1.Theme-1.1-Taxonomy and Morphology

Identifying Bamboos in the Vegetative Stage

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Abstract

Bamboos have always been a taxonomically challenging group of plants because while the classification of flowering plants depends largely on the characteristics of reproductive organs, flowering is rare in many bamboo species. Some bamboo species flower at intervals as long as 120 years and for some there is no report of flowering to date. Specimens kept in herbariums are not always reliable as they are fragmentary since most of the vegetative parts are bulky. It has now been realized that certain vegetative characters may be used effectively for the recognition of bamboo taxa without reference to flowers. Several studies have been carried out on details of vegetative morphology of bamboos in their natural locations, which have made their identification possible in the field. It has been found that most bamboos can be identified by either the presence of some unique character (s) or a unique combination of some characters. This paper discusses various features of vegetative morphology that can be very useful for the field identification of a majority of bamboos in vegetative stage.

Key words: Taxonomy, bamboos, morphological features, key

Introduction

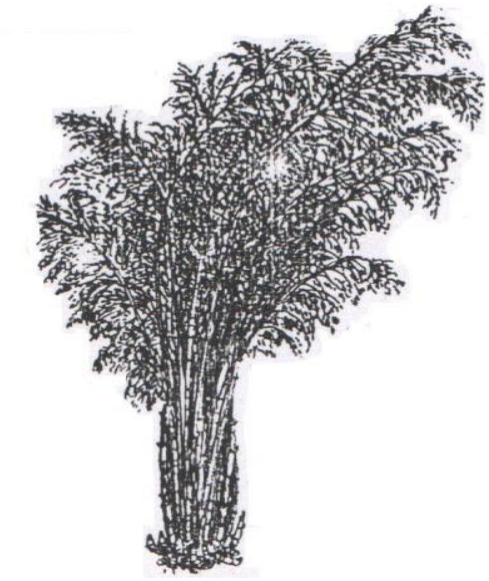
The correct identification of a plant species is very important for its cultivation and utilization. Also, any scientific study carried out on a plant becomes meaningful only if it is correctly identified. In today's world, as managers of natural resources, it is important for us to understand the diversity of our resources, and the correct identification of a species is important component of such an understanding. It is often easy to recognize a bamboo but very difficult to identify it scientifically. This is particularly true for bamboos in vegetative stage, which stage in bamboos with cyclic flowering, ranges from 7-120 years. The identification of bamboos has not been trustworthy in the past since bamboo taxonomy has remained neglected as compared to other plants. This has been primarily so because flowers in bamboos are infrequently available due to cyclic flowering, and grass taxonomists traditionally rely mainly on the flowers for identification of species. Bamboos not in flower have often been ignored by collectors and

avoided by taxonomists. Moreover, since most of the vegetative parts of bamboos (rhizomes, culms, branch complements *etc*.) are bulky and some are very delicate, they have often not been collected by collectors. As a result, herbarium specimens of bamboos are fragmentary and badly preserved so that these look different from similar parts from live plants. Also, in most cases, it is difficult to relate the vegetative parts of bamboos housed in various herbaria to the reproductive parts of the same species. The live collections of bamboos conserved in various bambuseta are inspiring but the various species are either not properly identified or wrongly identified. The identification keys given in various flora require information on plant parts not easily available. Because of all these limitations, bamboo species in the wild remain poorly studied. On the contrary, cultivated bamboos are better known and more easily identifiable.

It is encouraging to note that bamboo taxonomy has recently witnessed great activity and as a result, more information has become available on the detailed morphology of the bamboo plant. Consequently, it has now been realized that certain vegetative characters may be used effectively for the recognition of bamboo taxa without reference to flowers. The complexity of the bamboo plant provides ample vegetative characters to differentiate the various genera and species of bamboos. However, the external form of the homologous parts of a bamboo plant varies with their respective position on the culm, and with the increase in size of the whole plant. It is for this reason that some outward manifestations of gross morphology in the bamboo plant cannot always be applied in a rigid hierarchy of technical terms or seasoned concepts. However, in spite of all these limitations, vegetative parts of bamboos do provide characters of diagnostic importance. Realizing this, several studies have been carried out on details of vegetative morphology of bamboos in their natural locations which have made their identification possible in the field. It has been found that most bamboos can be identified either by the presence of some unique character (s) or a unique combination of some characters. A careful study of the various features of vegetative morphology, as discussed below, has been found very useful for the field identification of a majority of bamboos in vegetative stage.

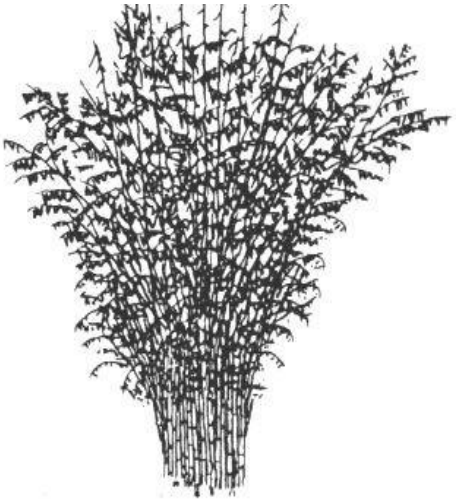
1. The habit: This refers to the overall appearance of a bamboo clump from a distance, whether strictly erect, arching over, strongly pendulous or assuming a climbing habit (Fig.1). The growth form of a bamboo *i.e*. whether tree-like (*e.g.* most species of *Bambusa* and *Dendrocalamus*), a shrub (species of *Arundinaria, Yushania, Chimonobambusa*,*Chimonocalamus, Indocalamus etc*.),or a reed-like (*Ochlandra* sp) , should be noted. Both the growth habit and the growth form of a bamboo is important for preliminary diagnosis of the genera and species. It is also so important to observe whether the aerial stems are growing in compact clumps or in loose clumps, or in a more open or clustered array. If growing in loose clumps or in an open array, it should then be confirmed whether this habit is due to

the presence of leptomorph (‘running type’) rhizome (*e.g.* monopodial bamboos) or due to the presence of long root necks in the pachymorph rhizome (*e.g. Melocanna baccifera, Yushania jaunsarensis*).



a. Erect and arching over

b. Reed bamboo



c. Shrubby bamboo

d. Semi-scandent straggler

Fig.1 (a-d): Various growth forms in bamboos.

2. The rhizome system: Rhizomes are subterranean stems (with nodes and internodes)which generate roots and aerial culms from nodes. General characteristics of rhizome such as length between adjacent culms, diameter, whether short and thick or long and slender, should be noted. The type of rhizome *i.e.* whether pachymorph (thick, with sympodial branching, Fig. 2a), or leptomorph (thin, with monopodial branching, Fig.2b), or metamorph(with leptomorph rhizomes and with both sympodial and monopodial branching, Fig. 2c), is taxonomically useful at the generic level.

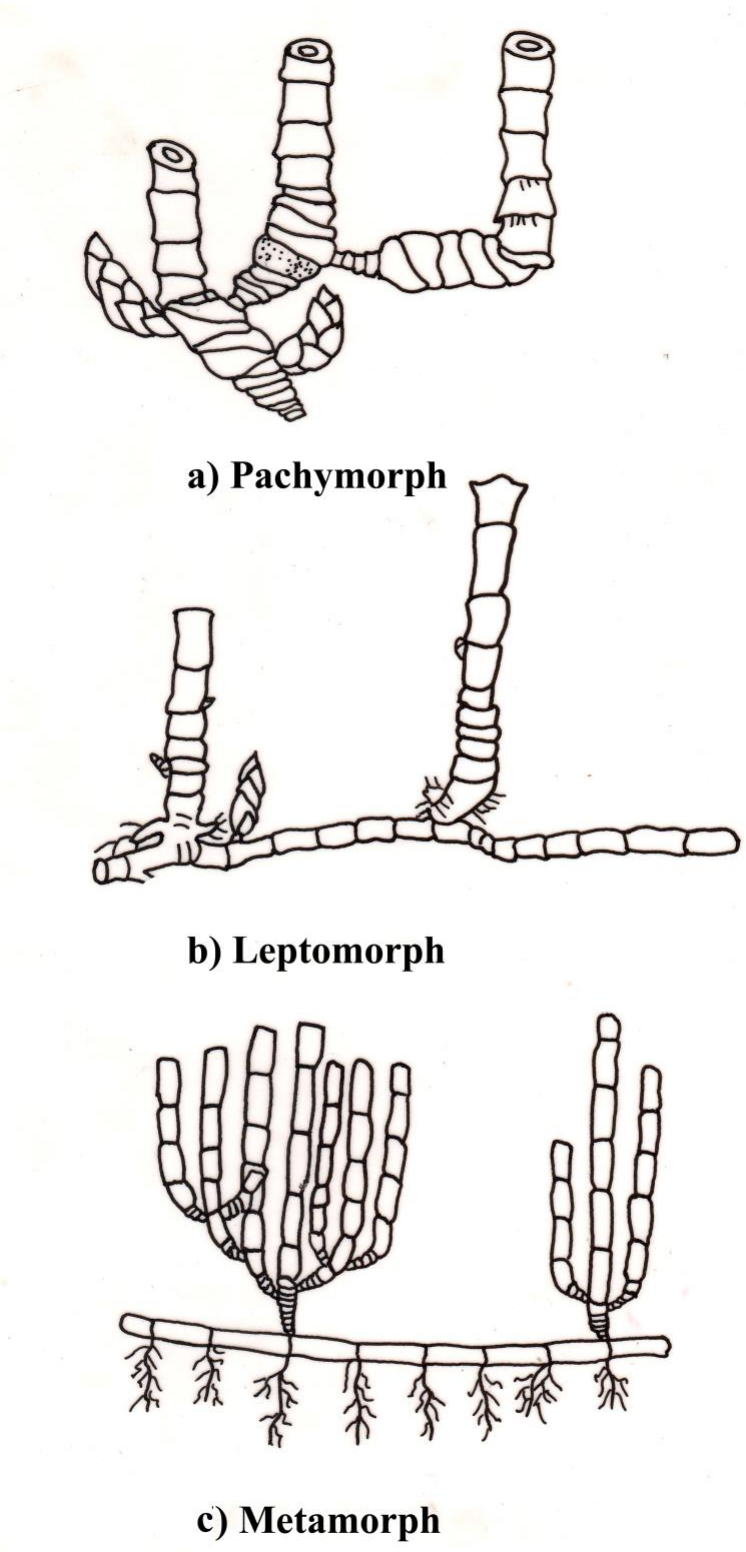


Fig.2(a-c): Rhizome type in bamboos.

3. The culm: The new culms in most bamboos emerge from the soil at full diameter and attain their full height in an average period of 1-3 (rarely 6 -7 months). These young emerging culms, also called new shoots or 'juvenile shoots', are highly distinctive in bamboos and the characters of sheaths that closely cover the juvenile shoots may be conveniently used to distinguish the various genera and species. External morphology of juvenile shoots has been used in framing keys for the identification of bamboos by some authors (Raizada and Chatterjee, 1963; Bahadur, 1979; Varmah and Bahadur, 1980). The following characters of culm, both young and mature, are also important in the field identification of bamboos.

a) Height: Height of the tallest culm and the diameter of the culm measured at the breast height for giant bamboos or the fourth or fifth internode from the ground in other bamboos.

b) Nodes: Total number of nodes (joints of the culm) on the tallest culm, and whether isolated or in close succession should be recorded. Nodes, whether raised or in level with the internodes, conspicuousness and morphology of sheath scar, presence of a transverse thickening or 'supra-nodal ridge', nodal line whether horizontal or dipping, presence of any spines or aerial roots at the nodes, presence of any hairs or a colored band above and/or below the node are taxonomically important and hence should be carefully recorded.

c) Internodes: Total number of internodes on the tallest culm, length of internodes; the combination and pattern of colors that varies from green, bluish -green and with or without white, yellow or green stripes ; form and texture of surface of internodes, presence of any channel or groove; and the presence and type of pubescence are important taxonomically. The internode should also be observed in cross-section to observe variations in shapes *e.g.* round, sulcate, plano-convex, hollow or solid, wall thickness and extent of pith. Many bamboos have characteristic white exudates on the surface of internodes that may vary from barely perceptible bloom (similar to that seen in some kind of plums and grapes) to a fluffy, flour-like deposit that conceals the green surface of internodes. Kurz (1876) mentions the characteristic "white pruinose" culms of *Dendrocalamus giganteus* and the presence of a "white fugacious meal" on the culms of *B. vulgaris* var. *vittata*). The 7th-8th internode from the ground should be selected as standard internode for various observations of internodal characters.

4. The branch bud and bud scale: The branch buds are present at the nodes, on alternate sides on the new growing culms, protected by the culm sheaths until they fall. The bud is entirely covered by a scale-like, membranous or thickened structure called a bud scale or prophyll . It is a two-keeled structure and varies between genera. The location of the bud on the node, its shape and numbers, and whether closed at the back and/or the front are taxonomically important.

5. Branching: The branching pattern is a very important character in the separation of bamboo genera. The habit of the main branch, whether thick or vine-like and secondary branches whether angled upwards or reflexed downwards should be recorded. A typical form of branch complement appears on mid-culm nodes with more branches above and fewer below. The number of branches in the first year of growth of the culm as well as the eventual number of branches should be noted. If there is multiple branching, then whether all the branches are of the same size (sub-equal) or whether the central branch is much larger (dominant) than all the others branches should be recorded. Depending upon the presence and number of lateral branches arising from a primary branch, these are classified as 'single branching' (with a solitary primary branch at nodes, *e.g.* genera *Olmeca, Indocalamus, Sasa, Sasamorpha,* Fig.3a), 'double branching' (with two branches at the node, *e.g.* genus *Phyllostachys,* Fig. 3b), 'triple branching' (with three branches at the nodes, *e.g.* species of *Chimonobambusa,Otatea* Fig. 3c) or 'multiple branching' (with more than three branches at the nodes *e.g.* genera *Dendrocalamus, Bambusa*, *Dinochloa etc*., Fig. 3d). When more than one branch arises at the nodes, one of these may be dominant (*e.g.* species of *Bambusa, Dendrocalamus, Gigantochloa,* Fig. 3d) or all the branches may be sub-equal (*e.g.* species of *Schizostachyum, Melocalamus, Dinochloa* and *Ochlandra,* Fig.3e,3f). The origin of the branch, whether from the nodal line or above the nodal line should also be observed. The mode of emergence of new branches in bamboos is also useful in bamboo identification. In one type known as "extravaginal" branching, the emerging branches break through the base of the culm sheath proper, leaving it in place, while in the other type called "intravaginal", the branch emerges without rupturing the sheath, but forcing it off the culm. There is a third type designated as "infravaginal" (Clark, 1985) which is a modification of extravaginal branching in which the developing subordinate branches emerge through the nodal sheath girdle without rupturing the upper part of the culm sheath *e.g.* species of *Chusquea* and *Dinochloa.* This type of emergence of branching has been suggested by Clarke (1985) to be correlated with the climbing habit of these bamboos.

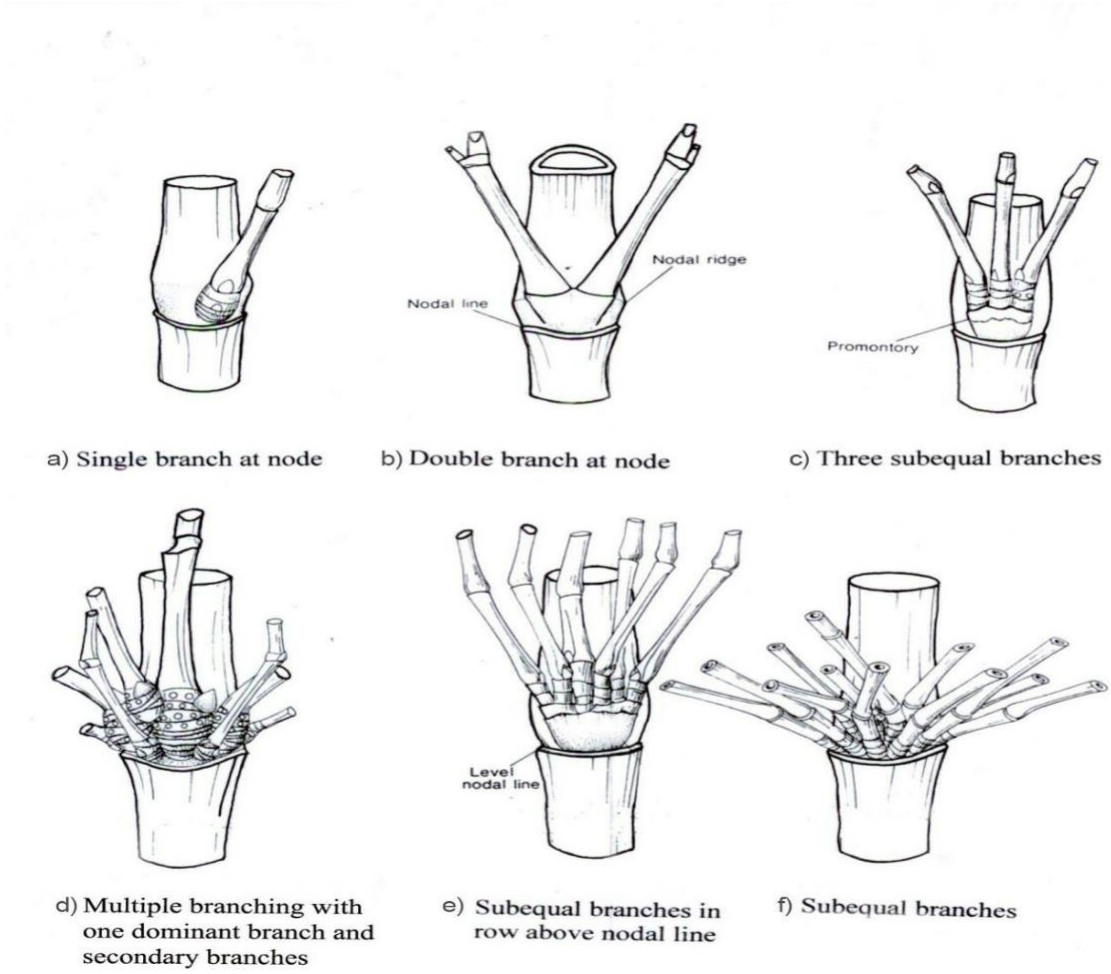


Fig. 3(a-f): Some branching patterns in bamboos.

6. New culms (New young culms): New culms , Juvenile culms, or juvenile shoots in bamboos usually develop with the beginning of the rainy season. The juvenile shoots of bamboos are highly remarkable and the overall appearance of the shoots and the sheaths that closely cover these shoots are useful in the separation of various genera and species. The colour of juvenile shoots and presence of waxy or powdery coating or hairs on the sheaths is taxonomically useful. Varmah and Bahadur (1980) presented a key to identification of 25 bamboo species, based on characters of young shoots which can be conveniently and effectively be used in the field for quick identification of bamboos. The limitation of such keys, however, is that this method of field identification can only be applied during the rainy season when the new vegetative shoots make their appearance.

7. Culm-leaves The culm -leaves are actually well differentiated 'leaves' borne on the nodes of new growing culms where they completely cover, support and protect the growing shoots and the branch

buds. Culm-leaves are very important for identification of bamboos, as they have unique morphological features. In culm- leaves, the sheath represents the greater part of the 'culm leaf' while the blade is under-developed, especially towards the base of the culm (Fig. 4).The size and shape of the culm- leaf blade in a species varies with their point of insertion on the culm. However, they are fairly uniform in shape on the mid-culm nodes. The culm- leaves are more or less distinctive for each species and are, therefore, of diagnostic value (Fig. 5). The culm-leaves, whether persistent, caducous or deciduous; relative dimensions of the length and breadth of the sheath proper; the thickness, texture of the sheath whether hard or soft; surface of the sheath, whether glaucous, waxy, mottled or striped, densely covered with hairs or glabrous, and the colour and pattern of distribution of hair are taxonomically significant. At the junction of sheath and blade is found a projecting tongue-like structure called inner ligule or simply 'ligule'.The shape, length and type of edges of the ligule (whether entire or variously divided) are also important.

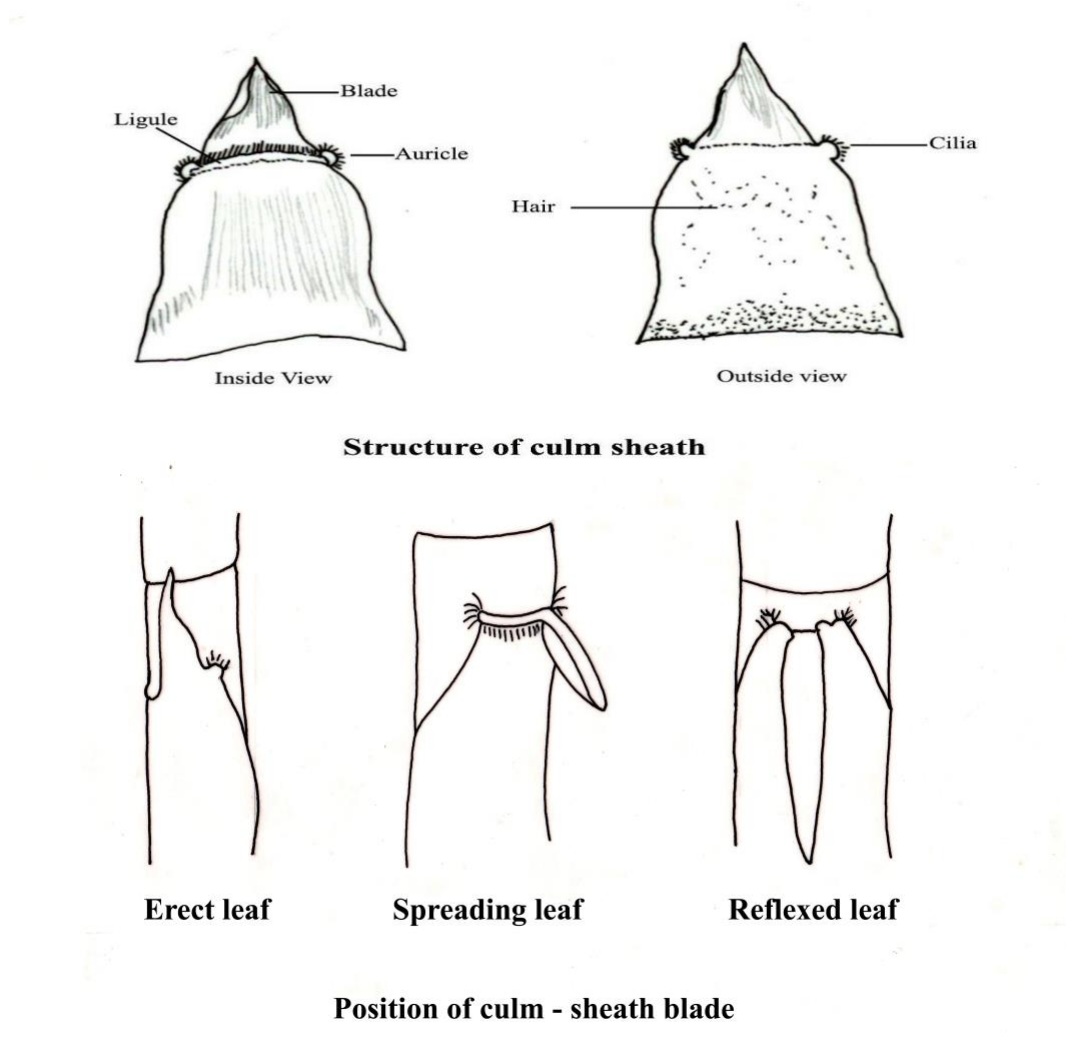


Fig. 4: Culm-sheath morphology and orientation of sheath blade in bamboos.

The culm- leaf blade varies in length and assumes various forms and shapes in different species. The length of the blade, and whether smaller than or longer than the sheath proper; the width of its base in relation to the top of the sheath proper, whether narrower or broader than the top of the sheath; the shape of the leaf; presence of any hairs; and any other unique feature should be carefully recorded. This blade on the top of the sheath is often decurrent into auricles (ear-like structures, one on either side), which are often fringed with stiff bristles in various patterns. The relative size and morphology of the two auricles and the size and colour of the bristles (oral setae) present on them should be recorded when the sheaths are intact on the culm. Position of the blade whether erect, reflexed or horizontal, should be carefully observed and recorded. The culm leaves should be collected from the mid-culm region where they are most representative in size and shape. If the sheath is persistent, it should be pulled from the culm and pressed flat. Keys for identification of some selected bamboos, based on characters of culm-leaves and new shoots have been published by Raizada and Chatterjee (1963), Bahadur (1979), and Varmah and Bahadur (1980).

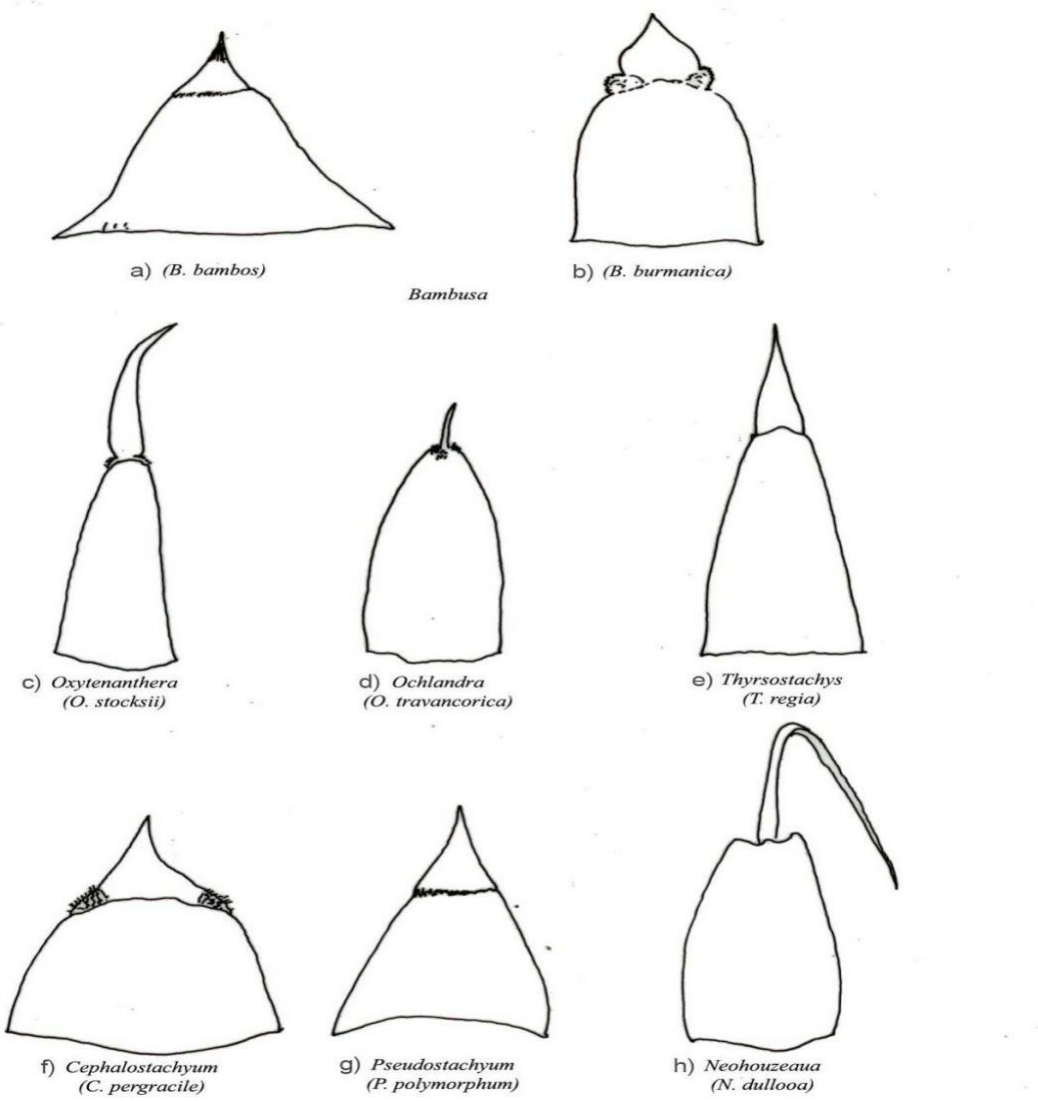


Fig. 5 (a-h): Culm-sheath forms in some bamboo genera.

Leaves: The foliage leaves are borne on the higher order branches. They possess well-developed blade, borne on a delicate sheath. Like the culm- leaves, the -sheaths have ligules, auricles, and oral setae at the junction of sheath and blade (Fig. 6). Presence or absence of all these parts of the leaf, as also the variations in their morphology, are also of diagnostic value. The variations in size, shape, thickness, and indumentum of foliage leaves, and the presence or absence of transverse veinlets (which connect adjacent parallel veins of all orders to give 'tessellate venation' or simply 'tessellation'), also provide characters of taxonomic importance.

After all the characters discussed above have been carefully studied and recorded, it is very convenient to frame keys for the field identification of various species of bamboos growing a particular geographic

region. An example of such key framed by us (based mostly on features of vegetative morphology, with few supporting feature of reproductive morphology) for the identification of various genera of Indian bamboos is given below. (Similar keys for the identification of various species within each genus have also been framed and would be discussed elsewhere).

KEY TO THE INDIAN GENERA OF BAMBOOS

(An artificial key based only on the genera and species found in India; wild or cultivated. The present key is based mostly on characters of vegetative morphology).

1. Rhizome pachymorph with short or long neck; culms uni caespitose, or diffuse in *Melocanna baccifera*, or plural caespitose in *Pseudostachyum polymorphum* and *Yushania*, due to very long necks of pachymorph rhizomes:

2. Branches at mid-culm nodes 3- many, with the central branch at each node dominant or dormant:

3. Scrambling bamboos with thin culms, dimorphic branches and very persistent culm leaves; inflorescence determinate (semelauctant), partially ebracteate; ovary without any apical appendage .....***Neomicrocalamus***

3a. Tall bamboos, twining climbers or reed-like bamboos; inflorescence indeterminate , fully bracteate; ovary with a conspicuous apical appendage:

4. The base of culm-leaf blade (along with the auricles) usually almost as broad as the top of the sheath proper; the culm-leaf blade more or less triangular, as long as or shorter than broad, usually upright, if reflexed then the twigs modified into spines; oral setae and auricles of culm-leaf sheath usually large .....***Bambusa***

4a. The base of culm- leaf blade much narrower than or at the most half as broad as the top of the sheath proper, culm- leaf blade much longer than broad, usually reflexed but the twigs not modified into spines; oral setae and auricles of culm-leaf sheaths usually small or absent:

5. Giant bamboos; culm habit erect and arching at the apice ; short aerial roots present on few nodes towards the base of culms; spikelets usually aggregated into heads on the branches of the panicle.....***Dendrocalamus***

5a. Tall bamboos; culm habit arching at the apice or drooping; generally no aerial roots present on the basal culm nodes; spikelets lax on the branches and arranged in panicles, not aggregated into heads:

6. Climbing bamboos; culm-leaves with rugose base; fruit globose to ovoid with fleshy pericarp, separable from the seed; spikelets 1- or 2-flowered:

7. Climbing bamboos, lofty twining; internodes on lower part of culm zig-zag; spikelets 1-flowered, without rachilla extension; lodicules none; palea 2- keeled .....***Dinochloa***

7a. Erect bamboos with diffuse culms arching at the apice ; internodes straight; spikelets 2-flowered, with rachilla extension, ; lodicules 3, palea not keeled,

rounded .....***Melocalamus***

6a. Tall bamboos with erect culms; culm- leaves without rugose base; fruit elongate with thin pericarp adnate to the seed; spikelets 1-3 or many-flowered:

8. Florets separated by a rachilla extension ; filaments of stamens free

.....***Thyrsostachys***

8a. Florets arising at about the same level, not separated by a rachilla extension ; filament of stamens connate in a thin monadelphous tube:

9. Culms usually tall, not branchedon the basal culm nodes; spikelets sub-ovate or oblong, many- flowered, palea - strongly 2-keeled .....***Gigantochloa***

9a. Culms weak, thin and whip-like at the tip and bending far over; spikelets long-cylindrical, 1-3-flowered, with 1-4 glumes attached; paleas of lower florets 2-keeled, those of upper florets none or convolute, not 2-keeled.....***Oxytenanthera***

2a. Branches at mid-culm nodes 3 to many, with the central branch at each node not -dominant but with many sub-equal secondary or tertiary branches:

10. Culm nodes with spines .....***Chimonocalamus***

10a. Culm nodes without spines:

11. Foliage leaf blade with tessellate venation:

12. Lateral branches sub-equal ; branch axes all subtended by sheaths:

13. Inflorescence dense, enclosed by large spathulate sheaths .....***Thamnocalamus***

13a. Inflorescence open, bracts and sheaths lacking .....***Indocalamus /Kuruna***

12a. Lateral branches not sub-equal; subtending sheaths of lateral branch axes absent:

14. Rhizome necks to >30cm, habit clumping and diffuse .....***Yushania***

14a. Rhizome necks to <30cm, habit clumping and dense .....***Borinda***

11a. Foliage leaf blades without tessellate venation:

15. Culm-leaves with membranous, fimbriate, pale, long-fringed edges on both sides at the top; a distinct corky collar present around each node .....***Ampelocalamus***

15a. Culm-leaves without any long-fringed edges at the top; no corky collar present around nodes :

16. Extravaginal branching type .....***Drepanostachyum***

16a. Intravaginal branching type :

17. Medium to large-sized bamboo, culm erect, drooping at the tip, thin-walled ; fruit a caryopsis with thin, dry pericarp:

18. Paleas convolute, keelless or inconspicuous keeled at the top:

19. Filaments connate.....***Neohouzeaua***

19a. Filaments free.....***Schizostachyum***

18a. Paleas 2-keeled:

20. Spikelets one-flowered ; lodicules 2-3.....***Cephalostachyum***

20a. Spikelets many-flowered; lodicules 3-5:

21. Culms diffuse; foliage leaves cross-veined; caryopsis small, depressed, globose; lodicules 3-5, large, and persistent in the fruit.....***Pseudostachyum***

21a. Culms cespitose ; Foliage leaves without cross-veins; caryopsis elongated, beaked; lodicules 0-3, not persistent in the fruit.....***Teinostachyum***

17a .Tree- like, shrubs or reed-like bamboos; fruit a berry with fleshy pericarp:

22. Shrubs, gregarious clump-forming reed-like bamboos; stamens 15-120; lodicules 1-many; fruit 2-5 cm long.....***Ochlandra***

22a. Tall, erect bamboo; stamens 6; lodicules 2-3; fruit 5-12 cm long:

23. Culm-leaves deciduous; culm-leaf sheath auricles prominent. Inflorescence in large densely glomerate heads; fruit globose, apple-shaped, *c*. 5 cm across.....***Stapletonia***

23a. Culm-leaves persistent; culm-

leaf sheath auricles absent; Inflorescence a large compound panicle of spikes; fruit pyriform, 7-12 cm long .....***Melocanna***

1a. Rhizomes leptomorph; culms habit diffuse :

24. Internodes of rhizomes, culms, and branches flattened or furrowed along its entire length beyond branches. Inflorescence indeterminate , ultimate branches terminating in sessile spikelets:

25. Small-sized bamboos, no more than 1m tall; culms habit diffuse , culms zig-zag; primary branches at mid-culm nodes 2-6; internodes of branches only 3, very short, 3-10 cm long; .....***Shibataea***

25a. Tall bamboo; 2-20 m tall; culms habit diffuse, culms straight or zig-zag; branches at mid-culm nodes generally 2, unequal in size (rarely with a small third branch); internodes of branches many, very long; .....***Phyllostachys***

24a. Internodes of rhizomes, culms, and branches nearly cylindrical, rarely somewhat compressed or furrowed at the base beyond branches, just above the bud. Inflorescence determinate , ultimate branches terminating in pedicellate spikelets:

26. Culm nodes with a ring of root thorns; primary branches on mid-culm nodes 3; culm sheaths deciduous, sheath blade minute .....***Chimonobambusa***

26a. Culm nodes without any thorns; branches on mid-culm nodes 1-many; culm-leaves persistent, culm- leaf blade well developed:

27. Culms habit diffuse ; nodal branches single or with 1 or 2 additional branchlets.....***Pseudosasa***

27a. Culms habit—dense, branches initially 1(-3) but ultimately multiple (one primary and several secondary):

28. Fimbriae of culm-leaf sheaths scabrous .....***Arundinaria/Sarocalamus***

28a. Fimbriae of culm-leaf sheaths glabrous.....***Pleioblastus***

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