

Leaf anatomical studies in some of the Indian bamboos - 1. *Dendrocalamus* Nees

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Abstract: Study on ten species of genus *Dendrocalamus* Nees was undertaken to assess the diagnostic value of the anatomical features of leaf cross-sections. The various anatomical features observed include: shape of the leaf blade, structure of midrib, presence or absence of adaxial and abaxial girders of sclerenchyma opposite the vascular bundles, number of bundle sheaths, presence and arrangement of bulliform cells, structure and arrangement of mesophyll tissue, presence and arrangement of fusoid cells and colourless cells in the mesophyll. The variations in these features have been found useful in the formulation of an artificial key for the identification of various species of the genus *Dendrocalamus*.

Keywords: *Dendrocalamus*, leaf anatomy, fusoid cells, arm cells, cross veins.

INTRODUCTION

Bamboos are tall, arborescent grasses belonging to the tribe Bambuseae, sub-family Bambusoideae of the family Poaceae. A total of about 1575 species belonging to 111 genera of bamboos are found worldwide (Ohrnberger, 1999). India possess second richest reserve of bamboo genetic resources after China with a total of 128 species in 18 genera (Seethalakshmi and Kumar, 1998).

Most bamboos flower at long intervals. Flowers in these plants are, therefore, scarcely available and one has to generally resort to distinguishing them by vegetative features. In bamboos, characters of vegetative morphology, anatomy, cytology and biochemistry hold great promise from systematic point of view. Grass leaf anatomy, as revealed by features of leaf transections, has been the subject of numerous investigations which have resulted in the establishment of a number of anatomical types in grasses such as the festucoid, panicoid, chloridoid, bambusoid, oryzoid and aristidoid types (Brown, 1958). These types characterize major groups of grasses which correspond to the

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emerging concept of subfamilies of the grass family, Poaceae.

However, compared to grasses, leaf anatomy is less well documented in bamboos. Taxonomically useful leaf anatomical characters of bamboos have been comprehensively defined and illustrated by few authors (Clifford and Watson, 1977; Cotton and Stace, 1977; Ellis, 1976, 1979; Soderstrom and Ellis, 1987). These characters are derived both from the leaf blade as viewed in transverse section as also the leaf epidermal peelings. Keeping in view, the usefulness of leaf anatomical features in identification, study on leaf cross-sectional anatomy of 10 Indian species of the genus *Dendrocalamus* were undertaken. Recently, leaf epidermal features of Indian species of *Dendrocalamus* have been reported by Richa and Sharma (2001). *Dendrocalamus* is a genus of about 35 species distributed in India and Sri Lanka to China and Philippines (Clayton and Renvoize, 1986). A total of 9 species by Majumder (1989) and 15 by Seethalakshmi *et al.* (1998) are recorded from India. The members are mostly arborescent, always unarmed and sometimes of very large size.

MATERIALS AND METHODS

Leaf material for the present study was collected from the bambuseta of the Kerala Forest Research Institute, Peechi, Kerala; Forest Research Institute, Dehradun; and P. N. Mehra Botanical Garden, Panjab University, Chandigarh. The species included in the present study are: *Dendrocalamus asper* (Schultes f.) Heyne, *D. brandisii* (Munro) Kurz, *D. calostachyus* (Kurz) Kurz, *D. giganteus* Munro, *D. hamiltonii* Munro, *D. hookeri* Munro, *D. longispachus* Kurz, *D. membranaceus* Munro, *D. sericeus* Munro and *D. strictus* (Roxb.) Nees.

For each species, middle portion of the 4th leaf from the top of first year growth, was selected for the study. The leaf material was treated with hydrofluoric acid (4%) to remove silica and latter preserved in F.A.A. (1:1:8). Cross sections (10-12µm) of leaves were made with a cryostat microtome (Yorko, Mumbai) following the method of Baker (1945). The leaf sections were stained with safranin-fast green combination, mounted in glycerin jelly, and observed under Olympus light microscope at various magnifications (100X, 250X and 400X).

RESULTS AND DISCUSSION

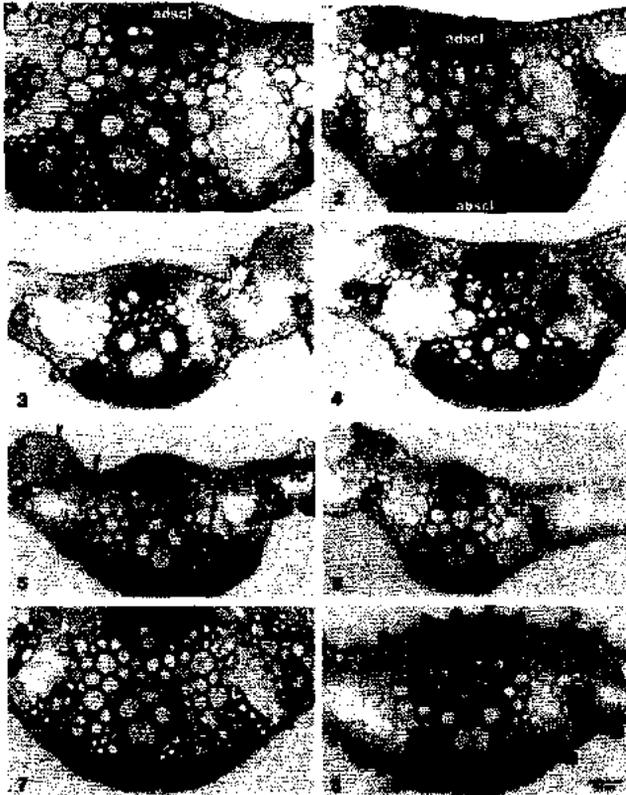
The leaf anatomical features of the various species of *Dendrocalamus* are presented in Table 1 and illustrated in Figures 1 and 2.

Leaf lamina outline

Leaf lamina around the midrib expanded, flat in all the species; asymmetrical, broadly V-shaped (7 species) or slightly S-shaped (3 species).

Table 1. Anatomical features of the leaf cross-section of various species of *Dendrocalamus*

S. No.	Species	Leaf outline	Total no. of bundles in the midrib	Arrangement of bundles in the midrib (adaxial+abaxial+lateral)	Total 1 st order bundles in the entire lamina	No. of layers of chlorenchyma	Leaf margins	
							No. of ribs	No. of sclerchymatous cells
1	<i>D. asper</i>	V-shaped	7	7(2+4+1)	9-11 pairs	3 (2+1)	2	22-25
2	<i>D. calostachyus</i>	V-shaped	2	1(1+1+0)	9-11	3 (2+1)	5	14
3	<i>D. brandisii</i>	V-shaped	8	8(2+5+1)	9-11	3-4 (2-3+1)	6	13
4	<i>D. giganteus</i>	S- shaped	8	8(2+5+1)	12-16	3 (2+1)	3	38
5	<i>D. hamiltonii</i>	V-shaped	5	5(1+3+1)	9-12	2 (1+1)	4	17
6	<i>D. hookeri</i>	V-shaped	6	6(2+4+0)	9-14	3 (2+1)	6	25
7	<i>D. longispathus</i>	V-shaped	11	11(3+6+2)	9-11	3 (2+1)	6	10
8	<i>D. membranaceus</i>	S- shaped	7	7(2+3+2)	4-8	3 (2+1)	6	4
9	<i>D. sericeus</i>	S- shaped	10	10(2+7+1)	10-12	4-5 (2-3+1-2)	6	34-36
10	<i>D. strictus</i>	V-shaped	6	6(2+3+1)	4-6	3 (2+1)	4	12

**Figure 1.** Transverse section of mid rib. a. *D. asper*; b. *D. membranaceus*; c. *D. calostachyus*; d. *D. brandisii*; e. *D. hookeri*; f. *D. hamiltonii*; g. *D. giganteus*; h. *D. strictus* (x25X)

(abs – abaxial sclerenchyma girder; ads – adaxial sclerenchyma girder; bc – bulliform cells; bse – bundle sheath extension; cv – cross vein; f – furrow; fc – fusoid cavity; pr – prickle; r – rib)

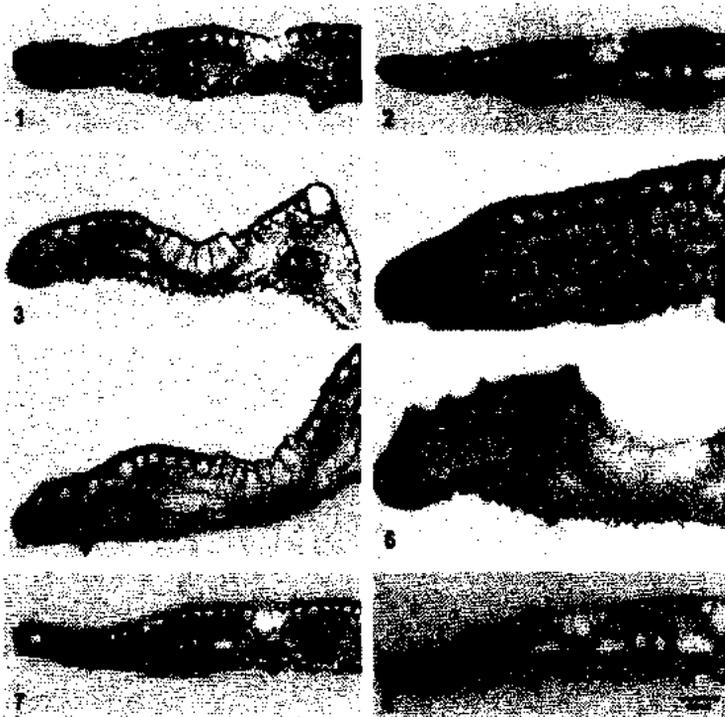


Figure 2. Transverse section of leaf lamina margin.

a. *D. asper*; b. *D. membranaceus*; c. *D. calostachyus*; d. *D. brandisii*; e. *D. hookeri*;
f. *D. hamiltonii*; g. *D. giganteus*; h. *D. strictus* (x25X)

Ribs and furrows

In all the species, the lamina immediately adjacent to one side only of the midrib is ribbed, as is the region of margin on the same side. The remainder of the lamina is without any ribs and furrow.

Midrib

Distinct, prominently projecting abaxially and complex in all the species with the total number of bundles varying from 2-11 in different species. These bundles are positioned adaxially and the lateral sides of the midrib. Four classes of bundles were observed in the midrib of *D. longispathus*, while in the remaining species only 3 classes of bundles were observed.

Vascular bundle arrangement

The distribution of bundles of different classes in the midrib of various species is shown in Table 1. In the lamina region, two classes of bundles (1st and 2nd order) are

present in majority of the species. In *D. membranaceus* and *D. longispäthus*, first and third order bundles were present. In majority of the species one first order bundle alternates with 6-9 second order bundles.

Vascular bundle description

The first order bundle of the midrib is rounded in all the species except *D. membranaceus*, where it is elliptical in shape. The second order bundles of the midrib are mostly rounded (5 species), rarely elliptical (5 species) while the third order bundles are mostly elliptical (6 species) or rounded (2 species) and not present in 2 species. In the lamina region, the first and second order bundles are mostly rounded, while the third order bundles, wherever present, are elliptical in shape.

Vascular bundle sheath

In the midrib region, two bundle sheaths are present in all the species. The outer sheath is parenchymatous and is interrupted by sclerenchyma, both on the adaxial and abaxial sides in all the species. The inner sclerenchymatous sheath is always complete. In the lamina region also, two bundle sheaths are present around all the bundles and the inner one is complete, while the outer one is variously interrupted by sclerenchyma.

Sclerenchyma

Sclerenchyma bands of various shapes are present opposite all the vascular bundles. In the midrib region, the abaxial sclerenchyma girder varies in shape from ribbon-shaped (4 species) to boat-shaped (6 species) while the adaxial girder is triangular (3 species), rectangular (3 species), oval (2 species) or squarish (2 species).

In the lamina region, sclerenchyma girder of variable shape is presented on both the adaxial and abaxial sides of all classes of bundles in all the species. The lamina margin possesses a small patch of sclerenchyma of only 4 cells (*D. membranaceus*) or a large patch of 10-38 cells (9 species).

Chlorenchyma

Chlorenchyma is non-radiate and mostly 3-layered in majority of the species (7 species), 2-layered in *D. hamiltonii*, 4-5-layered in *D. sericeus*, and 3-4-layered in *D. brandisii*. In all the species, only one layer is present next to the abaxial epidermis, above the fusoid cell cavities, the remaining layers being positioned adaxial to the fusoids. The cells of chlorenchyma show invaginations of walls into the lamina (arm cells) in all the species. The layer of chlorenchyma present just beneath the adaxial epidermis is differentiated into a palisade layer. Its cells are vertically longer than broad and possess conspicuous invaginations from the lower cell wall only.

Fusoid cell cavities

These are fusiform, colourless and thin-walled cells, frequently mistaken for intercellular spaces. Paired fusoid cell cavities are present in between the adjacent bundles of the lamina in all the species. The adjacent cavities of each pair are separated by a single chlorenchyma cell in *D. membranaceus* and *D. sericeus*, by 2-3 mesophyll cells in *D. calostachyus* and by 1-2 cells in the remaining species.

Colourless cells

These are parenchymatous cells (devoid of any chloroplast) present in the midrib region of majority of the species (9 species) in the form of adaxial extensions of the outer bundle sheath of the laterally disposed bundles.

Bulliform cells

Fan-shaped groups of 2 to 4 bulliform cells are present in the regions of furrows on the adaxial epidermis in all the species, with one group each located in between two adjacent bundles. The bulliform cells penetrate deeply into the lamina, extending up to half its width.

Adaxial epidermis

Adaxial epidermis cells are of uniform size and much larger than the abaxial epidermal cells in majority of the species (8 species) but in *D. membranaceus* and *D. strictus*, the cells of both the epidermis are of almost equal size. A continuous cuticle is present over the epidermis.

Abaxial epidermis

All the epidermal cells are of uniform size and each epidermal cell has individually thickened cuticle projected into narrow cuticular papillae, either single or bifurcating into two papillae in all the species.

Cross veins

Files of sclerenchymatous cells connecting the adjacent vascular bundles (cross veins) were observed in all the species.

The above observations show that the various species of *Dendrocalamus* possess a type of leaf cross-sectional anatomy, which is characteristic of the woody, erect, clump-forming bamboos belonging to the genera *Bambusa*, *Dendrocalamus*, *Gigantochloa* and *Oxytenanthera*. The leaf anatomy of all these bamboos is characterized by a flat abaxially projecting complex midrib and the presence of fusoid and arm cells in the

mesophyll. In addition to the above features, the various species of *Dendrocalamus* studied presently also possess adaxial and abaxial girdles of sclerenchyma opposite the vascular bundles, double bundle sheath around all the bundles, bundle sheath extensions of lateral bundles of mid rib, in the form of colourless cells, and the presence of cross-veins.

The differences in the leaf anatomical characters among the various species of *Dendrocalamus* have been found useful in the formulation of an artificial key for the separation and identification of various species, as shown below:

Key to *Dendrocalamus* species

- 1a Vascular bundles of midrib 10 or more: 2
 1b Vascular bundles of midrib 2-8: 3
 2a Lamina outline V-shaped in cross-section; chlorenchyma 3-layered
 *D. longispathus*
 2b Lamina outline S-shaped; chlorenchyma 4-5-layered
 *D. sericeus*
 3a Total midrib bundles 2; fusoid cell cavities separated by 2-3 mesophyll cells.....
 *D. calostachyus*
 3b Total midrib bundles 5-8; fusoid cell cavities separated by 1-2 mesophyll cells: 4
 4a Lamina outline V-shaped in cross-section: 5
 4b Lamina outline S-shaped in cross-section: 9
 5a Total first order bundles in the entire lamina 4-6 *D. strictus*
 5b Total first order bundles in the entire lamina 9-14 6
 6a Total midrib bundles 5; chlorenchyma 2-layered *D. hamiltonii*
 6b Total midrib bundles 6-8; chlorenchyma 3-4-layered7
 7a Colourless cells and lateral bundles absent in the midrib *D. hookerii*
 7b Colourless cells and one lateral bundle present in the midrib: 8
 8a Lamina margin with only 2 shallow ribs and a patch of 22-25
 sclerenchyma cells *D. asper*
 8b Lamina margin with 6 prominent ribs and a patch of about 13 sclerenchyma cells
 *D. brandisii*
 9a Total first order bundle in the entire lamina 12-16; sclerenchyma patch in the
 lamina margin massive, comprising up to 40 cells *D. giganteus*
 9b Total first order bundle in the entire lamina 4-8; sclerenchyma patch in the lamina
 margin scanty, comprising only 4 cells *D. membranaceus*

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