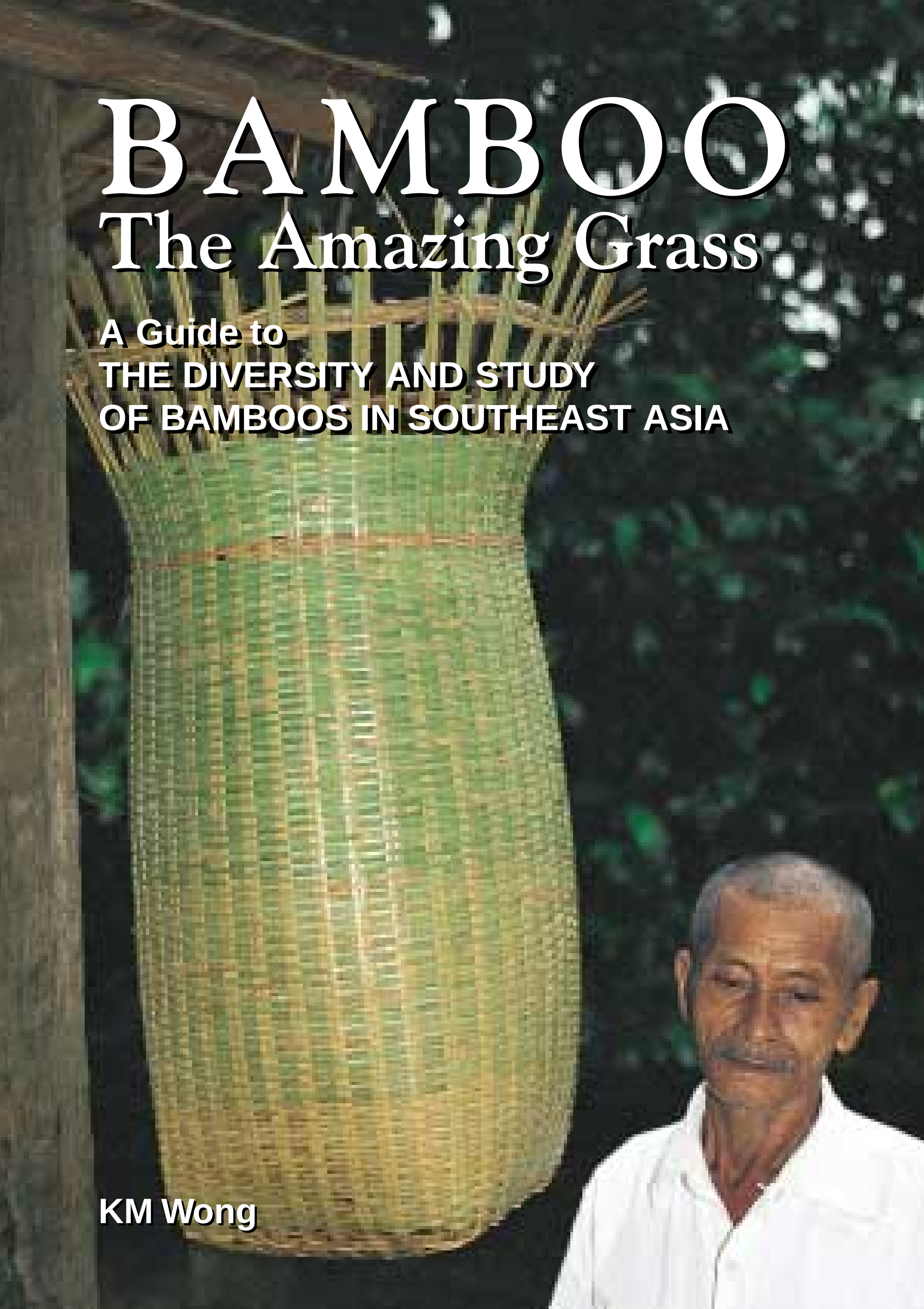
BAMBOO
The Amazing Grass

**A Guide to
THE DIVERSITY AND STUDY
OF BAMBOOS IN SOUTHEAST ASIA**



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A Guide to
THE DIVERSITY AND STUDY
OF BAMBOOS IN SOUTHEAST ASIA

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Front cover: Unfinished bamboo basket in a village in Nami, Kedah, Peninsular Malaysia, its maker pensive.
Back cover: Clump division and rhizome offsets of *Gigantochloa latifolia*, near Alor Setar, Kedah, Peninsular Malaysia, being taken for establishment in the Bambusetum of the Rimba Ilmu Botanic Garden, University of Malaya, an IPGRI-supported project.

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Contents

Foreword

The fundamental importance of bamboo as a plant resource has led to many international agencies, including the International Plant Genetic Resources Institute (IPGRI), supporting research and collection of genetic materials in a number of countries. In the countries of Southeast Asia, bamboo is an important feature of landscapes and traditional use. Yet, the taxonomic inventory of the bamboo flora progresses slowly, by force, because of the incomplete exploration of the flora and the inadequacy of scientific collecting. As landscapes change to an even greater extent, the ability to recognize the diversity of bamboos and efforts towards the conservation and collection of the important or rare species become even more significant.

One of the projects recently concluded was the establishment of a Bambusetum for national conservation and research at the University of Malaya's Rimba Ilmu Botanic Garden in Kuala Lumpur. The site was most appropriate because of its strategic location within the research environment of the University of Malaya, the oldest university in Malaysia and the presence of the specialist, Prof K.M. Wong, who has tremendous interest in research on bamboos. The successful conclusion of that establishment, and its encouraging progress since then, has led to the present account, which seeks to make available an introduction to bamboos as a useful plant resource and the multiple facets of their diversity and biology, in a way that draws attention to the many interesting features of bamboos in Southeast Asia in general. Malaysia and Singapore are the only countries in Southeast Asia where modern taxonomic accounts of the bamboo flora as a whole exist, and some other countries are approaching completion of their own guides.

It is the hope that this account will stimulate general interest and provide some perspectives into bamboo morphology, ecology and the taxonomic research required for understanding and conserving the diversity of bamboos. IPGRI continues in its efforts to promote the identification and conservation of the most important components of genetic resources among bamboos, and in making the associated information and approaches as accessible as possible.

Percy E. Sajise,
Regional Director, APO,
International Plant Genetic Resources Institute, IPGRI

(Opposite). Teratological form of *Gigantochloa scortechinii* with multiple primary branch buds at each node.

Preface

The research on the conservation and use of bamboo resources has been the concern of countries in Asia, particularly in south, southeast and east Asia where utilization of bamboo has been a traditional and cultural practice of many countries. The fast pace of development that is progressing in many countries in the region has threatened much of the natural resources including bamboo. IPGRI's support for the conservation and use of plant genetic resources has garnered the awareness of national governments that have hitherto begun to provide much-needed support for the increased R&D activities on plant genetic resources, including bamboo resources.

The *ex situ* collection of bamboos established at the Rimba Ilmu Botanic Garden, University of Malaya is perhaps the most comprehensive living collection of bamboos in Malaysia. IPGRI is proud to have been associated with Prof K.M. Wong in setting up this bambusetum for reference, research and education. The establishment of this *ex situ* collection has resulted in the present publication, which introduces the diversity of bamboos not only in Malaysia, but Southeast Asia as well. The publication has also included information on the conservation of some rare bamboo species in the region. This effort, we are sure, will continue to stimulate and promote the concern for conserving the diversity of bamboos, which, hopefully, will also encourage efforts for sustainable management and increased economic use of the bamboo resources.

Hong L.T. and **V. Ramanatha Rao,**
IPGRI-APO
International Plant Genetic Resources Institute, IPGRI

(Opposite). The bambusetum at the Rimba Ilmu Botanic Garden (top) and a section of newly established *Schizostachyum* plants.

Bamboos and Us

Bamboos, botanically considered a specialized group in the Grass family, are fascinating for different reasons. To many Chinese, Japanese, Indians and the peoples of Southeast Asia and South America, bamboos are intricately linked to both culture and even survival, since ancient times. The many uses of bamboo range from handicrafts made *ad hoc* in village settings, such as personal ornaments, utensils and a most incredible variety of baskets and other containers, bird cages, poultry coops, musical instruments, to water pipes, bridges, house construction and fishing contraptions (Kurz 1876, Wong 1995b) (Figs. 1–6). Bamboo scaffolding used during construction of buildings (Fig. 7), including high-rise structures, so evident in parts of India, Bangladesh and China, looks set to stay as a simple, inexpensive technology even in today's world of modern innovations. From bamboo blowpipes and small animal traps familiar to the more primitive technologies, the use of this material has graduated to modern factory-based production of paper, bamboo blinds

Fig. 1 (Opposite). Mud and bamboo feature in a simply constructed house wall, Sylhet, Bangladesh. **Fig. 2 (Above).** Ornamental wall panel woven from *Schizostachyum zollingeri*, a bamboo much used in the Mata Ayer district of Perlis, Peninsular Malaysia.

Fig. 3. Rice grain stores and living quarters with bamboo walls in a village at Changlun, Kedah, Peninsular Malaysia.

Fig. 4. *Gigantochloa scortechinii* bamboo used for vegetable baskets at Tapah, Perak, Peninsular Malaysia.

Fig. 5. A bamboo fishing lift-net device, Lasem, Java.

and barbeque skewers. The living bamboo provides edible shoots, fences, windbreaks, ornamentals and a means to counter erosion in some situations.

To the botanist, the 1200–1500 species of bamboo the world over still represent a diversity that is not well understood, with many species to be discovered or better documented, and very incomplete agreement as to how the many forms are to be classified. The silviculturist and agronomist, whose job it is to cultivate trees and bamboos profitably for economic products, are interested in their growth attributes, cultivation aspects and potential utilization. Resource managers are interested in ensuring that rare forms are conserved, and useful types of bamboo are better understood and made available for developing useful materials that can help people. The forester is concerned about which bamboos occur where, and in what abundance, and whether these have potential usefulness or may become weedy in their growth, smothering other more useful plants. A recent perspective is the realization that living bamboo stems house interesting animal communities, including some with specific associations (Kovac 1993).

One thing is certainly agreed among those who are conscious about the usefulness of bamboos. These very interesting and mostly useful plants can

Fig. 6. *Bubu*, or bamboo fish-trap used along the Belait river, Brunei.

be better understood, more systematically documented and managed as a resource. It is important to first understand the fundamental attributes of these plants, so that this basic knowledge can help foster better identification, utilization and conservation of the many species.

It is the aim of this book to provide a basic understanding of the bamboos and to give an introduction to some of the main types of bamboos found in Southeast Asia, where they are linked to everyday living, to the environment, industry, culture and folklore. The present account was precipitated by the establishment of a research collection of bamboos at the Rimba Ilmu Botanic Garden, University of Malaya, Kuala Lumpur (Malaysia), under the auspices of the International Plant Genetic Resources Institute (IPGRI). It complements earlier accounts of Peninsular Malaysian bamboos by the author (Wong 1995a, 1995b) and Sabah bamboos by Soejatmi Dransfield (1992), and various ongoing inventory projects in various parts of Southeast Asia. It also assembles, in a brief way, information on growth habit and structure, tips on identification of the more important bamboos, and notes on the main groups and species encountered, with a discussion of the importance of carefully established and documented, *ex situ* conservation collections.

Fig. 7. Bamboo scaffolding, mainly from *Bambusa balcooa* and *B. vulgaris*, Dhaka, Bangladesh.

How bamboos are classified

Bamboos are part of the Poaceae (sometimes also called Gramineae), the family of grasses. They share certain characteristics that place them apart from other grasses: segmented, typically hollow stems (called culms, as in all grasses) that are somewhat woody, which sprout from the underground stem portions (or rhizomes); a complex system of branching; and flowers that typically each have three perianth-like structures (lodicules) and 3–6 stamens (Soderstrom 1981).

Yet, the woody bamboos share other characteristics with some herbaceous (non-woody) grasses, notably leaf blades that have a distinctive internal organization of the tissues (including “arm cells” and “fusoid cells” not found in other grasses) and which are basally narrowed to form a stalk-like connection with the leaf sheath (sometimes called a “pseudostalk”). These are called the herbaceous bambusoid grasses. Different species of the bambusoid grasses (both woody and herbaceous) are grouped into genera (singular: genus) on the basis of similar characteristics, and genera further as subtribes and tribes (Soderstrom & Ellis 1987). The various tribes then comprise the bamboo subfamily (Bambusoideae) of the Grass family.

Bamboo classification or taxonomy is difficult because, often, relatively little is known or documented as many collectors shun collecting bamboos because of their size or the difficulties in trying to make good scientific specimens (Holttum 1958, McClure 1966) (Fig. 8). A comprehensive, natural classification of subtribes is still actively pursued and it is expected that advances in understanding DNA characteristics will shed more light on the relationships.

Fig. 8 (Opposite). Blanco did not list reference specimens when he named a bamboo *Bambusa levis*, so Merrill chose this to represent the species, which he recognized as a *Gigantochloa* instead, creating the new combination *G. levis*. The specimen has no culm sheaths and it is difficult to visualize the living plant from this alone.

Cultivated or wild, common or rare

In many parts of Southeast Asia, bamboos have long been recognized as village or cultivated bamboos and native or forest bamboos. The cultivated bamboos include known introductions to a number of places from their place of origin—for example, *Bambusa bambos* and *Dendrocalamus strictus* (native in India, Myanmar and Thailand), *Shibataea kumasasa* (originally from southern Japan) and *Thyrsostachys siamensis* (from Myanmar and Thailand)—and others that were first known in cultivation and not yet found wild anywhere, such as *B. heterostachya* in Peninsular Malaysia or *D. asper* generally in Southeast Asia.

In some cases, such as some species of *Gigantochloa* that are known only in cultivation in Peninsular Malaysia and Java, it is possible their present-day distribution reflects the historical migrations of people in the region. Indeed, some bamboos known only in cultivation may be products of selection over a long period of cultivation, following introduction from wild stock. One example is *Gigantochloa balui*, which is common in many parts of Borneo where it is known only in cultivation or near settlements, never truly wild, but which has later been found wild in Peninsular Thailand. Although this bamboo was first diagnosed scientifically from material from Borneo, yet in fact it must have been carried there from somewhere in the Malay Peninsula or Thailand a long time ago.

Around 200 species of bamboo occur in the Southeast Asian region, from Myanmar and Indo-China to Papua New Guinea, and including the Malay Archipelago (Dransfield & Widjaja, 1995). Among the countries of this region, there are few modern accounts of the bamboo flora published. This situation is understandable, given that very few specialists are involved in bamboo exploration and taxonomic work, many reference specimens (on

Fig. 9. *Schizostachyum grande* invades an old logging track, Kledang Saiong, Perak, Peninsular Malaysia.

which bamboo names are based) collected before the second half of the 20th century are incomplete or in poor condition, and many new discoveries and interpretations are still being made.

Common bamboos

There are common or well-known bamboos, and rare or little-known ones. *Bambusa vulgaris* (which, as its Latin name implies, is the "common bamboo") probably originated in Southeast Asia and is now pan-tropical, being commonly planted as an ornamental and for household uses in villages. Some bamboos, in fact, border on being weedy. In Peninsular Malaysia, three native species, *Gigantochloa scortechinii* (which is also the most useful species there), *Dendrocalamus pendulus* and *Schizostachyum grande* (Fig. 9), are very common and occur naturally in the foothills and valleys of mountain ranges, as well as colonize disturbed forest sites in the lowlands generally. In the northern part of Borneo, the climbing species of *Dinochloa* can become so common in logged-over lowland forest that they smother the tree regeneration (Fig. 10), forming a thick blanket of growth over the residual vegetation that appears penetrated only

Fig. 10. Invigorated by increased light from the fragmented forest canopy after logging, *Dinochloa sublaevigata* climbs smaller trees and smothers new forest regeneration, Sabah, Malaysia.

Fig. 11. *Vietnamosasa pusilla* carpets the ground under dry deciduous dipterocarp forest, northeast Thailand.

by the tallest trees. *Neololeba atra*, a lowland forest bamboo that also persists in open sites and seeds quite commonly, recorded from Mindanao (Philippines) through Sulawesi and Maluku to New Guinea and Queensland, has been documented as thicket-forming in Queensland.

The dwarf bamboo locally called *pek*, *Vietnamosasa pusilla*, forms extensive undergrowth in deciduous forest and thickets in scrubland in the seasonal areas of northeast Thailand (Fig. 11) and Indo-China (Dransfield 2000a). This species flowers and seeds gregariously, so large patches of regeneration are possible. In the high mountains of Taiwan and Luzon (Philippines), another dwarf bamboo *Yushania niitakayamensis* colonizes entire mountainside landscapes, effectively forming grasslands, by its sheer ability to spread (Figs. 12 & 13); indeed, its efficacy of spread has prompted its use in erosion control.

This commonness is due to various reasons. The first is an ability to adapt to many different site conditions, such as differing amount of light or shade, or nutrient status, although it is true that moderate to strong exposure and moist, fertile (non-acidic) conditions most favour the growth of the common species. Another reason is the ease of vegetative propagation, such

Fig. 12. *Yushania niitakayamensis*, a dwarf bamboo that rapidly colonizes open ground in the mountains, Taiwan.

Fig. 13. Vast areas in the Taiwan mountain landscapes are covered in *Yushania niitakayamensis*, which meets coniferous forests lower down. This bamboo also occurs in the Philippines.

as the sprouting of new plants from bits of scattered rhizome (e.g., during land clearance using tractors) or some culm and branch portions bearing buds. In the case of some native species, relatively frequent seeding, or seeding of a big population of individuals, can also play a part in their spread and increase in abundance, especially where disturbance has brought about suitable conditions for establishment (Wong 1986).

Rare (and endangered) bamboos

Some species are rare because their distribution is restricted to isolated localities, such as mountain peaks or specialized substrates, including limestone hills or swamps. Such places are "ecological islands", having very different conditions from the surrounding landscape, which engender the establishment of unique or specially adapted species. Many species of *Racemobambos*, for example, are known only from one or several mountain peaks (Dransfield 1983). *R. glabra*, an elegant montane bamboo, is found only on several peaks in the Meligan-Brunei-Mulu region of northwest Borneo. *R. hepburnii* (Fig. 14) and *R. gibbsiae* are sister species occupying lower and upper terrains, respectively, on Mount Kinabalu in Borneo and apparently have non-overlapping periods of flowering (Wong, Chan & Phillipps 1988). *Temochloa liliana* is a delicate scandent bamboo known only from some limestone sites in Peninsular Thailand (Dransfield 2000b).

Fig. 14. Thicket of *Racemobambos hepburnii* in a forest gap on the west shoulder of Mount Kinabalu, Sabah, Malaysia.

Some bamboo species can be possibly endangered, too. In Peninsular Malaysia, the clambering small bamboo, *Schizostachyum terminale* was once more common, growing in seasonally inundated sites along slow-moving streams and within mosaics of freshwater and peat swamps. It was first discovered in 1940 in Peninsular Malaysia, on the banks of the Krian River in Kedah state, and then only recorded again in the 1980s in the Rantau Panjang area near the coast in Selangor state, represented by a few remnant clumps in a roadside patch in the midst of a ricefield region. It is now no longer seen or easily found in Peninsular Malaysia's west coast, which has undergone tremendous changes in natural landscape during development that spanned more than a century. Only two other localities in Peninsular Malaysia, both in the east coast state of Pahang, have ever been known for this species—one, in 1988, at the Krau Game Reserve, and the other, in 2003, during an IPGRI-motivated bamboo survey in the coastal Merchong swamp area, where it appears to be uncommon and not abundant. Thanks to recently active collection in Borneo, this species is now also known to exist in similar habitat there (Fig. 15). However, it is clear that *S. terminale* is truly rare and vulnerable to extinction in Peninsular Malaysia.

In Peninsular Malaysia, *S. lengguanii*, another smallish elegant bamboo, is known only from the Tasik Chini and Merchong swamp areas. Elevation of the water level at Tasik Chini for tourism-related development caused the inundation and death of many lakeside clumps there, and logging activities at the Merchong area have included a track that ran through a population of this species. In southern Sumatra and South Kalimantan, in similar habitat, forest fires are a threat to the survival of this species (Muller 1998a).

This story reminds us of two things regarding species rarity. First, a species can be little-known and even rare in one instance, but is in fact more generally present, only it has not been discovered and documented elsewhere. Also, a species, although represented by more than one population, can disappear or go locally extinct over a period of disturbance and change to its natural habitat. This is particularly so if the species is specific in its requirements and landscape changes or disturbances especially affect its habitat. In Southeast Asia, isolated or restricted ecosystems vulnerable to destruction or intense change, where specialized species may be threatened, include places like swamp forests (prone to logging and

Fig. 15. Clambering *Schizostachyum terminale*, with mud-stained lower parts following recession of flood waters along the lower Kinabatangan river, Sabah, Malaysia.

conversion to cultivation), limestone hills (prone to quarrying for road metal and cement) and mountain peaks (prone to clearance and fires associated with recreational activities and development).

Rare species can also exist in the lowland forests generally, apart from the easily recognized "specialized" ecosystems. The impression that lowland forests are a "generalized" ecosystem with a uniform species composition could not be farther from the truth. Ecological research shows that a small number of species makes up the common ones, which are most abundant or widespread. In fact, the bulk of the species in a piece of rain forest are represented by small numbers of individuals, either scattered far apart or occurring only in certain patches. Also, in the lowland rain forest, many of the smaller plants, including especially herbaceous species, tend to be more restricted in distribution or site-specific. Thus a species can be rare in terms of a very scattered distribution of individuals (low frequency), or due to occurrence in only one or very few localities (narrow endemism).

It is not true that all forest bamboos become weedy when they are present in forest being badly disturbed, although the weedy ones (often the bigger ones) make their presence felt strongly. In Peninsular Malaysia, for example, there are a few rare, true forest bamboos adapted to forest understory conditions. One such bamboo is *S. aciculare*, known only as small clumps in a few localities in Negri Sembilan, Johor and the Kelantan-south Thailand region. Another rare understory bamboo is the clambering, pencil-thin *Racemobambos setifera*, which is rare or extinct outside the upper Endau River area in Johor (Wong 1987). It survives only in a narrow strip of forest bordering pristine streams and will not tolerate excessive exposure (as will occur with logging) or inundation (as will occur with river impoundment). Also a rare lowland endemic, *Soejatmia ridleyi* (Fig. 16) is only known in very few sites in Pahang and the Bukit Timah forest in Singapore. The unusual clambering bamboo *Temburongia simplex*, sole representative of its genus, is restricted to streamside forest in the Temburong district of Brunei (Dransfield & Wong 1996).

Some species are rare in the core rainforest region of Malaysia and Indonesia because they are naturally centred in the region farther north or south, where conditions are more seasonal. Species of the twining bamboo genus *Dinochloa* are most diverse and more easily encountered in the northern parts of Borneo (e.g., Sabah) and Peninsular Malaysia probably because of their preference for more seasonal conditions (the genus is also known in Java). The little-known *Gigantochloa rostrata* is known growing naturally only in Myanmar and the summit of Gunung Raya on Langkawi

Fig. 16. *Soejatmia ridleyi*, an endemic bamboo of the Malay Peninsula, Renggit Forest Reserve, Pahang, Peninsular Malaysia.

Island, in the extreme north-west of Peninsular Malaysia, a region more seasonal in climate than nearer the equator. *Gigantochloa balui*, native to the lowlands of Peninsular Thailand, has only been recently documented growing naturally in neighbouring Kedah, one of the northern states of Peninsular Malaysia.

Indeed, the narrow "neck" of the Malay Peninsula, including Peninsular Thailand and the extreme north of Peninsular Malaysia, by relative isolation through its intercalation between the land mass of Thailand proper and more equatorial Peninsular Malaysia, appears to be a special biogeographical region with its own specialities. The slender, small *Dendrocalamus elegans* occurs gregariously (i.e., in large numbers in an area) on the ancient weathered limestone on the Langkawi group of islands, where they grow on a thin soil from sea-level to the tops of cliffs, including in cracks and on ledges on cliff faces (Fig. 17). It also occurs on the Gua Musang limestone (Kelantan) and in peninsular Thailand. *D. dumosus* is another such limestone bamboo from the same region, and recent field work has discovered other

Fig. 17. Thickets of *Dendrocalamus elegans* on limestone senescing and yellowing in the early-year drought, on Langkawi island in the extreme northwest of Peninsular Malaysia.

Fig. 18. Open ridge sites clothed in a profusion of *Holttumochloa magica*, above 2000 m in the Cameron Highlands, Peninsular Malaysia.

bamboos special to Peninsular Thailand. *Temochloa liliana*, mentioned above, is also a speciality of this region.

Some bamboos can be locally common but are in fact rarities on a regional or wider geographical scale. *Holttumochloa magica* (Fig. 18) is documented only from the Fraser's Hill and Cameron Highland areas on the Pahang-Selangor border, at 1200–2000 m, in the cloud forest. *H. korbuensis* is known only from the summit of Gunung Korbu (Perak) and *H. pubescens* only from the summit of Gunung Stong (Kelantan). These bamboos are a significant component of the dwarfed cloud forest between about 1500 m and 2100 m. They form an undergrowth in short, extensively mossy forest but can be thicket-forming on very exposed, disturbed ridge-tops (Wong 1995b). Likewise, in northwest Borneo, *Kinabaluchloa nebulosa* is often encountered on the high mountains of the Crocker Range and associated ranges. In Java, *Schizostachyum aequiramosum* is documented only from the Meru Betiri National Park in the extreme southeast of the island, where its culms are even used by people. *S. caudatum*, peculiar among members of its genus for its solid culms (Fig. 19), is endemic to southern Sumatra (Widjaja 2001).

Fig. 19. *Schizostachyum caudatum*, a south Sumatran endemic, has solid culms.

The structure of the bamboo plant

The stem

A bamboo stem has an underground part, called the rhizome, and an emergent portion called the culm. If we examine the rhizome, the culm and its branches, we can see that they are segmented, i.e., there is a series of nodes (appearing as rings along the culm, where the sheaths, buds and branches arise) and intervals between the nodes that are simply called internodes. The internal space within the bamboo culm is compartmentalized into a series of hollows by each node bearing a transverse plate. It is this basically hollow cylinder-like structure with crosswalls placed at regular intervals along the culm that gives bamboo its inherent strength and flexibility.

Not all species have conspicuously hollow culms: sometimes species are encountered which have their culm walls so thick that the central hollow is inconspicuous or even absent altogether (Fig. 19). Not all bamboos have erect culms, either. There are some forest bamboos, in Southeast Asia for example, which have slender culms that can twine around tree trunks as they ascend during growth, behaving as other twining plants do (Fig. 20). Also, not all rhizomes are hollow. Bamboos growing in clumps where the culm bases nearly touch typically have solid, thickened and relatively short, spindle-shaped rhizomes. Those with a “running” habit where the culms are spaced out farther from one another usually have rhizomes that are slender and hollow, just like in the erect culms. The nodes on the rhizomes and, sometimes, at the basal portion of culms develop verticils of short roots.

The clumping or “running” habit of bamboos is a consequence of its rhizome growth behaviour. Typically, the rhizome that turns upwards to

Fig. 20. *Dinochloa malayana* culms twining around a forest tree, Langkawi island, Peninsular Malaysia.

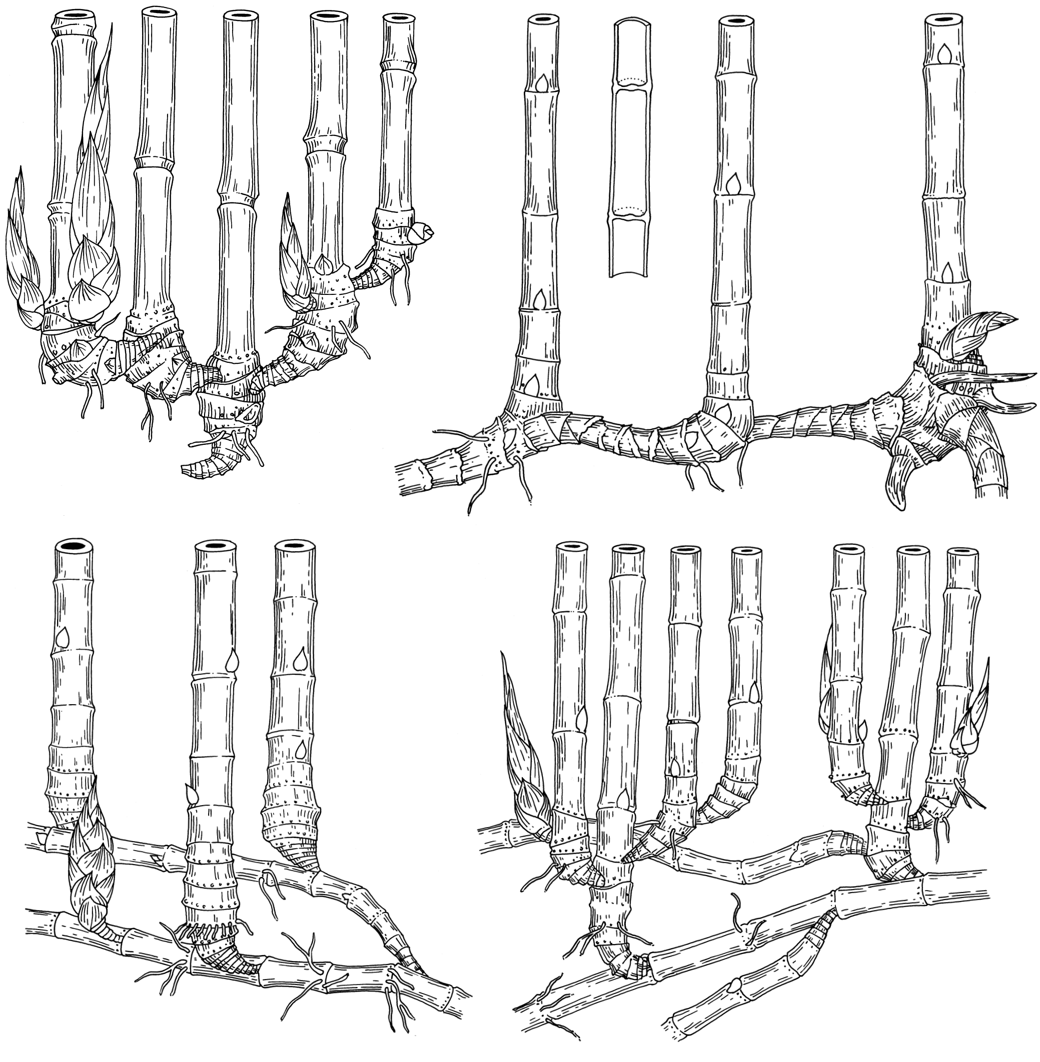

Fig. 21. A sympodial system with short rhizomes (top, left) has the culms close together, but long-necked sympodial rhizome units (top, right) carry the culms more apart, like those arising from monopodial rhizomes (bottom, left); a mixed or "amphipodial" system (bottom, right) has both sympodial and monopodial portions. Cut-away view of a culm shows internal spaces separated by crosswalls or diaphragms at the nodes.

continue as a culm also bears new rhizomes, which again also upturn to become culms, and these will then bear further "daughter rhizomes" and so on. In other words, wave-like successions of rhizomes build up as repeating units, which are of successively newer generation; this is said to form a sympodial series of rhizomes (Fig. 21). Sympodial rhizome systems most frequently bear short, thickened spindle-shaped rhizomes that form culms placed closely together, as distinct clumps. On occasion, the sympodial rhizome units have slender and elongated "neck" or proximal portions, and so carry well-spaced culms, but these are not common (Figs. 22 & 23).

True "running" bamboos are those with slender, hollow rhizomes that grow horizontally without typically upturning to form a culm; buds developing along the rhizome will either form new rhizomes or form culms directly, with the result that the culms are typically well spaced out over a wider area. Such rhizomes are also called monopodial rhizomes (Fig. 21). These form groves of single culms (Fig. 24), and not clumps. Monopodial-type bamboo genera are generally uncommon in the tropics and occur mainly in the temperate zone, where both types may be found also. In some bamboo species, a mixed condition occurs, with monopodial and sympodial rhizome portions in the same plant.

Fig. 22. Sympodial rhizomes with long "necks" carry the culms farther apart, as in *Racemobambos setifera*, upper Endau river, Johor, Peninsular Malaysia.

Fig. 23 (Above). A patch of well-spaced *Melocanna baccifera* culms formed by long-necked sympodial rhizomes, Mirpur, Bangladesh. **Fig. 24 (Opposite).** Culms arising singly from monopodial rhizomes are typical of *Phyllostachys* spp.

A new culm shoot always emerges with the same diameter at its base as it will have when full height is reached; the lack of actively dividing tissues which allow stem thickening means that internode diameter at any point along the culm is fixed. This is why a young bamboo plant will produce the smallest culms first and only gradually produce new culms that are progressively larger, until its mature dimensions are reached.

The branch complement

Although sometimes buds (and hence, branches) may not form at the lowermost culm nodes, they are usually present from at least the middle of the culm upwards. Generally, the mid-culm branch complement (the array of branches forming at a node in the middle portion of the culm) is the most fully developed and diagnostic of a particular species or group.

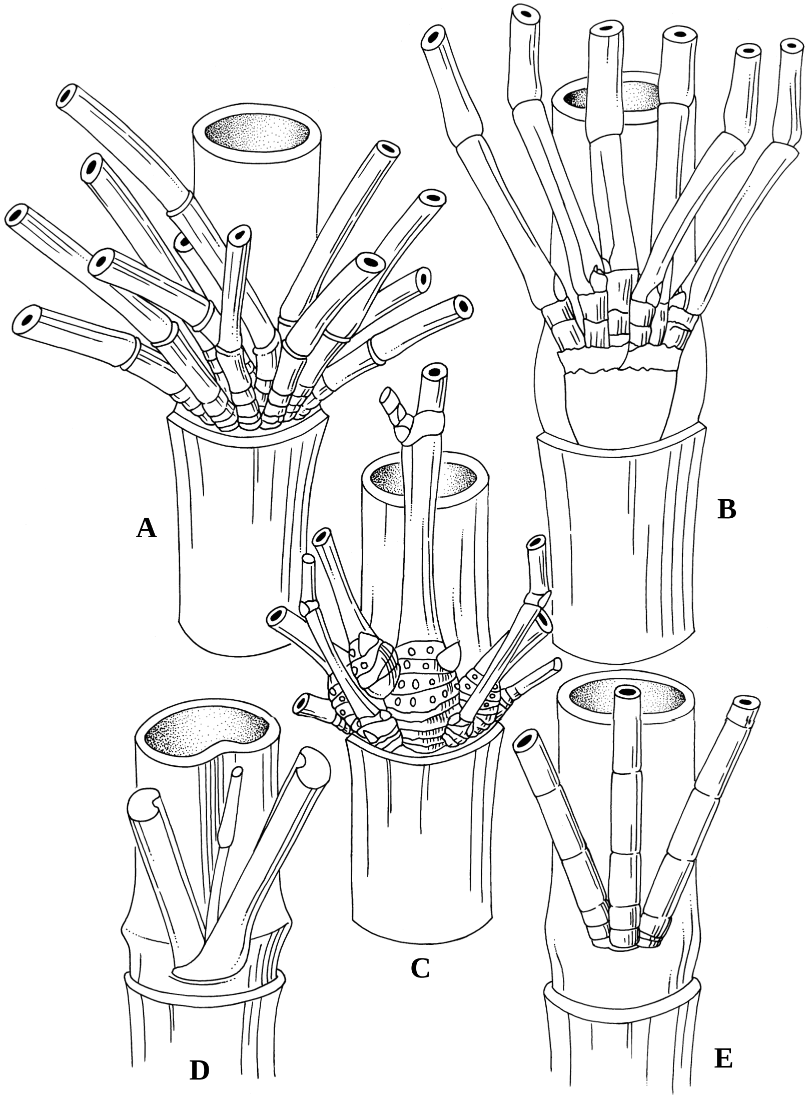

Fig. 25. Some bamboo branch complements: many slender branches from many individual primary buds, *Holttumochloa* (A); many slender branches from a single primary bud, *Schizostachyum* (B); dominant primary branch and smaller branches proliferating from its base, *Bambusa* (C); pair of unequal main branches from one primary bud, *Phyllostachys* (D); three subequal main branches arising together, *Chimonobambusa* (E).

The form of the branch complement is determined by the characters of the bud, which can be different among bamboos (Fig. 25). Nearly all bamboos in Southeast Asia have branch complements developing from a single bud at each node. An exception is found in *Holttumochloa*, in which the branch complement develops from several to many individual, very small primary buds arranged closely together in roughly two ranks in the small space occupied by the branch-bud complement at each node. This results in the branch complement having several to many slender primary branches at a node which produce a few similar-looking secondary branches at their base. These branches typically do not branch further away from their base.

In some bamboos, the primary (original or first) branch axis can grow bigger and longer than other subsequent branches that arise from its base (i.e., it is dominant over them) (Fig. 26), or the cluster of branches developing at a node may consist of a number of somewhat equal (subequal) branches (Fig. 27).

Leaves and sheaths

In the bamboo plant the leaves can assume two forms, with different functions. One of the forms is represented by the thickened, rigid, scroll-like structure that is held around and encloses much of an internode as it lengthens during early culm growth. Such “culm sheaths” (or “culm leaves”, as they are also called) play a protective role in encasing the tender lower part of an internode while its tissues actively divide and lengthen. Culm sheaths can be green or some other colour but they are usually persistent to a certain degree even after turning brown and can remain on the mature culms for some time. The other (perhaps more immediately recognizable) form of a bamboo leaf is that of the foliage leaf on the finer branches, with conspicuous, green blades, whose role is photosynthesis.

If both forms are examined, their basic structure is found to be the same (Fig. 28). Each type has a main stiff lower body, or the sheath proper, which bears a blade-like structure at its top and, often also, other associated parts. In the case of the culm sheath, the blade is small and does not remain green for long, while the sheath proper is conspicuous because it is an adaptation for protectively encasing the cylindrical culm internode during growth. The foliage leaf blades are well expanded as thinner, green structures with the full tissue complement for gas exchange and photosynthesis; these leaf-blades are attached to less conspicuous, lower sheath portions that still play a protective role encasing the young branch internodes.

In fact, even the rhizomes are clothed in sheaths as they develop, only these are seldom well observed because they are underground and easily damaged during excavation. The rhizome sheaths are much reduced and sometimes the blades are not at all distinct. All these leaf-like structures, whether on rhizome, culm or branch, and variously adapted for a mainly protective or photosynthetic function, are said to be homologous, i.e., with fundamentally the same structure and derived from one fundamental organ type. Thus we find that sheaths or leaves on the bamboo plant are arranged in two rows along any axis (rhizome, culm or branch) and arranged alternately left and right.

Culm sheaths and leaf sheaths often bear other parts in addition to the sheath proper and blade. The so-called “auricles” are smaller parts

Fig. 26 (Left). Severed mid-portion of *Dendrocalamus asper* culm, with a dominant primary branch, a few subdominant secondary branches and smaller branchlets, all developing from proliferation of a single bud. **Fig. 27 (Right).** *Schizostachyum blumei*, with a cluster of subequal branches developing from a single bud, characteristic of the genus. On the left is a young culm with its sheath.

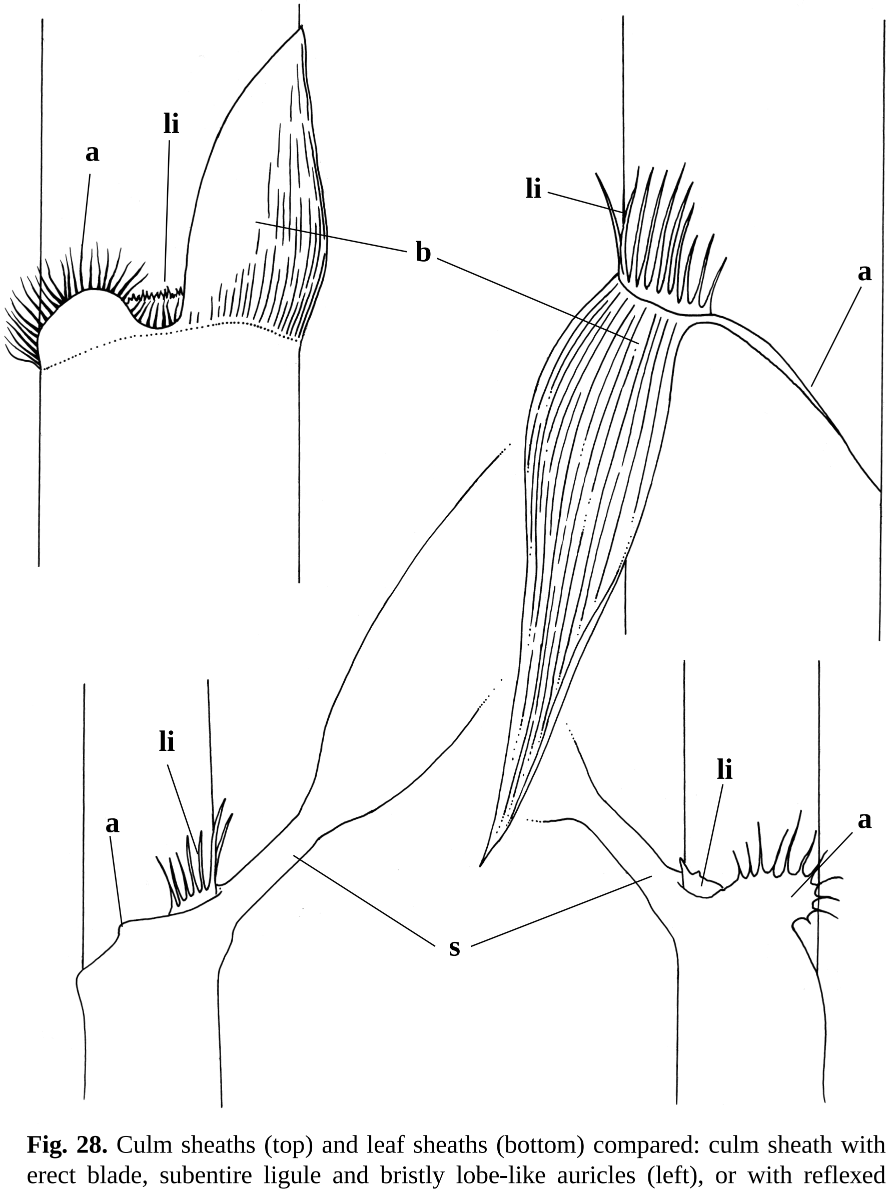

Fig. 28. Culm sheaths (top) and leaf sheaths (bottom) compared: culm sheath with erect blade, subentire ligule and bristly lobe-like auricles (left), or with reflexed blade, long-bristly ligule and rimlike auricles (right); leaf sheath with bristly ligule and inconspicuous auricles (left), or with rimlike ligule and bristly lobe-like auricles (right). a, auricle; b, blade; li, ligule; s, leaf "stalk" joining blade to sheath.

resembling lobes or rims at the base of the blade margin on both sides. They can be smooth or hairy on the edges, small to truly ear-like, depending on the species. In addition, there usually is an inconspicuous rim that develops at the junction between blade and sheath proper, on the inner side; this is called the "ligule" and can be variously smooth, cleft, toothed or hair-fringed. The shape and form of such structures, together with the general form, colour and hairiness of the sheath and its blade, often supply many characters for identifying a bamboo (see also Figs. 52–62).

Young bamboo shoots just emerging from the ground may be edible, but in the youngest stages they yield few characters for identification. It is the shoots which have grown to 0.5–1 m high or higher, on which are found well-developed culm sheaths that show the best formed characteristics. For identification from mature plants, the culm sheaths at the middle of the culm are often taken because they show the fully developed characters typical of the species.

Flowering branches

In bamboos, the inflorescences or specialized flower-bearing branches have complicated structures. The fundamental flower-bearing unit is the same as in grasses and is called a spikelet, the whole only several millimeters to a few centimeters long. The spikelet is really a tiny branch (the "rachilla") with two rows of overlapping scales, some of which hide the tiny flowers.

A single spikelet typically consists of one to several "empty" scales or bracts at its base called glumes (which do not embrace any flowers), and 1–several more specialized scales above these, called lemmas, each of which protects a flower (Fig. 29). A flower subtended by its lemma is termed a floret. Such spikelets are found in most grasses and bamboos such as *Chimonobambusa*, *Nastus*, *Racemobambos* and *Temburongia*. In some other bamboos, the short rachilla also bears 1–several small bracts, which each protect a tiny branch bud, at the very base of the spikelet proper. This kind of spikelet-bearing branch with bracts subtending buds at its base has been termed a "pseudospikelet" (Fig. 29) and is characteristic of many groups of bamboo in Southeast Asia. It is often impossible to distinguish among these different types of bracts without examining what occurs inner to each.

True spikelets not only lack the branch buds at their base, they also remain as single units as they mature (Fig. 30). In contrast, pseudospikelets not only possess basal bud-bearing bracts at their base, they also develop into

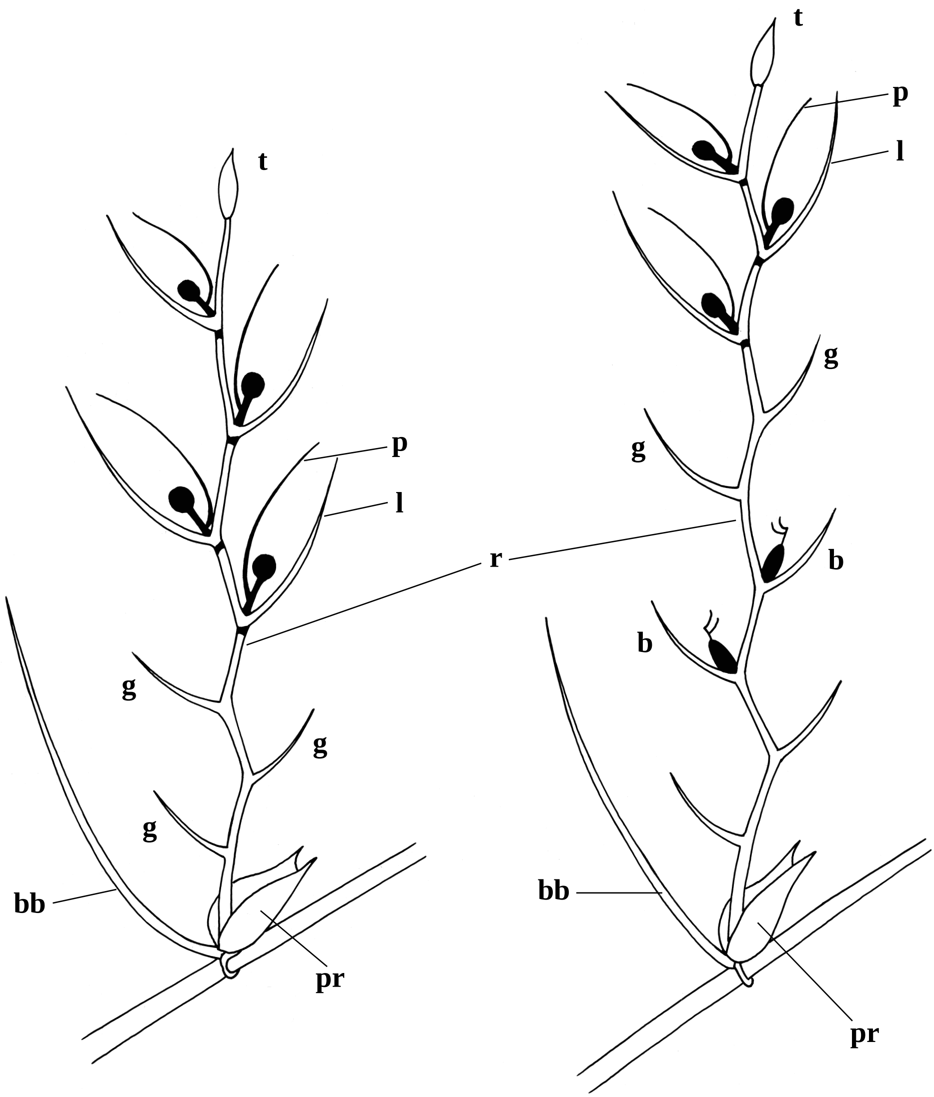

Fig. 29. Spikelet (left) and pseudospikelet compared. Dark dots represent flower structures inner to the palea; b, bracts protecting buds (dark structures with double-barred tips) that potentially repeat the structure of the pseudospikelet; g, glume; l, lemma; p, palea; r, rachilla; t, vestigial terminal flower. On the main axis, bb is the bract subtending the spikelet or pseudospikelet and pr is the prophyll or specialized initial bract of the rachilla.

Fig. 30 (Left). True spikelets at the end of a flowering branch, *Racemobambos gibbsiae*. **Fig. 31 (Above).** A cluster of pseudospikelets, *Gigantochloa rostrata*. One flower shows an extruded filament tube bearing six anthers.

a tuft of pseudospikelets as the basal buds start to produce more pseudospikelets (Fig. 31). Pseudospikelets are the basic unit of the inflorescence in the genera *Bambusa*, *Dendrocalamus*, *Dinochloa*, *Fimbribambusa*, *Gigantochloa*, *Holttumochloa*, *Kinabaluchloa*, *Maclurochloa*, *Melocanna*, *Phyllostachys*, *Schizostachyum*, *Soejatmia*, *Sphaerobambos* and *Thyrsostachys*.

The bamboo specialist F.A. McClure (1966) has called the bamboo inflorescence an indeterminate (or iterauctant) type if it has pseudospikelets as the basic units, because there is more than one period of spikelet production in the inflorescence. He called the bamboo inflorescence a determinate (or semelauctant) type if it had true spikelets as the basic units, as the ultimate flowering branch cannot then further branch and form any more flowers.

Flowers

Each flower, enclosed by its attendant lemma, is in fact a tiny side-branch of the rachilla (Fig. 29). The whole flower is embraced by a membraneous structure with two inflexed edges called the palea, which has its back against the rachilla. Distal to the palea and wholly enclosed by it, the floral axis typically bears three smaller membraneous structures called lodicules (comparable to the perianth, or sepals and petals, of an ordinary flower), stamens, and a female complement comprising the ovary and its style and stigma(s).

The flower is sometimes described as perfect when it has both male and female parts (represented by the stamens and ovary-style structure, respectively) within its palea. If these structures are not formed within the palea or lemma, the flower is simply called "empty" or "vestigial".

Fruits

In bamboos, the fruit is a one-seeded structure that does not split when ripe. Most often, the fruit is dry (as opposed to fleshy) and is technically called a caryopsis (Fig. 32), not much larger than a grain of rice or wheat. In a few genera of bamboos, such as *Cyrtochloa*, *Dinochloa*, *Melocalamus*, *Melocanna* and *Sphaerobambos*, the fruit is a fleshy, spherical to pear-shaped

Fig. 32 (Left). Caryopses (fruits) of *Gigantochloa rostrata*. **Fig. 33 (Right).** Rounded, fleshy fruits of *Dinochloa trichogona*.

Fig. 34. Rounded, fleshy fruits of *Sphaerobambos hirsuta* resembling beads, Poring, Sabah, Malaysia.

structure (Figs. 33 & 34) and in some species can reach the size of a large plum. In some (not all) of the fleshy-fruited bamboos, the seed germinates viviparously (i.e., while the fruit is still attached to the parent plant) (Kurz 1876, Stapf 1904, Dransfield 1981).

The flowering of bamboos

In most bamboos, every leafy branch can potentially develop into a flowering shoot. When this begins to happen, the leaves of such branches turn brown and gradually all drop off, and the branch apex starts to lengthen, bearing much smaller leaves or only reduced sheaths without expanded, green blades. Each such branch then develops the flowering units (pseudospikelets or spikelets) at its nodes and apices, and frequently also flowering side branches develop from its basal parts. A flowering culm can eventually have all of its originally leafy branches transformed into flowering shoots (Fig. 35), and buds at culm and branch nodes can also develop directly into pseudospikelet clusters.

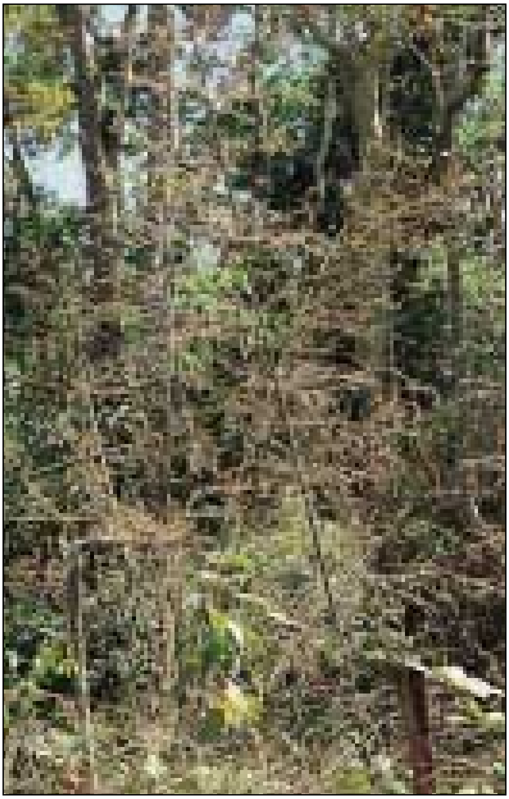

Fig. 35. Flowering *Schizostachyum zollingeri* culms in Perlis, Peninsular Malaysia.

In nature, the flowering of such bamboos (e.g., *Dendrocalamus pendulus*, *Gigantochloa scortechinii*, *Schizostachyum zollingeri*, *Vietnamosasa pusilla*) is often gregarious (i.e., involving most or all clumps over a large area in a kind of mass flowering) and at long intervals in some cases (up to many decades), and the clumps then die or regenerate from remaining rhizomes, with most replacement from seedlings (Figs. 36 & 37). These

Fig. 36 (Opposite). Senescent culms of *Gigantochloa balui* in a state of collapse following a gregarious flowering episode of this bamboo in the Surat Thani province, peninsular Thailand. **Fig. 37 (Above).** Short, flowering branches on clambering culms of *Racemobambos gibbsiae* during a gregarious flowering episode in 1981, Mount Kinabalu, Sabah, Malaysia.

species, and others, can also flower in a diffuse and sporadic manner (with just a few branches, culms or individual clumps coming into flower).

In many species of *Schizostachyum* in the everwet parts of the Malay Peninsula and Borneo, the flowering habit is different. After the leafy branches present on a culm start flowering and then gradually dry up at their tips, they produce a next crop of side-branches with normal leaves. This new set of branches repeats the cycle of leafing and flowering and in turn produces a further crop of branches that behave similarly (Fig. 38). About four to five such cycles of branch development occur on a single culm before it dies, so that the mature clump, with many culms at different stages of development, has more-or-less continuous flowering (Wong 1995a).

Flowering in the forest climbing bamboos *Dinochloa* and *Maclurochloa* is typically restricted to one or a few branch complements which become transformed into specialized, huge and sometimes much-branched (even fan-


Fig. 38 (Left). Continuous flowering in a mature clump of *Schizostachyum brachycladum* is maintained by culms of different ages, the oldest having the main branches flowering and then drying up at their tips, and succeeded by a few generations of side-branches that each repeat the leafing-flowering-rebranching sequence. **Fig. 39 (Right).** Old specialized flowering branches, visible against the sky, protruding from a mass of foliage, *Dinochloa scabrida*, Sabah, Malaysia.

like) flowering structures (Fig. 39). These large, flowering branches often protrude from tree crowns climbed by the bamboo, where presumably pollination by wind is more effective than within the tree crown.

In days gone by in India and Bangladesh, after the *muli* bamboo (*Melocanna baccifera*) had flowered over large tracts around settlements, the resulting intense fruit crop (the fruits are the size of small pears in this unusual bamboo) would fuel a population explosion of rats—and, then, either crop destruction or disease would be the tragedy of the day. The *muli* bamboo flowers and fruits every 30–60 years or so. Other gregarious bamboo fruiting events have also brought additional grain to relieve famines. However, most bamboo flowering has not been so dramatically linked to human affairs.

Identifying bamboos

The identification of a bamboo or other plant is a means of finding out its identity (by a name, whether scientific or common name) through recognizing its special characteristics. Being able to tell the identity of a species or genus often helps in searching for other information we may require: in this sense, the name “unlocks” further information. Identification is easier when it is possible to use easily examined features.

This is often different from taxonomic classification, which seeks to recognize naturally related groups through the use of characters considered most stable during evolution of the group and which may have “grouping” utility (i.e., reflecting common ancestry). Such characters often include those found in the reproductive parts (spikelets or flowers) and other material ordinarily difficult to examine (such as chemical or DNA characteristics, or internal structure of organs). This can be quite an involved and difficult process because of the need to check and collate many categories of information that are often not easily available for all bamboos at any one time.

The bamboo botanist examines as many features as possible by referring to the original reference specimens used when scientific names were first given (according to the *International Code for Botanical Nomenclature* that taxonomists agree to use). Botanists also study new evidence first-hand, where possible. Their objective is to make a list of bamboos in a particular group (such as a genus), or of a particular region (such as a district or country) using names they interpret to be correct. They might be interested in making improvements to the classification of a group, or simply in compiling an up-to-date account of one or more aspects (cultivation, uses, ecology, etc.) of the bamboos of a certain region and following an available classification.

Nevertheless, apart from unfamiliarity and lack of reference material, bamboo identification can sometimes be difficult. This is often caused by not knowing the full characteristics of key parts of a bamboo species, e.g., when there are few specimens known of a species, or poor material or documentation of the main vegetative parts of the plant. Attempts to identify bamboos using older accounts can turn out to be frustrating because they may not always include adequate descriptions of the most accessible parts of a bamboo plant (such as the culm or culm sheath characters). This is because an old scientific account may have named a bamboo species based on its unique spikelets or flowers, and did not have any diagnostic vegetative parts included, but the living bamboo plants most often accessible to us may not be flowering, remaining in a vegetative state for a very long period.

This is in fact the case for many countries, unless newer revisions of older works have managed to incorporate missing information. This kind of research usually involves re-collecting a comprehensive set of fresh material (including good flowering and vegetative material) for study against the old, incomplete specimens on which names have been based (see also Fig. 8). Many bamboos of the Indian-Myanmar and Indo-Chinese regions, for example, have names, but it is not a straightforward task to know which names apply to which bamboo plants because of this situation.

To obtain a reasonably modern and adequate revision of the bamboos for a developing country, the following are prerequisites: one or more trained botanists who can give time to studying bamboos; modest facilities and funds sufficient for collection, documentation and curation of materials in the home country; recourse to some or all reference specimens that have usually been incorporated in the research holdings kept overseas of past collectors and visiting specialists; and, preferably, collaboration and the support of one or more relevant specialists in the taxonomy of the group(s).

Here, we provide two aspects that may help with understanding the process of identification, at least of the commoner bamboos of southeast Asia. The first is a brief consideration of the kinds of characters found useful in recognizing species and genera. The second is a key to identifying the common or especially interesting bamboo genera of the region, using these various features.

Useful characters for identification

A number of characters and the states they assume are discussed below, with examples of how they differ among different bamboos. It should be noted, however, that rarely can a single character state be used to recognize

Fig. 40 (Opposite). A stiffly erect habit and yellow culms help distinguish *Schizostachyum brachycladum*.

a bamboo species immediately, except when this is done among a very selected few. More often, a combination or suite of character states is employed in identifying or classifying bamboos.

Culm habit. Although many bamboos have comparatively rigid culms that arch only slightly outwards from the clump, some have pronounced arching so a clump that is well developed assumes a kind of "mushroom" shape. The culms in some species can be so weak they bend nearly to the ground, whereas in others they are quite flexible or even actually twine.

EXAMPLES. Some stiffly erect culm habits are very distinctive, as in *Bambusa heterostachya*, *Chimonobambusa quadrangularis*, *Thyrsostachys siamensis* or *Schizostachyum brachycladum* (Fig. 40). The culms of some forest and forest-edge bamboos arch over to the ground if not supported by surrounding trees. This is seen in the reasonably big bamboos, *S. grande* (Fig. 9) and *Dendrocalamus pendulus*, and the smaller-sized *Kinabaluchloa wrayi*, *Maclurochloa montana*, *Melocalamus compactiflorus* (Fig. 41), *Racemobambos setifera*, *S. terminale*, *Soejatmia ridleyi* and *Sphaerobambos hirsuta*. It seems that these bamboos have adapted to the forest environment and come to depend on the support of adjacent vegetation. The slender, twining culms of *Dinochloa* species (Fig. 20) must be one of the most specialized culm habits known among bamboos, making them easily recognizable. This vine-like habit allows the bamboos to behave like some rainforest lianas and ascend to tree crowns where abundant foliage develops. The culms can twine both clockwise and anti-clockwise, not necessarily only in one direction as for some other climbers.

Culm form and hollowness. The culm internode is typically cylindrical (e.g., Figs. 19, 27, 44) but can be angled in exceptional bamboos, or have ridges and grooves that vary its overall form. Normally hollow, the internodes can be obliterated by the culm walls being very thick or when the central hollow space is filled up by tissue. Internodes can be basally swollen.

EXAMPLES. The culm base is often squarish in cross section in *C. quadrangularis*. *Chimonobambusa* and *Phyllostachys* culm internodes also have a flared portion bearing a ridge near the bottom of each internode and just above its node. In these genera, the internode also tends to be deeply grooved all along their length on the same side as the branch bud or branches (Fig. 25D). Internodes of the other bamboo genera are not, or only inconspicuously, grooved. Solid culms, or those with only narrow central hollows, are typical of the lower culm portions of many climbing species of

Fig. 41. Frames support the weak, floppy culms of *Melocalamus compactiflorus*, National Botanic Garden, Bangladesh.

Dinochloa, in *Schizostachyum caudatum* (Fig. 19), some *Gigantochloa ligulata* and *T. siamensis*. Internodes with basal swellings give the unusual appearance of a series of inflations along the culm and bamboos with this character, such as *B. vulgaris* cv. *wamin* (Fig. 42) or pot-grown *B. tuldoides*, are sometimes called "Buddha's Belly Bamboo". In *Dinochloa* species, every culm internode has a peculiar slight bulge or swelling at its base, related to the development of bending during growth in these climbing bamboos. Unusually long internodes reaching around a metre or more are typical or common in *Kinabaluchloa* (Fig. 43), *Nastus* spp. and *S. jaculans*.

Node characters. The nodes do not show any special characters in most species. Thus, when there are conspicuous thickenings, or presence of roots, thorns or hairs, the appearance may be distinctive.

EXAMPLES. Unusual thick, leathery "girdles" formed by external thickenings at the culm nodes (joined to the culm sheath base) are characteristic of *M. montana* and some *Schizostachyum* species, especially *S. grande* and *S. iraten*. A narrow plate-like or shelf-like extension (patella)

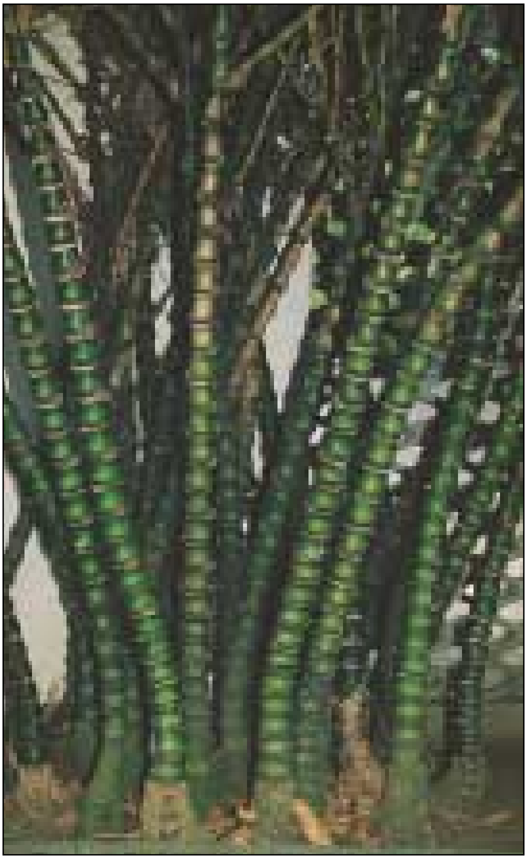

Fig. 42 (Left). Basally inflated culm internodes give an unusual appearance in *Bambusa vulgaris* cv. *wamin*. **Fig. 43 (Right).** Very long culms, with internodes reaching nearly 2 m long, are typical of *Kinabaluchloa nebulosa*, Mount Kinabalu, Sabah, Malaysia.

around the node is found in *Fimbribambusa* spp. from east Java and New Guinea, and *Temburongia simplex*, a rare Brunei bamboo. Short, downcurved root-thorns (rare in bamboos generally) develop around the basal nodes of mature *C. quadrangularis* culms. Verticils of normal, short roots frequently develop at the lower culm nodes in *B. vulgaris*, *D. asper, D. giganteus* and *D. pendulus*. A most unusual ring of spreading (patent) hairs is found around the culm nodes of *K. nebulosa* (Fig. 44) and *K. wrayi*, although this is most visible on younger culms.

Culm surface hairiness and wartiness. The culm internode surface in different species may be glabrous (hairless), or may be scantily or densely hairy. These irritant hairs, and also the itch caused by them, are called *miang* in Malay. The type of hairs and their colour are diagnostic, but may be lost (sloughed away or dropped off) from old culms. It is often safest to inspect both young and old culms when examining this feature. Wartiness is much less familiar as most bamboos have generally smooth culm surfaces (at least under their hair covering, when present), but when (rarely) present, the warts occur as small, rough protrusions or breaks over the culm surface.

EXAMPLES. Scattered dark hairs are frequently found on the internodes of many bamboo species (Fig. 45). However, short, appressed, white to pale-silvery hairs are found scattered over the internode surface in *D. longispathus, G. albopilosa*, all species of *Schizostachyum* (e.g., Fig. 27) and *T. siamensis*. A thick band of velvety silvery white, appressed hairs occurs just below each culm node in *M. montana*. But perhaps one of the most easily remembered characters in identification is the thick, complete covering of velvety brown hairs all over the basal internodes of the large-diameter *D. asper* (Fig. 46). This velvety hair covering does not detach easily and is not normally irritant to the skin. The lower and middle culm internodes of *C. quadrangularis* are typically rough warty-papillate, with scattered tiny prickly warts, instead of being generally smooth.

Culm surface waxiness. The culm internodes may also be powdery white-waxy in a number of species (Fig. 47). However, this is often best observed on fresh culms and, as with some hairiness, the character can be lost on very old culms frequently washed by the rain.

EXAMPLES. Whereas in many taxa (e.g., *B. polymorpha*, *D. giganteus*), the white-waxy bloom is distributed generally over the culm internodes, in *Melocanna* (Fig. 52) and *Schizostachyum* the white waxiness is restricted to, or more pronounced at, a zone just below each node. Thus, from afar, the newer culms appear as if there are regularly spaced, pale or white narrow “bands” along their length. Waxiness can be used to distinguish closely resembling species. *G. scortechinii*, one of Peninsular Malaysia and Sumatra’s most easily recognized bamboos, is intensely waxy on its culm surface, whereas the closely related *G. wrayi* is not. *G. thoii*, which is also generally waxy on its culm surface, has likewise been confusable with *G. levis*, which is not.

Branch buds and branching characters. Aside from the branch complement developing from one bud (e.g., Fig. 44) or many individual buds

Fig. 44 (Top Left). The culm node of *Kinabaluchloa nebulosa* with a characteristic ring of patent (spreading) hairs. Note solitary culm bud. **Fig. 45 (Top Right).** Scattered, dark irritant hairs on an internode of *Gigantochloa pseudoarundinacea*, Java. **Fig. 46 (Bottom left).** The basal culm portions of *Dendrocalamus asper* are completely covered by velvety, brown hairs. **Fig. 47 (Bottom right).** Intensely white-waxy culms of *Bambusa polymorpha*, Mirpur, Bangladesh.

(see above, under "Structure"), variations in the extent of branching and length of branches result in different interesting forms.

EXAMPLES. In *Bambusa*, *Dendrocalamus*, *Gigantochloa* and *Thyrsostachys*, the branch complement that develops from a solitary bud forms a clearly dominant (larger) primary branch axis, usually with one or two slightly smaller ("subdominant") secondary branches from its base, and a few branches along their length (Fig. 25). This is clearly seen in *B. blumeana*, *B. vulgaris*, *D. asper*, *D. giganteus*, *G. scortechinii*, *G. thoii* and *T. siamensis*. From afar, the dominant branches at every node are often clearly visible and their silhoutte gives a kind of "herring bone" impression, with the culm as a central axis bearing two rows of slanted dominant branches alternately left and right (Fig. 48). In *Phyllostachys*, the primary branch typically produces only a single secondary branch at its base and they form a divergent but unequal pair of branches (Fig. 25).

In contrast, a dense cluster of slender, subequal branches (without any clear dominant branch among them) is found at each node in *Kinabaluchloa*, *Melocanna*, *Nastus* and many *Schizostachyum* species. This is superficially similar to the branch complement of *Holttumochloa* (which develops from many primary buds) (Figs. 25, 49) but is fundamentally different because the branches all originate from the branching of a single primary bud. Also, in *Holtummochloa*,

Fig. 48. Part of a *Bambusa bambos* culm, showing the characteristic development of dominant primary branches at every node.

Fig. 49. Simple branches developing from many primary buds at one culm node of *Holttumochloa magica*, Cameron Highlands, Peninsular Malaysia.

Fig. 50. Long, whip-like main branches along strongly arching culms are characteristic of *Dendrocalamus pendulus*, Selangor, Peninsular Malaysia.

the branches do not normally rebranch along their length, but in the other bamboos mentioned, the branches rebranch clearly several times.

In *D. pendulus*, the dominant branch at each node becomes a remarkably long, whiplike branch bearing further leafy branchlets at its nodes (Fig. 50). These long flexible branches often entangle with adjacent trees, deriving some support. In smaller bamboos that effectively clamber over or climb other plants, viz., *S. terminale*, *Dinochloa, Maclurochloa* and *Soejatmia*, the dominant branches often grow as long and thick as the original culm and repeat its development. One record of *Dinochloa andamanica* having "culms up to 90 m" probably refers to a series of such repeated branchings.

Less diagnostic in value is the extent of development of "basal branches" in a bamboo clump. In *B. bambos, B. blumeana, Dendrocalamus hamiltonii* (Fig. 51) and *D. strictus*, basal branches often form a thicket around the base of the old clumps.

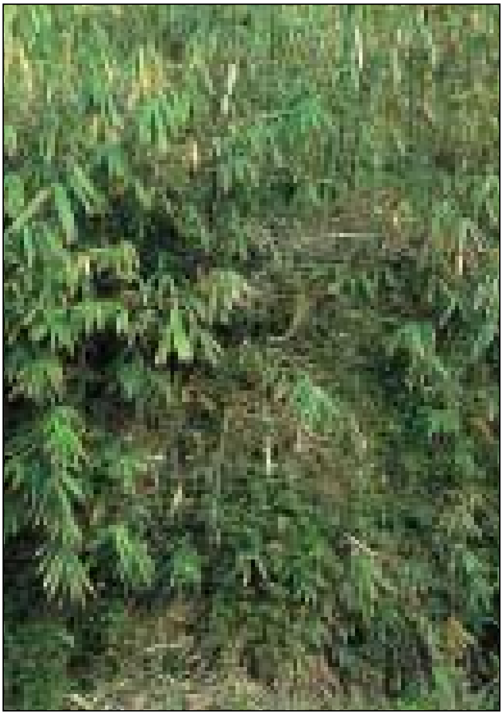

Fig. 51 (Left). A thicket of basal branches, bearing much smaller leaves than the upper branches, in a clump of *Dendrocalamus hamiltonii*, Sylhet, Bangladesh. **Fig. 52 (Right).** Culm sheath and internode of *Melocanna baccifera*, Mirpur, Bangladesh.

Branch spines. In a small number of bamboos, spines develop. The spines are in fact hardened, short, recurved branchlets at the nodes of the main and side branches.

EXAMPLES. *B. bambos* and *B. blumeana* are well-known spiny bamboos of Southeast Asia.

Culm sheath form. Most bamboos have rigid, plane sheaths wrapping over the cylindrical form of the culm internode. However, a few species have some peculiar features.

EXAMPLES. Sheaths of *Melocanna baccifera* have 1–2 characteristic transverse undulations (forming waves or grooves) across the upper part of the culm sheath (Fig. 52). In *Cyrtochloa*, *Dinochloa*, *Melocalamus*, *Neololeba* and *Soejatmia*, the very basal portion of the culm sheath is highly diagnostic because of a narrow zone of minute transverse wrinkles.

Culm sheath colour, hairs and wax. Sheath colours can be highly distinctive but best observed on growing shoots and young culms, as they turn brown or fall off in older culms. Some species have culm sheaths that are glabrous (hairless) or variously hairy or waxy.

EXAMPLES. The sheaths of *B. bambos* and *B. vulgaris* cv. *vittata* (Fig. 53) are medium green and often with yellow to orange streaks, those of *G. scortechinii* are often a diagnostic bright orange (Fig. 54), and those of *S. brachycladum* are a golden yellow-brown. *D. pendulus* sheaths often grade from green at their base to orange or pink near their apex. *Nastus elegantissimus* culm sheaths are pale greenish pink. Otherwise, sheaths tend to be generally green when still fresh. Glabrous culm sheaths are seen in *B. multiplex*, *B. tuldoides*, *Chimonobambusa quadrangularis*, *Soejatmia ridleyi*, sometimes in *B. bambos*, and frequently in *D. strictus*. The sheaths have jet-black hairs in *B. farinacea* and *Schizostachyum zollingeri*, red-brown hairs in *S. brachycladum*, dark-brown hairs in *B. blumeana*, and pale silvery white hairs in *D. longispathus*, *G. albopilosa*, *G. balui* (Fig. 55), *Maclurochloa montana* and *T. siamensis*. Some species, like *B. farinacea* (Fig. 56), *D. hirtellus* and *D. pendulus*, have copious amounts of conspicuous white wax as well on the back of the sheaths.

Culm sheath blade characters. The position of the culm sheath blade is often diagnostic because it is either stiffly erect or patent (spreading out) to reflexed in many species. Only in a few species is the blade orientation variable at different stages of culm development. Blade shapes and colours can also be helpful in identification.




Fig. 53 (Top left). Young shoot and culm sheaths of *Bambusa vulgaris* cv. *vittata*. **Fig. 54 (Top right).** Distinctive, bright orange culm sheaths of *Gigantochloa scortechinii*, Peninsular Malaysia. **Fig. 55 (Bottom left).** Silvery, white hairs on culm sheaths of *Gigantochloa balui*, Brunei. **Fig. 56 (Bottom right).** Black hairs on white-waxy sheaths, erect sheath blades and large, bristly auricles make the *Bambusa farinacea* shoot distinctive, Kedah, Peninsular Malaysia.

EXAMPLES. The blade is erect in nearly all known *Bambusa* (Fig. 56) and *Neololeba* species, some *Dinochloa*, some *Gigantochloa*, *Melocanna baccifera*, some *Schizostachyum* (Fig. 19), *Soejatmia ridleyi* and *T. siamensis*. It is spreading to reflexed in some *Dinochloa*, many *Gigantochloa*, some *Schizostachyum* (Figs. 27, 57) and many other bamboos. The blade is broadly triangular to dome-shaped in nearly all species of *Bambusa* (e.g., Figs. 53, 56), in some species of *Gigantochloa* and some species of *Schizostachyum* as well, where they are also often somewhat inflated (e.g., *S. brachycladum*, *S. grande*, *S. zollingeri*). Lanceolate blades are found in very many bamboos, as in *Dendrocalamus*, some *Dinochloa* spp., some *Gigantochloa* spp. (Figs. 54, 55), *Maclurochloa*, *Phyllostachys*,

Fig. 57 (Left). Patent (spreading), lanceolate, green culm-sheath blades of *Schizostachyum latifolium*, Pahang, Peninsular Malaysia. **Fig. 58 (Right).** Low, rim-like auricles and long, toothed ligules on the culm sheaths of *Gigantochloa latifolia*, Kedah, Peninsular Malaysia.

some *Schizostachyum* spp. (Fig. 57), and *Soejatmia*. Narrowly linear blades are found in *Holttumochloa magica, Kinabaluchloa* and *Racemobambos* spp. The culm-sheath blades of *Melocanna baccifera* are stiff and narrowly long-triangular, attenuating to a stiff point (Fig. 52). The culm-sheath blades are characteristically green and leaf-like in *Gigantochloa* (Figs. 55, 58) and *Maclurochloa*, and a few *Dendrocalamus* species. In some other bamboos, blade colours grade into those of the sheath proper, e.g., those of *D. asper* and D. *giganteus* are purplish green to a large extent; those in *D. hirtellus* and *D. pendulus* pinkish-orange-green; those in *S. brachycladum* a bronze-brown basally purple-tinged; and those of *S. grande* dark purple-brown.

Culm sheath auricles and ligules. Auricles can be inconspicuous or well developed and range from rim-like to lobe-like, glabrous to hairy on the margin. Once dry, they are rather fragile and the more elaborate ones tear or break easily. The ligules are not so visible, often somewhat hidden by the top of the sheath or the blade, but some are quite long and conspicuous.

EXAMPLES. Rather distinct, bristly lobe-like auricles are typical of *Bambusa* (Figs. 53, 56), *Dendrocalamus* and *Soejatmia*, except in *B. multiplex, B. tuldoides* and *D. strictus*, where they are rather small and inconspicuous. Low and rim-like auricles (Figs. 58 & 59) are typical of *Holttum-ochloa*, many *Gigantochloa* spp. (Figs. 55, 58), *Kinabaluchloa*, *Maclurochloa* and *Racemo-bambos*, but in *G. thoii* and a few other species of *Gigantochloa* they are large bristly lobes. Both kinds of auricles are found among *Schizostachyum* species. *D. gigan-teus* has fleshy, crisped auricles (Fig. 60). In *Fimbribambusa* from

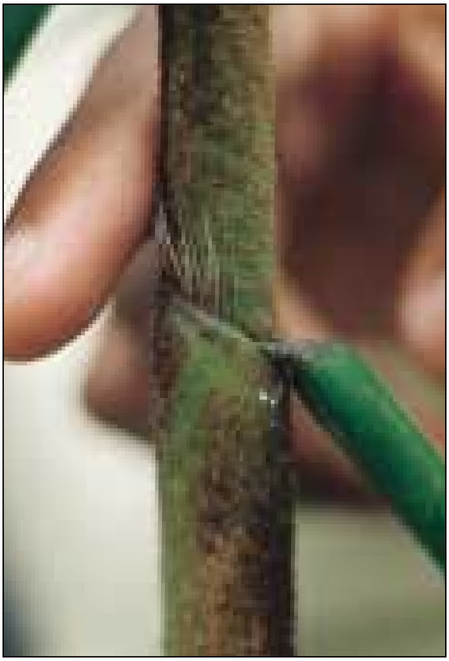

Fig. 59. Low, rim-like auricles with long erect bristles fringing the slanted top margins of the culm sheath, and a short-bristled ligule (at the junction with the blade) in *Schizostachyum jaculans*, Selangor, Peninsular Malaysia.

Fig. 60. Fleshy, crisped auricles and coarsely toothed ligules of *Dendrocalamus giganteus*.

east Java and New Guinea, each auricle is a stiff, erect, narrow lobe resembling a miniature finger or horn. The culm-sheath ligule is a low, subentire rim in many species of *Bambusa* and some species of *Dendrocalamus*, but is hairy or ciliate on the margin in *S. aciculare, S. brachycladum* and *T. siamensis*. The ligule margin bears fine bristles in *Holttumochloa, Kinabaluchloa, Racemobambos* (*R. setifera*), and *S. jaculans* (Fig. 59); coarse bristles or teeth in *D. hirtellus, D. pendulus* and a few species of *Gigantochloa* (Fig. 58); and irregular coarse divisions or clefts in *D. asper, G. ligulata, G. thoii,* and *S. grande*. In G. *ligulata*, the culm sheath ligule can be several centimeters long and very conspicuous! The ligule is hardly developed in some species, such as *S. terminale*.

Foliage leaf characters. In general, the foliage leaf blades yield fewer useful characters. In a few cases, size, hairiness and variegation are distinctive, as are leaf auricles (Fig. 61) or ligules (Fig. 62).

EXAMPLES. Very narrowly linear leaf blades (often less than 1 cm wide) are typical of *Holttumochloa* spp. (Fig. 49), *Racemobambos* spp., *T. siamensis* and *B. multiplex* cv. *riviereorum*. In contrast, leaf blades reaching

8 cm wide or more are common in *S. grande* (Fig. 9) and *Dinochloa trichogona*, and among *Neololeba* spp. Some species have glabrous leaf blades, but many have scattered to densely hairy lower leaf surfaces. The lower surfaces of leaves can also be pale bluish green, as in *B. farinacea, B. multiplex* and *T. siamensis*, but this may not be consistent. Variegated leaves (green leaves with yellowish-white striping) are found in the so-called *B. glaucophylla* and very rarely in *G. scortechinii*. In many species of *Bambusa* and other genera, the base of the leaf blade (where it constricts to form the false stalk, which joins it to the leaf sheath) is often somewhat rounded to

Fig. 61 (Left). Protruding, small horn-like auricles are found on foliage leaf sheaths in *Temburongia simplex*, Temburong river, Brunei. **Fig. 62 (Right).** Unusually long leaf ligules, brown and chaffy as they dry, in *Gigantochloa ligulata*, Kedah, Peninsular Malaysia.

truncate, whereas in some other bamboos the blade is more gradually tapered to a wedge-shaped base.

Spikelet and pseudospikelet characters. The essential difference between spikelets and pseudospikelets, discussed above (under "Structure"), is of value in classification and is a fundamental character of groups of genera. Spikelet structure, as influenced by the length of the rachilla and number of flowers and overall size, provides several consistent characters.

EXAMPLES. The pseudospikelet appears big (some several centimeters long) when there are more than 1–2 flowers and rachilla internodes are distinctly elongate, as in *Bambusa*, *Holttumochloa*, *Kinabaluchloa*, and *Soejatmia*. The rachilla internodes are jointed just below the lemma attachment and the internodes detach easily, so that pseudospikelets easily break apart, in these genera and also in *Maclurochloa* and *Thyrsostachys*. There are 2–3–5 or more perfect flowers per spikelet in *Bambusa*, *Gigantochloa*, *Holttumochloa*, and *Soejatmia*. Only 1–2 perfect flowers per spikelet are found in some species of *Dendrocalamus*, and in *Dinochloa*, *Kinabaluchloa* and *Maclurochloa*. The number of glumes below the flowers is not constant but is usually just one or two; *Maclurochloa*, however, has 3–5 glumes below the flowers. Each tuft of pseudospikelets is subtended by a conspicuous, semi-persistent spathelike bract in *Melocanna*, and secondary and higher-order pseudospikelets are characteristically subtended by a large bract almost as long as the lemma in *Kinabaluchloa*. A vestigial terminal flower (with only a lemma, or just a lemma and palea, often reduced in size and without other flower parts) in the spikelet is typical of a number of genera but more difficult to ascertain without special instruments, as are other details of the spikelets and flowers.

Flowers characters. A number of flower details are of importance in classifying species and telling them apart from closely related ones, but these are best learned through more specialized books or papers and by first-hand dissection using the microscope.

EXAMPLES. The palea of a bamboo flower typically has two sharp folds ("2-keeled" in structure) when it backs onto the rachilla internode below the next flower (as in *Bambusa*, *Schizostachyum* and others). The palea may not be keeled or only slightly so when there is just one flower (e.g., *Dinochloa*) or when it is found in a terminal flower which does not back onto any extension of the spikelet rachilla (e.g., in *Dendrocalamus strictus*, *D. pendulus* and allied species). In *Sphaerobambos*, the palea keels have a narrow extension or "wing". The palea apex may be rounded to acute (e.g., *Bambusa*), bifid (*Schizostachyum*), deeply cleft (*Thyrsostachys*), or with two hooked projections (*Soejatmia*). The number of veins on the back of the palea and on each inflexed edge is sometimes diagnostic of a species.

There are typically three lodicules per flower in *Schizostachyum* and *Bambusa*, two in *Melocanna*, or none in *Dendrocalamus*, *Neololeba* and a number of species of *Gigantochloa*. Exceptionally, a variable number have been found, e.g., 3–10 in *S. latifolium*. Whole subtribes and genera can have three stamens (in a single whorl) (e.g., *Chimonobambusa* and *Phyllostachys*) or six stamens (in two whorls of three) (e.g., the native genera in Malaysia) in the flower. In the Indian genus *Ochlandra* there may be numerous stamens in a flower (and at the same time more than just three lodicules). Transitions between stamens and lodicules are known in *S. latifolium*, and in *K. wrayi* the normally free stamens are occasionally found attached to the inner surface of fused lodicules. Stamen filaments are sometimes fused into a tube, as in *Gigantochloa* (Fig. 31) and some *Schizostachyum* species. The anther may be yellow or maroon and this is sometimes diagnostic for some species; this is possibly the easiest flower character to note during collection as the anthers are extruded and dangle from mature flowers in the spikelets or pseudospikelets.

In many bamboo genera, the style arises from the apex of the ovary, but in *Melocanna* and *Schizostachyum*, the ovary apex is extended as a tapering shell around a central strand of tissue thought to represent the true style. The style may be so short that the stigmas appear to arise directly from the ovary (e.g., some species of *Bambusa*, *Holttumochloa* and *Kinabaluchloa*) but typically it is elongate. A single stigma is found in some species of *Bambusa*, *Dendrocalamus* and *Gigantochloa*, but normally three in many species of *Bambusa*, *Nastus*, *Schizostachyum* and *Soejatmia*.

Southeast Asian bamboos

Statements about the character states found in one species or group, as opposed to those in others, are often presented as contrasting pairs (or couplets, each comprising two leads), so that the reader can select which lead is applicable and be guided to the species or group being identified. A series of such statements make up an identification key, and the identification process goes through a series of “true or false” decisions.

Clearly, a particular identification key is constructed with definite species or groups in mind; hence, if one attempts to use a particular key to identify something not included in the set of entities represented by the key, wrong interpretations may result. It is also possible that an entity may not been catered to in a key because it is simply unknown to the author.

Here we attempt a key for identifying the groups and genera of Southeast Asian bamboos that are botanically better known. Remember that some species and groups have yet to be completely documented and many obvious parts, such as shoots and branching, are not well known, so it is difficult to present a “simplified” key.

Identification Key

1A. Culms pencil-thin, climbing by twining around tree stems and branches. [Andaman & Nicobar Islands, Peninsular Thailand & Malaysia, Sumatra, Java, Borneo, Philippines, Sulawesi] .... **DINOCHLOA**

1B. Culms thick or thin but never twining; erect or leaning or flexuous and clambering with long branches which entangle with the surrounding vegetation. [Not restricted to the above localities]

> **2A**. Culms developing a narrow shelf-like or plate-like extension (patella) around each node. Leaf sheath auricles stiff, linear, horn-like extensions.

3A. Culm-sheath blade erect; auricles small rounded lobes. Inflorescence of true spikelets, in groups of 1-3 along the main flowering axis. [Brunei] .... **TEMBURONGIA**

3B. Culm-sheath blade patent to reflexed; auricles stiff, linear, horn-like structures. Inflorescence of pseudospikelets, in clusters of few to many along the main flowering axis. [East Java, New Guinea, Sulawesi, possibly also the Philippines] .... **FIMBRIBAMBUSA**

2B. Culms not developing a patella around each node. Leaf sheath auricles different.

4A. Branches at each mid-culm node all comparatively short and typically not rebranching away from their base. (In some cases, such as *Racemobambos*, the primary branch remains dormant and develops into a long dominant branch only later, so young culms appear to have clusters of short, simple branches; in other cases, such as *Neololeba*, new flowering side branches appear, bearing smaller leaves, as the branch enters a flowering phase, but these are not normally present prior to flowering.)

5A. Rhizome system mixed, basically monopodial, bearing culms directly as well as clusters of sympodial rhizomes; the culms well-spaced or in several clusters. Culm nodes prominently swollen. Branches at culm nodes each bearing just 1–2 leaf blades. [Sometimes cultivated in southeast Asia] .... **SHIBATAEA**

5B. Rhizome system sympodial; culms closely packed together in a clump. Culm nodes not conspicuously swollen. Branches at culm nodes each bearing many leaf blades.

6A. Culm sheath bases with a conspicuous, transversely wrinkled zone. Branches very steeply ascending and held near to the culm. Flower with no lodicules. (Leaf blades in several species very broad, typically 4–8(–15) cm.) [Mindanao, Sulawesi, Maluku, New Guinea, Solomon Islands and Queensland] .... **NEOLOLEBA**

6B. Culm sheath bases quite smooth. Branches spreading, often more than 45° from the vertical. Flower with 3 lodicules. (Leaf blades narrowly linear, typically not wider than 2–3 cm.)

7A. Branches at a culm node developing from many primary branch buds arranged alternately in two rows. Inflorescence of pseudospikelets. [Peninsular Malaysia] .... **HOLTTUMOCHLOA**

7B. Branches at a culm node developing from a single primary bud. Inflorescence of true spikelets.

8A. Primary branch always dominant in size, either as a dormant central bud or thicker main branch. Spikelet with several flowers. [Malay Peninsula, Borneo, Philippines, New Guinea, Solomon Islands] .... **RACEMOBAMBOS**

8B. Primary branch not conspicuous, the branch complement normally appearing as several to many subequal branchlets in a cluster. Spikelet with a single fertile flower.

9A. Low bamboo with scrambling-scandent culms. Culms reaching about 2 m long, internodes only 10–15 cm long and 1–2 mm in diameter. [Lowland limestone bamboo in Peninsular Thailand] .... **TEMOCHLOA**

9B. Erect or scrambling-climbing bamboo. Culms at least several metres tall, internodes always longer and thicker than 1–2 mm. [Montane bamboo found in Madagascar, Réunion, Java to the Solomon Islands] .... **NASTUS**

4B. Branches from each mid-culm node always conspicuously rebranching to 1–several orders along their length.

10A. Culm sheaths with a wrinkled basal portion. Mostly clambering forest bamboos.

11A. Leaf base with markedly unequal sides, one side rounded, the other oblique or sharply slanted. Spikelets 1-flowered. Fruit globose and fleshy. [Philippines] .... **CYRTOCHLOA**

11B. Leaf base with subequal or only slightly unequal sides, either rounded or slanted. Spikelets with more than one flower. Fruit globose and fleshy or a subcylindric grain. [Mainland southeast Asia]

12A. Leaf auricles large, papery, ovate to rounded, lobe-like structures. (Spikelets 3–5-flowered. Flower with 3 lodicules. Fruit a small, subcylindric grain.) [Peninsular Malaysia, Singapore] .... **SOEJATMIA**

12B. Leaf auricles leathery, crescent-shaped structures.

13A. Culm-sheath blades erect. Spikelets 3–12-flowered. Flower without lodicules. Fruit a small, subcylindric grain. [Mindanao, Sulawesi, Maluku, New Guinea, Solomon Islands and Queensland] .... some **NEOLOLEBA**

13B. Culm-sheath blades reflexed. Spikelets 2-flowered. Flower with 3 lodicules. Fruit globose and fleshy. [Bangladesh-Myanmar-Thai region] .... **MELOCALAMUS**

10B. Culm sheaths smooth, not conspicuously wrinkled, at their base. Clambering or erect bamboos.

14A. Basal culm nodes developing indurated, recurved, short root-thorns.

15A. Rhizomes monopodial. Culm bases often (not always) squarish in cross-section. [Sometimes cultivated in southeast Asia] .... **CHIMONOBAMBUSA**

15B. Rhizomes sympodial. Culm bases cylindrical. [South China, Taiwan, Philippines, Borneo] .... **YUSHANIA**

14B. Basal culm nodes with or without roots but never with indurated root-thorns.

16A. Small bamboos hardly 2 m high, forming large patches of ground cover in open or sparsely wooded sites in strongly seasonal areas in Thailand and Indo-China. Deeply growing rhizomes bearing culms with their underground basal portions developing slender leafy branches protruding from ground level. [Indo-China, Thailand] .... **VIETNAMOSASA**

16B. Larger bamboos over 3–4 m high; if smaller, not found as ground cover in the seasonal areas above (except some small *Dendrocalamus* on limestones in Peninsular Thailand and Peninsular Malaysia), and never with protruding subterranean branches arising from buried culm bases. [Not restricted to Indo-China or Thailand, or cultivated]

17A. Culm nodes with a ring of long spreading (patent) bristles. Culm internodes typically very long, more than 1.5 m. [Malay Peninsula, Borneo, possibly also Indo-China] .... **KINABALUCHLOA**

17B. Culm nodes without such spreading bristles. Culm internodes typically shorter than 1 m, usually much shorter.

18A. Primary branches at mid-culm nodes typically an unequal pair. Culm internodes deeply grooved along their length on the same side as the branches. [Sometimes cultivated in southeast Asia] .... **PHYLLOSTACHYS**

18B. Primary branches at mid-culm nodes never consistently a pair of main branches. Culm internodes not, or only inconspicuously, grooved.

19A. Branching at mid-culm nodes consisting of three major subequal branches at the same level. [Sometimes cultivated in Southeast Asia] .... some **CHIMONOBAMBUSA**

19B. Branching at mid-culm nodes made up of a solitary primary branch that branches basally to produce several to many higher-order branches.

20A. Culms with a distinctly white-waxy zone just below each node. Branch complement at mid-culm a cluster of slender subequal branches, without any clearly dominant branch.

21A. Inflorescence of true spikelets. Mostly clambering montane bamboos, rarely erect or lowlands. [Madagascar, Réunion, Java to the Solomon Islands] .... some **NASTUS**

21B. Inflorescence of pseudospikelets, developing into tufts of few to many pseudospikelets together. Mostly erect, rarely clambering bamboos of the lowlands, seldom in mountains.

22A. Culm sheaths with 1–2 strong transverse undulations at the upper part, the blades erect. Mature plants with an open habit, the culms widely spaced and appearing solitary due to long rhizome necks that bring each new culm farther away from the previous one. Pseudospikelet branches secundly arranged (apparently to one side of the axis). Fruit large and fleshy, berrylike. Paleas unkeeled. Lodicules 2. [Bangladesh, northeast India, Burma, Thailand, sometimes cultivated elsewhere] .... **MELOCANNA**

22B. Culm sheaths without transverse undulations, the blades erect or reflexed. Mature plants distinctly clump-forming, the culms clustered together. Pseudospikelet branches distichously arranged. Fruit small and thin-walled, a caryopsis. Paleas 2-keeled. Lodicules 3.

23A. Bracts and glumes at the base of the pseudospikelet with conspicuously long awns, the pseudospikelets aggregated into a spiky ball-like head. Flower with two stigmas. [Nepal to Thailand] .... **CEPHALOSTACHYUM**

23B. Bracts and glumes with pointed, not exceptionally prolonged apices, the pseudospikelets in clusters of few to many. Flower with three stigmas. [South China to Malay Archipelago] .... **SCHIZOSTACHYUM**

20B. Culms not white-waxy, or else the waxiness generally distributed over the culm surface and not restricted to a zone just below each node. Branch complement at mid-culm always with a distinctly dominant main branch.

24A. Slender clambering bamboos (typically less than 2–2.5 cm diameter) with flexuous culms and branches entangling with tree branches. (Culm sheaths not or only inconspicuously waxy, the auricles low and rim-like.)

25A. Culms without any distinct band of hairs just below the nodes. Culm-sheath blades linear. Inflorescences with true spikelets. [Malay Peninsula, Borneo, Philippines, New Guinea, Solomon Islands] .... some **RACEMOBAMBOS**

25B. Culms with a thick band of silvery white velvety hairs just below each node. Culm-sheath blades lanceolate and leaf-like. Inflorescences with pseudospikelets. [Peninsular Malaysia] .... **MACLUROCHLOA**

24B. Slender to big erect bamboos, the culms not clambering (but if leaning in habit and with long entangling branches then with culm sheaths with copious white wax and lobe-like auricles).

26A. Mature flower with palea longer than lemma and 2-keeled, the keels with narrow extensions ("wings"). Fruit globose and fleshy. Rare bamboos. [One species each in Sabah, Mindanao and Sulawesi] .... **SPHAEROBAMBOS**

26B. Mature flower with palea not longer than lemma and 2-keeled, the keels not "winged". Fruit a subcylindric, dry grain. Mostly common bamboos, sometimes localized. [India to south China and southeast Asia]

27A. Culm-sheath blades erect, rarely spreading out with age or at upper part of culm. Rachilla internodes jointed and disarticulating below the lemma attachment (the mature pseudospikelet easily breaking up into component fragments).

28A. Culm-bud prophyll (the scale-like bract enclosing the branch-bud at each node) with fused margins, the whole resembling a rounded hood held over the branch-bud. Culm sheaths most usually dark-hairy, with the auricles distinctly rounded coarse-bristly lobes (seldom tiny and inconspicuous as in *B. balcooa, B. multiplex*, sometimes *B. tuldoides*). Spikelets typically with 3–10 flowers. Paleas all with acute to rounded tips, only rarely slightly cleft. [India to south China, southeast Asia, sometimes cultivated] .. **BAMBUSA**

28B. Culm-bud prophyll with free margins, resembling a broad scale folded forward at the sides and embracing the branch-bud. Culm sheaths silvery-white hairy, with inconspicuous auricles. Spikelets with 2–3 flowers. Lower paleas deeply cleft or bifid. [Myanmar-Thai region, sometimes cultivated elsewhere] .... **THYRSOSTACHYS**

27B. Culm-sheath blades erect, patent or reflexed. Rachilla internodes not jointed below the lemma attachment (the mature pseudospikelet usually staying somewhat intact as a unit).

29A. Culm-sheath blade lanceolate to narrowly triangular, remaining green and leaf-like until the sheath dries. Culm-sheath auricles low, firm and distinct rim-like structures or rounded lobes. Flower with stamen filaments fused to form a firm tube. [Northeast India to south China, Indo-China, Malay Peninsula, Sumatra, Java, Borneo, Philippines, Sulawesi, sometimes cultivated] .... **GIGANTOCHLOA**

29B. Culm-sheath blade triangular, ovate or lanceolate but not green and leaf-like, being typically suffused with other coloration. Culm-sheath auricles low and inconspicuous, or rounded or crisped-undulating lobes. Flower with free stamen filaments, not forming a firm tube.

30A. Spikelets terete (i.e., not laterally compressed), the lemmas tightly overlapping. Flowers 1–3 in the spikelet, the terminal one not vestigial. [India to Thailand, Peninsular Malaysia, Sumatra, Borneo, sometimes cultivated] .... **DENDROCALAMUS**

(including *D. strictus*, with glabrous or sparsely golden brown-hairy culm sheaths, erect blades and inconspicuous auricles; *D. longispathus*, *D. membranaceus* and allies with pale- or dark-hairy culm sheaths, lanceolate reflexed blades and bristly lobe-like auricles; *D. hirtellus*, *D. pendulus* and allies, with copious loose white wax mixed with hairs on the culm sheaths)

30B. Spikelets slightly compressed, the lemmas slightly parted and loosely overlapping at maturity. Flowers 3–8 in the spikelet, with a vestigial terminal flower. [South China to Indo-China, possibly also India to Thailand, sometimes cultivated] .... **SINOCALAMUS**

(including *S. latiflorus*—originally *Dendrocalamus latiflorus*—with smooth, waxy culms and small hairy auricles, and bamboos now called *Dendrocalamus asper*, with a thick velvety covering of brown hairs on basal culm internodes and large bristly auricles, and *D. giganteus*, with sparsely hairy, waxy culms and fleshy, crisped-undulating culm-sheath auricles)

The last group of genera is difficult to key out with simple, easy-to-observe features mainly because of the closely related *Bambusa*, *Dendrocalamus* and *Gigantochloa* having many species with a large range of characteristics, and inadequate study of (and thus long-standing confusion about) the definition of *Dendrocalamus*. Botanically, some botanists recognize the genus *Sinocalamus* and a stricter definition of *Dendrocalamus* (using the differences given above). Studies to establish these limits will also need to address the status of some related species in the Indo-Malayan area that cannot be placed in one genus or the other with certainty.

Conserving bamboos

Conservation of bamboos, as is the case with many other plants, addresses two groups of species, those of known usefulness and (especially economic) importance, and other species that may be rare or vulnerable to endangerment.

The useful or potentially useful species

It is natural for useful plant species to be maintained or conserved by human communities. Len Muller (1996a, 1998b) discusses the possible role of selection in maintaining useful bamboo clones. He surmises that, in a place like Java, where a long history of folk agriculture exists, certain clones may have been historically maintained for their usefulness, just as Holttum (1958) had suggested the distribution of cultivated *Gigantochloa* species may well reflect the ancient migration of peoples.

In a number of bamboo species, clumps grow vegetatively for a certain period (even decades) and then flower intensely and gregariously (all together) before dying off, with the seeding producing a new generation. If hybrids between different species of bamboo existed, then in a number of them, seeding may be aberrant and unsuccessful. Furthermore, some of the hybrids, or variants of species, may not flower or die from their limited flowering and so make good cultivation subjects for a sustainable production of shoots or culms, traditionally the most useful items from bamboo (Fig. 63). Thus, where the diversity of bamboo species is great, such as in the case of *Gigantochloa* spp. in the Myanmar-Thai-Sumatra-Malayan region, hybrid swarms would yield a great number of such potential clones. In a place like Java, where an interesting range of *Gigantochloa* clones appears to have sustained for long periods without intense flowering and then death, such selection of bamboos from a swarm of hybrids may have taken place. These swarms are perhaps in distant lands from where ancestors of the present people had migrated.

Apparent sterility is met with in such cultivated forms as *Bambusa vulgaris* (no fertile seed known). More extremely, some clones may not even

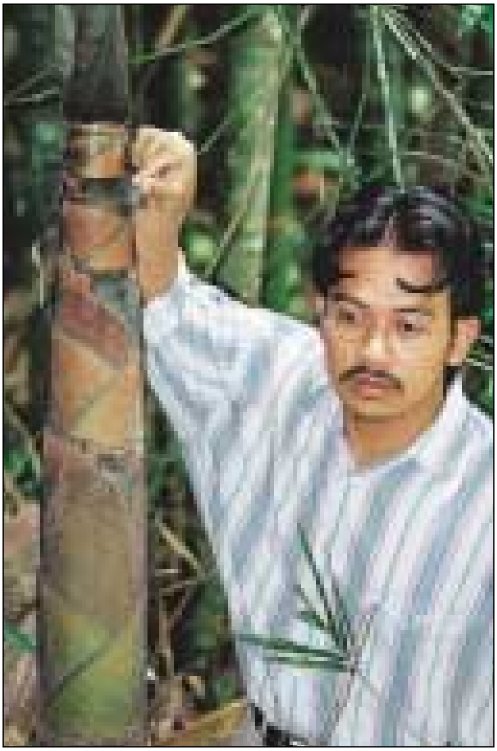

Fig. 63. *Gigantochloa thoii* in Peninsular Malaysia, much cultivated for its delicious shoots, is found as clumps that flower intensely and die, and others that show only diffuse, partial flowering. Selection of the latter has advantages for cultivation.

flower for long periods. The horticulturally popular *B. glaucophylla*, a bushy plant with variegated leaves whose precise origin is not determined, is not known to have flowered; it appears not to be a true species but a cultivar derived from some other species, possibly *B. heterostachya* (Muller 1999). *G. robusta* clumps planted in the Bogor Botanical Garden in 1844 during the time of the botanist Hasskarl have remained alive for over 150 years, i.e., they at least did not die from flowering, if any. Muller (1999) has referred to such bamboos as “ancient enduring clones”, which are preferable for many pragmatic reasons. For example, death following the 1994–95 gregarious flowering of *Dendrocalamus asper* material raised from a narrow genetic base for large-scale cultivation in Thailand has caused much economic loss (Thammincha, Suksard & Maneekul 1995, Muller 1996b). Apparently, 38,000 hectares of land planted with this bamboo became unproductive and 35,400 farmers lost their livelihood as a result. In contrast, it appears that there is a clone of *D. asper* in Java, possibly a selected form, that has only flowered diffusely, not intensely, over more than 60 years, so that whole-clump death has not resulted (Leu 1999). We know very little about such variation.

Some variation in natural species can be readily observed. One of the most obvious characters that can vary conspicuously is variegation in culms, in the form of pale striping of otherwise wholly green culms. Clumps (representing individuals) with either entirely green or pale-striped culms can be seen within populations of *G. ligulata* in northern Peninsular Malaysia or *G. balui* in Peninsular Thailand, for example. Where these have seeded (Fig. 64), some albino seedlings (producing only white leaves) occur among "normal" seedlings (with green leaves). Do these albinos represent a portion unable to produce chlorophyll normally and which will die off, and the green seedlings other offspring that will either produce wholly green or pale-striped culms? Systematic observations on this have not yet progressed very far. On the Mount Mirinjo farm at Innisfail, Queensland, Muller (1998b) observed the germination of seeds collected from a single parent clump of *G. ridleyi* (introduced from Bali) that had flowered. Roughly half the seedlings that germinated lacked chlorophyll and perished. This is difficult to interpret as it is, but at least, as a rough guide, collecting or planting both types of material, from such clumps with wholly green or pale-striped culms, would at least have gathered some degree of genetic diversity.

Fig. 64. Abundant seedlings spring from masses of *Gigantochloa balui* seed trapped atop a shelter in Khao Sok National Park, Peninsular Thailand, during a gregarious flowering of this bamboo in July 2000.

A further observation on *G. balui*, made by the present author in Peninsular Thailand in July 2000, may indicate that clumps with wholly green culms and others with striped culms have distinct flowering times. At Khao Sok National Park a total of 271 clumps observed along a 5-km trail segment included 179 flowering clumps and 55 non-flowering clumps of the green form; all 37 clumps of the striped form were not in flower. At a second locality near Sontphenong village, 78 flowering and 39 non-flowering clumps of the green form were noted, and all four clumps of the striped form were not flowering. In these populations, at least, the striped form was fewer in number than the green form and they seemed to come into flower at different times.

In India, *Dendrocalamus strictus* is a very variable species in many attributes, from overall size to the thickness of the culm wall, and drought resistance characteristics. There, documentation of character variation in this bamboo already exists and continues, aiding the identification of clones suited for particular purposes, but this kind of work is generally little done for other species, with the exception of *D. asper* (which is important for shoot production) and a few similarly useful species in various countries.

The agenda for conservation of useful bamboo species can therefore be thought of as including the following major elements:

a) identification and gathering of as many of the useful species as possible (a baseline collection that emphasizes species diversity);
b) recognition, gathering and study of distinct clonal material for species desirable for particularly important reasons, such as supporting the selection of high-yielding and sustainable material for cultivation purposes (in relation to an identified product, usually either culms or edible shoots) and the likelihood of the clone surviving in a productive state over as long a period as possible (emphasizing clonal diversity of selected species);
c) procurement of hybrid or suspected hybrid material from new sources, and their maintenance and study for the introduction of new, documented material.

Naturally rare or endangered species

The conservation of natural species is best done through protection of wild populations (Fig. 65). In some cases, this can only proceed when there is a sufficient knowledge of the species found in a region and their relative commonness or rarity, as well as possible endangerment, if any. Usually, during associated field work for such surveys, it is feasible to collect representative living material for *ex situ* conservation at a relevant centre, such as a research station or botanic garden.

In addition, a pragmatic assessment of both threats to particular wild populations, and to the species in general, as well as appropriate conservation measures, must be made. Highlighting the situation and recommendations to relevant parties and in reports, both technical and popular, often helps raise the level of awareness for conservation.

Fig. 65. *Kinabaluchloa nebulosa* is well protected within the Kinabalu Park and Crocker Range National Park in Sabah, Malaysia, which conserve a large area of its natural range.

Important collections of Southeast Asian bamboos

The idea of developing special living bamboo collections, or bambuseta, has not been a widely applied one in Southeast Asia, as traditionally, the preservation of the best clones is left to the (usually village-based) people who use bamboos most, and knowledge of the native bamboo flora is not always satisfactorily developed or easily accessible. As many landscapes are being altered now in the face of development, it is even more important to have the range of clones collected, documented and conserved.

Large, *ex situ* conservation collections can be land-extensive ventures if they aim to be somewhat comprehensive in scope. Both vegetatively propagated material (such as from rhizome offsets) and seed material would be of interest. Even then, there is a limit to the number of plants per species to be included, unless the collection more specifically targets a few species of some recognized importance. Thus, the existence and documentation of both small and larger collections are of importance, and the value of a

Fig. 66. The living bamboo collection of the Kebun Raya at Bogor, Indonesia, begun in the mid-19th century.

number of small collections in secure places in each country or region should not be underestimated. An agency such as the International Plant Genetic Resources Institute (IPGRI), in pooling together expertise and resources for bamboo conservation, can probably encourage a systematic, organized collection for conservation purposes through its network of parallel or participating organizations.

In the Appendix here, we list selected facilities with collections of Southeast Asian bamboo species maintained for long-term research or conservation.

Collecting bamboo specimens

Bamboo specimens are collected as research material or vouchers (representative evidence or records) of the species occurring in a particular locality or region. Because the whole plant can be very large, representative portions are taken as samples. All parts are individually tagged with the same collecting number or code as used for the collector's field notes recording features thought to be distinctive and which will not be retained with the samples, including those that will change with drying during preservative treatment later. Soderstrom & Young (1983) have given a very detailed protocol for such collecting, and here we describe the main features.

The parts to be collected as a set representing a particular bamboo plant (note that there can be more than one set, for distribution to various specialists or institutions) include: 1) a portion of the culm or at least one intact internode where feasible (alternatively, a section that includes one node with a short length of the internode at each end); 2) culm shoots with intact well-developed culm sheaths at least 0.5–1 m high (or several culm sheaths in good condition from the mid-culm portion, which may need to be collected from the ground); 3) a mid-culm node that bears a developed branch complement with the branches all trimmed back (as in Fig. 26); 4) one to several smaller branches bearing foliage leaves; and 5) flowering branches with spikelets or pseudospikelets, or fruits in good condition, if any. If not overly bulky, portions of the rhizome system can also be taken as specimens; these should display how culms are connected.

The minimal notes to be recorded for the collection would typically include: collector name and number; date; locality; elevation; habitat notes; common name and uses if known; rhizome type (monopodial, sympodial or variations thereof); culm habit (widely spaced or clump-forming, erect or otherwise); culm characters (total length, diameter and length of middle internodes, culm wall thickness, special features such as colour, hairiness, waxiness, etc.); special culm node characters if any; culm sheath characters at the mid-culm region (colour, hairiness, waxiness, blade position; auricle and ligule form, dimensions and their margins, whether bristled or otherwise); form of the branch complement at mid-culm; foliage leaf characters; and spikelet or pseudospikelet characters if known (e.g., colour of the lemma and its marginal hairs, if any; anther number and colour, filaments free or fused, stigma number).

Of course, some bamboo clumps are in an entirely vegetative state (without flowering material), and a flowering clump may not be producing young shoots and lack well-preserved culm sheaths altogether. Should some of these parts need to be taken from a different plant, even in the same locality, they should be considered a different collection with different numbering.

The parts collected are trimmed or folded down to a standard size that allows them to be pressed between newsprint folders of around 42 cm × 25 cm, and small bundles of these are protected with firm boards, secured tightly and dried thoroughly in a plant-drying oven at around 55°C. They are then suitably mounted (glued and stitched at relevant points) onto standard specimen boards of around the same size, together with a printed or neatly written note sheet containing the collecting information (the specimen label) (see specimen in Fig. 8). Specimen pressing and mounting is done such that the features are displayed maximally, e.g., both upper and lower leaf surfaces, and both sides of the culm sheath. Any photographs of the plant or its parts can be included with the specimen.

These mounted specimens are then archived in a cabinet or special room or building, which constitute the herbarium, a systematically curated reference collection of dried, preserved plant specimens. Bulky items, such as the trimmed branch complement of a large bamboo, need not be mounted and can be kept separately in boxes but retaining the same collecting number or herbarium accession number as the mounted specimens. Surplus or small amounts of flowering or fruiting material (spikelets or pseudospikelets), young culm buds, foliage leaf blades and root tips can be directly kept, with a tag, in FAA (90 parts of 50% ethyl alcohol, 5 parts glacial acetic acid, 5 parts formalin) or other preservative solution in suitable containers; these preserve without losing their form too much and can be more easily examined when required or (young spikelets and root tips) used for cytological studies. Duplicate material to be sent to others need not be mounted but kept (together with a copy of the specimen label) between folders or boxes to be separately dealt with. Such specimens are then amenable to study and interpretation by the specialist. Collecting and processing equipment, boards and containers, as well as preservative solutions, can often be obtained from herbaria, usually established in forestry research organizations, botanic gardens or university plant sciences departments, provided a set of the specimens goes to their holdings.

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Appendix:

Selected facilities with living collections of Southeast Asian bamboos

AUSTRALIA

Mount Mirinjo Farm, Innisfail, Queensland

BANGLADESH

Arboretum, Forest Research Institute, Chittagong
National Botanic Garden, Mirpur

BRUNEI DARUSSALAM

Brunei Forestry Centre at Sungai Liang

CHINA

Forest Research Institute, Guangzhou, Guangdong

INDIA

Bambusetum of the Forest Research Institute and Colleges, Dehra Dun
Indian Botanic Garden, Calcutta
Bamboorium, Arunachal Pradesh Centre, Basar, Arunachal Pradesh
Bambusetum, Van Vigyan Kendra, Chessa, Arunachal Pradesh
Bambusetum, Kerala Forest Research Institute

INDONESIA

Kebun Raya, Bogor (Fig. 66)
Arboretum, Agricultural University (IPB), Bogor
Perhutani Bamboo Germplasm Garden, Bogor
Cibodas Botanical Garden
Purwodadi Botanical Garden
Ekakarya Botanic Garden, Bali
Bamboo collection, PT. Great Giant Pineapple Co., Terbanggi Besar, Lampung Tengah, Sumatra

FRANCE

Bambouseraie de Prafrance, Anduze

MALAYSIA

Bambusetum, Rimba Ilmu Botanic Garden, University of Malaya, Kuala Lumpur
Bambusetum, Forest Research Institute Malaysia (FRIM), Kepong
Bamboo collection, Putra Jaya Wetlands, Putra Jaya
Taman Botani, Putra Jaya
Botanical Garden, Pulau Pinang
Agricultural Research Station, Ulu Dusun, Sabah

MYANMAR

Forest Research Institute, Yezin
Kandawgyi National Botanic Garden, Pyin-Oo-Lwin

PAPUA NEW GUINEA

Botanic Gardens, Lae
Agricultural Experimental Station, Laloki, Port Moresby

PHILIPPINES

Philippine Bambusetum, Baguio City
Botanical Garden, University of the Philippines at Los Baños
Forest Research Institute, College, Laguna

PUERTO RICO

Tropical Agriculture Research Station (TARS), Mayaguez: see also Edelman, Soderstrom & Deitzer (1985).

SINGAPORE

Singapore Botanic Garden

SRI LANKA

Botanical Garden at Peradeniya

THAILAND

Kanchanaburi Research Station
Queen Sirikit Botanical Garden, Chiangmai
Peninsular Botanical Garden, Trang

This book introduces the bamboos of Southeast Asia, a region well known for its incredible range of bamboo utilization and diversity. The author, a bamboo specialist in Malaysia, discusses the salient aspects of bamboo structure, biology and conservation and provides brief perspectives into the sometimes difficult tasks of bamboo classification and identification.