (Photo. 20), soft in texture and light grey in colour. Thickness of the bark in the bole region is about 2.0 mm.

STRUCTURE OF YOUNG TWIG:

Pith is wide, consisting of large, compact hexagonal cells. Pericycle is sclerenchymatous, narrow and continuous. Cortical cells are tangentially elongated and without intercellular spaces (Photomicro. 21). The layer of cortex immediately outside the pericycle contains rhomboidal crystals distributed sparsely. Epidermal cells are rectangular to barrel shaped with thick striated cuticle (Fig. 31).

STRUCTURE OF MATURE BARK:

Secondary phloem:

It consists of comparatively wide phloem blocks alternated by phloem rays which are wide towards the periphery (Fig. 32). Unlike the plants described earlier, phloem blocks are devoid of fibers but show sparsely distributed patches of hexagonal sclereids (Figs. 32, 33A,B). Sclereids either solitary or in groups of three or four are surrounded by a single layer of thick walled cells containing rhomboidal crystals (Figs. 34A,B).

Major portion of the phloem block consists of soft tissue which is similar to other plants described earlier (Photomicro. 22).

In transverse section sieve tubes are thick walled, rectangular to circular in outline (Figs. 33A,B; Photomicro. 22), while in longitudinal section they are long, cylindrical with inclined end walls (Photomicro. 23,24). In general, the end walls are perforated to form sieve plates, rarely vertical walls are also perforated to form sieve plates (Photomicro. 23,24). In case the sieve tubes have conical ends, the sieve plates occur on both the faces (Photomicro. 24). Each sieve plate has more than one sieve area and is thus compound. Number of sieve areas is variable from plate to plate (Photomicro. 23,24). Angle of inclination of the sieve plates ranges from 20 to 90 degrees with an average of 37.00 degrees. Usually the sieve plates are inclined between 30.0 to 40.0 degrees. The sieve tubes are 145.35 to 290.7 microns long and 11.63 to 25.19 microns wide. Average length and width of the sieve tubes is 229.65 and 18.15 microns respectively. Percentage of sieve tubes in different frequency classes of length and width is shown in text-figure 18. Slime is indistinct. However, in a few sieve tubes it occurs in the form of dark stained body (Fig. 35).

Each sieve tube is associated with one or two, traingular, rectangular or lense shaped companion cells in transverse section (Fig. 33A,B; Photomicro. 22).

Phloem parenchyma cells are circular to round in

transverse section (Figs. 33A,B; Photomicro. 22), and rectangular in longitudinal section. These cells possess crystals at places (Photomicro. 23).

Phloem rays, similar to the members of papilionataa, are of the first as well as second categories, one to three cells wide, and the cells are elongated to rectangular in transverse section. In radial longitudinal section they are homogeneous and uni-, bi- and multiseriate in tangential longitudinal section (Photomicro. 23).

Uniseriate rays have either conical or round ends (Photomicro. 23,24). Height ranges from 29.07 to 300.39 microns and width from 9.69 to 21.32 microns. Average height and width is 123.54 and 13.01 microns respectively. Percentage of these rays in different frequency classes of height and width is shown in text-figures 19 and 20 respectively.

Biseriate rays in general have single celled uniseriate ends or uniseriate extensions of varying lengths (Photomicro. 23,24). A few of these rays have one short biseriate end while the other end is uniseriate and extended (Fig. 36B). Biseriate rays with included uniseriate portions are also present (Fig. 36B). Height ranges from 77.52 to 319.77 microns and width from 13.57 to 29.07 microns. Average height and width is 173.82 and 19.15 microns respectively. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 19 and 20 respectively.

Mutiseriate rays are mainly three cells wide with

uniseriate, equal or unequal ends (Fig. 37; Photomicro. 24). Cells are circular to angular. Height ranges from 96.90 to 310.08 microns and with from 23.26 to 77.52 microns. Average height and width is 214.05 and 35.47 microns respectively. Percentage of these rays in different frequency classes of height and width is shown in text-figures 19 and 20 respectively.

Number of rays per square mm. is very high and ranges from 75 to 250 with an average of 165.0 rays. Percentage readings in different frequency classes of rays per sq. mm. are shown in text-figure. 21.

Percentage occurrence of uni-, bi- and multiseriate rays is 61.575, 35.454 and 3.03 respectively.

Expansion: As in plants described earlier, this also shows cortical and pericyclic expansion in the younger stages and ray expansion a little later.

Cortical expansion: It is similar to that observed in the members of Papilionaceae (Fig. 38).

Pericyclic expansion: Unlike the Papilionaceae members, a few parenchymatous cells intrude in between the pericyclic sclerenchyma. These cells stretch tangentially and divide anticlinally resulting in expansion of the pericycle. Cells in these parenchymatous regions are soon transformed into sclereids which are pentangular, rectangular or rod shaped.

Ray expansion: Most of the rays show expansion towards periphery of the bark. The mode of ray expansion is similar to

that in Erythrina. Patches of expansion tissue merge with each other towards the periphery forming a sort of pseudocortex (Fig. 32).

PERIDERM:

Periderm is superficial throughout. Its origin and initiation is similar to the Papilionaceae members studied (Fig. 31). Extent of the cork is more than that of phelloderm (Photomicro. 21,25). Cork cells are vacuolated, rectangular with suberised walls in transverse section (Photomicro. 25), and angular in surface view (Fig. 39). Mature cork shows alternate zones of crushed and uncrushed tissue (Photomicro. 25). Exfoliation takes place from the thin walled layers of the cork cells near the crushed band. Epidermis of the young branches cracks only after the formation of one or two cork layers.

Text-figures 18 to 21 — Caesalpinia pulcherrima

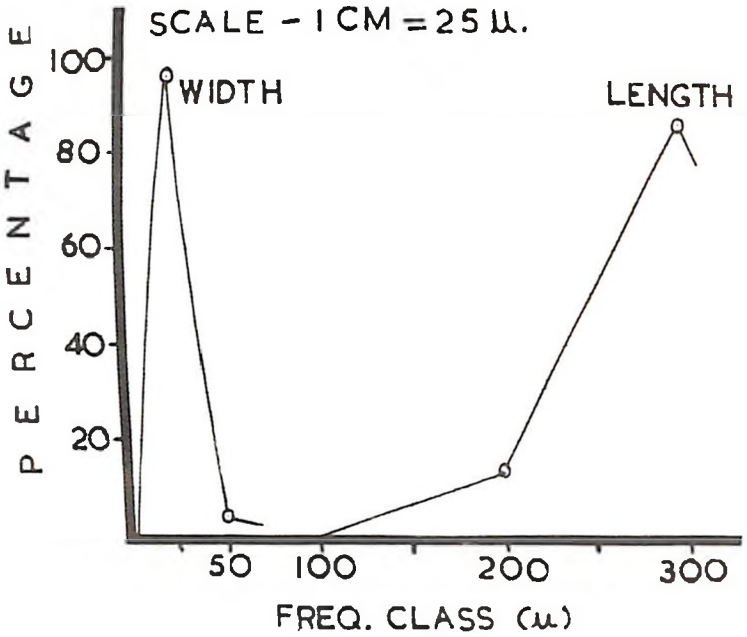
Text-figure 18 — Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 19 — Percentage of uni, bi and multiseriate rays in different frequency classes of height.

Text-figure 20 — Percentage of uni, bi and multiseriate rays in different frequency classes of width.

Text-figure 21 — Percentage readings in different frequency classes of number of rays per sq.mm.

UNI.RAYS - Uniseriate rays, BI. RAYS - Biseriate rays, MULTI. RAY - Multiseriate rays.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LENGTH
PERCENTAGE
100
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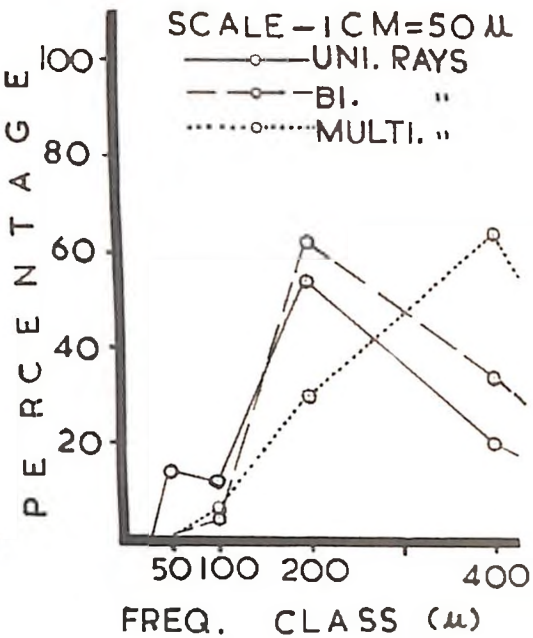
60
40
20
50
100
200
300
FREQ. CLASS (μ)

18


SCALE - 1 CM = 50 μ
UNI. RAYS
BI. "
MULTI. "
PERCENTAGE
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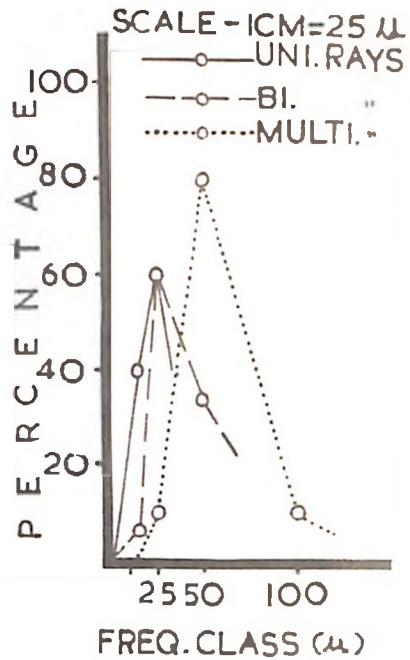
FREQ. CLASS (μ)

19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BI. "
MULTI. "
PERCENTAGE
100
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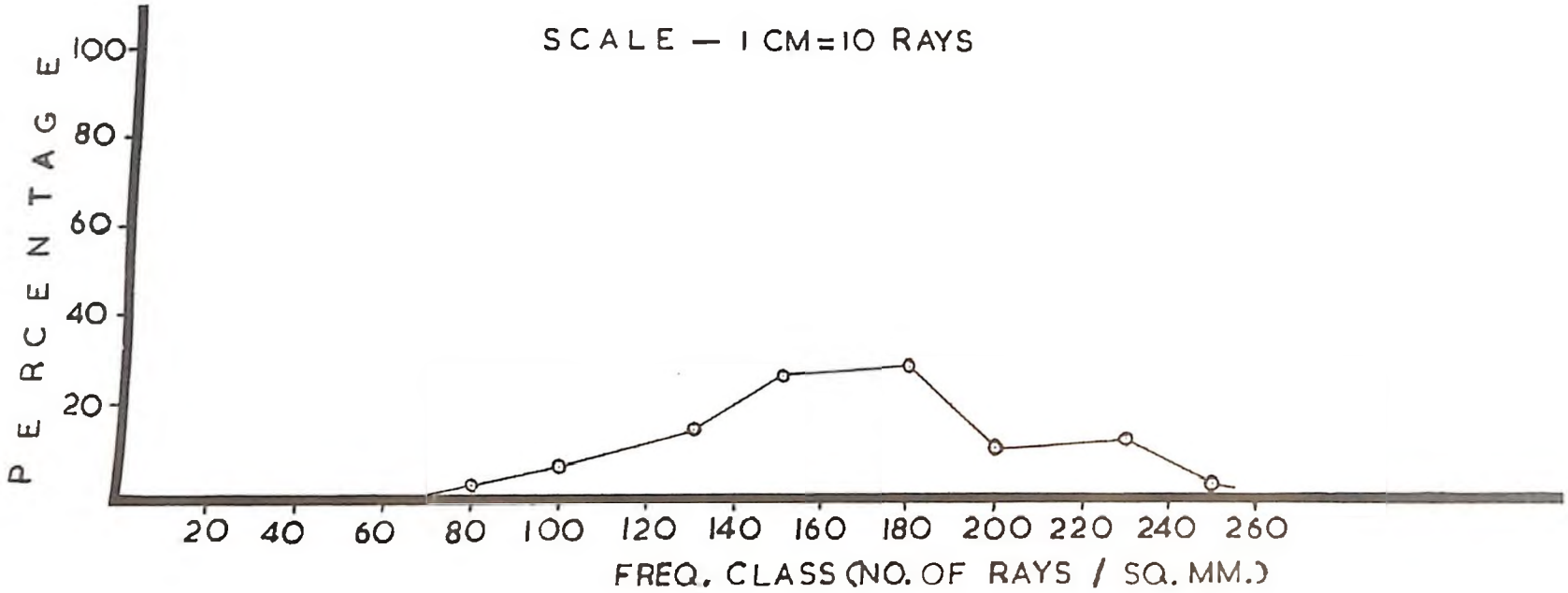
40
20
25
50
100
FREQ. CLASS (μ)

20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100
120
140
160
180
200
220
240
260
FREQ. CLASS (NO. OF RAYS / SQ. MM.)

21

DELONIX REGIA

EXTERNAL MORPHOLOGY:

Bole bark is smooth in appearance (Photo. 26), brittle in texture and light brown in colour. Bark of younger branches is green and smooth. Total thickness of the bole bark is 10.0 to 11.0 mm.

STRUCTURE OF YOUNG TWIG:

Pith is wide consisting of large, thin walled and angular cells having intercellular spaces peripheral cells are small and thick walled (Photomicro. 27). These cells contain sphaero-crystals. Pericycle is broad and sclerenchymatous. Cell walls of the outer two to three layers of pericycle are thick. Cortical cells are small, tangentially elongated and angular. Some of these contain sphaero-crystals. Epidermal cells are small, barrel shaped with slightly curved outer tangential walls. Cuticle is thin (Fig. 46; Photomicro. 28).

STRUCTURE OF MATURE BARK:

Secondary phloem:

It is characterised by the presence of wide phloem blocks alternating with phloem rays. Phloem blocks are characterised by the absence of fibers as well as patches of sclereids

intermingled with the sieve tubes or their rows (Fig. 42).

Phloem rays, similar to other plants are of first as well as second categories when viewed in transverse section. They are one to three cells wide. Cells constituting them are rectangular. Twisting of rays towards the periphery is prominent (Figs. 41; Photomicro. 29). Rays appear homogeneous in radial longitudinal section and uni-, bi- and multiseriate in tangential longitudinal section (Photomicro. 31).

Uniseriate rays have mostly round or conical end cells (Photomicro.31). Height ranges from 48.45 to 193.80 microns and width from 11.63 to 29.07 microns. Average height and width is 115.82 and 20.39 microns respectively. Percentage of uniseriate rays in different frequency classes of height and width is shown in text-figures 23 and 24 respectively.

Biseriate rays have single celled uniseriate ends (Photomicro. 31). Rays with equal or unequal extended ends also occur (Figs. 44A,B). Rarely rays have one end biseriate and the other uniseriate (Fig. 44C), while others include uni- and biseriate portions (Fig. 44A). Height ranges from 96.90 to 232,56 microns and width from 21.32 to 44.58 microns. Average height and width is 146.90 and 31.40 microns respectively. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 23 and 24 respectively.

Multiseriate rays are mostly three cells wide and have uniseriate ends. Some of the rays have uniseriate extensions

(Photomicro. 31), others have one end uniseriate and the other biseriate (Fig. 45A). Still others include uni- and biseriate portions (Fig. 45B). Height ranges from 155.04 to 484.50 microns and width from 34.89 to 67.83 microns. Average height and width is 258.26 and 48.30 microns respectively. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 23 and 24 respectively.

Number of rays per sq. mm. ranges from 24 to 46 with an average of 38.3. Percentage readings in different frequency classes of rays per sq. mm. are shown in text-figure 25.

Percentage occurrence of uni-, bi- and multiseriate rays is 21.456, 26.619 and 51.929 respectively.

Expansion: All the three types of expansion are shown by this plant also.

Cortical expansion: It is not very prominent and is only manifested in the tangential enlargement of the cells. Only a few anticlinal divisions have been observed here and there.

Pericyclic expansion: It is similar to that of the Caesalpinia pulcherrima (Photomicro. 28). Walls of the parenchymatous cells formed as a result of pericyclic expansion become thick due to lignification.

Ray expansion: It is also similar to that described in other plants earlier and results in wedges of expansion tissue (Fig. 41). Some of the rays show ununiform expansion which results in twisting of rays (Fig. 41; Photomicro.29).

Phloem proliferation: It is very prominent in the peripheral portions of the bark and wide patches of phloem proliferation tissue are formed due to the dilation of the axial phloem parenchyma. This dilation takes place in a similar fashion as in Dalbergia sisso. This phloem proliferation tissue merges with the ray expansion tissue towards the periphery.

Periderm:

Phellogen initiates in the sub-hypodermal layer but in the same way as in the plants described earlier (Fig. 46; Photomicro. 28). Cork and phelloderm is cut off almost equally. Cork cells are small, rectangular with outer and inner tangential walls thicker than the radial (Fig. 47). Deeper layers of periderm are not formed. Cork layers are regularly peeled off in the form of powdery mass.

Sclerosis takes place in the parenchymatous portions of the expansion tissue and phloem proliferation tissue. The cells become thick walled due to lignification but sclereids are not formed.

Text-figures 22 to 25 — *Delonix regia*

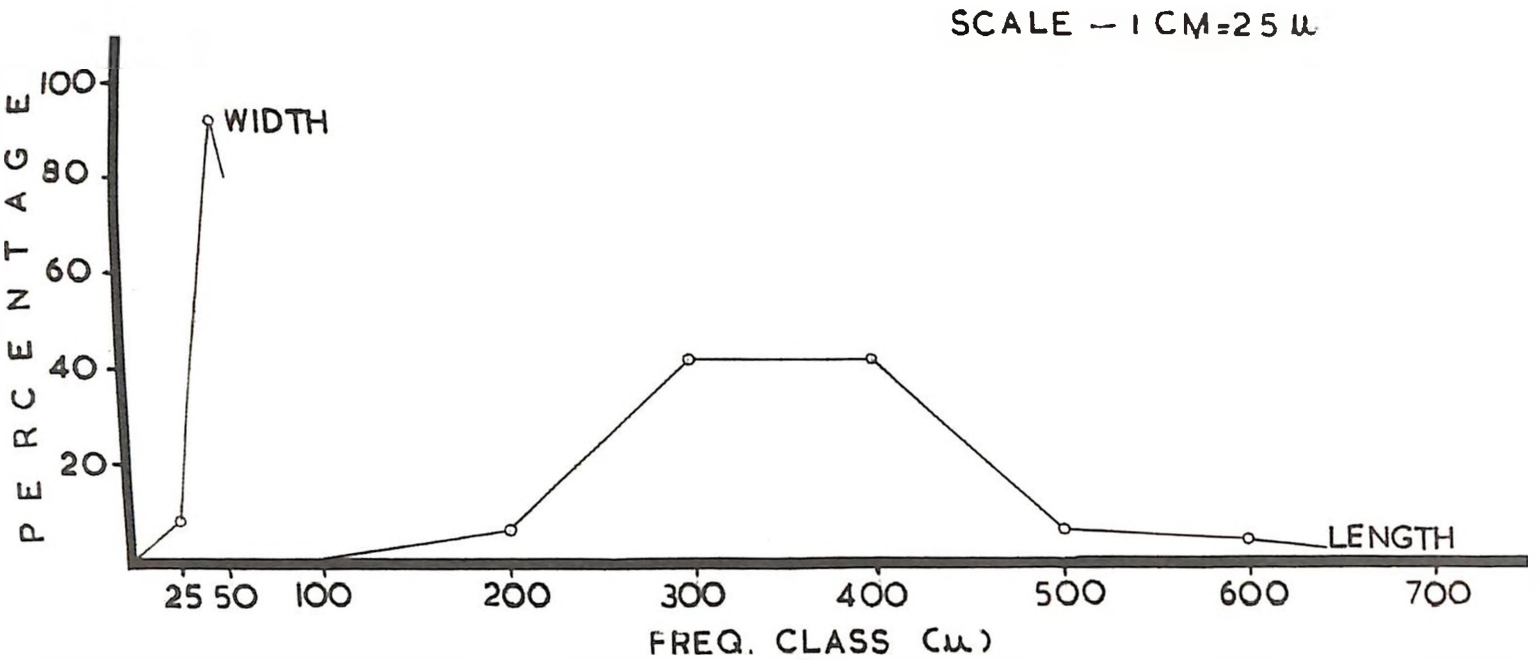
Text-figure 22 — Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 23 — Percentage of uni-, bi- and multiseriate rays in different frequency classes of height.

Text-figure 24 — Percentage of uni-, bi- and multiseriate rays in different frequency classes of width.

Text-figure 25 — Percentage readings in different frequency classes of number of rays per sq. mm.

UNI. RAYS - uniseriate rays, BI. RAYS - biseriate rays, MULTI. RAYS - multiseriate rays.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60
40
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WIDTH
LENGTH
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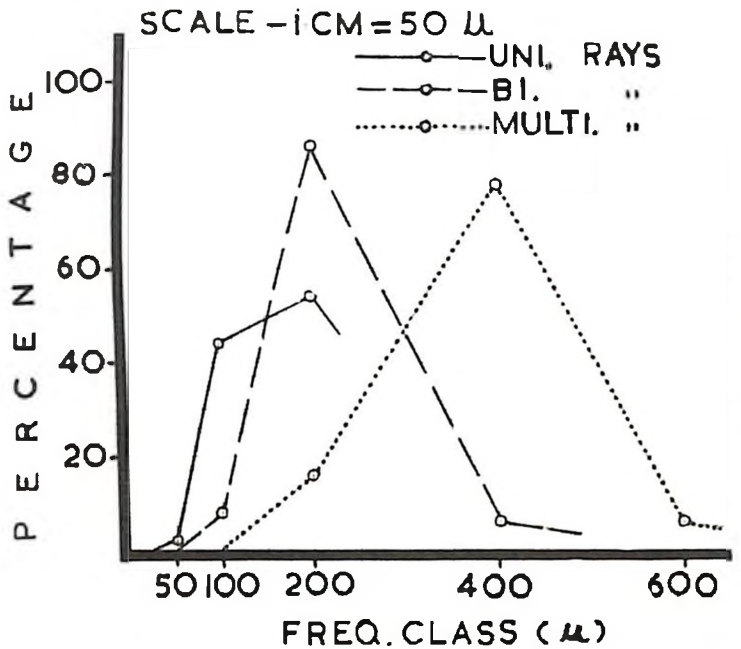
FREQ. CLASS (μ)

22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BI. "
MULTI. "
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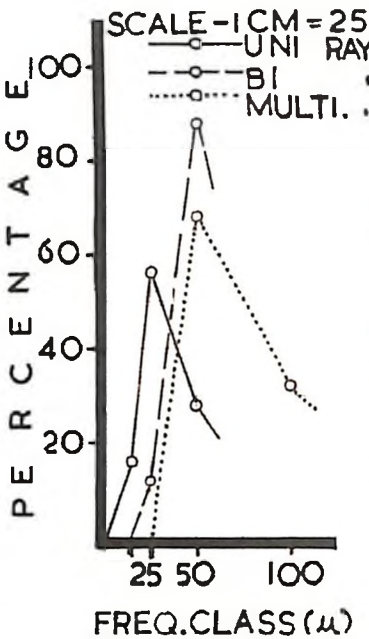
23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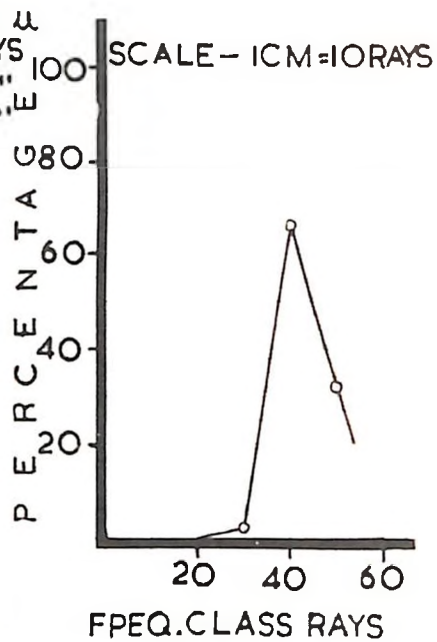
24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60
40
20
20 40 60
FPEQ.CLASS RAYS
PER SQ.MM.

25

CASSIA SPECIES

EXTERNAL MORPHOLOGY:

C. auriculata: Bark of the young branches is green and covered by fine pubescent hairs. Bole bark is smooth (Photo. 32) and reddish brown in colour. Thickness of bole bark is about 3.0 mm.

C. fistula: In young branches bark is smooth and pale grey in colour. Bole bark is rough (Photo. 39) and grey to light brown in colour. Thickness of bole bark is about 9.0 to 10.0 mm.

C. siamea: In young branches bark is green and smooth with dull grey longitudinal lines. Lenticels are prominent and horizontally oriented. Bole bark is smooth or very minutely fissured (Photo. 44). Thickness of the bole bark is about 6.0 to 7.0 mm. Outer bark is 1.0 to 2.0 mm. in thickness.

STRUCTURE OF YOUNG TWIG:

C. auriculata: Pith is wide consisting of loosely arranged, round, thick walled parenchymatous cells having rhomboidal or sphaerocrystals. The latter are present only in the small cells. Larger pith cells show anticlinal divisions. Pericycle is narrow (Photomicro. 33,34). Cortex consists of thin-walled, oval or round cells (Photomicro. 33,34). Cells of the

cortical layer immediately outside the pericycle contain rhomboidal crystals while that of the other cortical layers contain sphaerocrystals. Epidermal cells are narrow, radially elongated, papillate with conical outer tangential walls covered by thick granular cuticle (Fig. 48). Stem surface is covered by trichomes which are rooted in the cortex and covered by thick cuticle (Fig. 48).

C. fistula: Pith is wide consisting of thin walled, angular parenchymatous cells. Pericycle is wider than that in C. auriculata and consists of many sclerenchymatous layers (Photomicro. 40). Cell walls of a few outer layers of the pericycle are more thicker than that of the inner and the lumen of the outer layers is narrower than that of the inner (Photomicro. 40). Cortical cells are thin-walled, oblong, without intercellular spaces (Fig. 57; Photomicro. 40). Cells of the cortical layer immediately outside the pericycle contain sparsely distributed rhomboidal crystals. Epidermis is papillose with convex outer tangential walls (Fig. 57; Photomicro. 40). Cuticle is thick, striated as well as granular and covers almost half of the radial walls of the epidermal cells (Photomicro. 40).

C. siamea: Stem in transectional outline shows ridges and grooves. Pith is large, cells are polygonal in the centre and small thick-walled at the periphery alternated by radial rows of tangentially elongated thin walled cells (Photomicro. 45). Pericycle consists of many layers of sclerenchymatous cells which projects into the primary phloem at the angles and in this region cells walls are less thick. Cortical cells are large, angular,

thin walled and chlorenchymatous. Crystals are absent in the cortical cells immediately outside the pericycle. Epidermal cells are radially elongated (Fig. 62). Cuticle is thin. Small or large club shaped or pointed trichomes are present on the surface (Figs. 62,66; Photomicro. 46).

STRUCTURE OF MATURE BARK:

Secondary phloem:

It is characterised by broad phloem blocks in C. auriculata and C. siamea and narrow in C. fistula. Each phloem block is characterised by the presence of rectangular or oval fiber bands in C. auriculata and C. siamea and rectangular or squarish in C. fistula. These bands form regular tangential rows in C. auriculata and irregular in C. fistula and C. siamea (Figs. 58,63; Photomicro. 35-36, 41-42, 47). Each fiber band is lined by a single layer of crystalliferous cells having rhomboidal crystals (Figs. 49,59A,64B). Crystalliferous layer on both the sides are followed by parenchyma. In transverse section, fibers are oblong or angular with reduced lumen and thick walls (Figs. 49,59B,64B). Tangential extent of the fiber bands ranges from 38.76 to 155.04, 19.38 to 125.97 and 42.64 to 242.25 microns in C. auriculata, C. fistula and C. siamea respectively. Radial extent ranges from 29.07 to 77.52, 23.26 to 116.28 and 38.76 to 87.21 microns in C.auriculata, C. fistula and C.siamea respectively. Average tangential and radial extent is 73.33 and 44.73 microns in C. auriculata, 61.51 and 78.57 microns in C. fistula and 90.40 and 55.51 microns in C. siamea respectively.

Percentage of fiber bands in different frequency classes of tangentaial and radial extent is shown in text-figure 26,27 respectively.

In C. auriculata fibers have gradually tapering distal portions with conical, undulated or even forked ends (Figs. 50A, B). In C. fistula fibers are of the following types: (1) Long, nonseptate, ends gradually tapering, tips oblique but sharp or forked (Figs. 60A,B). (2) Septate with broad body and lumen, ends variable and each compartment contains rhomboidal crystals (Fig. 60C). Walls show cross pits. In C. siamea all fibers are similar, nonseptate with gradually tapering, sharp or undulated ends. Fiber length ranges from 467.50 to 1147.50 microns in C. auriculata, 722.50 to 1292.00 microns in C. fistula and 680.00 to 1785.00 microns in C. siamea. Average fiber length is 793.73, 1001.81 and 1101.01 microns in C. auriculata, C. fistula and C. siamea respectively. Percentage of fibers in different frequency classes of length in different Cassia species is shown in text-figure 28.

Sieve tubes are large, round or angular and irregularly distributed in C. auriculata and C. siamea (Figs. 49, 64A,B), while in aggregates or radial rows in C. fistula (Figs. 59A,B). In longitudinal sections they are cylindrical with inclined or rarely transverse end walls. Similar to other members of Caesalpineae, thesieve areas occur on the inclined end walls (Figs. 52A,B; 61A,B; 65A,B; Photomicro. 37, 43, 48), rarely on transverse or vertical walls (Fig. 51B). Each sieve plate has more than one sieve area variable in size and shape and arrangement

which is either uniseriate or biseriate in radial longitudinal section (Figs. 52A,B). The sieve plates are compound and are oriented between 20 to 80 degrees in C. auriculata and 40 to 90 degrees in C. fistula and C. siamea. Average angle of inclination of sieve plates is 40.3, 43.0 and 51.1 degrees in C. auriculata, C. fistula and C. siamea. Walls are thick and non-pitted in C. auriculata, thick and pitted in C. siamea and thin in C.fistula.

Slime occurs in the form of amorphous mass in C. fistula (Fig. 61B). It is indistinct in C. auriculata. In C. siamea, slime body is spindle shaped in differentiating sieve tubes and in mature sieve tubes it persists either as plugs of amorphous mass near the plate (Photomicro. 48), or in the form of strands emerging out from the sieve plate and running obliquely to the longitudinal walls (Figs. 65A,B).

Sieve tubes are 155.04 to 426.36 microns in length in C. auriculata, 145.35 to 319.17 microns in C. fistula and 87.21 to 406.98 microns in C. siamea. They are 11.63 to 23.25 microns wide in C. auriculata, 19.38 to 38.76 microns in C. fistula and 19.38 to 48.45 microns in C. siamea. Average length and width respectively is 233.45 and 17.71 microns in C. auriculata, 241.67 and 25.51 microns in C. fistula and 262.29 and 30.93 microns in C. siamea. Percentage of sieve tubes in different frequency classes of length and width in Cassia species is shown in text-figure 29.

Sieve tubes in the nonfunctional phloem are obliterated forming irregular bands of crushed tissue in between the fiber bands (Figs. 58,63; Photomicro. 35,36,41,47).

In transverse section one or two companion cells are associated with each sieve tube. They are triangular, circular or semilunar in shape (Figs. 49,59 A,B; 64 A,B). Companion cells numbering two to three in C. auriculata, one to four in C. fistula and three to four in C. siamea occur along the length of the sieve tube.

Phloem parenchyma cells are circular to oblong or angular in transverse section and rectangular in longitudinal section. Walls are pitted in C. auriculata and C. siamea.

Phloem rays, similar to other plants described earlier are of the first and second categories (Figs. 58,63; Photomicro. 35,41,47). The rays are one to three cells wide in C. auriculata, one to four cells wide in C. fistula and one to three or many cells wide in C. siamea. Cells are rectangular to oblong in C. auriculata and C. siamea and squarish or rectangular in C. fistula. The ray cells contain druses in C. siamea (Fig. 64A). Twisting of rays in prominent in all the species (Figs. 58,63; Photomicro. 35,41,47). Rays are homogeneous. Cells are small and rectangular in C. auriculata, oblong to rectangular in C. fistula and rectangular or squarish in C. siamea. In tangential longitudinal section the rays appear uni-, bi- and multiseriate. Cells are angular to oblong, smaller in C. fistula and thick walled in C. siamea.

Uniseriate rays have conical or oblique but sharp and cells in C. auriculata and conical in C. fistula and C. siamea (Photomicro. 37, 43). Height and width respectively ranges from 34.89 to 242.25 and 15.51 to 32.95 microns in C. auriculata, 29.07 to 189.93 and 9.69 to 29.07

microns in C. fistula and 34.89 to 116.28 and 7.75 to 25.19 microns in C. siamea. Average height and width is respectively 122.95 and 21.78 microns in C. auriculata, 116.05 and 16.71 microns in C. fistula and 67.71 and 61.61 microns in C. siamea. Percentage of uniseriate rays in different frequency classes of height and width is shown in text-figures 30 and 31 respectively.

Biseriate rays have uniseriate extensions which are equal or unequal (Fig. 53; Photomicro. 37,43,48). These rays also include uniseriate portions in between (Fig. 53; Photomicro. 37,43,48). Height and width respectively ranges from 96.90 to 348.84 and 19.38 to 48.45 microns in C. auriculata, 135.66 to 678.30 and 19.38 to 38.76 microns in C. fistula and 58.14 to 232.56 and 19.38 to 38.76 microns in C. siamea. Average height and width respectively is 180.89 and 26.67 microns in C. auriculata, 268.34 and 28.22 microns in C. fistula and 128.76 and 29.45 microns in C. siamea. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 32 and 33 respectively.

Multiseriate rays are three to four cells wide in general. Ends are uniseriate, extended equally or unequally (Photomicro. 37,43,48). Rarely one end is biseriate in C. auriculata (Fig. 54). Rays with included uni- and biseriate portions also occur. Height and width respectively ranges from 120.16 to 465.12 and 29.07 to 63.95 microns in C.auriculata, 116.28 to 353.23 and 29.07 to 58.14 microns in C. fistula and 116.28 to 465.12 and 34.89 to 63.95 microns in C. siamea.

Average height and width respectively is 287.25 and 43.61 microns in C. auriculata, 216.40 and 38.37 microns in C. fistula and 216.32 and 49.96 microns in C. siamea. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 34 and 35 respectively.

Number of rays per sq. mm. varies from 55 to 88 in C. auriculata, 86 to 118 in C. fistula and 45 to 66 in C. siamea. Average number of rays per sq. mm. is 71.12, 103.88 and 54.64 in C. auriculata, C. fistula and C. siamea respectively. Percentage readings in different frequency classes of rays per sq. mm. are shown in text-figure 36.

Percentage occurrence of the uni-, bi- and multiseriate rays in Cassia species is shown in table I.

TABLE I

(Showing percentage occurrence of the uni-, bi- and multiseriate rays in Cassia species).

Name of species	% uniseriate rays	% biseriate rays	% multiseriate rays	Total
C. auriculata	47.44	29.19	23.36	99.994
C. fistula	33.41	57.31	9.27	99.99
C. siamea	5.16	24.23	70.61	100.00

Expansion: All the species show cortical, pericyclic and ray expansion.

Cortical expansion: It takes place in a fashion similar

to that in Erythrina indica but in C. auriculata, anticlinal divisions in the cortical cells are more prominent opposite to the primary phloem rays.

Pericyclic expansion: Its initiation beings with the interpolation of the parenchyma in between the sclerenchymatous pericycle. Further changes similar to that in Erythrina indica, result in expanded parenchymatous portions which are soon transformed in to sclerieds of variable sizes and shapes (Figs. 59A, 64A; Photomicro. 34,40,46).

Ray expansion: It is similar to Erythrina and others and results in the wedges of ray expansion tissue (Figs. 55, 59A, 63; Photomicro. 35, 41, 47). Some of the rays show localised dilation resulting in finger like expansion tissue (Photomicro. 35). Ray expansion is not very extensive in C. fistula.

Phloem proliferation: Proliferation in the phloem parenchyma is prominent in C. auriculata and C. fistula. Its formation is similar to that in Dalbergia and Delonix and results in wedges of phloem proliferation tissue (Fig. 58; Photomicro. 35,41).

Periderm:

In all the three species periderm is superficial. Trichomes in C. auriculata and C. siamea persist until the initiation of the phellogen (Figs. 48,57,62; Photomicro. 34,46). Origin and initiation of the phellogen takes place in the subepidermal layer as in other plants (Figs. 48,57,62). However, in

C. siamea phellogen is also initiated in the third or the fourth layer of the cortex, but such a condition was observed only in relation to the formation of lenticels (Fig. 66; Photomicro. 46). The wave of phellogen initiation then extends to the sides and joins the phellogen initiated subepidermally (Fig. 66; Photomicro. 46). Extent of the cork formed is more than the phelloderm. In transverse sections, cork cells are regularly arranged, narrow and comparatively thick walled in *C. auriculata* (Fig. 56) and *C. fistula* than in *C. siamea*. In surface view the cork cells are squarish in *C. auriculata* (Photomicro. 38) and rectangular to polygonal in *C. siamea* (Photomicro. 49). Exfoliation takes place in the form of small scales of cork in *C. auriculata*, thick and hard scales in *C. fistula* and soft dull grey peels in *C. siamea*.

Sclerosis: It is quite common in the phloem proliferation, pericyclic and ray expansion tissues. It results only in the thickening of the walls in *C. auriculata*. In *C. fistula* and *C. siamea* the sclerosis extends even to the cells of the phelloderm. Sclerieds are of various types (Figs. 68A-D; Photomicro. 40,46).

Text-figures 26 to 36 — *Cassia* species.

Text-figure 26 — Percentage of fiber bands in different frequency classes of tangential extent.

Text-figure 27 — Percentage of fiber bands in different frequency classes of radial extent.

Text-figure 28 — Percentage of fibers in different frequency classes of length.

Text-figufe 29 — Percentage of sieve tubes in different frequency classes of length and width.

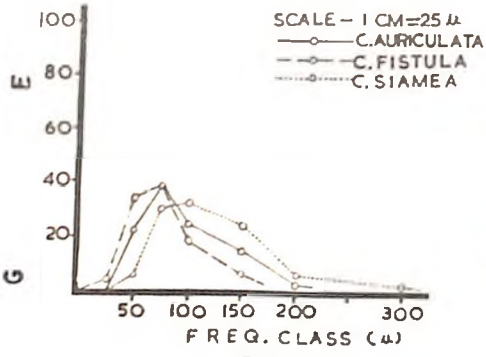
Text-figure 30 — Percentage of uniseriate rays in different frequency classes of height.

Text-figure 31 — Percentage of uniseriate rays in different frequency classes of width.

Text-figure 32 — Percentage of biseriate rays in different frequency classes of height.

Text-figure 33. — Percentage of biseriate rays in different frequency classes of width.

Text-figure 34 — Percentage of multiseriate rays in diffe-different frequency classes of height.



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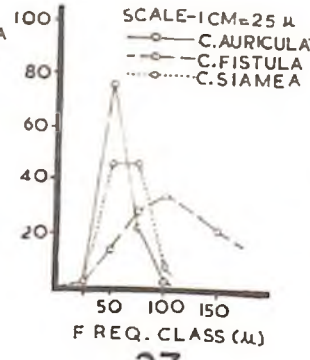

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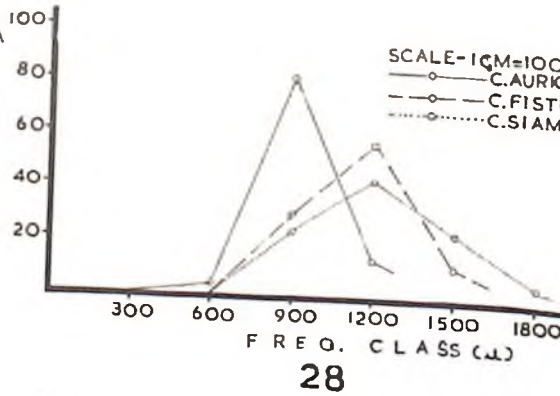

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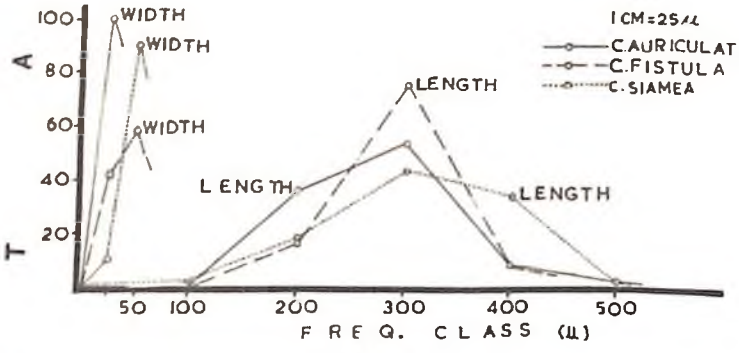

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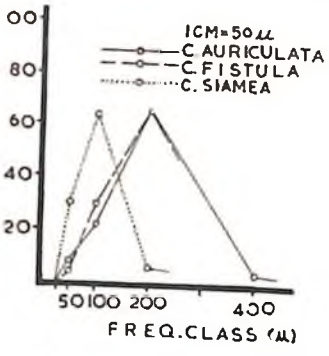

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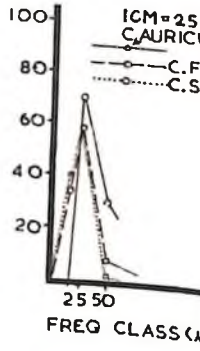

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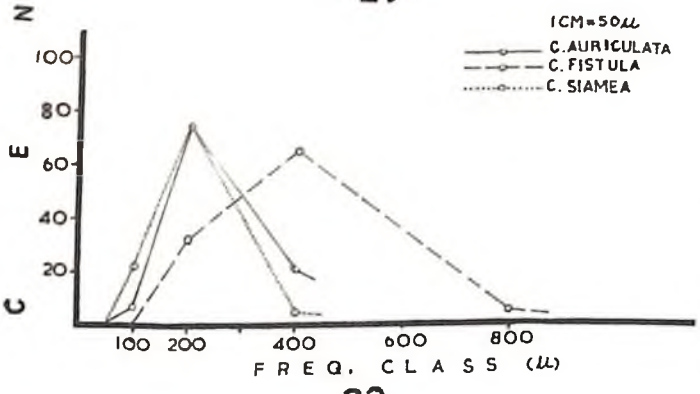

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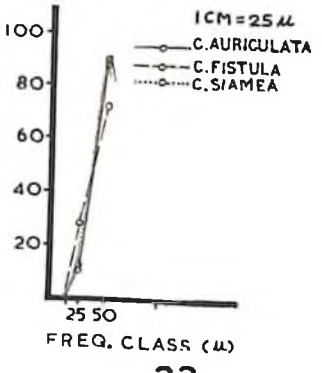

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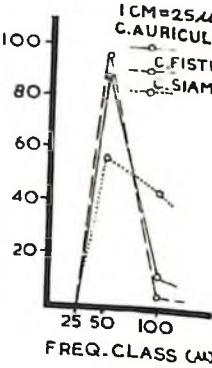

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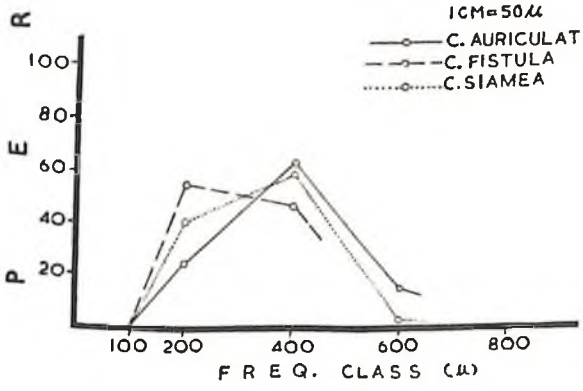

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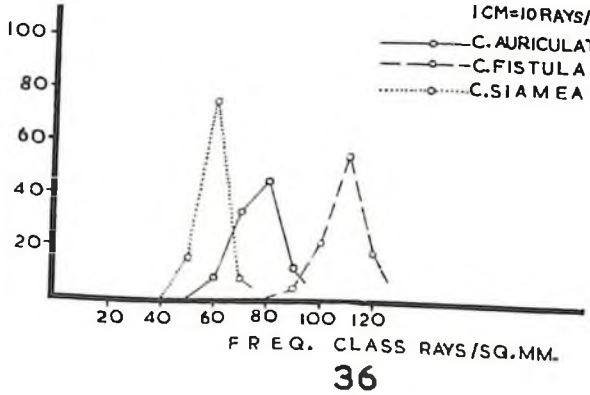


36

TAMARINDUS INDICA

EXTERNAL MORPHOLOGY:

Bark in the young branches is green and smooth. In the older branches it is fissured type and in the bole region it is scaly and deeply fissured with longitudinal and transverse cracks (Photo. 50). Colour of the bole bark is dull brown. Thickness of the bole bark is about 6.0 to 8.0 mm.

STRUCTURE OF YOUNG TWIG:

Pith consists of polygonal cells with intercellular spaces. Pericycle is wide, sclerenchymatous and continuous (Photomicro. 51). Cortical cells are angular, thick walled and parenchymatous (Photomicro. 51). Layer of the cortical cells immediately outside the pericycle contains rhomboidal crystals which are more frequent in the region of pericyclic grooves (Fig. 69; Photomicro. 51). Epidermal cells are small with thin cuticle (Fig. 69; Photomicro. 51).

STRUCTURE OF MATURE BARK:

Secondary phloem:

It has narrow phloem blocks alternated by narrow phloem rays. In each phloem block occur tangential fiber bands of variable shapes near to the cambium and fiber bands in association with patches of scleried, which are either abaxial or adaxial

or abaxial and adaxial both, towards the periphery of the bark (Fig. 70B). Fiber bands show irregular distribution along the circumference (Photomicro. 52). Each fiber band is lined by a single layer of crystalliferous cells on both the sides. This is followed by a few parenchymatous layers adaxially and abaxially (Fig. 70B). Fibers are angular in transverse section and have narrow lumen (Fig. 70B). Tangential extent of the fiber bands ranges from 19.38 to 242.25 microns and radial extent is 82.91 and 62.09 microns respectively. Percentage of fiber bands in different frequency classes of tangential and radial extent is shown in text-figure 37.

In macerated preparations fibers are non-septate, body is broad, ends gradually tapering, tips obtuse, undulated or sharply oblique (Figs. 71A-C). Walls show oblique pits. Fiber length ranges from 807.50 to 1572.50 microns with an average of 1079.50 microns. Percentage of fibers in different frequency classes of length is shown in text-figure 38.

Sieve tubes occur in aggregates as well as in radial rows of a few elements embeded in the phloem parenchyma (Fig. 70A). End walls are inclined and sieve areas are restricted to them forming sieve plates (Figs. 72A-C; Photomicro. 54, 55). Rarely sieve areas also occur on the vertical walls. Each sieve plate has usually two and rarely one sieve area and are thus compound as well as simple in contrast to other members of Caesalpineae. Sieve plate in transverse view is shown in Figure 73. Sieve plates are oriented at an angle ranging from 20.0 to 90.0 degrees with an average of 52.3 degrees. Usually the sieve

plates are inclined between 40.0 to 60.0 degrees. In surface view sieve tubes show lattices (Fig. 72C; Photomicro. 54,55). Radial as well as tangential walls are thick and pitted. Slime is very prominent and occurs in the form of darkly staining or amorphous plugs of variable shapes on one or both sides of the sieve plates (Figs. 72A-C; Photomicro. 54,55). The sieve tubes are obliterated in the peripheral part of the secondary phloem.

Sieve tubes are 67.83 to 348.84 microns in length and 15.51 to 27.13 microns in width. Average length and width is 220.82 and 20.23 microns respectively. Percentage of sieve tubes in different frequency classes of length and width is shown in text-figure 39.

In transverse section, each sieve tube is associated with one or two companion cells of variable shapes (Fig.70A). Two to four companion cells are present along the length.

Phloem parenchyma is distributed in between the sieve tubes in addition to the regular layers present adaxially and abaxially to the fiber bands.

Phloem rays, similar to other plants are of the first as well as second categories. They are mainly one or two and rarely three or more cells wide. Cells are squarish to rectangular with dark yellow contents. Rays are homogeneous and uni-, bi- and multiseriate in tangential longitudinal section (Photomicro. 54,55).

Uniseriate rays usually have conical end cells (Photomicro. 54,55). Height ranges from 29.07 to 261.63 microns

and width from 9.69 to 19.38 microns. Average height and width is 83.48 and 15.47 microns respectively. Percentage of uniseriate rays in different frequency classes of height and width is shown in text-figures 40 and 41 respectively.

Biseriate rays have short uniseriate ends or equal or unequal uniseriate extensions (Photomicro. 54,55). Some of the rays include uniseriate portions. Height ranges from 58.14 to 232.56 microns and width from 15.51 to 44.57 microns. Average height and width is 136.63 and 24.94 microns respectively. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 40 and 41 respectively.

Multiseriate rays are usually three cells wide with short uniseriate ends (Fig. 74). Height ranges from 48.45 to 310.08 microns and width from 13.57 to 32.95 microns. Average height and width is 180.12 and 24.32 microns respectively. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 40 and 41 respectively.

Number of rays per square mm. ranges from 55 to 104 with an average of 83.28. Percentage readings in different frequency classes of ray number per square mm. are shown in text-figure 42.

Percentage occurrence of uni-, bi- and multiseriate rays is 66.33, 21.67 and 12.00 respectively.

Expansion: The bark shows cortical, pericyclic and ray expansions which take place in a fashion similar to that

in other plants described earlier. The cells in the pericyclic expansion region become sclerosed (Figs. 69,75). The rays are twisted due to the partial expansion.

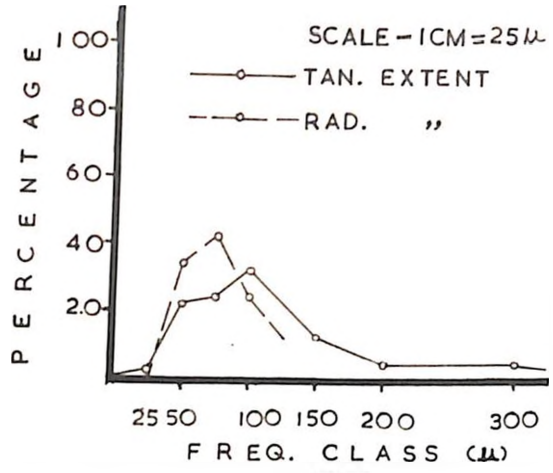
Periderm:

Periderm is superficial and the initiation, position and activity of the phellogen is similar to that in Erythrina (Fig. 69; Photomicro. 51). Extent of the cork is more than the phelloderm. Mature cork cells are of two types: (1) Sclerosed cells with outer and inner tangential walls comparatively more thicker than the radial and (2) Cells without sclerosis, rectangular in transverse section and angular in surgace view (Fig. 76; Photomicro. 57). A few layers of thin walled cells are crushed in between and are responsible for the zonation in the cork (Photomicro. 56).

Sclerosis: It is very prominent in the parenchymatous portions of the expanded pericycle, ray expansion tissue and so also in axial parenchyma. The sclerieds are of variable shapes (Figs. 77A-F).

Text-figures 37 to 42	Tamarindus indica
Text-figure 37	Percentage of fiber bands in different frequency classes of tangential and radial extent.
Text-figure 38	Percentage of fibers in different frequency classes of length.
Text-figure 39	Percentage of sieve tubes in different frequency classes of length and width.
Text-figure 40	Percentage of uni-, bi- and multiseriate rays in different frequency classes of height.
Text-figure 41	Percentage of uni-, bi- and multiseriate rays in different frequency classes of width.
Text-figure 42	Percentage readings in different frequency classes of number of rays per sq. mm.

TAN. EXTENT - Tangential extent, RAD. EXTENT - Radial extent, UNI. RAYS - uniseriate rays, BI. RAYS - Biseriate rays, MULTI. RAYS - multiseriate rays.



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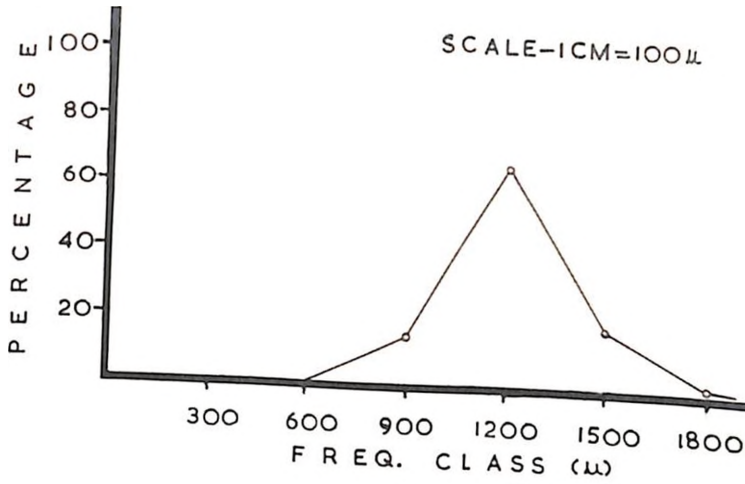

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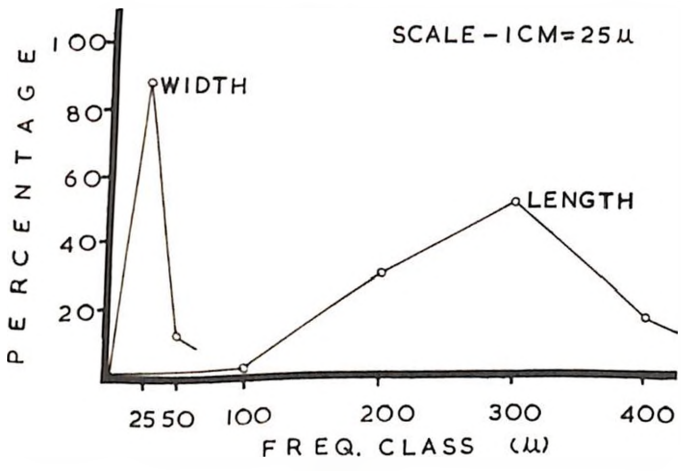

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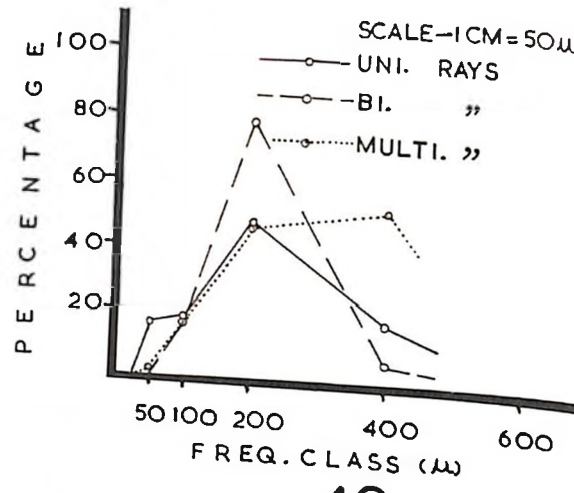

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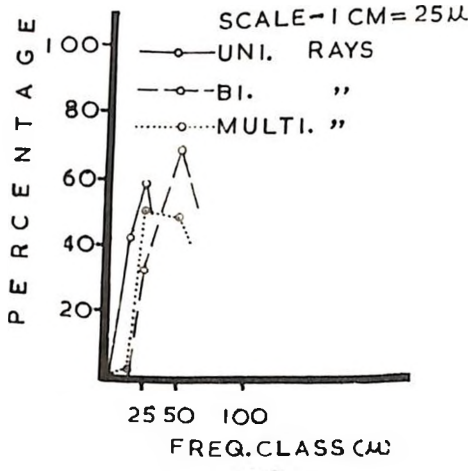

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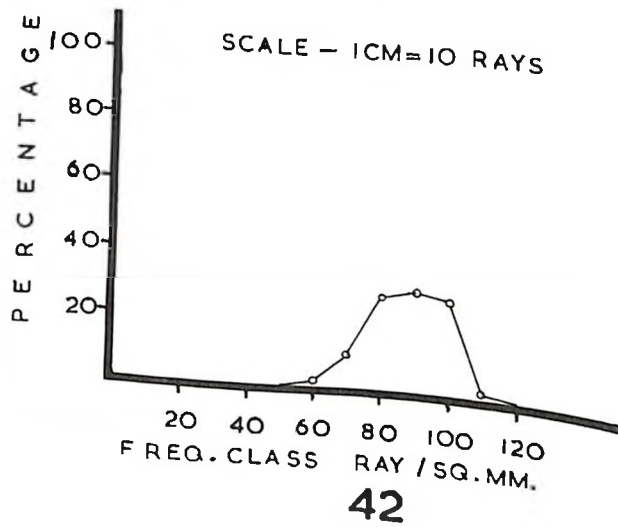


42

BAUHINIA VARIEGATA

EXTERNAL MORPHOLOGY:

Bark in the young branches is smooth, green and turns downy. Bole bark is also smooth (Photo. 58), but in some cases shows shallow longitudinal and horizontal cracks. Colour is light grey. Total thickness of the bole bark is 10.00 to 12.00 mm.

STRUCTURE OF YOUNG TWIG:

Pith is wide consisting of polygonal parenchymatous cells with small intercellular spaces (Photomicro. 59). Pericycle consists of alternate sclerenchymatous and parenchymatous patches (Photomicro. 59). Cortical cells are oblong with minute intercellular spaces and contain rhomboidal crystals (Photomicro. 60). Epidermal cells are barrel shaped with thick cuticle (Fig. 78).

STRUCTURE OF MATURE BARK:

Secondary phloem:

It consists of narrow phloem blocks which are alternated by narrow phloem rays. Similar to Cassia species the phloem blocks are characterised by the presence of fiber bands alternated by soft tissue. These fiber bands are small, very close to each other and distributed irregularly along the circumference

Phloem parenchyma is distributed irregularly and is intermingled with the sieve tubes and contain crystals.

Phloem rays, in transverse section are of the first as well as second categories. Ray cells are small, rectangular with darkly stained contents. Width is one, two or three cells (Photomicro. 61,62). Rays are homogeneous and uni-, bi- and multiseriate in tangential longitudinal section. Cells constituting these rays are thick walled and contain crystals or tannins.

Uniseriate rays have conical end cells (Photomicro. 63). Height ranges from 29.07 to 562.62 microns and width is 178.04 and 17.36 microns. Percentage of uniseriate rays in different frequency classes of height and width is shown in text-figures 45 and 46 respectively.

Biseriate rays have uniseriate ends which are either equal or unequal (Photomicro. 63). Some of the biseriate rays include uniseriate portions (Fig. 81). Height ranges from 116.28 to 604.66 microns and width from 13.57 to 38.76 microns. Average height and width is 263.65 and 27.20 microns respectively. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 45 and 46 respectively.

Multiseriate rays are three to four cells wide with uniseriate ends (Figs. 82A-C). Multiseriate rays with included uniseriate and biseriate portions also occur (Figs. 82A,B). Height ranges from 125.97 to 581.40 microns and width from

25.19 to 48.45 microns. Average height and width is 329.24 and 36.70 microns respectively. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 45 and 46 respectively.

Number of rays per square mm. varies from 75 to 225 with an average of 147.50. Percentage readings in different frequency classes of number of rays per sq. mm. are shown in text figure 47.

Percentage occurrence of uni-, Bi- and multiseriate rays is 39.60, 47.70 and 12.70 respectively.

Expansion: The bark from young branches as well as bole exhibits various degrees of cortical, pericyclic and ray expansion. Mode of their expansions is similar to that described earlier. Ray expansion results in the formation of wedges of parenchymatous tissue with broader side towards the periphery (Photomicro. 61).

Periderm:

Periderm is superficial and arises in the localised areas, ultimately it is formed all around. Unlike the plants described earlier, the initiation of the phellogen takes place in the sub-hypodermal layer. Further steps similar to Erythrina result in the formation of a phellogen layer (Fig. 78). This layer cuts off more cork layers than phelloderm. Cork cells are rectangular, thick walled, brown and bacome crushed (Fig. 83; Photomicro. 59,60).

Sclerosis: It takes place only in the regions of pericyclic expansion. No sclerosis has been observed in the ray expansion tissue.

Text-figures 43 to 47 — *Bauhinia variegata*.

Text-figure 43 — Percentage of fibers in different frequency classes of length.

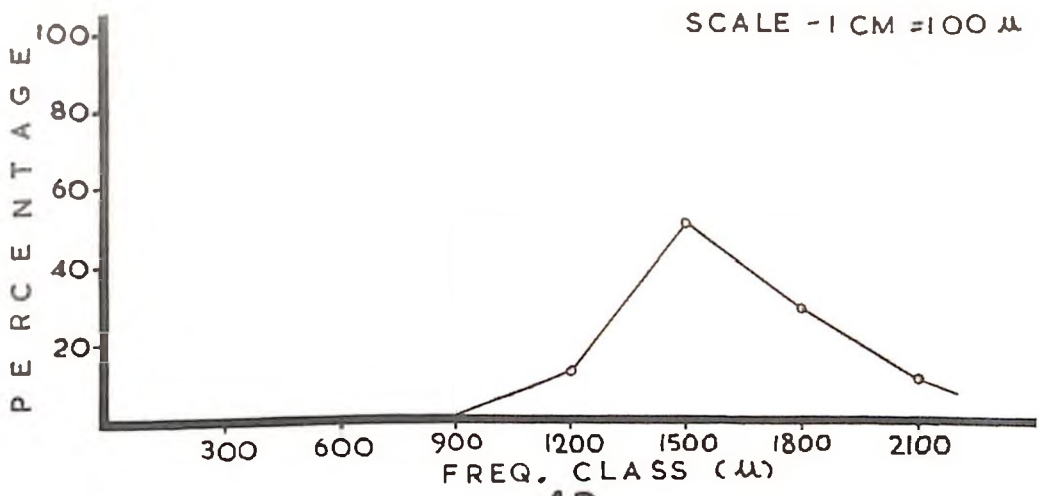
Text-figure 44 — Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 45 — Percentage of uni-, bi- and multiseriate rays in different frequency classes of height.

Text-figure 46 — Percentage of uni-, bi- and multiseriate rays in different frequency classes of width.

Text-figure 47 — Percentage readings in different frequency classes of number of rays per sq. mm.

UNI. RAYS - uniseriate rays, BI. RAYS - biseriate rays
MULTI. RAYS - multiseriate rays.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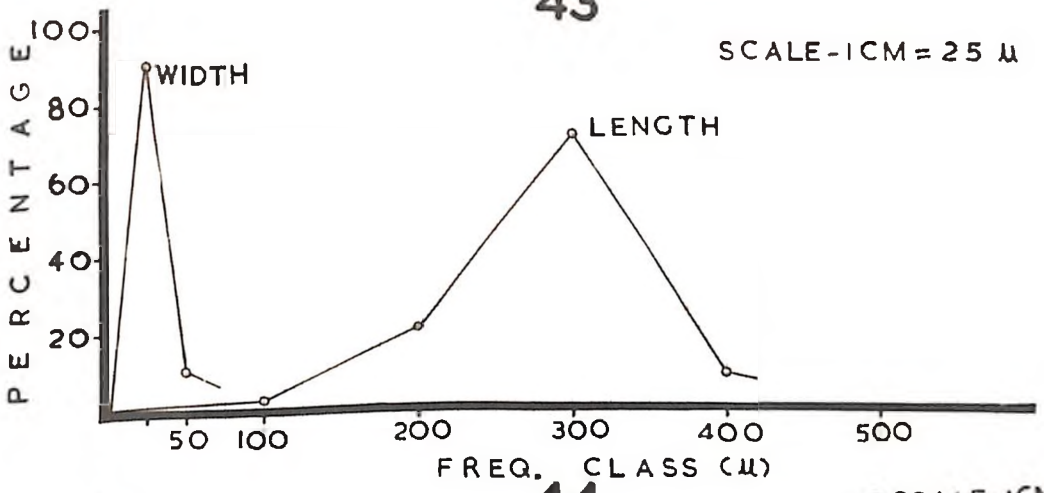
80
60
40
20
300
600
900
1200
1500
1800
2100
FREQ. CLASS (μ)

43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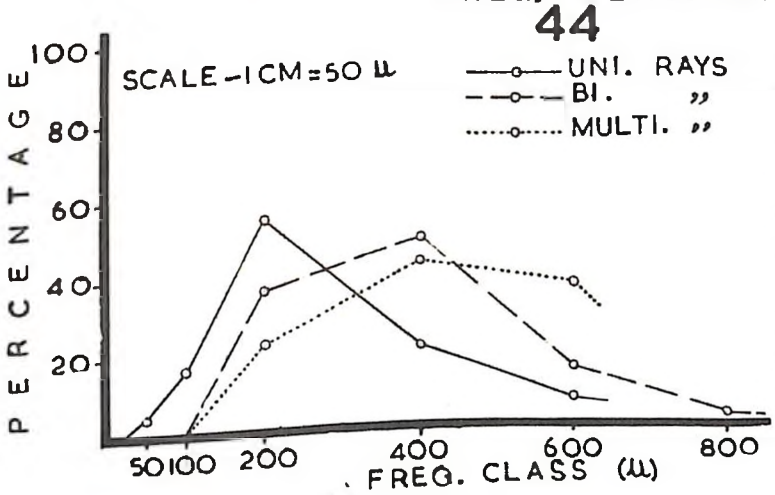
200
300
400
500
FREQ. CLASS (μ)

44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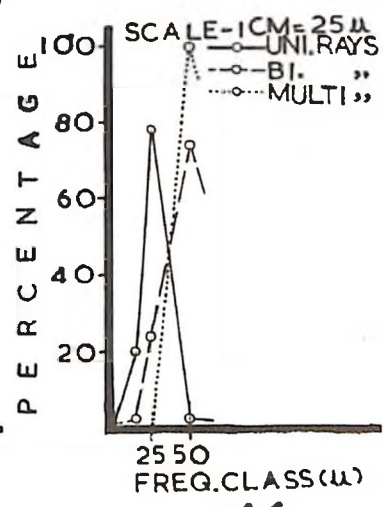
UNI. RAYS
BI. ,,
MULTI. ,,
PERCENTAGE
100
80
60
40
20
50
100
200
400
600
800
FREQ. CLASS (μ)

45


SCALE-1CM=25 μ
UNI.RAYS
BI. ,,
MULTI ,,
PERCENTAGE
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80
60
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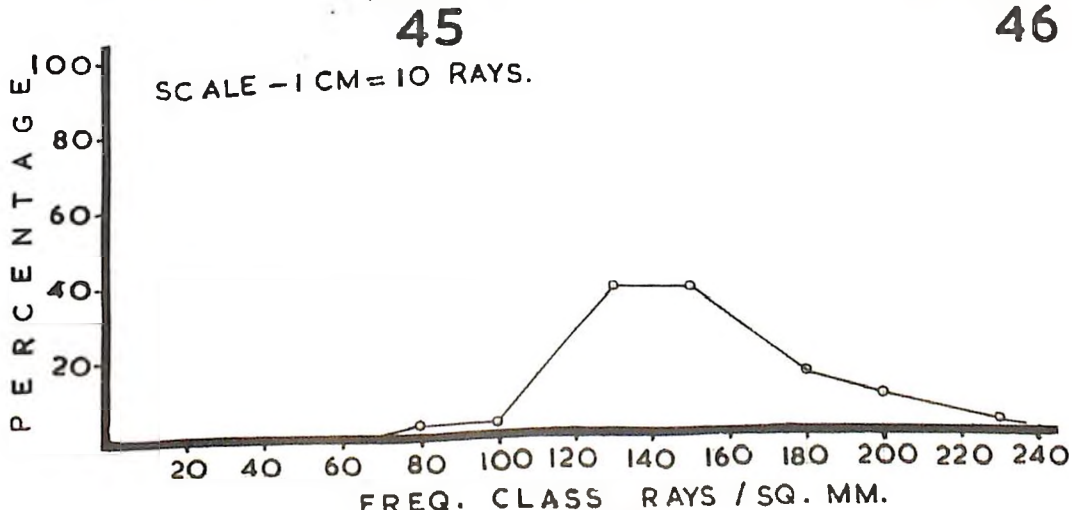
20
25
50
FREQ.CLASS(μ)

46


SCALE - 1 CM = 10 RAYS.
PERCENTAGE
100
80
60
40
20
20
40
60
80
100
120
140
160
180
200
220
240
FREQ. CLASS RAYS / SQ. MM.

47

PROSOPIS SPECIES

EXTERNAL MORPHOLOGY:

P. spicigera: In very young twigs bark is reddish to grey in colour. Bark in older branches is light brown in colour and smooth with spinous emergences having broad bases. Bole bark is rough, scaly and dull grey in colour. Longitudinal and horizontal cracks result in the formation of scales which adhere firmly to the inner bark resulting in rough surface (Photo. 64). Thickness of bole bark is about 10.0 to 12.0 mm.

P. juliflora: Bark in the young branches is smooth with a few thorns and dark green in colour. Bole bark is scaly and deeply fissured (Photo. 73). In surface view the fissures form rhomboidal areas. Bole bark is dark brown in colour. Thickness of bole bark is about 6.0 to 8.0 mm.

STRUCTURE OF YOUNG TWIG:

Pith in both the species is wide parenchymatous. The cells are polygonal. Pericycle is continuous and narrow in *P. spicigera* and wide in *P. juliflora*. Pericycle shows ridges and grooves. In *P. juliflora* the cell walls of a few outer layers of pericycle are comparatively more thicker than the inner. Cortical cells contain rhomboidal crystals in *P. juliflora* while they are absent in *P. spicigera* (Photomicro. 74). Epidermal cells are

large radially elongated with thick cuticle in P. spicigera and small with thick striated cuticle in P. juliflora. Cuticle covers almost half of the radial walls (Photomicro. 74).

STRUCTURE OF MATURE BARK:

Secondary phloem:

Similar to other plants it is characterised by alternate phloem blocks and phloem rays. Each phloem block is characterised by the presence of rectangular to oblong fiber bands in P. spicigera and rectangular bands in P. juliflora. These fiber bands alternate with the soft tissue which is similar to Erythrina (Figs. 85,93,98; Photomicro. 65-67, 75,76). Fiber bands are broken up into smaller units due to the rays of second category. These bands are arranged in regular tangential rows in both the species and are lined by crystalliferous cells abaxially and adaxially (Figs. 86,99; Photomicro.67,76). Crystalliferous layer is followed by a few parenchymatous layers adaxially, the number of which may increase towards the periphery. In transverse section the fibers are angular with thick walls and reduced lumen (Figs. 86,99). Pits in the fiber walls are either absent or inconspicuous. Tangential extent of the fiber bands ranges from 58.14 to 271.32 microns in P. spicigera and 29.07 to 242.25 microns in P. juliflora. The radial extent ranges from 21.30 to 56.80 microns in P. spicigera and 29.07 to 67.83 microns in P. juliflora. Average tangential and radial extent is 123.74 and 40.68 microns respectively in P. spicigera while 137.29 and 44.85 microns respectively in P. juliflora. Percentage of fiber

large radially elongated with thick cuticle in P. spicigera and small with thick striated cuticle in P.juliflora. Cuticle covers almost half of the radial walls (Photomicro. 74).

STRUCTURE OF MATURE BARK:

Secondary phloem:

Similar to other plants it is characterised by alternate phloem blocks and phloem rays. Each phloem block is characterised by the presence of rectangular to oblong fiber bands in P. spicigera and rectangular bands in P. juliflora. These fiber bands alternate with the soft tissue which is similar to Erythrina (Figs. 85,93,98; Photomicro. 65-67, 75,76). Fiber bands are broken up into smaller units due to the rays of second category. These bands are arranged in regular tangential rows in both the species and are lined by crystalliferous cells abaxially and adaxially (Figs. 86,99; Photomicro.67,76). Crystalliferous layer is followed by a few parenchymatous layers adaxially, the number of which may increase towards the periphery. In transverse section the fibers are angular with thick walls and reduced lumen (Figs. 86,99). Pits in the fiber walls are either absent or inconspicuous. Tangential extent of the fiber bands ranges from 58.14 to 271.32 microns in P. spicigera and 29.07 to 242.25 microns in P. juliflora. The radial extent ranges from 21.30 to 56.80 microns in P. spicigera and 29.07 to 67.83 microns in P. juliflora. Average tangential and radial extent is 123.74 and 40.68 microns respectively in P. spicigera while 137.29 and 44.85 microns respectively in P. juliflora. Percentage of fiber

bands in different frequency classes of tangential and radial extent is shown in text-figures 48 and 49 respectively.

In P. spicigera, fibers are of two types: (1) Non-septate showing abrupt changes in width, one end undulated while the other oblique but sharp (Fig. 87A) and (2) septate with broad lumen and gradually tapering ends which may be similar or dissimilar (Fig. 87B). In P. juliflora, fibers are non-septate with gradually tapering ends, tips are conical, lumen is reduced and can only be seen as narrow discontinuous streaks. Fiber length ranges from 714.00 to 1554.00 microns in P. spicigera and 668.50 to 1317.50 microns in P. juliflora. Average fiber length is 1106.95 and 1072.66 microns in P. spicigera and P. juliflora respectively. Percentage of fibers in different frequency classes of length is shown in text-figure 50 for both the species.

In transverse sections, the sieve tubes are variable in shape and occur in groups. In P. spicigera they are present upto some distance (from cambium to periphery) in the inner bark, while in P. juliflora they occur in the innermost zone near the cambium (Figs. 86,99; Photomicro. 67,76). In longitudinal sections the sieve tubes are variable in shape. They may have both ends oblique or one oblique and the other conical or one transverse and the other like a saw. End walls are usually inclined and perforated to form sieve plates (Figs. 88A,B, 100A,B). Rarely the sieve areas occur on the transverse or vertical walls. In P. spicigera, some of the sieve plate on the end walls are in continuation with the vertical plate (Photomicro. 70). Sieve

bands in different frequency classes of tangential and radial extent is shown in text-figures 48 and 49 respectively.

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plates have many sieve areas and are thus compound (Figs. 88A, B, 100A, B; Photomicro. 68-70, 78,79). Each sieve area has variable pores, through each of which passes a connecting strand enclosed in callose. Callose appears adjacent to the wall areas on either side of the sieve pore and completely covers it in the non-functional phloem. Size, shape, number of sieve areas and their arrangement is variable (Photomicro. 77). Sieve plates are oriented at an angle ranging from 25.0 to 90.0 degrees with an average of 46.6 degrees in P. spicigera and from 20.0 to 90.0 degrees with an average of 43.8 degrees in P. juliflora. Usually, the sieve plates are inclined at an angle of 30.0 to 50.0 degrees. Walls of the sieve tubes show lattices (Photomicro. 69). In P. spicigera walls are thick and pitted. In P. spicigera, slime occurs in the form of plugs of amorphous mass (Figs. 88A, B) while it is indistinct in P. juliflora.

Sieve tubes are 123.50 to 380.00 microns long and 19.10 to 38.20 microns wide in P. spicigera while 155.04 to 310.08 microns long and 17.44 to 29.07 microns wide in P. juliflora. Average length and width respectively is 268.77 and 25.97 microns in P. spicigera and 238.18 and 21.74 microns respectively in P. juliflora. Percentage of sieve tubes in different frequency classes of length and width is shown in text-figure 51 for both species.

In both species, sieve tubes show obliteration in the nonfunctional phloem forming irregular bands of crushed tissue in between the fiber bands (Photomicro. 66,76).

In transverse sections, one or rarely two companion cells are associated with each sieve tube and are variable in shape (Figs. 86,99). One to two companion cells are associated along the entire length. If one companion cell is associated with the sieve tube, it may run along the entire length or a part only.

Phloem parenchyma is distributed in between the sieve tubes in additon to the layers on the adaxial side of the fiber bands. These cells are large thick walled and contain tannin in P. spicigera and granular matter in P. juliflora.

Phloem rays are similar to those in other plants in being of the first as well as second categories. In transverse sections, they are one to many cells wide and the cells are usually rectangular (Photomicro. 66,76). In radial longitudinal sections the rays are homogeneous (Photomicro. 77) and uni-, bi- and multiseriate (Photomicro. 68,69,78). Ray cells are thick walled with inconspicuous intercellular spaces in P. spicigera and thin walled in P. juliflora.

Uniseriate rays are two to many cells high (Fig. 89). End cells are conical (Photomicro. 68,78). Height ranges from 32.95 to 135.66 microns and width from 7.75 to 25.19 microns in P. spicigera while in P. juliflora the height ranges from 25.19 to 141.47 microns and width from 7.75 to 15.51 microns. Average height and width for P. spicigera is 84.65 and 17.05 microns respectively and for P. juliflora 75.27 to 11.63 microns respectively. Percentage of uniseriate rays in different frequency

classes of height and width is shown in text-figures 52A and 53A respectively for P. juliflora and 52B and 53B respectively for P. spicigera.

Biseriate rays usually have uniseriate short ends. Some show equally or unequally extended ends while others show one end biseriate (Fig. 90; Photomicro. 68,78). Height ranges from 62.02 to 217.06 microns and width from 19.38 to 44.57 microns in P. spicigera while in P. juliflora height ranges from 48.45 to 232.56 microns and width from 13.57 to 32.95 microns. Average height and width respectively is 110.51 and 36.52 microns. in P. spicigera while 112.44 and 20.66 microns in P. juliflora. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 52A and 53A respectively for P. juliflora and 52B and 53B respectively for P.spicigera.

Multiseriate rays are three to four cells wide in P. spicigera and three to many cells wide in P. juliflora. Ends are uniseriate, similar or dissimilar (Figs. 91A,B; Photomicro. 68, 69,78). In P. juliflora some rays have one or both ends biseriate (Fig. 101). In both species multiseriate rays have included uni- or biseriate portions also (Fig. 91A; Photomicro. 68). Dissection of these rays is prominent in both the species and probably takes place due to intrusive growth of the elements like phloem fibers and sieve tubes (Fig. 92). Height ranges from 122.09 to 581.40 microns and width from 27.13 to 77.52 microns in P. spicigera while in P. juliflora the height ranges from 96.90 to 717.06 microns and width from 23.26 to 54.16 microns. Average height and width respectively is 330.35 and 54.96 microns in

P. spicigera while in P. juliflora average height and width respectively is 307.02 and 35.31 microns. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 52A and 53A respectively for P. juliflora and in text-figures 52B and 53B respectively for P. spicigera.

Number of rays per square mm. ranges from 35 to 72 with an average of 51.80 in P. spicigera while in P. juliflora it ranges from 27 to 61 with an average of 46.54. Percentage readings in different frequency classes of ray number per square mm. are shown in text-figure 54.

Percentage occurrence of uni-, bi- and multiseriate rays in P. spicigera is 11.76, 24.44 and 63.80 respectively while in P. juliflora it is 19.00, 24.20 and 56.80 respectively.

Expansion: In both the species bark shows cortical, pericyclic and ray expansions. Mode of all these three types of expansions is similar to that in other plants. Ray expansion results in the formation of wedges of parenchymatous tissue, the ray expansion tissue (Figs. 85,98; Photomicro, 66). Some of the rays dilate only for a short distance resulting in the finger like expansions (Figs. 85,93,98; Photomicro. 66). Partial expansion of ray results in its twisting.

Phloem proliferation: It takes place in a fashion similar to that in Dalbergia and results in parenchymatous proliferation tissue (Fig. 93).

Periderm:

Position, initiation and activity of first phellogen is similar to that in Erythrina (Figs. 84, 94, 97). The phellogen cuts off more cork which is peeled off regularly. Similar to Dalbergia, the bark cracks due to increase in girth in both the species and additional successive layers of periderm are formed in the secondary phleom. Because of the variations in the depths of the cracks at different levels along the circumference. Many strips of phellogen may arise simultaneously either from the pre-existing periderm or a new. These layers join each other and form periderm of a few layers. Each zone of periderm thus formed separates blocks of secondary phloem from the inner bark. Each phloem block thus isolated from the inner bark along with the periderm forms one rhytidome. These rhytidome layers adhere firmly to the inner bark and form scales (Photomicro. 71,72,75). The scales are comparatively large in P. juliflora than in P. spicigera. The scales are thick in P. spicigera and thin, long in P. juliflora.

Cork cells are arranged in regular rows and are small, squarish in P. spicigera and rectangular in P. juliflora. In surface view the cork cells are angular.

Sclerosis: In P. spicigera the sclerosis takes place in the region of pericyclic and ray expansion and phloem proliferation tissue forming mainly brachysclereids (Figs. 96A,B) while in P. juliflora sclerosis is limited only to the regions of pericyclic expansion and various types of sclerieds are formed (Figs. 103A-F).

Text-figures 48 to 54 — *Prosopis* species.

Text-figure 48 — Percentage of fiber bands in different frequency classes of tangential extent.

Text-figure 49 — Percentage of fiber bands in different frequency classes of radial extent.

Text-figure 50 — Percentage of fibers in different frequency classes of length.

Text-figure 51 — Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 52A — Percentage of uni-, bi- and multiseriate rays in different frequency classes of height in *P. juliflora*.

Text-figure 52B — Percentage of uni-, bi- and multiseriate rays in different frequency classes of height in *P. spicigera*.

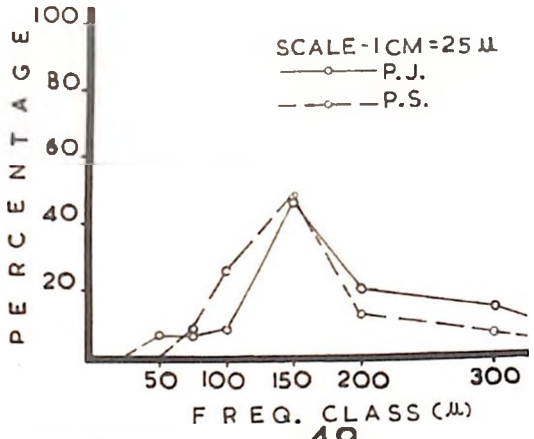
Text-figure 53A — Percentage of uni-, bi- and multiseriate rays in different frequency classes of width in *P. juliflora*.

Text-figure 53B — Percentage of uni-, bi- and multiseriate rays in different frequency

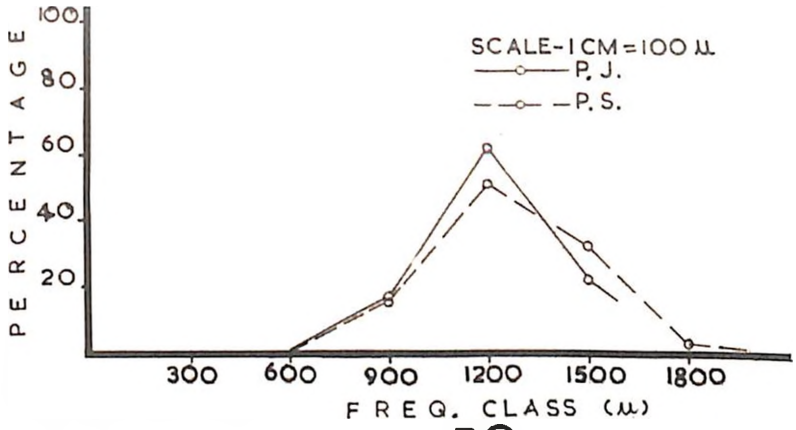
classes of width in P. spicigera.

Text-figure 54 Showing percentage readings in different frequency classes of number of rays per sq. mm.

BI. RAYS - biseriate rays, P.J. Prosopis juliflora, P.S. - Prosopis spicigera, MULTI. RAYS - multiseriate rays, UNI. RAYS - uniseriate rays.



48



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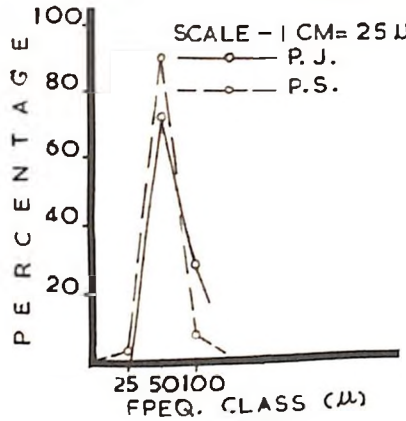

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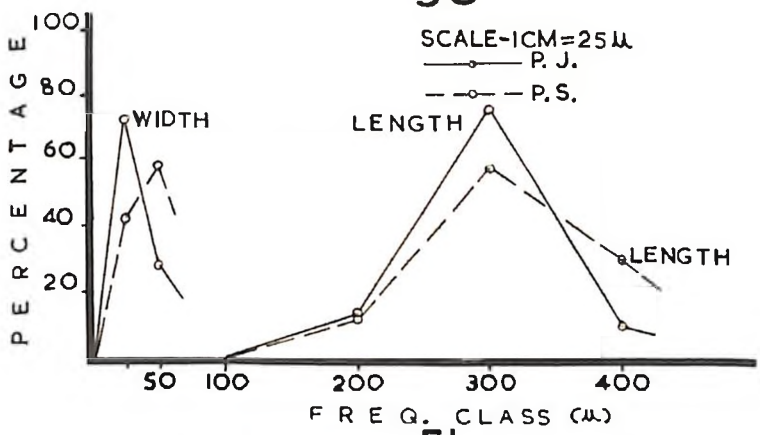

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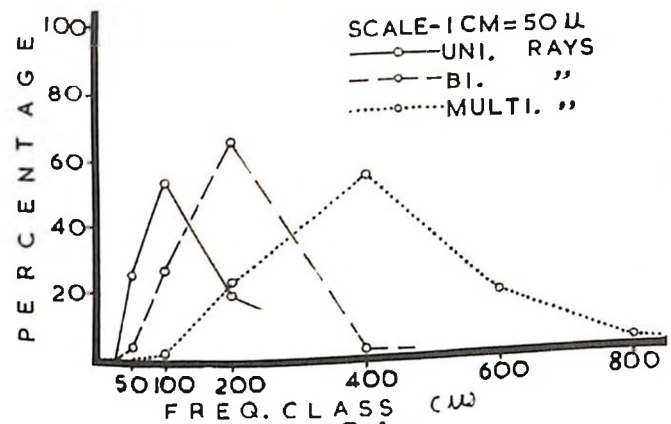
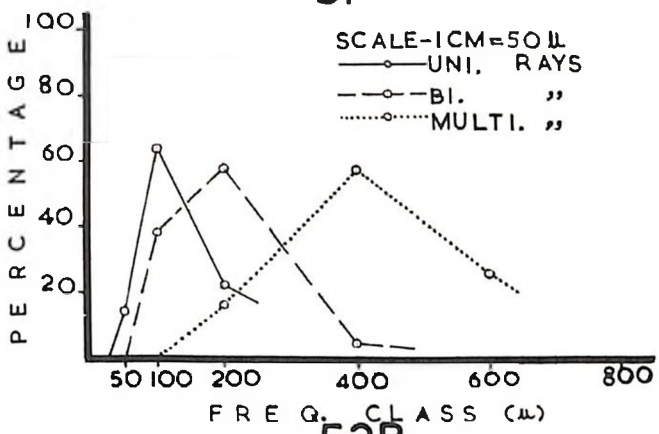


52A



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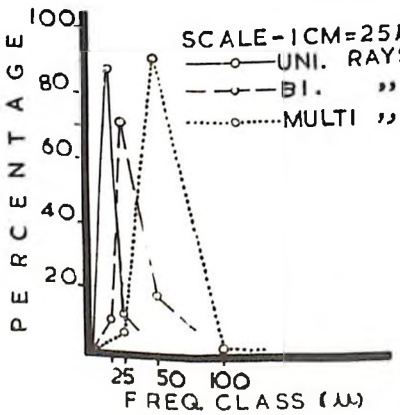
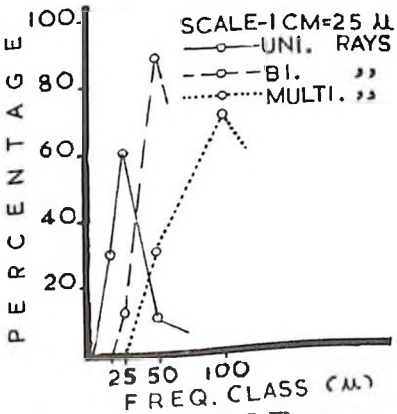


53A



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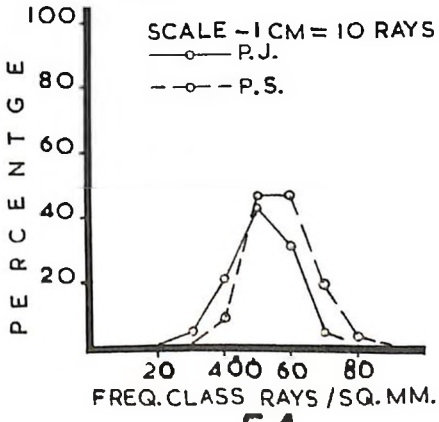


54

ACACIA SPECIES

EXTERNAL MORPHOLOGY:

A. nilotica: In young twigs, bark is smooth and green, pubescent, turns grey or downy. In older branches bark is smooth and dark brown in colour. Bole bark is dark brown to black with shallow longitudinal furrows, i.e., the bole bark is shallow fissured type (Photo. 80). Inner bark is brown in colour. Thickness of bole bark is 10.0 to 15.0 mm.

A. aneura: In young branches bark is smooth and brown. However, bole bark is dark brown with longitudinal cracks and gives the appearance of scaly bark. Thickness of bole bark is 1.5 to 2.0 mm.

A. benthamii: In young branches bark is smooth while in bole region it has vertical as well as transverse cracks which make the appearance scaly (Photo. 93). It is dull brown in colour. Thickness of bole bark is 2.5 to 3.0 mm.

A. salicina: In young branches bark is smooth in surface and greenish to red in colour. Bole bark is brownish to red in colour and shallow fissured in surface (Photo. 99). Thickness of bole bark is about 3.0 mm. Inner bark is about 2.0 mm in thickness.

A. cyanophylla: In young branches bark is dark brown in colour and smooth in surface. Bole bark is black and downy in colour and smooth in surface (Photo. 105). Thickness of bole bark is about 3.0 to 4.0 mm.

A. drepanolobium: In young branches bark is smooth and yellowish in colour. Bole bark is dark brown in colour and rough in surface (Photo. 109). Thickness of bole bark is about 10.0 mm.

A. hockii: In young branches bark is brown in colour and smooth in surface. Bole bark is yellowish brown and smooth with loose scales of cork (Photo. 115). Thickness of bole bark is 5.0 to 6.0 mm.

A. ligulata: In young branches bark is greenish to red in colour and smooth in surface. Bole bark is shallowly fissured with prominent cracks (Photo. 121) and brownish black in colour. Thickness of bole bark is 2.0 to 3.0 mm.

A. senegal: In young branches bark is whitish grey in colour and smooth in surface. Bole bark is yellowish in colour and smooth in surface (Photo. 125). Outer bark is papery. Thickness of bole bark is 5.0 to 7.0 mm.

A. sieberiana: Bole bark is yellowish green in colour and smooth in surface (Photo. 128). Outer bark is papery. Thickness of bole bark is about 3.0 mm.

A. spirocarpa: In young branches bark is reddish and smooth. Bole bark is brown with shallow cracks (Photo. 133).

Thickness of bole bark is about 5.0 mm.

A.victoriae: In young branches bark is green in colour and smooth in surface. Bole bark is fissured with wide furrows (Photo. 137) and brown in colour. Thickness of bole bark is 3.0 to 4.0 mm.

STRUCTURE OF YOUNG TWIG:

A. nilotica: Transectional outline is circular. Pith consists of circular cells with intercellular spaces. Pericycle is wide, continuous and sclerenchymatous (Fig. 104). Cortex consists of chlorenchymatous cells with intercellular spaces (Fig. 104). Layer of cortical cells immediately outside the pericycle contains rhomboidal crystals. Epidermal cells are isodiametric with convex outer tangential wall (Fig. 104; Photomicro. 81). Cuticle is striated (Fig. 104).

A.aneura: Pith is sclerified, cells contain tannin and have pitted walls. Pericycle is narrow, continuous and sclerenchymatous (Fig. 110). Cortex is three to four layered. Epidermal cells are papillate and covered with thick cuticle extending over the radial walls (Fig. 110,113; Photomicro. 88). Cuticle is striated outside and granular inside (Figs. 110,113). Stem surface is covered with glandular hairs which have two celled base and a four celled head. Distal end of some of the trichomes is single celled and funnel like. Trichomes are rooted below the level of the epidermis.

A. benthamii: Pith is sclerified and cells contain

starch. Cell walls are pitted. Pericycle is wider with ridges and grooves (Photomicro. 94). Endodermis is prominent with thick outer and inner tangential walls and contains crystals. Cortex is broader than in A. nilotica and A.aneura. Epidermal cells are with round outer tangential walls (Fig. 116). Cuticle is thick, striated and covers the radial walls (Fig. 116).

A. salicina: Pith is comparatively narrow, cells are angular (Photomicro. 100) and contain crystals of different types. Crystals are usually rhomboidal. Some of the pith cells have pitted walls. Pericycle is narrow and sclerenchymatous. Cortex is wide. Epidermal cells are papillate with round or conical outer tangential walls (Photomicro. 100, 101). Cuticle is thick, outer striated and inner granular.

A. cyanophylla: Young stem in transectional outline is triangular. Pith cells are angular with thick walls, crystals are rare. Pericycle is two to three layered, sclerenchymatous and continuous. Cortex is tanniferous but the layer immediately outside the pericycle is non-tanniferous (Photomicro. 106) and contains rhomboidal crystals. Epidermis is barrel shaped (Fig. 124; Photomicro. 106). Cuticle is thick and covers a portion of radial wall also. Stomata occur above the surface of the epidermis. Inner walls of the guard cells are covered by cuticle. In older branches even the epidermal cells contain tannin.

A. drepanolobium: Stem in transectional outline shows ridges and grooves. Pith cells are mostly rounded. Pericycle is wide sclerenchymatous. Cortex consists of thick walled

parenchymatous cells (Fig. 130; Photomicro. 110). Epidermal cells are more compact than in any other species and show stuby projections (Fig. 130). Trichomes are glandular and composed of long or broad terminal portions and a single basal cell (Photomicro. 110). These trichomes appear to be covered by the cuticle. Cuticle is thin.

A. hockii: Pith consists of thick walled angular cells. Pericycle is continuous and sclerenchymatous. Cortical cells are round with darkly stained contents. Epidermal cells are barrel shaped with thin cuticle (Fig. 137).

A. ligulata: Pith cells are angular and sclerified. Some of them contain tannin. Pericycle is narrow, sclerenchymatous. Cortical cells contain tannin and crystals (Photomicro. 122). Below the epidermis occur patches of radially elongated stone cells. Epidermal cells have round outer tangential walls (Fig. 146; Photomicro. 122). Cuticle is striated and granular and covers about one third of the epidermis (Fig. 146).

A. senegal: Pith consists of thin walled parenchymatous cells without any contents (Photomicro. 126). Pericycle is sclerenchymatous and narrow (Photomicro. 126). Cortex consists of rounded chlorenchymatous cells without intercellular spaces and is narrow. Inner most cortical layer contains rhomboidal crystals. Epidermal cells are barrel shaped with convex outer tangential wall covered by thin striated cuticle. On the surface occur sparsely distributed papillose trichomes.

A. spirocarpa: Pith cells are thick walled, pitted and some of them contain tannin. Pericycle is broad, sclerenchymatous. Cortex is wide, outer few layers contain tannin and inner layers are thick walled (Photomicro. 134). Cortical cells show anticlinal divisions against the primary rays or grooves in the pericycle. Epidermal cells are rectangular with thick radial walls (Fig. 166). Cuticle is thin.

STRUCTURE OF MATURE BARK:

Similar to other genera described earlier, mature bark of Acacia species consists of secondary phloem and periderm.

Secondary phloem:

It is similar to other plants in gross organization and has phloem blocks alternated by phloem rays. Each phloem block is characterised by the presence of tangential fiber bands which vary in shape from species to species and to some extent even within the same spacies. These bands regularly alternate with the soft tissue as in other plants and form almost parallel rows along the circumference in A. nilotica, A. benthamii, A. drepanolobium, A. hockii, A. senegal, A. sieberiana and A. spirocarpa while in A. aneura, A. salicina, A. cyanophylla, A. ligulata and A. victoriae fiber bands form slightly irregular rows (Figs. 105, 117, 119, 125, 131, 138, 147, 153, 159, 167, 170; Photomicro. 82, 83, 89, 91, 95, 102, 107, 111, 116, 117, 123, 124, 129, 130, 135, 138). Each fiber band is lined by crystalliferous layer adaxially as well as abaxially (Figs. 106, 111, 120, 126A, B, 132, 139, 148, 154, 160, 168, 171).

In A. nilotica, crystalliferous layer is discontinuous (Fig. 106). In A. ligulata, crystalliferous cells also occur mixed in the fibers (Fig. 148). In A. sieberiana there are more than one layer of crystalliferous cells at places (Fig. 160). Crystalliferous layer is followed by parenchyma on one or both sides. In A. nilotica, A. aneura, A. salicina, A. cyanophylla, A. hockii, A. senegal and A. sieberiana parenchymatous layers are present on both the sides (Figs. 106, 111, 120, 126A, B, 139, 154, 160). In A. aneura, parenchyma also occurs radial to the fiber band (Fig. 111). In A. benthamii, A. drepanoloboum, A. ligulata, A. spirocarpa and A. victoriae, parenchymatous layers are present adaxial to the fiber bands (Figs. 132,148, 168, 171; Photomicro. 100, 111, 112, 124, 135, 138). Fibers have variable diameter, angular to round transectional outline, reduced lumen and lignified walls.

Tangential and radial extent of the fiber bands is variable from species to species and even within the species. Minimum, maximum and average tangential and radial extent of the fiber bands in Acacia species is shown in table II. Percentage of fiber bands in different frequency classes of tangential and radial extent is shown in text-figures 55 A-L.

Macerated preperations of all the species show non-septate fibers with gradually tapering ends which have conical or sharply oblique tips, or broad at the middle and sharply tapering ends. The ends may be undulated. Fiber length shows a wide range of variations from species to species and so also within the species. Minimum, maximum and average fiber length

in Acacia species is shown in table III. Percentage of fibers in different frequency classes of length in all the species is shown in text-figures 56A-F.

In transverse sections, sieve tubes shown mainly three types of arrangements: (1) Isolated sieve tubes scattered in the parenchyma or in radial rows of a few elements as in A. nilotica and A. cyanophylla (Figs. 106, 126A; Photomicro. 84). (2) In aggregates of a few sieve tubes embedded in the phloem parenchyma as in A. aneura, A. benthamii, A. salicina, A. hockii, A. senegal and A. sieberiana (Figs. 111, 120, 139, 154, 160; Photomicro. 95). (3) In regular tangential zones as in A. drepanolobium, A. ligulata, A. spirocarpa and A. victoriae (Figs. 132, 148, 168, 171; Photomicro. 111, 112, 124, 135, 138). Sieve tubes are angular or circular and are distinct in all the species except A. nilotica, A. cyanophylla and A. hockii. End walls of the sieve tubes are usually inclined and form sieve plates. Rarely, the sieve plates are almost transverse or vertical as in A. nilotica, A. ligulata and A. victoriae (Figs. 149, 172A; Photomicro. 85, 139), or concavo-convex as in A. nilotica (Photomicro. 85). Each sieve plate has more than one sieve area arranged in uniseriate or biseriate fashion. Size shape and number of sieve areas are variable from plate to plate. The sieve plates are thus compound (Figs. 121A, B, 133, 140, 149, 155, 161A, B, 169A,B, 172A, B; Photomicro. 85, 86, 92, 96,103, 108, 113, 114, 118, 119, 127, 131, 136, 139). Connecting strands are very prominent in A. nilotica (Photomicro. 86). Sieve tubes in surface view show lattices. Angle of orientation of the sieve plates is variable from species to species

and even within the species. Minimum, maximum and average angle of inclination of the sieve plates is shown in table IV.

Slime is not distinct but in A. nilotica, A. aneura and A.benthamii it persists in the form of plugs of amorphous mass in some of the sieve tubes.

Walls of the sieve tubes in A. nilotica, A. aneura, A. salicina, A. cyanophylla, A. drepanolobium, A. ligulata and A. spirocarpa are thick and pitted. Walls are thin with pits in A. senegal and A. sieberiana and without pits in A. hockii and A. victoriae.

Length and width of the sieve tubes is variable. Minimum, maximum and average length and width of sieve tubes in Acacia species is shown in table V. Percentage of the sieve tubes in different frequency classes of length and width is shown in text-figures 57A-F.

In the non-functional secondary phloem the sieve tubes are obliterated to form bands of crushed tissue in almost all the species. In A. nilotica and A. senegal bands of crushed tissue alternate with parenchyma.

In transverse section, one companion cell is associated with each sieve tube in A. cyanophylla, A. drepanolobium and A. ligulata (Figs. 126A, 132, 148) and one or more than one in rest of the species(Figs. 106, 111, 120, 139, 154, 160, 168, 171). They are triangular, rectangular or dome shaped. Along the length there are one to two companion cells in A. aneura,

A. drepanolobium, A. sieberiana and A. victoriae; one to four with pitted walls in A. salicina; two to three in A. hockii and A. ligulata; two to four in A. nilotica, A. benthamii, A. cyanophylla and A. spirocarpa.

Phloem rays, like other genera, are of the first as well as second categories in this case also. They are upto two cells wide in A. aneura, three cells in A. salicina, A. ligulata and A. victoriae, upto four or six cells wide in A. nilotica, A. benthamii, A. cyanophylla, A. hockii, A. senegal, A. sieberiana and A. spirocarpa and upto many cells in A. drepanolobium. Twisting of rays is prominent in A. nilotica, A. aneura and A. senegal (Figs. 105, 153; Photomicro. 90). In radial longitudinal section rays are homogeneous in all the species and in tangential longitudinal section they are uni-, bi- and multiseriate except A. aneura. In A. aneura multiseriate rays are absent.

Uniseriate rays have conical end cells in all except A. cyanophylla, A. senegal and A. sieberiana (Photomicro. 87, 92, 96, 127, 136, 140). In these the end cells are conical, oval or round (Figs. 127, 162). Minimumm, maximum and average height and width in Acacias is shown in table VI and VII respectively. Percentage of uniseriate rays in different frequency classes of height and width is shown in text-figures 58A-F and 59A-F respectively.

Biseriate rays usually have uniseriate ends. In some the ends are equally or unequally extended (Figs. 112A, B, 128A, B, 134, 135, 150, 150A, 163, 173). In A. benthamii, A.salicina,

A. hockii, A. spirocarpa and A. victoriae rays with one or both biseriate ends also occur (Figs. 141,150A, 173; Photomicro. 136). Biseriate rays with included uniseriate portions are very common as in A. aneura (Fig. 112B), A. salicina, A. cyanophylla (Fig. 128B), A. drepanoplobium (Fig. 134), A. hockii (Fig. 141), A. ligulata (Figs. 150, 150A), A. victoriae (Photomicro. 140) and others also. Minimum, maximum and average height and width of biseriate rays in Acacia species are shown in table VI and VII respectively. Percentage of biseriate rays in different frequency classes of height and width in Acacia species are shown in text-figures 60A-F, 61A-F respectively.

Multiseriate rays usually have uniseriate ends which are small or extended (Photomicro. 87, 96, 113, 114, 118, 119, 127, 131, 136, 139, 140). Multiseriate rays with biseriate end were observed in A. ligulata and A. victoriae (Figs. 151, 173; Photomicro. 140) and with a triseriate end in A. salicina (Fig. 122B). Multiseriate rays with included uniseriate and biseriate portions were also observed (Figs. 122A, 142, 173). Minimum, maximum and average height and width of multiseriate rays are shown in tables VI and VII respectively. Percentage of multiseriate rays in different frequency classes of height and width in Acacia species is shown in text-figures 62A-F and 63A-F respectively.

Ray cells are circular to angular and thin walled in A. arabica, A. aneura, A. benthamii and A. hockii; large with thick walls in A. salicina and A. cyanophylla; round to oblong

in A. ligulata, A. senegal, A. sieberiana, A. spirocarpa and A. victoriae and thick walled with intercellular spaces in A. drepanolobium.

Number of rays per sq.mm. in Acacia species shows a wide range, Minimum, maximum and average number of rays per sq. mm. in Acacia species is shown in table VIII. Percentage readings of ray number of rays per sq. mm. in different frequency classes of ray number per sq. mm. are shown in text-figures 64A-F in Acacia species.

Percentage occurrence of uniseriate, biseriate and multiseriate rays in Acacias is shown in table IX.

Expansion: As in the plants described earlier the bark of Acacias also shows cortical, pericyclic and ray expansions.

Cortical expansion: Mode of cortical expansion is similar to the other plants described earlier. However, in A. cyanophylla cortical expansion mainly takes place in the layer immediately outside the pericycle. Cells of this layer divide anticlinally once, twice or even more. The walls are laid down either in the middle or on one side or even obliquely.

Pericyclic expansion: With the increase in the girth of the young stem, the pericycle becomes grooved mainly in the regions opposite the rays and patches of parenchyma become intercalated in the sclerenchyma-tous pericycle in these regions. Further changes are similar to other plants described earlier. The parenchymatous cells in these portions of the pericycle later

become transformed into sclereid (Figs. 108, 175; Photomicro. 134). Size, shape and arrangement of these sclereids depends upon the size, shape and arrangement of the cells in that region.

Ray expansion: Ray expansion is common but the extent of expansion differs from species to species (Figs. 105,117, 119, 125, 131, 138, 147, 153, 159, 167, 170, 175; Photomicro. 83,89,106,107,116,123,129,130,135). In addition to wedges of expansion tissue, dilation only in a portion of ray results in finger like expansion (A term used by Whitmore, 1962&1963). In some cases a few middle layers of multiseriate rays stretch tangentially and undergo anticlinal divisions. In this case marginal ray cells remain unaffected except that they are pushed apart. Still in others, expansion is partial. Cells of the rays only on one side take part in the expansion to some distance and the other part becomes twisted, then the expansion takes place on the side opposite to the first. This partial expansion is mainly responsible for the ray twisting as in A. nilotica, A. hockii, A. senegal and A. sieberiana (Photomicro. 83, 116, 129).

Phloem proliferation: It is distinct only in A. aneura, A. hockii and A. senegal where axial parenchyma enlarges and divides anticlinally as well as periclinally forming broad wedges of phloem proliferation tissue which resembles the ray expansion tissue (Figs. 138,153, Photomicro. 90,91).

Periderm: First phellogen is superficial in all Acacia species and arises in localized strips to begin with. However,

it is formed all along the circumference soon. It is initiated in the subepidermal layer in A. nilotica, A. aneura, A. benthamii, A.cyanophylla and A.hockii (Figs. 108, 110,113, 116,124,137; Photomicro. 81, 88, 106), and in subhypodermal layer in A. salicina, A. drepanolobium, A. ligulata, A. senegal and A. spirocarpa (Figs. 130, 146, 166; Photomicro. 134). The initiation of phellogen is similar to that of Erythrina indica in all the species except A. nilotica where phelloderm is formed first and then the outer layer divides by periclinal division to form the cork and phellogen (Fig. 108). The activity of this phellogen is not permanent in all the species except A. benthamii, A. cyanophylla, A. hockii, A. senegal and A. sieberiana.

Extent of the layers cut of by the phellogen to outside and inside differs from species to species in Acacias. In A. nilotica cork and phelloderm layers are cut off almost equally. Cork layers are regularly peeled off in the form of thin scales and hence cork remains very thin (Fig. 105). In A. aneura the phellogen cuts off cells only to outside (Figs. 111, 113; Photomicro. 88). In A. benthamii A. cyanophylla, A. drepanolobium the extent of cork is more than that of phelloderm while in A. salicina, A. hockii, A. senegal and A. spirocarpa the extent of cork and phelloderm is almost equal as in A. nilotica. In A. salicina, A. cyanophylla the cork cells are crushed immediately after their formation (Photomicro. 100, 104). The cork cells in A. hockii have thin radial and thick outer and inner tangential walls (Fig. 143; Photomicro. 120). The cork cells in rest of

the species are thin walled and regularly arranged. In surface view the cork cells are angular in almost all those cases where peelings could be taken off, however, they differ in size and thickness of the walls (Figs. 114, 144,152,157,165; Photomicro. 98,132).

In A. senegal phellogen cuts off two types of cells to outside. Two to three layers of thick walled angular cells are cut off first and then a single layer of thin walled elongated cells, the phelloid cells. Thus there is regular alternation of thick walled layers and thin walled layer (Fig. 153).

In A. benthamii, A. hockii, A. senegal and A.sieberiana the first phellogen remains active throught while in rest of the plants the activity of the first phellogen does not last long and the bark cracks. In A. nilotica the first phellogen is active for a considerable number of years before the bark cracks. However, it remains very thin. Once the bark cracks the first phellogen is replaced by additional layers of phellogen which arise in strips in the deeper layers of the secondary phloem. These layers originate in the phloem parenchyma cells as a response to the cracks and thus protect the inner tissues from exposure, desiccation and other adverse conditions. As the depth of the cracks varies along the circumference many successive layers of phellogen arise at different levels simultaneously. These layers form only a few layered periderm which separates blocks of secondary phloem from the inner uncracked portions (Photomicro. 82,89). In A. aneura plate like zone of sclerieds appears below each periderm (Photomicro. 89,90). The phloem

tissue thus isolated by the periderm layers constitutes rhytidome layers along with the periderm. These rhytidome together of singly form scales which are peeled off regularly. Size, shape and arrangement is variable in Acacia species. This variation is due to the variations in phellogen or periderm position along the circumference and so also the depth of the cracks at different levels. In A. benthamii, A. cyanophylla, A. hockii, A. senegal and A. sieberiana where the periderm is superficial throughout, the cork layers are peeled off regularly in the form of thin papery strips which are yellow in A. senegal and A. sieberiana.

Sclerosis: In Acacia species sclerosis is also very common and of variable degrees. The parenchymatous tissue formed as a result of pericyclic expansion is transformed into sclerieds in all the case. In addition sclerosis extends to the ray expansion and phloem proliferation tissue also in most of the cases. The various types of sclerieds are formed in these regions (Figs. 105, 109A-E, 117, 118A, B, 115A-D, 123A-C, 136A-E, 145A, B, 158A-E, 174A-F).

TABLE II

Showing minimum, maximum and average tangential and radial extent of fiber bands in Acacia species in microns

Name of the species	TANGENTIAL EXTENT			RADIAL EXTENT		
	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE
Acacia nilotica	44.57	358.53	149.26	34.88	106.59	47.63
A. aneura	38.76	193.80	88.06	23.26	58.14	38.14
A. benthamii	29.07	242.25	127.89	19.38	52.33	37.13
A. salicina	29.07	290.70	102.52	25.19	67.83	41.09
A. cyanophylla	38.76	445.74	117.83	38.76	67.83	49.61
A. drepanolobium	38.76	348.84	143.61	29.07	87.21	56.40
A. hockii	19.38	193.80	110.85	19.38	48.45	20.85
A. ligulata	38.76	242.25	124.61	23.26	67.83	45.21
A. senegal	19.38	290.70	140.78	29.07	96.90	57.48
A. sieberiana	48.45	261.63	116.13	29.07	77.52	42.60
A. spirocarpa	38.76	290.70	138.30	29.07	87.21	61.43
A. victoriae	38.76	193.80	111.59	29.07	77.52	49.28

TABLE III

Showing minimum, maximum and average fiber length in *Acacia* species in microns

Name of the species	Minimum	Maximum	Average
Acacia nilotica	765.00	1997.50	1236.75
A. aneura	484.50	867.00	671.50
A. benthamii	765.00	1785.00	1247.80
A. salicina	850.00	1853.00	1363.91
A. cyanophylla	680.00	1700.00	1157.70
A. drepanolabium	892.50	1912.50	1334.5
A. hockii	850.00	1445.00	1099.05
A. ligulata	765.00	2167.50	1472.03
A. senegal	935.00	2040.00	1316.14
A. sieberiana	1105.00	2167.50	1580.15
A. spirocarpa	1232.50	2762.50	1794.18
A. victoriae	977.50	1667.50	1311.21

TABLE IV

Showing minimum, maximum and average angle of inclination of sieve tube end walls and sieve plates in *Acacia* species

Name of species	Minimum Degrees	Maximum Degrees	Average Degrees
A. nilotica	15	70	34.9
A. aneura	15	60	40.2
A. benthamii	10	70	38.0
A. salicina	20	80	44.9
A. cyanophylla	20	70	44.4
A. drepanolobium	20	60	39.1
A. hockii	20	65	41.9
A. ligulata	10	70	37.8
A. senegal	20	80	46.7
A. sieberiana	15	60	37.7
A. spirocarpa	20	70	36.7
A. victoriae	15	50	33.5

TABLE V

Showing minimum, maximum and average length and width of sieve tubes in *Acacia* species in microns

Name of species	LENGTH			WIDTH		
	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE
Acacia nilotica	174.42	397.29	300.04	15.51	29.07	23.10
A. aneura	116.28	261.63	161.63	9.69	19.38	14.34
A. benthamii	164.73	344.26	259.84	13.57	25.19	18.53
A. salicina	77.52	348.84	258.14	17.44	29.07	22.64
A. cyanophylla	174.42	368.22	248.84	13.57	23.26	18.14
A. drepanolobium	155.04	426.36	274.65	17.44	31.01	23.18
A. hockii	116.28	218.01	205.62	13.57	23.26	16.12
A. ligulata	213.18	465.12	341.09	15.51	29.07	17.33
A. senegal	164.73	377.91	263.06	13.57	29.07	23.91
A. sieberiana	155.04	290.70	237.29	15.51	29.07	24.85
A. spirocarpa	174.42	348.84	268.68	15.51	29.07	21.59
A. victoriae	96.9	387.60	240.51	9.69	17.44	13.83

TABLE VI

Showing minimum, maximum amd average height of uni-, bi- and multiseriate rays in *Acacia* species in microns.

Name of the species	UNISERIATE RAYS			BISERIATE RAYS			MULTISERIATE RAYS		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Acacia nilotica	48.45	155.04	83.95	65.89	271.32	133.65	116.28	1056.21	425.23
A. aneura	34.88	532.26	58.73	67.83	377.91	149.96	Absent	Absent	Absent
A. benthamii	29.07	193.80	83.57	44.57	174.42	99.92	67.83	449.19	249.23
A. salicina	34.88	164.73	87.55	87.21	319.77	162.33	77.52	548.64	261.75
A. cyanophylla	42.64	251.54	126.38	73.64	562.02	205.47	116.28	503.88	308.34
A. drepanolebium	38.76	155.04	88.34	58.14	251.94	115.39	77.52	1124.04	318.74
A. hockii	29.07	213.18	83.21	38.76	213.18	111.63	87.21	746.13	288.57
A. ligulata	38.76	193.80	105.90	87.21	300.39	180.51	106.59	397.29	257.54
A. senegal	29.07	87.21	45.54	38.76	145.35	85.23	96.90	775.20	297.47
A. sieberiana	31.00	180.23	78.14	52.33	209.31	118.02	87.21	786.75	248.65
A. spirocarpa	29.07	290.70	104.73	48.45	358.53	135.29	77.52	988.38	401.53
A. victoriae	27.13	164.73	80.74	71.71	339.15	163.35	106.59	465.12	277.51

TABLE VII

Showing minimum, maximum and average width of Uni-, bi- and multiseriate rays in *Acacia* species in microns.

Name of the species	UNISERIATE RAYS			BISERIATE RAYS			MULTISERIATE RAYS		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Acacia nilotica	9.69	21.32	14.73	15.51	34.88	25.19	29.07	87.21	59.88
A. aneura	9.69	29.07	15.19	17.44	32.95	23.02	Absent	Absent	Absent
A. benthamii	9.69	23.26	14.08	13.57	29.07	21.67	23.26	67.83	44.11
A. salicina	11.638	34.88	20.08	15.51	52.32	33.53	32.95	77.52	50.33
A. cyanophylla	11.63	34.88	23.49	15.51	58.14	36.59	29.07	77.52	50.92
A. drepanolobium	9.69	19.38	14.07	15.51	34.88	25.19	23.26	131.78	60.89
A. hockii	9.69	29.07	16.74	15.51	38.76	26.47	29.07	81.40	53.64
A. ligulata	11.63	25.19	18.02	23.26	38.76	31.36	29.07	54.26	37.98
A. senegal	5.81	17.44	9.11	11.63	34.88	20.95	23.26	106.59	42.17
A. sieberiana	11.63	34.88	21.34	13.57	44.57	31.44	29.07	135.66	66.55
A. spirocarpa	9.69	27.13	15.71	15.51	38.76	26.36	29.7	116.28	63.08
A. victoriae	5.81	19.38	13.06	13.57	32.95	23.49	29.07	67.83	41.78

TABLE VIII

Showing minimum, maximum and average number of rays per sq. mm. in *Acacia* species

Name of species	Minimum	Maximum	Average
A. nilotica	13	24	17.76
A. aneura	125	250	158.00
A. benthamii	27	50	39.34
A. salicina	39	70	51.46
A. cyanophylla	38	62	51.84
A. drepanolobium	12	35	18.4
A. hockii	27	63	44.46
A. ligulata	36	53	44.36
A. senegal	24	46	30.52
A. sieberiana	21	49	31.42
A. spirocarpa	18	35	25.08
A. victoriae	49	88	66.36

TABLE IX

Showing percentage occurrence of uni-, bi- and multiseriate rays in *Acacia* species

Name of species	% Uniseriate rays	% Biseriate rays	% Multiseriate rays	Total
Acacia nilotica	6.757	14.977	78.266	100.000
A. aneura	97.566	2.243	-	99.999
A. benthamii	12.756	12.300	74.935	100.000
A. salicina	29.534	24.337	46.128	99.999
A. cyanophylla	38.053	30.913	30.973	99.999
A. drepanolobium	8.152	15.000	76.847	99.999
A. hockii	11.740	17.260	71.000	100.000
A. ligulata	34.900	37.450	27.640	99.990
A. senegal	0.980	7.000	91.690	100.000
A. sieberiana	14.226	19.976	65.795	99.000
A. spirocarpa	26.000	15.630	58.370	100.000
A. victoriae	36.467	24.211	39.421	99.999

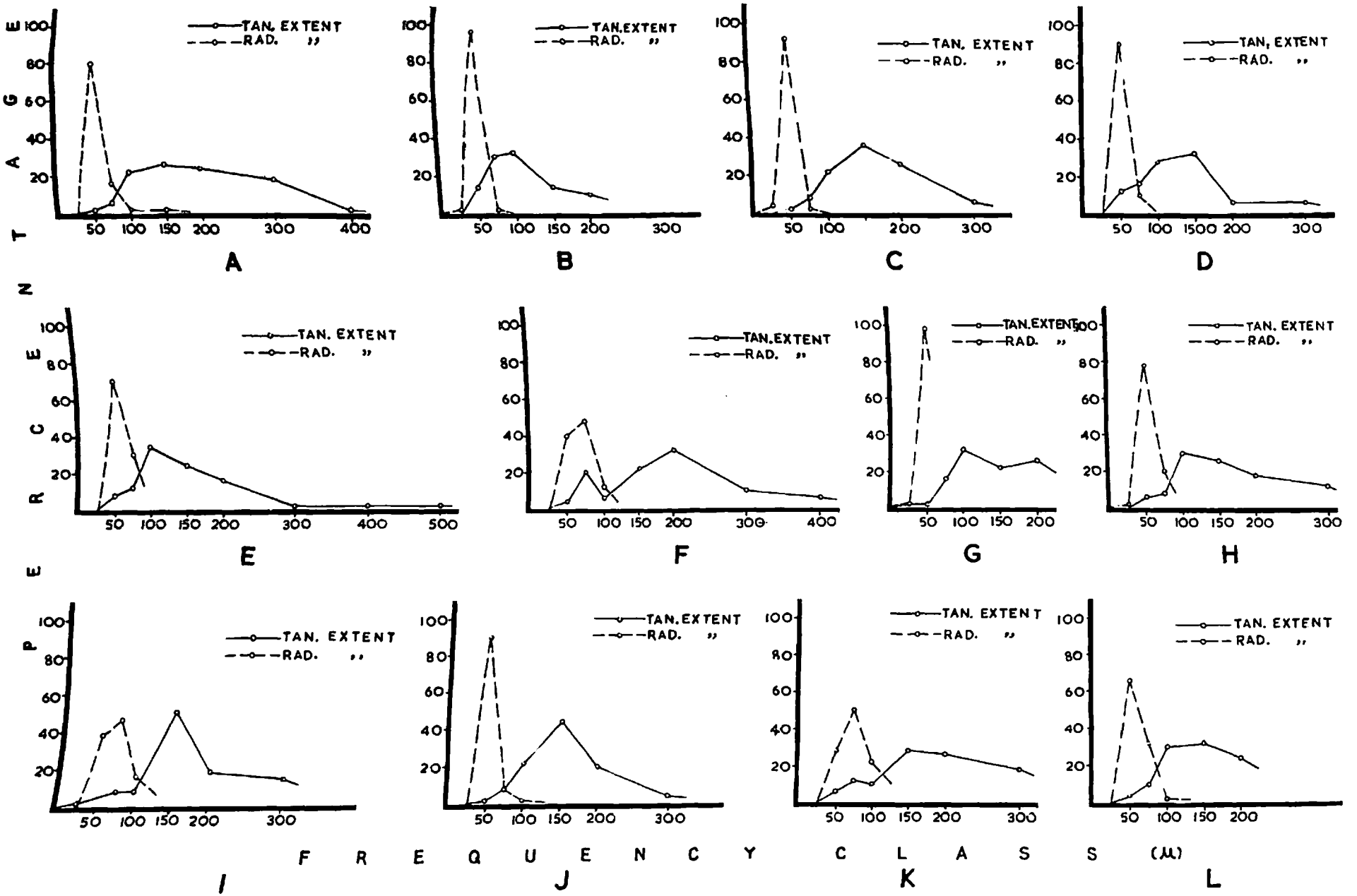
Text-figures 55A to 55L Percentage of fiber bands in different frequency classes of tangential and radial extent in *Acacia* species.

A. *A. nilotica*, B. *A. aneura*, C. *A. benthamii*; D. *A. salicina*, E. *A. cyanophyll* F. *A. drepanolobium*, G. *A. hockii*, H. *A. ligulata*, I. *A. senegal*, J. *A. sieberiana*, K. *A. spirocarpa*, L. *A. victoriae*.

TAN. EXTENT - Tangential extent,

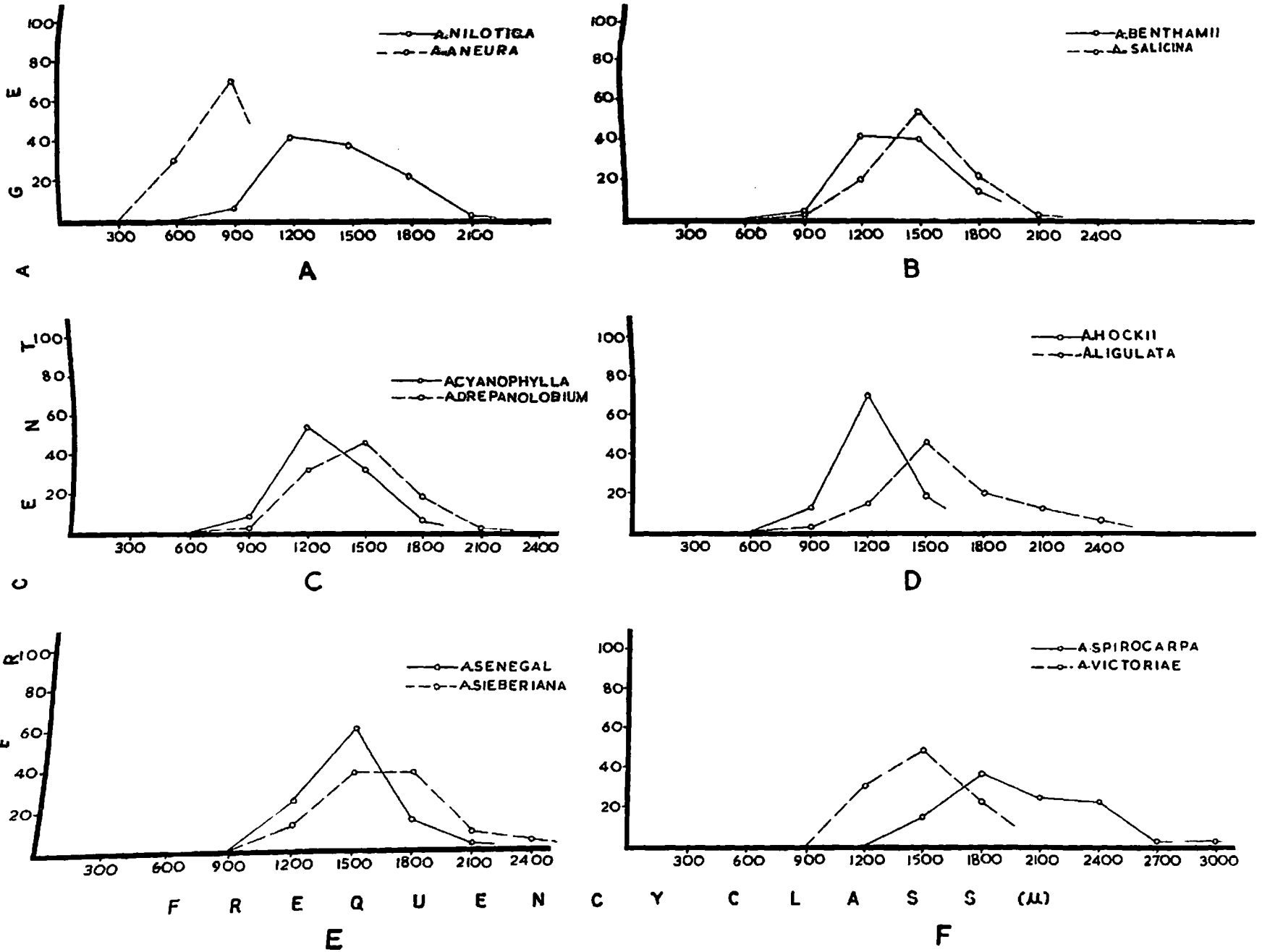
RAD. EXTENT - Radial extent.

SCALE – 1CM = 25 μ

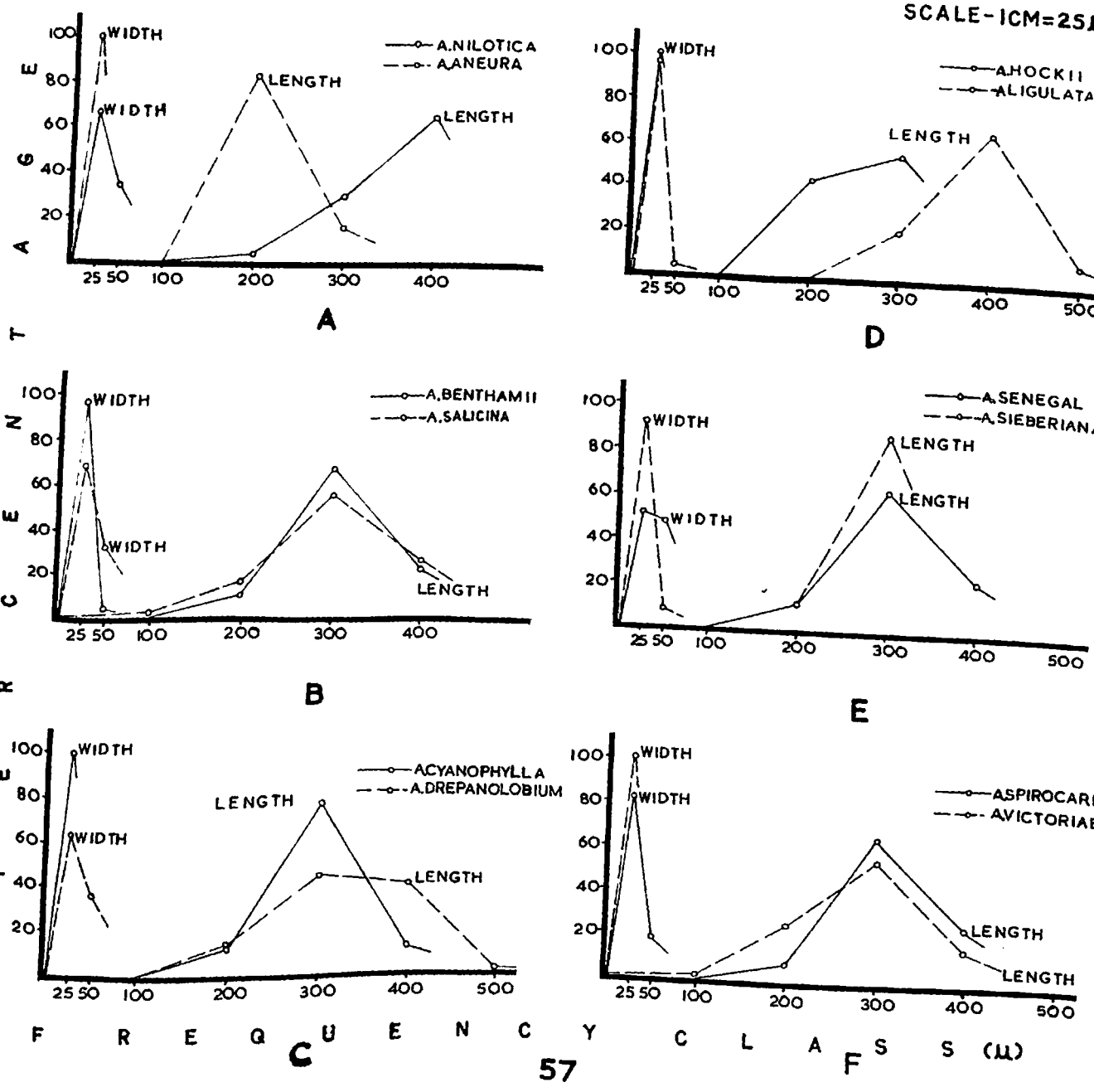


Text-figures 56 A to 56 F. Percentage of fibers in different frequency classes of length in *Acacia* species.

SCALE-1CM=100µ



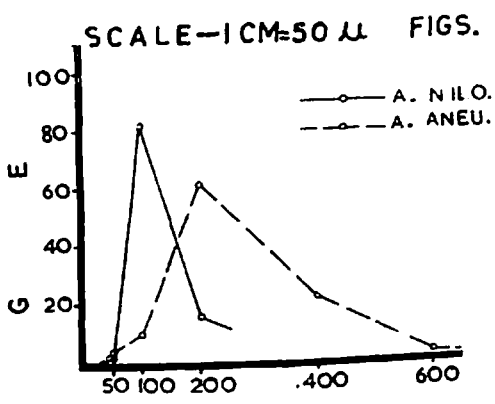
Text-figures 57 A to 57 F. Percentage of sieve tubes in different frequency classes of length and width in Acacia species.


SCALE-1CM=25μ
PERCENTAGE
A.NILOTICA
A.ANEURA
WIDTH
LENGTH
A
A.HOCKII
A.LIGULATA
D
A.BENTHAMII
A.SALICINA
B
A.SENEGAL
A.SIEBERIANA
E
A.CYANOPHYLLA
A.DREPANOLOBIUM
C
A.SPIROCARPA
A.VICTORIAE
F
FREQUENCY CLASS (μ)

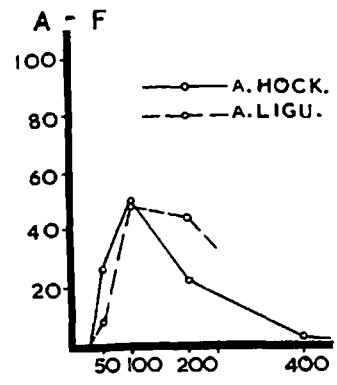
Text-figures 58A to 58F — Percentage of uniseriate rays in different frequency classes of height in *Acacia* species.

Text-figures 59 A to 59F — Percentage of uniseriate rays in different frequency classes of width in *Acacia* species.

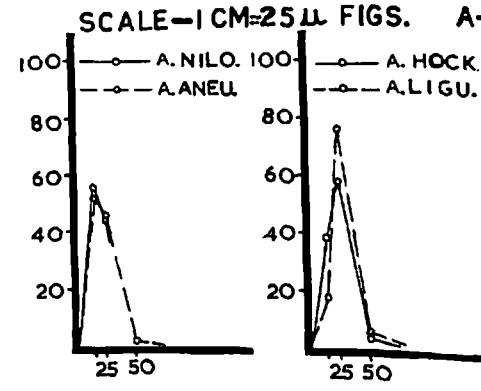
A. NILO. *A. nilotica*, A. ANEU. *A. aneura*, A. BENTH. *A. benthamii*, A. SALICI. *A. salicina*, A. CYANO. *A. cyanophylla*, A. DREP. *A. drepanolobium*, A. HOCK. *A. hockii*, A. LIGU. *A. ligulata*, A. SIEB. *A. sieberiana*, A. SPIRO. *A. spirocarpa*, A. VICTO. *A. victoriae*.



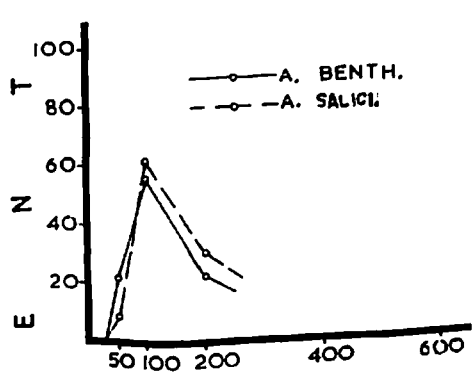
58A



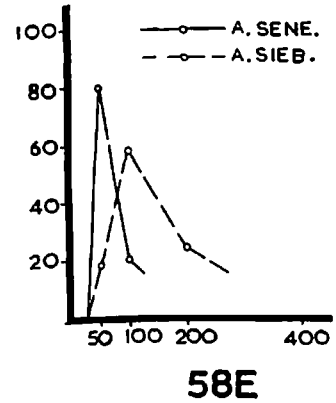
58D



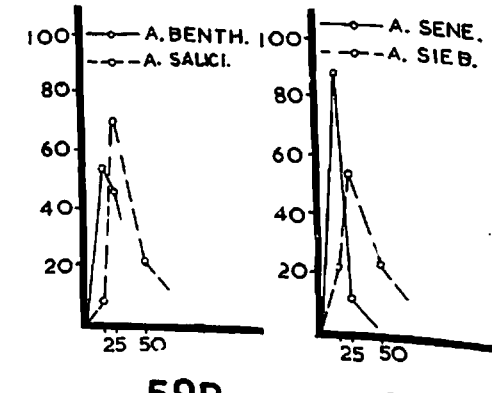
59A 59D



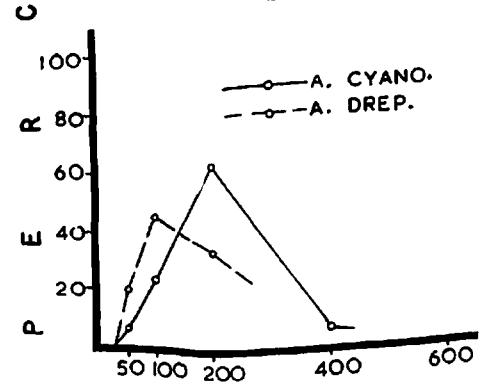
58B



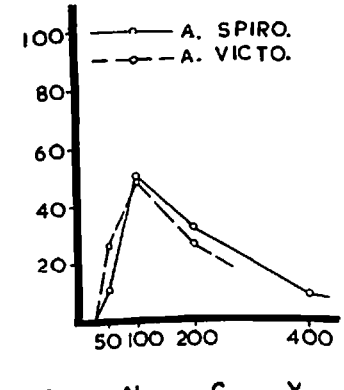
58E



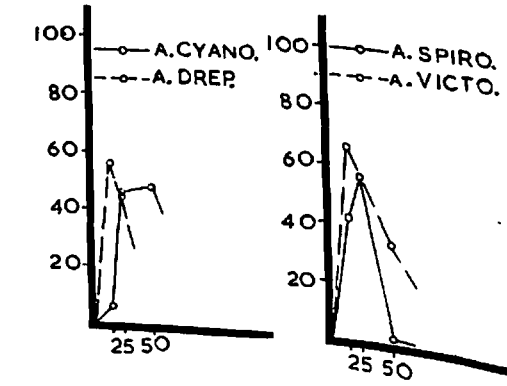
59B 59E



58C



58F

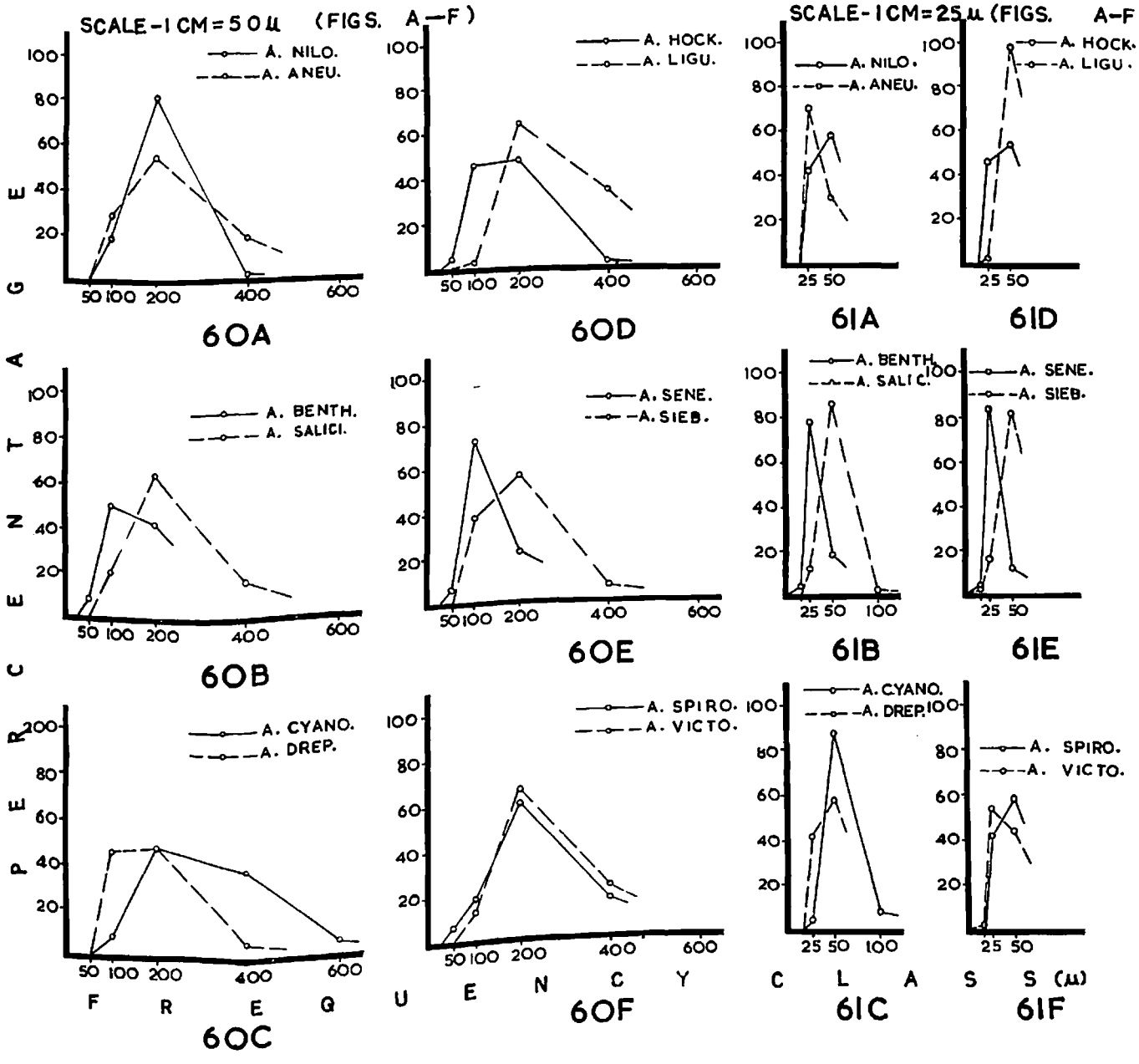


59C 59F

Text-figures 60 A to 60 F — Percentage of biseriate rays in different frequency classes of height in *Acacia* species.

Text-figures 61 A to 61 F — Percentage of biseriate rays in different frequency classes of width in *Acacia* species.

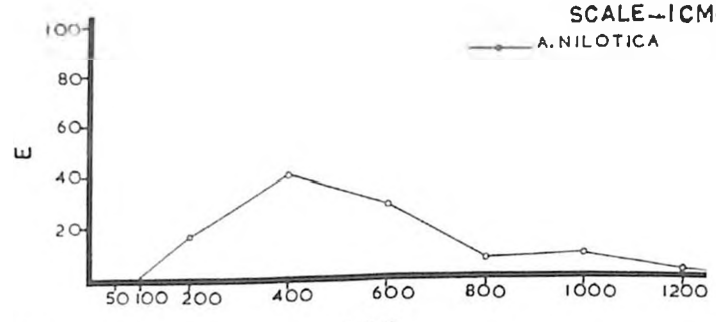
A. NILO. *A. nilotica*, A. ANEU. *A. aneura*, A. BENTH. *A. benthamii*, A. SALICI. *A. salicina*, A. CYANO. *A. cyanophylla*, A. DREP. *A. drepanolobium*, A. HOCK. *A. hockii* A. LIGU. *A. ligulata*, A. SIEB. *A. sieberiana*, A. SPIRO. *A. spirocarpa*, A. VICTO. *A. victoriae*.


SCALE-1 CM=50 μ (FIGS. A—F)
SCALE-1 CM=25 μ (FIGS. A—F)
A. NILO.
A. ANEU.
A. HOCK.
A. LIGU.
A. BENTH.
A. SALICI.
A. SENE.
A. SIEB.
A. CYANO.
A. DREP.
A. SPIRO.
A. VICTO.
PERCENTAGE FREQUENCY
CLASS (μ)
60A
60D
61A
61D
60B
60E
61B
61E
60C
60F
61C
61F

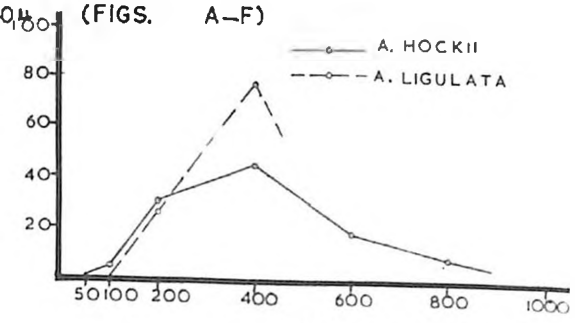
Text-figures 62 A to 62 F. Percentage of multiseriate rays in different frequency classes of height in *Acacia* species.

Text-figures 63 A to 63 F. Percentage of multiseriate rays in different frequency classes of width in *Acacia* species.

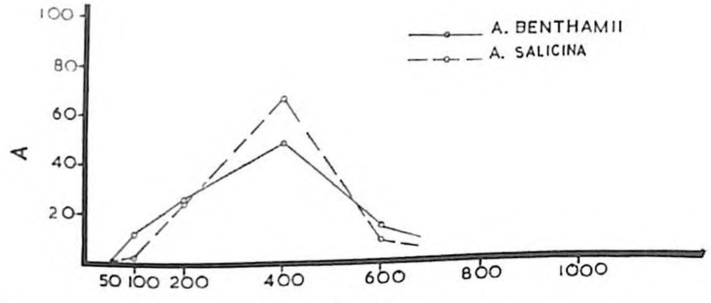
SCALE—1CM=50μ (FIGS. A—F)



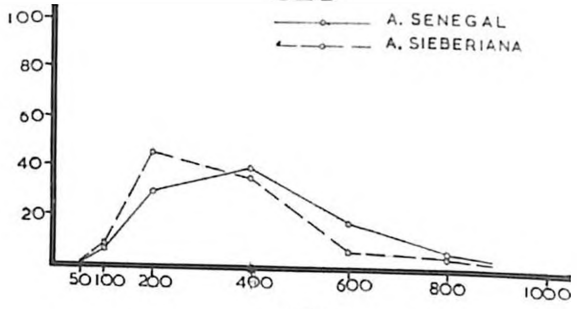
62A



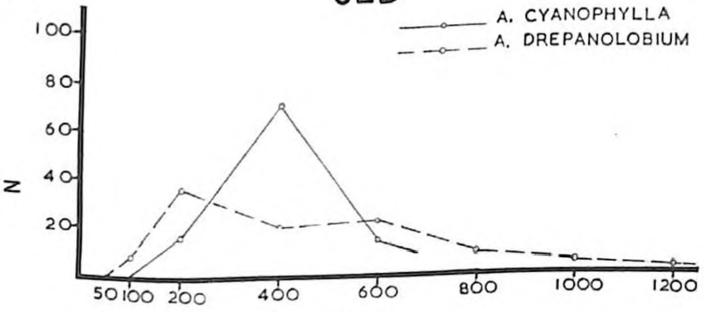
62D



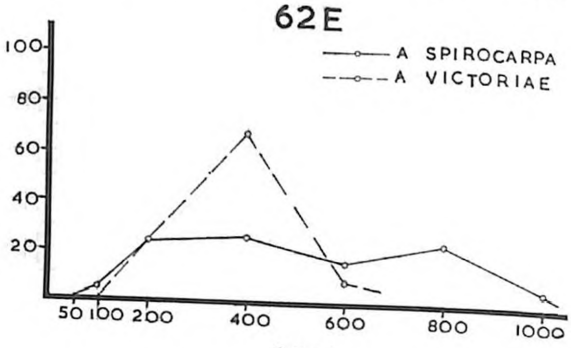
62B



62E

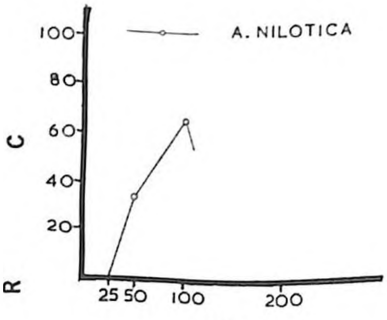


62C

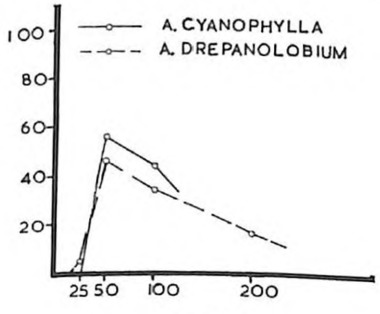


62F

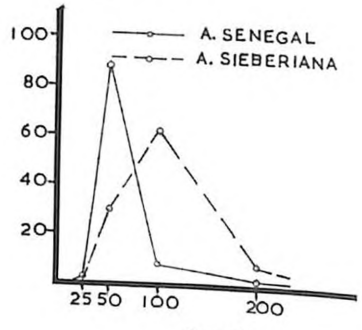
SCALE—1CM=25μ (FIGS. A-F.)



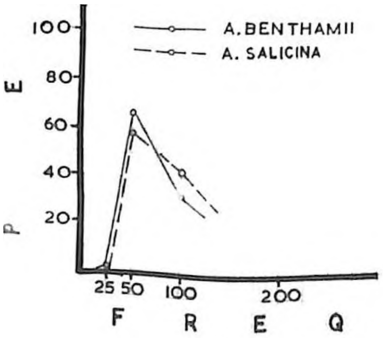
63A



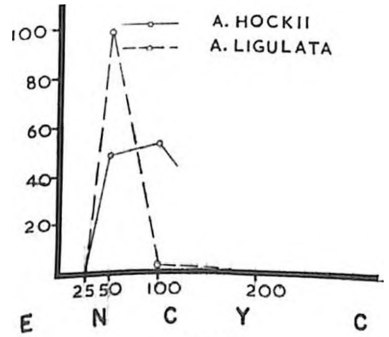
63C



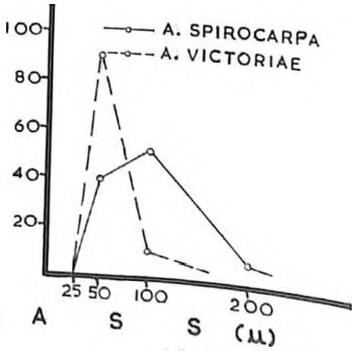
63E



63B



63D

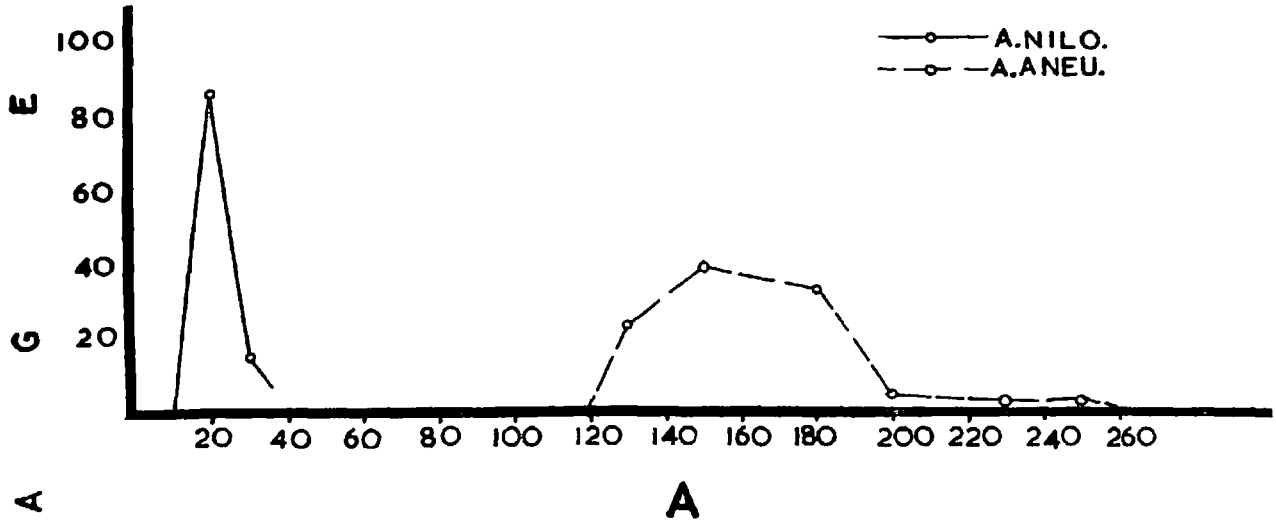


63F

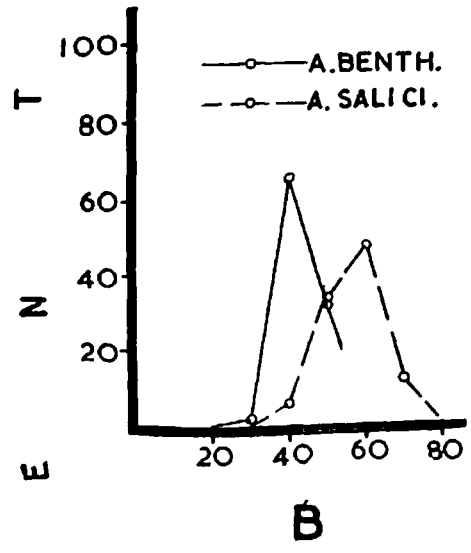
Text-figures 64 A to 64 F Showing percentage readings in different frequency classes of number of rays per sq.mm. in *Acacia* species.

A. NILO. *A. nilotica*, A. ANEU. *A. aneura*, A. BENTH. *A. benthamii*, A. SALICI. *A. salicina*, A. CYANO. *A. cyanophylla*, A. DREP. *A. drepanolobium*, A. HOCK. *A. hockii*, A. LIGU. *A. ligulata*, A.SIEB. *A. sieberiana*, A. SPIRO. *A. spirocarpa*, A. VICTO. *A. victoriae*.

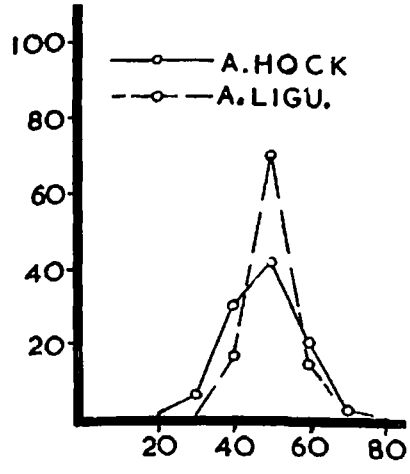
SCALE–1CM=10 RAYS



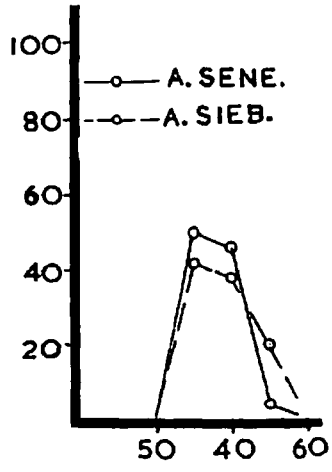
A



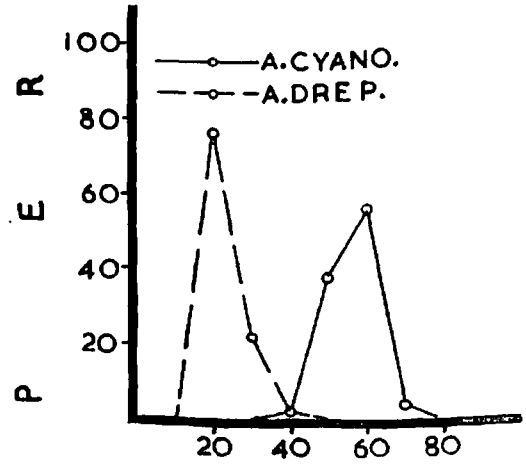
B



D

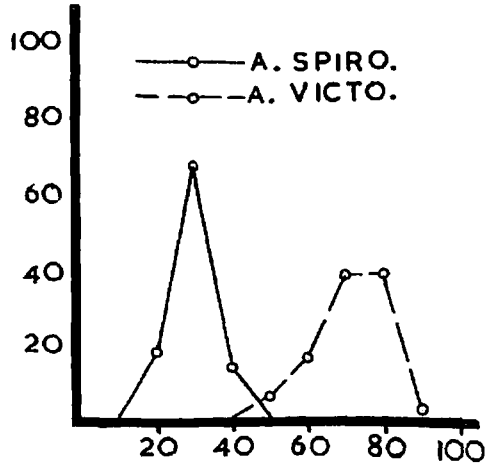


E



C

CLASS



F

ALBIZZIA LEBBECK

EXTERNAL MORPHOLOGY:

Bark of young branches is green and smooth. It turns pale brown to yellowish grey in older branches. Lenticels are prominent, raised above the surface and arranged in horizontal rows (Photo. 141) and dark brown in colour. Bole bark is rough, dippled type (Photo. 142) and light brownish in colour. Slash shows three distinct zones: (1) outer light brown to grey corresponding to the cork, (2) middle dark red corresponding to phelloderm and cortex and (3) inner pale yellow corresponding to secondary phloem. Thickness of the bole bark is 18.0 to 20.0 mm.

STRUCTURE OF YOUNG TWIG:

Young stem is squarish in transectional outline. Pith is extensive consisting of large, thin walled hexagonal cells containing starch. Pericycle is continuous, sclerenchymatous and grooved (Photomicro. 143). In the grooves, pericycle consists of a few layers of thick walled cells, while in the ridges cells of a outer few layers have thick walls and narrow lumen and those of inner have comparatively thin walls and wide lumen (Photomicro. 143). Cortex consists of small and large, oblong cells with small intercellular spaces and contain chloroplast. Cortical cells immediately outside the pericycle in the region of the ridges contain rhomboidal crystals. Epidermal

cells are barrel shaped or slightly radially elongated with thick cuticle (Fig. 176; Photomicro. 144). Impregnation of the cuticle takes place in such a way as to appear another cell layer above the epidermis (Photomicro. 144). Trichomes are simple with broad bases and gradually tapering ends. In addition, sparsely distributed globular trichomes are also present.

STRUCTURE OF MATURE BARK:

Secondary phloem:

It consists of phloem blocks separated from one another by horizontal phloem rays (Fig. 177; Photomicro. 145,146). Each phloem block is characterised by the presence of fiber bands arranged in tangential rows alternating with soft tissue (Fig. 177; Photomicro. 145,146). However, regular, parallel, tangential rows are not formed along the circumference. In transverse section each fiber band is rectangular or oblong (Fig. 177; Photomicro. 145,146). They are lined by a single layer of crystalliferous cells containing rhomboidal crystals adaxially and abaxially (Fig. 178). A few parenchyma layers occur on the abaxial side of each fiber band in addition to the crystalliferous layer (Fig. 178). Fibers are large in diameter and have lignified walls. Tangential and radial extent of the fiber bands ranges from 42.50 to 384.00 and 42.50 to 110.00 microns respectively. Average tangential and radial extent is 146.48 and 64.43 microns respectively. Percentage of fiber bands in different ffequency classes of tangential and radial extent is shown in text-figure 65.

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In macerated preparation, fibers are non-septate, long with gradually tapering ends. Tips are conical or slightly obtuse. Fiber length ranges from 1275.00 to 2720.00 microns with an average of 1940.64 microns. Percentage of fibers in different frequency classes of length is shown in text-figure 66.

In transverse section, sieve tubes are large and circular in outline. They are distributed either singly or in groups (Fig. 178; Photomicro. 146). End walls are inclined, rarely transverse. These walls are perforated to form sieve plates having more than one sieve area and are thus compound (Figs. 179A, B; Photomicro. 147,148). Sieve areas vary in size and shape and are arranged either in a single or in two rows (Figs. 180A,B; Photomicro. 149). The sieve plates are oriented at an angle ranging from 20.0 to 70.0 degrees with an average of 44.9 degrees. Slime does not occur in distinct form. However plugs of amorphous mass occur near the sieve plates (Figs. 179A,B). In surface view of longitudinal section, small, round or elliptical areas without any pores are seen. These probably represent lateral sieve areas which have ceased to function during ontogeny and are thus structures similar to lattices (Fig. 179A).

Sieve tubes are 222.87 to 562.02 microns in length and 23.26 to 56.21 microns in width. Average length and width is 390.33 and 33.69 microns respectively. Percentage of sieve tubes in different frequency classes of length and width is shown in text-figure 67.

The sieve tubes function only for a season. In non-functional phloem the sieve plates are covered completely by callose. Obliteration of the sieve tubes in the non-functional phloem is very common and results in the formation of irregular bands of crushed tissue in between the parenchyma of the axial system (Photomicro. 145,146).

Companion cells associated with each sieve tube vary in size, shape and number. In transverse section, one to three while in longitudinal section three companion cells are associated with each sieve tube (Fig. 180).

Phloem parenchyma forms major portion of the soft tissue coming in between the fiber bands. These cells are large, thin walled, circular and contain rhomboidal crystals as well as starch. The parenchyma cells are intermixed with the sieve tubes (Fig. 178).

Phloem rays, similar to other plants, are of the first as well as second categories. In transverse section, they are one, two or three to many cells wide (Fig. 178; Photomicro. 146). Ray cells are rectangular. In the peripheral part of the secondary phloem, rays become twisted. The rays are homogeneous (Photomicro. 149) and uni-, bi- and multiseriate. In tangential longitudinal sections ray cells are oval or round and walls are thick (Photomicro. 147,148).

Uniseriate rays usually have conical or round end cells (Photomicro. 147). Height ranges from 42.64 to 184.11 microns

with an average of 68.34 microns while width ranges from 9.69 to 29.07 microns with an average of 17.65 microns. Percentage of uniseriate rays in different frequency classes of height and width is shown in text-figures 68 and 69 respectively.

Biseriate rays show either short uniseriate ends or equal or unequal uniseriate extensions (Photomicro. 147). Biseriate rays with included uniseriate portions also occur. Height ranges from 42.64 to 242.25 microns with an average of 120.50 microns while width ranges from 13.57 to 38.76 microns with an average of 27.61 microns. Percentage of biseriate rays in different frequency classes of height and width is shown in text-figures 68 and 69 respectively.

Multiseriate rays have uniseriate short ends usually but rays with extensions are also common (Photomicro. 147, 148). Some of these rays are dissected due to the intrusive growth of the sieve tubes or phloem fibers. The ray cells contain drusses or rhomboidal crystals. Height ranges from 116.28 to 833.34 microns with an average of 376.98 microns while width ranges from 23.26 to 96.90 microns with an average of 45.14 microns. Percentage of multiseriate rays in different frequency classes of height and width is shown in text-figures 68 and 69 respectively.

Number of rays per square mm. ranges from 17 to 32 with an average of 23.5 per square mm. Percentage readings in different frequency classes of ray number per square mm. are shown in text-figure 70.

Percentage occurrence of uni-, bi- and multiseriate rays is 7.64, 18.53 and 73.83 respectively.

Expansion: The bark from young to maturity shows cortical, pericyclic and ray expansions.

Cortical expansion: It is more prominent in the regions opposite to the pericyclic grooves. The frequency of tangential stretching and anticlinal divisions increases gradually towards the periphery of the cortex (Photomicro. 143). Anticlinal walls are laid down on one or both sides of the cells.

Pericyclic expansion: It is similar to other plants (Figs. 177, 181; Photomicro. 150). The intercalated parenchymatous regions formed as a result of pericyclic expansion are transformed into sclerieds.

Ray expansion: It is also similar to the other plants described earlier and results in the formation of wedge shaped ray expansion tissue (Figs. 177, 182). Some of the rays show partial expansion and are thus twisted (Fig. 182A). Still in others expansion takes place only for a short distance forming fingure like expansion tissue (Fig. 182C).

Periderm:

The periderm is superficial throughout and initiates in the sub-epidermal layer and thus resembles Erythrina in its place of initiation. Cells of this layer become radially elongated and divide periclinally. Inner layer matures into

phelloderm while outer divides again to form phellogen adaxially and cork abaxially (Fig. 176). Thus the mode of initiation of phellogen resembles A. nilotica. Epidermis remains intact even after the formation of one to two cork layers (Fig. 183; Photomicro. 144). Extent of cork and phelloderm formed is almost equal. Cork cells are rectangular to squarish and thin walled to begin with but the walls soon become suberised and thick (Fig. 184; Photomicro. 143, 144). At places thin walled cells occur in between the thick walled cells. Some of the cork cells acquire crystals. In surface view cork cells are angular. Phelloderm cells are regularly arranged and densely protoplasmic. With the increase in the girth every year the cork cracks in the form "V" but these cracks do not reach the deeper layers of the cork. This phellogen remains active throughout and cuts off cork and phelloderm regularly.

Wound periderm: Its formation was observed in one sample of the bark of a young twigs and takes as follows. The injured tissue first becomes necrosed. Below this necrosed wounded tissue arises a strip of phellogen forming a few layered periderm which extends laterally and joins the outer periderm forming a crescent shaped layer around the wound (Fig. 185). The cells of this layer divide anticlinally forming a cup like crescent, the rim of which converges gradually and ultimately the two sides join each other (Figs. 186, 187). The wounded tissue is first completely enclosed by the wound periderm which separates from the main periderm

in the form of a ring. All the layers of this periderm become suberized. Extent of the wound periderm is five to six layered.

Sclerosis: It is a common phenomenon in the bark tissue and the extent of the sclerosis increases with the age. First of all it occurs in the parenchymatous portions formed as a result of pericyclic expansion. Then it extends to the phelloderm and ray expansion tissue. The whole of the cortex and phelloderm is converted into sclerieds and also acquire red contents which turn this zone completely red. During the development of sclereids the cells first become vacuolated followed by the thickening of the walls which takes place in the form of striations. However, thickening of the wall is not uniform and results in the formation of pit canals. Various types of sclerieds are formed as a result of this sclerosis (Figs. 188A-I).

Exfoliation takes place in the form of scales only. The scales turn blackish and then wither off. The process of exfoliation is very slow. The exfoliation of corky scales is helped to some extent by the thin walled layers coming in between the thick walled cork layers.

Text-figures 65 to 70 — Albizzia lebbeck

Text-figure 65 — Percentage of fiber bands in different frequency classes of tangential and radial extent.

Text-figure 66 — Percentage of fibers in different frequency classes of length.

Text-figure 67 — Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 68 — Percentage of uni-, bi-, and multiseriate rays in different frequency classes of height.

Text-figure 69 — Percentage of uni-, bi- and multiseriate rays in different frequency classes of width.

Text-figure 70 — Percentage readings in different frequency classes of number of rays per sq. mm.

TAN. EXTENT - Tangential extent, RAD. EXTENT - Radial extent, UNI RAYS - uniseriate rays, BI RAYS - Biseriate rays, MULTI. RAYS - multiseriate rays.

Text-figures 65 to 70 — Albizzia lebbeck

Text-figure 65 — Percentage of fiber bands in different frequency classes of tangential and radial extent.

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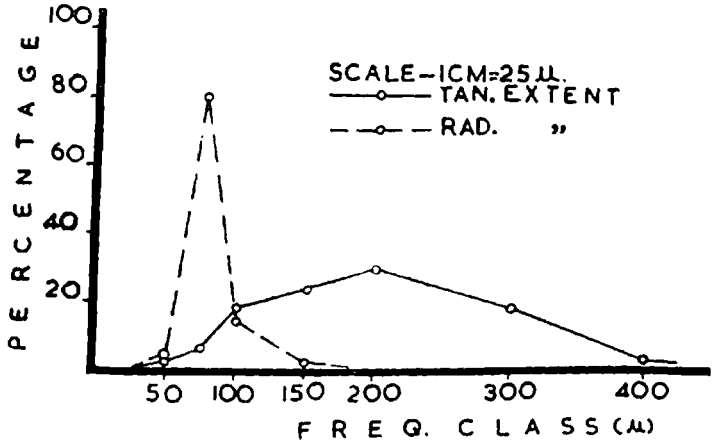
Text-figure 67 — Percentage of sieve tubes in different frequency classes of length and width.

Text-figure 68 — Percentage of uni-, bi-, and multiseriate rays in different frequency classes of height.

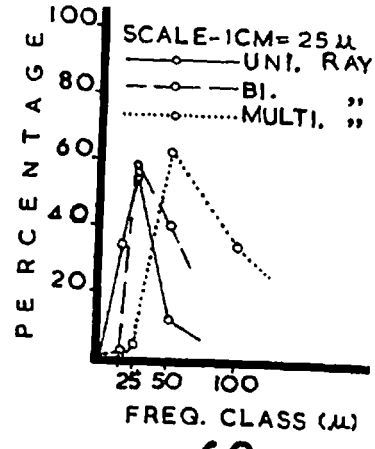
Text-figure 69 — Percentage of uni-, bi- and multiseriate rays in different frequency classes of width.

Text-figure 70 — Percentage readings in different frequency classes of number of rays per sq. mm.

TAN. EXTENT - Tangential extent, RAD. EXTENT - Radial extent, UNI RAYS - uniseriate rays, BI RAYS - Biseriate rays, MULTI. RAYS - multiseriate rays.



65



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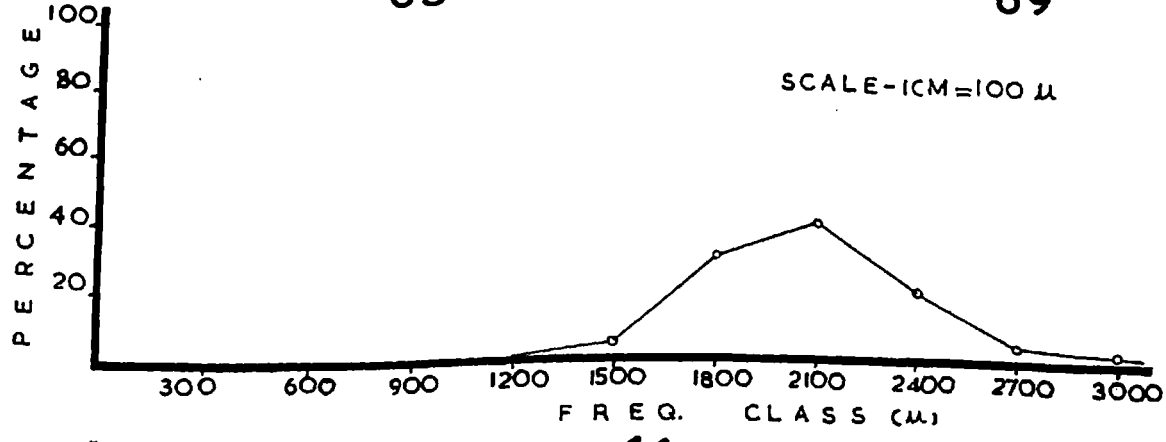

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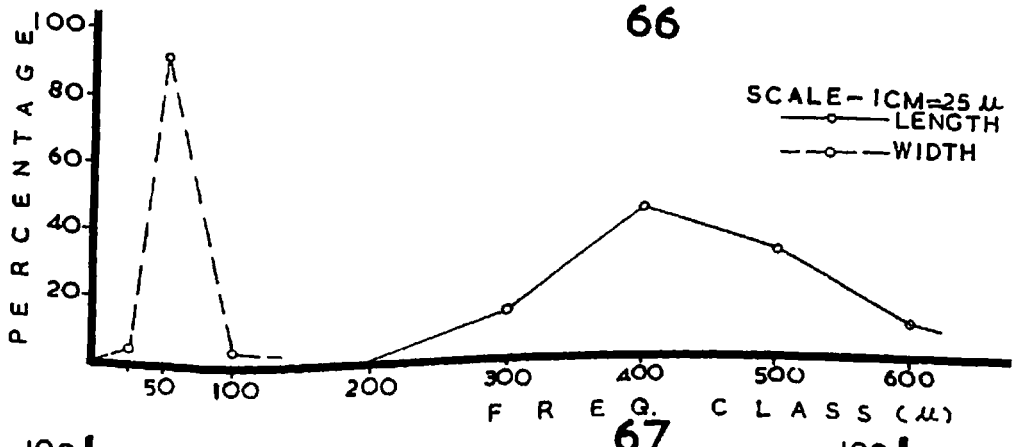

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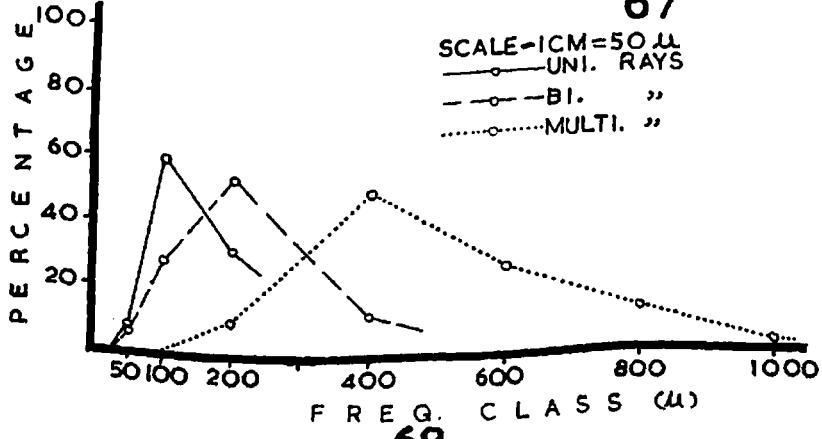
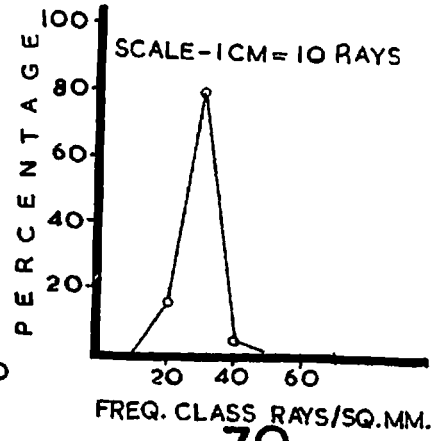


68

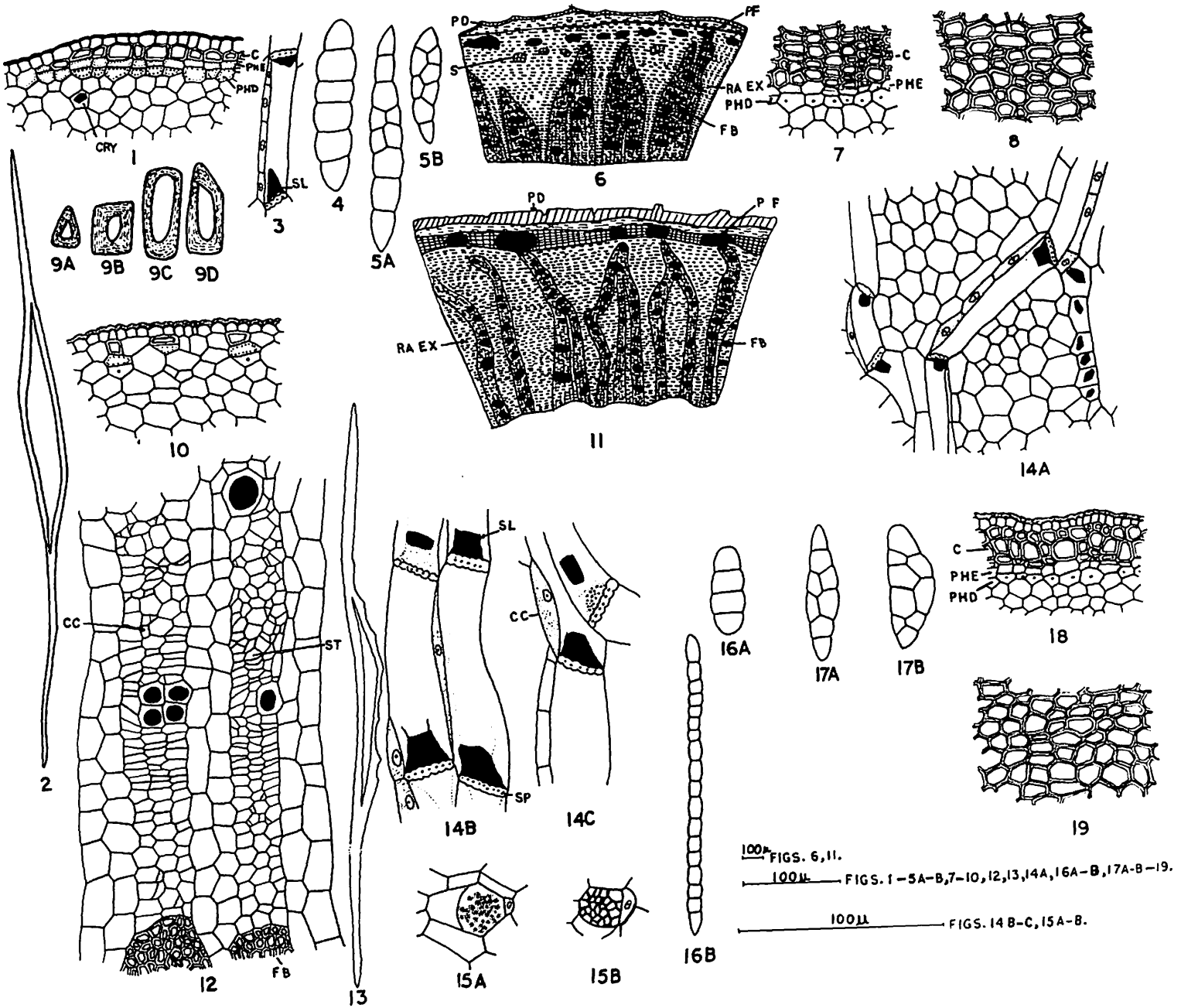


70

Figures 1 to 9D, *Erythrina indica*. Fig. 1, transverse section young twig showing epidermis with cuticle and initiation of phellogen; fig. 2, macerated fiber; fig. 3, sieve tube with simple sieve plate in tangential longitudinal section; fig. 4, uniseriate rays; figs. 5A & 5B, biseriate rays; fig. 6, transverse section mature bark; fig. 7, transverse section old branch showing extent of cork; fig. 8, cork cells in surface view; figs. 9A-D, types of sclereids.

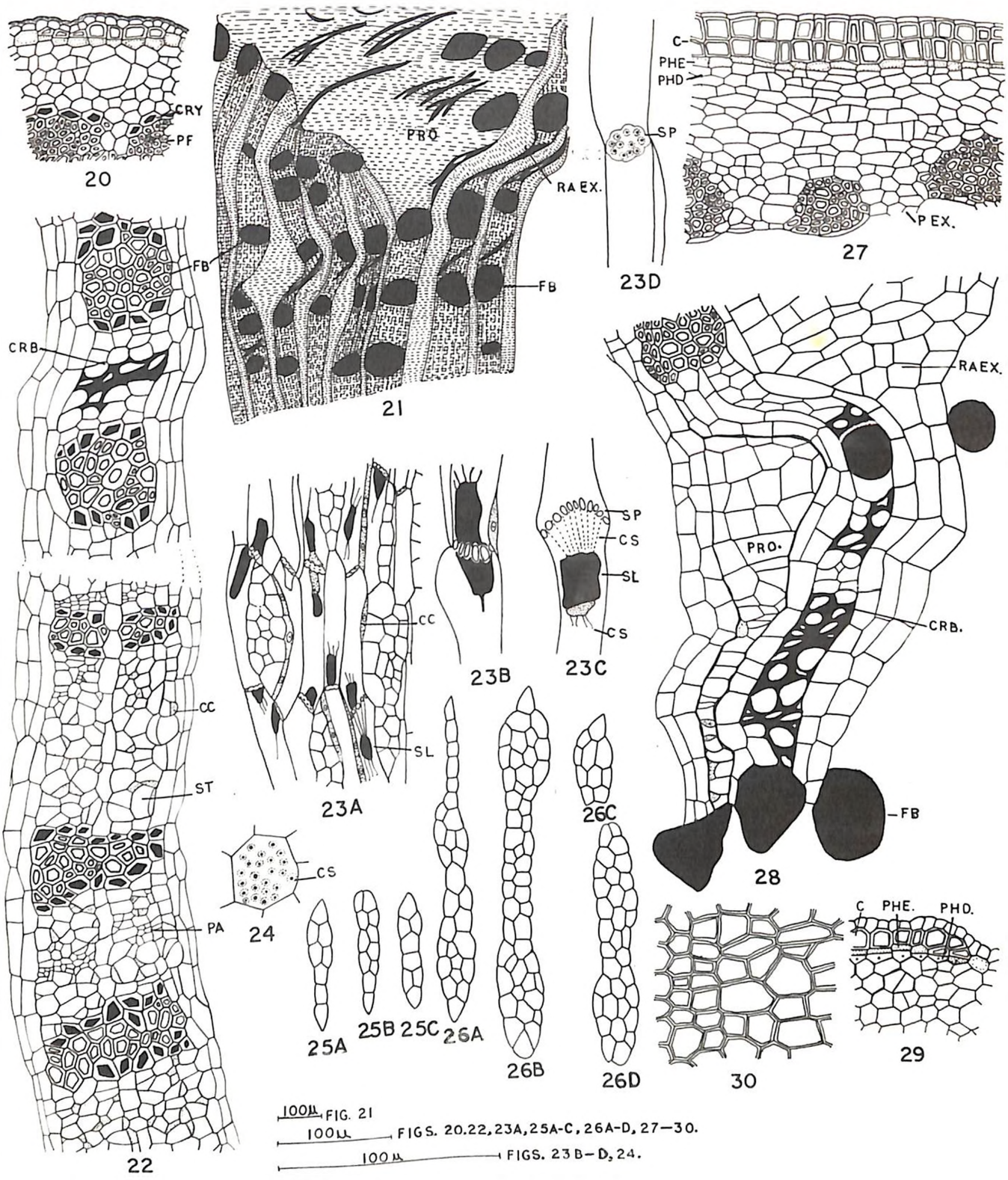
Figures 10 to 19, *Butea frondosa*. Fig. 10, transverse section young twig showing nature of epidermis and initiation of phellogen; fig. 11, transverse section mature bark; fig. 12, portion of phloem block in transverse section; fig. 13, macerated fiber; figs. 14A-C sieve tubes with simple sieve plates in tangential longitudinal section; fig. 15A, functional sieve plate in surface view; fig. 15B, non-functional sieve plate in surface view; figs. 16A-B, uniseriate rays; figs. 17A-B, biseriate rays; fig. 18, transverse section young branch showing activity of phellogen; fig. 19, cork cells in surface view.

C- cork, CC- companion cells, CRY- crystalliferous cells, FB- fiber bands, PD- periderm, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen, RAEX- ray expansion tissue, SL- slime, SP- sieve plate, ST- sieve tube.


C
PHE
PHD
CRY
1
SL
3
4
5A
5B
PD
PF
S
RA EX
FB
6
7
8
9A
9B
9C
9D
10
11
14A
2
CC
ST
12
13
SP
14B
14C
16A
16B
17A
17B
18
19
15A
15B
100μ FIGS. 6, 11.
100μ FIGS. 1-5A-B, 7-10, 12, 13, 14A, 16A-B, 17A-B-19.
100μ FIGS. 14B-C, 15A-B.

Figures 20 to 30, Dalbergia sisso. Fig. 20, transection young branch showing epidermis with cuticle, cortex and initiation of phellogen; fig. 21, transverse section of a protion of mature bark; fig. 22, portion of phloem block in transverse section; figs. 23A-D, sieve tubes with simple sieve plates in tangential longitudinal section; fig. 24, sieve plate in transverse section; figs. 25A-C, biseriate rays; figs. 26A-D, multiseriate rays; fig. 27, transverse section old branch showing cortical and pericyclic expansion and activity of the first phellogen; fig. 28, showing expansion in the ray and proliferation of the axial parenchyma; fig. 29, transverse section young twig showing initiation of first phellogen; fig. 30, cork cells in surface view.

C- cork, CC- companion cells, CRB- crushed tissue bands, CRY- crystalliferous cells, CS- connecting strands, FB- fiber bands, PA- parenchyma, PEX- pericyclic expansion, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen, PRO- phloem proliferation tissue, RAEX- ray expansion tissue, SL- slime, SP- sieve plate, ST- sieve tube.



100μ FIG. 21

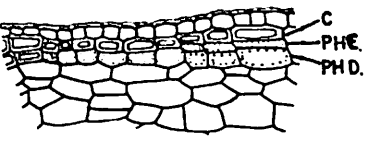
100μ FIGS. 20.22, 23A, 25A-C, 26A-D, 27–30.

100μ FIGS. 23B–D, 24.

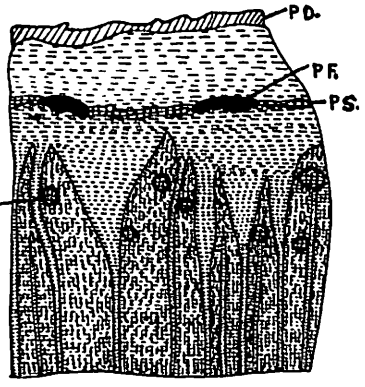
Figures 31 to 40B, Caesalpinia pulcherrima. Fig. 31, transverse section young twig showing epidermis with cuticle and initiation of phellogen; fig. 32, transverse section mature bark; figs. 33A-B, portion of phloem block in transverse section; figs. 34A-B, sclereid patches of phloem block; fig. 35, sieve tube with compound sieve plate in tangential longitudinal section; figs. 36A-B, biseriate rays; fig. 37, multiseriate ray; fig. 38, portion transection of old branch showing cortical expansion; fig. 39, cork cells in surface view; figs. 40A-B, sclereids.

Figures 41 to 47, Delonix regia. Fig. 41, transverse section mature bark; fig. 42, portion phloem block in transverse section; fig. 43, sieve tube with compound sieve plate in tangential longitudinal section; figs. 44A-C, biseriate rays; figs. 45A-B, multiseriate rays; fig. 46, transverse section young twig showing formation of periderm; fig. 47, transverse section bark portion showing cork.

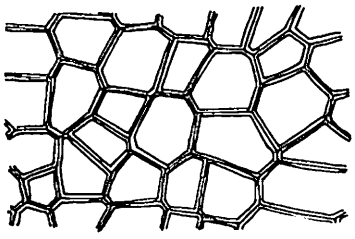
C- cork, CC- companion cells, CRB- crushed tissue band, CRY- crystalliferous cells, PD- periderm, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen, PS- pericyclic sclereids, RAEX- ray expansion tissue, S- sclereids, SA- sieve area, SL- slime, ST- sieve tube.



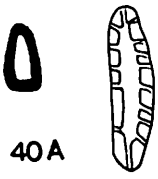
31



32

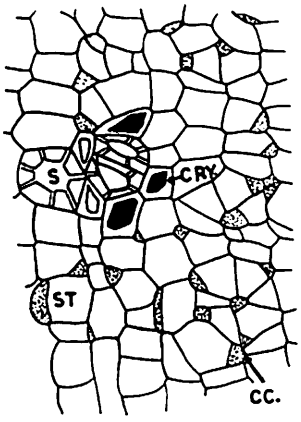


39

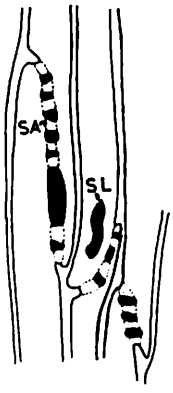


40A

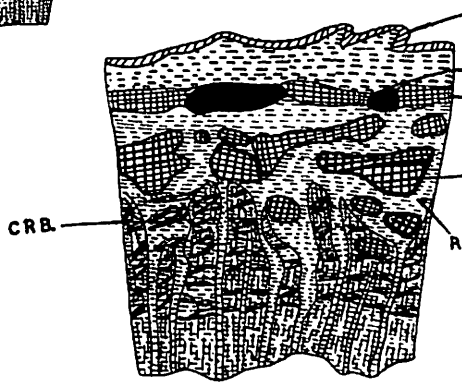
40B



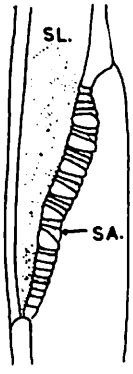
33A



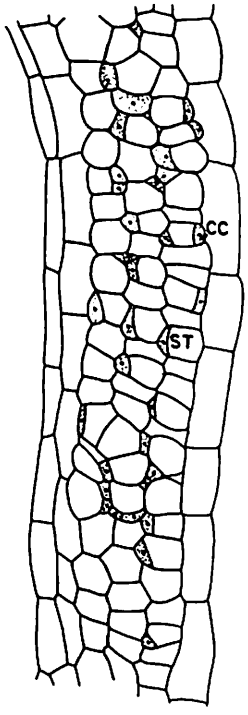
35



41



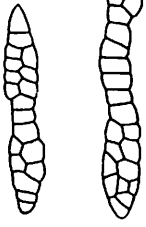
43



33B

44A

44C



42

44B

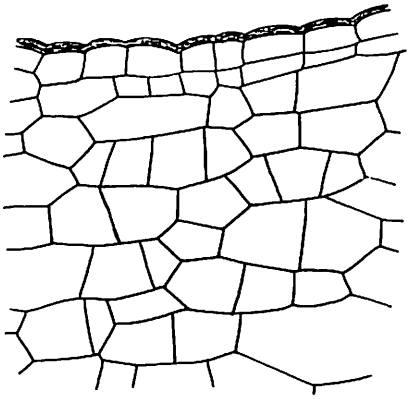
45B

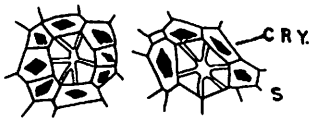
45A

36B

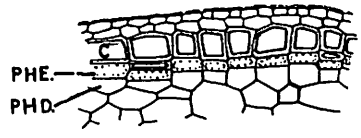
36A

37

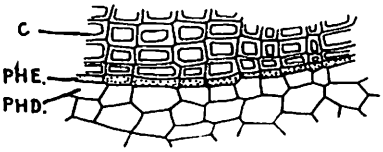




34A 34B



46



47

100 μ FIGS. 32, 41.

100 μ FIGS. 31, 36A-B TO 40A-B, 42, 38 44A TO 47.

100 μ FIGS. 33A-B, 34A-B, 35.

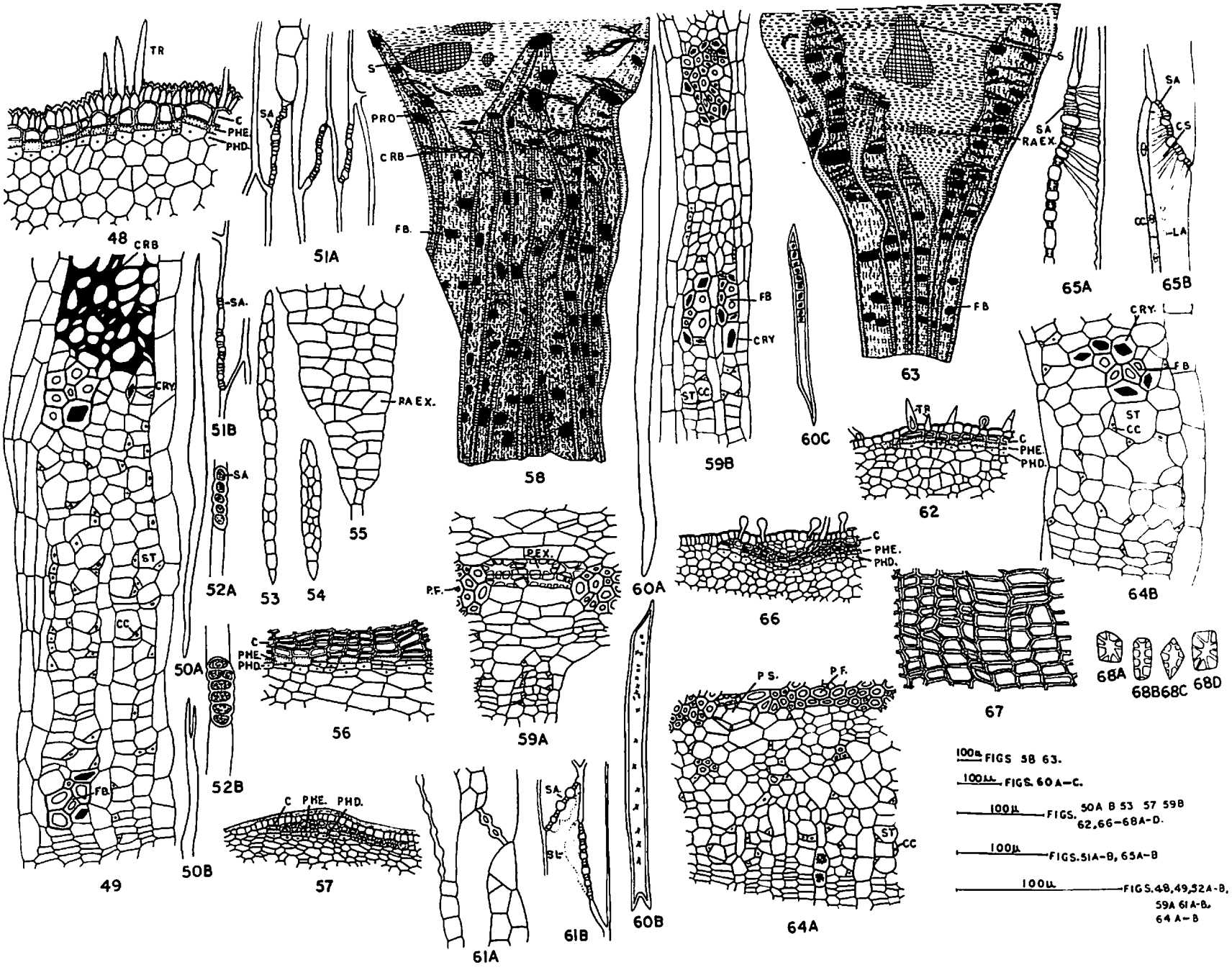
100 μ FIG. 43.

Figures 48 to 56, Cassia auriculata. Fig. 48, transverse section young twig showing epidermis with cuticle and trichomes and initiation of phellogen; fig. 49, portion phloem block in transverse section; figs. 50A-B, macerated fibers; figs. 51A-B, sieve tubes with compound sieve plates in tangential longitudinal section; fig. 53, biseriate ray with included uniseriate portions; fig. 54, multiseriate ray with a biseriate end; fig. 55, expansion of the ray; fig. 56, portion old branch showing extent of cork in transverse section.

Figures 57 to 61B, Cassia fistula. Fig. 57, portion young twig showing epidermis, cortex and initiation of phellogen in transverse section; fig. 58, transverse section mature bark; fig. 59A, transverse section old branch showing secondary phloem and pericyclic expansion, fig. 59B, portion phloem block of mature bark in transection; figs. 60A-B, nonseptate fibers; fig. 60C, septate fiber with crystals in each compartment; figs. 61A-B, sieve tubes with compound sieve plates in tangential longitudinal section.

Figures 62 to 68D, Cassia siamea. Fig. 62, transverse section portion young twig showing epidermis and initiation of phellogen; fig. 63, transverse section portion mature bark; fig. 64A, transverse section young bark showing secondary phloem and pericyclic expansion; fig. 64B, portion phloem block mature bark in transverse section; figs. 65A-B, sieve tubes with compound sieve plates in tangential longitudinal section; fig. 66, transverse section young twig showing deeper origin of phellogen; fig. 67, cork cells in surface view; figs. 68A-D, types of sclereids.

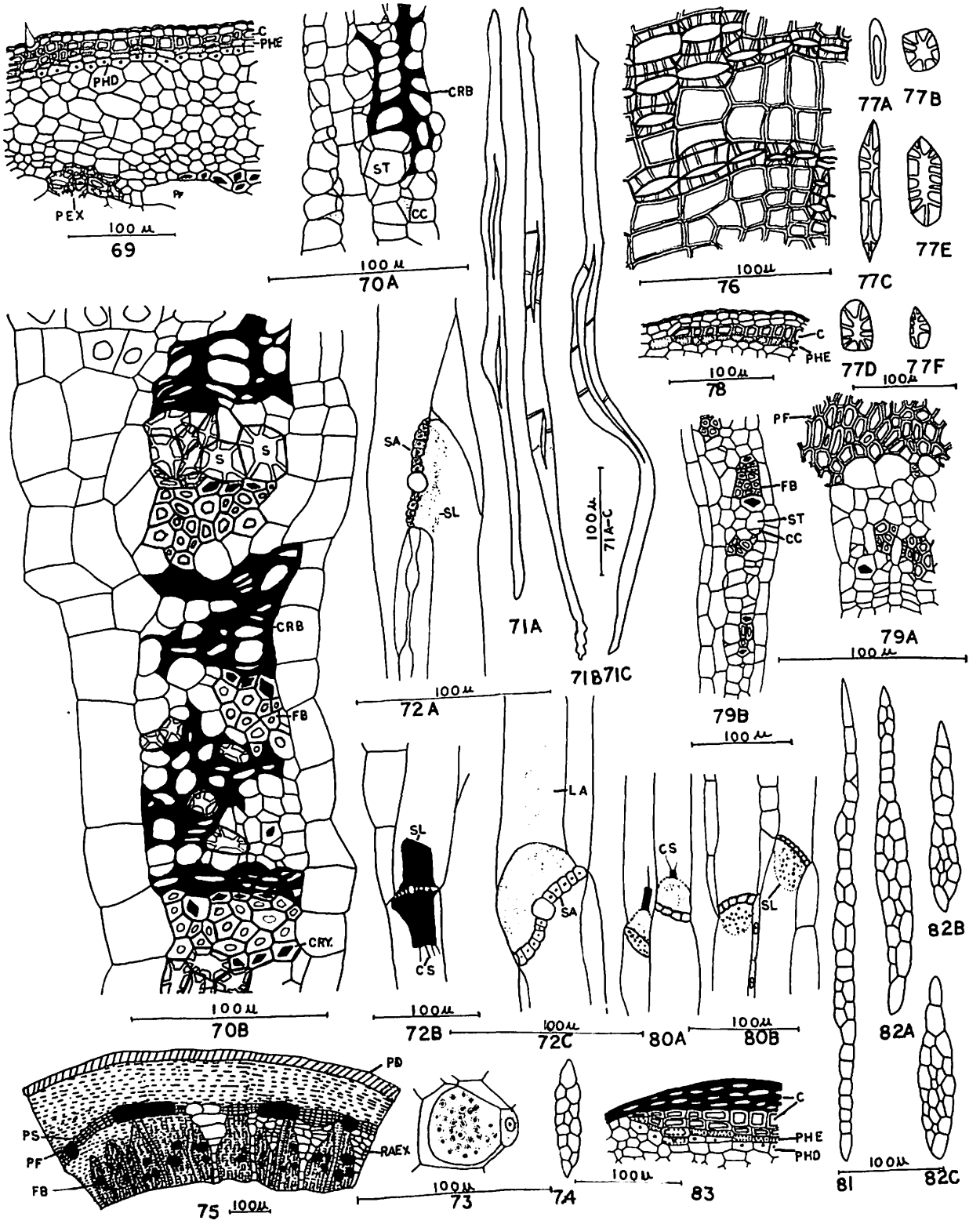
C- cork, CC- companion cells, CRB- crushed tissue band, CRY- crystalliferous cells, CS- connecting strands, FB- finer bands, PEX- pericyclic expansion, PF- pericyclic fibers, PHD- phellodérm, PHE- phellogen, PRO- phloem proliferation tissue, PS- pericyclic sclereids; RAEX- ray expansion tissue, S- sclereids, SA- sieve area, SL- slime, ST- sieve tube, TR- trichomes.


TR
C
PHE.
PHD.
48
CRB
CRY.
ST
CC
FB.
49
50A
50B
SA.
51A
51B
SA
52A
52B
C
PHE.
PHD.
53
54
RA EX.
55
56
57
S
PRO
CRB
FB.
58
P.EX.
P.F.
59A
FB
CRY
ST
CC
59B
60A
60B
61A
SA
61B
60C
63
SA
RA EX.
65A
SA
CS
LA
65B
TR
62
CRY.
FB
ST
CC
64B
66
P.S.
P.F.
ST
CC
64A
67
68A
68B
68C
68D
100µ FIGS 58 63.
100µ FIGS. 60A–C.
100µ FIGS. 50A B 53 57 59B 62, 66–68A–D.
100µ FIGS. 51A–B, 65A–B
100µ FIGS. 48, 49, 52A–B, 59A 61A–B, 64 A–B

Figures 69 to 77F, Tamarindus indica. figure 69, transverse section young twig showing epidermis, cortex, pericyclic expansion and initiation of phellogen; fig. 70A, portion phloem block (functional part) in transverse section; fig. 70B, portion phloem block (nonfunctional part) in transverse section; figs. 71A-C, macerated fibers; figs. 72A-C, sieve tubes with compound sieve plates in tangential longitudinal section; fig. 73, simple sieve plate in transverse section; fig. 74, multiseriate ray; fig. 75, transverse section young bark showing pericyclic and ray expansion; fig. 76, cork cells in transverse section; figs. 77A-F, types of sclereids.

Figures 78 to 83, Bauhinia variegata. Fig. 78, transverse section portion young twig showing epidermis with cuticle and initiation of phellogen; fig. 79A, transverse section of secondary phloem from young branch; fig. 79B, phloem block mature bark in transverse section; figs. 80A-B, sieve tubes with simple sieve plates in tangential longitudinal section; fig. 81, biseriate ray; figs. 82A-C, multiseriate rays; fig. 83, transverse section bark showing extent of cork.

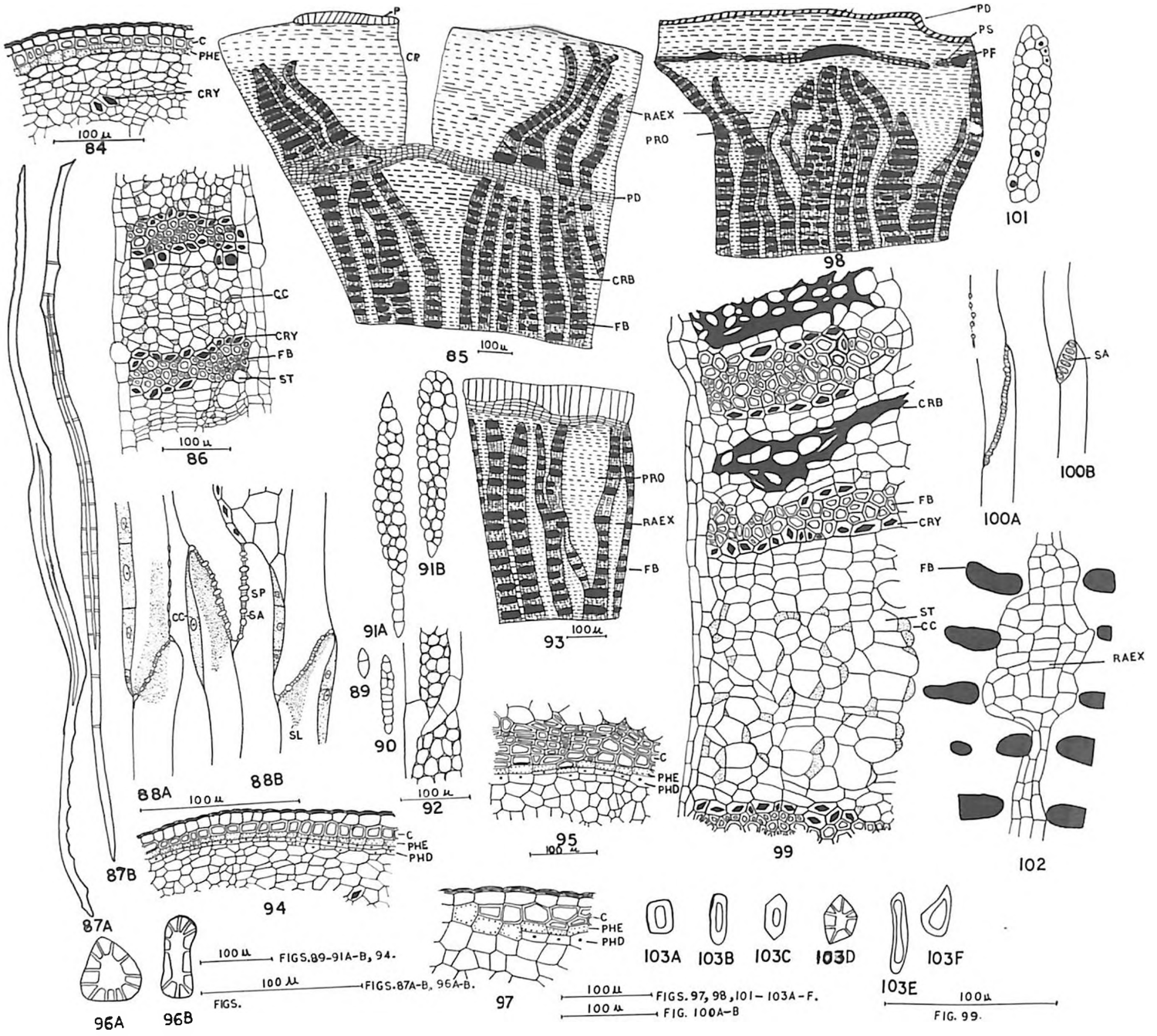
C- cork, CC- companion cells, CRB- crushed tissue bands, CRY- crystalliferous cells, CS-connecting strands, FB- fiber bands, LA- lattices, PD- periderm, PEX- pericyclic expansion, PS- pericyclic sclereids, RAEX- ray expansion tissue, S- sclereids, SA- sieve area, SL- slime, ST- sieve tube.


C
PHE
PHD
PEX
100 µ
69
CRB
ST
CC
100 µ
70A
77A
77B
77C
77E
100µ
76
C
PHE
100µ
78
77D
77F
100µ
SA
SL
71A
100µ
71A-C
71B
71C
PF
FB
ST
CC
79A
100 µ
79B
100 µ
S
S
CRB
FB
CRY
100µ
70B
100µ
72A
SL
CS
LA
SA
100µ
72B
100µ
72C
CS
SL
80A
100µ
80B
82B
82A
PD
PS
PF
FB
RAEX
75 100µ
100µ
73
7A
C
PHE
PHD
100µ
83
100µ
81
82C

Figures 84 to 96B, Prosopis spicigera. Fig. 84, transverse section young twig showing epidermis and initiation of phellogen; fig. 85, transverse section mature bark; fig. 86, portion phloem block in transverse section; fig. 87A, nonseptate fiber; fig. 87B, septate fiber; figs. 88A-B, sieve tubes with compound sieve plates in tangential longitudinal section; fig. 89, two cell high uniseriate ray, fig. 90, biseriate ray; figs. 91A-B, multiseriate rays; fig. 92, showing dissection of ray; fig. 93, transverse section mature bark showing proliferation tissue; figs. 94-95, transverse section of a branch showing periderm; figs. 96A-B, types of sclereids.

Figures 97 to 103F, Prosopis juliflora. Fig. 97, transverse section young twig showing epidermis and initiation of phellogen; fig. 98, transverse section mature bark; fig. 99, portion phloem block in transverse section; figs. 101A-B, sieve tubes with compound sieve plates in tangential longitudinal sections; fig. 102, showing expansion in a ray; figs. 103A-F, types of sclereids in the pericyclic region.

C- cork, CC- companion cells, CR- crack, CRB- crushed tissue bands, CRY- crystalliferous cells, FB- fiber bands, P- pericycle, PD- periderm, PF- pericyclic fibers, PRO- phloem proliferation, tissue, PS- pericyclic sclereids, PHD- phelloderm, PHE- phellogen, RAEX- ray expansion tissue, SA- sieve area, SL- slime, SP- sieve plate, ST- sieve tube.


C
PHE
CRY
100 µ
84
P
CR
PD
CRB
FB
100 µ
85
PD
PS
PF
RAEX
PRO
98
101
CC
CRY
FB
ST
100 µ
86
87A
87B
SP
SA
CC
SL
88A
88B
100 µ
91A
91B
89
90
92
100 µ
PRO
RAEX
FB
93
100 µ
CRB
FB
CRY
ST
CC
99
SA
100A
100B
FB
RAEX
102
C
PHE
PHD
95
100 µ
C
PHE
PHD
94
C
PHE
PHD
97
96A
96B
100 µ
FIGS. 89-91A-B, 94.
100 µ
FIGS. 87A-B, 96A-B.
FIGS.
100 µ
FIGS. 97, 98, 101-103A-F.
100 µ
FIG. 100A-B
103A
103B
103C
103D
103E
103F
100 µ
FIG. 99.

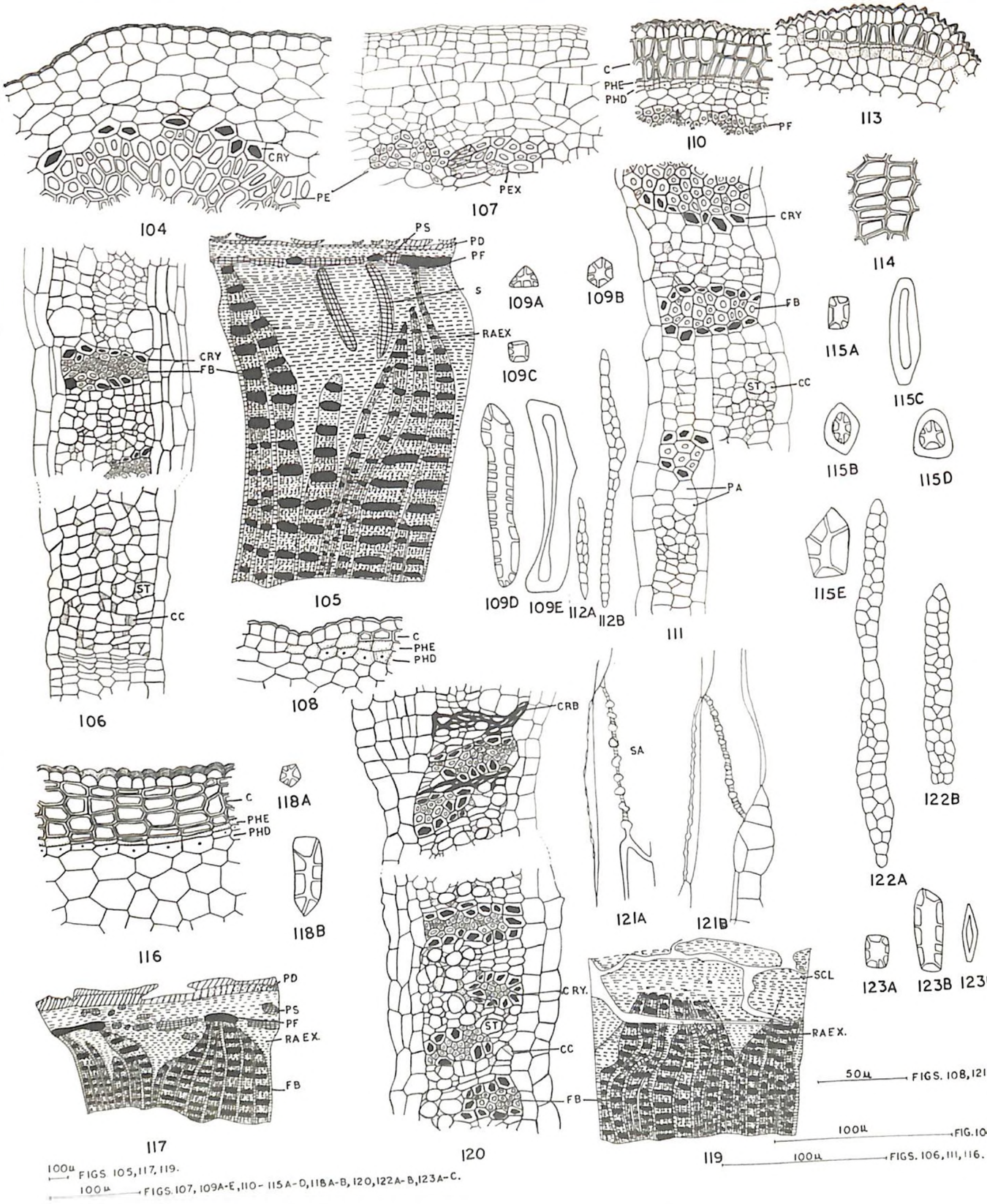
Figures 104 to 109E, *Acacia nilotica*. Fig. 104, transverse section portion young twig; fig. 105, transverse section mature bark; fig. 106, portion phloem block in transverse section; fig. 107, transverse section old branch showing cortical and pericyclic expansion; fig. 108, transverse section young twig showing initiation of phellogen; figs. 109A-E, types of sclereids.

Figures 110 to 115E, *Acacia aneura*. Fig. 110, transverse section young twig showing nature of cuticle, epidermis and initiation of phellogen; fig. 111, portion phloem block in transverse section; figs. 112A-B, biseriate rays; fig. 113, transverse section young twig showing initiation of phellogen; fig. 114, cork cells in surface view; figs. 115A-E, types of sclereids.

Figures 116 to 118B, *Acacia benthamii*. Fig. 116, transverse section of a branch showing periderm; fig. 117, transverse section mature bark; figs. 118A-B, types of sclereids.

Figures 119 to 123C, *Acacia salicina*. Fig. 119, transverse section mature bark; fig. 120, portion phloem block in transverse section; figs. 121A-B, sieve tubes with compound sieve plates in tangential longitudinal section; figs. 122A-B, multiseriate ray; figs. 123A-C, types of sclereids.

C- cork, CC- companion cells, CRB- crushed tissue bands, CRY- crystalliferous cells, FB- fiber bands, PA- parenchyma, PD- periderm, PEX- pericyclic expansion, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen, PS- pericyclic sclereids, RAEX- ray expansion tissue, S- sclereids, SA- sieve area, SCL- scale, ST- sieve tube.

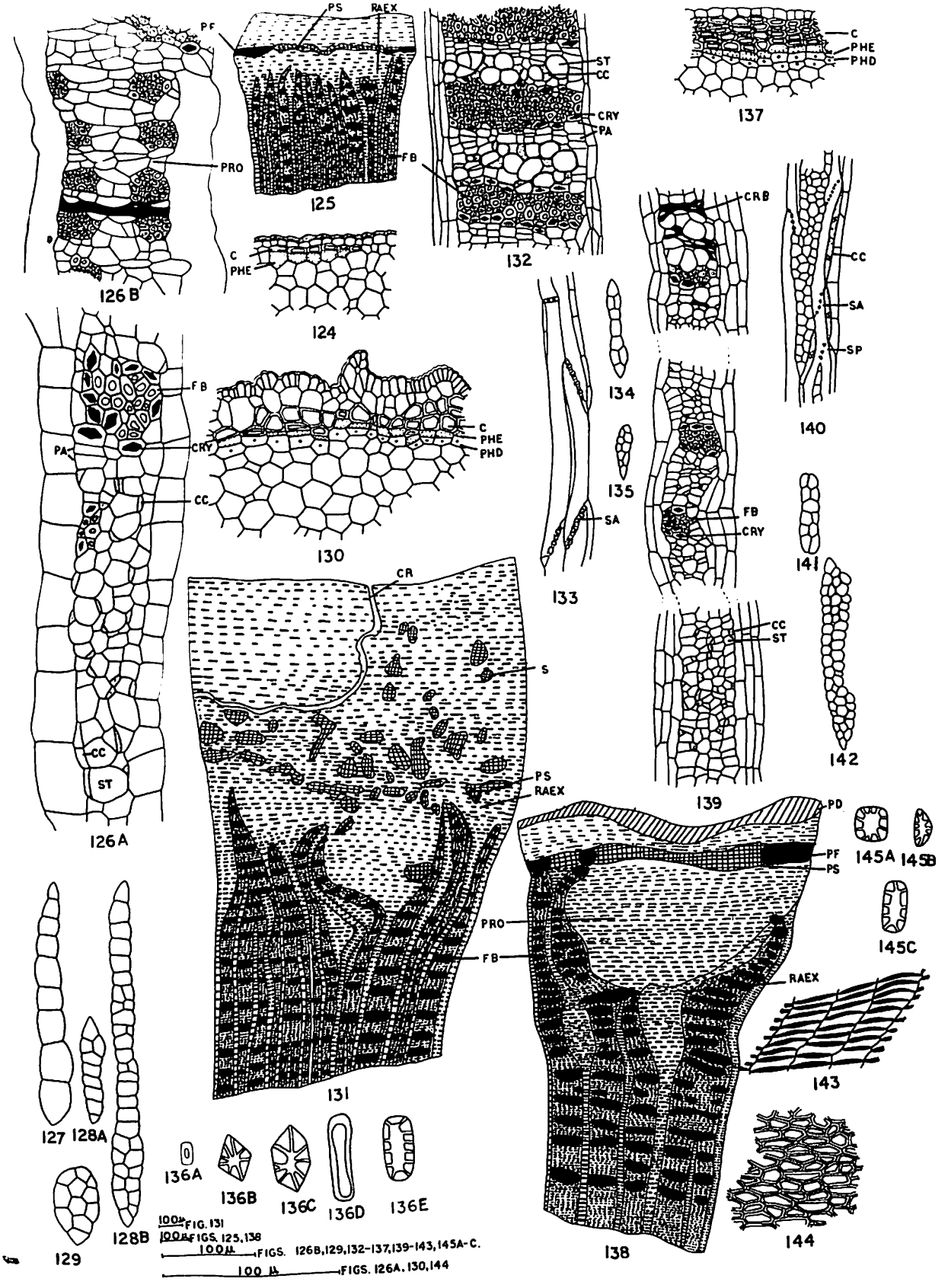

CRY
PE
104
PEX
107
C
PHE
PHD
PF
110
113
CRY
FB
ST
CC
PA
111
114
PS
PD
PF
S
RAEX
105
109A
109B
109C
109D
109E
112A
112B
115A
115B
115C
115D
115E
CRY
FB
ST
CC
106
C
PHE
PHD
108
CRB
SA
121A
121B
122A
122B
C
PHE
PHD
116
118A
118B
PD
PS
PF
RA EX.
FB
117
CRY.
ST
CC
FB
120
SCL
RAEX.
119
123A
123B
123C
50μ FIGS. 108, 121A-B
100μ FIG. 104.
100μ FIGS. 106, 111, 116.
100μ FIGS. 105, 117, 119.
100μ FIGS. 107, 109A-E, 110-115A-D, 118A-B, 120, 122A-B, 123A-C.

Figures 124 to 129, Acacia cyanophylla. Fig. 124, transverse section young twig showing epidermis, cortex and initiation of phellogen; fig. 125, transverse section mature bark; figs. 126A-B, portions phloem block in transverse section; fig. 127, uniseriate ray; figs. 128A-B, biseriate rays; fig. 129, multiseriate ray.

Figures 130 to 136E, Acacia drepanolobium. Fig. 130, transverse section young twig showing epidermis and initiation of phellogen; fig. 131, transverse section mature bark; fig. 132, portion phloem block in transverse section; fig. 133, sieve tube with compound sieve plate in tangential longitudinal section; figs. 134-135, biseriate rays; figs. 136A-E, types of sclereids.

Figures 137 to 145C, Acacia hockii. Fig. 137, portion young twig in transection showing epidermis and periderm; fig. 138, transverse section mature bark; fig. 139, phloem block in transverse section; fig. 140, sieve tubes with compound sieve plates in tangential longitudinal section; fig. 141, biseriate ray; fig. 142, multiseriate ray; fig. 143, cork in transverse section; fig. 144, cork cells in surface view; figs. 145 A-C, types of sclereids.

C- cork, CC- companion cells, CR- crack, CRB- crushed tissue bands, CRY- crystalliferous cells, FB- fiber bands, PA- parenchyma, PD- periderm, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen, PRO- phloem proliferation tissue, PS- pericyclic sclereids, RAEX- ray expansion tissue, S- sclereids, SA- sieve area, ST- sieve tube.

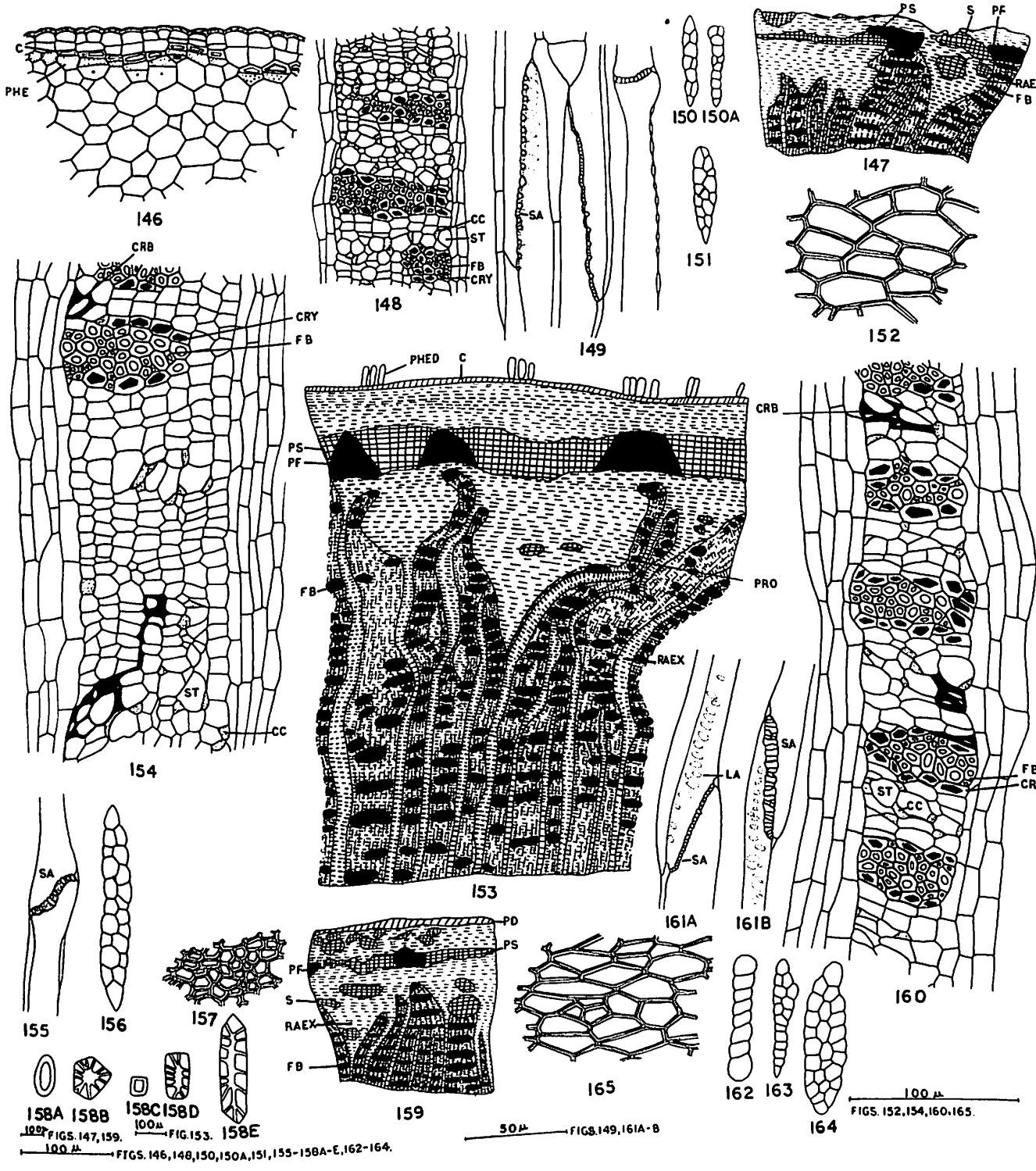

PF
PRO
126 B
PS
RAEX
125
C
PHE
124
ST
CC
CRY
PA
FB
132
C
PHE
PHD
137
CRB
CC
SA
SP
140
134
135
SA
133
FB
CRY
CC
ST
139
141
142
FB
PA
CRY
CC
ST
126 A
C
PHE
PHD
130
CR
S
PS
RAEX
131
PD
PF
PS
PRO
FB
RAEX
143
144
138
145A
145B
145C
127
128A
128B
129
136A
136B
136C
136D
136E
100μ FIG. 131
100μ FIGS. 125, 138
100μ FIGS. 126B, 129, 132–137, 139–143, 145A–C.
100μ FIGS. 126A, 130, 144

Figures 146 to 152, Acacia ligulata. Fig. 146, transverse section portion young twig showing epidermis, cuticle and phellogen initiation; fig. 147, transverse section mature bark; fig. 148, portion phloem block in transverse section; fig. 149, sieve tubes with compound sieve plate in tangential longitudinal section; figs. 150 & 150A, biseriate rays; fig. 151, multiseriate ray; fig. 152, cork cells in surface view.

Figures 153 to 158E, Acacia senegal. Fig. 153, transverse section mature bark; fig. 154, portion phloem block in transverse section; fig. 155, sieve tube with compound sieve plate in tangential longitudinal section; fig. 156, biseriate ray; fig. 157, cork cells in surface view, figs. 158A-E,

Figures 159 to 165, Acacia sieberiana. Fig. 159, transverse section mature bark; fig. 160, portion phloem block in transverse section; figs. 161A-B, sieve tubes with compound sieve plates in tangential longitudinal section; fig. 162, uniseriate ray; fig. 163, biseriate ray; fig. 164, multiseriate ray; fig. 165, cork cells in surface view.

C- cork, CC- companion cells, CRB- crushed tissue bands, CRY- crystalliferous cells, FB- fiber bands, LA- lattices, PD- periderm, PF- pericyclic fibers, PHD- phellodérm, PHE- phellogen, PHED- phelloids, PRO- phloem proliferation tissue, PS- pericyclic sclereids, RAEX- ray expansion, S- sclereids, SA- sieve area, ST- sieve tube.

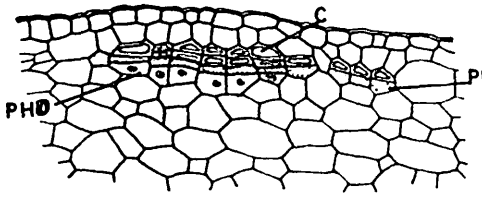

C
PHE
146
CC
ST
FB
CRY
148
SA
149
150 150A
151
PS
S
PF
RAE
FB
147
152
CRB
CRY
FB
ST
CC
154
PHED
C
PS
PF
FB
PRO
RAEX
153
CRB
FB
CR
ST
CC
160
LA
SA
161A
SA
161B
SA
155
156
157
PD
PS
PF
S
RAEX
FB
159
165
162
163
164
158A 158B
158C 158D
158E
100 µ
FIGS. 147, 159.
100 µ
FIG. 153.
100 µ
FIGS. 146, 148, 150, 150A, 151, 155-158A-E, 162-164.
50 µ
FIGS. 149, 161A-B
100 µ
FIGS. 152, 154, 160, 165.

Figures 166 to 169, Acacia spirocarpa. Fig. 166, transverse section of young twig showing epidermis, cortex and initiation of phellogen; fig. 167, transverse section mature bark; fig. 168, portion phloem block in transverse section; figs. 169A-B, sieve tubes with compound sieve plates in tangential longitudinal section.

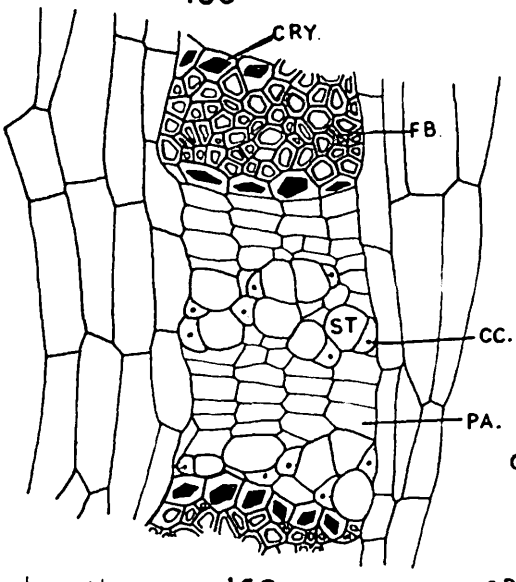
Figures 170 to 174F, Acacia victoriae. Fig. 170, transverse section mature bark; fig. 171, portion phloem block in transverse section; figs. 172A-B, sieve tubes with compound sieve plates in tangential longitudinal section; fig. 173, multiseriate ray; figs. 174A-F, types of sclereids.

Figure 175, transverse section old branch showing pericyclic and ray expansion in general.

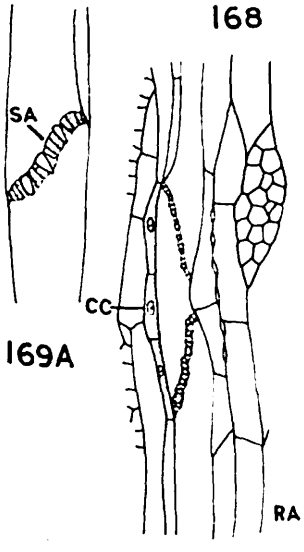
C- cork, CC- companion cells, CR- crack, CRY- crystalliferous cells, FB- fiber bands, LA- lattices, PA- parenchyma, PD- periderm, PF- pericyclic fiber, PHD- phelloderm, PHE- phellogen, PS- pericyclic sclereids, RAEX- ray expansion tissue, S- sclereids, SA- sieve area, SCL- scale, ST- sieve tube.



166

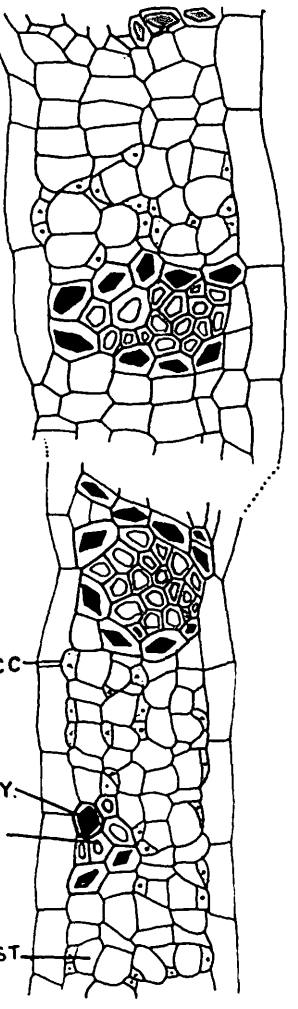


168



169A

169B



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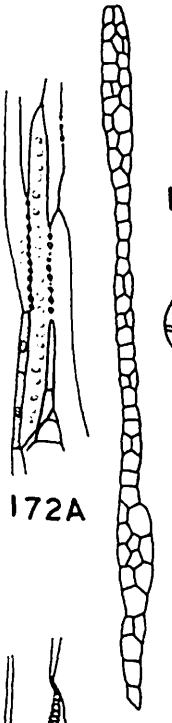
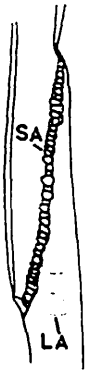


173



172B

172A

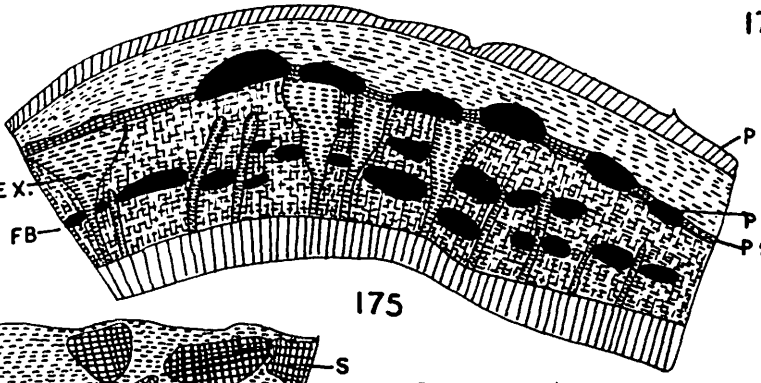
174A 174B

174C

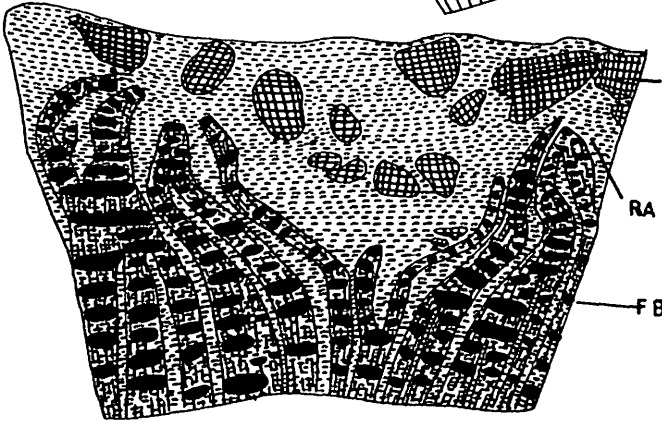
174D

174E

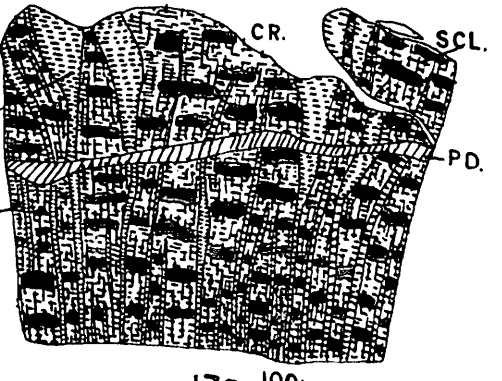
174F



175



167



170

100 μ FIGS. 166, 172A, 173, 174 A-F.

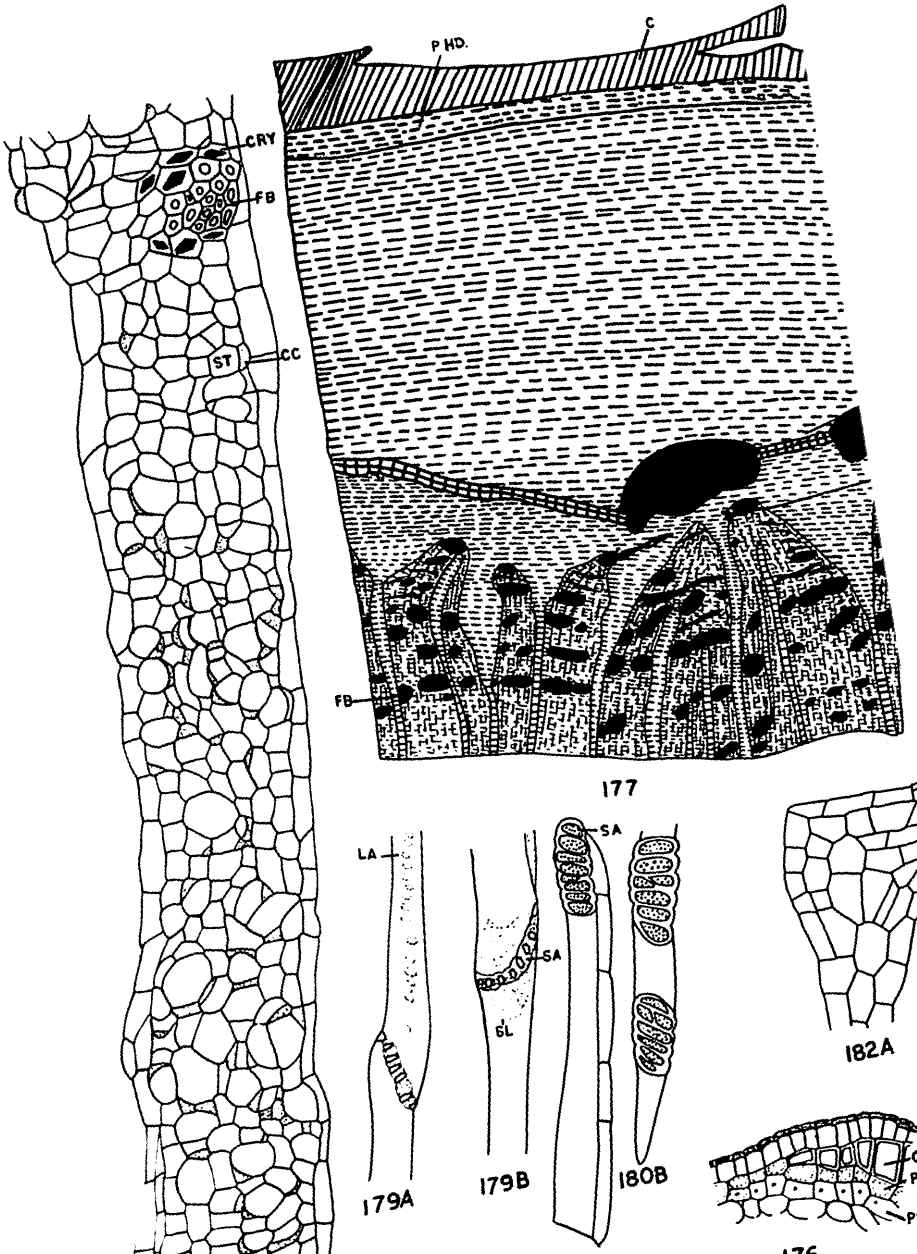
100 μ FIGS. 166, 169A-B, 171, 172B.

100 μ FIGS. 167, 170.

100 μ FIG. 175.

Figures 176 to 188I, Albizzia lebbeck. Fig. 176, transverse section young twig showing epidermis and initiation of phellogen; fig. 177, transverse section mature bark; fig. 178, portion phloem block in transverse section; figs. 179A-B, sieve tubes with compound sieve plates in tangential longitudinal section; figs. 180A-B, sieve tubes with sieve plates in radial longitudinal section; fig. 181, transverse section old branch showing cortical and pericyclic expansion; figs. 182A-C, showing different modes of ray expansion; fig. 183, transverse section young twig showing formation of cork; fig.184, cork cells in transverse section; figs. 185 to 187, stages in the formation of wound periderm; figs. 188A-I, various types of sclereids.

C- cork, CC- companion cells, CRB- crushed tissue band, CRY- crystalliferous cells, FB- fiber bands, LA- lattices, PEX- pericyclic expansion, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen, PS- pericyclic sclereids, RAEX- ray expansion tissue, SA- sieve area, SL- slime, ST- sieve tube, W- wound, WPD- wound periderm.


PHD.
C
CRY
FB
ST
CC
FB
177
LA
SA
SA
GL
179A
179B
180B
182A
C
PHE.
PHD
100μ FIGS. 177, 185-187. 180A
100 μ FIGS. 178, 180A-B 181, 182B, 183, 184, 176
188A-I.
50 μ
100μ FIG. 176.
FIGS. 179A-B, 182A &C.

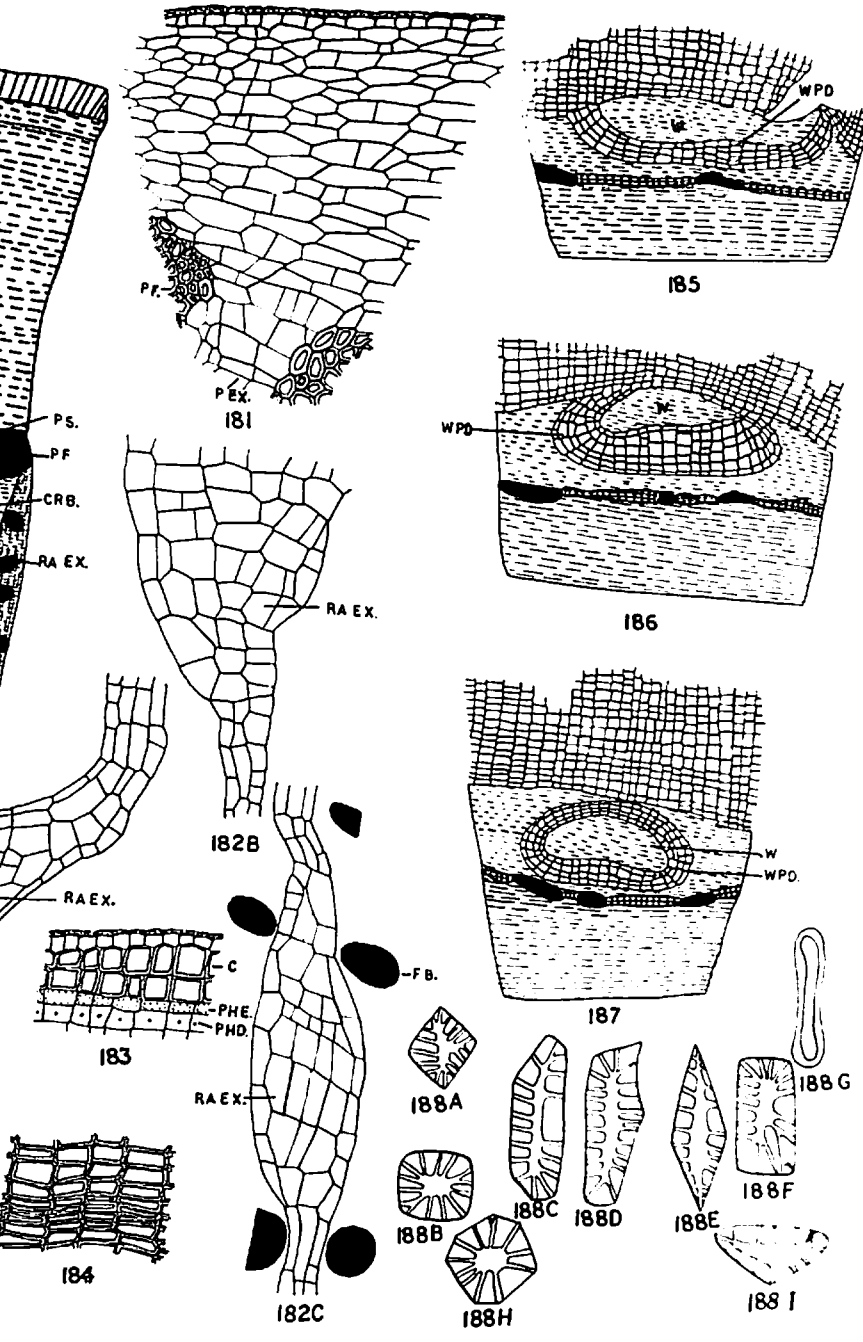

PS.
PF
CRB.
RA EX.
PF.
P EX.
181
WPD
185
WPD
186
RA EX.
182B
W
WPD.
187
RA EX.
C
PHE.
PHD.
183
F B.
RA EX.
182C
188A
188B
188C
188D
188E
188F
188G
188H
188 I
184

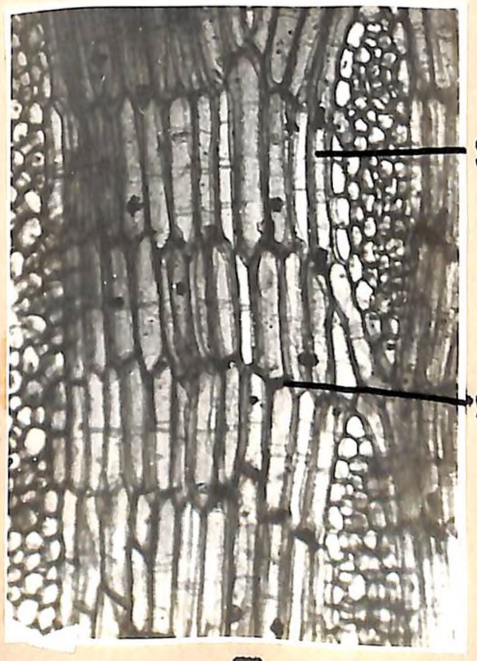
Photo.1. Bark surface *Erythrina indica*.

Photomicro.2. T.S. a portion inner bark *Erythrina indica*.

Photomicro. 3. T.L.S. secondary phloem *Erythrina indica*. CRB- crushed tissue band, FB- fiber band, SP- sieve plate, ST- sieve tube.

1

2



3

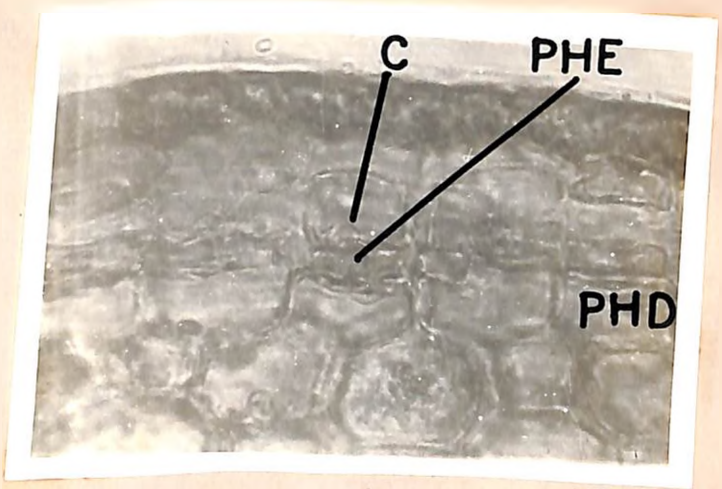
Photomicro. 4. T.L.S. secondary phloem *Erythrina indica*.

Photomicro. 5. Initiation of phellogen *Erythrina indica*

Photomicro. 6. Extent cork and phelloderm *Erythrina indica*.

C- cork, CC- companion cell, PHD- phelloderm, PHE- phellogen, SL- slime, ST- sieve tube.

4



5

6

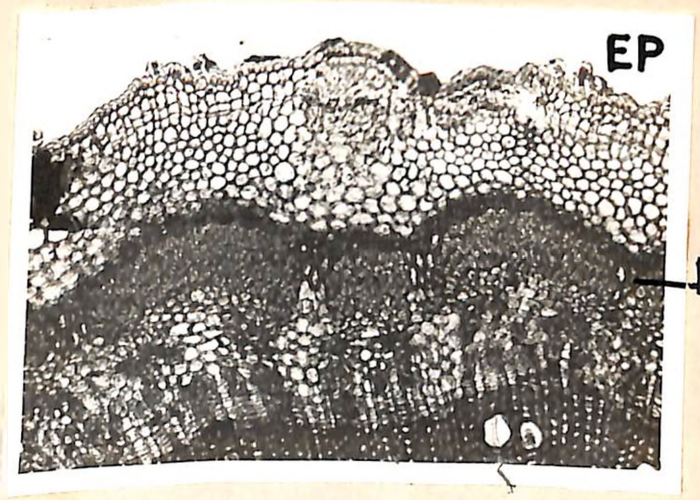
Photo. 7. Bark surface Butea frondosa.

Photomicro. 8. T.S. young twig Butea frondosa.

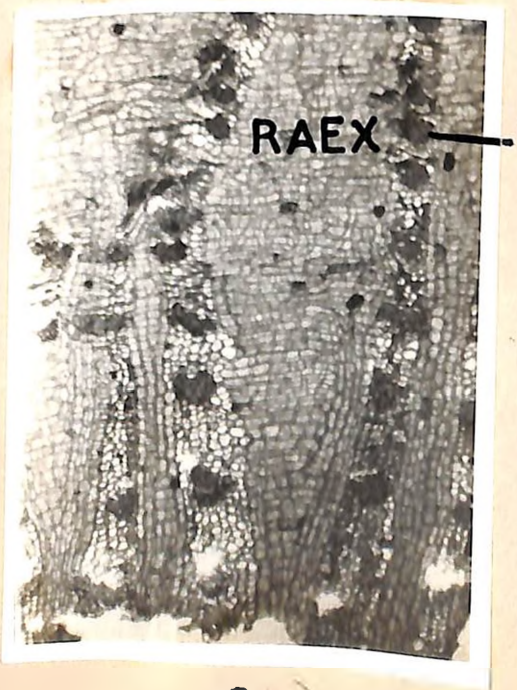
Photomicro. 9. T.S. inner bark Butea frondosa.

EP- epidermis, FB- fiber band, PF- pericyclic fibers, RAEX- ray expansion tissue.

7



8



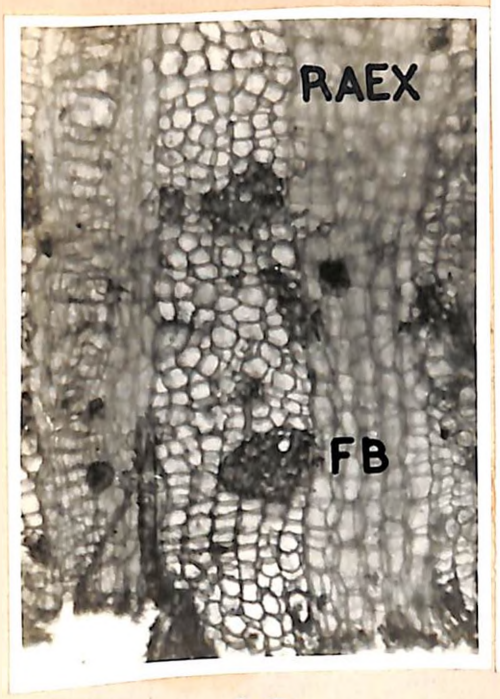
9

Photomicro. 10. T.S. phloem block Butea frondosa.

Photomicro. 11. T.L.S. secondary phloem Butea frondosa

Photomicro. 12 Initiation of phellogen Butea frondosa.

C- cork, FB- fiber band, PHD- phelloderm, PHE- phellogen, RAEX- ray expansion tissue, SL- slime, ST- sieve tube.



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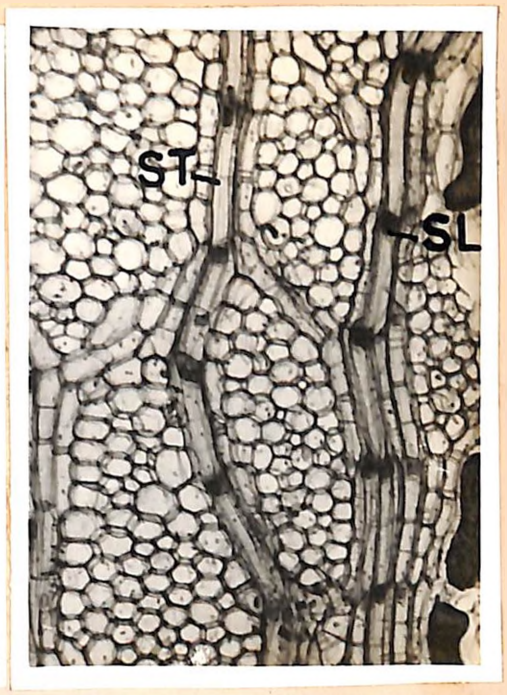
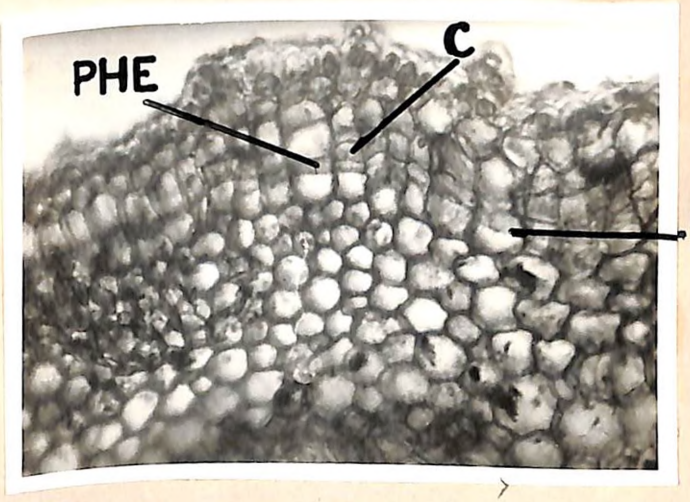


11



12

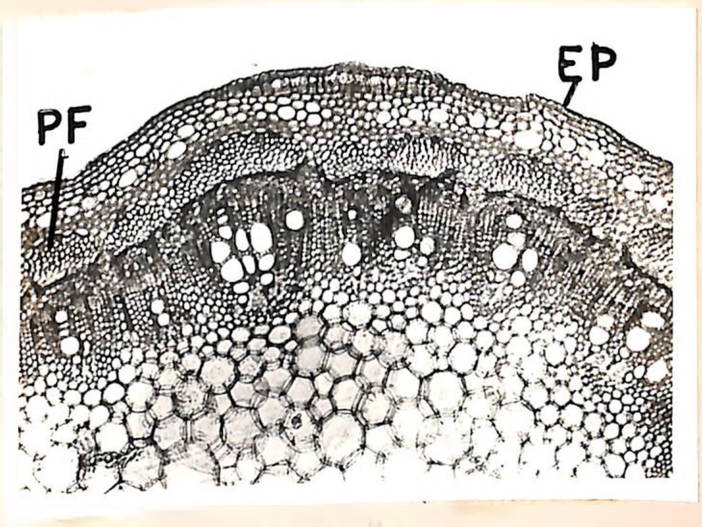
Photo. 13 Bark surface Dalbergia sisso

Photomicro. 14. T.S. young twig Dalbergia sisso

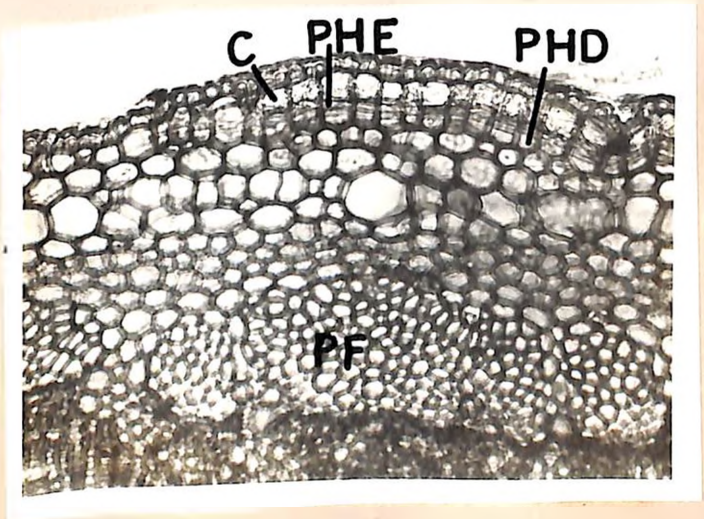
Photomicro. 15 Initiation of phellogen Dalbergia sisso.

C- cork, EP- epidermis, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen.

13



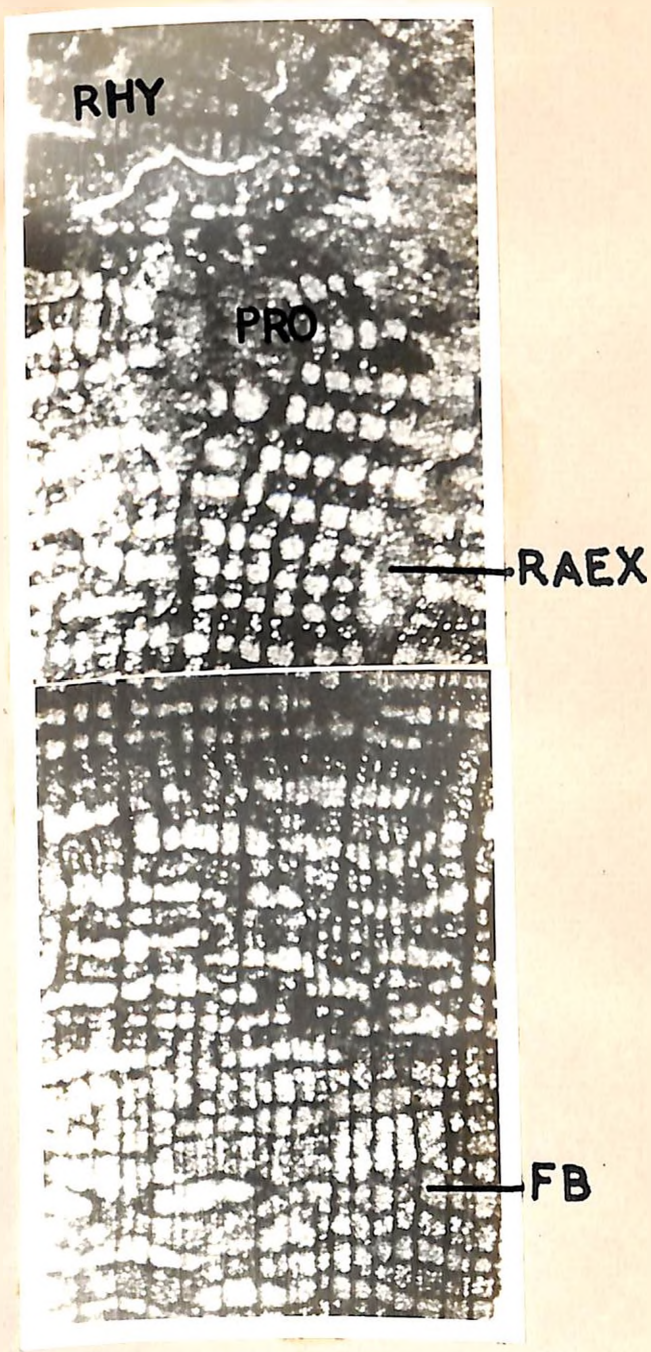
14



15

Photomicro. 16. T.S. mature bark *Dalbergia sisso*

FB- fiber band, PRO- phloem proliberation tissue, RAEX- ray expansion tissue, RHY- rhytidome.


RHY
PRO
RAEX
FB

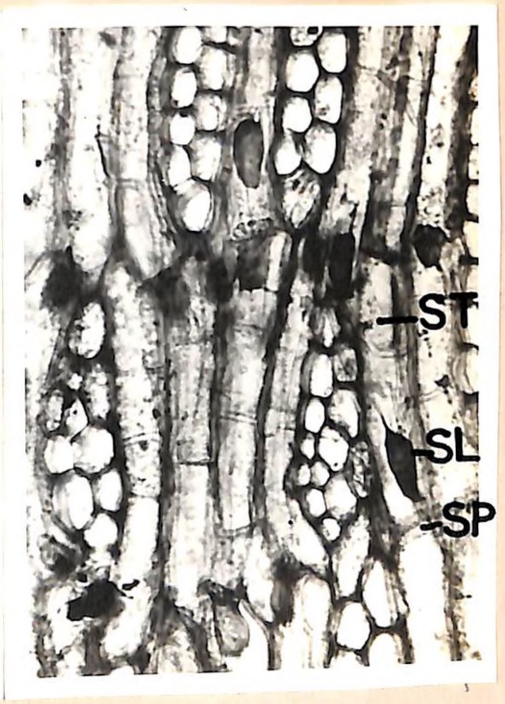
Photomicro. 17. T.S. secondary phloem *Dalbergia sisso*

Photomicro. 18 & 19. T.L.S. secondary phloem *Dalbergia sisso*.

FB- fiber band, SL- slime, SP- sieve plate, ST- sieve tube.

17

18



19

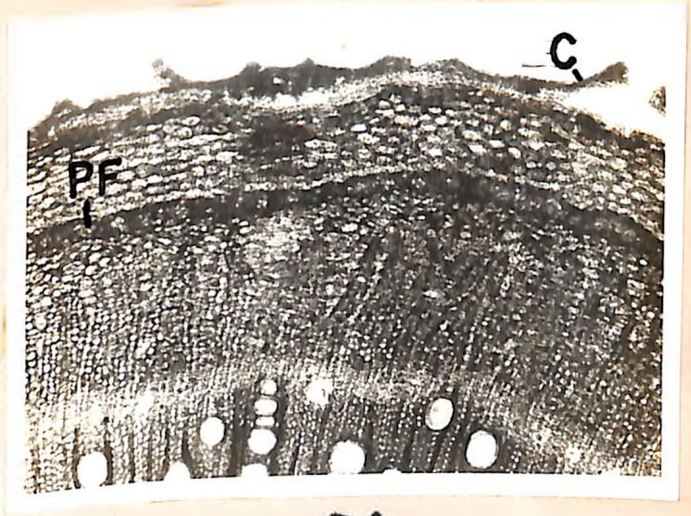
Photo. 20. Bark surface Caesalpinia pulcherrima.

Photomicro. 21. T.S. young twig Caesalpinia pulcherrima.

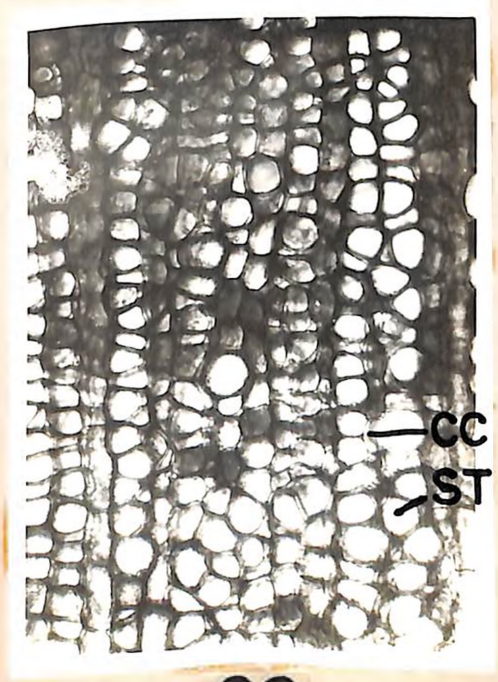
Photomicro. 22. T.S. secondary phloem Caesalpinia pulcherrima.

C- cork, CC- companion cells, PF- pericycl fibers, ST- sieve tube.

20



21

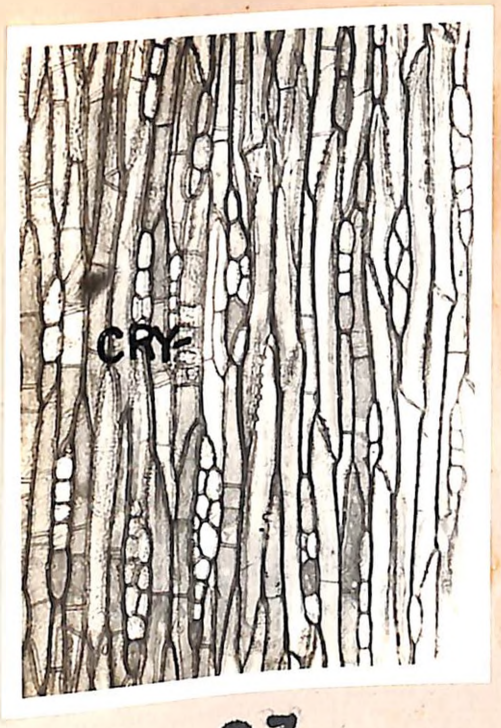


22

Photomicro. 23 & 24. T.L.S. secondary phloem Caesalpinia pulcherrima.

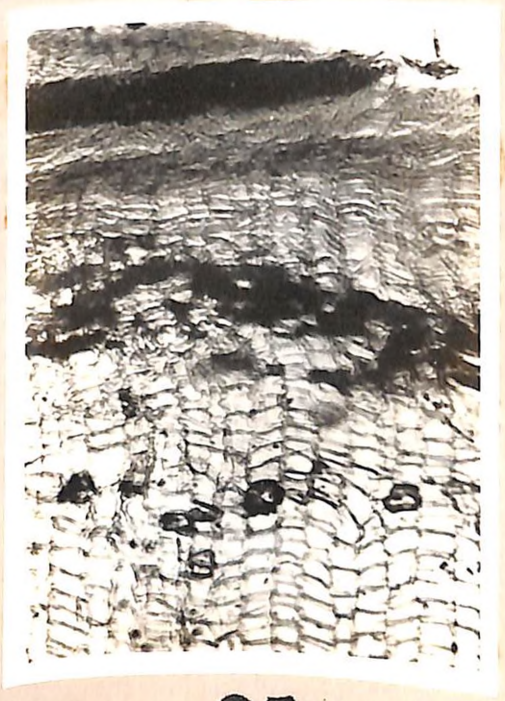
Photomicro. 25. T.S. cork Caesalpinia pulcherrima.

CRY- crystalliferus cells, SP- sieve plate, ST- sieve tube.



23

24



25

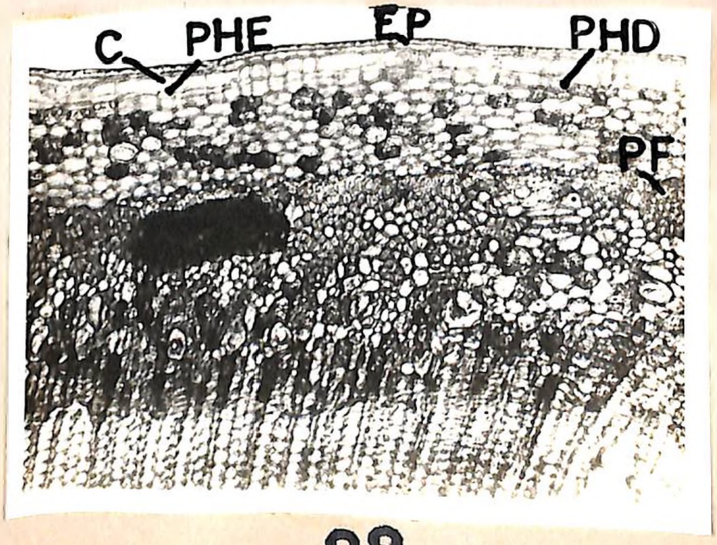
Photo. 26. Bark surface *Delonix regia*.

Photomicro. 27 & 28. T.S. young twig *Delonix regia*.

C- cork, EP- epidermis, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen.

26

27



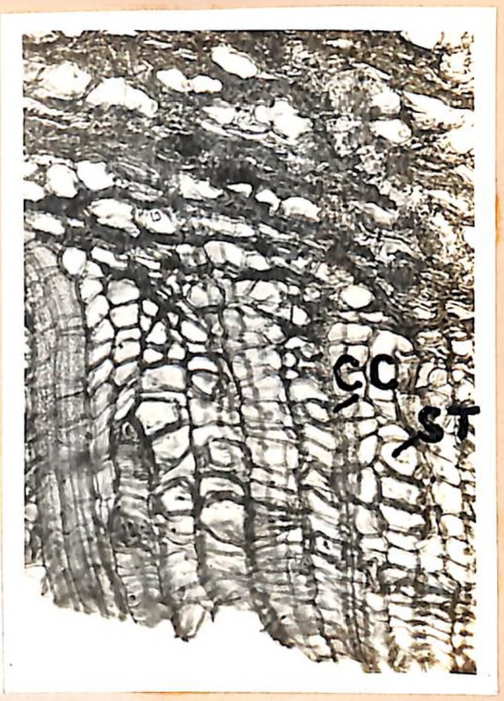
28

Photomicro. 29 & 30. T.S. inner bark *Delonix regia*.

Photomicro. 31. T.L.S, secondary phloem *Delonix regia*.

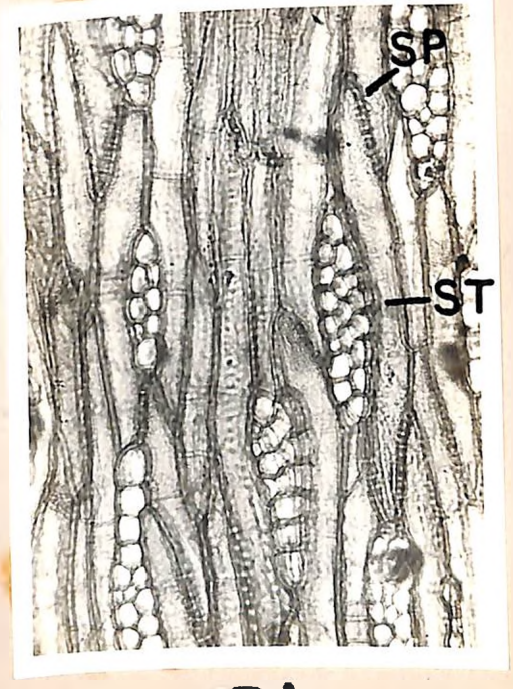
CC- companion cell, CRB- crushed tissue band, SP- sieve plate, ST- sieve tube.

29



30

CRB



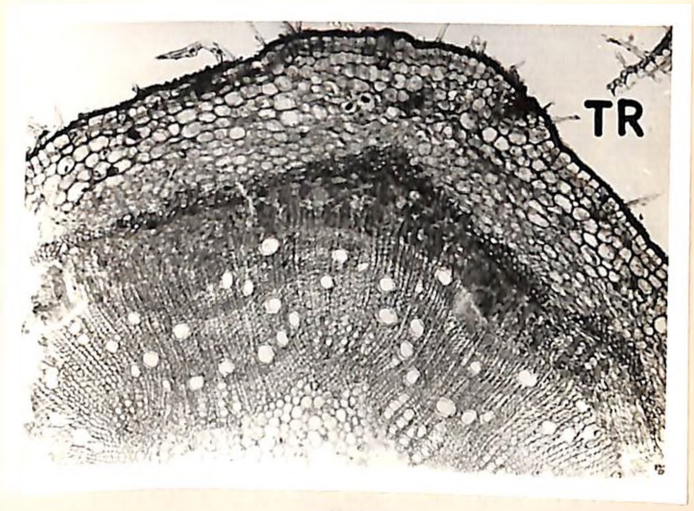
31

Photo. 32. Bark surface Cassia auriculata.

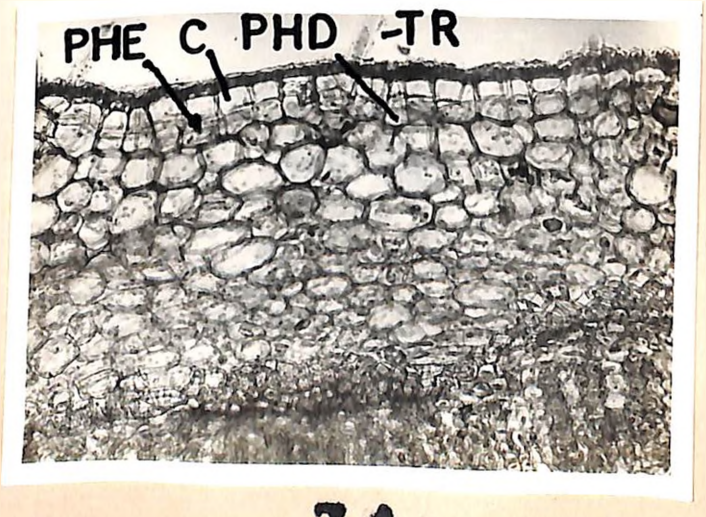
Photomicro. 33 & 34. T.S. young twig Cassia auriculata.

C- cork, PHD- phelloderm, PHE- phellogen, TR- trichome.

32



33



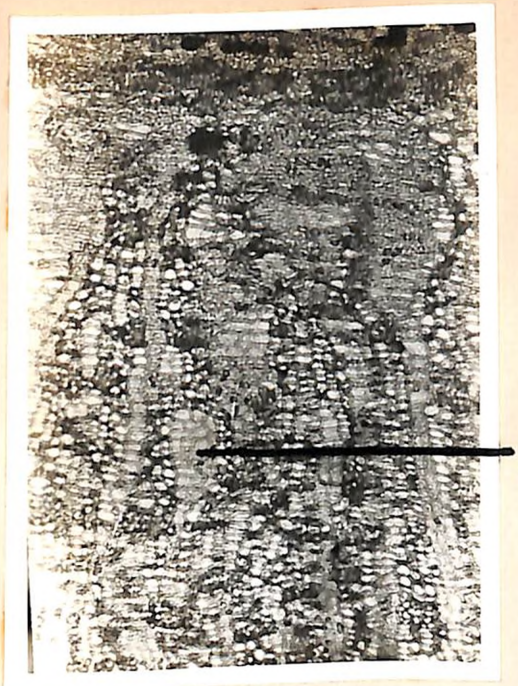
34

Photomicro. 35 & 36. T.S. inner bark Cassia auriculata.

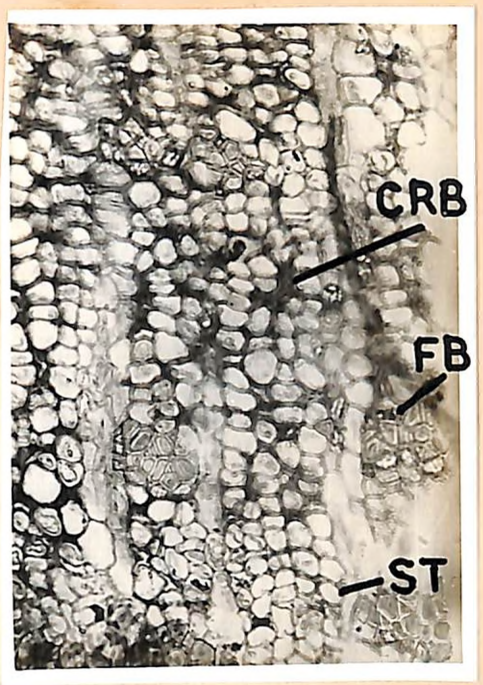
Photomicro. 37. T.L.S. secondary phloem Cassia auriculata.

Photomicro. 38. Cork layer Cassia auriculata in surface view.

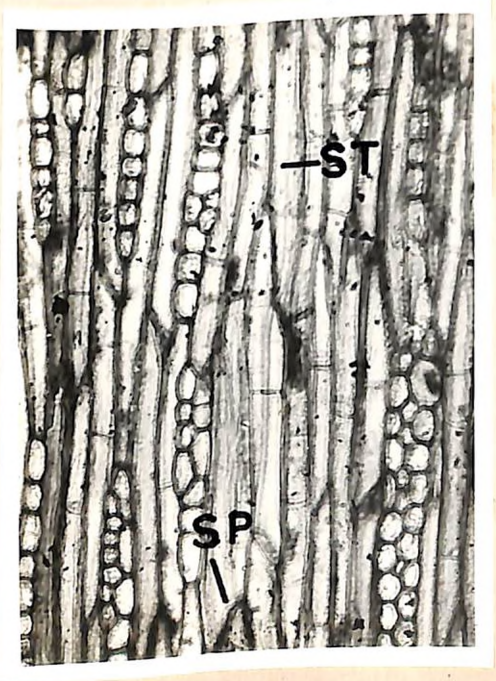
CRB- crushed tissue band, PB- fiber band, PRO- phloem proliferation tissue, SP- sieve plate, ST- sieve tube.



35



36



37

38

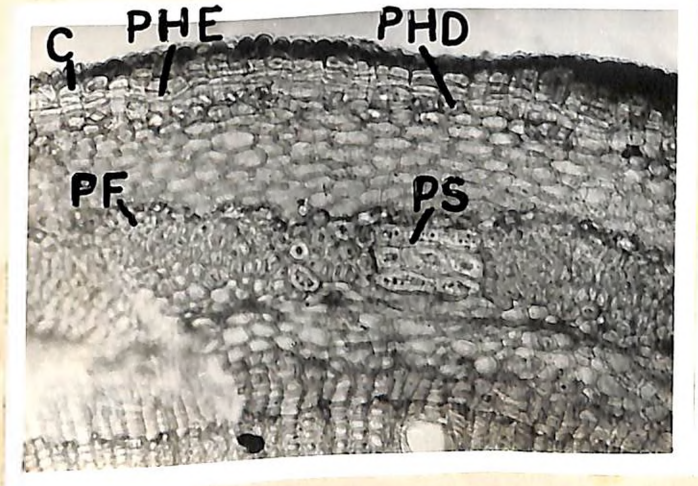
Photo. 39. Bark surface *Cassia fistula*.

Photomicro. 40. T.S. young twig *Cassia fistula*.

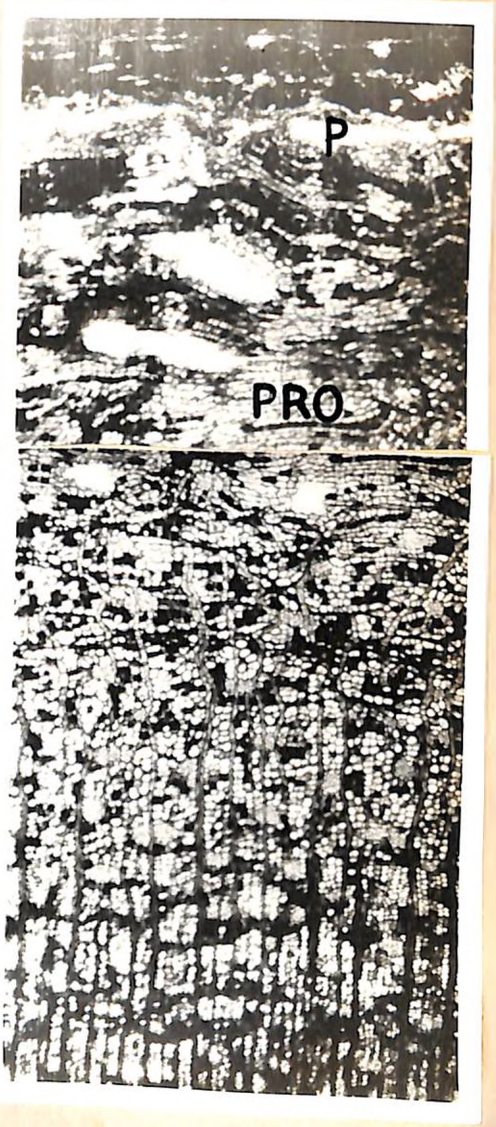
Photomicro. 41. T.S. bark *Cassia fistula*.

C- cork, P- pericycle, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen, PRO- phloem proliberation tissue, PS- pericyclic sclereids.

39



40

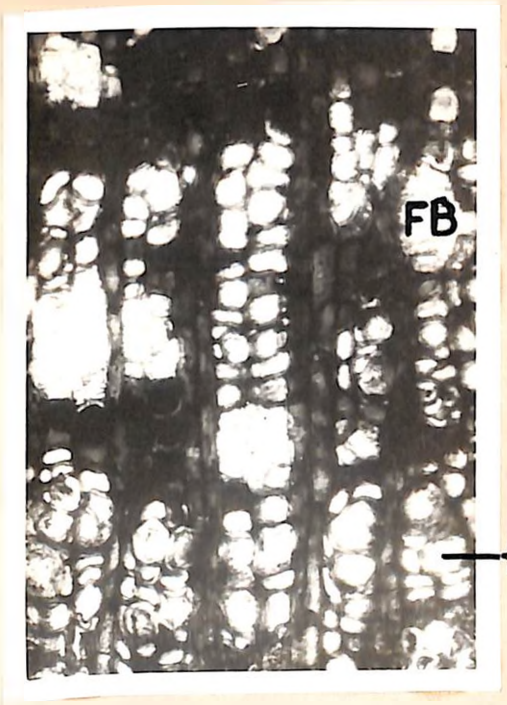


41

Photomicro. 42. T.S. portion inner bark Cassia fistula.

Photomicro. 43. T.L.S. secondary phloem Cassia fistula.

FB- fiber band, SP- sieve plate, ST- sieve tube.



42

43

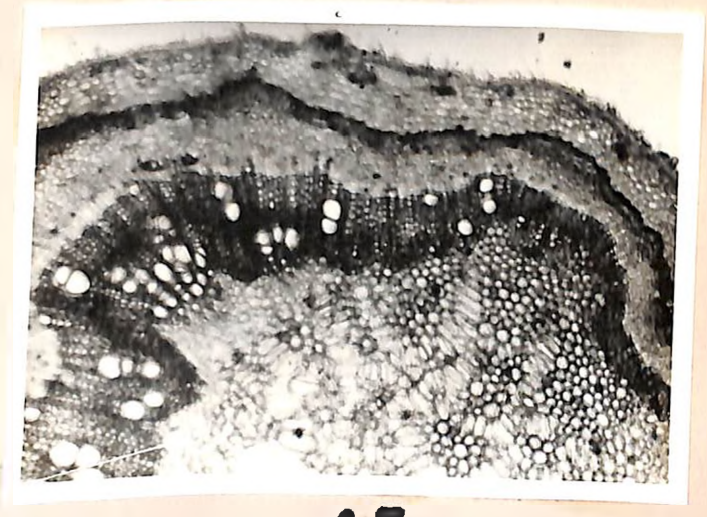
Photo. 44. Bark surface Cassia siamea.

Photomicro. 45. T.S. young twig Cassia siamea.

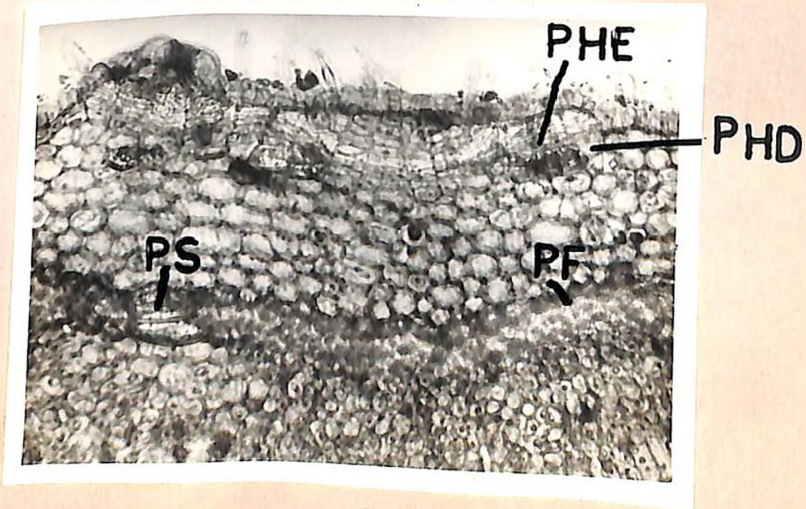
Photomicro. 46. Deeper origin of phellogen, T.S. young twig Cassia siamea.

PF- pericycli fibers, PHD- phelloderm, PHE- phellogen, PS- pericyclic sclereids.

44



45



46

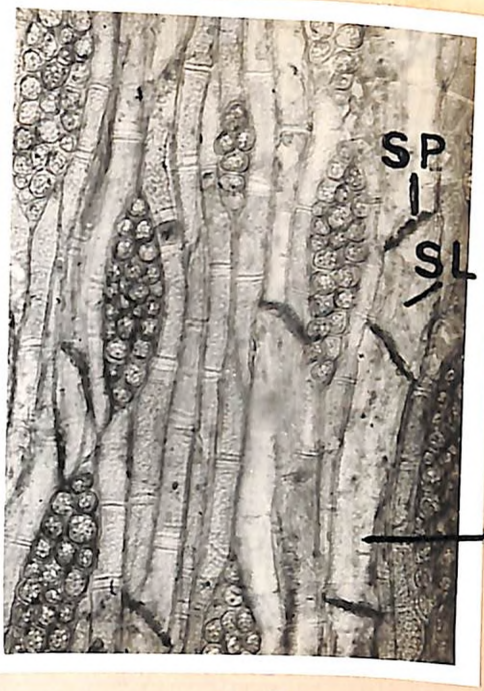
Photomicro. 47. T.S. inner bark Cassia siamea.

Photomicro. 48. T.L.S. secondary phloem Cassia siamea.

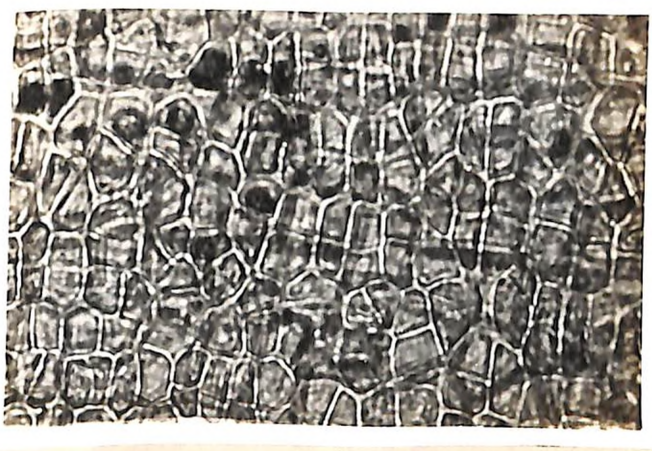
Photomicro. 49. Cork layer surface view Cassia siamea.

RAEX- ray expansion tissue, SL- slime, SP- sieve plate, ST- sieve tube.

47



48



49

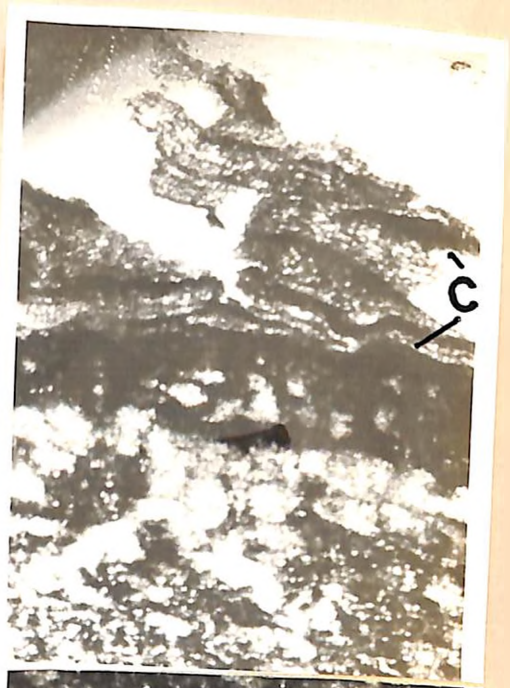
Photo. 50. Bark surface Tamarindus indica.

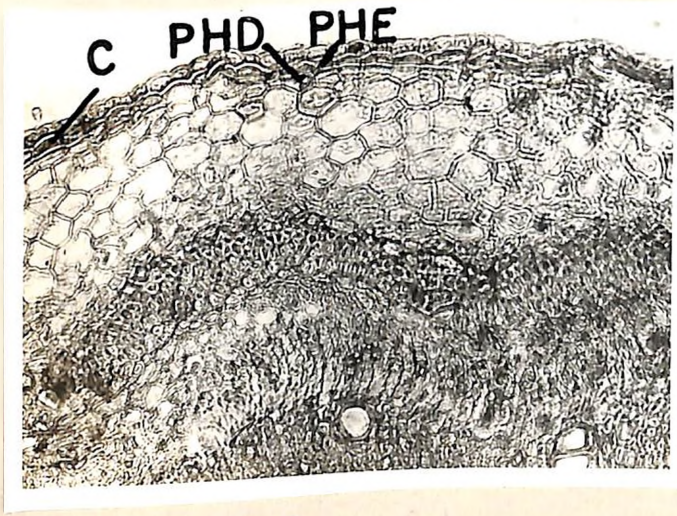
Photomicro. 51. T.S. young twig Tamarindus indica

Photomicro. 52. T.S. mature bark Tamarindus indica

C- cork, PHD- phellodam, PHE- phellogen.

50





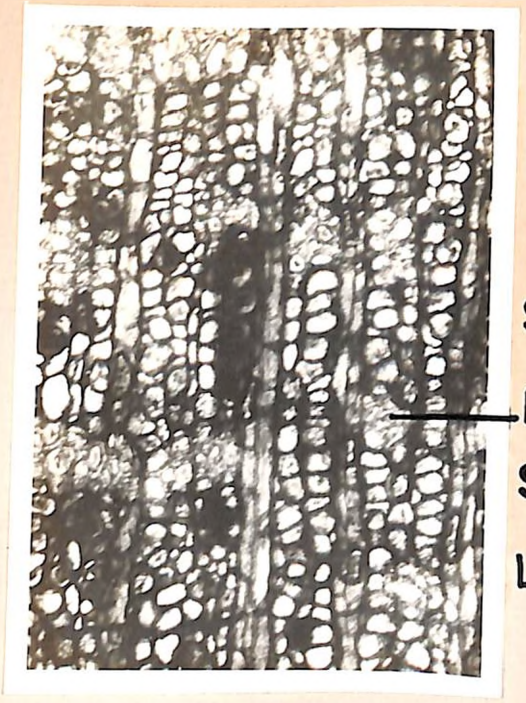
51

52

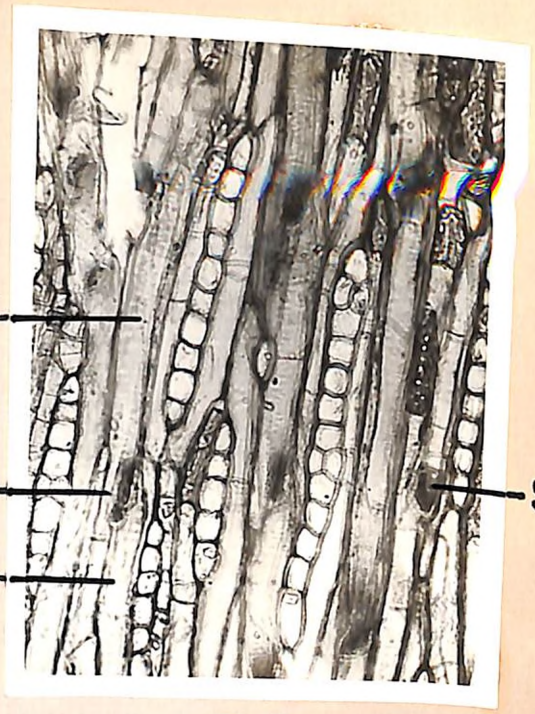
Photomicro. 53. T.S. secondary phloem Tamarindus indica.

Photomicro. 54 & 55. T.L.S. secondary phloem. Tamarindus indica.

FB- fiber band, LA- lattices, SL- slime, SP- sieve plate, ST- sieve tube.



53



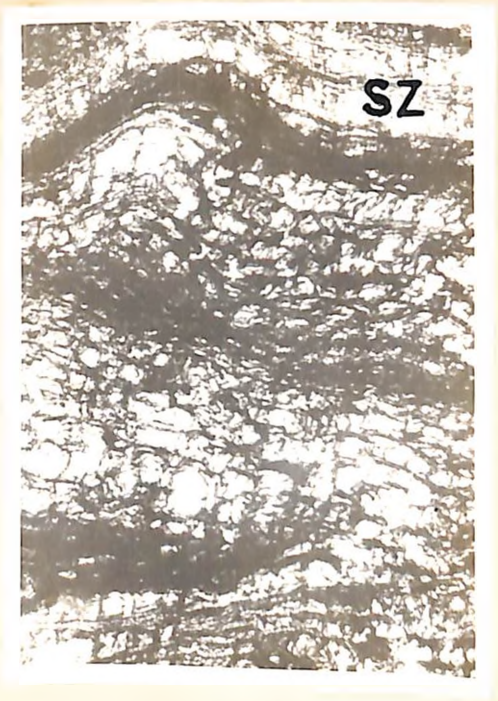
54

55

Photomicro. 56. T.S. cork Tamarindus indica.

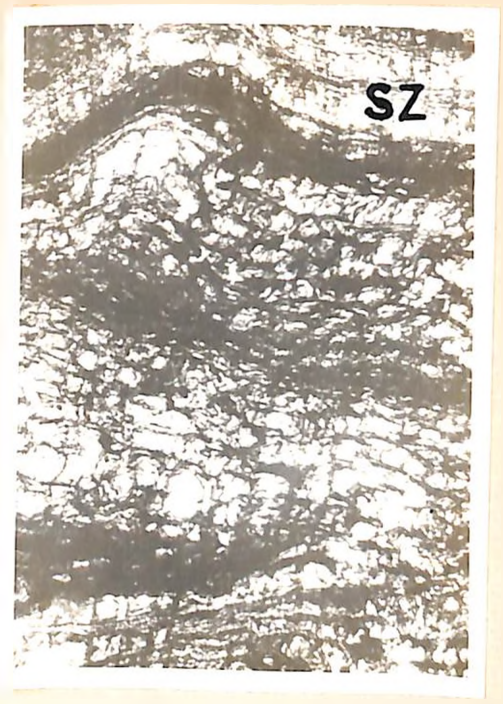
Photomicro. 57. Cork layer, Tamarindus indica in surface view.

C- cork, SZ- sclereid zone.

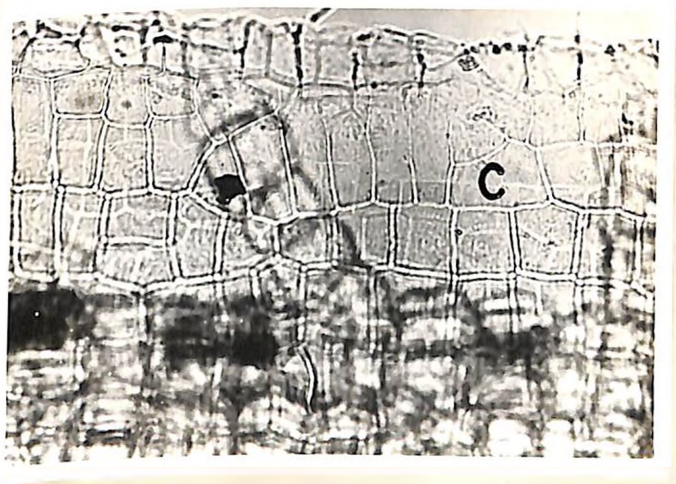


56

57



56



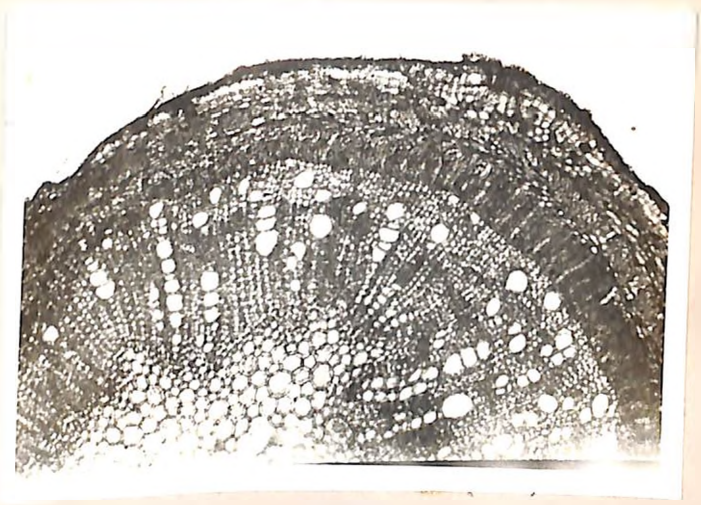
57

Photo. 58. Bark surface Bauhinia variegata.

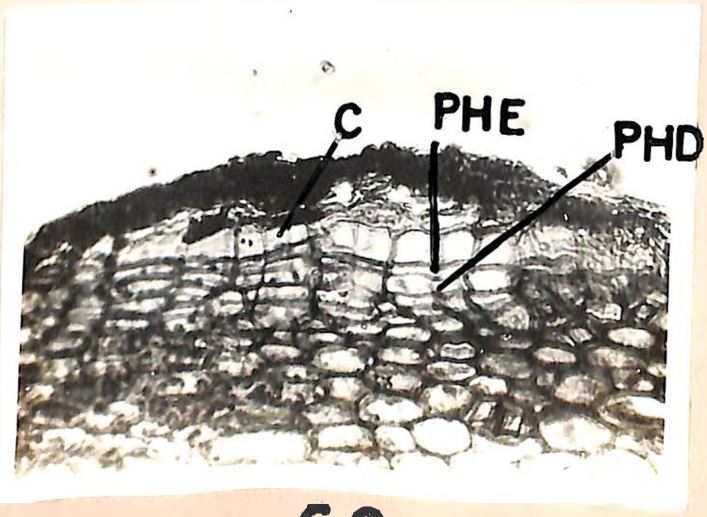
Phomicro. 59 & 60. T.S. young twig Bauhinia variegata.

C- cork, PHD- phelloderm, PHE- phellogen.

58



59



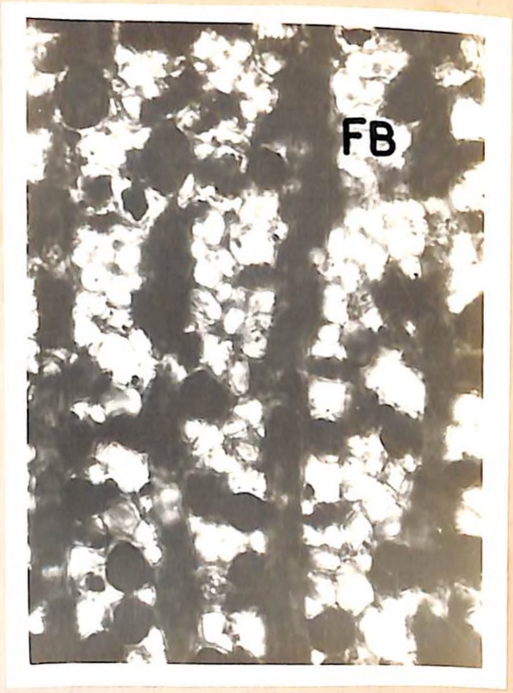
60

Photomicro. 61. T.S. bark Bauhinia variegata.

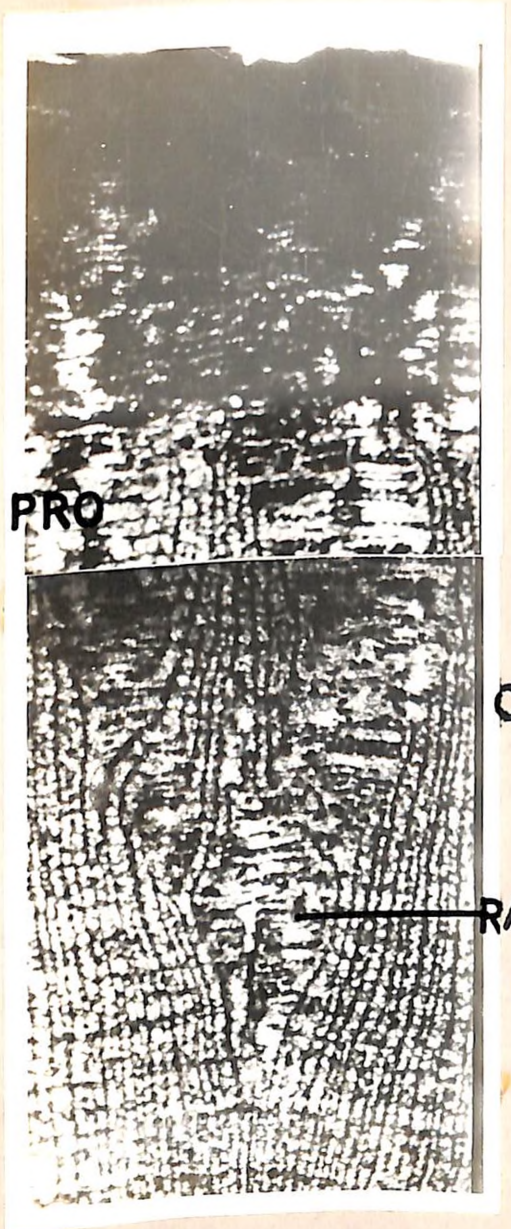
Photomicro. 62. T.S. portion inner bark Bauhinia variegata.

Photomicro. 63. T.L.S. secondary phloem, Bauhinia variegata.

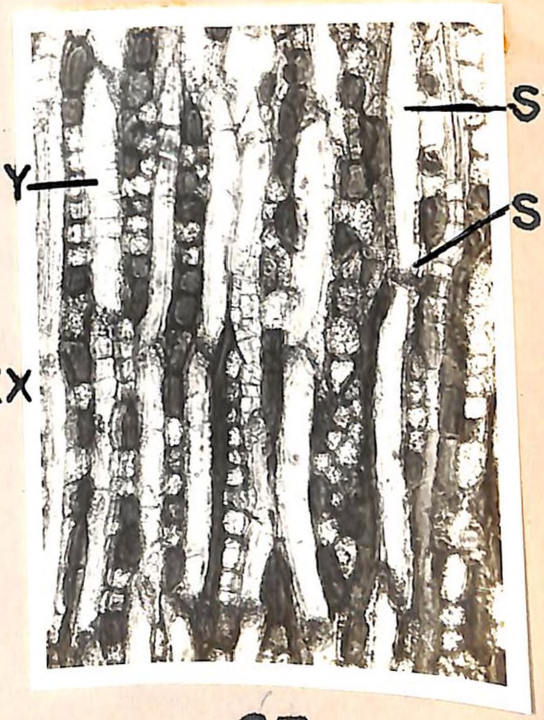
CRY- crystalliferous cells, FB- fiber band, PRO- phloem proliferation tissue, RAEX- ray expansion tissue, SP- sieve plate, ST- sieve tube.



62



61



63

Photo. 64. Bark surface Prosopis spicigera.

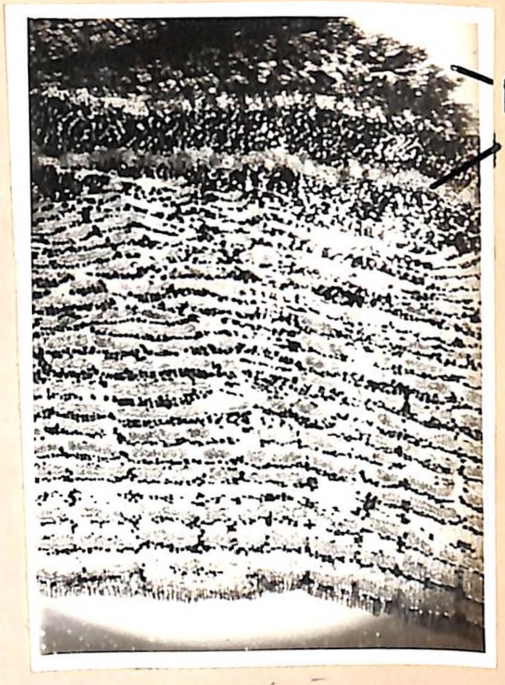
Photomicro. 65. T.S. bark Prosopis spicigera.

Photomicro. 66. T.S. inner bark Prosopis spicigera.

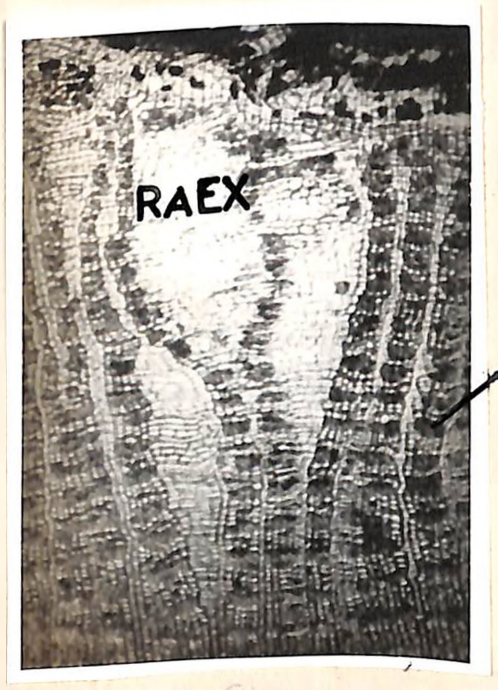
Photomicro. 67. T.S. secondary phloem Prosopis spicigera.

FB- fiber band, PD- periderm, RAEX- ray expansion tissue.

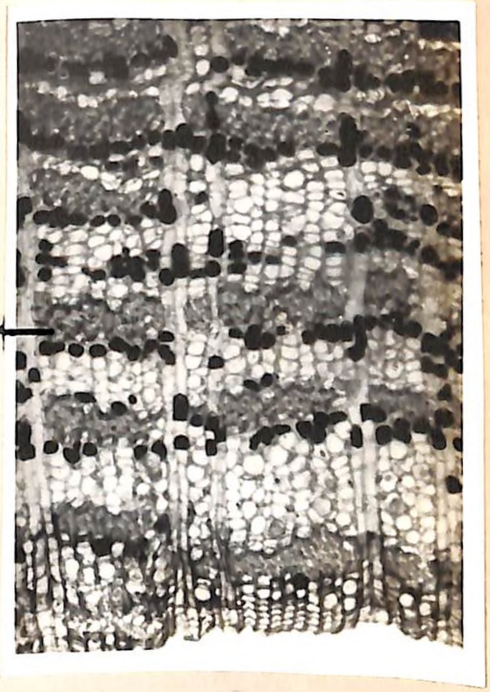
64



65



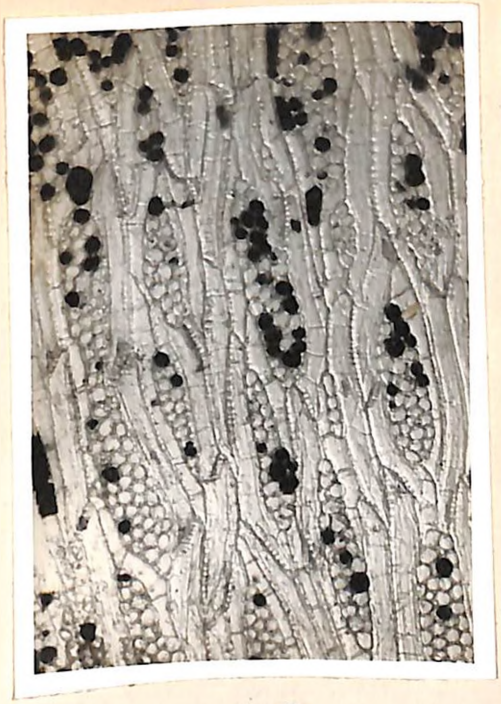
66



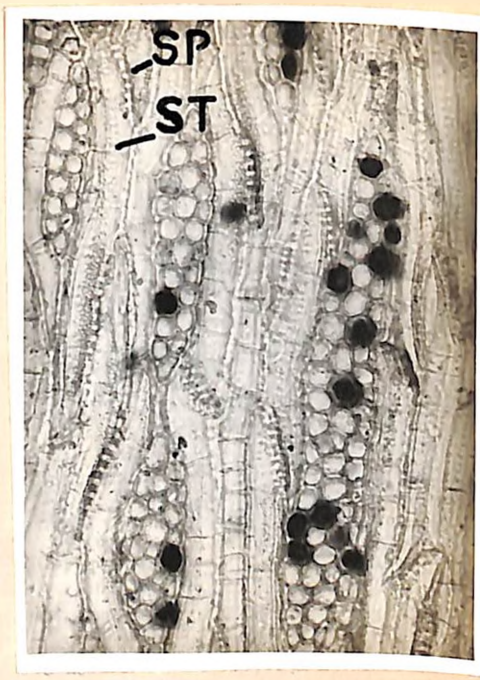
67

Photomicro. 68-70. T.L.S. secondary phloem *Prosopis spicigera*.

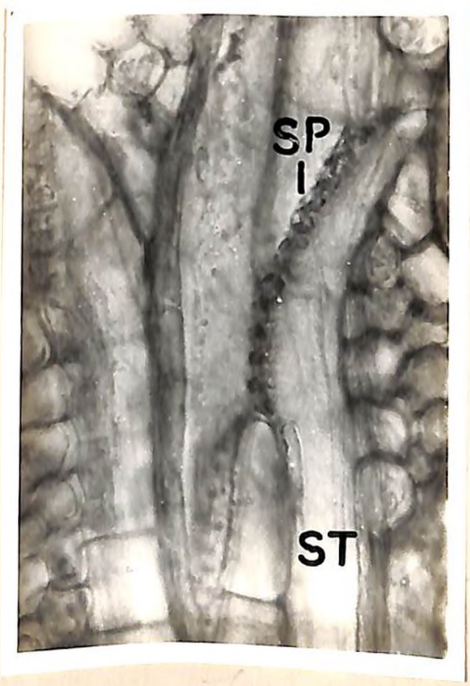
SP- sieve plate, ST- sieve tube.



68



69

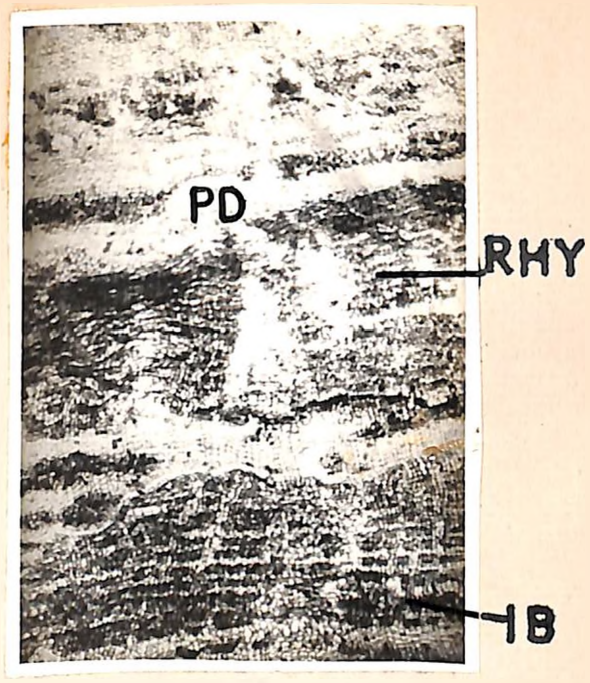


70

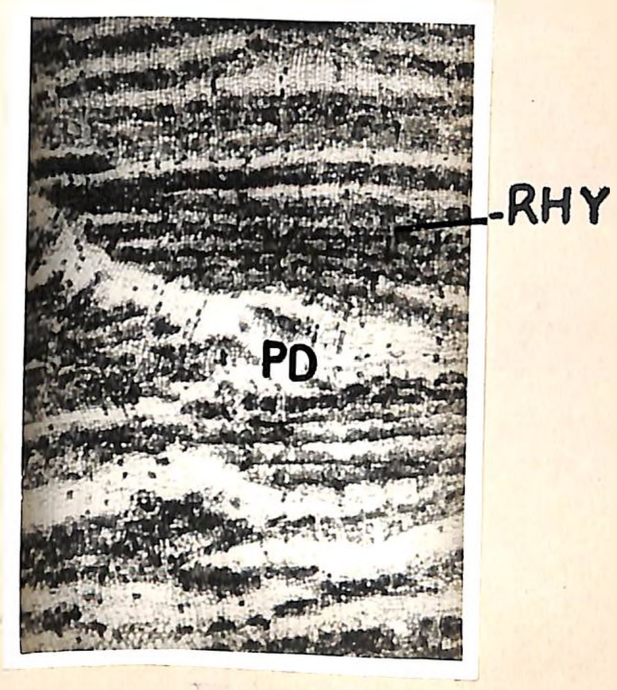
Photomicro. 71 - 72. T.S. outer bark Prosopis spicigera.

IB- inner bark, PD- periderm,

RHY- rhytidome,



71



72

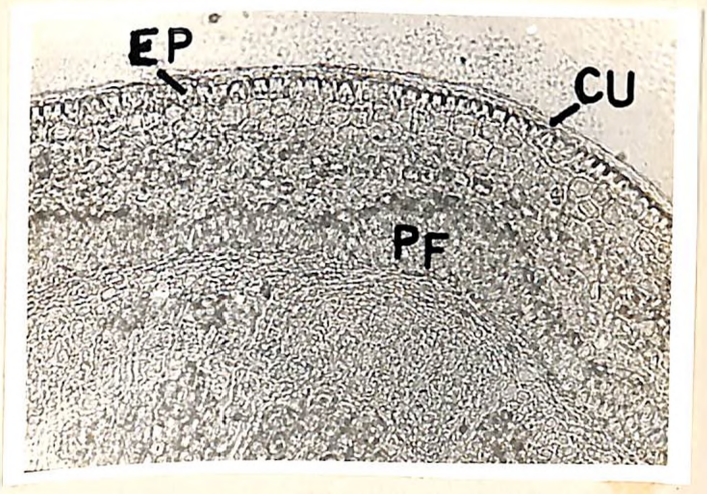
Photo. 73. Bark surface Prosopis juliflora.

Photomicro. 74. T.S. young twig Prosopis juliflora.

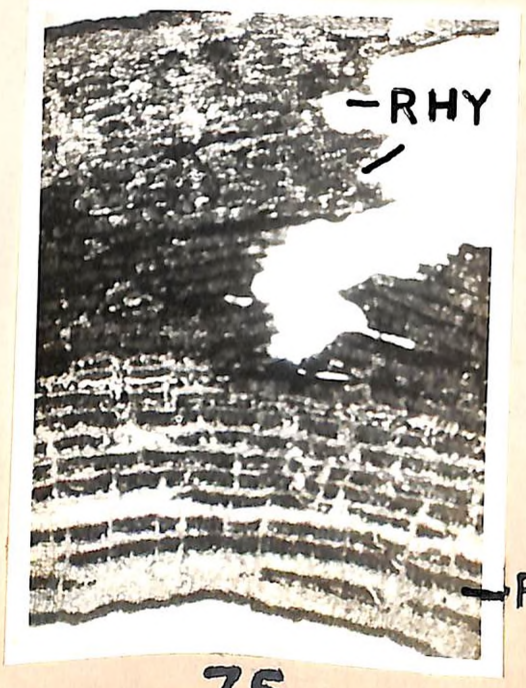
Photomicro. 75. T.S. bark Prosopis juliflora.

CU- cuticle, EP- epidermis, FB- fiber band, PF- pricyclic fibers, RHY- rhytidome.

73



74



75

Photomicro. 76. T.S. portion secondary phloem Prosopis juliflora.

Photomicro. 77. R.L.S. secondary phloem Prosopis juliflora.

Photomicro. 78 - 79. T.L.S. secondary phloem Prosopis juliflora.

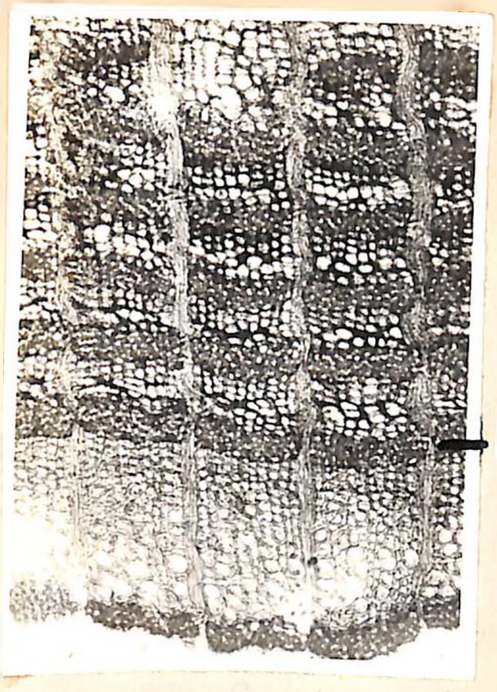
FB- fiber band, SP- sieve plate,
ST- sieve tube.

Photomicro. 76. T.S. portion secondary phloem *Prosopis juliflora*.

Photomicro. 77. R.L.S. secondary phloem *Prosopis juliflora*.

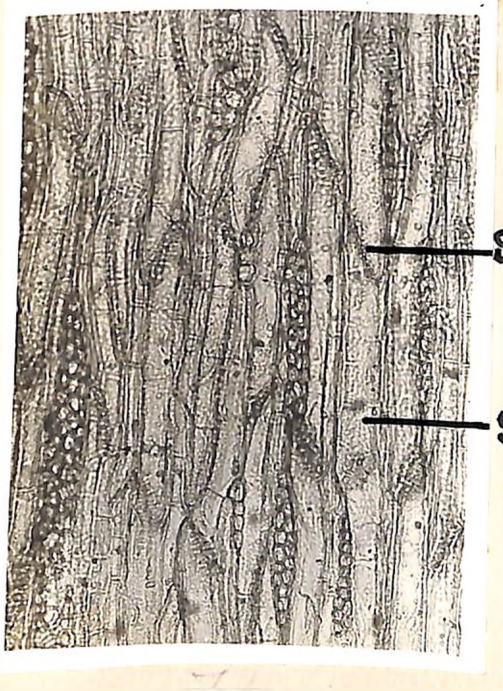
Photomicro. 78 - 79. T.L.S. secondary phloem *Prosopis juliflora*.

FB- fiber band, SP- sieve plate,
ST- sieve tube.

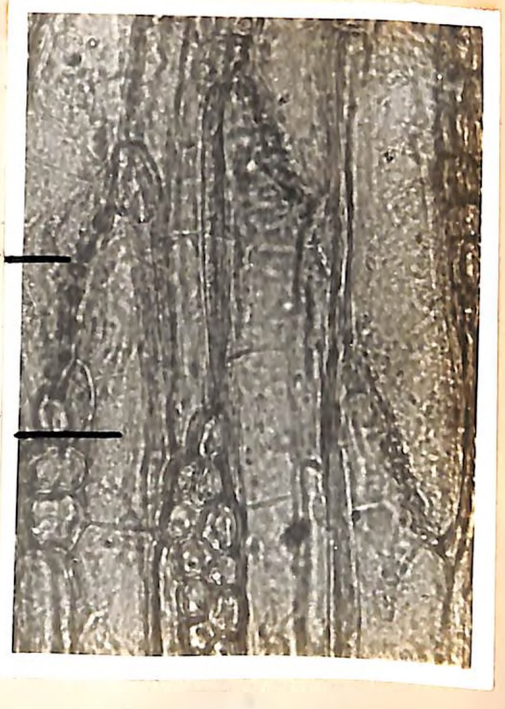


76

77



78



79

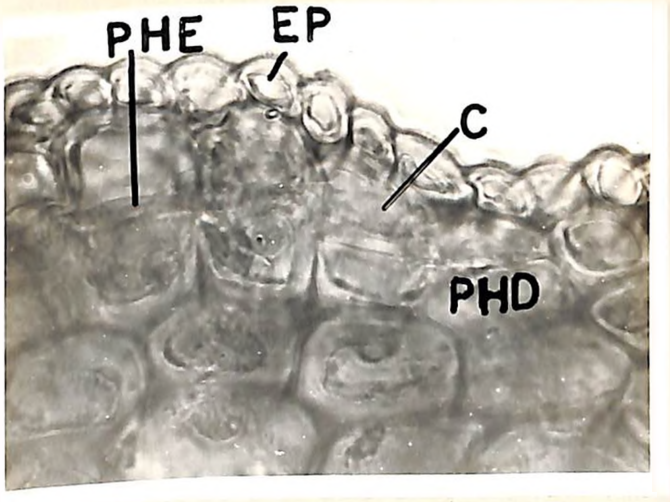
Photo. 80. Bark surface *Acacia nilotica*.

Photomicro. 81. Initiation of Phellogen *Acacia nilotica*.

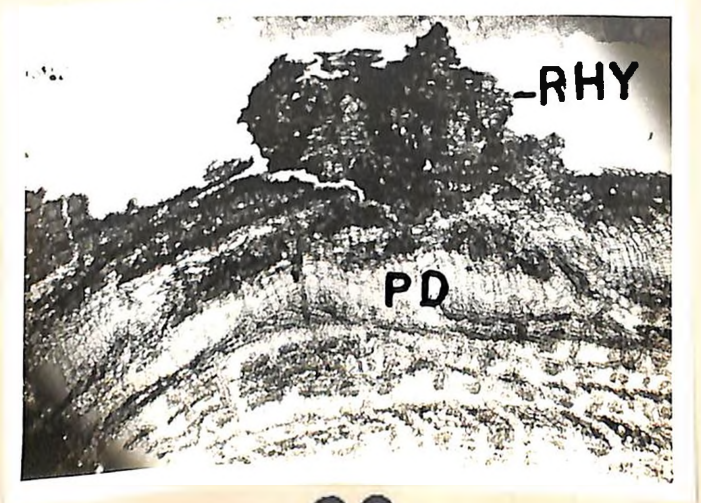
Photomicro. 82. T.S. bark *Acacia nilotica*.

C- cork, EP- epidermis, IB- inner bark, PD- periderm, PHD- phelloderm, PHE- phellogen, RHY- rhytidome.

80



81



82

Photomicro- 83. T.S. inner bark *Acacia nilotica*.

Photomicro. 84. T.S. secondary phloem *Acacia nilotica*.

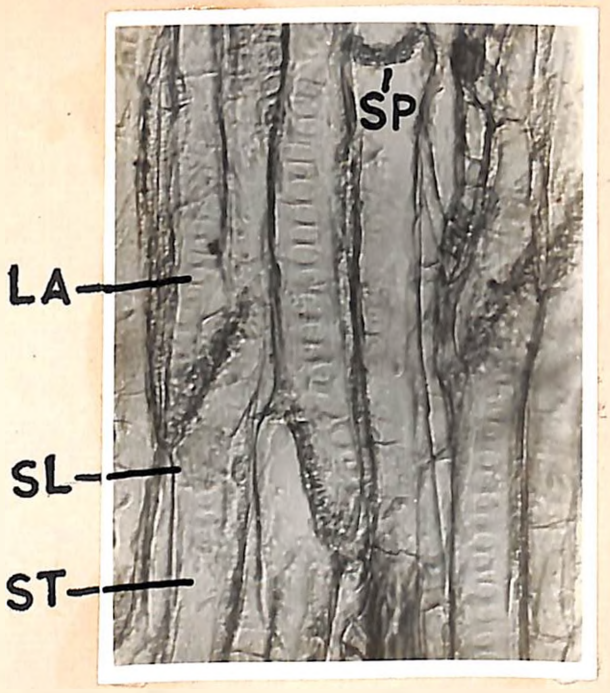
CC- companion cell, FB- fiber band,
RAEX- ray expansion tissue, S- sclereids,
ST- sieve tube.

83

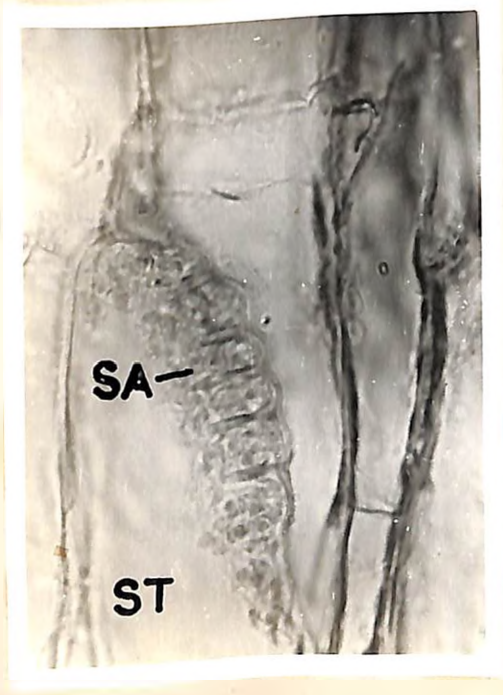
84

Photomicro. 85 - 87. T.L.S. secondary phloem *Acacia nilotica*.

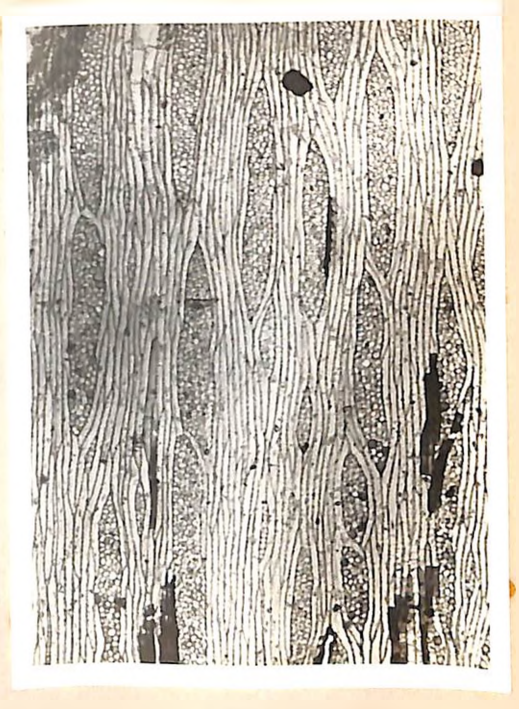
LA- lattices, SA- sieve area, SL- slime, SP- sieve plate, ST- sieve tube.



85



86

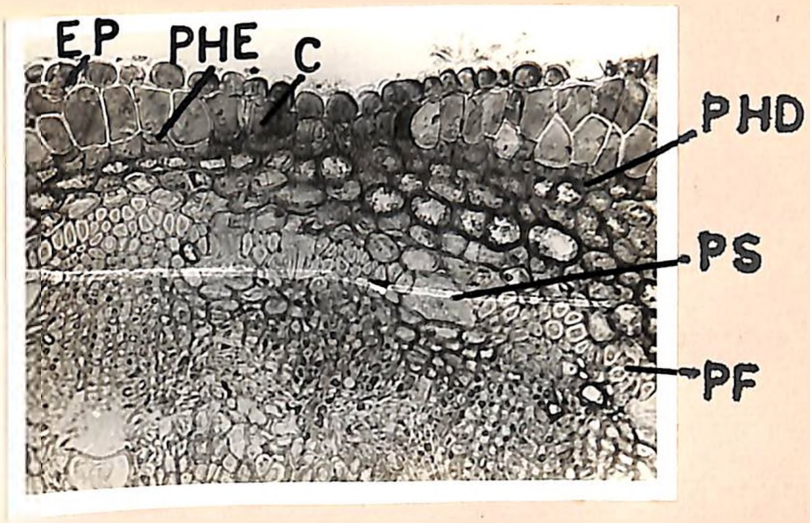


87

Photomicro. 88. T.S. young twig *Acacia aneura*.

Photomicro. 89. T.S. mature bark *Acacia aneura*.

C- cork, EP- epidermis, IB- inner bark, PD- periderm, PF- pericyclic fibers, PHD- phelloderm, PHE- phellogen, PS- pericyclic sclereids, RHY- rhytidome.



88

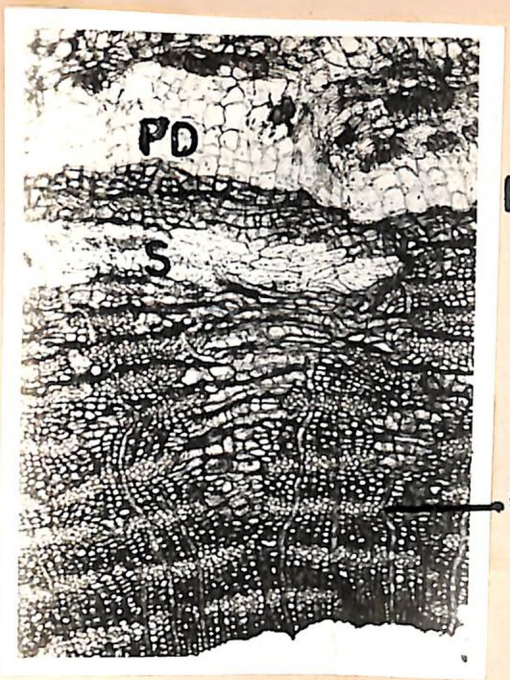
89

Photomicro. 90. T.S. bark *Acacia aneura*.

Photomicro. 91. T.S. portion inner bark *Acacia aneura*.

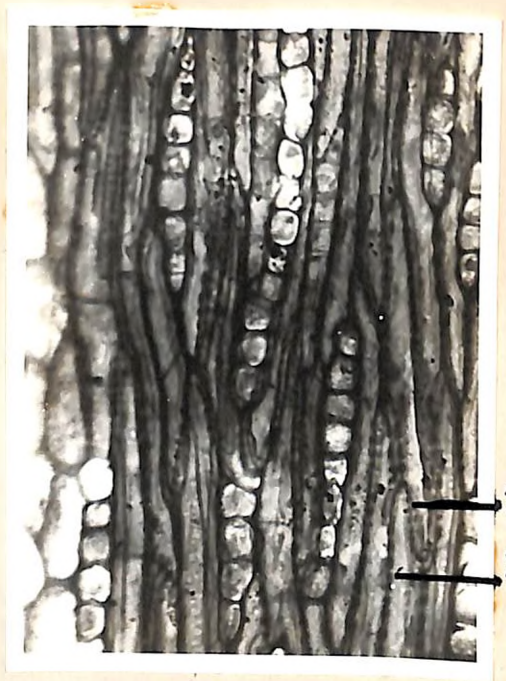
Photomicro. 92. T.L.S. secondary phloem *Acacia aneura*.

FB- fiber band, PD- periderm, PRO- phloem proliferation tissue, S- sclereids, SP- sieve plate, ST- sieve tube.



90

91



92

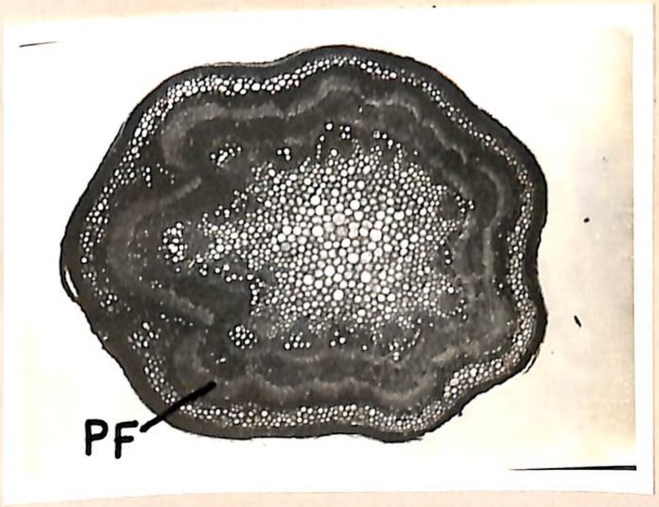
Photo. 93. Bark surface *Acacia benthamii*

Photomicro. 94. T.S. young twig *Acacia benthamii*

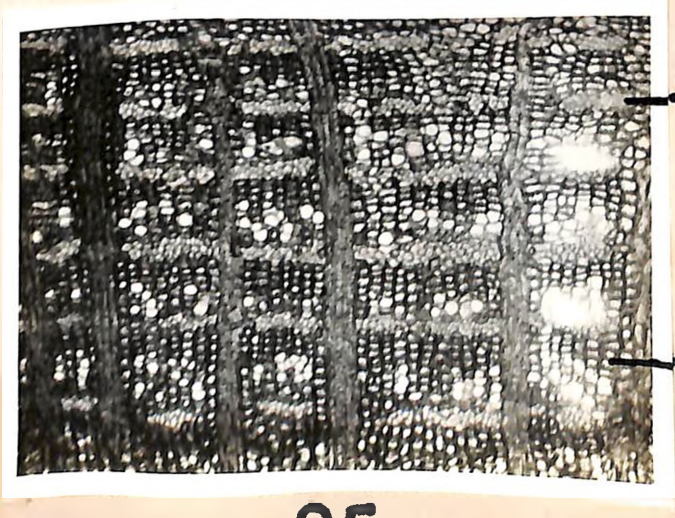
Photomicro. 95. T.S. portion inner bark (secondary phloem) *Acacia benthamii*.

PB- fiber band, PA- parenchyma,
PF- pericyclic fibers.

93



94



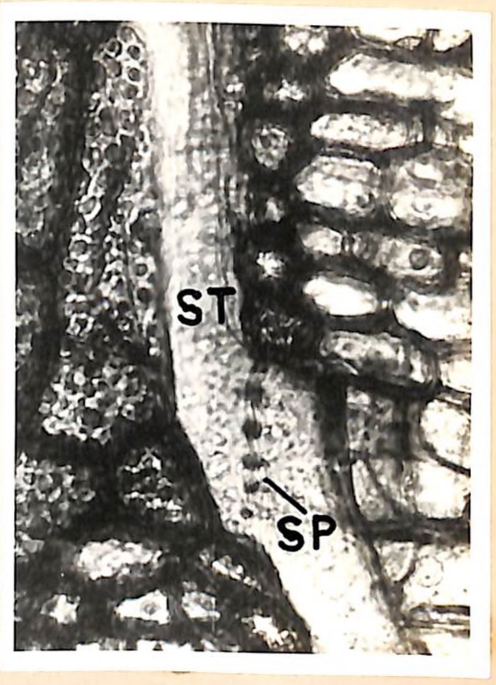
95

Photomicro. 96-97. T.L.S. secondary phloem *Acacia benthamii*.

Photomicro. 98. Cork layer *Acacia benthamii*.

SP- sieve plate, ST- sieve tube.

96



97

98

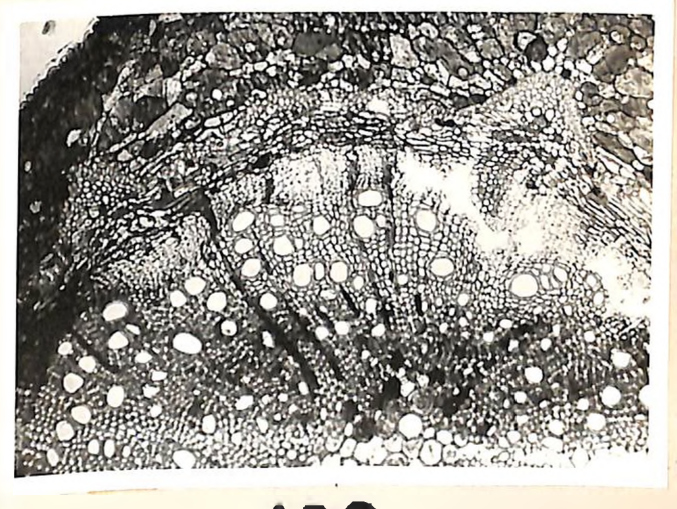
Photo. 99. Bark surface Acacia salicina.

Photomicro. 100-101. T.S.young twig Acacia salicina.

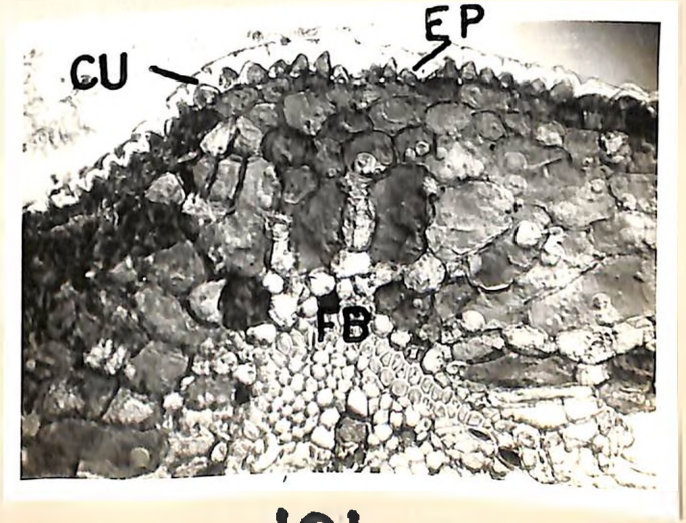
CU- cuticle, EP- epidermis.

PF- pericyclic fibers.

99



100



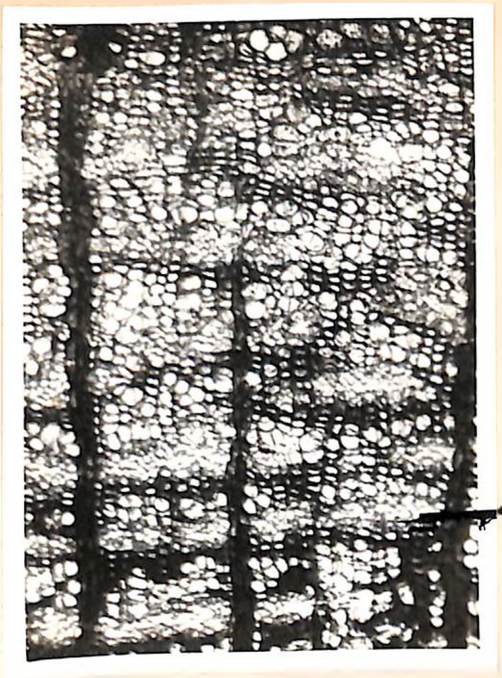
101

Photomicro. 102. T.S. secondary phloem *Acacia salicina*.

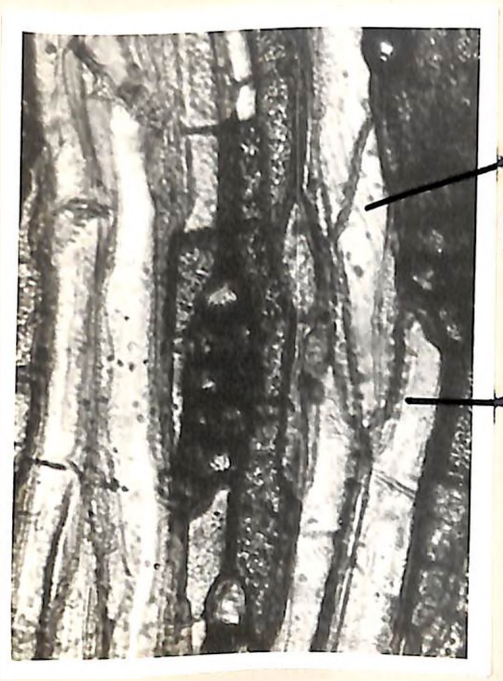
Photomicro. 103. T.L.S. secondary phloem *Acacia salicina*.

Photomicro. 104. T.S. old branch *Acacia salicina*.

FB- fiber band, RAEX- ray expansion tissue, SP- sieve plate, ST- sieve tube.



102



103

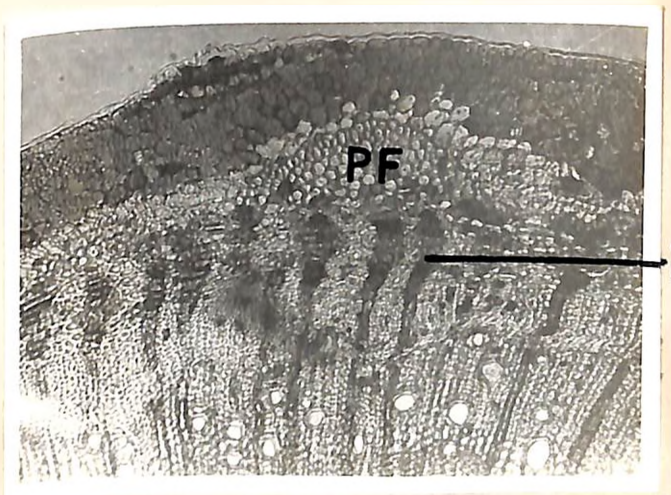
104

Photo. 105. Bark surface Acacia cyanophylla.

Photomicro. 106. T.S. young twig Acacia cyanophylla.

PF- pericyclic fiber, RAEX-
ray expansion tissue.

105



106

Photomicro. 107. T.S. bark *Acacia cyanophylla*.

Photomicro. 108. T.L.S. secondary phloem *Acacia cyanophylla*.

RAEX- ray expansion tissue, SP- sieve plate, ST- sieve tube.

107

108

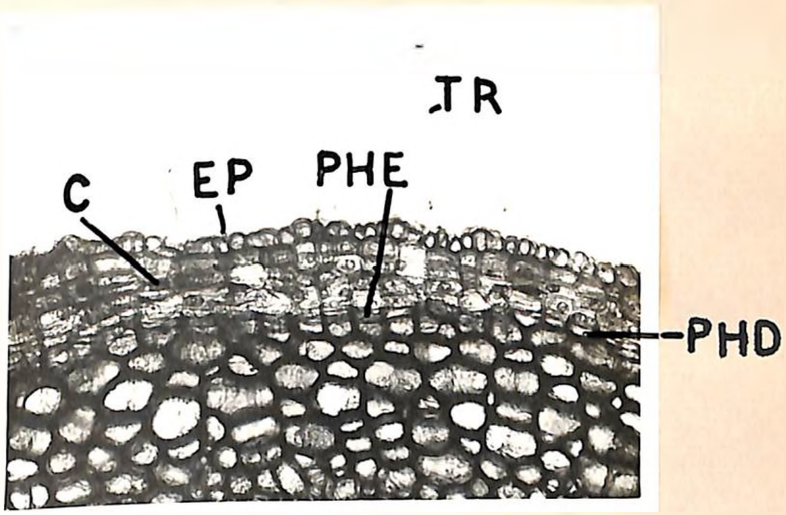
Photo. 109. Bark surface Acacia drepanolobium.

Photomicro. 110. T.S. young twig Acacia drepanolobium.

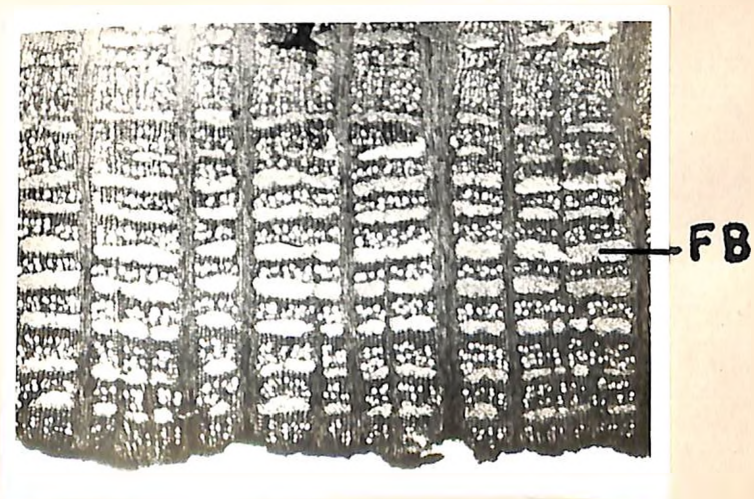
Photomicro. 111. T.S. portion inner bark (secondary phloem) Acacia benthamii.

C- cork, EP- epidermis, FB- fiber band, PHD- phelloderm, PHE- phellogen, TR- trichome.

109



110

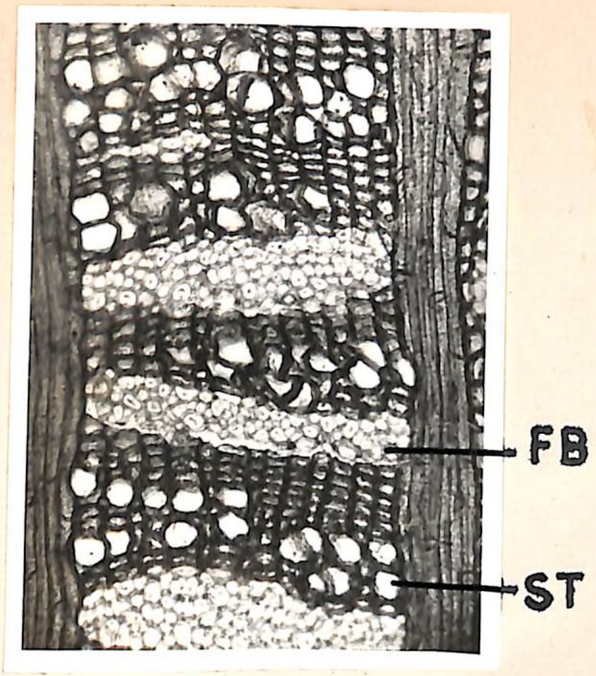


111

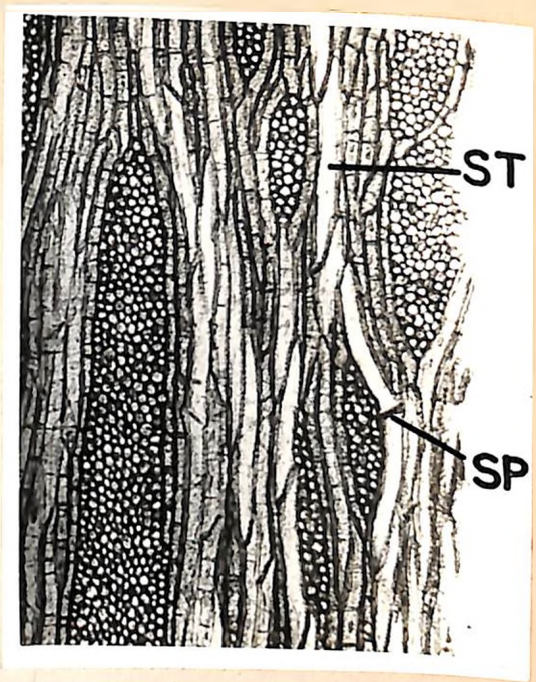
Photomicro. 112. T.S. portion phloem block Acacia drepanolobium.

Photomicro. 113-114. T.L.S. secondary phloem Acacia drepanolobium.

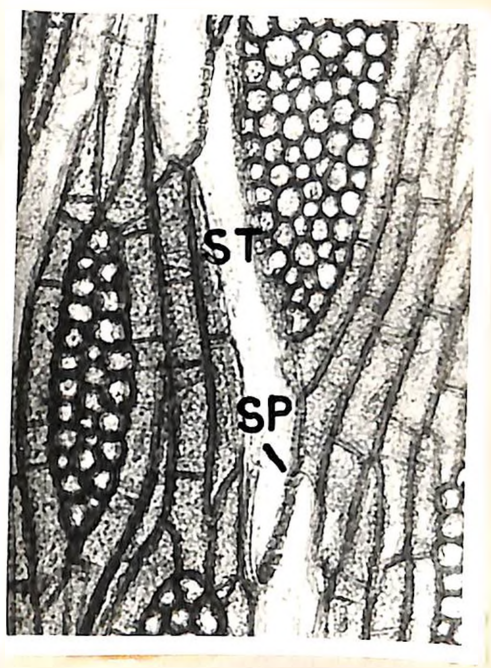
FB- fiber band, SP- sieve plate, ST- sieve tube.



112



113



114

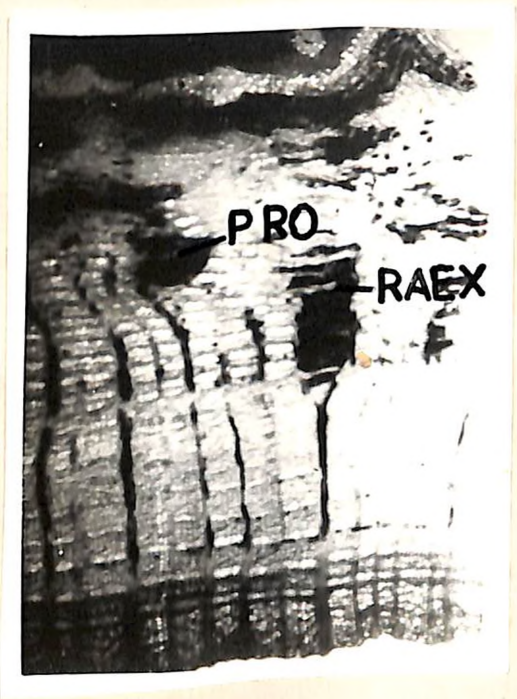
Photo. 115. Bark surface *Acacia hockii*.

Photomicro. 116. T.S. bark *Acacia hockii*.

Photomicro. 117. T.S. portion inner bark *Acacia hockii*.

FB- fiber band, PRO- phloem proliferation tissue, RAEX- ray expansion tissue.

115



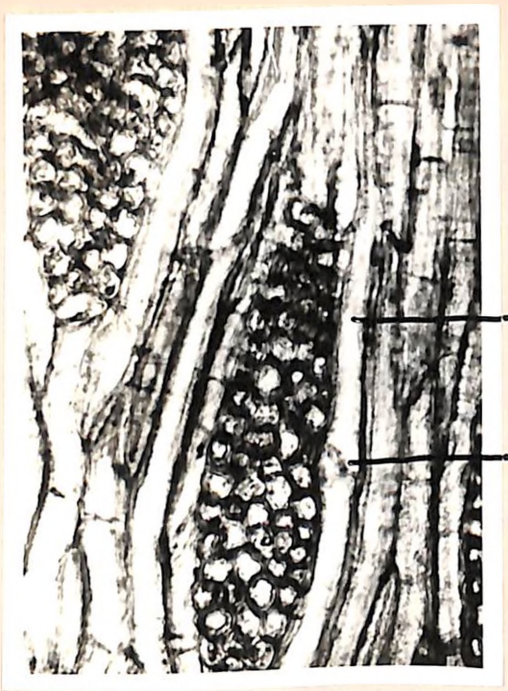
116

117

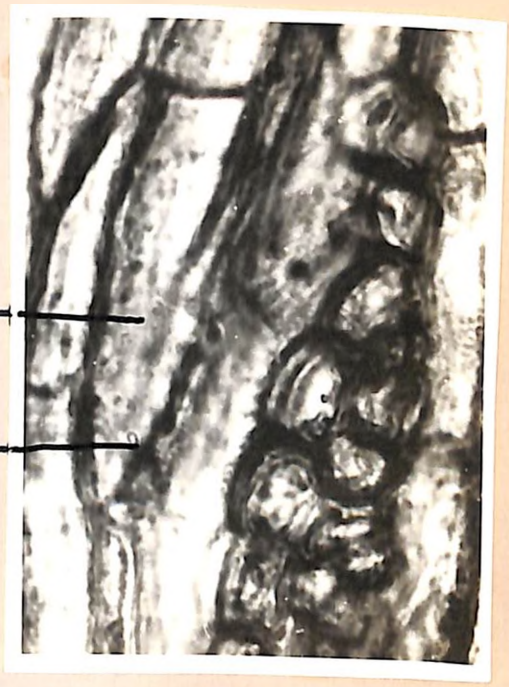
Photomicro. 118 - 119. T.L.S. secondary phloem Acacia hockii.

Photomicro. 120. T.S. cork Acacia hockii.

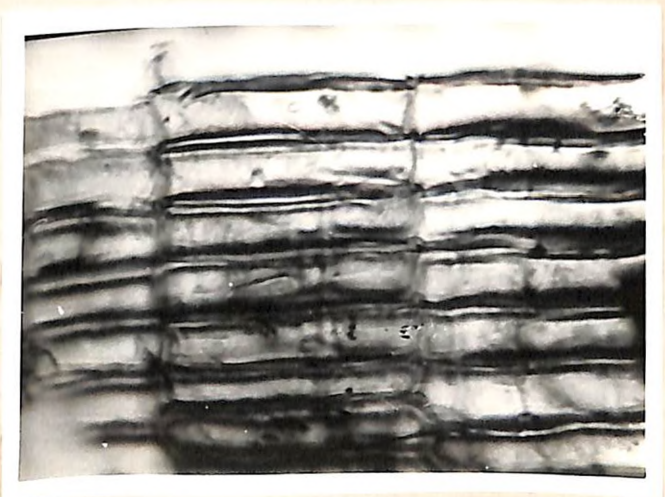
SP- sieve plate, ST- sieve tube.



118



119



120

Photo. 121. Bark surface Acacia ligulata.

Photomicro. 122. T.S. young twig Acacia ligulata.

PF- pericyclic fibers.

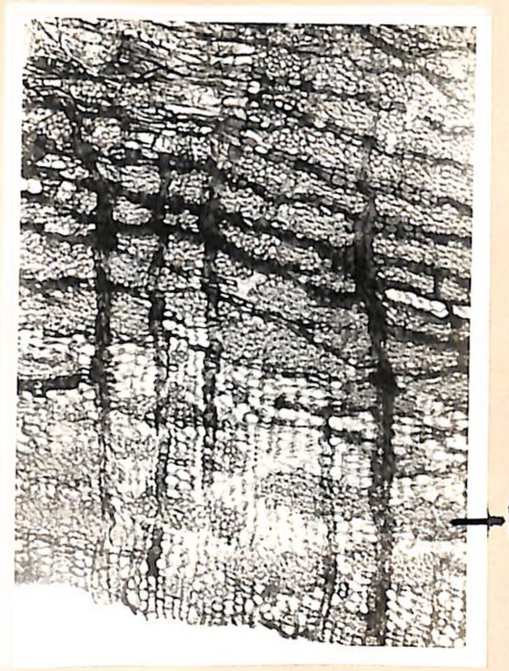
121

122

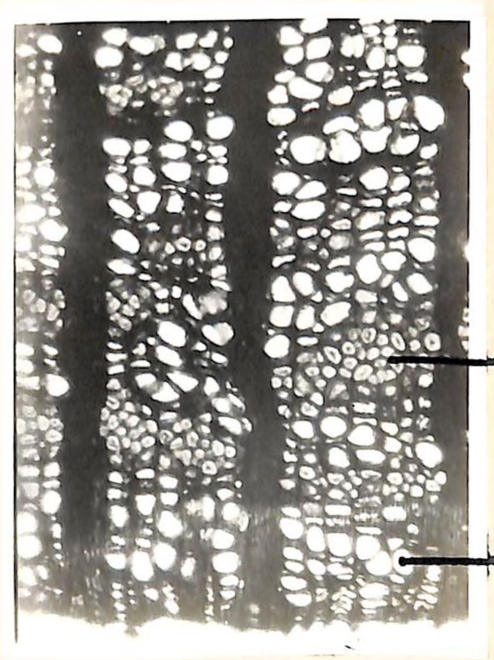
Photomicro. 123. T.S. inner bark Acacia ligulata.

Photomicro. 124. T.S. phloem block Acacia ligulata.

FB- fiber band, ST- sieve tube.



123



124

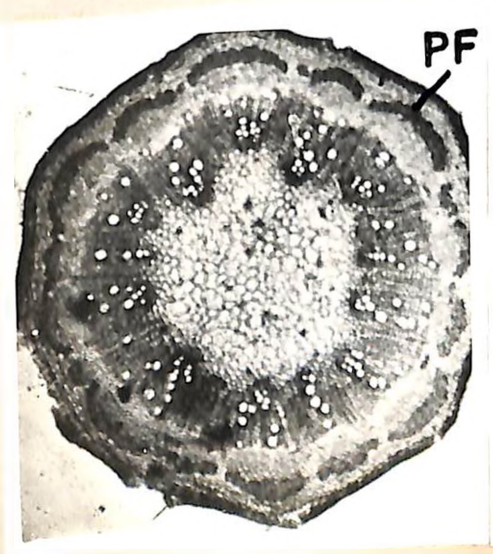
Photo. 125. Bark surface *Acacia senegal*

Photomicro. 126. T.S. young twig *Acacia senegal*.

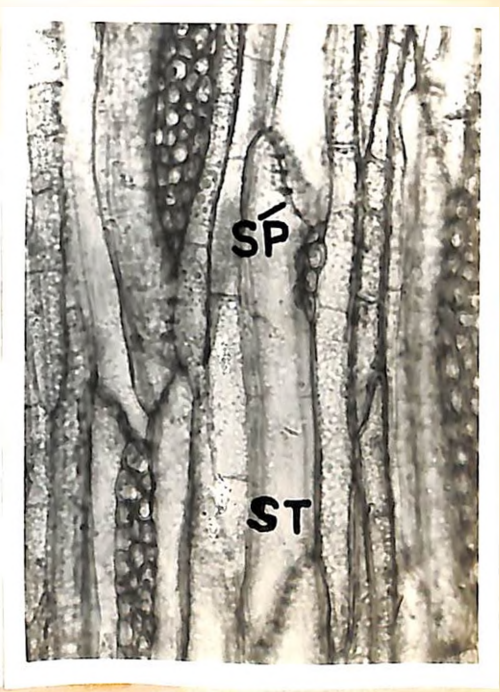
Photomicro. 127. T.L.S. secondary phloem *Acacia senegal*.

PF- pericyclic fiber, SP- sieve plate, ST- sieve tube.

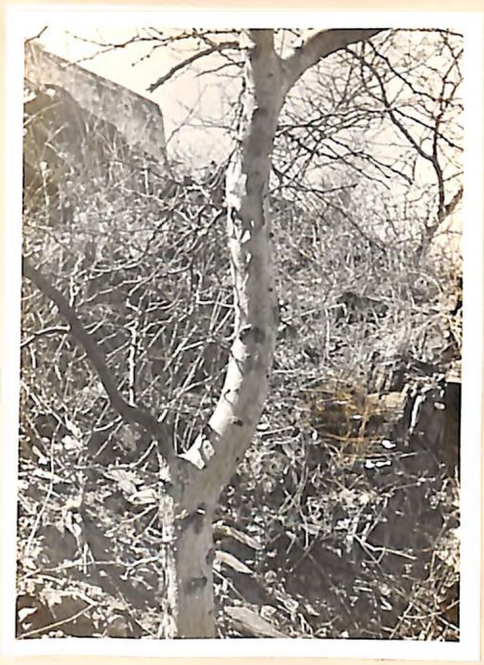
125



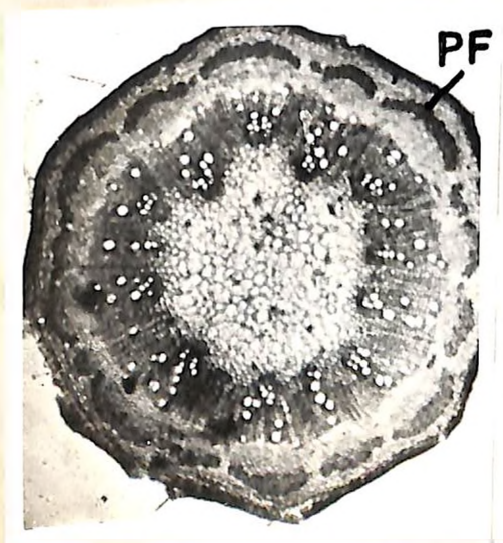
126



127



125



126

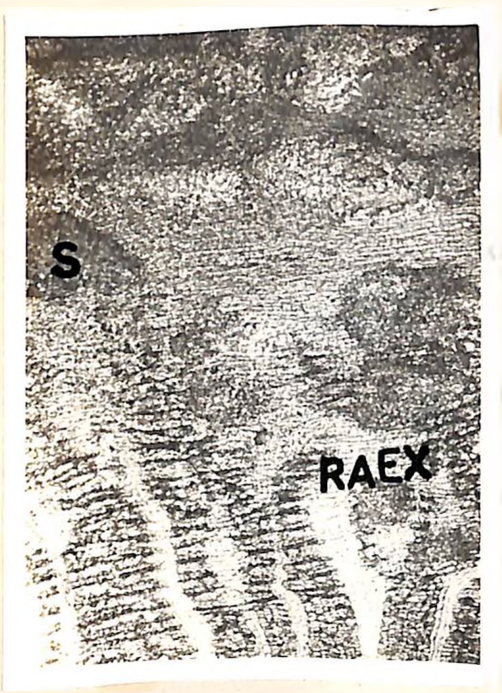
127

Photo. 128. Bark surface *Acacia sieberiana*.

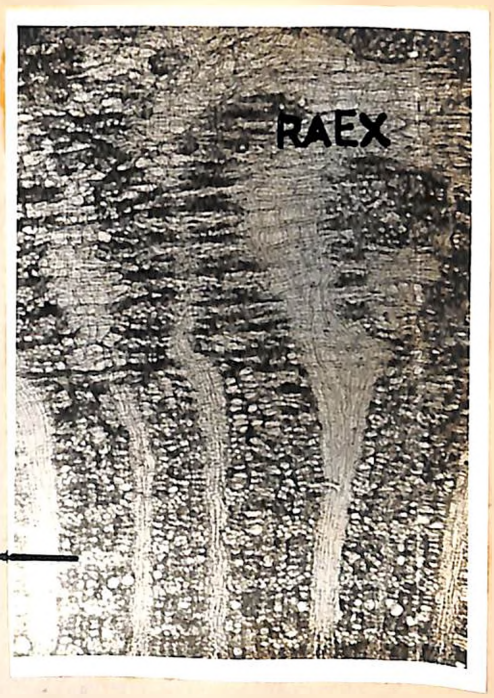
Photomicro. 129-130. T.S. bark *Acacia sieberiana*.

FB- fiber band, RAEX- ray expansion tissue, S- sclereids.

128



129

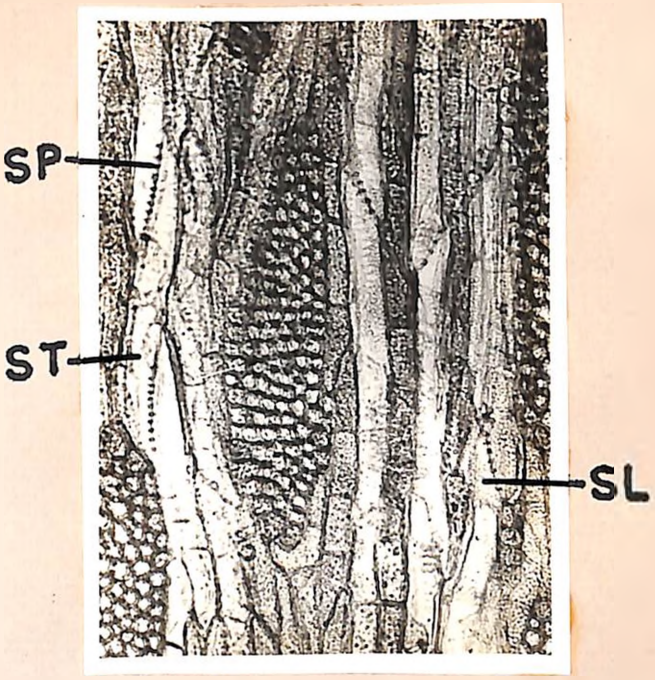


130

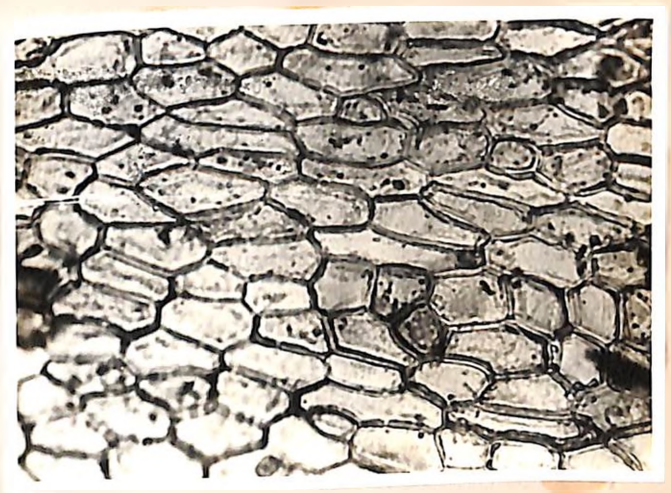
Photomicro. 131. T.L.S. secondary phloem *Acacia sieberiana*.

Photomicro. 132. Cork layer *Acacia sieberiana* in surface view.

SL- slime, SP- sieve plate, ST- sieve tube.



131

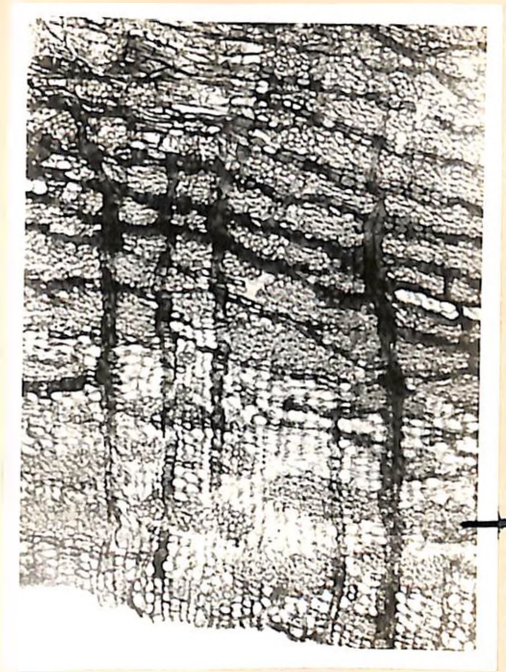


132

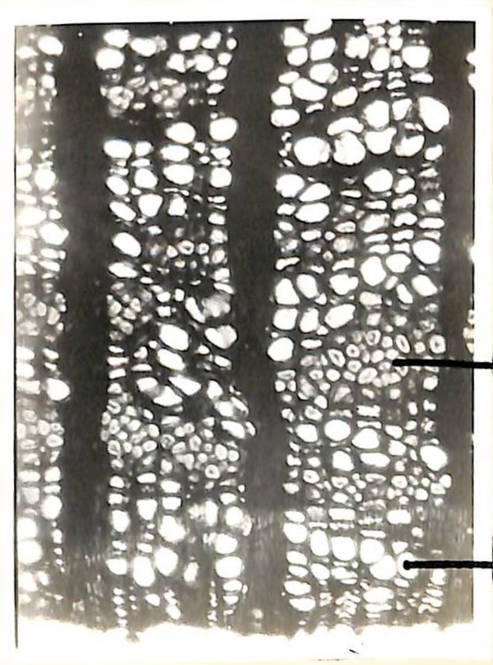
Photo. 133. Bark surface Acacia spirocarpa.

Photomicro. 134. T.S. young twig Acacia spirocarpa.

C- cork, EP- epidermis, PHD- phelloderm, PHE- phellogen.

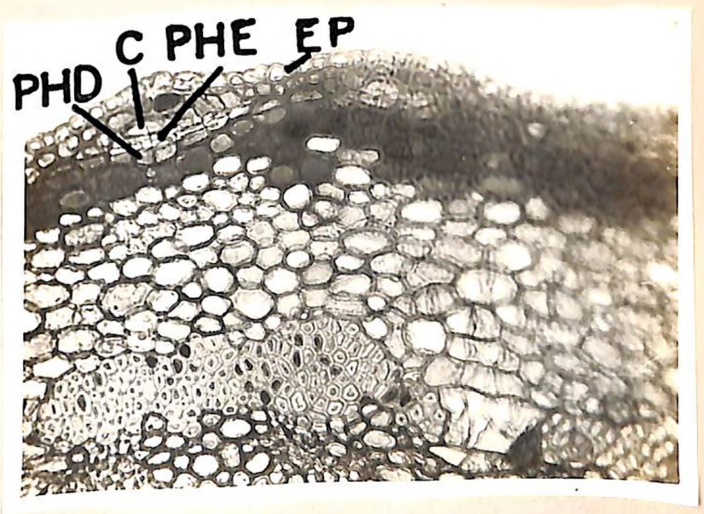


123



124

133

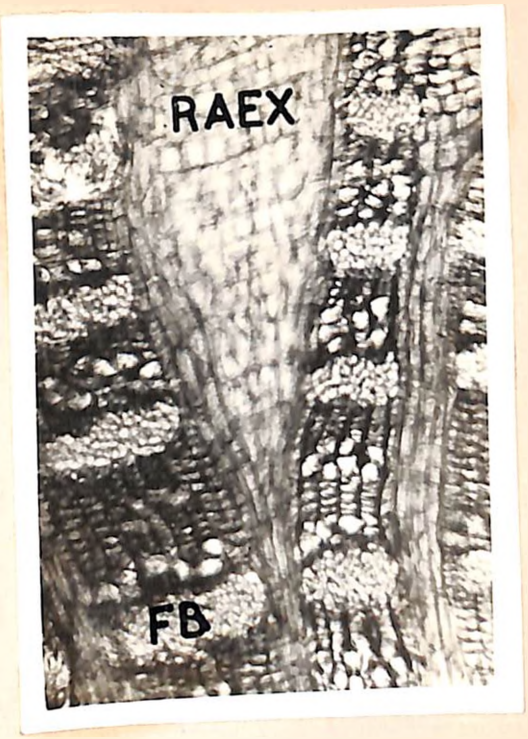


134

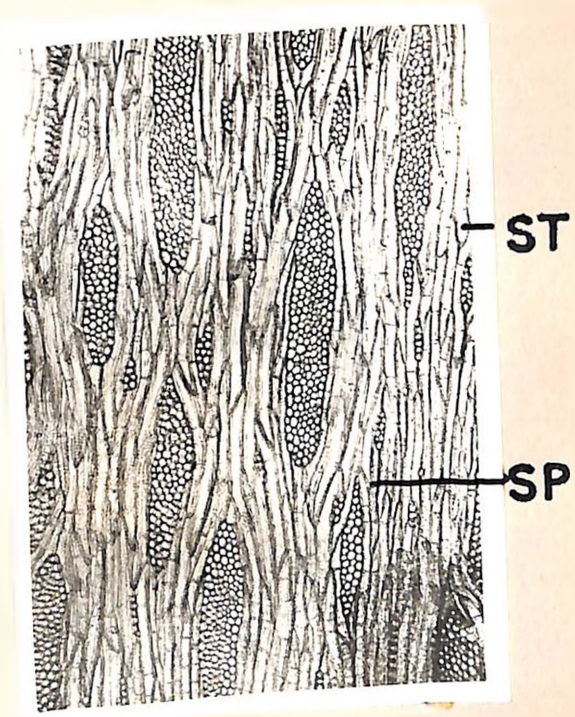
Photomicro. 135. T.S. portion inner bark *Acacia spirocarpa*.

Photomicro. 136. T.L.S. secondary phloem *Acacia spirocarpa*.

FB- fiber band, RAEX- ray expansion tissue, SP- sieve plate, ST- sieve tube.



135



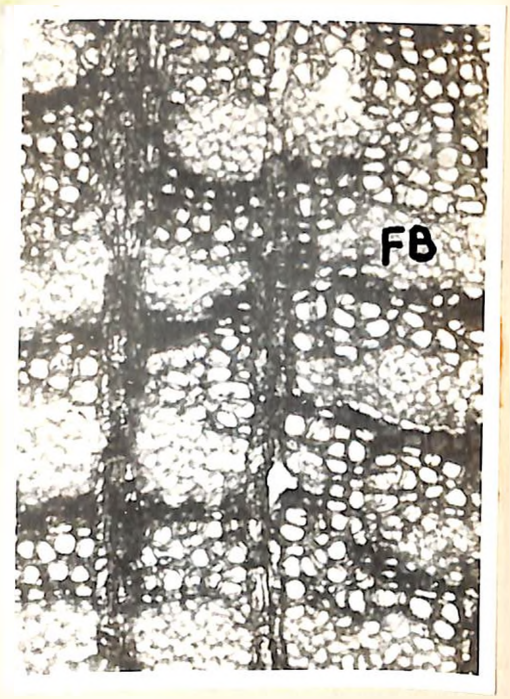
136

Photo. 137. Bark surface *Acacia victoriae*.

Photomicro. 138. T.S. portion inner bark *Acacia victoriae*.

FB- fiber band.

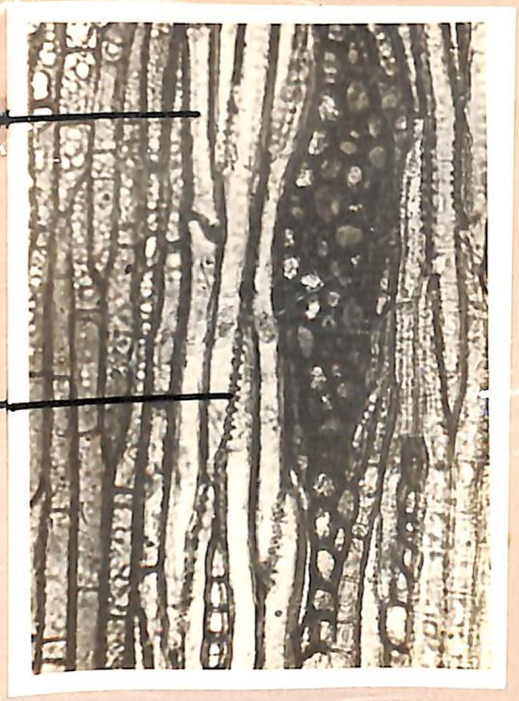
137



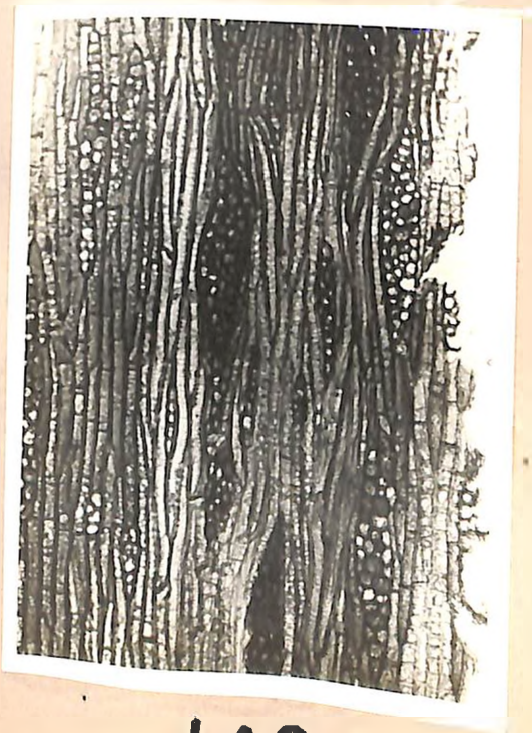
138

Photomicro. 139-140. T.L.S. secondary phloem *Acacia victorial*

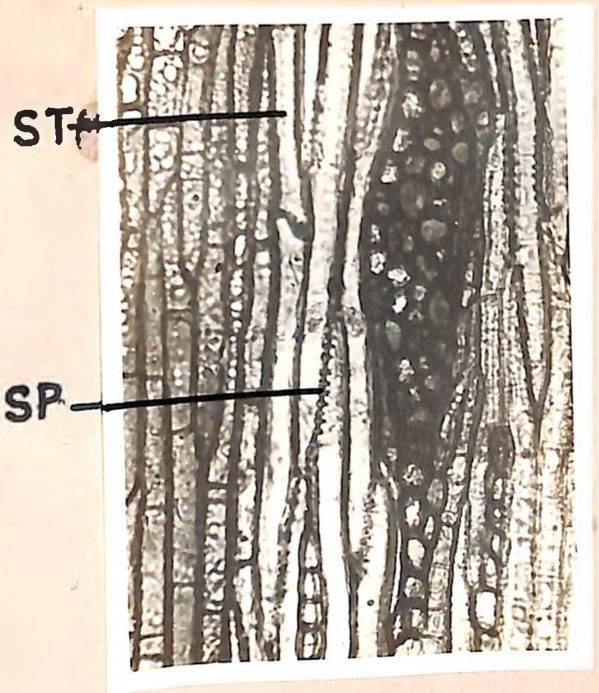
SP- sieve plate, ST- sieve tube.



139



140



139

140

Photo. 141. Bark surface Albizzia lebbeck.

Photo. 142. Cracked (dippled) bark surface Albizzia lebbeck.

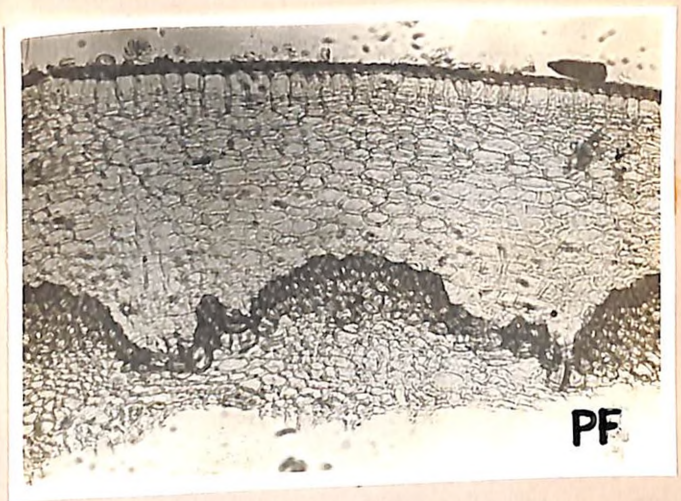
Photomicro. 143. T.S. young twig Abizzia lebbeck.

Photomicro. 144. Initiation of phellogen in Albizzia lebbeck.

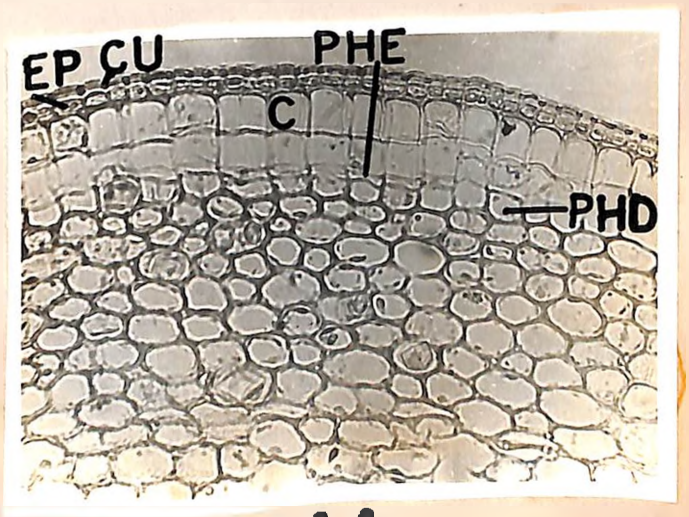
C- cork, CU- cuticle, EP- epidermis, PF- pericyclic fiber, PHD- phelloderm, PHE- phellogen.

141

142



143



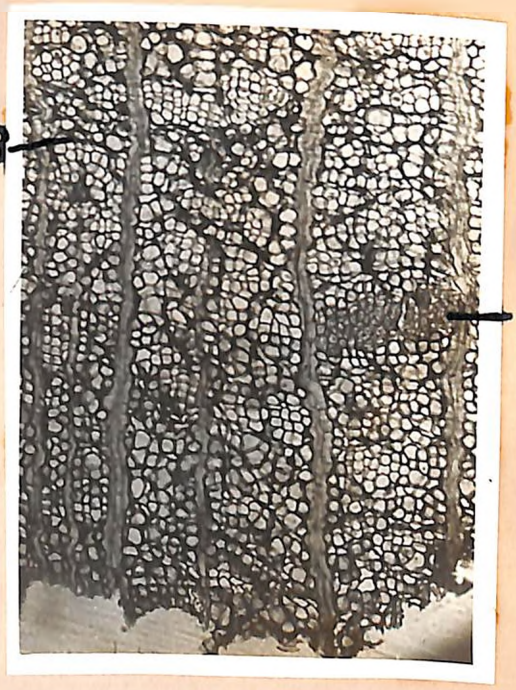
144

Photomicro. 145-146. T.S. inner bark (secondary phloem) Albizzia lebbeck.

Photomicro. 147-148. T.L.S. secondary phloem Albizzia lebbeck.

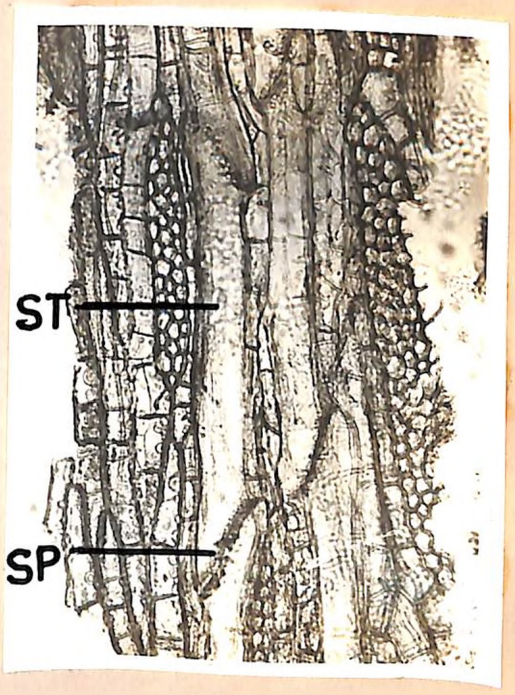
CRB- crushed tissue band, FB- fiber band, SP- sieve plate, ST- sieve tube.

145



146

147



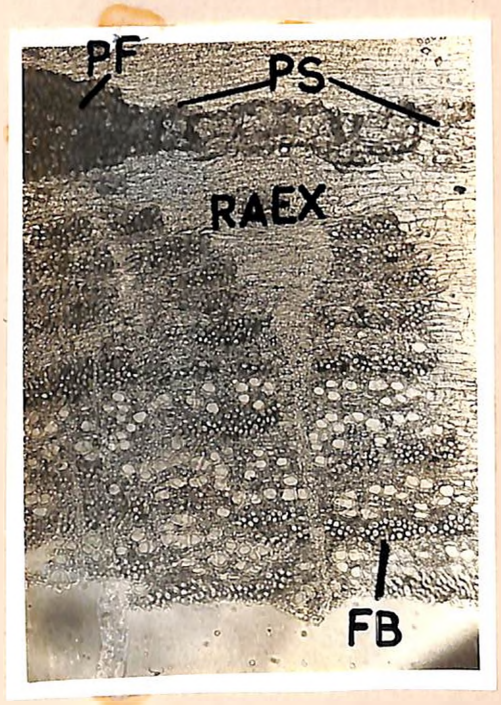
148

Photomicro. 149. R.L.S. secondary phloem Albizzia lebbeck.

Photomicro. 150. T.S. young bark with expanded pericycle and rays.

FB- fiber band, PF- pericyclic fiber, PS- pericyclic sclereids, RAEX- ray expansion tissue, SA- sieve area, SP- sieve plate.

149



150

DISCUSSION

Holdheide (1951), Zahur (1959) and Santos (1960) have emphasised that the distribution of fibers imparts some special characteristics to the secondary phloem. Further, Esau (1964) has mentioned that, (1) in some species fibers are lacking, (2) in others they are present and may be distributed in tangential bands or irregularly, (3) still others have fibers and sclereids or sclereids alone. The present study shows the occurrence of irregular fiber bands in Erythrina indica, Butea frondosa and regular bands in Dalbergia sisso of Papilionatae. Members of Caesalpineae studied show the following variations depending upon the presence or absence of fiber bands and of sclereids: (1) absence of fiber bands in the secondary phloem but the presence of irregularly distributed patches of sclereids as in Caesalpinia pulcherrima; (2) absence of fibers as well as sclereids but the presence of lignified parenchyma in the nonfunctional secondary phloem as in Delonix regia;(3) presence of fiber bands only as in Cassia species and Bauhinia variegata; (4) presence of fiber bands as well as sclereids in the nonfunctional part and fiber bands in the functional part of the secondary phloem as in Tamarindus indica. In Mimoseae, Prosopis species are characterised by rectangular fiber bands in regular parallel rows, Acacia species by regular or irregular fiber bands and Albizzia lebbeck by

irregular bands. The average tangential and radial extent of fiber bands (table X) shows that the plants studied can be categorised as follows: (1) fiber bands having more tangential extent than the radial as in Erythrina indica, Cassia auriculata, C. siamea, Tamarindus indica, Prosopis species, Acacia species and Albizzia lebbeck, (2) average tangential extent almost equal to radial or showing negligible differences as in Butea frondosa and Dalbergia sisso and (3) average tangential extent less than radial extent as in Cassia fistula.

According to Esau (1964) the fibers may develop from the sieve tubes which have ceased to function. However, the present study reveals that the fibers occur even in the functional phloem and that they develop directly from the cells cut off by the cambium.

In Cassia fistula and Prosopis spicigera phloem fibers are septate as well as nonseptate where as in others they are nonseptate alone.

Metcalfe & Chalk (1950) have classified the wood fibers into, short (upto 900 microns), medium (900 to 1600 microns) and long (above 1600 microns). Using similar criteria, the phloem fibers in the plants studied are classified as in table XI.

Wood fibers are 600.0 to 1700.0 microns long in Papilionatae, 700.0 to 1400.0 microns in Caesalpineae and 800.0 to 1750.0 microns in Mimoseae (Metcalfe & Chalk, 1950). In the plants studied phloem fibers are 1173 to 1906.39 microns long

in Papilionatae, 793.73 to 1487.84 microns long in Caesalpineae and 671.0 to 1940.6 microns long in Mimoseae (See table XI). Thus the phloem fibers are longer than the wood fibers in Papilionatae and Mimoseae and almost equal to wood fibers in Caesalpineae. Zahur (1959) also pointed out that in a given species the mode of elongation of phloem fibers is similar to that of wood fibers but it is not equal to it. In the present study, as evident from the table XI, the members of Papilionatae show approximate elongation of nine times during ontigeny in comparison to sieve tubes. In Caesalpineae elongation is less in Cassia species and more in Bauhinia variegata. In Mimoseae, Prosopis juliflora shows more elongation than P. spicigera. In Acacia species elongation is 4 to 5 times in A. nilotica, A. aneura, A. benthamii, A. cyanophylla, A. drepanolobium, A. ligulata and A. sieberiana; 5 to 6 times in A. salicina, A. hockii, A. senegal and A. victoriae and 6 to 7 times in A. spirocarpa. Albizzia lebbeck shows elongation of approximately five times in comparision to sieve tubes.

According to Cheadle and Whitford (1941), and Cheadle (1948) there are reasonable indications to assume that position of the end walls may be useful in determining the level of structural specialization of the sieve tubes. Using criterion they have suggested that transverse to slightly oblique end walls are considered highly specialized; very oblique end walls primitive. Table XII shows the average angle of inclination of the end walls and the sieve plates in the plants studied.

As indicated in table XII, members of Papilionatae show slightly oblique to almost transverse end walls and sieve plates oriented at an angle wider than 80.0 degrees. There is further increase in the angle of orientation from Erythrina indica to Dalbergia sisso through Butea frondosa. In Caesalpineae, Caesalpinia pulcherrima shows very oblique end walls with a narrow angle of inclination. This steepness of the end walls gradually decreases through Cassia species, Tamarindus indica, Delonix regia to Bauhinia variegata. In Mimoseae, Prosopis juliflora shows more inclined end walls than P. spicigera. In the Acacias end walls are very steep in A. victoriae which gradually decreases through A. nilotica A.spirocarpa, A. sieberiana, A. ligulata, A. benthamii, A. drepanolobium, A. aneura, A. hockii, A. cyanophylla, A. salicina to A. senegal which shows comparatively less inclined end walls. However, in Acacias the end walls are inclined between 33.5 to 46.4 degrees and hence they can be considered very inclined. Albizzia lebbeck also shows very inclined end walls.

Cheadle & Whitford (1941) and Cheadle (1948) have also stated that the sieve tube members with transverse to slightly oblique end walls are more frequently associated with regular arrangement than are the oblique end walls. Very oblique end walls on the contrary are nearly always coupled with an irregular arrangement of the sieve tube elements. Thus there appears to be a correlation between the type of arrangement and degree structural specialization. Regular arrangement of sieve tubes is highly specialized and advanced, and irregular, the primitive. However, regular arrangement is not always common even in those cases where the end walls are transverse.

As far as correlation between the inclination of the end walls and arrangement of the sieve tube is concerned members of Papilionatae having end walls almost transverse to slightly oblique, show regular arrangement of the sieve tubes while members of Caesalpineae and Mimoseae, having inclined end walls show regular as well as irregular arrangement of the sieve tubes. Thus it becomes clear that transverse to slightly oblique end walls are associated with regular arrangement of sieve tubes but there is no correlation between the oblique and very oblique end walls and the arrangement of the sieve tubes. The present observations conform to those of Cheadle & Whitford (1941) and Cheadle (1948).

Cheadle & Whitford (1941), Cheadle (1948), Cheadle & Uhl (1948) and Esau (1965a) have mentioned that long sieve tube is a primitive feature and short, advanced. As evident from table XI, in the members of Papilionatae, Erythrina indica shows longest sieve tubes and Dalbergia sisso smallest, while Butea frondosa is medium. In Caesalpineae, Delonix regia shows longest sieve tubes while the length gradually decreases through Cassia siamea, C. fistula, C. auriculata, Bauhinia variegata, Caesalpinia pulcherrima to Tamarindus indica which shows shortest sieve tubes. In Mimoseae, Prosopis juliflora shows shorter sieve tubes than Prosopis spicigera. In Acacias, the sieve tubes are longest in A. ligulata and shortest in A. aneura. From A. ligulata to A.aneura a gradual decrease in the length of sieve tubes has been observed through A. nilotica, A. spirocarpa, A. drepanolobium, A. senegal, A. benthamii, A. salicina, A. cyanophylla, A. victoriae, A. sieberiana and A. hockii

Sieve tubes are longest in Albizzia lebbeck and shortest in A. aneura among the three genera.

Localization of the sieve areas on the end walls of the sieve tubes is an advanced feature and their occurrence on the longitudinal walls, is primitive (Cheadle & Whitford, 1941; Cheadle, 1948; Cheadle & Uhl, 1948; Esau, 1965a). The present study shows that in the members of Papilionatae sieve areas are restricted to the end walls, a feature considered advanced, while in Caesalpineae and Mimoseae they occur on the vertical walls also representing a primitive feature. Thus Papilionatae shows structural advancement over Caesalpineae and Mimoseae. In most of the members of Caesalpineae and Mimoseae, the sieve tubes show rudimentary sieve areas, the lattices, a feature considered primitive (Eames & Mac Daniels, 1947).

Hemenway (1911, 1913), Eames & Mac Daniels (1947) and Esau (1965a) have mentioned that the sieve plates with more than one sieve area have been considered primitive structurally and phylogenetically while those with only one sieve area, the most advanced. The present study shows that the sieve plates in Papilionatae are simple having only one sieve area, while in Caesalpineae, Caesalpinia pulcherrima, Delonix regia and Cassia species show sieve plates with more than one sieve area and are thus compound; in Tamarindus indica the plates are usually compound and rarely simple while in Bauhinia variegata they are only simple but oblique. In Mimoseae, the sieve plates have more than one sieve area and are thus compound.

Considering the trends of specialization (Hemenway, 1911, 1913; Cheadle & Whitford, 1941; Cheadle, 1948; Cheadle & Uhl, 1948; Esau, 1965a), members of Papilionatae are structurally advanced over Caesalpineae and Mimoseae. As clear from tables XI and XII these trends of structural specialization do not seem to have taken place along one definite line. This is further proved by the length of the sieve tubes and nature of the sieve plates in Caesalpineae.

The evolution of the sieve tubes is being considered parallel to the vessels. Using the categories similar to those of vessels given by Dadswell & Eckerseley (1935) (Minute less than 100 microns, small-100 to 200 microns, medium- 200 to 300 microns and large- over 300 microns) they can be classified as follows:

Small: Dalbergia sisso, Butea frondosa and Acacia aneura.

Medium: Erythrina indica, Caesalpinia pulcherrima, Cassia species, Tamarindus indica, Bauhinia variegata, Prosopis juliflora, P. spicigera, Acacia benthamii, A. salicina, A. cyanophylla, A. drepanolobium, A. hockii, A. senegal, A. sieberiana, A. spirocarpa and A. victoriae.

Large: Delonix regia, Acacia nilotica, A. ligulata and Albizzia lebbeck.

Chalk (1938) has classified the vessels based on tangential diameter into extremely small (Upto 25 microns), very small (25 to 50 microns), moderately small (50 to 100 microns),

medium (100 to 200 microns), moderately large (200 to 300 microns), large (300 to 400 microns) and extremely large (above 400 microns). On similar lines sieve tubes can be classified as follows taking into consideration the average width:

Extremely small: Butea frondosa, Dalbergia sisso, Caesalpinia pulcherrima, Cassia auriculata, Tamarindus indica, Bauhinia variegata, Prosopis juliflora and Acacia species.

Very small: Erythrina indica, Delonix regia, Cassia fistula, C. siamea, Prosopis spicigera and Albizzia lebbeck.

In sieve tubes slime is very prominent in Papilionatae members studied. In Erythrina indica, Butea frondosa and Dalbergia sisso, sieve tubes show distinct slime plugs which are darkly stained. These plugs are present on one side of the sieve plate but in some of the sieve tubes plugs are present on both sides and are connected with each other by connecting strands passing through the sieve pores. In Butea frondosa, some sieve tubes show slime a little away from the sieve plate. In Dalbergia sisso, plugs show variable arrangements. In case they are present on both the sides they are connected with each other by connecting strands passing through the sieve pores. In some the darkly stained slime mass is isolated from the plate by amorphous plug. In still others the slime mass is present a little away from the sieve plate and shows strands emerging from it. These strands are attached with the sieve plate. In some cases

the darkly stained body shows fine strands emerging from both ends but these strands do not connect it with the sieve plate. These strands are probably incompletely dispersed slime strands emerging from the slime mass. All these conditions of slime occurrence have been described for Tilia by Evert & Derr (1964). In Mimoseae and Caesalpineae, the slime is not very distinct and wherever present occurs in the form of amorphous mass. In Tamarindus indica distinct plugs are present near the sieve plates. In Cassia siamea some of the sieve tubes show distinct fine strands which emerge from the sieve plate and run obliquely to the longitudinal walls. All these conditions of slime have been described for Robinia by Evert & Derr (1964).

Phloem rays: Similar to wood, the rays form another important component of the secondary phloem. Kribs (1935) and Barghoorn (1940,1941a, 1941b) have classified the wood rays into homogeneous and heterogeneous types. Since phloem rays in all the plants studied, consists of only procumbent cells, they are of the homogeneous type. The plants studied show uni-, bi- and multiseriate rays except Acacia aneura where multiseriate rays are absent and conform to homogeneous type II (Kribs, 1935). The present study reveals that the percentage occurrence of uni-, bi- and multiseriate rays is variable (See table XIII). Thus it was felt that they should be classified further in to subdivisions based on the dominant type of rays.

A- Uniseriate rays dominant, biseriate and multiseriate almost equal as in Cassia auriculata and Acacia cyanophylla.

B- Uniseriate rays dominant, multiseriate least as in Caesalpinia pulcherrima and Tamarindus indica.

C- Uniseriate rays dominant, biseriate negligible and multiseriate absent as in Acacia aneura.

D- Biseriate rays dominant, multiseriate minimum as in Cassia fistula and Bauhinia variegata.

E- Biseriate rays dominant, uniseriate and multiseriate almost equal as in Acacia ligulata.

F- Multiseriate rays dominant, uniseriate minimum as in Dalbergia sisso, Delonix regia, Cassia siamea, Prosopis spicigera, P. juliflora, Acacia nilotica, A. benthamii, A. salicina, A. drepanolobium, A. hockii, A. senegal, A. sieberiana and Albizzia lebbeck.

G- Multiseriate rays dominant, biseriate minimum as in Acacia spirocarpa and A. victoriae.

H- Multiseriate rays dominant, uniseriate and biseriate negligible as in Erythrina indica and Butea frondosa.

In the wood of Erythrina, Butea and Dalbergia multiseriate rays are lesser than uniseriate (Metcalfe & Chalk, 1950). The present observations on Erythrina indica, Butea frondosa and Dalbergia sisso indicate the dominance of multiseriate rays over uniseriate in the phloem. Wood rays are mostly uniseriate and biseriate and multiseriate are a few in Bauhinia and Cassia species (Metcalfe & Chalk, 1950), but the phloem of these genera

investigated shows that in Cassia auriculata the phloem is similar to wood in having dominant uniseriate rays while in Cassia fistula and Bauhinia variegata biseriate rays are dominant and in Cassia siamea multiseriate rays are dominant. Tamarindus indica phloem is similar to its wood in having dominant uniseriate rays.

Following Chalk's (1938) suggestions the International Association of Wood Anatomists (1939) has proposed the following classification for the wood rays based in their width extremely fine (upto 15 microns), very fine (15 to 25 microns), moderately fine (25 to 50 microns), medium (50 to 100 microns), moderately broad (100 to 200 microns), very broad (200 to 400 microns) and extremely broad (above 400 microns).

Using the same classification and taking into consideration the average width of the phloem rays the uni-, bi- and multiseriate rays can be classified into different categories as follows:

Uniseriate rays:

Extremely fine: Caesalpinia pulcherrima, Prosopis juliflora, Acacia nilotica, A. benthamii, A. drepanolobium, A. senegal and A. victoriae.

Very fine: Dalbergia sisso, Delonix regia, Cassia auriculata, C. fistula, C. siamea, Tamarindus indica, Bauhinia variegata, Prosopis spicigera, Acacia aneura, A.salicina, A. cyanophylla, A. hockii, A. ligulata, A. sieberiana,

A. spirocarpa and Albizzia lebbeck.

Moderately fine: Erythrina indica and Butea frondosa.

Biseriate rays:

Very fine: Caesalpinia pulcherrima, Tamarindus indica, Prosopis juliflora, Acacia aneura, A. benthamii, A. senegal and A. victoriae.

Moderately fine: Butea frondosa, Erythrina indica, Dalbergia sisso, Delonix regia, Cassia auriculata, C. fistula, C. siamea, Bauhinia variegata, Prosopis spicigera, Acacia nilotica, A. salicina, A. cyanophylla, A. drepanolobium, A. hockii, A. ligulata, A. sieberiana, A. spirocarpa and Albizzia lebbeck.

Multiseriate rays:

Very fine: Tamarindus indica:

Moderately fine: Dalbergia sisso, Caesalpinia pulcherrima, Delonix regia, Cassia auriculata, C. fistula, C. siamea, Bauhinia variegata, Prosopis juliflora, Acacia ligulata, A. senegal, A. victoriae and Albizzia lebbeck.

Medium: Prosopis spicigera, Acacia nilotica, A. benthamii, A. salicina, A. cyanophylla, A. drepanolobium, A. hockii, A. sieberiana, and A. spirocarpa.

Very broad: Butea frondosa.

Metcalfe & Chalk (1950) have mentioned that the number

of rays per square mm. in the wood of Caesalpinia pulcherrima, Cassia and Erythrina is a fewer than four, in Bauhinia, 13 to 20, in Dalbergia, 12 to 20. The present studies on the phloem of the above mentioned species show that in Erythrina indica the number of rays per square mm. is less than even one at places, Caesalpinia pulcherrima, Bauhinia variegata, Dalbergia sisso and Cassia species show much higher number of rays per square mm. The minimum number of rays per square mm. is one or less than one as in Erythrina indica, less than 20 in Butea frondosa, Acacia nilotica and A. drepanolobium, 21 to 30 in Acacia spirocarpa and Albizzia lebbeck; 31 to 40 in Delonix regia, Acacia benthamii, A. senegal and A. sieberiana; 41 to 50 in Prosopis juliflora, Acacia hockii and A. ligulata; 51 to 60 in Cassia siamea, Prosopis spicigera, Acacia salicina and A. cyanophylla; 61 to 70 in Acacia victoriae; 71 to 80 in Dalbergia sisso and Cassia auriculata; 81 to 90 in Tamarindus indica; 101 to 110 in Cassia fistula; 141 to 150 in Bauhinia variegata; 151 to 160 in Acacia aneura and maximum in Caesalpinia pulcherrima (165 rays per square mm.).

To accommodate the stress and strains put on the bark as a result of secondary growth it has to develop some mechanism. It is partly achieved by the activity of the phellogen. In addition, the tissues outside the vascular cambium show another type of secondary growth which, however, does not involve any meristem. De Bary (1884) was the first to describe this type of growth in the parenchyma. His observations have been substantiated by Esau (1948), Chattaway (1955C), Schneider (1955), and

Whitmore (1962a, 1963). This type of growth was termed as diffused secondary growth by Tomlinson (1961) based on his studies of palms. However, Esau (1965b) pointed out that this type of growth which is non-cambial results in the dilation of the perenchyma or rays. She further mentioned " It will be improper to call this growth in the dicots as secondary growth and has suggested that it may be called as intercalary secondary growth as contrasted with the cambial secondary growth". Sehneider (1955) and Chattaway (1955c), however, called this growth as " dilation growth". Esau (1964, 1965b) has also used the term "dilatation growth" in her writings. Whitmore (1962a) has differentiated dilation growth in Dipterocarpaceae into (1) phloem proliferation and (2) phloem expansion. In the former he includes the expansion of the axial parenchyma while in the latter, the expansion of rays. The present studies reveal that in addition to the dilation of the rays and proliferation of the axial parenchym of the phloem, expansion also occurs in the cortex and pericycle. Thus dilation growth has been differentiated into cortical expansion, pericyclic expansion, ray expansion and phloem proliferation as these terms indicate the tissues involved in the expansion.

During the expansion of the cortex in Erythrina indica, Butea frondosa, Dalbergia sisso and Albizzia lebbeck the tangential stretching and anticlinal divisions are more prominent in the regions against the primary phloem rays or the grooves in the pericycle. In Acacia cyanophylla, the cortical layer immediately outside the pericycle shows prominent divisions.

During the pericyclic expansion, in cases where the pericycle is continuously sclerenchymatous, parenchyma becomes interpolated in between. Whether this interpolation of parenchyma is cortical or phloic can not be determined. Tangential stretching and anticlinal divisions in the parenchyma cells are the two factors involved in pericyclic expansion.

Expansion of rays has been observed in all the plants studied. As described by earlier workers from time to time the formation of expansion tissue as a result of ray expansion is mainly of the following types: (1) expansion in the form of fingers occurring as narrow radial files formed by narrow individual rays, (2) expansion in wedges, (3) expansion in the form of cortex like zone (Pseudocortex, Whitmore, 1962a) as in Albizzia lebbeck, Caesalpinia pulcherrima, Erythrina indica, Butea frondosa and Cassia.

Holdheide (1951), Chang (1954) and Esau (1964) have stated that in the nonfunctional phloem, parenchyma gets sclerified. In the present investigation, sclerification of the parenchyma has been observed in the axial system of Tamarindus indica and Delonix regia. In the latter only the walls become thick and lignified. Sclerosis in the cortex is common in Erythrina indica, Albizzia lebbeck, Acacia senegal and Cassia siamea. In the expanded pericycle sclerosis occurs in all the plants except Dalbergia sisso. Sclerosis of variable degree occurs in the ray expansion and phloem proliferation tissue in all the plants studied except Butea frondosa, Bauhinia variegata and Prosopis juliflora. In Delonix regia cell walls

become considerably thick. In Cassia siamea, Prosopis spicigera and Tamarindus indica even the cells of the phelloderm or cork become sclerified.

Proliferation of the phloem parenchyma has been observed in Dalbergia sisso, Delonix regia, Cassia auriculata, C. fistula, Acacia cyanophylla, A. aneura, A. hockii, A. senegal and Prosopis spicigera. Schneider (1955) mentioned that during the proliferation, a meristem-like zone is involved; however, in the present study no such meristem has been observed.

Periderm:

In considering the place of origin of the phellogen, it is essential to distinguish between the first and subsequent periderms (Esau, 1965a). The phellogen may be initiated at different depths outside the vascular cambium (Esau, 1948; Metcalfe & Chalk, 1950 and Whitmore, 1962a). In many members of Leguminosae it may differentiate in the second or third cortical layer or even in the deeper. Metcalfe & Chalk(1950) and Esau (1965a) have mentioned that in Papilionatae, origin of cork ranges from sub-epidermal to pericycle. Such variation may be found even in a single genus or species. In Erythrina the origin of cork is in the middle cortex while in Dalbergia in the sub-epidermal or between this layer or sixth layer of cortex (Metcalfe & Chalk, 1950). However, present study of Erythrina indica and Dalbergia sisso shows that the origin of the phellogen is only sub-epidermal. In Butea frondosa (not mentioned in

earlier literature) the first phellogen is sub-epidermal. In Caesalpineae, genera like Bauhinia, Caesalpinia, Cassia and Tamarindus the phellogen is supercial (Metcalfe & Chalk,1950). The present study shows that in all the plants except Bauhinia variegata, Tamarindus indica and Cassia siamea, the phellogen arises in the subepidermal layer. In Cassia siamea in addition to sub-epidermal origin, the first phellogen has also been observed to arise in the deeper layers of the cortex. But such a origin has been observed only in relation to the formation of lenticels. In Mimoseae, the phellogen is initiated in the second or third layer of cortex and rarely in the sub-epidermal layer (Metcalfe & Chalk, 1950). Although Ghosh & Purkayastha (1962) have described the periderm in Acacia senegal they did not mention the place of origin of the first phellogen. The present study shows that in Prosopis species, Acacia nilotica, A. aneura, A. benthamii, A. cyanophylla, A. sieberiana, A. victoriae and Albizzia lebbeck it is sub-epidermal while in Acacia salicina, A. drepanolobium, A. ligulata, A. senegal and A. spirocarpae it is sub-hypodermal.

Esau (1965a) and Eames & Mac Daniels (1947) have mentioned that the phellogen is initiated by periclinal divisions. The first periclinal division in the given cell or cells gives rise to approximately two similar cells. Frequently the inner one does not divide further and differentiates as phelloderm cell or cells, while the outer one by another periclinal division forms two cells, the outer of which becomes the cork and the inner, the phellogen, which cuts off either the cork or phelloderm cells subsequently. Rarely, the first division

results in the formation of cork cells to outside while the inner cell by another division forms the phellogen and phelloderm. The present study shows that the first method is of rare occurrence among the plants studied and is exhibited by Acacia nilotica and Albizzia lebbeck only. The second condition which has been mentioned as of rare occurrence (Esau, 1965a) is more common and is represented by all the plants except Acacia nilotica and Albizzia lebbeck.

The present study shows mainly three patterns of cork formation: (1) extent of cork is almost equal to the phelloderm as in Erythrina indica, Delonix regia, Acacia nilotica, A. salicina, A. hockii, A. senegal and A. spirocarpa, (2) none or one or two layered phelloderm as in Acacia aneura; (3) extent of cork more than phelloderm as in Butea frondosa, Dalbergia sisso, Caesalpinia pulcherrima, Cassia species, Tamarindus indica, Bauhinia variegata, Acacia benthamii, A. cyanophylla, A. drepanolobium, A. ligulata, A. sieberiana, Prosopis species and Albizzia lebbeck.

Esau (1965a) has mentioned that the position of the subsequent layers of the periderm is variable and two typical modes have been observed in the plants. In some cases it encircles the whole of the axis similar to first phellogen (Esau, 1948) while in others it arises in discontinuous strips localized in various parts of the circumference. Holdheide (1951) and Whitmore (1962a) have mentioned that deeper layers of phellogen arise in the plants they have studied. De Bary (1884) has suggested the term rhytidome for the periderm and the tissues isolated by its development. In the present work, deeper layers

of phellogen have been observed to arise in Dalbergia sisso, Prosopis species, Acacia nilotica, A. aneura, A. salicina, A. drepanolobium, A. ligulata, A. spirocarpa and A.victoriae. The rhytidome layers thus formed vary in thickness, shape and arrangement resulting in variable external appearance of the bark.

The manner in which dead tissue saperates from the stem is determined by the nature of the periderm (De Bary, 1884; Muhldorf, 1925; Pfeiffer, 1928). In the present study Acacia aneura shows sclereid zone below the periderm while in Tamarindus indica cork shows zones of sclereids. In Acacia senegal thin walled cells (Phelloids, Esau, 1965a) are formed in between the thick walled cork scales. In rest of the plants exfoliation takes from the thin walled cork layers.

Some plants show considerable cohesion of successive layers of periderm and adhere firmly to one another (Esau, 1965a). The present studies are also similar to those described by Esau (1965a). The outer bark in these species thus becomes variably cracked. Such a nature has been described in Sequoia (Isenberg, 1943), Pinus (Chang 1954) and Dipterocarpaceae, 1962a, 1963).

CONCLUSIONS

The term bark was frequently used for the phloem tissue and tissues outside it. Bark is a nontechnical term, hence should be clearly distinguished from the technical terms like cortex and periderm (Eames & Mac Daniels, 1947). In stems and

roots having only primary tissues, bark mostly refers to the primary phloem and cortex. In cases where secondary growth takes place it includes secondary phloem, in addition to the primary tissues (Esau, 1964). Thus according to Esau (1964) all the tissues outside the vascular cambium are included in the bark. Periderm should also be clearly distinguished from the term bark. Bark has various meanings but commonly applied to all the tissues outside the vascular cambium. This usage includes primary phloem and cortex in an axis without secondary growth and primary and secondary phloem, various amounts of cortex and periderm in cases where secondary growth has taken place. Bark is also used more often to designate the tissue that accumulates on the surface of the axis as a result of phellogen activity. As periderm develope it separates, varying amounts of primary tissues and secondary phloem, from the adjacent living tissue by means of non-living cork layers. The term bark in its restricted sense is applied to this dead tissue along with the cork layers The use of the term bark in its wide sense is practical and convenient. If so used the cork and tissues isolated by it may be combined under the outer bark which has been called as rhytidome by De bary (1884).

Anatomical studies on the bark of Leguminous plants show that in the younger stages the bark includes the primary tissues while after secondary growth and towards maturity it shows differences. Mature bark can be divided into outer and inner. The former corresponds to the dead tissue and the latter to the living. Further, present study shows that the bark of *Erythrina indica*, *Butea frondosa*, *Caesalpinia pulcherrima*,

Delonix regia, Cassia species Tamarindus indica, Bauhinia variegata, Acacia hockii, A. benthamii, A. senegal, A. cyanophylla, A. sieberiana and Albizzia lebbeck consists of only cork layers while the inner bark includes not only the secondary phloem but also pericycle, cortex and phelloderm. In others the dead outer bark consists of layers of periderm and blocks of secondary phloem isolated by its development while the inner living inner bark consists of secondary phloem alone. To use the term rhytidone for outer bark will not be justified in all the cases as the outer bark in some cases is only cork. Similarly to use periderm for the outer bark will also not be justified as the outer bark in some cases includes cortex, pericycle or even various amounts of secondary phloem. Thus the retention of the bark in wider sense will be practical and convenient than the technical terms.

TABLE X

(Showing average tangential and radial extent of fiber bands in the plants studied).

Name of the plant	Av. tan. extent in microns	Av. rad. extent in microns
Erythrina indica	202.14	84.49
Butea frondosa	110.85	104.91
Dalbergia sisso	101.83	92.52
Cassia auriculata	73.33	44.73
C. fistula	61.51	78.57
C. siamea	96.40	55.50
Tamarindus indica	82.91	62.09
Prosopis spicigera	123.74	40.68
P. juliflora	137.28	44.85
Acacia nilotica	149.26	47.62
A. aneura	88.06	38.14
A. benthamii	127.89	37.13
A. salicina	102.52	41.09
A. cyanophylla	117.83	49.61
A. drepanilobium	143.61	56.50
A. hockii	110.85	20.85
A. ligulata	124.61	45.21
A. senegal	140.78	57.48
A. sieberiana	116.13	42.60
A. spirocarpa	138.30	61.43
A. victoriae	111.59	49.28
Albizzia lebbeck	146.48	64.43

TABLE XI

(Showing class and average length of Sieve tubes and Fibers and ration of elogation of Fibers in comparision to sieve tubes.)

Name of the Plant	SIEVE TUBES Class	SIEVE TUBES Av.length in microns	FIBERS Class	FIBERS Av.length in microns	Elongation Ratio of Fibers.
PAPILIONETAE:					
Erythrina indica	Medium	220.27	Long	1906.38	8.65
Butea frondosa	Small	160.16	Medium	1491.75	9.31
Dalbergia sisso	"	128.80	"	1173.73	9.11
CAESALPINEAE:					
Caesalpinia pulcherrima	Medium	220.90		Absent	-
Delonix regia	Large	314.73		Absent	-
Cassia auriculata	Medium	233.45	Short	793.73	3.40
C. fistula	"	241.67	Medium	1001.01	4.14
C. siamea	"	262.29	"	1101.01	4.19
Tamarindus indica	"	220.32	"	1079.50	4.88
Bauhinia variegata	"	232.42	"	1487.84	6.10
MIMOSEAE:					
Prosopis spicigera	"	268.77	Medium	1106.95	4.11
P. [illegible]iora	"	238.18	"	1072.66	4.50
Acacianilotica	Large	300.04	"	1236.75	4.12
A. aneura	Small	161.63	Short	671.50	4.15
A. benthamii	Medium	259.84	Medium	1247.80	4.80
A. salicina	"	258.14	"	1363.91	5.28
A. cyanophylla	"	248.84	"	1157.70	4.65
A. drepanolobium	"	274.65	"	1334.50	4.85
A. hockii	"	205.62	"	1099.05	5.34
A. ligulata	Large	341.09	"	1472.03	4.31
A. senegal	Medium	263.06	"	1316.14	5.01
A. sieberiana	"	237.29	"	1158.15	4.88
A. spirocarpa	"	268.68	Long	1794.18	6.67
A. victoriae	"	240.51	Medium	1311.21	5.45
Albizzia lebbeck	Large	390.33	Long	1940.64	4.97

TABLE XI

(Showing class and average length of Sieve tubes and Fibers and ration of elogation of Fibers in comparision to sieve tubes.)

Name of the Plant	SIEVE TUBES		FIBERS		Elongation Ratio of Fibers.
	Class	Av.length in microns	Class	Av.length in microns	
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A. cyanophylla	"	248.84	"	1157.70	4.65
A. drepanolobium	"	274.65	"	1334.50	4.85
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A. sieberiana	"	237.29	"	1158.15	4.88
A. spirocarpa	"	268.68	Long	1794.18	6.67
A. victoriae	"	240.51	Medium	1311.21	5.45
Albizzia lebbeck	Large	390.33	Long	1940.64	4.97

TABLE XII

(Showing average angle of inclination of the end walls and sieve plates in the plants studied).

Name of sub-family	Name of the plant	Av.angle in degrees
Papilionatae	Erythrina indica	80.8
"	Butea frondosa	81.6
"	Dalbergia sisso	85.9
Caesalpineae	Caesalpinia pulcherrima	37.0
"	Cassia auriculata	40.3
"	C. fistula	43.0
"	C. siamea	51.1
"	Tamarindus indica	52.3
"	Delonix regia	56.5
"	Bauhinia variegata	57.5
Mimoseae	Acacia victoriae	33.5
"	A. spirocarpa	36.7
"	A. sieveriana	37.7
"	A. ligulata	37.8
"	A. benthamii	38.0
"	A. drepanolobium	39.1
"	A. nilotica	39.9
"	A. aneura	40.2
"	A. hockii	41.9
"	Prosopis juliflora	43.8
"	A. cyanophylla	44.4
"	A. salicina	44.9
"	Albizzia lebbeck	44.9
"	Acacia senegal	46.6
"	Prosopis spicigera	46.6

TABLE XIII

Showing percentage of uni-, bi- and multiseriate rays in the plants studied.

Name of the plant	% uniseriate rays	% biseriate rays	% multi-seriate rays.
Erythrina indica	negligible	negligible	negligible
Butea frondosa	4.007	3.832	92.170
Dalbergia sisso	12.350	42.390	45.260
Caesalpinia pulcherrima	61.575	35.454	3.030
Delonix regia	21.456	26.619	51.929
Cassia auriculata	47.439	29.191	23.364
C. fistula	33.403	57.316	9.279
C. siamea	5.160	24.230	70.610
Tamarindus indica	66.330	21.630	12.000
Bauhinia variegata	39.600	47.700	12.700
Prosopis spicigera	11.760	24.440	63.800
P. juliflora	19.000	24.200	56.800
Acacia nilotica	6.756	14.977	78.266
A. aneura	97.756	2.243	absent
A. benthamii	12.766	12.300	74.935
A. salicina	29.524	24.327	48.118
A. cyanophylla	38.053	30.973	30.973
A. drepanolobium	8.152	15.000	76.847
A. hockii	11.740	17.260	71.000
A. ligulata	34.900	37.450	27.640
A. senegal	0.980	7.000	91.990
A. sieberiana	14.226	19.976	65.797
A. spirocarpa	26.000	15.630	58.280
A. victoriae	36.467	24.210	39.421
Albizzia lebbeck	7.640	18.530	73.830

SUMMARY

Twenty-five species belonging to three genera of Papilionatae, five of Caesalpineae and three of Mimoseae have been investigated.

In Papilionatae surface of bark is variable, while in Caesalpineae bark is smooth in all except Cassia fistula and Tamarindus indica where the bark is rough shallow fissured in Cassia fistula and rough scaly in Tamarindus indica. In Mimoseae, bark is scaly and rough in Prosopis species, rough in Albizzia lebbeck and rough scaly as well as smooth in Acacia species.

Mature bark consists of secondary phloem and periderm, however, in some cases it includes primary tissues like cortex and pericycle. The secondary phloem in all the cases consists of phloem blocks and rays alternating with one another. Each phloem block is characterised by the presence of fiber bands in Papilionatae and Mimoseae, while in Caesalpineae, Caesalpinia pulcherrima lacks fiber bands but shows presence of sclereids. Delonix regia is devoid of fiber bands as well as sclereids. Cassia and Bauhinia variegata show fiber bands which are very small, irregular and closely arranged in Bauhinia variegata. Tamarindus indica is characterised by the

presence of fiber bands in the functional part and fiber bands in association with sclereids in the nonfunctional part. Based on tangential and radial extent of fiber bands the following categories have been recognised:

(i) Fiber band with more tangential extent than radial as in Erythrina indica, Cassia auriculata, C. siamea, Tamarindus indica, Bauhinia variegata, Prosopis species, Acacia species and Albizzia lebbeck.

(ii) Fiber bands with almost equal tangential and radial extent as in Butea frondosa and Dalbergia sisso.

(iii) Fiber bands with more radial extent than tangential as in Cassia fistula.

Fibers are septate as well as nonseptate in Cassia fistula and Prosopis spicigera while nonseptate in the rest. Fibers are short (upto 900.0 microns) in Cassia auriculata and Acacia aneura, long (above 1600 microns) in Erythrina indica, Acacia spirocarpa and Albizzia lebbeck while medium (900 to 1600 microns) in the rest. Shortest fibers are met with in Acacia aneura and longest in Albizzia lebbeck.

Sieve tubes show simple and almost transverse sieve plates in Papilionatae, compound, inclined and vertical(rarely) in Mimoseae and Caesalpineae except Tamarindus indica and

Bauhinia variegata. In the former compound plates are dominant and simple plates rare, while in the latter sieve plates are simple but obliquely oriented.

Sieve tubes are small (100 to 200 microns) in Dalbergia sisso, Butea frondosa and Acacia aneura; large (over 300 microns) in Delonix regia, Acacia nilotica, A. ligulata and Albizzia lebbeck, while in the rest they are medium in size (200 to 300 microns). Sieve tubes are extremely small in diameter (width) in Butea frondosa, Dalbergia sisso, Caesalpinia pulcherrima, Cassia auriculata, Tamarindus indica, Bauhinia variegata, Prosopis juliflora and Acacia species while they are very small in width in Erythrina indica, Delonix regia, Cassia fistula C. siamea, Prosopis spicigera and Albizzia lebbeck. Shortest sieve tubes are met with in Dalbergia sisso and longest in Albizzia lebbeck. Minimum width of sieve tubes is in Acacia victoriae and maximum in Albizzia lebbeck.

Phloem rays are homogeneous type II in all the cases. Multiseriate rays are absent in Acacia aneura. Percentage of uni-, bi- and multiseriate rays variable and has been classified into various categories. Uniseriate rays are short and narrow in Acacia senegal, maximum in height in Butea frondosa and maximum in width in Erythrina indica. Biseriate rays are minimum in height in Acacia senegal and maximum in Cassia fistula. Width of biseriate rays is minimum in Caesalpinia pulcherrima and maximum in Butea frondosa. Multiseriate rays are minimum in height in Tamarindus indica and maximum in

Erythrina indica. Width is minimum in Tamarindus indica and maximum in Butea frondosa. Minimum number of rays per sq. mm. is found in Erythrina indica and maximum in Caesalpinia pulcherrima.

Ray expansion is prominent in all the cases except Acacia aneura and Cassia fistula. Phloem proliferation is prominent in Delonix regia, Prosopis spicigera, Acacia cyanophylla, A. hockii, A. senegal, Cassia fistula, and C. auriculata. Cortical and pericyclic expansion is common in all the plants studied.

Phellogen is superficial in all the plants and active throughout in some while in others it is replaced by subsequent periderm layers to form rhytidome.

Anatomy of the barks shows that the outer bark is made up of rhytidome layers in Dalbergia sisso, Prosopis species, and some species of Acacia. In these cases the inner bark is made up of only secondary phloem. In others the outer bark is only cork as in Caesalpineae and some species of Acacia while inner bark is made up of secondary phloem and cortex and pericycle.

ARTIFICIAL KEY FOR IDENTIFICATION OF GENERA STUDIED

LEGUMINOSAE

- Sieve plates simple, transverse — Papilionatae
  - Rhytidome present, fiber bands regularly arranged — *Dalbergia*
  - Rhytidome absent, fiber bands irregularly arranged — *Butea* and *Erythrina*
    - Fibers medium in length (between 900-1600 u) — *Butea*
    - Fibers long (above 1600 u) — *Erythrina*
- Sieve plates compound and simple but oblique — Caesalpineae
  - Sieve plates simple but oblique — *Bauhinia*
  - Compound sieve plates dominant, simple rare — *Tamarindus*
  - Sieve plates compound and oblique — *Cassia*, *Delonix*, *Caesalpinia*
    - Phloem blocks with fiber bands only — *Cassia*
    - Phloem blocks without fiber bands and sclereids — *Delonix*
    - Phloem blocks with sclereids alone — *Caesalpinia*
- Sieve plates compound, oblique — Mimoseae
  - Rhytidome present — *Prosopis* species & *Acacias* (some) (Not possible to separate)
    - Lenticels not prominent, bole bark smooth — *Acacia* (some)
    - Lenticels prominent, horizontal, bole bark dippled — *Albizzia*
  - Rhytidome absent — *Acacias* (some) & *Albizzia*

Artificial key for the identification of

Cassia species.

Characters	*C. auriculata*	*C. fistula*	*C. siamea*
Bark surface	Smooth, lenticels distinct	Rough lenticels indistinct	Smooth, lenticels distinct
Bark texture	Soft	Soft	Fiberous
Bark thickness	3.0 mm.	9.0 - 10.0 mm.	6.0 - 7.0 mm.
Fibers	Short (length up to 900 u)	Medium (length 900-1600 u)	Medium (length 900-1600 u)
Dominant rays	Uniseriate	Biseriate	Multiseriate
No. of rays per sq. mm.	71.12	103.88	54.64

Artificial key for the identification of

Cassia species.

Characters	*C. auriculata*	*C. fistula*	*C. siamea*
Bark surface	Smooth, lenticels distinct	Rough lenticels indistinct	Smooth, lenticels distinct
Bark texture	Soft	Soft	Fiberous
Bark thickness	3.0 mm.	9.0 - 10.0 mm.	6.0 - 7.0 mm.
Fibers	Short (length up to 900 u)	Medium (length 900-1600 u)	Medium (length 900-1600 u)
Dominant rays	Uniseriate	Biseriate	Multiseriate
No. of rays per sq. mm.	71.12	103.88	54.64

Artificial key for identification of

Prosopis species

Characters	*P. spicigera*	*P. juliflora*
Bark surface	Rough scaly	Scaly deeply fissured
Bark colour	Dull grey	Dark brown
Thickness	10.0 - 12.0 mm.	6.0 - 8.0 mm.
Fibers	Septate and non-septate	Non-septate.
Uniseriate rays	Very fine (Width 15-25 u)	Extremely fine (width below 15 u)
Biseriate rays	Moderately fine (width 25-50 u)	Very fine (width 15-25 u)
Multiseriate rays	Medium (width 50-100 u)	Moderately fine (width 25-50 u)

ARTIFICIAL KEY FOR I

Rhytidome present

A. aneura, *A. nilotica*, *A. ligulata*, *A. salicina*, *A. victoriae*, *A. drepanolobium*, *A. spirocarpa*.

Fiber band Radial extent between 25-50 microns

A. aneura, *A. nilotica*, *A. salicina*, *A. ligulata*

A. victoriae

Fiber band radial extent between 50-75 microns

A. spirocarpa, *A. drepanolobium*

Fibers short in length

(upto 900 microns)

A. aneura

Fibers medium in length

(900 - 1600 microns)

A. nilotica, *A. ligulata*,

A. victoriae, *A. salicina*

Fibers long

(above 1600 microns)

A. spirocarpa

Fibers medium in leng

(900-1600 microns)

A. drepanolobium

Multiseriate rays dominant

A. nilotica, *A. salicina*, *A. victoriae*

Biseriate rays dominant

A. ligulata

No. of rays per sq. mm. 11-20

A. nilotica

No. of rays per sq. mm. 51-60

A. salicina

No. of rays per sq. mm. 61-70

A. victoriae

Rhytidome present

A. aneura, *A. nilotica*, *A. ligulata*, *A. salicina*, *A. victoriae*, *A. drepanolobium*, *A. spirocarpa*.

Fiber band Radial extent between 25-50 microns

A. aneura, *A. nilotica*, *A. salicina*, *A. ligulata*

A. victoriae

Fiber band radial extent between 50-75 microns

A. spirocarpa, *A. drepanolobium*

Fibers short in length

(upto 900 microns)

A. aneura

Fibers medium in length

(900 - 1600 microns)

A. nilotica, *A. ligulata*,

A. victoriae, *A. salicina*

Fibers long

(above 1600 microns)

A. spirocarpa

Fibers medium in length

(900-1600 microns)

A. drepanolobium

Multiseriate rays dominant

A. nilotica, *A. salicina*, *A. victoriae*

Biseriate rays dominant

A. ligulata

No. of rays per sq. mm. 11-20

A. nilotica

No. of rays per sq. mm. 51-60

A. salicina

No. of rays per sq. mm. 61-70

A. victoriae

TIFICATION OF ACACIA BARKS

Rhytidome absent

A. hockii, *A. benthamii*, *A. cyanophylla*, *A. sieberiana*, *A. senegal*.

Fiber band radial extent upto 25 microns

A. hockii

Fiber band radial extent between 25-50 microns

A. benthamii, *A. sieberiana*, *A. cyanophylla*

Multiseriate rays dominant

A. banthamii, *A. sieberiana*

Biseriate rays least, bark with cracks, dull brown

A. benthamii

Uniseriate rays least, bark smooth, yellowish green

A. sieberiana

Uniseriate rays dominant

A. cyanophylla

Fiber band radial extent between 50-75 microns

A. senegal

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* Originals not seen.