THE CLASSIFICATION OF BAMBUSEAE BASED ON LEAF ANATOMY

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Introduction

The classification of the tribe Bambuseae is troublesome. There are some classifications which have been based on the reproductive organs worked by Gamble (1896), Holttum (1956), and Chase (1958). The trouble with these is that it is difficult to collect flowers of bamboos since some species seldom bloom. Therefore, the taxonomists have tried to change the basis of classification from the reproductive organs to the vegetative organs. But a classification based only on the gross morphology of vegetative organs is unreliable, since some external changes are merely due to the ecological factors. Anatomical studies of grass leaves have provided a great deal of valuable information for taxonomical work during recent years, and some workers have paid attention to the anatomy of the bamboo leaves. Brandis (1906), Metcalfe (1956), Page (1947), and Wu (1958, 1960) have suggested that important characteristics are shown in the cross section of the lamina. The detailed work of Ohki (1929, 1932) reported that the characteristics shown by the epidermis are also useful in classification. Thus the main purpose of the present paper is an effort to summarize the characteristics obtained from the study of the epidermis, mesophyll, venation, leaf margin, and midrib pattern of all species of bamboos known from Taiwan, and then to suggest a new classification of Bambuseae using the anatomical and histological features of leaves as the systematic criteria.

Material and Method

The materials for the present study were all collected here on Taiwan. There are 28 species, belonging to 10 genera, of which 13 species belong to the

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genus *Bambusa,* 5 to the genus *Phyllostachys,* 3 to the genus *Pleioblastus,* and each of the rest genera has only a single species. Some materials were kindly provided by Mr. Wei-Chih Lin, and the rest were collected by the writer herself. The following table gives a list of species studied, the date, and the localities from which they were collected.

Species No.	Scientific Name	Chinese Name	Localities	Date of Collection
201	*Bambusa Oldhami* Munro	Lu Chu	Yanmingshan, Taipei	4, 15, 1959
202	*Phyllostachys Makinoi* Hay.	Kuei Chu	Yanmingshan, Taipei	4, 15, 1959
203	*B. multiplex* (Lour) Raeusch	Kuanyin Chu	Yanmingshan, Taipei	4, 15, 1959
204	*Ph. edulis* (Carr.) Riviere	Mengtsung Chu	Chungli, Taipei	5, 8, 1959
205	*Sinocalamus latiflorus* (Munro) McClure	Ma Chu	Agr. Coll. Taichung	5, 11, 1959
206	*Ischurochloa stenostachya* (Hack) Nakai	Tzu Chu	Agr. Coll. Taichung	5, 11, 1959
207	*B. vulgaris var. striata* Gamble	Chinszu Chu	Agr. Coll. Taichung	6, 15, 1959
208	*Pleioblastus Kunishii* (Hay) Ohki	Taiwan Tsien Chu	Yanmingshan, Taipei	6, 21, 1959
209	*Pl. niitakayamensis* (Hay) Ohki	Yushan Tsien C.	Pa-Hsien Shan	6, 24, 1959
210	*B. floribunda* Zoll.	Fenghuang Chu	Pi-Yun Sze, Tainan	6, 28, 1959
211	*B. dolichoclada* Hayata	Changchih Chu	Min-Gsion, Chiayi	6, 29, 1959
212	*Pseudosasa Usawai* (Hay.) Makino	Paotoh Shih Chu	Sze-lin, Taipei	7, 6, 1959
213	*B. Beisitiku* (Odash.) Keng	Meshai Chu	Yanmingshan, Taipei	7, 18, 1959
214	*Shibataea kumasasa* (Zoll) Makino	Kangchi Chu	Yanmingshan, Taipei	8, 6, 1959
216	*B. breviflora* Munro	Chengkao Chu	Taiwai University Herbarium, Taipei	1, 2, 1960
217	*B. naibunensis* Nakai	Nei-Men Chu	Kengting, Hengchuan	1, 8, 1960
218	*Schizostachyum diffusum* Merr.	Shalao Chu	Kengting, Hengchuan	1, 8, 1960
220	*B. Shimadai* Hayata	Shihchio Chu	Plant Garden, Taipei	2, 15, 1960
221	*Ph. formosana* Hayata	Jenmien Chu	Fenchiho, Chiayi	4, 4, 1960
222	*Tetragonocalamus quadrangularis* (Fenzi) Nakai	Szefang Chu	Alishan, Chiayi	4, 18, 1990
223	*Ph. nigripes* Hayata	Wuchutzu	Lu-Kuei, Tainan	10, 15, 1960
224	*B. vulgaris* Schrader	Tai-Shan Chu	Lu-Kuei, Tainan	10, 15, 1960
225	*B. dolichomerithalla* Hayata	Huokuang Chu	Laoshuikeng, Taichung	10, 22, 1960
226	*Dendrocalamus strictus* Nees	Shih Chu	Szelin, Taipei	12, 2, 1960
227	*B. multiplex forma alphonso karri* Nakai	Su-Fang Chu	Lu-Kuei, Tainan	2, 8, 1961
228	*B. pachinensis* Hayata	Pa-Chih-Ian Chu	Lu-Kuei, Tainan	2, 12, 1961
229	*Ph. lithophila* Hayata	Shih Chu	Nandu	2, 24, 1961
230	*Pl. hindsii* (Munro) Nakai	Hsingshih Tsien Chu	Lu-Kuei, Tainan	2, 24, 1961

Each specimen was first studied carefully to examine its leaf margin, hair distribution, and venation. Then permanent slides including both paradermal

sections and transverse sections were prepared from each leaf by the paraffin method. Both old and young leaves were used and these were cut at three different levels, namely at the tip, the middle, and the base. The paradermal sections were prepared for studying the morphology of silica cells, stomata, hairs, and bulliform cells. Thus a set of slides was prepared from each leaf and several leaves were used in each case. Free hand sections were often used as a check.

It is impossible to peel off the epidermis of bamboo leaves; neither is it easy to prepare good paradermal sections. Therefore, the epidermal characteristics were often studied by soaking the leaves in 10% NaOH or KOH for two weeks or more, in order to remove the chlorophyll and to swell the epidermis; then the structure of the epidermis can usually be observed without staining.

Observation

I. Epidermis:

A. General characteristics of epidermis:

Both the upper and the lower epidermis are made of (1) epidermal cells and (2) modified epidermal cells. The epidermal cells are of two types: (a) long rectangular cells with wavy lateral walls and slightly undulated end walls, (b) short rectangular cells situated at the ends of the long epidermal cells. These long and short epidermal cells are disposed in several rows to make a longitudinal band, which is clearly separated by bands of bulliform cells in the upper epidermis. The upper and the lower epidermis can be divided into two kinds of districts—one over the chlorenchyma tissue and the other over the veins. Generally, the epidermal cells of the upper epidermis are relatively smooth and their walls are slightly wavy, whereas those of lower epidermis are roughened with numerous cuticular papillae and their walls are much more wavy. But in the case of *Schizostachyum diffusum,* both the upper and the lower epidermal cells are comparatively smooth and with slightly wavy walls, while in case of *Sinocalamus latiflorus,* both the upper and the lower epidermal cells have strongly wavy walls.

Some epidermal cells are highly modified and become quite different in appearance from the original cells. They are important in classification and are described as follows:

1. Hairs—Microhairs are very useful in systematics, and can be classified into four different types:

(a) Long hairs—These are narrow, long and 1-celled hairs which are formed by the elongation of the short epidermal cells (Plate III, Fig. 1-d). They are usually found on the epidermis covering the veins. They seldom exist on the upper epidermis, but they are widely dis-

tributed over the whole lower epidermis of all species of the genus *Bambusa* (except *B. vulgaris* and *B. vulgaris var. striata*), *Ischurochloa stenostachya,* and *Shibataea kumasasa;* or they are restricted to the base of the leaf, such as in all *Phyllostachys* species, and *Tetragonocalamus quadrangularis.* Long hairs are abundant on both surfaces of the leaves in *Dendrocalamus strictus,* and a few in *Pleioblastus niitakayamensis,* but absent on both surfaces in *Sinocalamus latiflorus, Pleioblastus hindsii, Pl. Kunishii, Pseudosasa Usawai, Schizostachyum diffusum,* and *Bambusa vulgaris.*

(b) Geniculate hairs—These are bicellular micro-hairs, the upper cell of which is usually collapsed, leaving a thread-like filament attached to the top of the lower cell (Plate III, Fig. 1-c). Usually this filament is broken off by external forces; the bicellular hair looks like a unicellular hair (Plate I, Fig 1; Pate III, Fig. 1-c). But in *Schizostachyum diffusum* the geniculate hair which is swollen at the tip looks quite peculiar (Plate II Fig 3; Plate III, Fig. 1-cc).

Geniculate hairs arise from the derivatives of the short epidermal cells, and are situated on the epidermis covering the chlorenchyma region, but never the veins. They are found on the lower epidermis of every species studied in this research; the difference between them is only quantitative. They exist on the upper epidermis of some species, but are absent from the rest of the species as shown in Table I.

(c) Spines—These are short, spine-like cells, which consist of two types:

(1) Those, which are rounded at the base and acute at the apex, are found on both surfaces of leaves over chlorenchyma region in most species (Plate I Fig. 1, Plate II, Fig. 4; Plate III, Fig. 1-b).

(2) Those, which are smaller and more or less spherical, are usually present on the upper epidermis over chlorenchyma region in some species, such as *Dendrocalamus strictus, Ischurochloa stenostachya,* and *Schizostachyum diffusum* (Plate I, Fig. 5; Plate III, Fig. 1-bb).

Spines are usually abundant on the lower epidermis; they are fewer or even absent on the upper epidermis.

(d) Bristles—These are nearly elliptical at the base, and cuspidate at the apex, and are found on the epidermis over the veins (Plate II, Fig. 4, 6; Plate III, Fig. 1-a). They are abundant on the lower epidermis of most species used in this research, but either absent on the upper epidermis of some species or disposed in only 2-4 rows near one margin in most species (Plate II, Fig. 6).

2. Silica cells:

Silica cells are noticeably characteristic. These are all saddle-shaped in cross section, but appear dumb-bell, rectangular, or saddle-shaped in the paradermal sections. The typical shape of the silica cells is not seen in most cases. There are many intermediate forms between them, so the descriptive words "nearly saddle" (Plate I, Fig. 4) or "nearly rectangular" (Plate II, Fig. 2, 3) are sometimes employed. The rectangular (Plate III, Fig. 2–a) and dumb-bell silica cells (Plate I, Fig. 3, 5; Plate III, Fig. 2–b) are common on the epidermis above the veins, whereas the saddle-shaped silica cells (Plate III, Fig. 2–c) are common on the epidermis above the chlorenchyma region. Usually, the silica cells on the epidermis above the veins are larger, and more regular in shape, whereas those above the chlorenchyma region are smaller and irregular in shape. For instances, The genera *Bambusa, Ischurochloa,* and *Sinocalamus* have dumb-bell shaped silica cells on the upper epidermis above the veins, and rectangular silica cells on the lower epidermis below the veins. The genera *Pleioblastus, Shibataea, Schizostachyum,* and *Tetragonocalamus* have rectangular silica cells on both epidermis over the veins.

The silica cells on the epidermis above the chlorenchyma region are irregular throughout the genera. There are no silica cells on the lower epidermis and only a few nearly rectangular silica cells on the upper epidermis in *Shibataea kumasasa.* In *Dendrocalamus strictus* and *Sinocalamus latiflorus* the silica cells on both surfaces of epidermis over the chlorenchyma region are quite peculiar. They consist of a rectangular central silica mass enclosed by a dumb-bell shaped envelope (Plate I, Fig 6, 7; Plate III, Fig. 2–b). The characteristics of the silica cella on both surfaces of leaves are shown in the Table I and II.

3. Stomata—Stomata of all the species can be classified into 2 types:

The first type is composed of the stomata on the upper epidermis. These are more or less rounded or ovoid in shape, few in number, usually arranged in one row, occasionally 2 on each side of a vein, and without finger-like protuberances. (Plate I, Fig. 4; Plate II, Fig. 1). But some stomata in *Bambusa vulgaris, B. vulgaris var. striata,* and *Schizostachum diffusum,* are provided with an irregular wavy layer coming forth from epidermal cells next to the guard cells.

The second type consists of stomata on the lower epidermis. These are larger, more or less elliptical in shape, numerous in number, and are disposed in 2–4 rows on each side of a vein. Each stoma possesses finger-like protuberances which come forth from the epidermal cells

next to the guard cells, and incline towards the center of stomata. The number of protuberances are definite in the different species, and are useful for classification. There are usually 4 around each stoma (Plate III, Fig. 3-c) in all species of *Bambusa* except *B. vulgaris, Pleioblastus niitakayamensis,* and *Shizostachyum diffusum;* 8 in *Bambusa vulgaris, Dendrocalamus strictus,* all species of *Phyllostachys* and *Pleioblastus* except *Pl. niitakayamensis,* and *Sinocalamus latiflorus.* These 8 protuberances are either unequal in length, usually 4 long and 4 short (Plate II, Fig. 4; Plate III, Fig. 3-a) or equal in length in *Bambusa vulgaris* (Plate III, Fig. 3-a). The stomata of *Tetragonocalamus quadrangularis* are quite peculiar; each possesses 4 long and many small protuberances. (Plate I, Fig 2; Plate III, Fig. 3-b).

In addition to protuberance, the number of rows of stomata are worth noting. On the lower epidermis in most species there are 2-3 rows of stomata on each side of a vein, but 3-4 rows are found in *Bambusa vulgaris, B. dolichomerithalla, Dendrocalamus strictus, Pleioblastus Kunishii, Schizostachyum diffusum, Shibataea kumasasa,* and *Sinocalamus latiflorus.* On the upper epidermis one row is common in most species, but 2 rows are found in *Bambusa vulgaris, Pseudosasa Usawai, Schizostachyum diffusum* and *Sinocalamus latiflorus.* The characteristics of the stomata are listed in Table I and II.

4. Bulliform cells:

These serve as a distinguishing characteristic of the upper epidermis and are formed by the modification of certain upper epidermal cells. Their origin is shown by the fact that there are no bulliform cells on the upper epidermis of very young leaves (Brandis, 1906). They are disposed in several rows to form a band, which is alternate with the band made by long and short epidermal cells. The bulliform cells occur on the epidermis above the chlorenchyma cells. The shape of bulliform cells is rectangular or polygonal in surface view, but elongate and arranged as a fan in cross section. The number of rows constituting the band varies from 1-9 according to the species and the distance from the midrib. In most cases there are usually 2-4 cells in a band. If the band consists of 3 rows of cells, the middle cell is either elongated (Plate III, Fig. 4-a) or polygonal (Plate III, Fig. 4-aa) according to the species. The bulliform cells are not on same level as the epidermal cells. Some of them protrude above the epidermal cells (Plate III, Fig. 4-bb); some indent below the epidermal cells (Plate III, Fig. 4-b). The characteristics of bulliform cells are shown in Table I.

B. Comparative study of leaf epidermis

Table I. Comparative Study of Upper Epidermis

Name of species	Hairs*				Silica cells		Bulliform cells			Stomata rows
	B	S	G	L	on vein	on C. R.*	rows	M. C.*	Condition	
Bambusa Oldhami	3	0	0	0	dumb-bell	rectangular	2-3	elongate	indent	1
B. multiplex	3-4	0	0	0	dumb-bell	nearly rectangular	2-4	elongate	protrude	1
B. vulgaris var. striata	3-4	+	+	0	dumb-bell	saddle-like	2-5	elongate	protrude	1-2
B. floribunda	2-3	0	0	0	dumb-bell	nearly rectangular	2-5	polygonal	protrude	1
B. dolichoclada	3-4	++	+	0	dumb-bell	nearly saddle	2-6	polgyonal	protrude	1
B. Beishitiku	3-4	++	0	0	nearly dumb-bell	dumb-bell	2-5	elongate	indent	1
B. naibunensis	3-4	++	0	0	dumb-bell	narrow saddle	2-3	elongate	protrude	1
B. breviflora	3-4	+++	+	0	nearly dumb-bell	saddle	2-6	elongate	protrude	1
B. Shimadai	4	0	+	0	nearly dumb-bell	saddle	2-3	elongate	protrude	1
B. vulgaris	4-5	0	+	0	nearly dumb-bell	dumb-bell	2-3	elongate	protrude	1-2
B. dolichomerithalla	4	0	+	0	nearly dumb-bell	dumb-bell	2-4	elongate	indent	1
B. multiplex forma alphonso karri	3	0	0	0	dumb-bell	dumb-bell	2-5	elongate	indent	1
B. pachinensis	3	++	+	0	dumb-bell	saddle	2-5	elongate	indent	1
Phyllostachys Makinoi	0	++	+	0	nearly rectangular	nearly rectangular	2-5	elongate	indent	1
Ph. edulis	0	0	0	0	nearly rect.	rectangular (scarce)	2-5	elongate	indent	1
Ph. formosana	0	0	0	0	nearly rect.	dumb-bell	2-6	elongate	indent	1
Ph. nigripes	0	0	0	0	nearly rect.	dumb-bell (scarce)	2-5	elongate	indent	1

Ph. lithophila	0	0	0	0	nearly rect.	dumb-bell (scarce)	2-6	elongate	indent	1
Sinocalamus latiflorus	4-5	+	+	0	dumb-bell	dumb-bell	2-9	elongate	protrude	1-2
Dendrocalamus strictus	2-4	++	+	++	nearly rect.	dumb-bell	2-5	elongate	protrude	1
Pleioblastus Kunishii	1	0	0	0	nearly rect.	nearly saddle	1-4	elongate	protrude	1
Pleioblastus niitakayamensis	0	0	0	+	nearly dumb-bell	nearly saddle	1-4	polygonal	indent	1
Pseudosasa Usawai	2	+	+	0	nearly rect.	nearly saddle	2-4	elongate	indent	1-2
Pl. hindsii	1	0	0	0	nearly rect.	nearly saddle	2-7	polygonal	indent	1
Ischurochloa stenostachya	2-3	++	++	0	dumb-bell	dumb-bell	2-3	elongate	indent	1
Shibataea kumasasa	0	0	0	0	rect.	nearly saddle (scarce)	2-5	polygonal	indent	1
Schizostachyum diffusum	2-3	+	0	0	nearly rect.	nearly saddle	2-4	elongate	protrude	1-2
Tetragonocalamus quadrangularis	3	0	0	0	nearly rect.	nearly rect.	2-7	polygonal	indent	1

* B=bristles in rows, S=spine, G=geniculate hair, L=long hair, M. C.=middle cell of 3-rowed bulliform cells, rect.=rectangular. C, R.=chlorenchyma region.

Table II. Comparative Study of Lower Epidermis

Name of species	Hairs*				Silica cells		Stomata	
	B	S	G	L	on vein	on C. R.*	rows	protuberances
Bambusa Oldhami	++	++	+	++	nearly rect.*	saddle	3	4 long
B. multiplex	++	++	+	++	nearly rect.	saddle	3	4 long
B. vulgaris var. striata	0	++	+	0	dumb-bell	dumb-bell	4-5	8 short
B. floribunda	++	++	+	++	nearly dumb-bell	dumb-bell	2-3	4 long
B. dolichoclada	++	++	+	++	nearly rect.	saddle	2-3	4 long
B. Beishitiku	++	++	+	++	nearly rect.	saddle	2-3	4 long
B. breviflora	+	++	+	++	rect.	saddle	2-3	4 long

B. naibunensis	++	++	+	++	nearly rect.	narrow saddle	3	4 long
B. Shimadai	++	++	+	++	nearly rect.	saddle	2-3	4 long
B. vulgaris	0	++	+	0	dumb-bell	dumb-bell	4-5	8 short
B. dolichomerithalla	++	++	+	++	dumb-ball	saddle	4	4 long
B. multiplex forma alphonso karri	++	++	+	++	dumb-bell	saddle	2-3	4 long
B. pachinensis	+	++	+	++	dumb-bell	narrow saddle	2-3	4 long
Phyllostachys Makinoi	++	++	++	+ base	dumb-bell	rect.	2-3	8(4 long, 4 short)
Ph. edulis	++	++	++	+ base	dumb-bell	rect.	2-3	4 long
Ph. formosana	++	++	++	+ base	dumb-bell	rect.	2-8	8(4 long, 4 short)
Ph. nigripes	++	++	++	+ base	dumb-bell	saddle	2-3	4 long
Ph. lithophila	++	++	+	+ base	dumb-bell	rect.	2-3	8(4 long, 4 short)
Sinocalamus latifiorus	++	++	++	0	rect.	dumb-bell	3-4	8(4 long, 4 short)
Dendrocalamus strictus	+	++	++	++	rect.	dumb-bell	3-4	8(4 long, 4 short)
Pleioblastus Kunishii	0	++	++	0	nearly rect.	saddle	3-4	8(4 long, 4 short)
Pleioblastus niitakayamensis	++	++	+	+	nearly rect.	nearly rect.	2-3	4 long
Pseudosasa Usawai	++	++	+	0	rect.	saddle	2-3	8(4 long, 4 short)
Pl. hindsii	++	++	++	0	nearly rect.	saddle	2-3	8(4 long, 4 short)
Ischurochloa stenostachya	++	++	+	++	nearly rect.	nearly rect.	3	4 long
Shibataea kumasasa	0	++	++	++	nearly rect.	absent	3-4	4 long
Schizostachyum diffusum	0	+	+	0	rect.	rect.	3-4	4 (long)
Tetragonocalamus quadrangularis	++	++	+	0	nearly rect.	nearly saddle	2-3	4 long, many short

* B=bristle, S=spine, G=geniculate hair, L=long hair; rect.=rectangular, C. R.=chlorenchyma region.

II. Mesophyll:

The mesophyll of bamboos belongs to the festucoid type in which the chlorenchyma cells are arranged parallel to each other instead of being radiately arranged. In addition to this, the mesophyll shows two outstanding features which place bamboos in a separate tribe of Gramineae. The first peculiarity is the presence of folds in the walls of the chlorenchyma cells. These folds may or may not deepen into the cells and divide the cells into a number of tubular compartments. This character can be seen very clearly in the cross section of the blade of *Phyllostachys* species. The chlorenchyma cells with such deep folds are usually in the layer immediately below the upper epidermis. The folds of the rest of the chlorenchyma cells proceed only half way or less than half to the middle of the cell.

The second peculiarity is the presence of translucent fusoid cells (Metcalfe, 1956), which are apparent in the cross section of the blade (Plate III, Fig. 6–a, 6–b). They may collapse at maturity and leave large intercellular spaces. Cross sections are frequently cut through these intercellular spaces. In order to avoid misunderstanding, the term "translucent fusoid cells" is still used for these enlarged, translucent areas. They are situated on each side of a vein below the upper epidermis without bulliform cells. They show clearly in most species, but are absent in *Phyllostachys edulis,* and a few in small leaves of *Bambusa floribunda* and *B. multiplex, Phyllostachys nigripes,* and *Shibataea kumasasa.* The size varies in the different species. The presence or absence of translucent fusoid cells is useful for classification. In addition to this, several other important characteristics in mesophyll are suggested as follows:

1. Mesophyll pattern:

   The mesophyll of bamboo leaves may be or may not be separated by the translucent fusoid cells. *Phyllostachys edulis* and small leaves of *Pleioblastus niitakayamensis* haven't such translucent areas and 4 layers of chlorenchyma cells are closely arranged. The mesophyll of the rest species is divided into 2 patterns: (a) 2:1 pattern consists of 2 layers of chlorenchyma cells above and 1 layer below the translucent fusoid cells (Plate III, Fig. 6–a). The cross sections of all species cut at the top levels of leaves show this pattern, but those at the base show various patterns. (b) 3:2 pattern composes of 3 layers of chlorenchyma cells above and 2 layers below the translucent fusoid cells (Plate III, Fig. 6–b). Most species at the base take this pattern. The patterns of mesophyll at the different levels are shown in Table III.

2. The cells between two translucent fusoid cells vary in number and are worth noticing. These cells, just like other chlorenchyma cells in the mesophyll, possess chloroplasts and infolded walls. They are situated

below the bulliform cells and between 2 translucent fusoid cells. They consist of 1-3 cells according to the species. Two cells, occasionally 3, are common in all species of *Bambusa* and *Phyllostachys, Schizostachyum diffusum, Shibataea kumasasa,* and *Tetragonocalamus quadrangularis.* One cell, occasionally 2, is common in all species of *Pleioblastus, Ischurochloa stenostachya* and *Pseudosasa Usawai.*

III. Midrib pattern:

These patterns are taken from the base of leaves, and were described fully in the writer's former paper. Only a brief description of each pattern is listed below.

1. Pattern 1—The midrib contains 3 vascular bundles: a medium, major one embedded in a strand of sclerenchyma in the abaxial series, and 2 later minor ones in a common strand of sclerenchyma in the adaxial series. These 2 strands of sclerenchyma may be connected together to form a continuous band or may be interrupted by a band of colorless parenchyma (Plate III Fig 7-a).

   Small leaves of *Bambusa multiplex, B. floribunda,* and *Pleioblastus niitakayamensis* have this pattern.

2. Pattern 2—The midrib at the base consists of seven vascular bundles: According to the arrangement of the vascular bundles, this pattern is better divided into 2 subgroups. Pattern 2a—In the abaxial series, 1 major and 2 minor bundles are embedded in a common strand of sclerenchyma, but two other minor bundles are embedded in separate masses of sclerenchyma and are situated at the middle of midrib. (Plate III, Fig. 7-c). In the adaxial series two minor bundles are in a common strand of sclerenchyma. The two series are separated by a band of colorless parenchyma. All species of *Phyllostachys* and *Shibataea kumasasa* have this pattern. Pattern 2b—This is as same as the pattern 2a except in two respects:
   (a) In the abaxial series 2 minor bundles situated at the middle of midrib in pattern 2a are lowered and connected with the lower epidermis. (Plate III, Fig. 7-b).
   (b) In the triangle region, the vascular system is more complicated. This pattern can be seen in all species of *Bambusa.*

3. Pattern 3—Eleven vascular bundles are present in the midrib at the base of leaf. In the adaxial series there are usually 3 minor vascular bundles embedded in a common strand of sclerenchyma or in the separate strands of sclerenchyma. In the abaxial series, there are three major and four or five minor bundles. Each bundle is embedded in a separate strand of sclerenchyma except the two minor bundles under the medium

major bundle. The two series are well separated by a broad band of colorless parenchyma. (Plate III, Fig. 7-d). This pattern is seen in *Pleioblastus hindsii, Pseudosasa Usawai, Pl. Kunisii, Sinocalamus latiflorus,* and *Tetragonocalamus quadrangularis.*

4. Pattern 4—More than 11 vascular bundles are present in the midrib at the base. The internal structure of this midrib is peculiar and complicated. The main difference lies in that there are more minor bundles in the adaxial series, and less minor bundles in the abaxial series. The two series may or may not be separated by the colorless parenchyma cells. The midrib at the base contains 13 or 14 vascular bundles in *Schizostachyum diffusum,* (Plate III, Fig. 7-e) 13 in *Bambusa vulgaris* var. *striata,* and 21 in *B. vulgaris.* There are 4-6 minor bundles in the adaxial series, usually 3 or 4 embedded in a common strand of sclerenchyma, the others in separate masses of sclerenchyma. There are 1-3 major and 6-8 minor vascular bundles in the abaxial series.

IV. Venation:

Veins in the blade of a bamboo leaf just like those in other monocotyledoneous plants are parallel to each other, but in reality there are numerous cross veins between these parallel ones. Some of these cross veins are closely arranged and thus are conspicuous to the naked eye, e. g. the leaves of all species of *Phyllostachys* and *Pleioblastus, Pseudosasa Usawai,* and *Shibataea kumasasa,*. But some of these cross veins are delicate, very loosely arranged, and thus inconspicous to the naked eye, e. g. the leaves of most species of *Bambusa, Dendrocalamus strictus, Ischurochloa stenostachya.* The former type of leaves in which the cross veins can be seen by the naked eyes, is considered as tessellate (Plate III, Fig. 5-c), whereas the latter type, in which the cross veins can't be seen by the naked eyes, is called as nontessellate (Plate III, Fig. 5-a). Another type is intermediate between the two extremes. The cross veins of this kind are shown under a hand lens with a magnification of 10×. These leaves are considered as sub-tessellate (Plate III, Fig. 5-b), e. g. the leaves of *Tetragonocalamus quadrangularis* and *Sinocalamus latiflorus.*

V. Leaf margin:

Leaf margins are also useful for classification. The leaf margins of the Bambuseae can be classified into 5 types. These are described below and are shown in Table III.

(a) One margin is loosely spinulose; the other is closely spinulose. All species of *Bambusa* (except B. vulgaris), *Ischurochloa stenostachya, Phyllostachys edulis, Pleioblastus niitakayamensis,* and *Tetragonocalamus quadrangularis* have this type of margin.

(b) Both leaf margins are closely spinulose. Bambusa vulgaris, *Dendrocalamus strictus,* and *Sinocalamus latiflorus* have this type of margins.

(c) Both margins are sparsely spinulose, e. g. Pseudosasa Usawai, *Schizostachyum diffusum,* and *Shibataea kumasasa.*

(d) One leaf margin is entire; the other is spinulose, e. g. *Phyllostachys formosana, Ph. Makinoi, Ph. nigripes, Ph. lithophila,* and *Pleioblastus hindsii.*

(e) Both leaf margins are entire, e. g. *Pleioblastus Kunishii.*

Table III. Comparative Study of Mesophyll, Midrib Pattern, Venation, and Margin

Name of species	Translucent fusoid cells	Mesophyll pattern	No. of c. c.* between 2T.F.C.*	Midrib pattern	Venation	Margin type
Bambusa Oldhami	apparent	3:2(m)* 3:2(b)*	1-2* occ. 3	2b	sub-tessellate	a, b
B. multiplex	sporadic (S)* apparent (L)*	2:1(m) 3:2(b)	1-2	1(S) 2b(L)	non-tessellate	a
B. vulgaris var. striata	apparent	3:2(m) 3:2(b)	1-2 occ. 3	2b(S) 4(L)	sub-tessellate	a, b
B. floribunda	sporadic (S) apparent (L)	2:1(m) 3:2(b)	1-2	1(S) 2b(L)	non-tessellate	a
B. dolichoclada	apparent	2:1(m) 3:1, 3:2(b)	1-2	2b	non-tessellate	a
B. Beisitiku	apparent	2:1(m) 3:2(b)	1-2	2b	non-tessellate	a
B. naibunensis	apparent	2:1(m) 3:2(m, b)	1-2	2b	non-tessellate	a
B. breviflora	apparent	2:1(m) 3:2(b)	1-2	2b	non-tessellate	a
B. Shimadai	apparent	2:1(m) 3:2(b)	2-3	2b	non-tessellate	a
B. vulgaris	apparent	3:2(m) 3:2(b)	1-2 occ. 3	4	sub-tessellate	b
B. dolichomerithalla	apparent	2:1(m) 3:2(b)	1-2	2b	non-tessellate	a
B. multiplex forma alphonso karri	apparent	2:1(m) 3:2(b)	1-2 occ. 3	2b	non-tessellate	a
B. pachinensis	apparent	2:1(m) 3:2(b)	1-2 occ. 3	2b	non-tessellate	a
Sinocalamus latiflorus	apparent	2:1(m) 3:2(b)	2-3	3	sub-tessellate	b

Dendrocalamus strictus	apparent	2:1(m) 3:2(b)	2-3	2b	non-tessellate	b
Phyllostachys Makinoi	apparent	2:1(m) 3:2(b)	1-2	2a	tessellate	d
Ph. edulis	absent	4	no	2a	tessellate	a, d
Ph. formosana	apparent	2:1	2-3	2a	tessellate	d
Ph. nigripes	sporadic	2:1	1-2	2a	tessellate	d
Ph. lithophila	apparent	2:1(m) 3:1(b) 3:2(b)	1-2	2a	tessellate	d
Pleioblastus Kunishii	apparent	2:1(m) 3:1(b) 3:2(b)	1-2	3	tessellate	e
Pleioblastus niitakayamensis	sporadic(L) absent(S)	2:1(m, b) 4	1-2 no	2b(L) 1(S)	tessellate	a
Pseudosasa Usawai	apparent	2:1(m, b)	1-2	3	tessellate	c
Pl. hindsii	apparent	2:1(m, b) 3:2(b)	1-2	3	tessellate	d
Ischurochloa stenostachya	apparent	2:1(m) 3:2(b)	1-2	2b	non-tessellate	a
Shibataea kumasasa	sporadic	2:1(m) 3:2(m, b)	2-3	2a	tessellate	c
Schizostachyum diffusum	apparent	2:1(m) 3:2(b)	1-2 occ. 3	4	non-tessellate	c
Tetragonocalmus quadrangularis	apparent	2:1(m, b)	2-3	3	sub-tessellate	a

* T. F. C.=translucent fusoid cell. c. c.=chlorenchyma cell. S=small. L=large.
m=middle, b=base, occ.=occasionally, 2=2 in common.

Discussion and Conclusion

From the observations and comparative studies of epidermis, mesophyll, midrib pattern, venation, and margin of 28 bamboo species, some conclusions regarding the systematic criteria for genera and species are suggested as follows:

I. Epidermal characteristics:

1. Epidermal cells:

The size of epidermal cells varies with the different species, but it has little diagnostic value. The characters of the wall including both the degree of waving and phenomena of culticulization are important for diagnosis. Generally the epidermal cells of the upper epidermis are relatively smooth, and their walls are slightly wavy, whereas those of the lower epidermis are usually roughened with numerous cuticular papillae and walls are greatly wavy. But there are a few exceptions. For instance, the lower epidermis of *Schizostachyum diffusum* is as smooth as the upper epidermis, and the epidermal cells of both surfaces have slightly wavy walls, while in *Sinocalamus latiflorus,* both epidermal cells have strongly wavy walls. These two cases possess wall characters quite different from the usual ones and thus they are separated from the rest as two distinct genera. This shows that wall characters are useful for classification.

The epidermis is made of elongate epidermal cells and the short epidermal cells. The latter may or may not undergo further division according to the species. If they do divide, their derivatives are modified either to be silica cells or micro-hairs. Therefore, each micro-hair or silica cell is always associated with a short epidermal cell. When two cells occur side by side, the one is a short epidermal cell and the other is a silica cell or a micro-hair. But when the short epidermal cells do not undergo division, they occur singly. Thus either silica cell or micro-hair is a derivative of a divided short epidermal cell.

2. Silica cells:

Silica cells are derived from the derivatives of the short epidermal cells, and thus silica cells and short epidermal cells are always in pairs on the epidermis over the chlorenchyma region as well as the veins. Silica cells over the chlorenchyma region are not only small, indistinct, and irregular in shape, but also may be absent in some cases. For instance, in *Shibataea kumasasa* there are no silica cells on the lower epidermis and very few on the upper epidermis (Plate II, Fig. 1). Thus they have little diagnostic value. But the silica cells on the epidermis over

the veins are large, distinct, and regular in shape throughout a given genus. Usually two types of silica cells, ractangular and dumb-bell shaped, are common over veins. Saddle shaped silica cells seldom appear over veins, but are very common over the chlorenchyma regions. Silica cells over the veins on both the upper and the lower epidermis of the same species may be same or different; they are considered as an important criteron for systematics.

3. Long hairs:

Among the 3 kinds of micro-hairs, long hairs are the most useful in classification, since they show their existence very regularly throughout the same genus. For instance, in the case of *Bambusa* long hairs are absent on the upper epidermis, but are uniformly distributed over the whole lower epidermis throughout the genus. In genus *Phyllostachys* long hairs are absent on the upper epidermis, but present on the lower epidermis at the base of the leaf.

4. Bulliform cells:

The number of rows of the bulliform cells, constituting a band, seems not so important, since they varies in the blade according to the distance from the midrib. Usually 2–4 rows are common in a band. The middle cell of a 3-rowed band varies in shape in the different species. Besides, some bulliform cells penetrate into the leafs, some elevate a little above the leaf. Whether it is indented or protruding is also according to the species.

II. Mesophyll:

Several characteristics have been noticed regarding the mesophyll. The existence of translucent fusoid cells seems the most important for classification, but it is not a genus character, since in *Phyllostachys* the translucent fusoid cells may be apparent in some species, or sporadic and even absent in other species. Besides, the mesophyll pattern may or may not be different at the tip, the middle, and the base of leaf. Usually the 2:1 pattern is at the tip of all leaves. Some species keep the 2:1 pattern throughout the middle level to the base, but some become the 3:2 pattern at the middle and the base. Among 28 species the majority of them have the 3:2 pattern at the base. Therefore, the patterns taken at the middle level seem more suitable for classification.

III. Midrib pattern:

The importance of the midrib as a systematic criteron is seen in the writer's recent paper (1960), in which 4 patterns according to the structure of the midrib at the base are suggested. This conclusion was based on 16 species, but no new patterns were discovered when 28 species were studied. However,

as more species are studied, more information can be obtained concerning each pattern. Thus some corrections are necessary. Firstly, it seems unnecessary to divide the pattern 3 into 3a and 3b, since more sections prepared show no main difference in the structure of the midrib at the triangular region in *Pleioblastus hindsii, Pl. Kunisii, Pseudosasa Usawai, Sinocalamus latiflorus,* and *Tetragonocalamus quadrangularis.* Secondly, the midrib of *Shibataea kumasasa* fits for pattern "2a" better than "2b". Thirdly, two types of midrib pattern are discovered in a same species. For instance, the midrib of *Bambusa vulgaris* var. *striata* show pattern "2b" in small leaves and pattern "4" in large leaves. Moreover, midribs of *Bambusa multiplex* and *B. floribunda* in the previous study show pattern "1" which does not follow the Bambusa pattern. These were once thought to be exceptions, but reinvestigations have shown that only midribs of small leaves show pattern "1"; those of large leaves always show pattern "2b" at the base. Therefore, each of these species really possesses two types of leaves. These corrections further demonstrate that the midrib pattern is useful in classifying genera of bamboos.

IV. Venation:

The cross veins, termed tessellate, sub-tessellate, or non-tessellate, seem to be a good criteron for distinguishing genera. Referring to the Table III, it is evident that the leaves of the whole genus *Bambusa* except a few exceptions are non-tessellate, and that the leaves of all species of the genus *Phyllostachys* and *Pleioblastus* are tessellate. But one thing should be remembered that the cross veins are really more or iess present in all bamboo leaves when viewed under a magnification of ×100. Therefore, sometimes cross veins may not be seen under magnification of ×10, but may be seen under a higher magnification. In this situation a definite magnification must be chosen as a standard. Magnification of ×10 is used as a standard in this research. If cross veins are shown lower than this magnification, the leaves are considered as tessellate; if higher, as nontessellate. For example, in *Bambusa dolichoclada* the cross veins are comparatively close, but are not shown until magnification is over ×20. Thus it is still considered as non-tesselate.

V. Leaf margin:

The leaf margin does not seem to be a reliable generic criteron for classification, since it is variable in the same genus. For instance, there are type "a" and "d" in genus *Phyllostachys*; type "a", "d", and "e" in genus *Pleioblastus.*

Based on these systematic criteria mentioned above, a new classification of Bambuseae as well as several new keys to the species may be suggested as follows:

Tribe Bambuseae

Key to the genera

1. Leaves tessellate (cross veins conspicuous, and visible to naked eye)..... 2
1. Leaves sub-tessellate (cross veins shown up under magnification of 10X).. 5
1. Leaves non-tessellate (cross veins inconspicuous)..... 7
2. Midrib pattern 2a..... 3
2. Midrib pattern 3..... 4
3. Silica cells absent on the lower epidermis over chlorenchyma region; very few on upper epidermis over chlorenchyma region .....VII. *Shibataea*
3. Silica cells present on both upper and lower epidermis over chlorenchyma region.....II. *Phyllostachys*
4. Mesophyll pattern 2:1 at the base.....IV. *Pseudosasa*
4. Mesophyll pattern 3:2 at the base.....III. *Pleioblastus*
5. Midrib pattern 2b.....I. *Bambusa.*
5. Midrib pattern 3 6
6. Walls of upper epidermal cells decidely wavy; peculiar type of dumb-bell silica cells on both upper and lower epidermis over chlorenchyma region; stomata on lower epidermis with 8 protuberances .....VI. *Sinocalamus*
6. Walls of upper epidermal cells slightly wavy; nearly saddle-like silica cells on both epidermis over chlorenchyma region; stomata on lower epidermis with many protuberances.....X. *Tetragonocalamus*
7. Midrib pattern 4; lower epidermis not roughened with cuticular papillae and with peculiar geniculate hairs over chlorenchyma region.....IX. *Schizostachyum*
7. Midrib pattern 2b; lower epidermis roughened with cuticular papillae, and with usual type of geniculate hair..... 8
8. Silica cells dumb-bell shaped on upper epidermis over veins; long hairs absent on upper epidermis, but abundant on lower epidermis..... 9
8. Silica cells rectangular on upper epidermis over veins; long hairs present on both upper and lower epidermis .....V. *Dendrocalamus*
9. Spine type 1 on upper epidermis over chlorenchyma region.....I. *Bambusa*
9. Spine type 2 on upper epidermis over chlorenchyma region..VIII. *Ischurochloa*

I. **Bambusa** Schreber

Leaves non-tessellate or sub-tessellate; leaf margin type a or b. Silica cells dumb-bell shaped on the upper epidermis over the vein, rectangular in shape on the lower epidermis over the veins except a few exceptions. Long hairs absent on the upper epidermis, but abundant on the whole lower epidermis

except in B. vulgaris and its variety. Bristles abundant on the lower epidermis over the veins, but only 3 or 4 rows near one margin and 1 or 2 rows near one side of midrib on the upper epidermis; spines absent or present on the upper epidermis over chlorenchyma region, but abundant on the lower epidermis. Geniculate hairs present or absent on the upper surface, but always present on the lower surface. Stomata on the upper epidermis without protuberances, few in number, and arranged in one row, occasionally 2, on each side of a vein, but those on the lower epidermis with 4 protuberances, numerous, and arranged in 2 to 3 rows on each side of a vein. Bulliform cells on the upper epidermis protrude or indent, 2–6 rows in a band, and the middle cell of a 3-rowed band elongate or polygonal.

The translucent fusoid cells apparent in mesophyll throughout the whole genus except in small leaves of *B. multiplex* and *B. floribunda*. Two chlorenchyma cells, occasionally 1 or 3, between 2 translucent fusoid cells. Mesophyll pattern 2:1 at the tip of leaves, 2:1 or 3:2 at the middle, and 3:2 at the base. Midrib pattern 2b throughout the genus, pattern 1 or 4 present in those species with 2 types of leaves.

Key to the species

1. Leaves non-tessellate; mesophyll pattern 2:1 at middle level; margin type a..... 2
1. Leaves sub-tessellate; mesophyll pattern 3:2 at middle level; margin type b or a and b.....11
2. Midrib pattern 2b; translucent fusoid cells always apparent 3
2. Midrib pattern of 2 types: pattern 1 and translucent fusoid cells sporadic in small leaves; pattern 2b and translucent fusoid cells apparent in large leaves.....10
3. No spines on upper epidermis over chlorenchyma region, but 3 or 4 rows of bristles over veins near one margin..... 8
3. Both spines and bristles present on upper epidermis 4
4. Bulliform cells indent..... 5
4. Bulliform cells protrude..... 6
5. No geniculate hairs on upper epidermis; silica cells dumb-bell shaped on upper epidermis over chlorenchyma region.....*B. Beishitiku*
5. A few geniculate hairs on upper epidermis; silica cells saddle-shaped on upper epidermis over chlorenchyma region.....*B. pachinensis*
6. Middle cells polygonal in a 3-rowed bulliform band.....*B. dolichoclada*
6. Middle cells elongate in a 3-rowed bulliform band 7
7. No geniculate hairs on upper epidermis.....*B. naibunensis*

7. A few geniculate hairs on upper epidermis.....*B. breviflora*
8. Four rows of stomata on each side of vein on lower epidermis .....*B. dolichomerithalla*
8. Two rows (occasionally 3) of stomata on each side of vein on lower epidermis..... 9
9. Bulliform cells protrude; silica cells narrow saddle-shaped on upper epidermis over chlorenchyma region .....*B. Shimadai*
9. Bulliform cells indent; silica cells dumb-bell shaped on upper epidermis over chlorenchyma region.....*B. multiplex form alphonse karri*
10. Silica cells nearly rectangular on lower epidermis below veins; middle cell elongate in 3-rowed bulliform band .....*B. multiplex*
10. Silica cells nearly dumb-bell shaped on lower epidermis below veins; middle cell polygonal in 3-rowed bulliform band.....*B. floribunda*
11. Long hairs absent on upper epidermis, but abundant on lower epidermis; stomata on lower epidermis with 4 protuberances....*B. Oldhami*
11. Long hairs absent on both upper and lower epidermis; stomata on lower epidermis with 8 protuberances.....12
12. Midrib pattern 4; silica cells dumb-bell shaped on lower epidermis below the veins; margin type b only.....*B. vulgaris*
12. Midrib pattern 2b or 4; margin type a or b; silica cells nearly rectangular on lower epidermis below the veins.....*B. vulgaris* var. *striata*

II. **Phyllostachys** Sieb et Zucc.

Leaf tessellate; leaf margin type mostly d. Midrib pattern 2a; translucent fusoid cells apparent, sporadic or absent. Four layers of chlorenchyma cells in the mesophyll, when the translucent fusoid cells are absent. 2:1 pattern at the tip and the middle level of leaf; 2:1 or 3:2 pattern at the base of leaf.

No long hairs on the upper epidermis and a few present on the lower epidermis at the base of leaf. Geniculate hairs, bristles, and spine cells absent on the upper epidermis except *Phyllostachys Makinoi,* but present on the lower epidermis of all species. Silica cells nearly rectangular on both the upper and the lower epidermis over veins; saddle or dumb-bell shaped on the epidermis over chlorenchyma region. Stomata on the upper epidermis without protuberances, and disposed in 1 row on each side of a vein; those on the lower epidermis with 4 or 8 protuberances and disposed in 2–3 rows.

Key to the species

1. Translucent fusoid cells apparent, 8 protuberances around each stoma of the lower epidermis..... 2

1. Translucent fusoid cells sporadic or absent; 4 protuberances around each stoma of the lower epidermis..... 4
2. With spine cells and geniculate hairs on the upper epidermis....*Ph. Makinoi.*
2. No hairs on the upper epidermis..... 3
3. Mesophyll pattern 3:2 at the base of leaf.....*Ph. lithophila.*
3. Mesophyll pattern 2:1 at the base.....*Ph. formosana.*
4. Translucent fusoid cells sporadic; plenty of long hairs on the lower epidermis at the base of leaf .....*Ph. nigripes.*
4. Translucent fusoid cells absent; long hairs sparse at the base of leaf .....*Ph. edulis.*

III. **Pleioblastus** Nakai

Leaf tessellate; leaf margin type a, d, e, quite irregular. Midrib pattern 3 except Pl. niitakayamensis; translucent fusoid cells apparent or absent. Four layers of chlorenchyma cells in mesophyll, when translucent fusoid cells are absent, 2:1 mesophyll pattern at the tip and the middle level of leaf; 2:1 or 3:2 pattern at the base of leaf, when translucent fusoid cells present. One chlorenchyma cell between 2 translucent fusoid cells in most cases.

No or a few long hairs on both surfaces of leaves; 1 or 2 rows of bristles on the upper epidermis near one margin, geniculate hairs and spine cells present on lower epidermis. Silica cells nearly rectangular on both surfaces over the veins; saddle or rectangular on epidermis over chlorenchyma region. Stomata on the upper epidermis a few in number, without protuberances, and disposed in 1 row on each side of a vein, but those on the lower epidermis numerous, with 4 or 8 protuberances and disposed in 2–3 rows.

Key to the species

1. Midrib pattern 3; translucent fusoid cells apparent 2
1. Midrib pattern 1 or 2b; translucent fusoid cells absent or sporadic .....*Pl. niitakayamensis*
2. Geniculate hairs absent on upper epidermis; bulliform cells indent and middle cell of 3–rowed band polygonal; leaf margin type d.....*Pl. hindsii*
2. Geniculate hairs present on upper epidermis; bulliform cells protruding, and middle cell of 3–rowed band elongated; leaf margin type e .....*Pl. Kunishii*

IV. **Pseudosasa** Makino

Pseudosasa Usawai Makino

Leaf tessellate; leaf margin type a or c; midrib pattern 3; translucent fusoid cells apparent; mesophyll pattern 2:1 from the tip to the base, usually 1 chlorenchyma cell between 2 translucent areas.

No long hairs, but a few geniculate hairs on both surfaces of leaf. Two rows of bristles and a few spines on the upper surface, but numerous bristles and spines on the lower surface. Silica cells on both surfaces nearly rectangular over the veins, and saddle-shaped over the chlorenchyma region. Stomata on the lower epidermis with 8 protuberances and disposed in 2–3 rows on each side of a vein.

V. **Dendrocalamus** Nees

Dendrocalamus strictus Nees

Leaf non-tessellate; leaf margin type b. Midrib pattern 2b; translucent fusoid cells apparent. Mesophyll pattern 2:1 at the tip and the middle level, but 3:2 pattern at the base. Two cells (occasionally 3) between 2 translucent fusoid cells.

Long hairs abundant on both the upper and the lower epidermis over the veins; geniculate hairs present on both surfaces over the chlorenchyma region; Bristles 2–3 rows over the veins near one margin and numerous spine cells type 2 over the chlorenchyma region on the upper epidermis. Spine cells type 1 abundant on the lower epidermis. Silica cells rectangular over the vein and dumb-bell shaped over the chlorenchyma region on both surfaces; these dumb-bell shaped silica cell quite peculiar (Plate II, Fig. 6; Plate III, Fig. 2–b). Stomata a few, in one row, without protuberances on the upper epidermis; numerous, in 3 or 4 rows, and with 8 protuberances on the lower epidermis.

VI. **Sinocalamus** McClure

Sinocalamus latiflorus McClure

Leaf sub-tessellate; leaf margin type b. Midrib pattern 3; translucent fusoid cells apparent. Mesophyll pattern 2:1 at the tip and the middle level, 3:2 pattern at the base. Two or three cells between 2 translucent fusoid cells.

Long hairs absent on both surfaces of leaves; geniculate hairs present on both surfaces. Bristles in 4 rows near one margin, no spine cells on the upper epidermis; both bristles and spine cells present on the lower epidermis.

Silica cells dumb-bell shaped on the upper epidermis over the veins and the chlorenchyma region, but rectangular on the lower epidermis over the veins. These dumb-bell silica cells are quite peculiar with a rectangular silica mass at the center. Stomata without protuberances, but surrounded by wavy walls of adjacent epidermal cells, in 2 rows on each side of a vein on the upper epidermis; with 8 protuberances, and in 3 or 4 rows on the lower epidermis. Bulliform cells protruding, 2–9 rows in a band, and middle cell elongate in 3-rowed band.

VII. **Shibataea** Makino

Shibataea kumasasa Makino

Leaf tessellate; leaf margin type c. Midrib pattern 2a and translucent fusoid cells sporadic. Mesophyll pattern 2:1 at the tip and the middle; 3:2 pattern at the middle and base. Two cells common between 2 translucent areas.

No hairs on the upper epidermis; many spines and geniculate hairs present on the lower epidermis over chlorenchyme region, and abundant long hairs over veins. Silica cells of rectangular type over veins on both surfaces; no silica cells on the lower epidermis over chlorenchyma region but a few on the upper epidermis. Stomata disposed 1 row along each side of a vein, without protuberances on the upper epidermis; 3 (occasionally 4) rows, with 4 protuberances on the lower epidermis. Bulliform cell indented, and middle cell polygonal in 3-rowed band.

VIII. **Ischurochloa** Nakai

Ischurochloa stenostachya (Hack) Nakai

Leaf non-tessellate; leaf margin type a. Midrib pattern 2b and translucent fusoid cells apparent. Mesophyll pattern 2:1 at the tip; 3:2 pattern at the middle and the base. Two cells common between the 2 translucent areas.

No long hairs on the upper epidermis, but abundant on the lower epidermis. Geniculate hairs present on both surfaces. Bristles and spines present on both surfaces. The spines type 2 on the upper epidermis; spines type 1 on the lower epidermis. Silica cells dumb-bell shaped on the upper epidermis over veins; nearly rectangular on the lower epidermis. Stomata without protuberances and disposed in 1 row along each side of a vein on the upper epidermis; 2–3 rows and with 4 protuberances on the lower epidermis. Bulliform cells indented and the middle cell elongated in 3-rowed band.

IX. **Schizostachyum** Nees

Schizostachyum diffusum Merr.

Leaf non-tessellate; leaf margin type b. Midrib pattern 4; translucent fusoid cells apparent. Mesophyll pattern 2:1 at the tip and the middle of leaf, but 3:2 pattern at the base. Two cells common, occasionally 1 or 3, between 2 translucent areas.

Epidermal cells of both surfaces of leaf smooth and with slightly wavy walls. Long hairs absent on both surfaces; geniculate hairs absent on the upper surface, but a peculiar type of geniculate hair present on the lower surface. Bristles 3 or 4 rows near one margin on the upper surface. Spines type 1 present on the lower surfaces over the chlorenchyma region; spines type 2 present on the upper epidermis. Silica cells rectangular on both surfaces over the veins; very narrow saddle-like over chlorenchyma region. Stomata with 4 protuberances and in 1 or 2 rows on each side of a vein on the upper surface; with 4 protuberances and in 4 rows on lower surface. Bulliform cells protruding; middle cell of a 3-rowed band greatly elongated.

X. **Tetragonocalamus** Nakai

Tetragonocalamus quadrangularis Nakai

Leaf tessellate, leaf margin type b. Midrib pattern 3; translucent fusoid cells apparent. Mesophyll pattern 2:1 at the tip, the middle, and the base; usually 2 cells between the 2 translucent areas.

No hairs except 3 rows of bristles near one margin on the upper surface; some geniculate hairs and spines on the lower surface over the chlorenchyma region, a few bristles near the midrib at the base. Silica cells rectangular on both surfaces over the veins and narrow saddle-like over the chlorenchyma region. Stomata scarce on the upper epidermis, but numerous, with peculiar type of protuberances, and in 2 or 3 rows on each side of a vein on the lower epidermis. Bulliform cells indented, and the middle cell polygonal in a 3-rowed band.

According to leaf characters, it is apparent that several points are necessary to be noticed. Firstly, *Pleioblastus niitakayamensis* does not agree with the characteristics of genus *Pleioblastus* in several respects.

1. The midrib pattern of *Pleioblastus niitakayamensis* belongs to pattern 1 or 2b instead of pattern 3, which is the general pattern of the other species of *Pleioblastus.*
2. The translucent fusoid cells are frequently absent in *Pleioblastus niitakayamensis,* whereas they are apparent and throughout in all other *Pleioblastus* species.
3. No bristles are present on the upper epidermis, but there are 1–2 rows near one margin in all other Pleioblastus species.
4. Leaf margin belongs to type a which is different from other Pleioblastus species.
5. Several long hairs are scattered on both surfaces of leaf, but no long hairs are present in all other Pleioblastus species.

Secondly, *Bambusa vulgaris* and *B. vulgaris* var. *striata* also possess

characteristics quite different from those of the other *Bambusa* species in the following points:

1. Both *Bambusa vulgaris* and *B. vulgaris* var. *striata* have the midrib pattern "4", which is not the usual pattern of the genus *Bambusa*. Pattern "4" is the most complicated one which is shared by *Schizostachyum diffusum*.
2. Long hairs are absent on both surfaces of epidermis; but they are abundant on the lower epidermis in all the other *Bambusa* species.
3. Stomata on the lower epidermis are with 8 protuberances, instead of 4 protuberances in all the other Bambusa species.
4. Leaf margin is type b instead of type a in all other Bambuse species.

Thirdly, *Bambusa Oldhami* is different in some characters from the other Bambusa species, such as sub-tessellate, with 2 types of leaf margin, and 3:2 mesophyll pattern at the middle level of leaf. But it is still better to place it in the genus Bambusa for the following points:

1. Long hairs are abundant on the lower epidermis of leaf.
2. Midrib pattern is 2b which is a common type of genus Bambusa.
3. Stomata on the lower epidermis are with 4 protuberances.
4. Silica cells on the upper epidermis over the veins are dumb-bell shaped; those over the chlorenchyma region are narrow rectangular in shape.

Judging from the above leaf characters, *Pleioblastus niitakayamensis* should be taken out from the genus *Pleioblastus*, and *Bambusa vulgaris* and *B. vulgaris var. striata* from the genus *Bambusa*. *Bambusa Oldhami* is better put in the original genus *Bambusa*.

竹族分類之新根據——葉之解剖

吳 志 英

本篇收集全臺產竹廿八種，分隸十屬，根據竹葉解剖所得之特性，列成新檢索表（詳見英文結論），以資分類上之應用亦爲本篇之最大目的。

本研究對竹葉之特性，在表皮，葉肉，中肋，脈序及葉緣五方面進行，將各品種之特性，列表作一比較解剖，就研究所得，認爲具有重要分類價值者，約有下述數端：

1. 表皮所被角質突起和毛茸及細胞壁之彎曲程度，有助于分類，多般上表皮較光滑，少毛茸，及胞壁略彎曲，下表皮恰相反，但箬箭竹，泰山竹及麻竹顯得特殊，因之極易識別。
2. 矽細胞分佈在葉脈上面之表皮者，較明顯而規律，普通有長方形和啞鈴形二型，馬鞍型者少見，在同一屬內之各品種，常具有同一式樣之矽細胞，其分類價值可見，
3. 毛茸分佈在竹葉表皮者，計有三種，即刺毛，雙胞毛，及長毛，其中以長毛最顯

著，而其存在亦劃一，例如在 *Bambusa* 屬中，長毛遍生于各品種之下表皮，却罕見于上表皮，似爲分屬特性。

4. 葉之中肋以維管束之數目及排列法形成四種圖式，各“屬”能呈現一定圖式，顯明爲分“屬”特性。
5. 竹葉之平行脈間具有橫脈，由于此類橫脈分佈之疏密，使葉呈現“分格”及“不分格”之現象，此現象有助于分類。

具有次要分類價值者，多數有利于分“種”特性，約分下列各點：

1. 葉緣在一“屬”內常不一律，故似爲分“種”特性。
2. 葉肉細胞在巨大透明細胞上下所列層數之比例及在兩透明細胞間之數目，可協助竹之分類。
3. 表皮分佈在葉肉上面者具有可協助分類之特性，例如（a）矽細胞之有無，多寡，及形狀，（b）雙胞毛及刺毛之存在與否及其形狀，（c）氣孔在葉脈兩旁之行數，及其四週之角質突起，（d）激動細胞之凹凸及排列。

根據以上葉之特性發見玉山箭竹 (*Pleioblastus niitakayamensis*)，金絲竹 (*Bambusa vulgaris* var. *striata*)，及泰山竹 (*B. vulgaris*)，均該提出本屬。

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Abbreviations used in the plate I and II

a—spine type 2.
b—bulliform cell.
d—dumb-bell silica cell over vein.
e—short epidemal cell.
E—long epidermal cell.
g—geniculate hair.
G—peculiar geniculate hair.
H—bristle over vein.
h—spine type 1.
i—peculiar dumb-bell silica cell over chlorenchyma region.
p—protuberance around stomata.
S—stomata.
s—saddle silica cell.
r—nearly rectangular silica cell over vein.

PLATE I

(All photographs in the paradermal sections)

Fig. 1. *Sinocalamus latiflorus* (×700). Lower epidermis showing several spine cells (type 1), a geniculate hair, stomata, and peculiar dumb-bell silica cells.

Fig. 2. *Tetragonocalamus quadrangularis* (×700). Lower epidermis showing peculiar stomata with many protuberances.

Fig. 3. *Bambusa multiplex forma alphonso karri* (×700). Upper epidermis showing dumb-bell silica cells and short epidermal cells in pairs above the vein; long epidermal cells with slightly wavy walls.

Fig. 4. *Pseudosasa Usawai* (×700). Upper epidermis showing stomata, narrow saddle silica cell and short epidermal cell in pair, and long epidermal cells.

Fig. 5. *Ischurochloa stenostachya* (×150). Upper epidermis showing dumb-bell silica cells above the vein, spine cells (type 2) above the chlorenchyma region, and 2 bands of bulliform cells.

Fig. 6. *Sinocalamus latiflorus* (×700). A portion of upper epidermis showing enlarged peculiar dumb-bell silica cells above the chlorenchyma region, and epidermal cells with strongly wavy walls.

Fig. 7. *Sinocalamus latiflorus* (×150). Upper epidermis showing a band of bulliform cells with a row of elongate middle cells; peculiar dumb-bell silica cells above the chlorenchyma region.

Plate I

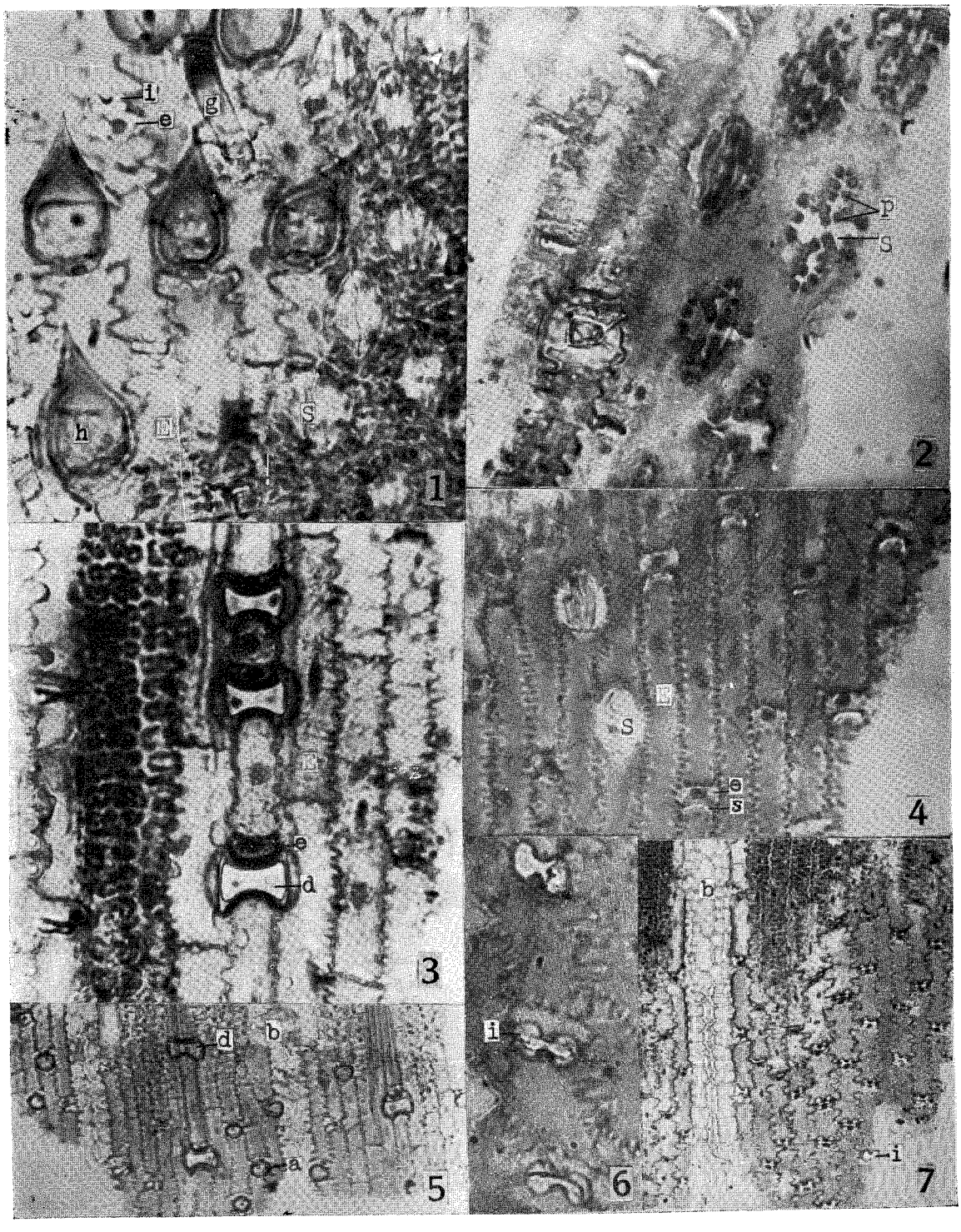

PLATE II

Fig. 1. *Shibataea kumasasa* (×150). Upper epidermis showing a row of stomata on one side of a vein, long epidermal cells, and short epidermal cells which are not always accompanied by silica cells.

Fig. 2. *Phyllostachys nigripes* (×150). Upper epidermis showing a band of bulliform cells, nearly rectangular silica cells above the veins.

Fig. 3. *Schizostachyum diffusum* (×150). Lower epidermis showing nearly rectangular silica cells below the veins, 3 rows of stomata on each side of a vein, and peculiar geniculate hairs swollen at the tip below chlorenchyma region.

Fig. 4. *Phyllostachys Makinoi* (×200). Lower epidermis showing bristles and nearly rectangular silica cells below the veins, spines (type 1) below chlorenchyma region, and 2 rows of stomata with 8 protuberances on each side of a vein.

Fig. 5. Different types of leaf margins (×15). Diagrams drawn with aid of camera lucida.

1′. *Bambusa vulgaris*
2′. *Phyllostachys Makinoi*
3′. *Bambusa dolichomerithalla*
4′. *Shibataea kumasasa*
5′. *Tetragonocalamus quadrangularis*
6′. *Pseudosasa Usawai*
7′. *Sinocalamus latiflorus*
8′. *Dendrocalamus strictus*
9′. *Phyllostachys formosana*

Fig. 6. *Bambusa Oldhami* (×10). Upper epidermis showing 4 rows of bristles above the veins near one margin.

Plate II

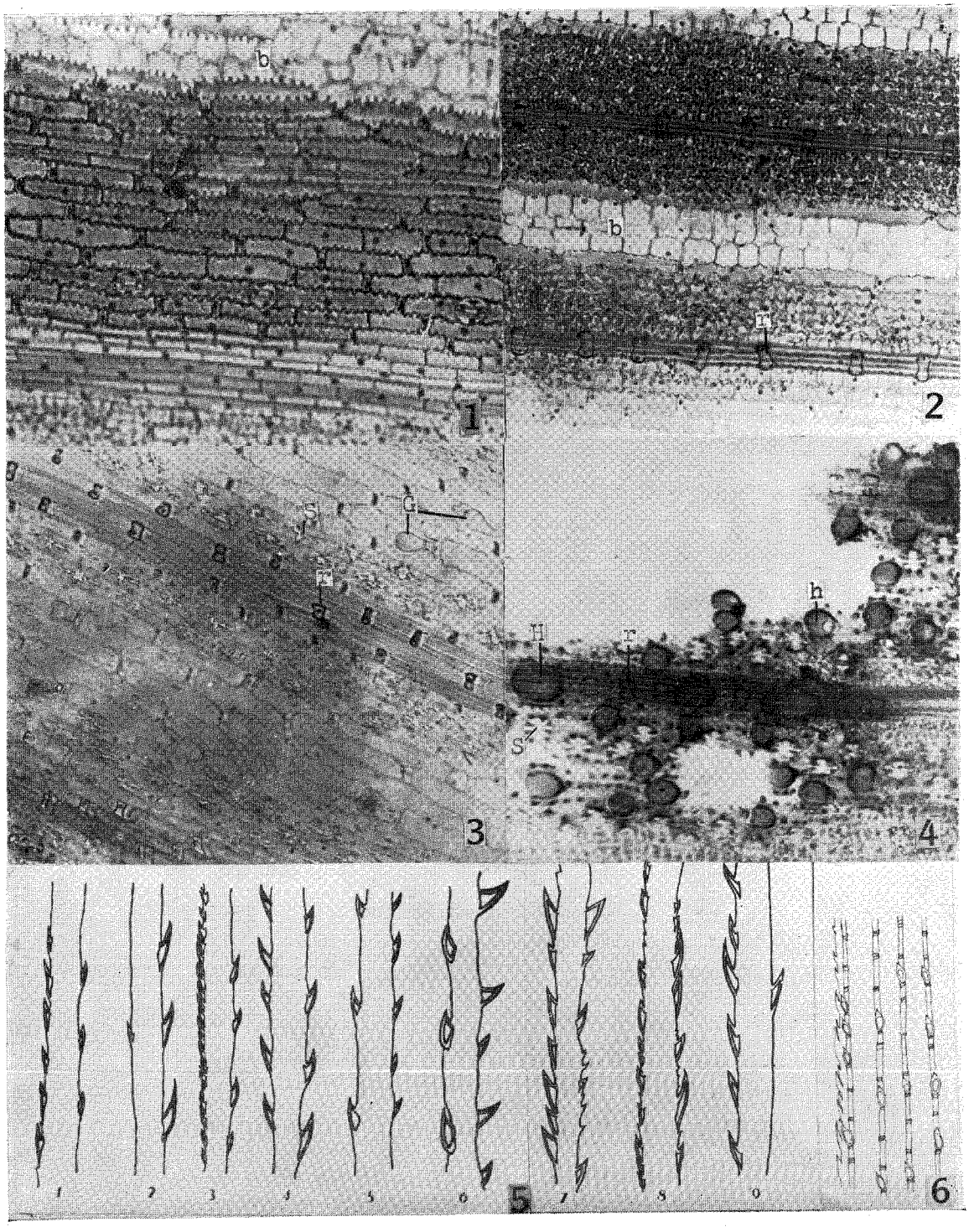

PLATE III

Fig. 1-a. Bristles on epidermis over veins.
Fig. 1-b. Spines on epidermis over chlorenchyma region.
Spine type 1—b, spine type 2—bb.
Fig. 1-c. Geniculate hairs (usual type).
Fig. 1-cc. Special geniculate hairs in *Schizostachyum diffusum.*
Fig. 1-d. Long hairs.
Fig. 2-a. Rectangular or nearly rectangular silica cells.
Fig. 2-b. Dumb-bell shaped silica cells. The last peculiar one found in *Sinocalamus latiflorus.*
Fig. 2-c. Saddle-like silica cells.
Fig. 3. Stomata on lower epidermis.
a—stomata with 8 protuberances.
b—stoma with many protuberances.
c—stoma with 4 protuberances.
Fig. 4. Bulliform cells in the paradermal section.
a—middle cell elongated in a 3-rowed bulliform band.
aa—middle cell polygonal in a 3-rowed bulliform band.
Bulliform cells in the cross section.
b—indent bulliform cells.
bb—protrude bulliform cells.
Fig. 5-a. non-tessellate, cross veins inconspicuous under magnification of 10×.
Fig. 5-b. sub-tessellate, cross veins delicately shown under magnification of 10×.
Fig. 5-c. tessellate, cross veins clearly shown to naked eye.
Fig. 6-a. Mesophyll pattern 2:1 type.
Fig. 6-b. Mesophyll pattern 3:2 type.
Fig. 7-a. Midrib pattern 1.
Fig. 7-b. Midrib pattern 2b.
Fig. 7-c. Midrib pattern 2a.
Fig. 7-d. Midrib pattern 3.
Fig. 7-e. Midrib pattern 4.

Plate III