

Comparative Anatomical Studies of the Stem of Ulmaceous Plants in Taiwan

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I. Introduction

It is generally recognized by botanists that the structures of the plant body vary with their functions. In other words, plant anatomy is intimately related to plant physiology. It seems that early plant taxonomists did not pay much attention to anatomical characteristics of plants until cytologists and geneticists had recently made great contributions to the classification of lower plants. They therefore began emphasizing internal morphology as a factor in the classification of higher plants.

For the three species of *Celtis* cited in this paper, no distinct differences were found among them with regard to internal morphology. As for their external morphology, the items for classification also seemed quite meager. (This point will be discussed later). So it was apparent that classifying plants solely on one aspect of characteristics was not prudent.

This paper was aimed at dissecting young stems of various plants to compare the primary tissues in order to determine their natural taxonomic kinships. The author here offers his thanks to Prof. T. S. Liu, National Taiwan University, Prof. & Head of Dept. of Botany, S. T. Yi, Prof. Y. C. Liu, Taiwan Provincial Chung Hsing University, Prof. C. N. Chang, Taiwan Prov. agricultural Institute and Mr. C. Liu, Taiwan Forestry Research Institute for their valuable assistance. Thanks also are given to the National Council on Science Development for the subsidies.

II. Materials and Methods

1. **Materials** Plants in the Ulmaceae are all woody plants, including 15 genera, about 140-150 species, distributed over the temperate, sub-tropical and tropical zones of the Northern Hemisphere. 8 genera are found in China of which 2 genera are indigenous. 5 genera and 10 species were found in Taiwan. They are listed as follows:

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No	Scientific Name	Collecting Date	Place	Collector
1.	<i>Aphananthe aspera</i> (Thunb.) Planch.	Apr. 10, 1965	Chi-San-Yan	Lee
2.	<i>Celtis formosana</i> Hay.	Mar. 15, 1965	Taipei Aboretum	Lee
3.	<i>Celtis nervosa</i> Hemsl.	Mar. 21, 1965	Kaoshung	Lee
4.	<i>Celtis philippenensis</i> Bl.	(omit)	(Lack)	Lee
5.	<i>Celtis sinensis</i> Pers.	Mar. 15, 1965	Taipei Aboretum	Lee
6.	<i>Trema cannabina</i> Lour.	Mar. 28, 1965	Sun-Moon Lake	Lee
7.	<i>Trema orientalis</i> (Linn.) Bl.	Mar. 15, 1965	Taipei Aboretum	Lee
8.	<i>Ulmus parvifolia</i> Jacq.	Mar. 15, 1965	Taipei Aboretum	Lee
9.	<i>Ulmus uyematsui</i> Hay.	Apr. 5, 1965	Ta-Shui-Shan	Lee
10.	<i>Zelkova formosana</i> Hay.	Apr. 15, 1965	Taipei Aboretum	Lee

After collection of the newly developed shoots, they were fixed with FAA immediately and brought back and cut into sections of desired length as required. As *Celtis philippenensis* is a native of Lan-yu, an off-island of Taiwan, it is regretted that a specimen could not be obtained.

2. Methods

A. Slide preparation. The above mentioned specimens were cut into one apical piece, 0.5--1 cm in length, and several succeeding pieces, each measuring 1 cm. The apical piece included the apical meristem and the region of differentiation. The other pieces were mature regions. Both cross sections and longitudinal sections were made with the paraffin method, then dyed with Delafields' haematoxylin and Safranin O, and prepared as permanent slide specimens.

B. Observations. As the primary tissues apparently had reciprocal relations with primary meristems, the observations were under three headings:

- (1) Epidermal tissue system--including epidermis and its appendages,
 - a. Thickness of tissue, morphology of cells, and outer walls of epidermis.
 - b. Kinds, morphology and structure of epidermal hairs.
- (2) Ground tissue system--including cortex, pith and pith rays.
 - a. Morphology and structures of cells in various parts.
 - b. Number and distribution of collenchyma cells.
 - c. Presence or absence and distribution of secretory cells.
 - d. Presence or absence and site of mucilaginous cavity.
 - e. Presence or absence and shape of crystals.
- (3) Vascular tissue system--including pericyclic region and vascular tissues.
 - a. Morphology of pericyclic sclerenchyma and parenchyma. Presence or absence and distribution of secretory cells.
 - b. Kinds, morphology and distribution of cells in phloem and xylem; morphology of cambial zone.

(As little difference was found among the apical meristematic tissues and among the tissue differentiating regions under the light microscope, they were not recorded respectively)

C. **Photography.** The above mentioned slides were photographed separately with a microscopic camera, and magnified. For comparison with textual descriptions, preciseness and accuracy were highly demanded.

III. Descriptions

1. **Chu-yi-shu** (Rough-leaved tree)

Scientific name *Aphananthe aspera* (Thunb.) Planch. in Dc. Prodr. XVII, (1873) 208.

Synonyms *Prunus aspera* Thunb. Fl. Jap. (1878) 201.

Homoioceltis aspera Blume Mus. Bot. Lugd-Bat. II, (1846) 64.

Celtis mukii Sieb. et Zucc. in abh. akad. muench. IV, 3(1846) 223.

Sponia nudiflora sieb. et Zucc. in l.c.

Celtis sinensis Dunn & Tutch. in Kew Bull. Misc. Inform. add. ser. X, (1912) 243. (Proparte)

Homoceltis japonica Hort. ex Rehd. in Bailey. Stand. Cycl. Hort. I, (1914) 208.

Deciduous trees or shrubs. Bark brown-grey, with blotches or wrinkles becoming long splits in old trees, scaly deciduous. Branchlets dark red brown. Buds brown, spindle-form or flat and crooked. scales with silverwhite soft hairs convolute in two layers, stiff hairs found on branchlet, leaf petiole and both sides of leaf blade. Shangtung, Kuangtung, Kungsi and Taiwan, Hardwood, leaves used for polishing copper and tin utensils.

- (1) Epidermal tissue system: Epidermis single layer, cells isodiametric, outer wall convex, cuticle significant. Unicellular hairs with swollen base and circular in shape, embedded in epidermis, causing conspicuous swellings, apex acute, wall especially thick, calcified, small papillae on the outer surface. Multicellular hairs with enlarged head, 4-5 glandular cells, stalk with 1-2 cells.
- (2) Ground tissue system: Cortex includes 1-2 layers of collenchyma cells with endodermoid and pericyclic region inside. Pith with large and spherical central cell, smaller cells bordering protoxylem, druse crystals dispersed in them. Pith rays 2-5 cells wide, reaching cortex.
- (3) Vascular tissue system:
 - a. Pericyclic region is composed of sclerenchyma and secretory cells; the latter contain gray mucilage.
 - b. Collateral vascular bundle phloem is narrow and acute on both sides, wide in center, of semicircular shape, sieve tubes and companion cells present, with large mucilaginous cells and parenchyma cells containing druse. Cambium layer curved like an arc, various sections wave-like. Xylem crescent in shape, sieve tubes and fibers alternately arranged, mostly single layered, radiate, vessel walls with spiral thickenings, end wall horizontal or slightly oblique, perforations simple.

2. **Taiwan Po-shu** (Taiwan Hackberry)

Scientific name *Celtis formosana* Hay. mat. Fl. Formos. (1911) 272

Synonym *Celtis sinensis* sensu Henry. List Pl. Formos. (1896) 85, non Pers.
Celtis philippenensis sensu. et Hay. in Journ. Coll. Sci. Univ.
Tokyo XXII, (1906) 369, non Blanco.

Evergreen or semi-deciduous trees, shade intolerant. Bark gray, rough, with many lenticels. Branches red brown, branchlets thin, smooth (hairy according to author's observation). Taipei. Taichung, Yusan, and Hengchun. Fuel wood.

(1) Epidermal tissue system: Epidermis single layer, cells isodiametric or somewhat longitudinally elongated, cuticle significant. Unicellular hairs slender and pointed, with swollen base in T shape, walls thick, calcified, smooth. Multicellular hairs with enlarged heads, glandular cells 4-6, stalk 3-4 cells, in single row.

(2) Ground tissue system: Cortical cells 7-9 layers, cells mostly longitudinally elongated. Druse crystals common. Endodermoid cells tangentially elongated in cross section. Pith with large round central cells, the longitudinal axis slightly shorter. Crystals disperse. Pith rays 1-3 layers wide, reaching cortex, with crystals at the end.

(3) Vascular tissue system:

a. Pericyclic region composed of sclerenchyma and parenchyma, the latter with druse crystals in it.

b. Vascular bundle phloem with sieve tubes and companion cells, and druse crystals in parenchyma cells. cambial zone with sections connected forming a wavy ringshape. Xylem with vessels radiately arranged in single rows alternately with fibers and parenchyma cells, occasionally with two rows, also with crystals. Vessels mostly with annular thickenings, end wall flat or slightly slanted, perforations simple.

3. She-sha-po (small-leaf Hackberry)

Scientific name *Celtis nervosa* Hemsl. in Journ. Soc. Bot. XXVI, (Ind. Fl. Sin. II)
Deciduous small trees or shrubs. Bark gray, rough, with lenticels. Leaf ovate. Indigenous in Southern Taiwan and Pa-long-wei of Taitung Hsin. Fuel wood.

(1) Epidermal tissue system: Epidermis single layer, cell cross section isodiametric, with slightly elongated axis, outer wall smooth, cuticle significant. Unicellular hairs pointed and slender, the base swollen longitudinally in T shape, wall thick, calcified, smooth in appearance. Multicellular hairs with swollen heads, glandular cells 6-9, stalk 3-5 cells, single row arrangement.

(2) Ground tissue system: Cortical cells 5-8 layers, isodiametric or slightly elongated in longitudinal axis. Druse Crystals common. Pith cells with shorter longitudinal axis, the central ones larger, the outer ones smaller. Pith rays 1-3 layers wide, reaching cortex, with many crystals at the end.

(3) Vascular tissue system:

a. Pericyclic region of sclerenchyma.

b. Collateral vascular bundle; phloem, with the exception of sieve tubes and companion cells, possessing crystals in parenchyma tissue. Cambial zone

incurved in V shape in the center. Xylem vessels radiately arranged in single row, sometimes biseriate, alternate with fibers and parenchyma cells, end wall transverse or slightly slanted. perforations simple.

4. Philippine po-shu (Philippine Hackberry)

Scientific name *Celtis philippenensis* Blanco. Fl. Filip. (1837) 197.

Evergreen shrubs; shade intolerant; prefer wet soil. Leaves leathery, elliptic. Distributed in Hainan island, Kungtung, the Philippines, Malay. Also indigenous in Lutao, Lanyu, two off-islands of Taiwan. Fuel wood (Specimen lacking)

5. Sa-po (Chinese Hackberry)

Scientific name *Celtis sinensis* pers. Syn. pl. I, (1805) 292.

Synonym *Celtis orientalis* sensu Thunb. Fl. Jap. (1784) 114, non Linn.

Celtis japonica Planch. in De. Prodr. XVII, (1873) 172.

Deciduous trees; shade intolerant; prefer wet soil. Bark gray brown, rough with many lenticels. Branchlets gray brown, densely haired, spreading or slightly drooping. Distributed in Southern China, lowland of Taiwan. Shade trees, fuel wood and ship making.

(1) Epidermal tissue system: Epidermis single layer, cells isodiametric, outer wall smooth, cuticle significant. Unicellular hairs pointed and slender, the base embedded under epidermal cell and elongated longitudinally, wall thick, calcified. Multicellular hairs with swollen heads, glandular cells 4-6, stalk 5-8, in single row.

(2) Ground tissue system: Cortical cells 5-8 layers, isodiametric or slightly elongated longitudinally, with sclerenchyma outside, parenchyma inside, all with chlorophyll. Pith cells isodiametric, central ones larger, outer ones small. Pith ray 1-4 layers wide, reaching cortex.

(3) Vascular tissue system:

a. Pericyclic region of sclerenchyma.

b. Collateral vascular bundles regular in shape, evenly arranged. Phloem parenchyma significant, druse crystals universal. Sieve tube members have only end wall with sieve plate, horizontal to slightly slanted. Cambial zone straight, sections connected in a circle. Xylem vessels radiately single row arranged, alternate with fibers and parenchyma cells, wall with spiral thickenings, end wall horizontal to slightly slanted, perforations simple.

6. Shan-yu-ma (Narrow-leaf Trema)

Scientific name *Trema cannabina* Lour. Fl. Cochinch. (1790) 563.

Synonym *Celtis amboinensis* Willd. Sp. Pl. IV, 2 (1805) 997.

Sponia amboinensis Decne. in Nouv. Ann. Mus. Paris IV, (1834) 498.

Trema amboinensis (Decne) Bl. Mus. Bot. Lugd. Bot II, 2 (1856) 61.

Sponia velutina Planch. in Ann. Sci. Nat. Bot. III, 10 (1848) 316.

Shrubs. Bark gray. Branchlets slender and long, brown with short hairs. Buds.

Leaves narrow lanceolate. Distributed in Southern China, the Philippines, Malay and Australia and hillsides of Taiwan. Wood reddish in color, semi-hard in texture, of no particular use.

(1) Epidermal tissue system: Epidermis single layer, cells slightly elongated longitudinally, outer wall somewhat convex. Cuticle not significant. Unicellular hairs pointed and slender, base globularly swollen and causing epidermis to be convex outwardly. Walls thick, calcified, tiny protuberances on the outer surface. Multicellular hairs swollen at base, glandular cells 5-8, stalk 3-5 cells, in single row.

(2) Ground tissue system: Cortical cells 4-6 layers, outer collenchyma longitudinally elongated, inner parenchyma cells isodiametric, with chlorophyll. Pith cells isodiametric, central ones large, outer ones smaller. Pith rays 1-4 layers wide, reaching cortex.

(3) Vascular tissue system:

a. Pericyclic region of sclerenchyma.

b. Collateral vascular bundles vary in size, but of even arrangement.

Phloem with only sieve tubes, companion cells, parenchyma and no fibers. Cambial zone connected forming a seven-sided figure with the sides parallel to the epidermis. Xylem vessels single row radiately arranged, two rows in larger vascular bundles, alternate with fibers; walls mostly with spiral thickenings, end wall horizontal to slightly slanted. Perforations simple.

7. San-huang-ma (India charcoal Trema)

Scientific name: *Trema orientalis* (Linn.) Bl. *mus.* Bot. Lugd. Bot. II, (1856) 62.

synonym *Celtis orientalis* Linn. sp. Pl. I, (1753) 1044.

Deciduous small or medium sized trees, shade intolerant, of fast growth and short-lived. Bark brown, many lenticels. Branchlets green with soft hairs. Buds naked. Leaves alternate, ovate. Distributed in southern China, India, Malay, Australia, Liuchu Islands. Found on Taiwan plains, abundant along streams, wood used for tools, charcoal, gun-powder, wood slippers, match sticks and paper-manufacture.

(1) Epidermal tissue system: Epidermis single layer, cells isodiametric, outer wall has papillae, cuticle significant. Unicellular hairs thick and stiff, can be seen with naked eye, and touched by hand, apex pointed, base swollen, causing epidermis to be slightly convex, walls thick, calcified, surface smooth. Multicellular hair head with glandular cells swollen like a sac. Stalk 4-6 cells, in single row.

(2) Ground tissue system: Cortical cells 8-10 layers, isodiametric, composed of parenchyma and sclerenchyma, sometimes with secretory cells, druse crystals generally present, especially in proximity to endodermoid. Pith cell large and round at center, horizontally elongated 2-3 times its diameter slightly smaller cells surrounding, and many secretory cells. Pith rays 1-3 layers wide, reaching cortex, cells mostly with fatty substance.

(3) Vascular tissue system:

- a. Pericyclic region with small amount of sclerenchyma, band-like, attached to the outside of phloem.
- b. Collateral vascular bundles vary in size, arrangement fairly uniform. No fibers present in the phloem; crystals and fatty substance generally present in parenchyma cells, but not in sieve tubes and companion cells. The cambial zones in large bundles are arc-like, those in small bundles straight, connecting together forming irregular rings. Xylem with vessels radiately arranged in single row, sometimes in two rows, alternate with fibers, vessel wall with spiral thickenings, end wall horizontal to slightly slanted, perforations simple. Fatty substances found in parenchyma.

8. **Lung-yu** (Chinese elm)

Scientific name *Ulmus parvifolia* Jacq. in *Pl. Rar. Hort. Schoenbr.* III, (1789) 6. t. 262.

Synonym *Ulmus sieboldii* Daveau. *Bull. Soc. Dendr. France* (1914) 24-25.
Ulmus chinensis Pers. *Syn. I*, (1805) 291.
Planera parvifolia Sweet. *Hort. Brit. ed 2*, (1830) 464.
Microptelea parvifolia Spach in *Ann. Sci. Nat. ser. 2*, XV, (1841) 358.

Deciduous trees; shade intolerant. Bark gray brown, rough, scaly deciduous. Branchlets with hairs. Winter buds brown, ovate and slightly flat, pointed at apex; scales smooth, imbricate, in two rows. Leaves elliptic. Distributed in Southern and Central China, Japan, Korea, also in southern jungles along streams of Taiwan.

- (1) Epidermal tissue system: Epidermis single layer, cells radially elongated, outer wall with papillae, cuticle not significant. Unicellular hairs with pointed apex, slightly swollen base, embedded in epidermal cells with apparent protuberances, wall thick, surface smooth. Multicellular hairs with head swollen, glandular cells 1-5, stalk 2-4 cells, in single row.
- (2) Ground tissue system: Cortical cells 5-7 layers, longitudinally elongated; the outermost 1-2 layers are sclerenchyma, regularly arranged, with many secretory cells, mucilaginous cavity and longitudinally elongated sac-like cell within, the latter distributed mostly along endodermoid. Pith circular in shape. Cells isodiametric, central ones larger, those of outer layer smaller, also with sac-like secretory cells. Pith rays slender and long, mostly single layer, reaching cortex.
- (3) Vascular tissue system:
 - a. Pericyclic region band like, with sections at the outside of vascular bundle, formed by sclerenchyma and a few secretory cells.
 - b. Collateral vascular bundles similar in size, of regular shape, arranged in a ring. Phloem with sieve tubes, companion cells and fiber strands, parenchyma cells large and significant. Cambial zone with sections straight, connected and forming a ring. Xylem with fibers, parenchyma and vessels; vessel wall

has spiral or pitted thickenings, end wall horizontal to slightly slanted, perforations simple.

9. Alishan yu (Alishan elm)

Scientific name *Ulmus uyematsui* Hay. Icon. Pl. Formcs. III, (1913) 174, t. 32.

Deciduous trees. Bark rough, scaly deciduous in old tree. Branches slender, slightly drooping. Buds brown, elliptic, scales smooth, imbricate, spirally arranged. Leaves elliptic to oblong, doubly serrate. Indigenous on Mount Ali, and Mount Tashi. Wood for furniture and utensils.

(1) Epidermal tissue system: Epidermis single layer, cells longitudinally elongated, outer wall slightly convex outward, cuticle prominent. Unicellular hairs short and pointed, base swollen into short pyramid, walls thick, calcified, surface smooth. Multicellular hairs with swollen head, glandular cells 2-4 stalk 2-4 cells, in single row.

(2) Ground tissue system: Cortical cells 7-14 layers, those near surface are collenchyma, the inner ones are parenchyma, all elongated longitudinally with prominent mucilaginous cavity. Secretory cells with a drop-like substance are found along endodermis. Pith cells isodiametric, central ones large, outer ones small, and secretory cells at the outermost layer. Pith rays narrow and long, 1-2 layer wide, reaching cortex, many secretory cells.

(3) Vascular tissue system:

a. Pericyclic region cap-like, secretory cells mixed in sclerenchyma.

b. Collateral vascular bundles vary in size, uneven in arrangement. Phloem with fibers, sieve tubes and companion cells, mucilaginous cells prominent. Cambial zone with sections straight, incurved or outcurved, forming irregular ring. Xylem vessels radially arranged in single row, alternate with fibers and parenchyma, vessel walls with spiral or pitted thickenings, end walls horizontal to slightly slanted, perforations simple.

10. Taiwan Chu (*Zelkova*)

Scientific name *Zelkova formosana* Hay. Icon. Pl. Formcs. IX, (1920) 104, f. 33, 1 & 2.

Synonym *Zelkova acuminata* sensu Hay. Ind. Fl. Formcs. (1916) 71, non Planch.

Zelkova tarokoensis Hay. Icon. Pl. Formcs. IX, (1920) 104, f. 33, 3 & 4.

Zelkova serrata (Thunb.) Mak. var. *tarokoensis* (Hay.) Li. in Journ. Wash. Acad. Sci. XIII, (1952) 40.

Deciduous large trees; shade intolerant, trunk straight. Bark gray, rough, scaly deciduous in old trees, brown and with conspicuous lenticels in small trees. Winter buds brown, ovate, scales imbricate, spirally arranged. Leaves long ovate. Indigenous at 300-1000 m altitude in broadleaved forests in Taiwan. Wood superior.

(1) Epidermal tissue system: Epidermis single layer, cells isodiametric, outer walls slightly convex, cuticle not significant. Unicellular hairs pointed, base swollen,

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walls thick, calcified, smooth surface. Multicellular hairs with round swollen head, glandular cells 1-4, stalk 1-2 cells in single row.

(2) Ground tissue system: Cortical cells 5-9 layers, those near epidermis are collenchyma, inner ones are parenchyma, all are longitudinally elongated, simple crystals of common occurrence; endodermoid significant, cells isodiametric, many secretory cells. Pith cells isodiametric, central ones large, outer ones small, with secretory cells. Pith ray cells 1-2 layers, reaching cortex, mostly secretory cells.

(3) Vascular tissue system:

- a. Pericyclic region with small amount of sclerenchyma, secretory cells disperse.
- b. Collateral vascular bundle similar in size, evenly arranged. Phloem with fibers and large parenchymatous secretory cells besides sieve tubes and companion cells. Cambial zone flat and straight, connecting into a ring. Xylem vessels radially arranged, alternate with fibers and parenchyma cells, vessel walls with spiral thickenings, end walls horizontal or slightly slanted, perforations simple.

IV. Key to Ulmaceous Trees in Taiwan

- A With crystals and secretory cells
 - B With druse crystals
 - C Unicellular hairs with papillae..... 1. *Aphananthe aspera*
 - CC Unicellular hairs with smooth surface.....7. *Trema orientalis*
 - BB With simple crystals.....10. *Zelkova formosana*
- AA With crystals, no secretory cells 2. *Celtis formosana*
..... 3. *Celtis nervosa*
..... 5. *Celtis sinensis*
- AAA With secretory cells, no crystals
 - B Cortex with secretory cells and mucilaginous cavity.....
..... 8. *Ulmus parvifolia*
 - BB Cortex with mucilaginous cavity, but no secretory cells
..... 9. *Ulmus uyematsui*
- AAAA No crystals, no secretory cells..... 6. *Trema cannabina*

V. Discussion

(1) The interrelationships among physiology, anatomy and taxonomy.

From what was observed in the above sections, it is clear that crystals, secretory cells and mucilaginous cavities are the most specific anatomical characteristics of ulmaceous plants. These facts may lead to hypotheses as follows:

1. The formation of crystals, secretory cells and mucilaginous cavities may be influenced by metabolism.
2. It is a general tendency that morphological characteristics are the results of physiological activities.

3. Both external morphological characters and internal morphological special structures can be used as prime evidences and important references for taxonomic purposes.
 4. An intimate connection exists among physiology, anatomy and taxonomy.
- (2) The suggestion of "Endodermoid"
- As far as the internal structure of the ulmaceous stem is concerned, generally there is no definite boundary between cortical and vascular regions.
1. In the young gymnospermous stems, starch grains are always found deposited in the innermost cells, to which the term "starch sheath" is applied.
 2. Endodermis, i.e., the innermost layer of cortex with Casparian strips, is found in the stems of some dicotyledonous plants, e.g., Ambrosia.
 3. Neither starch sheath nor endodermis is found in the stems of most seed plants. In other words, there is no morphological boundary between the cortex and the vascular system.
 4. When physiological or chemical methods are used, the different responses of outer fundamental tissue and inner vascular tissue make it evident that there exists a physiological boundary.
 5. In the many ulmaceous species observed, no Casparian strip exists, but several distinct features are found in the perivascular region cortex cells; they are (a) of somewhat regular arrangement, (b) tangentially elongated, (c) often concentrated with crystals and secretory cells.
 6. It is conceivable that these cells might have a physiological border effect, so that term "endodermoid" is suggested by the author.
- (3) Investigations on the pericyclic region
- In the stems of dicotyledonous plants, prior to formation of secondary tissue, continuous or discontinuous fibers are found in the outer layer of vascular tissue. Their origins vary with plants; some of the same origin as phloem are called primary phloem fibers, others originate from the outer meristematic tissue of phloem and are called perivascular fibers. Both kinds of fibers may be combined under the term primary extraxylary fibers.
- The observations obtained in ulmaceous plants are as follows:
1. Three distinct zones are found in the region of differentiation, i.e., protoderm, ground meristem, procambium.
 2. In the mature region, the primary tissues also include an epidermal tissue system, a ground tissue system and a vascular tissue system. Distinct boundaries exist. All specimens are in a similar condition.
 3. It is evident that the three primary tissues are developed from their primary meristematic tissues.
 4. The outer tissues of phloem, whether they are of sclerenchyma, or of combined sclerenchyma and parenchyma, are united with cambium and xylem, forming strands.
 5. The pericyclic region tissue and vascular tissue are found to be of the same

origin.

6. The pericyclic region includes those tissues which both in origin and in development might come from the outermost part of the procambium.

(4) Classification of species of *Celtis*

1. Four species of *Celtis* are found in Taiwan province. As *Celtis philippinensis* is produced on Langyu Island, only three species are included here.

2. The general external morphological characters for taxonomic work are:

- A Leaf base round or heart-shaped.....3. *Celtis nervosa*
- AA Leaf base oblique
 - B Leaf and young branch smooth in appearance, no hairs2. *Celtis formosana*
 - BB Leaf and young branch with short hairs5. *Celtis sinensis*

3. Leaf shapes are only of classificational value, and epidermal hairs are present in all ulmaceous plants observed by the author. It is thus self-evident that the above *Celtis* key is incorrect.

4. As this paper deals with plant taxonomic work based on anatomical characters, the external morphological characters, especially sizes and numbers, are not emphasized.

5. From the author's observation, these three species are quite identical in their primary tissues.

6. It is concluded that for the classification of *Celtis* species, the bases for taxonomy, whether of external or inner morphology, need further study.

臺灣產榆科(Ulmaceae)植物莖之比較解剖

李 春 序*

摘 要

(一) 省產榆科 (Ulmaceae) 植物共計 10 種 (其中菲律賓朴樹 *Celtis philippinensis* 一種未採到) 分隸五屬。

(二) 表皮毛為其共同特徵分為單細胞 (Unicellular) 毛及多細胞 (Multicellular) 毛二種。

(三) 分泌細胞 (Secretory cells) 及結晶體 (Crystals) 之有無種類等, 為其主要解剖特徵。

1. 有分泌細胞, 亦有結晶體者計 (1) *Aphananthe aspera* (7) *Trema orientalis* (10) *Zelkova formosana* 共三種。
2. 有分泌細胞, 無結晶體者計 (8) *Ulmus parvifolia* (9) *Ulmus uyematsui* 共二種。
3. 有結晶體, 無分泌細胞者計 (2) *Celtis formosana* (3) *Celtis nervosa*, (5) *Celtis sinensis* 共三種。
4. 無分泌細胞, 亦無結晶體者計 (6) *Trema cannabina* 一種。

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** 本文曾在臺灣省立博物館科學年刊第八卷 (五十四年十二月) 首篇以中文發表。

- (四) 生理學，解剖學及分類學一脈貫通，相互為用，具有因果關係。
- (五) 皮層最內層細胞雖無 Casparian strip 但略有形態上之差別及可能為生理上之界限，故特名之曰擬內皮 (Endodermoid)。
- (六) 維管束鞘區 (Pericyclic region) 之組織乃來自原始形成層 (Procambium)，似可置信。
- (七) 朴樹屬 (Celtis) 各種間在外部及內部形態上，其區別均不甚顯著。

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Description of Plates

a=Cross section of stem

b=Longitudinal section of stem

c=Longitudinal section of apical meristem

Plate	Figure	Number	Scientific name	section		
I	1.	1.	<i>Aphananthe aspera</i>	a	b	c
	2.	2.	<i>Celtis formosana</i>	a	b	c
	3.	3.	<i>Celtis nervosa</i>	a	b	c
II	4.	5.	<i>Celtis sinensis</i>	a	b	c
	5.	6.	<i>Trema cannabiana</i>	a	b	c
	6.	7.	<i>Trema orientalis</i>	a	b	c
III	7.	8.	<i>Ulmus parvifolia</i>	a	b	c
	8.	9.	<i>Ulmus uyematsui</i>	a	b	c
	9.	10.	<i>Zelkova formosana</i>	a	b	c



plate 1

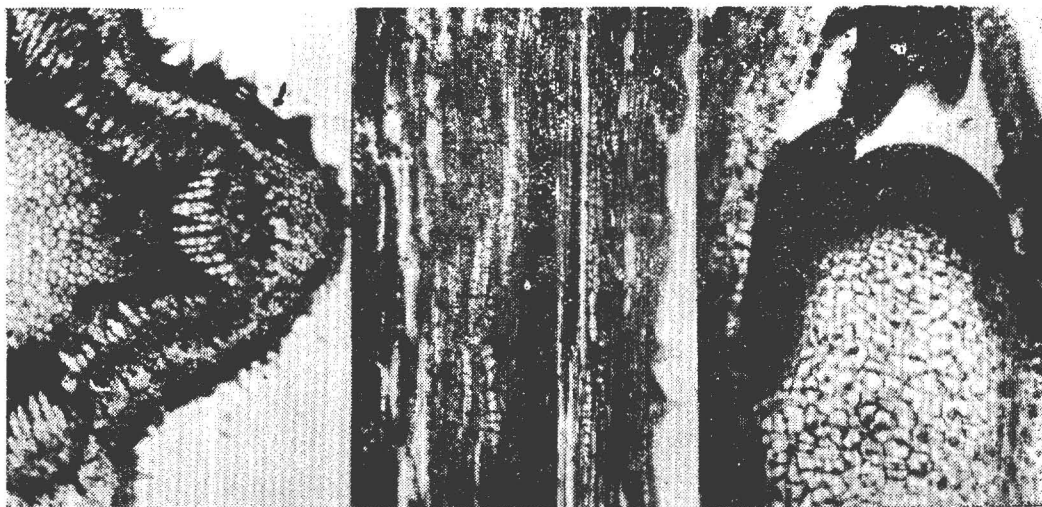


Fig 1. a×70

1. b×70

1. C×280



Fig 2. a×70

2. b×70

2. C×280

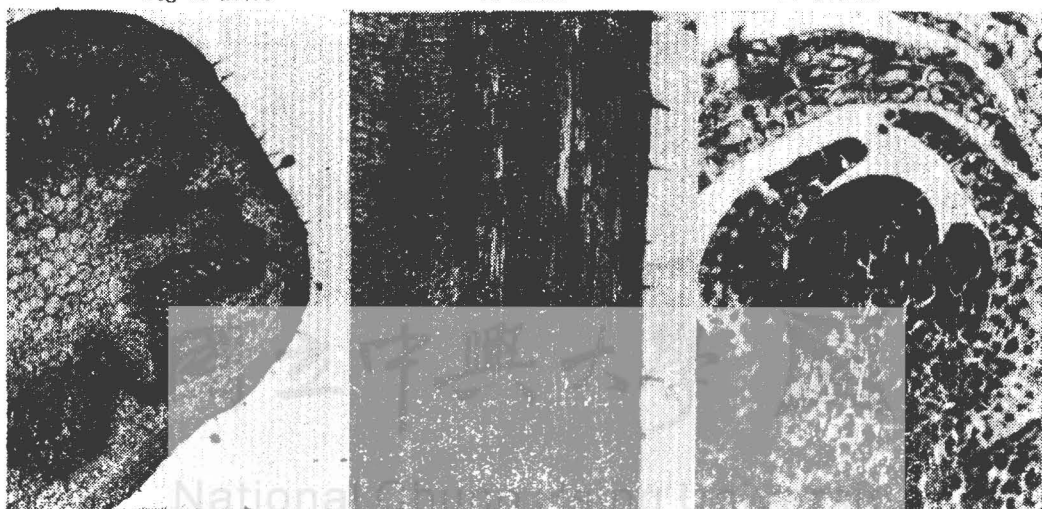


Fig 3. a×70

3. b×70

3. C×280

plate 2

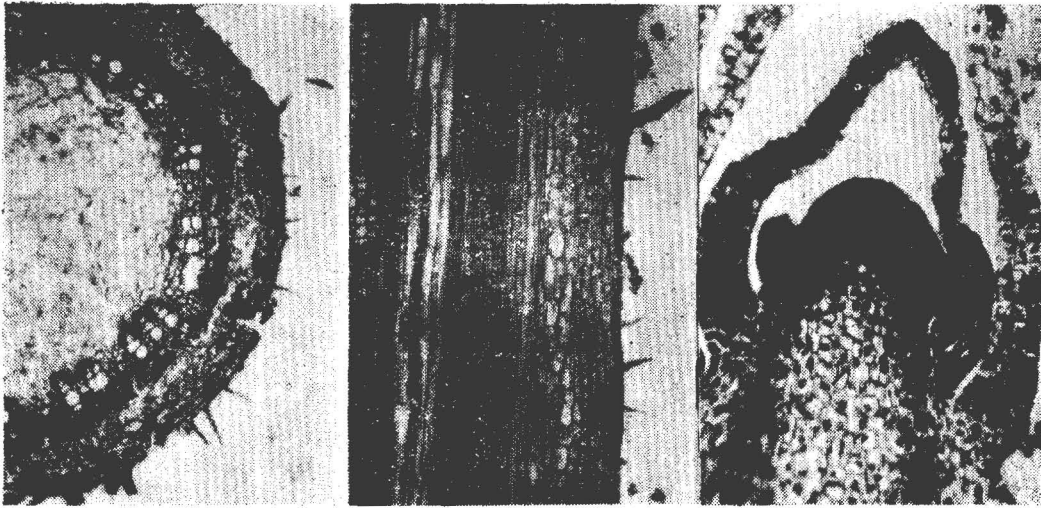


Fig. 4. a×70

4. b×70

4. C×280

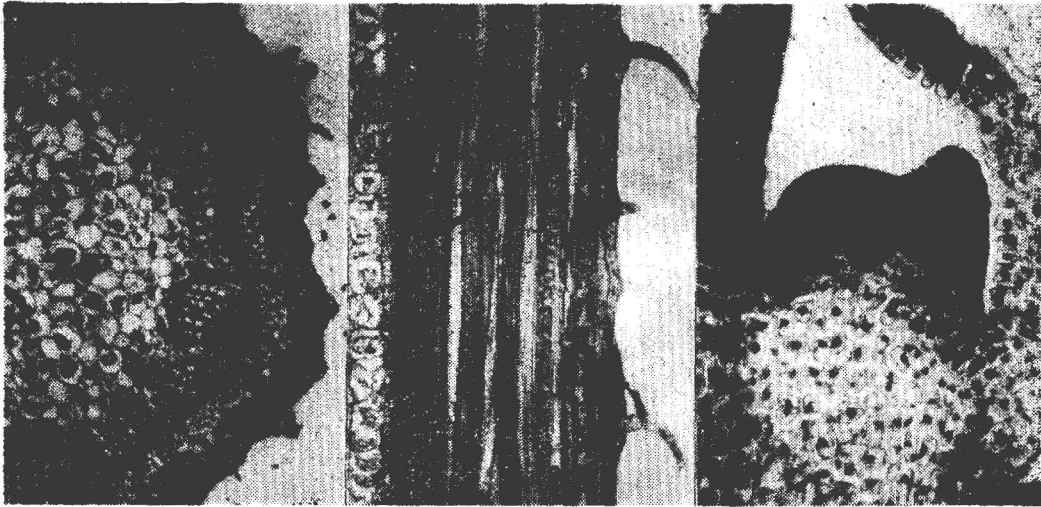


Fig. 5. a×70

4. b×70

4. C×208

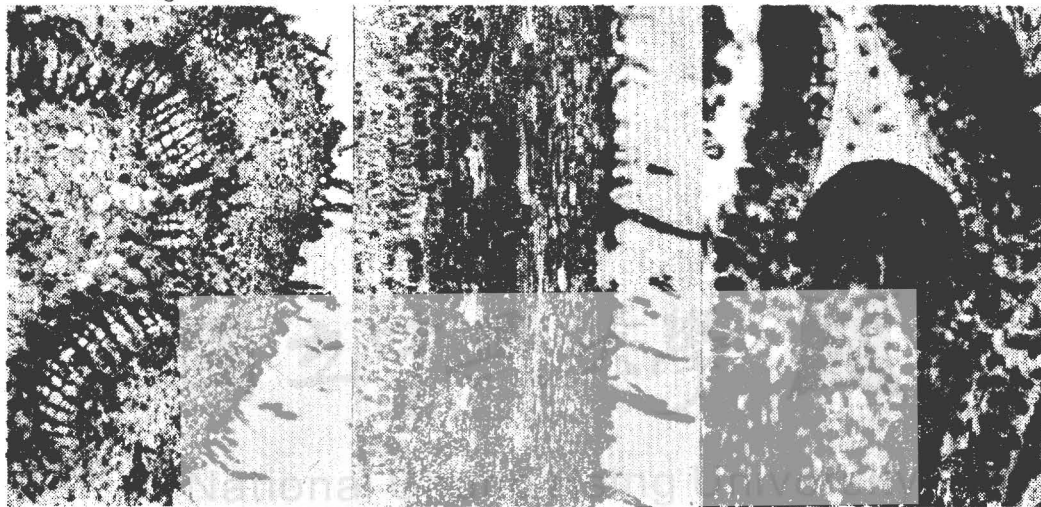


Fig. 6. a×40

6. b×40

4. C×280

plate 3

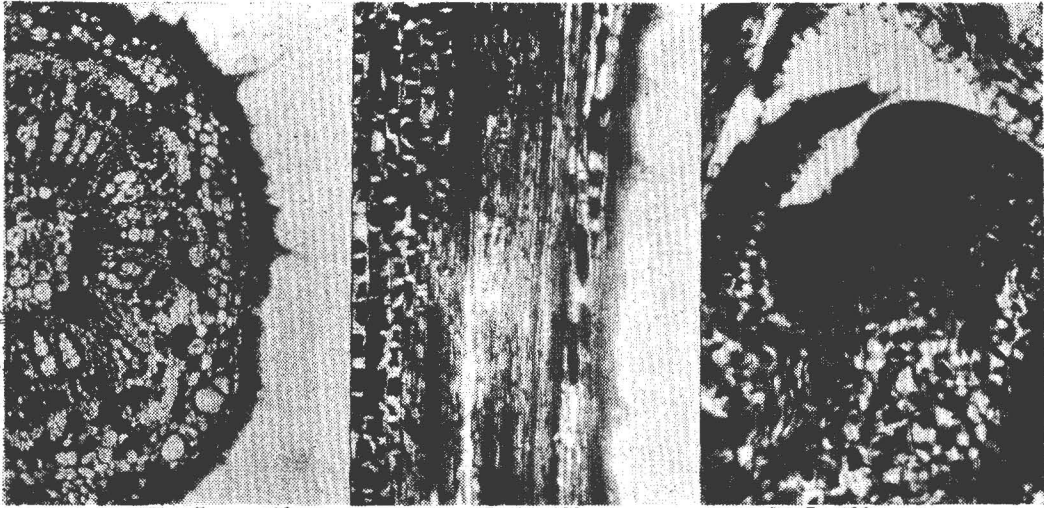


Fig. 7. a×100

7. b×100

7. c×280

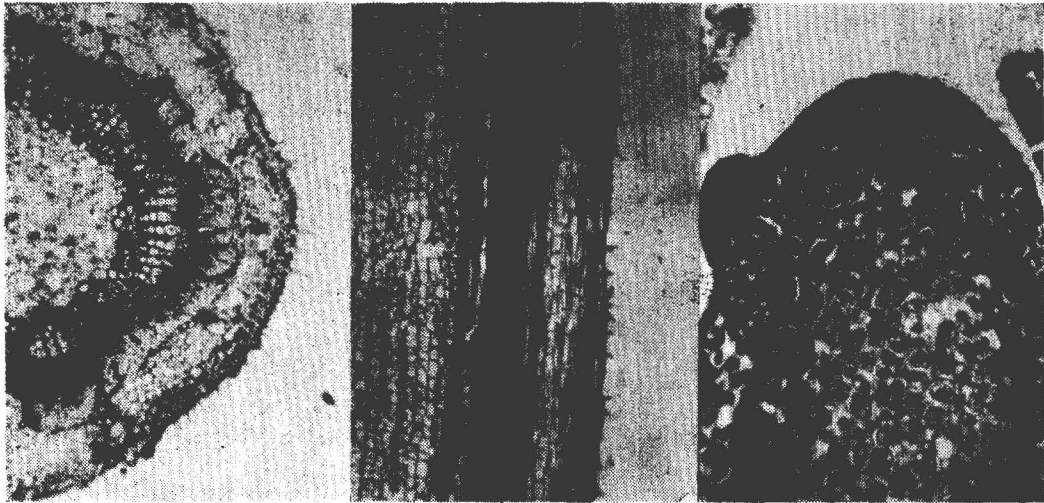


Fig. 8. a×40

8. b×40

8. c×280

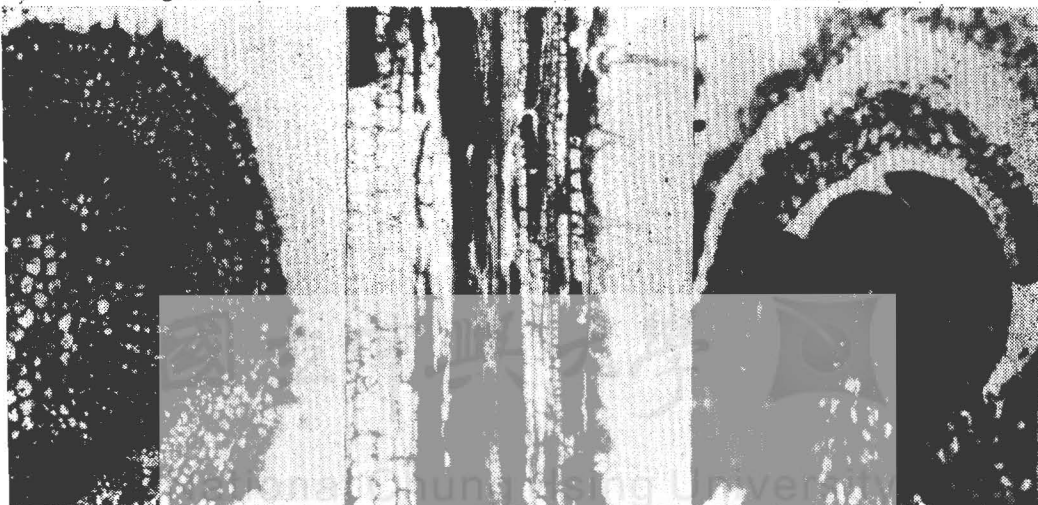


Fig. 9. a×100

9. b×100

9. c×280