



**A morphological investigation of some Himalayan bamboos  
with an enumeration of taxa in Nepal and Bhutan**

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This thesis has been composed by the author, and has not been submitted in any previous application for a degree. The work of which it is a record has been undertaken by the author, and specific reference has been made to the sources of all information.

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## Summary

The taxonomy of Himalayan bamboos has been neglected in the past because of their unpredictable flowering as well as their geographic and political inaccessibility. Recent awareness of the fragility of the Himalayan ecosystem, and the potential economic and conservational role of bamboos has highlighted this neglect. The introduction of various programs by the governments of Nepal and Bhutan to address their environmental problems has allowed the detailed study of many of their bamboos, in order to provide information of use to those implementing such programs. The opportunity to study live plants in their natural environments has allowed detailed morphological investigations to be undertaken, as well as the collection of much new herbarium material.

*Bambusa* and *Dendrocalamus* are the principal genera of large stature bamboos found at lower altitudes in the Himalayas. In classic treatments of the bamboos, they were considered to represent two different subtribes. Recent reorganisations within the bamboos have shown the inconsistencies in the characters used to distinguish between those two subtribes, and have highlighted the close similarities between *Bambusa* and *Dendrocalamus*. Despite this the adopted criteria for separation of the two genera have remained subjective and imprecise, with poor agreement between floral and vegetative characteristics.

The young inflorescences of four species representing a wide range of variation within the two genera were analysed to compare branching patterns and prophyll keeling. *Dendrocalamus hamiltonii* was seen to have single-keeled prophylls throughout the inflorescence, while *Bambusa tulda* had twin-keeled prophylls throughout. The other two species had both single-keeled and twin-keeled prophylls at different orders of branching.

All the Asian species of *Bambusa* and *Dendrocalamus* represented at Kew were inspected to broaden the relevance of the studies. It was found that the use of a simple and precise criterion, the number of keels on the prophyll enclosing the inflorescence, allowed accurate distinction between the two genera. All nineteen *Bambusa* species had twin-keeled prophylls, while twelve out of thirteen *Dendrocalamus* species had single-keeled

prophylls. When this character is combined with other floral characters such as rachilla length and disarticulation, and several vegetative characters, especially thickness of culm wax and presence of aerial roots, there does seem to be sufficient discontinuity for separation of the genus *Dendrocalamus* from the large genus *Bambusa*, although the gap between them is small.

While the prophylls at different orders of branching allow the boundary between the two genera to be drawn at different points, it is suggested that representatives of the genera *Bambusa* and *Dendrocalamus* should be separated by the number of keels on the prophyll enclosing the whole inflorescence, as this allows easy field identification, and necessitates the minimum number of new combinations. With the boundary between the genera clarified, it became possible to place two new Himalayan species, which are on the borderline between the two genera in several characteristics, into the most appropriate genus, *Bambusa*.

At higher elevations in the Himalayas smaller stature bamboos become more common. These bamboos, which were at one time all placed in *Arundinaria* Michaux, come from several controversial and disputed genera, most of which can be considered to fall in the subtribe *Thamnocalaminae* Keng, interpreted in a broad sense. Many of the species in this subtribe have not been collected or studied in the field at all for over a century, and different taxonomists consider them to represent between two and eight genera. A recent revision, (Chao & Renvoize, 1989), places them in the three genera *Thamnocalamus*, *Sinarundinaria*, and *Racemobambos*.

Comprehensive collections of fresh material were made in Nepal and Bhutan so that the vegetative prophylls and branching patterns from a range of species could be compared in detail. Considerable variation was found in mid-culm prophylls, bud scales at the bases of culms, and degree of replication of the lateral branch axes.

These characters allowed separation of seven different groups, which agreed well with the genera *Thamnocalamus* Munro, *Ampelocalamus* Chen Wen, & Sheng, *Fargesia* Franchet, *Yushania* Keng, *Drepanostachyum* Keng, *Himalayacalamus* Keng, and *Neomicrocalamus* Keng. Parallels between their vegetative and floral morphology seem to support the

recognition of these seven genera, although further studies need to be undertaken. From the point of view of the users of bamboo nomenclature in the field these genera are all highly practical and helpful, agreeing well with ecological habitats, different growth forms, utilisation characteristics, and management requirements. *Sinarundinaria* Nakai now seems most likely to be a synonym of *Fargesia* Franchet, but the flowers of the type species, *Sinarundinaria nitida*, are not well known.

After investigating the boundaries between the Himalayan genera, it was possible to enumerate the species more effectively. The bamboos encountered in the field constitute a large increase in known Himalayan bamboo taxa. In the enumeration of the flowering plants of Nepal, (Hara, Stearn & Williams, 1980), ten species were recorded, from four broadly interpreted genera. No enumeration of Bhutanese bamboos has previously been undertaken. In this work fifty four taxa from fifteen genera are included from within or close to Nepal and Bhutan. Because many taxa are represented by very few collections, which are often sterile, it is difficult to decide upon the claims of some of them to separate specific status, but it would appear that a surprisingly large number of new species have been encountered. This could be explained by the inaccessibility of the countries concerned, the poor availability of fertile material in these periodically flowering plants, and previously inadequate knowledge of bamboo morphology.

The enumeration includes thirty species from Nepal, and twenty eight species from Bhutan, with a total of 42 species collected within the two countries. Of the forty two species encountered, only twenty eight seem to have published names. There would seem to be fourteen new species. Several other taxa can be satisfactorily placed within well-known species, but it is felt necessary to distinguish them as they differ substantially from the type specimens of those species, and are consequently very difficult to identify. Therefore it is also considered necessary to describe four new subspecies and three new varieties. In addition rationalisation of the genera results in nine new combinations.

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## **1. Introduction**

### **1.1 Himalayan land-use**

#### **1.1.1 Countries, landforms and climates**

The countries of the Himalayas are outlined in fig 64 , but reference to an atlas, eg Philip's University Atlas pages 94, 95 & 98 will reveal the relief and locations much better. The Himalayas have always been a physical, cultural, and climatic barrier between the states of India to the south and the area of Chinese and Tibeto-Burman ethnic groups to the north. In the mountains the two groups of people have mixed, giving different ethnic groups with the full range of intermediate cultures and characters, many as different from those to the north and south as the terrain in which they live. This is reflected in the independent or partly autonomous states established along the mountain chain. Plant communities follow similar patterns, with altitudinally banded habitats following narrow ribbons along the slopes of the mountains.

The great variation of landforms reflects the enormous altitudinal difference between the low plains of India and the high Tibetan plateau. It occurs over a relatively short distance, with continuing tectonic uplift in a climate with seasonally heavy rainfall. This leads to enormous natural erosion and deposition from mass wastage on the scale of the entire mountain system. This is increased by man-made surface erosion, although Carson (1987) showed the man-made element to be relatively insignificant, and in no way responsible for flooding in the plains below, although it is certainly disastrous in the hills through loss of fertility.

A useful generalisation widely used in Nepal divides the country into three landforms, the plains, the middle hills, and the high mountains. Various attempts to define these generalisations altitudinally have not been very satisfactory. A more useful distinction is based upon the nature of cultivated land. In the plains this is all basically flat. In the middle hills cultivation of whole intricately terraced hillsides is common, while in the high

mountains permanent cultivation is largely restricted to the valley floor, and the lower slopes on each side.

The plains below the mountains are a mosaic of fertile alluvial areas and areas of infertile conglomerates, gravels and sands, crossed by large rivers with enormous sediment loads which change course frequently, changing the fertility of large tracts of land as they do so. The wet low-lying areas predominating in Nepal are known as *terai*, while drier areas to the east are known as *duar*.

Rising from the plains are recently uplifted soft sandstones and conglomerates, forming the severely eroded hills of the *bhabar* zone, which merge into the first substantial but unconsolidated mountains, known as the Churia or Siwalik hills, which reach 800 to 1,800 m. Between these and the more consolidated and uplifted foothills are some large river valleys known as *dun* valleys, such as Dehra Dun and Hetauda.

The next mountain range is known in Nepal and India as the Mahabharat Lekh. From the top of this ridge at 1,500 to 2,800m, progressively higher ridges rise up to the main mountain ranges, with large rivers cutting down into deep valleys at 300 to 600 m, often flowing in an east-west orientation in Nepal, before turning to the south. The height of the ridges in the Mahabharat Lekh and the middle hills depends upon the degree of metamorphism of the rock. In Nepal fragile rocks such as shales, schists, and quartzites are very common throughout the middle hills well into the interior of the country. These have been deeply eroded, even under complete forest cover, to give fairly uniform slopes from ridge-tops at 1,600 - 2,500m to rivers at 300 - 1,000m, and the erosion continues, regardless of man's activities. Such slopes contain large contiguous belts of terraced and cultivated land, supporting the majority of the population, who effectively ride on a permanently changing topography.

The high mountains have a lower population, concentrated in the valleys between higher ridges of stronger rocks such as granites and gneiss. Erosion is intrinsically slower, because the rocks are harder, and because rainfall is lower in such rain-shadow valleys. In Bhutan the relatively greater degree of metamorphism of most of the rocks in the country leads to high mountain landforms closer to the plains, with much less middle-hill terrain,

and cultivatable land generally restricted to valley bottoms and separated pockets on the slopes. These landforms are similar to those of south-east Tibet, and the more mountainous regions of western Nepal, rather than the middle hills of central and eastern Nepal, so that in Bhutan the people, their culture, and also many of the habitats and their plants, have more in common with Tibet than India or much of Nepal. Thus over-population and erosion in Bhutan are effectively limited by the geology, as well as any deliberate actions of man.

Climatic data for Nepal were presented in detail in Jackson, (1987). The mountain chain increases precipitation on its southern flanks throughout the year. Summer rainfall is highest at the eastern end of the Himalayas, falling off gradually to the west. Winter rainfall is highest in the west, with a severe reduction eastwards from western Nepal, so that snowfall is neither a physical threat to plants, nor does it contribute greatly to reducing water stress in the following spring drought. From eastern Nepal across Bhutan, however, winter cloud and mist is very important in reducing evapotranspiration above 1,800m, so that plants which cannot survive in central Nepal can be found, even though the rainfall does not increase significantly with altitude, Howell (1991). This trend increases across Bhutan where the first mountain ranges are also much taller, so that cloud forest is predominant surprisingly close to the plains, and the reduction in water stress allows some very demanding plants to grow. Five genera of bamboos not known in Nepal thrive in these cloud forest areas. Beyond the high mountains and in deep valleys rainfall is dramatically reduced, giving semi-arid environments, where frost and high winds may make the habitats even more inhospitable.

### **1.1.2 Economies and development**

The landforms control which areas are most habitable, and the economies of the districts concerned. In cultivatable middle-hill areas, such as those which support most of the Nepalese population, the large tracts of heavily dissected but fertile hill slopes in subtropical climates have led to high population densities. The intractable communication problems have resulted in self-sufficiency rather than production of cash crops for trading. The high population densities, often with radically different ethnic groups co-

existing close together, have caused social as well as environmental problems. Hopes of transforming economies dramatically in such districts have now largely been abandoned, and the emphasis is upon stabilising a self-sufficient population by improved health, education and land-use. A vast array of other development activities are underway, including agriculturally based industries, hydroelectric power generation, mining, tourism etc, but these are localised, and the stabilisation of the rural economies is seen as the greatest priority, as 95% of the population still derive their income directly from the land, and international trade is difficult for land-locked countries.

Both agriculture and forestry are strongly emphasised in Nepal's development plans, with both private and communally managed multipurpose mixed tree crops being advocated at all levels of development work, to provide the day-to-day needs for firewood and animal fodder, as well as construction materials, fruit and agricultural fertilisers. The management of trees, bushes, hedges, live fences, bamboos and grasses are all heavily interwoven with agricultural crops, livestock, and soil conservation in an intricate farming system which defies economic analysis, but sustains a very high population density in a very fertile but also very unstable environment. The number of plants which farmers grow is enormous, but each plant may have its own propagation and cultivation requirements, as well as its own particular role in land-use.

Development work based upon improving such a system requires detailed knowledge of the plants, and taxonomy is the corner-stone of such knowledge. Investigations into improved propagation techniques for widely used bamboos have shown that optimum techniques are different for different species. Several species flower frequently, but only one species can be relied upon to produce good seed each year, (Stapleton, 1987, 1990). Many other species can be propagated from culm cuttings, (Stapleton, 1985a, 1986), but others will not respond well to this technique and still require more traditional methods, (Stapleton & Tamrakar 1983a). Aspects of management also require sound identification. Shoot borers damage some bamboo species, while other species can resist attack by producing secretions which discourage them, (Stapleton, 1985b). Thus sound plant identification seems a pre-requisite of good land-use.

In the high mountain areas such as northern and western Nepal as well as much of Bhutan, population densities are necessarily much lower, as cultivatable land is much scarcer. Economies have diversified where this is possible: trading, animal-breeding, and mercenary activities have supplemented a mainly pastoral economy in the past. Tourism in Nepal has brought in a new source of income there. Fruit production is important in Bhutan and in areas of Nepal where roads allow export. Diversification is easier where transport is possible.

Bhutan benefits from greater metamorphosis of its rocks by having more stable road alignments deep into high mountain areas. A small population the size of only one of Nepal's districts, good relations with India, and good communications have allowed much greater diversification. The forest resource is cautiously being opened up, primarily for the country's domestic requirements, (the highest per capita for the whole of Asia), but ultimately as an important export crop, within the constraints of wildlife conservation and the unwillingness of rural populations to change from an agricultural and pastoral lifestyle to a forestry-based one. Export of hydro-electric power to India, and international aid, provide per capita resources in the order of 10 to 20 times the per capita amount available to Nepal, (UNDP, 1985), and the administration has only to cope with a population one fortieth the size of the population of Nepal, or one two-hundredth that of Bangladesh.

In the high mountains the agricultural economy is still very important, but it tends to be more strongly linked to the environment as a whole. The fragility of temperate ecosystems allows greater potential for disaster if delicate balances are altered. As plant growth rates and yields are low, management techniques are less intensive, often involving extensive grazing of livestock in forest areas, and in some areas also involving shifting agriculture and burning of forest. There is often widespread harvesting of minor forest products and medicinal plants.

Activities such as forestry and livestock improvement have to be undertaken with great care. Forest regeneration and wildlife conservation require understanding of plant communities and the ability to identify many local plants. For example, some bamboos will prevent natural regeneration of timber trees if the canopy is removed too quickly, while others will not. Clearcutting systems would necessitate expensive replanting where certain

bamboo species are present, so that shelterwood systems of management are more appropriate, even though extraction is less economical. Similarly some bamboos provide better shelter and food for wildlife, having more open clumps or more palatable shoots, (Stapleton & Tamrakar, 1983b). In many other situations detailed knowledge of local ecosystems is needed to assess the impact of development activities upon the environment and upon other enterprises.

## **1.2 Plant enumeration in the Himalayas**

### **1.2.1 Historic activities**

The Himalayas were the hunting grounds of many famous taxonomists of the last few centuries, such as J D Hooker, Wallich, Roxburgh & King. Areas now part of India such as Sikkim, Kashmir, Himachal Pradesh and Uttar Pradesh were readily accessible and frequently visited. Their work enabled the construction of the present day classification systems, and the plants of the more accessible areas were covered quite comprehensively by large numbers of botanists. Local institutions such as the Royal Botanic Gardens in Calcutta took an interest in the whole range of the flora, and worked on a systematic and long term basis.

Other parts of the Himalayas, together forming the majority of the range, were visited by a restricted number of more pioneering collectors, such as Griffith, Cooper, & Kingdon-Ward. Despite their great knowledge and diligence, they could not cover the whole flora adequately. They were often funded by private horticultural companies and concentrated their attention upon groups of plants which would be successful and popular in European gardens. Cooper actually made extensive collections of less horticulturally important plants which were later abandoned or ignored by others, (Long, 1979). Nepal and Bhutan were both largely closed to foreigners until the middle of this century, although more collectors managed to get into Nepal than into Bhutan. Tibet and the north-eastern Indian state of Arunachal Pradesh were, and still are, even more difficult for foreign botanists to visit.

Cultivated plants have usually been neglected by ordinary plant collectors, although they are often the most important plants to local inhabitants. Plants which were not in flower were also paid less attention. Consequently non-flowering cultivated bamboos were not usually the first priority of plant collectors. Concerted efforts to remedy this situation were made by the Indian Forest Service, but correlation between isolated flowering specimens collected by itinerant collectors and the widespread stands of bamboo in vegetative growth have not generally been very satisfactory.

### **1.2.2 Present activities**

Since the middle of this century the number of botanical expeditions to Nepal and Bhutan has increased greatly, while access to parts of India has become much more difficult for foreigners. At the same time the endeavours of nationals of all the states and countries in the Himalayas have increased, often using facilities originally established by the British, but they are hampered by the location of most type specimens in western herbaria. In addition, the Japanese have organised several expeditions, and much material is now stored in Japan.

Private collectors and foreign institutions have continued the tradition of concentrating upon the collection of plants which could be horticulturally important in the west, and books concentrating upon the identification of temperate wild flowers have been privately produced. The British Museum produced a broader basic enumeration of the flowering plants known from Nepal in collaboration with Japanese collectors and the Royal Botanic Gardens at Godawari, (Hara, Stearn & Williams, 1978, 1979). The Royal Botanic Gardens in Edinburgh started a much more ambitious Flora of Bhutan in the 1970s, but restrictions on collecting by foreigners limit its coverage. Decision makers in Bhutan were apparently concerned that the project could encourage illegal extraction of Bhutan's plants, many of which are of actual or potential medicinal or horticultural importance. They may have underestimated the enormity of the task they were setting their own botanists, the degree of specialisation of modern-day taxonomists, and the vast amount of effort which has gone into establishing present-day botanical knowledge and classification systems from which the whole world can freely

benefit. It is worth noting that practically all of the agricultural and horticultural crops grown in Bhutan today originated in other parts of the world.

The importance of plant identification to aid projects in many programs in the natural resources sector throughout the Himalayas has recently become more apparent to international agencies. However, the conflicting priorities of foreign plant collectors, national institutions in undeveloped countries, the various line agencies within their governments, and those of international agencies assisting them, have yet to be reconciled. An atmosphere of misunderstanding and mistrust still persists, undermining the activities of all those who try to make a contribution to our knowledge of Himalayan plants.

### **1.3 Bamboo taxonomy**

#### **1.3.1 Historic treatments**

The development of early bamboo classification systems has been fully described, (Soderstrom & Calderón, 1979). Several Indian genera were known by the middle of the last century, and Munro added more in his monograph of 1868. He divided the bamboos into subtribes which were widely recognised for a while, but have not stood the test of time. Gamble (1896) added many further species in his monograph of the Indian bamboos, including several new ones from the Sikkim and Darjeeling areas. The number of genera decreased with increasing altitude at that time because of the relative inaccessibility of most of the Himalayas, Gamble placing all subtropical and temperate bamboos in one genus, *Arundinaria*. Camus, (1913), incorporated the work of Munro & Gamble into a monograph of all the known bamboos, with little modification of previous treatments of Himalayan bamboos.

#### **1.3.2 Recent developments**

Eastern taxonomists began to contribute to the study of bamboos at the same time as the European studies declined around the end of the

nineteenth century, and they have continued to dominate bamboo taxonomy in quantitative terms ever since. Japanese taxonomists studied vegetative characteristics as well as the floral details which westerners had concentrated upon, and soon separated their own temperate genera from *Arundinaria*, (Makino 1901, 1914, Nakai 1925). Chinese taxonomists also studied their bamboos more closely and have steadily increased the number of Chinese genera and species, making important contributions to the genera which spread into the Himalayas from the Chinese side.

Morphological studies have more recently thrown light upon new characters specifically important to bamboo classification. Studies of inflorescence structure attempted to describe and correlate tropical and temperate bamboos, e.g. Holttum (1956a), McClure (1966). Studies on vegetative morphology and anatomy attempted to provide new characters for identification, such as branch complement structure, (Usui, 1957), rhizome growth patterns, (McClure, 1966), vascular bundle composition, (Grosse & Liese, 1973), and leaf anatomy, (e.g. Soderstrom & Ellis, 1982). McClure attempted to bring floral and vegetative characters together for the South American bamboos, (1973), and Keng attempted a revision of all the known genera, (1982-3), including a greatly modified but still somewhat tentative system of subtribes.

American studies of leaf anatomy attempted to place the bamboos in a broad system of grass classification, (Soderstrom & Ellis, 1988). Clayton & Renvoize, (1986) attempted an interpretation of the bamboo inflorescence as a highly sophisticated development of the basic grass pattern, and rejected much of the work undertaken by Chinese taxonomists in their revision of the genera. Campbell (1988), Öhnberger et al (1985, etc), and others have since given more informal western support to the genera proposed by the Chinese.

### **1.3.3 Present aims, objectives, and constraints**

The principal aim of the project was to catalogue the Himalayan bamboos, to allow the identification of the most important Nepalese and Bhutanese species in the field during vegetative growth, by professional and

technical staff of projects in the natural resources sector, adhering to present standards in the fields of systematics and nomenclature.

To achieve this the first objective became the clarification of the boundaries between the genera, and reconciliation of the enormous discrepancies between genera recognised in Europe and China. The second aim was to enumerate previously described species found in Nepal and Bhutan, and the third was to provide names for the many unnamed taxa. A further objective was to describe the vegetative characters which are important in distinguishing between known and new taxa in the field, whether they are genera, species or below species level. Many descriptions of Himalayan taxa have been very sketchy, and in several cases the location in which the type specimen was collected is unknown. Many type specimens are of flowering material only, with no vegetative material to relate the type to non-flowering living plants, and one species has no type material at all.

Practical considerations placed many constraints upon the work. Collections in western herbaria are scanty and inadequate for either morphological investigations or comprehensive enumeration. Access to many parts of the Himalayas is politically restricted and physically problematic. The funding agency, ODA, required that the main output resulting from this work ought to be a field guide with information allowing the recognition of different genera and species in the field, from vegetative characteristics alone. In Nepal and Bhutan the Forestry Departments required user-friendly research findings, with simple terminology, sufficient illustrations, and keys. In Bhutan a royal directive had recently forbidden study of the Bhutanese flora or fauna by non-nationals, but the Forestry Department had made a special case for bamboos because of the present difficulties in their identification. These objectives and constraints were rather difficult to reconcile in the time allocated for the project. It is hoped that about three-quarters of the species from Nepal and Bhutan have now been included.

## **1.4 Usage of nomenclatural categories**

### **1.4.1 Species delimitation**

Although the species has always been the basic unit of taxonomic systems it has been defined in many different ways, and there are several different species concepts which are applicable in particular sub-disciplines. Radford (1986) listed five different species concepts, based upon logic, evolution, biology, taxonomy, and morphology, but it would seem that the two most important concepts arise primarily from morphological and biological considerations. Davis and Heywood (1963) portrayed the use of a "dualistic approach whereby morphological evidence is used to recognise species which are defined in genetic terms." The importance of breeding barriers to the establishment and maintenance of distinct populations is fundamental to the biological species concept. However, biological considerations can be kept in perspective, and Davis and Heywood have stated (1963) that:-

"The ability to cross can only be considered as a further taxonomic character, which must be assessed as any other single character."

Wagner (1984) expressed the difficulties faced by those favouring biological concepts:-

"After a number of decades of contributions from biosystematics we still have the problem of expressing them taxonomically. Perhaps ..... we should merely report our findings and leave classification alone."

Davis and Heywood (1963) reported that morpho-geographical and biological species frequently co-incide in sexual outbreeding groups. Nevertheless they did imply a degree of conflict stating that :-

"the impracticality of defining species in genetic terms is now widely acknowledged", adding "to abandon the practical, almost universal use of the term species in a primarily morphological-geographical sense for orthodox classification in favour of a restricted usage for impractical largely theoretical units in terms of gene pools and reproductive barriers, would surely be short sighted and unrealistic."

Apart from their importance in systematics, morphological characters have other uses which justify concentrating investigations upon them, especially in the pioneer stage of taxonomy. Once species delimitation has produced taxonomic species, the nomenclature has to be applied in species identification. This is usually effected through the use of keys, often applied in the field, using the minimum number of characters possible. Simple

morphological characters are by far the most useful. Biosystematic evidence and other endomorphic characters such as details of anatomy, phytochemistry, or cytology can be difficult to incorporate into popular keys, however valid discontinuities in these characters may be, unless there is agreement between those characters and more readily assessable morphological ones.

Although the biological species concept is readily applicable in animals, it seems less so in most plants, and the periodic flowering habit of bamboos makes data on their reproductive isolation particularly hard to obtain. Therefore, it would seem that a simple morpho-geographical species concept is quite suitable for most bamboos at the present time. Periodic flowering also means that field identification must rely upon sterile material for up to a hundred years or more in some species. Moreover, once flowering has started (when most collections are made), vegetative material is usually not available, as flowering bamboos drop most of their leaves and culm sheaths. Therefore, to facilitate identification of species at any time in their life, it is very useful to find parallel morphological gaps in floral and vegetative organs.

#### **1.4.2 Infra-specific variation**

Biosystematic principles are of particular relevance below species level, where most theories concerning speciation developed. Classic Neo-Darwinist adaptive radiation and selection are still fundamental to our analysis of much infra-specific variation, although their limitations have been shown by knowledge of different systems of reproductive biology.

The earliest biological approaches to infra-specific variation in plants such as the investigations of Turesson (1922, 1925) appeared to promise clarification of the basis for the different categories of sub-species and variety. Unfortunately later investigations and refinements of concepts such as the ecotype, ecospecies, and microspecies have made it more difficult to translate biological findings into meaningful nomenclature at this level. This may be because the biological concepts are not inherently hierarchical, as suggested by Wagner (1984).

The categories of subspecies and variety have often been defined in a rather biological manner. Davis and Heywood (1963) reported a tendency to regard subspecies as evolutionarily incipient species, adding that they may also represent originally distinct species in an early stage of fusion. However, their usage seems to follow a morpho-geographical approach, using the criterion of geographical range to assign either sub-specific or varietal status. This practice is followed in the enumeration given here, with populations which can be clearly distinguished on either floral or vegetative morphology, but not both, being given sub-specific status if their distribution is known to cover a broad geographical area, or varietal status if they seem more localised. The description of sub-species usually implies reasonably extensive knowledge of the species concerned. It seems that inadequately known taxa are often initially described as separate species, even though that may seem to suggest a somewhat narrow species concept in some cases.

### **1.4.3 The genus concept**

Stebbins (1974) illustrated at length how the characters which are used to separate genera and families in certain groups of plants are invariably found to delimit species or populations elsewhere. He used this precept to propose the idea that a single character alone could not define a genus or family. Instead he proposed the concept of canalisation, whereby a suite of common characters would occur in closely related species as complex initially adaptive structures retained long after they had been of selective value. These would form the foundations upon which the recognition of higher categories could be based. He also pointed out the great disparity in size between different genera, emphasizing that the genus concept cannot be defined in terms of size.

This is essentially in agreement with the assertion by van Steenis (1969) that the Darwinian concept of survival of only totally adapted individuals is rather simplistic at best, and that nature's 'morphological caprices' can thrive, especially in benign environments with low selection pressures, leading to rather erratic unpredictable evolution. However, there does seem to be conflict between the gentle evolutionary model for the origins of higher characters described by Stebbins (1974), in which

characters separating races develop in time to separate future genera and families, and mechanisms such as the saltatory processes described by van Steenis (1969). What is generally agreed upon is the need to delimit genera and families by a combination of several different characters.

The pioneer phase of taxonomy often involved the adoption of a single character for the delimitation of genera. Estes & Tyrl (1987) described this as a reversion from sounder Aristotelian principles to a Platonic dichotomous concept. Some later treatments have responded to the inconsistency of a single character by the merger of genera into larger groups. However, this practice can lead to polyphyletic groupings, such as those resulting from Hackel's treatment of genera in the Andropogoneae, where sub-generic combinations became widely used, (Clayton, 1987).

The importance of phylogeny becomes much more apparent at the generic level. Davis & Heywood (1963) stated that naturalness is the cornerstone of the modern genus concept. Modern techniques of multivariate analysis have become valuable tools for phenetic and phylogenetic studies at this level. Cladistic analyses can often break larger groupings into monophyletic units. Barkworth & Everett recently undertook such an investigation in the Stipeae (1987). In their opinion current generic concepts in that family are too artificial, stemming from an over-reliance upon floret morphology, a situation which is also prevalent in the bamboos. They found that different cytological, morphological, and anatomical characters were all useful in distinguishing genera, but that the usefulness of particular characters varied in different parts of the tribe. They managed to produce monophyletic groupings, but were reluctant to ascribe any taxonomic category to them.

Both numerical phenetic systems and cladistic systems may require a large amount of information on a range of different characters. This information is generally unavailable in more neglected groups of plants such as the bamboos. Where monophyletic groupings are based upon characters which are relatively difficult to determine, such as those of anatomy, cytology, palynology, or embryology, such groupings may be hard to recognise in the field. Moreover, phylogenetic and cladistic systems rely on some assumptions as to which characters are ancestral and which are derived. There is considerable disagreement concerning the evolutionary

pathways which have led to present-day bamboos, and such uncertainty could make it rather dangerous to use a cladistic approach.

The appropriate breadth of the genus concept is also controversial. McFarlane, in his treatment of the subfamily Pooideae (1987), accepted that generic concepts always will vary widely, but he considered there to be a need to represent the range of variation fully, a need which broad concepts of genera often fail to meet. He contrasted broad concepts of genera in the Triticeae, such as those of Bentham, who recognised 6 genera (1883), with the recognition of 38 genera by Löve (1982, 1984), and compromises such as that of Watson (1985), recognising 20 genera.

Davis & Heywood (1963) described four considerations which should be taken into account in the decision of whether to ascribe generic or sub-generic rank to a group. The technical criteria cover the degree and consistency of its identifying characteristics relative to overall variation within the family, and the size of the morphological gap separating groups relative to the size of the groups. They also included a practical consideration close to the hearts of users of nomenclature: the desirability of stabilising binary names in common usage. They also pointed out the unsatisfactory situation whereby concepts tended to be narrower in groups with showy flowers. They are often broader in those with obscure or less well known flowers.

From the point of view of those who must identify plants it can seem very convenient for nomenclature to incorporate a narrow concept of the genus whenever discontinuities can be demonstrated. On the other hand it can become much more difficult to define such genera, and there are many cases of bamboo genera being described with grossly inadequate delineation from 'other' genera. This form of splitting can be a hindrance to identification rather than a help. In addition, in the bamboos discontinuities which justify separation of different genera should ideally be founded upon both floral and vegetative morphology, so that the genus of a bamboo can be established both in the field during the long vegetative component of its life cycle, and in the herbarium from fertile collections. Rejection of small bamboo genera by later authorities has usually been based upon their authors relying upon either floral or vegetative characters alone, and this principle is followed here, several smaller genera being treated as synonyms in the enumeration.

McClure (1966) made valuable contributions to our bamboo genus concept by thoroughly reviewing many characters of both vegetative and floral morphology which had previously been misunderstood or undervalued. He later brought together many morphological characters from rhizome, bud, branch, inflorescence, and floret to delimit the genera of bamboos in the new world, (McClure 1973), using a practical and consistent genus concept, which differed from previous concepts in that importance was placed upon vegetative characters. Most Chinese taxonomists have adopted a similar concept, also using a wide range of readily determinable morphological characters, eg Keng (1982-3), giving vegetative and floral morphology equal status. Dransfield has shown a similar genus concept in her treatments of Malesian bamboos (1982, 1989), but with emphasis placed upon floret morphology in a more traditional style, backed up by details of vegetative morphology including growth habit and culm sheaths characteristics, as well as embryology and vegetative branching when enough information is available.

Clark (1989), in a revision of part of the South American bamboo genus *Chusquea*, used a similar concept implying the need for consistently and readily distinguishable differences in both floral and vegetative morphology. She decided to treat *Swallemochloa* McClure as a section of *Chusquea* on the grounds of strong similarities in spikelet structure, as well as inconsistencies in the vegetative distinctions described by McClure (1973). Soderstrom and Calderon (1978) had previously considered the status of *Swallemochloa* at length. They had decided that the differences in branch insertion, angle, and size, as well as culm sheath persistence, leaf characters, and ecological habitat were together sufficient for separation from *Chusquea*, but it seems that they had worked with a narrower range of available information. In a review of higher categories in the bamboos in which they listed all the genera which they recognised, Soderstrom and Ellis (1988) revealed a similar concept of the bamboo genus, also close to that of McClure and many Chinese taxonomists.

In marked contrast Clayton & Renvoize (1986) seemed to adopt a very much broader generic concept in the bamboos, although they stressed that their treatment was rather speculative. Because of the great importance of their publication this has distorted perceptions of the accepted breadth of

the genus concept in the bamboos considerably. Their broad interpretation of many temperate genera may have followed phylogenetic considerations arising from their interpretation of the iterant bamboo inflorescence as a highly derived structure, developed through a complicated series of expansions and reductions from the standard grass inflorescence. This interpretation was speculative and is not universally accepted. In addition, because vegetative morphology is poorly documented in the bamboos, they gave it relatively little weighting. Chao & Renvoize (1989) followed the categorisation of Clayton & Renvoize (1986) closely, with a very broad treatment of many temperate bamboos in a single poorly circumscribed genus, *Sinarundinaria* Nakai.

Thus although very broad and very narrow generic concepts have been used in the bamboos by a few authors, there does seem to be a general consensus as to the appropriate breadth, and the grounds necessary for recognition of genera, although some of the recent publications from Kew retain a much broader concept, albeit with the clear proviso of provisional status.

## **2. MATERIALS AND METHODS**

### **2.1 General methodology**

#### **2.1.1 Collecting procedure**

Bamboo material in western herbaria is generally inadequate for detailed morphological examinations or for any realistic attempt at enumeration, both in qualitative and quantitative terms. Therefore, the investigations had to be based mainly upon newly collected material.

Collections were made over several years of residence in Nepal and Bhutan, during which time involvement with forestry projects allowed repeated travel between western Nepal and eastern Bhutan. Most travel was undertaken by road, most collections being made at the road-side. Only a few of the more remote areas could be visited, as broad coverage of the two countries and the many genera concerned was a high priority,

concentrating upon the more common and accessible bamboo species presently of economic importance. Many roads are quite new, and pass through relatively undisturbed forest in Bhutan. Transport by road or on foot was accompanied by the usual administrative, political, climatic and mechanical problems, which served to restrict the depth of coverage.

All collections were documented and packaged in a manner suitable for such bulky but delicate material. Preservation of fragile parts such as culm sheath auricles and oral setae preclude simple pressing. Collections included rhizomes, sections of young and old culms, immature and mature branch complements, leaves of different sizes and ages, culm sheaths, and inflorescences in different stages of development. It was found that these were best packaged as a tight cylinder inside the culm sheaths, which when inserted inside each other protect the appendages and surface coverings. They were then transported back to Forestry Department research buildings for analysis. A proportion of the material collected was mounted for herbarium use, to represent the taxa investigated and enumerated adequately. Most Nepalese material was eventually brought back to the UK, where it is being deposited in the Royal Botanic Gardens in Edinburgh. The small size of the Forestry Department herbarium in Bhutan and the absence of a national herbarium, along with severe restrictions on collection of material meant that only a small amount of material could be deposited in Bhutan, and duplicates could not be lodged in UK herbaria. Photographs and drawings compensate for this lack of deposited material to some extent.

### **2.1.2 Examination of collections**

Material was examined in the research offices in Nepal and Bhutan using a hand lens or low power binocular microscope. As past descriptions of bamboos have often defied comparison because of the inconsistencies in terminology and range of characters studied, a standardised format was developed to list the characters of different collections in as consistent a manner as possible. Different formats were used for the subtribes *Bambusinae* and *Thamnocalaminae*, as different characters are most useful in separating species in different subtribes. Terminology used which is specific to the bamboos followed McClure's 1973 glossary.

Because of the confused state of generic nomenclature in these bamboos, and the possibility of new species being encountered, the bamboos were provisionally separated on approximate morpho-geographical grounds, with a consecutive numbering system initially identifying taxa. They are listed here according to this system as well as the names resulting from later nomenclatural investigations. After suitable material for generic morphological studies had been collected it was compared to a range of other collections to ensure that it truly represented the taxon under investigation. Details of collection locations are given in the enumeration, with reference to voucher specimens where appropriate.

To relate the newly collected material to existing nomenclature the collections at Kew and the British Museum were then examined in detail. Type material for nearly all the Himalayan bamboo species is available at Kew, much of it brought back at the time of Indian independence. A request for the loan of type material of several recently described Tibetan species was made to the Forestry School of Sichuan Province in China, but no reply was received. Fortunately those species are very well described and well illustrated in the literature.

### **2.1.3 Dissection technique**

Facilities for undertaking detailed morphological examinations in Nepal and Bhutan were limited. Erratic electricity supply and absence of sophisticated laboratory equipment necessitated the use of the most basic dissecting microscopes, which still suffered from persistent condensation and fungal problems in the absence of a controlled environment or maintenance procedures. Drawing was also a problem under erratic temperature and humidity conditions.

A hand-lens on a stand was used for some dissections, while simple binocular microscopes with a magnification of x 10 and x 20 were also used as available, with simple battery-powered incident lighting. Razor blades and needles were used to prepare and explore the bud contents, which were examined in as fresh a state as possible.

Under the extremely difficult conditions for collecting and analysing material it was only possible to examine a relatively small number of

samples from each taxon, and the results have to be interpreted bearing in mind this shortcoming. It can only be considered a preliminary study using the most elementary of techniques under arduous conditions with a refractory and neglected group of plants. Further studies are necessary to validate the results obtained so far.

## 2.2 Examination of inflorescences in the *Bambusinae*

Material from four species from the *Bambusa-Dendrocalamus* group was collected, in an attempt to cover the full range of variation in vegetative and floral characteristics in the genera. Their vegetative characteristics are given in table 16. The inflorescences were dissected and drawn, and translated into 2-dimensional branching pattern diagrams with organs borne upon the axes classified by position for comparison.

A *Bambusa* species (B21, *Tharu bans*) from Kathmandu, later identified as a new subspecies of *Bambusa tulda*, and a *Dendrocalamus* species, *D. hamiltonii* (D4 *Choya bans*) were used to represent the two extremes of the range of variation. They were complemented by two further species which are intermediate in many characters, *Bambusa balcooa* (D23 *Dhanu bans*, which is more closely allied to *Bambusa*), and a new species (D21 *Tama bans* from Kathmandu), which seems a little closer to *Dendrocalamus*.

The iterant nature of flowering in these genera results in prolific and complex branching patterns. The compression of the flowering axes and the lateral forces associated with their geometric increase make investigations in any but the youngest material extremely difficult and interpretation becomes increasingly unreliable. Most herbarium material was too old for accurate interpretation at the time of collection and has since deteriorated. Quantities of flowering material are usually too small to allow destructive dissection anyway. Therefore young inflorescences were sought in the field to allow investigation of lower order branching, although older material was of use for examination of higher orders of branching including the pseudospikelet level. Lower and higher orders could eventually be combined to give a more complete picture.

An example of the younger material required is given in fig 1 . The shoot would have borne functional leaves at all nodes if flowering had not been initiated. However, progressive acropetal reduction in leaf blades has taken place, so that the terminal sheaths still attached have reduced non-functional leaf blades. Such young axes are found before the general dehiscence of leaves which attracts attention to the clump, and are rarely collected.

At this stage of development the contents of the smaller buds have not emerged completely from the bud-scales. They would normally expand by repeated branching to form the capitate inflorescences commonly observed and collected. At this stage however, the relationships of all branches, bracts, and sheaths in a single inflorescence cluster from one bud can be plotted after careful dissection, and then translated into a branching pattern diagram for clarity and ease of interpretation. A classification system had to be devised for all the elements of the branching network so that they could be referred to in an unambiguous fashion for comparison between different inflorescences.

### **2.2.1 Further studies**

Ambiguities in the branching patterns and nature of organs were followed up by further studies and collection of slightly different material.

Splitting of bracts under lateral pressure occurred in the densest of inflorescences, particularly those of the type variety of *Dendrocalamus hamiltonii* from Nepal. Less congested inflorescences from a similar bamboo, *Dendrocalamus hamiltonii* var *edulis* from Bhutan, were collected and dissected when the type variety from Nepal proved too ambiguous. This provided insight into the true situation in that bamboo, interpretation of which could then continue.

To corroborate findings up to ten inflorescences of each species were dissected and the patterns depicted were sometimes built up from several different collections. In *D. hamiltonii* var *hamiltonii* samples were taken several hundred miles apart to determine whether the interesting duplication of axes was widespread, or a freak phenomenon.

Once experience had been gained in the dissection of these species it became possible to interpret structures on older herbarium material to a certain degree without dissection so that a wider range of species could be sampled at a more superficial level.

### **2.3 Vegetative branching in the *Thamnocalaminae***

The initial detailed dissections were undertaken using large quantities of fresh branch material collected in Nepal and Bhutan. For detailed dissections newly developing mid-culm branch complements on young culms were examined first. These were then compared to complements further up and down the culm, undeveloped culm buds, and buds on the rhizomes. Mid-culm branch complements were found to be the most useful for showing distinctions between the genera, therefore most of the illustrations which follow relate to mid-culm characteristics.

A wide range of proposed genera was studied to explore the full range of variation in the subtribe, initially only using a small sample of species for each genus. This small sample was obviously insufficient for any conclusions to be drawn, so the investigations were backed up by examination of the available herbarium material, including the type collections of the type species of the genera concerned. It was found that once knowledge of the different branching patterns had been obtained from detailed dissections of fresh material, it was possible to recognise the different patterns from more superficial non-destructive examination of herbarium material.

The full range of variation within the subtribe *Thamnocalaminae* was covered, *Thamnocalamus* and *Drepanostachyum* representing two extremes. Representatives of *Ampelocalamus*, *Fargesia*, *Sinarundinaria*, and *Yushania* are essentially intermediate, although they have their own peculiarities.

It was at first difficult to relate the variation in branching seen in the field to the different genera, as the nomenclatural situation was so poor that it was often not possible to assign species other than the type species to a particular genus with any confidence, even when flowers were available. It

was necessary, therefore, to start with a partially subjective impression of different groups, according to their ecological habitats and growth forms, and to relate these groups to the type species of the published genera at a later stage.

Because of the tentative affiliation of several of the field species the type species of *Sinarundinaria* and *Fargesia* were also collected in the UK, where they are widely cultivated as ornamental plants. *Arundinaria nitida* Mitford is the type species of *Sinarundinaria* Nakai, and *Arundinaria murielae* is considered a synonym of *Fargesia spathacea* Franchet, (Campbell 1988), which is the type species of *Fargesia*.

After examination of representatives of the subtribe *Thamnocalaminae*, some other well-known genera from different subtribes were briefly examined to put the results from Himalayan bamboos into a broader context.

### **3. *Bambusa* and *Dendrocalamus*: Inflorescence branching patterns and the value of prophylls in the delineation of the genera**

#### **3.1 Background**

##### **3.1.1 The importance of the distinction between the genera**

The genera *Bambusa* and *Dendrocalamus* are of considerable importance in rural economies and as an export crop throughout the densely populated areas of South and South-east Asia.

*Bambusa* species are well known and widely distributed, occurring naturally throughout Asia and in parts of South America, and being cultivated in Africa and North America. *Dendrocalamus* species are less well known as they are concentrated in the hills of the Himalayan and Malayan regions, where they have received little scientific attention. As well as providing a profusion of rural requirements, they also form the basis of the expanding canned shoot industry. Several new species have been brought to light during enumeration, and natural forest stands of potential value for edible shoot production await identification. The present ambiguous distinctions between the genera cause great difficulties in field

identification. This makes rational species selection very difficult, whether it be for community forestry or industrial-scale shoot production.

### **3.1.2 Classic distinctions between the genera: subtribes *Eubambuseae* and *Dendrocalameae***

The consequences of the poor availability of bamboo flowers for taxonomic investigations are nowhere more apparent than in the continued reliance upon the severely flawed classic separation of the genera *Dendrocalamus* and *Bambusa*.

These genera were placed in separate divisions of the *Bambusaceae* by Munro, (1868), with *Dendrocalamus* in the "berry-bearing bamboos" of *Bacciferae* Munro, while *Bambusa* was placed in *Bambuseae verae* Nees. This separation was maintained by Bentham, (1883), although he modified these two divisions into three subtribes, with *Bambusa* in his *Eubambuseae* and *Dendrocalamus* in his *Dendrocalameae*, the former having a thin pericarp, and the latter having a fleshy or crustaceous pericarp separable from the seed.

Neither Munro nor Bentham had examined a sufficiently wide range of species to make these distinctions, (Holtum, 1956a), both basing their investigations on *Dendrocalamus strictus*, a species in which Munro could not discern the location of the embryo as it has a rigid (though hardly fleshy or crustaceous) pericarp. Although this is the type species, this characteristic is atypical of the genus, most other species having clearly visible embryos. These subtribes were adopted by Gamble, (1896) and subsequent authorities, but rejected by Clayton and Renvoize, (1986).

Holtum later studied a wide range of Malaysian genera, (1956a), and found the use of fruit structure highly unsatisfactory for delineating subtribes. He found important differences in ovary characteristics, however, and proposed the replacement of Bentham's system with a system based on the structure of the ovary and the style. He could not find any consistent distinction between Malaysian representatives of *Bambusa* and *Dendrocalamus* in either fruit or ovary structure, and considered them to be

very closely related, a radical departure from the wide separation given to them by previous authorities. Grosse and Liese (1973) studying vascular bundle anatomy substantiated Holttum's findings, arriving at proposed groupings which agreed well with Holttum's own, *Bambusa* and *Dendrocalamus* again being placed together.

Clayton and Renvoize (1986) were the first authorities to reject Munro's system in a monographic work. They adopted a modification of Holttum's system, with the two genera together in the subtribe *Bambusinae*, attributed to Agardh, (1823). Soderstrom and Ellis, (1988) agreed with this arrangement in their review of the bamboo subtribes, which unfortunately marked the culmination of Soderstrom's career in bamboo taxonomy.

### 3.1.3 Modern distinctions between the genera

Having rejected the classic distinction taxonomists have fallen back upon inconsistent characters within the pseudospikelet to separate the genera. The most recent advances in bamboo taxonomy have been restricted to highly complex details of leaf anatomy as most herbarium collections consist largely of leaves.

Holttum (1956a) proposed the separation of *Dendrocalamus* from *Bambusa* on the basis of a feature of the inflorescence structure, its non-elongated and non-jointed rhachilla, a distinction which he used in his description of the Malaysian bamboos, (1958). McClure, (1966) used the same distinction for American species. This characteristic is rather subjective and unreliable in intermediate species. A progressive elongation occurs during development of the rhachilla, so that, in some species, samples collected at different stages of development can be identified as different genera.

Clayton and Renvoize (1986) followed this distinction adding the universal presence of 2-keeled uppermost paleas in the *Bambusa* inflorescence, and also the universal absence of lodicules in *Dendrocalamus*. The latter, however, does not hold true for Himalayan species.

Lin (1978) in the flora of Taiwan used the more accurate scarcity or absence of lodicules in *Dendrocalamus*. This feature had been noted in Gamble's description of the genus, although he did not use it in his keys (1896). Lin also used the short style with 3 stigmas in *Bambusa* contrasted with the longer style with a single feathery stigma found in *Dendrocalamus*. The single stigma may hold true for the three species in Taiwan, but that also is not consistent throughout the genus, *Dendrocalamus hamiltonii* and other species often having 1, 2, or 3 stigmas.

### **3.1.4 Difficulties arising from present distinctions**

The present distinctions between the two genera based upon rhachilla extension and disarticulation are not adequate for field recognition of the two genera from vegetative features, nor do they even allow accurate, precise, or consistent delimitation of the genera when floral material is available.

In addition a group of bamboos are intermediate in most of the distinguishing features making their classification highly subjective and their recognition extremely difficult. This group includes new Himalayan species which have yet to be assigned to genus. McClure recognised the occurrence of this group (1940) and proposed a new genus *Sinocalamus* to cover species with intermediate characteristics from China. He gradually came to reject this genus later, (1966), as he could not define it accurately.

When followed rigorously the present distinctions are not only ambiguous, they also conflict with the classic delineation which was probably based largely upon vegetative features because of the unworkable distinction in caryopses, which were largely unavailable anyway. Therefore following them requires new combinations, and also a change in the traditional concept of the genera in vegetative terms.

Soderstrom and Ellis, (1988), in their attempt to revise the family remarked upon the need for new characters to distinguish between these two genera more satisfactorily.

### **3.1.5 New characters of potential use at the generic level: inflorescence branching patterns, prophylls, and flowering mechanisms**

There is no accepted underlying evolutionary trend in bamboo inflorescence development upon which a natural taxonomy can be based. Inflorescence branching characters have not been investigated properly in the bamboos, although it is felt that they probably hold the greatest potential for rationalizing bamboo taxonomy.

As shown by Holttum, (1956a) classic characters such as fruit structure are largely unreliable, and new characteristics such as ovary structure, leaf structure, and vascular bundle anatomy, only seem to be useful at the subtribe level. Details of components of the florets are of great value at the specific level, but generalisations of these between the genera are not reliable. Therefore it was felt necessary to investigate the possibility of finding other features to delineate the boundary between the genera more satisfactorily if *Dendrocalamus* is to be upheld as a separate genus from *Bambusa*.

Inflorescence branching patterns have been widely used in the taxonomy of other grasses. However, understanding of the structure of the bamboo inflorescence has been less than satisfactory and its compressed nature in the *Bambusinae* has deterred close examination.

While the work of McClure, (1934, 1966), and others has greatly increased our knowledge of bamboo inflorescence structure, there is still no consensus of opinion upon the homologies between different bamboo inflorescences, nor between bamboo inflorescences and those of other grasses. This is not surprising given the reluctance of bamboos to flower and their relatively remote environments, but it is surprising that there is still little agreement upon the relationships between the inflorescences of grasses and those of other monocots, or even between monocots and dicots. Without such fundamental knowledge it is hard to see how any taxonomic system can claim to be natural.

Closely associated with the branching pattern in many bamboo inflorescences are prophylls and bracts with varying degrees of blade development. The homologies of these organs is as poorly understood as the branching patterns themselves. Consequently they have largely been ignored and when mentioned given ambiguous names or names which assume hypothetical and unproven homologies, especially within the floret.

The degree to which they are retained in bamboo genera varies greatly and is a valuable taxonomic tool, even when their origins remain obscure. A sound understanding of branching patterns probably depends upon a sound understanding of what these various bracts represent. Their interpretation has been moulded by preconceived relationships between axes upon which they are borne in the past, rather than using them to formulate the relationships in the first place.

It is suspected that further information on the relationships between these genera could also be found by studying their behaviour during flowering and fruit production. There are different mechanisms involved during anthesis, and this may also be the case with pollination and fertilisation.

Thus the areas of inflorescence branching, prophyll presence and nature, and flowering mechanisms all hold potential clues to the natural relationships between the species in these groups. Comparative studies to elucidate evolutionary trends within monocot, grass, and bamboo inflorescences, and detailed studies of inflorescence structure within all the bamboo families seem to be prerequisites of a sound taxonomic system. Flowering studies are of course greatly hindered by the reluctance of bamboos to flower, and comparative studies require much broader knowledge than has been acquired so far by either bamboo or grass experts.

In the short term it is felt that a good contribution can be made by detailed studies of the inflorescence branching patterns and the insertion of bracts, using descriptive terminology which avoids classifications based upon preconceived homologies.

### **3.1.6 Past studies on inflorescence branching in the *Bambusinae***

Detailed studies in the *Bambusinae* have concentrated upon inflorescences of *Bambusa* species, assuming that *Dendrocalamus* species will be the same. Variations in the nature of the prophylls do not seem to have been recorded.

McClure investigated the flowers of *Bambusa* species while in China but when writing up his theories, (1966), he described indeterminate (iterant) inflorescences on the basis of close examination of the only flowering specimens to hand in America, *Bambusa multiplex*, which is highly atypical of the genus, having a simple branching pattern. He then depicted a poor specimen of a pseudospikelet of *Dendrocalamus sikkimensis* crediting the prophyll with characteristics far from visible in the illustration, and which do not seem to hold true.

Holttum (1958) described the inflorescence of another species with a simple branching system, *Bambusa heterostachya*. Earlier (1956) he had declared that, "It would be almost impossible to observe accurately the complex series of branching in one of the very dense tufts of *Dendrocalamus* spikelets, but the essentials of the process are clear and I have tried to show them in a simplified diagram..", but the diagram is labelled *Bambusa*.

## **3.2 Investigations undertaken**

### **3.2.1 General objectives**

The objectives of the studies were to describe and compare the branching patterns and the characteristics of bracts and if possible to explain variation found in terms of bamboo inflorescence development patterns.

Accurate and unambiguous documentation of variation in branching patterns and bracts borne on the axes of the inflorescences required detailed dissections. As discreet differences between prophylls had been noted during casual inspections it was felt necessary to pursue these differences in terms of between species and within species variation despite the time-consuming nature of such work.

Because of the vacuum in understanding of relationships between different inflorescences, and between organs borne upon the axes of the inflorescences, it was also considered justifiable to analyse in sufficient depth to consider the functional significance of the variation found, in the hope of gleaning some insight into those relationships. While the evidence gained from an in depth study of a restricted range of species would be of little use on its own, it was hoped that it would be complemented by further studies of different genera at a later date.

### **3.3 Results**

#### **3.3.1 *Bambusa* sp. B21 Tharu bans (Kathmandu, Nepal)**

This bamboo was later identified as a new subspecies of *Bambusa tulda*, named subsp *tharu*. It is the commonest bamboo of the Kathmandu valley. The flowering material was collected from sporadically flowering culms at Bansbari, 5 km north of Kathmandu, 27 44'N 85 20'E. Stapleton 912 (E) represents this subspecies.

##### **3.3.1.1 Branching pattern**

A plan of the visible contents of a young inflorescence is given in fig 2 . This approximates to a cross-section through the contents of one bud such as those in fig 1 . Sheaths are depicted according to their dimensions near their bases as though they were all inserted at the same level. In this way extension of the bud contents and narrowing of sheaths above their bases

does not complicate the pattern, as would be the case in a true cross-section.

The bud scale is represented by the outermost encircling line. It has two keels which back onto the axis which bears it. These are depicted as two black triangles. This symbolism is repeated inside the bud scale, some sheaths having black triangles indicating keels. The insertion of a prominently keeled prophyll is taken to mark a point of branching. The orientation of the keels indicate which axis it has branched from. For ease of interpretation the sheaths accompanying the major higher orders of branching are depicted in fig 3. They are numbered acropetally along the axis upon which they are borne, so that 0,(1) is the first sheathing organ on axis 0 , etc.

The pattern of axes which is implied by the relative position of these sheaths is given in fig 4. Five orders of branching are present, typified by axis 0, axis 0,1, axis 0,1,1, axis 0,1,1,1, and axis 0,1,1,1,1. Axis 0 is borne at a node of the last axis which had fully extended internodes. In the two major lateral sections of the inflorescence borne on axes 0,1 and 0,2 the fifth order of branching, e.g. axis 0,1,1,1,1, represents the rhachilla, as do all higher orders represented at that time by partially differentiated primordial masses.

New axes are initially at right angles to their parent axes, becoming more variable at higher orders of branching. Insertion of successive branches on the same axis can be distichous and alternate or considerably trimerous.

### **3.3.1.2 Prophylls and adjacent bracts**

The first sheathing appendage on all axes is a prophyll. Bracts on particular axes were numbered sequentially, the first bract on the first axis, axis 0, being named 0,(1), etc. The first prophyll encountered, 0,(1), encloses the bud. This is depicted in fig 5 . Two strong ciliate keels are evident with well developed margins beyond the keels. The prophyll is asymmetrical with one margin larger than the other.

Following this on axis 0 is a symmetrical mucronate bract 0,(2) with no keel, terminating in a hard short point. Lying in the axil of the prophyll 0,(1) is a further prophyll, 0,1,(1). This is depicted in fig 6 . It is essentially the same as 0,(1). Following this on the axis 0,1 is a further mucronate bract, 0,1,(2). This differs slightly from 0,(2) in having a few ciliae on a short slightly keel-like structure half way up its back.

This pattern is repeated for three more orders, with little difference in the prophylls 0,1,1,(1), and 0,1,1,1,(1) while 0,1,1,1,1,(1) is probably a palea. Similarly the bracts following the prophylls 0,1,1,(2), 0,1,1,1,(2), and 0,1,1,1,1,(2) are essentially the same as 0,(2), without any further recurrence of partly keel-like structures. 0,1,1,1,1,(2) is probably a transitional glume in the basal region of the pseudospikelet.

### **3.3.1.3 Prophylls within the lateral pseudospikelet**

Dissection of mature inflorescences showed there to be prophyllate buds in the axils of the prophylls at the base of the pseudospikelet and the following one or two transitional glumes preceding the fertile lemmas. The prophylls enclosing these buds and the axes they represent were again two-keeled and identical to the prophylls seen at lower orders, enclosing further prophyllate buds and mucronate sheaths.

### **3.3.1.4 Summary**

The pattern and nature of branching and bracts followed the descriptions of McClure (1966) and Holtum (1958). All possible axes below the pseudospikelets were developed and all axes bore a two-keeled prophyll as the first sheathing organ. The second sheathing organ on all axes was symmetrical, and only rarely bore ciliae on a poorly defined keel, see fig 6.

### **3.3.2 Intermediate species *Bambusa balcooa* D23 (Tansen, West Nepal)**

This well known slightly thorny species is found throughout Nepal. The material collected for this study came from sporadically flowering culms on a clump in Tansen town (TWP guest house), in Palpa district of west Nepal, 27° 52'N 83° 33'E.

### **3.3.2.1 Inflorescence branching pattern**

A plan of the contents of a young inflorescence is given in fig 7 . To allow easier appreciation of the insertion and shape of the higher order sheaths, they are outlined in fig 8 , and the branching pattern is interpreted in fig 9 . Five orders of branching are discernible. There are no functional differences between this pattern and the pattern seen in B21.

### **3.3.2.2 Prophylls and adjacent bracts**

Bracts throughout the inflorescence are appreciably shorter in this species than in B21. This is associated with a reduction in rhachilla internode length, and together with shorter rhachillas, this results in a more compressed and congested inflorescence. As well as making dissection more difficult this leads to lateral pressures during development which cause longitudinal splitting of some bracts. This leads to the possibility of misinterpretation and necessitates careful dissection to the line of insertion to determine whether two apparently discreet consecutive bracts do indeed have separate origins.

The first prophyll encountered, prophyll 0,(1) is a case in point. Fig 10 shows a situation where the bud scale appears to be composed of two separate bracts. Fig 11 shows the next node where 0,(1) can be seen to be split almost to the line of insertion. Thus the prophyll 0,(1) is in fact very similar to its counterpart in B21.

At the next order of branching the prophylls start to differ. Bract 0,1,(1) lacks the second ciliate keel completely. 0,2,(1) is a 2-keeled bract. 0,3,(1) is a further bract with only one keel, see fig 12 . At higher orders the prophylls are all 2-keeled, identical to their counterparts in B21.

The bracts following the prophylls on the same axis follow a similar pattern to the prophylls. The first such bract 0,(2) which lies adjacent to the 2-keeled bract 0,(1) is similar to its B21 counterpart. At the next order there are differences accompanying the different forms of the prophylls. Bract 0,2,(2), which lies inside the clearly 2-keeled prophyll, 0,2,(1) is identical to its B21 counterpart. Bract 0,3,(2), however, which lies inside the single-keeled prophyll 0,3,(1) has a strong ciliate keel. These two bracts are depicted in fig 12 .

Such a combination of a single-keeled prophyll and a single-keeled following bract is never seen in B21. To compare the prophylls and following bracts in this species with those in B21 accurately it is necessary to reflect the cross-section, as in fig 13 for comparison with fig 3. It can also be seen from this comparison that the regular distichous insertion of sheaths and branches is not so clearly manifested in this species.

At higher orders the prophylls and following bracts were all identical to their counterparts in B21.

### **3.3.2.3 Prophylls within the pseudospikelet**

There were no differences between these and the prophylls in B21.

### **3.3.2.4 Summary**

The branching pattern was fundamentally identical to that seen in the previous *Bambusa* species B21. The prophylls and the following bracts were similar to those of B21 at the lowest and highest orders of branching. At one intermediate order of branching however, they were often radically different, both being asymmetrical, and both bearing a single ciliate keel, see fig 12.

### **3.3.3 D21 Intermediate species Tama bans (Kathmandu, Nepal)**

This bamboo was later described as a new species, *Bambusa nepalensis*. It is the second commonest bamboo in the Kathmandu valley. Material for this examination came from sporadically flowering culms on clumps in Bansbari, 5 km north of Kathmandu, 27° 44'N 85° 20'E. It is represented by Stapleton 719 and 920 (E.).

### **3.3.3.1 Inflorescence branching pattern**

The layout of bracts in a young cluster is depicted in fig 14 . This is simplified for comparison with figs 3 and 13 in fig 15 and interpreted in a functional branching pattern in fig 16 , which shows that there is no significant difference from B21 and D23.

### **3.3.3.2 Prophylls and adjacent bracts**

The first prophyll, 0,(1) is identical to its counterparts in B21 and D23. At the next two orders of branching prophylls 0,1,(1), 0,2,(1), 0,1,1,(1), etc are different from their counterparts in D23 in that they are consistent, each having only one well-defined keel, and also being narrower, so that they do not enclose their contents to the same degree. Thus the discrepancies found in D23 when comparing the prophylls to those of the classic *Bambusa* pattern are present to a more marked degree in this species.

At higher orders the prophylls are all two-keeled and do not differ from their counterparts in B21 or D23.

The nature of the bracts following the prophylls is more consistent. There are cases where the bract is paired with a prophyll, both having single ciliate keels, see fig 15 , but this is not generally the case, most bracts being non-keeled.

### **3.3.3.3 Prophylls in the pseudospikelet**

There are no differences between the prophylls in the pseudospikelets of this species and those of D23 or B21.

### 3.3.3.4 Summary

The branching pattern was fundamentally the same as that of the previous two species. The prophylls and following sheaths were again the same as those of the *Bambusa* species B21 at the lowest and highest orders of branching. At two intermediate orders of branching, however they consistently differed from the form described by McClure (1966) and Holttum (1958). At these orders of branching the prophylls were all single-keeled and some of the following bracts bore ciliate keels, see fig 17.

### 3.3.4 *Dendrocalamus hamiltonii* D4 Tama bans (Kathmandu, Nepal)

This well known species extends along most of the Himalayas, but is quite variable. The material examined here came from sporadically flowering culms on a clump of the type variety at Bansbari, 5 km north of Kathmandu, 27 44'N 85 20'E, from which seedlings were raised in Chalnakhel nursery, 15 km south of Kathmandu.

#### 3.3.4.1 Inflorescence branching pattern

The pattern of sheaths in this species is much more complicated. A section of a young inflorescence is portrayed in fig 18 . Understanding of even this small section first required a thorough consideration of the nature and relationships of the prophylls and associated bracts. Without the examination of intermediate species D21 and D23 it would have been extremely difficult to correlate the branching pattern with that of *Bambusa* species B21.

It was eventually realised that a fundamental difference in branching pattern was present in this species. Fig 19 is a simplification of this cross-section and fig 20 shows the corresponding branching pattern. There is a duplication of branching of the axis 0,1 without an intervening sheath. These two axes were given the names 0,1a and 0,1b. Axis 0,2 is also duplicated.

The stronger of these duplicated axes bears further duplication at a higher order, giving axes 0,1b,1a, 0,1b,1b, 0,2b,1a and 0,2b,1b.

Examination of further inflorescences from this plant showed that this duplication did not always take place, and also that axis 0,1a was sometimes represented by a thin ciliate strand as depicted in fig 21 .

Examination of young inflorescences from a gregariously flowering clumps of the same variety from the Teesta river 10 km north-east of Siliguri, West Bengal, India, showed the same pattern, with the duplication present to varying degrees in different inflorescences. Seedlings from this stand are in cultivation in Kew. A section of an inflorescence with duplication of only the second order of branching is shown in fig 22 . An inflorescence with no duplication except a rudiment of 0,1a is shown in fig 23 and simplified in fig 24 for comparison with figs 3, 13 and 15.

Where no duplication was present the branching pattern was again fundamentally the same as in the preceding species, B21, D21, and D23.

#### **3.3.4.2 Prophylls and adjacent bracts**

The prophylls were seen to be consistent at all orders, bearing only one ciliate keel, and being so narrow as to barely enclose half their contents.

Bracts following the prophylls on all axes were similar to the prophylls, all bearing a single ciliate keel, developed to varying degrees. These two adjacent narrow bracts together enclosing the axis are shown in fig 21.

One possible explanation of this pattern would be that a single bract has split under the lateral pressure exerted by the rapid ramification inside the bract. Material of a very similar bamboo, D46 from Shemgang in Eastern Bhutan, later identified as *Dendrocalamus hamiltonii* var *edulis* Munro, was collected and examined to gain insight into the effects of splitting. This species differed from *Dendrocalamus hamiltonii* from Kathmandu and Siliguri in having longer bracts throughout the inflorescence. This results in less lateral expansion and splitting so that it is easier to compare split and unsplit bracts. The universal presence of two single-keeled bracts was so

clearly apparent in this species that any doubts as to their nature in the type variety of *Dendrocalamus hamiltonii* were totally dispelled. *D hamiltonii* var *edulis* is represented by Grierson & Long 1344 (E.) as well as the more fragmentary type material from Sikkim at Kew.

This pattern is most evident in the first prophyll 0,(1), enclosing the whole inflorescence. At the back the two bracts may overlap for the entire distance between the keels. Where there is no overlap it is extremely difficult to ascertain the separate insertion of the two sheaths, giving an appearance similar to that in fig 10. However, the edges of the bracts were straight and membraneous, while in situations where there had been splitting the edges had been jagged and thick. In addition inspection of the sheaths immediately underneath the bud scale or scales shows that there is no following sheath 0,(2) separating it/them from the prophylls marking axes 0,1 and 0,2. Therefore 0,(2) must have been present as a single-keeled bract matching the single-keeled prophyll. The margin of bract 0,(2) plunges inside 0,1,(1), see figs 24 . If the edge of this bract was in fact the edge of 0,(1) it would pass over 0,1,(1) instead.

### **3.3.4.3. Prophylls in the pseudospikelet**

In the absence of mature flowers of the type variety of *Dendrocalamus hamiltonii* those of var *edulis* from Eastern Bhutan were examined. A specimen is portrayed in fig 25. As at lower orders of branching, the prophyll bears only one keel and the following bract often has a ciliate keel itself.

### **3.3.4.4 Summary**

The prophylls and following sheaths were consistently different to those of the *Bambusa* species B21 at all orders of branching, both being narrow structures bearing a single ciliate keel, see fig 21.

The branching pattern was fundamentally different to the patterns seen before. The lowest orders of branching were often duplicated, two branches being inserted in the axil of a single prophyll. In addition, at the highest orders of branching within the pseudospikelets a further axis was present, borne in the axil of the prophyll basal to each pseudospikelet.

### 3.3.5 Further *Dendrocalamus* species in Kew herbarium

Examination of material at Kew revealed single-keeled prophylls throughout the inflorescences of 13 *Dendrocalamus* species with good floral material, see table 1. Two-keeled prophylls were never seen. Flowers of one species, *D colletianus*, were inadequate for a proper examination.

### 3.3.6 Further *Bambusa* species in Kew herbarium

Inspection of the *Bambusa* material showed that all species with reliable floral material except *B. copelandii* had two-keeled prophylls enclosing the inflorescence buds. Five species had more compressed inflorescences which would disqualify them from *Bambusa* by present criteria : *B. binghami*, *kingiana*, and *copelandii* from the Indian subcontinent; and *B. beechyana* and *oldhami* from China. Of these the latter three had been placed in the genus proposed for intermediate species, *Sinocalamus*. *B. binghami* and *oldhami* had two-keeled prophylls at all orders of branching while *B. kingiana* had single-keeled prophylls at intermediate orders, and *Bambusa copelandii* had single-keeled prophylls throughout. It was not possible to inspect *B. beechyana* thoroughly but bud scales were two-keeled. *B. affinis* did not have enough suitable material for examination, while the collections for *B. khasiana* and *B. vulgaris* were too confused.

Thus from material available it seems that only three species at present in *Bambusa* have any single-keeled prophylls in their inflorescences. These are *B. balcooa*, *B. copelandii*, and *B. kingiana*. None of these satisfy the current interpretation of *Bambusa* species as those having elongated disarticulating rhachilla sections.

### 3.3.7 Further genera

Superficial examination of other genera in the *Bambusinae* at Kew indicated that single-keeled prophylls were also found in the compressed

inflorescences of Asian representatives of *Oxytenanthera*, (which are now commonly combined with *Dendrocalamus*), and in *Gigantochloa*, while the genus *Melocalamus* had two-keeled prophylls throughout its highly compressed inflorescences.

In the *Melocanninae*, *Cephalostachyum* and *Melocanna* had some single-keeled prophylls while *Schizostachyum*, *Teinostachyum*, *Pseudostachyum* and *Thyrsostachys* seemed to have two-keeled prophylls throughout their inflorescences.

Thus the characteristics of prophylls may also be of use in distinguishing between other genera with iterant inflorescences.

prophylls single-keeled throughout inflorescence	single-keeled and twin-keeled prophylls	prophylls apparently all two-keeled
<i>D. strictus</i>	<i>B. balcoa</i>	<i>B. tulda</i>
<i>D. sericeus</i>	<i>B. kingiana</i>	<i>B. nutans</i>
<i>D. membranaceous</i>		<i>B. teres</i>
<i>D. sikkimensis</i>		<i>B. burmanica</i>
<i>D. hookeri</i>		<i>B. polymorpha</i>
<i>D. hamiltonii</i>		<i>B. pallida</i>
<i>D. giganteus</i>		<i>B. affinis?</i>
<i>D. calostachys</i>		<i>B. khasiana?</i>
<i>D. latiflorus</i>		<i>B. glaucescens</i>
<i>D. longispathus</i>		<i>B. vulgaris?</i>
<i>D. brandisii</i>		<i>B. oliveriana</i>
<i>D. longifimbriatus</i>		<i>B. binghami</i>
<i>D. parishii</i>		<i>B. lineata</i>
		<i>B. schizostachyoides</i>
		<i>B. griffithiana</i>
<i>B. copelandii</i>		<i>B. arundinacea</i>
		<i>B. longispiculata</i>
		<i>B. oldhami</i>
<i>Sinocalamus latiflorus</i>		<i>Sinocalamus oldhami</i>
<i>Sinocalamus copelandii</i>		<i>Sinocalamus beechyana</i>

**table 1 Keeling of prophylls in a wide range of *Dendrocalamus*, *Bambusa*, and *Sinocalamus* species.**

### **3.4 Summary of results**

#### **3.4.1 Comparison of the four species studied in depth**

##### **3.4.1.1 Branching pattern**

The fundamental branching pattern did not vary consistently between the species. This shows how closely related they are. *Dendrocalamus hamiltonii* sporadically duplicated part of the pattern with double insertion of major axes at nodes of the rhachis without intervening sheaths, showing an apparently aberrant branching pattern which was clearly distinguishable from the pattern seen in the other species. A wider range of *Dendrocalamus* species would have to be examined in detail before any conclusions could be drawn concerning the taxonomic value of this phenomenon. Its sporadic nature suggests that it may not be of much use, however.

The insertion of successive branches and orders of branches in the inflorescences showed a largely distichous pattern in B21, with successive orders of branching approximately at right angles to each other. There was less regularity in the intermediate species, D21 and D23, and least regularity of all in D4, *Dendrocalamus hamiltonii*, in which the large number of branches are forced into a much more convoluted, though consistent, pattern.

##### **3.4.1.2 Prophylls and following bracts**

A progressive alteration in the shape and ornamentation of the prophylls and the following bracts was seen in the four species sampled. Different progressive alteration patterns were discernible at three different levels of branching. This is summarised in table 2, and detailed below.

###### **3.4.1.2.1 First-order of branching (bud scales)**

In *Bambusa* species B21 the prophyll at the first order of branching, 0,(1), completely encloses the bud and has two strongly developed ciliate

keels. The following bract 0,(2) completely encloses its contents at the base and does not have a ciliate keel. This is the standard pattern as described by McClure, (1966).

In the two intermediate species D21 and D23 the prophyll 0,(1) is fundamentally the same although a little shorter and less ciliate. The following bract 0,(2) is similar to its B21 counterpart in that it does not have a ciliate keel, but differs slightly in that it does not completely enclose its contents at the base.

At the first order of branching in *Dendrocalamus hamiltonii* D4, however, it appears that the prophyll, 0,(1) has only one keel and encloses only half the bud. It also appears that the following bract 0,(2) matches the prophyll almost exactly, having a strongly ciliate keel, and enclosing the other half. Thus there is a discreet difference between the first order prophylls and following sheaths of *Dendrocalamus hamiltonii* and the other three species.

#### **3.4.1.2.2 Intermediate orders of branching**

The second order of branching shows the best progressive change in the nature of the prophylls and the following bracts. In *Bambusa* species B21 we see two-keeled prophylls 0,1,(1) and 0,2,(1), with non-ciliate following bracts completely enclosing their contents. In the intermediate species D23 and D21 we normally see single-keeled prophylls 0,1,(1) and 0,2,(1) with following bracts with non-ciliate keels which do not enclose their contents. In *Dendrocalamus hamiltonii* the prophylls and following bracts are all single-keeled and ciliate.

#### **3.4.1.2.3 Prophylls basal to the lateral pseudospikelets**

McClure (1966) contrasted the terminal pseudospikelet with lateral pseudospikelets, pointing out the different location of the prophyll, and

taking the lateral pseudospikelet as being predominant and a more characteristic manifestation of the iterant process.

Therefore descriptions of pseudospikelets here apply to lateral pseudospikelets which have their origins in other pseudospikelets, rather than as lower orders of branching in the inflorescence. His distinction is rather simplistic as there is no clear distinction, the prophyll basal to the pseudospikelet merely becoming further away with lower orders of branching.

The prophylls basal to the pseudospikelets at the highest orders of branching followed the pattern seen in the first order prophylls. All those in *Dendrocalamus hamiltonii* were single-keeled, followed by a single-keeled bract, while all those in the other three species were two-keeled followed by a non-keeled bract.

#### **3.4.1.2.4 Paleae**

All paleae which backed onto an axis of appreciable size had two keels. As Holttum, (1956a), pointed out, the presence or absence of a terminal rudiment in the pseudospikelet influences the nature of keels at the apex of the pseudospikelet. Therefore discrepancies between species at this point were not taken into account.

#### **3.4.2 Further species**

The distinction between species with single-keeled and those with twin-keeled prophylls matched the present classification into *Dendrocalamus* and *Bambusa* species almost exactly.

A brief examination of all the *Dendrocalamus* and *Bambusa* species at Kew showed that nearly all of them fell quite clearly into the patterns described for *Bambusa* species B21 and *Dendrocalamus hamiltonii* D4, see table 1.

Of those species which had intermediate inflorescences which could be interpreted as either *Dendrocalamus* or *Bambusa* on the basis of rhachilla extension, only *Bambusa kingiana* seemed to have single-keeled prophylls at intermediate orders of branching. The others seemed to have twin-keeled prophylls throughout, but this could not be conclusively ascertained without undue damage to the specimens.

The representatives of *Sinocalamus* McClure spanned the division, two members having single-keeled prophylls throughout and two members having twin-keeled prophylls.

### **3.5 Discussion**

#### **3.5.1 Implications for delineation of the genera *Dendrocalamus* and *Bambusa***

##### **3.5.1.1 Branching pattern**

As the fundamental pattern is the same there seems little scope for it being used to delineate the genera, although the duplication of axes in *Dendrocalamus hamiltonii* could be more promising if it occurs in more species.

The larger number of branch axes in *Dendrocalamus hamiltonii* might be of use, were it not for the difficulty of quantifying it consistently.

##### **3.5.1.2 Nature of the prophylls**

The occurrence of single-keeled as opposed to double-keeled prophylls gives a clear and finite distinction. This is more precise than the relative and variable characters: rhachilla internode length, and readiness of disarticulation of separate florets. As the possession of single-keeled prophylls varies within some species at different orders of branching, there is potential for some flexibility in where the genera are delimited.

Table 2 shows the variation in prophyll keeling at different orders of branching in these four species. From the table it appears that the genera could be defined in two ways, uniting the intermediate species with either *Dendrocalamus* or *Bambusa*.

Emulating the present distinction based upon rhachilla extension and disarticulation would result in the line being drawn somewhere between D23 and B21, i.e. combining intermediate species with *Dendrocalamus*. This definition would be very hard to interpret in terms of prophyll characteristics. It also does not reflect the present position of several species, which have non-elongated rhachilla internodes but are still found in *Bambusa*. A definition based upon prophyll details to correspond to the rhachilla distinction would be:-

1	Prophylls with 1 keel present in the inflorescence	<i>Dendrocalamus</i>
1a	Prophylls with 2 keels throughout the inflorescence	<i>Bambusa</i>

As one-keeled prophylls are found at obscure intermediate orders of branching in inflorescences which which are otherwise two-keeled, to ascertain the correct identification of a species would require thorough dissection of several samples, which necessitates both access to ample material and considerable understanding of iteraxant inflorescences.

The alternative would be to include all the intermediate species in *Bambusa*. This retains the status of those intermediate species, but necessitates the rejection of rhachilla features as definitive tools. The thorough definition would then be:-

1	Prophylls with 2 keels present in inflorescence	<i>Bambusa</i>
1a	Prophylls with 1 keel throughout inflorescence	<i>Dendrocalamus</i>

The investigations undertaken indicate that it is not necessary in this case to ascertain details of prophylls at intermediate orders of branching. All inflorescences with two-keeled prophylls present anywhere had two-keeled prophylls enclosing the inflorescence as bud-scales. Therefore examination of the bud-enclosing prophyll alone is sufficient:-

1 Single two-keeled bract enclosing the inflorescence bud *Bambusa*

1a Inflorescence bud enclosed by 2 single-keeled bracts *Dendrocalamus*

With reasonable material to hand, this distinction is by far the easiest to use, and when a flowering clump is encountered in the field it is very easy to quickly inspect the back of a few inflorescences without even removing them. With poor quality older deteriorating material it is not so easy, however. As material ages, successive orders of pseudospikelets fall off, and the prophylls basal to them are visible, although this requires a hand lens or microscope.

It is also possible to distinguish between the same two clearly separated groups using the number of keels on such prophylls basal to the pseudospikelets, strengthening the case for drawing the dividing line to include intermediate species in *Bambusa*. All inflorescences studied which had two-keeled prophylls enclosing the inflorescence bud also had these at the base of lateral pseudospikelets. Therefore examination of these alone would also be sufficient:-

1 Buds at base of pseudospikelet enclosed by single-keeled prophylls *Dendrocalamus*

1a Buds at base of pseudospikelet enclosed by two-keeled prophylls *Bambusa*

Therefore it seems more appropriate from the full range of species at Kew that the intermediate species are put into *Bambusa*, and that only

prophylls	B21	D23	D21	D4
bud enclosing bract 0, (1)	2	2	2	1
major branches 0,1,(1) 0,2,(1) 0,3,(1)	2	1 or 2	1	1
minor branches 0,1,1,1,(1) etc	2	2	2	1
basal buds in lateral pseudospikelet	2	2	2	1

**table 2** Number of keels on prophylls at different orders of branching of inflorescences for the four different species

	B21	D23	D21	D4
diameter of central mid-culm branches cm	<3	<8	<8	<8
culm wax	absent	dense	dense	v.dense
culm sheath auricles	v.large	absent	small	small
leaf size cm	<30	<50	50	<50
aerial rooting	rare	common	common	prolific
wall thickness cm	<2.5	<2.5 <2	<2	
basal branching	dense	dense	absent	variable

**table 3** Vegetative characteristics of the four species

those species with single-keeled prophylls at all orders of branching are included in *Dendrocalamus*.

### 3.5.1.3. Agreement between floral and vegetative characteristics

Table 3 compares several important vegetative characteristics in the four species. It is apparent from the table that the intermediate species have vegetative characteristics in common with both *Dendrocalamus* species D4 and *Bambusa* species B21.

There are several vegetative characteristics in which considerable variation is found in these two genera. It does not seem possible to distinguish between them consistently using a suite of characters, but a largely subjective boundary has become accepted by bamboo taxonomists. As *Bambusa* was the first of the two genera to be described the general process over the last century and a half has been to remove those species with definite affinities to *Dendrocalamus* from *Bambusa*. This has left intermediate species in the latter genus, and has engendered a broader concept of *Bambusa* than *Dendrocalamus* from vegetative features.

The need for good agreement between floral distinctions between the genera, and currently accepted vegetative distinctions supports the inclusion of intermediate species in *Bambusa*. To that end rhachilla extension is not an ideal characteristic for distinguishing between the genera, while the number of keels on the bud-enclosing prophyll of the inflorescence does allow a close agreement between accepted vegetative and floral distinctions.

The absence of a consistently definable suite of vegetative characters distinguishing these two genera could be considered sufficient grounds for merging the two genera. However, having two genera serves a useful function in the identification of all but a small number of intermediate species, and allows generalisations to be made concerning the management and propagation of these two groups of bamboos, which have markedly different uses, site requirements, pests, propagation techniques, and possibly also different flowering mechanisms.

It was hoped that the nature of the floral prophylls would be paralleled in their vegetative counterparts, the bud enclosing bracts on leaf-bearing axes. This would have given further useful distinctions in vegetative as well as floral morphology. Unfortunately this is not the case. All vegetative bud scales examined from the four species were similar to the *Bambusa* pattern prophyll, all being broad with two keels and margins fused together at the front. The long dormancy of many such buds and the relatively demanding subtropical conditions could preclude any reduction of the prophyll. Prophylls from higher orders of branching within the bud were scarce and extremely small. They also had two keels.

### 3.5.2 Implications for related genera

The similarity of the prophylls in *Gigantochloa* and Asian *Oxytenanthera* species to those in *Dendrocalamus* supports the contention that they should be merged with *Dendrocalamus*. On the other hand they still have either a different spikelet termination or connate filaments and so can be separated satisfactorily. As they do not extend into the Himalayas they are not considered further.

The genera *Cephalostachyum*, *Teinostachyum*, *Schizostachyum*, and *Pseudostachyum* in the *Melocanninae* have been upheld as different genera, (Dransfield, 1980), or combined under *Schizostachyum*, (Clayton & Renvoize, 1986). Brief inspection of some representatives has shown that both single-keeled and two-keeled prophylls can be found in their inflorescences. If a wider range of young flowering material were available it might be possible to shed some further light upon these genera through similar investigations to those described here.

In genera of the *Thamnocalaminae* distinctions between prophyll keeling are observable in vegetative growth, allowing easier examination of a wider range of material and simplifying field identification.

### 3.6 Conclusions

Examination of four species in depth and a brief inspection of a further thirty four species has shown that even though the classic distinction made by Munro (1868) has been totally rejected it is still possible to distinguish between the two genera *Bambusa* and *Dendrocalamus*.

The criteria for separating *Dendrocalamus* species from *Bambusa* species proposed by Holttum, (1958), and adopted by McClure,(1966) and Clayton & Renvoize, (1986) are difficult to apply consistently and objectively. They also conflict with the present position of several intermediate species, and their adoption requires the transfer of all such species from *Bambusa* into *Dendrocalamus*.

A distinction based upon the numbers of keels on the prophylls enclosing the inflorescences is much more objective and requires only one new combination. It is therefore proposed that the following distinction is used in the separation of the genera on a floral basis:-

- |    |  |                            |
|----|--|----------------------------|
| 1  | Single two-keeled prophyll enclosing the inflorescence bud | ..... <i>Bambusa</i>       |
| 1a | Inflorescence bud enclosed by two single-keeled bracts     | ..... <i>Dendrocalamus</i> |

If the prophyll surrounding the inflorescence is not available for inspection, while older pseudospikelets are available, the buds at the base of the pseudospikelet can also be used for identification, those of *Dendrocalamus* species being enclosed by prophylls with one keel, while those of *Bambusa* species are enclosed by prophylls with two keels.

The only new combination required to allow all species from the Indian subcontinent held at Kew to fit into this classification would be *Dendrocalamus copelandii* transferred from *Bambusa copelandii* Gamble (*Sinocalamus copelandii* (Gamble) Raizada).

Although the absence of clear-cut vegetative distinctions between these two genera makes it possible to make out a case for merging them, retaining the separate genera is felt to be of great value in the practical applications of identification and management. It is possible to separate the genera on a combination of several vegetative characters, and now that an objective and quantifiable criterion exists for distinguishing between the flowers of the two genera, the case for maintaining them is considerably strengthened. The morphological gap between the genera is small, but *Bambusa* is a large genus, so that a small gap would be expected, (Davis & Heywood, 1963).

### 3.7 Summary

Despite recent reorganisations of the bamboo subtribes which reject the classic distinction between these two genera and recognise their close similarities, the adopted criteria for their separation remain subjective and imprecise with poor correlation between floral and vegetative features.

The young inflorescences of four species representing the full range of variation were analysed to compare branching patterns and prophyll structures. *Dendrocalamus hamiltonii* was seen to have single-keeled prophylls throughout the inflorescence, while a *Bambusa* species had twin-keeled prophylls throughout. The other two species had both single-keeled and twin-keeled prophylls at different orders of branching.

All the species of *Bambusa* and *Dendrocalamus* at Kew were inspected to broaden the relevance of the studies. It was found that the use of a simple and precise criterion, the number of keels on the prophyll enclosing the inflorescence, allowed an accurate distinction between the genera which correlated well with the existing assignment of species to genus.

It is suggested that the genera *Bambusa* and *Dendrocalamus* should be separated in terms of prophyll details, rather than by using rhachilla extension and disarticulation.

#### **4. Subtribe *Thamnocalaminae* Keng : vegetative branching patterns and prophylls in the delineation of the Himalayan genera**

##### **4.1 Introduction**

###### **4.1.1 The scope of the subtribe**

The subtribe is concentrated in the Himalayas and SW China, but a few species are found in Africa and Indo-China. The boundaries of the subtribe are not clearly defined, and it is interpreted here in a broad sense. Most genera have 3 stamens, semelauctant inflorescences which are not capable of further development from basal buds, and pachymorph rhizomes in which all axes turn upwards to become aerial culms. They constitute an interesting bridge between the tropical bamboos with their simple morphology, and more advanced grass-like bamboos and true grasses. Keng separated out genera with large numbers of branches, such as the South American genus *Chusquea*, and the Himalayan genus *Drepanostachyum*, placing them in the subtribe *Chusqueinae*.

All but one of the smaller stature bamboo genera in the Himalayas are in this subtribe, with habitats ranging from subtropical to sub-alpine. Although they are not economically as important as the large tropical bamboos which provide building materials and industrial products such as pulp and canned shoots, they are important in montane rural economies, and in the ecology of the temperate forests. They are also planted as ornamentals in Europe and the USA.

Many genera have been proposed within the subtribe, but there is no consensus as to which should be recognised, and different taxonomists have recognized from two to eight genera. Distinguishing between these genera in the field is almost impossible, and different taxonomists have interpreted them in different ways.

#### **4.1.2 Evolution and taxonomy within the bamboos**

Several commentators on the bamboos have pointed out that there is insufficient fundamental knowledge of bamboo morphology for accurate delimitation of genera, eg McClure, (1973), Soderstrom & Calderón, (1979), Calderón & Soderstrom, (1980). There are different theories concerning the relationships between different bamboo inflorescences, and between those of bamboos and other grasses. This makes it difficult to set up evolutionary trends on which to base a natural taxonomic system. These theories are impossible to resolve until paths of evolution within the monocots as a whole have been established. At the moment there is not even a consensus of opinion on evolution within the angiosperms, the Magnoliifloran or Ranalean theory conflicting with the theory of Burger, which puts early monocots as the ancestral angiosperms, (Dahlgren, Clifford, & Yeo, 1985).

The irregular flowering of bamboos compounds this difficulty and, along with the scarcity of taxonomically useful floral features, leads to a need to emphasise vegetative features a little more strongly, even if only to assist identification in the field. Taking a pragmatic approach it seems sensible to use whatever characters seem of use at the generic level, rather than placing absolute faith in a few potentially flawed assumptions about the evolution of inflorescences.

#### **4.2 The principal genera**

Among the many genera proposed several are important because they have chronological precedence or have become recognised by several authorities. These genera were usually not all that well described when first published, because of insufficient knowledge or understanding at the time, so that it is quite difficult to define their boundaries accurately. The importance of some of them lies to a certain extent in the type species and the publication date as much as the diagnosis or description originally given.

#### 4.2.1 *Arundinaria* Michaux

All small bamboos were initially placed in *Arundinaria*. It has since been realised that this genus should contain only those species with leptomorph rhizomes, (in which the rhizomes usually continue underground indefinitely sending branches upwards as aerial culms). The type species is North American, and although over 450 binomials have been published, some authorities consider it to be a monotypic genus.

#### 4.2.2 *Thamnocalamus* Munro

Munro proposed the new genus *Thamnocalamus* for two temperate Himalayan species *Thamnocalamus spathiflorus* and *T falconeri* in 1868. This differed from *Arundinaria* in having large spathes around the inflorescences, and distinct bracts at the points of branching within the inflorescence. This genus was recombined with *Arundinaria* by several authorities until it became clear that its rhizomes were substantially different.

#### 4.2.3 *Fargesia* Franchet

Farges found another species with spathes around the flowers in China, and Franchet later named it *Fargesia spathacea*, (1893), apparently unaware of Munro's *Thamnocalamus spathiflorus*. He also noted a somewhat unilateral disposition of the spikelets in the inflorescence. This genus has often been combined with *Thamnocalamus*, on the grounds that they both have compressed inflorescences enclosed by spathes.

#### 4.2.4 *Sinarundinaria* Nakai

Nakai proposed *Sinarundinaria* in 1935 for the type species *Arundinaria nitida* Mitford, and also *A. murielae* Gamble, realising that these species differed substantially from *Arundinaria*, but he did not know the plants well and mistakenly described them as being monopodial, assuming that they had leptomorph rhizomes. Chao, Chu & Hsiung, (1981) pointed out

that Nakai had been mistaken about the rhizomes, which are not leptomorph at all, but pachymorph.

According to Keng, (1987), the generic description was insufficient, without proper details of the reproductive characters. Nevertheless this genus has been widely recognised in the west, and also sometimes in China, because it fills a gap for those bamboos with inflorescences which are open with long pedicels, not compressed inside prominent spathes as in the other recognised pachymorph genus *Thamnocalamus*.

The problem here is that one of the two species included by Nakai when he first described his genus, *S murielae*, has compressed inflorescences and has consequently been transferred to *Thamnocalamus* as a synonym of *T spathaceus* (Franchet) Soderstrom, (1979). The type species of *Sinarundinaria*, *S nitida*, is very similar indeed to *S murielae*, and presumably also has compressed inflorescences. Therefore it is strange for this generic name to be in use for a group of bamboos which are defined essentially by having open rather than compressed inflorescences.

If *S murielae* is very similar to or synonymous with *Fargesia spathacea*, which is the type species of *Fargesia* Franchet, then *Sinarundinaria* should be treated in the first case as a synonym of *Fargesia*. If in addition *Fargesia* is treated as synonymous with *Thamnocalamus*, because the compression of inflorescences is the only characteristic considered important, then *Sinarundinaria* would also have to be considered synonymous with *Thamnocalamus*. That would leave no genus for those subtropical and temperate bamboos with open inflorescences. Either way it does not seem possible to justify *Sinarundinaria* as a separate genus with *S nitida* as its type species.

#### **4.2.5 *Yushania* Keng f.**

Keng proposed *Yushania* in 1957, realising that the temperate bamboos with pachymorph rhizomes could be divided into those with short rhizomes which grew in clumps and those with long rhizomes which spread widely. The latter did not fit into any of the above genera, which either had long running leptomorph rhizomes, or short pachymorph rhizomes. He based the genus on the Taiwan species *Y niitakayamensis*.

This genus has also been considered part of *Sinarundinaria* by western taxonomists and some taxonomists in China, as the inflorescences are open, the spikelets having long pedicels.

#### **4.2.6 *Drepanostachyum* Keng f**

Keng established this genus in 1983, for pachymorph clump-forming bamboos similar to those in *Thamnocalamus*, but having open rather than compressed inflorescences. As Franchet before him in his description of the genus *Fargesia* he noted a partially unilateral nature to the inflorescences, which causes them to curve, hence the name. As pointed out by Chao, Chu, and Hsiung, (1981) however such unilateral appearance can be caused by the restriction of growth within a spathe rather than any truly secund nature.

This genus has also been included in *Sinarundinaria* by many western authors, presumably on the grounds that its inflorescences are open, not compressed.

#### **4.2.7 Summary**

In summary, the temperate pachymorph bamboos can be divided up according to the compression of the inflorescences, the presence of bracts at inflorescence branching, and the length of the rhizomes, but only the first characteristic has been used by western taxonomists, and they have neither defined nor produced an acceptable name for the genus which contains those bamboos with open inflorescences. In addition fertile herbarium specimens usually have no rhizomes, so that although the importance of rhizomes has been appreciated, it has not been possible to correlate inflorescence and rhizome characters.

### 4.3 New characters of taxonomic value at the generic level:

#### 4.3.1 The importance of branching patterns and prophylls

Traditional taxonomy has always concentrated upon reproductive characters. Characteristics of inflorescence branching are widely used to distinguish genera in other tribes of the *Gramineae*. Characteristics of vegetative branching have rarely been used however, because, unlike the bamboos, very few grasses in other tribes have well developed branches. Davis & Heywood included branching in their list of neglected morphological characters, (1963).

The parallels between vegetative and floral branching have often been espoused in the bamboos, (eg Holttum, 1956a). Although there are few detailed studies to back this up, it seems a logical concept, and worth pursuing, given the great variation in vegetative branching in the bamboos, and the lack of flowering material for identification.

Vegetative branching patterns do not seem to have been studied in any detail until Usui investigated them in the Japanese genera, (1957). McClure (1966) followed up on this adding illustrations of further Asian genera. He tried to analyse the processes involved in the production of different forms of branch complement, and established some basic terminology, which he was to start to refine later after studying South American bamboos, but his death interrupted this work, and some of his illustrations of branching are still clearly inaccurate. More recent studies, (Hsiung et al 1987, Usui 1987) have not been sufficiently comprehensive to show generic distinctions, and have not touched the subtribe *Thamnocalaminae* at all.

Branching in bamboos is often accompanied and detectable at an early stage by the presence of morphologically distinct prophylls. Although McClure pioneered the study of prophylls in floral branching patterns he did not pay much attention to vegetative prophylls, except when they covered buds. The potential value of variation in the characteristics of prophylls at the points of inflorescence branching has been shown in the *Bambusinae* (see section 3 page 24), where *Dendrocalamus* can be separated from

*Bambusa* by the presence of single-keeled rather than 2-keeled prophylls. However, the prophylls and branching patterns were too similar to be of diagnostic value during vegetative growth .

Within the subtribe *Thamnocalaminae*, however, the variation in vegetative branching and prophyll characteristics is much greater than in the *Bambusinae*. Using this variation it is possible to distinguish several different groups of bamboos which correspond well to most of the genera proposed.

#### **4.4 The foundations of branching systems**

##### **4.4.1 Background**

Floral diagrams have long been used to portray reproductive branching systems by the spatial relationships of the components. Arber compared bamboo flowers to those of other grasses using such diagrams, (1934). Vegetative branch buds in the bamboos have also been portrayed in this pseudo-cross-sectional manner, and branching systems extrapolated from them, (eg Usui, 1957), but comparisons have been hindered by the lack of an understanding of the fundamental units, and by the lack of a nomenclatural system to describe them unambiguously.

Studies on the floral anatomy in the Himalayan *Bambusinae* have allowed the development of a nomenclatural system for naming all the axes and sheaths even in a highly complex iteraxillary floral branching system, (see section 3 page 24), and such in-depth studies have allowed a clearer view of the fundamental units, the significance of their spatial relationships, and how different patterns relate to each other. This understanding can be transferred directly from inflorescence branching in the *Bambusinae* to vegetative branching in the *Thamnocalaminae*.

##### **4.4.2 Basic components of bamboo architecture**

Diagrams and descriptions of branching in the bamboos have usually relied upon preconceived ideas for their interpretation, and this has caused

problems when comparing different patterns. However, it is possible to break the bamboo structures down into the most basic units, and to describe them in a simple manner to allow accurate comparisons which are not coloured by too much interpretation. For example terms such as prophyll mean different things to different people and have to be treated very carefully. The first sheath on an axis is a much more accurate way of describing a structure.

One basic unit of any axis in the bamboos consists essentially of a node bearing a sheath and a meristematic region which produces the internode by intercalary growth. Successive sheaths are alternate and distichous, distal sheaths being located inside proximal sheaths until intercalary growth separates them, see fig 26 . Successive sheaths can be numbered, so that an axis called axis 0, has sheaths 0,(1) 0,(2) 0,(3) etc along the axis and inside each other in the bud.

The meristematic regions also give rise to branch axes in the axils of the sheaths which subtend them, and other structures such as roots. The branch axes are more or less perpendicular to their mother axis, and like the sheaths, are alternate and distichous. Branching leads to different blocks of sheaths within the bud. The successive axes can be numbered according to which sheath they are axillary to, so that the axis arising from a bud in the axil of sheath 0,(2) can be called axis 0,2 and the first sheath on it can be called 0,2,(1), see fig 27 .

Using this terminology the term prophyll is restricted to the first sheath on any axis, such as 0,(1) on axis 0 or 0,2,(1) on axis 0,2 . Blocks representing branch axes are often rectangular with rounded corners. Branching of new axes causes new blocks to lie in different orientations. In addition the rounded corners leave gaps. These gaps are usually filled by thickenings on adjacent sheaths on the new axis, presumably to prevent passage of pathogenic agents. In this way the first sheath on the axis will have two keels if it is wide. If it is narrow it will have one sheath, and the second gap will be filled by a thickening on the second sheath.

In this way sheaths associated with branching can be recognised not only by their orientation, but also by thickenings, which are often ciliate, known as keels. When the sheaths are wide they can fill two gaps by having two keels. When they are narrow two successive sheaths have a single keel,

fig 28 . Alterations to the basic pattern can occur through replication, reduction, or through fusion of originally separate parts. The greatest alteration occurs in the outermost sheaths, which can develop in many ways into structures which protect their contents better, and are best known as bud scales.

In the Himalayan *Thamnocalaminae* all branching structures can be broken down into these units. Processes such as reduction, replication, and fusion can be witnessed. There is considerable room for speculation as to how the different structures have developed, and thus how closely different groups of bamboos are related. What is more important is that it is also clearly possible to define different groups of bamboos which share certain features in their branching patterns and prophylls, and to put this into use for field recognition.

#### **4.5 Results: Analysis of vegetative branching in representatives of the Himalayan genera**

##### **4.5.1 Material examined**

Because of the present confusion concerning the characteristics of the genera in the *Thamnocalaminae*, and the uncertain generic affinities of many Himalayan species, it was necessary to start with a partially subjective impression of different groups of species, according to their natural habitats and growth habits as shown in table 4 , and to begin by examining the branching in representatives of these groups. It was possible to relate these groups to the published genera at a later stage, by investigating the type species of each genus.

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clump-forming running		
<b>temperate</b>	<b>Group 1</b>	<b>Group 2</b>
<b>(tessellate)</b>	<i>Thamnocalamus</i> <i>Fargesia</i>	<i>Sinarundinaria</i> <i>Yushania</i>
<b>subtropical</b>	<b>Group 3</b>	<b>Group 4</b>
<b>(non-tessellate)</b>	<i>Drepanostachyum</i> <i>Himalayacalamus</i> <i>Ampelocalamus</i>	<i>Neomicrocalamus</i>

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**table 4 Four groups of bamboos within the *Thamnocalaminae* and generic names associated with them**

#### 4.5.2 Group 1 Temperate clump-forming (short-necked pachymorph) species

##### 4.5.2.1 T44 *Thamnocalamus aristatus* (Gamble) Camus

This species has compressed inflorescences which do not extend far beyond the sheaths which subtend them. The ultimate branches of the inflorescences are usually also subtended by well developed sheaths, and there are prominent vestigial buds in the axils of the two transitional glumes basal to the spikelet, which are particularly well developed in this subspecies. These characteristics seem to set the genus off from all others in the subtribe. Relationships between different forms of inflorescence and different branching patterns are discussed later, section 4.6.4 .

This bamboo was later given the name *Thamnocalamus aristatus* subsp *bhutanensis*. Material studied came from Pele La (west side)

The contents of a bud which would have developed into a typical branch complement from the mid-culm region are shown in fig 29 . The bud-scale surrounding the bud has two prominent keels, shown by black triangles. Within this there are five main blocks, each representing one of the five major branches in the mid-culm complement. The branching pattern which is represented is mapped in fig 30 .

The main central branch, axis 0, is in the centre of fig 30 . The bud-scale is the first sheath on this axis, labelled 0,(1). It is a prophyll with two keels. Subtended in the axil of this prophyll is a branch, axis 0,1 . The first sheath on that branch is another two-keeled prophyll 0,1,(1). This prophyll encloses a block which contains all the sheaths and branches borne on axis 0,1 . The rest of the bud contents are enclosed by the second sheath on the main axis, sheath 0,(2). Prophyll 0,2,(1) and the third sheath on the main axis, 0,(3) are inside sheath 0,(2). This pattern continues to show that the branch complement consists of the main branch axis, called axis 0, and four lateral axes called 0,1 0,2 0,3 and 0,4, which arise in the axils of the first four sheaths on the axis 0 called sheaths 0,(1) 0,(2) 0,(3) and 0,(4) respectively. This seems to be a fairly complete manifestation of a fundamental branching pattern. All branching axes are subtended by

sheaths, although several sheaths, such as 0,1,(1) and 0,1,(2) do not have axillary branch axes.

The appearance of the branch complement viewed from the front is illustrated in fig 31 . This is how an old branch complement would appear, most of the sheaths falling off to leave only a basal scar to show their locus of insertion. The fronts of the sheaths on the principal axis, 0,(1), 0,(2), 0,(3), and 0,(4), have been removed to allow the prophylls of axes which they subtend to be seen. The basal scars of the sheaths are still visible. The horizontal spread of the branches is illustrated in fig 32 .

It can be seen that there are usually five main axes in the branch complement in the first year, a central branch and up to four laterals arising from unextended internodes at the base of the central branch. Development of further orders of branching can occur in later years from basal buds. In this way small branches such as axes 0,1,4 and 0,2,4 can extend behind the culm from the second year on. All expected sheaths are present on the principal axis, axis 0. The four laterals arising from it to give the branches 0,1, 0,2, 0,3, and 0,4 are separated by sheaths 0,(2), 0,(3), and 0(4). The branching pattern is regular and fairly uniform over several mid-culm nodes, with the number of branch axes greatest in the mid-culm region, diminishing towards the base or apex of the culm.

All prophylls in the branching system had two prominent keels which were usually ciliate, and were usually substantially taller than their breadth between the keels. The two-keeled bud-scale which is the prophyll 0,(1) encircles the bud, but it remains open at the front, even in the lowest bud on the culm. During development of the bud contents the prophyll often splits down the back, but this can readily be determined by the margins of the two halves which are jagged and torn and never ciliate.

#### 4.5.2.2 T43 *Fargesia grossa* Yi affinis

This species is considered to bear strong resemblances to certain species described as species of *Fargesia* in China, a genus which is included in *Thamnocalamus* Munro by Clayton and Renvoize, 1986, and Chao and Renvoize, 1989. It differs from the description of *Fargesia grossa*

Yi in several ways and seems to be a new species. The inflorescence is distinct from that of *Thamnocalamus* in having fewer bracts subtending ultimate branches, only rings of hairs, and very few vestigial buds in the axils of the two transitional glumes basal to the spikelet. There are some pulvini. The inflorescence is a panicle with quite long pedicels, extending well beyond the enclosing spathes. The name *Fargesia bhutanensis* was later given to this species.

Branching in this species was found to be substantially more complex than the branching seen in *Thamnocalamus aristatus*, with different prophyll characteristics and a different relationship between lateral branches and subtending sheaths on the main branch axis. See figs 33 and 34 and compare to figs 29 and 30 for *Thamnocalamus aristatus*.

It appeared that the two principal lateral axes 0,1 and 0,2 of the fundamental pattern as seen in *Thamnocalamus* were often complemented by further axes of an unknown origin replicated beside them.

The lateral axes 0,1 and 0,2 are duplicated twice on each side, giving three similar lateral branches on each side, termed 0,1, 0,1a, 0,1b, and 0,2, 0,2a, and 0,2b, giving a total of seven main axes in the mid-culm region. This meant that the appearance of the branch complement was very different, see fig 35 . After removal of the bud-scales, marked 0,(1) base and 0,(2) base, three lateral branches were immediately visible on each side of the central branch, each enclosed in a prophyll with a prominent ciliate keel. In *Thamnocalamus* species T44 after removal of the bud-scale, only one lateral axis had been visible. Others were hidden inside the sheaths 0,(2), 0,(3), and 0,(4), see fig 31 .

Prophylls classified as 0,(1) were narrow and single-keeled from about the seventh bud upwards, but symmetrical two-keeled bud scales were found below this, as depicted in fig 37 (iii). When two-keeled the symmetrical nature of the bud scale, and the absence of a further sheath in the expected location of sheath 0,(2) suggested that it represents prophyll 0,(1) and sheath 0,(2) fused together to form a single bud-scale. The presence of intermediate forms of prophyll a little higher up with various degrees of deep cleavage at the back support this contention further. It is possible that

sheath 0,(2) has become reduced and disappeared altogether, although this does seem unlikely from the material examined here.

The prophylls at higher orders of branching were all broad, with margins which overlapped and completely enclosed their contents. Prophylls 0,1,(1) and 0,2,(1) only had one well developed keel in this species however, sheath 0,(3) bearing strong keels instead.

At the lowest node of the culm bud-scales were always closed at the front as well as the back, as in fig 37 , (i) . For a few nodes above this, patterns (i), (ii), and (iii) in fig 37 were all visible.

The replicated lateral axes, 0,1a, 01b, 0,2a and 0,2b not only increased the number of branches, but also extended the horizontal branch spread behind the culm in the first year of growth, see fig 36 . In *Thamnocalamus* species T44 this was only possible in the second year of growth.

#### **4.5.2.3 *Fargesia murielae* (Gamble) Yi**

This species is one of the most widely cultivated bamboos in Europe. It is considered by Soderstrom, (1979), and Campbell, (1988), to be synonymous with the type species of *Fargesia* Franchet, *Fargesia spathacea*. This material was collected in Cruikshank Botanic Gardens Aberdeen, but the clump has now been moved to the old fishing buildings below the Brig o' Balgownie at nearby Bridge of Don.

Dissection of a mid-culm bud showed that it was essentially the same as T43 in terms of branching and prophyll details, although a larger proportion of bud-scales were 2-keeled with suggested fused origins, single-keeled prophylls only being found from the 10th bud upwards. The basal bud of every culm was closed at the front, as in fig 37 , (i). Rhizome buds were all open at the front.

Inflorescences of this species are similar to those of T43 in having few sheaths at ultimate points of branching, very few vestigial buds in the axils of

glumes basal to the spikelet, and no pulvini, but they are smaller, composed of racemes with short pedicels, so that they appear enclosed in their spathes, superficially similar to those of *Thamnocalamus*.

Lateral branches were only duplicated once, see fig 38 , giving five branches, but the clumps were growing in unnaturally harsh conditions in Aberdeen, which may have stunted their growth, and reduced the number of laterals.

#### 4.5.2.4 *Sinarundinaria nitida* (Mitford) Nakai

This species is important as the type species of *Sinarundinaria* Nakai. Although the rhizomes are only about 15cm long in Sussex and less than 10 cm in Aberdeen, so that its clump habit is similar to that of the preceding three species, Chao, Chu & Hsiung (1981) reported that much more extension of the rhizome neck is found in its native environment in China. They considered this to justify the existence of a spreading genus, *Sinarundinaria* Nakai, separate from *Fargesia* or *Thamnocalamus*, but taking precedence over Keng's spreading genus *Yushania*. However it seems that there is considerable confusion between this species, *Arundinaria nitida* Mitford, which is the type species of *Sinarundinaria* Nakai, described from cultivated plants in the UK, and a different species *Arundinaria nitida* Mitford ex Stapf, which is now known as *Yushania confusus* in China, (T.P. Yi, 1983). Nakai was being highly speculative when he created *Sinarundinaria*, and his description of the new genus is wildly inaccurate with regard even to its type species. *S nitida* cultivated in the UK has not flowered, but T.P. Yi collected flowers from what he considers to be *Sinarundinaria nitida* Mitford at Nanpin in Sichuan Province (Yi 84137) and a photograph of these clearly shows their close similarity to the well known inflorescence of *Sinarundinaria murielae*.

This material was collected in Cruikshank Botanic Gardens Aberdeen, but the clump has now also been moved to the old fishing buildings below the Brig o' Balgownie at nearby Bridge of Don.

Branching was also essentially the same as in T43 above, with single-keeled prophyll and matching single-keeled following sheath 0,(2) from the fourth bud upwards, merged into a two-keeled prophyll at the lowest nodes. There was extensive duplication of the two lateral axes, see fig 39 . The lowest bud on the culm had a bud scale which again was always closed at the front, as in fig 37 (i). Rhizome buds were all open at the front.

#### **4.5.3 Group 2 Temperate running (long-necked pachymorph) species**

##### **4.5.3.1 T41 *Arundinaria hirsuta* Munro**

This species from Thimphu district of Central Bhutan seems to be close to the running species known as *A jaunsarensis* in NW India, which may be synonymous with *A anceps* as commonly cultivated in the UK, (Blatter 1929, cited in Chao & Renvoize 1989). The inflorescence of *A pantlingi* Gamble, which is very similar to this species, is semelauctant with the sheaths subtending ultimate branches reduced to tufts of hairs, no vestigial buds subtended by the transitional glumes, long pedicels, and frequent pulvini, thus being essentially very similar to the bractless inflorescence common in non-bambusoid grasses.

Mid-culm branching in this species was again found to be more complex than in *Thamnocalamus* with the two principal lateral axes 0,1 and 0,2 duplicated as in the *Fargesia/Sinarundinaria* species described above, see figs 40 and 41 for plan of bud contents and branching pattern suggested by the spatial relationships of the sheaths. Fig 42 relates these to the physical appearance of the branch complement and fig 43 gives its horizontal layout.

The duplicated axes 0,1a and 0,2a were smaller than their counterparts in the previous species, and were located further back, thus not being immediately visible from the front of the bud.

The prophylls 0,(1), and following sheaths 0,(2) were usually narrow and single-keeled, from bud 3-7 upwards. The absence of an additional following sheath in the normal position for 0,(2) again confirmed the 2-keeled

bud-scale to have developed from two separate fused single-keeled bracts as in *Fargesia* species T43 above.

The lowest bud on all culms had bud scales which were open at the front, as in fig 37 , (iii), unlike those of the preceding two species *S murielae* and *S nitida*. Rhizome buds were also open at the front.

The duplicated lateral axes 0,1a and 0,2a extended behind the culm in the first year of growth, as in T43, *nitida* and *murielae*, see fig 43. The central branch was well developed, especially towards the base of the culm, where it was often similar in diameter to the culm.

Thus the branching and prophylls were not greatly different from those seen in the 3 *Fargesia/Sinarundinaria* species described above, the main differences being the degree of replication of lateral axes, and the open front to the basal buds.

#### **4.5.3.2 T50 *Arundinaria microphylla* Munro**

This species from Thimphu district, Central Bhutan, is identified as *Arundinaria microphylla* Munro, which is a similar species to *Arundinaria maling* Gamble, but has hollow rhizomes, a different culm surface, and different leaf margins. The flowers are not known. It is much smaller in overall stature than T41.

The contents of a well developed bud are given in fig 44 . The prophyll and following sheath 0,(2) were narrow and single-keeled as in T41, from the fourth bud upwards. Lateral axes 0,1 and 0,2 were again duplicated, although this variety, from Changkaphug regeneration plots, has a more dominant central branch, axis 0, in the mid-culm region, and replicated axes were not well developed until higher up the culm. At the base of the culm the bud scales were two-keeled, but still sometimes subtended two prophyllate axes, and thus are again considered to be the result of the merging of two sheaths, 0,(1) and 0,(2). The basal bud scales and those on the rhizome were all open at the front, as in fig 37 (iii).

#### 4.5.3.3 T53 *Arundinaria maling* Gamble

This small bamboo from Chukka district of southern Bhutan is similar to *Arundinaria maling* but may be a separate taxon. It differs in having no auricles or setae on the leaf sheath, a ciliate leaf sheath edge, less scabrous new culms and culm sheaths, and very thin culm walls. Its inflorescence is not known.

Later fieldwork showed this bamboo could not be consistently separated from *A maling* Gamble, and it was included in that species.

The appearance of the mid-culm bud and branch complement was very similar to T41, and the contents of a mid-culm bud are portrayed in fig 45. As in T50 the axes 0,1a and 0,2a were not very extensively developed until higher up the culm. The essential characteristics of prophylls and branching were as described for the previous two species.

#### 4.5.4 Group 3 Subtropical clump-forming species (short-necked pachymorph)

##### 4.5.4.1 T49 *Drepanostachyum khasianum* (Munro) Keng

Five or more species in the group called *Drepanostachyum* Keng are well known and several others await description. They differ substantially from all the species in the previous three groups in the appearance of their buds and branch complements, and they are adapted to drier, warmer conditions, in subtropical rather than temperate climatic zones. This species is sometimes considered synonymous with the type species, *Drepanostachyum falcatum* (Munro) Keng, (Chao & Renvoize, 1989). This material came from Thinleygang, near Wangdi, C Bhutan.

The inflorescences are open with long pedicels and only a few vestigial sheaths or tufts of hair at the ultimate points of branching, and no pulvini. The glumes basal to the spikelet are empty, and differ from those in all previous species by being membraneous and rapidly disintegrating. The

inflorescence is a panicle, often composed of several different orders of branching, but the first internodes of the central branch axes are compressed, so that the panicle branches are strongly fasciculated. Some species show a reduction in the number of branches in each fascicle, leaving empty sheaths with no subtended axes at the base of the inflorescence. The flowers of this species are not known.

The content and branching pattern of a typical mid-culm bud of T49 are shown in figs 46 and 47 .

It can be seen that a more complicated branching pattern is involved, with a much greater degree of replication of the lateral axes, giving rise to four or more main lateral axes on each side, 0,1, 0,1a, 0,1b, 0,1c, and 0,1d etc, and a total of nine or more subequal branches in the top row, even on small culms. The replication of axes continues into higher orders of branching, with axes such as 0,1,1 and 0,2,1 duplicated by axes 0,1,1a and 0,2,1a.

The bud is short, broad, and very open, with most of its contents visible from the front. First-year branch development is much more prolific than in any of the previously described species, with all axes shown in fig 46 developing together to give not only the 16 branches labelled in fig 46 but also the smaller axes such as 0,1,1a (fig 47), to give a total of 30 or more subequal branchlets.

These branchlets quickly obscure their prophylls, therefore the appearance of a typical mid-culm bud is given in fig 48 for comparison with prophylls in complements of previous species. The approximate horizontal layout of a complement in its first year is given in fig 49. Six or more of the main laterals extend behind the culm in the first year, along with several minor branches, thus giving the best horizontal spread of foliage of all the groups.

The mid-culm prophylls 0,(1) were all single-keeled. At the lowest nodes they were similar to those in the previous three species, merged at the back with the following sheath 0,(2) to give a 2-keeled sheath, but still open at the front. The prophyll 0,(1) and the sheath 0,(2) are short and narrow and allow the bud contents to be seen clearly. All the prophylls are

short, in clear distinction to the long prophylls of the previous groups. The two-keeled prophylls such as 0,1,(1) are very short and they do not obscure their contents in the same way. Thus not only the rank of central branch and replicated laterals is visible, but also a lower rank of shoots, secondary to the upper rank, see fig 48 , with prophylls such as 0,2,1,(1) visible behind their enclosing prophylls such as 0,2,(1), which are only about half the height of prophyll 0,(1).

#### **4.5.4.2 T1 *Drepanostachyum intermedium* (Munro) Keng**

This species is well known and clearly distinguishable from the type species *D falcatum*, and from *D khasianum*, by its densely pubescent leaf sheaths and persistent strongly ciliate falcate leaf sheath auricles. The inflorescence shows no reduction in branching or floret numbers.

The layout of sheaths in a mid-culm branch complement of this species was almost exactly as depicted for T49 in fig 46 , with three replications of the lateral branches on each side. The buds and prophylls were very similar to those of *Drepanostachyum khasianum*. This material came from Dhankuta district of East Nepal, (PAC).

#### **4.5.4.3 T27 *Himalayacalamus falconeri* (Hooker f ex Munro) Keng**

Several clump-forming bamboos grow at a slightly higher altitude than species of Keng's *Drepanostachyum*, but not as high as species of *Fargesia* and *Thamnocalamus*. In winter they are readily distinguishable from species of *Drepanostachyum* in the same sites as their leaves are still green, and one even has discernable tessellation. Differences in culms and culm sheaths are also apparent. The branching is simpler, often with a dominant central branch which may bear roots.

Inflorescences are semelauctant, with only tufts of hairs at the ultimate points of branching, and no buds in the axils of transitional glumes. The trend described in *Drepanostachyum* for the fascicled panicle branchlets to be suppressed, leaving sheaths with no subtended axes on the main lateral axes of the inflorescence, and for spikelets to have reduced numbers of

florets is taken further, *Himalayacalamus* species having more racemose inflorescences, with only one floret per spikelet.

This collection from Phulchowki, Kathmandu, has flowers which seem identical to those of the holotype, and the location is very close to that of the holotype (Shivapuri, Kathmandu).

The contents of a typical mid-culm node are portrayed in fig 50 . It can be seen that there is replication of laterals to give three main branches on each side of the central branch, as seen in *Fargesia* species T43. There also can be duplication of higher orders of branches, as seen in *Drepanostachyum* species T49 and T1, to give axes such as 0,1,1a and 0,2,1a etc. As in *Drepanostachyum* several orders of branching arise in the first year, with all the elements in such a complement as fig 50 developing together to give up to about 20 branches. These are very different in size, however, with 3 to 5 strong branches and a further fifteen or so in a lower rank of much smaller branches. Three small branches together at the front on each side, such as nos 9, 10 and 11 in fig 50, are very distinctive in this species.

The prophylls were short, and similar to those seen in *Drepanostachyum*, although prophyll 0,(1) was sometimes fused with sheath 0,(2) at the front as well as the back at the very base of the culm, fig 37 (i) & (iii). In addition, the prophylls of the laterals such as 0,1,(1) were similar in height to 0,(1) and were always tall enough to hide prophylls of higher orders, so that only one rank of prophylls is visible in the bud, see fig 51 , and this distinguishes them easily from buds of *Drepanostachyum*.

Thus the branching pattern is closest to that of *Fargesia* in number of laterals, but similar to *Drepanostachyum* in replication of higher orders, while the prophylls are closest to those of *Drepanostachyum* in height although they did sometimes fuse with sheath 0,(2) at the front as in *Fargesia* and their greater height made it impossible to see higher orders of branching in the bud.

#### 4.5.4.4 T52 *Himalayacalamus falconeri* (Hooker f. ex Munro) Keng

This species is similar to T27 in its vegetative and floral characteristics, but has a smaller central branch. This variety was collected in southern central Bhutan. The contents of a bud are given in fig 52 . It can be seen that there are strong similarities to T27, with the same replication of lateral axes, higher order axes, and single-keeled open prophyll 0,(1). The prophylls were short, similar to those of T27 in fig 51 , but prophylls 0,1(1) and 0,2,(1) had only one keel, figs 50 & 52.

#### 4.5.4.5 T3 *Dendrocalamus patellaris* Gamble

This species was incorrectly named as a *Dendrocalamus* species when Gamble was given flowers of *D hamiltonii* in conjunction with vegetative material from this species by one of his collectors. It shares several characteristics with a group named *Ampelocalamus* in China by Chen, Wen and Sheng (1981), and this species seems to be similar to or synonymous with *Ampelocalamus scandens*, as described by Hsueh and Yi, (1985), although that species is described from Yunnan.

The inflorescence retains some primitive characters, having bracts at most points of branching and vestigial remains in the axils of upper glumes basal to the spikelet. It has fascicled branchlets and long pedicels similar to those of *Drepanostachyum*, rather than the open inflorescence with pulvini of *Yushania*.

The contents of a lower mid-culm node are depicted in fig 53 . The lateral axes on both sides were clearly duplicated as in the *Fargesia*, *Sinarundinaria* and *Yushania* species described previously, to give axes 0,1a and 0,1b , 0,2a and 0,2b . There was also some duplication of higher orders of branching, as seen in *Drepanostachyum* and *Himalayacalamus*, giving axes such as 0,2,1a. There is substantial reduction of some sheaths, such as 0,(3), while others sometimes merge together or become fused. In some buds the pattern is more irregular with confusing reduction and fusion, irregular shapes and extended keels. In the first year up to twelve subequal axes develop, with up to seven branches in the top row.

The appearance of the contents of a simpler bud with the bud-scale removed, are depicted in fig 54 . As in *Drepanostachyum* and *Himalayacalamus* the prophylls were short, with their width similar to their height. The absence of a sheath 0,(2) after the bud-scale and replication of the lateral axis on the right can clearly be seen.

Fig 53 shows a bud completely enclosed by a two-keeled bud scale which is closed at the front as well as the back. This bud-scale is identified as the prophyll 0,(1) fused with the sheath 0,(2) as there does not seem to be a sheath 0,(2) between it and the sheath 0,(3), but as this bud-scale is never composed of two single-keeled sheaths as seen in species of *Fargesia* etc it is more difficult to ascertain its origin. As the same replication of axes is seen in this species as in *Fargesia* etc, it is assumed that the bud-scale has developed in the same way.

The absence of a separate sheath 0,(2), sets this species off from *Thamnocalamus*, and the fusion of the front of this bud-scale in the mid-culm region distinguishes it from all the previous species.

This genus is the only one known with both semelaucant inflorescences and fully closed bud-scales.

#### **4.5.5 Group 4 Subtropical running (long-necked pachymorph) species**

##### **4.5.5.1 S41 *Neomicrocalamus prainii* (Gamble) Keng f**

This species differs from all the previous species in having six stamens instead of three. It is a scandent bamboo with strongly developed central branches, narrow culms, long internodes, and long rhizome necks. It has leaves without tessellation, but is only found in the coolest of subtropical areas just below the frost-line, probably because it requires lower evapotranspiration rates.

This species has been collected from the Naga hills in Assam, but was included in the species *Arundinaria prainii* Gamble, which is now considered to be a species of either *Racemobambos* Holttum or *Neomicrocalamus* Keng, according to whether the latter genus is recognised. It differs from *N prainii* in having hollow culms, largely glabrous culm sheaths, and swollen geniculate branchlet nodes, and was later named *Neomicrocalamus ringshu*.

A plan of the sheaths in a mid-culm branch complement is given in fig 55 . It can be seen that there are no missing or reduced sheaths, and no replicated lateral axes. The prophyll 0,(1) is two-keeled, although it often splits as the large complement develops, and it is always open at the front. Some higher order prophylls such as 0,1,(1) are narrower, and single-keeled. When there are more branches in the complement, a greater number have such single-keeled prophylls.

Thus the branching is simple, with no reduction, replication, or fusion of sheaths. Looking at the front of the branch complement the sheaths 0,(2), 0,(3), etc hide the lateral branches as in *Thamnocalamus*.

It is essentially the same as the pattern in the *Bambusinae* and *Melocanninae*, as described above for *Thamnocalamus aristatus*. As in *Thamnocalamus* the open fronts of the mid-culm bud prophylls 0,(1) distinguish this from *Bambusinae* and *Melocanninae*, but other characteristics of the branch complement are more similar to those of *Bambusa* than *Thamnocalamus*. Examples of these are the width of sheaths, the dominance of the central branch, and especially the rapid proliferation of large numbers of higher orders of branches.

These characteristics, along with the presence of six stamens instead of three, suggest that *Neomicrocalamus* is as closely related to *Bambusa* as it is to any members of *Thamnocalaminae* Keng.

#### 4.5.6 Summary of results

The most important differences in prophyll and branching characteristics found in this sample of species have been summarised in

table 5 . Six different patterns could be separated, A to F indicated by the dotted lines.

Pattern A featured the simplest and most complete patterns of branching, and no reduction in the width or keeling of the prophylls. *Thamnocalamus aristatus* and *Neomicrocalamus* sp S41 both followed this pattern. They differed from all the other species studied in having two-keeled mid-culm bud-scales which were derived from a prophyll 0,(1) alone. Lateral branches were not replicated, all branch axes being subtended by a sheath.

All other patterns had two separate narrow single-keeled bracts identifiable as reduced prophyll 0,(1) and sheath 0,(2), or seemingly compound two-keeled bud-scales apparently incorporating both sheaths 0,(1) and 0,(2) fused at the back or front or both. Various degrees of replication of lateral branch axes were seen, the replicated axes having no subtending sheaths.

Pattern B included the clump-forming temperate bamboos associated with the genera *Fargesia* and *Sinarundinaria*, *F grossa* aff., *S nitida* and *F murielae*. They all had tall narrow single-keeled prophylls, matched by tall narrow single-keeled 0,(2) sheaths. Buds at the base of the culm were surrounded by 2-keeled bud-scales which seem most likely to represent the prophyll and following sheath 0,(2) fused together at the back. The most basal bud was also closed at the front by fusion of the front margins. Lateral branch axes were replicated once or twice on each side.

Pattern C included the spreading temperate species with much longer rhizome necks associated with the genus *Yushania*: *A hirsuta*, *A microphylla*, and *A maling*. They all had tall prophylls and a limited degree of replication of axes. Compared to the clump-forming species of pattern B they had less replication of branch axes over the culm as a whole, and they also had basal bud-scales which were open at the front without fusion of the front margins. It was hoped that the closure of the front of the basal buds might be associated with closure of rhizome buds, but when rhizome buds were examined, they were open in all these species of both patterns B and C.

Subtropical clump-forming species all had shorter prophylls and buds. The width of the buds was similar to or greater than their height. Three further patterns were distinguishable.

Pattern D consisted of two species associated with the genus *Drepanostachyum*. They had very short and narrow bud-scale sheaths behind which many more subequal initials could be seen from the front of the bud, representing several higher orders of branching, arising from a much greater degree of replication of branch axes than seen in any other pattern, with up to five replications on each side.

Pattern E included the bamboos allied to *A falconeri* and the genus *Himalayacalamus*. The buds had slightly taller prophylls than those in pattern D and there were fewer initials visible. The lateral axes were only replicated once or twice, resulting in fewer branches which included a larger and more dominant central branch.

Pattern F seems to be represented by only one species in the Himalayas, *Dendrocalamus patellaris*, which seems to be a member of genus *Ampelocalamus* rather than *Dendrocalamus*. It could be distinguished from all the others by the complete closure of the front of all bud-scales, and also by the fusion of several sheaths and keels inside the bud, along with two replications of each lateral branch axis.

#### **4.5.7 Additional herbarium material**

It is possible to determine some of the characteristics in table 5 from herbarium material without dissection. The number of keels on the sheath 0,(1) can be deduced from the appearance of the 0,(1) and 0,(2) sheath scars at the front of the branch complement. The height of prophylls is usually observable even at a minor point of branching, and the replication of lateral branches can also usually be observed as long as the collection includes a point of branching on a culm or reasonably large subsidiary branch. Whether culm base buds are open or closed at front and back is not assessable as culm bases are rarely to be found in herbarium collections.

Thus it is possible to distinguish between most of the patterns from reasonable herbarium collections by branch and prophyll characteristics alone, although separating patterns B and C is not possible, nor can patterns D and E be distinguished without good branch complements.

The type collections of the type species of the genera *Thamnocalamus* Munro, *Fargesia* Franchet, *Drepanostachyum* Keng, *Himalayacalamus* Keng and *Ampelocalamus* Chen, Wen & Sheng were examined. Vegetative material from the type collection of the type species of *Yushania* Keng was not available, but a good specimen of the type species from the same mountain in Taiwan was available, determined by a respected Taiwanese bamboo expert. The characteristics of these specimens are given in table 6 . It was obviously not possible to make full and detailed dissections.

It can be seen that even this superficial examination clearly supports some of the principal differences in branching. It verifies the distinctions between pattern A (*Thamnocalamus* and *Neomicrocalamus*), patterns B and C (*Fargesia* and *Yushania*), and patterns D, E and F (*Drepanostachyum*, *Himalayacalamus*, and *Ampelocalamus*).

Other less quantifiable branching characteristics allow further division of such material with experience. The spreading branches of *Neomicrocalamus* species are distinct from the upright branches in *Thamnocalamus*. The geniculate branchlets in *Ampelocalamus* are distinct from those of either *Drepanostachyum* or *Himalayacalamus*, which can themselves be separated by discrepancy in branch size.

Thus the different branching and prophyll patterns seen in the material collected in the Himalayas are recognisable in the type collections of the type species of the genera concerned. A key to separate them by their bud and branching characteristics is given below, summarising the results of this section.

species	0,(1) keels (mid-culm)	front & rear of culm base bud	front of mid-culm bud	prophylls (2-keeled)	lateral branch replications		
PATTERN A							
T44	<i>aristatus</i>	2	open	closed	open	tall	0
S41	<i>prainii aff</i>	2	open	closed	open	tall	0
.....							
PATTERN B							
T43	<i>grossa aff</i>	1	closed	closed	open	tall	1-2
	<i>nitida</i>	1	closed	closed	open	tall	1-2
	<i>murielae</i>	1	closed	closed	open	tall	1-2
.....							
PATTERN C							
T41	<i>hirsuta</i>	1	open	closed	open	tall	0-1
T50	<i>microphylla</i>	1	open	closed	open	tall	0-1
T53	<i>maling aff</i>	1	open	closed	open	tall	0-1
.....							
PATTERN D							
T49	<i> khasianum</i>	1	open	closed	open	v short	3-5
T1	<i>intermedium</i>	1	open	closed	open	v short	3
.....							
PATTERN E							
T27	<i>falconeri</i>	1	op/cl	closed	open	short	1-2
T52	<i>falconeri aff</i>	1	?	?	open	short	1-2
.....							
PATTERN F							
T3	<i>patellaris</i>	1	closed	closed	closed	short	2

? not conclusively established

**table 5 comparison of diagnostically useful species characteristics**

Genus	Type species	no of keels <sup>1</sup> on 0,(1) height	prophyll <sup>2</sup>	branch replications <sup>3</sup>
<i>Thamnocalamus</i>	<i>spathiflorus</i>	2	tall	0
<i>Neomicrocalamus</i>	<i>prainii</i>	2	tall	0
.....				
<i>Fargesia</i>	<i>spathacea</i>	1	tall	1
<i>Yushania</i>	<i>niitakayamensis</i> <sup>4</sup>	1	tall	0?
.....				
<i>Drepanostachyum</i>	<i>falcatum</i>	1	v short	3?
<i>Himalayacalamus</i>	<i>falconeri</i>	1	short	2?
<i>Ampelocalamus</i>	<i>actinotrichus</i>	1	short	2
.....				

1 no. of keels on the mid-culm branch prophyll

2 relative height of the mid-culm branch prophyll

3 no. of replications of the lateral branch axes on each side  
of the central branch at mid-culm height

4 not type specimen, but from same locality, reliably determined

**table 6 Branching and prophyll characteristics of the type specimens of the type species of the genera studied**

Key to genera studied, relying mainly upon characteristics of vegetative buds and branching, based upon examination of Himalayan representatives of the genera, and type collections available at Kew

- 1 Broad mid-culm bud-scales with two keels, and all branch axes subtended by sheaths
  - 2 Branches all arising at an acute angle to the culm ..... ***Thamnocalamus***
  - 2a Branches arising at acute and obtuse angles to culm ..... ***Neomicrocalamus***
  
- 1a Mid-culm bud surrounded by separate one-keeled bracts, often with lateral branch axes replicated side by side without subtending sheaths
  - 3 Front of mid-culm bud-scale closed by fusion of margins ..... ***Ampelocalamus***
  - 3a Front of mid-culm bud-scale open with free margins
    - 4 Height of mid-culm buds similar to breadth of bud; > 10 branches in the first year
      - 5 Two rows of branch initials visible in bud, developing into up to 70 subequal branchlets ..... ***Drepanostachyum***
      - 5a One row of initials visible in bud, developing into up to 30 branches, strongly dissimilar in size, diameter of central branch up to 4 times that of smallest branchlets ..... ***Himalayacalamus***
    - 4a Height of mid-culm buds more than twice breadth; < 10 branches in the first year
  
- 6 Basal culm buds closed at the front by fusion of margins, rhizomes solid, up to 30 cm long; culms with erect bases in dense clumps or with culm bases curving outwards in more open clumps ..... ***Fargesia***
- 6a Basal culm buds open at the front with margins free; rhizomes solid or hollow, up to 2 m long, widely spreading bamboos; culm bases always erect ..... ***Yushania***

## 4.6 Discussion

### 4.6.1 Taxonomic value of branching patterns and prophyll characteristics in the *Thamnocalaminae*

These branching and prophyll characteristics allow separation of groups of species which were not separable at all in the past without flowering material. Analysis of these characteristics from a plan of the complement layout is a powerful tool. The layouts are quite distinctive and often provide a form of fingerprint which allows recognition of groups of species or even separate species.

It can be seen quite clearly from table 5 that these characteristics have the potential for rapid and decisive division of the Eastern Himalayan representatives of this subtribe into six different groups of species which seem well related to the genera proposed in China. It is obvious that this limited range of species is not sufficient for reliable generic descriptions to be made, but it seems likely that several of these characters at least may be consistent throughout the genera. The examinations of herbarium material of the type species suggests a wider applicability, but fresh material from a wider range of species would be required to prove this, and such material is hard to obtain.

The distinctions between some of the groups are very clear-cut, while others are a little harder to assess, especially from poor herbarium material, and consequently they are not so useful, although they do throw some light upon the less well known genera, such as *Ampelocalamus* and *Neomicrocalamus*.

The most consistent and useful distinction is based upon the presence of narrow single-keeled prophylls rather than the more usual broad two-keeled prophyll. This also seems to be associated with the presence of replicated lateral branch axes without subtending sheaths. It very clearly separates *Thamnocalamus* and *Neomicrocalamus* from the other genera, and can often be determined from old or fragmentary herbarium material. *Thamnocalamus* and *Neomicrocalamus* seem to retain what is presumably an ancestral condition, with a simple and almost complete pattern of sheaths

and branch axes, and no reduction of their prophylls, which remain broad and two-keeled.

*Neomicrocalamus* also has what is presumably a more ancestral inflorescence, with six stamens instead of three and prominent bracts at points of branching. The presence in this subtribe of a bamboo with such a different inflorescence to the semelauctant three-stamened versions seen in all the other genera is very unsatisfactory, and placing this genus in the subtribe *Bambusinae* would seem more appropriate. It is interesting, however, that its branching is so similar to that of *Thamnocalamus*, as this would suggest that *Thamnocalamus* might be retaining more ancestral characteristics than any other genus in the subtribe.

This is important as it strengthens the distinction between *Thamnocalamus* and the other genera in the subtribe, including *Fargesia* Franchet. *Fargesia* has been included in *Thamnocalamus* on the grounds of its compressed inflorescence, which is partially enclosed by a spathe in a similar manner to that seen in *Thamnocalamus*, (see 4.6.4). The differences in vegetative branching and prophyll form shown here suggest that *Fargesia* is actually substantially different from *Thamnocalamus* Munro, with several more derived characteristics. Therefore it would seem reasonable to recognise *Fargesia* as a separate genus on these grounds.

The status of the genus *Sinarundinaria* Nakai is determined by the status of *Fargesia* Franchet. As shown here, (4.5.2.3 & 4.5.2.4), the type species of *Fargesia*, *F. spathacea* (represented by synonym *F. murielae*), and that of *Sinarundinaria*, *S. nitida*, share the same vegetative branching pattern, and they also seem to have very similar inflorescences. The evidence seems to suggest that the type species of the two genera are congeneric, and that one of the genera should be considered a synonym of the other. *Fargesia*, described by Franchet in 1893, clearly has precedence over *Sinarundinaria* Nakai, which was not described until 1935. Therefore *Fargesia* would appear to be the appropriate genus in which to place these species, which are the most commonly planted bamboos in the UK and most of Europe.

Other differences in branching pattern and prophyll characteristics are less profound, but still of taxonomic value. Closure of the dormant bud-scale

in the mid-culm region, and at the culm base, are also very useful, although new shoots are required to use these distinctions. They help to separate groups of species such as those put into *Yushania* and *Ampelocalamus* in China from *Fargesia*. This was not possible before without flowers and rhizomes. Similarly bud-scale height and appearance of branch initials can separate species of *Drepanostachyum* from those of *Himalayacalamus*. The elucidation of further details of the less well known genera such as these serves to reinforce their claims to recognition as separate genera.

The real taxonomic significance of these branching characteristics should only be assessed when considered in the light of other branching patterns in the bamboos, as well as avenues of inflorescence development.

#### **4.6.2 Relationships to other bamboo branching patterns.**

The range of branching patterns seen here seems to extend from two forms of a complete basic pattern, to what appears to be a substantially derived form. Different avenues of development can be seen in other bamboo subtribes, see fig 55a. In the *Bambusinae* typified by *Bambusa* the pattern is similar to that seen in *Thamnocalamus* but has more compression. *Racemobambos* can be seen as a development of this. In the *Shibataeinae* typified by *Phyllostachys* the pattern is similar to that seen in *Thamnocalamus*, but with less compression. The genus *Shibataea* can be seen as a refinement of that pattern. In the *Chusqueinae* of South America the pattern is similar to that described for the most advanced genera of *Thamnocalaminae*, but even more advanced.

##### **4.6.2.1 *Bambusa* pattern**

This is another basic pattern, similar to that seen in *Thamnocalamus* or *Neomicrocalamus*. It differs from the pattern in those two genera in that the prophyll 0,(1) forming the bud-scale is thickened and closed at the front, and the insertion of buds on the central axis is interrupted. At the base of the *Bambusa* central branch there are buds on the first two nodes which give rise to a precocious first phase of branching, developing as the central branch develops.

Further up the branch at the top of the compressed section there are further buds, such as those enclosing axes 0,6, 0,7, and 0,8. These remain dormant in the first year, only developing in subsequent years. This pattern of interrupted bud insertion with two basal buds developing precociously also occurs on several orders of progressively smaller branches, so that in the first phase each branch has two smaller branches arising from its base, positioned at 4-o'clock and 8-o'clock.

Thus the branch complement seems more derived than that of *Thamnocalamus*. It features compression of a larger number of nodes, interrupted bud insertion, and a clear dichotomy between non-dormant and dormant buds, which leads to more distinct phases of branching. It is the presence of large dormant buds on the base of the central branch which allows vegetative propagation from branch and culm cuttings in these genera. The absence of such buds explains why such techniques consistently fail in bamboos from those subtribes.

#### **4.6.2.2 *Phyllostachys* pattern**

The origins and relationships of the branching patterns in the *Shibataeinae* of China and Japan have been described well by Usui, (1957). A reduction in the number of branches can be seen in several genera, *Chimonobambusa* species having only three branches, while *Phyllostachys* species have only two. The pattern of sheath insertion remains unmodified, but there are no unextended internodes at all so that the complement and the sheath layout are as simple as they can possibly be. This trend is exemplified in the subtribe *Shibataeinae* by species of *Phyllostachys*, while species of the genus *Shibataea* are described by Usui as having single-keeled prophylls, while having no replication of lateral branches. The pattern seen in *Phyllostachys* is simpler than that of *Thamnocalamus* while that of *Shibataea* seems to be more advanced in having reduced prophylls with single keels.

The *Phyllostachys* pattern seems to be a development running in a very different direction to that seen in the species studied here, leading to a reduction in branch number, rather than fasciculation. This may be related

to the more spreading rhizome habit, and the greater stature which reduces browsing pressure.

#### 4.6.2.3 *Chusquea* pattern

In the *Chusqueinae* of South America the pattern of reduced prophylls and replicated axes as described above for genera *Fargesia*, *Yushania* etc has progressed considerably further. The presence of large numbers of separate initials apparently arising simultaneously in level bands or sweeping curves without an enclosing bud-scale is difficult to explain. McClure, (1973) described it as the result of multiple insertion of buds, for which he coined the term pleioclade. He envisaged the duplication of entire branch complements many times over from adventitious buds. Clark, (1985, 1989), supported this view.

The explanation for these patterns is probably much simpler. Fig 56 shows the layout of a small branch complement from the tip of a culm of *Chusquea culeou*. Mid-culm branch complements are much larger but presumably remain fundamentally the same. As well as the eight initials there are thick strands of hardened tissue which look suspiciously like vestigial remains of reduced prophyll keels.

If the pattern portrayed here is compared to the sheath layout in a mid-culm complement of *Fargesia nitida* as depicted in fig 39 , there are strong similarities. If the vestigial keels are expanded to complete sheath 0,(2) and two prophylls, 0,1,(1) and 0,1a,(1), and their counterparts on the other side are also added, 0,(1), 0,2,(1), and 0,2a,(1), and sheath 0,(3) is placed in the centre,, as depicted in fig 57 (i), and these are superimposed on top of the *Chusquea* pattern, as in fig 57 (ii), the result is almost identical to the pattern seen in *Fargesia nitida*, fig 39 .

If this explanation of the origins of the complements described by McClure as pleioclade is correct, then the term pleioclade is not helpful, as it seems to imply a different process entirely. More accurate terminology should describe four processes, reduction of the bud-scale prophyll 0,(1) to

a one-keeled structure, replication of branch laterals, loss of the bud-scale 0,(1) altogether, and loss of other sheaths within the complement.

#### 4.6.2.4 *Racemobambos* pattern

In the Malaysian genus *Racemobambos* the branch complement appears similar to that seen in *Chusquea*, because of the large number of small axes on each side of the central branch. Fig 58 shows a complement of *R hepburnii* from Sabah, collection number S Dransfield 718, with the principle sheathing on the central axis and the pattern of tiny subordinate branches on both sides. It differs from the pattern seen in *Neomicrocalamus* species S41 in having much narrower sheaths throughout the complement. This is expressed in the presence of two narrow unkeeled sheaths enclosing the bud, prophyll 0,(1) and sheath 0,(2).

In addition the dominance of the central branch is more pronounced, and the rest of the complement arises from only the first two branches off the central branch, axes 0,1 and 0,2 , whereas in S41 several branches from the main axis ( seven in fig 55 ) gave rise to the lateral portions of the complement. The many subordinate branchlets on each side seem to represent repeated ramification of the two axes, 0,1 and 0,2, the different orders becoming surprisingly equal in size, and many sheaths being reduced to very narrow almost vestigial sheaths to accommodate this. There seems to be no replication, but analysis of a smaller complement is necessary to confirm this. Whether there is replication or not, the pattern is substantially different from that described for *Neomicrocalamus* species S41, reinforcing the differences in inflorescences and spikelets which seem to justify recognition of two different genera.

The combination of single-keeled prophylls and no replication of laterals was also described for *Shibataea*, although these two genera do not seem closely related.

#### 4.6.2.5 Conclusions on relations to other branching patterns

It seems that the 3-stamened genera in the *Thamnocalaminae* represent ancestral to substantially derived forms of branching. The most advanced of these are well separated from three other paths taken in the bamboos, the simple branching of *Phyllostachys*, the 2-phase branching of *Bambusa* and the highly unequal but regular branching of *Racemobambos*, but they could lead on directly to the more derived patterns seen in *Chusquea*. The 6-stamened genus *Neomicrocalamus* has a simple branch pattern close to that of *Thamnocalamus*, but seems to lie on a different path of branch development to the other genera in this subtribe, leading to *Racemobambos* types of branching rather than *Fargesia* types.

#### 4.6.3 Possible origins of the derived forms of branching seen in the *Thamnocalaminae*

The replication of similar lateral axes beside each other without intervening sheaths, as witnessed here in the bamboos of the genera *Fargesia*, *Yushania*, *Drepanostachyum*, and *Himalayacalamus* could be explained in different ways.

One explanation would be a process of reduction, whereby the intervening sheaths become reduced in size and then disappear altogether. This would mean that axes called 0,1a , 0,2a , 0,1 , and 0,2 would really represent axes 0,1 , 0,2 , 0,3 , and 0,4 respectively, sheaths 0,(3) and 0,(4) having disappeared. This seems to be the explanation suggested by Hsiung et al, (1987) for more complex branching patterns found in some leptomorph bamboos.

The other explanation for the replication of axes would be a precocious division of the young lateral axis primordium, that is some form of originally aberrant development rather than a process of reduction.

It is very difficult to say which process is more likely to be the correct explanation. Anatomical studies of vascular bundles in the complement

might be able to show that sheaths were once present if reduction has occurred. One consideration in the argument could be the apparent absence of intermediate forms with vestigial remnants of reduced sheaths as seen in *Chusquea culeou*. These were not encountered at all during these investigations, and this would seem to argue against reduction being the explanation.

While its explanation remains obscure, the manifestation of the process is clearly very useful. It is clearly an advancement, showing some bamboos to be ancestral in this morphological character, while others are relatively derived, and it shows clear-cut distinctions between different groups of species, which are very useful in the recognition and separation of different taxa.

The functional value of this advancement lies in the increased number of branch axes which are produced, and the improved horizontal area which branches can exploit at each node by extending all around the culm. This probably enables much faster domination and suppression of other plants competing for the light, along with improved ability to regrow new leaves and branches after browsing, drought, or fire. The large central branch seen in spreading temperate species such as *Arundinaria hirsuta* may be a further adaptation to allow rapid re-establishment of foliage after browsing. These species also have rapidly proliferating branches and are commonly found in flatter more heavily browsed and more open areas than clump-forming species, which are commoner on slopes under heavier shade. These functional and ecological considerations strengthen the argument that the replication of branch axes described here is a relatively derived characteristic, and also support the separation of different genera.

#### **4.6.4 Agreement between groupings on vegetative and floral characteristics**

Any groupings on vegetative grounds must bear in mind parallel trends in inflorescence structure if they are to be taken seriously. In a natural system there should be good agreement between the two.

As stated earlier knowledge of inflorescence structure and patterns of evolution are rather inadequate, and also controversial. The accepted view of bamboo inflorescence evolution among many agrostologists, as described by Clayton & Renvoize (1986), is that inflorescences with 6 stamens such as those of *Bambusa* are derived, while those with 3 stamens such as those of *Yushania* or *Drepanostachyum* are ancestral. This results from the assumption that bamboos have developed from grasses, most grasses having 3 stamens, and that inflorescences with bracts have arisen by reduction of bractless panicles onto supporting vegetative bract-bearing axes.

The pattern of branch development described here seems to run from simple branching in *Thamnocalamus* to relatively derived branching patterns with replication and reduction in *Yushania* and *Drepanostachyum*.

The characteristics of the inflorescences in the species studied here, or species close to them, are listed in table 7 . It would appear that there is a clear trend of reduced occurrence of bracts from *Thamnocalamus* to *Drepanostachyum* and *Yushania*. This is accompanied by a reduction in the presence of bud-like structures in the axils of glumes, an overall expansion from compressed inflorescences to open ones, and the occurrence of specialised features such as fasciculation and pulvini, which are more typical of non-bambusoid grass inflorescences.

Therefore, if we consider that bract-bearing compressed inflorescences are derived from bractless open ones, as suggested by Clayton and Renvoize, (1986), then the pattern of branch development seems to run contrary to the perceived direction of inflorescence development within this subtribe.

**table 7 Features of the inflorescences of representatives of the genera studied**

<b>species</b>	<b>glume buds</b>	<b>bracts</b>	<b>fasciculation</b>	<b>pulvini</b>	<b>florets</b>
<i>Thamnocalamus</i> T44	common	usual	none	no	many
<i>Ampelocalamus</i> T3	common	often	yes	no	many
<i>Fargesia</i> T43	rare	few	no	few	many
<i>Yushania</i> T41	none	none	no	many	many
<i>Drepanostachyum</i> T1	none	none	yes	no	2 - several
<i>Himalayacalamus</i> T27	none	none	reduced	no	1

If we want inflorescence development to complement branching pattern development rather than to contradict it, the inflorescences would have to be viewed in a slightly different manner. The trend would essentially be from primitive inflorescences with vestigial buds in the transitional glumes and bracts at points of inflorescence branching derived from pseudospikelets as seen in the *Bambusinae* with 6 stamens and 3 lodicules, towards more open inflorescences without buds or bracts, as seen in the non-bambusoid grasses, with 3 stamens and 2 lodicules.

If we take this view, then from inflorescences similar to those seen in *Thamnocalamus* it would appear that three different pathways have been taken, leading to characteristics expressed most strongly in inflorescences of *Yushania*, *Ampelocalamus* and *Himalayacalamus*. These are similar to the pathways suggested by the branching patterns and prophyll characteristics.

While it is possible to look at overall trends, the detailed parallels between floral and branching distinctions separating the individual genera are difficult to determine, because of the lack of material. There are clear distinctions between the inflorescences of the species sampled here for each genus, but it is not known how consistent these characters are within the genera. If such characters are consistent, then the ability to separate the genera on such clear floral characteristics would serve to strengthen the importance of vegetative distinctions such as those described. Floral and branching characteristics of the closer genera may agree as well as those of the more distantly related however. *Yushania* and *Fargesia* may overlap, as may *Drepanostachyum* and *Himalayacalamus*.

#### **4.7 Conclusions**

It is concluded that there is sufficient variation in prophyll and branching characteristics for the separation of several groups of species from the Himalayan representatives of the subtribe *Thamnocalaminae* Keng. The selection of inflorescences available suggests that these groups also show sufficient differences in inflorescence structure for them to be

considered separate genera, as proposed by several Chinese bamboo taxonomists.

The branching and prophyll characteristics, if proven consistent throughout all species in the genera concerned, would allow separation of the genera without flowers, and thus greatly assist in field identification of the smaller stature Himalayan bamboos.

These results suggest that *Thamnocalamus* Munro, *Ampelocalamus* Chen Wen & Sheng, *Fargesia* Franchet, *Yushania* Keng, *Himalayacalamus* Keng and *Drepanostachyum* Keng should be recognised for bamboos in the subtribe *Thamnocalaminae* Keng from the Himalayas. *Sinarundinaria* Nakai seems to be reduced to a synonym of *Fargesia* Franchet, and many species transferred to it are more appropriately placed in other genera. *Butania* Keng is synonymous with *Yushania* Keng. *Chimonocalamus* Hsueh & Yi has not yet been encountered in the Himalayas, and the six-stamened genus *Neomicrocalamus*, which has different branching and prophyll characteristics from species of the genus *Racemobambos*, should not be in the subtribe *Thamnocalaminae*.

The generic names considered appropriate for the species studied here are listed in table 5 . On the grounds of these results and considerations it is considered necessary to make a few new combinations for some of these species studied, as well as other Himalayan species.

#### **4.8 Summary**

This subtribe, treated broadly, contains most of the small stature Himalayan bamboos. They have not been studied in the field for over a century, and different taxonomists consider them to represent between two and eight genera. The latest revision, (Chao & Renvoize, 1989), places them in the genera *Thamnocalamus*, *Sinarundinaria*, and *Racemobambos*, except for one species which remains misplaced in *Dendrocalamus*. Their identification is very difficult because of infrequent flowering, poor knowledge of the vegetative characteristics of species named from flowers alone, and their general inaccessibility.

Material was collected in Nepal and Bhutan so that the prophylls and branching patterns from a small range of species could be compared in detail. Considerable variation was found in mid-culm prophylls, bud scales at the bases of culms, and degree of replication of the lateral branch axes.

Numbers of samples taken were small, the range of species studied was not extensive, and the number of characters studied was limited. Further information on leaf morphology, cytology, vascular structure, and flowering mechanisms are required before sound conclusions on the generic affinities of these bamboos can be reached, but this work has shed light upon some new characters which can be readily assessed in the field and so are of particular value for recognition of these plants by the end-users of any taxonomic systems.

These characters allowed separation of seven different groups, which related well to the genera *Thamnocalamus* Munro, *Ampelocalamus* Chen Wen, & Sheng, *Fargesia* Franchet, *Yushania* Keng, *Drepanostachyum* Keng, *Himalayacalamus* Keng, and *Neomicrocalamus* Keng. Parallels between these vegetative characters and different forms of inflorescence, along with considerations of avenues of branch development in the bamboos as a whole and their functional significance, seem to strengthen their significance. They support the recognition of seven genera, proposed in France and China. It is concluded that *Sinarundinaria* Nakai is probably a synonym of *Fargesia* Franchet, and that several new combinations are required.

species reference code	most recently published name	closest or published species	most appropriate genus
T44	<i>Thamnocalamus aristatus</i>		<i>Thamnocalamus</i>
T43	-	<i>Fargesia grossa</i>	<i>Fargesia</i>
	<i>Fargesia murielae</i>		<i>Fargesia</i>
	<i>Sinarundinaria nitida</i>		<i>Fargesia</i>
T41	<i>Sinarundinaria hirsuta</i>		<i>Yushania</i>
T50	<i>Sinarundinaria microphylla</i>		<i>Yushania</i>
T53	-	<i>Arundinaria maling</i>	<i>Yushania</i>
T49	<i>Drepanostachyum khasianum</i>		<i>Drepanostachyum</i>
T1	<i>Drepanostachyum intermedium</i>		<i>Drepanostachyum</i>
T27	<i>Himalayacalamus falconeri</i>		<i>Himalayacalamus</i>
T52	<i>Himalayacalamus falconeri</i>		<i>Himalayacalamus</i>
T3	<i>Dendrocalamus patellaris</i>		<i>Ampelocalamus</i>
S41	-	<i>Neomicrocalamus prainii</i>	<i>Neomicrocalamus</i>

**table 8 Species studied with the genus considered most appropriate**

## **5. Enumeration of Himalayan genera and species**

### **5.1 Introduction**

As described in section 1.2.1, most botanists working in the Himalayas concentrated their studies in the more accessible regions, such as the areas around the Indian hill stations, now in the states of Himachal Pradesh, Uttar Pradesh, West Bengal and Sikkim. This was especially the case in the nineteenth century and the first half of the twentieth century, when the independent countries of Nepal, Bhutan, and Tibet all tried to isolate themselves from the rest of the world as much as possible. These three countries received relatively few collectors, and their floras are poorly represented in the world's herbaria.

In addition to the poor coverage of Nepalese and Bhutanese plants in general, the bamboos are particularly poorly represented because their flowers are difficult to find unless a gregarious flowering is in progress, and the periods between gregarious flowerings may be up to 150 years in some species. Even when flowers have been found, they may still be of limited value. During gregarious flowerings bamboos usually lose all normal leaves and culm sheaths, so that it can be impossible to relate flowers collected on their own to the plants in vegetative growth.

Since Nepal and Bhutan established closer ties with the rest of the world it has been possible for foreigners not only to visit the countries, but also to live there for long periods of time, assisting in development activities through bilateral or multilateral aid. The initiation of forestry programs has involved the propagation and management of many forest species, including the bamboos. This has allowed the development of much greater familiarity with Nepalese and Bhutanese bamboos, and the collection of flowers from the sporadically flowering clumps which can occasionally be encountered in between the gregarious flowerings if a substantial time is spent in the area. These collections are particularly important because they allow collection of both flowering and vegetative material, as bamboos often do not drop all their leaves and die as a result of sporadic flowering.

During this enumeration many districts of Nepal and Bhutan were visited in connection with development projects involving bamboo propagation or management. The enumeration primarily covers bamboos encountered during such fieldwork, and thus concentrates upon those which are presently of economic or ecological importance in Nepal or Bhutan. In addition extra coverage is given to hardy bamboos which are cultivated in temperate regions as ornamental plants, as their nomenclature has become confusing for horticulturalists.

Thus for several reasons the bamboos of Nepal and Bhutan have been severely neglected in the past, and a relatively large proportion of new taxa is included in this treatment. The opportunities to study the bamboos in more depth arising from the recent development efforts made in the two countries has allowed more taxa to be included.

The bamboos enumerated constitute a large increase in the number of bamboo taxa known. In the enumeration of the flowering plants of Nepal, (Hara, Stearn & Williams, 1980), ten species were recorded from five genera, but one genus, *Semiarundinaria*, and one species, *Arundinaria pantlingi*, seem to have been incorrectly identified, and do not seem to have been found in Nepal so far. No enumeration of Bhutanese bamboos had previously been undertaken. In this work fifty four taxa from fifteen genera have been included from within or close to Nepal and Bhutan, see table 9. These include thirty species for Nepal, and twenty eight species for Bhutan, with a total of 42 species collected within the two countries.

Of the fifty four taxa encountered, only twenty four seem to have satisfactory published names (44%). Among the others it is considered that there are fourteen new species, four new subspecies, and three new varieties. In addition rationalisation of genera following the investigations described in the previous two sections results in nine new combinations. Despite this significant increase in numbers of taxa, it is suspected that many more species remain undiscovered in areas of Nepal and Bhutan which were not visited, and the enumeration still cannot be considered complete.

## 5.2 *Bambusa* Schreber in Gen. Pl. : 236 (1789)

Syn, (Clayton & Renvoize, 1986) :

- Bambos* Retz. in Obs. Bot. 5: 24 (1788) *nom rejic*  
*Bambusa* Caldas in Seman. Nueva Grenada: 131 (1809)  
*Guadua* Kunth in J. Phys. Chim. Hist. Nat. 95: 150 (1822)  
*Isurochloa* Buse in Miq., Pl. Jungh.: 389 (1854)  
*Bonia* Balansa in J. Bot. Paris 4: 29 (1890)  
*Arundarbor* Kuntze in Rev. Gen. Pl. 2: 760 (1891)  
*Leleba* Nakai in J. Jap. Bot. 9: 9 (1933)  
*Tetragonocalamus* Nakai in J. Jap. Bot. 9: 88 (1933)  
*Lingnania* McClure in Lingnan Univ. Sci. Bull. 9: 34 (1940)  
*Bambusa* subgen *Dendrocalamopsis* Chia & Fung in Acta Phytotax.  
 Sin. 18: 214 (1980)  
*Dendrocalamopsis* (Chia & Fung) Keng in J. Bam. Res. 2: 11 (1983)  
*Neosinocalamus* Keng in J. Bam. Res. 2: 148 (1983) *pro parte*

### 5.2.1 Generic status and separation

The commonest genus in the Indian subcontinent, also found native as far away as South America, and cultivated in all tropical regions of the world. This genus is very similar to two other genera which occur in or near the Himalayas, *Dendrocalamus* and *Gigantochloa*, neither of which are at all easy to separate from *Bambusa* satisfactorily without flowers.

*Gigantochloa* species, which occur mainly in Burma and Malaysia, although they have been found in Assam, are easily distinguished when flowering by the termination of their spikelets in a long empty lemma. Their stamens also have filaments fused into a tube, but the spikelet termination is considered a better distinguishing characteristic, (Holttum, 1946).

*Dendrocalamus* species were originally separated from those of *Bambusa* by seed characters, but these were later shown to be incorrect and misleading, (Holttum, 1956a). The separation and disarticulation of rhachilla internodes was later adopted as the best way of distinguishing the genera, but this is unsatisfactory in several intermediate species.

Soderstrom & Ellis, (1988), in their preliminary attempt to revise the bamboo genera, remarked upon the need for new characters to distinguish between these two genera more satisfactorily.

Investigations into the inflorescences of *Bambusa* and *Dendrocalamus* species from the Himalayas reported elsewhere have shown that the number of keels on the prophyll subtending the inflorescence can distinguish between the two genera without ambiguity, all *Bambusa* species having two keels, while all *Dendrocalamus* species have only one. It was also seen that all *Gigantochloa* species at Kew have single-keeled prophylls.

### **5.2.2 Species encountered in Nepal, Bhutan, and West Bengal**

This is a large genus, Clayton & Renvoize, (1986), giving 120 as the approximate number of species, but it has not been comprehensively revised since the monograph of Camus in 1913, in which 73 species were given. Considerable variation is found within several species, while the boundaries between other similar taxa remain rather uncertain. Because of the distribution of many *Bambusa* species across the plains of India or Bangladesh away from the Himalayas, and the lack of modern information on the Indian species in particular, it is not possible to give a satisfactory treatment of all the species in Nepal and Bhutan after studying Himalayan representatives alone. Therefore efforts have been concentrated upon those species which are mainly restricted to the hills.

Several well-distinguished species have been encountered, including the thorny bamboo, *B arundinacea*, the dwarf species *B glaucescens*, with its cultivars, the variegated *B vulgaris*, and the distinctive *B polymorpha* with its falcate auricles, but these are all very limited in extent in the Himalayas. The common Himalayan species are less well known, and a little harder to distinguish.

The common bamboos with prominent ciliate culm sheath auricles are part of a group of several species which has caused considerable confusion in the past, as they are very similar in their vegetative characteristics. In the Himalayas they seem to represent two species, *B nutans* and *B tulda*. In their culm sheaths they are also similar to *B vulgaris*, which is much rarer in

the Himalayas, although the taller culms with thinner walls and no stripes readily distinguish them in the field. The approximate distribution of these species and their subspecies is shown in fig 59 .

The commonest cultivated bamboo of the plains of Assam and northern West Bengal is the typical subspecies of *B tulda* Roxb. It comes right up to the foothills of southern Bhutan next to Assam, but it does not seem common in the Nepalese plains. The commonest species along the eastern foothills and plains of Nepal, and in the Bhutanese foothills as far east as Tashigang district, known as *mal bans* in Nepali, has conventionally been identified in Sikkim and Darjeeling as *B nutans* Wall ex Munro, a species described from material collected in Dehra Dun in N W India. From herbarium culm sheaths and foliage these two populations seem indistinguishable, but there are significant differences in the spikelets which need to be documented, therefore a new subspecies, *malbans*, is described for the eastern representatives. Maintaining the species name is considered desirable until further fieldwork has been undertaken to revise the species in this group found in the four countries and five Indian states concerned.

*B nutans* is clearly separable from *B tulda* by its cylindrical rather than flattened spikelets, while in vegetative growth *B tulda* has a persistent ring of white pubescence above the node not found in *B nutans*, as well as stronger branching. *B nutans* also has longer rhizomes, giving a more open clump. *B nutans* seems to have been brought down from the hills across the wet plains of Nepal, (terai), accompanying the spread of agriculture after malarial eradication, while in Bhutan *B tulda* has been brought across the cultivated dry plains (duar), to the base of the historically uncultivated hills.

Further west into the hills of central Nepal *B nutans* is replaced by a different species, which is clearly distinguishable from both *B tulda* var *tuldaa* in the plains of West Bengal and *B nutans* from the eastern hills, having brown rather than black culm sheath pubescence, less cupped culm sheath blades, distinct sulcation on smaller culms, and less of a white pubescent ring above the nodes. Its flowers are essentially the same as those of *B tulda* in West Bengal. It is named here as *B tulda* sunsp *tharu* following its local name. The tharu ethnic group live in the terai, but surprisingly this species has not been found there, the commonest terai species being further taxa, locally known as *chab bans* or *than bans*. Their

flowers are not known, and the bamboos on the Indian side of the border would have to be studied to decide upon correct nomenclature for the Nepalese species in this area.

Wild *Bambusa* species of the forests of the Nepalese plains (terai) are *B balcooa*, and *B vulgaris* around Chitwan national park. *B balcooa* is also widely cultivated in the central and western Nepalese terai and hills, as well as West Bengal and Assam. The habitats of any wild *Bambusa* species of the middle hills have largely been terraced for agriculture. However, several cultivated species are restricted to the middle hills, suggesting that they are remnants of the natural vegetation, persisting and cultivated in gulleys and other areas not suitable for field crops. *B balcooa* may also be native in the drier western hills as well as the plains.

A second dwarf species, similar to *B glaucescens* but with large auricles, is quite common at the eastern end of the Nepalese plains, and has also been encountered near the Assamese border in central Bhutan. This species has been described in Bangladesh without a name, (Alam, 1982), and is named here as *B alamii*. Although at present quite limited in its distribution, it is valuable as one of only two useful small bamboos known to grow in the heat of the terai, and is likely to spread further.

Species without large prominent culm sheath auricles are more difficult to distinguish from *Dendrocalamus* species when flowers are not available. Such intermediate species include *B balcooa*, which has no auricles at all, and two species restricted to the hills, which have very small ciliate auricles. The approximate distribution of these species and the dwarf species *B alamii* are shown in fig 60 .

One of the two species with small auricles is common throughout the hills of central and eastern Nepal, and the other species replaces it in Bhutan. When they were first encountered, it was not possible to assign these species to either *Dendrocalamus* or *Bambusa*, even with flowering material, and this stimulated the search for more characters of diagnostic value at the generic level. After studying the inflorescence branching and sheathing closely in a range of species, it was decided that the number of keels on the prophyll enclosing the inflorescence was the most useful

character, (see section 3), and that using this feature, they belonged in *Bambusa* rather than *Dendrocalamus*.

These species have certain characteristics in common with *Gigantochloa* species from S E Asia as well as *Bambusa* and *Dendrocalamus*. Vegetative appearances are similar, and flowers also have superficial similarities, eg the extraordinarily large spikelets of *B clavata* appear similar to those of *G latispiculata* Gamble. The genera *Sinocalamus* McClure and *Neosinocalamus* Keng have been suggested for such species, but it does not seem to have been possible to define either genus accurately on vegetative or floral characters. Even the genera *Bambusa*, *Dendrocalamus* and *Gigantochloa* are difficult to separate and might not be upheld as separate genera were they not so well established. McClure later decided not to recognise his genus *Sinocalamus*, and Soderstrom & Ellis (1988), and Clayton & Renvoize (1986), followed that decision. The 2-keeled prophylls, variable spikelet termination, and free filaments of these two intermediate species suggest that they are best placed in *Bambusa*, although some Chinese authorities may like to publish new combinations for them in the genera *Sinocalamus* or *Neosinocalamus*.

The Nepalese intermediate species has no single distinctive character, which is why it has remained obscure for so long. Its distribution justifies the name *B nepalensis*. The Bhutanese species has a distinctive cleavage in its culm sheath ligule when growing vigorously, occurring on alternate sides of the ligule at alternate nodes. This peculiarity explains the name *B clavata*.

### 5.2.3 Enumeration of species in Nepal and Bhutan, and part of West Bengal

#### 1. *Bambusa arundinacea* (Retz.) Willd in Spec. II : 245 (1799)

Basionym: *Bambos arundinacea* Retz. in Obs. Bot. 5:24 (1788) *nom rejic*

Syn.: *Bambusa spinosa* Roxb. in Hort. Bengal.: 25 (1814)

*Bambusa orientalis* Nees in Linn. ix : 475 (1834)

*Bambusa arundo* Klein ex Nees in Linn. ix : 471 (1834)

*Bambusa neesiana* Arn ex Munro in Trans. Linn. Soc. 26: 105 (1868)

*Bambusa pungens* Blanco in Fl. Filip. I : 270

*Bambos arundinacea* Retz in Obs. v. 24 (1789)

*Arundo bambos* Linn in Sp. Pl. : 81 (1753)

INDIA: West Bengal, Binnaguri, Rajmaha, *Stapleton 723* (Taba).

Local name *kante bans* (Bengali).

This species is widespread in central and north-east India and is likely to also occur in S W Bhutan and W Nepal, especially as its seed is widely available. It should only be planted as a live fence as its thorny branches make extraction of culms from the clump almost impossible.

#### 2. *Bambusa vulgaris* Schrader ex Wendl. in Collect. Pl. II : 26, tab 47 (1810)

Syn.: *Bambusa thouarsii* Kunth in Not. Gen. Bambusa in J. Phys.: 148 (1822)

*Bambusa surinamensis* Ruprecht in Act. Acad. Caes. Petrop.: 49 (1840)

*Bambusa sieberi* Griseb. in Fl. Brit. W. Ind. : 528

*Bambusa humilis* Reich ex Ruprecht op. cit : 50 (1840)

*Bambusa arundinacea* Moon in Catal : 26

*Bambusa striata* Loddiges ex Munro in Trans. Linn. Soc. 26: 121 (1868)

*Bambusa auriculata* Kurz ex Houz. de Lehaie non Brandis  
*Nastus viviparus* Raspail ex Houz. de Lehaie

BHUTAN: Chirang, Damphu, *Stapleton* 816 (Taba).

NEPAL: Chitwan area. Kathmandu, Lazimpat police plantation (exotic).

Local names *singhane bans* (Nepali, Chirang), *kada bans* (Nepali, Kathmandu), *koraincho bans* (Nepali, Chitwan).

The small size, twisting culms and thick walls make this species most suitable for pulp-production, although its striped culms are sometimes considered ornamental, and the cultivar grown in Chirang seems more useful than most.

**3. *Bambusa glaucescens*** (Willd.) Sieb. ex Munro in Trans. Linn. Soc.  
 26:89 (1868)

Basionym: *Ludolfia glaucescens* Willd. in Ges. Naturf. Freunde Ber. Mag. 2:  
 320, (1808)

Syn.: *Arundinaria glaucescens* Beauv., Essai Agrost. : 144, 152 (1812)

*Bambusa nana* Roxb. in Fl. Ind. 2nd Ed. 2: 199 (1832) *nom subnud*

*Bambusa nana* Roxb. ex Munro in Trans. Linn. Soc. 26 :  
 89(1868)

*Bambusa multiplex* sensu Backer in Handb. Fl. Java 2: 269,  
*non Arundo multiplex* Lour. (1790).

NEPAL: Kathmandu, cultivated in the Royal Botanic Gardens.

INDIA: West Bengal, Kalimpong, *Pradhan* s n (Taba).

The nomenclature of this species is fully discussed in Holttum, 1956c, and 1958. It was apparently introduced from China into Calcutta in 1794, as a fencing plant. Several cultivars with striped culms or small leaves are known.

**4. *Bambusa polymorpha*** Munro in Trans. Lin. Soc. 26: 98 (1868)

INDIA: West Bengal, Binnaguri, Rajmaha, *Stapleton* 724 (Taba).

Local name *tehi bans*.

The falcate culm sheath auricles distinguish this species clearly, and it is likely to occur in southern Bhutan.

**5. *Bambusa balcooa*** Roxb. in Hort. Beng.: 25 (1814)

Syn.: *Bambusa capensis* Ruprecht in Acta Acad. Caes. Petrop. : 54 (1840)

*Dendrocalamus balcooa* Voigt in Hort. Sub. Calc. : 718

NEPAL: Widespread, cultivated around Royal Palace, Kathmandu.

BHUTAN: Gaylegphug. Sarbhang.

INDIA: Widespread throughout West Bengal.

Local names *dhanu bans*, *bhalu bans* (Nepali), *bhalkhu bans* (Maithili).

The large culms produced in the terai find few uses in Nepal but are highly sought after in India. Intensive management in the western hills reduces its size to more manageable dimensions.

**6. *Bambusa tulda*** Roxb. in Hort. Bengal: 25 (1814)

Syn: *Bambusa macala* Buch.-Ham. in Wall. Cat. 5026A

*Dendrocalamus tulda* Voigt in Hort. Sub. Calc.: 718

subsp **tulda**

BHUTAN: Gaylegphug, *Stapleton* 811 (Taba).

Local name *tulda bans* (Bengali).

Difficult to distinguish from *B nutans* but it grows in denser clumps with stronger branching and has a persistent white ring above the nodes.

**7. *Bambusa tulda* subsp. *tharu* Stapleton subsp. nov.**

*Bambusa tulda* Roxb. typica similis, cujus flores habet, sed pilis vaginarum culmorum atro-brunneis, quae in *B tulda* typica et *B nutans* nigrissima sunt, laminis vaginarum culmorum paullo angustioribus differt, a *B nutans* subsp. *malbans* culmis minoris sulcatis distinguitur.

Basionym: *Bambusa tulda* Roxb. in Hort. Bengal: 25 (1814)

Syn.: *Bambusa nutans* Type B21 Stapleton in Jackson (ed) Manual of Afforestation in Nepal : 208 (1987)

NEPAL: Kathmandu, Bansbari, *Stapleton* 916 (**holo.** E).  
Pokhara.

Local names *tharu bans* (Kathmandu), *sate bans* (Pokhara).

Similar to typical *Bambusa tulda*, and having the same flowers, but differing in its very dark brown culm sheath hairs, which are blacker in typical *B tulda* and *B nutans*, and somewhat narrower culm sheath blades. It can be distinguished from *B nutans* by the sulcation on smaller culms.

This is the most common bamboo in the Kathmandu valley, also widely planted as far as Dolakha district to the east, and Palpa district in the west, but apparently isolated in the hills and not known in the terai. Spikelets of this subspecies are usually infected with an orange and black crustaceous fungal growth.

**8. *Bambusa nutans* Wall. ex Munro subsp. *malbans* Stapleton subsp. nov.**

A *Bambusa nutans* typicis ciliis carinarum plearum brevioribus, antheris bifidis non penicillatis differt.

Basionym: *Bambusa nutans* Wall. ex Munro in Trans. Linn. Soc. 26: 92  
(1868)

Syn.: *Bambusa nutans* Type B1 Stapleton in Jackson (ed) Manual  
of Afforestation in Nepal : 208 (1987)

NEPAL: Sankhuwasabha dist., Khandbari, *Stapleton* 141 (**holo.** E).

BHUTAN: Wangdi Phodrang dist., Chirang dist., Tashigang dist.

Local names *mal bans* (Nepali), *jhu shi* (Dzongkha)

It differs from the typical *Bambusa nutans* in its shorter palea keel ciliae and its anthers which are bifid and not penicillate.

The most common cultivated bamboo of eastern Nepal, extending at least as far as East Bhutan, separated from *B nutans* of Uttar Pradesh by *B tulda* of central and western Nepal.

### 9. *Bambusa alamii* Stapleton **sp. nov.**

Species nova *B glaucescens* (Willd.) Sieb ex Munro amplitudine similis, sed auriculis ciliatis vaginarum grandioribus, vaginis culmorum asymmetricis, foliis glabris differt. Inflorescentia ignota.

Syn.: *Bambusa sp.* Alam in A guide to 18 species of bamboos from  
Bangladesh FRI Chittagong Plant Tax. Bull. 2: 4, 15, fig 8  
(1982)

NEPAL: Jhapa district, Damak, *Stapleton* 907 (**holo.** E)

BHUTAN: Gaylegphug, *Stapleton* 813 (Taba)

Local names, none in Nepal, *mugi bans* in Gaylegphug.

New species similar in size to *B glaucescens*, but differing in the larger ciliate auricles, asymmetrical culm sheaths, and glabrous leaves. Inflorescence not known.

This species may be native to the region, or like *B glaucescens*, it may be introduced. It may possibly be the species named *Arundo multiplex* by Loureiro (1790) in the Phillipines, but he neither described that species properly, nor referred to a type specimen.

#### 10. *Bambusa nepalensis* Stapleton **sp. nov.**

*Bambusa kingiana* Gamble affinis, sed spiculis minoribus, lemmatis paucioribus (2-3), ciliis carinarum plearum paucioribus, stylis longioribus differt.

NEPAL: Dolakha, Thulopakhar, *Stapleton* 319 (**holo.** E). Dhankuta, Hile *Stapleton* 109, Kathmandu, *Stapleton* 920; 317.

Local names *tama bans* (Kathmandu), *phusre bans*; *khosre bans* (East Nepal)

Related to *B kingiana*, but with smaller spikelets with fewer flowering glumes (2-3), fewer ciliae on the palea keels, and longer styles.

After *B tulda* subsp. *tharu* the second commonest bamboo in the Kathmandu valley, and widely planted throughout central and eastern Nepal. Usually confused with *D hamiltonii* in the past.

#### 11. *Bambusa clavata* Stapleton **sp. nov.**

*Bambusa nepalensis* mihi affinis, sed spiculis majoribus purpuratis, cera culmis albis non nisi sub et super nodis in biannatis insidentibus, et praeterea a species insignis ligulis vaginarum culmorum suis plerumque semel clavatis erosis (fissura in lateris oppositis ad nodos alternantes alternans) differt.

BHUTAN: Gaylegphug, *Stapleton* 814 (**holo.** Herb. For. Dept. Taba)

Local name *chile bans* (Nepali), *pag shi* (Dzongkha).

Related to my *B nepalensis* but differing in its larger purple spikelets, the white culm wax only located in a double ring above and below the nodes, and differing especially from all known species by the frequent occurrence of a single bite-like cleavage in the culm sheath ligule, which alternates between opposite sides of the ligule at alternate nodes.

Widely cultivated in central and southern Bhutan.

### 5.3 *Dendrocalamus* Nees in Linnaea 9: 476 (1834)

Syn.: *Klemachloa* Parker in Indian Forester 58: 7 (1932)

*Sinocalamus* McClure in Lingnan Univ. Sci. Bull. 9: 66 (1940)

*pro parte*

*Neosinocalamus* Keng in J. Bamboo Res. 2 (2): 148 (1983)

*pro parte*

#### 5.3.1 Generic status and separation

As remarked under *Bambusa*, the traditional seed-based separation between *Dendrocalamus* and *Bambusa* has been discredited, but the genus is still universally recognised, although it is now distinguished by rhachilla disarticulation and prophyll keeling. *Dendrocalamus* species have single-keeled prophylls throughout their inflorescences, which are more branched and congested than those of *Bambusa*, and spikelets which dehisce intact without disarticulation of the rhachilla. They also have much scarcer lodicules, these being completely lacking in many species, and long styles.

The highly congested inflorescences of most *Dendrocalamus* species do not allow for much opening of the florets, so that lodicules become dispensable, and the apical exertion of stigmas demands a long style. Reduction of prophylls from 2-keeled to narrow single-keeled structures could be another consequence of the extensive branching within the inflorescence. It would allow more physical space for further orders of branching, and concentrate more resources on floret components, while the

close packing of spikelets within the inflorescence would make up for any reduction in protection against insects.

Highly branched inflorescences allow for greater pollen production, allowing greater chances of cross-pollination in the damp windless understorey and gully sites in which Himalayan *Dendrocalamus* species are naturally found. *Bambusa* species tend to occur in drier and more open sites which tend to be windier, allowing easier cross-pollination. The scarce occurrence of seed production in more than one floret of each *Dendrocalamus* spikelet supports this contention, and may also explain the lack of rhachilla disarticulation.

Profuse production of aerial roots on the culm nodes, and on the large rhizomatous branch bases are also characteristic of *Dendrocalamus* species. This may be an adaptation to their damp gully environments, where rooting of distal portions of fallen culms is an effective means of dispersal. This characteristic, along with thick or dark-coloured culm pubescence, usually distinguishes *Dendrocalamus* species from those of *Bambusa*, although intermediate species such as *B balcooa*, *B nepalensis*, and *B clavata* also have aerial roots and thick fur-like bloom on the culms.

### **5.3.2 Species and varieties encountered in Nepal, Bhutan, and West Bengal**

By far the commonest Himalayan *Dendrocalamus* species is *Dendrocalamus hamiltonii*. This species is apparently found along the entire Himalayan range, where it grows in gulleys in the subtropical forests especially along the outer range of hills, the Siwaliks or Mahabharat Lekh. It is also found further into the hills where it is quite widely planted. It has several distinct varieties, two of which are very common in Nepal or Bhutan, var *edulis* Munro, and a new variety, var *undulatus*, which is found in central and east Nepal. This variety is quite distinct from typical *D hamiltonii*, with much shorter and broader culm internodes which are slightly swollen towards the base, and more crinkled culm sheath blades. Although it is vegetatively quite distinct, the flowers seem indistinguishable from those of

typical *D hamiltonii*, and the distribution overlaps, therefore it is named as a variety of *D hamiltonii*, var *undulatus*.

Central Bhutan has a further variety of *D hamiltonii*, var *edulis* Munro. It is reportedly a better variety for shoot production, called *guliyo tama bans* in Nepali (sweet shoot bamboo). As both Bhutan and Nepal are canning *D hamiltonii* shoots, the distinction between this and other varieties is of obvious importance.

In contrast to var *undulatus*, this variety is very difficult to separate in vegetative growth, although the flowers are readily distinguishable. Munro described the variety, on the basis of a few collections from Sikkim, as having more flowers in the spikelets, occasional lodicules, larger inflorescences, and broader leaves. The width of the leaves does not seem a reliable characteristic, however, the leaf in the type specimen apparently coming from the apex of a new shoot, which is always uncharacteristic. Comparison of living material in the field has shown that in general form this variety is more pendulous, with fewer small recurved branchlets at lower nodes. In finer detail the culm sheath hairs are a lighter brown, the culm sheath ligule is more evenly dentate, and the leaf sheath ligule is often shorter, but these differences are quite variable within the varieties and within individual clumps or culms, so they need to be used with caution.

The most useful floral characteristics are the lack of red colouration on the body of the anthers, while their long tips remain dark purple, and the thin texture, length and reduced purple colouration of the flowering glumes. In addition there is often considerable pubescence on the branch bearing the inflorescences, and on both the outside and the inside of the flowering glumes, while the type variety has pubescence limited to the infra-nodal section of the branch, and pubescence restricted to the distal part of the flowering glume interior. Var *edulis* has similar flowers to *D longispathus* Kurz, but its glabrous leaves and leaf sheaths, and thick culm sheaths with erect glabrous blades and no depressed sinus separate it from that species as described by Gamble (1896), and Alam (1982).

Both this variety and the type variety are found in southern Bhutan, but var *edulis* is the commonest variety further into the hills, especially around Shemgang. One collection from Pokhara (*Hawkins s n*) also seems to

belong to this variety, and collections have also been made from Assam and Meghalaya. The main distributions of these varieties of *D hamiltonii* are shown in fig 62 . *D hamiltonii* from Dehra Dun in the N W Himalayas also has paler anthers than the type, but they still retain substantial red colouration, and are not as large as those of var *edulis*.

In comparison with *D hamiltonii*, all other *Dendrocalamus* species are scarce, and usually fairly localised. In the Nepalese terai a small-stature variety of *D strictus* is quite common. The solid knobby culms are used as truncheons (*latthi*) for controlling herds of animals or demonstrating crowds. The only other species known to occur in the plains of Nepal or West Bengal is *D giganteus*, recognisable from afar by its stature alone. Reaching over 30 m in height this species stands substantially taller than any other bamboo species in the region.

Into the hills of Bhutan and West Bengal *D sikkimensis*, the largest common species after *D giganteus*, is distinguished by the thick erect velvet-like culm sheath hairs and the long bristles on both culm and leaf sheath auricles. From central Bhutan to central Nepal *D hookeri* also reaches large dimensions, but it is easily distinguished from *D sikkimensis* by its less hairy culm sheaths with appressed hairs, much smaller ciliate auricles, and the absence of oral setae on its leaf sheaths.

The approximate distribution of these species is shown in fig 61 .

A further, as yet unidentified, large stature bamboo with characteristics of both *D hookeri* and *D sikkimensis* has been planted in a few sites around Kathmandu, notably Kalikasthan, but has not been seen elsewhere. A second unidentified species of either *Dendrocalamus* or *Bambusa*, locally known as seto bans, occurs near Jaigaon in West Bengal, but this has not been seen elsewhere, and its flowers have not been found.

### 5.3.3 Enumeration of species & important varieties in Nepal, Bhutan and part of West Bengal

#### 1. *Dendrocalamus hamiltonii* Nees & Arn. ex Munro in Trans. Linn. Soc. 26: 84 (1868)

Syn.: *Bambusa monogyna* Griffith in Notulae: 63, Icon 2

*Bambusa maxima* Buch-Ham in Wall. Cat. 5039

*Bambusa falconeri* Munro in Trans. Linn. Soc. 26: 95 (1868) *pro parte*

var **hamiltonii**

BHUTAN: Gaylegphug, Norbuling *Stapleton* 725 (Taba).

Chirang, Chhokarna, *Stapleton* 815 (Taba).

NEPAL: Widespread.

Local names *tama bans*, *choya bans* (Nepali), *pag shi*, *pat tsa* (Dzongkha).

#### 2. *Dendrocalamus hamiltonii* Nees & Arn ex Munro var. **undulatus** *Stapleton* var. **nov.**

A varietal typical internodis culmorum latioribus leviter irregulariter ventricosis, vaginis culmorum latioribus, laminis vaginarum culmorum undulatis differt. Spiculae illis varietatis typicae minor purpureus.

Syn.: *Dendrocalamus* sp. Dhungre bans Type D6 *Stapleton* in Jackson Manual of Afforestation in Nepal : 210 (1987)

NEPAL: Kathmandu, Balaju, *Stapleton* 456 (**holo.** E);915.

Dolakha, Charikot, *Stapleton* 301.

Dhankuta, Pakhribas, *Stapleton* 146.

Local name *dhungre bans*.

Differing from the type variety in its broader culm internodes, which belly out irregularly, and its undulating culm sheath blades on broader culm sheaths. Spikelets less purple than those of the type variety.

This variety is most common in Dolakha district, central Nepal, where it is found in conjunction with the type variety. It is distinguished locally because of its irregularly shaped culms which are only suitable for making pillars and containers, and not for weaving, so that the culms are often lopped for fodder, and not felled.

**3. *Dendrocalamus hamiltonii* Nees & Arn ex Munro var. *edulis* Munro**  
in Trans. Linn. Soc. 26: 84 (1868)

BHUTAN: Shemgang, Tingtibi, *Stapleton* 709 (Herb. For. Dept, Taba).

INDIA: Sikkim, Ramoon & Rato valleys, *Hooker & Thompson* s.n. 1850 (type K). Sikkim, Rilli valley, *Gamble* 8058. Meghalaya, Khasia Hills, Thoyung, *Clarke* 37585. Assam, Kamrup, *Mann* s.n.. Assam, Kangra, Hamirpur, *Parker* 3255.

NEPAL: Pokhara, Mahendra Cave, *Hawkins* s.n. 1983.

Local name *pag shi* (Dzongkha), *guliyo tama bans* (Sikkim nepali).

This variety is very difficult to separate from the type variety without flowers, but the culms are more pendulous with thinner walls, and there are fewer small recurved branchlets at lower nodes. Its shoots are reputedly more palatable than those of the type.

**4. *Dendrocalamus hookeri* Munro in Trans. Linn. Soc. 26: 151 (1868)**

BHUTAN: Wangdi Ph, Chhusutsa, *Stapleton* 818 (Taba herbarium).

NEPAL: Widespread in Mechi & Koshi zones.

Local names *kalo bans*, *bhalu bans* (Nepali), *pag shi* (Dzongkha).

**5. Dendrocalamus sikkimensis** Gamble in Hooker's Icon Plant. table  
1770

BHUTAN: Shemgang, Tingtibi, *Stapleton* 810 (Taba).

Local name *dem chhering* (East Bhutan).

**6. Dendrocalamus giganteus** Munro in Trans. Linn. Soc. 26: 150  
(1868)

Syn.: *Bambusa gigantea* Wall. Cat. Bot. Gard. Calc.: 79

INDIA: West Bengal, Hasimara, *Stapleton* 452.  
West Bengal, Raniganj, *Stapleton* 906.

Local names *tokla bans* (West Bengal), *rachhasi bans* (East Nepal).

**7. Dendrocalamus strictus** Nees in Linnaea 9: 146 (1834)

Syn.: *Dendrocalamus monadelphous* Thwaites ?

*Bambos stricta* Roxb. in Comor.: pl. 1, non tab 80

*Bambusa stricta* Roxb. Hort. Beng.: 25 (1814)

*Bambusa pubescens* Lodd. in Lindl., Pennny Cycl.3: 35 (1835)

*Bambusa tanoea* Buch.-Ham. ex Wallich in Wall. Cat. 5038A

NEPAL: Widespread in central and eastern terai.

Local name *latthi bans*.

Gamble suggested there were two varieties, a large variety from Southern India and Burma, and a small variety from central India and the Siwaliks. The native Nepalese representatives evidently belong to the latter variety. Plants recently raised across the country by the Forestry Department from seed of *D strictus* from India are hopefully from the former variety.

**5.4 *Fargesia* Franchet** in Bull. Soc. Linn. Paris 2: 1067 (1893)

Syn: *Sinarundinaria* Nakai in J. Jap. Bot. 11: 1 (1935)

#### 5.4.1 Generic status and separation

Clump-forming frost-hardy bamboos with more or less compressed inflorescences have often all been treated as species of *Thamnocalamus* Munro, (Soderstrom 1979, Chao & Renvoize 1989). In China they are usually divided into *Thamnocalamus* Munro and *Fargesia* Franchet, (Keng 1982-3, Yi, 1983b). Other species with more open inflorescences are also included in *Fargesia* in China, (Yi 1983b). Those species would usually be placed in *Sinarundinaria* Nakai by western taxonomists, (Chao & Renvoize 1989, Campbell 1988), who separate *Sinarundinaria* from *Thamnocalamus* on the grounds of lack of compression of the inflorescence alone.

Studies on vegetative branching have shown that species of *Fargesia* with either compressed or open inflorescences are clearly and unambiguously distinct from *Thamnocalamus* species in branching and prophyll characteristics. Other floral features such as inclusion of bracts, and vestigial buds in glume axils, can be used to separate *Thamnocalamus* and *Fargesia*, regardless of the compression of inflorescences. These characters can be considered less reversible than compression and expansion.

If *Fargesia* is accepted as a separate genus from *Thamnocalamus* then *Sinarundinaria* Nakai has little meaning as its type species *Sinarundinaria nitida* is clearly very similar to the type species of *Fargesia* Franchet. Thus *Sinarundinaria* can be treated as synonymous with *Fargesia*, at the same time recognising *Yushania* Keng for the widely spreading species put in *Sinarundinaria* by western taxonomists. The open inflorescences of *Fargesia* species differ from those of *Yushania* species in retaining some bracts at points of branching, some vestigial buds in glume axils, and having fewer pulvini. *Fargesia* species have closed culm basal buds and short rhizomes not seen in *Yushania* species.

It might be considered useful to separate *Fargesia* species with compressed racemose inflorescences from those with open paniculate inflorescences, but it seems impossible to separate these two groups consistently on branching or other vegetative characteristics alone. Yi divided *Fargesia* into sections and series, (1988), but his divisions do not reflect this distinction at all, and he has a very broad view of the genus, some of his divisions being synonymous with other genera. As Franchet, (1893), described *Fargesia* as having compressed inflorescences, only one species being known at the time, it would seem that some modification of the description of the genus would be necessary if it becomes more widely recognised.

#### 5.4.2 Previously described species

The type species, *F. spathacea* Franchet, was collected in Sichuan province of China. This collection was very similar to three species later described on the basis of other Chinese collections or plants brought back from China and cultivated in the UK, i.e. *Arundinaria murielae*, *A. sparsiflora* and *A. nitida*. Several other Chinese species have recently been added.

Yi described ten more species from Tibet, (1983b). He had previously considered five of these to be *Sinarundinaria* species, and one a *Thamnocalamus* species. He also implied that he considered *Arundinaria racemosa* Munro to be a *Fargesia* species, but he obviously had not seen its rhizomes. These species are listed in table 10. None of the descriptions include flowers. Two of these were collected by Yi himself, the rest being collected by 6 or 7 different collectors, with species citation numbers ranging from 1 to 4 in the herbarium of the Forestry School of Sichuan Province.

Although many of these collections come from sub-tropical areas of south-east Tibet, none of them have been placed in the subtropical genera, *Drepanostachyum* or *Himalayacalamus*. Two of these species

have no tessellation, and, in conjunction with a further two species which are described as having obscure tessellation, possess features strongly characteristic of *Drepanostachyum* and *Himalayacalamus*. *Fargesia ampullaris* has strongly concave attenuation to its culm sheath, a long culm sheath ligule, and two ranks of short initials in the culm buds which are also suggestive of *Drepanostachyum* species. *Fargesia collaris* has culm sheaths highly suggestive of *Himalayacalamus falconeri*. *Fargesia gyirongensis* appears similar to *Himalayacalamus asper*, but without the ridged culm surface. *Fargesia semiorbiculata* appears similar to *Drepanostachyum* species such as *D khasianum*. Campbell, (1988), also noticed the similarity between *Fargesia collaris* and *Himalayacalamus falconeri*.

*Fargesia crassinoda* has the erect culm sheath blade and broadly sagittate ligule seen in species of *Thamnocalamus*. It is well known from Nepal and is in cultivation in the UK, and a new combination seems appropriate. *Fargesia farcta* has some characteristics indicative of *Yushania*, but the rhizomes illustrated do have short necks typical of *Fargesia*, rather than *Yushania*.

After removing five of Yi's species which do not seem appropriate in *Fargesia*, five binomials remain from Tibet. No species have been described from within Nepal, Sikkim, or Bhutan, or from adjacent areas of Tibet, where they could reasonably be expected to occur. No species of *Fargesia* have been reported from outside Tibet and China, although species from South Africa, Sri Lanka, and S E Asia show certain similarities, particularly *Arundinaria tessellata* Nees. Bor included a further Tibetan species, *Arundinaria macclureana*, in the flora of Assam, (1957). This is very similar to species described by Yi from similar areas in Tibet, such as *F grossa* and *F setosa*, (1983b).

Thus in addition to the type species *F spathacea* Franchet and similar species from China proper such as *F nitida*, six taxa described from Tibet to the north and east of Arunachal Pradesh seem to deserve inclusion in *Fargesia* Franchet, and possibly also other species from further afield. All the species described from Tibet immediately adjacent to Nepal and Bhutan, (Yi, 1983b), seem to be misplaced as *Fargesia* species. New combinations are proposed for these in revisions of the appropriate genera, as they are

likely to be encountered in Nepal or Bhutan in the future. The distinctions between Yi's five species and Bor's *macclureana* are not clear, although the descriptions seem to justify different species, as far as can be judged without flowers. *F. grossa*, *F. bhutanensis* and *F. glabrifolia* are all quite similar, but the flowers of *F. grossa* and *F. glabrifolia* are not known. The characters which separate them can be very misleading in old or less comprehensive material.

#### 5.4.3 Species encountered in Nepal and Bhutan

No species have been found in Tibet at the same latitude as Nepal or Bhutan, Bor's *macclureana* and Yi's species coming from further east. However, two rare species have been encountered in Nepal, one here named *F. chigar* from western Nepal, and another named *F. emeryi* from eastern Nepal. A third species, named *F. bhutanensis* is common across central Bhutan, and a fourth species, named *F. geduensis* has been encountered once in southern Bhutan. The characteristics of these species and the published species considered appropriate in *Fargesia* are given in table 11.

*F. bhutanensis* is found as an understorey element in mixed conifer and hemlock forest types across most of Bhutan, and it is widely harvested in large quantities for roofing and fencing, being one of the most economically important minor forest products. It differs from all the species previously described, being larger than any of them, having attractive glaucous culms with a thick wax layer, densely pubescent undersides to the leaves, and no leaf sheath auricles but erect glabrous setae. The Tibetan species are similar, but *F. grossa* has no wax at all and much smaller leaves and *F. glabrifolia* has no hairs, while *F. setosa* has rough culms with bristles. The only species represented in western herbaria, *A. macclureana* Bor, has leaf sheath auricles and densely scabrous setae. Its glumes and paleas are shorter and more pubescent with more ciliate margins and keels, in shorter more flattened spikelets, and the pollen is orange, while it is white in *F. bhutanensis*.

Emery has collected a further species in a remote and unpopulated part of eastern Nepal between the Kasua and Barun valleys on the upper

Arun (Emery 54 and Emery 10). These collections seem to represent a new species, which differs from the Bhutanese species in having no leaf sheath setae or leaf hairs, and narrower florets with less pubescent flowering glumes and paleas which are more bifid and nearly glabrous between the keels. Old culm sheaths from the area between Chainpur and the Milke Danda may also represent this species, (Emery 111). It does not seem to be very widespread or economically important in Nepal. Better collections are required.

A further species was found below the site of a proposed pheasant reserve (Pipar) on the mountain Machhapuchhare which lies on the southern flank of the Annapurna massif in western Nepal, (*Stapleton* 315), first mentioned in *Stapleton & Tamrakar* (1983b). At the time of its collection the importance of buds and branching was not fully appreciated, and the material collected does not allow reliable assignment of this species to the genus *Fargesia*. Study of a similar new species in Bhutan does suggest that it is most likely to belong in this genus, however.

The Nepalese species is distinctly different from known species of *Fargesia* or of any other genus, having extraordinarily long ligules on the culm and leaf sheaths. They are subulate on culm sheaths, and up to 5mm long on leaf sheaths. The bud characters seem to place it in *Fargesia*, but only very small buds have been seen. It also differs from all the known *Fargesia* species in having culm sheaths without clearly defined blades, very small branches and extremely narrow leaves, as well as the peculiar ligule characteristics. The culms sweep outwards from the ground, and give an open form of clump.

The rarer of the two Bhutanese species, *F geduensis*, shares some characteristics of *F chigar*, and reinforces its assumed generic affinity. It also has culms which sweep out at the base. The rhizomes are as long as possible for *Fargesia* species, up to c 30 cm, but the sweeping culm bases increase the separation of the culms, giving a very open clump, or more contiguous stands. The culm sheaths are also very thin and brittle. Other culm sheath and leaf sheath details are closer to those of *F bhutanensis* than *F chigar*.

#### 5.4.4 Enumeration of the species known from Nepal and Bhutan

##### 1. *Fargesia chigar* Stapleton **sp. nov.**

Species ligulis longissimis laminis angustis a speciebus nobis notis bene distincta. Culmis ascendentibus, vaginis culmorum tenuis a *F geduensi* mihi similis.

NEPAL : Kaski district, Pipar, *Stapleton* 315 (**holo.** E)

Local name *chigar*.

Well distinguished from all the known species by its very long ligules and its narrow leaves. Similar to *F geduensis* in its curving culms and thin culm sheaths.

##### 2. *Fargesia emeryi* Stapleton **sp. nov.**

*Fargesia macclureana* (Bor) Stapleton affinis, sed laminis glabris, vaginis foliarum sine setis oralis, lemmatis gracilioribus vel glabris ad marginem breviter pubescentibus differt.

NEPAL : Sankhuwasabha district, Younglay 27°44', 87°12', *Emery* 54 (**holo.** K). Sankhuwasabha district, Dore 27°43' 87°16' *Emery* 10.

Local name *kalo nigalo*.

Similar to *Fargesia macclureana* but with glabrous leaves, leaf sheaths without oral setae, and narrower flowering glumes shortly pubescent or glabrous towards their margins.

This species is not well known and good culm sheaths have not been collected. It had previously been identified as *Arundinaria pantlingii* Gamble, a species which is now better known, having been found to occur widely in Bhutan.

### 3. *Fargesia geduensis* Stapleton **sp. nov.**

Basibus culmorum ascendentibus, vaginis culmorum tenuis a *F chigar* mihi similis, sed ligulis brevioribus, laminis foliarum latioribus differt. A *F bhutanensis* mihi laminis glabris, culmis haud farinosis, setis oralis scabrosis differt.

BHUTAN: Chukha, Gedu, *Stapleton* 904 (**holo.** Herb. For. Dept. Taba)

In its upwardly curving culm bases and its thin culm sheaths similar to my *F chigar*, but differing in its shorter ligules and broader leaves. Differing from my *F bhutanensis* in its glabrous leaves, culms without wax, and distinctly scabrous oral setae.

### 4. *Fargesia bhutanensis* Stapleton **sp. nov.**

*Fargesia macclureana* (Bor) McClure affinis, sed omnibus partibus grandibus, glumis et lemmatis longioribus brevius pubescentibus, vaginis foliarum haud auriculis, setis oralis vaginarum foliarum glabris differt; a *Fargesia grossa* Yi internodiis farinosis, laminis foliarum longioribus subtile pilosioribus distinguitur.

BHUTAN: Tongsa district, Dorji Gompa *Stapleton* 412 (**holo.** Herb. Forestry Dept. Taba); 854. Tongsa district, Nobding 2700m *Stapleton* 867 Taba.

Local name *rhui* (Tongsa dialect), *baa* (Dzongkha).

Similar to *Fargesia macclureana* but larger, with longer more shortly pubescent glumes and paleas, leaf sheaths without auricles, glabrous leaf sheath oral setae; distinguished from Yi's *Fargesia grossa* by its waxy internodes and longer leaves which are more hairy underneath.

## 5.5 *Cephalostachyum* Munro in Trans. Linn. Soc. 26: 138 (1868)

### 5.5.1 Generic status

Along with two other little known Himalayan genera *Pseudostachyum* Munro, and *Teinostachyum* Munro this genus has received little attention since its description.

According to Gamble, (1896), Kurz had considered that *Teinostachyum* should be merged with *Cephalostachyum*, but Gamble maintained the separation between the genera in his treatment of the Indian bamboos.

According to Holttum (1956a), *Cephalostachyum*, *Teinostachyum*, and *Pseudostachyum* should be merged with the Malaysian genus, *Schizostachyum*. Unfortunately he did not give a detailed explanation for this opinion, but the characteristic used by Munro (1868) to separate *Cephalostachyum* and *Teinostachyum* is the same pericarp feature which he decided was not valid for separating *Bambusa* and *Dendrocalamus* in the same paper. Clayton & Renvoize (1986) followed Holttum's suggestion and merged all four genera into *Schizostachyum* Nees. However, Dransfield (1980) considered that *Cephalostachyum*, *Teinostachyum* and *Pseudostachyum* should be kept separate from *Schizostachyum* and still holds this view (pers. com.), after gaining much experience of S E Asian bamboos.

McClure (1966) in his generic key separated *Cephalostachyum* with prominent culm sheath auricles and 2 stigmas, from *Schizostachyum* without prominent auricles and with 3 stigmas. It is not clear what he intended for the intermediate genus *Teinostachyum*, species of which have 2-3 stigmas, and different degrees of auricle development.

From a practical point of view, *Pseudostachyum* with its long rhizomes and very thin-walled culms, and peculiar inflorescences seems to justify

separate generic status. *Teinostachyum* is vegetatively very similar to *Cephalostachyum*, but has a much more open inflorescence, and seems to occupy a different range of ecological habitats, extending to much lower elevations. *Schizostachyum* seems to have more in common with *Teinostachyum* than with the other genera, but *Schizostachyum* has no representatives in the Himalayas, and has not been considered in this work.

There are not sufficient species in the Himalayas to allow detailed comparisons of vegetative and floral branching as undertaken in the *Bambusinae* and *Thamnocalaminae*, and flowers of *Teinostachyum* and *Pseudostachyum* have not been found for dissection. Such detailed investigations would be necessary before any new treatment of these genera could be proposed.

### 5.5.2 Species encountered in Nepal and Bhutan

No representatives of *Cephalostachyum* or *Teinostachyum* have been encountered in Nepal during this work, although a species of *Cephalostachyum* has been collected once from Phulchowki, near Kathmandu, (Godawari herbarium). This species no longer seems to exist on that mountain, or in the villages around it. The usual local name for these bamboos (ghopi bans) is locally known, but it usually refers to *Dendrocalamus patellaris* Gamble. This suggests that representatives of these genera are very rare indeed in Nepal. Destruction of their natural habitat by cultivation of marginal land and overgrazing of forest may have resulted in their elimination.

One species is common in wet cool subtropical forests across most of Bhutan. This species is clearly *Cephalostachyum fuchsianum* Gamble. Unfortunately Gamble's *C fuchsianum* is very similar to three of Munro's species from the eastern Himalayas and the hills of Assam, which all have priority over it. It usually has the rounded inflorescences of *C capitatum* Munro, and these are often pale, as in *C pallidum* Munro, when they have not been exposed to the cold which makes them purple-brown in colour. In addition the leaves are often very broad, as in *C latifolium* Munro. The leaf sheaths can be extremely confusing, some branches having sheaths with prominent distinctive fimbriate mouths, while others on the same plant have

no oral setae. Gamble used this as one of the characteristics to distinguish between *C latifolium* and his *C fuchsianum*.

Therefore, while the name *Cephalostachyum fuchsianum* Gamble can be given to the Bhutanese material perfectly accurately, it seems likely that Munro's species such as *C capitatum* are likely to take precedence over that name when enough material has been collected for a full revision to be made.

### 5.5.3 Enumeration of species in Nepal and Bhutan

#### 1. *Cephalostachyum fuchsianum* Gamble in Ann. R. B. G. Calcutta 7: 107 (1896)

BHUTAN: Chukha, Gedu. Gaylegphug, 1500-1800m. Punakha, Tashitang.

Local names *ghopi bans* (Nepali), *jhi?* (Dzongkha).

### 5.6 *Teinostachyum* Munro in Trans. Lin. Soc. 26: 142 (1868)

#### 5.6.1 Generic status

This genus differs florally from the previous genus in approximately the same manner that *Bambusa* differs from *Dendrocalamus*. The pseudospikelets are longer with extended rhachilla sections, giving a more open panicle than the congested heads found in *Cephalostachyum*. A cursory examination of material at Kew suggested that similar distinctions in prophyll keeling to those shown in *Dendrocalamus* and *Bambusa* may also be present.

Camus (1922) proposed a genus *Neohouzeoua*, and transferred two species with filaments united in a tube from *Teinostachyum*, including the common Bhutanese species *T. dulloa*. Holttum (1946), however, stated

that the presence of a filament tube is not by itself a satisfactory character for the distinction of a genus. Although Dransfield (1980) recognised *Neohouzeoua*, Clayton and Renvoize, (1986), Soderstrom and Ellis, (1988), and Campbell, (1988), have not recognised it.

### 5.6.2 Species encountered in Nepal and Bhutan

No species have been encountered in Nepal. One species has been found in Bhutan. This species is clearly the species named by Gamble as *T dullooa*, but as in *Cephalostachyum* the distinctions between Gamble's species and the species previously described by Munro, in this case *T helferi* (Munro) Gamble from the Assam hills, are not very clear, so that further synonymy is possible.

As in *Cephalostachyum* the collections upon which Munro based his species were not entirely satisfactory, so that it is difficult to proceed further until better material has been collected in the Assam hills. Meanwhile the name *Teinostachyum dullooa* Gamble is satisfactory, especially as the local name for this bamboo is *dal* in Assam and Bangladesh.

### 5.6.3 Enumeration of species

**1. *Teinostachyum dullooa*** Gamble in Ann. R. B. G. Calcutta : 101  
(1896)

Syn.: *Neohouzeoua dullooa* (Gamble) Camus in Bull. Mus. Hist. Nat.  
28: 100 (1922)

BHUTAN: Gaylegphug, 500m. Deothang, Nirpong, 1900m. Punakha,  
Tashitang 1700m

Local names *tokhre bans* (Nepali), *dal* (Assam).

**5.7 *Ampelocalamus*** Chen, Wen & Sheng in Acta Phytotax. Sinica. 19  
(3): 332 (1981)

**5.7.1 Generic status**

The semi-scandent habit of these species sets them off from the other genera in the subtribe which are all fully self-supporting. The culm apices are thin and flexible with long internodes, and sometimes reach right down to the ground. In *A patellaris* the culm nodes bear a corky collar, which can assist in supporting the culms on tree branches, as in *Dinochloa* species. Branches are strongly geniculate at nodes close to the culm to facilitate reorientation towards changing sources of light in the tree canopy. Mid-culm branches are initially fewer than in other genera in this subtribe, having aerial roots on the larger branch bases, which can consequently be used for vegetative propagation. All branch buds on the culms are closed at the front, while other genera in the subtribe have open mid-culm buds, although *Fargesia* species have closed buds at the culm base.

Clayton and Renvoize, (1986) placed these bamboos in their mixed assortment of bamboos included under the genus *Sinarundinaria* Nakai. Soderstrom and Ellis, (1988) and Campbell, (1988) recognised *Ampelocalamus* as a separate genus.

**5.7.2 Species encountered in Nepal and Bhutan**

Chen, Wen and Sheng initially described the genus *Ampelocalamus* with six species restricted to China proper. However there are obvious similarities between the Chinese species described and the Himalayan bamboo *Dendrocalamus patellaris* which was incorrectly included by Gamble (1896) in *Dendrocalamus* on the basis of flowers of *Dendrocalamus hamiltonii* sent to him as flowers of the species to be described as *D patellaris* by a Sri Gopal Bannerjee.

The closest species, *A scandens* Hsueh & Yi, comes from Yunnan, and it is surprising to find a species so far away from the rest of the genus. Most of the clumps seen in Nepal are in cultivation, so it may have been brought from China, but if that is the case it must have happened a long time ago as it is quite widespread in Nepal.

The inflorescence of *A scandens* is not known, so it is not possible to decide whether that species is synonymous with *A patellaris*.

### 5.7.3 Enumeration of species

#### 1. *Ampelocalamus patellaris* (Gamble) Stapleton **comb. nov.**

Basionym: *Dendrocalamus patellaris* Gamble *pro parte*, in Ann. R.B.G. Calcutta 7: 86 (1896) Type: Sikkim, Jungat 4000ft, *Gamble* 10045 (lectotype K, chosen here)

Syn.: *Bambusa patellaris* Kurz *ined*

*Bambusa annulata* Gamble *ined*

*Arundinaria* sp "Type T3" Stapleton in Bamboo in East Nepal, For. Res. & Info. Centre Kathmandu report: 50,52 (1982)

*Chimonobambusa jainiana* Das & Pal in J. Econ. & Tax. Bot. 4(3):1023 (1983) *syn. nov.*

*Drepanostachyum jainianum* (Das & Paul) Majumder in Bull. Bot. Surv. of India 25:235-238 (1985) *syn. nov.*

*Ampelocalamus scandens* Hsueh & Yi in J. Bamboo Research 4 (2) : 1-8 (1985) *syn. nov.*

INDIA: Sikkim, Jungat 4000 ft, *Gamble* 10045, Simonbong, *Kurz* s.n. 1868, Ramti, *Gammie* s.n. 1889. Assam, Massang Parbat, Naga Hills, *Mann's collector Sri Gopal Bannerji* 22655(not flowers!) (All Kew). Kalimpong, *Pradhan* s n (Taba)

NEPAL: Terhathum, 1800m, *Stapleton* 132, Pakhribas, 1750m, *Stapleton* 190, Ilam, *Stapleton* 195.

Local names *nibha* (East Nepal), *ghopi bans* (Pokhara), *lewas bans* (Palpa).

A medium-stature bamboo forming clumps with more or less pendulous habit, not truly scandent. Locally common as a cultivated plant, not known wild in Nepal.

The only flowers known for Gamble's *Dendrocalamus patellaris* (Sri Gopal Bannerji 22655) were considered suspect by Mann, who considered them to represent *Dendrocalamus hamiltonii*, but Gamble decided that they differed significantly from those of *D hamiltonii*, and still used them for his description. The correct flowers were found near Tehratum in East Nepal in 1981, and briefly described and illustrated in 1982 as *Arundinaria* sp Type T3. No published genus was appropriate for this species at that time. Meanwhile in India flowers were also found, and a new species was described and placed in *Chimonobambusa* following Nakai's unfortunate treatment of other Himalayan subtropical species, (1925), then transferred to Keng's new genus *Drepanostachyum*. Illustrations of flowers of *Ampelocalamus luodianensis* and culm sheaths of *A scandens* in 1985 drew attention to the similarities between those species and *Dendrocalamus patellaris* Gamble. Comparison with the type collection of *Ampelocalamus actinotrichus* (Merr. & Chun) Chen, Wen, & Sheng at Kew and duplicates of other species kindly sent to Kew from Nanjing showed that *Ampelocalamus* is indeed the correct genus for this species, despite the surprising geographical disparity. *Ampelocalamus scandens* Hsueh & Yi from Yunnan may be synonymous, but its flowers are not known.

## 5.8 *Thamnocalamus* Munro in Trans. Lin. Soc. 26: 33 (1868)

### 5.8.1 Status of the genus

This well established genus was originally defined on the basis of the sheathing around its compressed inflorescences, and the bracts within them. Studies of vegetative branching have shown that it can be distinguished very clearly from similar genera such as *Fargesia* Franchet by the possession of 2-keeled mid-culm bud prophylls, and the absence of branch replication, leading to fewer branches.

Species of *Fargesia* Franchet and *Himalayacalamus* Keng have often been included in this genus by some authors e.g. Soderstrom, 1979a, 1979b, Clayton & Renvoize, 1986, Chao & Renvoize, 1989, but such genera have single-keeled mid-culm bud prophylls and more branches. *Ampelocalamus* Chen Wen & Sheng is also similar, but has closed 2-keeled mid-culm prophylls and more branches.

Close examination of inflorescences in the subtribe has suggested that the presence of many vestigial buds in the axils of glumes and many bracts at points of inflorescence branching, along with the absence of strong fasciculation or pulvini can be used to separate *Thamnocalamus* from closely related genera, while the degree of compression of the whole inflorescence is less useful.

The retention of what seem to be primitive characteristics in the inflorescence, and the absence of apparently derived characteristics in the vegetative branching system suggest that this genus retains more characteristics of primitive members of the subtribe *Thamnocalaminae* Keng than any other genus. Consequently this genus also seems to be the most closely related to bamboos in subtribes with 6 stamens and iterant inflorescences.

Soderstrom and Ellis (1982), in a discussion of whether certain species from China, South Africa and the Mascarene Islands should be included in

*Thamnocalamus* suggested that such a wide distribution implied that the genus was very old indeed.

### 5.8.2 Species described in the literature

The original description of the genus included two species, both from the Himalayas. One of these has since been transferred to *Himalayacalamus* Keng. The other was later divided into two separate species. A further species described from Tibet seems to belong in this genus although it was initially described as a species of *Fargesia*.

Some species from areas away from the Himalayas have also been assigned to *Thamnocalamus*. Examination of the branching and prophyll characteristics in the collections of these species held at Kew has suggested that some of them are better placed in *Fargesia*, although at least two species from outside the Himalayas do seem to warrant inclusion in *Thamnocalamus*.

#### 5.8.2.1 Himalayan species

Munro assigned *Thamnocalamus spathiflorus* (Trin.) Munro as the type species of his new genus in 1868, and also included his *Thamnocalamus falconeri*, now known as *Himalayacalamus falconeri* (Munro) Keng. Gamble did not recognise *Thamnocalamus* in his monograph of 1896, but he separated out the eastern representatives of *A spathiflora* Trin as *A aristata* Gamble.

The type collection of *A spathiflora* Trin (*Wallich* 5041) came from an unrecorded location in Nepal in 1821, but other collections by Wallich in 1821 came from central Nepal, Kathmandu-Gosainkund area, so it is assumed that this collection also came from central Nepal. The type collections of *A aristata* Gamble came from further east, in Sikkim. Camus, (1913), returned these bamboos to *Thamnocalamus*, where they have remained.

In addition a Tibetan species described as *Fargesia crassinoda* Yi appears from its description, (Yi 1983b), to be a *Thamnocalamus* species. Similar collections have been made in Nepal close to the location of the *T crassinoda* type, and similar plants are in cultivation in the UK.

Thus three binomials have been published for these bamboos, *T spathiflorus* (Trin) Munro, *A aristata* Gamble, and *Fargesia crassinoda* Yi. Table 12 attempts a comparison of the species from their descriptions, but this is difficult because of the inadequacies of the material on which the older descriptions were based, and the lack of flowers for the Tibetan species.

Flowers of *T spathiflorus* and *T aristatus* have been distinguished principally by the width of the sheaths enclosing the inflorescences, and the number of spikelets enclosed. However, the spathes are merely leaf sheaths and the dimensions of both leaves and leaf sheaths are quite variable in these species, and the number of spikelets also seems very variable, especially towards the east. It has been suggested, (McClintock, 1985), that Gamble was not justified in separating two species, and that *T aristatus* should be treated as a subspecies of *T spathiflorus*, but that opinion was based upon a comparison of the plants cultivated in the U.K., where plants called *T spathiflorus* and *T aristatus* are probably all *T aristatus* instead.

#### 4.8.2.2 Non-Himalayan species

*Arundinaria sparsiflora* Rendle from Hupeh province in China, *Arundinaria tessellata* Nees from South Africa, *Arundinaria ibityensis* A Camus from Madagascar, a further unnamed species from Mauritius, and other species from Sri Lanka are all potential candidates for inclusion in *Thamnocalamus*.

*Arundinaria sparsiflora* Rendle has been treated as *Fargesia sparsiflora* (Rendle) McClure, as *Thamnocalamus sparsiflora* (Rendle) Keng, and as a synonym of the type species of *Fargesia* Franchet, *Thamnocalamus spathaceus* (Franchet) Soderstrom.

<i>A spathiflora</i> Trin sensu Gamble	<i>F crassinoda</i> Yi	<i>A aristata</i> Gamble
---	---------------------------	-----------------------------

**culm sheath :-**

outline	symmetrical	symmetrical	symmetrical
hairs	glabrous	glabrous	sparse
auricles	?	none	?
oral setae	few	none	few (6-8)
margins	ciliate	ciliate	?

**leaf sheath :-**

callus	ciliate	?	shaggy
--------	---------	---	--------

**inflorescence :-**

spathes	narrow	?	broad
palea	short	?	long

table 12 Comparison of Himalayan *Thamnocalamus* species from the literature

It is possible to separate *Thamnocalamus* species from those of *Fargesia*, *Himalayacalamus*, etc. by their branching patterns and prophyll characteristics. The type collection of *A sparsiflora* Rendle Keng, Henry 938 BM, has branching which is very similar to that of *F spathacea*, *murielae*, and *nitida* with single-keeled prophylls. Therefore it seems that *A sparsiflora* Rendle should be treated as a species of *Fargesia* Franchet as suggested by McClure, rather than as a species of *Thamnocalamus*.

*Arundinaria tessellata* Nees, from southern Africa, also has the branching and prophyll characteristics of *Fargesia* species, with branch axes lacking subtending sheaths. Soderstrom and Ellis (1982) analysed the branching of *A tessellata* in detail and actually noted the absence of sheaths. However they did not compare this to the branching in the type species *Thamnocalamus spathiflorus* nor to the branching in *Sinarundinaria nitida*. Presumably they did not consider branching to be of generic significance. Instead they concentrated their comparative studies on leaf anatomy, finding that *A tessellata* shared 10 characters out of 11 studied with *T spathiflorus*, which was enough for them to conclude that *A tessellata* was a *Thamnocalamus* species. However, from their own results it can be seen that it also shared 7 characters with *Sinarundinaria nitida*, (syn of *Fargesia nitida*) and shared only 5 characters with *Thamnocalamus aristatus*. Moreover, *T spathiflorus* and *T aristatus* only had 6 characters out of 11 in common themselves.

This suggests that the anatomical characters which they were using were of more use at the specific level than the generic level. Their results do not seem to be sufficient to establish *A tessellata* as a *Thamnocalamus* species. If *Thamnocalamus* and *Fargesia* are separated on the grounds of branching and prophyll characteristics, then it would appear that *A tessellata* is a species of *Fargesia*. If greater priority is given to leaf anatomy than to branching, then this could also lead to *T spathiflorus* and *T aristatus* being placed in different genera.

They also considered *A ibityensis* Camus from Madagascar to be synonymous with their *Thamnocalamus tessellatus* (Nees) Soderstrom & Ellis, although the branching is manifestly different from that described for *A tessellata*, with no replicated axes and with all sheaths present and clearly visible. This bamboo evidently cannot be conspecific with *A tessellata* Nees,

which their own diagram shows to have a very different branching pattern, and it would seem more likely to be a species of *Thamnocalamus*.

A further bamboo from Mauritius also has all branch sheaths present, but looks substantially different from the Madagascan species, (Vaughan, no A/139 Jan 87). This may be a further *Thamnocalamus* species.

Thus in addition to the three Himalayan species described, there seem to be at least two further species, well separated from the main distribution of the genus. As Soderstrom and Ellis remarked, (1982), bearing in mind the chronology of plate tectonic movements in the region, this suggests that the genus is very old indeed.

### 5.8.3 Variation seen in the Himalayas

Collections available for study are from N W India, (Himachal Pradesh), to eastern Bhutan, but with little material available from western Nepal. Considerable variation in important floral and vegetative characteristics can be seen. All collections are clearly congeneric, with similar clump and culm form and similar texture and approximate shape of culm sheaths. Branch and prophyll characteristics separate them clearly from species of other genera.

The characteristics of the flowers known are given in table 13 . The vegetative characteristics are presented in table 14 , arranged approximately according to the latitude at which they were collected. Locations of collections from Nepal and Bhutan are given in fig 63 .

The flowers found show substantial differences, suggesting that there is definitely more than one species in this group. The type of *A spathiflora* Trin, Wallich 5041 from central Nepal has cylindrical florets with slightly scabrous flowering glumes, which enclose the palea and rachilla well and are closed at the base by overlapping margins. In contrast, those of *T aristatus* Gamble from Sikkim are more boat-shaped,

1>

collection	24341	308	5041	Gammie	804	413
representing		T26	spathiflorus	aristatus	T44	T44
latitude	c. 77°	83.9°	c 85°	88.5°	89.7°	90.6°
lemma length	12-22 mm	23-33 mm	10-14 mm	12 -15 mm	11-16mm	11-19 mm
" scabridity	slight	slight	slight	dense	dense	dense
" base	open/closed	closed	closed	open	open	open
rachilla	scabrous	scabrous	pubescent	scabrous	scabrous	scabrous
palea back	scurfy	glabrous	scabrous	scabrous	scabrous	scabrous
width of spathes	5 - 7 mm	5 - 9 mm	4 - 6 mm	8 - 10 mm	5 - 8 mm	4 - 8 mm

table 13 Details of *Thamnocalamus* flowers from examination of field and herbarium material

2>

type	Gamble	spa <sup>1</sup>	T26	T26	cra <sup>3</sup>	T36	T36	T36	ari <sup>2</sup>	T51	T44	T44		
coll no	23470		308	892		326	355	363		871	803	851		
latitude	78°?	?	83.9		85.9	85.3		85.4	86.4	85.1	88.5	89.9	89.7	90.6
thick culm wax	●	-	●	?	●	●	●	-	-	-	●		●	
c sheath:- asymmetry	●	?	-	-	-	-	-	-	-	-	●		●	
hairs	-	?	-	-	●	●	●	●	●	●			●	
edge ciliation	●	?	-	-	●	●	●	-	-	-	-		-	
auricles	●	?	-	-	-	●	●	?	●	●			●	
leaf sheath:- hairs	-	-	●	●	-	-	-	-	-	-	-		-	
oral setae	●	-	-	-	-	-	●	●	●	●			●	
ligule ciliation	-	-	-	-	●	●	-	-	-	-	-		-	
edge ciliation	●	-	-	-	-	-	●	-	-	-	-		-	
swollen nodes	-	-	-	-	●	-	-	-	-	-	-		-	
large branches	-	-	-	-	●	-	-	-	-	-	-		-	
small leaves	-	-	-	-	●	●	●	-	-	-	-		-	

( ● present, - absent, ? not known )

<sup>1</sup> *Arundinaria spathiflora* Trin Wallich 5041      <sup>2</sup> *Arundinaria aristata* Gamble Gammie s.n.

<sup>3</sup> *Fargesia crassinoda* Yi

table 14 Variation in some vegetative characters of *Thamnocalamus* collections with latitude

with more densely scabrous flowering glumes with longer awns and open bases, the margins gaping to reveal the rachilla and palea.

Flowers collected to the west of the type of *T spathiflorus* (eg Gamble 24341 from Uttar Pradesh) are very similar to those of the type, differing in the possession of rachilla segments with bristles of c 0.1 mm which make the rachilla segments scabrous, rather than the pubescence of c 0.25 mm seen in the type, and longer flowering glumes. The flowers of the type are not accompanied by good vegetative material, but some leaf sheaths are present, and they definitely have no oral setae at all, whereas those from further west all have stout persistent setae. Both those with and without oral setae have completely glabrous culm sheath backs, and this seems to be the best way of distinguishing *Thamnocalamus spathiflorus* from *T aristatus* without flowers, see table 14.

Therefore within *Thamnocalamus spathiflorus* (Trin) Munro sensu Camus, two taxa are distinguishable, both with cylindrical florets. The first, only known from North-West India, has prominent oral setae, while the second, from Nepal has no oral setae. The similarity in their flowers suggests that they do not justify separate specific status. As they seem to come from geographically distinct areas, subspecies are proposed, rather than varieties.

This treatment is not entirely satisfactory, as some peculiar collections still remain within these subspecies. One collection from west Nepal (*Stapleton* 308) differs in having much longer flowering glumes. The flowers found are old but seem to have full-sized yellow instead of purple anthers. It has symmetrical glabrous culm sheaths, thick culm wax, and no oral setae on shortly pubescent leaf sheaths. A collection from close by flowering at the same time, however, has normal shorter flowering glumes, and clearly purple anthers, (*Sayers* 2378 BM). A cultivated specimen flowering in the UK also has abnormal flowers with a large number of florets in each spikelet, (Campbell, 1990).

The easternmost collection of *Thamnocalamus spathiflorus* (*Stapleton* 892) comes from Nyalam, Tibet, latitude 85.9°.

Collections from east of 86° all bear more similarities to the type collection of *T aristatus* than to that of *T spathiflorus*, all flowers found having less cylindrical florets which are more boat-like in shape, without overlapping edges at the bases of the flowering glumes. All collections have bristly culm sheath backs. Collections with the vegetative characteristics of Gammie's type collection of *T aristatus*, have been made from Kathmandu to western Bhutan, *Stapleton* 363 & 871. They all seem quite similar, although a specimen from Balutar, East Nepal, *Emery* 54 BM has slightly less scabrous lemmas than the rest.

Central Bhutanese collections differ from those to the east, however, in having culm sheaths which are strongly asymmetrical, while their culms are densely waxy, *Stapleton* 803, & 851. The flowers are quite similar to those of the type, although the awn is slightly less pronounced, *Stapleton* 804 & 413.

Therefore it would seem that a further distinguishable taxon occurs to the east of the range of typical *T aristatus*. Pantling's collections from Mimi-Onchi, Sikkim/Bhutan frontier are similar. As its flowers are not clearly distinguishable from those of typical *Thamnocalamus aristatus* a new species does not seem justified, and as the geographical ranges seem distinct, subspecies again seem more appropriate.

As with *Thamnocalamus spathiflorus* there remain some collections with peculiarities. Griffith made a collection (leaves only) with very pubescent characters near Chapcha, western Bhutan, to which he gave the name, unpublished, of *Arundinaria bhutanica*. Further pubescent collections have not been made. It is possible that in both *T aristatus* and *T spathiflorus* there are peculiar plants where the two subspecies overlap, possibly with hybrid origins.

Around latitude 85-86° several interesting collections have been made, but flowers are not known. They share characters which distinguish them from those to the west and east, but they are surprisingly variable, *Stapleton* 326, 355. These characters include ciliate leaf sheath ligules, substantially swollen nodes with sturdy branches, smaller, narrower leaves, more

pronounced culm sheath shoulders bearing a larger number of longer ciliae or setae, all present to varying degrees in different collections. Most collections have pubescent culm sheaths, (eg Jackson's 1960 collection growing at Kew), but one collection from around 85.5° (Edwards Gosainkund 1973 growing at Benmore under no. 758007) apparently has no bristles on the back of the culm sheath, but clearly ciliate edges. *Polunin* 416 & 1618 BM are similar to *Stapleton* 326.

Several of these characters were described for *Fargesia crassinoda* Yi. These bamboos are of horticultural importance because of the attractively small leaves which some of them possess. Their great variability and characters associated with vigour suggest a hybrid origin. They come from the area where the distributions of *T spathiflorus* and *T aristatus* overlap. The name *T crassinodus* seems appropriate and is useful to label the plants cultivated in Europe, but it is very difficult to separate this as a taxon in the field because of its variability, and the admirably precise description of the type given by Yi, (1983b), requires a little generalisation for the taxon to have much meaning in the field.

The proposed Himalayan taxa are keyed out on vegetative characters. Their approximate distributions are shown in fig 64 .

#### 5.8.4. Enumeration of the Himalayan taxa

**1. *Thamnocalamus spathiflorus*** (Trin) Munro in Trans. Linn. Soc. 26:  
34 (1868)

Basionym: *Arundinaria spathiflora* Trin in Mem. Acad. St. Petersb. VI Sci.  
nat. 1: 617 (1835)

subsp. ***spathiflorus***

NEPAL: Location unknown *Wallich* 5041

TIBET: Nyalam, 3,200m, 85.9°W *Stapleton* 892

Local name *jarbutto*.

**Key to Himalayan *Thamnocalamus* species and subspecies using vegetative characters**

1 Culm sheath top strongly asymmetrical

2 culm sheath back without bristles or bases of fallen bristles  
 ..... ***spathiflorus subsp. occidentalis***

2a culm sheath back with bristles or bases of fallen bristles  
 ..... ***aristatus subsp. bhutanensis***

1a Culm sheath top not strongly asymmetrical

3 culm sheath back without bristles or bases of fallen bristles

4 leaves broad, up to 2 cm wide, culm sheath and  
 leaf sheath margins glabrous, leaf sheaths  
 pubescent at top, culms waxy  
 ..... ***spathiflorus subsp. spathiflorus***

4a leaves narrow, < 8mm wide, or culm or leaf sheath  
 margins strongly ciliate, or leaf sheath ligule strongly  
 ciliate,  
 or nodes substantially raised with strong branches  
 ..... ***crassinodus***

3a culm sheath back with bristles or bases of fallen bristles

5 leaves up to 9 cm long, up to 1 cm wide, culm sheath and  
 leaf sheath margins glabrous, culms not waxy  
 ..... ***aristatus subsp. aristatus***

5a leaves < 8 cm long, < 8mm wide, or culm or leaf sheath  
 margins strongly ciliate, or leaf sheath ligule strongly  
 ciliate,  
 or nodes substantially raised with strong branches  
 ..... ***crassinodus***

2. **Thamnocalamus spathiflorus** (Trin) Munro in Trans. Linn. Soc. 26:  
34 (1868) subsp. **occidentalis** Stapleton **subsp. nov.**

Subspecies typica affinis, sed setis oralis vaginarum foliarum crassis, vaginis culmorum asymmetricis differt.

INDIA: Uttar Pradesh, Kedarkanda? *Gamble* 24341 (**holo.** K). Himachal Pradesh, Narkanda? Simla? 9,500ft *Gamble* 6075A.

Differs from the type subspecies in its stout oral setae on the leaf sheaths and its asymmetrical culm sheaths.

3. **Thamnocalamus aristatus** (Gamble) Camus in Les Bambusees: 54  
(1913)

Basionym: *Arundinaria aristata* Gamble in Ann. R.B.G. Calcutta 7: 18  
(1896)

Syn.: *Thamnocalamus spathiflorus* (Trin) Munro subsp *aristatus* (Gamble)  
McClintock in Moorea 4: 20 (1985)

subsp. **aristatus**

INDIA: Sikkim, Phalut, *Gammie* s. n. May 1890 (lectotype K)

NEPAL: Kathmandu, Daman, *Stapleton* 363. Dolakha district, Marbu,  
3200m, *Stapleton* 355.

BHUTAN: Thimphu, Dorchula, *Stapleton* 871.

Local name *rato nigalo*.

4. **Thamnocalamus aristatus** (Gamble) Camus in Les Bambusees:  
54 (1913) subsp. **bhutanensis** Stapleton **subsp. nov.**

Subspecies typica vaginis culmorum asymmetricis, internodis culmorum juvenis dense farinosis differt.

Basionym: *Arundinaria aristata* Gamble in Ann. R.B.G. Calcutta 7: 18 (1896)

BHUTAN: Gasa, Koena, *Stapleton* 804 (**holo.** Herb. For. Dept. Taba); *Stapleton* 803. Tongsa, Yotong La, *Stapleton* 851; 413.

Local name *hum*.

Differs from the type subspecies in its asymmetrical culm sheaths and its densely waxy young culm internodes.

### 5. *Thamnocalamus crassinodus* (Yi) Stapleton **comb. nov.**

Basionym: *Fargesia crassinoda* Yi in J. Bamboo Research 2 (2) : 24-27 (1983) Type *Li Yanlan & Da Tunzhu* 1 (holotype in Herb. Forestry School of Sichuan Province)

TIBET. Zheng Xing, Gyirong Xian, 2,900m, *Li & Da* 1

NEPAL. Gore Tabela, Langtang, 3,450m, *Stapleton* 326.

Local name *ghunre nigalo* (Nepali).

A variable species, possibly a hybrid between *Thamnocalamus spathiflorus* and *Thamnocalamus aristatus*, distinguished by its relatively swollen nodes, and often having unusually small narrow leaves.

### 5.9 *Drepanostachyum Keng* in J. Bamb. Res. 2 (1) : 15 (1983)

#### 5.9.1 Generic status and separation

After Japanese *Arundinaria* species had been studied, and several new genera described for the species previously placed in that genus (Makino, 1914, 1918, 1920) it became clear that the Himalayan *Arundinaria*

species also did not all belong in that genus, having different forms of rhizome. Nakai transferred several of them to *Chimonobambusa*, (1925), but that genus is actually even less appropriate than *Arundinaria*, having the wrong type of inflorescence as well as the wrong form of rhizome.

Nakai later described *Sinarundinaria* for two Chinese temperate bamboos, but he was not very familiar with the species he included in it, incorrectly assuming them to have leptomorph rhizomes. Clump-forming subtropical bamboos have recently been transferred into Nakai's *Sinarundinaria* by Chao & Renvoize, 1989, although new genera published in China had seemed more suitable for these Himalayan bamboos to others, e.g. Keng 1982-3, Majumder 1985, Stapleton 1987, Soderstrom & Ellis 1988, Campbell 1988.

Field and herbarium studies have shown that the subtropical genera can easily be distinguished from the temperate genera *Thamnocalamus* and *Fargesia* without flowers, by the possession of much shorter mid-culm prophylls and bud-scales, and a larger number of branch initials, which do not normally develop into full-size branches in the year of culm emergence. Florally they differ in having no vestigial buds in the axils of the empty glumes basal to the spikelets, and these glumes are very fragile and more deciduous. The inflorescences are strongly fasciculated panicles or panicles reduced to racemes. The panicles have (or had) many more orders of branching than those seen in *Thamnocalamus* or *Fargesia*. Unlike *Yushania*, *Arundinaria* and some *Fargesia* species they have no pulvini in the axils of inflorescence branches.

Detailed field investigations into branching and bud details in the Himalayas reported elsewhere, along with studies of inflorescences, have suggested that *Sinarundinaria* Nakai is best treated as a synonym of *Fargesia* Franchet, and that the clump-forming subtropical bamboos are best placed in the two genera described by Keng in 1983, *Drepanostachyum* and *Himalayacalamus*.

Keng distinguished *Drepanostachyum* species from *Himalayacalamus* species by the presence of more than one floret in each spikelet. Field studies have shown other morphological and ecological characteristics which separate these two genera. The most useful is the characteristic

described by Gamble for *Arundinaria falcata*, (1896), the scabrous upper region of the culm sheath interior, and the interior surface of the ligule. This region is more or less scabrous in all Himalayan *Drepanostachyum* species seen so far, and apparently smooth in all other genera.

*Drepanostachyum* species are mostly forest understorey plants of the warm broadleaved forest types such as *Schima-Castanopsis*, although a few species are also widely cultivated. They do not occur below 500m, where absolute maximum temperatures rise to 40°C, and their leaves are not tolerant of either hard frosts or strong UV light so that they are generally replaced by species of *Himalayacalamus* above about 2,200m.

### 5.9.2 Species encountered in Nepal & Bhutan

*Drepanostachyum* species occur mainly between 850m and 2000m across the length of the Himalayas. This covers a mosaic-like habitat, repeatedly interrupted by dry river valleys and cold mountain ridges. Not surprisingly there is a great deal of variation, and many species can be found, although most of them are rare and presently of little importance. They are not hardy in cultivation in temperate climates, and unless they are common or widely cultivated in the Himalayas they are not covered in this work.

In Eastern Nepal *D intermedium* is widely cultivated and also frequent in the remaining warm broadleaved forest. It is clearly distinguishable by its densely hairy leaf sheaths and abaxial leaf surface, and its reflexed leaf sheath auricles with widely spreading setae. This bamboo has been seen as far east as Dagana in southern Bhutan. In central and west Nepal this is replaced by *Himalayacalamus fimbriatus* as the commonly cultivated small bamboo.

In Chukha district of southern Bhutan a different species is common, distinguished by its ring of hairs around the culm sheath base. This seems to be a new species, named here as *D annulatum*.

In Wangdi and Punakha districts of central Bhutan the *Drepanostachyum* species has neither the hairy leaves and leaf sheaths of *D intermedium* nor the ring of hairs of *D annulatum*. It has persistent but small leaf sheath auricles and a distinctively pubescent leaf sheath ligule, glabrous culm sheaths, and glabrous undersides to the leaves. *D khasianum* (Munro (Keng) from the hills of Meghalaya was not described well, but this species seems to fit its description approximately, so it is identified as *D khasianum* until a better comparison can be made. Chao & Renvoize reduced *D khasianum* (Munro) Keng to a synonym of their *Sinarundinaria falcata*, but the implied range of that species, from Pakistan to Meghalaya and even Tamil Nadu, seems rather unlikely for a bamboo in this genus. Further collections and field studies are required in India.

In west Nepal around Pokhara a species with a very long leaf sheath ligule is also cultivated. This species is distinct from the long-liguled species from West Bengal named *Arundinaria polystachya* Kurz ex Gamble, which has discernible tessellation, a very unusual feature in *Drepanostachyum* species. *D falcatum* (Nees) Keng also has a long ligule, although apparently not usually as long as the ligule in this area. As the flowers of this bamboo have not been found, it is included in *D falcatum*. Better collections are required from India.

In Chirang district of southern Bhutan the commonly cultivated small stature bamboo is not a *Drepanostachyum* species, but *Himalayacalamus hookerianus*.

### 5.9.3 Enumeration of principal *Drepanostachyum* species from Nepal and Bhutan

#### 1. *Drepanostachyum intermedium* (Munro) Keng in J. Bamboo Res. 2(1): 18 (1983)

Basionym: *Arundinaria intermedia* Munro in Trans. Linn. Soc. 26: 28 (1868)

Syn.: *Chimonobambusa intermedia* Nakai in J. Arn. Arb. 6: 151 (1925)  
*Sinarundinaria intermedia* (Munro) Chao & Renvoize in Kew Bull. 44(2): 357 (1989)

NEPAL: Dhankuta, Pakhribas, *Stapleton* 110. In widespread cultivation.

BHUTAN: Dagana, Daga Dzong (in cultivation).

Local name *tite nigalo*, (Nepal).

#### 2. *Drepanostachyum falcatum* (Nees) Keng in J. Bamboo Res. 2(1): 17 (1983)

Basionym: *Arundinaria falcata* Nees in Linn. 9: 478 (1834)

Syn.: *Chimonobambusa falcata* (Nees) Nakai in J. Arn. Arb. 6: 151 (1925)  
*Sinarundinaria falcata* (Munro) Chao & Renvoize in Kew Bull. 44(2): 357 (1989)

NEPAL: Darchula, *Blake* 1. Palpa, Bhairabsthan, *Stapleton* 369. Kaski, Naudanda, *Stapleton* 313.

Local name *diu nigalo*, *sano nigalo*.

**3. *Drepanostachyum khasianum* (Nees) Keng** in J. Bamboo Res.  
2(1): 18 (1983)

Basionym: *Arundinaria khasiana* Munro in Trans. Lin. Soc. 26: 14 (1868)

Syn.: *Chimonobambusa khasiana* Nakai in J. Arn. Arb. 6: 151 (1925)  
*Sinarundinaria intermedia* (Munro) Chao & Renvoize in Kew Bull.  
44(2): 357 (1989) *pro parte*

BHUTAN: Gasa, Geon Damji, *Stapleton* 808 (Herb For Dept Taba).  
Wangdi Ph., Thinleygang. Wangdi Ph., Wacha.

**4. *Drepanostachyum annulatum* Stapleton *sp. nov.***

*Drepanostachyum khasianum* (Munro) Keng affinis, sed annulatis pilosis circumcirca fundos vaginarum culmorum differt.

BHUTAN: Chukha, Taktichu, *Stapleton* 713 (**holo.** Herb. For. Dept, Taba). Chukha, Chukha, *Stapleton* 898 (Taba).

Close to *Drepanostachyum khasianum* (Munro) Keng but differing in its ring of hairs all around the base of the culm sheaths.

Local name *him* (Dzongkha), *nigalo* (Nepali).

## 5.10 *Himalayacalamus* Keng in J. Bamboo Res. 2 (1): 23-25 (1983)

### 5.10.1 Generic status and separation

This genus was described in 1983 for a single subtropical clump-forming species with single-flowered spikelets, previously known as *Thamnocalamus falconeri* Munro. Although subtropical clump-forming genera are clearly distinct from temperate clump-forming genera such as *Thamnocalamus* and *Fargesia* on both vegetative and floral characteristics, no appropriate genera had been described for them until 1983, when Keng described both *Drepanostachyum* and *Himalayacalamus*.

*Himalayacalamus* was described as having only one complete floret in most spikelets, and many sheaths at the base of each raceme. *Drepanostachyum* species have two or more complete florets in most spikelets, and branches in all or most of the sheaths so that the inflorescence is more paniculate. Thus *Himalayacalamus* inflorescences can be considered as reduced versions of the *Drepanostachyum* inflorescence.

Relating vegetative characteristics to this floral distinction was difficult with only one species, but while Keng originally described *Himalayacalamus* as a monotypic genus, many other taxa with strong similarities to *H falconeri* have been encountered in the Himalayas. In addition Yi has described a *Fargesia* species from Tibet which would appear to be better placed in *Himalayacalamus*, as would *Drepanostachyum hookerianum* (Munro) Keng, giving a total of around eight species so far. This allows a more satisfactory consideration of the agreement between floral and vegetative characters, and consequently strengthens the justification for recognising *Himalayacalamus*.

*Himalayacalamus* species are all a little larger than those of *Drepanostachyum*, up to 3.5 cm rather than 2.5 cm dbh, and they occupy a different ecological habitat, 1850 - 2800m rather than 1000 - 2200m, having greater tolerance of light frosts and strong UV light, but less tolerance of drought. Their branches are fewer, up to 30, rather than 80, and show greater disparity in size. The culm sheaths are usually wide at the top with strongly convex attenuation, and a broad short ligule, although *H hookerianus* is an exception to this rule. The interior of the ligule and the

interior of the sheath immediately below it are smooth, while in *Drepanostachyum* they are distinctly scabrous. Leaf sheath ligules are pubescent, and new shoots are often edible, lacking the bitter flavour found in shoots of *Drepanostachyum* species. The leaves are usually smaller, and in conjunction with the fewer branches, lead to more upright culms and clumps with a more graceful appearance. The increase in internode length at the base of the culm is more gradual, and there is a greater tendency for nodes towards the base to have no buds or branches.

Recent revisions of bamboo genera have considered *Himalayacalamus* to be synonymous with either *Thamnocalamus*, (Chao & Renvoize, 1989), or *Drepanostachyum* when that genus is recognised, (Soderstrom 1988, Campbell 1988).

Although many *Himalayacalamus* species are not of any economic importance in the Himalayas, there is potential for introducing them elsewhere as ornamental plants. The genus is tolerably hardy in warmer parts of Europe and the USA, and at least two species are already in cultivation there.

### 5.10.2 Taxa encountered in Nepal and Bhutan

According to Keng, (1983), and Gamble, (1896), identification in this genus should be simple, as it is supposedly monotypic with the one species restricted to Nepal. However, several different varieties of that species have been encountered, across Bhutan as well as Nepal, and several other species have also been found. To complicate matters further the Wallich holotype of Munro's *A falconeri* has neither good vegetative material nor a record of where it was collected. In addition it seems that two further *Himalayacalamus* species have been incorrectly placed in other genera, requiring new combinations.

One common bamboo from central Nepal has flowers which are identical to those of the Wallich holotype of *A falconeri*. This bamboo, found on Phulchowki, near Kathmandu, is selected as the type variety, as Wallich is known to have been in this area around the time the holotype was collected. Another bamboo from the Annapurna region in west Nepal, is

vegetatively quite similar, but is of larger stature with longer internodes which make it a more useful bamboo for weaving. It also has copper-coloured culm sheath ciliae and faint leaf tessellation. It seems best to describe this as a variety of *H falconeri* until its flowers have been found.

Five further previously undescribed Nepalese taxa are more clearly differentiated from the two varieties of *H falconeri*. One comes from central Nepal to the north of the range of *H falconeri*, and has finely ridged culms, erect leaf sheath setae, and scabrous flowering glumes. This is named *Himalayacalamus porcatus*.

The second, from the Annapurna region of west Nepal, has scabrous culm sheaths and spreading setae on falcate auricles. It is found in a belt below *H falconeri* var *cupreiciliatus*. This is named *Himalayacalamus asper*.

A third, from central Nepal, is distinguished by its level culm nodes and its narrow leaves. It also comes from central Nepal to the north of the range of *H falconeri*. It is named *Himalayacalamus aequatus*.

A fourth, also from central Nepal, where it is the only small bamboo in cultivation, has highly distinctive fimbriate culm sheath ligules, and a dense ring of hairs around the culm sheath base. It is named *Himalayacalamus fimbriatus*.

The fifth, common in East Nepal, where it is cultivated in combination with *Drepanostachyum intermedium*, *H hookerianum* and *Ampelocalamus patellaris*, is distinguished by its short culm internodes and its erect culm sheath blades. It has been confused with *Arundinaria hookeriana* Munro in the past, but is clearly a separate species, named here as *Himalayacalamus brevinodus*.

Flowers are not known for the latter four taxa, so that it is not possible to place them in *Himalayacalamus* rather than *Drepanostachyum* with absolute certainty, but the nature of both culm sheaths and branching strongly suggest that they belong in *Himalayacalamus*.

*Fargesia gyirongensis* Yi, a species from Tibet quite close to the location of the central Nepalese ridged-culmed species, *H porcatus*, seems

fairly similar to that species, but the description does not mention ridged culms, which are a distinctive feature of *H porcatus*, nor the flowers. Therefore the ridged-culmed Nepalese bamboo will be described as a new species, and the Tibetan species will be transferred to *Himalayacalamus*. The correct status of these taxa cannot be decided until more comprehensive Nepalese and Tibetan collections have been made and compared.

*Drepanostachyum hookerianum* (Munro) Keng is a distinctive species with strongly glaucous culms. The spikelets usually contain only one fertile floret, which places the species quite clearly in *Himalayacalamus* Keng, rather than *Drepanostachyum* Keng. Most other characters of *Himalayacalamus* species are also present, although the culm sheaths attenuate concavely, while those of other *Himalayacalamus* species are convexly attenuate. However, the inner surface of sheath and ligule are completely glabrous, and the branching is light.

Two further *Himalayacalamus* taxa have been seen in Bhutan. One, from Gedu in south-western Bhutan flowered gregariously last year, so it is difficult to describe its vegetative characteristics adequately. It differs from the geographically closest species *Himalayacalamus brevinodus* from eastern Nepal in its thinner culm sheaths with reflexed blades and white basal pubescence, and from *H falconeri* from Kathmandu in several minor vegetative characteristics which would influence uses and propagation, although its flowers are very similar. It is treated here as a further variety of *H falconeri*, var *geduensis*.

A further collection from Moshi in eastern Bhutan (*Stapleton* 432) also has thin culm sheaths, but they are glabrous, and the central branches are large, often with aerial roots. The culms are smooth with more substantially raised nodes, and the culm sheaths are less convexly attenuate at the top. This taxon has not yet been collected adequately, so it is included in *H falconeri* var *falconeri* until it is better known.

### **5.10.3 Enumeration of the species and varieties known from Nepal and Bhutan**

**1. Himalayacalamus falconeri** (Hook.f.) Keng in J. Bamboo Res.  
2 (1): 24 (1983)

Basionym: *Thamnocalamus falconeri* Hooker f. ex Munro in Trans. Linn.  
Soc. 26:34 (1868)

Syn.: *Arundinaria falconeri* (Munro) Benth. & Hook. f., Gen. Pl. 3:1208  
(1883); Gamble in An. Roy. Bot. Gard. Calc. 7: 20 (1896)

*Fargesia collaris* Yi in J. Bamboo Res.2 (2): 21-24 (1983) **syn.**  
**nov.**

var. **falconeri**

NEPAL: Location unrecorded, *Wallich* 5040 (1821) (holotype K) .  
Kathmandu, Phulchowki, *Schilling* 781 . Kathmandu, Phulchowki,  
*Stapleton* 893; 894; 322; 323; 324; 325. Dolakha, Marbhu, *Stapleton*  
356.

Local names *thudi nigalo* near Kathmandu, and *gorey nigalo* in Dolakha  
district.

The type variety, differing from others in the species by its culms with  
average length internodes of around 20 - 25 cm, its glabrous striped culm  
sheaths, and white marginal culm sheath ciliae.

The holotype has little vegetative material, and its source is unknown,  
but its flowers match those from Phulchowki very well, and *Wallich* was in  
the Kathmandu & Gosainkund area in August 1821, (Wall. Cat 677, *Plantae*  
*Asiaticae Rariores* 2: 81-82), so it is assumed that the type material was  
collected in that area, and represents this variety. The Phulchowki *H*  
*falconeri* has attractive shoots with purple and yellow stripes on the young  
culm sheaths, but no stripes on the culms.

**2. Himalayacalamus falconeri** (Hook. f.) Keng in J. Bamboo Res.  
2 (1): 24 (1983) var. **cupreiciliatus** Stapleton **var. nov.**

A varietate typica internodis longioribus, ciliis vaginarum culmorum cupreis, nervillis transversis distinguibilibus differt. Inflorescentia ignota.

Syn.: *Drepanostachyum* species type T24 Stapleton in Jackson J K (ed) Manual of Afforestation in Nepal : 212 (1987)

NEPAL : Kaski district, Pipar, *Stapleton* 306 (**holo.** E )

Local name in Kaski district is *malinge nigalo*.

Differing from *var falconeri* in its longer internodes of up to 40 cm, its copper-coloured culm sheath ciliae, and the presence of discernible transverse veinlets. Inflorescence not known.

This highly valuable forest bamboo from north of Pokhara in west Nepal is more useful than typical *H falconeri* from central Nepal because of its longer internodes. It grows to large dimensions in this high rainfall area, and the culms are systematically harvested for weaving material, while some edible shoots are also harvested. Its flowers are not known, so it seems best to treat it as a variety of *H falconeri*.

**3. Himalayacalamus falconeri** (Hook. f.) Keng in J. Bamboo Res. 2 (1): 24 , 1983 var. **geduensis** Stapleton **var. nov.**

A varietata typica vaginis culmorum tenuis culmis adhaerentibus, ramo centrali graciliore, culmis subtiliter porcatis, lemmatis basibus longioribus pilosis differt.

BHUTAN: Chukha district, Gedu, *Stapleton* 905 (**holo.** Forestry Dept. Herbarium Taba)

Differing from the type variety in its thinner culm sheaths adhering to the culm, its more slender central branch, its finely ridged culm, and its lemmas with longer hairs at the base.

Found flowering gregariously by the road near Gedu in 1990, this variety has several vegetative differences from typical *H falconeri* from

Kathmandu, but the flowers are very similar. Its distribution and detailed vegetative characteristics are not known.

#### 4. *Himalayacalamus brevinodus* Stapleton **sp. nov.**

*Himalayacalamus falconeri* affinis, sed internodis brevioribus, laminis vaginarum foliarum erectis differt. Inflorescentia ignota.

Syn.: *Drepanostachyum* species T3/2B Stapleton in Jackson J K (ed) Manual of Afforestation in Nepal : 212 (1987)

NEPAL : Dhankuta district, Pakhribas, *Stapleton* 908 (**holo.** E )

Local name in East Nepal is *malinge nigalo*.

Differs from *H falconeri* in having shorter internodes of up to only 20 cm, and erect culm sheath blades. Its flowers are not known.

Cultivated in Terhathum and Taplejung districts in East Nepal, where its culms are highly valued for weaving material. It has often been confused with *H hookerianus*.

#### 5. *Himalayacalamus porcatus* Stapleton **sp. nov.**

*Himalayacalamus falconeri* (Munro) Keng affinis sed internodiis porcatis, setis oralibus erectis, ciliis vaginarum foliarum, lemmis scabris differt.

Syn.: *Drepanostachyum* species Type T29 pro parte Stapleton in Jackson (ed) Manual of Afforestation in Nepal : 212 (1987)

NEPAL : Rasuwa district, Syabru, *Stapleton* 332 (**holo.** E ); 331

Local name *seto nigalo* (Nepali), *bra ma* (Tamang).

A species which differs from *H. falconeri* in its finely ridged culms, its erect oral setae, its ciliate leaf sheaths, and its scabrous lemmas.

A cultivated species which produces larger weaving material than *H aequatus* from the nearby Langtang Khola, but it is not popular as it cuts the hands of those who weave it. It may also occur in forest towards Gosainkund. The malinge nigalo from higher up the Langtang Khola valley was at first assumed to be the same as this, until a better collection showed it to be a separate species, *H aequatus*.

#### **6. Himalayacalamus gyirongensis** (Yi) Stapleton **comb. nov.**

Basionym: *Fargesia gyirongensis* Yi in J. Bamboo Res. 2 (2) : 37-40 (1983)

TIBET : Gyirong Xian 2450 m *Li Yanlan & Da Tunzhu* 2 (type in Herb. For. School of Sichuan Prov.)

From the description and illustration of the buds, branches, and culm sheaths it appears to be much more like *H. falconeri* than any *Fargesia* species. It has oral setae, but no auricles, and culm sheaths which are sometimes basally scabrous, therefore it is similar to *H porcatiss* and *H asper*. Its flowers are not known.

#### **7. Himalayacalamus asper** Stapleton **sp. nov.**

*Himalayacalamus porcatiss* mihi affinis, sed culmis laevibus, vaginis culmorum scabris, setis vaginarum foliarum oralibus divaricatis, auriculis vaginarum foliarum distinguibilibus interdum falcatis, marginibus vaginarum foliarum non ciliatis differt. Inflorescentia ignota.

NEPAL: Kaski district, Pipar, *Stapleton* 314 (**holo.** E). Kaski district, Khare, *Stapleton* 312.

Local name *gorey nigalo*.

Similar to my *H. porcatus*, but with smooth culms, scabrous culm sheaths, spreading oral setae, distinguishable leaf sheath auricles which may be falcate, and glabrous leaf sheath margins. Its flowers are not known.

This bamboo is not of economic importance as its culms do not produce good material for weaving, and it is not harvested. It occurs below the range of *H falconeri* var *cupreiciliatus* in the Seti Khola valley north of Pokhara.

**8. Himalayacalamus hookerianus** (Munro) Stapleton **comb. nov.**

Basionym: *Arundinaria hookeriana* Munro in Trans. Linn. Soc. 26: 29 (1868); Gamble in An. Roy. Bot. Gard. Calc. 7: 16 (1896)

Syn.: *Sinarundinaria hookeriana* (Munro) Chao & Renvoize in Kew Bull. 44(2):358-9

*Chimonobambusa Hookeriana* Nakai in J. Arn. Arb. 6: 151 (1925)

*Drepanostachyum hookerianum* (Munro) Keng in J. Bamb. Res. 2(1): 17 (1983)

INDIA: Sikkim, Yoksum, *Hooker* s. n. 1848 (type K)

NEPAL: Dhankuta district, Hile, *Stapleton* 117.

Local name is *padang*.

This species should be in *Himalayacalamus* Keng rather than *Drepanostachyum* Keng as the spikelets usually contain only one fertile floret. It is cultivated in Koshi and Mechi zones of East Nepal, and Chirang district of Southern Bhutan. It is easily recognised by its blue culms and the strongly attenuated culm sheaths, which are not scabrous within.

**9. Himalayacalamus aequatus** Stapleton **sp. nov.**

A *H. falconeri* (Munro) Keng nodis culmorum infernis aequatis non elevatis, internodis infernis brevioribus, laminis foliarum angustis, a *H brevinodus* mihi laminis vaginarum culmorum reflexis recedit. Inflorescentia ignota.

Syn.: *Drepanostachyum sp.* Type T29 *pro parte* Stapleton **in** Jackson (ed) Manual of Afforestation in Nepal : 212 (1987)

NEPAL: Rasuwa district, Langtang khola, *Stapleton* 328, 918 (**holo** E )

Local names *malinge nigalo* (Nepali), *bar ma* (Tamang).

Separable from *H falconeri* (Munro) Keng by its even unraised lower culm nodes with shorter internodes and its narrower leaves, and from my *H brevinodus* by its reflexed culm sheath blades. Its flowers are not known.

This species is common in the mixed broadleaved forest of the Langtang Khola valley. It was assumed to be the same as *H porcatus* until better material was available for study.

#### **10. Himalayacalamus fimbriatus Stapleton sp. nov.**

*H. falconeri* (Munro) Keng affinis, sed ligulis vaginis culmorum fimbriatis, vaginis culmorum basibus cinnamomeis pubescentibus, ligulis vaginis foliarum longioribus, interdum auriculis setiis vaginarum foliarum juvenis differt.

Syn.: *Drepanostachyum khasianum* Type T21 *sensu* Stapleton **in** Jackson (ed) Manual of Afforestation in Nepal : 212 (1987)

NEPAL: Kathmandu, *Stapleton* 910 (**holo.** E ). Sindhu Palchowk, Chautara, *Stapleton* 337

Local name *tite nigalo*.

Similar to *H falconeri*, but with fimbriate culm sheath ligules, cinnamon-coloured hairs at the base of the culm sheaths, longer leaf sheath ligules, and sometimes with setaceous auricles on the young leaf sheaths.

This species is widely cultivated throughout the middle hills of central Nepal, where it is very intensively harvested from terrace risers and pathsides for weaving material and animal fodder.

## 5.11 *Chimonobambusa* Makino in Bot. Mag. Tokyo. 28: 153 (1914)

### 5.11.1 Generic status

A distinctive and uncontroversial genus with thorny nodes on the upright well spaced culms, sometimes expanded to include those with no thorns but a greatly raised supra-nodal ridge otherwise placed in *Quiongzhuea* Hsueh & Yi. Rhizomes are leptomorph, with culms arising singly from long narrow rhizomes which can continue under the ground indefinitely. Flowers are itercauctant.

Nakai correctly transferred Munro's thorny Himalayan species *Arundinaria callosa* into this genus. He also mistakenly transferred many other thornless clump-forming Himalayan species into it as well. These species are now recognised as species of *Himalayacalamus* Keng and *Drepanostachyum* Keng.

*Chimonobambusa* species are quite closely related to the better known Chinese and Japanese bamboos in the genus *Phyllostachys*. They have similar grooving on one side of the culm, although this is much more marked in *Phyllostachys*, and a branch complement reduced to only three branches at most nodes, while *Phyllostachys* species have only two.

A superficially similar genus found in China, *Chimonocalamus* Hsueh & Yi, has thorny culms arising in clumps from short pachymorph rhizomes, and semelauctant inflorescences. Some of them have edible shoots.

### 5.11.2 Species encountered

Only one species has been found, *C. callosa* (Munro) Nakai. This species is mainly known in Mizoram, Manipur and Meghalaya, but is common in the high rainfall areas of southern Bhutan, and also extends into the upper Mo Chu.

A Himalayan representative of *Chimonocalamus* Hsueh & Yi, *C. griffithiana*, has been described from the Rechi La between Sikkim, Darjeeling and Bhutan, but its rhizomes are not known. It comes from an area where *C. callosa* and *Yushania* species are abundant, and much of the material under *C. griffithiana* in Kew can be attributed to other well-known species, such as *Chimonobambusa callosa*. No clump-forming bamboos with thorns at the nodes were encountered in Nepal or Bhutan during this enumeration.

### 5.11.3 Enumeration of species

#### 1. *Chimonobambusa callosa* (Munro) Nakai in J. Arn. Arb. 6: 151 (1925)

Syn.: *Arundinaria callosa* Munro in Trans. Linn. Soc. 26: 30 (1868)

*Arundinaria griffithiana* Munro in Trans. Linn. Soc. 26: 20

*Chimonobambusa griffithiana* (Munro) Nakai in J. Arn. Arb. 6: 151 (1925)

*Chimonocalamus griffithiana* (Munro) Hsueh & Yi in Acta Bot. Yunnan 1(2): 84 (1979)

*Sinarundinaria griffithiana* (Munro) Chao & Renvoize in Kew Bull. 44(2): 353 (1989)

BHUTAN: Chukha, Gedu, *Stapleton* 881 (Taba).

Local names, *u* (Dzongkha), *rawa* (Kengkha), *khare bans* (Nepali).

### 5.12 *Melocanna* Trinius in Sprengel Neue Entd. 2: 43 (1821)

Syn.: *Beesha* Kunth in J. Phys. Chim. Hist. Nat. 95: 151 (1822)

### 5.12.1 Generic status

This genus has always been clearly defined and well recognised. It has a distinctive pear-sized fruit, extended rhizome necks giving an open clump, and distinctive culm sheaths. Along with other members of the *Melocanninae* it has long hollow styles.

Only one species is well documented, occurring in large stands in the Chittagong Hills, and cultivated in many other districts of Bangladesh. It has been widely planted because of the straightness and strength of its culms, especially near tea estates in Assam, West Bengal, and the Nepalese terai, and in Palpa district of western Nepal. It has probably also been planted in southern Bhutan. A second species from Burma is not well known.

### 5.12.2 Species encountered

One species has been encountered, always as an exotic introduction in areas of tea estate development or where soldiers have returned from duty abroad.

### 5.12.3 Enumeration of *Melocanna* species

**1. *Melocanna bambusoides*** Trin. in Springel Neue Entd. 2: 43 (1821)

Syn.: *Bambusa baccifera* Roxb. in Hort. Bengal 25 (1814)

*Beesha reedii* Kunth in Not. sur genre Bambusa in J. de Phys. (1822)

*Beesha baccifera* Sch. in Syst. Veg. 1336

*Nastus baccifera* Rasp. in Ann. Sc. Nat. 5: 442

NEPAL: Jhapa, Kakarvita, *Stapleton* 878 (Taba).  
Palpa, Dharampani.

Local names *philim bans* (Jhapa), *lahure bans* (Palpa).

### **5.13 *Pseudostachyum* Munro** in Trans. Linn. Soc. 26: 141 (1868)

#### **5.13.1 Generic status**

This genus, which is probably monotypic, can be separated from the other genera in the *Melocanninae* by the combination of long rhizome necks and extremely thin walls. It has small inflorescences which often develop into hairy, curled masses, presumably after attack by insects.

The diffuse thin-walled culms have a form of semi-scandent habit. After growing rapidly through the lower branches of trees and shrubs in a self-supporting manner as tall, delicate, extremely thin-walled shoots, the upper regions of the culms sprawl over the supporting tree branches, the culm often splitting under the weight of its branches.

#### **5.13.2 Species encountered**

Only one species is known. It is encountered in warmer high rainfall areas in association with canes. Destruction of most of its natural habitat may have resulted in its elimination from Nepal.

#### **5.13.3 Enumeration of species**

**1. *Pseudostachyum polymorphum* Munro** in Trans. Linn. Soc. 26: 142 (1868)

BHUTAN: Shemgang, Tingtibi, 950 m, *Stapleton* 708 (Taba).

Local names, *dai* (Kengkha).

**5.14 Neomicrocalamus Keng** in J. Bamboo Res. 2(2): 10 (1983)

Syn: *Microcalamus* Gamble in J. Asiatic Soc. Bengal 59 : (1980) non Franchet 1889.

#### 5.14.1 Status of the genus

This genus of scandent bamboos with 6 stamens can be considered to be separate from the similar Malaysian genus *Racemobambos* Holttum on the grounds of its much broader mid-culm bud-scales with two keels instead of one, and lower number of lateral branches enclosed in much broader sheaths. Campbell, (1988), also keyed the two genera out on the grounds of glume number, with *Neomicrocalamus* having one glume, while *Racemobambos* has two to three.

Clayton and Renvoize (1986), and Chao & Renvoize (1989) included *Neomicrocalamus* in *Racemobambos*.

#### 5.14.2 Species described

The type species, *Neomicrocalamus prainii* (Gamble) Keng was based upon a collection by Prain in Nagaland of a bamboo known locally as Sampit which has solid culms. Collections from Meghalaya (Jaintia) with the local name U-spit were included in *A prainii* Gamble, although they differ in having hollow culms, nodal swellings, and much smoother culm sheaths.

Another species, *Arundinaria mannii* Gamble, from Meghalaya, (Jaintia), also has solid culms. It was also reported as occurring in Arunachal Pradesh, (Burkhill, 1924, cited in Campbell 1988). *A clarkei* (Gamble ex

Brandis) from Manipur is considered synonymous with *A mannii* Gamble (Campbell 1988).

*Neomicrocalamus microphyllus* (Hsueh & Yi) Keng & Wen, from S. E. Tibet has nearly solid culms and very rough sheaths as well as small leaves. Kingdon-Ward also collected this bamboo in the same districts (Medog & Bomi, 95° & 96°). Thus four species are known from around the eastern end of the Himalayas, Tibet and N E India towards Burma.

### 5.14.3 Himalayan representatives

Only one species has been encountered in Nepal or Bhutan, restricted to wetter areas of eastern Bhutan. It matches the collections from Meghalaya (Jaintia) called *U-split* and included by Gamble in his *A prainii*, and it is named here as a new species. As *Arundinaria mannii* Gamble has been reported from Arunachal Pradesh, it may also occur in Bhutan, therefore a new combination is also made here for that species.

### 5.14.4 Enumeration of Himalayan species

#### 1. *Neomicrocalamus ringshu* Stapleton **sp. nov.**

*Neomicrocalamus prainii* affinis, sed culmis fistulosis, vaginis culmorum glabris, nodis ramulorum geniculatis tumidis differt.

Basionym: *Arundinaria prainii* Gamble pro. parte. in Ann. R. B. Gdns. Calcutta 7: 21 (1896)

Syn: *Microcalamus prainii* Gamble nom. illeg. in J. Asiatic Soc. Bengal 59: 207 (1890)

*Racemobambos prainii* (Gamble) Keng & Wen) in J. Bamboo Res. 5(2): 13 (1986)

BHUTAN: Tashigang district, Deothang, Nirpong, *Stapleton* 454a (**holo.** Herb. Bhut. For. Dept. Taba).

INDIA: Meghalaya, Jaintia Hills, Jowai, *Mann* s. n. 1889. (Kew).

Local names *ringshu* (E Bhutan), *ula* (Kengkha), *langma* (Nepali), *u-spit* (Jaintia).

Similar to *Neomicrocalamus prainii* (Gamble) Keng, and included by him in that species, but differing from that species in its hollow culms, glabrous culm sheaths, and swellings on the geniculate branchlet nodes.

This attractive bamboo is highly valuable, having hard shiny flexible culms which are stained and woven into ornamental food containers.

## 2. *Neomicrocalamus mannii* (Gamble) Stapleton **comb. nov.**

Basionym: *Arundinaria mannii* Gamble in Ann. R. B. Gdns. Calcutta 7: 26 (1896)

Syn: *Racemobambos mannii* (Gamble) Campbell ined. (1988)  
*Arundinaria clarkei* Gamble ex Brandis in Indian Trees : 666 (1906)  
*Racemobambos clarkei* (Gamble ex Brandis) Campbell ined. (1988)

INDIA: Meghalaya, Jaintia Hills, *Mann* s. n. 1889 (holo. K)  
 Arunachal Pradesh (Burkhill, 1924)

**5.15 Yushania Keng** in Acta Phytotaxa Sinica 6 (4): 355-360 (1957)

Syn. *Butania* Keng in J. Bamboo Res. 1(2): 41 (1982)

### 5.15.1 Generic status

This genus was established specifically for spreading temperate bamboos with pachymorph rhizomes, with *Y niitakayamensis* from Taiwan as the type species. It is now well accepted that these species are clearly separated from the genus *Arundinaria* which has leptomorph rhizomes which can continue underground growth indefinitely. However, they are still often grouped with clump-forming bamboos of the genera *Fargesia* or *Drepanostachyum*, and the name *Sinarundinaria* is often used in a broad sense to cover some or all of these genera.

Studies of branching and prophyll characteristics have shown finite distinctions between this and other genera which justify its recognition as a separate genus. It is now definable by possession of semelaucant inflorescences with very few bracts and no vestigial buds, a tall single-keeled mid-culm prophyll, 0-1 replicated branch axes on each side of the complement, open-fronted double-keeled bud-scales at the culm base, and pachymorph rhizomes with long necks, many of which are longer than 30 cm. The type species of *Sinarundinaria* Nakai, *S nitida*, is considered here to be a species of *Fargesia* Franchet, so that the name *Sinarundinaria* cannot be used for these bamboos, and *Yushania* Keng is the appropriate generic name for them.

Keng, (1982) described a new genus with thorny culms, *Butania*, apparently on the basis of Gamble's suggestion, (1896), that his *Arundinaria pantlingi* might turn out to be close to the mythical thorny species *Arundinaria griffithii* Gamble, which now seems likely to be synonymous with *Chimonobambusa callosa* (Munro) Nakai. Gamble (1812) reiterated that *A pantlingi* might be thorny at the nodes, but keyed it out on the assumption that it was not thorny. *Yushania pantlingi* in Bhutan is certainly not thorny.

### 5.15.2 Himalayan species described

The only species described at all adequately in the classic monograph of Gamble, (1896), was *Arundinaria pantlingi* Gamble. Confusion between *Arundinaria maling* Gamble and *Arundinaria racemosa* Munro led to improved descriptions in Gamble, (1912) and Camus (1913). The species *A hirsuta*, *A rolloana* and *A microphylla* were only briefly mentioned. The Chinese literature includes two species from Tibet, *Y xizangensis* Yi, and *Y yadongensis* Yi (synonymous with *Y longissima* Yi *nom. illeg.* ).

The characteristics of these species which have been found most useful in separating *Yushania* species in the field are given in table 15 , as interpreted from their descriptions. It can be seen that the Chinese descriptions are the most comprehensive.

### 5.15.3 Variation encountered in Nepal and Bhutan

Five species have been encountered so far in Nepal and Bhutan. The most important characteristics for distinguishing between them are given in table 16 .

*Yushania hirsuta* and *Y pantlingi* are large and vigorous species which often form dense impenetrable thickets and suppress tree regeneration after clearfelling. They are resilient deeply-rooted species which survive in relatively dry sites. They have few uses and are categorised as invasive weeds. They are substantially different in several morphological details, but appear very similar from a distance, and occupy ecologically similar habitats.

*Yushania maling* and *Y microphylla* are usually much smaller stature species. *Y maling* is a common component of the temperate forest understorey in eastern Nepal and southern Bhutan. *Y microphylla* is a similar species, but has hollow rhizomes, while those of *Y maling* are solid. The hollow rhizomes allow *Y microphylla* to succeed on flatter wetter sites than other *Yushania species*, and consequently it forms large

	<i>hirsuta</i> <i>longissima</i>	<i>microphylla</i>	<i>maling</i>	<i>pantlingii</i>	<i>xizangensis</i>	
<b>rhizome</b>	?	?	?	?	solid	hollow
<b>culm sheath base</b>	?	?	?	hair ring	glabrous	glabrous
<b>leaf sheath auricles</b>	large	?	?	?	none	none
<b>leaf margins</b>	?	thickened	?	?	?	?
<b>culm wax present</b>	?	?	?	?	none	
<b>leaf sheath ligule</b> 0.5mm	elongate	v short	?	rather long	1 mm	truncate
<b>max internode lgth: cm</b>	34	?	?	> 19	40	34
<b>type locality</b>	Khasia Yadong Tibet	Bhutan	Sikkim	Darjeeling	Cona	Tibet
<b>latitude</b>	91°	91.5°	88.5°	89°	92°	89°

table 15 Main differences in vegetative characteristics of published species of *Yushania* from around Bhutan from their original descriptions



	<i>hirsuta</i>	<i>microphylla</i>	<i>maling</i>	<i>pantlingi</i>
<b>rhizome</b>	solid	hollow	solid	solid
<b>culm sheath base</b>	hair ring	glab/ring	glab/ring	hair ring
<b>leaf sheath auricles</b>	large	none/small	small	none
<b>leaf margins</b>	thin	thickened	thin	thin
<b>leaf sheath edge</b>	ciliate	cil/glab	cil/glab	glabrous
<b>culm wax</b>	none	distinct	none	none
<b>culm walls</b>	thick	thick	thick/thin	thick
<b>culm surface</b>	level	level	lev/ridged	level
<b>scabridity</b>	< 1.5 mm	none/<.2	< 1.5 mm	<.5mm
<b>leaf sheath ligule</b>	1-2 mm	< 1 mm	< 1.5 mm	< 1mm
<b>maximum internode length</b>	50 cm 40 cm		30 cm	35 cm
<b>range</b>	W Bhutan	Nep & Bht	Nep & Bht	C & E Bhutan

table 16 Main differences in vegetative characteristics between *Yushania* species encountered in Nepal and Bhutan

areas of pastureland in central Bhutan as well as occurring in the forest understorey. It is often dwarfed by grazing to a low sward with very small leaves, although leaves can become substantially larger when plants are not heavily grazed. These two species show more intraspecific variation than the other species, but it is very difficult to divide them into consistently separable taxa, however, as heavy grazing pressure complicates the vegetative characteristics. The flowers of *Y microphylla* have never been found.

The two Tibetan species were very well described although the type specimens were infertile. *Y yadongensis* (longissima) seems very close to *Y microphylla*. It comes from nearby Yatung in the Chumbi Valley between Sikkim and Bhutan. Assuming that it also has a thickened leaf margin, (not mentioned in the description) it could be treated as a synonym of *Y microphylla*. *Y xizangensis* seems from its description to be very similar to *Y maling*. It occurs north of Bhutan and Arunachal Pradesh, and apparently differs from *Y maling* in having no leaf sheath auricles or oral setae. The species known from Nepal and Bhutan are keyed out below:

- |  |                                |
|--|--------------------------------|
| 1 rhizome neck hollow  | .... <b><i>microphylla</i></b> |
| 1a rhizome neck solid  |                                |
| 2 new culm sheath base glabrous or<br>with small deciduous ring of hairs | ..... <b><i>maling</i></b>     |
| 2a new culm sheath base with prominent<br>and persistent ring of hairs   |                                |
| 3 leaf sheath auricles large & persistent<br>oral setae spreading widely | ..... <b><i>hirsuta</i></b>    |
| 3a leaf sheath auricles small or absent<br>oral setae erect              | ..... <b><i>pantlingi</i></b>  |

#### 5.15.4 Enumeration of the species known in Nepal and Bhutan

##### 1. *Yushania maling* (Gamble) Stapleton **comb. nov.**

Basionym: *Arundinaria maling* Gamble in Kew Bull. of Misc. Info. : 139 (1912)

Syn.: *Sinarundinaria maling* (Gamble) Chao & Renvoize in Kew Bull 44(2): 356 (1989)

*Fargesia racemosa* Yi in J. Bamboo Res. 2(1): 39

?*Yushania xizangensis* Yi J. Bamboo Res. 2(2): 49-51 (1983)

INDIA: Darjeeling dist. Tonglo, *Osmaston* s. n. May 1904 (lectotype K selected in Chao & Renvoize, 1989)

NEPAL: Sankuwasabha dist., Barun Khola, *Emery* 20; 21; 102; 146; 147 BM

BHUTAN: Chhukha dist., Bunakha, *Stapleton* 882 (Herb. For. Dept. Taba)

Local names *maling*, *malingo*, *khosre malingo*, (Nepali).

In Bhutan some plants have a ring of light hairs at the base of the culm sheath, the culms are not quite so rough and some have thinner walls, lower leaf sheaths have ciliate edges, and the leaf sheath auricles are often larger. However, these differences do not seem consistent enough to justify a new subspecies.

##### 2. *Yushania microphylla* (Gamble) Stapleton **comb. nov.**

Basionym: *Arundinaria microphylla* Munro in Trans. Linn. Soc. 26 : 32 (1868)

Syn.: *Sinarundinaria microphylla* Chao & Renvoize in Kew Bull. 44(2): 354 (1989)

*Yushania yadongensis* Yi in J. Bamboo Res. 4(2):33 (1985) *syn. nov.*

*Yushania longissima* Yi J. Bamboo Res. 2(2): 46-48 (1983) *nom. illeg.*

BHUTAN: Tashigang distr., Sana, *Griffith* 623 (holotype K). Paro, Shana, *Stapleton* 801 Taba. Thimphu, Changkaphug, *Stapleton* 821. Wangdi, Phubjika, *Stapleton* 817. Tongsa, Pele La, *Stapleton* 856 Taba.

TIBET: Yadong Xian, *Cidan Langjie* 2.

NEPAL: Dolakha district, Mure, *Stapleton* 457.

The leaves used for the original description were taken from heavily grazed plants, and were unrepresentative of the species. The principle characteristics of this species are the hollow rhizomes, the thickened exterior leaf edge, and the smooth culms. Its flowers are still not known.

### 3. *Yushania pantlingi* (Gamble) Stapleton **comb. nov.**

Basionym: *Arundinaria pantlingi* Gamble in Ann. R.B.G. Calcutta 7:129 (1896)

Syn.: *Semiarundinaria pantlingi* (Gamble) Nakai in J. Arn. Arb. 6: 151 (1925)  
*Butania pantlingi* (Gamble) P. C. Keng in J. Bamboo Res. 1(2): 31 (1982)

*Sinarundinaria pantlingii* (Gamble) Chao & Renvoize in Kew Bull. 44(2): 359 (1989)

INDIA: Darjeeling dist/Sikkim border, Rechi La, *Pantling's collectors* s. n. (holotype K).

BHUTAN: Tashigang, *Stapleton* 431b Taba.

Nepal collections cited in Chao & Renvoize (1989) are not this species, but *Fargesia emeryi*.

Local name *hima* (Dzongkha).

### 4. *Yushania hirsuta* (Munro) Stapleton **comb. nov.**

Basionym: *Arundinaria hirsuta* Munro in Trans. Linn. Soc. 26 : 30 (1868)

Syn.: *Sinarundinaria hirsuta* Chao & Renvoize in Kew Bull. 44(2): 355 (1989)

INDIA: Khasi Hills, *Griffith* 6726 (lectotype K, chosen in Chao & Renvoize 1989).

BHUTAN: Thimphu, Yosipang, 2600m *Stapleton* 858 Taba.

Local name *hima* (Dzongkha).

**5.16 *Arundinaria* Michaux** in Fl. Bor. Am. 1: 73 (1803)

#### **5.16.1 Generic status**

This genus has been gradually reduced by recognition of new genera, and has been more clearly defined, (McClure, 1973). It now includes only one Himalayan species. The combination of leptomorph rhizomes, which can continue under the ground indefinitely, and tall 2-keeled mid-culm bud scales separates it from all other Himalayan genera.

#### **5.16.2 Enumeration of the species from Nepal and Bhutan**

**1. *Arundinaria racemosa*** Munro in Trans. Linn. Soc. 26: 17 (1868)

Syn: *Fargesia racemosa* Yi in J. Bamboo. Res. 2(1): 39 (1983)

INDIA: Darjeeling dist, Birch Hill, *Thomson* s. n. Aug 1857 (lectotype selected by Chao & Renvoize 1989 K)

BHUTAN: Tongsa, Yotong La, *Stapleton* 852 (Taba). Thimphu, Dorchula, *Stapleton* 872 (Taba). Bumthang, Lame Gompa, *Bürgi* s. n. (Taba).

Local name not known, often called *maling* (Nepali) in error.

*Arundinaria maling* (*Yushania maling*) was removed from this taxon on the grounds of *A maling* having rough culms rather than the smooth culms of *A racemosa*. However *Y maling* and *A racemosa* are found in association with other low-growing high-altitude smooth-culmed bamboos such as *Yushania microphylla* and browsed *Thamnocalamus aristatus*, so that care should still be taken in the identification of a bamboo as *A racemosa*, as it is not a common species. It is very consistent in its characteristics, and has recently flowered gregariously in Bhutan, (1990), where it is used for making arrows.

**APPENDIX 1**  
**DESCRIPTIONS OF NEW TAXA**

1.1 *Bambusa tulda* subsp *tharu*

Clumps dense. Rhizomes pachymorph, up to 50 cm long. Culms erect to drooping in habit, maximum length 23 m; at breast height maximum diameter 8 cm, walls up to 1.5 cm thick; nodes hardly raised with no roots; maximum internode length 40 cm; smaller culms sulcate above branches; surface with thin white wax at first, becoming glossy or slightly matt, with no distinct rings above or below nodes. New culm sheath from breast height c. 30 cm wide at base, height to ligule c. 24 cm; blade c. 8cm long, c. 16 cm wide, cupped & cordate, very persistent. Sheath deciduous, with appressed/erect hairs all over, although glabrous towards base with dense basal ring, hairs dark brown (not black), dense and erect inside blade; auricles c. 3.5 cm broad, 1 cm tall, with dense oral setae c. 1 cm long, upright/bent, reddish brown; ligule 2-4 mm tall, finely serrate. New leaf sheath distally lightly pubescent at first, margins glabrous; callus prominent, glabrous; auricles triangular; oral setae 2-5, deciduous, 7-10 mm long, delicate; ligule short, < 2mm. Leaf blade maximum length and breadth 25 x 4 cm, abaxial densely 0.2-0.5 mm pubescent all over, adaxial glabrous; petiole abaxial glabrous, adaxial very shortly pubescent. Branches or buds present to base of culm; central branch up to 2 cm in diameter, rarely rooting; mid-culm lateral branches up to 1 cm in diameter; branches unarmed. Inflorescence branching moderately congested, young inflorescences with 5-20 spikelets, older ones up to 7 cm in diameter with 100 spikelets or more; prophylls all bearing 2 keels. Pseudospikelet with 2-3 gemmiparous bracts, no empty bracts, 4-9 fertile glumes; terminating in a rudimentary floret; rhachilla sections up to 3 mm long, flattened, largely glabrous but with 0.2-0.5 mm long ciliae around apex, disarticulating very readily. Fertile glumes 10-14 mm long; margins just overlapping at base; inner margin glabrous; outer margin with c. 0.5-0.2 mm long ciliae on base and proximal half. Palea 10-12 mm long, apex acute and penicillate, edges glabrous, margins very shortly pubescent; keels prominent, distal 2/3 with 0.5-1 mm long ciliae. Lodicules short to very long, 2-7 mm, fimbriate. Anthers yellow, 6-8 mm long, shortly apiculate or slightly bifid. Ovary oblong; style short, hairy; stigmas 2, white, plumose.

1.2 *Bambusa nutans* subsp *malbans*

Clumps open. Rhizomes pachymorph, up to 75 cm long. Culms erect to drooping in habit, maximum length 25 m; at breast height maximum diameter 9 cm, walls 1.5-2 cm thick; nodes scarcely raised at all, no roots; maximum internode length 59 cm; no sulcation on smaller culms; surface with thin white wax at first, becoming glossy, with thin deciduous white ring above nodes at first. New culm sheath from breast height c. 30 cm wide at base, height to ligule c. 25 cm; blade c. 12 cm long x 20 cm wide, broadly cordate, promptly deciduous. Sheath with jet black appressed or erect deciduous hairs all over, and very short light-coloured appressed hairs in lines inside blade; auricles varied, up to 3 cm wide, 2 cm tall, separate or merging into blade; oral setae light-coloured, bent, up to 1 cm long; ligule narrow, 1-2 mm tall, margin finely serrate. New leaf sheath glabrous; margins glabrous; callus prominent, glabrous; auricles indistinct, narrow; oral setae deciduous, 1-4 on young leaves, erect, c. 1 cm long; ligule short, <2 mm; blade up to 31 cm long x 5 cm wide. Branches or buds present to base of culm; mid-culm central branch up to 2 cm in diameter, never rooting; mid-culm lateral branches up to 1 cm in diameter; branches unarmed. Inflorescence branching rarely congested, young inflorescences with up to 10 spikelets; prophylls all 2-keeled. Pseudospikelet with 2 gemmiparous bracts; empty bracts absent; c. 5 fertile glumes; terminating in an incomplete floret; rhachilla sections glabrous with very shortly ciliate apices, disarticulating very readily. Fertile glumes 12-20mm long, glabrous; margins wide and rolled. Palea up to 15 mm long; keels with short stout ciliae up to 0.4mm long; veins and tessellation evident between keels; apex single, usually minutely penicillate. Lodicules 1.5-2.5 mm long, 1 obovate, 2 oblique and laterally thickened. Anthers yellow; tips shortly bifid. Ovary orbicular to oblong. Style short or medium length, branching promptly into 2 stigmas.

### 1.3 *Bambusa alamii*

Clumps dense. Rhizomes pachymorph, up to 30 cm long. Culms erect to drooping in habit, up to 12 m long; at breast height maximum diameter 3.5 cm, walls up to 0.5 cm thick; nodes scarcely raised, no roots; maximum internode length 40 cm; surface thinly covered with white wax at first, becoming glossy. New culm sheath from breast height c. 16 cm wide at base, asymmetrically triangular, attenuating evenly to c. 6 cm width at top; height to ligule c. 14 cm; blade c. 12 cm long, sagittate, quite persistent, firmly attached to culm above bud. Sheath persistent, completely glabrous; auricles dissimilar, one 1-2 cm tall and rounded, one 2-5 cm long and elongated or tapering, both lightly corrugated and prominently veined; oral setae dense, 10-30 on one auricle, 30-50 on the other, 3-10 mm long, curving or bent, brown; ligule 0.5-2 mm wide, entire, asymmetrical. New leaf sheath glabrous; margins glabrous; callus pronounced, glabrous; auricles 1-2 mm wide, ovoid, erect or reflexed, larger on lower sheaths; oral setae 1-5 each side, 3-10 mm long, deciduous, glabrous, straight, erect or spreading; ligule c. 1 mm long, truncate; blade up to 250mm long x 23 mm wide, glabrous. Branches or buds present to ground; maximum diameter of mid-culm central branch 7 mm, no roots; maximum diameter of mid-culm laterals 3 mm; no thorns. Inflorescence not known.

1.4 *Bambusa nepalensis*

Clumps dense. Rhizomes pachymorph, up to 50 cm long. Culms drooping in habit, up to 20 m long; at breast height diameter up to 10 cm, walls 1-1.5 cm thick; nodes scarcely raised at all, no roots; internode length up to 40 cm; surface with fairly thick very persistent white furry wax, thicker and browner below nodes. New culm sheath from breast height broad, c. 50 cm wide at base, height to ligule c. 25 cm; blade up to 9 cm long x 12 cm wide, cordate, appressed to culm, very persistent, with dense scattered hairs inside in triangle above ligule. Sheath persistent, sheath and blade uniformly covered in fine appressed mid-brown fawn or honey-coloured hairs; shoulders broad; auricles small, 2-7 mm wide; oral setae 5-10 each side, 3-5 mm long, curved; ligule 3-5 mm tall, uniformly serrate. New leaf sheath with bright or dull white appressed or erect hairs, hairs quite persistent; distal 1/4 of overlapping margin shortly ciliate; callus well developed, very shortly ciliate or glabrous; auricles none; oral setae none or 1-2 at first, c. 2mm long, erect, deciduous; ligule 2-3 mm long, truncate, serrate or ragged, waxy; petiole adaxial shortly pubescent, abaxial glabrous or waxy; blade maximum length 30 cm, breadth 6 cm. Branches absent at basal 6-10 nodes; mid-culm central branch up to 3 cm in diameter, bearing roots; lateral branches up to 1 cm; branchlets unarmed. Inflorescence with moderate branching, young inflorescence capitate to slightly cuboid with 7-25 spikelets, older ones more capitate with 100 spikelets or more. Prophylls around inflorescence usually 2-keeled. Prophylls basal to the pseudospikelet always 2-keeled. Pseudospikelet with 1-3 gemmiparous bracts, 1 empty bract, 2-3 fertile glumes, terminating in a tiny rudiment; rachilla sections glabrous, not readily disarticulating, 0.5-1 mm long, glume insertion marked by a red line. Fertile glumes 6-7 mm long, green with purple tips, apex very shortly pubescent internally and externally; distal 1/4 of margins with c. 0.2 mm ciliae. Palea 5-7 mm long, green with purple tips; margins distal 1/3 to 1/2 up with c. 0.5 mm ciliae; keels basal 1/2 indistinct, distal 1/2 to 1/5 with c. 0.5 mm ciliae, apex blunt with c. 0.5 mm ciliae. Lodicules 3, well developed, 0.7 to 3 mm tall, variously ovate, long fimbriate, apices tinged purple. Anthers 5-6 mm long, 0.5 mm wide, yellow with purple tinges; tips purple, long apiculate, often shortly penicillate. Ovary narrowly linear-lanceolate, glabrous; style up to 5 mm long with 3 purple pubescent to shortly plumose stigmas.

1.5 *Bambusa clavata*

Clumps dense. Rhizomes pachymorph, up to 50 cm long. Culms drooping, maximum length 20 m; at breast height maximum diameter 9 cm, walls up to 2 cm thick; nodes slightly raised, no roots; internodes up to 40 cm long, surface with thin wax covering at first, glossy later, persistent thick white rings of wax above and below nodes. New culm sheath from breast height c. 34 cm wide at base, height to ligule c. 22 cm; deciduous, uniformly covered with mid to very dark brown appressed deciduous hairs at first with more persistent basal ring; blade large, c. 11 cm long, 18 cm wide, cordate, with light hairs towards edges at first, deciduous; auricles small, rounded, 5-10 mm wide; oral setae up to 30 each side, 3-5 mm long, curved; ligule 2-15 mm tall, fimbriate, asymmetrical with single deep cleavage when growing strongly, cleavage on alternate sides at alternate nodes. New leaf sheath glabrous, margins of upper sheaths glabrous, overlapping edge of lower sheaths ciliate; callus pronounced, glabrous; auricles very small; oral setae 1-5, 2-5 mm long, erect or curving; ligule short, < 1mm, obliquely truncate, very shortly pubescent, often long ciliate at edges; petiole glabrous. Branches or buds absent at basal 5-10 nodes, buds shortly acuminate, maximum diameter of mid-culm central branch 3 cm, bearing roots, maximum diameter of mid-culm lateral branches 1 cm. No thorns. Inflorescence branching extremely limited at first, initially only 1-3 large spikelets per inflorescence, later and in the next season up to 30 smaller spikelets in capitate inflorescence. Prophylls all 2-keeled. Pseudospikelet with 3 gemmiparous bracts, 0-1 empty bracts, 5-8 fertile glumes, terminating in a rudiment or complete floret; rhachilla sections 1-2mm long, sheath insertion marked by a red band, disarticulation reluctant. Flowering glume 5-29 mm long, green where protected, exposed parts dark purple, fading to straw colour, exterior glabrous, very shortly pubescent inside apex; margins glabrous. Palea abaxial glabrous with lightly scabrous wings, shorter than flowering glume, 4-15 mm long, narrow; apex acute or shortly bifid; margins very shortly ciliate for distal 1/3 matching keel ciliation; keels in lower florets pronounced and ciliate from base to apex, ciliae up to 1mm long, upper florets ciliate for distal 1/2 only, ciliae up to 0.5 mm. Lodicules 3, lateral pair ovate-acute, 3-6 mm tall, shortly fimbriate, rear ovate, 5-7 mm tall, with fimbriae of c. 1 mm. Anthers 8-10 mm, yellow with purple apiculate or penicillate tips. Ovary triangularly ovate, pubescent, tapering slowly into a 2 mm style and branching promptly into 2-3 plumose purple stigmas.

1.6 *Dendrocalamus hamiltonii* var *undulatus*

Clumps dense. Rhizomes pachymorph, up to 75 cm long. Culms drooping, not pendulous, maximum length 23 m; at breast height maximum diameter 15 cm, walls 2-2.5 cm thick; nodes slightly raised, rooting at basal 6-10 nodes; internodes often swollen by 1-3 cm diameter towards base, maximum length 35 cm (short for diameter). Culm surface with dense white to light brown furry wax at first, remaining dull. New culm sheath from breast height c. 60 cm wide at base, height to ligule c. 28 cm; blade up to 10 cm long x 12 cm wide, triangular, strongly and deeply dimpled, bottom corners corrugated, persistent. Sheath deciduous, with dense appressed light to dark brown hairs from base to 2 cm below blade; auricles small, triangular or rounded, variable, naked; oral setae none; ligule narrow, 1-3 mm long, serrate in centre, dentate at edges. New leaf sheath with white appressed hairs at first, becoming glossy; margins glabrous; callus prominent; auricles none; oral setae none; ligule projecting, rounded or pointed, up to 10 mm long x 8 mm wide; blade maximum length and breadth 42 x 10 cm. Branches or buds absent at up to 10 basal culm nodes; maximum diameter of mid-culm central branch 5 cm, rooting prolifically; maximum diameter of mid-culm laterals 1 cm, often also rooting; branchlets unarmed. Inflorescence capitate with highly congested branching, young inflorescences with more than 20 spikelets, older ones with more than 100. Prophylls narrow, usually 1-keeled, those basal to pseudospikelet often with weak second keel. Pseudospikelet with 2 gemmiparous bracts, 2 empty bracts, 2-3 fertile glumes, terminating in a complete floret, rachilla sections < 0.5 mm long, not disarticulating. Flowering glumes green, c. 6mm long; margins ciliate to base, proximally with ciliae c. 1 mm long, distally with ciliae c. 0.5 mm; exterior glabrous, interior very shortly pubescent near apex. Palea 4-5 mm long; margins with c. 0.5 mm ciliae to base; apex acute; keels with 0.2-0.5 mm ciliae to near base. Lodicules 0-3, narrow, 0.5-2 mm long, fimbriate, unthickened. Anthers c. 3 mm long, honey-coloured with darker tips, tips aciculate or apiculate, often penicillate. Ovary triangularly ovate, pubescent. Style long, c. 2 mm, with 1-2 purple, plumose, club-shaped stigmas.

1.7 *Fargesia chigar*

Clumps open. Rhizome pachymorph, up to 30 cm long, solid. Culms drooping, curving outwards at the base; at  $\frac{1}{4}$  height diameter up to 1.5 cm, walls up to 2 mm thick; nodes slightly raised, persistent sheath base lightly white-pubescent at first, unarmed; maximum internode length 15 cm; surface with very dense white wax over entire internode, culm remaining dull. New culm sheath from  $\frac{1}{4}$  height c. 75 cm wide at base, height to ligule c. 27 cm, attenuating triangularly from base; upper  $\frac{1}{2}$  membranous, disintegrating rapidly, transverse veinlets prominent; blade always erect, c. 3 cm long x 5 mm wide, very persistent, interior very shortly pubescent beside ligule; hairs scattered to quite dense, erect, clear, with bulbous bases; shoulders and auricles absent, blade continuous with sheath; oral setae absent; ligule triangular to subulate, edges sparsely ciliate or penicillate; upper  $\frac{1}{2}$  of both edges with rather sparse stout brittle ciliae <1 mm long. New leaf sheath surface glabrous, margins glabrous; callus not pronounced, with ciliae up to 1 mm long; auricles none; shoulders rising very steeply, shortly ciliate; oral setae none; ligule extremely long, up to 5 mm, glabrous, ragged. Leaf blade up to 110 mm long x 6 mm wide; abaxial and adaxial surfaces glabrous and glaucous; petiole glabrous, narrow, long; tessellation distinct, but transverse veinlets well spaced out; base attenuate. Branches small, from elliptical buds with broad rounded wings; central branch up to 1 mm in diameter with no aerial roots. Inflorescence not known.

1.8 *Fargesia emeryi*

Clump form and rhizome not known. Culm nodes slightly raised, unarmed, internodes finely ridged and waxy. Old culm sheath glabrous. Old leaves glabrous, tessellation distinct. Old leaf sheaths glabrous with glabrous margins; callus not pronounced; no auricles or oral setae; ligule c. 1.5 mm long, truncate. Spikelets up to 40 mm long, with 2 empty glumes and up to 6 fertile florets, terminating in an incomplete floret. Lower empty glume 6-11 mm, glabrous with a very shortly scabrous awn. Upper empty glume 8-14 mm, glabrous with a very shortly scabrous awn. Flowering glume 13-17 mm long, very shortly pubescent all over or glabrous near margins, tip scabrous. Palea 10-12 mm long, tip bifid for at least 1 mm and scabrous; keels proximally glabrous, distal  $\frac{1}{2}$  with c. 0.3 mm ciliae. Rhachilla segments 5-6 mm long, flattened, shortly pubescent, with c. 0.5 mm ciliae at tip. Stigmas 2-3. Anthers yellow, bifid or blunt, not penicillate; pollen yellow. Lodicules 3, similar, with c. 0.5 mm ciliae.

1.9 *Fargesia geduensis*

Clumps open. Rhizome pachymorph, 15-30 cm long, solid. Culms erect to drooping, often curving out at base; maximum length 4 m; at  $\frac{1}{4}$  height diameter up to 1.5 cm, walls up to 3 mm thick; nodes slightly raised, unarmed; internodes up to 21 cm long, surface quite distinctly ridged, especially upper  $\frac{1}{2}$ , often with narrow ring of white or brown c. 0.5 mm long spines for 3 mm below node. New culm sheath from  $\frac{1}{4}$  height c. 5 cm wide at base, attenuating from  $\frac{1}{2}$  height triangularly to neck c. 3 mm wide, thin, papery; basal  $\frac{1}{4}$  slightly thicker, with black spots or small splodges at base; basal  $\frac{1}{2}$  fairly persistent, top  $\frac{1}{2}$  rapidly disintegrating in situ; height to ligule c. 26 mm, sheaths strongly imbricated; blade erect or decurrent, c. 10 mm long x 1.5 mm wide, glabrous, edges not scabrous, very quickly deciduous; bristles scattered to dense, quite persistent, light to dark brown, bulbous based, 0.5 to 1 mm long, mostly appressed in random orientation; base with ring of 1-2 mm orange-brown erect hairs, remaining on persistent sheath base; shoulders ciliate; auricles none; oral setae 3-7 each side, scabrous, erect, bent or wavy, 3-6 mm long; ligule 1-2 mm long, truncate, very shortly pubescent, margin very shortly ciliate to shortly fimbriate; overlapping edge ciliate to base, inner edge distally ciliate, ciliae c. 1 mm long and clear. New leaf sheath glabrous, distally waxy; overlapping edge ciliate on proximal sheaths, glabrous on distal sheaths; callus pronounced, with c. 0.1 mm ciliae; auricles absent; shoulders with c. 0.1 mm ciliae, rising steeply; oral setae 4-6 each side, erect, stiff, basally scabrous, 3-6 mm long; ligule 2-3 mm long, asymmetrically truncate or depressed, glabrous, waxy, margin almost entire. Leaf blade 10-15 (-20) cm long, breadth 8-12 (-15) cm; both surfaces completely glabrous; petiole glabrous but waxy; tessellation distinct. Branch buds present at all culm nodes; mid-culm bud up to 10 mm tall, 6 mm wide, on c. 3 mm promontory, with c. 1 mm wide wings and c. 1 mm ciliae. Mid-culm branches up to 15, up to 9 in first year, central branch up to 2mm in diameter with no aerial roots. Inflorescence not known.

1.10 *Fargesia bhutanensis*

Clumps dense. Rhizomes pachymorph, up to 25 cm long, solid. Culms drooping, maximum length 10 m; at ¼ height maximum diameter 4.5 cm, walls up to 5 mm thick, nodes not substantially raised, unarmed; maximum internode length 50 cm; surface finely ridged; entire internode covered with wax, new culms strongly glaucous, densely waxy below nodes. New culm sheath from ¼ height up to 12 cm wide at base, attenuating triangularly and convexly to a width of up to 10 mm at the neck, persistent till branching; height to ligule c. 26 cm; bristles scattered, deciduous, brown, bulbous-based, antrorsely erect, c. 1 mm long; blade decurrent, erect at tip of new shoot, up to 70 mm long, c. 2 mm wide, lightly covered with c. 0.5 mm deciduous bristles, edges scabrous, quickly deciduous; base pubescent or pilose with ring of slender 2-3 mm light brown hairs; shoulders with c. 0.2 mm ciliae, bearing setae at edges; auricles absent on basal sheaths to very small at shoot apex; oral setae 6-10 each side, 3-8 mm long, thick, erect, straight, honey-brown, glabrous with fine spiralling striations, extending onto edges of sheaths near culm base; ligule 1-2 mm long, shortly fimbriate, densely 0.3-0.5 mm pubescent, concave or truncate, or convex and asymmetrical at culm base with one end extending down the sheath margin; edges c. 1 mm ciliate, overlapping edge ciliate to base, inner edge only ciliate on distal ¼, ciliae merging with oral setae on sheaths from culm base. New leaf sheath lightly c. 1 mm pubescent at first (proximal sheaths) or glabrous (distal sheaths); margins glabrous; callus not pronounced, 0.2(-1) mm ciliate; auricles absent; shoulders c. 0.1 mm ciliate; oral setae 2-5 each side, wavy, erect, glabrous, 3-5 mm long; ligule 15-25 mm long, c. 0.1 mm puberulent, truncate. Leaf blade 8-14(-26) cm long, breadth 8-15(-25)mm; abaxial lightly to densely and persistently pubescent all over with c. 1 mm long hairs, adaxial glabrous; petiole abaxial with dense c. 1 mm hairs, adaxial proximally pubescent with <0.3 mm hairs; tessellation distinct. Branch buds present at all nodes, 1.5-3 cm tall, narrow, on promontory of 2-5 mm; basal bud dorsally and ventrally closed; mid-culm branches 5-7 in first year, up to 16 branches later; central branch up to 3 mm in diameter, with no aerial roots. Inflorescence semelaucant, a panicle usually with rings of hairs subtending ultimate branches rather than reduced sheaths, pedicels of up to 3 cm, few pulvini. Spikelet length up to 55mm, with 2 empty glumes, up to 10 fertile florets, terminating in an incomplete floret. Lower empty glume 9-15 mm long, glabrous, with very shortly scabrous awn. Upper empty glume 13-17 mm long, glabrous, with a very shortly scabrous awn. Occasional reduced buds in empty glume axils. Flowering glume 15-20 mm long, usually very shortly pubescent but with longer hairs of up to 0.7 mm near margins, tip scabrous. Palea 10-12 mm long, apex acute or < 1 mm bifid; tip shortly ciliate; keels shortly c. 3 mm ciliate distal ½ and tip. Rhachilla segments 4-6 mm long, flattened, puberulent to 0.7 mm pubescent at apices. Stigmas 2-3. Anthers c. 9 mm, yellow; tips slightly purple, blunt or penicillate, not bifid; pollen white. Lodicules 3, similar, with ciliae of c. 1 mm.

1.11 *Thamnocalamus spathiflorus* subsp *occidentalis*

Clumps dense. Rhizomes pachymorph. Culm with nodes substantially raised, unarmed; internodes with light deciduous wax all over. New culm sheath from ¼ height c. 45 mm wide at base, persistent, base tough; attenuation convex in distal 1/3 to c. 10 mm wide neck, asymmetrical, one shoulder 2-5 mm higher than the other; height to ligule c. 160 mm; blade erect, c. 20 mm long x 8 mm wide, often split and bifid, deciduous; surface completely glabrous; auricles none; oral setae few, c. 2 mm long; ligule c. 2 mm long x 10 mm broad, thin, margin curling or ragged; edges with c. 1 mm ciliae at top. New leaf sheath surface glabrous; overlapping edge with ciliae of up to 1 mm on distal half; inner edge ciliate at apex only; callus narrow but pronounced, 0.2-0.3 mm ciliate; auricles none or very small; oral setae up to 10 each side, tough, purple, scabrous, sulcate, rounded or flattened, 4-6 mm long, straight, erect; ligule broad, truncate, c. 2 mm long, puberulent, margin with ciliae of 0.1 mm. Leaf blade maximum length and breadth 120 x 18 mm, both surfaces and petiole glabrous, tessellation very distinct. Mid-culm central branch up to 2 mm in diameter with no aerial roots. Inflorescence a compressed panicle, semelauctant, branching usually subtended by reduced sheaths; pedicels 2-14 mm long, waxy; spikelets 3-5 cm long, 2-3 mm broad, c. 2 mm thick, with 2 empty glumes and 3-8 fertile florets. Lower empty glume 10-15 mm long, glabrous except scabrous tip. Upper empty glume 12-18 mm long, glabrous except scabrous tip. Flowering glume 12-22 mm long, including awn of 3-5 mm, very shortly scabrous all over. Palea up to 12 mm long, glabrous, bifid for c. 1 mm, waxy; keels distally 0.2 mm scabrous; rhachilla very shortly (c. 0.1mm) scabrous all over, with ring of c. 0.5 mm hairs at segment tips. Anthers purple, 6-7 mm, bifid.

1.12 *Thamnocalamus aristatus* subsp *bhutanensis*

Clumps dense. Rhizomes pachymorph. Culms drooping, maximum length 6m; at ¼ height diameter up to 1.5 cm, walls up to 2 mm thick; nodes raised by c. 3 mm, unarmed; internodes up to 20 cm long; surface with dense white wax over entire internode, wax thicker below node, becoming flaky later; new culms green, becoming yellow or mottled purple-brown with age. New culm sheath from ¼ height c. 5 cm wide at base; attenuation convex and strongly asymmetrical, in distal 1/10th of sheath on one side, and distal 1/20th on opposite side where shoulder is up to 1 cm higher; neck c. 10 mm wide; height to ligule c. 19 cm; blade erect, c. 40 cm long and 6 mm wide, short-scabrous both sides, adaxial surface proximally 0.1 mm pubescent, persistent; hairs scattered, white, thin, 1-1.5 mm long, erect; persistent base of sheath glabrous; auricles often dissimilar, more triangular or larger on raised shoulder; oral setae 0-3 each side, slightly scabrous, 1-2 mm long, erect; ligule 1-2 mm long, shortly ciliate, scurfy, often raised on one side to meet auricle; edges glabrous or ciliate on distal 1/10th of sheath. Leaf blade maximum length and breadth 9 x 2 cm; abaxial and adaxial surfaces glabrous or with scattered erect thin 1.5 mm hairs on smaller leaves; petiole abaxial glabrous, adaxial proximally very shortly pubescent; tessellation very distinct. New leaf sheath surface and margins glabrous; callus pronounced, thin, reflexed, with uniform 0.2-0.5 mm long ciliae; auricles large, reflexed or decurrent; oral setae 10-20 each side, scabrous, curved, spreading widely, 3-5 mm long; ligule rounded or triangular, 1-1.5 mm long. Branching absent at some basal culm nodes; buds ovate; maximum diameter of mid-culm central branch 2 mm; no aerial roots; up to 8 branches per mid-culm node, usually 5 in first year. Inflorescence a compressed panicle, semelauctant, slightly fascicled, branching nearly always subtended by reduced sheaths, rarely by hair-rings; pedicels 1-7 mm long; partially enclosed in spathes up to 8 mm wide, enclosing 1-5 spikelets. Spikelets 2-4 cm long, flattened, c. 5 mm broad x 2 mm thick; empty glumes 2, often subtending small vestigial buds, 3-8 fertile florets; termination an incomplete floret. Lower empty glume 6-9 mm long, glabrous except scabrous tips. Upper empty glume 10-13 mm, glabrous except scabrous tips. Flowering glume 11-19 mm including awn of 4-6 mm, flattened, width up to 3.5 mm, densely scabrous all over, edges gaping at base, not overlapping. Palea c. 8 mm, not waxy, often distinctly bifid for > 1 mm; keels distally shortly ciliate and scabrous between keels. Rhachilla segments c. 3 mm, very shortly scabrous, tip with c. 0.3 mm ciliae. Stigmas 3, plumose, up to 2 mm long, from 2 or 3 main branches off the c. 1 mm long style. Anthers up to 5 mm long x 1 mm wide, purple, with white or pink pollen. Lodicules 3, similar, up to 2 mm tall, broadly lanceolate, shortly ciliate at apex.

1.13 *Drepanostachyum annulatum*

Clumps dense. Rhizomes pachymorph. Culms pendulous, maximum length 3 m; at 1/4 height diameter c. 6 mm, walls c. 2 mm thick; nodes substantially raised, with ring of deciduous 1 mm colourless hairs pointing downwards on new culms, unarmed; maximum internode length 21 cm; surface with uniform dense white wax at first, culms becoming dark glossy green with some purple colouring above and below node. New culm sheath from 1/4 top height up to 25 mm wide at base, deciduous; attenuation concave or convex, in distal 1/3 of sheath; height to ligule c. 65 mm; exterior glabrous except dense ring of 1-2 mm upright colourless hairs around base, with irregular purple blotches especially in upper 1/3; interior scabrous for 1 cm below ligule; shoulders very shortly ciliate; auricles absent; oral setae absent; ligule margin entire or shortly ciliate, interior scabrous, exterior puberulous or glabrous; edges with 1 mm ciliae on distal 1/4 of overlapping side and distal 1/8 of inner side. New leaf sheath glabrous; overlapping edge distally 0.2 mm ciliate at first; callus pronounced, thin, evenly up to 0.1 mm ciliate; auricles absent, shoulders ciliate, rising up to 2 mm; oral setae absent; ligule 1-3 mm long, rounded or pointed, glabrous. Leaf blade maximum length and breadth 160 mm x 18 mm; abaxial proximally 0.5 mm pubescent one side of midrib; adaxial glabrous; petiole glabrous; tessellation absent. Branch bud elliptical with up to 12 initials visible in 2 ranks; maximum diameter of mid-culm central branch 1 mm; no aerial roots; maximum number of mid-culm branches 70. Inflorescence a fasciculated panicle with small sheaths or hair rings subtending branches; pedicels 2-8 mm long. Spikelet length 8-12 mm, with 2 empty glumes, 2-3 fertile glumes, terminating in a rudiment or incomplete floret on 1-3 mm rhachilla segment. Lower empty glume 4-7 mm, slightly scabrous, membranous, disintegrating rapidly. Upper empty glume 5-7.5 mm, scabrous, membranous, disintegrating rapidly. Flowering glume 7-9.5 mm, exterior scabrous all over, interior glabrous, margins membranous, darkened, edges distally 0.3 mm ciliate when young, glabrous when old. Palea 8.5-10 mm, at maturity 1-2 mm longer than flowering glume, exterior and margins scabrous all over, apex shortly bifid or truncate; keels scabrous, not pronounced. Rhachilla sections scabrous, with 0.5 mm pubescence in apical ring. Anthers yellow, 4-5 mm, tips apiculate.

1.14 *Himalayacalamus falconeri* var *cupreiciliatus*

Clumps dense. Rhizomes pachymorph, up to 25 cm long. Culms drooping to pendulous; maximum length 8 m; at  $\frac{1}{4}$  height diameter up to 30 mm, walls c 0.5 mm thick; nodes slightly raised, unarmed; maximum internode length 40 cm, with uniform light covering of glaucous wax. New culm sheath from  $\frac{1}{4}$  height c. 75 mm wide at base, deciduous, glabrous; attenuation in distal  $\frac{1}{4}$  convex to 10-13 mm wide neck, texture tough and smooth with raised veins only on distal  $\frac{1}{10}$ th; height to ligule up to 34 cm; blade erect, 10-15 mm long, 7-8 mm wide, glabrous, persistent; shoulders c. 2 mm wide, glabrous, level; auricles absent; oral setae absent; ligule short, broad, 0.5-1 mm long, 5-7 mm across, interior and exterior glabrous; edges with uniform 1-1.5 mm glossy quite persistent copper-coloured ciliae on distal  $\frac{1}{8}$ th of overlapping edge and distal  $\frac{1}{15}$  th of inner edge; surface smooth. New leaf sheath surface and edges glabrous; callus not pronounced, 0.1-0.2 mm ciliate; auricles absent, shoulders 0.1-0.2 mm ciliate; oral setae absent; ligule 1-1.5 mm, densely puberulous or tomentose. Leaf blade maximum length and breadth 200 mm x 25 mm; both surfaces and petiole glabrous; tessellation barely distinguishable. Branch buds broadly ovate, mid-culm branches up to 30, central branch up to 2 mm in diameter with no aerial roots. Inflorescence not known.

1.15 *Himalayacalamus falconeri* var *geduensis*

Clumps dense. Rhizomes pachymorph, up to 25 cm long. Culms drooping; maximum length 4 m; at ¼ height c. 12 mm, walls c. 2 mm thick; nodes raised by c. 2 mm, unarmed; maximum internode length 16 cm, surface with thick wax over entire internode, developing into persistent dark blotches, lightly & finely striate, especially below nodes. New culm sheath from ¼ height c. 18 mm wide at base, glabrous, persistent, thin; attenuation in distal 1/10th convex, to 5 mm wide neck; height to ligule 9 cm; persistent base lightly short-pubescent with ring of c. 0.5 mm white retrorse hairs; auricles absent; oral setae absent; ligule broad, interior and exterior glabrous; overlapping edge short ciliate at base; inner edge glabrous & membranous. New leaf sheath surface and edges glabrous; callus pronounced, glabrous; auricles absent; oral setae absent; ligule c. 1 mm long, rounded, very shortly pubescent. Leaf blade maximum length and breadth 150mm x 14 mm, both surfaces and petiole glabrous; tessellation absent. Branch buds broadly ovate; mid-culm central branch up to 1.5 mm diameter; basal branch sheaths pubescent; mid-culm branches up to 20, up to 12 in first year. Inflorescence paniculate with reduced fasciculated branches, semelauctant; branching marked by rings of hairs or reduced sheaths; pedicels smooth, 4-6(-16) mm long; spikelets 8-12 mm long, with 2 empty glumes, 1 (rarely 2) complete floret, terminating in a tiny -0.3 mm rudiment on a 2-8 mm rhachilla segment. Lower empty glume 3-7 mm long, narrow, tip penicillate, thin, glossy, deciduous. Upper empty glume 4-8 mm, tip penicillate, membranous, glossy, adhering or deciduous. Flowering glume 7-9 mm long, mostly glabrous, distally waxy, bearded with a prominent ring of 0.3-1 mm white hairs around the base; distal 1 mm of edges 0.5 mm ciliate. Palea 7-9 mm long, up to 0.5 mm longer than flowering glume; margins glabrous; tip blunt and glabrous or 0.1 mm penicillate at tip; keels not prominent, glabrous or slightly scabrous on distal 1 mm. Anthers yellow, c. 5 mm, apiculate or slightly bifid.

1.16 *Himalayacalamus brevinodus*

Clumps dense. Rhizomes pachymorph, up to 25 cm long. Culms drooping; maximum length 9 m; at  $\frac{1}{4}$  height maximum diameter 25 mm, walls up to 3 mm thick; nodes slightly to distinctly raised, purple colouration around node, unarmed; internodes short, up to 19 cm, covered with very thin wax when young, becoming distinctly yellow. New culm sheath from  $\frac{1}{4}$  height c. 8 cm wide at base, deciduous, interior and exterior glabrous, exterior often with distinct purple brown lines, distal  $\frac{1}{3}$ rd very thin with impression from superior node evident and tessellation distinct; attenuating convexly in distal  $\frac{1}{4}$ ; neck c. 5 mm wide, rolled at junction with blade; height to ligule c. 25 cm; blade erect, c. 8 cm long x 4 mm wide, curving, rolled, glabrous, persistent, firmly attached; auricles absent; oral setae absent; ligule c. 2 mm tall x 5 mm wide, serrated, exterior puberulous, interior glabrous; edges glabrous. New leaf sheath surface and margins glabrous; callus not pronounced, very shortly ciliate; auricles absent; oral setae absent; ligule obliquely truncate, up to 1 mm long, puberulous. Leaf blade maximum length and breadth 200 mm x 25 mm, both surfaces glabrous; petiole glabrous or basally very shortly pubescent; tessellation absent. Branch buds absent at basal 4-6 culm nodes, broadly ovate, only 3 initials visible; mid-culm central branch up to 2 mm in diameter, with no aerial roots; up to 30 mid-culm branches, up to 15 in first year. Inflorescence unknown.

1.17 *Himalayacalamus porcatus*

Clumps dense, rhizomes pachymorph, up to 25 cm long. Culms drooping, maximum length 6 m; at  $\frac{1}{4}$  height diameter up to 2.5 cm, walls up to 4 mm thick; nodes substantially raised, unarmed; internode length up to more than 25 cm, surface uniformly covered in a dense persistent wax, surface clearly marked with prominent ridges, no purple colouration. New culm sheath from  $\frac{1}{4}$  height c. 6 cm wide at base, deciduous, completely glabrous, tops of sheaths pink, imbricating and membranous, edges rolled outwards; attenuation in distal  $\frac{1}{4}$  convex to c. 5 cm wide neck; height to ligule up to 30 cm; blade erect or reflexed, 2-5 cm long, c. 2 mm wide, basal 5 mm of adaxial surface shortly pubescent, otherwise scabrous, abaxial glabrous, persistent; shoulders 0.1 mm ciliate, auricles absent; oral setae initially up to 8 each side, weak, up to 6 mm long, white, glabrous, erect, deciduous, arising from shoulder and edge of ligule; ligule 2-4 mm wide, 1-4 mm tall, glabrous both sides, margin lacerate; edges largely glabrous. New leaf sheath surface glabrous; edges glabrous or overlapping edge with 1 mm white ciliae to base on proximal sheaths; callus pronounced, 0.1 mm ciliate; auricles absent; oral setae 4-8 each side, weak, white, erect, 2-4 mm long each side, glabrous, deciduous; ligule 1-4 mm tall, rounded to acutely rhomboid, exterior puberulous or tomentose, interior glabrous, thin, margin largely entire. Leaf blade maximum length and breadth 190 mm x 12 mm, adaxial surface glabrous; abaxial usually glabrous, or proximally sparsely pubescent one side of midrib, or sparsely shortly pubescent all over (small leaves); petiole abaxial glabrous, adaxial 0.1-0.5 mm pubescent; tessellation absent. Mid-culm branches up to 30; central branch with no aerial roots. Inflorescence a reduced fascicled panicle, semelauctant; pedicels 3-9 mm long, smooth; spikelet length 9-11 mm, with 2 empty glumes, 1 (rarely 2) complete florets, terminating in a rudiment or incomplete floret on 2-4 mm rhachilla segment; lower empty glume 7-9 mm, membranous; upper empty glume 7-9 mm, membranous; flowering glume 8-10 mm, exterior shortly scabrous all over, interior distal 2 mm scabrous to shortly pubescent, edges mainly glabrous, but c. 0.5 mm ciliate at tip; palea longer than flowering glume, 9-11 mm, glabrous, tip blunt; keels not distinguishable, glabrous; rhachilla densely scabrous. Caryopsis c. 6.5 x 1.5 mm, persistent style base glabrous.

1.18 *Himalayacalamus asper*

Clumps dense, rhizome pachymorph, up to 25 cm long. Culms drooping, maximum length 6 m; at ¼ height diameter 2 cm, walls up to 3 mm thick; nodes substantially raised, unarmed; internodes up to 30 cm long, surface covered with thin wax, smooth with no ridges. New culm sheath from ¼ height c. 65 mm wide at base, attenuating convexly in distal 1/4 to neck 6-12 mm wide, deciduous, coriaceous with veins raised; height to ligule c. 25 cm; blade reflexed, 5-7 cm long, 4-6 mm wide, glabrous, persistent; exterior covered with tiny clear retrorse bulbous-based spines, shoulders glabrous, rising steeply beside ligule; auricles absent; oral setae absent; ligule up to 15 mm broad, up to 6 mm tall, glabrous both sides, margin lacerate; edges both sparsely 0.5 mm ciliate in distal 1/20th, ciliae clear or white. New leaf sheath surface and edges glabrous; callus pronounced, very shortly ciliate; auricles small, reflexed, deciduous; oral setae few to many, short; ligule rounded, c. 1 mm long, densely puberulous. Leaf blade maximum length and breadth 170 x 20 mm; abaxial glabrous but with light hairs beside base of midrib; adaxial glabrous; petiole glabrous; tessellation absent. Branches up to 30 in mid-culm; buds present at c. 3 basal nodes then absent for several nodes, bud shape broadly ovate; no aerial roots. Inflorescence unknown.

1.19 *Himalayacalamus aequatus*

Clumps dense. Rhizomes pachymorph, up to 20 cm long. Culms drooping, up to 5 m long; at  $\frac{1}{4}$  height diameter up to 15 mm, walls up to 4 mm thick; nodes level, hardly raised at all, unarmed; supra-nodal ridge absent in proximal  $\frac{1}{2}$  of culm; persistent sheath base narrow; internodes up to 20 cm, noticeably shorter in proximal  $\frac{1}{2}$  of culm, surface with little wax, soon becoming glossy, smooth with no ridges, with some purple colouration immediately above and below nodes. New culm sheath from  $\frac{1}{4}$  height deciduous, c. 40 mm wide at base; attenuating convexly in distal  $\frac{1}{3}$  to c. 2 mm wide neck; height to ligule c. 18 cm; texture tough and smooth with membranous recurved margins, distally thinner with persistent impression from underlying node; blade reflexed, up to 40 mm long, 2 mm wide, proximally scabrous, quite persistent; shoulders very shortly pubescent; auricles absent; oral setae absent; ligule c. 4 mm broad x 2 mm tall, exterior very shortly pubescent, interior glabrous, margin slightly serrated; distal  $\frac{1}{3}$  of both edges with white c. 1 mm ciliae. New leaf sheath surface and edges glabrous, or overlapping edge distally short-ciliate; callus not pronounced, glabrous; auricles absent; oral setae absent; ligule short, up to 1 mm long, rounded, densely puberulous. Leaf blade maximum length and breadth 130 x 10 mm; surfaces and petiole glabrous; petiole often pigmented; tessellation absent; mid-rib & secondary veins very distinct. Branches up to 20 at mid-culm, basal c. 6 nodes with no branches or buds; buds broadly ovate, with up to 12 initials visible, in 1 or 2 rows; mid-culm central branch up to 1.5 mm, no aerial roots. Inflorescence unknown.

1.20 *Himalayacalamus fimbriatus*

Clumps dense. Culms drooping, up to 7 m long; at  $\frac{1}{4}$  height diameter up to 18 mm; nodes substantially raised, unarmed, persistent sheath base bearing dense ring of retrorse orange hairs; internodes up to 27 cm long, basal length increment gradual, surface uniformly thinly to densely white waxy, smooth with no lines; supra-nodal ridge purple. New culm sheath from  $\frac{1}{4}$  height c. 55 mm wide at base; attenuation convex and asymmetrical in distal  $\frac{1}{3}$  to c. 8 mm wide neck, deciduous, mostly glabrous but proximally with persistent ring of erect dense orange 3-5 mm hairs, blotched purple especially distal  $\frac{1}{2}$  and proximal 1 cm; height to ligule c. 19 cm; blade reflexed, up to 50 mm long x 4 mm wide, deciduous; shoulders shortly pubescent, rising steeply both sides, up to 8 mm tall; auricles absent; oral setae absent; ligule c. 5 mm broad x 4 mm wide, concavely depressed, 6-8 mm fimbriate, outer surface lightly pubescent, inner with dense pubescence merging into fimbriation extending c. 2 mm below ligule, edges both 2-3 mm ciliate in distal  $\frac{1}{5}$ . New leaf sheath surface glabrous; overlapping edge 0.5 mm ciliate distal 2 cm, inner edge ciliate beside shoulder only; callus inconspicuous; auricles small, quickly deciduous or persistent, c. 1 mm long, falcate, reflexed; oral setae up to 20 each side, 2 mm long, stout, glabrous, spreading, deciduous with auricle; ligule rounded to pointed, up to 5 mm long, very shortly pubescent. Leaf blade maximum length and breadth 200 x 20 mm, abaxial mostly glabrous with 1 mm hairs beside base of mid-rib, adaxial glabrous; petiole glabrous or adaxial proximally short pubescent; tessellation absent. Mid-culm branches up to 20, basal 2 nodes followed by 1-3 nodes without branches or buds; buds broadly ovate, c. 3 initials visible at breast height; mid-culm central branch up to 2.5 mm in diameter, with no aerial roots. Inflorescence unknown.

1.21 *Neomicrocalamus ringshu*

Clumps small, open, spreading. Rhizomes pachymorph, up to 2 m long. Culms semi-scandent, maximum length 12 m, maximum diameter 1 cm, hollow, walls up to 3 mm thick; nodes raised substantially; internodes up to 40 cm long; surface extremely smooth, shiny and tough, with no hairs or wax, becoming dark glossy green. New culm sheath from breast height up to 2.5 cm wide at base; height to ligule c. 14 cm, persistent, tough, surface completely glabrous and smooth, mottled with purple spots and darker at the base; blade up to 1 cm long, <1 mm wide, persistent but delicate, needle-like; shoulders glabrous; auricles absent; oral setae absent; ligule barely distinguishable, very short. New leaf sheath surface and edges glabrous; callus pronounced, glabrous or very shortly ciliate; auricles absent; oral setae absent; ligule 1-3 mm long, rhomboid or acute, glabrous, very shortly (0.1 mm) ciliate. Leaf blade maximum length and breadth 120 x 13 mm; broadly linear-lanceolate, surfaces and petiole glabrous. Branches up to 20 at mid-culm; central branch often strongly dominant, up to 1 cm in diameter, without aerial roots; branch nodes strongly geniculate and swollen. Inflorescence not known.

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