Plant Resources of South-East Asia

No 7

Bamboos

S. Dransfield and E. A. Widjaja (Editors)

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Foreword

There is hardly any rival to bamboo in the plant kingdom with regard to diversity of taxa, habitat, distribution and uses. Since time immemorial, this tall, perennial and handsome grass has been linked to human livelihood, fulfilling our needs for food, shelter, furniture, transport and entertainment. A Chinese philosopher has aptly said, 'A diet without meat makes one emaciated. A living environment without bamboo makes one vulgar. I would rather eat no meat than live without bamboo'.

The International Development Research Centre (IDRC) recognized the importance of bamboo for both ecological stability and economic security. For more than a decade, IDRC has supported research covering a wide spectrum, ranging from natural stand management and enlargement of service life to the development of protocols for micropropagation and production of building boards. Such research initiatives, concentrated in Asia, the haven of bamboos, have also been extended to South America and Africa, signifying the growing global interest in this group of plants.

The recent emergence of the International Network for Bamboo and Rattan (INBAR) from the informal network nurtured by IDRC, largely through the efforts of Dr C.B. Sastry, and the attention it is receiving from the governments of the countries concerned as well as the donor community, is testimony to that initiative and the potential of bamboo to promote sustainable living.

It is against this background that IDRC has joined hands with Prosea in bringing out this volume. The wealth of information contained, and the gaps in understanding the potential of this magnificent resource will, I trust, spur greater international action and cooperation.

I record my sincere appreciation of the efforts of contributors, editors and others, in and outside Prosea, involved in the production of this book.

Ottawa, October 1994

Anne V. Whyte
Director General
Environment and Natural Resources Division
International Development Research Centre

1 Introduction

1.1 General

1.1.1 What is a bamboo?

Bamboos, commonly grown as woody bamboos, belong to the *Gramineae*, and form the tribe *Bambuseae* of the subfamily *Bambusoideae*. They often have a tree-like habit and can be characterized as having woody, usually hollow culms, complex rhizome and branch systems, petiolate leaf blades and prominent sheathing organs. Moreover, all members possess similar anatomical features in the leaf blades, i.e. fusoid cells and arm cells, which set the bamboos apart from grasses. In tropical Asia and America, several members of this tribe grow into giant bamboos, which are a familiar sight in rural South-East Asia.
Bamboo is frequently confused with rattan and its derived product cane. Bamboo furniture is often referred to as rattan or cane furniture, and vice versa. However, the products are very different. Bamboos, with very few exceptions, have hollow stems which cannot be bent easily unless split. Rattans and canes are always solid and flexible, and belong to the *Palmae*.

1.1.2 Choice of species

It proved difficult to select useful species to be included as major species in Chapter 2. There are an estimated 1000 or so species of bamboo belonging to about 80 genera in the world (Table 1) of these about 200 species of which are found in South-East Asia and belong to approximately 20 genera (Table 2). Many of the species are indigenous to the monsoon area of South-East Asia. Some species are utilized and widely found in the region, whereas others are present only in limited areas but are extensively used. These species, 45 in all, belonging to 8 genera (*Bambusa* Schreber, *Cephalostachyum* Munro, *Dendrocalamus* Nees, *Gigantochloa* Kurz ex Munro, *Melocanna* Trin., *Phyllostachys* Sieb. & Zucc., *Schizostachyum* Nees and *Thyrsostachys* Gamble) are dealt with as major species in this volume.
Minor species are dealt with in Chapter 3, including infrequently used species with limited distribution and species which are currently lesser-known but of potential interest. Some of the latter belong to genera containing major species, and many to other genera such as *Dinochloa* Büse, *Melocalamus* Benth., *Nastus* Juss., *Neohouzeaua* A. Camus, *Racemobambos* Holttum, *Shibataea* Makino ex Nakai and *Yushania* Keng f.
Lesser-known species not included in the text are listed in Table 3.
Several bamboo species which are important locally such as 'bayog' and 'laak' (*Bambusa* spp.) from the Philippines or 'kuring' (*Gigantochloa* sp.) from In-

Table 1. Approximate number of woody bamboo genera and species in the world.

region	genera	species
Asia		
tropical & subtropical	24	270 (the majority are *Bambusa*)
temperate	20	320 (the majority are *Sasa*)
Africa	3	3 (endemic)
Madagascar	6	20 (endemic)
Australia	2	3
Pacific	2	4
America		
tropical	20	410 (the majority are *Chusquea*)
Total	77	1030

donesia have not been included in this volume because their identity is still uncertain.
Because bamboo classification is far from complete, and research in South-East Asia is still continuing, there will inevitably be changes in the scientific names. Moreover, new information will become available on other aspects as well in the near future.

1.1.3 Origin and geographic distribution

Bamboos occur in the tropical, subtropical and temperate regions of all continents except Europe and western Asia, from lowlands up to 4000 m altitude. Most, however, occur at low to medium elevations in the tropics, growing wild, cultivated or naturalized in a great variety of habitats (Table 2).
Because bamboo classification is far from complete and most genera are still not well understood, it is therefore impossible to provide precise information on their origin. There has been some speculation, however, on possible centres of diversity of bamboos, such as tropical America, Madagascar, and the region including southern China and northern Burma (Myanmar), Thailand and Vietnam. The genera in tropical America (about 20, reasonably well defined) are not found outside the region (McClure, 1973; Soderstrom & Ellis, 1987), whereas all known native species in Madagascar are endemic. The geographical distribution of bamboo is greatly influenced by human activities (Holttum, 1958). Forest destruction, e.g. by logging and building of new roads, has encouraged the spread of native bamboos, which subsequently become abundant and form mixed or pure bamboo forests. Most of the genera included in this volume are native to tropical Asia.
Bambusa is the most widespread genus of bamboos in tropical and subtropical Asia. There are about 37 species in South-East Asia. Of these, 16 species grow wild, each with a limited distribution; 6 species are only found in cultivation (*B. balcooa* Roxb., *B. multiplex* (Lour.) Raeuschel ex J.A. & J.H. Schultes, *B.*

Table 2. Distribution of woody bamboo genera native to South-East Asia.

Genus	Number of species	Distribution
Bambusa	c. 37	tropical and subtropical Asia, especially in monsoon and wet tropics; mostly cultivated
Cephalostachyum	11	from northeastern Himalayas to Thailand and Mindoro; mountain to lowland forest
Dendrocalamus	c. 29	from Indian subcontinent throughout South-East Asia; dry and humid tropics
Dinochloa	c. 20	Malesia; hill and lowland dipterocarp forest
Gigantochloa	c. 24	South-East Asia, wild or cultivated; humid tropics
Holttumochloa	3	Peninsular Malaysia; hill forest
Kinabaluchloa	2	Malaysia; montane forest
Maclurochloa	1	Peninsular Malaysia; mountain forest
Melocalamus	1	Bangladesh, India, Burma (Myanmar), Thailand, southern China; lowland
Nastus	c. 15	Indonesia, Papua New Guinea (also in Mascarene and Madagascar); montane forest
Neohouzeaua	2	Bangladesh to Thailand; wild or cultivated in lowlands
Pseudostachyum	1	Burma (Myanmar) and India
Racemobambos	c. 16	Malesia; mostly montane forest
Schizostachyum	c. 30	South-East Asia; wild or cultivated mostly in lowlands
Soejatmia	1	Peninsular Malaysia; wild in lowland and hill forest
Sphaerobambos	3	Malesia; lowland forest
Thyrsostachys	2	Thailand to Vietnam; dry lowlands
Vietnamosasa	3	Thailand to Vietnam; dry grassland, lowland to hill forest
Yushania	2	Taiwan to Sabah (Malaysia); mountain forest

oldhamii Munro, *B. tuldoides* Munro, *B. utilis* Lin and *B. vulgaris* Schrader ex Wendland).

There are, however, two species with a wide distribution. *Bambusa vulgaris*, for example, is pantropical, planted or naturalized in all kinds of habitats, but particularly along river banks; its origin is not certain. The hedge bamboo *B. multiplex* is widely planted in the tropics, subtropics, and even outdoors in temperate regions as an ornamental or a hedge since it can withstand low temperatures.

Dendrocalamus and *Gigantochloa* are also native to tropical Asia. They comprise some species which are found solely in cultivation, and some which have limited distribution or are endemic to relatively small areas. There are about 29 species of *Dendrocalamus* growing in South-East Asia, mainly occurring in the lowlands from the Indian subcontinent to Indo-China and Peninsular Malaysia. *D. asper* (Schultes f.) Backer ex Heyne is planted throughout in the region, from the lowlands up to about 1500 m altitude; its origin is not known. *Gigantochloa*, with about 24 species, is mainly confined to the area from Burma (Myanmar), Indo-China to Peninsular Malaysia. It has been recorded that only one species of *Gigantochloa* in Java is native; the others are believed to

Table 3. Lesser-known woody bamboo species not included in this volume.

Arundinaria argentostriata (Regel) Vilmorin (introduced from China)
A. graminea (Bean) Makino (introduced from China)
A. pygmaea (Miq.) Ascher. & Graeb. (introduced from China)
Bambusa brevispiculata Holttum (New Guinea)
B. cornuta Munro (Java)
B. dolichoclada Hayata (introduced from Taiwan)
B. farinacea K.M. Wong (Malaysia)
B. fruticosa Holttum (New Guinea)
B. hirsuta Holttum (Papua New Guinea)
B. laxa K.M. Wong (Malaysia)
B. macrolemma Holttum (New Guinea)
B. microcephala (Pilger) Holttum (New Guinea)
B. oldhamii Munro (Philippines, Indonesia)
B. riparia Holttum (New Guinea)
B. solomonensis Holttum(Papua New Guinea)
Dendrocalamus elegans (Ridley) Holttum (Malaysia)
D. nudus Pilger (Thailand)
D. sinuatus (Gamble) Holttum (Peninsular Malaysia)
Gigantochloa latifolia Ridley (Thailand)
Holttumochloa korbuensis K.M. Wong (Malaysia)
H. magica (Ridley) K.M. Wong (Malaysia)
H. pubescens K.M. Wong (Malaysia)
Maclurochloa montana (Ridley) K.M. Wong (Malaysia)
Oxytenanthera densa G. Camus (Cambodia, Laos, Thailand, Vietnam)
O. hosseusii Pilger (Thailand)
O. parvifolia Brandis (Thailand)
Phyllostachys pubescens Mazel ex H. de Leh. (introduced from China)
Schizostachyum alopecurus (Stapf) Holttum (New Guinea)
S. brachythyrsus (K. Schum.) Holttum (New Guinea)
S. curranii Gamble (Luzon)
S. fenixii Gamble (Luzon)
S. insulare Ridley (Malaysia)
S. luzonicum Gamble (Luzon)
S. pleianthemum S. Dransf. (Indonesia)
S. textorium (Blanco) Merrill (Luzon)
S. toppingii Gamble (Luzon)
S. undulatum S. Dransf. (Indonesia)
S. whitei Holttum (New Guinea)
Soejatmia ridleyi (Gamble) K.M. Wong (Malaysia)
Sphaerobambos hirsuta S. Dransf. (Sabah, Peninsular Malaysia)
S. philippinensis (Gamble) S. Dransf. (Mindanao)
S. subtilis S. Dransf. (Sulawesi)
Vietnamosasa ciliata (A. Camus) Nguyen (Cambodia, Thailand)
V. pusilla (A. Chev. & A. Camus) Nguyen (Vietnam, Thailand)

have been introduced from the Asian mainland during the migration of people from the north.

Cephalostachyum, *Melocanna* and *Thyrsostachys* are mainly found on the mainland of Asia from the Indian subcontinent to Thailand, Vietnam and Laos.

Cephalostachyum is an interesting but poorly known genus of about 11 species, 5 of which occur from the Himalaya to northern Burma (Myanmar), whereas the others are found from Burma (Myanmar) to Vietnam, mostly growing in the lowlands, and one species is found in Mindoro (the Philippines). *Melocanna* seems to have one species only, *M. baccifera* (Roxb.) Kurz, which is found in Bangladesh, Assam (India), Burma (Myanmar) and Thailand. It has been introduced elsewhere in the tropics. *Thyrsostachys* is native to Thailand and Burma (Myanmar) and consists of two species. *T. siamensis* Gamble is one of the most useful bamboos in Thailand. It has been introduced into other countries in South-East Asia.

Schizostachyum is distributed throughout South-East Asia, extending into the Pacific Islands, with its centre of distribution in Malaysia and western Indonesia. There are about 30 species, most of them having a limited distribution.

The genus *Phyllostachys* is native to China, comprising about 50 species. Some species have been introduced and cultivated in Japan, Europe, North America and the tropical highlands. *P. aurea* A. & C. Rivière has become naturalized in many parts of the tropics.

Dinochloa, comprising about 20 species, is found from the Andaman Islands and southern Thailand throughout Malaysia, western Indonesia and the Philippines. Species are found scattered in lowland and hill dipterocarp forest, but they become weeds in logged and disturbed areas.

Racemobambos is confined to Malesia including the Bismarck Archipelago and the Solomon Islands, but so far has not been found in Sumatra, Java or the Lesser Sunda Islands. It consists of about 16 species.

Nastus is found mainly in the southern hemisphere from Madagascar to the Solomon Islands, although it has been recorded in the northern hemisphere in Sumatra. It consists of about 15 species.

1.1.4 Uses

Bamboo is one of the natural resources of the tropics, and because of its wide distribution, availability, rapid growth, easy handling and desirable properties, has been used widely in the daily life of the local community as a sustainable resource. Bamboos are utilized intensively for a wide range of purposes. 'No plant is known in the tropical zone which could supply to man so many technical advantages as the bamboo. The strength of the culms, their straightness, smoothness, lightness combined with hardness and greater hollowness; the facility and regularity with which they can be split; the different sizes, various lengths and thickness of their joints make them suitable for numerous purposes to serve which other material would require much labour and preparation' (Kurz, 1876). Even in this mechanical age, their usefulness continues and is likely to continue, because they are a necessity of life in South-East Asian communities (Holttum, 1958). In recent years bamboos have entered the highly competitive world market in the form of pulp for paper, parquet, plybamboo, and as a canned vegetable.

The most significant uses in South-East Asia are for building material, for making various types of baskets, and as a vegetable. Other important uses are as a source of raw material for making paper, for musical instruments and handicrafts.

Building material

Bamboo culms have many characteristics that make them suitable for numerous construction purposes (Kurz, 1876; McClure, 1953). Some species are used only for building material (pillars, walls, roofs and floors). When used for pillars, bridges or scaffolding, culms should have a large diameter with thick walls and relatively short internodes. In South-East Asia species suitable for this purpose belong to *Bambusa* (e.g. *B. bambos* (L.) Voss, *B. blumeana* J.A. & J.H. Schultes, *B. tulda* Roxb. and *B. vulgaris*), *Dendrocalamus* (e.g. *D. asper*) and *Gigantochloa* (e.g. *G. apus* (J.A. & J.H. Schultes) Kurz, *G. atter* (Hassk.) Kurz, *G. levis* (Blanco) Merrill, *G. pseudoarundinacea* (Steudel) Widjaja, *G. robusta* Kurz and *G. scortechinii* Gamble).
Species with culms of medium diameter and with relatively thin walls are suitable for the construction of walls, floors and roofs (e.g. *Schizostachyum brachycladum* Kurz, *S. zollingeri* Steudel, *Gigantochloa levis*). In South-East Asia there are several methods of preparation. The commonest and easiest way to make walls is to cut the culms to appropriate length, split them on one side only and then flatten them out; they are either used as such and joined together vertically, or they are woven into a large piece. In the most elaborate method, the culms are split into very thin long strips which are plaited into larger pieces with attractive motifs. This kind of plaited bamboo is also used for partitions and ceilings. In houses with floors raised above the ground, the floor is often made of split bamboo culms of about 5 cm wide, joined together and secured with strips of bamboo culms or other material. In roof construction the culms are split in two and laid in such a way that they resemble corrugated iron. In Bali, bamboo tiles, 30 cm × 5 cm, are used for roof construction. Locally, bamboo culms are used to reinforce cement/concrete structures in China, India, Japan, the Philippines and Indonesia.

Baskets

Bamboo species with culms of smaller diameter, relatively thick walls (e.g. *Gigantochloa apus*, *G. scortechinii*, *Schizostachyum zollingeri*), and which split easily are used for making various types of baskets (Widjaja, 1984; Wong, 1989). In many parts of East and South-East Asia, local people still prefer baskets made from split bamboo rather than from plastics for carrying vegetables and fruits, poultry or pigs, because braided bamboo 'breathes'. Although plastics are used ubiquitous, simple carrying baskets and boxes of bamboo are still being produced. In some parts of Indonesia, local people prefer to use thin-walled bamboos (such as *Bambusa atra* Lindley, *B. forbesii* (Ridley) Holttum, *Schizostachyum brachycladum*) for making a fine basket, as this saves having to split the bamboo beforehand.

Vegetables

Bamboo shoots ('rebung') are an important vegetable in East and South-East Asia. A shoot is the new growth of the rhizome apex into a young culm and consists of young internodes protected by sheaths. After removing these sheaths, the shoot is cut into small pieces or shredded and then cooked in boiling water.

The pieces are then used as a vegetable ingredient for various dishes such as pickles, fried meat or vegetables, meat or vegetables cooked in coconut milk. In general the shoots emerge during the rainy season and the desired shoot is the one which grows from the rhizome buried deep in the soil. In many parts of South-East Asia, shoots are consumed locally, but in Thailand a large-scale canned bamboo-shoot industry has developed.
In general, young shoots of many bamboo species are edible, but only a few bamboos produce superior shoots, i.e. *Dendrocalamus asper*, *Gigantochloa levis*, *G. albociliata* (Munzo) Kurz and *Thyrsostachys siamensis*. In China, superior bamboo shoots are produced by *Phyllostachys pubescens* Mazel ex H. de Leh., *Dendrocalamus latiflorus* Munro and *Bambusa oldhamii*.

Paper

For centuries the Chinese have used bamboo in paper making (e.g. *Phyllostachys pubescens*). In South-East Asia (e.g. Indonesia, the Philippines and Thailand) paper mills have been established using some bamboo species as raw material, such as *Bambusa bambos*, *B. blumeana* and *Dendrocalamus strictus* (Roxb.) Nees). In India, the principal species used is *D. strictus*.

Musical instruments

Bamboo musical instruments have been developed by most tribes in South-East Asia. There are 3 types, i.e. idiophones (percussion or hammer instruments), aerophones (blown instruments) and chordophones (stringed instruments). Apparently, bamboo musical instruments have been known in South-East Asia for a long time, because flutes are known to every tribe. Filipinos, Indonesians and Thais have stringed instruments, although the number of strings varies. Species of the genus *Schizostachyum* are the most suitable for making aerophones (like 'kan' or 'sompotan'), because of small diameter culms, long internodes and thin walls. The main species used for making idiophones (e.g. 'angklung') and chordophones are *Gigantochloa atroviolacea* Widjaja, *G. atter*, *G. levis*, *G. pseudoarundinacea* and *G. robusta*; sometimes *Dendrocalamus asper* and *Gigantochloa apus* are also used. The large-diameter culms of *G. atroviolacea* are used for making bass drums and bass horns.

Handicraft

Another important use of bamboo is in the handicraft industry. Table mats, handbags, hats and other woven bric-à-brac can be made of bamboo. The best developed bamboo handicraft industry is the weaving of bamboo splits. In weaving the bamboo splits, many different patterns have been created. However, there are some handicrafts made of unsplit bamboo. Usually this kind of handicraft consists of engravings on the outer part of the culm or the rhizome. The species employed in woven handicrafts are mostly species with long and flexible fibres such as *Bambusa atra*, *Gigantochloa apus*, *G. scortechinii*, and *Schizostachyum latifolium* Gamble. Species that are easily engraved are *Bambusa vulgaris*, *Dendrocalamus asper* and *Schizostachyum brachycladum*.

Furniture

People of South-East Asia living in bamboo-rich areas have long used bamboo culms to make their furniture. Recently, bamboo furniture has become popular, and elite bamboos are sought after. A number of species of *Bambusa*, *Dendrocalamus* and *Gigantochloa* are commonly used in the furniture industry (Widjaja, 1980). Two of the favoured species are *Gigantochloa atroviolacea* and *Dendrocalamus asper*, whose culms are straight and smooth.

Hedge, wind-break, ornamental

Some bamboos are used as a living hedge or wind-break when planted close together such as *Thyrsostachys siamensis* and *Bambusa multiplex*. Several species (e.g. *Bambusa multiplex*, *B. vulgaris*, *Schizostachyum brachycladum*) are planted as ornamental. The thorny bamboos (e.g. *Bambusa bambos*) are often planted around fruit orchards, vegetable fields, smallholdings or villages to protect them from intruders (e.g. wild animals).

Other uses

Culms of *Dendrocalamus asper*, for instance, are also used as containers for collecting water or palm juice, for pipes and troughs, etc. Unsplit internodes, e.g. of *Schizostachyum brachycladum*, are used as pots for cooking vegetables, meat, rice or glutinous rice. The internode is usually lined with banana leaf before being filled with uncooked food, and is placed over a fire. Glutinous rice with coconut milk cooked in a bamboo internode ('lemang') is a popular dish in South-East Asia.
Forest destruction has allowed some bamboo species to become abundant; they are a major source for native people to develop cottage industries of chopsticks, satay sticks and incense sticks (e.g. *Gigantochloa scortechinii*).
Fish traps are made of split bamboo joined together with either rattan strips or bamboo strips.
Bamboo rafts are usually made from culms with medium diameter and relatively thin walls.
Bamboo leaves are often used as fodder. Large and smooth leaf blades are used for wrapping food (e.g. Chinese 'bak chang' made of glutinous rice). In Indonesia, large leaves are also used to make 'tangerang' hats for working in rice fields or tea plantations.
Bamboo culms are used for various poles, e.g. carrying poles, vegetable and fruit props, fishing rods, outriggers, boating poles, posts and fences.

1.1.5 Properties

Physical properties

- Moisture content. The moisture content (m.c.) of bamboo culms is important and can influence mechanical properties. It is determined by the weight of the water in the culm, expressed as a percentage of the dry weight of the culm: (weight – dry weight)/dry weight × 100%. The moisture content of ma-

ture culms of fresh bamboo ranges from 50–99% and of immature culms from 80–150%, whereas for dried bamboo it varies between 12–18%.
The moisture content of culms increases from bottom to top, and from 1–3 years; it decreases in culms older than 3 years. It is much higher in the rainy season than in the dry season.

- Density. Density is given at a certain moisture content in kg/m^3. For example, it ranges from 600–900 kg/m^3 at 12% moisture content for *Dendrocalamus strictus*. Specific gravity is sometimes given calculated for 0% moisture content and is a dimensionless parameter.
- Fibre saturation point. The fibre saturation point is the point at which there is no more free water in the culm, but the cell walls are still saturated with water. Apparently, fibres and parenchyma have different fibre saturation points, leading to different values. The fibre saturation point is given as a percentage and is 20% for *Dendrocalamus strictus*.
- Shrinkage. Unlike wood, bamboo begins to shrink directly after harvesting, but it does not continue uniformly. Shrinkage affects both the thickness of the culm wall and the diameter (Liese, 1985). Drying green mature bamboo to about 20% moisture content, leads to a shrinkage of 4–14% in the wall thickness and 3–12% in diameter. Shrinkage is slightly more in the radial direction than in the tangential diameter (about 7% compared with 6%), but differences between the inner and outer wall are greater; shrinkage in the longitudinal direction is less than 0.5%.

Mechanical properties

The mechanical properties generally used for bamboos are the same as those for wood, and values are given at a certain moisture content. All values for strength properties increase with a decreasing moisture content and are positively correlated to specific gravity. The parameters for bending strength and compression strength refer to the whole culm of the bamboo and not to split bamboos. However, some authors have tested the mechanical properties of split bamboos as well.

- Bending. For (static) bending strength the following parameters are used:
  - Modulus of elasticity (in N/mm^2) indicates the ratio between the bending stress in the material and the relative deformation caused by this bending stress; it is a measure of rigidity; thus higher values indicate more rigid material. The modulus of elasticity is directly related to the amount of fibres, thus in a culm the value of this parameter decreases from the outer side to the inner side. The normal range for air-dried culms is 17 000–20 000 and for green culms 9000–10 100 N/mm^2.
  - Modulus of rupture (= fibre stress at maximum load, maximum fibre stress, ultimate bending stress, stress at breaking point) indicates the stress necessary to bring about failure of the tested material when bent (in N/mm^2). The normal range is 72–94 (without nodes), 84–120 (with nodes) N/mm^2. The modulus of rupture is approximately 0.14 × density (in kg/m^3) for dry bamboo (12% moisture content), 0.11 × density for green bamboo (Janssen, 1990).
- Compression. For compression the following parameters are used:
  - Compression strength parallel to grain (maximum crushing strength, ulti-

mate compression stress) indicates the stress applied parallel to the direction of the fibres necessary to bring about failure ('crush') in a sample (in N/mm^2). Normal ranges: 21.6–38.8 (bottom), 26.6–41.4 (middle) and (17.4–)31–49.9 (top) N/mm^2. The compression strength parallel to grain is approximately 0.094 × density for dry bamboo (12% moisture content) and 0.074 × density for green bamboo (moisture content 60% or more) (Janssen, 1990). Compression strength perpendicular to grain is sometimes given, but is not very common.

- Shear strength is the stress necessary to make surfaces slide over each other parallel to the direction of the grain (in N/mm^2). Shear strength in bamboo is higher than in wood, but the hollowness of bamboo causes problems in this respect. Normal ranges: 6.0–9.5 (bottom), 6.1–11.3 (middle) and (5.4–)7.6–12.6 (top) N/mm^2. The shear strength is approximately 0.021 × density for dry bamboo (12% moisture content) (Janssen, 1990).

Strength parameters for (static) bending and compression, as cited above, are commonly determined for round bamboo samples, but they can all be determined for split bamboo as well. Some authors specify how tests to determine these values are performed. Bending tests can vary in that loads are applied at different points, at the node or internode, at samples from different positions along the culm, and at different ages of the culm.

Loading at a node or at the centre of an internode influences the outcome of values: the modulus of rupture is up to 20% less when loaded at the centre of an internode, but can also be slightly more (up to 10%). However, these rather large differences are not very frequent; the modulus of elasticity is always larger, approximately 10%, for tests with loads at the centre of internodes (Limaye, 1952). The modulus of rupture is least in the middle part of the culms, sometimes there is a slight tendency to increase with increasing height along the culm. This trend holds better for the modulus of elasticity, but is not valid for all tests known from literature. Compression parallel to grain is rather similar for samples taken at different heights along the culm; presence of nodes hardly influences the value of this parameter (Atrops, 1969). Values for strength parameters are sometimes expressed in MPa (Mega Pascal), which is equal to N/mm^2. For the parameters commonly given in N/mm^2, some authors use kg/cm^2 as unit of measure; 1 kg/cm^2 equals 0.098 N/mm^2.

Chemical properties

- Major chemical components. The major components of bamboo culms are cellulose, hemicellulose and lignin; the minor components include resins, tannins, waxes, and inorganic salts (Liese, 1985). Cellulose and hemicellulose, also called holocellulose, are the solid residue of the total polysaccharide fraction that remains after extraction of minor components and lignin by mild oxidation. Hemicellulose is extracted from holocellulose with a 17.5% NaOH solution, the residue being cellulose, sometimes referred to as α-cellulose. Pentosans are the main constituents (80–90%) of hemicellulose of bamboos. In cold water some dyes and tannins can be dissolved, while hot water extracts more substances from bamboo culms, such as starch and some toxic substances. Alcohol-benzene 1 : 2 (1/3 ethanol and 2/3 benzene) extracts almost all substances not belonging to the cellulose groups and lignin. Ether

is used to extract alkaloids which do not dissolve in water.

- Pulp and paper manufacture. The chemical composition of bamboo is of special interest to the pulp and paper industry. The following components are generally cited (in %, i.e. percentage of the oven-dry weight; only for ash percentage of moisture-free weight): holocellulose (61–71%), pentosans (16–21%), lignin (20–30%), ash (1–5(–9)%), silica (0.5–4.0%, being part of the ash); solubility in cold water (1.6–4.6%), hot water (3.1–7.0%), alcohol-benzene (0.3–5.3(–7.8)%), 1% NaOH (15–30(–39)%) and sometimes ether (0.2–1.8%). Hemicellulose contributes to the strength of paperpulps. Higher lignin content implies more chemicals to be used for pulping to extract the lignin to a certain content. Greater alcohol-benzene and water solubility also imply increased consumption of chemicals in pulping. The 1% NaOH solubility indicates the amount of low molecular weight carbohydrates consisting mainly of hemicellulose and degraded cellulose; as such, it may indicate the degree of decay, e.g. by fungi, heat, and oxidation. Silica is the main constituent in ash; silica will ultimately present problems for the pulp and paper-making process. The silica content of bamboo culms is generally higher than that of wood, viz. 0.5–4.0% and most of it is deposited in the epidermis. Since bamboo contains more impurities than wood, cooking is more costly and the pulp yield is less.
  The percentage of pulp extracted from the culm is 40–50%.
- Edible young shoots. For the chemical composition of young shoots the following components are given in g or mg per 100 g edible portion: water 89–93 g, protein 1.3–2.3 g, fat 0.3–0.4 g, carbohydrates 4.2–6.1 g, fibre 0.5–0.77 g, ash 0.8–1.3 g, Ca 81–96 mg, P 42–59 mg, Fe 0.5–1.7 mg, vitamin B_1 0.07–0.14 mg, vitamin C 3.2–5.7 mg, glucose 1.8–4.1 g. Energy value 118–197 Joules; HCN content: 44–283 mg/kg.

1.1.6 Cultural aspects

Since time immemorial, bamboos have exerted profound influence on the life and cultures of Asian people. For example, bamboos always figured in local paintings, legends, songs, folklore, etc. Since prehistoric time, bamboo has been used as one of the weapons for hunting and fighting. In Peninsular Malaysia, the Temiar and Semoi make their traditional hunting weapons such as blowpipes from two internodes of bamboo. For both peoples, the blowpipe has both a symbolic and a practical value: the possession of a blowpipe is a sign that a man has reached adult status so that he is able to join hunting parties and become a full member of the community. In Irian Jaya, people make their arrowheads from small bamboo species of *Racemobambos* and of *Nastus*, and the arrow shafts from small, straight, thin bamboo culms of *Schizostachyum* species. Bamboo is also employed in traditional ceremonies; for example, in Bali the yellow variety of *Schizostachyum brachycladum* is used during the burial ceremony because yellow is considered the sacred colour of Hinduism. The roof of traditional houses and rice barns in Toraja, Sulawesi (Indonesia) is made from the green variety of the same species. 'Garong' baskets are made of several internodes of another *Schizostachyum* species tied together with split bamboo or rattan; the baskets are filled with rice wine during the Gawai festival in Sarawak, Malaysia (Sandin, 1963).

From the earliest times peoples have used a bamboo knife to cut the umbilical cord at birth. This custom occurs not only in South-East Asian countries but also in Japan, China and India. As well as being used to cut the umbilical cord, the bamboo knife is also used for circumcision by the Muslims in Indonesia and Malaysia (Kurz, 1876).

1.1.7 Problems of interpretation of names

The identification and naming of bamboos in South-East Asia present many problems because classification of bamboos is not complete. The botanical names applied in this volume and their identification are based on several sources such as previous bamboo literature, herbarium specimens and field observations.

Vernacular or local names are not considered very important for identifying bamboos because they are often not reliable. Therefore, great caution is required in the interpretation of vernacular names.

Because bamboo can be found almost everywhere, especially in tropical and subtropical Asia, and is readily available for various purposes, research on various aspects of bamboo is also considerable in the region. The information accumulated from such research is supposed to provide a background for similar research conducted in other areas; therefore it should be transferable. However, if the bamboo species are not correctly identified, and if voucher specimens are not made or cited, the result has little value. If bamboo researchers wish to cooperate, as recommended by the Third Bamboo Workshop 1988, then they should be able to communicate with each other on the same correctly named bamboo species. This means that research should have a firm taxonomic base. In order to be able to give the correct scientific name for a bamboo species, a complete herbarium specimen is required.

Collecting bamboos is time consuming and requires patience and skill. Most researchers do not bother to make full collections and like to take short cuts. Vernacular names have been used to find out scientific names by consulting literature citing both vernacular and Latin names. Some researchers have relied on cited names from checklists; very often they have uncritically gathered or cited taxonomic information from second-hand sources (i.e. literature accumulated from previous taxonomic works). Many of the published accounts from such research have been disregarded in this Prosea volume, because the names given are doubtful.

1.2 Botany

Most of the information on morphology presented here is based on the work of previous authors. Kurz (1876) was the first botanist to provide a general impression of bamboo morphology, and later Gamble (1896) extended the work of Kurz with his monograph of Indian bamboos. These two works are followed by an excellent account by Holttum (1958) on the Malayan bamboos. The terminology and definitions are mostly taken from McClure (1966).

1.2.1 Morphology (see Fig. 1)

Habit

Although bamboos are generally thought of as erect, in fact they vary in habit. A distinction can be made between clump-forming, single-stemmed and climbing bamboos. In South-East Asia they may be large and erect (e.g. some *Bambusa* spp., *Dendrocalamus* spp. and *Gigantochloa* spp.), small, slender and erect (e.g. *Thyrsostachys* spp. and some *Schizostachyum* spp.), erect with drooping or pendulous tips (e.g. *Schizostachyum* spp.), slender and scrambling (e.g. *Nastus* spp., *Racemobambos* spp.), or climbing (e.g. *Dinochloa* spp.). In scrambling bamboos, the culms grow to considerable height and bear many branches at each node; the lower culm part is straight and erect, whereas the upper part cannot support itself and scrambles or leans on nearby vegetation. Superficially this habit resembles a climber, but a proper climbing bamboo has culms which cannot support themselves and therefore twine around tree trunks.
The clump-forming (or tufted) bamboos, represented by the genera *Bambusa, Schizostachyum, Gigantochloa* and *Dendrocalamus* are predominant in the tropics, while non-clump forming or open bamboos like *Phyllostachys* predominate in the temperate zones.

Rhizome

The rhizome is of great importance in bamboos, because there is no central trunk as in trees, and the rhizome becomes the foundation of the plant. The bamboo rhizome has been described as a segmented, complex subterranean system (Holttum, 1958; McClure, 1966). There are two basic types of rhizomes: pachymorph (determinate, sympodial) and leptomorph (indeterminate, monopodial). The native bamboos of South-East Asia have a pachymorph rhizome system, in which each individual rhizome has short internodes and an apex that will continue to grow and become a culm. In this type of rhizome, the basal part ('neck') is short, narrower and more slender than the upper part. The culms are usually close together, and form a densely tufted clump. In *Melocanna baccifera* the slender 'necks' elongate for up to 1 m, so that culms are distant and form a very open or diffuse clump.
Many of the temperate bamboos have a leptomorph rhizome system. Here the rhizome is long and slender and usually hollow, and the apex extends and grows horizontally. Each internode has a solitary bud giving rise to either a culm or a rhizome. The clump has a spreading habit.

Shoot

A young shoot is a new growth of the distal end of a pachymorph rhizome or of a lateral bud of a leptomorph rhizome. It consists essentially of a short, massive, little-differentiated stem packed with nutrients and protected by numerous two-ranked, rigid sheaths (Holttum, 1958). This new growth develops slowly at first, then elongates rapidly, forming a new culm. The structure of a young shoot is often very characteristic in recognizing a bamboo species.

Figure 1. Morphology – 1–5, habit (erect, erect with drooping or pendulous tips, scrambling, climbing); 6, pachymorph (determinate) rhizome; 7, leptomorph (indeterminate) rhizome; 8–10, young shoots; 11, culm leaf: upper one at abaxial side, lower one at adaxial side (consisting of sheath, blade, ligule and auricles); 12, auricles with long bristles; 13, branches with middle branch dominant; 14, branches all of subequal size; 15, semelauctant (determinate) inflorescence; 16, iterauctant (indeterminate) inflorescence; 17, pseudospikelet; 18–21, fruits; 22, seedling.

Culm

A bamboo culm is separated by horizontal partitions ('nodes') into joints ('internodes'). Most culms have cylindrical and hollow internodes and this, together with the dense, hard, thick (or thin) walls and nodes, gives the culm great mechanical strength. The diameter of the culm depends on the species and the environment, and varies between 0.5–20 cm. The diameter of the mature culm is already determined by the diameter of the young shoot.
The internodes are usually glabrous and smooth, or rough and hairy when young, becoming glabrous at maturity. In some species the internodes are covered with white substance or wax when young. Midculm internodes are generally longer than the lower or upper ones; they are delimited by a sheath scar, which marks the insertion of the culm sheath or culm leaf to the culm. The nodes may be swollen, and the lower ones often bear aerial roots.
The culm is usually not a reliable characteristic in recognizing a bamboo species. However, it is very characteristic for certain species. For example, *Bambusa vulgaris* culms are not straight and the nodes are slanting, and *Dinochloa* culms are nearly always zig-zag.

Culm leaf

Young shoots and young culms are protected by modified leaves which embrace the developing internodes, and usually fall off when the culm becomes mature. A culm leaf consists of a sheath proper (culm sheath), a blade, a ligule, and sometimes one or two auricles. The blade is attached to the sheath along the narrow top part of the sheath. The ligule is a growth from the top of the sheath, membraneous with entire or serrate apex and with or without bristles, and the auricles are the lateral extension of each side of the blade base. The structure of the culm sheath is very important for recognizing bamboo species. The inside is smooth and shiny; when young the outside or the back is usually covered with irritant hairs which may be white, pale brown, golden brown or black. The sheaths also vary in colour and may be green, bluish or purplish-green, or yellow tinged with orange. The shape of the culm blade and the position of its attachment to the sheath (erect or deflexed) also vary.

Branch

Branches are a characteristic feature of bamboos. Each internode bears a branch bud (primordium) just above the culm leaf scar. The branch buds are arranged on alternate sides of the culm, and may be found from the lowermost node upwards or from the midculm node upwards. Branches develop while the culm is still growing, or they develop only after the culm reaches its full height. In South-East Asian bamboos, the branch bud is solitary. The branch system is often very characteristic of a bamboo genus. In *Schizostachyum*, for example, branches are many at each node, equal or subequal in size. In *Dinochloa*, the primary branch axis of the branch bud is dormant but produces short secondary branches from its basal nodes. If the apex of the culm is damaged, the dormant primary branch axis of each node will grow and elongate to replace the main culm. The array of branches that may develop at a single culm node is called branch complement.

Leaf

Each of the ultimate branchlets bears 8–18 leaves, except for *Shibataea kumasasa* (Zollinger) Nakai. They differ from the blade of the culm leaf by having a petiole and a pronounced midrib. Each leaf blade is connected to the sheath at the base of the petiole. In general the leaf blade is not useful for recognizing bamboo species. The ligule is usually very short and entire, but may be very long and deeply laciniate. Auricles may be present at the top of the sheath, and are often furnished with very long bristles.

Inflorescence and flower

Being members of the grass family, bamboos typically have a compound inflorescence consisting of many flowers. Bamboo flowers or florets are usually very small (2–15 mm long); each floret comprises a lemma, a palea, three lodicules (sometimes absent), 3 or 6 stamens, and an ovary with 1 or 3 stigmas. Usually 2 or more (rarely one) florets are borne along jointed branchlets together with one to several glumes below the florets. The whole structure is called a 'spikelet'. These spikelets are arranged in an inflorescence. Basically, there are two types of inflorescences (McClure, 1966). The first is the 'semelauctant' type, indicating a determinate inflorescence with spikelet borne in a raceme or a simple panicle, emerging and dying almost simultaneously. The second is the 'iterauctant' type, indicating an indeterminate inflorescence. In the latter type, the basic unit is a pseudospikelet with the distal portion resembling a true spikelet and the basal portion bearing buds, each of which is supported by a sheath and bears another sheathing organ called a prophyll. These buds will eventually develop into pseudospikelets, the process continuing almost indefinitely until the culm's reserves are exhausted. In South-East Asia the semelauctant type of inflorescence is characteristic of *Racemobambos*, *Nastus* and *Yushania*, whereas the iterauctant inflorescence may be found in the other genera.

Fruit

Basically the bamboo fruit (caryopsis) does not differ from the caryopsis of other members of the grass family. It consists of a pericarp enclosing the seed; the seed itself consists of endosperm and an embryo comprising a radicle, a plumule and a scutellum. In four Asian genera, namely *Dinochloa*, *Melocanna*, *Melocalamus* and *Sphaerobambos*, the pericarp of the fruit is thick and fleshy and is traversed by several vascular bundles; its ground tissue is mainly parenchymatous with cells containing numerous small globular starch grains. In this type of fruit the endosperm is much reduced and the embryo has a large scutellum containing a large number of starch grains that function as food storage.

Seedling

Because many bamboos produce seeds infrequently, published records on bamboo seedlings are very fragmentary (Arber, 1934; McClure, 1966; Soderstrom,

1981). A bamboo seedling consists of a primary root and a primary culm. The primary root, developed from the radicle, is a slender, unsegmented axis. The primary culm, which develops from the plumule, is a segmented axis. The coleoptile, a sheathing structure protecting the growing apex of the embryo, can be observed at the base of the primary culm. It is usually very short. Each node of the primary culm has a sheath, and the first 2–3 sheaths do not possess blades. These precede the first developed culm sheath in which the blade is broad and horizontally positioned. The situation can be observed in seedlings of e.g. *Dendrocalamus strictus* (Troup, 1921), *Melocanna baccifera* (Stapf, 1904), and *Schizostachyum zollingeri* (Wong, 1981).

1.2.2 Anatomy

A bamboo culm consists of approximately 50% parenchyma, 40% fibres and 10% conducting cells (i.e. vessels and sieve tubes). Parenchyma and conducting cells are more frequent in the inner part of the culm, fibres more frequent in the outer part. In the internode the cells are axially oriented whereas the direction of the cell elements in the nodes is arranged perpendicular to the internode to provide the transverse interconnections. The amount of fibre increases from bottom to top while the parenchyma content decreases.

Vascular bundles

Vascular bundles in bamboo culms consist of the xylem with 1–2 smaller protoxylem elements and two large metaxylem vessels (diameter 40–120 μm) and the phloem with thin-walled, unlignified sieve tubes connected to companion cells. The metaxylem vessels and phloem tissue is surrounded by sclerenchyma sheaths. At the peripheral zone of the culm, the vascular bundles are small and numerous, at the inner part larger and fewer. The total number of vascular bundles decreases from outer to inner parts within the culm, and from the bottom to the top. The type of vascular bundles can be differentiated into 4–5 types, depending mainly on the size and degree of isolation of the sclerenchyma sheaths associated with the vascular strands (Liese, 1980, 1987).

Fibres

Bamboo fibres are characterized by sclerenchyma cells surrounding the vascular bundle and are separated by parenchyma but they sometimes converge, forming bundles of sclerenchyma.
Fibre length may vary considerably with species. It often increases from the periphery of the culm to a maximum at about the middle, and decreases toward the inner part. The fibres are 20–40% shorter in the inner zone. An even greater variation exists longitudinally within one internode. The shortest fibres are found near the nodes, the longest fibres in the middle part of the internode. Polylamellate wall structures of fibres lead to an extremely high tensile strength (40–320 N/mm^2 from the inside to the periphery of a culm).
Anatomical features of fibres often cited are: (average) length (L, in mm), diameter (D, in μm), lumen diameter or lumen width (l, in μm) and wall thickness (w, in μm). The pulp and paper industry uses parameters derived from these

anatomical features, i.e. slenderness ratio (L/D), flexibility ratio (l/D × 100) and Runkel ratio (2w/l); the Runkel ratio should be 1 or less to be acceptable for this industry. As these ratios can easily be calculated from the anatomical features (using the same units of measure, e.g. mm), they will not be mentioned separately for species described in this volume. Ranges for the different anatomical features based on information from the literature for South-East Asian bamboos are: fibre length 1.45–3.78 mm, fibre diameter (11–)14–22 μm, lumen diameter 2–7 μm and wall thickness 4–9 μm (The Committee for Bamboo, 1984).

1.2.3 Taxonomy

The taxonomy and classification of bamboos are far from satisfactory. This is because the herbarium specimens available do not represent the bamboos of the world; moreover, they are often inadequate to represent the species. Most herbarium specimens are leafy or flowering branches. They show nothing of the complex periodic flowering behaviour nor elaborate vegetative morphology (such as rhizome system, culm leaf structure and branch architecture). Moreover, because many bamboos flower infrequently, they are often ignored completely by plant collectors.

Munro's monograph on world bamboos (1868) has become and remains to this day the foundation of all later works. He recognized 120 species belonging to 21 genera which are divided into three groups, based on the number of stamens and lodicules, and fruit structure. Later Bentham (1883) used Munro's system as a basis for his bamboo classification, with four subtribes largely based on fruit structure. Gamble (1896), in his monograph on Indian bamboos, adopted Bentham's system without modification. In the following century, Holttum (1946, 1956), regarding the existing system of classification as somewhat unnatural, proposed a new scheme based primarily on ovary structure, dividing the genera into four groups. He emphasized (1956), however, that further work on the detailed structure of the ovary and fruit in all genera was necessary to place his tentative scheme on a firm footing.

More recently, two new systems of bamboo classification have been proposed: one by Clayton & Renvoize (1986) and the other by Soderstrom & Ellis (1987). In their treatment of the *Gramineae*, Clayton & Renvoize (1986) recognize 49 bamboo genera in the tribe *Bambuseae*, which are placed in three subtribes, namely *Arundinariinae* Benth., *Bambusinae* Presl, and *Melocanninae* Reichenb. Their system of classification is based mainly on a suggestion by Holttum (1956), that the ovary appendage might be used as a primary criterion. In 1987, Soderstrom and Ellis published and proposed a system of classification which relies greatly on characters of the leaf anatomy, along with those from the spikelet, flower, and fruit. They recognize about 54 genera divided into nine subtribes, and 5 genera of uncertain placement. The subtribes are *Arthrostylidiinae* Soderstrom & Ellis, *Arundinariinae* Benth., *Bambusinae* Agardh, *Chusqueinae* Soderstrom & Ellis, *Guaduinae* Soderstrom & Ellis, *Nastinae* Soderstrom & Ellis, *Neurolepidinae* Soderstrom & Ellis, *Shibateinae* (Nakai) Soderstrom & Ellis, and *Schizostachydinae* Soderstrom & Ellis (which has now become a synonym for *Melocanninae* Reichenb.). Since then there have been further taxonomic studies on some genera belonging to different subtribes. Stapleton (1991, 1994) has proposed a new subtribe, *Racemobambosinae*, to ac-

commodate *Racemobambos*, which has no place in Soderstrom & Ellis' system. Clark (pers. comm.) does not recognize the subtribe *Neurolepidinae*, and suggests including the only genus, *Neurolepis*, in *Chusqueinae*. Based on the latter system of classification and on these recent studies, the tribe *Bambuseae* can provisionally be summarized as indicated in Table 4.

Because bamboos are of great importance in Asia, research on all aspects (including taxonomy) has been concentrated there. In 1876, Kurz published 'Bamboo and its use' containing original information on species occurring in South-East Asia. Gamble's monograph covers species from India, Sri Lanka, Burma (Myanmar) and Malaysia, and later (1910) also the Philippines. Later, Merrill (1923) also wrote accounts of bamboos from the Philippines. E.G. Camus and A. Camus (1923) published in 'Flore Générale de l'Indo-Chine' (vol. 7) an account of bamboos of Indo-China. Backer's work covers Javanese bamboos (1928). In 1958, Holttum produced a critical and excellent account of Malayan bamboos, and in 1967 published on species from New Guinea.

Some works on local flora concerning bamboos are merely the account of species (Brown & Fisher in Brown, 1951; Lin, 1968; Santos, 1986). Critical taxonomic work on South-East Asian bamboos started in the 1980s. Revisions of bamboo genera are being carried out, and complete specimens have been collected for this purpose. Since then, many new species and a few new genera have been published (Dransfield 1981, 1983a, 1983b, 1992; Widjaja 1987; Wong 1982, 1993a, 1993b).

1.2.4 Growth and development

Vegetative growth

New rhizomes are produced from the previous years' rhizomes. Culms are produced annually from the youngest rhizomes mostly, thus new culms develop near the previous year's culms (Chaturvedi, 1990; McClure, 1966). Annual production may be 5–10(–20) culms per clump for vigorous arborescent species, while in the more shrubby species 50–100 culms may be produced annually per clump (Troup, 1921). Natural clumps may consist of more than one original seedling. In Thailand, it is reported that large yields of culms occur in alternate 'on' and 'off' years (the production in the 'on' years being 2–3 times higher than in 'off' years) (Smitinand & Ramyarangsi, 1980).

The total average length of culms is 15–20 m, but in certain species like *Schizostachyum caudatum* Backer ex Heyne it is only 8 m whereas in *Dendrocalamus asper* it may reach 30 m. The internode length increases from the base towards the middle part of the culm and then decreases further upwards. The average length of internodes for most species is about 35 cm, but it may reach as much as 150 cm (as in *Schizostachyum lima* (Blanco) Merrill). Culms reach their full height 60–120 days after emergence of the young shoot. The shoots elongate at an average rate of 10–30 cm per day, but in *Bambusa tulda* the rate may reach 70 cm per day. The elongation of shoots of tropical bamboos appears to take place mostly during the night. Not all shoots sent up by the rhizome will reach maturity.

The development of branches begins after the culm reaches its full size. In most species of *Dendrocalamus*, *Gigantochloa* and *Bambusa*, the first branches

Table 4. The classification of woody bamboo genera (subtribes and genera arranged alphabetically).

Gramineae

Subfamily *Bambusoideae* Ascher. & Graeb.

Tribe *Bambuseae* Nees

Subtribe *Arthrostylidiinae*:
13 genera confined to the New World

Actinocladum
Alvimia
Apoclada
Athroostachys
Arthrostylidium
Atractantha
Aulonemia
Colanthelia
Elytrostachys
Glaziophyton
Merostachys
Myriocladus
Rhipidocladum

Subtribe *Arundinariinae*:
14 genera confined to temperate regions and mountains in the tropics of the Old World (1 genus extending to North America)

Acidosasa
Ampelocalamus
Arundinaria
Borinda
Chimonocalamus
Drepanostachyum
Fargesia
Himalayacalamus
Indocalamus
Indosasa
Pseudosasa
Sasa
Thamnocalamus
Yushania

Subtribe *Bambusinae:*
10–13 genera, mostly tropical Asia

Bambusa
Dendrocalamus
Dinochloa
Gigantochloa
Holttumochloa
Kinabaluchloa
Maclurochloa
Melocalamus
Oreobambos
Oxytenanthera
Soejatmia
Sphaerobambos
Thyrsostachys

Subtribe *Chusqueinae*:
2 genera, New World tropics

Chusquea
Neurolepis

Subtribe *Guaduinae*:
5 genera, confined to the New World tropics

Criciuma
Eremocaulon
Guadua
Olmeca
Otatea

Table 4. Continued.

Subtribe *Melocanninae* (= *Schizostachydinae*):
8 genera, mostly tropical Asia

Cephalostachyum	*Ochlandra*
Davidsea	*Pseudostachyum*
Melocanna	*Schizostachyum*
Neohouzeaua	*Teinostachyum*

Subtribe *Nastinae*:
6 genera, mostly in the southern hemisphere of the Old World tropics

Decaryochloa	*Hitchcockella*
Greslania	*Nastus*
Hickelia	*Perrierbambus*

Subtribe *Racemobambosinae*:
3 genera, Himalaya and tropical Asia

Neomicrocalamus
Racemobambos
Vietnamosasa

Subtribe *Shibateinae*:
5 genera, temperate Asia

Chimonobambusa	
Phyllostachys	*Shibataea*
Semiarundinaria	*Sinobambusa*

Source: based on Soderstrom & Ellis, 1987, with some modifications developed as a collaborative effort by C. Stapleton, S. Dransfield, L.G. Clark, and K.M. Wong.

emerge from the upper third of the culm continuing from the middle part; these are followed by more branches from the uppermost part. After all the apical branches have emerged, branches start to develop on the lower part of the culm of *Bambusa*. In some species, branches are found 1–1.5 m above the ground, in others they may emerge just above the ground.

Flowering and fruiting

It has long been known in China and India that in many bamboos plants of the same species flower stimultaneously, at intervals of 20–120 years, and then all culms die, to be replaced by seedlings. There are, in fact, three main flowering types:

- gregarious: a whole population flowers over a period of 2–3 years and then dies, although the rhizomes may still be alive (flowering cycle of e.g. *Bambusa bambos* 32–45 years, *Dendrocalamus strictus* 20–65 years, *Melocanna baccifera* 30–45 years);

- sporadic: individuals flower seasonally or occasionally, and only the flowering culms die afterwards, while the rhizomes continue to live (e.g. *Gigantochloa scortechinii*);
- continuous: individuals produce flowers all year round, the culms which produce flowers do not die (most *Schizostachyum* species).

The extent of flowering of the gregarious type tends to be later and less on good sites and under proper management; congested clumps show more extensive flowering. Grazing and the incidence of fire increase the intensity of flowering and bamboo forests near villages also exhibit a greater flowering intensity (Dwivedi, 1990).

Pachymorph species produce more fertile seeds than leptomorph bamboos (Liese, 1985). The viability of bamboo seed is short and mostly does not exceed 35 days in *Melocanna baccifera* and 21 months in *Thyrsostachys siamensis*.

After gregarious flowering, seeds germinate at the beginning of the rainy season and the best germination is obtained on bare soil. After germination the ground is carpeted with seedlings.

1.3 Ecology

In South-East Asia, bamboos may be found in a wide range of habitats from lowland to mountain forests in both the dry and humid tropics, on wastelands, swamps, and dry or regularly flooded river banks. There are no records of bamboo occurring in mangrove forest. However, very little has been published on the ecology of bamboo.

South-East Asia has various climates, ranging from per-humid to semi-arid tropical and subtropical. Some bamboo species are characteristic for the drier tropics and subtropics, whereas others are found in the humid tropics only. *Dendrocalamus strictus*, for example, is found abundantly in the region including the Indian subcontinent, southern China (southern Yunan) and Vietnam, where the dry season is pronounced. It may be found in mixed forest or as pure bamboo forest. *Thyrsostachys siamensis*, for instance, is a native in the drier areas covering central Thailand and Vietnam, and also Burma (Myanmar). It is often found in pure bamboo forest as well. Although both species usually grow in the drier areas, they perform well when planted in the humid tropics. Most species of *Schizostachyum* are encountered in the humid tropics, for instance, in lowland and hill dipterocarp forest. Most species of *Racemobambos* and *Nastus* usually grow in the montane forests of the humid tropics.

Bamboo species of the humid tropics rarely form pure bamboo forest, but they may become dominant in overlogged forest. *Dinochloa* species, for example, are usually found in lowland and hill dipterocarp forest. However, after the forest has been disturbed by logging, they become abundant as weeds, causing much concern that they may prevent the regeneration of commercial timbers (Liew, 1973). In Peninsular Malaysia, with a humid climate, three bamboos (*Dendrocalamus pendulus* Ridley, *Gigantochloa scortechinii* and *Schizostachyum grande* Ridley) commonly dominate the landscape in areas where forest has been logged or cut. This phenomenon has been observed in Indonesia and southern Thailand as well.

Bamboos are remarkably adaptable to any kind of soil. For example, *Bambusa vulgaris*, a pantropical species, grows on a wide range of soils. However, bam-

boos perform best on well-drained rich soils; on poor soils, culms are shorter and have a much smaller diameter. *Dendrocalamus elegans* (Ridley) Holttum is found, however, only on limestone hills in northern Peninsular Malaysia and southern Thailand. Other species, such as *Dinochloa obclavata* S. Dransf. and *Racemobambos rigidifolia* Holttum, both from Sabah (Malaysia), are confined to forest on ultramafic rock.
An inventory of the bamboo resources in Peninsular Malaysia revealed that bamboos occur significantly more often in logged-over areas than in undisturbed forest. Logging creates a light-abundant environment favourable for bamboos (Nor & Wong, 1987).

1.4 Exploitation and cultivation

1.4.1 History of bamboo exploitation and cultivation

For centuries, people of tropical Asia have been utilizing bamboos collected from the wild, as well as from species already domesticated. In Thailand, young shoots of *Thyrsostachys siamensis* were collected from the wild for local consumption only, but recently they have become very popular and they are now canned for export. Most shoots are still collected from bamboos growing in the wild.
Paper mills have been built in areas where *Dendrocalamus strictus*, a bamboo producing good quality pulp, grows abundantly. In Peninsular Malaysia, *Gigantochloa scortechinii* becomes abundant in logged forest. In the past it was used only for making rough baskets for carrying vegetables, but recently this bamboo has become a major wild-growing resource for developing cottage industries. Bamboo here is often overexploited, giving rise to a shortage of raw material, which is a serious problem in the local cottage industry. In the past, local people exploited these wild bamboos in a sustainable way. In Indonesia, in particular in eastern Java and southern Sulawesi, *Bambusa bambos* has been overexploited because it is a major resource for paper mills. A similar situation has developed in Sumbawa where it is used as a raw material for a developing chopstick industry.
Some bamboos have been planted for centuries in parts of Asia for local use. In Java, for example, useful bamboo species are only found in cultivation and were presumably introduced from mainland Asia. They are planted around villages, often becoming naturalized and growing spontaneously. Traditionally, villagers have used bamboos on a more or less sustainable basis, renewing their gardens by planting new plants.
In several areas of South-East Asia, plantations of bamboo have been established for various purposes. In Thailand, plantations for shoot production (mainly *Dendrocalamus asper*) are located in Prachinburi Province (4465 ha). Plantations for culm as well as shoot production are found at Chiang Mai, Kanchanaburi, Songkhla, Khon Kaen, and Phitsanulok. Species included are *Bambusa bambos*, *B. blumeana*, *B. burmanica* Gamble, *Dendrocalamus asper*, *D. brandisii* (Munro) Kurz, *D. strictus*, *Gigantochloa albociliata* and *Thyrsostachys siamensis*. In Indonesia, there is a plantation of *Dendrocalamus asper*, *D. giganteus* Wallich ex Munro, *D. latiflorus* and *Gigantochloa pseudoarundinacea* in Lampung (1100 ha), and a 50 ha plantation of *Dendrocalamus asper* for culm production has been established at Mojokerto (East Java).

1.4.2 Propagation

Various methods are used to propagate bamboos: generative propagation by seed and vegetative propagation by rhizome cuttings, culm cuttings, branch cuttings, layering, and tissue culture (Bamboo Information Centre, 1990; Institute of Forest Genetics and Tree Breeding, no date; McClure, 1966; Othman et al., 1990; Ramanuja Rao et al., 1989).
Unfortunately, the availability of seed for propagation is unreliable because of the tendency of most bamboos to flower gregariously. Hence this method is very risky for large-scale establishment of plantations. Rhizome cuttings and culm cuttings are the most widely used methods of vegetative propagation. Rhizome cuttings seem more appropriate for the bamboos that do not form clumps, while culm cuttings are used for the clump-forming species (The Committee for Bamboo, 1984; Uchimura, 1978). For vegetative propagation, it is essential that viable buds be present. Moreover, the conditions for dormancy break and prolonged dormancy (in the case of transport after the propagule has been severed from the mother plant) still have to be determined (McClure, 1966).

Propagation by seed

This method of propagation depends on seed availability. Some bamboos only flower at long intervals and when flowering they rarely produce viable seeds (McClure, 1966). When seeds are available, mass propagation can be established readily: as soon as they are mature the fleshy-type fruit and the grass-type seed will germinate readily in a moist medium in a nursery, if sown immediately after gathering. The viability of the seed decreases if it is not kept under suitable conditions. For most species, viability lasts only up to about 2 months. Seed longevity could be prolonged up to 60 days in *Melocanna baccifera* by storing the seed in dry sand (Banik, 1994). Seeds may retain their viability for a much longer period of time (up to 2 years) when stored under cool conditions (Huberman, 1959). For instance, *Thyrsostachys siamensis* seeds remained viable even after 27 months when stored with a low initial moisture content of 6–10% at low temperatures (–5°C and 2–4°C) (Ramyarangsi, 1990).
After germination, seedlings should be transplanted into individual containers. When 0.75–1 m tall, the plants can be planted out in the field. The advantage of using seed in bamboo propagation is that it can be transported easily and it gives a broad genetic base to the plantation.

Propagation by rhizome cuttings

Rhizome division is traditionally the best way to propagate bamboo vegetatively. Local people prefer this method of propagation because young clumps are quickly produced. For propagation by rhizome cuttings or offsets, 1- and 2-year-old culms are used. They are cut at least at 0.3 m, and the culm with the attached rhizomes is separated from the mother plant and planted (Vongvijitra, 1990) either directly in the field during the rainy season or first in the nursery (Lantican et al., 1987). One drawback of this method is the risk of impairing the health and vigour of the mother plant when preparing many offsets

(Uchimura, 1978). Other problems are the transport of the bulky material, which is susceptible to drying out, and the high labour costs involved in collecting the offsets for mass propagation on a large scale (Sharma, 1982). Shoots are produced after 2–3 months, followed by the formation of roots. After 6 months, young plants in the nursery are ready for transplanting to the field.

Propagation by culm cuttings

It is suggested that in order to obtain good propagules, 2-year old culms should be cut before or after they have started to produce shoots. In West Java, the local people have observed that the best mother plant for propagation is a culm which has produced shoots twice or is 2 years old. Either the whole culm or culm segments can be used as vegetative propagules. If the whole culm is used, it is buried. This will stimulate the alternating buds to produce young branch shoots, which gradually transform into stronger culmlets which at the same time form roots. McClure & Kennard (1955) suggested that 2-year-old culms will produce the highest percentage of planting material. It has been found, however, that 1-year-old culms of tropical bamboos give the highest percentage of plantlets.

The second method involves culm portions bearing 1 or 2 nodes taken from culms at the age of 6 months to 2 years, usually 1 year, depending on the species. The part of the culm best suited for making the cuttings differs per species. It is reported that one internode of a culm bearing 2 buds or branches will form 2 developed young plants rapidly. The branches are pruned to a length of 10–20 cm and foliage is removed. Cuttings are planted horizontally at a depth of 5–10 cm; 1-noded cuttings can be planted obliquely with the node buried. Prior to planting, growth hormones may be applied to the cut surface to improve survival and growth (Sharma, 1982; Uchimura, 1978). After 2–3 months, young shoots emerge and will form the main culms, followed by the formation of roots.

Two-noded cuttings may be planted horizontally, level with the ground, and a hole is made in the internode and filled with water; this method is successful for *Bambusa vulgaris*. The dormant buds sprout at the nodes (Sharma, 1980).

Although rhizome cuttings are traditionally the preferred mode of vegetative propagation, culm cuttings have the advantage that more cuttings can be obtained from one clump and the costs of transport, handling and labour are lower.

Propagation by branch cuttings

Branch cuttings seem to be promising for future mass propagation, for instance of *Bambusa vulgaris* and *Dendrocalamus asper*. In Thailand, this method is very suitable for establishing of large-scale plantations of *Dendrocalamus asper* (Vongvijitra, 1990). Branches with 3 nodes are collected from 1- to 2-year-old culms; care should be taken not to injure the dormant buds. The presence of root primordia is essential for successful propagation, induction of root primordia in situ may well be possible (McClure, 1966). They may be treated with 100 ppm indoleacetic acid (IAA) and propagated in sand (Lantican et al., 1987). Normal branch cuttings develop roots after only 3–6 months and rhizomes af-

ter 12–15 months. Propagules bearing roots, rhizomes and shoots are considered essential for successful establishment and development of bamboo plantations. Artificial induction of roots and rhizome formation at branch base is possible by chopping the culm tops and removing newly emerging culms yielding 'pre-rooted and pre-rhizomed' plants (Banik, 1987).

Layering

Several methods can be applied for propagation by layers. Either a whole culm or only that part of the culm bearing branches is bent down to the ground into a shallow trench and fastened in place by hooked or crossed stakes; sometimes it is notched below the branch-bearing nodes. It is then covered with soil or some other suitable medium. However, this is a rather cumbersome method and is probably useful only for very small bamboos. Stump layers may be prepared by cutting off one or more culms in a clump, leaving 1–2 nodes with a bud or a branch complement. The stumps prepared in this way are then covered with a suitable mulch. The third method is a form of air layering in which a culm is kept erect, and may or may not be notched below each branch complement. The base of the branch complements in the midculm section is surrounded by a suitable propagating medium, held inplace by a receptacle (McClure, 1966). When roots and shoots develop at the nodes, the buried or covered parts are separated from the mother plant, the internodes cut, and the layers planted separately. Layering of *Bambusa vulgaris* and *Dendrocalamus giganteus* showed only 10% success (Banik, 1987; Lantican et al., 1987; Liese, 1985; Sharma, 1982), whereas *Melocanna baccifera* did not respond to any layering method (Banik, 1987). Air layering in *Dendrocalamus asper* appeared to be fairly successful in Indonesia (up to 50%).

Tissue culture

Tissue culture is becoming increasingly important, but results from experimental research are available on a small scale only. In India, large numbers of somatic embryos of *Dendrocalamus strictus* and *Bambusa bambos* were obtained by culturing mature embryos and explants from seedlings grown aseptically (Usha Rao et al., 1990). Plantlets have also been obtained from nodes of mature plants of *Bambusa vulgaris* and *Dendrocalamus strictus*, and precocious rhizome induction is possible to accelerate plantlet growth in the field (Ramanuja Rao & Usha Rao, 1990).

1.4.3 Management

In order to manage bamboo stands properly, three aspects should be taken into consideration: management of natural regeneration, maintenance, and fertilizer application.

Management of natural regeneration

Protection of natural regeneration is an important measure to be taken. A detailed study in Bangladesh on the natural regeneration of *Bambusa tulda* and

Dendrocalamus longispathus Kurz showed that seedling mortality was high because of suppression and competition by weeds. Almost all seedlings died within 7–12 months under complete shade. The dead mother clumps provided partial shade to the seedlings, and this condition seemed to favour the regeneration process. Burning or clear-felling the mother bamboo clumps within 1–3 months after seed germination was found to stop the regeneration process by killing all the bamboo seedlings. The effect was less negative if burning was done 6–9 months after seed germination (Banik, 1990), since bamboo seedlings generally produce an underground rhizome within 4–6 months after germination (McClure, 1966; Troup, 1921). Therefore, felling of dead culms in the early stage of the regeneration process should be discouraged because the dead clumps considerably benefit the regenerating bamboo crop and lead to a well-developed stand with healthy clumps (Ahmed, 1954; Seth, 1954). Thinning of the naturally regenerated seedlings of both species yielded 700–1000 seedlings/m^2 and enhanced seedling survival and development after 12 months (Banik, 1990).

Maintenance

Ideally, bamboo stands should be managed on a yearly basis, not only for harvesting but also for maintenance. Usually, the felling cycles are 3–4 years. Systematic and regular exploitation increases the production of the bamboo stock.
In the management of bamboo forests, maintenance cannot be overlooked: all efforts are aimed at encouraging the formation of healthy and vigorous clumps for high production of new culms. Over-mature and other non-marketable culms should be cut out to preserve maximum vigour and productivity of the rhizomes and culms (Huberman, 1959). Culms should be cut close to the ground to prevent the remaining stumps congesting the clump and reducing productivity.
Culms of *Bambusa blumeana* are often cut at a height of 2–3 m, i.e. just above the dense growth of spiny branches. Removal of the spines and the cutting of culms close to the ground increased the number of shoots that appeared each year, reduced shoot mortality and reduced the number of deformed culms, as shoots no longer had to work their way through the thicket of spines (Bumarlong, 1980). Green culms produce new sprouts after cutting (coppice). If dry culms are not removed from a clump, the coppice shoots produced in such a clump may also cause congestion. Coppice shoots are thinner than the culms and are sometimes referred to as switches (Chaturvedi, 1990).
The protection of the forest from grazing and fire is essential to proper bamboo forest management. Furthermore, earth should be mounded or heaped around the bamboo culms each year before the rainy season. A light shade from overhanging trees enhances bamboo growth (Chaturvedi, 1990). However, bamboo areas managed for shoot production require more light than those for culms used in construction (Liese, 1985).
The optimum spacing for productivity is very important in the management of bamboo plantations, but very little research has been done on this subject.
Newly planted areas should be weeded. Young bamboo plants cannot compete with weeds like *Mikania cordata* (Burm.f.) B.L. Robinson and *Pennisetum polystachion* (L.) Schultes.

Thinning of culms is important in bamboo plantations either for shoot production or for culm production. Congestion is a specific problem for clump-forming bamboos; culms are so densely packed that new culms do not develop well. Congested clumps result from damage, especially at the periphery, by grazing, fire, insects, but also by improper management like cutting indiscriminately around the periphery, continual removal of young tender shoots or digging up culms with the rhizome attached. In time, a dense mass of dead rhizomes prevents the living rhizomes from spreading outwards. The latter develop within the clump, where the new culms are also produced year after year, resulting in congestion, with the new culms bending in all directions in their effort to penetrate the dense mass of older culms (Troup, 1921). To relieve congestion, it is recommended to either (1) to cut out all congested culms, even if that leaves only the current year's culms (Chaturvedi, 1990), (2) to cut two tunnels at right angles in a clump and thin the remaining segments (Sharma, 1980), or (3) to clear-fell part of the clump in the form of a horseshoe and thin the remaining sections (Sharma, 1980; Suwannapinunt, 1990).
The thinning design for shoot production differs from that for culm production, because light is essential for shoot development. Hence, 4–5 culms that are 1–3-years old should remain uncut, e.g. 2 culms that are 1 year old, 1 culm that is 2 years old and 1–2 culms that are 3 years old. During the rainy season, a mulch with bamboo and grass leaves is recommended to encourage shoots to sprout. Shoots produced in this way are usually sweeter and more tender than those without mulching.

Fertilizer application

Traditionally, people never apply fertilizers to their bamboo groves. It has been demonstrated, however, that fertilizer application increases the production of shoots and culms. In the case of *Thyrsostachys siamensis*, *Dendrocalamus asper* and *D. strictus* the application of 15-15-15 NPK fertilizer resulted in a significant increase in yield of culms and shoots by applying 100,100 and 200 kg/ha of fertilizer respectively (Suwannapinunt & Thaiutsa, 1990). In China, compound fertilizer of N, P, K and Si applied in furrows at 375 kg/ha gave a yield increase of about 7.9 t/ha of culm, being nearly 47% (Fu et al., 1991).

1.4.4 Diseases and pests

Little information is available on diseases and pests of living or harvested bamboos.
In bamboo nurseries damping off by *Rhizoctonia solani* is the major disease, although it can be effectively controlled by fungicidal application (Mohanan, 1990). In young bamboo plantations, fungal attack of rhizome buds may affect both culm production and rhizome proliferation. Culm rot and culm sheath rot are the other important diseases affecting culm production in plantations. In Bangladesh, bamboo blight is one of the serious diseases affecting the growing culm; it is caused by the sheath rot pathogen of rice, *Sarocladium oryzae* (Boa, 1987). Witches' broom disease is common in South-East Asia. However, there are no reports of this disease affecting culm and shoot production.
Furthermore, bamboo mosaic virus (BoMV) is another important disease at-

tacking leaves, shoots and young culms. It causes shoots to harden resulting in poor quality for consumption and canning.
The most common pests of bamboo in South-East Asia affect the shoots by boring and sucking sap. *Oregma bambusae* can be a serious pest of bamboo shoots. Although uncut bamboo culms are usually healthy, culm borers (e.g. *Cyrtotrachelus dux*, *C. longimanus*) may affect culms because their larvae bore long tunnels that pass internally through several internodes (Singh, 1990). Infestation is usually worse when culm density is high. The bamboo hispine beetle (*Estigmena chinensis*) is the most important pest affecting bamboo stands in natural forests.
The most important pests of harvested culms are borers (*Dinoderus ocellaris*, *D. minutus* and *D. brevis*) which usually attack culms with high starch content (Singh, 1990).
Since more emphasis is being placed on bamboo as a suitable plant for resource-poor farmers, the potential for disease and pest damage is bound to increase (Boa, 1994).

1.4.5 Harvesting

Bamboo should be harvested in accordance with the part to be used (culm or shoot), the age and the season. For culm production, harvesting is carried out during the dry season or is started at the beginning of the dry season, to prevent culms being attacked by borers. Moreover, during the dry season the starch content is at its lowest (Sulthoni, 1987). The 1–2-year old culms are suitable to be harvested for handicraft purposes and for pulp production. The 3-year-old culms are mostly suitable for building material, furniture and other cottage industries (e.g. chopsticks).
There are two methods of harvesting culms: clear-felling (or clear-cutting) and selective felling. With clear-felling the entire clump is cut down, which causes the clump to produce smaller culms in the following year. It is not advisable to use this method when aiming at sustainable production of culms. With selective felling, only suitable culms of a certain age are harvested. By regulating the harvest correctly, it is possible to increase yield. In addition, a regular cutting system might influence the flowering behaviour of a bamboo stand. The selective felling method is generally used for exploiting and maintaining bamboo clumps. Various techniques for selective felling are applied to promote a higher productivity of clumps: i.e. the horseshoe technique, tunnel technique, M-shaped technique, and V-shaped technique.
With regard to felling intensity, it is essential to retain a number of culms for mechanical support of new shoots and to maintain the rhizomes in full vigour (Huberman, 1959). It is noted, however, that it may be rather difficult to approach the harvestable bamboos without sacrificing a few young culms growing on the periphery (Varmah & Bahadur, 1980). Recommendations regarding the felling intensity are: 50% of the old culms (Troup, 1921), or leaving at least 6 mature culms older than 1 year if the clump contains at least 12 mature culms (Varmah & Bahadur, 1980). Other sources state that all bamboo culms of 3 years and older should be cut, as they no longer provide mechanical support for new shoots because shoots are not formed close to old culms (Chaturvedi, 1990; Suwannapinunt, 1990). For sustained yield management in Malaysia,

the recommended harvesting intensity per clump in a 3-year cutting cycle is about 70% i.e. leaving about one-third of the culms in the original clump (Ahmad & Haron, 1994).
Shoots are harvested during the rainy season and preferably cut off before they emerge above the soil, when they are still fresh and tender.

1.4.6 Yield

Annual yields of bamboo culms vary according to species, environmental conditions and management. It is reported that the productivity of *Thyrsostachys siamensis* in Thailand, which mostly occurs on low-fertility soils, is on average 1500 culms/ha per year. The annual production of this bamboo is 9–15 t/ha in 'on' years and 3–5 t/ha in 'off' years. The growing stock (being the total fresh weight of living culms in a stand) of this bamboo ranges from 33.4–109.2 t/ha. The productivity of *Bambusa bambos* in Thailand is 5000–8000 culms/ha per year, and the annual production is approximately 24.7 t/ha during 'on' years and 5–8 t/ha in 'off' years, with a growing stock of 88 t/ha (Smitinand & Ramyarangsi, 1980). In the Philippines, natural stands of *Bambusa blumeana* may produce 960–1600 culms/ha per year (The Committee for Bamboo, 1984). In India, with a growing stock of *Bambusa bambos* of approximately 32 t/ha the annual production is about 3.5 t/ha (Lakshmana, 1994). However, data on yield are in general rather scarce.
Yield records for shoot production are also very rare. It is reported from Thailand that the production of *Dendrocalamus asper* shoots in 1984 in Prachinburi Province amounted to about 38 000 t. Although there are no actual figures for bamboo shoots harvested from natural forests, it is estimated that several hundred thousands t of bamboo shoots are harvested annually in Thailand (Thammincha, 1987). About 14 000 t were exported in 1985 from Thailand to Japan, United States, Hong Kong and Western Europe (Thammincha, 1990).

1.4.7 Post-harvest handling and processing

Culms

Bamboo culms become degraded during transport and storage due to attack by staining and rotting fungi, and insects (beetles, borers, termites). The durability of bamboos mainly depends on climatic conditions. Untreated bamboo may last 1–3 years when exposed directly to the atmosphere and soil, but up to 7 years when protected. Because of its low durability, treating with preservative is necessary. Two methods can be used to enhance the durability of bamboos: non-chemical methods and chemical methods (Liese, 1981).

- Non-chemical methods. The non-chemical methods are those traditionally used by the people in South-East Asia and include curing, smoking, lime painting, tar painting and submerging in water or mud. Curing involves leaving harvested culms with branches and leaves still attached in the open air. The leaves continue to transpire, so the starch content of the culms falls. It is said, however, that culms treated this way are not resistant to borers but only to termites and fungi. The second traditional method is to smoke bamboo culms above the fire. This is considered an effective treatment

against insects as well as fungi. Painting of culms with lime is widely used for walls and said to be effective against fungi. Sometimes culms are painted with tar mixed with sand, or plaster with cow dung mixed with lime to prevent attacks by fungi and insects. The fifth non-chemical method commonly used in South-East Asia is to submerge culms in either stagnant or running water, or mud for several weeks. This method is said to confer resistance to borers but not to termites and fungi. Submergence in water may result in the bamboo becoming stained.

- Chemical methods. The chemical methods for preservation are more effective but not always applicable and economical. There are 5 major chemical methods of preservation. The first is fumigation of culms with methyl bromide or other chemicals. The second method is brushing and spraying or paint-coating using borax and boric acid (1:1), varnish or melamine. This method is used against borers and mould, but is considered not very effective. The third method is butt treatment. The base of a freshly cut culm with branches and leaves still attached is placed in a container of preservative that will penetrate the vessels of the bamboo. This method is applicable only for short culms. The fourth method is the open-tank method, in which culms are soaked in a preservative for a few days. The age of the bamboo and the permeability of the skin determine how quickly the solution permeates the culm. It is therefore suggested that this method is more suitable for split bamboo than for whole culms. A higher concentration of the preservative is required to soak green culms than to soak dried bamboo. There are a few modifications of the open-tank preservation method i.e. hot dipping treatment or cold dipping treatment. These treatments are successfully applied by using 20% copper sulphate and zinc chromate followed by 20% sodium bichromate. The fifth method of preservation is the boucherie method. In essence, this method is forcing preservative to penetrate a culm by gravity. The preservative is dripped from a container which is placed higher than the culm through a pipe connected to the butt-end of the bamboo. The boucherie method has been modified by applying pneumatic pressure over the preservative fluid, thereby significantly reducing the treating time. This method can only be used on green bamboo or bamboo with a high moisture content. A successfully applied solution is a mixture of boric acid and borax (1:1).

Culms for pulp and paper making

Formerly, culms were first crushed and then chipped; however, in new mills only chippers are used. Pulping is mainly carried out through the sulphate method using caustic soda and sodium sulphide in the cooking liquor. It produces unbleached pulp that can be used for making paperboards, wrapping and bag papers. Bleached pulp is used for producing a wide range of writing, printing and wrapping papers, newsprint and paperboards. For the production of 1 t of unbleached pulp, 2 t of clean, chipped bamboo are required. To produce 1 t of bleached pulp, 2.5 t of air-dried bamboos (4 t fresh) are needed (Liese, 1981; The Committee for Bamboo, 1984).

Shoots

Degradation of bamboo shoots occurs during transport, due to browning caused by physiological activities. Active carbon from bamboo is effective for keeping bamboo shoots fresh (Hosokawa & Minamide, 1994). Young shoots of many bamboo species contain cyanogenic glucosides, which cause a bitter taste. Cooking freshly cut shoots in boiling water (changing the water 1–2 times) removes the bitter taste. In West Java, villagers bury bamboo shoots in mud or running water for 3–4 days before further preparation (Widjaja, 1987).

1.5 Breeding and genetic resources

In South-East Asia, the breeding of bamboos is still in its infancy. In China, hybridization experiments among native species (e.g. *Dendrocalamus latiflorus* × *D. hamiltonii* Nees and *D. latiflorus* × *Sinocalamus stenoauritus* W.T. Li) are carried out as part of selection and breeding programmes for shoot production (Zhang & Chen, 1994). The scope of the species selected for this purpose, however, is very limited because of the irregularity of flowering. Most of the cultivated bamboos producing good quality culms and shoots are believed to be the result of selection and domestication by mankind. These bamboos are usually homogeneous and show little morphologic and genetic variation. Because these bamboos flower and fruit infrequently, they are traditionally propagated by rhizome, culm and branch cuttings. The progeny, therefore, is usually identical. On the other hand, there is a large intraspecific variation in many wild-growing species and even in some cultivated species.

Tissue culture is very promising for the breeding of bamboos through hybridization using protoplasts and through in-vitro flowering (Mascarenhas et al., 1990).

Bamboos in South-East Asia provide a rich source of genetic variation which has not yet been investigated intensively.

Germplasm collections have been established in various parts of South-East Asia such as in Kanchanaburi and Chiang Mai (Royal Department of Forestry, Thailand), Lampung (private enterprise, Indonesia), various botanical gardens (Xishuangbuana, Nanjing, Bogor, Singapore, Hong Kong), Los Baños and Baguio (Ecosystems Research & Development Bureau, the Philippines), Kepong (Forest Research Institute of Malaysia), Forest Department of Brunei, Lae (Papua New Guinea), Peradeniya (Sri Lanka), Kerala (Kerala Forest Research Institute, India), and Calcutta and Dehra Dun (India).

1.6 Prospects

1.6.1 Management of the wild resource

The world demand for bamboos has increased recently, and this goes hand-in-hand with the increasing use of modern and sophisticated technology for processing bamboo products for traditional and modern society. On the other hand, bamboo is still and will continue to be used by local people who use it on a more or less sustainable basis. Local bamboo stands are usually planted around villages and are readily available. In many parts of Thailand, the

northern part of Peninsular Malaysia, and several areas in Indonesia, bamboos can be seen dominating the landscape. In India, Thailand and southern China, culms have been harvested for a long time from wild-growing bamboos, mainly for use in paper manufacture. In other places, culms have been collected for local needs such as house construction or for making household utensils. Bamboos from these wild populations have been exploited for use in cottage industries established by local people or communities (often supported or funded by the government), to produce items such as chopsticks and handicrafts for export. There is a great potential of bamboos from these wild populations, because of their abundance and the various end-uses for the culms. To maintain the sustainability of the wild resource, however, management of the wild population is essential.

1.6.2 Cultivation

In South and South-East Asia, large-scale plantations of some bamboo species (such as *Dendrocalamus asper*, *Thyrsostachys siamensis*) have been initiated to meet the demand of bamboo industries (especially plywood, parquet, furniture and canned shoots). Because bamboo has the ability to grow on various soils, some species have been planted for use in agroforestry in China (Huang & Hueng, 1991), reforestation and reclamation of degraded land. The prospects for bamboo cultivation are promising but there are various problems to be solved before the success of establishing a large-scale bamboo plantation will be guaranteed (e.g. selection of species, propagation, cultivation methods).

1.6.3 Trade

For centuries, South-East Asian bamboo products have been sold and shoots have been consumed locally. These products were produced by local people from culms obtained from farmers or bamboo growers. Usually, the culms were harvested on a sustainable basis, and in most cases the availability of raw material was sustained as well. Therefore, on a small scale, the trade in bamboo will continue to be reasonably promising. These local industries provide a small but steady income to local people who have marginally survived the competition with the plastics industry.

In recent years, the number of bamboo products on sale in the western hemisphere, most of which are imported from South-East and East Asia, has been increasing. There are no precise data on the international demand for these products. However, it seems likely that the global prospects for the bamboo trade are promising. China, for instance, yearly exports considerable quantities of small poles for horticultural purposes.

1.6.4 Research priorities and development

Because bamboos have many unique features and multiple uses, they provide a wide range of topics meriting investigation. In South, South-East and East Asian countries, research on many aspects of bamboos such as biology, properties, propagation, silviculture and utilization is being carried out to improve the contribution to the rural community and to support agriculture, forestry

and horticulture. These research programmes have received financial support mainly from the International Development Research Centre (IDRC, Canada), the United Nations Industrial Development Organization (UNIDO, Vienna, Austria) and the Food and Agriculture Organization of the United Nations (FAO, Rome, Italy). Since the first International Bamboo Workshop in Singapore in 1980, initiated and supported by IDRC, various international and national conferences and workshops have been organized to exchange information. Research needs, priorities and development have always been the main topics of discussion, and have recently been summarized by the International Fund for Agricultural Research (IFAR) (Williams, 1991). A new network, the International Network for Bamboo and Rattan (INBAR) has been established as an outgrowth of a network initiated by IDRC (Canada) to identify and support research on bamboo and rattan.

Researchers have always disagreed about the correct scientific name of bamboo species mentioned in the above research programmes. The establishment and use of the correct names, therefore, is essential in order to be able to exchange information.

The priorities for bamboo research and development are as follows:

(1) Survey existing resources:
- to work on critical taxonomic accounts as a basis for further development of the resources; this can be implemented either by revising each South-East Asian bamboo genus or by making an inventory in each country;
- to document the habitat, acreage, population density, uses and economic potential of the species of each genus revised, and to evaluate the biodiversity of the bamboo resources of each country;
- to explore the genetic diversity of bamboo from the wild to enable the selection of promising species and intra-specific variation.

(2) Silviculture:
- to establish methods of management of sustainable resources in natural stands and in plantations in order to improve methods of propagation, planting, maintenance and harvesting;
- to explore the use of bamboo species in agroforestry and for reforestation programmes in deforested and degraded areas, areas prone to flooding and marginal land;
- to investigate the nature of the vigorous spread of bamboo species in logged forests in order to control this spread, since it otherwise will become weedy and this prevents the regeneration of important timber tree species.

(3) Utilization and socio-economics:
- to expand the extent of post-harvest technology;
- to investigate the potential use of other parts of the culm (e.g. leaves, sheaths);
- to evaluate the employment opportunities for local people in cottage industries using bamboo as raw material collected from natural stands;
- to investigate various aspects for further development (e.g. properties, morphology, propagation, plantation, preservation) of species which locally have great economic potential but are still little known;
- to expand the extent of marketing systems locally and internationally for local industries such as cottage industries and handicrafts.

(4) Breeding and genetic improvement:

- to expand the selection of species for breeding programmes and genetic improvement.

(5) Conservation:

- to expand the extent of germplasm collection and to promote in-situ conservation;
- to identify bamboo species on which local people depend, and to protect them from over-exploitation for larger industries.

With the rapidly extending research activities on bamboos in Asia, global scientific information and training on various aspects of bamboos are very important. Bamboo Information Centres have been established, one in China and one in India; both are funded by IDRC. Training on various subjects has been initiated, especially in China and India, and it should be extended to South-East Asian countries.

Research priorities may vary for each country in South-East Asia. In Thailand and its neighbouring countries (Vietnam, Laos, Cambodia, Burma (Myanmar)), for example, where bamboo is utilized extensively, the inventory of bamboo resources is not widely carried out. However, such an inventory is essential for the further research and development of various important bamboo species in the region as a whole.

2 Alphabetical treatment of species

Bambusa atra Lindley

Penny Cyclop. 3: 357 (1835).
GRAMINEAE
$2n = 72$ (hexaploid)

Synonyms *Bambusa lineata* Munro (1868), *B. rumphiana* Kurz (1870, p.p.), *Dendrocalamus latifolius* Laut. & K. Schum. (1900).

Vernacular names Indonesia: loleba (Moluccas), nena (Sangihe).

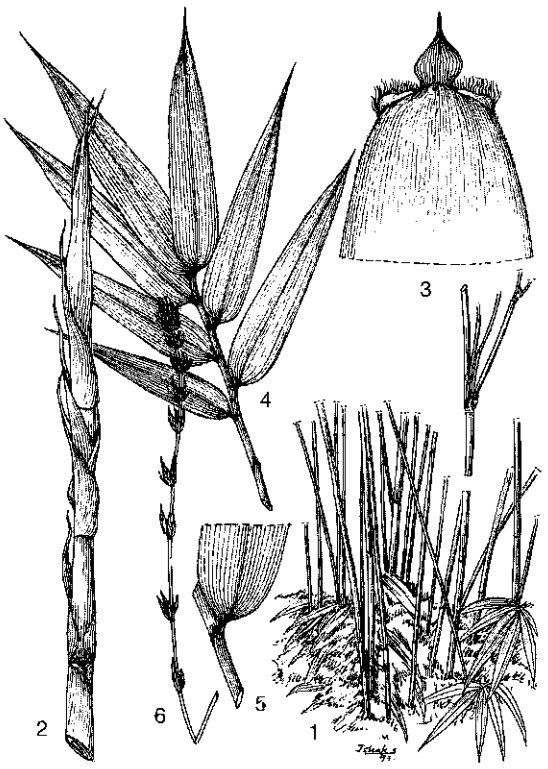
Origin and geographic distribution *B. atra* is a native of New Guinea, the Moluccas and Sangihe Island. It has also been reported to occur in the southern part of Mindanao, the Philippines. It is occasionally cultivated elsewhere, e.g. in botanic gardens in Bogor (since 1860), Calcutta and Peradeniya, and has sometimes escaped (e.g. in India).

Uses The thin-walled culm of *B. atra* is used locally in basketry and other handicrafts. Strips of culms are used as binding material in roofings, fish traps and screens.

Production and international trade *B. atra* is only locally collected from the wild. No statistics are available on the trade in handicrafts made from it.

Botany Densely or loosely tufted, sympodial bamboo. Culm up to 8 m tall, 2–4 cm in diameter near the base, wall relatively thin; internodes 35–70 cm long, sometimes only 3 long ones are found in one culm, upper part covered by appressed brown hairs when young, otherwise glabrous and smooth; nodes not prominent. Branches 2–3 at each node in the upper part of the culm, the primary one dominant. Culm sheath thin, 12–18 cm × 8–10 cm, pale brown hairy on the back; blade erect, broadly ovate-lanceolate, 8–15 cm × 4–7 cm, rounded at the base, attached to the sheath by a rather narrow base, hairy towards the base adaxially; ligule 1 mm long with a fringe of 5–6 mm long stiff hairs; auricles 12 mm long, extending horizontally on each side of the base of the blade, bearing rather long bristles along the edge. Leaf blade oblong-lanceolate, 30–60 cm × 5–10 cm, base truncate to cordate; sheath glabrous; ligule short, with long bristles; auricles up to 3 mm long, bearing bristles. Inflorescence usually terminating a leafy branch, comprising groups of pseudospikelets; spikelet laterally compressed, up to 20 mm × 4.5 mm, consisting of 3 glumes, containing up to 12 florets; lemma with long, curved, pointed tip. Caryopsis not known.

B. atra is a rather variable species in which several varieties have been distinguished. In the Moluccas two forms are distinguished: plants with green culms ('loleba putih') and plants with purplish-green culms ('loleba hitam'). Plants growing on wet soils and along river banks have longer culm internodes than plants growing on poor or dry soils. *B. atra* flowers continuously, and does not die off after flowering.



Bambusa atra Lindley – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, lower part of leaf; 6, flowering branch.

B. atra has several relatives which are also found in the eastern part of Indonesia and throughout New Guinea and the Solomon Islands, such as *B. amahussana* Lindley, *B. forbesii* (Ridley) Holttum, *B. hirsuta* Holttum and *B. solomonensis* Holttum. They share similar features such as large leaf blades, inflorescences terminating leafy branches, laterally compressed spikelets and lemmas with long, curved, pointed tips. A critical investigation is needed to find out the taxonomic relationships of these species. It is difficult to differentiate species using herbarium specimens, but in the field they can readily be distinguished from each other.

Ecology *B. atra* is a lowland species, growing along river banks and on lower hill slopes. It is also found on limestone.

Agronomy *B. atra* can be propagated by rhizome cuttings. Large-scale plantations do not exist. The culms can be harvested at any time of the year. Local people usually only harvest at a certain phase of the moon.

Genetic resources and breeding A private germplasm collection is available in Lampung (Sumatra, Indonesia). There are no breeding programmes.

Prospects *B. atra* has a bright future for the handicraft industry. Because the culms are thin, only the skin is used, which guarantees a good handicraft quality. More research is needed on natural variability and appropriate cultivation methods.

Literature |1| Holttum, R.E., 1967. The bamboos of New Guinea. Kew Bulletin 21: 268–271. |2| Rumphius, G.E., 1750. Herbarium Amboinense. Vol. 4. M. Uytwerf, Amsterdam. pp. 1–4.

E.A. Widjaja

Bambusa balcooa Roxb.

Fl. Ind. (Carey ed.) 2: 196 (1832).

GRAMINEAE

$2n = 72$

Synonyms *Dendrocalamus balcooa* (Roxb.) Voigt (1845).

Vernacular names Bangladesh: balku bans, borak bans, boro bans. India: baluka (Assam), boro bans.

Origin and geographic distribution *B. balcooa* is only known from cultivation. It is thought to originate from northern India and Bangladesh where it is widely cultivated. Occasionally it is cultivated outside this region, e.g. in Java, Australia and in many botanic gardens.

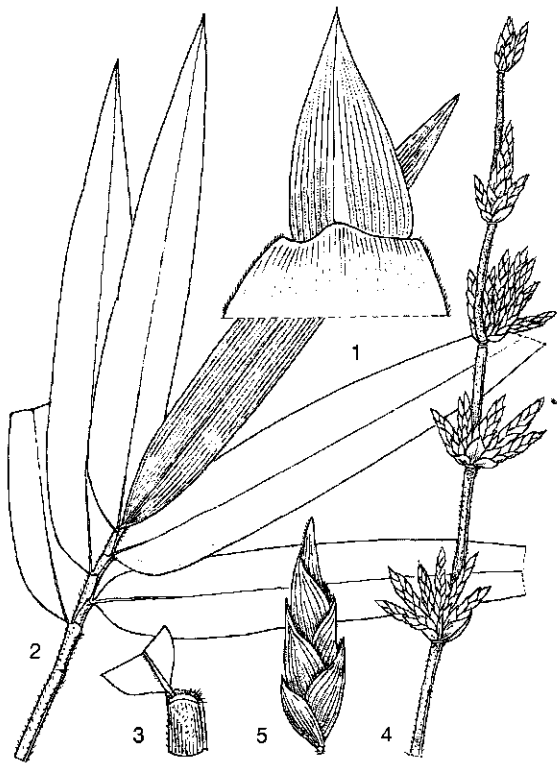
Uses The culms are used as building material for houses, bridges, temporary fishing floats, frames of rickshaw hoods, to prepare agricultural and fishing implements and to weave mats and baskets. In India the culms also serve as raw material for paper. Young shoots are used as a vegetable. In Bangladesh, leaves are used as emergency fodder.

Production and international trade *B. balcooa* is only cultivated on a small scale, in home gardens or village groves. No statistics are available. Whole culms or pieces are sold in local markets in Bangladesh and transported from rural to urban areas and from the northern to the southern part of the country. In Bangladesh the average price per culm was about US$ 2 in 1994.

Properties Fibres in the culm of *B. balcooa* have the following average dimensions: length 2–21 mm, diameter 24 µm, lumen diameter 17 µm, wall thickness 3.2 µm. The moisture content of 2–5-year-old green culms ranges from 97% to 146%. Specific gravity of 2–5-year-old culms ranges from 0.46–0.69 (green culms) and 0.73–0.82 (oven-dried culms). Mature culms (3 year or older) suffer very little or no collapse on air drying. After being dried to about 12% moisture content, the average shrinkage of mature green culms ranges 7–24% for wall thickness and 2–11% for diameter. For 3–5 year-old green and air-dried culms the following mechanical properties have been reported: modulus of elasticity 5800–11 600 N/mm^2 (green), 7100–13 700 N/mm^2 (air dried); modulus of rupture 42.8–89.0 N/mm^2 (green), 52.9–99.0 N/mm^2 (air dried); compression strength parallel to grain 24.2–42.7 N/mm^2 (green), 29.8–65.2 N/mm^2 (air dried).

Description A densely tufted, sympodial bamboo. Culm erect with pendulous tip, (5–)17.5(–30) m tall, 2.5–10 cm in diameter near the base, wall more than 2 cm thick, dirty silvery-brown pubescent; internodes 20–45 cm long, 6th–8th internodes generally longest, sometimes slightly sulcate; nodes swollen, with a supranodal ridge, lower nodes bearing aerial roots, above and below the nodes with a circular band of fine whitish-brown hairs. Branches arising from all nodes, those from the lower nodes bearing no leaves, small and sometimes recurved and thornlike. Culm sheath 15–35 cm × 15–40 cm, in lower nodes much shorter and wider than in upper ones, deciduous, green when young, covered with blackish-brown hairs on the back, margin ciliate along one edge, along the other edge only at the top; blade triangular, erect, 6–8 cm × 5–7 cm, adaxial surface dark brown pubescent, margin ciliate; ligule membranous, 5–8 mm long, denticulate; auricles absent or very small, ciliate. Young shoot blackish-green, covered with blackish hairs. Leaf blade oblong-lanceolate, 15–30 cm × 2.5–5 cm, glabrous, margin ciliate. Inflorescence compound, up to 1 m long, bearing spicate branches with pseudospikelet groups; spikelet ovoid, lanceolate or flattened, 6–12 mm × 4–6 mm, with 4–6 fertile and 0–2 sterile florets. Caryopsis not known.

Growth and development The shoots of *B. balcooa* emerge above the ground during the rainy season and reach full culm length within 2–3 months. The lateral branches develop simultaneously with the elongation of the culm. A culm becomes mature in 3–4 years. From an experiment



Bambusa balcooa Roxb. – 1, upper part of culm leaf (abaxial side); 2, leafy branch; 3, leaf sheath; 4, flowering branch; 5, pseudospikelet.

on culm production and clump expansion in Bangladesh, in which planted offsets were left undisturbed during 10 years, it appeared that the average clump diameter increased from 9.5 cm one year after planting to 80 cm after 5 years and 130 cm after 10 years. The average production of full-grown culms per year increased from one in the first year to 3 after 5 years and decreased to 2 in the remaining years, probably due to increased competition. The average culm length increased almost linearly from 2.5 m in the first year to about 23 m in the 7th year and remained constant at about 22 m in the following years. The average culm diameter increased linearly from 1.5 cm in the first year to a constant maximum of about 8 cm from the 7th year onwards. It seems advisable to start harvesting mature culms about 6 years after planting; selective cutting may encourage new culms to develop.

B. balcooa flowers rarely but gregariously; the flowering cycle is estimated at 35–45 years.

Other botanical information *B. balcooa* can be confused with *Dendrocalamus calostachyus* (Kurz) Kurz from upper Burma (Myanmar) which has similar culms and culm sheaths. In Burma (Myanmar) it is used as construction material for small buildings and for domestic purposes.

Ecology *B. balcooa* is grown at altitudes up to 600 m, in a tropical monsoon climate with an annual rainfall of 2500–3000 mm and a dry season of up to 6 months. It grows in any type of soil but prefers heavy textured soils with good drainage and pH of about 5.5.

Propagation and planting *B. balcooa* can be propagated vegetatively by rhizome, culm and branch cuttings. Root formation in culm cuttings is effectively promoted by treatment with growth regulators like naphthalene acetic acid (NAA), but auxin and kinetin are most effective in two-nodal branch cuttings that are 1 year old. The propagules are raised in a nursery and after they have produced roots and developed rhizomes they are planted out in the field during the rainy season in pits filled with a mixture of cow dung and soil, at recommended distances of 4–5 m × 4–5 m.

Husbandry Young plants need watering when rainfall is not sufficient. Before the start of the monsoon rains, clumps are generally mulched and culm bases are covered with soil. Congested clumps should be drastically cleared and annual thinnings are necessary.

Diseases and pests In Bangladesh a serious disease of *B. balcooa* is bamboo blight, attacking young bamboos during or soon after the elongation growth and resulting in dieback. *Sarocladium oryzae* (= *Acremonium strictum*) is the main fungus associated with blight symptoms, but the causal agent is not yet known. Insects spread the disease within a culm but also to other culms. Improvement of cultural practices (burning of infested parts, mulching and covering clumps with soil before the rainy season, not overharvesting culms) promotes the growth of more healthy and vigorous culms in clumps, and such culms are less susceptible to blight. Drenching the soil of affected clumps with fungicide (e.g. fytolan 0.4% or dithane M45 0.4% before the rainy season also promotes survival of new culms.

Harvesting Mature culms (yellowish) are generally harvested during the dry season by cutting them close to the ground level. Young shoots are usually harvested during the rainy season.

Yield In Bangladesh a good clump produces 3–4 mature culms per year. With 400 clumps/ha (distance 5 m × 5 m), annual production can amount to 1200–1600 culms/ha.

Handling after harvest After cutting, the

culms are debranched and traditionally are immersed for 2 months in stagnant water to protect them against powder-post beetles. After drying, whole culms or culm segments are sold in local markets. The natural durability of *B. balcooa* is poor. Various preservative treatments are known, but no specific information is available for *B. balcooa*. Green culms can be treated according to the boucherie process method in which culms are immersed in a preservative solution.

Genetic resources and breeding Small germplasm collections of *B. balcooa* are available in India (Arunachal Pradesh Centre bambusetum, Basar and in Van Vigyan Kendra, Chessa) and Bangladesh (Bambusetum of Bangladesh Forest Research Institute, Chittagong). Although always propagated vegetatively, variation occurs in culm diameter, culm height, number of young shoots and internode length. Larger germplasm collections have to be established before selection programmes can be carried out. Variability is best visible in clumps 4.5 years old.

Prospects In Bangladesh, *B. balcooa* is one of the most important village bamboos used for construction. It is worthwhile investigating if this bamboo can be cultivated equally successfully in South-East Asia. Many aspects, however, still require more research, particularly shoot production, food value of shoots, selection of disease-resistant and high-yielding cultivars, cultivation methods and mechanical properties of the culms.

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M.K. Alam

Bambusa bambos (L.) Voss

Vilm. Blumengärtn. ed. 3, vol. 1: 1189 (1896).
GRAMINEAE
$2n = 70, 72$

Synonyms *Arundo bambos* L. (1753), *Bambusa arundinacea* (Retzius) Willd. (1797), *B. spinosa* Roxb. (1814).

Vernacular names Spiny bamboo, thorny bamboo (En). Indonesia: bambu duri (Indonesian), pring ori (Javanese). Philippines: Indian bamboo. Burma (Myanmar): kya-kat-wa. Cambodia: rüssèi khléi, rüssèi préi. Laos: phaix pa:x. Thailand: phai-pa (general), phai-nam. Vietnam: tre l[af] ng[af], tre gai r[uw]ng.

Origin and geographic distribution *B. bambos* is native from India to southern China, including Thailand and Indo-China. It is also cultivated

throughout the tropics, in South-East Asia especially in East Java, Singapore, Peninsular Malaysia, Thailand and the Philippines.

Uses *B. bambos* is a multipurpose bamboo with a range of uses ranging from edible shoots (vegetable), leaves (forage) and seeds (famine food) to valuable culms for household uses and basic construction materials. It is often planted as windbreaks around farms and along rivers to check floods. In rural areas the culms are used for flooring and roofing of cottages. The culms are among the best and strongest for building purposes and scaffolding, and when well seasoned they are durable. In logging areas the culms are used for floating heavy timbers. At present the culms are important raw material for paper, pulp and plywood industries. The richly and uniformly branched culms are suitable ladders. Such natural ladders may serve for more than 2 years and they are, for example, extensively used to climb tall sugar palms to tap the sweet sap from the young inflorescence. When young, the culms of *B. bambos* are covered with wax (up to 0.25% of the weight). This wax can be used as a base for shoe polish, cheap-grade sealing wax, carbon paper and waterproof kraft paper.

In India the leaves of *B. bambos* are used in the Ayurvedic system of medicines for blood purification, leucoderma and for treatment of inflammatory conditions. An infusion of the leaves is used as an eye wash and internally it is given for bronchitis, gonorrhoea and fever.

Production and international trade The production of *B. bambos* culms in South and South-East Asia is considerable, but no statistics are available. Most culms are used locally, domestically and industrially, but there is some export. India is certainly the largest producer and consumer, e.g. in Maharashtra State alone, natural and planted *B. bambos* occupies an area of 13 000 km^2 and in Karnataka State annual production is 160 000 t. In Thailand, for example, one paperpulp factory consumes over 2000 culms daily.

Properties Fibres in the culm of *B. bambos* have the following dimensions: length 1.73–2.52 mm, diameter 16.34–22.0 µm, lumen diameter 4.93–7.44 µm, wall thickness 5.37–8.0 µm.

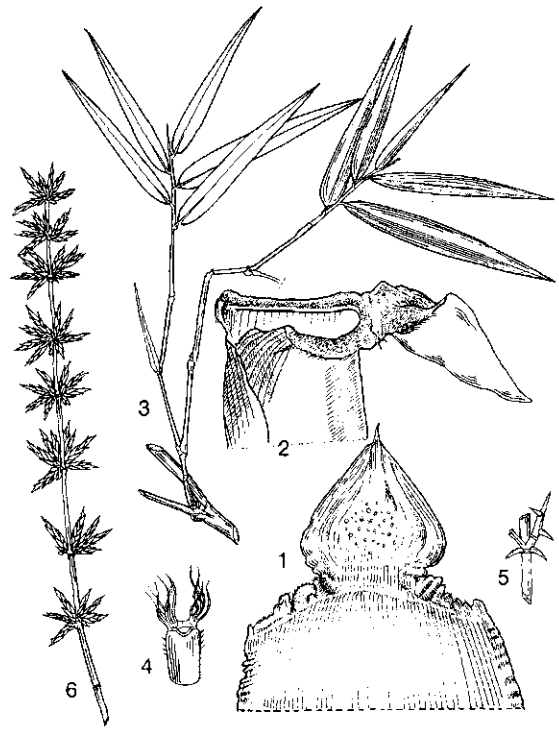
The average density of green bamboo (moisture content 104.1%) is 438 kg/m^3, of air dried bamboo (moisture content 14.3%) 664 kg/m^3. *B. bambos* seasons without much degrade. Mature culms dry rather slowly, showing very little cracking. Thick-walled pieces collapse slightly and thin-walled immature pieces may develop deformations. The following shrinkage percentages have been reported: in wall thickness for immature culms 9.6% (air dried), 12.3% (oven dried) and for mature culms 13.4% (air dried), 16.4% (oven dried); in diameter for immature culms 7.1 % (air dried), 10.5% (oven dried), for mature culms 9.9% (air dried), 13.4% (oven dried). The mechanical properties for air dried (moisture content 14.3–15.6%) and green (moisture content 104.1%) culms are respectively: modulus of elasticity 3099–12 190 N/mm^2 and 2687 N/mm^2, modulus of rupture 47.3–95.6 N/mm^2 and 45.2 N/mm^2, compression strength parallel to grain 40.3–64.9 N/mm^2 and 34.0 N/mm^2, shear strength 47.18 N/mm^2.

The approximate chemical composition of the culm is: holocellulose 58–67%, pentosans 20%, lignin 22–30%, ash 3–5%, silica 3–4%; the solubility in cold water is 4.6%, in hot water 6%, in alcohol-benzene 1.2% and in 1% NaOH 19%. Per 100 g edible portion young shoots contain: water 87–88 g, protein 3.9–4.4 g, fat 0.5 g, carbohydrates 5.5 g, fibre 1 g, ash 1 g, Ca 20–24 mg, P 40–65 mg, Fe 0.1–0.4 mg, vitamin A 76 IU, vitamin B_1 0.16 mg, vitamin B_2 0.05 mg, vitamin C 0.3–0.5 mg. The energy value is about 185 kJ/100 g. Young shoots also contain 0.03% HCN (after hydrolysis of cyanogenic glucosides) which should be removed by sufficient cooking before eating.

The approximate chemical composition of the leaves on dry matter basis is: protein 19%, fibre 24%, ash 12%, N-free extract 41%; Ca 56 mg and P 170 mg per 100 g. The digestible crude protein fraction is 13.5% and the total digestible nutrient content 46.5%.

The chemical composition of the grains (caryopsis) per 100 g edible portion is approximately: water 8 g, protein 13.5 g, carbohydrates 73 g, fibre 1 g, fat 0.4 g, ash 1.7 g, Ca 87 mg, P 163 mg. The protein content is comparable to wheat and in quality it is comparable to rice. The 1000 seed weight is 11.6 g.

Description Densely tufted, sympodial bamboo. Culm erect, up to 30 m tall and 15–18 cm in diameter, wall very thick, sometimes almost solid in upper part of culm and distal parts of branches; internodes usually 20–40 cm long, bright green; nodes slightly swollen, lower ones sometimes with aerial roots. Branches develop from all nodes, lower branches spreading, spine-like, bearing recurved spines, forming a dense, nearly impenetrable thicket in the lower part of the clump, upper leafy branches horizontal or ascending and bearing small spines, or spineless; spines usually in groups of 3. Culm sheath 15–35 cm × 18–30 cm, coriaceous, wrinkled at the top, brown hairy when



Bambusa bambos (L.) Voss – 1, culm leaf (abaxial side); 2, culm leaf (side view); 3, leafy branch; 4, top of leaf sheath with ligule and auricles; 5, part of branch with spines; 6, flowering branch.

young, glabrous when old, deciduous at the time the branches develop; ligule continuous with sheath top, 2 mm long, white ciliate; blade more or less reflexed, persistent, much shorter than the sheath, triangular, with a broad sloping and wrinkled base on either side (constituting the auricles), glabrous abaxially except for the brown, pilose wrinkled portion, adaxially densely dark-brown hairy. Leaf blade lanceolate to linear, 6–22 cm × 1–3 cm, glabrous, slightly glaucous beneath; ligule short, entire; auricles small, bearing a few bristles. Inflorescences at first terminating leafy branches, ultimately resulting in small clusters of pseudospikelets at the nodes of leafless branches; spikelet lanceolate, about 2 cm long when mature, consisting of 0–2 empty glumes, 3–7 fertile florets (lower ones hermaphrodite, upper ones male) and 1–3 imperfect florets. Caryopsis ellipsoidal, 4–8 mm long.

Growth and development *B. bambos* readily establishes from seed. The clump reaches about 5 m height in 7 years and about 20 years are necessary to reach full growth comprising 25–50 (–100) culms. Twelve-year-old clumps are regarded as mature. Undisturbed clumps are almost impenetrable after some years because of the interlacing thorny branches.

B. bambos flowers gregariously over a region at intervals of (16–)32(-45) years. A complete flowering period of the whole clump takes as long as 3 years. Flowering is followed by profuse seeding after which the old clump dies. In bamboo areas protected from fire and grazing natural regeneration occurs without difficulty.

Other botanical information *B. bambos* is related to and resembles *B. blumeana* J.A. & J.H. Schultes but has larger, straighter culms, more open branching, narrower smoother leaves and its culm sheaths bear very hairy blades that are gradually decurrent along each side of the top of the sheath and the decurrent parts are curled and not auricle-shaped.

The nomenclature of *B. bambos* is complex; many authors prefer the name *B. arundinacea* (Retzius) Willd., and consider *Arundo bambos* of Linnaeus as a 'nomen confusum'.

B. bambos is a very variable species, ranging from clumps with handsome, straight, large culms up to 27–30 m tall (tallest recorded up to 40 m) with a diameter of 15–17 cm, to clumps with almost dwarf, thick-branched, very thorny small culms up to 7 m tall. Thornless (or almost thornless) forms exist as well.

Ecology *B. bambos* prefers a humid tropical climate and grows best along river valleys and in other moist conditions. It is found most abundantly in mixed moist deciduous forest, and not so commonly in mixed dry deciduous forest and in semi-evergreen forest on hills up to 1000 m altitude.

Propagation and planting *B. bambos* is propagated by seed, rhizome cuttings and by tissue culture. Fresh seed germinates readily in 5–10 days after sowing, with a germination percentage of up to 80%. Seeds remain viable for about 6 months when stored at 5°C or when stored dry in sealed containers (with $CaCl_2$) at room temperature. Seeds stored without lowering temperature or moisture content will lose viability completely within 3 months.

Propagation by seed is most practical for large-scale plantings. Although *B. bambos* flowers and fruits gregariously at long intervals, every year individual clumps can be found flowering and fruiting in various regions of a country. As fruits are abundant, seed is seldom the limiting factor for propagation. Seedlings are normally raised in a nursery for up to 2 years before being transplant-

ed to the field at the onset of the rainy season. In the nursery seedlings should preferably be grown in large containers (18 cm × 40 cm) to facilitate optimum development.
Propagation by rhizome cuttings (offsets) is possible if only few plants are required. For successful propagation, rhizome length should be at least 5 times the basal girth of a culm.
Propagation by culm cuttings (1–3 noded, planted horizontally), has been successful when they have been treated with root-promoting chemicals like coumarin, naphthalene acetic acid or boric acid.
In India, promising results have been obtained by tissue culture using explants from selected superior plants (node, shoot tip, base of leaf sheath, rhizome part, somatic embryo plantlets) and by a technique called macroproliferation in which young seedlings are forced to multiply by manipulating their young rhizomes (up to 7 times per seedling for *B. bambos*).
Recommended planting distances have not been reported but 6 m × 6 m seems to be appropriate.

Husbandry *B. bambos* planted as a hedge around a farm or field requires little care.
A basal application of 5–10 kg farmyard manure or compost per plant before planting is beneficial to early growth. A later application of N fertilizer promotes growth and biomass production. Young plants must be watered, especially during prolonged drier periods. On a plantation scale *B. bambos* is a difficult crop. This bamboo is difficult to manage because of the thorny and interlacing branches of the culms in the clump. Dry and dead material has to be removed. Clearing the lowest 2 m of the clump enables culms from the centre to be reached. In South-East Asia, *B. bambos* forests are often natural grazing areas for domestic animals. A decline of those forests can be prevented by regulating the grazing periods and by maintaining the basal cover of the clumps by cutting culms at a higher level. In any case, after gregarious flowering of a natural bamboo forest, clear felling may only be practised after seedfall and the area should be rigidly protected against fire and closed to grazing.

Diseases and pests *B. bambos* is usually only locally seriously damaged by diseases and pests. Major diseases reported from India are damping-off (*Rhizoctonia* sp., *Fusarium* spp.), culm rot (*Fusarium* spp., *Arthrinium* sp., *Craterellus* sp.), and rhizome and root rot (*Merulius eurocephalus*).
Major pests recorded in India are the bamboo leaf roller (*Pyrausta coclesalis*), the bamboo hispine borer (*Estigmena chinensis*), the bamboo aphid (*Oregma bambusae*) and the bamboo culm borer (*Cyrtotrachelus dux*). Most diseases and pests can be controlled satisfactorily by treatment with chemicals. Research towards 'environmentally friendly' control methods is starting.

Harvesting Normally 3–4 year old culms are harvestable. They are cut 2–3 m above the ground. This should be done after the growing season in order to avoid damaging young shoots and young culms.
Clear felling of *B. bambos* clumps is practical but results in poor regeneration; the clumps remain in a congested and bushy state for 3–5 years and only after 5 years are new culms of sizeable length produced. The felling cycle in clear felling is 5–12 years.
Selective felling of individual culms results in better regeneration of the clump. Preferably, only culms older than 2 years are cut at 15–30 cm from ground level and if possible not from the periphery of the clump, so as to prevent congestion. At least half of the culms per clump, a minimum of 8–10, should be left. Extraction of rhizome parts for propagation should be prohibited and clear felling should only be allowed after flowering and fruiting.

Yield In India culm yield is on average 5 t/ha per year, but may vary from 2.5–36 t. In Thailand an annual production of 5000–8000 culms per ha is reported.

Handling after harvest In South-East Asia, traditional non-chemical methods to increase the durability of bamboo culms are widely used on a village scale, including curing, smoking, whitewashing and soaking. For preserving culms, chemical treatments are usually more effective than traditional methods. Fumigation with methyl bromide for insect control, brushing and spraying with 5% DDT, 0.5% gamma BHC or 0.5% dieldrin has proven to be effective against bamboo borers like *Dinoderus brevis*, *D. minutus* and *D. ocellaris*.
In India, good results have been obtained by dipping green culms in a solution of 1% lindane or 3% boric acid-borax mixture (1:2). The service life of culms can be extended by a treatment with boric acid, and, if used in ground contact, by immersing the butt end for 7 days in a 10% copper sulphate solution. Cheaper and safer methods for insect control and preservation are still in the experimental stage.
In some areas in India, *B. bambos* culms are grouped into 3 quality classes: class 1 with culms of 9 m or more long, class 2 with culms from 6–9

m, class 3 with culms up to 6 m long.

Genetic resources No germplasm collections of *B. bambos* are known to exist. It is worthwhile to start living plant collections to preserve its rich variability.

Breeding *B. bambos* is highly allogamous and provides opportunity for selection of desired characteristics. In India, seedlings are grouped into 4 types: grassy, grassy-erect, erect and very erect. The erect types grow fast and are more vigorous. Other breeding techniques in the experimental stage include selection of mutants (e.g. thornless types), ploidy changes and somatic cell hybridization. Pollen of *B. bambos* can be stored well at 4°C.

Prospects *B. bambos* is considered an important raw material for the paper and pulp industry in South-East Asia. In the past, most of the culms supplied to the industry were collected from natural stands, resulting in the decline of natural *B. bambos* forests. For large-scale production, the cultivation of *B. bambos* is recommended. More research is needed on cultivation techniques and the development of superior cultivars of this very useful multipurpose bamboo.

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S. Duriyaprapan & P.C.M. Jansen

Bambusa blumeana J.A. & J.H. Schultes

Syst. veg. 7: 1343 (1830).
GRAMINEAE
$2n = 78$

Synonyms *Bambusa spinosa* Blume ex Nees (1825), *B. pungens* Blanco (1837), *Bambus arundo* Blanco (1845).

Vernacular names Spiny bamboo, thorny bamboo (En). Indonesia: bambu duri (Indonesian), haur cucuk (Sundanese), pring gesing (Javanese). Malaysia: buloh duri, buloh sikai. Philippines: kauayan-tinik (Tagalog), batakan (Bisaya), kawayan-siitan (Ilokano). Cambodia: rüssèi roliëk. Laos: phaix ba:nz. Thailand: phai-sisuk. Vietnam: *tre gai*.

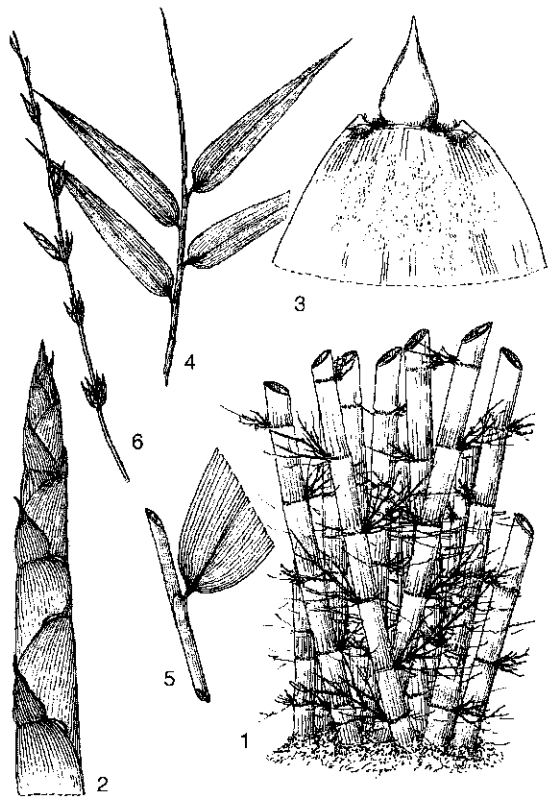
Origin and geographic distribution The exact origin of *B. blumeana* is not known, but it is believed to be native in Sumatra, Java, Lesser Sunda Islands and Borneo. It is found planted or cultivated in Peninsular Malaysia (northern provinces), Thailand, Vietnam, southern China and the Philippines. In the Philippines it was probably introduced in prehistoric times and can be found throughout the settled areas at low and medium altitudes.

Uses Young shoots are eaten as a vegetable, usually boiled and shredded. The culms are used for construction, basketry (baskets are very popular), furniture, parquets, concrete reinforcements, kitchen utensils, chopsticks, hats and toys. Culms are also used as firewood if wood is scarce. The culms are suitable for making paper. It is often planted along water courses to prevent soil erosion. It is planted around farmhouses as windbreaks, in fields as living fences or to mark boundaries.

Production and international trade In the Philippines *B. blumeana* is the most important bamboo used as building material, to make furniture and chopsticks, and for the production of paper. The Philippines exported bamboo furniture with a total value of US$ 741 505 in 1987. In Tarlac, 20 ha of *B. blumeana* have been planted for the export of chopsticks to Japan; 12 000 culms are produced per year, from which 1200 million chopsticks are made. No statistics are available from other countries in South-East Asia.

Properties In culms of *B. blumeana* the number of fibrovascular bundles increases from 2.37/mm^2 in the butt to 3.30/mm^2 in the apex. The fibre dimensions are: length 1.95–2.56 mm, diameter 15–20 µm, lumen diameter 4–9 µm, wall

thickness 5–7 µm. Fibre length increases from the 2nd to the 18th internode, after which it decreases. In the lower internodes fibre diameter and wall thickness are slightly larger. On average, the weight of a green culm is 32 kg, its branches 7 kg, its leaves 1.5 kg, and a culm has 65 internodes and 30 branches. At a moisture content of 94.5% culms have a density of 1000 kg/m^3, at about 15% the density is 500 kg/m^3. Shrinkage of culms at seasoning from green to oven-dry condition is about 8% in diameter and 13% in wall thickness. For green culms (moisture contents 94.5% and 136% respectively) the modulus of elasticity is 4110 N/mm^2 and 9000 N/mm^2, the modulus of rupture 110.9 N/mm^2 and 32.1 N/mm^2, the compression strength parallel to grain 27.1 N/mm^2 and 38.3 N/mm^2 and the shear strength 4.8 N/mm^2. The chemical composition of mature culms on dry weight basis is approximately: holocellulose 67.4 %, pentosans 19%, lignin 20.4%, ash 4.8%, silica 3.4%; the solubility in hot water is 4.3%, in alcohol-benzene 3.1% and in 1% NaOH 39.5%.
Silica content is high and internodes are sometimes completely filled with a hard, white, siliceous mass which damages any instrument used to cut it.
Per 100 g edible portion, young shoots (7–15 days old) contain approximately: water 89 g, protein 4 g, fat 0.5 g, carbohydrates 4 g, fibre 1 g, ash 1 g, Ca 37 mg, P 40 mg, Fe 1.5 mg, vitamin B_1 0.1 mg, vitamin C 10 mg. The energy value is about 120 kJ/100 g.



Bambusa blumeana J.A. & J.H. Schultes – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, lower part of leaf; 6, flowering branch.

Description Densely tufted, sympodial bamboo, with spiny basal branches forming a densely interlaced thicket to 2–3 m high. Culm erect, 15–25 m tall, up to about 20 cm in diameter, wall 0.5–3 cm thick; internodes usually hollow, 25–60 cm long, glabrous, green; nodes prominent, the lower ones bearing aerial roots. Branches arising from nearly all nodes, the lower ones spreading horizontally and bearing stout straight or curved spines in groups of (1–)3(–5) (the central one usually larger and longer than the others), the upper branches ascending, branched at the base. Culm sheath up to 30 cm × 22 cm, the lower ones short and narrow, increasing progressively upwards, coriaceous, dull, the back covered with stiff, appressed, short, deciduous dark brown hairs; blade narrowly lanceolate, up to 15 cm × 1.5 cm, erect in basal and apical sheaths, horizontal to deflexed in middle sheaths, margins incurved, apex narrowly acute, glabrescent abaxially, adaxially with scattered, short, appressed dark hairs; ligule stiff, to 5 mm long, the middle tallest and shortly fringed, the outer parts with stiff bristles to 12 mm long; auricles on either side of the base of the blade, leathery, bearing numerous curved bristles 5–15 mm long. Young shoots with yellowish-green sheaths and blades. Leaf blade linear-lanceolate, 15–20 cm × 1.5–2 cm, base rounded, margins scabrous, apex narrowly acute; sheath striate; ligule truncate, short, fimbriate; auricles small, bearing a few bristles about 3 mm long. Inflorescence borne on leafy branches and on branches of a leafless culm, consisting of pseudospikelet groups 1–5 cm or more apart; spikelet laterally compressed, up to 5 cm long, comprising 2–3 empty glumes and 5–12 florets. Caryopsis is not known.

Growth and development Planted culm cuttings at first send up thin shoots and culms are produced only after about 3 years. The number and size of the culms produced increases yearly until the clump reaches maturity. The following data are available from an experiment in the Philippines: 3 years after planting, per clump 2

culms with average height of 3 m were present; after 5 years 5 culms with average height of 8.5 m (maximum height 16.9 m, maximum diameter 10 cm). A planted cutting develops into a harvestable clump in 6–8 years. A mature clump (containing 10–40 culms) may develop about 30 shoots per year of which only about one-third to one-fourth reaches maturity because of diseases and pests, wind damage, and shortage of water and nutrients. Culms reach about full height in approximately 5 months, which means for the larger culms (25 m or more) a daily growth of about 17 cm. The most rapid growth usually occurs near the end of the growth period in the latter part of the rainy season. In that period, daily growth may reach 45 cm on average.

B. blumeana flowers very rarely, perhaps once in 20–30 years, and plants die after flowering. In the Philippines, sporadic flowering was observed in 1990; a 100-year-old clump had 6 flowering culms, a 45-year-old clump had 3 and 5 clumps of 3-year-old had 3–5; flowering extended from January to October, after which the culms died; no fruits were formed.

Other botanical information Culm diameter and internode length vary greatly. The maximum culm diameter is attained at about 6 m above ground level, the internodes are shortest in the lower part of the culm. In the Philippines plants generally have longer internodes than plants grown in Indonesia and Malaysia.

B. blumeana much resembles *B. bambos* (L.) Voss, but they can easily be distinguished from each other by their culm sheaths. In *B. blumeana* the auricles of the culm sheath are prominent, bearing numerous curved bristles along the edges, whereas in *B. bambos* they are not auricle-like, but formed as extensions of the base of the blade, covered by dark brown hairs. *B. blumeana* does not grow as large as *B. bambos* and its culms are also less durable.

Ecology Where *B. blumeana* occurs in the wild, it grows up to 300 m altitude, often on heavy soils and on marginal land. *B. blumeana* grows well along river banks, hill slopes and freshwater creeks and it tolerates flooding. Optimum pH is 5–6.5; saline soils are not tolerated.

Propagation and planting *B. blumeana* is propagated vegetatively by culm cuttings, branch cuttings, layering, marcotting and tissue culture. Propagation by culm cuttings is most common. Cuttings about 50 cm long (with 2–3 nodes) are taken from the middle portion of 1–2-year-old culms with a relatively large diameter. They are planted horizontally at 10 cm depth. Application of growth hormones, e.g. 200–600 ppm α-naphthalene acetic acid (NAA), gives a better rooting rate and longer roots. They should be planted immediately in a nursery or directly into the field in direct sunlight. Before planting, the field is cleared and cuttings or rooted cuttings are planted at a distance of 8–10 m all sides, resulting in 100–150 clumps/ha. Planting is preferably done at the beginning of the rainy season. After planting, mulch is distributed around the plant.

In the Philippines good results have also been obtained with 3-noded-cuttings from branches, up to 1.5 cm in diameter, from 1–2-year-old culms. Treated with 100 ppm IAA and planted in a sand bed, the cuttings could be potted when rooted (after about 20 days) and transplanted to the field after 2–3 months.

Husbandry During the first two years after planting, the plantation should be weeded whenever necessary. If rainfall is not sufficient, watering or irrigation is necessary during the initial period of development.

On poor soils, application of fertilizer is recommended, e.g. compost or a NPK mixture. A recommended rate per ha is in total 20–30 kg N, 10–15 kg P, 10–15 kg K and 20–30 kg silica, applied in two rounds, 1 month and 4 months after planting. Removal of spiny branches and old culm bases in the clump will increase culm production and improve access.

Diseases and pests *B. blumeana* has no serious diseases or pests during growth. In the Philippines tar spot (*Phyllachora shiriana*) and leaf rust (*Phakopsora louditiae*) are common diseases on *B. blumeana* and mites (*Schizostatranycus floresi*) are most prevalent on the leaves. Young plantations should be protected against animals which eat young shoots. Harvested culms are liable to attack by fungi (brown, white and soft rot) and especially by insects (beetles, termites). For *B. blumeana* no specific data on deteriorating organisms have been reported.

Harvesting Bamboo shoots emerge during the rainy season and can be harvested for food after 7–15 days. In *B. blumeana* plantations, the harvesting of culms may start 5 years after planting. The harvesting depends on the end use but should preferably be effected in the dry season. For handicraft purposes, 1-year-old culms can be taken. For construction purposes, 3-year-old culms are suitable. Culms are cut 2–3 m above the ground, just above the dense growth of spiny branches. The remaining basal portion should be cut back

close to the ground within 6 months of the harvest. In order to ensure sustained yield, the number of culms that can be cut annually should not exceed 60% of the standing mature culms in the clump.
Removal of the basal spiny thickets and basal parts of harvested culms makes access easier, promotes the development of healthy shoots and reduces the number of deformed culms.

Yield About 6–7 edible shoots can be harvested per clump per year. Managed (cleaned) clumps produce an average of 8 culms per year (800–1200/ha), unmanaged (uncleaned) clumps only 5 (500–750/ha). In the Philippines the marketable length of culms varies from 7–16 m, with diameter (at base) of 7–12 cm and average internode length of 34 cm. The average dry weight production ratio for culms, branches and leaves is 83.5%, 12.8% and 3.7% respectively. Standing crop production (dry weight) is estimated at 143 t/ha (120 t for culms, 18 t for branches, 5t for leaves). Per ha, about 9t pulp for paper can be produced per year.

Handling after harvest Fresh harvested young shoots are washed carefully, sliced and boiled before they are sold in local markets. Harvested culms should be dried first. Air drying (in sheds) takes about 2–4 months, kiln drying 1–2 weeks, depending on required moisture content and drying conditions.
The natural durability of untreated culms is poor: 1–3 years outdoors, 2–5 years indoors, 6 months or less in seawater. Preservation treatment considerably increases the service life of culms and is recommended, but no specific data are available for *B. blumeana*.
In South-East Asia the traditional treatment of bamboo culms after harvesting is to soak them for about 2 months in running or brackish water before drying, or to expose culm pieces for some time to the smoke and heat of a fireplace.
Culms harvested for wickerwork are allowed to wither in the shade for 3–5 days, then the nodes are removed and each internode is split lengthwise into a number of pieces. The internodes from the middle of the culms are preferred. The inner material and the outer layer are removed. The remaining material is flattened and divided into 4–10 layers, the outermost layers under the skin considered the best.

Genetic resources and breeding Germplasm collection of *B. blumeana* has been started in Indonesia (private company in Lampung (Sumatra) and Ministry of Forestry). Breeding programmes will be restricted to selection of superior genotypes, as *B. blumeana* rarely flowers.

Prospects *B. blumeana* has a promising future as a very useful bamboo for tropical lowlands. Large-scale cultivation started in the Philippines, e.g. as a pulp source for paper of various qualities, but could possibly be extended to other areas in South-East Asia as well. More research is needed on the optimal techniques for cultivation and preservation and other possible applications. To improve *B. blumeana* as a crop plant it is recommended to collect germplasm from all areas where it grows or is cultivated.

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C.A. Roxas

Bambusa heterostachya (Munro) Holttum

Journ. Arn. Arb. 27: 341 (1946).
GRAMINEAE
$2n$ = unknown

Synonyms *Gigantochloa heterostachya* Munro (1868), *G. latispiculata* Gamble (1896), *Bambusa latispiculata* (Gamble) Holttum (1946).

Vernacular names Malaysia: buloh telang, buloh galah, buloh pengait.

Origin and geographic distribution *B. heterostachya* is only found in cultivation, and its origin is unknown. It is planted near villages in southern Peninsular Malaysia (Melaka, Negeri Sembilan and Johor) and Singapore. It has been introduced in Sabah, and in Batam Island (Indonesia).

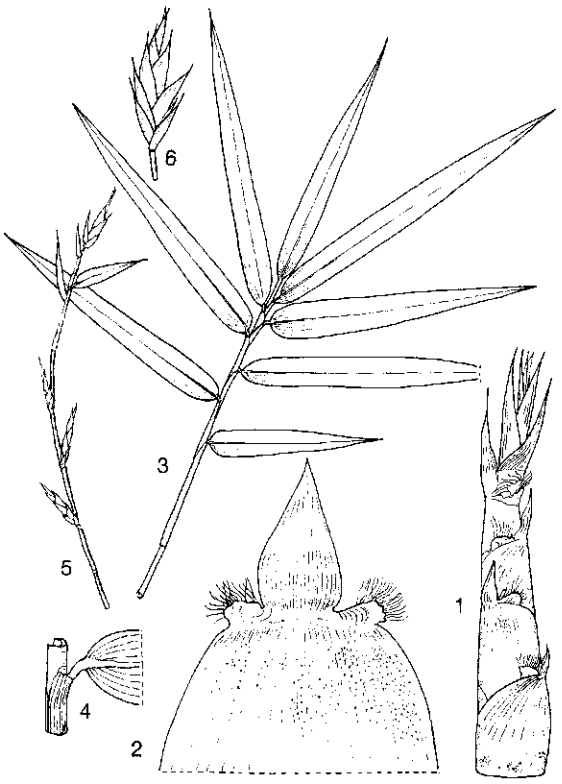
Uses In Peninsular Malaysia and Singapore, strips of the culm are used to make baskets and as tying material (e.g. to attach coconuts). The strong, straight, medium-sized culms are used as poles to harvest fruits and to pollinate flowers of oil palm. In Kuala Lumpur a small form has been planted as a roadside ornamental.

Production and international trade No data are available on production and trade. So far, *B. heterostachya* has only been of local importance in Malaysia, but its culms might attract international interest.

Properties The moisture content of green culms (1–4 years old) ranges from 115–129%; the oven-dry density ranges 440–520 kg/m^3.

Botany A loosely tufted, sympodial bamboo. Culm erect, 6–12(–16) m tall, 3–4(–6) cm in diameter, green, irregularly streaked with pale green or whitish-green; wall 8–10 mm thick; internodes 30–80 cm long, when young white powdery and dark hairy below the nodes, glabrous with age; nodes not swollen. Branches arising from the mid-culm upwards, many at each node with the primary branch dominant. Culm sheath about 18 cm × 12 cm, dark green, covered with black hairs outside; blade broadly triangular, 7 cm × 5 cm, erect; ligule 6 mm long, entire, bearing bristles 3 mm or more long; auricles large, 1 cm long and 2.5 cm wide, bearing up to 1.5 cm long curly bristles along the edge. Leaf blade 20–40 cm × 2–5 cm, glabrous; sheath usually glabrous, occasionally with scattered appressed black hairs; ligule 1–2 mm long, irregularly toothed and with short bristles; auricles absent or small and round. Inflorescence iterauctant, borne on short leafless or leafy branches; pseudospikelets in groups of 2–3 at each inflorescence node; spikelet laterally compressed or flattened, 3–4 cm long, comprising 2 glumes and up to 10 florets. Caryopsis obovoid-cylindrical, 5–6 mm long, thickened and hairy at apex.

B. heterostachya flowers regularly. The culm characteristics are as good as those of useful *Gigantochloa* species, the culms are straight and strong and can be split into strips for making baskets.



Bambusa heterostachya (Munro) Holttum – 1, young shoot; 2, culm leaf (abaxial side); 3, leafy branch; 4, lower part of leaf; 5, flowering branch; 6, pseudospikelet.

The culm sheaths resemble those of *B. vulgaris* Schrader ex Wendland but are smaller and the ligule is different.

Ecology *B. heterostachya* seems well adapted to a humid tropical lowland climate without a strict dry season.

Agronomy *B. heterostachya* is propagated by rhizome cuttings. When a rhizome part is taken from a flowering clump, the new clump will also produce flowers, but its culms are smaller in size. A mature clump contains 40–50 culms.

Genetic resources and breeding No germplasm collections or breeding programmes of *B. heterostachya* are known to exist.

Prospects Being locally a useful bamboo, the prospects for promoting *B. heterostachya* are good. More research is needed on its ecological requirements, appropriate cultivation methods and possibilities for wider application.

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S. Dransfield

Bambusa multiplex (Lour.) Raeuschel ex J.A. & J.H. Schultes

Syst. veg. 7: 1350 (1830).
GRAMINEAE
$2n = 72$ (hexaploid)

Synonyms *Arundo multiplex* Lour. (1790), *Bambusa nana* Roxb. (1832), *B. glaucescens* (Willd.) Sieb. ex Munro (1868).

Vernacular names Hedge bamboo, Chinese dwarf bamboo (En). *Indonesia*: bambu cina, buluh pagar, aor selat (West Kalimantan). Malaysia: buloh cina, buloh pagar. Philippines: kawayan tsina (Tagalog), kawayan sa sonsong (Bikol). Burma (Myanmar): pa-lau-pinan-wa. Thailand: phai-li-ang. Vietnam: cay hop.

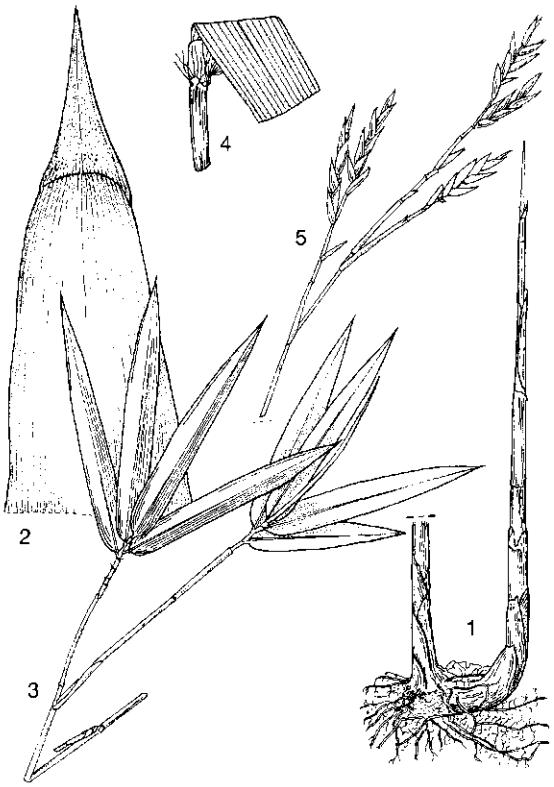
Origin and geographic distribution *B. multiplex* is only known from cultivation. It probably originated from Indo-China and southern China, but is now widely cultivated throughout the tropics and subtropics, including South-East Asia.

Uses *B. multiplex* makes excellent hedges and is a common ornamental in gardens. The culms are often used as umbrella handles and for fishing poles. In Indonesia and Thailand it is also used to make handicrafts such as bookcases. In the Philippines this bamboo is being tested for its suitability as paperpulp. In Taiwan it is planted as a wind-break. Several dwarf cultivars are attractive pot plants.

Production and international trade Several cultivars have become popular ornamental plants and are traded on a small scale throughout the world.

Properties The average fibre dimensions of the culm are: length 1.36 mm, diameter 18 µm, lumen diameter 2 µm, wall thickness 8 µm. At a moisture content of 15.5%, the culms have a density of 897–938 kg/m^3, the modulus of rupture is 57.0–71.0 N/mm^2 (with nodes), 78.0–98.3 N/mm^2 (without nodes), the compression strength parallel to grain 20.0–27.2 N/mm^2 (with nodes), 26.5–35.7 N/mm^2 (without nodes), the shear strength 49.0–62.0 N/mm^2.

Botany Densely tufted, sympodial bamboo. Culm slender, erect with arching tips, 2.5–7 m tall, 1–2.5 cm in diameter, hollow but with relatively thick walls; internodes 30–50 cm long, glabrous, smooth, white waxy when young; nodes not swollen. Branches up to 20 or more at each node, primary branch hardly prominent. Culm sheath 12–15 cm × 6–8 cm, light green when young, turning reddish-brown to straw-coloured, smooth, glabrous, apex rounded with one side lower than the other; blade persistent to the sheath, triangular, 9–12 cm long, erect, acuminate or tapering to the tip, the base attached to the sheath along the rounded top, therefore unequal or oblique, with an auricle-like structure at each side, bearing short bristles; ligule less than 0.5 mm long, irregularly toothed. Leaves usually at the end of a branch, 6–13 together; sheath glabrous, with small auricles bearing fine bristles up to 5 mm long; ligule less than 0.5 mm long; most fully developed blades 7–12 cm × 1–1.5 cm, rounded at base, dark green and glabrous on the upper surface, glaucous and slightly hairy on the lower surface. Inflorescence terminating a leafy branch or ultimately resulting in elongate clusters of several pseudospikelets at the nodes of a leafless branch; spikelet linear-lanceolate, 3–4 cm long, consisting of 2 glumes with up to 10 fertile



Bambusa multiplex (Lour.) Raeuschel ex J.A. & J.H. Schultes – 1, young shoot; 2, culm leaf (abaxial side), 3, leafy branch; 4, lower part of leaf; 5, flowering branch.

florets, the uppermost one rudimentary.

Flowering may be induced if *B. multiplex* is allowed to grow for several years without pruning or clipping. Some cultivars flower easily and frequently, others flower sporadically.

Several cultivars have been developed:

- 'Alphonse Karr' (*B. multiplex* var. *multiplex* f. *alphonso-karri* (Satow) Nakai): culms, sheaths and branches striped orange-yellow and green, tinged pink when young. Common in Japan. Introduced as ornamental plant in South-East Asia.
- 'Fernleaf' ('Wang tsai'): the fernleaf hedge bamboo with smaller culms and twigs and its leaves closely 2-ranked, 10–20 on a twig, 2.5–6 cm × 5–10 mm; common in South-East Asia as pot plants.
- 'Golden Goddess': small bamboo with golden culms, leaves larger than in 'Fernleaf'.
- 'Riviereorum' (*B. multiplex* var. *riviereorum* (R. Maire) Chia & Fung): the Chinese goddess bamboo is a small miniature bamboo with solid culms and fern-like leaf blades of 1.6–3 cm × 0.3–0.8 cm. In Indonesia and Thailand it is a popular pot plant and is increasing in importance elsewhere. It tolerates temperatures as low as –8°C.
- 'Silver Stripe': the tallest cultivar. Culms, sheaths and leaves are variously striped white or yellow. It is a popular ornamental plant in Indonesia and Australia.

Ecology In South-East Asia *B. multiplex* is cultivated up to 1500 m altitude on various soil types. It thrives well on sandy loams and survives several degrees of frost.

Agronomy *B. multiplex* is usually propagated by rhizome cuttings (offsets). Propagation by tissue culture using shoot tips and culm buds for adventitious and axillary shoots, is in an advanced experimental stage. For hedges the propagules are planted close together. In well-established hedges, the plants are pruned regularly to maintain a good height. When the hedge is not pruned, the plants will grow to full height and form a compact hedge with arching culm-tips. Seedlings of forest or other trees should be removed from the hedge because the trees can smother the bamboo entirely if not controlled.

Prospects As an ornamental, the prospects for *B. multiplex* are good, both as garden and as indoor pot plant. Development of strong and reliable cultivars is worthwhile.

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S. Dransfield & E.A. Widjaja

Bambusa polymorpha Munro

Trans. Linn. Soc. 26: 98 (1868).
GRAMINEAE
$2n = 72$ (hexaploid)

Vernacular names Burma (Myanmar): kyathaungwa. Thailand: phai-hom (northern).

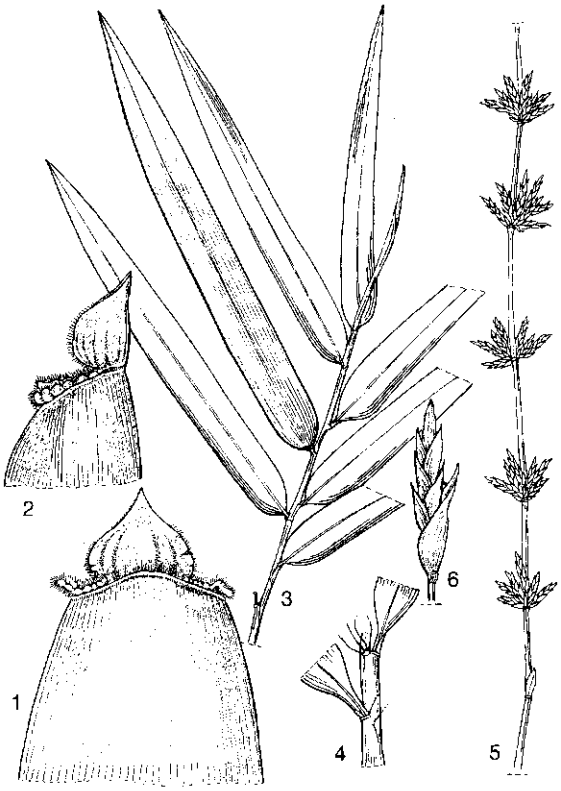
Origin and geographic distribution *B. polymorpha* most probably originated from Burma (Myanmar); its natural range extends westward to eastern Bangladesh and eastward to northern Thailand. It is most important in Burma (Myanmar). Occasionally it is grown outside its natural area in botanical gardens or other collections (e.g. in Indonesia, India, United States, Puerto Rico).

Uses Culms of *B. polymorpha* are used for construction (walls, floors, roofs), matting, handicrafts, paper- and board-making. The young shoots are edible but are reputed to taste very bitter.

Production and international trade Production of *B. polymorpha* should be considerable in Burma (Myanmar) where it is the major source for bamboo constructions, and in Bangladesh where it is an important source for paperpulp and board, but no statistical data are available. Trade is mainly local.

Properties From *B. polymorpha* culms, the following data have been reported: fibre length 2.4–2.5 mm, fibre diameter 16–23 µm, lumen diameter 5–13 µm, fibre wall thickness 5 µm, density 619 kg/m^3 at moisture content 95% (green bamboo) and 659 kg/m^3 at moisture content 13.9% (air-dried bamboo); for green and air-dried culms the modulus of elasticity is 3070 N/mm^2 and 4315 N/mm^2 and the modulus of rupture 27.8 N/mm^2 and 34.8 N/mm^2 respectively; for green culms the compression strength parallel to grain is 31.5 N/mm^2. The chemical composition of the culms (oven dried) is approximately as follows: holocellulose 54–62%, pentosans 18–21%, lignin 21–22%, ash 1.7–1.8% (silica 0.3%); the solubility in cold water is 3–5%, in hot water 7%, in alcohol-benzene 1.7–1.9%, in 1% NaOH 18–22%.
From an analysis in Puerto Rico it has been reported that the edible portion of young shoots is about 18% and that the canning quality is good.

Description Densely tufted, sympodial bamboo, sometimes deciduous. Culm erect, curving outward at the top, 15–25 m tall, 7.5–15 cm in diameter, wall 12–20 mm thick, with appressed white deciduous hairs and white wax when young, when older white-pruinose, bluish-to greyish-green; internodes 60–100 cm long; nodes thickened. Branches arising from nodes in upper half of the culm. Culm sheath 15–17.5 cm × 30–35 cm, thick, junction with blade distinctly upcurved towards middle, long persistent, with appressed white hairs on back; blade ovate-triangular, erect or slightly diverging, 12–15 cm long, strongly convex, green or purple, base decurrent band-like



Bambusa polymorpha Munro – 1, culm leaf (abaxial side); 2, culm leaf (side view); 3, leafy branch; 4, lower parts of leaves; 5, flowering branch; 6, pseudospikelet.

along apex of sheath, lower margins long ciliate, apex thorn-like, outside with appressed, white, deciduous hairs, inside glabrous; ligule 4–5 mm long, irregularly dentate, ciliate; auricles at first embracing the culm, later becoming obliquely erect, long ciliate. Leaf blade lanceolate or linear-lanceolate, 7.5–20 cm × 8–20 mm, slightly rough from minute tubercles, at first hairy on both surfaces; sheath compressed, slightly keeled at top, green; ligule very short; auricles 0.25–0.5 mm, ciliate. Inflorescence consisting of pseudospikelet groups born on long branches; pseudospikelet brownish, enclosed in a long curved glabrous bract; spikelet comprising 1–3 empty glumes and 2–3 florets. Caryopsis ovoid, 5 mm long, plano-convex with hairy top.

Growth and development The life cycle of *B. polymorpha* is estimated at 60 years. It normally flowers gregariously during 2–3 years, after which the clump dies. A clump in the Botanic Garden of Bogor (Indonesia) flowered from 1970–1978. Natural regeneration is through seed, which is produced abundantly. A seedling needs more than 10 years to develop into a mature clump. In a mature clump the ratio new to old culms is about 1 to 4. In India some 6-year-old clumps, developed from rhizome cuttings, contained on average 80 culms that were 11 m tall and 17 cm in diameter.

Ecology *B. polymorpha* is abundant throughout the more humid types of mixed deciduous forest in Burma (Myanmar), particularly on the lower slopes and in well-drained valleys. It flourishes best and reaches its largest dimensions on deep fertile loams. It is commonly associated with teak (*Tectona grandis* L.f.) and is an indicator of deep, rich, well-drained soils on which teak also develops well. On such soils, *B. polymorpha* is often gregarious to a marked degree, frequently accompanied by *Cephalostachyum pergracile* Munro, a bamboo of almost equal importance but extending also into forests of a somewhat drier type than that in which *B. polymorpha* is characteristically found.

Propagation and planting *B. polymorpha* can be propagated by seed, rhizome, branch and culm cuttings. Natural propagation is by seed. The weight of 1000 seeds is about 38 g. Germination percentage is about 40%. Seedlings are raised in a nursery and are usually transplanted to the field when about 30–50 cm tall. Seedlings may also be collected from natural stands, for planting out. Rhizome cuttings are preferably taken from 2-year-old culms; their survival rate is almost 100%. For larger plantations, rhizome cuttings are not practical because too many mother clumps have to be damaged. Branch cuttings, planted under humid conditions, have been successful in Bangladesh (90% success rate); induction of roots and rhizomes on branches still on the living plant had a 80% success rate. Whole culm cuttings have been quite successful in the United States: one or two-year-old whole culms produced about 3.5 new plants per 3 m culm, especially from middle and top parts; culms 3 years or older produced on average about 1 plant per 3 m culm. Culm cuttings (parts) are usually planted in the early rainy season, 7–15 cm deep in a rooting medium (e.g. coarse sand) and at a slant (about 45° with soil surface). Planting in the field is done in holes of about 45 cm × 45 cm × 45 cm at distances 4 m × 4 m.

Husbandry Regular weeding is necessary until the plants are well-established. Watering is needed when rainfall is insufficient. Application of farm manure or other fertilizer is very beneficial. *B. polymorpha* has a tendency to grow very densely, so thinning and removal of culm remnants promote culm and clump development.

Diseases and pests No serious diseases or pests are known for *B. polymorpha*.

Harvesting Harvesting of culms may start when clumps are more than 5 years old. Culms to be harvested should be older than 1.5 years; for construction purposes, 3–4-year-old culms are preferred. For a sustainable yield, at least 8–10 old culms should be left in the clump.

Yield In a 10-year trial in Burma (Myanmar), 2 culms per clump were cut annually without a visible weakening effect for the clumps. For the paper industry in India, a yield of 22 t/ha of air-dried culms in a 3-year rotation has been reported for *B. polymorpha*.

Handling after harvest The natural durability of *B. polymorpha* is poor. Untreated, exposed culms are destroyed within 19 months by termites, fungi and borers. Traditionally, harvested culms are submerged for 10–20 days in running water and air dried before being used. Green culms lose about 40% of their weight when air dried. Preservative treatments can be given before or after drying. For green bamboo good results are obtained by soaking whole or half-split culms in a hot creosote/fuel oil mixture (1 : 1) for 3–6 hours; for air-dried culms (whole or split) by soaking in a 5% copper-chrome-arsenic solution for 6–12 days.

Genetic resources and breeding For *B. polymorpha* a small germplasm collection is maintained in India (Bambusetum Van Vigyan Kendra, Chessa, Arunachal Pradesh). More collections

are needed from all areas of its natural distribution. No breeding programmes exist for *B. polymorpha*.

Prospects *B. polymorpha* is a very useful bamboo and of major importance in rural areas of its natural range. To protect natural bamboo forests, proper harvesting regulations should be established. Research efforts should focus on properties to widen its utilization and on possibilities for large-scale cultivation inside and outside its natural range.

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P.C.M. Jansen & S. Duriyaprapan

Bambusa tulda Roxb.

Fl. Ind. (Carey ed.) 2: 193 (1832).

GRAMINEAE

$2n = 72$

Synonyms *Dendrocalamus tulda* (Roxb.) Voigt (1845).

Vernacular names Bengal bamboo (En). Philippines: spineless Indian bamboo. Burma (Myanmar): thaik-wa, deo-bans. Laos: bông. Thailand: phai-bongdam (general), bong-dam (north), phai-hangchang (central). Vietnam: tre xi[ee]m.

Origin and geographic distribution The natural range of *B. tulda* extends from northern India (including Assam) and Bangladesh to Burma (Myanmar) and Thailand, where it occurs wild and cultivated. Occasionally it has been introduced on a small scale elsewhere (e.g. in Java and in the Philippines). In Bangladesh *B. tulda* is one of the most important bamboos (vernacular name: metinga).

Uses *B. tulda* culms are generally used for construction, scaffolding, furniture, boxes, basketry, mats, household utensils, handicrafts and as raw material for paperpulp. The young shoots are edible but taste slightly bitter, therefore they are preferably pickled (e.g. in India and Thailand). In Thailand the handicrafts made of this bamboo, polished with a mixture of Young oil and oleoresin, are famous. In its natural area *B. tulda* is also often planted as a wind-break around farms and fields.

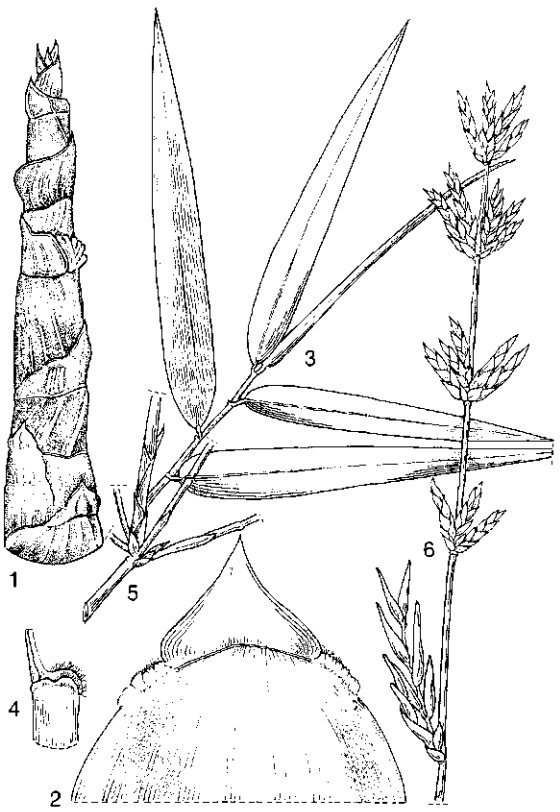
Production and international trade In India and Bangladesh *B. tulda* is one of the major commercially exploited bamboos, but no statistics are available. In northern Thailand it is one of the two most important species producing edible shoots.

Properties The fibre dimensions of the culm are: length 1.45–3.0 mm, diameter 15–20 µm, lumen diameter 5–5.6 µm, wall thickness 3.2–7.5 µm.

The following physical and mechanical properties have been published for culms of *B. tulda*: at a moisture content of 12% (air dried): density 722 kg/m^3, modulus of elasticity 10 070–12 304 N/mm^2, modulus of rupture 66.7–87.9 N/mm^2, compression strength parallel to grain 68 N/mm^2; at a moisture content of 73.6%: density 658 kg/m^3, modulus of elasticity 7980 N/mm^2, modulus of rupture 51 N/mm^2, compression strength parallel to grain 40.7 N/mm^2.

The approximate chemical composition of the culm is: holocellulose 64%, pentosans 18%, lignin 25%, ash 2–3%; the solubility in cold water is 2.6%, in hot water 5%, in alcohol-benzene 1.9% and in 1% NaOH 21.8%.

Description An evergreen or deciduous, tufted, sympodial bamboo. Culm (7–)16–23(–28) m tall, diameter at breast height (5–)10(–19) cm, wall thickness at breast height 1–2.5 cm, glabrous, green to grey-green or streaked with yellow; internodes 40–70 cm long, white-scurfy when young, with white ring below the nodes; nodes not or slightly swollen, lower ones with aerial roots. Branches developing from all nodes, numerous, usually 3 larger ones at each node, at lowest nodes



Bambusa tulda Roxb. – 1, young shoot; 2, culm leaf (abaxial side); 3, leafy branch; 4, leaf sheath; 5, branch complement; 6, flowering branch.

slender, horizontal and almost leafless. Culm sheath 15–25 cm × 15–25 cm, coriaceous, deciduous, often bearing appressed brown hairs on abaxial surface; blade broadly triangular, cuspidate, coriaceous, erect, minutely retrorse-hispid inside; ligule narrow, entire, minutely ciliolate; auricles unequal, continuous with the blade (larger one) or sinuately separated, margins ciliate. Young shoots green with yellow stripes. Leaf blade lanceolate to oblong, 15–25 cm × 2–4 cm, glaucescent and puberulous beneath, glabrous above except for the scabrous veins; sheath striate, glabrous; ligule very small; auricles fringed with long white hairs. Inflorescences variable, borne on leafless branches or on short leafy branches; pseudospikelets in clusters of 2–5, supported by chaffy bracts; spikelet linear-lanceolate, 2.5–7.5 cm long, consisting of 2–4 glumes, 4–6 fertile florets and 1–2 imperfect or male terminal florets. Caryopsis oblongoid, 7.5 mm long, furrowed, hirsute at the apex.

Growth and development About one month after germination a seedling produces its first stem and at this stage the rhizome also starts to develop. After 9 months 4–5 young culms have been formed. In Bangladesh an observation to investigate culm production and clump expansion has been carried out. The observation started with vegetatively propagated offsets planted in the field when 1 year old. For 20 clumps, the average number of full grown culms was 3 after 1 year increasing to 8.8 after 5 years and decreasing to 2.7 after 10 years. Clump girth increased from 87 cm in the first year to 4.4 m in the fifth and 5.9 m in the tenth year. Culm height increased from 3.5 m in the first year to 12 m in the fifth and 16 m in the tenth year. In Thailand shoot growth starts yearly at the beginning of the rainy season and it takes approximately 1 month to emerge above the ground. Shoot development may attain as much as 70 cm per day. Culms complete their growth within 2–3 months after their emergence as shoots, and their diameter and height do not increase as they become older. Under dry conditions, *B. tulda* may shed its leaves.

B. tulda normally flowers gregariously for a period of 2 years in a cycle of 25–40 years, and produces viable seed. However, it also often flowers sporadically or in small groups, without an obvious cycle.

Other botanical information In Bangladesh several forms are distinguished: 'tulda bans' is the normal form; 'jowa bans' is a large form with longer and thicker culms, mainly used for scaffolding and construction; and 'basini bans' is a form with a larger cavity in the culms and is mainly used for basketry.

Ecology In its natural range *B. tulda* occurs in mixed deciduous forest in plains, valleys, and along streams, up to 1500 m altitude. In moist areas it often grows together with *Cephalostachyum pergracile* Munro, in drier parts with *Dendrocalamus strictus* (Roxb.) Nees.

Propagation and planting *B. tulda* can be propagated by seed, rhizome cuttings, culm cuttings and by tissue culture. Under ambient conditions, seed remains viable for about 1 month only; when stored dry (in a desiccator over silica gel) viability can be extended to up to 1.5 years. Seed weight is about 70 g per 1000 seeds. Seed germination is 70% within 8 weeks after sowing. In India excellent plantable seedlings were obtained 18–20 weeks after sowing when the seedlings were fertilized with a mixture of 100 ppm urea and 50 ppm P_2O_5 in split applications 4, 6, and 8

weeks after germination. In Bangladesh, seedlings at 2–4 leaf stage are often collected from the forest floor, potted in the nursery and planted out later.

Propagation by rhizome cuttings with direct planting in the field is very successful (survival more than 90%) and average height of shoots 2.5 months after planting is 1.35 m. Rhizome parts can best be taken at the beginning of the rainy season from 1–2-year-old culms and planted in pits of 60 cm^3 at a spacing of 8 m × 8 m.

Propagation by culm cuttings gives varying results. The survival rate was only 10% in a trial in Bangladesh using culm parts 1–1.5 m long bearing 3–4 nodes with viable buds. In India, promising results were obtained with 1-year-old culm cuttings, each with 2 nodal segments, planted horizontally, 5–10 cm deep. The application of growth-promoting substances (coumarin, NAA or boric acid, 10 or 100 mg/l injected as a 300 ml solution in the internode) had no positive effect whatsoever. Planting in May (dry season) was more successful than in August (rainy season). Good results were obtained with 2-year-old whole culm cuttings: 9 months after planting 4 rooted plants per 3 m culm were available.

Branch cuttings can also be successful, but air and ground layering are not.

Propagation by tissue culture is very promising and is already at nursery stage but is still experimental.

In Bangladesh *B. tulda* is successfully propagated by dividing 9-month-old seedlings into 3 parts, each bearing roots, old and young rhizome, shoots and rhizome buds.

Husbandry Clumps of *B. tulda* grown for household purposes need no special attention. New plantings need watering in prolonged dry periods, to ensure establishment. Application of animal manure stimulates growth and culm production. Culms of 3 or more years old should be removed and the number of shoots should be checked to promote proper growth and development of new culms. After *B. tulda* in natural forests has flowered, it is recommended not to disturb the development of seedlings (e.g. by weeding, protection from grazing and cutting operations).

Diseases and pests *B. tulda* has no serious diseases or pests. It is slightly to moderately susceptible to bamboo blight (*Sarocladium oryzae*) which attacks young bamboos during or soon after elongation growth, usually followed by secondary insect infestation which aggravates the damage. Drenching the soil of affected clumps with a fungicide (e.g. dithane M45) before the rains start improves the survival rates of new culms. Shoot borers (e.g. *Dinoderus* spp., *Lyctus africanus*, *Stromatium barbatum*) can cause considerable losses in cut culms. Treating the culms with 1% lindane or 3% boric acid/borax mixture (1 : 2) can give complete protection, but safer protection methods still have to be developed.

Harvesting Young shoots to be used as a vegetable should preferably be harvested while they are still underground. In plantations, selective felling of older culms may start 5–7 years after planting. Normally 3–4-year-old culms are harvested, retaining at least 3–6 evenly spaced culms per clump. A 4-year felling cycle is often adopted.

Yield In India (Assam) the annual yield of dry culms of *B. tulda* is about 3 t/ha. From a selection of 28 superior full-grown *B. tulda* clumps in India (Arunachal Pradesh) the following data were reported per clump (averages of a 4-year period): number of matured culms 256, culms cut 75, new culms 36; height of culms 20 m, thickness 2 cm, girth 25 cm, length of internodes 43 cm.

Handling after harvest Traditionally, *B. tulda* culms are submerged for 10–20 days in running water to improve resistance to powder-post beetles. Subsequently the culms are air dried for 1.5–3.5 months. Culms of *B. tulda* suffer considerably from cracking and collapse. Cracks often extend along the entire length of the internodes and the culm collapses at these cracks. To improve their durability, culms can be treated with solutions of sodium carbonate, calcium hydroxide or copper sulphate.

Genetic resources and breeding Germplasm collections of *B. tulda* are available in India at Arunachal Pradesh (Chessa, Namsai, and in the Centre bamboorium). Representative collections from all areas of its natural distribution are necessary. Breeding programmes have been started on a small scale in India, especially by selecting superior *B. tulda* clumps. Much more research is needed, however.

Prospects *B. tulda* is a valuable multipurpose bamboo which is hardly used outside its natural range. More research is needed to determine its potential outside this area. To protect natural stands, management and cultivation techniques have to be improved.

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P.C.M. Jansen & S. Duriyaprapan

Bambusa tuldoides Munro

Trans. Linn. Soc. 26: 93 (1868).

GRAMINEAE

$2n$ = unknown

Synonyms *Bambusa pallescens* (Doell) Hackel (1908), *B. ventricosa* McClure (1938), *B. longiflora* W.T. Lin (1980).

Vernacular names Punting pole bamboo, verdant bamboo, Buddha's belly bamboo (En). Indonesia: bambu blenduk. Malaysia: buloh balai. Vietnam: h[os]p.

Origin and geographic distribution *B. tuldoides* is a native of southern China and Vietnam. It is widely cultivated in southern China, Japan, South-East Asia and has also been introduced to Europe, the United States, Honduras, Puerto Rico and Brazil.

Uses *B. tuldoides* is mainly cultivated as an ornamental, often as a hedge. When cultivated in pots or under unfavourable circumstances, the plant remains small with swollen internodes ('Buddha's belly bamboo') and is thus much treasured in bonsai and horticulture. The culms are used for farm equipment and as punting poles and scaffolding, while the splits are employed in weaving utensils and handicrafts. Young shoots are edible. Shavings of the culm cortex ('chuk yu') are used in Chinese medicine for febrile diseases, haematuria, epistaxis and infantile epilepsy.

Production and international trade Production and trade of *B. tuldoides* as ornamental (bonsai) and as medicine is considerable, especially in tropical Asia, but no statistics are available.

Properties For green culms, the nodal portion amounts to 6% of the fresh weight, the fibrous material constitutes about 60% of the culm volume. Fibre length is (1.49–)1.97(–3.17) mm. At moisture contents of 13.5% (lower parts) and 17.8% (upper parts) the following properties have been reported for culms of *B. tuldoides*: density 970–950 kg/m^3; modulus of rupture 94.0–79.0 N/mm^2 (with node), 115.2–84.0 N/mm^2 (without node); compression strength parallel to grain 30.2–30.0 N/mm^2 (with node), 37.8–38.3 N/mm^2 (without node); tensile strength 112.0–95.8 N/mm^2 (with node), 140.5–98.0 N/mm^2 (without node); shear strength 50.0–59.0 N/mm^2. Young shoots have an average fresh weight of 938 g before peeling, 137 g after peeling and the edible portion is 15%; they are bitter, creamy and tender when cooked; canning quality is not good.

Description Densely tufted, sympodial bamboo. Culm erect with slightly nodding tip, 6–10 m tall, diameter 3–5 cm near the base, wall 4–5 mm thick, glabrous, when young thinly covered with white wax; internodes 30–36 cm long, not swollen; nodes slightly swollen, lowermost 1–2 nodes with a ring of greyish silky hairs above the sheath scar. Branches frequently from the basal 1st or 2nd node upwards, branch complement few to many, with the primary branch dominant, thornless. Culm sheath caducous, glabrous or sparsely covered with a few deciduous appressed brown hairs on the outer surface, marked with 1–3 yellowish stripes towards outer margin, ribbed-striated when dried, the apex asymmetrically arched-con-

Bambusa tuldoides Munro – 1, culm leaf (abaxial side); 2, leafy branch; 3, leaf sheath; 4, flowering branch.

vex and slanted along outer margin for 1/10 to 1/8 the length of the sheath; blade erect, asymmetrically triangular to narrowly triangular, acuminate and subulate, the base 3/4 as wide as the apex of the sheath, the basal margins adnate to the auricles, glabrous or sparsely covered with a few deciduous appressed brown hairs on the outer surface, rough hairy on the lower half on the inner surface; ligule 3–4 mm long, laciniate and shortly and densely fringed; auricles prominent, bearing slender bristles along the edge, slightly unequal, the larger one ovate to ovate-elliptical, undulate-wrinkled, the smaller one broadly ovate to elliptical. Young shoots glabrous. Leaf blade lanceolate to narrowly lanceolate, 10–18 cm × 1–2 cm, glabrous or sparsely pubescent toward the base above, densely soft-hairy beneath; auricles developed or lacking, narrowly ovate or falcate, bearing straight or curled bristles along the edge. Inflorescence borne on long leafless branches, consisting of groups of pseudospikelets, scattered along the branches; spikelet 2–5 cm × 2–3 mm, greenish yellow or with a purple hue, bearing 2–5 perfect florets and above these 1–2 reduced florets. Caryopsis terete, slightly curved, 8 mm × 1.5 mm, thickened and hairy at the apex.

Pot-grown specimens: culm 0.25–1.5 m tall, diameter 0.5–2 cm; internodes shortened and swollen, club- or bottle-shaped, 2–6 cm long; branch internodes also shortened and swollen.

Growth and development Shoots of *B. tuldoides* emerge above the soil in the rainy season and develop to their full height in less than a year. The lateral branches often develop before the culm reaches its full height. A culm becomes mature in 2 years.

From an experiment in Canton, China, the following data are available (for a planted 1-year-old single-culm rhizome cutting): average culm height increased from 3 m in the 1st year to 12 m in the 5th year after planting, average culm diameter increased from 3 to 5.8 cm, number of new culms increased from 4 to 21, total number of culms from 4 to 73 showing a decrease in the ratio of numbers of new culms to old from 4 to 0.4. In Puerto Rico *B. tuldoides* rhizome cuttings developed 30–40 culms within 6 years after planting. About 10–12 years after planting, clumps were considered mature because at that age the annual number of new shoots was equal to the annual number of culms that died; maximum height was 13–14 m. In Florida (United States) a maximum culm height of 18 m has been reported.

Flowering may start at the age of 50 years. In southern China clumps usually die after flowering. Seed production is very low. Individual plants, however, may show a deviant flowering behaviour: some plants in Honduras (introduced from southern China), for example, have shown some culms in a flowering state (without producing seed) ever since their introduction, with no apparent reduction in vegetative vigour.

Other botanical information *B. tuldoides* is closely related to *B. pervariabilis* McClure (also named 'punting pole bamboo') and *B. eutuldoides* McClure, both also natives of southern China. In *B. pervariabilis* the basal internodes are marked with yellow vertical stripes, the basal nodes are decorated with a ring of greyish silky hairs both above and below the sheath scar, and the larger auricle on a culm sheath is strongly wrinkled. In *B. eutuldoides* the larger auricle on a culm sheath is decurrent and four times larger than the smaller one and the basal nodes are each decorated with a ring of greyish silky hairs both above and below the sheath scar.

The dwarf form of *B. tuldoides* has long been con-

sidered as a form of *B. ventricosa* McClure, although it was known that these plants, when grown in open ground, could develop into normal plants with cylindrical internodes.

Ecology In tropical Asia *B. tuldoides* grows naturally at low altitudes. In the United States (California, Florida) it grows well in subtropical areas and is noted to be frost-hardy (to –7°C).

Agronomy *B. tuldoides* is propagated by rhizome and culm cuttings. In southern China the traditional preferred method of propagation is by rhizome cuttings. Individual rhizomes from the periphery of the clumps are severed at the neck and the propagules are each composed of the lower part of a single culm with the rhizome axis basal to it. The cuttings are raised in a nursery and when they have produced roots, transplanted to the field. Survival rate is almost 100%.

For large-scale propagation of *B. tuldoides*, culm cuttings are more appropriate.

Satisfactory results have been obtained with whole culm cuttings in Puerto Rico. It is recommended to plant 2-year-old culms. In Puerto Rico they produced in 9 months on average 7.4 plants per 3 m culm, the middle and tip zones of the culm being most productive. Branch cuttings were not successful; after 2 years in the propagation bed, bud dormancy persisted in more than 95% of the cases. Once plants have established, little care is needed. No serious diseases and pests have been reported. Harvesting of culms may start when clumps are 5–6 years old. Culms are harvested when 2–4 years old, preferably in the dry season. In Puerto Rico about 25% of the culms in a mature clump are harvested annually without adversely affecting the production of new culms; with a clump of 30 culms this means an annual production of about 7–8 culms. As yet there are no commercial plantations of *B. tuldoides*.

Genetic resources and breeding No germplasm collections exist for *B. tuldoides*, apart from specimens present in several botanical gardens. Because fruits are occasionally found in the natural environment of this bamboo, breeding programmes could be developed, but as yet there are none.

Prospects The prospects for *B. tuldoides* are promising, especially as ornamental hedge plants and pot plants. It could be a good source for paper fibres because it grows fast and is easy to maintain. Research should focus on applicability of the culms, large-scale cultivation and commercialization, whereas the medicinal uses of culm-cortex shavings need further investigation.

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P.P.H. But & L.C. Chia

Bambusa vulgaris Schrader ex Wendland

Collect. pl. 2: 26, t. 47 (1810).

GRAMINEAE

$2n = 72$ (hexaploid)

Synonyms *Bambusa thouarsii* Kunth (1822), *B. surinamensis* Ruprecht (1839), *Leleba vulgaris* (Schrader ex Wendland) Nakai (1933).

Vernacular names Common bamboo (En). Grand bambou (Fr). Indonesia: bambu kuning (yellow culms), bambu ampel (green culms), domar (Ambonese). Malaysia: buloh minyak, buloh kuning (Peninsular), tamelang (Sabah). Philippines: kauayan-kiling (Tagalog), kabaloan (Bikol), butong (Visaya). Burma (Myanmar): wanet. Cambodia: rüssèi kaèw. Laos: s'a:ng kh'am'. Thailand: phai-luang (general), phai-ngachang (peninsular).

Vietnam: phai-bongkham (northern), tre m[owx], tre tr[owf].

Origin and geographic distribution *B. vulgaris* originated in the Old World, probably in tropical Asia. It is arguably the most widely cultivated bamboo throughout the tropics and subtropics, but is also found spontaneously or naturalized on river banks. In South-East Asia it is the most commonly encountered cultivated bamboo, found everywhere in villages, on river banks and as an ornamental in towns.

Uses Although the culm of *B. vulgaris* is not straight, it is the most used of all bamboos. The culms are used e.g. in boats for masts, rudders, outriggers, boating poles, as carrying poles, for fencing and props. It is rarely used as a building material because it is very susceptible to powder-post beetle attack. If no other bamboo is available for building purposes, the culms are used in temporary constructions, for example as wattle in outhouses or barns in Sri Lanka. In El Salvador, split culms are used to support and protect walls. The culms furnish the main material for the bamboo furniture industry and they also produce good quality pulp to make paper. In Irian Jaya (Indonesia) culms are used to make traditional combs and penis gourds ('koteka') in the phallocrypt tradition. The very young shoots are edible but are rarely sold as a vegetable. Water in which young shoots of the yellow culm form have been boiled is used as a medicine to cure hepatitis. Plants of the yellow culm group and the Buddha's belly group are often planted as ornamentals. Plants of the green and yellow culm groups are often planted as hedges to border land. Leaves of *B. vulgaris* are sometimes used as forage.

Production and international trade The worldwide production and trade of *B. vulgaris* and derived products is considerable, but no statistics are available.

Production and use are mainly local and at village level. Large-scale commercial activities include production and trade of furniture, handicrafts and paper. Young shoots of *B. vulgaris* are rarely sold in the market because they become too fibrous for vegetable use if not consumed immediately after harvesting.

Properties Fibre dimensions for green-culm cultivars of *B. vulgaris* are: length 2.02–2.82 mm, diameter 13.0–17.0 µm, lumen diameter 2.7–5.5 µm, wall thickness 5.7–7.0 µm; for yellow-culm cultivars: length 1.66–3.76 mm, diameter 17–21 µm, lumen diameter 2–5 µm, wall thickness 6–8 µm. For green-culm cultivars the density at 12% moisture content is about 626 kg/m^3, and shrinkage from green to 11.3% moisture content is 9.7–14.0% radial, 6.0–11.9% tangential and 0.26–0.41% longitudinal. For yellow-culm cultivars the density at 12% moisture content is about 630 kg/m^3. For green-culm cultivars average mechanical properties at respectively 40% and 17% moisture contents are: modulus of rupture 106.6 N/mm^2 and 84.3 N/mm^2, compression strength parallel to grain 31.6 N/mm^2 and 24.9 N/mm^2 and shear strength 9.77 N/mm^2 and 6.64 N/mm^2. For yellow-culm cultivars average mechanical properties at respectively 90% and 16% moisture contents are: modulus of elasticity 6960 N/mm^2 and (no data) modulus of rupture 60.9 N/mm^2 and 86.0 N/mm^2, compression strength parallel to grain 28.2 N/mm^2 and 32.0 N/mm^2, shear strength 4.53 N/mm^2 and 4.26 N/mm^2. For green-culm cultivars and yellow-culm cultivars the average chemical composition is respectively: holocellulose 66.5% and 63.6%, pentosans 21.1% and 21.5%, lignin 26.9% and 25.9%, ash 2.4% and 3.0%, silica 1.5% and 1.3%; solubility in hot water 5.1% and 3.9%, in alcohol-benzene 4.1% and 3.7%, in 1% NaOH 27.9% and 24.7%. Young shoots have an average fresh weight of 2085 g before peeling and 375 g after peeling, giving an edible portion of about 18%. They are whitish-pink in colour, are tender and have a fair canning quality. The approximate chemical composition of young shoots per 100 g edible portion for green-culm and yellow-culm cultivars respectively is: water 90 g and 88 g, protein 2.6 g and 1.8 g, fat 4.1 g and 7.2 g, carbohydrates 0.4 g and 0 g, fibre 1.1 g and 1.2 g, ash 0.9 g and 0.8 g, Ca 22.8 mg and 28.6 mg, P 37 mg and 27.5 mg, Fe 1.1 mg and 1.4 mg, vitamin C 3.1 mg and 0 mg. Dried leaves, used as forage, contain amongst others: water 8.6%, protein 10.1%, ether extract 2.5%, fibre 21.7%, ash 21.3%, P 0.0860%, Fe 0.0134%, vitamin B_1 0.0001%, vitamin B_2 0.0025%, carotene 0.0123%.

Description Open, not closely tufted, sympodial bamboo. Culm erect, sinuous or slightly zig-zag, 10–20 m tall, 4–10 cm in diameter, wall 7–15 mm thick, glossy green, yellow, or yellow with green stripes; internodes 20–45 cm long, with appressed dark hairs and white waxy when young, becoming glabrous, smooth and shiny with age; nodes oblique, slightly swollen, basal ones covered with aerial roots. Branches arising from midculm nodes upward, occasionally also at lower nodes, several to many at each node with primary branch dominant. Culm sheath more or less broadly triangular, 15–45 cm × 20 cm, upper ones longest,

Bambusa vulgaris Schrader ex Wendland – 1, young shoot; 2, culm leaf (abaxial side); 3, leafy branch; 4, leaf sheath with auricles and pseudopetiole; 5, flowering branch; 6, pseudospikelet.

deciduous, light green or stramineous, covered with appressed black hairs, margins hairy, apex slightly rounded at the junction with the blade; blade erect, broadly triangular, 4–5 cm × 5–6 cm, slightly narrowed at the junction with the sheath, stiffly acuminate, hairy on both surfaces and along the lower part of the margins; ligule 3 mm long, slightly serrated; auricles relatively large, 0.5–2 cm long, with pale brown bristles 3–8 mm long along the edges. Young shoots yellow-green, covered with black hairs. Leaf blade 6–30 cm × 1–4 cm, glabrous; ligule a subentire rim 0.5–1.5 mm long; auricles small rounded lobes 0.5–1.5 mm long with a few bristles 1–3 mm long. Inflorescence usually borne on a leafless branch of a leafless culm or on a culm with small leaves, bearing small groups of pseudospikelets at the nodes, 2–6 cm apart; spikelet 12–19(–35) mm × 4–5 mm, laterally flattened, comprising 5–10 perfect florets and a terminal vestigial floret. Caryopsis not known.

Growth and development In Bangladesh, rhizome cuttings (offsets) of *B. vulgaris* develop into mature clumps producing culms of maximum length in about 7 years. Culms reach the maximum diameter after 9 years. The clumps expand rapidly the first 5–6 years (from 0.5 m diameter in first year to 4.5 m in 6th year) and slower thereafter (after 10 years to 7 m). The number of young shoots per clump that develop into full-grown culms increases on average from 1.6 in the first year to a maximum of 5.3 in the 4th year and decreases to 2.5–3.5 from the 9th year onward. Young shoots of *B. vulgaris* grow rapidly. In 2 weeks they can develop into young culms 3–4 m tall, reaching 20 m length in 3 months. On average, a mature clump produces 3–4 new culms per year and bears 50–90 culms (green culm group) or 30–60 culms (yellow culm group). Young shoot growth occurs in the rainy season; for example, extending over 1–3 months in the Philippines. Young shoots emerging in the later part of the rainy season grow faster and become taller than the ones starting at the beginning. A mature green culm of *B. vulgaris* weighs about 16 kg, the green weight of its branches is about 5 kg and of its leaves 3 kg. It reaches maximum diameter about 4 m above the ground and the wall is thickest at ground level. It develops about 43 nodes and the longest internode is at about 2–3 m above the first branch. Flowering in *B. vulgaris* is not common. When a culm flowers, it produces a large number of flowers but no fruits, and eventually the culm dies. It is remarkable that in spite of never having reproduced sexually (as far as is known), *B. vulgaris* is still one of the most vigorous of all known bamboos.

Other botanical information *B. vulgaris* is the most easily recognized species of all known bamboos. In a young culm, the primary branches are prominent, borne alternately along the culm, together forming a gigantic fan-like structure which is conspicuous from some distance.

B. vulgaris is essentially only known from cultivation (although escaped, naturalized populations exist), and it is grown pantropically. Its variability is great. Classification of the different forms should preferably be done at cultivar level (e.g. cultivar groups, cultivars). A thorough study of the worldwide variation is necessary. At least three groupings of cultivars can be distinguished:

- Green culm group. Culms green. Existing name: *B. vulgaris* var. *vulgaris* (thought to comprise the type of *B. vulgaris*). Vernacular names: Indonesia: bambu ampel, haur. Malaysia: buloh

aur, buloh pau, buloh minyak.
- Yellow culm group. Culms yellow, often with green stripes of different intensity. Usually the culms have thicker walls than the green culms. Culm sheaths light green with light yellow-green stripes. Existing names: *B. striata* Lodd. ex Lindley (1835), *B. vulgaris* var. *vittata* A. Rivière (1878), *B. vulgaris* var. *striata* (Lodd. ex Lindley) Gamble (1896), *Leleba vulgaris* (Schrader ex Wendland) Nakai var. *striata* (Lodd. ex Lindley) Nakai (1933), *B. vulgaris* cv. Vittata (McClure, 1955). Vernacular names: Golden bamboo (En). Indonesia: bambu kuning. Malaysia: buloh gading, aur gading, buloh kuning. Sabah: tamalang silau (Dusun). Philippines: yellow bamboo (Tagalog).
- Buddha's belly group. Culms up to about 3 m tall, 1–3 cm in diameter, green, with short, 4–10 cm long, inflated internodes in lower part. Existing names: *Bambusa? wamin* Brandis ex Camus (1913), *B. vulgaris* cv. Wamin (McClure, 1966), *B. vulgaris* f. *waminii* T.H. Wen (1985). Vernacular names: Buddha's belly bamboo (En). Indonesia: bambu blenduk. Burma (Myanmar): wamin. This group probably originates from southern China.

Ecology *B. vulgaris* can be found growing pantropically from low elevation up to 1200 m altitude. It grows best at low altitudes; above 1000 m altitude culms become smaller in length and diameter. It thrives under a wide range of moisture and soil conditions. Along rivers and lakes it grows almost in permanently humid conditions, but it also grows in areas with a severe dry season where the plants become completely defoliated. It is frost hardy to -3°C. In South-East Asia the green-culm plants are widely naturalized on river banks, road sides, wastelands and open ground. In Peninsular Malaysia it even grows well on degraded soils containing tin.

Propagation and planting *B. vulgaris* can be propagated by rhizome, culm and branch cuttings, by layering and by tissue culture. Rhizome cuttings (offsets) always give a good result when taken from 1–2-year-old culms, but damage the mother clump and are not convenient for large-scale plantations. The easiest and most practiced propagation method is by culm or branch cuttings. In general, parts should preferably be taken from culms that are neither too young nor too old. In the Philippines, best results have been obtained with one-node cuttings from the lower parts of 6-month-old culms, planted horizontally in moist soil at about 20 cm depth. Treating of cuttings with a 100 ppm solution of the growth hormone indole butyric acid gave better results. Planting during the late rainy season period is recommended, at planting distance 6–12 m × 6–12 m. The often apparently wild occurrence of *B. vulgaris* can easily be explained by its remarkably easy vegetative propagation. Culms are often used for boating poles, and because *B. vulgaris* is easily available the poles are often thrown away after being used. If such poles have been freshly cut from a living plant, the piece of culm may survive and produce roots and establish new growth on river banks. Clumps may also be established from pieces of culms used for fences, props, stakes and posts set on river banks for mooring boats.

Husbandry Weeding in the first 2–3 years after planting, 2–3 times per year, preferably during the rainy season, is recommended. Irrigation and fertilizer application (e.g. 20–30 kg N, 10–15 kg P, 10–15 kg K and 20–30 kg Si per ha per year) considerably improve growth and yield.

Diseases and pests No serious diseases in *B. vulgaris* have been reported in South-East Asia. The most serious disease of *B. vulgaris* in Bangladesh is bamboo blight, caused by *Sarocladium oryzae*, killing affected clumps within 3–4 years. Harvested culms are very vulnerable to attack of powder-post beetles (*Dinoderus* spp.). Termite damage can be serious, especially of harvested culms in contact with ground.

Harvesting Being the most common village bamboo, culms of *B. vulgaris* are harvested whenever needed. Normally, harvesting may start 3 years after planting. Full production is reached 6–8 years after planting. Selective cutting of culms 2-year-old or older is recommended. Young shoots should be harvested in the first week of their emergence.

Yield For the Philippines, annual yield per ha is estimated at 2250 culms or 20 t dry weight. The dry weight ratio for culm, branches and leaves is about 70%, 22% and 8% respectively. The ratio paperpulp/culm production is about one-third.

Handling after harvest Traditionally, harvested culms of *B. vulgaris* are immersed in running or muddy water for about 3 months. Because culms are very susceptible to powder-post beetles, chemical preservation is necessary if long-term use is intended. Young shoots should be consumed or prepared immediately after harvesting because they become inedible within some hours if left untreated.

Genetic resources and breeding A small germplasm collection of *B. vulgaris* is available in

Lampung, Sumatra (Indonesia). This bamboo is represented in most botanical gardens in the tropics. There are no breeding programmes. Because of the wide variability of this bamboo, extensive, worldwide germplasm collection is recommended.

Prospects Prospects for *B. vulgaris* are promising. Because of its common occurrence, its easy propagation and its wide uses, *B. vulgaris* will remain very important. Developmental research on appropriate technologies applicable at the village level (e.g. on chemical preservation) is much needed.

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S. Dransfield & E.A. Widjaja

Cephalostachyum pergracile Munro

Trans. Linn. Soc. 26 : 141 (1868).

GRAMINEAE

$2n = 72$ (hexaploid)

Synonyms *Schizostachyum pergracile* (Munro) Majumdar (1989).

Vernacular names Tinwa bamboo (En). Burma (Myanmar): tinwa. Laos: khauz hla:m. Thailand: phai-khaolam, phai-kaolarm, mai-pang.

Origin and geographic distribution *C. pergracile* is widespread in the eastern parts of India, in Nepal, in Burma (Myanmar), throughout northern Thailand and in Yunnan Province of China. It is occasionally cultivated there and also outside its natural area (e.g. Hong Kong, Guangzhou in South China Botanic Garden, Lampung (Indonesia), Puerto Rico).

Uses Culms of *C. pergracile* are widely used in building, (house posts, walling mats, shingles) and as fishing rods. They are easily split into thin strips which are used for basketry. The outer green layer can be split very finely and is used to make handicrafts. The culms are also used as a raw material for paperpulp.

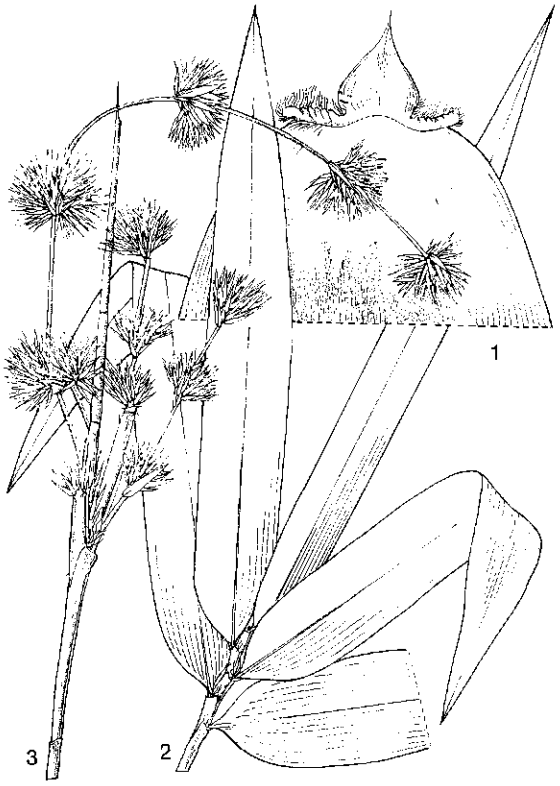
C. pergracile culms are highly esteemed for cooking rice in Burma (Myanmar) and Thailand. Glutinous rice is traditionally cooked in the internode of a 1-year-old culm. Young shoots are edible but have a bitter taste. This bamboo is also recommended as an ornamental because of its glaucous green culms clothed with reddish-brown sheaths.

Production and international trade In Burma (Myanmar) and Thailand, *C. pergracile* is used widely and traded locally. No statistics are available.

Properties The fibre dimensions of the culm are: length 2.15–2.80 mm, diameter 16.25–16.46 µm, lumen diameter 3.85–9.33 µm, wall thickness 3.89–6.09 µm; parenchyma content 17.3–18.3%. The culm contains lignin 24-9% and pentosans 18.4%. Average fresh weight of young shoots is

825g before peeling, 168 g after peeling; the edible portion is 20%. The young shoots still taste bitter after cooking. Their canning quality is unsatisfactory.

Botany Tufted, deciduous, sympodial bamboo. Culm erect with pendulous tip, 7–30 m tall, 2.5–7.5 cm in diameter, wall very thin, glaucous green, somewhat whitish puberulous below the nodes; internodes 20–45 cm long; nodes slightly thickened. Branches arising from the higher nodes, many at each node, about equal in size. Culm sheath 10–15 cm × 15–20 cm, thick and leathery, promptly or tardily deciduous, reddish-brown, shiny, usually covered with appressed, blackish, stiff, deciduous hairs toward the base; blade ovate, cordate, cuspidate, 5 cm long, about half as wide as apex of sheath, densely hirsute on adaxial surface; ligule very narrow, 1.5–2 mm long, entire, densely white ciliolate; auricles horizontally extending along the top of the sheath, linear-lanceolate, 3–4 mm wide, densely wavy-bristly along the margins. Leaf blade linear-lanceolate, 10–35 cm × 1.5–6.0 cm, rough on both the surfaces and margins sparsely puberulent beneath; sheath faintly striate, glabrous, ending in a small ciliate callus; ligule very low, entire; auricles usually lacking, leaving 2–3 early caducous, white, long bristles. Inflorescence borne terminally on a leafy or leafless branch, drooping, bearing distant broad heads of pseudospikelets supported by small chaffy bracts; spikelet 1–2 cm long, consisting of 1–2 sterile florets at base, then a fertile floret, ending in a sterile floret or a filiform rachilla. Caryopsis ovoid-cylindrical, about 1 cm long, shiny, ending in a straight beak up to 1 cm long.



Cephalostachyum pergracile Munro – 1, culm leaf (abaxial side); 2, leafy branch; 3, flowering branch.

Clumps develop very slowly; under favourable conditions they take 12–15 years to produce full-sized culms, while under unfavourable conditions this may take up to 30 years. In a mature clump the ratio of new to old culms is about 1:3. In India, 4 years after planting offsets the clumps had on average 20 culms, 6 m tall and 4 cm in diameter; 6 years after planting, the clumps had 38 culms, 10 m tall and 4.4 cm in diameter.

C. pergracile usually flowers sporadically almost every year. Occasionally it flowers gregariously over extensive areas. Nothing is known about its life cycle. When it flowers sporadically, it generally does not produce viable seed. In 1987 it flowered gregariously in Thailand and the abundance of seed triggered a population explosion of rats. The next season the rats invaded the rice fields, causing severe loss of the crops.

Ecology *C. pergracile* is one of the commonest and most widespread bamboos in mixed deciduous forests of Burma (Myanmar) and Thailand. In the moister forests it co-occurs with *Bambusa polymorpha* Munro but in the driest forests where *Dendrocalamus strictus* (Roxb.) Nees is the prevailing bamboo, it is stunted. It is characteristic of low, hilly country, thriving best on well-drained loams and it grows in large stands.

Agronomy *C. pergracile* can be propagated by seed, rhizome and culm cuttings. Seedlings are often collected from the forest. Offsets (rhizome parts with roots and 1–1.5 m long parts of 1–2-year-old culms) can be planted directly. Culm cuttings are rarely successful. Only whole culm cuttings gave good results in a trial, 1- and 2-year-old culms produced 3.6 and 4.1 plants per 3 m culm, respectively. In 2-year-old culms the basal parts were best, in 1-year-old culms the middle and top parts were best. Suitable spacing varies according to the purpose of planting. For wind-breaks and fences 3–4 m × 3–4 m is used, for plantations 8 m × 8 m.

Weeding and watering are necessary until the

clump is fully established. The application of organic and chemical fertilizer promotes clump and culm development. Natural stands of *C. pergracile* need to be protected against fire and grazing. Removal of old culms and thinning of congested clumps stimulate the production of good culms. There are no reports of serious diseases. In India, the bamboo hispine beetle (*Estigmena chinensis*) is the most important pest of standing bamboo; the lesser leaf roller (*Pyrausta bambucivora*) and the defoliator *Pyrausta coclesalis* sometimes cause damage. In Thailand, *C. pergracile* is remarkably resistant to stem borers. Young immature culms are harvested, to be used for cooking sticky rice. For other purposes, mature culms (2 years and older) are harvested. Yield figures are scarce: about 7 t/ha of air-dried culms per year are reported from India and Burma (Myanmar) from a crop with a cutting cycle of 3 years.

Genetic resources and breeding Although *C. pergracile* is present in several botanical gardens, no special germplasm collections and no breeding programmes are known for this bamboo.

Prospects The prospects for *C. pergracile* in its natural area are good because of its many uses. Outside this area it may be a promising ornamental. It is recommended to start germplasm collections and to investigate the feasibility of developing faster-growing cultivars.

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S. Duriyaprapan & P.C.M. Jansen

Dendrocalamus asper (Schultes f.) Backer ex Heyne

Nutt. pl. Ned.-Ind., ed. 2, vol. 1: 301 (1927).
GRAMINEAE
$2n$ = unknown

Synonyms *Bambusa aspera* Schultes f. (1830), *Dendrocalamus flagellifer* Munro (1866), *Gigantochloa aspera* (Schultes f.) Kurz (1876), *Dendrocalamus merrillianus* (Elmer) Elmer (1915).

Vernacular names Giant bamboo (En). Indonesia: bambu betung (Indonesian), awi bitung (Sundanese), buluh batung (Batak). Malaysia: buloh beting, buloh betong, buloh panching. Philippines: bukawe (Tagalog), botong (Bikol), butong (Visaya). Singapore: rebong china. Laos: hok. Thailand: phai-tong. Vietnam: manh tong.
Note: 'Giant bamboo' is also applied to *Dendrocalamus giganteus* Wallich ex Munro.

Origin and geographic distribution The origin of *D. asper* is not certain, but is thought to be somewhere in South-East Asia. It is planted throughout tropical Asia, and in many parts of Malaysia (e.g. Sabah and Sarawak) and Indonesia (e.g. Sumatra, East Java, South Sulawesi, Seram, western Irian Jaya) it has become naturalized. It has also been introduced in other tropical countries, such as Madagascar and Sri Lanka. It has been planted in botanical, experimental or private gardens in the New World and Australia, even in warm temperate areas.

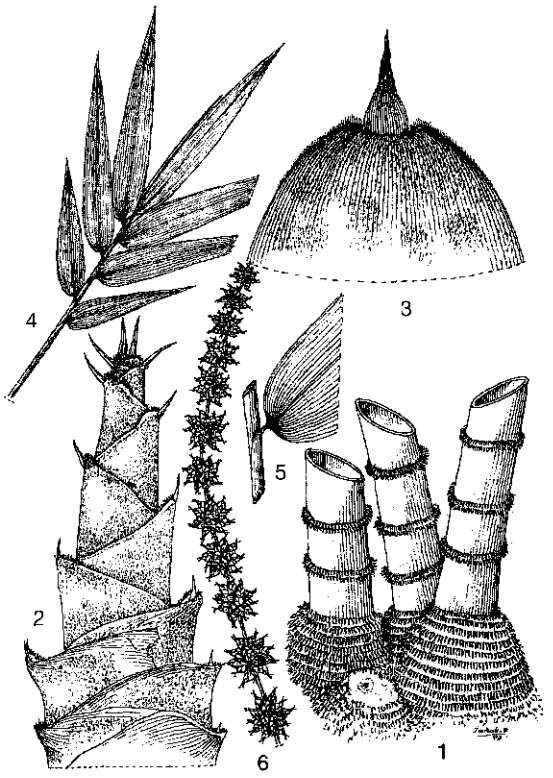
Uses The culms of *D. asper* have thick walls and are very strong and durable. They are used as building material for houses and bridges. The upper internodes of the culm, which are longer than the lowermost ones, are used as containers for water or to collect juice being tapped from palm inflorescences. In Sarawak, the internodes of this and other bamboo species are also used as ready-made cooking pots in the field. The internode is opened at one end (or the node) and filled with vegetables, meat or rice, and water, and is then covered and placed on a fire. The young and tender shoots ('rebung') are consumed as a vegetable. In Thailand *D. asper* is known locally as sweet bamboo, because the shoot is not bitter. In the areas where culms of *D. asper* are highly valued for building material, the shoots are rarely collected as a vegetable. On the other hand, where the culm is not much used, this bamboo is planted solely for its shoots. The shoots of *D. asper* are the best among those of other tropical Asiatic bamboos.

Production and international trade In tropical Asia bamboos are of great economic impor-

tance in rural areas, and *D. asper* is one of the most important. It is planted on a small scale or harvested and collected from naturalized populations. It has recently been planted commercially in Thailand for its young shoots. The culm is used for local consumption only, and there are no statistics on its economics and production. The shoot has just come onto international markets. In Thailand the planted area of *D. asper* is estimated to be 6000 ha. In Prachinburi Province (Thailand) shoot production in 1984 was 37 975 t from 4465 ha. The price was 2–8 Baht/kg, depending on the time of the year.

Properties The approximate fibre dimensions of the culm of *D. asper* are: length 3.78 mm, diameter 19 µm, lumen width 7 µm, wall thickness 6 µm. The moisture content of green culms averages 55% (76% at bottom, 36% at top), of air-dry culms 15% (15–17% lower half, 13–14% top). The specific gravity is about 0.7. At drying, radial shrinkage is about 5–7%, tangential shrinkage 3.5–5%. For green (moisture content 55%) and air-dry (moisture content 15%) culms, the modulus of rupture is 81.6 N/mm^2 and 103.4 N/mm^2, the compression strength parallel to grain 22.8 N/mm^2 and 31.4 N/mm^2 and the shear strength 6.96 N/mm^2 and 7.25 N/mm^2, respectively. The chemical composition of the culm is approximately: holocellulose 53%, pentosans 19%, lignin 25%, ash 3%; the solubility in cold water is 4.5%, in hot water 6%, in alcohol-benzene 1%, in 1% NaOH 22%.
The edible portion of young shoots is about 34%, weighing on average 5.4 kg before peeling and 1.8 kg after peeling. Their canning quality is good.

Description Densely tufted, sympodial bamboo. Culm erect with pendulous tip, 20–30 m tall, diameter 8–20 cm near the base, wall 11–36 mm thick, sometimes almost solid at base, when young covered with fine, velvety, golden-brown appressed hairs, later glabrous; internodes from 10–20 cm (lowermost) to 30–50 cm or more (upper ones) long, white waxy below the nodes; nodes swollen, lowest nodes bearing many aerial roots. Branches arising from the midculm nodes upwards, few at each node with the primary one dominant. Culm sheath 20–40 cm × 20–25 cm, smallest in lower part, covered with dark brown to pale brown hairs; blade lanceolate, 30 cm × 3 cm, at first erect, later deflexed; ligule about 10 cm long, lacerate; auricles prominent, bearing slender bristles along the edges. Young shoots covered with dark brown to black hairs, blades small and deflexed. Leaf blade 30 cm × 2.5 cm, base shortly attenuate, glabrous above, hairy or glabrescent



Dendrocalamus asper (Schultes f.) Backer ex Heyne – 1, habit culm bases; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

below; sheath glabrous or with scattered appressed pale hairs; ligule very short; auricles absent. Inflorescence borne on a leafless branch of a leafy or leafless culm, with groups of pseudospikelets at the nodes; spikelet slightly laterally flattened, 6–9 mm × 5 mm, pubescent, comprising 4–5 florets often with a sterile apical floret. Caryopsis not known.

Growth and development As in any large tropical bamboo the shoots of *D. asper* emerge above the soil during the rainy season and develop to their full height in less than a year. However, in exceptionally brief rainy seasons the growth ceases and will continue when the next rain starts. The lateral branches develop when the culm reaches its full height. A culm becomes mature in 3–4 years. A good healthy clump can produce several shoots annually. Initially, a young plant raised from a lateral branch cutting will produce small shoots which will develop into small culms. The culms produced later are larger than those

produced from previous years. Full-size culms appear five or six years after planting. A mature clump may attain a diameter of 3 m or more and contains about 60 culms.

Other botanical information *D. asper* can be confused with *Gigantochloa levis* (Blanco) Merrill because of its large culms. *G. levis* is believed to be native in the Philippines; it is found planted or naturalized in many parts of Borneo (Sabah and Sarawak) and in the eastern part of Indonesia. Culms of *G. levis* have thinner walls than culms of *D. asper*, the internodes are not covered by golden-brown hairs and the nodes are not prominently swollen.

A primitive cultivar of *D. asper* in Indonesia, characterized by blackish culms, has almost become extinct.

Ecology In tropical Asia *D. asper* is planted or naturalized from low altitudes up to 1500 m altitude. It thrives best, however, at 400–500 m above sea-level, in areas with average annual rainfall of about 2400 mm. *D. asper* will grow in any type of soil, but it grows better on heavy soils with good drainage. In Thailand, according to local farmers, *D. asper* will grow well on sandy and rather acidic soils.

Propagation and planting *D. asper* can be propagated by rhizome, culm and branch cuttings and by tissue culture. The propagules are raised in the nursery and after they have produced roots they are planted out in the field before or during the first half of the rainy season. They are planted in holes containing a mixture of manure and chemical fertilizer, at distances 5–10 m × 5–10 m. Tissue culture is still experimental, but promising results have been obtained in Thailand, where already 1 million plantlets are distributed yearly.

Husbandry Young plants require regular watering and weeding during the growing period because they cannot compete for nutrients, light and moisture. It is recommended to fertilize mature clumps yearly, one year with 100–300 kg/ha of 15-15-15 NPK and the next year with 50–60 kg/clump of manure, to improve soil texture and fertility. Mulching is necessary to increase the production of young shoots.

Diseases and pests In Indonesia, *D. asper* is sometimes attacked by a witches' broom (*Epichloe bambusae*), which, however, causes little visible damage. The powder-post beetles *Dinoderus minutus* and *D. brevis* cause considerable damage to harvested culms.

Harvesting Young shoots are usually harvested during the rainy season (in Java from November to May, in Thailand from May to June). Culms are preferably harvested in the dry season. It is recommended to harvest mature culms, 5–7 years old, and always to leave some mature culms in the clump.

Yield No data are available on culm yield. In Thailand, a properly managed plantation may produce 10–11 t young shoots per ha per year. A 5–7-year-old plantation with 100 clumps/ha can produce 1000 young shoots per year. According to local farmers in Indonesia, a good clump bearing about 10 culms produces 60 young shoots annually. A well-managed plantation with 400 clumps/ha may produce 20 t young shoots per ha per year.

Handling after harvest Traditionally, harvested culms are soaked in water or mud to decrease starch and sugar contents. For better preservation, several treatments with chemical solutions are possible. In Indonesia a modified boucherie treatment, using chemicals based on borax and boron, is most successful. The young shoots of *D. asper* are sold for local consumption, usually fresh or boiled, but in markets in Sulawesi and the Moluccas dried shoots also are offered for sale. In Thailand, shoots are also steamed.

Genetic resources and breeding In Lampung (Indonesia) a germplasm collection of *D. asper* has been established. There are no breeding programmes. *D. asper* is available in many botanical gardens in the tropics. It is not clear whether the populations of *D. asper* in Indonesia and Malaysia are genuinely wild populations. Due to its vegetative reproduction, the plants are everywhere very similar.

Prospects The prospects for *D. asper* are very promising. Young shoots can be produced in large quantities from plantations to meet increasing demand. The culms are promising for the development of furniture and chopstick industries. Many aspects, however, still require further investigation, e.g. propagation, management and the fertilizer requirements for young shoots and for culm production.

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S. Dransfield & E.A. Widjaja

Dendrocalamus brandisii (Munro) Kurz

Forest flora of British Burma 2: 560 (1877).
GRAMINEAE
$2n = 72$ (hexaploid), 74

Synonyms *Bambusa brandisii* Munro (1868).

Vernacular names Burma (Myanmar): kya-lowa, wabo. Laos: hôk. Thailand: phai-bongyai (general), phai-sangyen (northern).

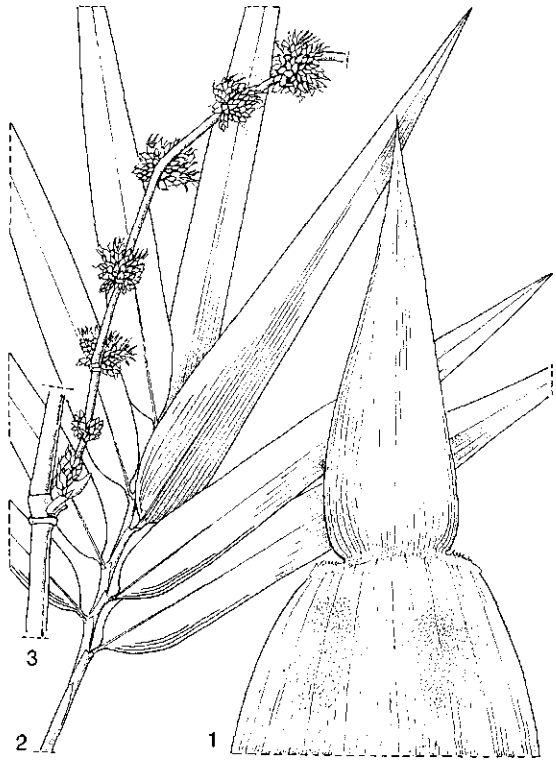
Origin and geographic distribution The origin of *D. brandisii* is not known. Its native area extends from north-eastern India (Manipur), Burma (Myanmar), to northern Thailand, Indo-China, China (Yunnan Province) and the Andaman Islands (India). *D. brandisii* is also frequently planted in botanical and experimental gardens in the tropics and subtropics and sometimes has been introduced (e.g. in various regions in India). It is occasionally cultivated in small plantations.

Uses The culms are used for building purposes, furniture, farm implements, baskets and other woven wares and handicrafts. In Thailand and southern China the young shoots are used as a vegetable.

Production and international trade The production, use and trade of culms of *D. brandisii* are mainly local, but no statistics are available. In Thailand young shoots are also exported; on the local market their price was about 2 Baht/kg in 1987.

Properties Per 100 g edible portion young shoots contain approximately: water 92 g, protein 1.1 g, fat 0.3 g, carbohydrates 1.8 g, fibre 0.8 g, ash 0.6 g.

Description Loosely tufted, sympodial bamboo. Culm erect with pendulous tip, up to 30 m tall, diameter 15–20 cm at base, wall 2.5–4 cm thick, ashy-grey or greenish-grey to dull green, dirty yellowish-grey tomentose when young; internodes 30–60 cm long, sometimes sulcate, with a shiny brown pubescent transverse band below and above the nodes; nodes slightly swollen, supranodal lines distinct, with aerial roots on lower half of culm. Branches usually arising from upper mid-culm part, lower half usually more or less branchless but with a tuft of slender branches near the



Dendrocalamus brandisii (Munro) Kurz – 1, culm leaf; 2, leafy branch; 3, flowering branch.

base; primary branches dominant, secondary branches slender. Culm sheath 40–60 cm × 20–35 cm, longer than internodes, elongate, rounded at top, whitish-brown, thick, leathery, early deciduous, covered with black hairs when young; blade lanceolate to long acuminate, 15–46 cm × 8–13 cm, reflexed, deciduous, appressed hairy within; ligule continuous with the sheath top, 1–2 cm long, deeply lacerate; auricles not reaching the edge of the sheath, up to 2 cm long, slightly pleated, bearing bristles. Young shoots conical, sheaths covered with shiny black hairs, blades reflexed. Leaf blade oblong-lanceolate, 20–30 cm × 2.5–5 cm, upper surface pale green and glabrous, lower surface slightly whitish and sparsely pubescent; sheath striate, pubescent when young, with long deciduous cilia at mouth; ligule long, acuminate, fimbriate. Inflorescence a long leafless branch, with long spicate flagelliform branches, bearing bracteate heads of 1–1.5 cm diameter, containing many small pseudospikelets; spikelet ovoid, 5–8 mm × 5–8 mm, minutely pubescent, comprising 1–2 empty glumes and 2–4 florets. Caryopsis ovoid, 2–5 mm long, hairy above, tipped with the persistent style, pericarp crustaceous.

Growth and development The young shoots of *D. brandisii* emerge above the soil during the rainy season and develop to their full height in 4–6 months. After that the lateral branches start to develop. A culm becomes mature in 3–4 years. A good healthy clump produces several shoots every year. *D. brandisii* flowers sporadically as well as gregariously. Its life cycle is not known; in India an interval of 45–50 years between two gregarious flowerings has been reported.

Other botanical information Along with *D. giganteus* Munro, *D. brandisii* is one of the largest bamboos. Both species are somewhat similar but *D. brandisii* has much thicker, dirty tomentose culm walls, and much smaller spikelets.

Ecology *D. brandisii* grows in wet, evergreen tropical forest, up to 1300 m altitude. In Burma (Myanmar) it is frequently found on limestone, but it also grows well on well-drained loamy soil.

Agronomy Although culms and young shoots are mostly collected from wild populations, *D. brandisii* can be propagated by seed, by rhizome and culm cuttings, and by tissue culture. Some seed is usually available after sporadic flowering and constitutes a good source for propagation. Rhizome cuttings (part of rhizome and part of culm, with roots and dormant buds) can always be taken and are planted just before or during the rainy season in holes enriched with a mixture of cow dung and soil. Culm cuttings have been successful in India; parts of one internode with a node at each side were laid horizontally just below the soil surface; the growth of the resulting shoots was slow, in 3 years a maximum height of 2 m was reached. In Thailand promising results have been obtained with tissue culture, working with seeds from which multiple shoots emerge. Young plants require watering if rainfall is insufficient. Weeding, mulching (e.g. with well-rotted rice straw) and earthing up of clumps are recommended. There are no reports of diseases or pests. Culms of 3 years or older are harvested, preferably in the dry season. The yield of young shoots is high; their quality is good when fresh, but they rapidly turn brown during transport.

Genetic resources and breeding No germplasm collections or breeding programmes are known for *D. brandisii*.

Prospects *D. brandisii* is a promising species being one of the strongest and largest bamboos for construction purposes. Many aspects, however, still require investigation, e.g. ecological requirements, cultivation methods, management, propagation, physical, mechanical and chemical properties, preservative treatments. Germplasm collections are urgently needed.

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M.K. Alam

Dendrocalamus giganteus Wallich ex Munro

Trans. Linn. Soc. 26: 150 (1868).

GRAMINEAE

$2n = 72$ (hexaploid)

Synonyms *Bambusa gigantea* Wallich (1814, nomen nudum).

Vernacular names Giant bamboo (En). Indonesia: bambu sembilang. Malaysia: buloh betong, bambu sembilang (Peninsular). Burma (Myanmar): wabo, ban. Cambodia: russey prey. Laos: po'. Thailand: phai-po (general), phai-pok (northern). Vietnam: m[aj]nh t[oo]ng to. Note: 'giant bamboo' is also applied to *Dendrocalamus asper* (Schultes f.) Backer ex Heyne.

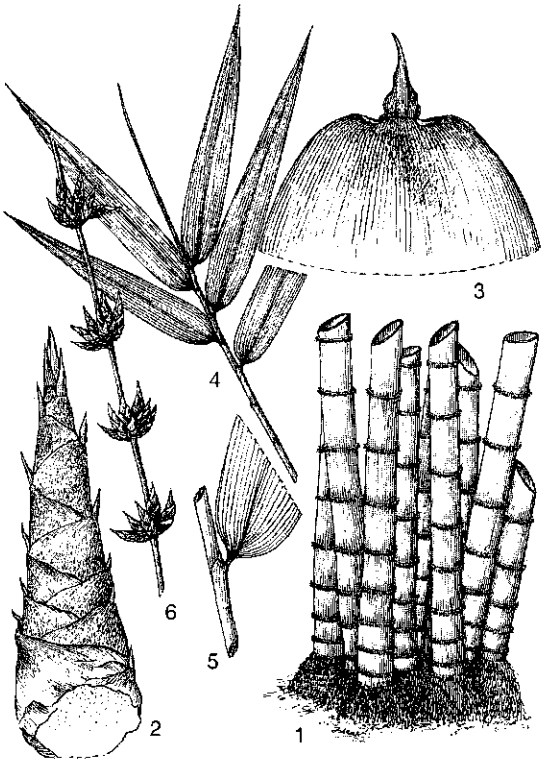
Origin and geographic distribution The origin of *D. giganteus* is not known precisely, but could possibly be in southern Burma (Myanmar) (Tenasserim) and north-western Thailand. It is commonly planted in Sri Lanka, India, Bangladesh and southern China. In Peninsular Malaysia several old clumps of *D. giganteus* have been found growing scattered in the Penang Hills, but it is not known whether this population is natural or a naturalized escape from cultivation. *D. giganteus* has been introduced and planted in many botanical gardens, e.g. in Indonesia (around 1910), the Philippines (1990s), Indo-China, Madagascar (also outside botanical gardens).

Uses The large culms of *D. giganteus* are used for many purposes, e.g. construction, scaffolding and rural housing, water pipes, buckets, boat masts, matting, woven wares and paper production. The thick-walled culms are especially good for the production of bamboo boards, which are ideal material for room decoration and other practical interior applications such as walls, ceilings, floors, doors, shelves, etc. The young shoots are edible (creamy and tender when cooked) but they are not widely consumed. They have a fair canning quality. *D. giganteus* can be planted to protect soil against erosion. As one of the largest bamboo species, it has a high ornamental value. In Thailand the large culm sheaths are used to make hats.

Production and international trade Cultivated on a small scale, *D. giganteus* is locally important in South-East Asia, but no statistics are available. There are no reports of more extensive cultivation.

Properties The fibre length of *D. giganteus* culms varies from 1.4–4.6 mm (averaging about 2.7 mm), diameter 26 µm, lumen diameter 19 µm, wall thickness 3.9 µm. These data indicate good paper-making quality. At a moisture content of 19% the density of the culm is about 900 kg/m^3. Specific gravity is 0.71. The modulus of elasticity is about 14 044 N/mm^2 (Indonesia); the modulus of rupture is 179 N/mm^2 (Indonesia), 93 N/mm^2 (with nodes, Brazil), 124 N/mm^2 (without nodes, Brazil); the compression strength parallel to grain is 61.5 N/mm^2 (Indonesia), 39 N/mm^2 (with nodes, Brazil), 46 N/mm^2 (without nodes, Brazil); the shear strength is about 4.5 N/mm^2 (Brazil); the tensile strength is about 187 N/mm^2 (Indonesia), 110 N/mm^2 (with nodes, Brazil), 135 N/mm^2 (without nodes, Brazil).

Description Densely tufted, sympodial, giant bamboo. Culm erect with arching tip, up to 30 m tall, 18–25 cm in diameter near the base, wall up



Dendrocalamus giganteus Wallich ex Munro – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

to 2.5 cm thick, covered with a white waxy layer when young, becoming smooth, whitish to greyish-green; internodes 25–55 cm long, lowermost shortest; nodes not swollen, lower ones bearing aerial roots. Branches arising from midculm nodes, comprising one dominant branch and several smaller branches. Culm sheath caducous, 25–50 cm × 25–50 cm, widest at lower internodes, with dark brown hairs on the back; blade spreading, broadly triangular (on lower sheaths) to narrowly triangular, 13–38 cm × 9 cm, stiff, edges inflexed towards stiff acuminate apex, with scattered hairs adaxially, especially near the base; ligule 8–12 mm long, stiff, shortly fringed; auricles crisp, 1.5 cm × 3 mm, brown, not bristly. Young shoots purplish. Leaf blade oblique-oblong, 20–40 cm × 3–7 cm, glabrous, slightly rough, with distinct cross veins; ligule 2–3 mm long, irregularly toothed; auricles small and glabrous. Inflorescence borne on a leafless branch with few to many pseudospikelets crowded at each node, axes and internodes finely hairy; spikelet flattened, 13–17 mm × 4–5 mm, consisting of 4–6 florets, the uppermost one sometimes imperfect. Caryopsis oblongoid, 7–8 mm long, hairy above.

Growth and development In Burma (Myanmar), offsets consisting of young shoots with small portions of attached rhizome produce small culms in the first year. Subsequent culms increase in size each consecutive year until, after 7 years, they have attained a girth of about 25 cm and a height of about 12 m. They are then harvested. However, culms attain full size ultimately at an age of 15–16 years.

Observations made in India reveal that *D. giganteus* culms grow very fast, averaging 20 cm per day during 3.5 months. At first, the growth of a young shoot is very slow, quickening gradually during a period of 4–6 weeks until the culm is about 4 m tall. Then maximum growth is attained and maintained for several weeks (e.g. on average, 32 cm per day), after which growth gradually decreases until it stops when full height is attained at the age of 3.5 months. Rapid growth seems to be induced by high relative humidity, irrespective of light and temperature, causing a high turgescence in the culm. Lower relative humidity increases the evaporation, which in turn decreases the turgescence and consequently the growth rate. *D. giganteus* flowers gregariously and the flowering cycle is estimated to be 30–40 years; after flowering, the clump dies.

In Indonesia it has been observed that clumps survive when flowering culms are cut down. Culms grown from seed reached 6–8 m height and 10 cm diameter 3 years after sowing.

Other botanical information In Burma (Myanmar) wild *D. giganteus* is found from Upper Chindwin through the Shan Hills to Moulmein. One-year-old culms are dark green with excessive white mealiness which easily comes off, and with loosely attached sheaths or brown remnants of sheaths present on the nodes. In the second year all sheaths have fallen, the ashy-grey remnants are still present, the culms are green but tinged yellowish near the nodes, especially in the lower half, and the white mealiness is 50% less than in the first year; more than half of the upper culm is covered with branches. In the third and fourth years, branching is even stronger and the mealiness is inconspicuously greyish-white and difficult to remove.

Ecology *D. giganteus* grows naturally in humid tropical highlands, up to 1200 m altitude. It can, however, be grown successfully in tropical lowlands on rich alluvial soils. In northern Thailand it is found in natural forests with teak.

Propagation and planting *D. giganteus* is normally propagated by clump division. If available it can be propagated by seed. Propagation by culm and branch cuttings is possible, although difficult. Artificial induction of roots before taking the cuttings is possible and reasonably successful. In an 8 ha plantation in Burma (Myanmar), 40–50 clumps were grown per ha.

Husbandry Competition between culms in a clump may cause 'abortive shoots', affecting about 50% of all new shoots. Young abortion-prone shoots usually grow within 20 cm from a culm, attaining about 13 cm height before dying. Such young shoots are suitable for vegetable use.

Diseases and pests No serious diseases or pests are known to attack *D. giganteus*. The fungus *Pycnoporus sanguinus* and powder-post beetles may attack dry harvested culms. Submerging in mud for 1–4 weeks after cutting may give some protection against diseases and pests. Sometimes young bamboo shoots suffer from sap-sucking aphids *(Oregma bambusae)* which may cover young shoots completely and cause them to die. Spraying kerosene oil in soap emulsion can control the pest. Witches' broom may also occur in *D. giganteus* but without causing much damage.

Harvesting The harvesting of culms from young clumps may start 7 years after planting. All 3-year-old culms from mature clumps (15–16 years old) can be cut annually.

Yield A mature clump may yield 3–4 culms per

year. With 50 clumps per ha, annual yield can attain up to 200 culms and 200 young shoots. The edible portion of young shoots is about 33%, or 550 g on average.

Handling after harvest Traditionally, culms are submerged in running water or in mud to obtain some protection against powder-post beetles, and are air dried afterwards.

Genetic resources and breeding Germplasm collections of *D. giganteus* are available in Bangladesh (Forest Research Institute, Chittagong), India (Arunachal Pradesh Centre bamboorium, Basar) and in Indonesia (Lampung, Sumatra). Representative collections from all provenances are needed. In India some work is being done on the selection of superior forms, but no breeding programmes are known.

Prospects Although the prospects for *D. giganteus* as a source of raw material for bamboo board, as an ornamental and as a vegetable (young shoots) are promising, it is necessary to investigate its requirements and appropriate cultivation techniques first and then to develop the required technology.

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E.A. Widjaja

Dendrocalamus latiflorus Munro

Trans. Linn. Soc. 26 : 152 (1868).

GRAMINEAE

$2n = 72$ (hexaploid), 64, 48

Synonyms *Bambusa latiflora* (Munro) Kurz (1873), *Sinocalamus latiflorus* (Munro) McClure (1940).

Vernacular names Taiwan giant bamboo, ma bamboo (En). Indonesia: bambu taiwan. Philippines: botong (Tagalog). Burma (Myanmar): wani. Thailand: phai-zangkum (northern). Vietnam: m[aj]nh t[oo]ng hoa to, tre ta[uf]. Japan: machiku.

Origin and geographic distribution The origin of *D. latiflorus* is not known precisely but it is distributed from Burma (Myanmar) to southern China and Taiwan where it is also found in cultivation (most importantly in Taiwan, 90 000 ha). It has been introduced in India, Thailand, Japan, in the early 1970s in the Philippines (Davao and Cotabato Provinces) and in 1980 in Indonesia.

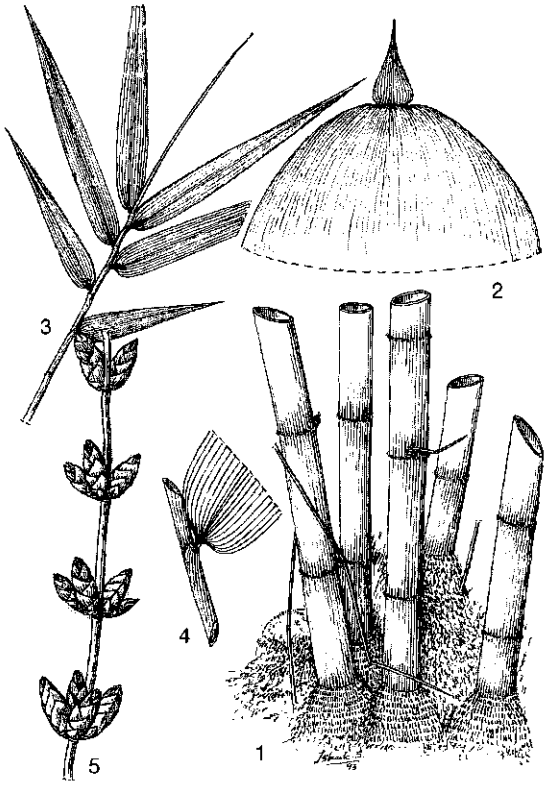
Uses *D. latiflorus* is most important for its young shoots which are used as a vegetable and considered delicious. Mature culms are used as water pipes, to make small rafts for fishing in streams, to weave baskets, and are also used in house construction and for making paperpulp. The leaves are used to make hats, roofs for boats and as material for packing. In Taiwan *D. latiflorus* is also cultivated as an ornamental.

Production and international trade Production and trade of young shoots of *D. latiflorus* is very important in southern China and Taiwan. China exported 140 000 t young bamboo shoots in 1985, Taiwan exports about 40 000 t yearly. The main importer is Japan (value about US$ 40 mil-

lion per year), but dried or canned shoots are also exported to Europe, the United States, Canada and South-East Asian countries. Since 1973, the Philippines has also been exporting young shoots to Japan.

Properties The fibre dimensions in the culm are: length 3.01 mm, diameter 18.1 µm, wall thickness 5.6 µm. The chemical composition of the culm is approximately: holocellulose 80.15%, pentosans 19.40%, lignin 24.76%, ash 2.82%; the solubility in hot water is 5.77%, in alcohol-benzene 7.37% and in 1% NaOH 26.60%. Per 100 g edible portion, young shoots contain: water 92 g, protein 1.2 g, carbohydrates 1.2 g, fat 0.5 g, fibre 0.8 g, ash 0.7 g.

Description Densely tufted, sympodial bamboo. Culm erect with pendulous tip, 14–25 m tall, 8–20 cm in diameter, wall 0.5–3.0 cm thick; internodes 20–70 cm long, smooth and glabrous, covered with white wax when young; nodes rather prominent, the lower ones often bearing aerial roots, surrounded by a ring of brown silky hairs above and below the sheath scar. Branches numerous at each node, the primary one usually distinctly larger. Culm sheath longer than the lower and shorter than the upper internodes, deciduous, coriaceous, hard and brittle, rounded at the apex, orange-yellow when young turning pale brown with age, abaxially dull brown pubescent, margin entire; blade ovate to lanceolate, deflexed, 10–15 mm × 3–4 mm, puberulent near the base abaxially; ligule 2–3 mm long, minutely fringed or toothed; auricles firm, 1.0–1.5 mm wide, ciliolate along the margins. Leaf blade elliptical to oblong-lanceolate, 15–40 cm × 2.5–7.5 cm, top acute; sheath 10–22 cm long, sparsely covered with appressed or spreading bristly glabrescent hairs; ligule very conspicuous, convex, rounded or truncate, 1.5–2 mm long; auricles absent. Inflorescences borne on leafless branches between the leafy branches at a node, up to 80 cm long, consisting of clusters of 1–7 pseudospikelets; spikelet ovoid, laterally compressed, 1–2 cm × 0.8–1.2 cm, reddish to dark purple, comprising 6–8 florets. Caryopsis cylindrical to ovoid, 8–12 mm × 4–6 mm, light brown, pericarp thin.



Dendrocalamus latiflorus Munro – 1, habit; 2, culm leaf (abaxial side); 3, leafy branch; 4, base of leaf; 5, flowering branch.

Growth and development In Taiwan, vegetatively propagated plants can develop in 3 years into clumps with 20–25 culms on average 5–6 m tall and 3–4 cm in diameter. In the Philippines, 5 years after planting, average culm height was 15 m, diameter 7 cm. Flowering is rare in Taiwan; sporadic flowering and fruiting is a normal occurrence in the Philippines, Indonesia and China.

Other botanical information In Taiwan 2 cultivars of *D. latiflorus* have been developed:

- 'Subconvex' (*D. latiflorus* Munro var. *lagenarius* Lin): culm 5–10 m tall, 4–12 cm in diameter; internodes 10–30 cm long, ventricose, pear-shaped; cultivated for ornamental purposes.
- 'Mei-nung': culm and branches yellow-green with narrow darker green stripes on the internodes; culm sheath yellow-brownish green with a few slender pale yellow stripes; commonly cultivated for its edible shoots and useful culms.

In China a form with puberulent branches and leaves with distinct transverse veinlets is distinguished (*Sinocalamus latiflorus* var. *magnus* T.H. Wen).

Ecology In its area of natural distribution *D. latiflorus* occurs under subtropical conditions as in northern Taiwan where it is found up to 1000 m altitude, tolerating temperatures as low as –4°C. In the tropics it is cultivated in the lowlands (Indonesia) as well as in the highlands (the Philippines). It prefers high rainfall. It grows best in

moist, fertile soils. Heavy clay, gravel alkaline or acidic soils are not suitable for the production of edible shoots.

Propagation and planting *D. latiflorus* can be propagated by seed and by rhizome and culm cuttings. Seed rapidly loses its viability. When sown directly after collection, seed germinates within 2 weeks at a germination rate of 90%. As seed is usually rather rare, vegetative propagation by cuttings is normal practice. The preferred cuttings are taken from 2-year-old culms, are 50 cm long (2-noded), and are planted horizontally 6–10 cm deep. The rooted cuttings are preferably transplanted in the rainy season when 2 years old. Usual spacing is 4–5 m × 4–5 m, giving 400–625 plants per ha. Propagation by tissue culture is practised successfully in Taiwan.

Husbandry Regular weeding (twice a year) is necessary. The plants must never be allowed to become short of water until they are well-established. For edible shoot production it is recommended in Taiwan to:

- mulch each clump 3 times per year with 40–60 kg mulch (dry grass, bamboo or sugar-cane leaves);
- loosen the soil around each clump regularly;
- cut the culms back to 2.0–2.5 m in the second year after planting, to maintain a bush-like clump as protection against wind damage;
- apply 20–25 kg compost or manure to each clump as basic organic fertilizer before each growing season;
- apply chemical fertilizers 4 times per year, each time at a rate of 40 kg N, 10 kg P, 30 kg K and 0.65 kg Si per ha.
- maintain only 3–4 culms per mature clump, to increase the area for young shoot growth.

Diseases and pests The most common diseases of *D. latiflorus* are: bamboo mosaic virus (Taiwan, the Philippines), leaf rust (the Philippines: *Phakopsora louditiae*; China: *Uredo dendrocalami*), bacterial wilt disease attacking shoots (Taiwan: *Erwinia sinocalami*; China: *Fusarium semitectum*), wood rotting (Japan: *Poria vaporaria*). No serious pests have been reported.

Harvesting Young shoots are harvested 7–25 days after emergence, when they are 35–60 cm tall. Harvesting may start in the 2nd year of growth of a clump. Harvesting of culms may start when clumps are 3–7 years old. To ensure sustainable yields, only over-mature and a few mature culms should be harvested at one time, and the number of harvested culms should not exceed 3/5 of the standing mature culms. In the Philippines, culms are usually harvested in the dry season, i.e. from November to May.

Yield A 1–2-year-old culm can produce 5–10 shoots weighing 3–5 kg. In Taiwan, average young shoot production per clump increases in the first 5 years after planting from 30 kg in the 2nd year to 60 kg in the 3rd year to 80 kg in the 4th year, to a maximum of about 100 kg in the 5th year. With 200–400 mature clumps per ha, total annual yield averages 20–40 t per ha. In southern China, young shoot yield per year averages 12 t/ha, but can be as high as 30 t/ha. In the Philippines, a mature clump can produce 80–160 culms annually under ideal circumstances, but usually average production is 20–30 culms or 10 000 culms per ha.

Handling after harvest Harvested shoots are steamed, cut lengthwise, cleaned and sterilized for 15 minutes in pure or salted (2 tablespoons NaCl per 0.25 l) boiling water before eating or canning. When boiled in pure water a white compound (containing 90% tyrosine) usually precipitates, which can be removed by boiling for 1.5 hours in a 0.06–0.07% citric acid solution, followed by 12 hours of washing. For the production of fermented dry shoots, the middle parts of shoots are boiled first and then left to ferment for 2–4 weeks, and subsequently sliced into parts of 4–5 cm × 2.8 mm. In the Philippines harvested culms are either dried directly in the sun or shade or first kept in running water for several weeks before being air dried.

Genetic resources Germplasm collections of *D. latiflorus* are available in China (Forest Research Institute, Guangzhou, Guandong), Taiwan, Indonesia (Lampung, Sumatra) and the Philippines (Ecosystems Research and Development Bureau, Baguio). *D. latiflorus* has been planted in many botanical gardens all over the world.

Breeding In China, *D. latiflorus* is used in breeding programmes to develop hybrid cultivars that grow fast and provide quality construction material with wide adaptability and high economic value, or to provide better tasting shoots. In a *D. latiflorus* floret, the pistil appears first, followed by the stamens a few days later. Pollen viability fluctuates between 5–40%. Promising hybrids have been developed from crossings of *D. latiflorus* with *Bambusa pervariabilis* McClure (for paper-making material), *Bambusa textilis* McClure (for culm production) and *Dendrocalamus minor* (McClure) Chia & Fung (for culm production). For young shoots, the hybrid with *Bambusa pervariabilis* is promising.

Prospects The prospects for *D. latiflorus* are

promising, especially for edible shoot production and export. It seems worthwhile to investigate the feasibility of large-scale cultivation, including in South-East Asian countries. In the Philippines, promising experimental plantations have existed since 1971, in Indonesia since 1987.

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C.A. Roxas

Dendrocalamus membranaceus Munro

Trans. Linn. Soc. 26: 149 (1868).

GRAMINEAE

$2n = 72$ (hexaploid), 70

Vernacular names Waya (En). Burma (Myanmar): waya, wamu, wapyu. Laos: s'a:ng, hôk hnhaix. Thailand: phai-sangnuan, phai-nuan, phai-sangdoi (northern).

Origin and geographic distribution *D. membranaceus* is native to Thailand (especially northern and northeastern), Burma (Myanmar) (eastern and down to Tenasserim) and Laos. It is occasionally cultivated in its native area and has been introduced in many botanical and private gardens (e.g. in Indonesia (Bogor, Lampung) and in India (Kerala)).

Uses Culms of *D. membranaceus* are used for building purposes, bamboo board, furniture, basketry, matting and handicrafts, and as props for fruit trees. They are said to be very promising for the production of paperpulp. Young shoots are edible; they have a slightly bitter taste but are excellent for processing because they are nearly smooth and easy to handle. When administered to hamsters, the aerial part of the plant induced anti-implantation activity.

Production and international trade *D. membranaceus* is produced and traded locally in its native area. No statistics are available.

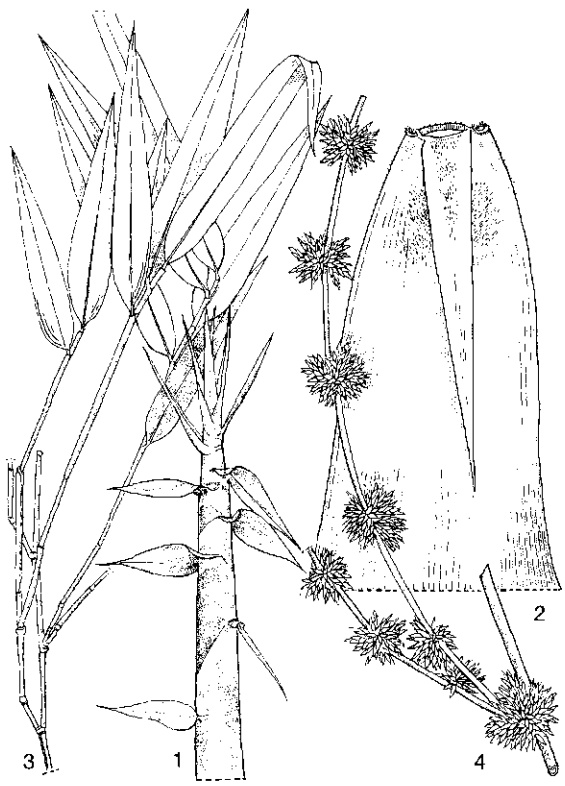
Properties At a moisture content of 102.5% green culms have a density of 551 kg/m^3; dry culms have a density of 664 kg/m^3 at 7.2% moisture content. The fibre length is 2–3(–4.5) mm. At culm moisture contents of 102.5% and 7.2% the modulus of elasticity is 2393 N/mm^2 and 3697 N/mm^2, the modulus of rupture 25.8 N/mm^2 and 37.1 N/mm^2 and the compression strength parallel to grain 39.7 N/mm^2 (no data for 7.2%) respectively. The average fresh weight of young shoots is 1167 g and the edible portion is about 40%. After cooking, shoots are creamy-white and tender.

Botany Sympodial bamboo, forming rather open clump. Culm very straight, 20–24 m tall, 6–10 cm in diameter, wall 6–10 mm thick, covered with white powdery deciduous scurf when young, turning green on maturity; internodes 22–38 cm long; nodes prominent, basal ones with aerial roots. Branches arising from all nodes, upper ones slender and drooping. Culm sheath 30–50 cm × 12–20 cm, glabrous or with appressed dark brown hairs; blade narrowly lanceolate, 25–40 cm × 2–3 cm, reflexed, brown hairy on both sides; ligule about 5

mm long, dentate; auricles dark brown, wavy, fringed. Leaf blade lanceolate, 12–25 cm × 1.5–2.5 cm, thin, pale, hispid above, hairy on the midrib beneath, margins scabrous, apex acuminate; sheath striate, ending in a callus, cleft nearly to the base; ligule very short, obtuse, hairy; auricles falcate, wavy-bristly, 1 cm long, purplish ciliate, very white hairy when young. Inflorescences on leafless branches, consisting of distant globular spinescent heads 2.5–5.0 cm apart and up to 2.5 cm in diameter; spikelet slightly compressed, 10–13 mm × 2–5 mm, glossy, nearly glabrous, with 2 empty glumes and 2–3 fertile florets. Caryopsis broadly ovoid, 5.0–7.5 mm long, grooved on one side and somewhat flattened, ending in a sharp point.

D. membranaceus sheds its culm sheaths very early. It flowers gregariously, in Thailand between October and April (dry season), but a flowering cycle is not known. In India it flowered in a botanical garden at an interval of 20 years.

D. membranaceus resembles glabrous forms of *D. strictus* (Roxb.) Nees and may easily be mistaken for it. It can be distinguished from the latter by its glabrous spikelets, thinner leaves, culm sheath with wavy hairy auricles, recurved apical leaf, and the more elongate grooved caryopsis.



Dendrocalamus membranaceus Munro – 1, young shoot; 2, culm leaf (abaxial side); 3, leafy branch; 4, flowering branch.

Ecology The natural habitat of *D. membranaceus* is a tropical mixed deciduous or monsoon forest below 1000 m altitude. In northeastern Thailand (Tak), where *D. membranaceus* is native, annual average minimum temperature is 21.7°C (14.5°C in January, 25.6°C in April) and average maximum temperature 33.3°C (30.5°C in December, 38.1°C in April); the average annual rainfall is 950 mm with a dry season from November to April.

Agronomy *D. membranaceus* can be propagated by seed and by rhizome and culm cuttings. Fresh seed has a germination percentage of 90%. Seed remains viable for quite a long period (60% germination after 6 months); if stored at 4–5°C, germination percentage was 80% after 6 months. Propagation by tissue culture is promising but still in the experimental stage. Planting is done in the rainy season. Young plants need watering in the dry season. No serious diseases or pests are known. The culms are rather resistant to culm borers but not to fungi. For construction purposes fully mature, 3–4-year-old culms are harvested, for basketry 2-year-old culms are used. Culms with the largest diameters are preferred for the bamboo board industry. After harvesting, culms are traditionally submerged in running water for 10–20 days. Preservation by boiling culms for 10–20 minutes in a solution of sodium carbonate, calcium hydroxide and copper sulphate is also practised. It takes about 3 months to air dry the culms. Mature culms dry with little cracking, immature ones are liable to collapse and shrink excessively. Culms used for weaving and handicrafts are cleaned by rubbing with ash, coconut husks or rice straw, which leaves the shiny surface undamaged; sandpaper cleaning is used for furniture. For furniture making, culms are roasted above fire at 110–130°C for 15–20 minutes 2–3 times.

Genetic resources and breeding A germplasm collection of *D. membranaceus* is available at the Centre bamboorium of Arunachal Pradesh in India. More collections are urgently needed from its native areas. There are no breeding programmes.

Prospects Most of *D. membranaceus* resources in natural forests have been overexploited for many decades. Given the increasing demand for culms for local uses, studies on proper methods for cultivation, harvesting, and conservation are ur-

gently needed. *D. membranaceus* is potentially of interest for the production of edible shoots in other South-East Asian countries.

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S. Duriyaprapan & P.C.M. Jansen

Dendrocalamus pendulus Ridley

Journ. Straits Settlem. Roy. Asiat. Soc. 44: 210 (1905).

GRAMINEAE

$2n$ = unknown

Synonyms *Cephalostachyum malayense* Ridley (1911), *Schizostachyum subcordatum* Ridley (1920).

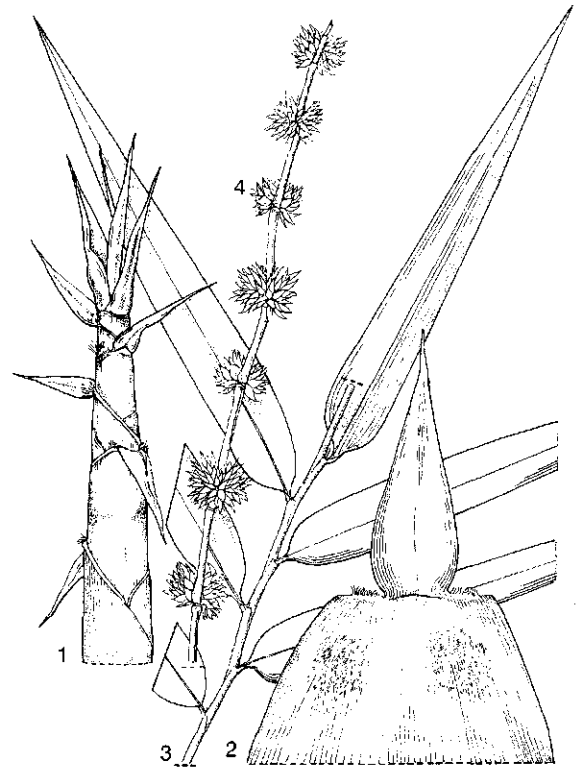
Vernacular names Peninsular Malaysia: buloh akar, buloh tali.

Origin and geographic distribution *D. pendulus* is native to Peninsular Malaysia where it is very common in the foothills of the Main Range. Occasionally it is grown in botanical gardens (e.g. in Singapore).

Uses The culms are used for making baskets and handicrafts.

Production and international trade In Peninsular Malaysia production and consumption of culms of *D. pendulus* is considerable, reaching 20% of the total annual bamboo culm consumption by the local industry.

Botany Closely tufted, sympodial bamboo. Culm 10–30 m tall, diameter 6–12 cm, wall 5–11 mm thick, arching over with pendulous tip, smooth and dark green when old; internodes about 40 cm long, with white wax below nodes and pale brown hairs; nodes somewhat prominent. Branches slender, central ones very long, pendulous. Culm sheath 16–25 cm × 20–30 cm, narrowing towards the apex, rigid except edges at the top, green tinged with pink at the top, covered with thick white wax and felted white easily deciduous hairs on the back; blade broadly lanceolate, 7–12 cm × 2.5–3 cm, erect or deflexed, glabrous or with scattered hairs adaxially; ligule 3–4 mm long, irregularly toothed; auricles about 15 mm long in lateral extent, bearing long bristles of 15–20 mm along the edges. Young shoot pinkish green, with white wax and white hairs. Leaf blade 15–25 cm × 1.5–2.5 cm, usually glabrous; sheath



Dendrocalamus pendulus Ridley – 1, young shoot; 2, culm leaf (abaxial side); 3, leafy branch; 4, flowering branch.

glabrous, often covered with white wax when young; ligule very short; auricles small. Inflorescence terminating a leafy or a leafless branch, consisting of pseudospikelets in dense heads at each node; spikelet about 10 mm long, consisting of several glumes and one (rarely 2) perfect floret. Caryopsis not known.

In Peninsular Malaysia, *D. pendulus* is very abundant and of quite uniform character. A mature clump bears 30–40 culms.

Ecology *D. pendulus* is found on hillsides and in forest margins of secondary forest at 400–1000 m altitude. It seems to appear spontaneously in places where forest is disturbed or new roads are built.

Agronomy In Peninsular Malaysia culms are harvested from wild populations. It is not known, however, when and how they are harvested. Culms are cut into certain lengths and transported to markets or other places where they are utilized for making baskets, e.g. to transport vegetables.

D. pendulus may suffer from leaf spot diseases, caused by *Colletotrichum* and *Nigrospora* species.

Genetic resources and breeding There are no germplasm collections or breeding programmes.

Prospects *D. pendulus* provides local communities and industries with culms readily available from wild populations. The prospects are very good, but more investigations on various aspects (e.g. management of natural stands, properties, cultivation methods) are needed.

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S. Dransfield

Dendrocalamus strictus (Roxb.) Nees

Linnaea 9: 476 (1834).

GRAMINEAE

$2n = 72$ (hexaploid), 70

Synonyms *Bambos stricta* Roxb. (1798).

Vernacular names Male bamboo, solid bamboo (En). Malaysia: buloh batu. Burma (Myanmar): myinwa. Laos: s'a:ng. Thailand: phai-sang. Vietnam: t[aaf]m v[oo]ng.

Origin and geographic distribution *D. strictus* is widespread and native in India, Nepal, Bangladesh, Burma (Myanmar) and Thailand. It is most common in India, especially between the Ganges and Ramganga rivers. Outside its native area it is sometimes also cultivated, often only in botanical or experimental gardens (e.g. in Sri Lanka, Indo-China, Indonesia, Malaysia, the Philippines, Puerto Rico, Cuba, United States).

Uses The culms of *D. strictus* are used for many purposes, such as for building material, furniture, mats, baskets, sticks, agricultural implements, rafts and woven wares. In India it is the principal source of paperpulp. In Thailand it is an important species in the bamboo board industry. Young shoots and seeds are edible. Leaves are used as forage.

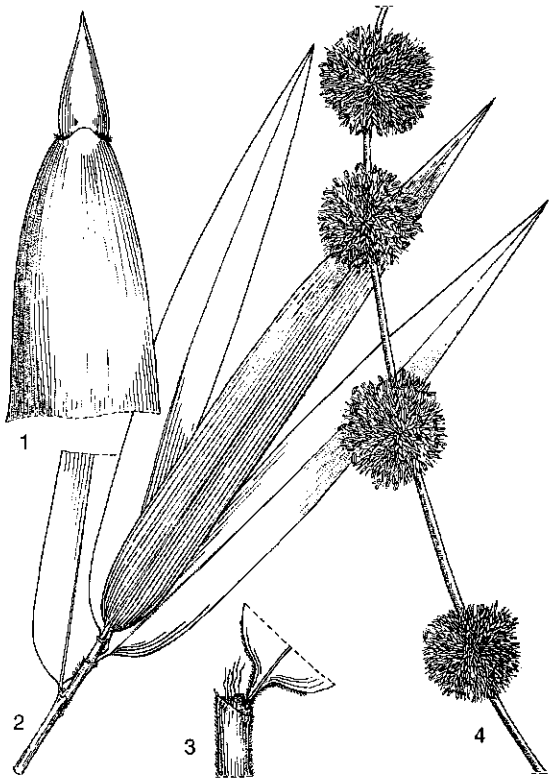
Production and international trade *D. strictus* is the most common, most widespread and most universally used bamboo in India, but no accurate statistics are available on its production and trade. The total area under bamboos in India (all species) is estimated at 10 million ha, with a potential annual production of 4.5 million t. About half of the area and production is ascribed to *D. strictus*. Production of paperpulp (for which *D. strictus* is the major source) is estimated at 3–3.5 million t per year.

Properties Fibre dimensions of the culm are on average: length 2.45 mm, diameter 14.51 µm, lumen diameter 2.88 µm, wall thickness 5.20 µm. The fibre saturation point is 20%. The moisture content of 3–4-year-old green culms of *D. strictus* ranges from 46–77% (top) to 78-108% (bottom). At drying from green to oven dry, tangential shrinkage is 6–13%. At 12% moisture content and for green culms the density is approximately 600–700 kg/m^3 and 540–780 kg/m^3 respectively, the modulus of elasticity 13 730–17 650 N/mm^2 and 6000–11 790 N/mm^2, the modulus of rupture 84–98 N/mm^2 and 50–153 N/mm^2, the compression strength parallel to grain 56–66 N/mm^2 and 42–57 N/mm^2, the shear strength 13–15 N/mm^2. Climatic and soil conditions affect some of the physical and

strength properties of *D. strictus*. Culms grown in dry conditions have a higher modulus of elasticity and modulus of rupture than culms grown in humid areas. The chemical composition of the culms is approximately: holocellulose 60–62%, pentosans 15–18%, lignin 24–29%, ash 1–2%; the solubility in cold water is 3–7%, in hot water 4–8%, in alcohol-benzene 1.5–2%, in 1% NaOH 17–23%, in ether 1–2%.

Per 100 g edible portion the chemical composition of young shoots is approximately: water 90 g, protein 2.9 g, fat 0.3 g, carbohydrates 2 g, fibre 1 g, ash 1 g, Ca 15 mg, Fe 0.6 mg, P 46 mg, vitamin A 133 IU, vitamin C 0.2 mg; the energy value is about 90 kJ/100 g. Seed meal contains approximately 15.3% crude protein, 1.3% ether extract, 4.3% fibre, 77.4% N-free extract, ash 1.7%, Ca 0.35%, P 0.21%. The energy value per g dry matter is about 20 kJ.

Description Densely tufted, sympodial bamboo. Culm much curved, (6–)8–16(–20) m tall, 2.5–8(–12.5) cm in diameter, thick-walled or solid, glaucous when young, turning dull green or yellowish, glabrous; internodes 30–45 cm long; nodes somewhat swollen, basal ones often with aerial roots. Branches arising from nearly all nodes (including the lower ones), usually several at each node, unequal, the central one dominant. Culm sheath variable, lower ones shortest, 8–30 cm long, striate, glabrous or with golden-brown hairs on the back; blade erect, triangular, up to half the length of the sheath, with stiff narrow tip and hairy at both sides; ligule 2–3 mm long, toothed, not bristly; auricles small and covered with short hairs, not bristles. Young shoot brownish-green with very thick dark brown hairs and short apex. Leaf blade linear-lanceolate, up to 25 cm × 3 cm, largest in moist areas, rough and often hairy adaxially, with soft hairs abaxially; ligule short; auricles sometimes with a few slender bristles. Inflorescence a large leafless branch with dense globular heads 4–5 cm apart and 2.5 cm in diameter; spikelets 7.5–12 mm × 2.5–5 mm, usually hairy, the fertile ones intermixed with many sterile smaller ones; fertile spikelets with 2–3 perfect florets and 2 or more empty glumes. Caryopsis ovoid to subglobose, about 7.5 mm long, brown, shiny.



Dendrocalamus strictus (Roxb.) Nees – 1, culm leaf (abaxial side); 2, leafy branch; 3, lower part of leaf; 4, flowering branch.

Growth and development New rhizomes of seedlings first bend downwards before curving upwards to form aerial shoots, so successive shoots are not only larger than the preceding ones but arise from rhizomes deeper in the soil. Early shoots are thin, wiry and grass-like and die off sooner or later. After a stage with whippy culms, thin woody culms develop. A clump is considered mature when it starts producing full-sized culms. Under natural (forest) conditions, *D. strictus* seedlings require 11–13 years to form a mature clump; under artificial conditions, 6 years are required.

A mature clump continually grows in all directions, provided there are no obstructions (e.g. rocks or hard soil layers) until a balance is reached between the formation of new culms and the dying off of old culms. The ratio of new to old culms in a clump is usually 1:5. Climatic and soil conditions play a major role in culm and internode lengths. When the soil is poor, dry or hard, or when clumps suffer injury, clumps may become congested. In that case culms are packed tightly together and are often bent and twisted. This congestion can also be caused by unrestricted cutting at the periphery of a clump, by the browsing of young shoots by cattle, by harvesting young shoots for use as a vegetable, or by digging up young rhizomes for propagation.

Young shoots usually arise in the rainy season. Given sufficient rainfall, as many as 20 new culms may be produced annually from fair-sized clumps. A mature clump contains on average 20–40 culms, but up to 200 are possible. Individual culms are considered mature when they are 3 years old but they may become 7–8(–15) years old before dying. The life cycle of a *D. strictus* clump is most variable, ranging between 20 and 65 years.

Flowering in *D. strictus* is variable. Sporadic flowering, involving only a few culms in a clump, happens irregularly. The flowering culms die after flowering, but the clump does not. A possible explanation for this phenomenon might be that the clump has developed from several seedlings. Normally, a clump flowers gregariously at the end of its life. Usually, in a certain region, all or almost all culms in all clumps flower simultaneously within a period of 2–4 years and die thereafter. Fruiting is usually abundant after gregarious flowering. The phenomenon of gregarious flowering is not well understood; some authors believe that unfavourable circumstances (e.g. congestion, grazing, fire, poor soils) increase the intensity and frequency of gregarious flowering.

Other botanical information In dry areas *D. strictus* is deciduous, but in humid climates or in moist environments it remains evergreen.

D. strictus is a polymorphic species, varying in habit of culms and clumps, thickness of culm wall, texture and pubescence of culm sheaths, branching habit, and size of leaves. Based on the hairiness of the lemmas, 2 varieties have been distinguished: var. *strictus* (var. *prainiana* Gamble) with lemmas almost glabrous, and var. *sericeus* Gamble with silky pubescent lemmas. A third named variety, var. *argentea* A. & C. Rivière has silvery white lines on the leaf blades and dark green and yellowish stripes on the culm sheaths.

In India, 3 habits are distinguished:

- the common type: including culms with rather thick walls (the ordinary form, medium sized), culm with thin walls (growing under favourable conditions, large), culms solid or almost so (growing under hot, dry conditions, small);
- the large type: culms very large with long, straight, smooth internodes and no side branches to a great height, clumps not congested (growing under optimum conditions);
- the dwarf type: culms very small, only exceptionally forming clumps, it is the poorest form (growing under unfavourable conditions).

Ecology *D. strictus* occurs naturally in tropical and subtropical regions of South Asia. The optimum mean annual temperature is between 20–30°C, but it can withstand extremes as low as –5°C and as high as 45°C. Mature plants are frost hardy but frost will kill young plants. Optimum annual rainfall is between 1000–3000 mm with 300 mm per month during the growing season. *D. strictus* is, however, a very drought resistant tropical bamboo, still growing rather well with 750–1000 mm rainfall per year. It prefers low relative humidity and is found from sea-level up to about 1200 m altitude, particularly on hilly ground with cooler and drier conditions. It grows on all soils with good drainage, preferring sandy loams on a stony subsoil with pH 5.5–7.5. *D. strictus* thrives in relatively open types of mixed deciduous forest.

Propagation and planting *D. strictus* can be propagated by seed, rhizome and culm cuttings, or by tissue culture.

Propagation by seed is the commonest method for the large-scale production of propagules. Seed weight is very variable, ranging from 0.1–1.4 g. Seeds lose their viability within 2–3 months. With moisture content reduced to 8%, stored at a temperature of 3–5°C, seeds keep their viability for at least 3 years. Germination percentage is normally 60–70%. Direct sowing in the field is possible, requiring about 1 kg seed per ha, after which thinning and weeding are necessary. Sowing in a nursery on beds is more common. A bed of 10 m × 1.5 m may produce 4000 plants when 0.2–0.4 kg seed is sown in drills about 20 cm apart and lightly covered. Seedlings are usually transplanted to the field when they are one year old. Sowing in polythene bags (23 cm × 23 cm) also gives excellent results and it economizes seed when seed is scarce. A vegetative propagation system called 'macro-proliferation of seedlings' has been successfully developed in India for large-scale propagule production. Seed is sown in polythene bags (24 cm × 18 cm) filled with fertilized soil (NPK). In 8 months 3–8 young culms develop per seedling (per bag) which are then separated into propagules, each with some rhizome and roots. On average, 6 propagules are available per bag, 5 of which are planted out in the field, leaving one for the next multiplication round following the same system. This method ensures a continuous supply of propagules.

Rhizome cuttings (or single-culm clump division) are the traditionally preferred method of propagation, but this method is not practised for large-scale propagation. Preferably, one-year-old culms with rhizome should be used.

Culm cuttings are not very successful in *D. strictus* when parts of a culm are used. In an experiment, whole culms (1–2 years old) were used and gave good results: 1–1.5 new plants per 3 m culm (most from the middle and top parts).

Tissue culture applied to propagate *D. strictus* is still in its experimental stage but results are promising.

During the early stages of development of *D. strictus* some shading might be beneficial or even essential, since in areas exposed to full sun natural regeneration is conspicuously absent.

Sowing and transplanting should be done at the beginning of the rainy season. Transplanting seedlings when about 30 cm tall from natural forest is very successful and cheap. Recommended planting distance in the field is 3–5 m × 3–5 m, resulting in 400–1000 clumps per ha. A well-stocked natural *D. strictus* stand contains on average 150–225 clumps/ha.

Husbandry To assure a good regeneration of a natural stand or forest of *D. strictus* it should be protected from grazing and fire for at least 6–7 years after the gregarious flowering period.

In a plantation, regular weeding and supply of sufficient water (by rainfall or artificially) are necessary until the plants are well established. NPK application is recommended (e.g. 200 kg/ha of a 15-15-15 mixture). In India, growth of new shoots is promoted by applying green manure (leaves of bushes) before the onset of the rainy season. To obtain a higher production of culms, M-shaped thinning of the clump is recommended.

Diseases and pests Major nursery diseases of *D. strictus* are damping-off (caused by *Rhizoctonia solani* and *Fusarium* spp.) and leaf blight (many causal fungi, e.g. *Alternaria* spp., *Colletotrichum gloeosporioides, Cercospora* sp., *Dactylaria* sp.). Major diseases of adult plants are: rhizome rot (*Ganoderma lucidum*), culm rot (*Fusarium* sp.), culm sheath rot (*Glomerella cingulata*) and leaf rust (*Dasturella divina*). Witches' broom disease is rather common in *D. strictus* (infected plants show excessive branches at the nodes), but does not visually harm the culms.

Major pests are defoliators (e.g. the greater bamboo leaf roller *Pyrausta coclesalis*), shoot and culm borers (e.g. bamboo weevils (*Cyrtotrachelus* spp.) and the bamboo hispine beetle (*Estigmena chinensis*), and sap-suckers of shoots (e.g. the aphid *Oregma bambusae*), stems, leaves and seeds (e.g. the pentatomid bug *Ochrophara montana*). Integrated pest management practices with the emphasis on cultural, biological and genetic control still have to be evolved.

Bamboo seedlings have many natural enemies (e.g. rats, squirrels, pigs, porcupines, hares, deer, goats and cattle). The major pests of felled or dried culms are the powder-post beetles *Dinoderus ocellaris, D. minutus* and *D. brevis*, and termites, which may cause immense damage. Protection can be obtained by prophylactic and preservative treatments (e.g. soaking in a 5% aqueous solution of a copper-chrome-arsenic (CCA) mixture gives good results) but safer, environmentally friendly insecticides still have to be developed.

Harvesting Harvesting may start 3–4 years after a clump has begun to produce culms of maximum size. Only culms older than 3 years are harvestable and harvesting should never be done during the growing season. It is recommended to cut the culms lower than 30 cm above the ground level, but not below the 2nd node. Debris and cut branches should always be removed completely.

In India various felling cycles are followed with various felling intensities, each giving good results. Much depends on the size of the clump, the number of old and new culms per clump and the average diameter of the culms when determining a sustainable harvesting method and cycle. Some general rules are widely accepted: clear-felling usually kills the clump; in every clump, in addition to the young culms (younger than 1 year) some older culms should also be left standing; loosening the soil and heaping it up around the base of the clump stimulates young shoot growth; culms left standing should be evenly distributed over the clump. A felling cycle of 3–4 years leaving all new culms and double that number of old culms per clump seems suitable. After gregarious flowering, clumps need to be harvested completely as soon as possible after seeds have developed and matured.

Yield Yield figures for *D. strictus* culms in India vary considerably and depend on many factors. A plantation of 400 clumps/ha may produce 3.5 t culms per ha annually. A natural *D. strictus* forest with 200 clumps/ha may produce 2.8 t culms per ha annually, but the yield is usually lower. In a well-managed natural stand in India, with earthing up, M-shaped thinning and application of NPK fertilizer (0.5 kg) to the clumps, annual yields of about 17 t green culms per ha could be obtained.

Handling after harvest Air drying of harvested culms is most practical and takes about 3 months in India. Drying in hot and dry winds

should be done carefully (slowly and gradually) to avoid cracking. Mature culms (3–7 years old) dry satisfactorily, immature culms (younger than 3 years) may deform or show a certain amount of collapse. On average mature culms show a wall thickness shrinkage of 11% and a diameter shrinkage of 12% on air drying. For immature culms, those figures are 25% and 23%, respectively.

Culms of *D. strictus* are not durable. In the tropics in the open their life time is 2–3 years (they are destroyed by powder-post beetles, termites and fungi). Various preservative treatments (e.g. soaking in acidic copper-chrome solutions or in a mixture of 1:1 creosote and fuel oil) can extend the durability satisfactorily. Non-poisonous preservation methods still have to be developed. The traditional method to submerge culms for 10–20 days in running water reduces starch and sugar content and thus makes them less attractive for, but not resistant to, insect borers.

In Thailand, to obtain a shiny surface, culms are rubbed with ash, coconut husks or rice straw. To obtain a smooth surface (not shiny) culms can be rubbed with sandpaper. To make furniture, culms are roasted above fire at 110–130°C for 15–20 minutes 2–3 times.

Genetic resources and breeding Germplasm collections of *D. strictus* are being built up in India by the National Bureau of Plant Genetic Resources, New Delhi and its stations in Trichur, Shillong and Ranchi, and by the Indian Council for Agricultural Research in the Arunachal Pradesh Centre. Due to overexploitation, the natural *D. strictus* forests in India are suffering and protective conservation measures, in addition to germplasm collections, are badly needed. In India, several breeding programmes exist to produce superior cultivars of *D. strictus*.

Prospects The prospects for *D. strictus* are promising. It is one of the best studied bamboos and its introduction on a larger scale in the drier parts of South-East Asia is worthwhile. In its natural area, conservation programmes and extended germplasm collections are absolutely necessary to retain its rich variability.

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P.C.M. Jansen & S. Duriyaprapan

Gigantochloa albociliata (Munro) Kurz

Forest flora of British Burma 2: 555 (1877).
GRAMINEAE
$2n$ = unknown

Synonyms *Oxytenanthera albociliata* Munro (1868).

Vernacular names Burma (Myanmar): wa-hpyu-ka-le. Laos: laix. Thailand: phai-rai, phai-ruaklek, phai ruak.

Origin and geographic distribution *G. albociliata* is a native bamboo of Burma (Myanmar) (Pegu, Martaban, Tenasserim) and Thailand where it is widely distributed in dry forest hills in the central and northern parts of the country. It has been introduced in India (e.g. West Bengal, Assam, Arunachal Pradesh) and Indo-China (e.g. common in Laos).

Uses Culms of *G. albociliata* are used in light construction (cottage walls, frames of thatched roofs), as trellises for climbing vegetables, for fence construction (typical in western part of central Thailand), tool handles (basal culm parts), furniture (with proper firing culms can be bent like rattan), woven wares and as raw material for paper and board. Young shoots are eaten as a vegetable. *G. albociliata* is also grown as an ornamental plant in gardens.

Production and international trade Production and trade of culms and young shoots of *G. albociliata* is considerable in its native area, but no statistics are available. In Thailand, young shoots are also canned and exported (e.g. to Japan). Farmers receive about 0.07 US$/kg for young shoots.

Description Densely tufted, sympodial, evergreen or deciduous bamboo. Culm elongate arcuate-decurved, (5–)10(–16) m tall, 2–7 cm in diameter, wall up to 1 cm thick, greyish-green with white stripes, hispid when young; internodes 15–60 cm long; nodes prominent. Branches arising at nodes especially in upper part, usually erect and almost solitary, nearly as strong as the culm. Culm sheath 10–20 cm × 15 cm, folded and coriaceous at the base, apex truncate and narrow, covered with dense, tawny, appressed hairs when young, becoming glabrous and smooth; blade lanceolate, 10–20 cm long, spreading, acuminate, membranous; ligule 1.5–2.5 cm long, truncate, toothed; auricles small, indistinct. Young shoot with reflexed blades and short, pointed apex. Leaf blade linear-lanceolate, 15–20 cm × 2–2.5 cm, base rounded, apex subulate-acuminate, glabrous, chartaceous, glaucescent beneath; sheath striate, smooth; ligule long, hairy; auricles indistinct. Inflorescence large, consisting of a main branch with slender spreading branchlets bearing clusters of 10–20 pseudospikelets at each node, supported by yellow, chaffy, white ciliate bracts; spikelet elongate-linear, more or less curved, rarely straight, 1.5–2 cm × 2–2.5 mm, glaucous-green, comprising 1–2 empty glumes, 1–2 male florets and 1–2 hermaphrodite florets. Caryopsis elongate-oblong, cylindrical, acuminate, glabrous.

Gigantochloa albociliata (Munro) Kurz – 1, young shoot; 2, culm leaf; 3, leafy branch; 4, flowering branch; 5, pseudospikelet.

Growth and development A 6-year-old clump raised from a rhizome cutting produced 27 culms with average height 10.5 m (ranging 5–16 m), and average diameter 2 cm (ranging 1–3 cm). A mature clump in natural stanas in Thailand bears 50–60 culms.

G. albociliata flowers sporadically and gregariously. In Thailand, sporadic flowering is common and occurs usually from October to December. Mature seeds are available from February to April. Gregarious flowering is very rare. A flowering cycle of 30 years has been reported from Assam (India).

Other botanical information In the dry season, *G. albociliata* often sheds its leaves.

Ecology The natural habitat of *G. albociliata* is the dry tropical mixed forest at low to medium altitude, with average annual rainfall of 800–1300 mm, annual mean temperature of 28°C and well-drained soils of poor to medium fertility. In Burma (Myanmar) it is common in low altitude mixed forest, but does not enter savannas.

Propagation and planting *G. albociliata* can be propagated by seed and by rhizome cuttings (offsets). Seed is usually available because of the common sporadic flowering. Rhizome cuttings are planted, using portions of culm 30–50 cm long. For small-scale planting seedlings are also collected from the forest. No large-scale plantations exist, because rich natural stands are available.

Husbandry Weeding is necessary, especially during the rainy season, until a plantation is fully established. Fire control and regulation of grazing of domestic cattle are important for the management of natural stands. Chemical and organic fertilizers stimulate growth and productivity. Thinning and spacing of clumps (removing of culms older than 3 years, and shoots growing too closely) are recommended.

Diseases and pests No serious diseases or pests of *G. albociliata* are known. Wild hogs may cause considerable damage by grazing young shoots and uprooting small clumps. After harvest, culms are prone to fungi and borer attack.

Harvesting Normally, 3-year-old culms are harvested in a 3-year felling cycle, usually at the end of the dry season. Culms used for furniture are harvested when 2 years old, and cut close to the ground (basal 1–2 m part is most useful because of thicker wall), because 3-year-old culms are too stiff to bend and younger culms normally shrink during firing. Culms harvested at the end of the dry season are more resistant to borer attack. Young shoots are harvested in the rainy season.

Yield In Thailand, annual culm production in natural stands is 9–46 t/ha.

Handling after harvest Traditional and chemical treatments are employed to preserve culms. Traditionally, culms are submerged in running water for 10–20 days. The culms are cleaned by rubbing with coconut husks or rice straw dipped in wet wood ash for a shiny surface, otherwise sandpaper is used. Chemical treatments include boiling the culms for 15–20 minutes at 95°C in a solution of 0.2% sodium carbonate or 0.1% calcium hydroxide, or at 80°C in a 0.3% copper sulphate solution. After the treatments, culms are washed with water, dried in the sun for 1–2 days, and stored in well ventilated rooms. Young shoots, mainly collected from natural stands, are cleaned, sliced, cooked and canned for export.

Genetic resources and breeding No germplasm collections or breeding programmes for *G. albociliata* are known.

Prospects *G. albociliata* is an under-utilized natural resource of Burma (Myanmar) and Thailand although its natural stands are often over-exploited and degraded. More research is needed to investigate the industrial potential of the culms. In Thailand, *G. albociliata* might become important for the furniture industry. Germplasm collection and research towards management of sustainable natural stands are recommended.
For other South-East Asian countries, *G. albociliata* is potentially interesting for the production of edible shoots and the development of a furniture industry.

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S. Duriyaprapan & P.C.M. Jansen

Gigantochloa apus (J.A. & J.H. Schultes) Kurz

Nat. Tijdschr. Ned. Ind. 27: 226 (1864).
GRAMINEAE
$2n = 72$ (hexaploid)

Synonyms *Bambusa apus* J.A. & J.H. Schultes (1830), *Gigantochloa kurzii* Gamble (1896).

Vernacular names Indonesia: bambu tali, pring tali, pring apus (Javanese), awi tali (Sundanese).

Origin and geographic distribution *G. apus* is probably native to Burma (Myanmar) (Tenasserim) and southern Thailand. It was possibly introduced to Java during prehistoric human migrations. In Java it is now widely cultivated, but wild or naturalized populations of *G. apus* also occur on Mount Salak (West Java) and in Blambangan (East Java). In Indonesia it has spread to South Sumatra, Central Sulawesi and Central Kalimantan. Occasionally it is cultivated in experimental or botanical gardens in the tropics.

Uses *G. apus* is very important in the Indonesian rural economy because it is much used for making cooking utensils, fishery utensils, furniture, ropes or strings, and in basketry.

Its culms are durable and used as building material for roofings, walls, scaffoldings and bridges. Culms can be split into fine strips for weaving hats, baskets and other objects; when split fine and the pieces bent, the surface does not chip off. In the absence of more suitable species, *G. apus* is sometimes used to make musical instruments, although the quality of the tones produced is inferior. *G. apus* is unsuitable for making chopsticks or toothpicks mechanically, because it has overlapping fibres.

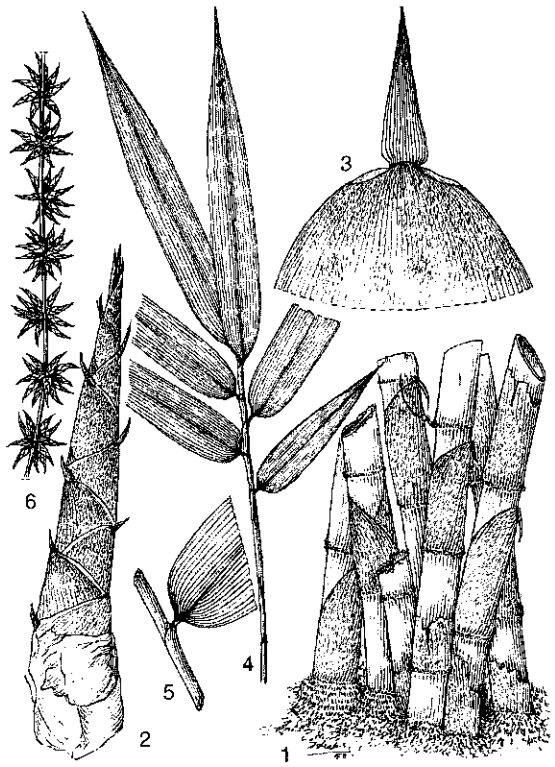
Young shoots are very bitter. In Java the freshly cut shoots are burried in mud for 3–4 days to remove the bitter taste, before they are consumed as a vegetable.

Production and international trade *G. apus* is the most important bamboo of Indonesia, but no production figures are available. It is traded mainly locally, e.g. to handicraft producers.

Properties The fibre dimensions in the culm of *G. apus* are: length 0.9–5.5 mm, diameter 5–36 µm, wall thickness 1–3 µm. At an average moisture content of 54.3% (green culms) and 15.1% (air-dried culms) the mechanical properties of 3-year-old culms are respectively: modulus of rupture 102.0 N/mm^2 (green, with nodes), 71.5 N/mm^2 (green, without nodes), 87.5 N/mm^2 (air dried, with nodes), 74.9 N/mm^2 (air dried, without nodes); compression strength parallel to grain 24.0 N/mm^2 (green, with nodes), 23.5 N/mm^2 (green, without nodes), 37.5 N/mm^2 (air dried, with nodes), 33.9 N/mm^2 (air dried, without nodes); shear strength 7.68 N/mm^2 (green, with nodes), 5.99 N/mm^2 (green, without nodes), 7.47 N/mm^2 (air dried, with nodes), 7.65 N/mm^2 (air dried, without nodes); tensile strength 294 N/mm^2 (green), 299 N/mm^2 (air dried).

The approximate chemical composition of the culm is: holocellulose 52.1–54.7%, pentosans 19.1–19.3%, lignin 24.8–25.8%, ash 2.7–2.9%, silica 1.8–5.2%; the solubility in cold water is 5.2%, in hot water 5.4–6.4%, in alcohol-benzene 1.4–3.2% and in 1% NaOH 21.2–25.1%. Starch content fluctuates between 0.24–0.71%, depending on the season. The nodes often contain a dull bluish-white deposit of silicic acid.

Description Open tufted, sympodial bamboo. Culm erect, 8–30 m tall, 4–13 cm in diameter, wall up to 1.5 cm thick, greyish-green to bright or yellowish green, glabrous, shiny, covered with white wax when young; internodes 20–60(–75) cm long; nodes slightly swollen on the outside. Branches arising from the upper half only. Culm sheath narrowly trapezoid, 7–35 cm × 8–26 cm, persistent, green and covered with dark brown hairs when young, turning yellow-brown and glabrous at maturity; blade ovate-triangular, 3–10(–18) cm × 2–5 cm, spreading to deflexed when the culm elongates, ultimately deciduous, on adaxial side covered with deciduous dark brown, appressed hairs; ligule 2–4 mm long, irregularly toothed; auricles 4–8 mm wide, 1–3 mm long, firm, tallest at the outer ends, with slender bristles on the edges. Young shoots slender, with appressed blackish brown hairs, light green to grey-green, the blades spreading to deflexed, tinged yellowish. Leaf blade lanceolate, 13–49 cm × 2–9 cm, slightly hairy beneath when young; sheath dark brown hairy along the margin; ligule 2–4 mm long, finely hairy at the edge; auricles 1–2 mm long, rounded, firm, glabrous. Inflorescences borne on leafy branches bearing groups of pseudospikelets 1–8.5 cm apart, each group with up to 30 pseudospikelets; spikelet



Gigantochloa apus (J.A. & J.H. Schultes) Kurz – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

narrowly ovate, 13–22 mm × 2–3 mm, slender, with 2–3 empty glumes and 3 perfect florets. Caryopsis up to 12 mm × 2 mm, glabrous, longitudinally furrowed on one side.

Growth and development One year after planting the vegetatively obtained propagules, about 10–15 culms will emerge; they are harvestable 1–3 years later, depending on the use. A young culm grows to its full height before starting to produce branches. Branching is initiated at about 8–11 nodes from the top and is followed by branching from the next two nodes down. Then development continues both upward and downward along the culm until branches are produced at all nodes in upper half of the culm. *G. apus* flowers very rarely. In Indonesia, flowering may start 50–60 years after planting. When flowering, viable seed is produced that can be used for propagation. It is not advisable to propagate vegetatively from flowering clumps, as the new plants will also start flowering soon after planting. The overlapping of rhizomes in old clumps often raises the middle portion of the clump high above the ground.

Other botanical information The culm size of *G. apus* can vary considerably. In Indonesia, local people use different names for plants with different culm sizes.

Ecology *G. apus* prefers the tropical humid lowlands, but also occurs on hill slopes up to 1500 m altitude. It is found in open areas, disturbed forest and on river sides on sandy or clayey soils. In drier areas culms remain smaller.

Propagation and planting *G. apus* can be propagated by seed, when seed is available. It is, however, most commonly propagated by rhizome, culm or branch cuttings. Rhizome cuttings consist of fragments of young rhizomes bearing 1–2 culm buds. They are raised in a nursery and, when well rooted, are transplanted to the field at a spacing of 5–7 m^2. Culm cuttings consist of culm segments or whole culms. Good results were obtained with 1-year-old culm segments bearing 2 buds each. The cuttings are set upright or at an angle, with the node well covered with soil. So far, no good results have been reported from treating cuttings with root-promoting substances. In Indonesia, the best time for planting is from December to March.

Husbandry Once a clump has established normal care is required, including weeding. Application of organic or chemical fertilizer can be expected to increase productivity.

Diseases and pests Rhizome cuttings often suffer seriously from rot fungi. *G. apus* is frequently attacked by a witches' broom disease caused by *Epichloe bambusae*, but without visible harmful effects on culm production. *Dinoderus minutus* is the most typical borer attacking harvested culms. Pest infestation of harvested culms is the most serious problem of *G. apus*.

Harvesting The best time to harvest culms is during the dry season when the starch content is lowest (in Indonesia between April and October) so as to minimize borer infestation. Only culms of 2 years or older should be harvested.

Yield It is estimated that a plantation of 1 ha can sustainably produce 6 culms per day during the dry season. In Indonesia, harvesting from April to October should provide an annual yield of about 1000 culms per ha.

Handling after harvest After harvesting, culms are traditionally dried before use by leaning them against a large tree for a few days. Sometimes culms are immersed in running water or mud or, more recently, are treated with caustic soda, boric acid, chrome-arsenic acid formalin or borax-boron for preservation. To protect handicraft

and furniture products, melamine or varnish is applied as a finishing.

Genetic resources and breeding A small germplasm collection has been established in Lampung, Indonesia. Breeding programmes do not exist.

Prospects *G. apus* can be propagated and cultivated easily, and is very important for the handicraft industry, especially in Indonesia. More research is needed to obtain better culm preservation methods after harvest. Breeding programmes to obtain pest-resistant cultivars have also been suggested. It seems worthwhile to investigate whether this bamboo can be cultivated in other South-East Asian regions with ecological conditions comparable to Java's.

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E.A. Widjaja

Gigantochloa atroviolacea Widjaja

Reinwardtia 10(3): 323 (1987).

GRAMINEAE

$2n = 72$ (hexaploid)

Synonyms *Gigantochloa verticillata* (Willd.) Munro sensu Backer (p.p.).

Vernacular names Black bamboo (En). Indonesia: bambu hitam (Indonesian), pring wulung (Javanese), awi hideung (Sundanese).

Origin and geographic distribution *G. atroviolacea* is only known from cultivation and its origin is unknown. It is widely cultivated on a small scale in Central and West Java, and occasionally it has been introduced elsewhere in Indonesia (e.g. southern Sumatra). Outside Indonesia it is grown in botanical gardens (e.g. Calcutta, India and Peradeniya, Sri Lanka) and in the 1980s it was introduced into Thailand and the Philippines.

Uses In the past *G. atroviolacea* culms were exclusively used in West Java to make the famous bamboo musical instruments (angklung, calung, gambang and celempung). Apparently its thin culm has specific features that make it suitable for such instruments. The peculiar blackish culms, however, have also caught the attention of the handicraft and furniture industries, so that at present most of the culms disappear into these industries, creating a shortage of material to make musical instruments.

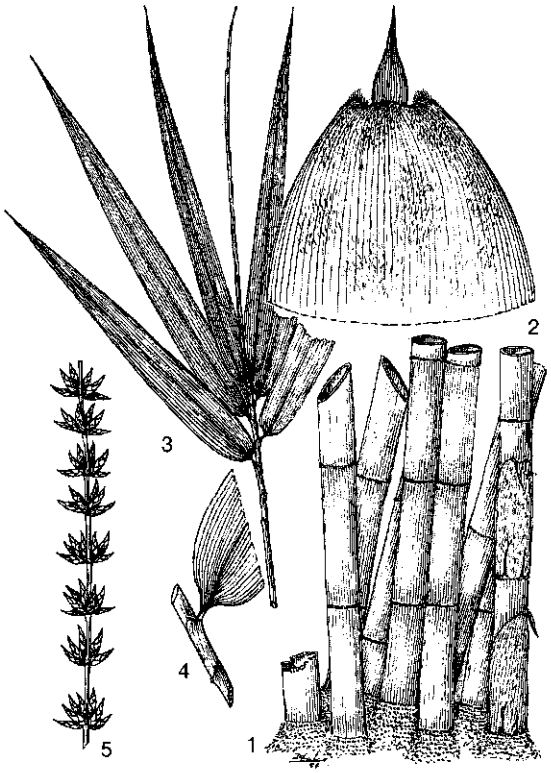
The young shoots are edible, turning yellow-pinkish after cooking.

Production and international trade In Java, the production of *G. atroviolacea* culms and derived products is considerable, but no statistics are available. Trade is mainly local, but some export of furniture occurs.

Properties The number of vascular bundles in culms of *G. atroviolacea* ranges from 1.83–2.30/mm^2. Average fibre dimensions are: length 3.6 mm, diameter 25.9 µm, lumen diameter 16.8 µm, wall thickness 4.5 µm.

The moisture content of green culms ranges from 120% (top) to 154% (bottom); on average it is 16.8% in air-dried culms. Specific gravity ranges from 0.37–0.48 for green, and is 0.65 for oven-dried material.

Description Loosely tufted, sympodial bamboo. Culm up to 12 m tall, 6–8 cm in diameter at the base, wall up to 8 mm thick, dark green when young, turning greenish to dark brownish-purple with age, with distinct pale or whitish rings at the nodes, covered by dark brown glabrescent hairs; internodes up to 40–50 cm long; lower nodes with aerial roots. Branches numerous from 2–3 m upward, usually one branch is dominant at each node. Culm sheath 16–20 cm long, lower ones slightly persistent, with dark brown appressed hairs on the back; blade ovate to oblong, 4–9 cm long, spreading to reflexed; ligule up to 2 mm long, irregularly denticulate; auricles small, rounded to



Gigantochloa atroviolacea Widjaja – 1, habit; 2, culm leaf (abaxial side); 3, leafy branch; 4, base of leaf; 5, flowering branch.

slightly curved outward, not joined to the base of the blade, 3–5 mm long and up to 4 mm in lateral extent, provided with bristles up to 7 mm long. Young shoots slender, dark green-brown, sometimes with a light green flash on the tips of the blades. Leaf blade lanceolate, 20–28 cm × 2–5 cm, glabrous; sheath covered with whitish hairs when young; ligule up to 2 mm long, irregularly toothed; auricles small, rim-like, up to 1 mm long and joined to ligule. Inflorescence consisting of branches with groups of pseudospikelets (up to 18 in a cluster) 3–5 cm apart; spikelet ovoid-lanceolate, 8–11 mm × 3 mm, comprising 4 perfect florets and 1 imperfect terminal floret. Caryopsis unknown.

Growth and development *G. atroviolacea* is a slow grower. Usually only 1–2 young shoots arise from the rhizome at the base of an old culm so that clumps are usually smaller than those of other bamboos. Yet it has been recorded that 2 years after planting 15 culms can be present. Culms reach their maximum length within 5 months. The average growth rate is about 9 cm per day. Culm size increases with the age of the clump; average height is 3 m in the first year after planting, 6.4 m in the 2nd and 9.3 m in the 3rd; average diameter increases from 2.2 cm in the first year, 5.5 cm in the 2nd, to 7.6 cm in the 3rd year after planting. Branching starts by the formation of some rudimentary branches at the first node from below. Then branching continues at about the 10th node from the top, followed by the next two nodes down, and then development continues both up and down the culm from this area until branches have been produced from all nodes situated higher than 2–3 m from the ground.

Other botanical information *G. atroviolacea* is closely related to *G. atter* (Hassk.) Kurz but can be distinguished from it by its purplish culm, its rounded to curved culm sheath auricles and its narrow palea with acute tip. Moreover, cells of the culm epidermis of *G. atroviolacea* are longer and less wavy than those of *G. atter*.

Kurz considered *G. atroviolacea* to be a variety of *G. atter* and later authors (Flora of Java) followed this view but considered *G. atter* to be a part of *G. verticillata*. The latter, however, has lodicules which are absent in *G. atroviolacea* and *G. atter*.

Variability in *G. atroviolacea* is such that several forms can be distinguished as already practised by local growers in Java. Culms with large diameter and thick walls are more suitable for the furniture industry, while those with small diameter and thin walls are preferred for making musical instruments. The latter form occurs especially in West Java.

Ecology *G. atroviolacea* grows well in the perhumid lowland tropics, with annual rainfall of 1500–3700 mm, relative humidity of over 70% and average temperature of 20–32°C. In Java it occurs mostly on red and reddish-brown latosols and lateritic soils, but it prefers drier limestone soils. In dry areas the purplish colour of the culms is more prominent.

Propagation and planting *G. atroviolacea* is only propagated vegetatively by rhizome or culm cuttings. In an experiment in Indonesia, 1-noded, 20 cm long cuttings of one-year-old culms were used in a nursery protected against heavy rains. Survival rate was 60%. Transplanting to the field was carried out about one year later, when the plants were about 75 cm tall. Recommended planting distance in the field is 8 m × 7 m, giving about 200 clumps per ha.

Husbandry To guarantee a satisfactory establishment of young plants, regular watering, weeding and loosening of the soil are necessary until 2–3 years after transplanting. Overcrowded

clumps are thinned. Cleaning clumps of culm remnants and earthing up regularly stimulates the development of young shoots.

Diseases and pests Witches' broom disease, caused by *Epichloe bambusae*, commonly attacks *G. atroviolacea* but causes no real damage. Young plants may be harmed by termites. Harvested culms and derived products are damaged by powder-post beetles (e.g. *Dinoderus minutus* and *Chlorophorus annularis*). The damage is more serious when the harvested culms are not quite mature.

Harvesting Harvesting may start 4–5 years after planting. It is recommended to harvest only in the dry season.

Yield In Java the average yield of mature *G. atroviolacea* clumps is estimated at 20 culms per 3 years (or with 200 clumps per ha, about 4000 culms per ha every 3 years).

Handling after harvest Traditionally, harvested culms are immersed in running or stagnant water for 15–30 days and then air dried. Chemical preservation is possible by soaking the culms in a 5% borax solution for 3 days. Penetration in the walls of whole culms is about 50% for borax.

Genetic resources and breeding There are no germplasm collections of *G. atroviolacea*, but some conservation is effected in botanical and experimental gardens. In Indonesia some material is present in Dramaga, Pasir Awi, and Oray Tapa. There are no breeding programmes.

Prospects The future is bright for this purplish-black bamboo because of the increasing interest of the furniture, handicraft and musical instrument industries. More research is needed regarding propagation, cultivation, and preservation, and plantations of suitable cultivars should be established for different purposes.

Literature |1| Rifai, M.A., 1983. Observations on witches' brooms and Encoelia disease of bamboo in Java. Proceedings of Biotrop Symposium on forest pests and diseases in Southeast Asia, Bogor, Indonesia, 14–16 October 1981. Biotrop Special Publication 20. pp. 207–212. |2| Sulthoni, A., 1983. Preliminary study on the traditional method of bamboo preservation in Yogyakarta, Indonesia. Proceedings of Biotrop Symposium on forest pests and diseases in Southeast Asia, Bogor, Indonesia, 14–16 October 1981. Biotrop Special Publication 20. pp. 213–221. |3| Sutiyono, 1990. Propagation of six Gigantochloa species by culm cuttings [Indonesian]. Buletin Penelitian Hutan 522: 29–32. |4| Sutiyono, 1992. The growth rate of clump stands of four Gigantochloa bamboo species derived from culm cuttings [Indonesian]. Buletin Penelitian Hutan 522: 51–58. |5| Widjaja, E.A., 1987. A revision of Malesian Gigantochloa (Poaceae–Bambusoideae). Reinwardtia 10(3): 291–380.

E.A. Widjaja

Gigantochloa atter (Hassk.) Kurz

Nat. Tijdschr. Ned. Ind. 27: 226 (1864).
GRAMINEAE
$2n = 72$ (hexaploid)

Synonyms *Bambusa thouarsii* Kunth var. *atter* Hassk. (1848), *Gigantochloa verticillata* (Willd.) Munro sensu Backer (p.p.).

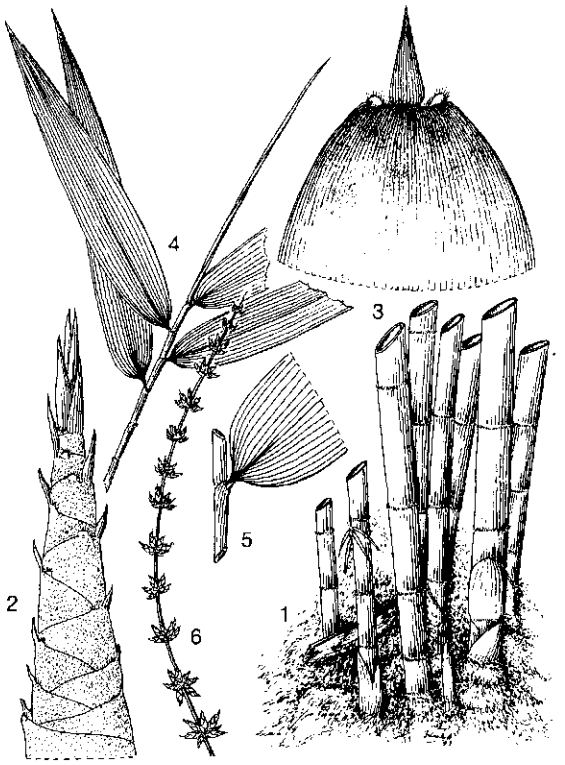
Vernacular names Indonesia: bambu ater (Indonesian), pring legi (Javanese), awi temen (Sundanese), péréng keles (Madurese), buluh jawa (eastern Indonesia). Philippines: kayali (Tagalog).

Origin and geographic distribution The origin of *G. atter* is unknown. In Indonesia *G. atter* is widely cultivated in rural areas of Java; on the other islands it mostly occurs wild. In the Philippines it is cultivated in Davao, Mindanao Province. It is also planted in Brunei and probably also in Sarawak (Malaysia).

Uses The culm of *G. atter* is much used for building material (framework, fences, walls). It is also used to make household utensils (e.g. furniture, beds, cooking utensils), meat skewers, chopsticks, toothpicks and handicrafts (e.g. basketry, lampshades). In West Java it is used as a substitute material for bamboo musical instruments when culms of *G. atroviolacea* Widjaja are not available. In the Philippines culms of *G. atter* are used to stake banana infructescences, although not as much as *Bambusa* sp. ('laak'). The young shoots are eaten as a cooked vegetable and said to be as delicious as those of *Dendrocalamus asper* (Schultes f.) Backer ex Heyne.

Production and international trade As a locally common bamboo in Indonesia, production and local trade are considerable, but no statistics are available. Some export of chopsticks and toothpicks from Indonesia to Japan and Taiwan exists.

Description Densely tufted, sympodial bamboo. Culm up to 25 m tall, 5–10 cm in diameter, wall up to 8 mm thick, bluish-green with distinct pale rings on the nodes; internodes 40–50 cm long, on upper part with dark brown appressed hairs; lower nodes with a few aerial roots. Branches arising from nodes above 2–3 m from the ground.



Gigantochloa atter (Hassk.) Kurz – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

Culm sheath narrowly triangular with truncate apex, 21–36 cm long, black hairy on the outer side, deciduous but usually lower ones rather persistent; blade lanceolate, about 10 cm × 3 cm, deflexed, deciduous; ligule 3–6 mm long, irregularly toothed; auricles rounded to slightly curved outward, 6–9 mm wide, 3–7 mm long, with bristles 4–6 mm long. Young shoots slender, green to dark green, with appressed black hairs. Leaf blade oblong-lanceolate, 20–44 cm × 3–9 cm, glabrous; ligule 2 mm long; auricles firm and low, 2 mm × 1 mm. Inflorescence borne on leafy branches with pseudospikelet groups at the nodes, each with up to 35 pseudospikelets; spikelet ovoid-lanceolate, 9–12 mm × 3–4 mm, containing 4 perfect florets and one terminal imperfect one. Caryopsis unknown.

Growth and development After a cutting has been planted it may develop up to 24 culms in 3 years; the height of the culms increases from 2.1 m in the first year to 6.5 m in the second and 9 m in the third year, and the diameter from 2.3 cm to 4.2 cm and to 6.7 cm, respectively. Young shoots grow rapidly at first and culms attain their maximum length in 2–4 months. Branching begins when the lengthening phase of the culms is over, usually at 8–11 nodes from the top, followed by the growth from the next two nodes down, and then development continues both up and down the culm from this area until branches have been produced from all nodes above 2–3 m from the ground. Usually one branch is dominant in each group. In Indonesia it has been recorded that *G. atter* flowers gregariously about 50–60 years after planting, and subsequently dies.

Other botanical information *G. atter* was formerly united with *G. atroviolacea* Widjaja, *G. pseudoarundinacea* (Steudel) Widjaja and *G. robusta* Kurz in one complex species *G. verticillata*. *G. atter* can easily be distinguished from the 3 related species by its rounded and slightly outward curved culm sheath auricles.

Ecology *G. atter* is found in the tropics from sea-level up to 1400 m altitude. It grows well in areas with an annual rainfall of more than 2500 mm, but unlike many other *Gigantochloa* species it also tolerates drier environments with annual rainfall of 1000 mm. It prefers latosols but can be grown also on alluvial, limestone, and sandy loam soils.

Propagation and planting *G. atter* is only propagated vegetatively by rhizome or culm cuttings. In an experiment in Indonesia with 2-noded culm cuttings, survival rate was 60%. It is recommended to protect cuttings in the nursery from heavy rain and to transplant one-year-old plants when 75 cm tall. Planting is done preferably at the beginning of the rainy season. Recommended planting distance for culm production is 7–8 m × 7 m, giving 180–200 clumps per ha.

Husbandry Watering and weeding are necessary in the first years after planting. When the clump becomes too crowded it should be thinned. Regularly cleaning clumps of old culm remnants and loosening the soil stimulates the development of young shoots.

Diseases and pests No serious diseases or pests are known to damage *G. atter*. Often a witches' broom (*Epichloe bambusae*) develops in *G. atter*, without causing apparent damage, however.

Harvesting Harvesting of culms may start 4–5 years after planting. It is recommended to cut 2–3-year-old culms just above the ground, preferably in the dry season.

Yield In Indonesia the average yield of a *G. atter* clump is estimated at 6–7 culms per year, or,

with 200 clumps per ha, 1200–1400 culms per ha per year.

Handling after harvest In certain areas, harvested culms are traditionally soaked in water for some weeks. Better preservation can be obtained by soaking culms in chemical solutions.

Genetic resources and breeding A small germplasm collection of *G. atter* is available in Indonesia in Lampung, Sumatra. Collections from other areas are needed to conserve the variability of this bamboo. No breeding programmes have so far been initiated.

Prospects The prospects for *G. atter* are promising because of its wide utility (vegetable, furniture, construction, handicrafts). More research is needed regarding its properties, the feasibility of cultivation at plantation scale, and its improvement.

Literature |1| Rifai, M.A., 1983. Observations on witches' brooms and Encoelia disease of bamboo in Java. Proceedings of Biotrop Symposium on forest pests and diseases in Southeast Asia, Bogor, Indonesia, 14–16 October 1981. Biotrop Special Publication 20. pp. 207–212. |2| Sutiyono, 1990. Propagation of six Gigantochloa species by culm cuttings [Indonesian]. Buletin Penelitian Hutan 522: 29–32. |3| Sutiyono, 1992. The growth rate of clump stands of four Gigantochloa bamboo species derived from culm cuttings [Indonesian]. Buletin Penelitian Hutan 552: 51–58. |4| Widjaja, E.A., 1987. A revision of Malesian Gigantochloa (Poaceae–Bambusoideae). Reinwardtia 10(3): 291–380.

M.A. Rifai

Gigantochloa balui K.M. Wong

For. Dept. Occ. Pap., Brun. 1: 1–10 (1990).

GRAMINEAE

$2n$ = unknown

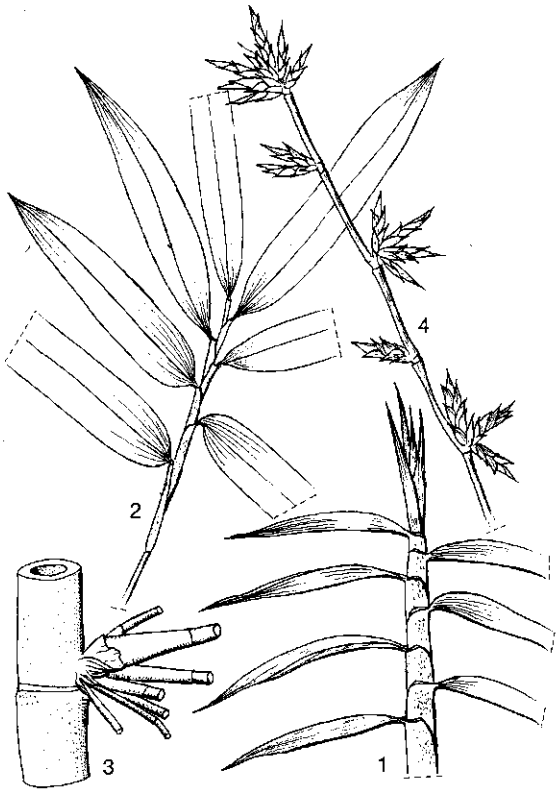
Vernacular names Indonesia: buluh abe (Kalimantan). Brunei: buluh balui (Brunei, Dusun). Malaysia: balui (Sabah: Dusun, Bajau, Murut; Sarawak: Bidayuh), bambu taris (Sabah: Brunei).

Origin and geographic distribution The origin of *G. balui* is still uncertain but could possibly be in Indo-China; several collections from southern Thailand, which appear to be this species and which have been taken from plants growing wild, have been made. This bamboo is always found in association with settlements in Sabah, Sarawak (Malaysia), Brunei and West Kalimantan (Indonesia) but has never been noted in situations where it might be truly considered wild. It thus appears to have been introduced to Borneo.

Uses *G. balui* is cultivated in many villages in Sabah, Sarawak and Brunei for its useful culms. In Brunei, the culms are used as poles and split for plaiting baskets. In Sabah, the culms have been reportedly used as fishing stakes, sailing masts and for framing, in addition to being used in the split form for basketry. In Sarawak, the culm internodes have been used for cooking meat and vegetables, and for making handicrafts. In West Kalimantan (Indonesia) the culms are used for building structures (walls, floorings) and traditional basketry. The young shoots are reported as edible in Sabah and Brunei, but this is not a popular or extensive use of the species. The young shoots of *G. levis* (Blanco) Merrill (in Borneo and the Philippines) and *Dendrocalamus asper* (Schultes f.) Backer ex Heyne, for instance, are much preferred to those of *G. balui*.

Description Densely tufted sympodial bamboo. Culm erect, slightly arching outwards, up to 12 m tall, diameter 3–8 cm near the base, plain green or white or pale yellow stripes at the base; internodes non-waxy, up to 40 cm long, covered with appressed pale silver hairs; nodes not conspicuously swollen. Branch complement at each midculm node arising from a single bud, consisting of a dominant primary branch, 1–2 subdominant branches from its base and several lesser branchlets of higher orders. Culm sheath pale green, sometimes with faint yellow stripes, covered with appressed pale silver hairs; blade broadly triangular on lower sheaths, broadly lanceolate on midculm and upper sheaths, green or sometimes flushed purple, spreading to reflexed; ligule lacerate, the base 1–3 mm long, the lacerations to 4 mm long; auricles low and rimlike, up to about 2.5 mm tall, glabrous, dark green to dark purple. Leaf blade 20–35 cm × 2–4 cm, lower surface slightly glaucous and hairy; ligule a low glabrous rim to c. 1 mm long; auricles small rounded glabrous lobes to c. 1 mm long. Inflorescences borne on branches of leafy or leafless culms, bearing groups of 3–10 pseudospikelets at each node; pseudospikelet 9–12 mm long, with 3–5 glumes, 2–3 perfect florets and a vestigial terminal floret represented by an empty lemma 9–10 mm long. Caryopsis unknown.

Growth and development No information exists from systematically observed populations. In a trial plot of *G. balui* at Sungai Daling, Sandakan, Sabah, Malaysia, observed in 1992 at eight years after planting from cuttings, the number of healthy mature culms per clump was estimated at



Gigantochloa balui K.M. Wong – 1, young shoot; 2, leafy branch; 3, branch complement; 4, flowering branch.

20–40. Further development is being monitored by the Forest Research Centre at Sepilok, Sandakan. Flowering clumps are not commonly encountered, which is probably a major reason why the botanical identity of *G. balui* eluded workers for a long time. However, when a clump does flower, most or all culms gradually become generative, and an entire flowering episode can last up to a whole year. One clump observed in Brunei Darussalam flowered during a period of 14 months, followed by new regeneration from the rhizome system.

Other botanical information The presence of pale silver hairs on the culm sheaths and internodes, and the glabrous rim-like culm-sheath auricles allow rapid identification of *G. balui* in the field.

Ecology *G. balui* appears to grow best on rich alluvial sites, especially near rivers, and also establishes well in secondary forest. In dense groves of *G. balui* documented in Brunei Darussalam it grows in tight clumps to the exclusion of most other plants. This is partly due to the accumulation of much siliceous leaf litter on the ground, which decays only slowly and prevents effective establishment of other plants.

Propagation and planting Rhizome cuttings (offsets) and culm cuttings can be used quite effectively to propagate clones of *G. balui*. In Sabah, the use of culm cuttings taken from mature, but not senescent culms guarantees a high degree of success in producing new plants in 3–4 months, provided water is not limiting. Rooted cuttings with several leafy branches can be planted out in the field, in holes into which manure and fertilizer have been put. Preliminary observations of a trial in Sandakan, Sabah, indicate that a distance of 4–6 m between individual clumps facilitates optimum growth and minimizes weed problems.

Diseases and pests So far, no serious diseases have been observed in *G. balui*. Even witches' broom disease, common in cultivated *G. levis* in Brunei, has not been observed thus far.

Harvesting Only mature culms, 2 or more years old, are being harvested. In West Kalimantan 1-year-old culms are preferred for basketry.

Genetic resources and breeding There are no germplasm collections of *G. balui*. If indeed *G. balui* has been introduced to Borneo from mainland Asia, then the genetic base of the populations established in northern and western Borneo is likely to be a narrow one. A germplasm collection with representatives from all growing areas could widen the base for selection and breeding purposes.

Prospects There is potential for *G. balui* as a plantation crop for bamboo-shoot and culm production. This can only be pursued with the appropriate pilot-scale investigations into aspects of the establishment, growth and development and management of this bamboo.

Literature [1] Wong, K.M., 1990. Gigantochloa balui (Poaceae–Bambusoideae), a Bornean bamboo new to science. Brunei Forestry Department, Occasional Papers 1: 1–10.

K.M. Wong

Gigantochloa hasskarliana (Kurz) Backer ex Heyne

Nutt. pl. Ned.-Ind., ed. 2, vol. 1: 299 (1927).

GRAMINEAE

$2n = 72$ (hexaploid)

Synonyms *Schizostachyum hasskarlianum* Kurz (1876).

Vernacular names Indonesia: bambu lengka

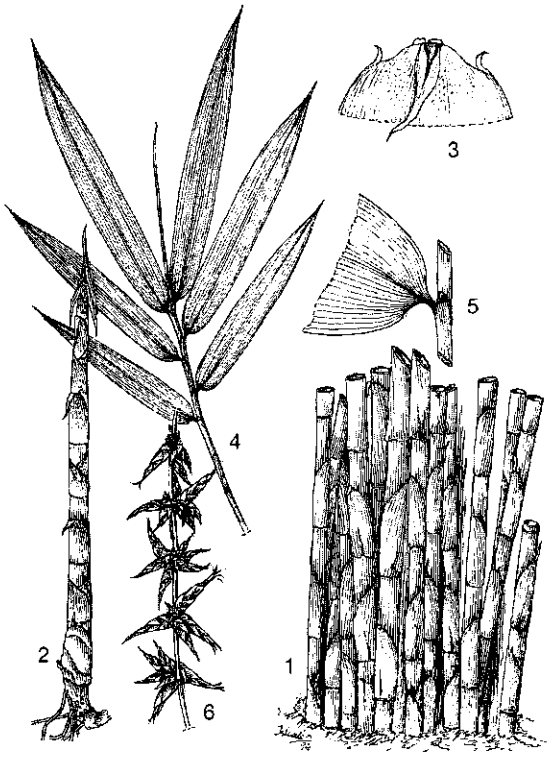
tali (Indonesian), bulok busi (Kalimantan: Dayak Kenyah), buluh sorik (Sumatra: Tapanuli).

Origin and geographic distribution *G. hasskarliana* is native to parts of western Indonesia (Sumatra, Java, Bali, Kalimantan), where it occurs wild and cultivated. Occasionally it is cultivated in botanical gardens and for hedges, e.g. in Malaysia, Singapore and Papua New Guinea.

Uses In West Kalimantan *G. hasskarliana* is planted extensively to prevent soil erosion on steep hills. In East Kalimantan it is used to make basketry. In its native area it is often planted as a hedge.

Production and international trade Production and trade are mainly local and no statistics are available.

Botany Densely tufted, sympodial bamboo. Culm up to 10 m tall, 3–6 cm in diameter, wall 8–10 mm thick; internodes up to 51 cm long, green, when young covered with dark brown hairs in upper parts, glabrous later. Culm sheath triangular, 10–27 cm long, rather late deciduous, covered with appressed blackish-brown hairs; blade lanceolate with narrow base and acute apex, 2–14 cm × 5–15 mm, usually deflexed but sometimes erect at base of culm; ligule up to 3 mm long, irregularly toothed, ending in fine hairs; auricles firm, rim-like, up to 3 mm long, the ends usually somewhat raised, glabrous, edge of culm sheath extends beyond auricles. Young shoots very slender, grey-green with dark brown hairs appressed on the back of sheaths, sheath blades initially erect, becoming spreading to deflexed. Leaf blade lanceolate, 8–35 cm × 1–5 cm, glabrous on lower surface; leaf sheath with dark brown hairs along the margin; ligule to 2 mm long, toothed, each tooth ending in a fine hair; auricles small, rounded, up to 1 mm long and 1 mm in lateral extent, glabrous. Inflorescences borne on leafless branches of a leafy culm, consisting of clustered pseudospikelets (up to 20 in a cluster) at regular distances; spikelet slender, narrowly ovoid, 8–22 mm × 2–3 mm, slightly flattened near the base, consisting of 2 glumes, 3–4 fertile florets and 1 sterile apical floret. Caryopsis narrowly cylindrical, hairy at the apex.



Gigantochloa hasskarliana (Kurz) Backer ex Heyne – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

G. hasskarliana is a very fast-growing bamboo species, developing readily from rhizome and culm cuttings.

The bamboo which is identified as *G. hasskarliana* in Thailand and is found growing abundantly in pure stands in the northern and western parts of the country, is not conspecific with *G. hasskarliana*. The culm sheath of the Thai bamboo has a large, broadly triangular, usually erect blade. Its correct name, unfortunately, is not yet confirmed. Therefore, more investigations should be carried out on this common bamboo.

Ecology *G. hasskarliana* usually occurs in the lowland but can be found up to 1500 m altitude (e.g. in Bali). It prefers humid conditions.

Agronomy *G. hasskarliana* can be propagated by seed, and by rhizome and culm cuttings. Propagation by culm cuttings is mostly used for establishing hedges and for erosion control measures. It is easily attacked by a witches' broom (*Epichloe bambusae*), which does not cause visible damage, however.

Genetic resources and breeding Germplasm collections of *G. hasskarliana* are available in Indonesia in the Bogor Botanical Gardens and in Lampung, Sumatra. More collections are urgently needed. There are no breeding programmes.

Prospects For the humid tropics, *G. hasskarliana* is an interesting species for erosion control and for large living hedges. More research is need-

ed to investigate its physical, mechanical and chemical properties, its applicability, its ecological requirements and optimal cultivation methods.

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E.A. Widjaja

Gigantochloa levis (Blanco) Merrill

Amer. Journ. Bot. 3: 61 (1916).

GRAMINEAE

$2n$ = unknown

Synonyms *Bambusa levis* Blanco (1837), *Gigantochloa scribneriana* Merrill (1906), *Dendrocalamus curranii* Gamble (1910).

Vernacular names Brunei: buluh betung (Dusun). Indonesia: buluh suluk (Kalimantan), buluh tup (Dayak). Malaysia: poring, pering (Sabah, Dusun), paling (Sabah, Murut). Philippines: bolo (Tagalog), kabolian (Bikol).

Origin and geographic distribution The origin of *G. levis* is unknown. It is commonly cultivated in the Philippines and in northern and western Borneo. In the Philippines it has apparently naturalized to a certain extent.

Uses In the Philippines and Sabah, *G. levis* is best known as a bamboo which yields good quality edible shoots. The culms are used in rough house construction, as framework, and are split for plaiting walls. In the Philippines, modern furniture is crafted from the culms, and in the fishing industry, culms are used for making rafts, fish traps, outriggers and fish pens. It is also one of the several bamboos used in the handicraft industry. In Sabah, many specific uses of *G. levis* culms can be found, from temporary water pipes to fences and bathing platforms beside rivers. One Philippine study indicated that *G. levis* is suitable as raw material for kraft pulps from the standpoint of pulp strength, pulp yield and acceptable level of silica content.

Production and international trade In the Philippines and northern Borneo production and trade of edible shoots and strong culms is locally important, but no statistics are available.

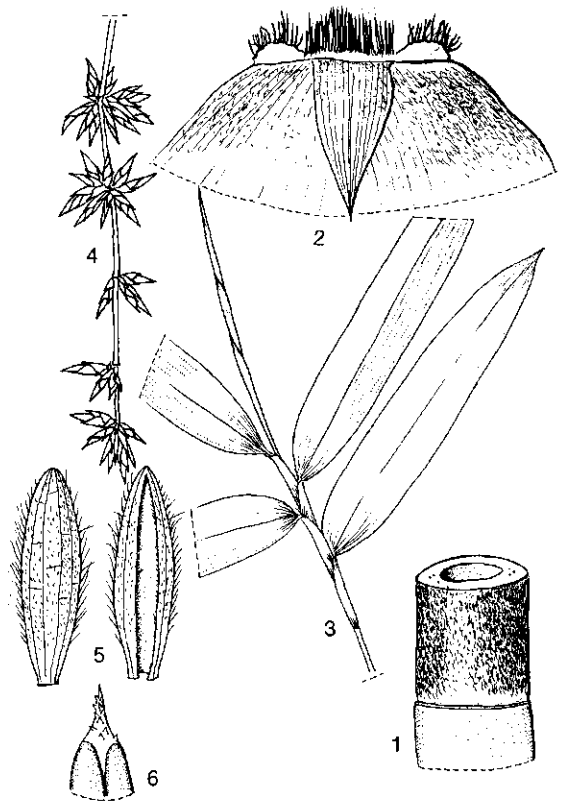
Properties The fibre dimensions of the culms are: length 1.5–2 mm, diameter 16–22 µm, lumen diameter 4–6 µm, wall thickness 6–8 µm; number of fibrovascular bundles 1-2/mm^2, vessel length 0.6–1.1 mm, vessel diameter 0.19–0.23 mm.

The moisture content of green culms ranges from 94–143%; specific gravity is 0.5–0.6. During drying from green to oven dry, culms shrink 9–13% in thickness and 5.8% in diameter.

For green culms the modulus of elasticity is 8900–11 000 N/mm^2, modulus of rupture 20–26 N/mm^2, compression strength parallel to grain 38–44 N/mm^2 (with nodes), 39–43 N/mm^2 (without nodes).

The chemical composition of mature culms on dry weight basis is approximately: holocellulose 63%, pentosans 19%, lignin 24%, ash 5.3%, silica 2.8%. The solubility is 3.2% in alcohol-benzene, 4.4% in hot water and 28.3% in 1% NaOH. Per 100 g edible portion young shoots (7–15 days old) contain approximately: water 87 g, protein 3 g, fat 7 g, carbohydrates 0 g, fibre 1.5 g, ash 1 g, Ca 30 mg, P 27 mg, Fe 1 mg, thiamine 0.07 mg, vitamin C 4 mg.

Description Densely tufted, sympodial bamboo. Culm erect, up to 20 m tall, diameter up to 16 cm or possibly slightly more, plain green; nodes not conspicuously swollen; internodes up to 45 cm long, densely dark-hairy all over at the base of the culm, otherwise scattered dark-hairy on the upper parts, without any conspicuous white waxiness. Branches at each midculm node arising from a single bud consisting of a dominant primary branch, with usually one subdominant secondary branch from its base on each side, and several lesser leafy branchlets from the base of secondary branches. Culm sheath broadly triangular, 19–34 cm long, pale to medium green, with dark brown hairs on the back; blade broadly lanceolate, green, spreading to reflexed, hairy at base; ligule lacerate, the base 2–4 mm long, the lacerations 7–15 mm long; auricles large lobes to 10 mm long, with bristles 5–20 mm long on the margin, dark green to purplish green. Young shoot slightly triangular in outline, brown-green to green, covered with dark brown hairs, with green tips. Leaf blade 8–35 cm × 2–7 cm, lower surface short pale-hairy; ligule a subdentate rim-like structure 0.5–1.5 mm long; auricles small lobes with fine bristles to 4 mm long on the margin. Inflorescences, usually on leafless culms, consist of puberulent long branches with clusters of up to 75 pseudospikelets at the nodes, the clusters 1.5–12 cm apart; pseudospikelet 10–12 mm long, with 2–3 gemmiferous bracts, 2–3 glumes, 4–5 perfect florets and a vesti-



Gigantochloa levis (Blanco) Merrill – 1, part of culm; 2, culm leaf (abaxial side); 3, leafy branch; 4, flowering branch; 5, palea (abaxial and adaxial side); 6, anther tip.

gial terminal floret usually represented by an empty lemma. Caryopsis unknown.

Growth and development From a plantation started with culm cuttings, the following observations are available from the Philippines (average of 7 clumps): number of culms increased from 3.6 (1.5 years after planting) to 4.3 (3 years after planting) and to 9.4 (5 years after planting); the average height increased from 3.7 m to 5.5 m and to 10.4 m, and the average diameter from 2 cm (1.5 years planting) to 11 cm (5 years after planting). The average number of young shoots per clump per year increased from 2 (first year) to 2–4 (3rd year), to 3–5 (4th year), to 7–9 (6th year) and to 10–15 (10th year after planting).

An average of 31% of culms produced by a mature clump reach maturity. Full height is achieved by new culms in approximately 5 months, which means an average daily growth rate of about 13 cm. In the Philippines, young shoot growth starts at the beginning of the rainy season but is most rapid in the latter part of the season (up to 2.73 m per week). In a *G. levis* plantation in Mindanao (Davao Del Norte) an average of 40 culms per mature clump was counted, of which 11 (about 28%) were one year old and the rest older.

Flowering occurs over many months in a fertile clump, in one to several or all culms. After flowering, culms senesce, but sometimes clumps regenerate from the rhizome.

Other botanical information *G. levis* can be distinguished from *G. thoii* K.M. Wong of Peninsular Malaysia with which it has been confused, by the less hairy and copiously white-waxy culms of the latter.

Ecology *G. levis* grows reasonably well on a large range of sites, except where the soil is too sandy or too dry. In the Philippines it occurs in secondary forest and abounds in and around towns and villages in the lowland.

Propagation and planting *G. levis* is propagated only vegetatively, usually by rhizome or culm cuttings. For culm cuttings it is recommended to take pieces of about 50 cm in length, including a well-developed branching node, and to plant it horizontally at 10 cm depth. Cuttings are planted first in a nursery or, as documented in the Philippines, directly in the field, at the onset of the rainy season. The recommended spacing for a plantation is 6–7 m × 7 m, which will result in about 200–240 plants per ha.

Husbandry Newly planted material is very susceptible to drying out and requires regular watering. Per ha 20–30 kg N, 10–15 kg P, 10–15 kg K, 20–30 kg silica, and compost are recommended to stimulate growth, given in two applications, 1 and 5 months after planting. Weeding is important until the bamboo canopy is fully established. Malformed, diseased or otherwise useless culms should be removed.

Diseases and pests In Borneo, severe infestations of witches' broom have been observed in some populations of very old clumps. These clumps may have flowered previously, and the culms may be physiologically weakened and therefore more susceptible to attack by disease.

Harvesting Shoots can be harvested 7–15 days after emergence. Whereas younger shoots have less protein and fat and more iron, they also have much less crude fibre per 100 g edible portion. Because the best texture in shoots is present just one week after emergence, that may also be the best time to harvest. Culms of about a year old can be harvested for making handicrafts, but only culms

of at least 3 years old should be taken for construction purposes. It has been estimated that a clump should only be harvested 5–8 years after planting, and not more than 60% of all standing mature culms should be harvested from any clump per year.

Yield In the Philippines the annual yield per ha from a plantation belonging to the Davao Fruits Corporation (Davao del Norte, Mindanao), was estimated at 9300 culms of average 6.5 cm in diameter and 16.7 m in height. These dimensions suggest that clumps were not in their best condition and may reflect detrimental effects of the past overharvesting. The culm dry-weight production for this plantation was estimated at 115.8 t/ha.

Handling after harvest In the Philippines, the shoots of *G. levis* are marketed fresh, pickled or dried. In Sabah, shoots are sold fresh or pickled. Harvested culms apparently are more durable and resistant to insect and fungal attack if they have been immersed in water for about 60 days. In some cases in the Philippines, prior to use, culms are sun-dried (for 4 weeks or more) or kiln-dried (for about 9 days) and then subjected to curing with smoke or painted with slaked lime ('whitewashing'). Another method of traditional curing is to leave the branches and leaves on a harvested culm for some time, which is said to reduce the amount of moisture and starch in the culm via transpiration through the leaves. Of the various chemical methods of preservation suggested as suitable, painting the culms with a water emulsion of 0.5–1% gamma benzene hexachloride requires the least capital investment. In spite of these preservation methods, *G. levis* culms are said to have moderate natural durability.

Genetic resources and breeding Populations raised from seed are not known or else not properly documented. Material from each provenance is apparently raised from clonal stocks and therefore of limited genetic variability. These aspects cannot be clearly elucidated without precise information on reproductive biology.

Prospects *G. levis* is a large-diameter useful bamboo that can provide both good edible shoots and strong culms. It is already commonly but usually casually cultivated in the Philippines and northern Borneo. This bamboo is among the best candidates for cultivation and exploitation, though clearly more information on its agronomy and use is desirable.

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K.M. Wong

Gigantochloa ligulata Gamble

Ann. Roy. Bot. Gard. Calcutta 7: 67 (1896).
GRAMINEAE
$2n$ = unknown

Vernacular names Peninsular Malaysia: buloh tikus, buloh tilan (Pahang), buloh tumpat (Kedah). Thailand: phai-damphra, phai-nae, phai-lai (peninsular).

Origin and geographic distribution *G. ligulata* is native to the northern part of Peninsular Malaysia (Perlis, Kedah, Kelantan) and the southern, peninsular part of Thailand (Surathani).

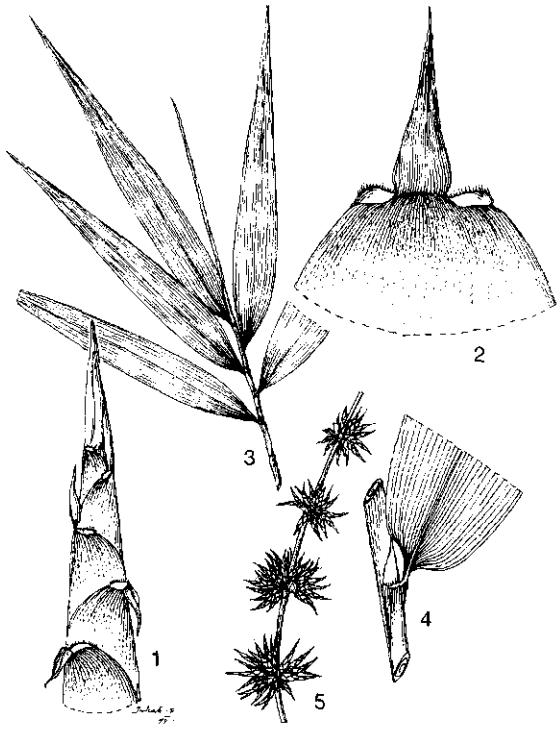
Uses In Peninsular Malaysia (Kedah), the slender, thick-walled culms are used to frame chairs,

tables and screens, as walking sticks and as poles for vegetable support. In Thailand they are used for rural construction, agricultural implements and as raw material for paperpulp. Young shoots are locally used as a vegetable and considered as delicious in northern Peninsular Malaysia. Sometimes *G. ligulata* is grown as an ornamental.

Production and international trade In its native area *G. ligulata* is of considerable economic importance, but no statistics are available. Consumption and trade are mainly local and the useful parts are collected from natural stands.

Properties Although culms of *G. ligulata* are thick-walled or often even solid, they can be bent easily.

Description Densely tufted, sympodial bamboo. Culm 6–9(–15) m tall, diameter 1.5–4(–8) cm, wall usually about 10 mm thick, often solid in major part (not at base or at top); internodes 20–35(–45) cm long, dark green often with pale green streaks, covered with pale hairs and when young with very dark brown hairs below the nodes, glabrescent later; nodes prominent. Branches arising from the nodes in the lower half of the culm, few from the midculm nodes and usually absent from the upper nodes; the middle branch is dominant and often as big as the main culm. Culm sheath 14–22(–30) cm long, slightly persistent, green to yellow-green, covered with dark brown to black hairs that are easily shed; blade erect, narrowly to broadly lanceolate, 2–5 cm wide, about 5 cm long on the lower to middle part of the culm, 18–20 cm long on the higher part, glabrous, not deciduous; ligule thin, very prominent, 5–10(–20) mm long, irregularly incised, longest at its ends; auricles more or less down-curved on the edges of the top of the sheath on each side of the base of the blade, forming a low firm smooth rim 1 mm tall and 1.5–2.5 mm long in lateral extent, without or almost without bristles. Young shoots green, ending in a sharp pointed apex. Leaf blade oblong-lanceolate, 27–30(–42) cm × 4–6(–7) cm, soft pale hairy below; sheath glabrous or with scattered pale hairs; ligule very pronounced, thin, 2–5 cm long, usually entire; auricles inconspicuous. Inflorescences terminating leafy and leafless branches, drooping, 80 cm or longer, comprising pseudospikelets in clusters of up to 60 at each node and 1–5 cm apart; spikelet ovate-lanceolate in outline, 12–15 mm × 4 mm, consisting of 3–4 glumes, 2–4 perfect florets and 1 sterile floret; lemma fringed with dark brown hairs. Caryopsis ovoid, 9 mm × 2 mm, hairy at the apex.



Gigantochloa ligulata Gamble – 1, young shoot; 2, culm leaf (abaxial side); 3, leafy branch; 4, base of leaf; 5, flowering branch.

Growth and development About 8 weeks after sowing, the first culm of a seedling is 13 cm tall with 5–6 expanded leaves. A mature clump of *G. ligulata* contains (15–)30–40(–70) culms and usually produces 13–15 young shoots per year. Sporadic flowering is quite often seen but gregarious flowering of whole clumps has rarely been reported. Gregarious flowering of many clumps over large areas has never been observed. The flowering cycle is still not known. In a case of gregarious flowering in Kedah the flowering period lasted 6 months (November–April), after which the clump died.

Other botanical information *G. ligulata* is a very variable species that still needs further investigation. Roughly, two groups of specimens can be distinguished (unnamed): one with medium-sized, thick-walled culms with 2 perfect florets in the pseudospikelets and another with larger culms, larger culm-sheath ligules and 3–4 perfect florets in the pseudospikelets (the vernacular names for the latter group in Peninsular Malaysia are: buloh bilalai, buloh gala, buloh mata rusa). *G. ligulata* much resembles *G. latifolia* Ridley and they possibly form a hybrid complex.

Ecology In Peninsular Malaysia, *G. ligulata* is found in overlogged forest, margins of secondary forest and wastelands along roadsides, up to 1500 m altitude. In southern Thailand it is found in mixed forest on sandy soil near the coast and on wastelands along the roads.

Agronomy *G. ligulata* culms and young shoots are harvested from wild populations only. First trials on cultivation are being carried out in Malaysia. Deglumed seed germinates within 2 weeks after sowing in a 1:3 soil-sand mixture (germination rate 76%). Application of fertilizer (1 g NPK (15:15:15) per plant) every 2 weeks considerably promotes the growth and development of seedlings.

Genetic resources and breeding No germplasm collections or breeding programmes for *G. ligulata* are known to exist. Germplasm collection is urgently recommended.

Prospects Like many other wild species in the South-East Asian region (e.g. *G. scortechinii* Gamble (Peninsular Malaysia) and *G. albociliata* (Munro) Kurz (Thailand, Indo-China)), *G. ligulata* has the potential to become a sustainable source of raw material for cottage industries. The prospects are promising, but more investigation on relevant aspects is required.

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S. Dransfield

Gigantochloa manggong Widjaja

Reinwardtia 10(3): 365 (1987).

GRAMINEAE

$2n$ = unknown

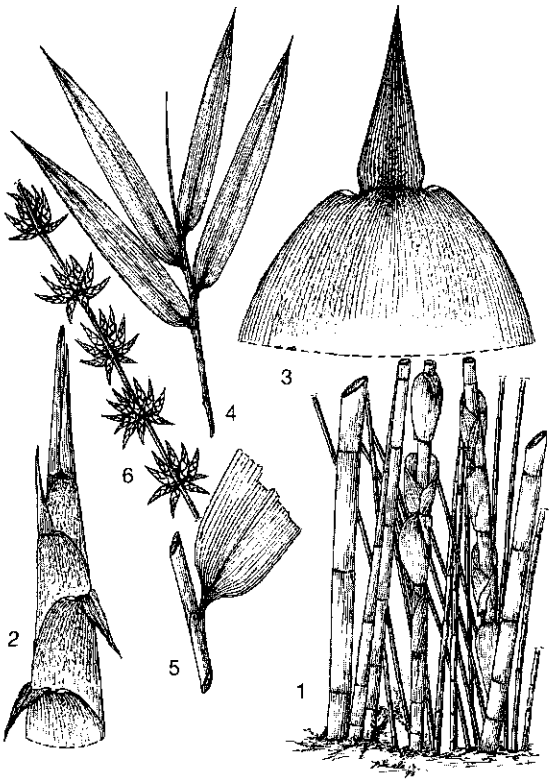
Vernacular names Indonesia: pring manggong (Banyuwangi, East Java), tiying jahe (Balinese).

Origin and geographic distribution The origin of *G. manggong* is not known. It grows wild in eastern Java (Meru Betiri National Park, Soko, Licin, Kalisetail) and in Bali (Candikuning), but it is quite rare. Occasionally it is also planted in botanical or experimental gardens (Java: Purwodadi, Bandung; India: Amherst).

Uses Culms of *G. manggong* are used for construction, scaffolding and other small-scale household uses, but possibly due to their limited distribution, they are considered inferior to those of *G. apus* (J.A. & J.H. Schultes) Kurz. They are also suitable for making chopsticks, toothpicks and paperpulp. Young shoots are used as vegetable but taste bitter.

Production and international trade Being a rare species, production and trade of culms and young shoots are only of some importance locally in East Java and Bali. Formerly, a small amount of culms was processed by the paper mill at Basuki Rachmat but now a larger amount is consumed by the chopstick and toothpick factory in East Java.

Description Densely tufted, sympodial bamboo. Culm up to 15 m tall, 5–7 cm in diameter, wall up to 10 mm thick; internodes up to 34–40 cm long, smooth, green turning yellowish. Branches arising from nearly all nodes from 2–3 m upwards; usually one branch is dominant in each group of branches. Culm sheath appressed with truncate but centrally slightly raised apex, 30–33 cm long, dull yellow, dark brown glabrescent, slightly persistent; blade erect, narrowly triangular, 18–25 cm × 9–11 cm, covered with dark brown hairs adaxially, deciduous at age; ligule 5 mm long, irregularly dentate; auricles up to 4 mm long, forming a firm rim which is raised towards the end and joined to the blades, dark brown to purplish brown, without bristles. Leaf blade lanceolate, 27–29 cm × 3–4 cm, glabrous, thick; sheath yellowish with purple margins, when young covered with detaching dark brown hairs, glabrescent; ligule 1 mm long, irregularly toothed; auricles rounded, up to 1 mm long, raised, joined to ligule at the end, purplish. Inflorescences borne on leafy branches, consisting of pseudospikelet groups 0.5–5 cm apart, each containing up to 35 pseu-



Gigantochloa manggong Widjaja – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

dospikelets; spikelet ovate-lanceolate in outline, 7–15 mm × 2–3 mm, slender and narrowed at the apex, comprising 2 glumes and 3 perfect florets. Caryopsis unknown.

Growth and development Plants raised from rhizome cuttings develop one shoot in the first year. In the next two years the number of new shoots and the height they attain gradually increase. From the third year on, culms can reach full length. Three years after planting, up to 25 culms may be present. Growth of new culms starts at the beginning of the rainy season and culms attain full length in 4–5 months. Growth may be briefly interrupted by short rainy periods. *G. manggong* flowers gregariously, after which the clump dies, but a flowering cycle is not known.

Ecology *G. manggong* occurs in a tropical climate, with average annual rainfall of 1400 mm, from sea-level up to 1500 m altitude. It grows on river banks, mountain slopes and even steep cliffs.

Agronomy *G. manggong* can be propagated easily by rhizome cuttings, but culm and branch cuttings also give good results. The cuttings can best be planted in a nursery, in containers filled with a mixture of soil and manure. About one year after planting, when roots and a shoot have developed, the plants can be transplanted into the field in well-prepared holes at 5 m × 5 m. Transplanting is preferably carried out in the rainy season. No diseases and pests of *G. manggong* are known. Culms are harvested when needed, selecting those that are older than 2 years and with a diameter of more than 7 cm. Yield of harvestable culms of a natural stand is estimated at 5–10 per clump per year.

Genetic resources and breeding Small germplasm collections of *G. manggong* are being established by the Forest Research and Development Centre in Indonesia and kept at Darmaga Station, Bogor and Arcamanik Station, Bandung. There are no breeding programmes for *G. manggong*.

Prospects *G. manggong* is a promising bamboo. It grows fast and is suitable for the production of paperpulp, chopsticks and toothpicks. Research should focus on physical and mechanical properties and on the feasibility of large-scale cultivation.

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Sutiyono & E.A. Widjaja

Gigantochloa nigrociliata (Büse) Kurz

Nat. Tijdschr. Ned. Ind. 27: 226 (1864).

GRAMINEAE

$2n = 72$ (hexaploid)

Synonyms *Bambusa nigrociliata* Büse (1854), *Oxytenanthera nigrociliata* (Büse) Munro (1868) (p.p.), *Schizostachyum serpentinum* Kurz (1876).

Vernacular names Indonesia: bambu lengka (Indonesian, Sundanese), awi ular (Banten), tiying tabah (Balinese).

Origin and geographic distribution The origin of *G. nigrociliata* is not known. It grows wild in Indonesia (West Java, northern Sumatra) and in southern Thailand. Formerly it also occurred widely in East Java, Bali and eastern Indonesia where it has now become rare.

Uses In West Java (Sukabumi) young shoots of *G. nigrociliata* are consumed as a cooked vegetable after being fermented in running water or river mud. In northern Sumatra the culms are used to make household utensils and basketry. In West Java culms, although not long-lasting, are applied in the construction of rafters, fences and watch houses.

Production and international trade *G. nigrociliata* is only produced and traded locally in Indonesia, but no statistics are available.

Description Loosely tufted, sympodial bamboo. Culm up to 20 m tall, 3–6 cm in diameter, wall up to 6 mm thick, conspicuously clean and bright green; nodes not swollen; internodes up to 35(–50) cm long, bright green with dark brown hairs on upper parts. Branches arising from all nodes from 2–3 m upwards with usually one dominant branch at each node. Culm sheath triangular but with truncate apex, 11–18.5 cm long, slightly persistent, brown appressed hairy outside; blade narrowly triangular, 6–10 cm × 2–3.5 cm, erect to spreading, brown hairy at the base inside; ligule 2–3 mm long, irregularly dentate; auricles rounded, 2–4 mm long, ending in curved sheath extensions. Young shoots grey-green, bearing appressed dark brown and white hairs. Leaf blade lanceolate, 19.5–35 cm × 2.5–4.5 cm, glabrous above, hairy beneath; ligule 1–2 mm long, ciliate; auricles rim-like along the leaf sheath, up to 1 mm long, at the apex curved and joined to the ligule. Inflorescences on branches up to 80 cm long, consisting of pseudospikelet groups 1–6 cm apart each containing up to 11 pseudospikelets; spikelet ovate-lanceolate in outline, 15–22 mm × 3–4 mm, slender, flattened at the base, brown ciliate, comprising 3 perfect florets. Caryopsis ovate-lanceolate in outline, about 15 mm long, apex hairy.

Gigantochloa nigrociliata (Büse) Kurz – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

Growth and development *G. nigrociliata* flowers quite often, after which the clump dies. Natural regeneration is through seed which is produced abundantly.

Other botanical information According to older literature *G. nigrociliata* also occurs in India and on the Andaman Islands. Most probably these records refer to other species. So far *G. nigrociliata* has only been found in Indonesia and Thailand.

Ecology *G. nigrociliata* is found in the humid tropics, usually along streams and on lower slopes, up to 600(–1400) m altitude. It grows well on latosols in areas with an average annual rainfall of more than 3000 mm.

Agronomy *G. nigrociliata* can be propagated by seed and by rhizome or culm cuttings. Culm cuttings are mostly used, with about 85% survival. For shoot production, recommended planting distance is 4 m × 4 m, for culm production 5–6 m × 5–6 m. Weeding is necessary in the first year after planting. Application of organic and inorganic fertilizers, removal of culm remnants and regular earthing up of clumps are recommended.

No serious diseases or pests are known to damage *G. nigrociliata*.

Culms are usually harvested when needed, without much selection because this thin bamboo is rather uniform. Nevertheless, a selective felling system in a 3-year cycle is recommended, with only culms 3 years old or older being cut. A mature clump can produce 12–16 culms per year.

Young shoots are harvested during the rainy season, peeled and sometimes also sliced and put in running water or mud to ferment.

Genetic resources and breeding In Indonesia, a germplasm collection of *G. nigrociliata* is available in Lampung (Sumatra) and in Thailand in Chiang Mai, but there are no breeding programmes.

Prospects *G. nigrociliata* will remain locally important for its young shoots. More research is needed to investigate the feasibility of the production of paperpulp.

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E.A. Widjaja

Gigantochloa pseudoarundinacea (Steudel) Widjaja

Reinwardtia 10(3): 305 (1987).

GRAMINEAE

$2n = 72$ (hexaploid)

Synonyms *Bambusa pseudoarundinacea* Steudel (1854), *Gigantochloa verticillata* (Willd.) Munro (1868) (p.p.), *G. maxima* Kurz (1876).

Vernacular names Indonesia: bambu gombong, pring surat (Javanese), awi andong (Sundanese), buluh batuang danto (Padang, Sumatra).

Origin and geographic distribution The origin of *G. pseudoarundinacea* is not known; it is only found in cultivation. It is widely cultivated in Indonesia (Java, Bali, Sumatra, Mentawai Islands) and has been introduced to Peninsular Malaysia and India.

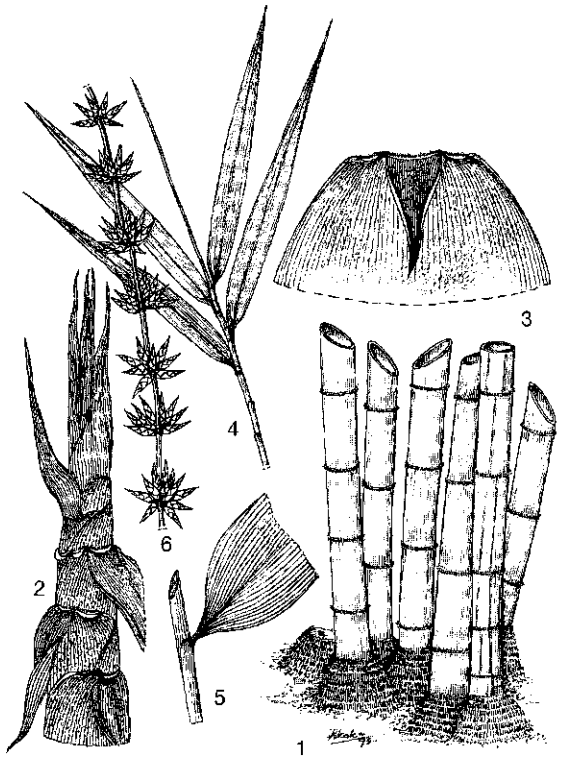
Uses In Indonesia *G. pseudoarundinacea* is used for building material, water pipes, furniture, household utensils, chopsticks and toothpicks. It is also used to make basketry (although *G. apus* (J.A. & J.H. Schultes) Kurz is preferred) and musical instruments (although *G. atroviolacea* Widjaja is preferred). The young shoots are eaten as a vegetable, especially those of less robust forms. The culms might be used to make charcoal.

Production and international trade In Indonesia, *G. pseudoarundinacea* is the second in importance after *G. apus* and plays a prominent role in the rural economy. Local production and trade of culms and derived products are considerable, but no statistics are available.

Properties The fibre dimensions for culms of *G. pseudoarundinacea* are: length 2.75–3.27 mm, diameter 24.55–37.97 µm; the number of fibres increases by about 10% from the bottom to the top of the culm. Specific gravity is 0.5–0.7 (internodes) and 0.6–0.8 (parts with nodes). The modulus of elasticity is 19 440–28 594 N/mm^2, the modulus of rupture 171–207 N/mm^2, the tensile strength 128–192 N/mm^2. The energy value for charcoal of culms of *G. pseudoarundinacea* is about 30 000 kJ/kg.

In Indonesia (West Java) *G. pseudoarundinacea* culms grown on hill slopes (500 m altitude, 4200 mm annual rainfall) are stronger (higher specific gravity, bending and tensile strength) than culms grown in valleys.

Description A densely tufted, sympodial bamboo, with the centre of the clump irregularly raised above the ground. Culm 7–30 m tall, 5–13 cm in diameter, wall up to 2 cm thick; internodes up to 40–45(–60) cm long, green to yellow-green, yellow striped, initially with scattered appressed brown hairs on the upper parts, glabrous and smooth when older; lower nodes with verticillate aerial roots. Branches arising from all nodes above 2–3 m from the ground with one dominant branch at each node. Culm sheath truncate, 35 cm long or longer, deciduous, when young, dark green and papery at the margin and brown hairy becoming glabrous with age; blade ovate-oblong, acute at the apex, about as long as the sheath, hirsute at base, spreading to reflexed; ligule up to 5 mm long, dentate, fine hairy at top; auricles up to 4 mm tall and 17 mm long in lateral extent, with a variable low and wavy rim, when young with up to 5 mm long bristles. Young shoots yellow-green, flushed with orange on the sheath apices and green striped, with appressed, acute, brown to golden-brown hairs. Leaf blade lanceolate, 22–25 cm × 2.5–5 cm, glabrous or finely hairy at lower surface; lower sheaths with slightly emarginate collar-like callus; ligule up to 2 mm long, irregularly toothed with fine hairs; auricles firm, raised at the end up to 1 mm and joined to the ligule. Inflorescences appearing on leafless culms, up to 75 cm long, with clustered pseudospikelet groups 1–9 cm apart and up to 148 pseudospikelets in a cluster; spikelet ovoid, subacute, 7.5–10 mm long, with 4 perfect and 1 sterile florets. Caryopsis unknown.



Gigantochloa pseudoarundinacea (Steudel) Widjaja – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

Growth and development One year after planting of a cutting, 7–10 culms have emerged. Per year about 8–9 culms per clump reach full size. A young culm grows fast, attaining full height in 3–4 months with an average growing rate of 3.4 cm per day.
Flowering occurs when the clump is 50–60 years old; it flowers gregariously, after which the clump dies.

Other botanical information *G. pseudoarundinacea*, *G. atter* (Hassk.) Kurz, *G. atroviolacea* Widjaja and *G. robusta* Kurz, were formerly united into one complex species *G. verticillata*. They can easily be distinguished from each other. *G. atroviolacea* has purplish to violet culms while *G. pseudoarundinacea* has yellow striped yellowish-green ones. The culm sheath auricles of *G. pseudoarundinacea* are up to 17 mm long and up to 4 mm tall with a wavy rim; in *G. atter* they are rounded and slightly curved outward, 6–9 mm long and 3–7 mm tall; in *G. robusta* they are well-developed along the sheath apex, crisped and joined to the blade's base, up to 7 mm tall with long bristles; in *G. atroviolacea* they are rounded, 5–8 mm wide and 4–8 mm tall.
G. pseudoarundinacea is quite variable in West Java, where people distinguish 3 forms: (1) 'awi andong': the most robust form, with walls 1.5–2 cm thick, mostly green with few yellow stripes, most frequently used for construction; often some internodes are not closed by partitions so that the central cavity runs without interruption for some length (useful for water pipes and containers); (2) 'awi andong leah': a less robust form with walls up to 1 cm thick and rather short lower internodes with prominent nodes, more prominently yellow striped; this form is preferred for its tasty young shoots; (3) 'awi andong keukeus': the smallest form, mostly used for its edible young shoots.
In Central and East Java *G. pseudoarundinacea* is apparently uniform because only one kind is known, called 'pring surat'.

Ecology *G. pseudoarundinacea* is grown in the perhumid tropics from sea-level up to about 1200 m altitude, in areas with an annual rainfall of 2350–4200 mm, average temperature of 20–32°C and average relative humidity of over 70%. It occurs on sandy loams and alluvial soils.

Propagation and planting *G. pseudoarundinacea* is only propagated vegetatively by rhizome, culm or branch cuttings. Cuttings from flowering clumps should be avoided because they will start flowering soon after planting. Culm cuttings have shown a survival rate of nearly 100%. In Indonesia, the best time for planting is in the rainy season from December to March. Recommended spacing is 8 m × 8 m, and high rainfall areas are preferred.

Husbandry Weeding, watering and loosening of the soil are important until the clumps are well-established. Organic and chemical fertilizers are applied for high production, but no recommended amounts are known. Cleaning the clumps from culm remnants and earthing up stimulate the growth of new culms.

Diseases and pests *G. pseudoarundinacea* is usually attacked by a witches' broom (*Epichloe bambusae*) but this disease has no harmful effect on culm production. The most serious pest causing much damage is *Dinoderus minutus*, a borer attacking harvested culms.

Harvesting First harvesting may start 3 years after planting, preferably in the dry season (April–October in Java). It is recommended to harvest only 3-year-old culms and to cut just above the ground. To promote regeneration, it is recom-

mended to earth up and to mulch the base of the harvested culms. For East Java, a half clear-felling system in a cycle of 3 years is recommended.

Yield The annual yield of mature culms from a plantation with 275 clumps per ha (6 m × 6 m) is estimated at 1650 per ha or about 6 culms per clump. If converted to charcoal, about 18% good charcoal and 4% brand and broken charcoal are produced.

Handling after harvest Traditionally, culms are left leaning upright against a tree for some days before being used. Sometimes culms are first soaked in running water or mud for some time. Experiments with preservation by soaking in a chemical solution of e.g. caustic soda or boric acid show promising results.

Genetic resources and breeding In Indonesia small germplasm collections exist in Bogor (experimental gardens of the Forest Research and Development Centre, Arboretum of the Agricultural University (IPB) and the Perhutani Bamboo Germplasm Garden) and in Lampung (Sumatra). Conservation of existing variation is needed. There are no breeding programmes; in the germplasm collection at Lampung natural hybrids of *G. pseudoarundinacea* produced viable seed.

Prospects The prospects for *G. pseudoarundinacea* are promising. It produces valuable construction material and its culms also appear to be suitable for the chopstick industry. Although research is needed on large-scale cultivation techniques, priority should be given to obtaining cultivars resistant to post-harvest pests.

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E.A. Widjaja

Gigantochloa robusta Kurz

Ind. For. 1: 344 (1876).

GRAMINEAE

$2n = 72$ (hexaploid)

Synonyms *Gigantochloa verticillata* (Willd.) Munro sensu Backer (1928), (p.p.).

Vernacular names Indonesia: awi mayan (Sundanese), tiying jelepung (Balinese), buluh riau (West Sumatra).

Origin and geographic distribution The origin of *G. robusta* is unknown, but it is found growing wild in Java (Banten, West Java and Banyuwangi, East Java). It is mainly known from cultivation in Sumatra, Mentawai Islands, Java and Bali.

Uses Culms of *G. robusta* are widely used for water pipes, floors and walls for houses, to make handicrafts and bamboo musical instruments. In West Java a typical water carrying vessel ('kele') is made from the culm by the Baduy. Young shoots are eaten as a vegetable.

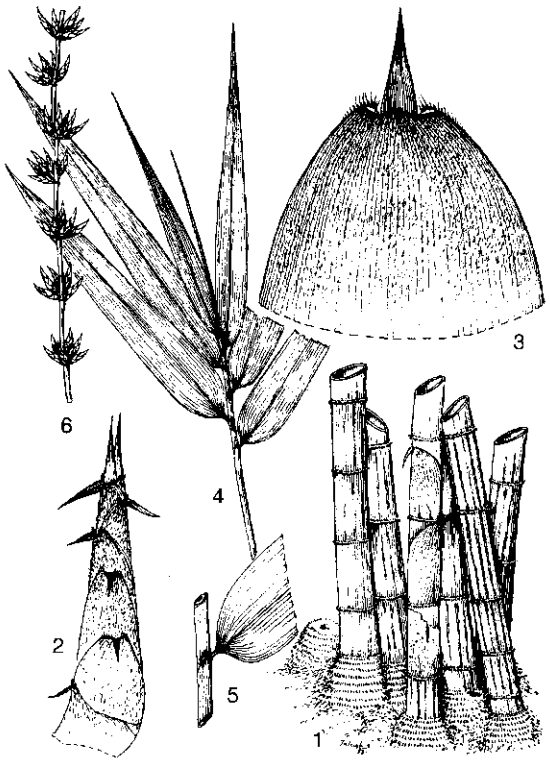
Production and international trade Locally, especially in Sumatra, *G. robusta* is important as a garden crop, but no statistics on production or trade are available. There is no large-scale cultivation. In Jakarta young shoots of *G. robusta*, originating from southern Banten, are sold in vegetable markets. It is possible that customers in Jakarta are deceived because the young shoots look rather similar to those of *Dendrocalamus asper* (Schultes f.) Backer ex Heyne, which are considered as the best.

Properties In culms of *G. robusta* the average number of vascular bundles ranges from about 1.54/mm^2 in the lower part, to 1.94/mm^2 in the central part, and 2.32/mm^2 in the upper part. Its fibre dimensions are: length 3.6 mm, diameter 30–32 µm. In the Indonesian wood criteria on pulp and paper, those fibres are classified as flexible and having medium strength (flexibility ratio is 0.64).

The moisture content of green culms averages

118% and increases from bottom to top. Specific gravity ranges from 0.38 to 0.62 (average 0.55). The average mechanical properties measured in Indonesia on split green bamboo parts (30 cm × 2 cm × 0.5–1 cm) are: modulus of elasticity 9829 N/mm^2, modulus of rupture 136 N/mm^2, compression strength parallel to grain 52 N/mm^2, and tensile strength 191 N/mm^2.

Description Densely tufted, sympodial bamboo. Culm up to 20 m tall, 7–9 cm in diameter, wall up to 18 mm thick, dirty yellow to light green with yellow stripes in lower 2 m; internodes up to 40 cm long, non-waxy, with scattered brownish hairs on upper parts; lowest nodes with aerial roots. Branches arising from almost all nodes from 2–3 m upwards, with one branch dominant at each node. Culm sheath deltoid but with truncate apex, 17–35 cm long, covered with dark brown hairs 2 mm long, deciduous with age but often long persistent on lower part of the culm; blade triangular, 10–14 cm × 3.5–5 cm, reflexed; ligule 5 mm long, irregularly incised and with 10 mm long bristles; auricles rounded, up to 7 mm long, well developed along the sheath apex, crisped and joined to the base of the blade, with bristles up to 5 mm long. Young shoots stubby and massive, brown-green, covered with dark brown hairs. Leaf blade lanceolate, 15–27 cm × 2.5–5 cm, hairy on the lower surface; ligule 1 mm long, denticulate, with fine hairs 3 mm long; auricles firm, 1 mm long, with bristles up to 5 mm long. Inflorescences borne on branches about 50 cm long, consisting of pseudospikelet groups 1–4 cm apart, each with up to 110 clustered pseudospikelets; spikelet flattened ovoid, 9–10 mm × 4 mm, slightly hairy on the tip, comprising 4 perfect and 1 imperfect florets. Caryopsis unknown.



Gigantochloa robusta Kurz – *1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.*

Growth and development After planting of a cutting, 1–5 culms develop in the first year, gradually increasing up to 11 culms in the next years. One year after planting, culm height averages 4.7 m and diameter 3.9 cm; these figures increase to 6.7 m and 5.4 cm in the 2nd year and to 12.3 m and 8.3 cm in the 3rd year, respectively.

Young shoots grow rapidly at first and culms attain their maximum height in 2–4 months. Branching begins when the lengthening phase of the culm is over, usually at 8–11 nodes from the top, followed by growth from the next two nodes down, and then development continues both up and down the culm from this area until branches have been produced from all nodes from 2–3 m upwards.

In Indonesia it is said that *G. robusta* clumps flower gregariously more than 50 years after planting. Flowers attract honey bees and other insects, but seed has never been observed.

Other botanical information *G. robusta*, *G. atter* (Hassk.) Kurz, *G. atroviolacea* Widjaja and *G. pseudoarundinacea* (Steudel) Widjaja were formerly united into one complex species *G. verticillata*. Its yellow striped green-yellow culms and its characteristic sheath auricles make *G. robusta* distinctive. In herbarium specimens *G. robusta* looks similar to *G. levis* (Blanco) Merrill. It differs in having a non-waxy culm without brown hairy rings on internodes, slightly persistent culm sheaths, narrow and acuminate lemma apex and long hairs on the anther tips.

Ecology *G. robusta* can be found growing in the perhumid tropics from sea-level up to 1500 m altitude, in areas with average annual rainfall of 2350–4200 mm, temperatures of 20–32°C, and relative humidity of over 70%. It normally grows on latosols.

Propagation and planting *G. robusta* is only propagated vegetatively by rhizome or culm cut-

tings. Culm cuttings have a survival rate of nearly 100%. For large-scale planting, cuttings are raised in a nursery and transplanted to the field when the plants are about one year old. It is recommended to plant in holes of about 1 m × 1 m × 1 m to which compost or other organic fertilizer has been applied. Recommended planting distance is 8 m × 8 m (about 155 clumps per ha).

Husbandry Weeding and watering (if rainfall is insufficient) is necessary during the first 2 years after planting. *Mikania cordata* (Burm.f.) B.L. Robinson, however, often occurs as a troublesome weed which can even kill young established bamboo clumps, and makes frequent weeding continuously necessary. Depending on soil fertility, chemical fertilizers are applied.

To promote young shoot production, mulching and thinning dense clumps until a few evenly spaced culms are left are recommended. Culm production benefits form removal of old culm remnants and regular earthing up.

Diseases and pests Throughout its growing phase, no serious diseases and pests occur on *G. robusta*. Witches' broom caused by *Epichloe bambusae* often occurs but does not harm the culms. Harvested culms and derived products suffer seriously from powder-post beetles.

Harvesting First harvesting may start 4–5 years after planting. It is recommended to harvest in the dry season by cutting mature culms just above the ground. A selective felling system in a 3-year cycle is recommended in Indonesia.

Yield In Indonesia it is estimated that a mature clump produces yearly an average of 6 mature culms (about 900 culms per ha at planting distance of 8 m × 8 m).

Handling after harvest Traditionally, culms are soaked in mud or running water for a few weeks and then air dried. *G. robusta* culms suffer heavily from borer attack; therefore, for large-scale production, chemical preservation treatment is necessary. Promising experimental results were obtained by soaking culms for 3–7 days in a solution of boron or wolmanit.

Genetic resources and breeding Small germplasm collections of *G. robusta* are available in Indonesia in Lampung (Sumatra) and in Bogor (Java). Because this bamboo is rather variable, the existing variation should be properly conserved. There are no breeding programmes for *G. robusta*.

Prospects *G. robusta* is a promising bamboo, especially for its culms. More research is needed regarding other possible uses (e.g. edibility of young shoots), large-scale cultivation, and breeding of cultivars for culms resistant to borer attack after harvesting.

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E.A. Widjaja

Gigantochloa scortechinii Gamble

Ann. Roy. Bot. Gard. Calcutta 7: 62 (1896).

GRAMINEAE

$2n$ = unknown

Vernacular names Indonesia: buluh kapal (Sumatra). Peninsular Malaysia: buloh semantan, buloh telor, buloh rayah (var. *scortechinii*); buloh seremai (var. *albovestita*).

Origin and geographic distribution *G. scortechinii* is found in Indonesia (Sumatra), in central and northern Peninsular Malaysia and in southern Thailand. At present it has become naturalized and is found mostly in disturbed (logged-over) forest in the area. It is occasionally cultivated in and around villages and outside the area in botanical gardens.

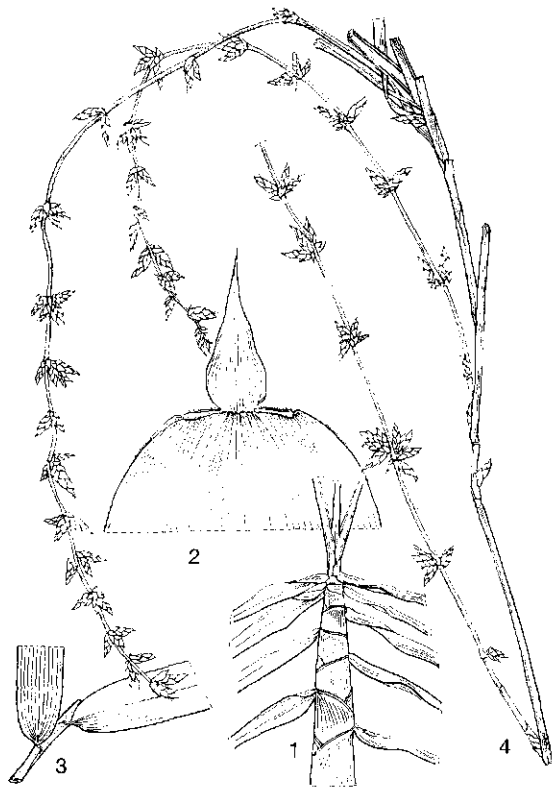
Uses *G. scortechinii* is the commonest and most used bamboo of Peninsular Malaysia. In villages or in the home its culms have numerous uses, e.g. in constructions and scaffolding, to make baskets and other utensils and a wide variety of handicraft materials. In small-scale enterprises, culms are used to produce chopsticks, toothpicks, skewers, blinds, joss sticks, large baskets, poultry cages and paper. The young shoots are rarely used as a vegetable because they are rather bitter.

Production and international trade In Peninsular Malaysia the total area under *G. scortechinii* is estimated at 328 000 ha, but it often oc-

curs mixed with other species. Economically it is one of the major species and it is mainly collected from natural or naturalized populations. Production and trade are mainly local but some export exists (e.g. In 1993, 17.25 t was exported to Taiwan, valuing M$ 5005). The paper mill price for a culm of 8–10 m length is about M$ 1.0–1.5.

Properties Mature, 3-year-old green culms have an average basic density of 557 kg/m^3. Their average fibre dimensions are: length 4.24 mm, diameter 17 µm, lumen diameter 3 µm, wall thickness 8 µm. The vascular bundle frequency is 1.83/mm^2. At a moisture content of about 90%, for 3-year-old green culms the average modulus of elasticity is 4960 N/mm^2, the modulus of rupture 59.43 N/mm^2, the compression strength parallel to grain 28.79 N/mm^2 and the shear strength 4.52 N/mm^2. The culm contains mainly holocellulose 63.3% (alpha-cellulose 39.1%), and lignin 20%.

Description Densely tufted, sympodial bamboo. Culm erect, up to 20 m tall, up to 12(–20) cm in diameter, wall 5–10 mm thick, when young covered with a fine white waxy powder, bright green when old; internodes up to about 60 cm long, basal ones with light green stripes. Branches arising from the midculm node upward with primary and secondary ones. Culm sheath 15–25 cm long, light orange, covered with appressed black hairs, not easily deciduous; blade spreading to reflexed, lanceolate, 9–13 cm × 1–3 cm, leaf-like, light green, much narrower than top of sheath; ligule dentate or deeply incised, ending in bristles, up to 9 mm long; auricles forming a low dark green rim along the sheath apex, sometimes terminated by a few bristles. Young shoots light orange with light green blades covered with appressed dark hairs. Leaf blade 20–30 cm × 2-3 cm, softly hairy on the lower surface; sheath hairy; ligule 2 mm long, sometimes bearing bristles; auricles small, 1 mm long with a few bristles up to 6 mm long. Inflorescences borne on leafless branches, bearing at the nodes head-like clusters of pseudospikelets about 5 cm apart, each cluster with 2–5 large fertile pseudospikelets mixed with a few small sterile ones; spikelet ovoid to oblongoid, flattened, 18–20 mm × 5–6 mm, densely yellow-brown hairy or velvety, consisting of 2–3 empty glumes, then 3–5 perfect florets, terminating with an imperfect floret. Caryopsis ellipsoidal, glabrous, hairy at truncate top.



Gigantochloa scortechinii Gamble – 1, young shoot; 2, culm leaf (abaxial side); 3, leaf bases; 4, flowering branch.

Growth and development Under natural conditions, shoots of *G. scortechinii* emerge above the ground during the rainy season (August–mid October in Peninsular Malaysia) and develop to their full height in 4 months. A strong, positive correlation exists between the amount of previous year rainfall and the number of emerging shoots. Culm sheaths start to fall when 4–5 months old and branching starts when the culm has reached its full length. A culm becomes mature in 3 years. A good, healthy clump can produce 48–60 shoots annually, but only about 40% of these reach maturity. One-year-old seedlings attain about 1.10 m in length; in the next year they develop 2–4 new culms, after which clump formation develops rapidly.

G. scortechinii is a gregarious species, easily occupying large open areas. Plants raised from culm cuttings initially produce small shoots (3 the first year) which develop into small culms. In the following year shoots develop into larger culms, and after 6–7 years the shoots develop into full-sized culms.

Flowering of *G. scortechinii* is sporadic, i.e. only a portion of one clump flowers at a time; gregarious flowering has never been reported.

Other botanical information Vegetatively, *G. scortechinii* looks rather similar to *G. wrayi* Gamble, but its orange-green young shoots are quite distinctive in the field.

Two varieties have been distinguished within *G. scortechinii*:

- var. *scortechinii*: culm sheath covered with blackish-brown hairs, auricles bristly; the most common variety;
- var. *albovestita* Holttum: culm sheath covered with white hairs, auricles glabrous; not so common.

Ecology In Peninsular Malaysia natural forests of *G. scortechinii* occur up to 1000 m altitude but they are best at altitudes between 400–800 m. Annual mean maximum temperature is about 32°C, mean minimum temperature 22°C. Annual rainfall is about 2500 mm, quite evenly distributed over the year. *G. scortechinii* will grow in any soil type but does best on sandy loams with good drainage and pH 5.0–6.5. It thrives well in ravines, gulleys and logged-over areas and is quite aggressive once it is exposed to sunlight.

Propagation and planting *G. scortechinii* can be propagated by seed, rhizome and culm cuttings. Germination rate of seed is 70–75%. Rhizome cuttings (rhizome part, with roots and 60–100 cm basal part of a one-year-old culm) are planted out directly and are successful, but this method is not suitable for large-scale propagation. Culm cuttings are raised in a nursery for 4–6 months and transplanted when they have produced roots, preferably at the onset of the rainy season. It is recommended to prepare holes of 60 cm × 60 cm × 60 cm, to apply organic and inorganic fertilizers and to plant at distances of 3–6 m × 3–6 m. Due to the abundance and ubiquity of the species in the forest, in Peninsular Malaysia plantations of *G. scortechinii* do not exist.

Husbandry Weeding and watering in young plantations are necessary until the plants are well established. Annual fertilizer application of 20–30 kg N, 10–15 kg P, 10–15 kg K and 20–30 kg Si is recommended in Malaysia.

Diseases and pests Leaves of *G. scortechinii* sometimes suffer from a leaf spot disease caused by *Colletotrichum* sp. and *Pestalotia* sp. Spraying with fungicides like thiram, benlate or captan controls the disease. Major pests are stem borer beetles (*Estigmena chinensis*, *Conarthus jansoni*) which attack young culms, and leaf rollers (*Pyrausta coclesalis*). Pest control is effective by removal of affected culms and thinning of congested clumps (sun kills the beetles).

Harvesting Only mature culms of 3 years or older should be harvested, taking care not to harvest from the periphery of a clump and to leave the culms evenly spaced in the clump. In Peninsular Malaysia culms are harvested all the year round. Felling intensities up to 70% (70% of total number of culms of a clump) are possible without visible negative effect on regrowth.

Yield A properly managed plantation may produce 3600–4000 culms/ha or 40–50 t (green weight) per year.

Handling after harvest Culms of *G. scortechinii* are quite durable, but for preservation they are traditionally soaked in running water for 18–24 hours. For the poultry cages industry at Guar Chempedak (Peninsular Malaysia) culms are collected from natural forests and transported in 7–8 m lengths by lorry to the factory. There they are sawn into suitable lengths and split. The crosswalls at the nodes of the culms are then knocked away to allow greater flexibility. The strips are cut tangentially into two thinner parts which are used to weave the cages and their covers. Broader unsliced strips are used to reinforce the bottoms. For the joss stick production in Ulu Langat (Selangor) the culms are cut and smoothed into fine sticks. These are sun-dried for a few days before being coated with a mixture of fine sawdust, adhesive and perfume which make up the incense.

Genetic resources and breeding For *G. scortechinii* no germplasm collections and no breeding programmes are known to exist.

Prospects The prospects for *G. scortechinii* are promising. Its culms are fully utilized and are in great demand. Investigations are in progress on natural stand management, fertilizer requirements and optimum felling intensity. It is recommended to start a representative germplasm collection.

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Azmy Hj. Mohamed

Gigantochloa thoii K.M. Wong

Sandakania 1: 18 (1992).
GRAMINEAE
$2n$ = unknown

Synonyms *Gigantochloa levis* (Blanco) Merrill sensu Holttum (1958), sensu Widjaja (1987), pro parte; *G. verticillata* (Willd.) Munro sensu Ridley (1925).

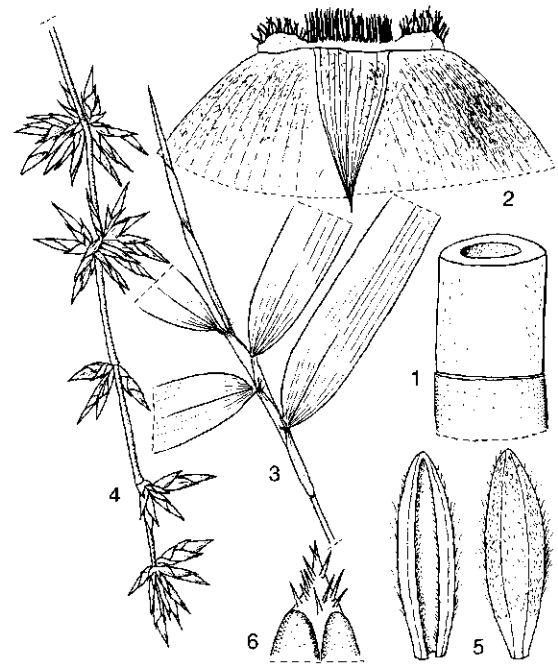
Vernacular names Peninsular Malaysia: buloh betung (Malay), in common with *Dendrocalamus asper* (Schultes f.) Backer ex Heyne.

Origin and geographic distribution *G. thoii* is known only in cultivation in Peninsular Malaysia. Holttum surmises a Thai-Burmese origin for many *Gigantochloa* species now known only in cultivation in South-East Asia but, despite the poor state of bamboo exploration in Burma (Myanmar), no evidence has been found that this species exists there.

Uses The young shoots of *G. thoii* are relished as a vegetable-delicacy. Although the culms are large and strong, they are not taken for any industry, probably because culms from adequately abundant wild populations of two other *Gigantochloa* bamboos, *G. scortechinii* Gamble and *G. wrayi* Gamble, are available, whereas *G. thoii* has not yet been planted as such a resource.

Production and international trade There are no recorded economic and production data, as the shoots are used for local consumption only. They are usually sold in small quantities obtained from clumps grown in villages.

Description Densely tufted, sympodial bamboo. Culm erect, up to 16 m tall, diameter up to 12 cm, plain green; internodes copiously white-waxy, scantily dark-brown hairy at the upper part; nodes not conspicuously swollen. Branches at each midculm node arising from a single bud consisting of a dominant primary branch, with (usually) one subdominant secondary branch from its base on each side, and several lesser leafy branchlets from the base of secondary branches. Culm sheath pale to medium green, with dark brown hairs on the back; blade broadly lanceolate, green, spreading to reflexed; ligule lacerate, the base 2–4 mm long, the lacerations 5–18 mm long; auricles large lobes to 10 mm long, with bristles 10–18 mm long on the margin, dark green to purplish-green. Leaf blade 8–32 cm × 2–6 cm, lower surface softly pale-hairy; ligule shortly toothed, 0.5–1.5 mm long; auricles small lobes, with fine bristles to 4 mm long on the margin. Pseudospikelet 10–15 mm long, with 2–3 gemmiferous bracts, 2–3 glumes, 4–5 perfect florets and a vestigial terminal floret usually represented by an empty lemma. Caryopsis unknown.



Gigantochloa thoii K.M. Wong – 1, part of culm; 2, culm leaf (abaxial side); 3, leafy branch; 4, flowering branch; 5, palea (abaxial and adaxial side); 6, anther tip.

Growth and development Young shoots mainly develop during the rainy season. Flowering occurs in just a few culms in the clump, or can sometimes involve an entire clump. Reproductive culms senesce after flowering but regeneration from rhizomes in clumps that have senesced is possible. Flowering extends over many months in a fertile clump, but no seed has been found thus far.

Other botanical information Several features allow *G. thoii* to be easily distinguished from true *G. levis* which is a common bamboo in the Philippines and Sabah, with which it has been confused in the past. *G. thoii* has white-waxy culms and the basal internodes are scantily dark-haired at the upper part only; its floret has no lodicules, a palea with a 2–4-veined back and the anther apical cusps bear long spines c. 0.1 mm long. True *G. levis* has culms which are non-waxy, and basal internodes that are densely dark-haired all over; its floret has 3 lodicules, a palea with a 4–5-veined back, and the anther apical cusps bear only short triangular spines hardly 0.05 mm long.

Ecology *G. thoii* is grown under tropical lowland conditions of Peninsular Malaysia.

Propagation and planting Either rhizome cuttings (offsets) or culm cuttings may be used for vegetative propagation. Cultivated clumps from which new shoots are frequently removed for food develop rooted rhizome-like swellings at branch bases. Such 'aerial rhizomes' may be useful as vegetative planting material. It is likely, as has been demonstrated for some species of *Bambusa*, that regular debudding of rhizomes and removal of newly emerged culm shoots can encourage the development of 'aerial rhizomes'. Planting distance in the field is 3.5 m × 3.5 m.

Husbandry Weeding was noted as an important aspect in the now non-existent shoot-producing *G. thoii* plot at Kepong. This could have been because the clumps were rather open in structure due to regular removal of shoots, leaving behind only several leafy mature culms. No reliable data on fertilizer application could be obtained.

Diseases and pests The brown lesion disease, caused by *Colletotrichum* spp., can bring about serious damage. Heavy infestation of the leaves and subsequent insect attack can cause withering of foliage and senescence. The disease manifests as brown spots coalescing to form lesions. Fungicides such as thiram, benlate or captan have been recommended as prophylactics and control measures. Regular cleaning of bamboo clumps has been suggested, to reduce the risk of such infestation.

Yield Only one incidence of an organized farm of *G. thoii* is known. The small holding of about 4.5 ha of *G. thoii*, in Kepong near Kuala Lumpur in Peninsular Malaysia, was said in 1983 to have had a young shoot production of up to 1000 katties (6000 kg) per week; off-peak production was estimated at 200–400 katties (1200–2400 kg) per week. The farm was started before 1957 but does not exist any more.

Handling after harvest *G. thoii* shoots have so far only been sold fresh, or (after removal of sheaths) maintained in a brine solution. However, there is no standard prescription.

Genetic resources and breeding As *G. thoii* exists only as cultivated clumps in Peninsular Malaysia and seeding has not been observed so far, it is likely that the genetic base will remain narrow. There are no germplasm collections and breeding programmes.

Prospects The excellent quality of *G. thoii* shoots for table use suggests it has potential as a plantation crop for bamboo-shoot production. However, bamboo shoots probably cannot form the sole raw material for a profitable canning or dried food industry because the required scale would involve cultivation on very large farms and shoot production is only seasonal.

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K.M. Wong

Gigantochloa wrayi Gamble

Ann. Roy. Bot. Gard. Calcutta 7: 64 (1896).
GRAMINEAE
$2n$ = unknown

Synonyms *Gigantochloa kurzii* Gamble (1896) pro parte, *G. maxima* Kurz var. *viridis* Holttum (1958).

Vernacular names Indonesia: buluh dabo (Sumatra). Peninsular Malaysia: buloh beti, buloh mata rusa, buloh minyak (Malay).

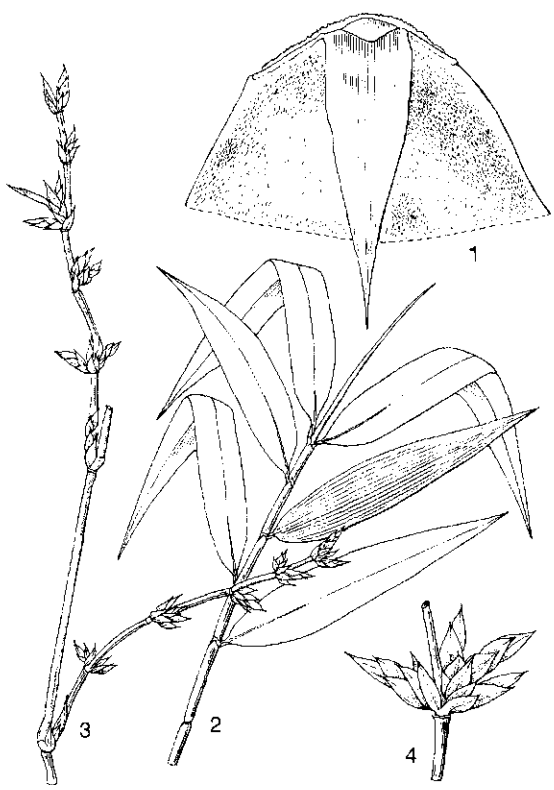
Origin and geographic distribution *G. wrayi* is native to Peninsular Malaysia and southern Thailand. It has also been found cultivated in southern Sumatra (Indonesia). In its native area it is probably also cultivated in villages.

Uses In Peninsular Malaysia, especially in the north, *G. wrayi* occurs sympatrically with *G. scor-*

techinii Gamble and its culms are of comparable quality and used in the same way, e.g. to prepare incensed prayer sticks used by the Chinese community, vegetable baskets, poultry cages and handicrafts. In rural areas in Peninsular Malaysia and southern Sumatra they are used when needed for fences, poles, roughly plaited house walls and other household items.

Production and international trade *G. wrayi* is only used locally and no statistics on production or trade are available.

Description Densely tufted, sympodial bamboo. Culm erect, slightly arching outwards, up to 12 m tall, diameter 2–20 cm, plain green or sometimes streaked yellow at the base; internodes non-waxy, up to 40 cm long, with scattered appressed dark-brown hairs on the upper parts; nodes not conspicuously swollen. Branches at each midculm node arising from a single bud, consisting of a dominant primary branch, 1–2 subdominant branches from its base and several lesser branchlets of higher orders. Culm sheath pale green, sometimes with faint yellow stripes, covered with dark brown hairs; blade broadly triangular on lower sheaths, broadly lanceolate on midculm and upper sheaths, green or sometimes flushed purple, spreading to reflexed, hirsute at base and along midrib on lower half; ligule lacerate, the base 1–2 mm tall, the lacerations to 8 mm long, bristly along rim when young; auricles low and rimlike, 2–4 mm long, sometimes raised at the outer ends, glabrous except for a few scattered pale bristles 2–5 mm long near the outer ends, dark green to dark purple. Leaf blade 9–40 cm × 1.5–6 cm, lower surface covered with soft pale hairs; ligule subentire, not bristly, 1–2 mm long; auricles small rounded lobes 1–2 mm long with a few pale bristles 2–3 mm long. Pseudospikelet 10–20 mm long, with 2–3 gemmiferous bracts, 3–4 glumes, 3–4 perfect florets and a vestigial terminal floret represented by an empty lemma 8–17 mm long. Caryopsis cylindrical-ellipsoidal, about 10 mm long, grooved on one side, apex thickened and hairy.



Gigantochloa wrayi Gamble – 1, culm leaf (abaxial side); 2, leafy branch; 3, flowering branch; 4, cluster of pseudospikelets.

Growth and development No information exists from systematically observed populations. It appears that the growth is very similar to that of *G. scortechinii*, as observed sympatric clumps apparently have the same vigour. Flowering occurs on one to several culms in a clump, which can continue to show new vegetative growth during and after such flowering.

Other botanical information In the field *G. wrayi* can be distinguished from *G. scortechinii* by its non-waxy culms with scattered dark hairs at the upper parts of internodes.

Ecology *G. wrayi* is common in Peninsular Malaysia only in the north, on alluvial sites and in the foothills of the Main Range. It establishes naturally on poor clayey soils but does not produce as large culms as when it grows on alluvial soils. Nevertheless in many wasteland areas it can establish as whole stands, mixed with secondary-forest trees and also with *G. scortechinii* and sometimes *Schizostachyum grande* Ridley. In such dense stands, its leaf litter accumulates on the ground and appears to prevent effective establishment of other plants.

Agronomy Rhizome cuttings (offsets) and culm cuttings can be effectively used in vegetative propagation. Any experience with systematic planting has not been reported.

Genetic resources and breeding Wild populations of *G. wrayi* are composed of both seed individuals and clones which establish from clump or rhizome fragmentation. There are no germplasm

collections and breeding programmes for *G. wrayi*.

Prospects *G. wrayi* is a useful bamboo, and may be usefully brought under organized cultivation for culm production. More research is needed on cultivation methods, properties and applications. Germplasm collection is urgently needed.

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K.M. Wong

Melocanna baccifera (Roxb.) Kurz

Prelim. rep. for. veg. Pegu, app. B: 94 (1875).
GRAMINEAE
$2n = 72$ (hexaploid)

Synonyms *Bambusa baccifera* Roxb. (1819), *Melocanna bambusoides* Trin. (1821).

Vernacular names Muli, berry bamboo (En). India: tarai, watri, wati. Bangladesh: muli, paiya. Burma (Myanmar): kayinwa, tabinwa.

Origin and geographic distribution *M. baccifera* occurs naturally in Bangladesh, Burma (Myanmar) and north-eastern India. It is occasionally cultivated and has been introduced and planted in many botanical and private gardens all over the world, especially in South-East Asia, including Hong Kong and Taiwan.

Uses In its native area, especially in Bangladesh, *M. baccifera* is one of the most useful bamboos. Its culms are widely used in house building, to make woven wares (baskets, mats, handicrafts, wall plates, screens, hats) and domestic utensils, and are an important source of superior paperpulp. The young shoots are edible and during the rainy season constitute one of the important foods of tribal people of Chittagong and Chittagong hill tracts in Bangladesh. The shoots are also sliced and dried in the sun for preservation.

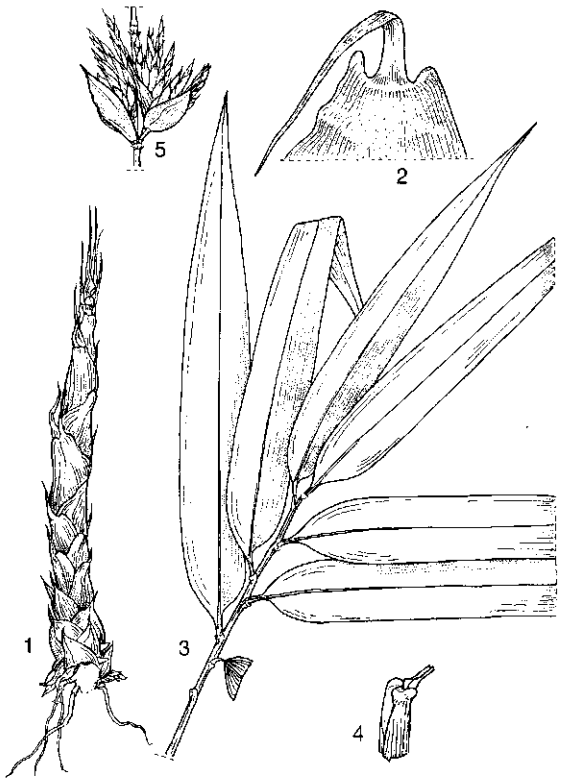
The remarkable large fruits of *M. baccifera* are fleshy and edible; they are used as famine food and relished by wild and domestic animals. The leaves may be used in brewing liquor. Tabashir can be collected from the culms.

Production and international trade In its native area, *M. baccifera* is mainly a wild growing forest species, occupying e.g. about 100 000 ha in Bangladesh (Sylhet and Chittagong hill tracts) and 700 000 ha in Burma (Myanmar) (Arakaan Yoma). Potential annual production of air-dried culms in Bangladesh is estimated at 300 000 t. Production, trade and consumption of culms and young shoots are mainly local and national, no statistics are available. In Bangladesh culms are sold at US$ 10 per 100; most are used by the paper industry (Karnaphuli). In the pulp mills culms are sold per air dry t; 1000 air dry culms weigh about 1.8–2.0 t.

Properties The fibre dimensions of the culms are: length (1.62–)2.80(–3.85) mm, diameter 15.60 µm, lumen diameter 3.55 µm. For 3-year-old culms of *M. baccifera*, the following average physical and mechanical properties are reported: moisture content 71% (top), 102% (butt); specific gravity for green culms 0.55 (butt), 0.64 (top), for oven-dried culms 0.70 (butt), 0.75 (top); shrinkage from green to 12% moisture content is 6.6% in wall thickness and 4.1% in diameter; the modules of elasticity is 17 800–23 700 N/mm^2 (green culms), 18 800–28 100 N/mm^2 (air-dried culms); the modules of rupture is 62.2–72.8 N/mm^2 (green culms), 68.7–78.2 N/mm^2 (air-dried culms); the compression strength parallel to grain is 37.0–44.2 N/mm^2 (green culms) and 46.4–55.1 N/mm^2 (air-dried culms). The chemical composition is approximately: holocellulose 62.3%, pentosans 15.2%, lignin 24.1%, ash 1.9%, silica 1.5%; the solubility in cold water is 3.3%, in hot water 6.5%, in alcohol-benzene 1.4%, in 1% NaOH 19%. The edible portion of young shoots is about 40%; after cooking they are sweet, tender, greenish-white; they have a good canning quality.

Description Bamboo with a sympodial rhizome having slender elongated necks, forming an open and diffuse clump with some distance (up to 1 m) between the culms. Culm erect and straight but with pendulous tips, 10–15(–20) m tall, diameter 1.5–7.5 cm near the base, wall thick at base but thin above, green when young turning yellow or yellow-brown when old, often finely striated; internodes hollow, at midculm 25–50 cm long, smooth, glabrous, with white ring below the nodes; nodes not swollen. Branches from midculm upwards, many at each node, subequal, easily removable from the node. Culm sheath 8–15 cm long, 14 cm wide at the base, up to 6 cm wide near the truncate or concave apex, persistent, light green when young becoming stramineus, covered with pale or fine white hairs; blade erect with spreading tip, broadly to narrowly lanceolate, 10–20(–30) cm × 7–18 mm, glabrous, persistent;

ligule very short; auricles indistinct. Young shoot yellowish-brown, sheath margins and top pinkish. Leaf blade oblong-lanceolate, 14–28 cm × 3–5 cm, glabrous (young seedlings have larger leaf blades than adult plants); sheath glabrous; ligule very short; auricles indistinct, bearing long bristles. Inflorescence usually terminating a leafy branch (occasionally borne on a leafless branch), 15–45 cm long, with few to several lax flexuous branches of different length, each bearing groups of pseudospikelets at each node along one side of the axis; spikelet 15 mm long, glabrous, mucronate, comprising 2–4 glumes, one fertile and one abortive floret. Fruit an ovoid to globose baccate caryopsis, 4–12 cm × 3–6 cm, pear-like with more or less curved beak, glabrous, smooth, weighing 47–180 g; pericarp fleshy, very thick but thinner at base, enclosing an oblongoid fruit cavity; endosperm much reduced; embryo with relatively large scutellum containing starch grains (food storage) and basally the plumule and radicle; the fruit often germinates while it is still on the parent plant.



Melocanna baccifera (Roxb.) Kurz – 1, young shoot; 2, culm leaf (abaxial side); 3, leafy branch; 4, leaf sheath; 5, groups of pseudospikelets at a node.

Growth and development Germination commences at the beginning of the rainy season, roots and shoots being produced from the thick end of the fruit. Seedlings, unlike those of most bamboos, grow vigorously from the beginning, producing usually 1–2, but up to 5 shoots (the latest up to 3 m tall) in the 1st season, crowded together in a clump. During the 2nd season more shoots are produced, up to 7 m tall and the clump expands. By the 5th season culms attain almost their maximum height but are still thin and crowded together. Per clump more than 70 culms may be present. Later, the culms become spaced out with the gradual extension of the rhizomes. Clumps are mature after about 10 years, reaching 4–5 m in diameter and producing 30–40 new culms annually. Young shoots emerge above the soil during the rainy season (May–September in Bangladesh) and develop to their full height within 4–6 months. Lateral branches emerge and develop in the following season (April–May).

M. baccifera is an aggressive bamboo, easily occupying large open areas, due to its vigorous long rhizomes and, when fruiting, due to its easily germinating fruits. It flowers gregariously, with a flowering cycle of 30–45 years. In the season before flowering no new shoots are produced. Flowering is in December or January and may continue for about 10 years over a tract that is sometimes called a flowering wave. Soon after flowering the leaves wither and fall, the culms turn yellow and the fruit forms rapidly, ripening and falling from April to June. Many fruits fail to mature and those produced from the earlier flowering part are larger than those from the later part. Eventually, clumps that have flowered die.

Other botanical information No infraspecific taxa have been described for *M. baccifera*. In the vegetative stage the plant is remarkably uniform in its morphological expression. Three slightly different fruit-shapes can be distinguished. In shape and texture the culm sheath is characteristic for the species.

Ecology In one of its native areas in Bangladesh (Chittagong hill tracts) average annual minimum temperatures range from 10°C (January) to 25°C (July, August), maximum temperatures from 24°C (December) to 36°C (April). Average annual rainfall ranges from 2000–3000 mm with a long dry season from November to March. It grows well in plain or lower hill forests on well drained sandy loam or almost pure sand. It occurs in pure stands or mixed with other vegetation. Pure stands often

result from shifting cultivation. The flowering and fruiting of *M. baccifera* appears to induce a vast and comparatively sudden increase of rats.

Propagation and planting *M. baccifera* can be propagated by seed (fruit), single-culm clump division and rhizome and culm cuttings. When seeds are available they afford the best means of propagation. They are sown in a nursery and seedlings are transplanted to the field in the rainy season or directly sown in the field. Since the seed usually germinates very promptly upon maturing, even while the fruit is still on the mother plant, procurement of fruits from a distance presents special problems. Germination percentage is higher (80%) in shade than in sunlight (33%). Early produced seeds (May–June) germinate better than later ones (September). Normally seed remains viable for about 35 days. Storage in air-conditioned rooms increases its lifespan up to 45 days, and when stored with dry sand in gunny bags, up to 60 days.

Germination starts within 10 days after sowing and rhizome development begins 30–40 days after germination. Due to its tall and soft stem, the seedling gets easily damaged during handling and transportation. Therefore chopping the seedling stem tips at 3–5 nodes is recommended. Frequent shifting of seedlings from one bed to another helps in minimizing root and rhizome intermingling at the nursery stage. Most convenient for the propagation of *M. baccifera* is a single-culm clump division. These should be made from the youngest culms, while the lateral buds of the rhizome are still dormant, or before they have pushed more than 5.0–7.5 cm. Most of the culm and the long slender rhizome neck may be discarded for convenience. Each propagule is planted in a separate hole. Recommended spacing is 3.5 m × 3.5 m. Culm cuttings are preferably taken from 2-year-old culms. Propagation with rhizome cuttings is easy and successful. In fact the rhizomes are very vital and start growing easily. Due to this, eradication of *M. baccifera* from cleared bamboo forest is very difficult because every rhizome part left in the ground quickly develops into a new plant.

Husbandry In artificial plantations of *M. baccifera*, young plants require watering during the dry season. After establishment of the plants, not much care is needed other than protection from grazing.

Diseases and pests No serious problems are known. Root rot disease, caused by *Poria rhizomorpha*, and young shoot boring by the bamboo weevil *Cyrtotrachelus longipes*, may cause some damage. In the rainy season grazing porcupines may damage young shoots in Bangladesh.

Harvesting Harvesting may start 5–6 years after planting. Young shoots are harvested in the rainy season. Culms are considered mature when 2 years old. In Bangladesh culms are harvested in a 3 years felling cycle. Harvested culms are 2 years or older and should have a minimum length of 5–6 m without any defect and a minimum diameter of 2.5 cm at 1.5 m height.

Yield In Bangladesh the average green culm yield is estimated at 12 000 culms/ha per 3 years, weighing about 84 t. Other reported culm yield data per 3 years per ha in air dry weight are: 38 t (Bangladesh), 21 t (Burma (Myanmar)) and 17.5 t (India).

Handling after harvest In Bangladesh harvested culms are made into bundles and often transported as rafts through waterways. Green whole culms can be treated with preservatives following the boucherie method. Split bamboo can be treated by soaking in waterborne preservatives.

Genetic resources and breeding For *M. baccifera* no germplasm collections or breeding programmes are known to exist.

Prospects The possibilities for *M. baccifera*, with its straight and smooth, strong and durable culms and its edible shoots, to become also an important bamboo species outside its native area are promising. It is a fast grower and easy to propagate. Nevertheless, it has received little attention in South-East Asia. Investigation on cultivation techniques, food value, preservation methods and applicabilities are urgently needed, as are germplasm collections.

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M.K. Alam

Phyllostachys aurea Carr. ex A. & C. Rivière

Bull. Soc. Acclim. ser. 3, 5: 716, f. 36 (1878).
GRAMINEAE
$2n = 48$ (tetraploid)

Synonyms *Phyllostachys bambusoides* Sieb. & Zucc. var. *aurea* (A. & C. Riv.) Makino (1897), *P. formosana* Hayata (1918).

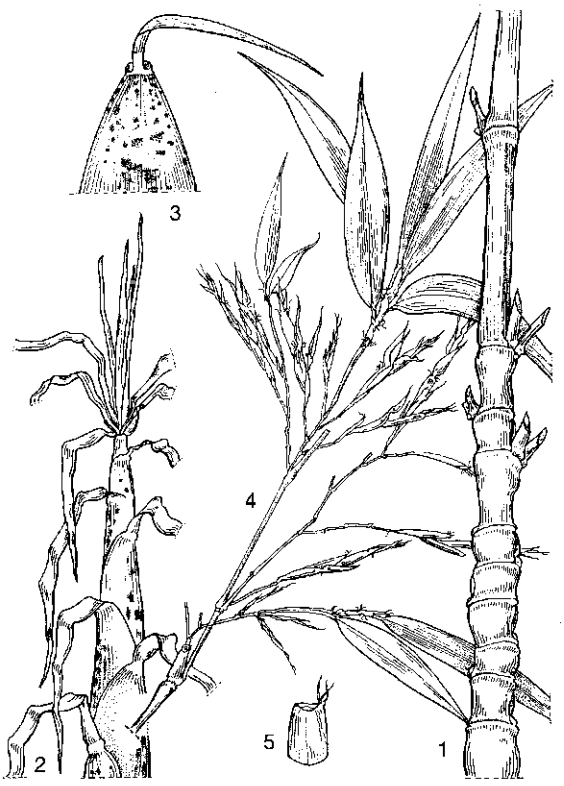
Vernacular names Fishpole bamboo, hoteichiku (En). Indonesia: pring uncue (Javanese). Vietnam: tr[us] v[af]ng.

Origin and geographic distribution *P. aurea* is believed to originate from temperate and subtropical southern China and Japan. It has been introduced into most countries of the world and is often grown as an ornamental, even in temperate climates. In some countries it has also naturalized, e.g. in Indonesia (Merapi Mountain in Central Java).

Uses Because of the abnormal internodes (irregularly shortened and swollen) in the lower part of the culms, *P. aurea* is a popular garden ornamental (also as hedge). Its basal culm parts are used and sold as walking sticks, umbrella and fan handles and as various other souvenirs. The straight upper culm parts are used as fishing rods, ski poles, javelins and for furniture and construction. The young shoots are occasionally used as a vegetable.

Production and international trade There are no plantations of *P. aurea*. Production and trade are mainly local for the tourist souvenir industry but statistics are not available.

Description Open, sometimes tufted, monopodial bamboo. Culm erect, straight, 2–8(–12) m tall, 2–3(–9) cm in diameter, wall 4–8 mm thick, green when young, golden-yellow when older; internodes 10–20 cm long, below the nodes white powdery waxy, the lower ones often irregularly shortened and swollen, thrusting the sheath scars into an irregularly slanted zigzag pattern; nodes prominent, lower ones close together and oblique, upper



Phyllostachys aurea Carr. ex A. & C. Rivière – 1, part of culm; 2, young shoot; 3, culm leaf (abaxial side); 4, flowering branch; 5, leaf sheath.

ones distant and horizontal, young sheath scars fringed with short white hairs. Branches usually paired in the midculm part, unequal in thickness. Culm sheath 12–18 cm long, promptly deciduous, when young green or light orange-yellow with purple-red or light green ribbed striations and brown spots, covered with short white hairs toward the base; blade lanceolate to narrowly lanceolate, 3–6 cm long, erect or spreading, sometimes wrinkled; ligule 1–2 mm long, long ciliate at apex; auricles absent. Young shoots light brownish-yellow, sometimes reddish, brownish spotted or dotted. Leaf blade lanceolate, 5–15 cm × 5–20 mm, glabrous to densely soft-hairy, margins spinulose-scabrous; sheath 2.5–3.5 cm long, minutely soft hairy when young, glabrous with age, sparsely ciliolate along the margins; ligule 1 mm long, long ciliate; auricles rudimentary or lacking, when present bearing 0–3 bristles. Inflorescences borne on leafy or leafless branches, occupying nearly the whole culm; spikelet 18–25 mm long, usually with 1 papery glume and 2 fertile florets. Caryopsis linear-lanceolate in outline, 6–8 mm × 1.5–2.0 mm, grooved on back, style persistent.

Growth and development Young shoots appear in spring (April in China); they grow rapidly, reaching full height within 1 month, after which the branches and leaves develop before the summer starts. A culm matures in 3–5 years. Flowering is rare, but sporadic and gregarious flowering has been observed. Gregarious flowering may occur when a clump is 15–30 years old, after which the clump does not die. In Java *P. aurea* has never flowered. In Japan one gregarious flowering period has been reported to occur from 1916–1921.

Other botanical information *P. aurea* is a variable species and numerous subclassifications have been proposed. Some better known cultivars are:

- 'Albo-variegata': culms slender, leaves striped white.
- 'Holochrysa': culms yellow, sometimes striped green; leaves occasionally striped.
- 'Violascens': culms up to 6 m tall, swollen, green and finally striped purple or yellow in time, ultimately violet; nodes prominent; branches short and dense; leaves up to 12 cm long, glossy above, glaucous beneath.

Ecology Small natural forests of *P. aurea* occur in southeastern China from low altitudes up to 1000 m and up to 2000 m in southwestern China. *P. aurea* is frost hardy, and will tolerate up to –10(–18)°C. It grows best on rich, deep and well-drained sandy soils. In Indonesia it mostly grows in the highlands above 700 m altitude but plants grown in the lowland have shorter and smaller culms. In the Philippines it grows very well in Baguio at 1500 m altitude with average temperatures of 18–26°C. Because *P. aurea* has a leptomorph rhizome system, it can be an invasive bamboo if not well controlled.

Agronomy *P. aurea* can be propagated by seed and by clump division. Because seed is rarely available, the normal propagation method is by clump division. Clump parts, 0.5–1.0 m long are taken, having a rhizome, roots and 1–several culm parts. They are planted in previously prepared holes, enriched with organic manure. Preservation of culms has been tried using cold soaking treatment. Boron penetration after an immersion period of 5 days was about 93% for split and 79% for unsplit culm parts.

Genetic resources and breeding No germplasm collections are available for *P. aurea*, but it is present in many botanical gardens. There are no known breeding programmes.

Prospects The future of *P. aurea* as ornamental plant, especially in temperate climates, is promising. For South-East Asia *P. aurea* remains of interest in the production of souvenir articles. Germplasm collections are urgently needed. More research is needed to develop cultivation methods and specific cultivars.

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Chu Chengde & E.A. Widjaja

Schizostachyum blumei Nees

Agrost. Bras.: 535 ('blumii') (1829).
GRAMINEAE
$2n$ = unknown

Synonyms *Melocanna zollingeri* Steudel var. *longispiculata* Kurz ex Munro (1866), *Schizostachyum longispiculatum* (Kurz ex Munro) Kurz (1870).

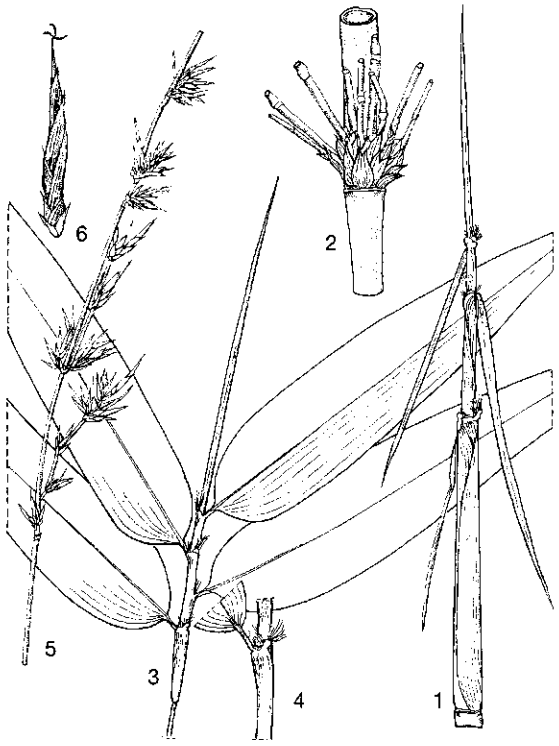
Vernacular names Brunei: buluh lacau (Iban). Indonesia: awi tamiyang (Sundanese). Malaysia: tombotuon (Dusun, Sabah), buloh anap (Kedayan, Sabah), bongulungul (Murut, Sabah). Note. In Sundanese 'awi tamiyang' is also used for *S. iraten* Steudel.

Origin and geographic distribution *S. blumei* is probably native in Borneo, but it also occurs in Sumatra and has been introduced into Java. It may also be cultivated occasionally.

Uses The long slender culms of *S. blumei* are used for making fishing rods and traditional flutes.

Production and international trade Production and trade of culms of *S. blumei* are only local and no statistics are available.

Description Densely tufted, sympodial bamboo. Culm erect with long pendulous, whip-like tip, 3–7 m long, 1–2 cm in diameter, wall c. 2 mm thick, light green to dark green, rough when young, becoming smooth; internodes 30–60 cm long, with appressed white hairs initially, glabrous later, below the nodes with white waxy rings; nodes not prominent. Branches many, from midculm nodes upward, more or less subequal. Culm sheath 15–20 cm × 4–5 cm, widest at base, especially when young covered with appressed fine white hairs, line with the junction of the blade more or less horizontal, 8–10 mm long; blade narrowly lanceolate, tapering, 13–15 cm × 7–8 mm, at the junction with the sheath 3–4 mm wide, erect first, later deflexed, densely hairy adaxially especially near the base, glabrescent abaxially; ligule very short, irregularly dentate, bearing short bristles; auricles about 4 mm tall and 8 mm long, bearing bristles up to 11 mm long along the edge. Young shoots light green. Leaf blade 19–39 cm × 3.5–6.5 cm, base more or less rounded, tapering, dark green, usually glabrous; sheath usually glabrous; ligule short, serrate; auricles small but prominent, 1 mm long with bristles up to 13 mm long along the edge. Inflorescence 20–35 cm long, terminating a leafy branch; spikelet 20–25 mm long, slender, comprising one perfect floret and a rachilla extension bearing one rudimentary floret. Caryopsis unknown.



Schizostachyum blumei Nees – 1, young shoot; 2, midculm branch complement; 3, leafy branch; 4, base of leaf; 5, flowering branch; 6, pseudospikelet.

Growth and development Young shoots are produced continuously in a mature clump. At first a young shoot is erect, up to about 2 m tall, and later the upper part becomes pendulous. When leafy branches develop, the culm cannot support itself and flops over older culms. In the field a clump of *S. blumei* looks like a compact bush, with old culms flopping over and young shoots sticking up above the old culms.

Flowers can be found all the year round, but fruits are rare.

Other botanical information *S. blumei* is easily recognized by its large leaf blades and the erect and slender young shoots with pendulous tips. *S. blumei* is related to *S. latifolium* Gamble. The clump of *S. latifolium* is open, its culms are erect with drooping tips and culms and leaves are light green.

Ecology *S. blumei* can be found in lowland forest, often along rivers and in hill dipterocarp forest up to 800 m altitude, in forest margins and in lowland wasteland along roads.

Agronomy No information is available on the agronomic aspects of *S. blumei*. Its culms are collected from wild populations.

Genetic resources and breeding No germplasm collections or breeding programmes of *S. blumei* are known to exist. Some accessions are present in the botanical garden of Bogor (Indonesia).

Prospects More research is needed on various aspects of *S. blumei* to be able to predict its poten-

tial fully. It is unlikely to become an economically important bamboo.

Literature |1| Dransfield, S., 1983. Notes on Schizostachyum (Gramineae–Bambusoideae) from Borneo and Sumatra. Kew Bulletin 38: 330–331. |2| Dransfield, S., 1992. The bamboos of Sabah. Sabah Forest Records No 14. Forestry Department, Sabah, Malaysia. pp. 58–60. |3| McClure, F.A., 1936. The generic type, and a new species, of the bamboo genus Schizostachyum from Java. Blumea 2: 86–97. |4| Monod de Froideville, C., 1968. Gramineae. In: Backer, C.A. & Bakhuizen van den Brink, R.C. (Editors): Flora of Java. Vol. 3. Wolters–Noordhoff, Groningen, the Netherlands. p. 640.

S. Dransfield

Schizostachyum brachycladum Kurz

Journ. As. Soc. Bengal 39(2): 89 (1870).
GRAMINEAE
$2n$ = unknown

Vernacular names Indonesia: buluh lemang (Indonesian), buluh tolang (North Sumatra), buluh sero (Moluccas). Malaysia: buloh lemang, buloh silau (Sabah), buloh telang (Sarawak). Philippines: buho, kauayang buho (Tagalog). Thailand: phai-por, kriap.

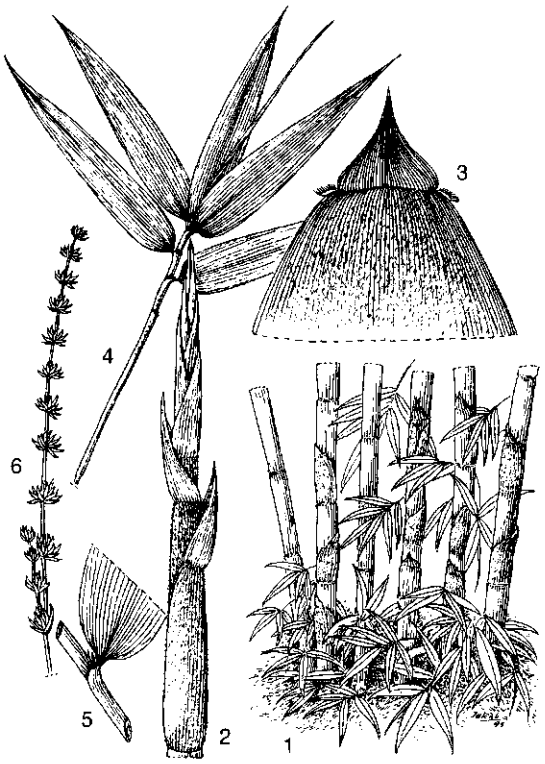
Origin and geographic distribution *S. brachycladum* is widespread in South-East Asia, occurring in Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, Sulawesi, the Moluccas, Bali and Luzon, growing wild, cultivated or naturalized.

Uses The culms of *S. brachycladum* are widely used, e.g. for roofs (split lengthwise as for the Toraja rice barn and traditional house in Sulawesi), water containers, handicrafts, banana props and as container for cooking glutinous rice ('lemang'). Native people in Sarawak usually use *S. brachycladum* culms for many purposes and if it is not available it is substituted by other thin-walled bamboos; the internodes are used for making water pipes to smoke tobacco; decorated with a pattern carved in low relief ('serobok'), also for various carved containers, for instance, the one used for holy wine served during the Gawai festival ('Garong basket'). Formerly, women in North Sulawesi made clothes from the fibres, after chewing and washing the soft inner part of the culms to extract the fibres. In Bali and Toraja (Sulawesi) the culms are used during burial ceremonies. Young shoots are edible, but rather bitter. The forms with yellow culms are often cultivated as ornamentals. In Sabah this bamboo is also planted on hill slopes to prevent landslides.

Production and international trade Production and trade of *S. brachycladum* are mainly local. Economically it is an important bamboo, but no statistics are available.

Properties The culms of *S. brachycladum* have thin walls and are easily split. The fibres are quite easy to separate from the internodes; they are strong and supple and can be woven into cloth.

Description Densely tufted, sympodial bamboo. Culm erect with pendulous tip, 7–15 m tall, 7–10 cm in diameter, wall 3–5 mm thick, green, bluish-green, or golden-yellow often with narrow green stripes; internodes 30–58 cm long, smooth, usually covered with scattered white hairs when young, becoming glabrous; nodes not swollen, without root primordia. Branches arising from the midculm nodes upward, at each node with a tuft of 25–30 slender subequal branches. Culm sheath rigid, 12–27 cm × 18–35 cm, long persistent, covered with light-brown to brown hairs, junction of top of sheath with blade horizontal; blade triangu-



Schizostachyum brachycladum Kurz – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

lar with stiff acuminate apex, 4–18 cm × 4–10 cm, erect, rigid, usually glabrous, many nerved; ligule 3 mm long, entire; auricles small, 10 mm long and 2.5 mm tall, bearing crisped bristles 4–5 mm long. Young shoots with rigid culm sheaths and hard broad blades, covered with light brown to brown hairs. Leaf blade lanceolate, 26–32 cm × 3.5–6 cm, hairy below, glabrous above; ligule short, entire; auricles very small, with long bristles. Inflorescence 16–30 cm long, consisting of dense tufts of pseudospikelets 1–3 cm apart at the nodes on the rigid distal part of a leafy branchlet; spikelet 15–25 mm long, comprising 1–2 perfect florets and a rachilla extension bearing a rudimentary floret. Caryopsis not known.

Growth and development A mature clump contains about 30–50 culms. *S. brachycladum* flowers continuously and each mature culm in an established clump bears inflorescences terminating leafy branches. Mature fruits are rarely found. Normally, all plants (clumps) retain their vegetative vigour undiminished after flowering.

Other botanical information Two unnamed forms (varieties) are distinguished within *S. brachycladum*: one with green to bluish-green culms, the other with golden-yellow culms sometimes with green streaks. The yellow form is a popular garden plant in the tropics. It grows commonly and spontaneously in Sabah ('buloh rugading') and in West Sumatra ('talang kuning'). The green form is often cultivated in rural areas. A form with larger culm-sheath auricles (up to 7 mm tall and spreading beyond the width of the top of the sheath) has been described as var. *auriculatum* Holttum from Singapore, but probably originates from Indonesia.

S. brachycladum is related to *S. zollingeri* Steudel, a common bamboo in southern Thailand, Peninsular Malaysia and Sumatra.

Ecology In the wild, *S. brachycladum* can be found in disturbed or secondary forest in South-East Asia, up to 600 m altitude, rarely in undisturbed forest. It is also commonly found spontaneously or naturalized along roadsides and is frequently cultivated in villages. This bamboo can be grown on any kind of soil but does best in a well-drained sandy clay or sandy loam. The form with bluish-green culms is found above 250 m altitude in Sumatra, Kalimantan, Sulawesi and the Moluccas.

Agronomy Although *S. brachycladum* is commonly cultivated in South-East Asia, almost nothing has been reported on its cultivation method. It can be propagated by rhizome and culm cuttings. Rhizome cuttings, consisting of a rhizome part, roots and a culm part, are most common (e.g. this is how the yellow form is sold in pots). Cuttings should be planted at the beginning of the rainy season, horizontally and with fresh buds sideways, about 20–30 cm deep. The soil should be finely crumbed. Recommended spacing is 3 m × 3 m. Nothing is known about diseases and pests, harvesting and yield.

Genetic resources and breeding A small germplasm collection is present at the Philippine Bambusetum in Baguio City. No breeding programmes are known. *S. brachycladum* is represented in many botanical and private gardens all over South-East Asia. The variation of *S. brachycladum* is quite limited to culm colour and size.

Prospects *S. brachycladum* is a useful bamboo, escaping the attention of agronomists but of considerable importance in the daily life of many South-East Asian rural people. Its common occurrence and ready availability have discouraged large-scale cultivation. Nevertheless, it seems worthwhile to investigate its ecological requirements, cultivation methods and possibilities for improvement. Germplasm collection is recommended.

Literature |1| Abd. Razak Othman, Hashim Md. Noor & Azmy Hj. Mohamed, 1990. Panduan menanam buluh [Guide to plant bamboos]. FRIM Technical Information No 19. Forest Research Institute Malaysia. 8 pp. |2| Baja-Lapis, A. & Sy, M.U., 1986. Sustained bamboo production: a potential livelihood opportunity. Canopy International 12(6): 5–7. |3| Dransfield, S., 1992. The bamboos of Sabah. Sabah Forest Records No 14. Forestry Department, Sabah, Malaysia. pp. 60–61. |4| Holttum, R.E., 1958. The bamboos of the Malay Peninsula. The Gardens' Bulletin, Singapore 16: 45–47. |5| Santos, J.V., 1986. Bamboos. In: Umali, R.M. et al. (Editors): Guide to Philippine flora and fauna. Vol. 4. Natural Resources Management Center, Ministry of Natural Resources, the Philippines and University of the Philippines, Los Baños, Laguna. pp. 23–24.

S. Dransfield

Schizostachyum grande Ridley

Journ. Straits Settlem. Roy. Asiat. Soc. 82: 204 (1920).

GRAMINEAE

$2n$ = unknown

Vernacular names Indonesia: buluh lemeng

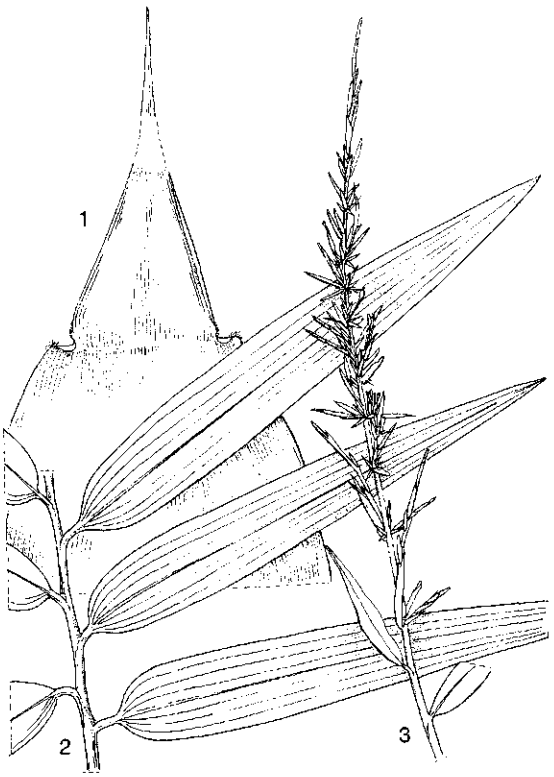
(Sumatra). Peninsular Malaysia: buloh semeliang, buloh seminyeh. Thailand: pai marieng.

Origin and geographic distribution *S. grande* is a native bamboo of northern Sumatra, Peninsular Malaysia and southern Thailand.

Uses The culms of *S. grande* are used as frames, for plaiting dish covers and winnowing trays, and as containers to cook glutinous rice ('lemang'). The leaves are used as wrappers for a Chinese glutinous rice dumpling. Young shoots are used as a vegetable and also much liked by orang utans in Sumatra.

Production and international trade The production and trade of products of *S. grande* are mainly local but no statistics are available.

Description Open tufted, sympodial bamboo. Culm erect when young, later drooping to the ground or leaning on nearby vegetation, 3–11(–21) m long, 5–12 cm in diameter, wall 2–10 mm thick; internodes 50–70(–125) cm long, white hairy and white powdery when young, later glabrous and green to dull dark green with a white ring below the nodes; nodes with a purplish girdle at the junction with the culm sheaths. Branches arising from all nodes and all branches at one node more or less of equal length. Culm sheath more or less rigid, 20–35 cm long, 18–30 cm wide near the base, 4–12 cm at the apex, junction with blade horizontal, pale yellowish-green to pale green, pale pinkish tinged at the top, covered with white powder and white appressed hairs; blade narrowly to broadly triangular, 20–35 cm × 7–10 cm, erect, tapering to a long tip, early deciduous, reddish-brown to dark brown in young shoots, abaxial surface glabrous and smooth, adaxial surface densely covered with pale appressed hairs; ligule 4–10 mm long, irregularly toothed; auricles small, with bristles 5 mm long. Young shoots cylindrical and straight, whitish or whitish-green, with dark brown to blackish blades. Leaf blade (27–)50(–60) cm × (4–)7(–10) cm, usually glabrous, base somewhat asymmetrical, apex acuminate; sheath hairy to glabrescent, the top ascending above the attachment of the pseudopetiole on either side and joined across by the ligule; ligule 2–8 mm long, sometimes bearing some slender bristles; auricles small, without bristles. Inflorescence terminating a leafy or leafless branch, bearing dense groups of pseudospikelets at the nodes of its axis; spikelet 3–4 cm long, comprising 3 hermaphrodite florets and 1 rudimentary terminal floret, with long rachilla internodes. Caryopsis cylindrical, 8–12 mm long, abruptly narrowed into a stiff curved beak (remaining style), 13–15 mm long.



Schizostachyum grande Ridley – 1, culm leaf (abaxial side); 2, leafy branch; 3, flowering branch.

Growth and development A mature clump of *S. grande* contains on average 10–25(–60) culms. Young shoots and inflorescences are produced all the year round.

Other botanical information The composition of the pseudospikelets in *S. grande* with 3 perfect florets and long rachilla internodes is very different from the typical pseudospikelet structure in the genus *Schizostachyum*. In Peninsular Malaysia, *S. grande* is regarded as a weed in overlogged forest, where it occurs abundantly, together with *Gigantochloa scortechinii* Gamble and *Dendrocalamus pendulus* Ridley.

Ecology *S. grande* is one of the commonest gregarious bamboos of open places in the foothills of the Main Range in Peninsular Malaysia above 400 m altitude (up to 1000 m). In Kelantan and Pahang (Peninsular Malaysia) and in southern Thailand it can be found at the edge of forests at about 50 m altitude.

Agronomy Because of its behaviour as an aggressive weed in overlogged forest, *S. grande* is seldom cultivated. Its green culm weight averages

3.2 kg, branches and leaves 3.1 kg. Diseases and pests are not known.

Genetic resources and breeding No germplasm collections or breeding programmes for *S. grande* are known to exist.

Prospects In the past, in Peninsular Malaysia efforts were directed towards eradication of *S. grande*. At present, the exploitation of those weedy bamboos as material for local cottage industries is being promoted, more successfully for *Gigantochloa scortechinii* and *Dendrocalamus pendulus* than for *S. grande*. As a thin-walled bamboo, culms of *S. grande* could be used to make baskets and other handicrafts. More research is needed on how to reclaim land in certain areas occupied by *S. grande*.

Literature |1| Azmy Hj. Mohamed, 1991. Three Malaysian wild bamboos. Nature Malaysiana 16(4): 130–135. |2| Azmy Hj. Mohamed & Abd. Razak Othman, 1991. Field identification of twelve commercial Malaysian bamboos. FRIM Technical Information No 25. Forest Research Institute Malaysia. 12 pp. |3| Azmy Hj. Mohamed, Wan Razali Wan Mohd & Fauzidah Ahmad, 1991. Characteristics and volume-weight relationship of four Malaysian bamboos. Journal of Tropical Forest Science 4(1): 87–93. |4| Holttum, R.E., 1958. The bamboos of the Malay Peninsula. The Gardens' Bulletin, Singapore 16: 49–51. |5| Wong, K.M., 1989. Current and potential uses of bamboo in Peninsular Malaysia. Journal of the American Bamboo Society 7(1–2): 1–15.

S. Dransfield

Schizostachyum iraten Steudel

Syn. pl. glumac. 1: 332 (1854).

GRAMINEAE

$2n$ = unknown

Synonyms *Schizostachyum biflorum* McClure (1936).

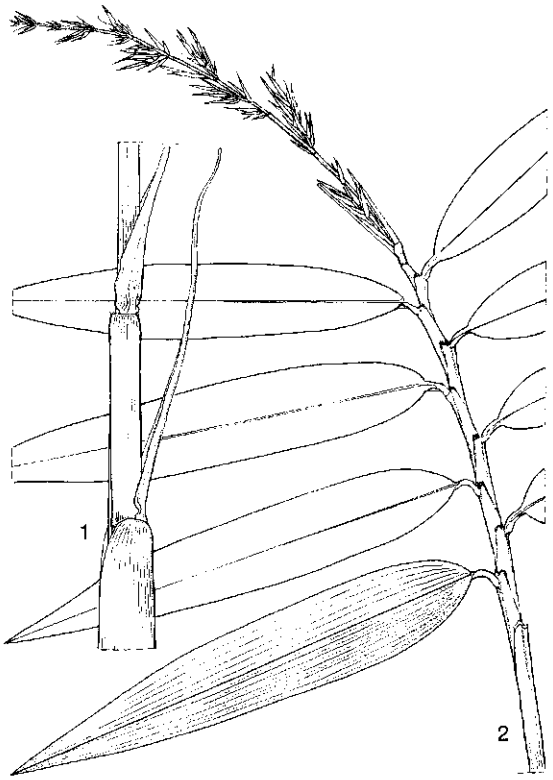
Vernacular names Indonesia: awi tamiyang, awi bunar (Sundanese), pring wuluh (Javanese).

Origin and geographic distribution *S. iraten* is native in Java, Sumatra and Bali. Occasionally it has been introduced or planted elsewhere, e.g. in Bukit Lagong, FRIM Arboretum, Kepong, Peninsular Malaysia.

Uses Culms of *S. iraten* are used for fishing rods and to make blowpipes and flutes.

Production and international trade Production and trade of *S. iraten* products are mainly local. No statistics are available.

Description Densely tufted, sympodial bamboo. Culm erect with drooping tip, 6–10 m long, 2–5 cm in diameter, wall 3–7 mm thick; internodes of the midculm 70–120 cm long, whitish green and covered with short appressed pale hairs when young, becoming pale to light green with a conspicuous whitish ring below the nodes; nodes prominently swollen. Branches arising from midculm nodes upward, slender, usually subequal. Culm sheath 20–28 cm × 9–17 cm, truncate, persistent, subrigid, lemon-green often tinged with light pink, becoming stramineous, bearing pale brown hairs and with many prominent veins; blade narrowly lanceolate, tapering to a long tip, 11–30 cm × 10–15 mm, erect first, later reflexed or spreading, light green, deciduous, glabrous but hairy adaxially especially near the base; ligule 3 mm long, serrate; auricles short, about 7 mm long, with bristles. Young shoots pale green. Leaf blade lanceolate or linear-lanceolate, 15–45 cm × 1.5–9 cm, usually glabrous; sheath glabrous; ligule very short; auricles short with long bristles. Inflorescences usually terminating leafy branches, 10–26



Schizostachyum iraten Steudel – 1, culm leaves; 2, flowering branch.

cm long, with clusters of pseudospikelets at the nodes 1–3 cm apart; spikelet cylindrical, 1.7–2.5 cm long, slender, glabrous, consisting of 1–2 perfect florets and a rachilla extension bearing a rudimentary floret. Caryopsis not known.

Growth and development A 3-year-old clump of *S. iraten* in East Java contained 40 culms, however, a mature clump may contain up to 100 culms. A mature clump in the botanical garden in Bogor produces young shoots and flowers all the year round.

Other botanical information Pseudospikelets fall off as soon as they reach maturity, therefore mature fruits have rarely been found. In Peninsular Malaysia, *S. iraten* has never been found flowering.

S. iraten is closely related to *S. lima* (Blanco) Merrill (from the Philippines to New Guinea) and *S. jaculans* Holttum (Peninsular Malaysia).

Ecology In Java, *S. iraten* can be found in scrub vegetation, disturbed forest, village groves, and secondary hill forest, up to 600 m altitude. It nearly always occurs as scattered specimens, but is sometimes rather common (e.g. at the foot of mount Salak in West Java).

Agronomy *S. iraten* is also cultivated in Java, although rarely, but no agronomic information is available. There are no reports of diseases and pests.

Genetic resources and breeding There are no germplasm collections or breeding programmes for *S. iraten*.

Prospects The future of *S. iraten* is in danger. In Java, its occurrence in the wild is threatened with extinction and germplasm collection is urgently needed.

Literature |1| Dransfield, S., 1983. Notes on Schizostachyum (Gramineae–Bambusoideae) from Borneo and Sumatra. Kew Bulletin 38: 332. |2| Monod de Froideville, C., 1968. Schizostachyum Nees. In: Backer, C.A. & Bakhuizen van den Brink, R.C (Editors): Flora of Java. Vol. 3. Wolters–Noordhoff, Groningen, the Netherlands. pp. 639–640.

S. Dransfield

Schizostachyum jaculans Holttum

Kew Bulletin 1953(4): 494 (1953).

GRAMINEAE

$2n$ = unknown

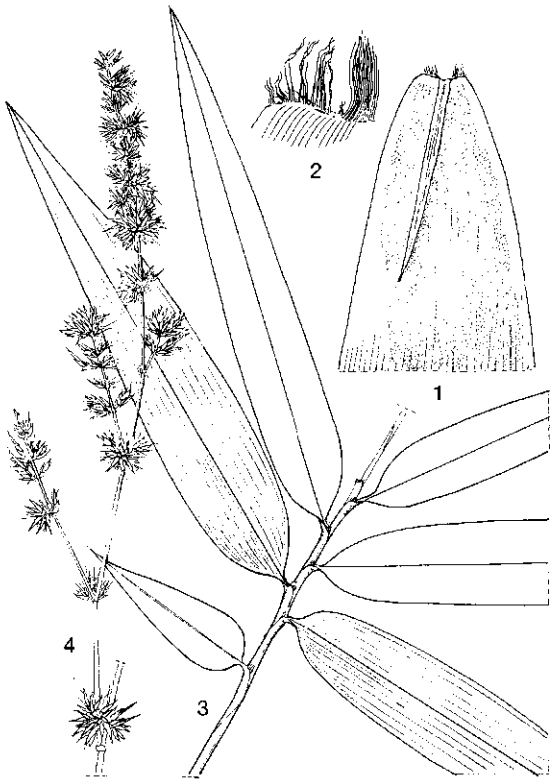
Vernacular names Peninsular Malaysia: buloh sumpitan, buloh temiang, buloh kasap.

Origin and geographic distribution The origin of *S. jaculans* is not known. It is widely planted throughout Peninsular Malaysia, but it probably occurs wild in the northern parts.

Uses The culms of *S. jaculans* are used to make blowpipes. Two internodes are very carefully joined and then put into a stronger tube made from a larger part of the culm. In Kepong (Malaysia) this bamboo is also used for soil stabilization and erosion control on forest roads.

Production and international trade Production and trade of culms of *S. jaculans* are only local and no statistics are available.

Description Densely tufted, sympodial bamboo, forming a compact clump. Culm slender, 6–10 m tall, 2–4 cm in diameter, wall 2 mm thick, erect with long pendulous tip, dull green; internodes 70–100(–125) cm long, covered with appressed pale hairs, glabrous when older, with white waxy ring below the node; nodes without prominent girdle. Branches arising from midculm nodes up-



Schizostachyum jaculans Holttum – 1, culm leaf (abaxial side); 2, part of top of culm sheath with auricle bristles; 3, leafy branch; 4, flowering branch.

ward, all more or less of equal size. Culm sheath 20–30 cm × (3–)9–15 cm, narrowest at truncate top, yellow-green, becoming stramineous, covered copiously with easily detached light brown hairs, junction with blade slightly curved; blade narrowly lanceolate, tapering to a fine long tip, 15–26 cm × 7–10 mm, erect first, later deflexed, when young densely covered with light brown hairs adaxially; ligule short, barely 2 mm long, fringed with fine bristles; auricles absent, replaced by long bristles. Young shoots pale green. Leaf blade 14–38 cm × 2.5–7.5 cm, in flowering branches 7–9 cm × 1 cm, glabrous above, pubescent below; sheath glabrous or with pale hairs along the margins; ligule very short; auricles very short, bearing slender bristles 4–10 mm long. Inflorescences terminating almost leafless branches, 9–17 cm long, consisting of dense tufts of pseudospikelets at the nodes 1–4 cm apart; spikelet cylindrical with pointed tip, about 17 mm long, glabrous, usually without a rachilla extension, containing only one perfect floret. Caryopsis not known.

Growth and development Young shoots are produced almost all the year round. Contrary to most other species in the genus *Schizostachyum*, *S. jaculans* very seldom flowers. In most species of *Schizostachyum* the inflorescences terminate leafy branches and are present in almost all culms of a clump. In *S. jaculans* however, inflorescences are usually found on almost leafless branches on only some of the culms in a clump.

Other botanical information In Peninsular Malaysia, another bamboo, *Kinabaluchloa wrayi* (Stapf) K.M. Wong, is reputed for its long internodes (up to 2 m) from which blowpipes are made. They are said to be superior to those of *S. jaculans* because being made from one internode only.

Ecology *S. jaculans* is usually cultivated in lowland Peninsular Malaysia, up to 200 m altitude.

Agronomy Although *S. jaculans* is widely cultivated in Peninsular Malaysia, its agronomic aspects have not been reported. It can be successfully propagated by planting offsets of one-year-old culms. There are no reports of diseases and pests.

Genetic resources and breeding There are no known germplasm collections and breeding programmes for *S. jaculans*. It is found in some botanical gardens, e.g. in the FRIM Arboretum, Kepong near Bukit Lagong (Peninsular Malaysia) and in the Singapore Botanic Garden.

Prospects It can be expected that economically, *S. jaculans* will remain a rather unimportant bamboo unless other applications can be developed. For this, more research is needed. Germplasm collection is nevertheless recommended.

Literature [1] Holttum, R.E., 1953. A Malaysian blow-pipe bamboo. Kew Bulletin 1953: 493–496. [2] Holttum, R.E., 1958. The bamboos of the Malay Peninsula. The Gardens' Bulletin, Singapore 16: 40–42.

S. Dransfield

Schizostachyum latifolium Gamble

Ann. Roy. Bot. Gard. Calcutta 7: 117 (1896).
GRAMINEAE
$2n$ = unknown

Synonyms *Schizostachyum longispiculatum* (Kurz ex Munro) Kurz sensu Holttum (1870), *Ochlandra ridleyi* Gamble (1896), *Schizostachyum ridleyi* (Gamble) Holttum (1947).

Vernacular names Brunei: buluh lacau (Iban). Indonesia: buluh suling (North Sumatra). Malaysia: buloh engkalad (Iban, Sarawak), buloh pisa (Bedayuh, Sarawak), buloh pelupu (Kadazan, Sabah). Singapore: buloh kasip.

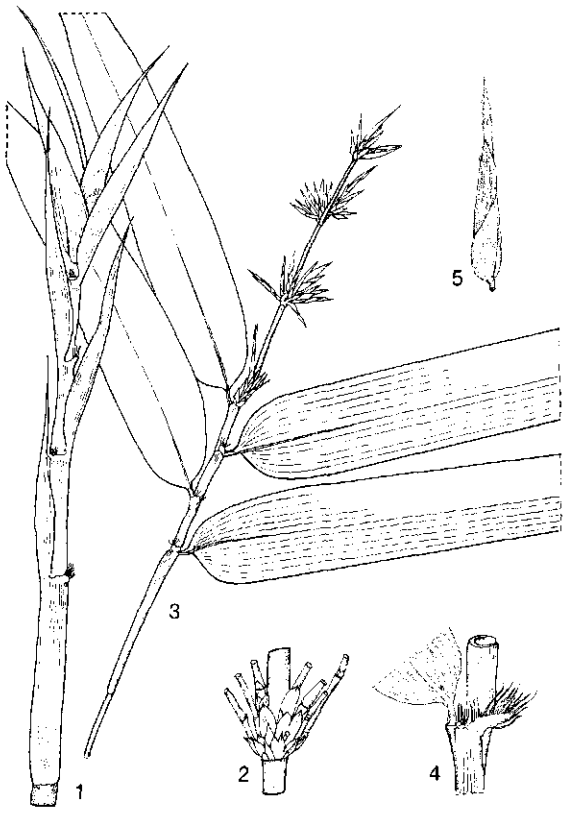
Origin and geographic distribution *S. latifolium* is native and widespread in Borneo, Peninsular Malaysia and Sumatra. It is also occasionally planted in villages.

Uses The culms of *S. latifolium* are used in Sabah to make fine woven baskets ('seraung') and in Sarawak to make blowpipes, tobacco containers (part of internode, carved in low relief), baskets and other ornamental woven objects such as mats.

Production and international trade The production and trade of *S. latifolium* products are mainly local and no statistics are available. Cultivation is only small-scale.

Properties In general, culms of *Schizostachyum* spp. are easily split but not easily split further into strips. Culms of *S. latifolium* however, can be split into fine strips which are suitable to be woven into very fine baskets.

Description Open tufted, sympodial bamboo. Culm erect with long arching tips, 3–6 m tall, 1–2.5 cm in diameter (reduced to 5 mm at the tip), wall 3–4 mm thick, light green, white hairy when young, becoming glabrous and smooth; internodes 35–80 cm long, whitish below the nodes; nodes not swollen. Branches many at each node, all subequal in size. Culm sheath 10–16 cm × 4–5 cm, light green turning yellow-brown when dry, long persistent, covered with appressed light brown hairs; blade 8–15 cm long, 14–17 mm wide near the base



Schizostachyum latifolium Gamble – 1, young shoot; 2, midculm branch complement; 3, flowering branch; 4, base of leaf; 5, pseudospikelet.

but only 5–10 mm wide at the junction with the sheath, tapering to the tip with rolled edges, erect first, later deflexed, glabrous but hairy adaxially near the base; ligule very short, entire; auricles prominent, 5–15 mm × 3–6 mm, extending laterally as narrow free lobes 5 mm beyond the base of attachment, with bristles 5–10 mm long along the edge. Young shoots light green. Leaf blade 12–30 cm × 2.5–5.5 cm, base usually rounded, glabrous, pale to light green; sheath glabrous; ligule very short, entire, bearing long bristles; auricles prominent, 4–5 mm long with bristles up to 12 mm long. Inflorescence terminating leafy branches, 20–30 cm long, bearing groups of pseudospikelets at the nodes; spikelet slender, 2–3 cm long, containing one perfect floret and a rachilla extension bearing a rudimentary floret. Caryopsis not known.

Growth and development In mature clumps, young shoots and inflorescences are produced all the year round. Mature fruits are rarely found.

Other botanical information *S. latifolium* is often confused with *S. blumei* Nees because both species possess large leaves and long pseudospikelets. In the field they can usually be distinguished by the colour of the culms and the leaves: light green in *S. latifolium*, dull or dark green in *S. blumei*.

Ecology *S. latifolium* grows scattered in tropical lowland up to 1000 m altitude. It is found in various habitats: in forest along rivers, forest edges, secondary forest and wasteland by roadsides.

Agronomy Although *S. latifolium* is often cultivated in its native area, nothing is known about its agronomic aspects. There are no reports of diseases and pests.

Genetic resources and breeding A small germplasm collection of *S. latifolium* is present in Sabah (Malaysia) at the Agricultural Station in Ulu Dusun. More accessions are needed. There are no breeding programmes.

Prospects The prospects for *S. latifolium* are promising because of its suitability to be split into fine strips which can be woven into very fine wares in cottage industries. To improve possibilities for local industries, aspects such as ecological requirements, propagation and cultivation methods should be investigated in more detail. Cultivation on larger scale is recommended because, although widespread, *S. latifolium* does not occur abundantly.

Literature |1| Dransfield, S., 1983. Notes on Schizostachyum (Gramineae–Bambusoideae) from Borneo and Sumatra. Kew Bulletin 38: 331. |2| Dransfield, S., 1992. The bamboos of Sabah. Sabah Forest Records No 14. Forestry Department, Sabah, Malaysia. pp. 62–63. |3| Holttum, R.E., 1958. The bamboos of the Malay Peninsula. The Gardens' Bulletin, Singapore 16: 48–49.

S. Dransfield

Schizostachyum lima (Blanco) Merrill

Amer. Journ. Bot. 3: 62 (1916).

GRAMINEAE

$2n$ = unknown

Synonyms *Bambusa lima* Blanco (1837), *Schizostachyum hallieri* Gamble (1910).

Vernacular names Indonesia: buluh toi (Moluccas). Malaysia: sumbiling (Sabah: Murut, Dusun). Philippines: anos (Tagalog), bagakai (Bisaya), sumbiling (Tagbanua).

Origin and geographic distribution *S. lima* is native to the Philippines, Borneo, Sulawesi, the

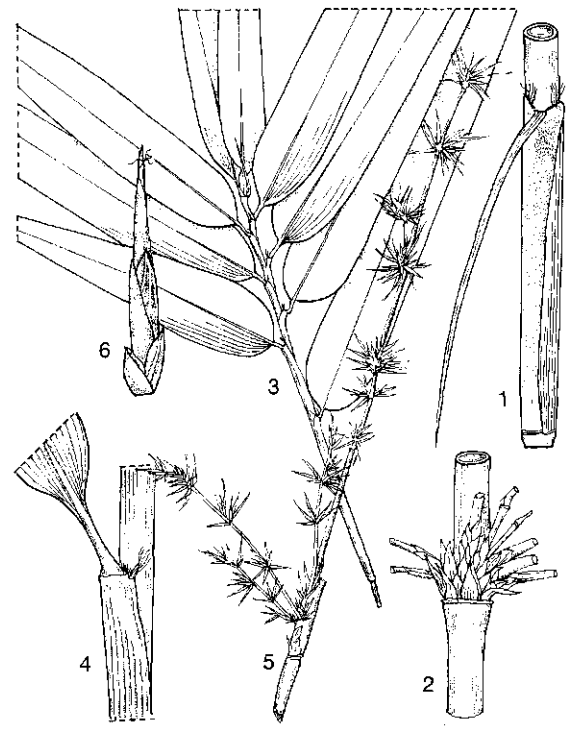
Moluccas, New Guinea and the Solomon Islands. In New Guinea it is often also cultivated.

Uses The specific epithet 'lima' is derived from Greek and means file, alluding to the rough surface of the culm, which was used for smoothing bronze in the Philippines. In the Philippines the culms are also used as material for housing, to make bamboo mattings ('sawali') and other woven wares, to make musical instruments and fishing rods. Young shoots are eaten as a vegetable. In Sulawesi the culms serve to make flutes and they are also flattened to use for flooring. In Ternate the long internodes are often used as containers for molasses which is produced on a small scale from sugar cane. In Sabah and Sarawak pieces of the internodes are used as tobacco containers, usually carved with a beautiful low relief; the culms are also used to make spears. In New Guinea the culms are often used as walls, sometimes after being flattened and woven into sheets, and also for bow strings.

Production and international trade In its native area *S. lima* is produced and traded mainly local. Its economic importance at village level is considerable, but no statistics are available. There are no known commercial plantations.

Properties The dimensions of the fibres in the culms of *S. lima* are approximately: length 1.67 mm, diameter 22 µm, lumen diameter 4 µm, wall thickness 9 µm. The very tough fibre bundles in the culm wall can easily be separated. Green culms have an average moisture content of 43%–117% (decreasing from bottom to top). Specific gravity is 0.54. The modulus of elasticity is 10 100 N/mm^2, the modulus of rupture 23.7 N/mm^2 and the compression strength parallel to grain 41.3 N/mm^2.

Description Densely tufted, sympodial bamboo. Culm erect with drooping tip, 7–10(–13) m tall, diameter 2–4 cm, wall 2 mm thick, rough, hairy when young but becoming glabrous, green; internodes 30–100 cm long, when young covered with white waxy powder. Branches many at each node, subequal. Culm sheath 18–30 cm × 8 cm, green when young, covered with brown to dark brown hairs, middle of top recessed at attachment of blade; blade 13–25 cm × 6–12 mm, erect first, then deflexed, hairy adaxially, especially near the base; ligule short, with slender bristles 3 mm long; auricles not prominent, bearing curved bristles up to 8 mm long. Leaf blade 19–30 cm × 3.5–7 cm, glabrous above, glabrescent below; sheath glabrous; ligule short, irregularly toothed; auricles short with long bristles. Inflorescence up to 20 cm long, terminating leafy branches or borne on short leafless branches; pseudospikelets in groups of few to several at each node of the flowering axis; spikelet 12–15 mm long, slender, glabrous, one-flowered with a rachilla extension bearing a rudimentary floret (sometimes absent). Caryopsis has not been described.



Schizostachyum lima (Blanco) Merrill – 1, part of culm with culm leaf; 2, midculm branch complement; 3, leafy branch; 4, base of leaf; 5, flowering branch; 6, pseudospikelet.

Growth and development Hardly any information is available on growth and development of *S. lima*. Three-year-old clumps contain on average 150 culms. At maturity, culms and leaves turn from a fresh green to a dull green colour. Culms have their maximum diameter 2 m above ground level. Sporadic flowering occurs regularly, but gregarious flowering has never been reported.

Other botanical information *S. lima* may be confused with *S. lumampao* (Blanco) Merrill, native in the Philippines, from which it can be distinguished by its much longer internodes. *S. lima* is closely related to *S. iraten* Steudel from Java and *S. jaculans* Holttum from Peninsular Malaysia, by having a narrow, long, deflexed blade of the culm sheath. It differs from *S. iraten*

in having one-flowered pseudospikelets, and from *S. jaculans* by its acuminate palea.

Ecology *S. lima* grows in the lowland tropics up to 700 m altitude. It can be found growing wild in forest, forest margins, along rivers or river banks, or spontaneously on roadsides, wasteland or near villages. It requires relatively moist soil conditions.

Agronomy So far, *S. lima* is only propagated by seedlings collected from natural stands and by rhizome cuttings (offsets). Cuttings with rhizome part, one-year-old culm portion (1 m tall) and roots are planted during the rainy season, at 5 m × 5 m, either directly or after 0.5–1 year in a nursery. Until fully established, young plants require regular watering. There are no reports of damage caused by diseases or pests. The culms are resistant to fungal decay. Plants with shorter internodes were more susceptible to insect infestation. Depending on the end use, culms can be harvested when 1 year old or older. They are cut close to the ground, preferably during the dry season (in the Philippines from November to May). Most harvesting is done from natural populations. In New Guinea small-scale cultivation around villages is common. Average green weight of the culms is 2.7 kg, of the branches 0.4 kg, of the leaves 0.3 kg. In the Philippines, bamboo mattings are impregnated with a preservative (absorbing 8 kg/m^3) when intended for indoor use.

Genetic resources and breeding No germplasm collections or breeding programmes are known to exist for *S. lima*.

Prospects Because of its long internodes, and its easily separated tough fibre-bundles, *S. lima* is a very useful bamboo, although it is possibly undervalued at present. More research is needed on botanical, agronomic and economic aspects. Germplasm collection is strongly recommended.

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C.A. Roxas & S. Dransfield

Schizostachyum lumampao (Blanco) Merrill

Amer. Journ. Bot. 3: 65 (1916).

GRAMINEAE

$2n$ = unknown

Synonyms *Bambus lumampao* Blanco (1837).

Vernacular names Philippines: buho, lumampao (Tagalog), bagakan (Bisaya).

Origin and geographic distribution *S. lumampao* is native to the Philippines and occurs extensively in the Provinces of Pangasinan, La Union, Ilocos Norte, Ilocos Sur, Leyte and on the Islands of Panay and Basilan. It is cultivated occasionally.

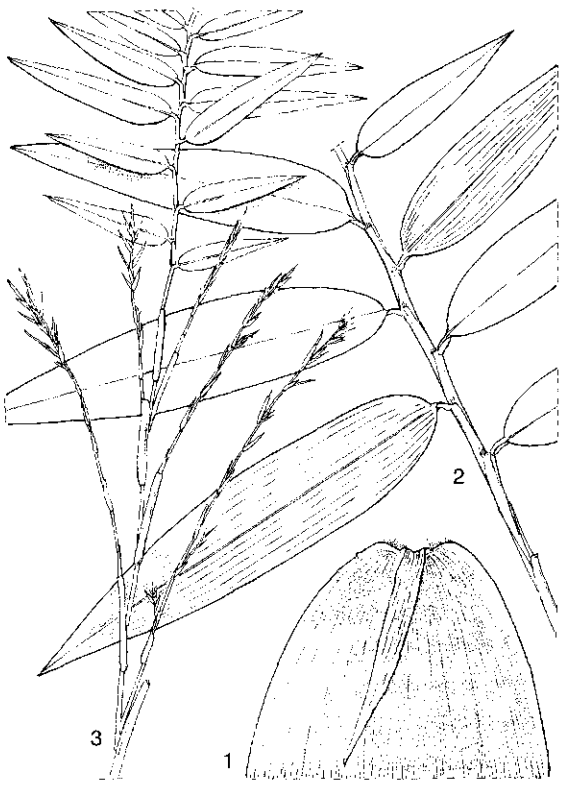
Uses The culms are widely used in making bamboo matting known as 'sawali', a material woven from thin strips, which is variously used in rural areas. They are also commonly used to make baskets, fences, spears, fish pens, flutes, handicrafts and for many other purposes, including constructions, plybamboo panels and paperpulp.

Production and international trade *S. lumampao* is one of the economically important bamboos in the Philippines. It grows extensively in natural stands but there are no large-scale plantations. Its exploitation is generally unregulated and no economic or production statistics are available. Consumption and trade are mainly local in rural areas. In the northern Philippines a processing plant has been established to make plybamboo, utilizing natural stands.

Properties Fibres in the culm of *S. lumampao* have the following average dimensions: length 2.42 mm, diameter 14 µm, lumen diameter 6 µm, wall thickness 4 µm. The density of green *S. lumampao* culms is 460 kg/m^3. Shrinkage from green to dry (16% moisture content) is about 19% radial and 6% tangential. For green culms (moisture content 174%) the modulus of elasticity is 6120 N/mm^2, modulus of rupture 35.9 N/mm^2, compression strength parallel to grain 30.2

N/mm^2. The chemical composition of the culm is approximately: holocellulose 60–66%, pentosans 20.5–21.5%, lignin 20.5%, ash 9.5%, silica 6.5–7.5%; the solubility in hot water is about 5%, in alcohol-benzene 1–5%, in 1% NaOH 20–30%.

Description Densely tufted, sympodial bamboo. Culm erect to ascending, 10–15 m tall, 4–8 cm in diameter, wall 4–5(–10) mm thick; internodes 25–50(–80) cm long, glabrous, green; nodes oblique. Branches several to numerous at the upper nodes. Culm sheath 24–26 cm long, up to 33 cm wide at the base, persistent, covered with yellowish, sharp hairs; blade lanceolate, 9 cm × 1.9 cm, reflexed, shortly pubescent on both surfaces, hairs mostly deciduous; ligule very short, minutely ciliate; auricles not distinct. Leaf blade linear-lanceolate, 30–36 cm × 2.5–3.0 cm; sheath glabrous; ligule very short, dentate, glabrous to puberulent; auricles not distinct. Flowering branches arise at the upper nodes, bearing groups of pseudospikelets at their nodes; spikelet linear-lanceolate, about 15 mm × 1.5 mm, glabrous, comprising 2 empty glumes and one fertile floret. Caryopsis oblongoid, 6–8 mm × 1–1.5 mm, brown.



Schizostachyum lumampao (Blanco) Merrill – 1, culm leaf (abaxial side); 2, leafy branch; 3, flowering branch.

Growth and development Young shoots emerge during the rainy season and develop to their full height in 4–6 months. Culms become mature in 1–2 years; they reach their maximum diameter at 5 m height. A healthy clump produces several young shoots annually, up to about 10% of the number of mature culms. The number of culms per ha in natural stands averages about 9000, but can be as high as 25 000 in dense stands. The dry weight rate of the above ground parts of a culm is approximately 89% for the culm, 7% for the branches, 4% for the leaves. In the Philippines, flowering is from January to May, fruiting from June to July.

Ecology *S. lumampao* grows naturally in thickets and secondary forest at low and medium altitudes up to 1500 m. Sometimes it nearly exclusively occupies large areas (e.g. in Bataan, Zambales, Cagayan valley). It grows best on a well-drained sandy loam or clay loam found on forested hills with pH 5.0–6.5, at average temperature of 28–32°C and annual rainfall of 1900 mm.

Propagation and planting *S. lumampao* can be propagated by seed, rhizome and culm cuttings. Seed is not commonly available; it should be sown immediately in plastic bags in the nursery and transplanted after 5–6 months when seedlings are 30–60 cm tall. Rhizome cuttings (part of clump with roots, rhizome part and culm part) survive better than culm cuttings. Culm cuttings (2-node portions) can be taken from 0.5–2-year-old culms, kept in the nursery for 3–5 months and planted out in the field in the rainy season. Recommended planting distance is 3 m × 3 m.

Husbandry For 2–3 years after planting, weeding is necessary about 2–3 times a year; cut weeds can be used as mulch. Until young plants are well established, watering is necessary if rainfall is insufficient. For optimum growth, especially on poor soils, the application per ha of 20–30 kg N, 10–15 kg P, 10–15 kg K, 20–30 kg Si and organic manure is recommended. The fertilizer may be applied in two portions, the first during planting, the second 4 months later. During the first 2 years, regular maintenance of the plantation is recommended. For management of natural stands, an initial moderate thinning (removing culms older than 2 years) is recommended.

Diseases and pests No serious diseases or pests have been reported for *S. lumampao*. The leaves can be attacked by tip blight disease (*Ascochyta* sp.) and by a leaf spot (*Leptostroma* sp.).

Harvesting In the Philippines, *S. lumampao* culms can best be harvested in the dry season (January–May). In a newly established plantation, harvesting may start 5 years after planting. Most harvesting, however, is done from natural stands. It is recommended to harvest only culms 3 years old or older in a 2-year-felling cycle, leaving about 40% of the standing mature culms evenly spaced in the clump.

Yield It has been estimated that dense natural stands of *S. lumampao* can yield 2500 culms/ha per year, which is 15 t on a dry-weight basis. The total dry weight of an average standing crop in natural stands is estimated at 59–73 t/ha (culms 55–65 t, branches 3–5 t, leaves 1–3 t).

To produce 50 t pulp (for paper) per day, it is estimated that about a minimum of 4000 ha planted with *S. lumampao* is necessary; pulp yield is on average about 43% of the culm yield.

Handling after harvest Traditionally, harvested culms are air dried in the sun or in the shade for about 1 month. Kiln drying takes about 9 days. *S. lumampao* is classified in the Philippines as moderately resistant to deterioration. Traditional methods are often used to preserve culms. These include soaking, curing, smoking and whitewashing. For industrial use, several chemical preservation methods are possible.

Genetic resources and breeding Germplasm collections of *S. lumampao* are available in the Philippines in the botanical garden of the University of the Philippines at Los Baños and in the bambuseta of Baguio, Los Baños (Luzon) and Davao (Mindanao). There are no breeding programmes.

Prospects The prospects for *S. lumampao* are very promising. The reasonably durable culms are widely used and are suitable for industrial application. With a growing demand for culms, large-scale plantations should be established. Research should focus on large-scale propagation methods, cultivation methods, management of natural stands and ecological requirements.

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F.D. Virtucio & V.O. Sinohin

Schizostachyum zollingeri Steudel

Syn. pl. glumac. 1: 332 (1854).

GRAMINEAE

$2n$ = unknown

Synonyms *Schizostachyum chilianthum* Kurz sensu Gamble p.p., not *Chloothamnus chilianthus* Büse.

Vernacular names Indonesia: bambu lampar (East Java), buluh telor, buluh nipis (Sumatra). Malaysia: buloh nipis, buloh dinding, buloh telor (Peninsular). Thailand: phai-miangfai.

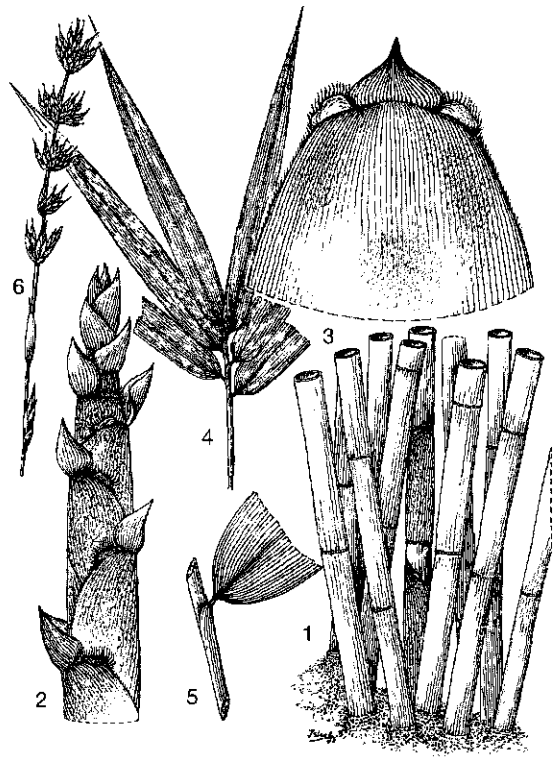
Origin and geographic distribution *S. zollingeri* occurs naturally in Indonesia (Java, Sumatra), Peninsular Malaysia, Vietnam and southern Thailand. In Peninsular Malaysia it is also often cultivated in villages, especially in Perak and Perlis, in Indonesia (Java) in the eastern part of East Java.

Uses The culms are commonly split and woven into screens which serve as walls, floors, roofs, mats and for handicrafts. They are also used for weaving baskets and fishing screens and to make rafts, small implements and containers to prepare the traditional rice food ('lemang') in Malaysia. Young shoots are edible but not commonly eaten. *S. zollingeri* is sometimes planted for ornamental purposes.

Production and international trade Production, consumption and local trade are probably considerable, especially in rural areas, but no statistics are available. The bamboo screens of *S. zollingeri* are very popular in housing and constructional work for parts that are not meant to carry weight. The only cultivation is small-scale.

Properties The woven screens of split *S. zollingeri* culms are strong, flexible and versatile, but no figures on strength are known. The following chemical data for the culms have been reported: holocellulose 68.8–74.3%, lignin 20.1–22.7%, sugar 0.03–0.05%, starch 0.013–0.016%; the solubility in cold water is 2.7–5.4%, in hot water 3.7–6.5%, in alcohol-benzene 2.2–2.7% and in 1% NaOH 21.8–26.8%. The culms are reported as promising as a raw material for paper and pulp.

Description Densely tufted, sympodial bamboo. Culm stiffly erect with slender drooping whip-like tips, (4–)10–15(–19) m tall, (1.5–)4.5–7.0(–10.0) cm in diameter, wall thickness 4.6–13.9 mm (base), 1.5–3.3 mm (apex), when young with short appressed pale hairs and a distinct pale white waxy zone just below each internode; internodes 46–80 cm long. Branches arising from the midculm nodes upward, comprising 25–30 slender subequal branches at each node. Culm sheath with rounded top, up to 15 cm long, stiff, long persistent, light brown or flushed with purple near top when young, the back more or less covered with appressed shiny dark brown to black hairs; blade rigid, erect, broadly triangular, 7–9 cm × 7–9 cm (lower ones wider than long), strongly convex, stiffly pointed, flushed with purple when young, upper surface covered with pale hairs; ligule up to 4 mm long, edge smooth or covered with short hairs; auricles up to 7 mm or more tall, spreading laterally beyond the width of the top of the sheath or sometimes smaller, margins with very close, curved, slender bristles. Young shoots light to dark brown. Leaf blade oblong-lanceolate, (12–)20–35(–40) cm × (1–)2–4(–6.5) cm, lower surface glabrous or slightly hairy, more or less rough to the touch, upper surface smooth; sheath hairy when young; ligule short; auricles usually well-developed, sometimes spreading laterally, brown, bearing many slender bristles. Inflorescence consisting of dense tufts of pseudospikelets 1–3 cm apart at the nodes on the rigid distal part of a leafy branchlet (or, in gregarious flowering, on long leafless branches); spikelet 15–20 mm long, comprising 2 basal glumes, 1 perfect floret and a rachilla extension bearing a small rudimentary floret. Caryopsis ellipsoidal, c. 6 mm × 3.5 mm, with persistent style of 9–10 mm, dark green to purplish.



Schizostachyum zollingeri Steudel – 1, habit; 2, young shoot; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

Growth and development About 4 days after sowing the coleorrhiza and primary root emerge from the base of the grain, followed by elongation of the primary root and emergence of the coleoptile. By the end of the 2nd week, shoot segmentation has become distinct with elongation of the shoot, and the first leaf has fully expanded. In the 6th week the 5th and 6th leaves develop and the culm is about 10 cm tall.

The rhizome is gradually built up by the successive emergence of new culms from the bases of preceding ones. Culms that emerge become pro-

gressively larger until they are of full size in mature clumps, a phase reached after some years. Many of the earlier culms have died by then.
Culm cuttings take about 1 year to establish and produce full size culms after 3 years.
Shoots of natural stands emerge above the ground during the onset of the rainy season and develop to their full height in 5–6 months. The lateral branches develop subsequently. A culm becomes mature in 3 or more years. A healthy mature clump has 50–70 culms.
S. zollingeri flowers sporadically every year in practically all areas. Annual gregarious flowering during the dry season and over a 2–3 month period is reported from the northernmost part of Peninsular Malaysia (Mata Air district). In sporadic flowering, fruit formation is rare, after gregarious flowering, fruits are abundant. During the flowering period, bees (*Apis* sp. and *Trigona* sp.) were active between about 9:30–10:30 a.m. in northern Peninsular Malaysia and in East Java. After flowering and fruiting a culm dies but the rhizome remains alive and regenerates new culms.

Other botanical information *S. zollingeri* is a variable species. In Java the culms have a smaller diameter (1.5–5 cm) and in the florets the lemmas and lodicules are smaller. Also in Peninsular Malaysia culm diameter decreases in specimens collected from north to south. Young culms can be conspicuously glaucous or less so and bear sparse pale hairs. The culm sheath auricles are sometimes rather small. In general, *S. zollingeri* is easy to recognize by its drooping whip-like culm tips, the presence of the dark shiny hairs on the culm sheaths and the peculiar shape of the blades of the culm sheaths (inflated, 1–3 times as long as wide).

Ecology In the wild, *S. zollingeri* can be found in primary forest (northern Peninsular Malaysia), but more often in disturbed areas (forest edges, forest clearings), normally between 50–200 m altitude, but up to 400 m altitude is possible. It will grow in any type of well-drained soil, preferring sandy loams or clay loams. In Peninsular Malaysia *S. zollingeri* is often growing together with *Gigantochloa ligulata* Gamble. In East Java, *S. zollingeri* is resistant to long droughts.

Propagation and planting *S. zollingeri* can be propagated by seed and by rhizome or culm cuttings. Seed should be sown as soon as possible after harvesting but a short period of storage is possible (at 12–14°C, moisture content about 15%: germination rate more than 80% after 1 month, more than 50% after 2 months). For large-scale planting, culm cuttings taken from the top and middle portions are commonly used and show nearly 100% survival. The propagules are raised in the nursery for about 5 months and transplanted in the field in the rainy season. They are planted in holes enriched with organic and chemical fertilizer at a spacing of 4–6 m × 4–6 m.

Husbandry Young plants require regular watering during the period of establishment and in that period are weeded twice a year. For 2 years after planting the clumps are thinned by removing poor culms. Fertilizer is applied to mature clumps in two doses, one before and one during the rainy season. For average soils, per clump 100–600 g NPK (15:15:15) per year is recommended.

Diseases and pests No disease or pest problems on *S. zollingeri* in the wild have been reported. In the nursery and at planting sites, however, leaf roller infestation may cause damage. This pest is the caterpillar of the butterfly *Pyrausta coclesalis* (*Pyralidae*). It can be effectively controlled by spraying with systemic insecticides.

Harvesting Culms are usually harvested all year round but mostly in the dry season (in Perlis, northern Peninsular Malaysia, from November to April). Culms should be 3 years old or older. Harvested culms are air-seasoned.

Yield A well-managed, mature clump can produce 5–8 culms/year, or, with 400 clumps, 2000–3200 culms/ha. A green culm weighs (2.0–)8.6 (–17.7) kg. Branch and leaf weight averages 5.2 kg (1.6–9.5 kg). Green culm production per year can be 17–27 t/ha.

Genetic resources and breeding In Lampung (Sumatra) a small germplasm collection of *S. zollingeri* is available. There are no breeding programmes.

Prospects The prospects for *S. zollingeri* are very promising because the strong flexible screens made from its culms are in great demand. Many aspects, however, still require investigation, e.g. reliable cultivation methods, management of wild and cultivated populations, fertilizer requirements, harvesting and post-harvest technology. More germplasm collection is urgently needed.

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Abd. Razak Othman

Thyrsostachys siamensis Gamble

Ann. Roy. Bot. Gard. Calcutta 7: 59 (1896).
GRAMINEAE
$2n$ = unknown

Synonyms *Thyrsostachys regia* (Munro) Bennet (1988).

Vernacular names Monastery bamboo, umbrella-handled bamboo (En). Indonesia: bambu jepang, bambu siam. Philippines: Thailand bamboo. Burma (Myanmar): tiyowa, kyaung-wa. Thailand: phai-ruak.

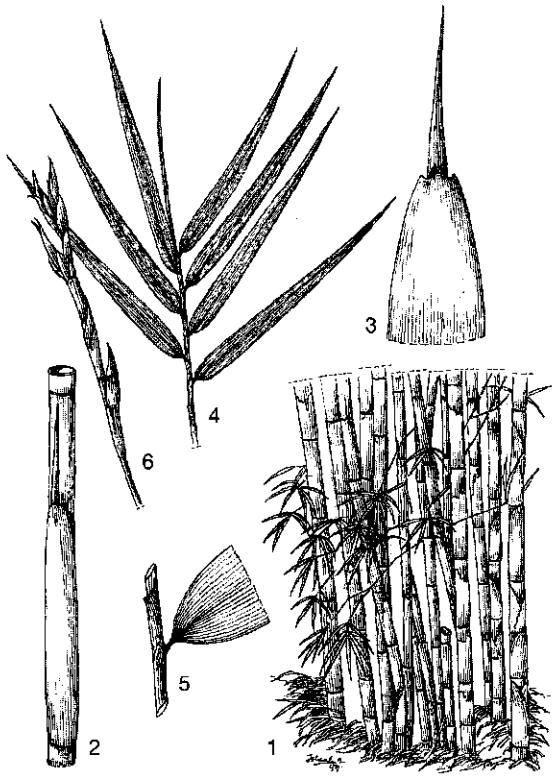
Origin and geographic distribution *T. siamensis* is native in Burma (Myanmar) and Thailand, where it occurs widely and often abundantly in pure stands. In many other tropical regions, especially in South-East Asia, it has been introduced and is cultivated widely as an ornamental and as wind-break.

Uses In its native area, *T. siamensis* is one of the most useful bamboos. The culms serve for house construction and general household uses, as well as raw material for cottage industries. In Thailand the culms are also widely used to make baskets, chopsticks, umbrella and broom handles, handicrafts, fishing rods and they serve as raw material for paperpulp and as fuel. Young shoots are consumed as a vegetable and considered as among the best bamboo shoots. Because of its elegant habit (compact clumps of outcurving slender culms bearing many small leaves on slender branches) *T. siamensis* is a popular ornamental plant. It is also planted in rows as wind-break.

Production and international trade In Thailand, *T. siamensis* is commercially one of the most important bamboos and is extensively exploited from natural stands. Annual production fluctuates between 30–40 million culms. In central Thailand the occurrence of *T. siamensis* as pure stands is estimated at 450 000 ha. In northern Thailand 100 000 ha occurs in mixed forest. In Lampang (Thailand), about 500 000 culms of *T. siamensis* are sold annually. Here, 6 chopstick and cocktail stick factories use 5000 t bamboo as raw material and 16 ceramic factories use 100 000 m^3 dry bamboo culm per year as fuel. In Kanchanaburi (Thailand) a paper mill uses culms of *T. siamensis* exclusively, producing about 10 t paper per day or 3500 t/year, consuming 5 million culms or about 9000 t (air dry). In 1985, 1986 and 1987 about 8350 t, 4250 t and 4500 t culms of *T. siamensis*, worth about US$ 55 000, 50 000 and 66 000 respectively, were exported to Europe, especially to Germany, United Kingdom and Italy. Harvesting of *T. siamensis* shoots from natural stands and selling to processing factories provides subsistence income to local people. In Phu Khieo district (Chaiyaphum Province, north-eastern Thailand) it is estimated that over 500 t of shoots are harvested annually. Steamed shoots are available in most local markets all year round. Shoots are also exported (e.g. to Japan).

Properties The fibres in the culms of *T. siamensis* are on average 3.14 mm long and 17.1 µm wide. The chemical composition of the culms is approximately: holocellulose 68%, lignin 24%, pentosans 17%, ash 2%; the solubility in hot water is about 5.7%, in alcohol-benzene 6.1%. Per 100 g edible portion, young shoots of *T. siamensis* contain approximately: water 89.5 g, protein 3.8 g, fat 0.3 g, carbohydrates 4.5 g, fibre 0,7 g, ash 1.0 g, Ca 12.8 mg, Fe 40.2 mg, P 0.2 mg, vitamin B_1 0.01 mg, vitamin B_2 0.09 mg and traces of vitamins A and C. The energy value is about 140 kJ/100 g. The 1000-seed weight is about 500 g.

Description Densely tufted, sympodial bamboo. Culm erect or with arching tips, 8–14 m tall, 2–7.5 cm in diameter, wall very thick, solid in lower part, smooth, greyish-green, usually covered with persistent old culm sheaths; internodes 15–30 cm long, bearing a white ring below the nodes; nodes not swollen. Branches arising from midculm nodes upwards, with many branches at each node of which the primary one dominant. Culm sheath 20–25 cm long, 10–20 cm wide near the base, narrowing up to 2.5 cm wide at the apex, persistent, pale to purplish-green turning stramineous and thin with age, covered with scattered, pale appressed hairs; blade narrowly lanceolate, 6–15 cm × 5–12 mm, erect, pubescent adaxially; ligule very short, shortly laciniate; auricles absent or very small. Young shoots pale to purplish-green. Leaf blade narrow, linear, 7–14 cm × 5–8 mm, pale green, usually glabrous; sheath striate, white hairy along the margins; ligule very short,



Thyrsostachys siamensis Gamble – 1, habit; 2, part of culm with culm leaf; 3, culm leaf (abaxial side); 4, leafy branch; 5, base of leaf; 6, flowering branch.

entire, ciliate; auricles absent or very short. Inflorescences borne terminally on leafy or leafless branches, consisting of a main branch and many thin branchlets bearing bracteate clusters of few pseudospikelets; spikelet about 17 mm long, comprising 1 empty glume, usually 2 perfect florets and a rachilla extension bearing a rudimentary floret. Caryopsis cylindrical, about 5 mm × 2.5 mm, surmounted by a yellowish, glabrous, soft, long beak.

Growth and development Seeds of *T. siamensis* germinate immediately after ripening and germination percentage is 90–95%. Stored at 25–30°C, at moisture content of 10% or 6%, seed remained viable for 3 months; after 6 months, germination percentage had dropped to 60% and 86%, after 9 months to 33% and 82%, after 15 months to 1.5% and 71% and after 21 months to 0% and 1% respectively. With storage at 2–4°C and at –5°C, with moisture content between 6–10%, seed remains viable for at least 27 months.

In natural populations *T. siamensis* produces young shoots during the rainy season (in Thailand mainly between May and July). In Thailand 'on' years with many new shoots, alternate with 'off' years with many fewer new shoots. Generally, more shoots are produced if rain is abundant. A clump is considered as good if it has 30 culms on average, but clumps may have up to 100 culms. In Thailand, a 3-year-old plantation of *T. siamensis* raised from seeds, produced on average 38 culms per clump with average diameter 1.4–2.3 cm, of which 28 culms per clump were harvestable on average.

Flowering of *T. siamensis* is sporadic and gregarious. In Thailand sporadic flowering is common, and usually occurs between November and February. Mature seed can be collected from February to April. After flowering, culms usually die. Gregarious flowering is rare and the flowering cycle is not known. In seasonal climates, *T. siamensis* is deciduous in the dry season.

Other botanical information Some doubts exist regarding the correct botanical naming of *T. siamensis*. It may be that the first validly published name for the species was *Bambusa regia* Thomson ex Munro (1868), but here the views of Gamble and Holttum are followed who consider *B. regia* as a dubious name.

Ecology The natural habitat of *T. siamensis* is a dry or semi-evergreen forest on poor soils. However it will grow on a wide range of soils, provided they are not waterlogged. Its growth is not much hampered by partial shading. In Thailand it grows in mixed deciduous and teak forest in the north and north-east and pure stands often occur in hill forest in the central part, at altitudes 300–400 m, with annual rainfall of 800–1000 mm.

Propagation and planting *T. siamensis* can be propagated by seed, rhizome cuttings and by tissue culture. Due to its common sporadic flowering, seed is always available. Propagation by rhizome cuttings (offsets) is most generally practised. The cuttings are taken from 1-year-old culms with rhizome part, roots and up to 1 m long culm part, planted in a nursery for 2–3 months and transplanted to the field in the rainy season. In general, 10 rhizome cuttings can be taken from a 5–6-year-old clump, retaining 4–5 one-year-old culms in the clump. Optimum planting distance for *T. siamensis* is 4 m × 4 m. Propagation by tissue culture is still experimental. Promising results were obtained by induction of multiple shoots from single seedlings.

Husbandry Weed control is necessary during

early establishment of plantations. Regular earthing up of clumps, annual application of 100 kg/ha NPK (15-15-15) fertilizer, or 600–900 kg/ha animal manure are recommended. It is very important to protect natural stands and plantations against fire and grazing.

Diseases and pests No serious diseases or pests have been reported for *T. siamensis*. Powder-post beetles and fungi can cause damage to harvested culms, although 3-year-old culms are considered relatively resistant.

Harvesting Preferably, 3–4-year-old culms are cut in a 3-year-felling cycle. One-year-old culms are left to produce new shoots and 2-year-old culms serve to support the clump. In Thailand, in the dry season one person can harvest about 1700 culms per month from natural stands, giving an income of 4500 Baht (225 US$) per month. In the rainy season about 1500 kg young shoots per month can be harvested, giving an income of 1500–6000 Baht.

Yield From natural stands, the average annual production in Thailand is estimated at 1500 culms/ha. In 'on' years, however, annual production may rise to 2500–3000 culms/ha (9–15 t/ha). No data are available on shoot production.
A plantation of *T. siamensis* starts to produce harvestable culms and shoots 3 years after planting. Profits can be made from the 4th–5th year onward by selling culms and young shoots. In the third year 1.5–2.5 t/ha of air-dried culms are produced.

Handling after harvest Culms are traditionally submerged for 10–20 days in running water to reduce starch and sugar contents, and subsequently cleaned, polished and dried. For furniture making, culms are fire cured, which requires much skill to avoid damage. Chemical preservation methods include boiling for 15–20 minutes at 95°C in a 0.2% sodium carbonate or 0.1% calcium hydroxide solution, or at 50–70°C in a 0.3% copper sulphate solution. For home consumption, young shoots are boiled or parched. For commercial purposes, young shoots are steamed and peeled within 24 hours after harvesting and stored in vacuum containers or canned, either sliced or whole.

Genetic resources and breeding No germplasm collections or breeding programmes are known to exist for *T. siamensis*.

Prospects The future of *T. siamensis* is bright: the demand for culms and young shoots is increasing. Promotion of *T. siamensis* cultivation is urgently needed, because of overexploitation of natural stands. Research should focus on proper cultivation methods and management of natural stands. Germplasm collection is urgently needed to conserve natural variability.

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S. Duriyaprapan & P.C.M. Jansen

3 Minor bamboos

Bambusa amahussana Lindley

GRAMINEAE

Vernacular names Indonesia: bambu nitu (Ambon).

Distribution Native in Ambon and Seram (Indonesia).

Uses The culm is often used as string or rope.

Observations Culm 2–3 m tall, often reclining, diameter 8 mm, thin-walled; internodes 13–18 cm long. Culm sheath pale hairy on the back; blade narrowly triangular, erect first then deflexed; ligule short; auricles small, bearing long bristles. Leaf blade 18–45 cm × 2.5–8 cm; auricles small with long bristles. Inflorescence usually terminating a leafy branch. Pseudospikelets flat, in groups of 3–6 at the nodes. Usually found on lowlands near the sea.

Selected sources 15.

Bambusa burmanica Gamble

GRAMINEAE

Vernacular names Burma (Myanmar): thaikwa. Thailand: phai-bongnam.

Distribution Native in Upper Burma (Myanmar), also found in Thailand and in Assam (India).

Uses In Thailand, culms are used in temporary constructions.

Observations Culm erect, 15–20 m tall, diameter 8–10 cm, thick-walled; internodes about 30 cm long. Culm sheath green, tinged with yellow along the margins, covered with dark brown to golden-brown hairs on the back; blade broadly triangular, erect; auricles relatively large, with long bristles. Leaf blade 25–30 cm × 3–5 cm. Inflorescence borne on leafless branches; pseudospikelets about 2 cm long, in groups of 2–5 at the nodes. *B. burmanica* is related to *B. tulda* Roxb. and *B. polymorpha* Munro by its large auricles of the culm sheath. In Burma (Myanmar) it is found on dry hill slopes. Potentially, it might also be of interest for other countries in South-East Asia.

Selected sources 12, 18.

Bambusa forbesii (Ridley) Holttum

GRAMINEAE

Vernacular names Indonesia: sasa, akoya, warire (Irian Jaya). Papua New Guinea: aku (Buang), hodzjima (Mumuni).

Distribution New Guinea, New Britain, Cape York Peninsula (Australia).

Uses In the highlands of Irian Jaya (Indonesia), culms are used for making arrow heads, water pipes and traditional handicrafts. In Morobe district (Papua New Guinea) local people use culms for casual drinking vessels.

Observations Densely tufted bamboo. Culm 4–5 m tall, erect first then drooping or leaning on nearby vegetation, diameter 3 cm at the base, relatively thin-walled; internodes up to 60 cm long. Culm sheath covered with pale hairs; blade broadly ovate with cordate base, spreading; auricles large with long bristles. Leaf blade 30–60 cm × 6–10 cm, base cordate. Inflorescence usually terminating a leafy branch; pseudospikelets flat, up to 10 mm long, several to many in a cluster at each node. Throughout New Guinea it is found from sea-level up to 1500 m altitude, on river banks, margins of disturbed lower montane forest and is common in low regrowth vegetation.

Selected sources 15.

Cephalostachyum mindorensis Gamble

GRAMINEAE

Vernacular names Philippines: bagto (Tagalog).

Distribution Mindoro and Luzon (Camarine Province).

Uses Culms are used for fences and household articles.

Observations Scrambling bamboo. Culm 6–8 m

tall, diameter 2–5 cm, relatively thin-walled; internodes 20–25 cm long. Leaf blade 20–30 cm × 2.5–4 cm. Inflorescence terminating a leafy or leafless branch; pseudospikelets slender, 6–8 mm long, many in a cluster at each node. The inclusion of this species in the genus *Cephalostachyum* should be investigated, because the structure of its inflorescences and pseudospikelets is very different from that of species in the Indian subcontinent.

Selected sources 19.

Cephalostachyum virgatum (Munro) Kurz

GRAMINEAE

Vernacular names Burma (Myanmar): waba. Thailand: pai hia.

Distribution Upper Burma (Myanmar). The occurrence of *C. virgatum* in Thailand is not certain.

Uses The culms are used for matting and various household utensils.

Observations Culm 6–7 m tall, thin-walled, Inflorescence borne on leafless branches; pseudospikelets slender, about 15 mm long, several to many at each node. In evergreen forests. The inclusion of *C. virgatum* in the genus *Cephalostachyum* is doubtful; potentially it is of interest for the rest of South-East Asia.

Selected sources 2, 12, 14, 18.

Dendrocalamus hamiltonii Nees

GRAMINEAE

Vernacular names Thailand: phai-nual-yai, pai-hok (North), waa-klu (Karen). Vietnam: manh tong nua. Laos: ko hoe, hôk.

Distribution From the foothills of the Himalayas (Nepal) to the northern part of Burma (Myanmar), Thailand, Laos, Vietnam.

Uses Culms are used for temporary constructions (houses, bridges) and various household utensils; split culms for making baskets and mats. Young shoots are widely consumed as a vegetable. The leaves are used as fodder.

Observations Large bamboo. Culm up to 25 m tall, diameter 10–20 cm, relatively thick-walled, greyish-white when young, becoming green at maturity. Culm sheath usually glabrous, with truncate top; blade ovate to lanceolate; auricles small, without bristles. Leaf blade 20–30 cm × 4–6 cm; ligule conspicuous; auricles not present. Inflorescence a large leafless branch, with ovoid pseudospikelets, arranged in semi-globular heads at the nodes. Growing wild in mixed forest, often cultivated in villages. *D. hamiltonii* is easily propagated by culm or branch cuttings. Seed is often available after sporadic flowering. Because of its edible young shoots, *D. hamiltonii* is potentially of interest for other South-East Asian countries.

Selected sources 2, 4, 12, 18, 20, 17.

Dendrocalamus hirtellus Ridley

GRAMINEAE

Vernacular names Malaysia: buloh kapor.

Distribution Native in Peninsular Malaysia (Johor, Kedah, Kelantan) and in Borneo (West Kalimantan).

Uses The culms are used for basketry.

Observations Culm up to 15 m tall, 8 cm in diameter, with pendulous tip, whitish and waxy when young. Culm sheath covered with white wax and pale to light brown hairs; blade spreading to reflexed; auricles curled, 15 mm in lateral extent, bearing bristles 25 mm long. Young shoots orange to yellowish, covered with pale hairs. Leaf blade 20–40 cm × 3–6 cm, lower surface velvet-hairy. Inflorescence on leafless branches; spikelet containing 1–2 florets. Caryopsis truncate with slightly hairy tip. Found in open ground or disturbed forest.

Selected sources 14, 24.

Dendrocalamus longispathus Kurz

GRAMINEAE

Vernacular names Thailand: phai-lammalok, mai-hokdam (North). Burma (Myanmar): waya, talagu.

Distribution Northern Thailand, Burma (Myanmar), Bangladesh and India.

Uses Culms are used for temporary constructions, furniture, and mats. Young shoots are edible.

Observations Culm up to 20 m tall, diameter 8–12 cm, wall 12 mm thick, glaucous green when young; internodes 25–60 cm long; nodes slightly swollen, bearing aerial roots. Culm sheath with dark brown hairs on the back; blade lanceolate, reflexed; ligule toothed with brown bristles; auricles membranaceous, bearing bristles along the edge. Leaf blade 20–30 cm × 1.5–3 cm. Inflorescence borne on leafless or leafy branches; pseu-

dospikelet up to 6 cm long. Caryopsis ovoid. Found in mixed and disturbed forest, on rather fertile soil and along riversides. Propagation by culm cuttings of 1-year-old culms gives the best results. Fibre length of the culm is 2.70 mm, diameter 15.02 µm, lumen diameter 3.39 µm. Potentially, *D. longispathus* is also of interest for the rest of South-East Asia.

Selected sources 12, 18.

Dinochloa Büse

GRAMINEAE

Major species and synonyms

- *Dinochloa scandens* (Blume) Kuntze. Synonyms: *Bambusa scandens* Blume, *Nastus tjankorreh* Schultes, *Dinochloa tjankorreh* (Schultes) Büse.
- *Dinochloa sublaevigata* S. Dransf.
- *Dinochloa trichogona* S. Dransf.

Vernacular names

- *Dinochloa* spp.: climbing bamboo (En).
- *D. scandens*: Indonesia: cankoreh (Sundanese).
- *D. sublaevigata*: Malaysia: buloh wadan (Sabah).
- *D. trichogona*: Malaysia: buloh wadan (Sabah).

Distribution *Dinochloa* comprises about 20 species, widely distributed in South-East Asia, from the Andaman and Nicobar Islands, southern Thailand, Peninsular Malaysia, Sumatra, to the eastern part of the Lesser Sunda Islands (Flores), with great diversity in Borneo, the Philippines and Sulawesi. *D. scandens* is found only in West Java; the records of its occurrence in other parts of South-East Asia (Peninsular Malaysia, Borneo, the Philippines) are primarily based on incorrect identification. *D. sublaevigata* is endemic to Sabah. *D. trichogona* is found widespread in Borneo, but very common in Sabah.

Uses Mature culms of *D. scandens* are used by local people for making rough baskets to carry stones from rivers. The liquid exuded by freshly cut culms or internodes is reputed to be good as eye drops. The large smooth leaf blades of *D. sublaevigata* and *D. trichogona* are used for wrapping a food made of glutinous rice (hokkien bak chang) by local Chinese in Sabah (Malaysia). Young shoots are eaten as a vegetable.

Observations Open tufted, sympodial climbing bamboos. Culms zig-zag, usually solid, rarely hollow. Branches 3–18 at each node with primary branch dormant (but developing in a way similar to the main culm when the apex of the main culm is damaged). Culm sheaths consisting of two parts, the hard, expandable rugose base, glabrous or hairy, and the smooth upper part, glabrous or hairy; blades ovate to ovate-lanceolate, erect or deflexed; auricles present or absent. Young shoots purplish green or green, covered with white wax. Leaf blades from small (7 cm × 1.2 cm) to large (35 cm × 7 cm), smooth or rough. Inflorescences usually up to 3 m long; spikelets 2–9 mm long, with 2–3 glumes and one floret. Caryopsis (fruit) fleshy, globose or subglobose. Species of this genus are found scattered in lowland and hill dipterocarp forest, up to 1200 m altitude. These bamboos present a considerable problem, because they become weeds in logged and disturbed forest, preventing regeneration of commercial timber.

Selected sources 8, 11, 13.

Gigantochloa achmadii Widjaja

GRAMINEAE

Vernacular names Indonesia: buluh apo (Simalur, Sumatra).

Distribution So far found only in the Island of Simalur and in West Sumatra.

Uses The culms are potentially useful for constructions.

Observations Culm up to 20 m tall, diameter 9 cm; internodes 25–35 cm long, yellowish-green with whitish hairs below the node. Culm sheath covered with dark brown hairs; blade ovate with narrow base, reflexed; ligule dentate with long bristles; auricles rounded, raised towards the outer ends, with 4 mm long bristles. Inflorescence borne on leafless branches, with a group of 3–5 pseudospikelets at each node. Found in forest on heavy clay soil.

Selected sources 23.

Gigantochloa pruriens Widjaja

GRAMINEAE

Vernacular names Indonesia: buluh belangke, buluh regen (Batak Karo), buluh yakyak (Gayo).

Distribution North Sumatra (Indonesia).

Uses Culms used for building material, such as pillars, walls and roofing, and also for making the Batak traditional calendar 'perhalaan'; young culms for cooking glutinous rice ('lemang'). Young shoots are used as a vegetable.

Observations Culm erect, up to 15 m tall, diameter 6–12 cm, dark to faintly bluish-green; internodes 40–60 cm long, with long scattered dark

brown hairs below the nodes. Culm sheath covered with dark brown hairs; blade ovate-lanceolate, reflexed; ligule dented; auricles well developed, 15 mm long. Leaf blade hairy on the lower surface. Inflorescence borne on leafless or leafy branches, with about 5 ovate-oblong pseudospikelets at each node. Found in the lowlands up to 400 m altitude. Propagation by culm cuttings.

Selected sources 23.

Gigantochloa ridleyi Holttum

GRAMINEAE

Vernacular names Indonesia: tiying kaas, tiying aya (Bali).

Distribution Found only in cultivation in Singapore, Peninsular Malaysia and Bali (Indonesia).

Uses In Bali, culms are used for roofing. In Singapore and Peninsular Malaysia *G. ridleyi* is often planted as an ornamental.

Observations Erect and densely tufted bamboo. Culm up to 18 m tall, diameter 10 cm; internodes 30–47 cm long with scattered dark brown hairs below the nodes. Culm sheath green with brownish-black appressed hairs on the back; blade triangular, erect; auricles small, rigid, bearing bristles 2 mm long. Leaf blade 40 cm × 8 cm, glabrous. In Bali found in the drier parts.

Selected sources 14, 23.

Kinabaluchloa nebulosa K.M. Wong

GRAMINEAE

Distribution Sabah (Mt. Kinabalu, Crocker Range), Sarawak (Kelabit Highlands), and Brunei (Pagon Range).

Uses The long, thin-walled internodes are used for making musical instruments ('sompoton' in Sabah, 'engkrui' in Sarawak).

Observations Open tufted, scrambling bamboo. Culm 10–20 m tall or more, lower part erect, upper part leaning or scrambling over nearby vegetation or drooping to the ground, diameter 1.5–2 cm, wall thin; internodes 40–80(–120) cm long, green with dark brown hairs when young, becoming glabrous. Culm sheath covered with black hairs; blade narrowly lanceolate. Leafy branches up to 60 cm long, bearing 9–17 leaf blades. Inflorescence borne on a leafy branch; pseudospikelets rigid, cylindrical. Found in lower montane forest.

Selected sources 11, 26.

Kinabaluchloa wrayi (Stapf) K.M. Wong

GRAMINEAE

Synonyms *Bambusa wrayi* Stapf.

Vernacular names Malaysia: buloh bersumpitan (Malay), buloh sewor (Temiar Senoi, Negrito).

Distribution Endemic to Peninsular Malaysia (Main Range, Bintang Range and Trengganu Highlands).

Uses The internodes (1.6–2 m long) are prized for crafting the inner tube of superior blowpipes among Temiar Senoi and Negrito peoples in central and northern Peninsular Malaysia.

Observations Densely tufted sympodial bamboo. Culm basally erect, upper part drooping or mostly leaning onto nearby vegetation, 12–18 m tall, diameter 1.5–2.5 cm, relatively thin-walled; internodes 1.6–2 m long; nodes prominent with a thick girdle encircled by brown hairs. Culm sheath with short brown hairs on the back; blade linear, reflexed; ligule with pale brown to golden-brown bristles to 5 m long; auricles inconspicuous. Leaf blade 15–25 cm × 1.5–3 cm, usually glabrous except for scattered hairs at base and along midrib on upper surface. Inflorescence borne on leafless branches; pseudospikelets in clusters at each node, subtended by large bracts. Caryopsis narrowly cylindrical, glabrous to slightly hairy at the apex. Only known from lower and upper montane forest.

Selected sources 14, 26.

Melocalamus compactiflorus (Kurz) Benth.

GRAMINEAE

Vernacular names Bangladesh: lota bans. Thailand: lai-mong. Vietnam: ca truc, tre lim.

Distribution From Bangladesh and Burma (Myanmar) to Thailand, Vietnam and southern Yunnan (China).

Uses Culms are used for making crude baskets.

Observations Scrambling, densely tufted bamboo. Culm 10–15 m tall, slightly zig-zag, diameter 1.5 cm, wall relatively thick; internodes 20–30 cm long. Culm sheath covered with white powder when young; blade broadly triangular, erect first then deflexed; auricles relatively large with long bristles. Leaf blade 10–30 cm × 4–6 cm. Inflorescence borne on a leafless branch; pseudospikelets crowded at each node, 3–5 mm long; spikelet containing 2 florets. Caryopsis (fruit) subglobular or

rounded, 1–3 cm in diameter, pericarp thick and fleshy. Growing wild in evergreen or secondary forest up to 1700 m altitude, and also in open clearings in north-eastern Thailand. *M. compactiflorus* is potentially of interest also for other South-East Asian countries.

Selected sources 1, 2, 12, 18.

Nastus Juss.

GRAMINEAE

Major species and synonyms

- *Nastus elatus* Holttum.
- *Nastus elegantissimus* (Hassk.) Holttum. Synonyms: *Bambusa elegantissima* Hassk., *Schizostachyum elegantissimum* Kurz.

Vernacular names

- *N. elatus*: Papua New Guinea: mingal (Changlap), mengagi (Kerowagi).
- *N. elegantissimus*: Indonesia: awi eul-eul (Sundanese, West Java).

Distribution The genus *Nastus* is mainly found in the southern hemisphere from Madagascar and Réunion to the Solomon Islands, with great diversity in Madagascar and New Guinea. In South-East Asia, there are about 11 species, each of them having a very limited distribution and being found only in montane forest. *N. elatus* grows wild in the highlands of Papua New Guinea (altitude 1200–1900 m); *N. elegantissimus* is endemic in Pangalengan area in West Java, Indonesia (altitude about 1000 m).

Uses

- *N. elatus*: culms used for housebuilding and musical instruments; shoots edible, often eaten raw.
- *N. elegantissimus*: culms used to construct frames for drying tobacco leaves and for fences.

Observations Slender, erect or scrambling bamboos (climbing in Madagascar). Culms up to 20 m long, diameter 1–5 cm; internodes usually hollow, 20–40 cm long. Branches many at each node, subequal. Inflorescence semelauctant, a panicle or raceme, borne on a leafy branch; spikelet 10–25 mm long, consisting of 3–5 glumes, one floret and a rachilla extension. In New Guinea about 8 species are found in mixed lower montane rainforest, disturbed montane forest, or mossy forest. *N. elatus*, a large erect native bamboo species in the highlands, about 20 m tall and 5 cm in diameter, is of considerable importance and has also been introduced in the lowlands of Queensland (Australia).

Selected sources 3, 7, 15.

Neohouzeaua dulloa (Gamble) A. Camus

GRAMINEAE

Vernacular names Bangladesh: dolu. Thailand: mai hia. Vietnam: cai noa, kei noua.

Distribution Widely distributed from Bangladesh to Vietnam.

Uses Culms are used for masts, poles, and for light constructions.

Observations Open tufted bamboo. Culm 7–9 m tall, erect or leaning to nearby vegetation, slender, diameter up to 1 cm, thin walled; internodes 40–60 cm long; nodes slightly swollen. Branches many at each node. Culm sheath glabrous; blade narrowly lanceolate, tapering, deflexed; auricles absent. Leaf blade 14–26 cm × 2–4 cm. Inflorescence terminating a leafy branch; pseudospikelets slender, about 2 cm long, 2 or 3 at each node. Usually found wild in evergreen forest at 300–700 m altitude, but commonly planted in villages. Originally *N. dulloa* was described under *Teinostachyum* Munro, then transferred to *Neohouzeaua* A. Camus, and suggested to be included in *Schizostachyum* Nees. It has been assigned to *Neohouzeaua* until a critical revision of the genera mentioned is available. *N. dulloa* is potentially of great interest for other South-East Asian countries.

Selected sources 6, 14.

Racemobambos Holttum

GRAMINEAE

Major species and synonyms

- *Racemobambos congesta* (Pilger) Holttum. Synonym: *Arundinaria congesta* Pilger.
- *Racemobambos gibbsiae* (Stapf) Holttum. Synonym: *Bambusa gibbsiae* Stapf.
- *Racemobambos raynalii* Holttum.

Vernacular names

- *R. congesta*: Papua New Guinea: dim (Weng, Busilmin), twengom (Wapi, Miwaute), mal (Mendi).

Distribution The genus *Racemobambos* (16 species) is confined to Malesia up to the Solomon Islands, with great diversity in New Guinea (about 6 species), but so far has not been found in Sumatra, Java, and the Lesser Sunda Islands. *R. congesta* is found in Papua New Guinea and Goodenough Island; *R. gibbsiae* is endemic on Mount Kinabalu, Sabah (Malaysia); *R. raynalii* is found in Irian Jaya (Indonesia).

Uses In New Guinea culms are used for bow strings, straps for fire making, and arrow heads. All *Racemobambos* species have potential ornamental value.

Observations Scrambling bamboos. Culms slender, lower part erect, upper part leaning or scrambling over nearby vegetation, up to 20 m long, diameter 8–9 mm, walls thin; internodes 25 cm long. Branches several to many at each node, with the primary branch dominant. Inflorescence semelauctant, a panicle or raceme, terminating a leafy branch; spikelet consisting of 2–3 glumes, 3–8 perfect florets, and one terminal rudimentary floret. Found in mountain or mossy forest, except for *R. hirsuta* Holttum which grows in the lowlands of Sabah (Malaysia) and Palawan (the Philippines). *R. congesta* and *R. gibbsiae* form dense thickets in montane forest.

Selected sources 9, 15, 16.

Schizostachyum aciculare Gamble

GRAMINEAE

Vernacular names Malaysia: buloh padi, buloh akar. Thailand: kasian, lawk.

Distribution Native in Peninsular Malaysia and in southern Thailand.

Uses In Thailand split culms are used for making handicrafts like hats and baskets.

Observations Small slender bamboo. Culm 4–5 m tall, diameter 8–10 mm, erect with pendulous tip, often scrambling over nearby vegetation; internodes up to 65 cm long. Culm sheath with long narrow reflexed blade. Pseudospikelet slender, 5 cm long. Found in forest and forest margins.

Selected sources 4, 14, 18.

Schizostachyum caudatum Backer ex Heyne

GRAMINEAE

Vernacular names Indonesia: buluh bungkok, bambu buta (Lampung).

Distribution Endemic to Lampung (Sumatra, Indonesia).

Uses Local people consider this bamboo as sacred, giving protection against evil influences.

Observations Densely tufted bamboo. Culm about 8 m tall, erect with drooping tips, dull green, diameter 1.5–4 cm, almost solid or with very small lumen; internodes to 20 cm long. Culm sheath light green, tinged with orange, covered with dark brown hairs; blade broadly triangular, erect; auricles large, with long bristles. Inflorescence terminating a leafy branch; pseudospikelets slender. Caryopsis about 6 mm long, with long persistent style, pericarp thick, easily separated from the seed. Found from the lowlands to 1000 m altitude. In the Bogor Botanic Garden (Indonesia) *S. caudatum* continues to produce flowers and fruits, which often germinate instantly on the ground below the mother clump, but rarely develop into mature plants.

Selected sources 3, 13.

Schizostachyum gracile (Munro) Holttum

GRAMINEAE

Vernacular names Malaysia: buloh rapen, buloh akar. Indonesia: buluh alar (Riau), buluh giling (Lampung).

Distribution Southern Peninsular Malaysia and eastern Sumatra (Indonesia).

Uses Potentially, *S. gracile* is an attractive ornamental for ponds.

Observations Loosely tufted bamboo. Culm 3–4 m tall, usually erect, dull green, diameter 1.5–2 cm; internodes 25–30 cm long. Culm sheath covered with appressed light brown hairs; blade broadly triangular, erect; auricles relatively large with long bristles. Inflorescence terminating a leafy branch; pseudospikelet 12–14 mm long. Caryopsis 6.5 mm long, with long style. Found in forest, forest margins, wastelands, along roadsides and in swampy areas.

Selected sources 14.

Schizostachyum hantu S. Dransf.

GRAMINEAE

Vernacular names Malaysia: buloh hantu (Sarawak, Bedayuh).

Distribution So far found only in western Sarawak (Malaysia) (Division I and Gunung Matang).

Uses Culms are used to make baskets.

Observations Open tufted bamboo. Culm erect first, then leaning on trees, with long drooping tip, 15–20 m long, diameter 1.5–2.5 cm, wall relatively thick; internodes 80–100 cm long, with white appressed hairs when young; nodes swollen. Culm sheath covered with white to light brown hairs on the back; blade broadly lanceolate, erect first,

then deflexed; auricles small with long bristles. Inflorescence terminating a leafy branch; pseudospikelets 2.5 cm long in groups of 2–3.

Selected sources 10.

Schizostachyum pilosum S. Dransf.

GRAMINEAE

Vernacular names Malaysia: buloh pus (Dusun, Sabah).

Distribution So far found commonly only in Keningau and Tambunan (Sabah, Malaysia).

Uses Culms are used for flooring.

Observations Densely tufted bamboo. Culm about 15 m tall, erect and covered with white wax when young, when mature leaning on trees or drooping to the ground, diameter 5 cm at the base, wall relatively thin; internodes up to 30 cm long. Culm sheath covered with white wax and appressed white or light brown hairs; blade broadly lanceolate, tapering to a long tip, erect, covered with dense white hairs adaxially, especially near the base. Leaf blade large, 30–40 cm × 3–7 cm. Inflorescence terminating a leafy branch; pseudospikelets 2.4 cm long, few at each node. Found in forest, forest margins and wastelands along roadsides. *S. pilosum* is related to *S. grande* Ridley from Peninsular Malaysia.

Selected sources 10, 11.

Shibataea kumasasa (Zollinger) Nakai

GRAMINEAE

Distribution *S. kumasasa* originated in southern Japan and has been introduced in tropical Asia (including Malesia), Europe and America.

Uses *S. kumasasa* is used as hedge and as ornamental plant.

Observations Monopodial bamboo. Culm up to 1.5 m tall, 3–5 mm in diameter. Branches 2–6 at each node, each bearing one leaf blade. It has a running habit, as the rhizome system is monopodial. Propagation is by rhizome cuttings.

Selected sources 21, 22.

Thyrsostachys oliveri Gamble

GRAMINEAE

Vernacular names Burma (Myanmar): thanawa. Thailand: phai raakdam.

Distribution Native in Upper Burma (Myanmar) and northern Thailand.

Uses Culms are used for building material and broom handles; the seed is edible.

Observations Densely tufted sympodial bamboo. Culm erect, straight, up to 25 m tall, diameter about 5 cm, wall relatively thin; internodes 30–60 cm long. Culm sheath thin, stramineous. Inflorescence terminating a short leafless branch, bearing a large reduced sheath (or bract) at each node enclosing a cluster of pseudospikelets. Caryopsis cylindrical, glabrous, about 1 cm long. In Burma (Myanmar), found in moist hill forest; in Thailand in mixed or teak forest, occasionally planted in villages. Potentially, *T. oliveri* is also of importance for other countries of South-East Asia.

Selected sources 2, 5, 12, 18.

Yushania Keng f.

GRAMINEAE

Major species and synonyms

- *Y. niitakayamensis* (Hayata) Keng f. Synonym: *Arundinaria niitakayamensis* Hayata.
- *Y. tessellata* (Holttum) S. Dransf. Synonym: *Racemobambos tessellata* Holttum.

Vernacular names

- *Y. niitakayamensis*: Philippines: utod (Igorot).

Distribution *Y. niitakayamensis* is native in Taiwan and Luzon (the Philippines); *Y. tessellata* is endemic in Sabah (Mt. Kinabalu, Bukit Ampuan, and Melingan) (Malaysia).

Uses *Y. niitakayamensis* is planted for erosion control. Both species are or are potentially useful ornamental plants.

Observations Sympodial, open tufted bamboos, with long-necked rhizomes. Culms erect, 1.6–5 m tall, diameter 3–15 mm, walls relatively thin; internodes 30–40 cm long; nodes with prominent supranodal ridge bearing few to several spine-like aerial roots below. Branches two to several at each node. Inflorescences semelauctant, paniculate, terminating leafy branches; spikelets with 4–10 florets. In Luzon (the Philippines), *Y. niitakayamensis*, a small erect bamboo up to 1.6 m tall, grows gregariously in open grassland and mossy forest at 2100–2800 m altitude. In Sabah, *Y. tessellata* grows in mountain forest at 1500–1800 m altitude.

Selected sources 11, 19.

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Acronyms of organizations

- BIC (China): Bamboo Information Centre (Beijing, China).
- BIC (India): Bamboo Information Centre (Kerala, India).
- CAF: Chinese Academy of Forestry (Beijing, China).
- CRDB: Centre for Research and Development in Biology (Bogor, Indonesia).
- DGIS: Directorate-General for International Cooperation (Den Haag, the Netherlands).
- FAO: Food and Agriculture Organization of the United Nations (Rome, Italy).
- FINNIDA: Finnish International Development Agency (Helsinki, Finland).
- FORSPA: Forestry Research Support Programme for Asia and the Pacific (Bangkok, Thailand).
- FRIM: Forest Research Institute of Malaysia (Kuala Lumpur, Malaysia).
- ICFRE: Indian Council of Forestry Research and Education (Dehra Dun, India).
- IDRC: International Development Research Centre (Ottawa, Canada).
- IEBR: Institute of Ecology and Biological Resources (Hanoi, Vietnam).
- IFAR: International Fund for Agricultural Research (Washington, D.C., United States).
- INBAR: International Network for Bamboo and Rattan.
- IPB: Institut Pertanian Bogor [Bogor Agricultural University] (Bogor, Indonesia).
- IUFRO: International Union of Forestry Research Organizations (Vienna, Austria).
- KFRI: Kerala Forest Research Institute (Kerala, India).
- LIPI: Indonesian Institute of Sciences (Jakarta, Indonesia).
- PCARRD: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (Los Baños, the Philippines).
- PROSEA: Plant Resources of South-East Asia (Bogor, Indonesia).
- TISTR: Thailand Institute of Scientific and Technological Research (Bangkok, Thailand).
- UNESCO: United Nations Educational, Scientific and Cultural Organization (Paris, France).
- UNIDO: United Nations Industrial Development Organization (Vienna, Austria).
- UNITECH: Papua New Guinea University of Technology (Lae, Papua New Guinea).
- WAU: Wageningen Agricultural University (Wageningen, the Netherlands).

Glossary

abaxial: on the side facing away from the axis or stem (dorsal)
accession: in germplasm collections: plant material of a particular collection, usually indicated with a number
acuminate: ending in a narrowed, tapering point with concave sides
acute: sharp; ending in a point with straight or slightly convex sides
adaxial: on the side facing the axis (ventral)
adpressed (appressed): lying flat for the whole length of the organ
aerophone: a musical instrument which produces a sound when blown
air layering: see marcotting
alluvium: soil material deposited by running water in recent geological time
alternate: leaves, etc., inserted at different levels along the stem, as distinct from opposite or whorled
aneuploid: with other than the exact multiple of the haploid chromosome complement
anther: the part of the stamen containing the pollen
apex (plural apices): tip or summit of an organ
apical: at the point of any structure
apiculate: ending abruptly in a short point
appressed (adpressed): lying flat for the whole length of the organ
attenuate: gradually tapering
auricle: a small lobe or ear
auriculate: eared, having auricles
awn: a bristle-like appendage, especially occurring on the glumes of grasses
axillary: arising from the axil
axis: the main or central line of development of a plant or organ
baccate: berrylike; pulpy or fleshy
bamboos: a taxonomic group of plants comprising the tribe *Bambuseae* of the *Bambusoideae*, a subfamily of the *Gramineae*; living plants, or culms (stems) severed from plants of this group
beak: a long, prominent and substantial point, applied particularly to prolongations of fruits
bending strength: see Introduction
berry: a juicy indehiscent fruit with the seeds immersed in pulp; usually several-seeded without a stony layer surrounding the seeds
blade: the expanded part of a leaf or petal
boucherie method (bamboos): see Introduction
bract: a reduced leaf subtending a flower, flower stalk, a whole or a part of an inflorescence
branch complement: the array of branches that develop at a single culm node, including the primordial one and any that arise by proliferation from buds at its proximal nodes
breeding: the propagation of plants or animals to improve certain characteristics
bristle: a stiff hair or a hair-like stiff slender body
bud: the nascent state of a flower or branch; in the usage here adopted, bud is applied to those primordial vegetative or reproductive branches that are enclosed in a prophyllum and have a resting stage
butt: the base of a plant from which the roots spring
caducous: falling off early
callus: small hard outgrowth at the base of spikelets in some grasses; tissue that forms over cut or damaged plant surface
calyx: the outer envelope of the flower, consisting of sepals, free or united
canopy: the uppermost leafy layer of a tree or a forest
cartilaginous: hard and tough
caryopsis: the fruit of a grass, in which the outer layer (testa) of the seed proper is fused to the ovary wall
cellulose: see holocellulose and Introduction
chartaceous: papery
chordophone: a stringed musical instrument
chromosome: a structural unit in the nucleus which carries the genes in a linear constant order; the number is typically constant in any species
ciliate: with a fringe of hairs along the edge
clone: a group of plants originating by vegetative propagation from a single plant and therefore of

the same genotype

coleoptile (coleoptilum, coleophyllum): the first leaf in germination of monocotyledons, which sheathes the succeeding leaves

coleorhiza: the sheath of a monocotyledonous embryo, when pierced by the true radicle

collapse (in wood): a defect due to abnormal and irregular shrinkage and resulting in a wrinkled or corrugated appearance of the surface and sometimes also an internal honeycombing

compression parallel to grain: see Introduction

coppice: a small wood which is regularly cut at stated intervals, the new growth arising from the stools

coriaceous: of leathery texture

corolla: the inner envelope of the flower of free or united petals

corrugated: wrinkled

crisped: curled

cross-pollination: placement of pollen from one flower on the stigma of a flower of another plant which is not of the same clone

culm: the stem of grasses and sedges

culm leaf: consists of a sheath, blade, ligule and (usually) two auricles

culm sheath: the sheath of the culm leaf, borne singly at each node of the culm proper, below the level at which the sheaths of foliage leaves take their place

cultivar (cv., plural cvs): an agricultural or horticultural variety that has originated and persisted under cultivation, as distinct from a botanical variety. A cultivar name should always be written with an initial capital letter and given single quotation marks (e.g. banana 'Gros Michel')

cuneate: wedge-shaped; triangular, with the narrow end at the point of attachment, as the bases of leaves or petals

curing (in bamboos): traditional method for preserving bamboo culms by which harvested culms with branches and leaves still attached are left in the open air for some time to reduce the starch content of the culms due to continued transpiration of the leaves

cutting: the severed portion of a plant, used for propagation

damping-off: a disease of seeds or seedlings caused by fungi which cause various effects, from failure to germinate to the dying off of the seedling

deciduous: shedding or prone to shedding, applied to leaves, petals, etc.

deflexed (reflexed): abruptly recurved; bent downwards or backwards

density: weight (kg) per volume (m^3) at a certain moisture content of the culm

dentate: margin prominently toothed with the pointed teeth directed outwards

denticulate: minutely toothed

determinate: of inflorescences, when the terminal or central flower of an inflorescence opens first and the prolongation of the axis is arrested; of shoot growth, when extension growth takes the form of a flush, i.e. only the previously formed leaf primordia unfold

diffuse: growing in open array; characterizes the normal mature clump habit typical of most bamboos with leptomorph rhizomes, and those whose pachymorph rhizomes have a greatly elongated neck, as in *Melocanna baccifera*, for example

diploid: with two sets (genomes) of chromosomes, as occurs in somatic or body cells; usually written $2n$, having twice the basic chromosome number of the haploid germ cells

distal: situated farthest from the place of attachment

dorsal: back; referring to the back or outer surface of a part or organ (abaxial)

ellipsoidal: a solid which is elliptical in outline

elliptical: oval in outline but widest about the middle

embryo: the rudimentary plant within a seed, developed from a zygote (sexual) or from other nuclei in the embryo sac or cells of the nucellus or integuments (apomictic)

endemic: exclusively native to a specified or comparatively small region; also used as a noun for a taxon thus distributed

endocarp: the innermost layer of the pericarp or fruit wall

endosperm: the starchy or oily nutritive material stored within some seeds, sometimes referred to as albumen; it is triploid, having arisen from the triple fusion of a sperm nucleus and the two polar nuclei of the embryo sac

energy value: the heat produced by the combustion of a unit weight of a fuel

entire (botany): an even margin without teeth, lobes, etc.

erect: directed towards summit, not decumbent

evergreen: bearing foliage all year long; a plant that changes its leaves gradually

ex situ: in an artificial environment or unnatural habitat

fermentation: a chemical change accompanied by effervescence and suggestive of changes pro-

duced in organic materials by yeasts

fertile (botany): bearing pollen which fecundates the ovules; said of pollen-bearing anthers or of seed-bearing fruits

fibre: any long, narrow cell of wood or bast other than vessel or parenchym elements

fibre saturation point: the point at which there is no more free water in the culm but the cell walls are still saturated with water

filament: thread; the stalk supporting the anther

fimbriate: fringed

fleshy: succulent

flexibility ratio: parameter used by the pulp and paper industry, derived from the fibre dimensions of the culm: fibre lumen diameter divided by fibre diameter, multiplied by 100

floret: a small flower, one of a cluster as in grasses or *Compositae*

flowering branch: a leafy or leafless segmented axis that bears one or more inflorescences

fodder: something fed to domesticated animals, especially coarse, dried food from plants (hay, straw, leaves)

forage: grassland and fodder plants suitable as feed for herbivores, usually with lower nutrient concentration and digestibility than concentrates such as grain

fruit: the ripened ovary with adnate parts

genetic erosion: the decline or loss of genetic variability

genotype: the genetic makeup of an organism comprising the sum total of its genes, both dominant and recessive; a group of organisms with the same genetic makeup

genus (plural genera): the smallest natural group containing distinct species

germplasm: the genetic material that provides the physical basis of heredity; also a collection of genotypes of an organism

girdle: a conspicuous horizontal band of tissue inserted circumaxially at the nodes of some bamboos

glabrescent: becoming glabrous or nearly so

glabrous: devoid of hairs

glaucous: pale bluish-green, or with a whitish bloom which rubs off

globose: spherical or nearly so

glume (plural glumes): the chaffy or membranous two-ranked members of the inflorescence of grasses and similar plants; lower glume and upper glume, two sterile bracts at the base of a grass spikelet

glycosides: compounds that are acetal derivatives of sugars and that on hydrolysis yield one or more molecules of a sugar and often a noncarbohydrate

grain (wood anatomy): the general direction or arrangement of the fibres; texture

gregarious: growing in associated groups or clusters but not matted; at the same time; in bamboos gregarious flowering is used to indicate that a whole population flowers over a period of 2–3 years and then dies, although sometimes the rhizomes remain alive

habit: external appearance or way of growth of a plant

habitat: the kind of locality in which a plant grows

head: a dense inflorescence of small crowded often stalkless flowers (a capitulum)

hemicellulose: see holocellulose and Introduction

herbaceous: with the texture, colour and properties of a herb; not woody

hermaphrodite: bisexual; in flowers, with stamens and pistil in the same flower

hexaploid: having six sets of chromosomes ($6n$)

hirsute: with rather coarse stiff hairs

hispid: covered with long rigid hairs or bristles

holocellulose: the total polysaccharide cellulose and hemicellulose fraction of wood

hybrid: the first generation offspring of a cross between two individuals differing in one or more genes

hybridization: the crossing of individuals of unlike genetic constitution

idiophone: a percussion or hammer musical instrument

imbricate: overlapping like tiles; in a flower bud when one sepal or petal is wholly external and one wholly internal and the others overlapping at the edges only

in situ: in the natural environment

incised: cut deeply

indehiscent: not opening when ripe

indeterminate: of inflorescences, a sequence in which the terminal flowers are the last to open, so that the floral axis may be prolonged indefinitely by the terminal meristem. Of shoot growth: when the shoot apex forms and unfolds leaves during extension growth, so that shoot growth can continue indefinitely

indigenous: native to a particular area or region

indumentum: a covering, as of hairs, scales, etc.

inflorescence: the arrangement and mode of development of the flowers on the floral axis

internode: the portion of the stem (culm) between two nodes

iterauctant: embracing more than one major period of growth; the branching system, or the

branching habit, of an indeterminate bamboo inflorescence may be said to be iterauctant

keel (carina): a ridge like the keel of a boat; the two anterior and united petals of a papilionaceous corolla; the principal nerve of a sepal or glume

keeled (carinate): having a keel or carina

kiln dried: being seasoned in a kiln

kraft pulp: = sulphate pulp

lacerate: torn; irregularly cleft or cut

lacinate: with narrow parted lobes

lamina: see blade

lanceolate: lance-shaped; much longer than broad being widest at the base and tapering to the apex

leaf: (in bamboos): the chlorophyll-bearing, usually petiolate, blade of a leaf sheath proper

leaf sheath: one of the leaf-bearing sheaths inserted at the distal nodes of each aerial vegetative axis of a bamboo, whether culm, branch, or twig; the conspicuous part of a leaf sheath is the usually petiolate blade inserted at the apex of the leaf sheath proper

lemma: the lower of the two membranous bracts enclosing the flower in grasses; the lower of the two glumes which surround each floret in the spikelet of grasses

leptomorph: a term coined especially to designate a slender, elongated type of rhizome (see also Introduction)

lignin: a colloidal polymer of varying chemical structure used as secondary wall material in xylem vessels, tracheids and sclerenchyma fibres

ligule: a membranous outgrowth on the upper surface of a grass leaf at the junction of the sheath and the blade. It may be presented by a ridge or by a line of hairs; an elongated flattened strap-shaped structure

linear: long and narrow with parallel sides

lobe: any division of an organ or specially rounded division

lodicule: one of the small, usually thin, delicate and transparent structures inserted usually in a single whorl of 3, immediately below the stamens in the bamboo flower

longitudinal: lengthwise

lumen (plural lumina): the space enclosed by the walls of an organ, such as the central cavity of a cell; the central cavity of a hollow internode of any segmented axis of a bamboo plant

Malesia: the biogeographical region including Malaysia, Indonesia, the Philippines, Singapore, Brunei and Papua New Guinea

mangrove: a brackish-water coastal swamp of tropical and subtropical areas that is partly inundated by tidal flow

marcotting (air layering): a form of layering in which soil (rooting medium) is brought to the branch to be layered; the ball of soil in a polyethene cover is wrapped around the girdled branch; after adventitious roots grow out above the girdle, the layer can be separated

maximum crushing strength: = compression parallel to grain, see Introduction

membranous: thin and semi-transparent, like a fine membrane

meristem: undifferentiated tissue of the growing point whose cells are capable of dividing and developing into various organs and tissues

midrib: the main vein of a leaf which is a continuation of the petiole

modulus of elasticity: see Introduction

modulus of rupture: see Introduction

moisture content: the weight of water in the culm expressed as a percentage of the dry weight of the culm; the moisture content of green culms can be much more than 100%

monopodial: of a primary axis which continues its original line of growth from the same apical meristem to produce successive lateral branches; in bamboos used to designate a type of rhizome (see leptomorph and Introduction)

mucronate: ending abruptly in a short stiff point

naturalized: introduced into a new area and established there, giving the impression of wild growth

neck: the constricted basal part, characteristic of all, or most, of the segmented vegetative axes of a bamboo plant

node: the point on the stem or branch at which a leaf or branch is borne

oblique: slanting; of unequal sides

oblong: longer than broad, with the sides parallel or almost so

oblongoid: a solid object which is oblong in section

obovate: reverse of ovate

obovoid: a solid object which is obovate in section

obtuse: blunt or rounded at the end

offset (rhizome cutting): a lateral shoot used for propagating

open tank method: having timber absorb a preservative without applying any vacuum or pressure

ovary: that part of the pistil, usually the enlarged base, which contains the ovules and eventually becomes the fruit

ovate: egg-shaped; a flat surface which is scarcely

twice as long as broad with the widest portion below the middle

ovoid: a solid object which is egg-shaped (ovate) in section

pachymorph: a term coined especially to designate a short, thick type of rhizome (see also Introduction)

palea: the upper of two membranous bracts enclosing the flower in grasses

panicle: an indeterminate branched racemose inflorescence

paniculate: resembling a panicle

pantropical: distributed throughout the tropics

parenchyma: tissue composed of more or less isodiametric cells, e.g. the pith and mesophyll

particle board: board made from bonded particles of wood and/or other ligno-cellulosic material

pedicel: stalk of each individual flower of an inflorescence

pendent, pendulous: drooping; hanging down from its support

pentosans: the main constituents of hemicellulose of bamboos

perennial: a plant living for many years and usually flowering each year

perfect flower: a flower possessing both male and female organs

pericarp: the wall of the ripened ovary or fruit whose layers may be fused into one, or may be more or less divisible into exocarp, mesocarp and endocarp

persistent: remaining attached; not falling off, not deciduous; applies to organs that remain in place after they have fulfilled their natural functions

petiolate: having a petiole

petiole: the stalk of a leaf

phloem: the principal food-conducting tissue of vascular plants; the bast element of a vascular bundle and basically composed of sieve elements, parenchyma cells, fibres and sclereids

pilose: hairy with rather long soft hairs

pistil: the female part of a flower (gynoecium) of one or more carpels, consisting, when complete, of ovary(s), style(s) and stigma(s).

plumule: the primary bud of an embryo or germinating seed

plybamboo: see plywood

plywood: a structural material consisting of sheets of wood glued or cemented together with the grains of adjacent layers arranged at right angles or at a wide angle

pollen: spores or grains borne by the anthers containing the male element (gametophyte)

polymorphic: polymorphous, with several or various forms; variable as to habit

polyploid: an organism with more than two sets (genomes) of chromosomes in its somatic cells

posterior: next to or towards the main axis

powder-post beetle: a *Lyctid* or *Bostrychid* beetle damaging wood by characteristic round holes of about 1–3 mm in diameter with the wood reduced to flour-like dust

preservative: a liquid absorbed by timber to increase its durability

primordial: first in order of appearance

primordium: a group of undifferentiated meristematic cells, usually of a growing point, capable of differentiating into various kinds of organs or tissues

prop roots: aerial roots

propagule: a part of a plant that becomes detached and grows into a new plant

prophyll: the bracteole at the base of an individual flower

proximal: the part nearest the axis (as opposed to distal)

pruning: cutting off the superfluous branches or shoots of a plant for better shaped or more fruitful growth; M-shaped pruning in bamboos: pruning a clump by removing culms so that the culm-less part looks like a M; cf. also horseshoe-shaped pruning

pseudopetiole: a structure resembling a petiole, but not being one

pseudospikelet: a spikelet-like branch of an indeterminate (indeterminately branching) inflorescence (see Introduction)

puberulent: covered with down or fine hairs

puberulous: minutely pubescent

pubescent: covered with soft short hairs

pulp: the soft fleshy part of the fruit; mechanically ground or chemically digested wood used in manufacturing paper and allied products

raceme: an unbranched elongated indeterminate inflorescence with stalked flowers opening from the base upwards

rachilla: a diminutive or secondary axis, as the stalk of the spikelet in grasses

rachis (plural rachides): the principal axis of an inflorescence or a compound leaf

radial: lengthwise, in a plane that passes through the pit; radiating, as from a centre

radical: arising from the root, or its crown

radicle: the first root of an embryo or germinating seed

recurved: bent or curved downward or backward

reduced: subnormal in size; connotes also either a

failure to fulfill a normal function, or a diminution in the expected number of parts in a set (of stamens, for example)

reflexed: abruptly bent or turned downward or backward

rhizome: an underground stem which is distinguished from a root by the presence of nodes, buds, and leaves or scales

rhizome cutting: see offset

rootstock: see rhizome

rudimentary: of organs which are imperfectly developed and nonfunctional

rugose: wrinkled

Runkel ratio: parameter used by the pulp and paper industry, derived from the fibre dimensions of the culm: two times the fibre wall thickness divided by the fibre lumen diameter

runner: a specialized stem that develops from a leaf axil at the crown of a plant, grows horizontally along the ground, and forms a new plant at one of the nodes, usually at or near the tip (as in strawberry)

scabrid, scabrous: rough to the touch

scandent: climbing

scrub: vegetation whose growth is stunted because of lack of water coupled with strong transpiration

season (of timber): to reduce the moisture content of timber either by air-drying (air-season) or kiln-drying (kiln-season). Timber is fully seasoned when the moisture content has dropped to the equilibrium moisture content of the ambient climate

seed: the reproductive unit formed from a fertilized ovule, consisting of embryo and seed-coat, and, in some cases, also endosperm

seedling: the juvenile plant, grown from a seed

self-sterile: failure to complete fertilization and obtain seed after self-pollination

semelauctant: embracing but a single grand period of growth; a determinate bamboo inflorescence may be said to be semelauctant

senescence: advancing in age

serrate: toothed like a saw, with regular pointed teeth pointing forwards

sessile: without a stalk

shear strength: see Introduction

sheath: a tubular structure surrounding an organ or part, as the lower part of the leaf clasping the stem in grasses

sheath blade: a distinct foliar part, the lamina, that is appended apically on the laminiferous culm sheaths proper and branch sheaths proper in any series

sheathing organ: any sheathing structure inserted at a node of any vegetative or reproductive axis in a gramineous plant; among the bamboos, distinguishable types of sheathing organs are rhizome sheaths, neck sheaths, culm sheaths, branch sheaths, leaf sheaths, prophylla, bracts, empty glumes, lemmas, and pales

shoot: a young growing branch or twig; the ascending axis, when segmented into dissimilar members it becomes a stem

silica body: globular or amorphous conglomerate of siliceous material, generally included in parenchymatous cells

silica cells: epidermal short cells each of which is more or less completely filled by a single silica body

slenderness ratio: parameter used by the pulp and paper industry, derived from the fibre dimensions in the culm: fibre length divided by fibre diameter

smoking (bamboo culms): traditional method of preservation of bamboo culms by keeping them for some time above a fire

spathe: a large bract enclosing a spadix, or two or more bracts enclosing a flower cluster

specific gravity: ratio of the weight of a volume of material to the weight of an equal volume of water of 4°C

spike: a simple indeterminate inflorescence with sessile flowers along a single axis

spikelet: a secondary spike, one of the units of which the inflorescence is made in grasses, consisting of one or more florets on a thin axis, subtended by a common pair of glumes

spine: a short stiff straight sharp-pointed hard structure arising from the wood of a stem

spinose: having spines (spinous)

sporadic: widely dispersed or scattered; irregular, in time; when the individual plants of a given generation of bamboos (from seeds of a common origin) enter the reproductive phase at different times or at irregular intervals, the flowering is said to be sporadic

stamen: one of the male reproductive organs of a flower; a unit of the androecium

stem: the main ascending axis of a plant; in bamboos usually named culm

sterile: failing to complete fertilization and produce seed as a result of defective pollen or ovules; not producing seed capable of germination; lacking functional sexual organs (sterility)

stigma: the portion of the pistil which receives the pollen

straggling: extremely divergent, spreading very

far apart

stress at limit proportionality: = compression perpendicular to grain, see Introduction

striate: marked with fine longitudinal parallel lines, as grooves or ridges

style: the part of the pistil connecting the ovary with the stigma

sub-: somewhat or slightly, e.g. subacute

subfamily: a taxonomic rank between the family and the tribe denoting a part of a family

subglobose: nearly globular

subspecies: a subdivision of a species, in rank between a variety and a species

sulphate pulp: a chemical wood pulp obtained through application of a solution of sodium hydroxyde and sodium sulphate

sympodial: of a stem in which the growing point either terminates in an inflorescence or dies, growth being continued by a new lateral growing point; in bamboos also used to designate the branching habit of a rhizome (see pachymorph and Introduction)

tangential: lengthwise, in a plane at right angles to the radius but not passing through the pith (see radial)

taxon (plural taxa): a term applied to any taxonomic unit irrespective of its classification level

taxonomy: the study of principles and practice of classifying living organisms (systematics)

terminal: borne at the end or apex

termite: insect damaging wood by characteristic irregular honeycombing or wide channels with dry bore-dust or dust cemented together

tetraploid: having four times ($4n$) the basic number of chromosomes or twice the diploid number ($2n$)

thinning: removing trees, stems or plants from immature or mature stands in order to stimulate the growth of the remaining trees, stems or plants

tissue culture: a body of tissue growing in a culture medium outside the organism

tomentose: densely covered with short soft hairs

tribe (plural tribae): a taxonomic rank between the family and the genus

truncate: cut off more or less squarely at the end

trunk: the main stem of a tree apart from its limbs and roots

tufted: growing in tufts (caespitose)

ultramafic rock: rock containing high concentrations of magnesium and iron hence the term ultramafic. Contains more than 70% mafic minerals

unarmed: devoid of thorns, spines or prickles

undulate: wavy, said for instance of a leaf margin if the waves run in a plane at right angles to the plane of the leaf blade

unisexual: of one sex, having stamens or pistils only

variety: botanical variety which is a subdivision of a species; an agricultural or horticultural variety is referred to as a cultivar

vein: a strand of vascular tissue in a flat organ, such as a leaf

velvety: with a coating of fine soft hairs; the same as tomentose but denser so that the surface resembles (and feels like) velvet

ventral: faces central axis (adaxial), opposed to dorsal

verticillate: of leaves in a whorl of several arising at the same node

viability: ability to live, grow and develop

villose (villous): with long weak hairs

vine: a plant having a stem that is too slender to hold itself erect and therefore supports itself by climbing over an object

viviparous: germinating or sprouting from seed or bud while attached to the parent plant

waterlogged: flooded with water, generally for a period of at least a few weeks

woody bamboos: see bamboos

Sources of illustrations

Figure 1. Morphology: McClure, F.A., 1966. The bamboos, a fresh perspective. Harvard University Press, Cambridge, Massachusetts, United States. p. 39, Fig. 19 (habit), p. 21, Fig. 8 (rhizome types), p. 118, Fig. 55 (fruits), p. 127, Fig. 57 (seedling); Holttum, R.E., 1958. The bamboos of the Malay Peninsula. The Gardens' Bulletin, Singapore 16. p. 11, Fig. 4 (young shoots); Chao, C.S., 1989. A guide to bamboos grown in Britain. Royal Botanic Gardens, Kew. p. 3, Fig. 2 (culm leaf, auricles), p. 4, Fig. 3 (branches with dominant middle branch); Soderstrom, T.R. & Young, S.M., 1983. A guide to collecting bamboos. Annals of the Missouri Botanical Garden 70. p. 132, Fig. 3 (branches of subequal size), p. 133, Fig. 4 (inflorescences, pseudospikelet). Redrawn and adapted by P. Verheij-Hayes.

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Dendrocalamus latiflorus: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens and a living collection of E.A. Widjaja.

Dendrocalamus membranaceus: diapositive S. Dransfield (young shoot); Gamble, J.S., 1896. The Bambuseae of British India. Annals of the Royal Botanic Garden, Calcutta 7. Plate 71 (culm leaf, leafy branch, flowering branch). Drawn, redrawn and adapted by P. Verheij-Hayes.

Dendrocalamus pendulus: diapositive S. Dransfield (young shoot); herbarium Kew, F.R.I. (Wong) 32341 (culm leaf), S. Dransfield 1184 (leafy and flowering branches). Drawn by P. Verheij-Hayes.

Dendrocalamus strictus: Gamble, J.S., 1896. The Bambuseae of British India. Annals of the Royal Botanic Garden, Calcutta 7. Plate 68 (culm leaf, lower leaf part, flowering branch); Camus, E.G., 1913. Les bambusées, monographie, biologie, culture, principaux usages [The Bambuseae, monography, biology, cultivation, principal uses]. Atlas. Paul Lechevalier, Paris. Planche 87B (leafy branch); diapositive S. Dransfield (flowering branch). Redrawn and adapted by P. Verheij-Hayes.

Gigantochloa albociliata: diapositive S. Dransfield (young shoot); Camus, E.G., 1913. Les bambusées, monographie, biologie, culture, principaux usages [The Bambuseae, monography, biology, cultivation, principal uses]. Atlas. Paul Lechevalier, Paris. Planche 91A (culm leaf, pseudospikelet); Gamble, J.S., 1896. The Bambuseae of British India. Annals of the Royal Botanic Garden, Calcutta 7. Plate 61 (leafy branch); herbarium Kew, Phloenchit 1333 (flowering branch). Drawn, redrawn and adapted by P. Verheij-Hayes.

Gigantochloa apus: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens and in Bogor.

Gigantochloa atroviolacea: original drawing by Iskak Syamsudin, based on Bogor herbarium material, E.A. Widjaja s.n., 12, 51, 68, 74.

Gigantochloa atter: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens.

Gigantochloa balui: original drawing by M. Molubin, based on living plants at the Forest Research Centre, Sandakan, Sabah.

Gigantochloa hasskarliana: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens.

Gigantochloa levis: original drawing by M. Molubin, based on living plants at the Forest Research Centre, Sandakan, Sabah.

Gigantochloa ligulata: original drawing by Iskak Syamsudin, based on Bogor herbarium material, No 22999, 3887, Holttum SFN 38417, 38422.

Gigantochloa manggong: original drawing by Iskak Syamsudin, based on Bogor herbarium material, E.A. Widjaja 1741.

Gigantochloa nigrociliata: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens.

Gigantochloa pseudoarundinacea: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens and on Bogor herbarium material, Bakhuizen v.d. Brink 6316, E.A. Widjaja s.n., Koorders 21169B.

Gigantochloa robusta: original drawing by Iskak

Syamsudin, based on living plants in the Bogor Botanical Gardens and on Bogor herbarium material, E.A. Widjaja s.n.

Gigantochloa scortechinii: Widjaja, E.A., 1987. A revision of Malesian Gigantochloa (Poaceae–Bambusoideae). Reinwardtia 10(3). p. 343, Fig. 21 (young shoot), p. 342, Fig. 20 (culm leaf, leaf bases), p. 344, Fig. 22 (flowering branch). Redrawn and adapted by P. Verheij-Hayes.

Gigantochloa thoii: original drawing by M. Molubin, based on living plants at the Forest Research Centre, Sandakan, Sabah.

Gigantochloa wrayi: original drawing by M. Molubin, based on living plants at the Forest Research Centre, Sandakan, Sabah. Redrawn and adapted by P. Verheij-Hayes.

Melocanna baccifera: Sastrapradja, S. & Soenarko, S. (Editors), 1977. Beberapa jenis bambu [Some species of bamboo]. Lembaga Biologi Nasional – LIPI 4, Proyek Sumber Daya Ekonomi 37, Bogor, Indonesia. p. 68 (young shoot); Li, Hui-lin et al. (Editors), 1978. Flora of Taiwan. Epoch Publishing Company, Taipei. Vol. 5. p. 782, pl. 1520 (culm leaf, leafy branch, leaf sheath, pseudospikelets). Redrawn and adapted by P. Verheij-Hayes.

Phyllostachys aurea: drawing provided by the author Chu Chengde (part of culm, culm leaf, flowering branch); Ohwi, J., 1976. Bambusoideae. In: Walker, E.H. (Editor): Flora of Okinawa and the southern Ryukyu Islands. Smithsonian Institution Press, Washington, D.C., United States. p. 171, Fig. 21A (young shoot); Li, Hui-lin et al. (Editors), 1978. Flora of Taiwan. Epoch Publishing Company, Taipei. Vol. 5. p. 724, pl. 1489 (leaf sheath). Redrawn and adapted by P. Verheij-Hayes.

Schizostachyum blumei: Dransfield, S., 1992. The bamboos of Sabah. Sabah Forest Records No 14. Forestry Department, Sabah, Malaysia. p. 59, Fig. 21. Redrawn and adapted by P. Verheij-Hayes.

Schizostachyum brachycladum: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens.

Schizostachyum grande: original drawing by P. Verheij-Hayes, based on Kew herbarium material, S. Dransfield 702 (culm leaf), 915 (leafy branch); diapositive S. Dransfield (flowering branch).

Schizostachyum iraten: original drawing by P. Verheij-Hayes, based on Kew herbarium material, Forman 536 (culm leaves), Carocci-Buzi 160 (flowering branch).

Schizostachyum jaculans: Holttum, R.E., 1953. A Malaysian blow-pipe bamboo. Kew Bulletin 1953. p. 495 (culm leaf, auricle bristles); Kew herbarium, J. Wyatt-Smith 71511 (leafy branch, flowering branch), K.M. Wong 28980 (culm leaf). Drawn, redrawn and adapted by P. Verheij-Hayes.

Schizostachyum latifolium: Dransfield, S., 1992. The bamboos of Sabah. Sabah Forest Records No 14. Forestry Department, Sabah, Malaysia. p. 63, Fig. 23. Redrawn and adapted by P. Verheij-Hayes.

Schizostachyum lima: Dransfield, S., 1992. The bamboos of Sabah. Sabah Forest Records No 14. Forestry Department, Sabah, Malaysia. p. 64, Fig. 24. Redrawn and adapted by P. Verheij-Hayes.

Schizostachyum lumampao: original drawing by P. Verheij-Hayes, based on Kew herbarium material, Merrill 891 (culm leaf), Fénix 29875 (leafy branch, flowering branch).

Schizostachyum zollingeri: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens and on Bogor herbarium material, E.A. Widjaja 410.

Thyrsostachys siamensis: original drawing by Iskak Syamsudin, based on living plants in the Bogor Botanical Gardens and on Bogor herbarium material, No 3845.

Map of South-East Asia for Prosea: original design of R. Boekelman.

Index of scientific plant names

Page numbers printed in bold refer to main treatment.

Index of vernacular plant names

For transcriptions of Vietnamese names, see at the end of the index.

Transcriptions of Vietnamese characters

[aa]	= â	[ar]	= ả	[ax]	= ã	[ej]	= ẹ	[oo]	= ô	[ow]	= ơ	[uj]	= ụ	[uwx]	= ữ
[aaf]	= ầ	[as]	= á	[ee]	= ê	[er]	= ẻ	[oof]	= ồ	[owf]	= ờ	[ur]	= ủ	[ux]	= ũ
[aaj]	= ậ	[aw]	= ă	[eef]	= ề	[es]	= é	[ooj]	= ộ	[ooj]	= ợ	[us]	= ú		
[aar]	= ẩ	[awf]	= ằ	[eej]	= ệ	[ex]	= ẽ	[oor]	= ổ	[owr]	= ở	[uw]	= ư		
[aas]	= ấ	[awj]	= ặ	[eer]	= ể	[if]	= ì	[oos]	= ố	[ows]	= ớ	[uwf]	= ừ		
[aax]	= ẫ	[awr]	= ẳ	[ees]	= ế	[is]	= í	[oox]	= ỗ	[owx]	= ỡ	[uwj]	= ự		
[af]	= à	[aws]	= ắ	[eex]	= ễ	[of]	= ò	[or]	= ỏ	[ox]	= õ	[uwr]	= ử		
[aj]	= ạ	[awx]	= ẵ	[ef]	= è	[oj]	= ọ	[os]	= ó	[uf]	= ù	[uws]	= ứ		

The Prosea Foundation
(Plant Resources of South-East Asia)

Name, location, legal status and structure

- Prosea is a Foundation under Indonesian law, with an international charter, domiciled in Bogor. It is an autonomous, non-profit, international agency, governed by a Board of Trustees. It seeks linkage with existing regional and international organizations;
- Prosea is an international programme focusing on the documentation of information on plant resources of South-East Asia;
- Prosea consists of a Network Office at Bogor (Indonesia) coordinating 6 Country Offices in South-East Asia, and a Publication Office in Wageningen (the Netherlands).

Participating institutions

- Forest Research Institute of Malaysia (FRIM), Karung Berkunci 201, Jalan FRI Kepong, 52109 Kuala Lumpur, Malaysia;
- Indonesian Institute of Sciences (LIPI), Widya Graha, Jalan Gatot Subroto 10, Jakarta 12710, Indonesia;
- Institute of Ecology & Biological Resources (IEBR), Nghia Do, Tu Liem, Hanoi, Vietnam;
- Papua New Guinea University of Technology (UNITECH), Private Mail Bag, Lae, Papua New Guinea;
- Philippine Council for Agriculture, Forestry and Natural Resources Research & Development (PCARRD), Los Baños, Laguna, the Philippines;
- Thailand Institute of Scientific and Technological Research (TISTR), 196 Phahonyothin Road, Chatuchak, Bangkok 10900, Thailand;
- Wageningen Agricultural University (WAU), Costerweg 50, 6701 BH Wageningen, the Netherlands.

Objectives

- to document and make available the existing wealth of information on the plant resources of South-East Asia for education, extension work, research and industry;
- to make operational a computerized data bank on the plant resources of South-East Asia;
- to publish the results in the form of an illustrated, multi-volume handbook in English;
- to promote the dissemination of the information gathered.

Target groups

- those professionally concerned with plant resources in South-East Asia and working in education, extension work, research and commercial production (direct users);
- those in South-East Asia depending directly on plant resources, obtaining relevant information through extension (indirect users).

Activities

- the establishment and operation of data bases;
- the publication of books;
- the sponsorship, support and organization of training courses;
- research into topics relevant to Prosea's purpose;
- the publication and dissemination of reports and the research results.

Implementation

The programme period has been tentatively divided into 3 phases:
- preliminary phase (1985–1986): publication of 'Plant Resources of South-East Asia, Proposal for a Handbook' (1986);
- preparatory phase (1987–1990): establishing cooperation with South-East Asia through internationalization, documentation, consultation and publication; reaching agreement on the scientific, organizational and financial structure of Prosea;
- implementation phase (1991–2000): compiling, editing and publishing of the handbook; making operational the computerized data bank with the texts and additional information; promoting the dissemination of the information obtained.

Documentation

A documentation system has been developed for information storage and retrieval called SAPRIS (South-East Asian Plant Resources Information System). It consists of 6 data bases:
- BASELIST: primarily a checklist of more than 6200 plant species;
- CATALOG: references to secondary literature;
- PREPHASE: references to literature from South-East Asia;
- ORGANYM: references to institutions and their research activities;
- PERSONYM: references to specialists;
- TEXTFILE: all Prosea publications and additional information.

Publication

The handbook in blue cover (hardbound) is distributed by Backhuys Publishers, Leiden (formerly by Pudoc, Wageningen). The handbook in green cover (paperback) is distributed in two price-classes: a low-price paperback, distributed by Prosea South-East Asia for all developing countries; a medium-price paperback, distributed by Backhuys Publishers, Leiden, for developed coun-

tries (becoming available two years after publication of the hardbound edition). The bibliographies are distributed by Prosea South-East Asia.

The handbook

- No 1. Pulses. L.J.G. van der Maesen and Sadikin Somaatmadja (Editors). Pudoc, Wageningen. 1989/ESCAP CGPRT Centre, Bogor. 1990 (out of print)/Prosea, Bogor. 1992.
- No 2. Edible fruits and nuts. E.W.M. Verheij and R.E. Coronel (Editors). Pudoc, Wageningen. 1991/Prosea, Bogor. 1992.
- No 3. Dye and tannin-producing plants. R.H.M.J. Lemmens and N. Wulijarni-Soetjipto (Editors). Pudoc, Wageningen. 1991/Prosea, Bogor. 1992 (out of print)/ Prosea, Bogor. 1994.
- No 4. Forages. L. 't Mannetje and R.M. Jones (Editors). Pudoc, Wageningen. 1992/Prosea, Bogor. 1992.
- No 5(1). Timber trees. Major commercial timbers. I. Soerianegara and R.H.M.J. Lemmens (Editors). Pudoc, Wageningen. 1993/Prosea, Bogor. 1994.
- No 5(2). Timber trees. Minor commercial timbers. R.H.M.J. Lemmens, I. Soerianegara and Wong Wing Chong (Editors). (expected publication date 1995).
- No 5(3). Timber trees. Lesser-known timbers. M.S.M. Sosef, Wong Wing Chong and I. Soerianegara (Editors). (expected publication date 1997).
- No 6. Rattans. J. Dransfield and N. Manokaran (Editors). Pudoc, Wageningen. 1993/Prosea, Bogor. 1994.
- No 7. Bamboos. S. Dransfield and E.A. Widjaja (Editors). Backhuys Publishers, Leiden. 1995/Prosea, Bogor. 1995.
- No 8. Vegetables. J.S. Siemonsma and Kasem Piluek (Editors). Pudoc, Wageningen. 1993/Prosea, Bogor. 1994.
- No 9. Plants mainly producing carbohydrates. F. Rumawas and M. Flach (Editors). (expected publication date 1995).
- No 10. Cereals. G.J.H. Grubben and S. Partohardjono (Editors). (expected publication date 1995).
- No 11. Auxiliary plants in agriculture and forestry. F.H. Ibrahim and L.J.G. van der Maesen (Editors). (expected publication date 1995).
- No 12. Medicinal and poisonous plants.
- No 13. Spices.
- No 14. Vegetable oils and fats.
- No 15. Cryptogams. W.F. Prud'homme van Reine and M.A. Rifai (Editors). (expected publication date 1996).
- No 16. Stimulants.
- No 17. Fibre plants.
- No 18. Plants producing exudates.
- No 19. Essential-oil plants.
- No 20. Ornamental plants.

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- Bibliography 2: Edible fruits and nuts. Edition 1. Part 1 and part 2. N. Wulijarni-Soetjipto and J.S. Siemonsma (Editors). Prosea, Bogor/Pudoc, Wageningen. 1993.

- Bibliography 3: Dye and tannin-producing plants. Edition 1. N. Wulijarni-Soetjipto and J.S. Siemonsma (Editors). Prosea, Bogor/Pudoc, Wageningen. 1991.
- Bibliography 4: Forages. Edition 1. N. Wulijarni-Soetjipto (Editor). Prosea, Bogor/Pudoc, Wageningen. 1994.
- Bibliography 5(1): Timber trees: Major commercial timbers. Edition 1. Part 1 and part 2. Sarkat Danimihardja and Soedarsono Riswan (Editors). Prosea, Bogor/Pudoc, Wageningen. 1994.

Miscellaneous
- A Selection. E. Westphal and P.C.M. Jansen (Editors). Pudoc, Wageningen. 1989/Prosea, Bogor. 1993.
- Basic list of species and commodity grouping. Version 1. R.H.M.J. Lemmens, P.C.M. Jansen, J.S. Siemonsma, F.M. Stavast (Editors). Prosea Project, Wageningen. 1989. (out of print).
- Basic list of species and commodity grouping. Final version. P.C.M. Jansen, R.H.M.J. Lemmens, L.P.A. Oyen, J.S. Siemonsma, F.M. Stavast and J.L.C.H. van Valkenburg (Editors). Pudoc, Wageningen. 1991/Prosea, Bogor. 1993.
- Proceedings of the First Prosea International Symposium, May 22–25, 1989. Jakarta, Indonesia. J.S. Siemonsma and N. Wulijarni-Soetjipto (Editors). Pudoc, Wageningen. 1989. (out of print).

In brief, Prosea is

- an international programme, focused on plant resources of South-East Asia;
- interdisciplinary, covering the fields of agriculture, forestry, horticulture and botany;
- a research programme, making knowledge available for education and extension;
- ecologically focused on promoting plant resources for sustainable tropical land-use systems;
- committed to conservation of biodiversity;
- committed to rural development through diversification of resources and application of farmers' knowledge.

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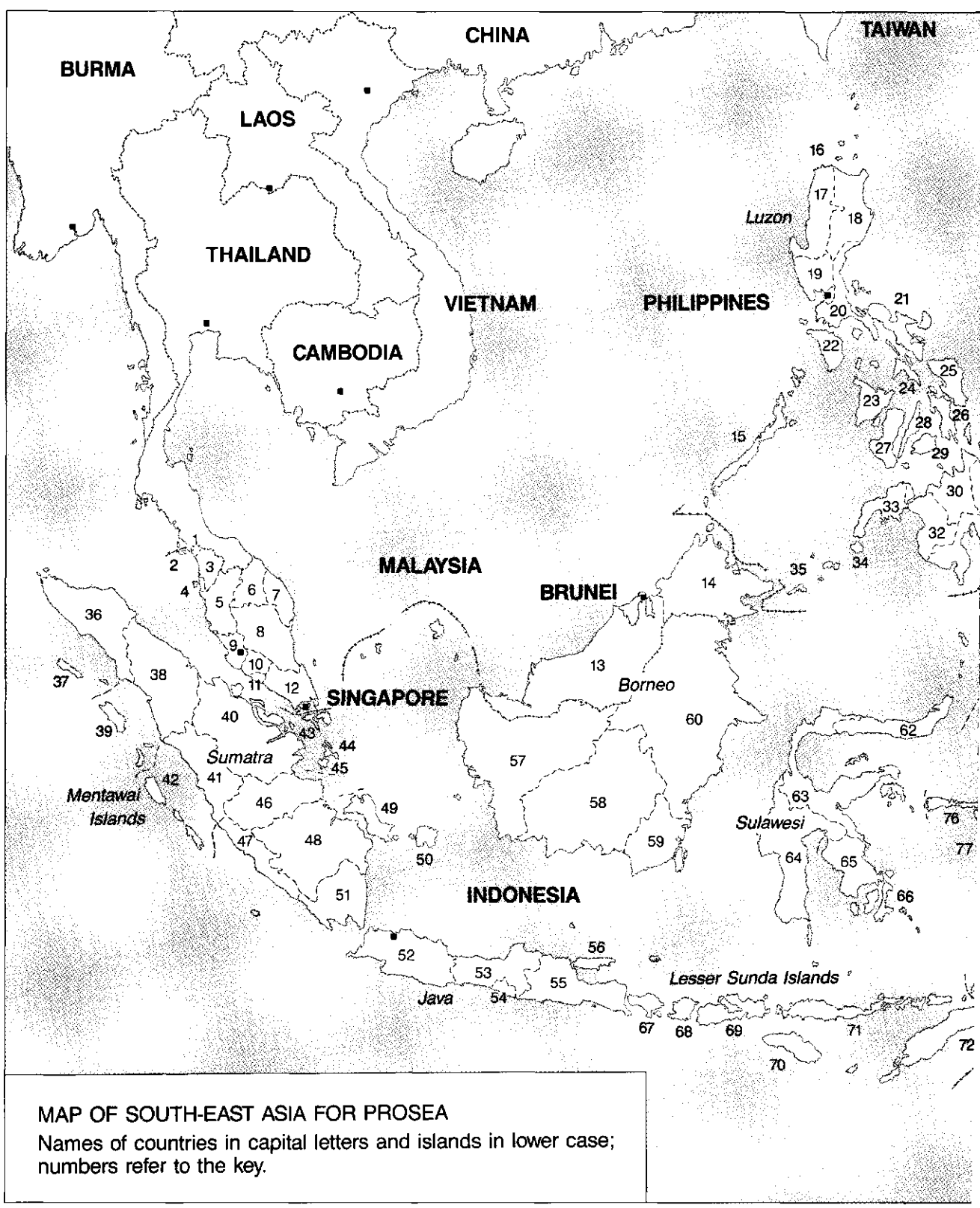
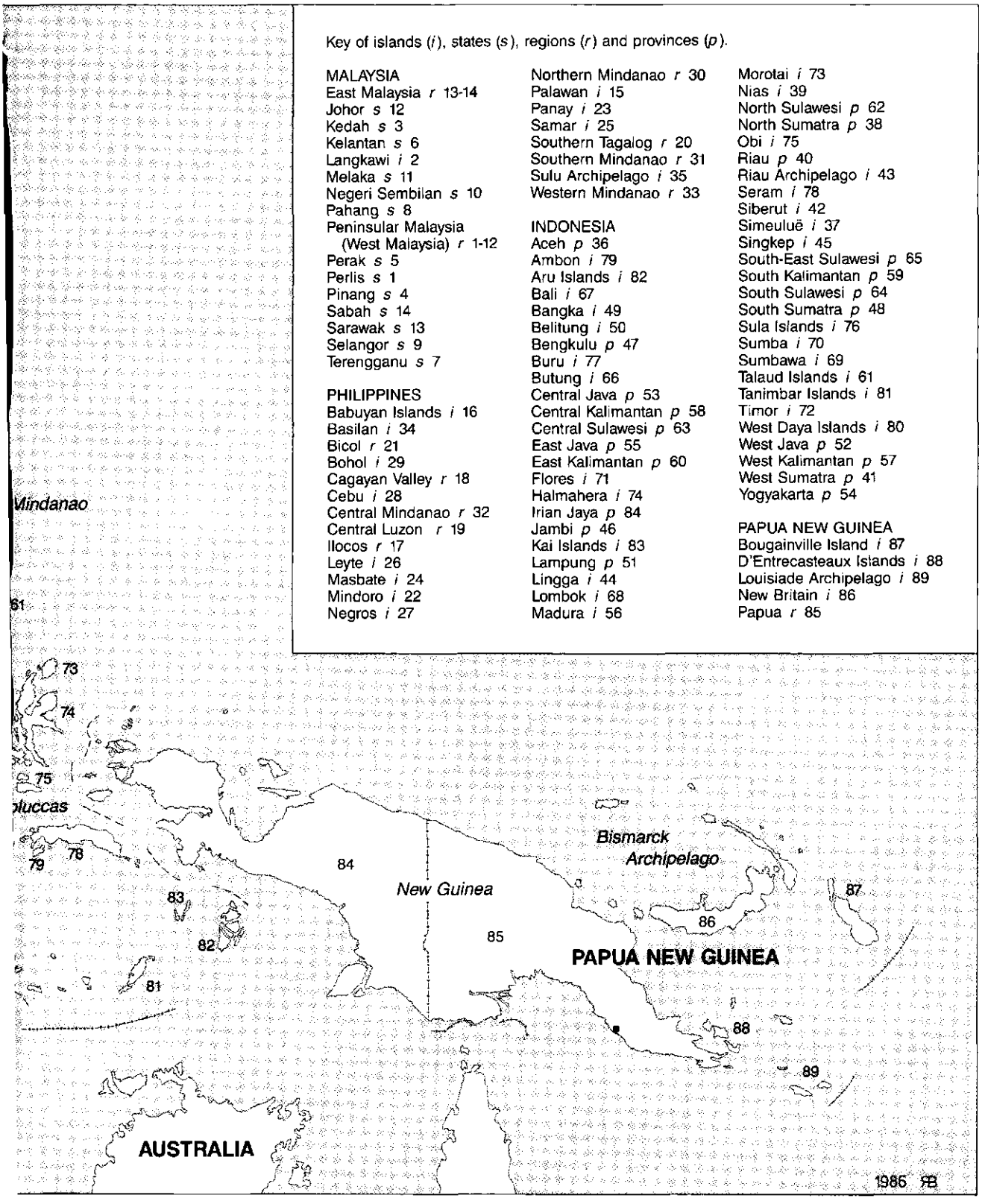


MAP OF SOUTH-EAST ASIA FOR PROSEA

Names of countries in capital letters and islands in lower case; numbers refer to the key.


Key of islands (i), states (s), regions (r) and provinces (p).
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