

*Technical Paper*

# Exotic Bamboo Species in Uganda: Identification and Assessment

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Ministry of Foreign Affairs of the  
Netherlands



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The International Bamboo and Rattan Organization (INBAR) is an intergovernmental organization dedicated to the promotion of bamboo and rattan for sustainable development. For more information, please visit [www.inbar.int](http://www.inbar.int).

### **About this Working Paper**

This work is an INBAR publication produced as part of the Dutch-Sino East Africa Bamboo Development Programme—Phase II, funded by the Kingdom of the Netherlands and the Chinese government. The Dutch-Sino East Africa Bamboo Development Programme II is a triangular South-South cooperation to support livelihood development, food security, and better environmental management by developing robust bamboo value chains and a sustainable bamboo industry in Ethiopia, Kenya, and Uganda.

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## Foreword

INBAR has encouraged several initiatives around the world aimed at utilizing the potential of bamboo to transform the economy of member states through its use as a fast renewable and sustainable alternative to conventional woody biomass for applications ranging from construction to biofuel. Since 2017, the Dutch-Sino East Africa Bamboo Development Programme, covering Ethiopia, Kenya, and Uganda, has sought to apply the experience gained in other parts of the world to develop value chains and support livelihoods. The role of bamboo plantations in forest landscape restoration, soil erosion control, water conservation, and climate change mitigation and adaptation is being recognized.

A remote sensing study by INBAR–Tsinghua University estimated the bamboo growing area to be 54,533 ha in Uganda’s protected areas (PAs) (INBAR, 2018). The National Forestry Authority (2017) identified about 11 exotic bamboo species in Uganda. The Uganda National Bamboo Strategy and Action Plan for 2019–2029 (Ministry of Water and Environment, 2020) was launched to promote bamboo development, and the country expects to restore 375,000 ha of degraded forest land with bamboo by 2030. Widespread adoption of bamboo planting is expected to significantly contribute to Uganda’s commitments to increasing forest cover under other programs, including the Bonn Challenge, AFR100, the U.N. Sustainable Development Goals (SDGs), Uganda Vision 2040, Uganda Forestry Policy 2001, National Forest Plan 2012, National Land Use Policy 2013, and National Energy Policy 2002, as well as commitments to the Convention on Conservation of Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC). The contribution of bamboo to meeting the commitments of several SDG goals is now widely acknowledged, notably SDG 1 (End poverty), SDG 7 (Affordable and clean energy), SDG 11 (Sustainable cities and communities), SDG 12 (Sustainable consumption and production), SDG 13 (Climate change), SDG 15 (Life on land), and SDG 17 (South–South cooperation).

A field study conducted in November 2022 during the implementation of Phase II of the Dutch-Sino East Africa Bamboo Development Programme in Uganda looked into the identification of species introduced earlier, for which the documentation was not satisfactory, and assessed the performance of the species in different agro-ecological zones. The study is expected to provide guidance to farmers and other stakeholders in the precise identification of exotic bamboo species and match the species to sites that are best suited to bringing out their potential in terms of productivity and utilization.

This report, which is the outcome of the study, will provide useful detailed information on the species for decision making by policy makers and other stakeholders in the value chain to optimize the use of bamboo for economic and environmental benefits.

Ali Mchumo  
Director General  
International Bamboo and Rattan Organization

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Authors

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## Executive summary

The bamboo resources of Uganda consist of two native species and several exotic bamboo species introduced by different agencies to improve bamboo diversity in the country. Other than the traditional uses for construction, handicrafts, household implements, and edible shoots, the vast potential of bamboo as an industrial raw material for modern applications, such as engineered bamboo, biofuel, and as a tool for landscape restoration and soil conservation has yet to be well explored in the country. One limitation has been the dearth of scientific information on the exotic species pertaining to their identification, properties, propagation, and cultivation methods.

The Dutch-Sino East Africa Bamboo Development Programme, implemented by INBAR in 2017 in Ethiopia, Kenya, and Uganda, brought a fresh perspective to the bamboo sector, with opportunities for sharing experiences from around the world. A field study conducted in November 2022 as part of Phase II of the program in Uganda had the objective of assessing the scenario of exotic bamboo species in the country. The study involved field visits to observe the species trials and bamboo plantations located in different agro-ecological zones (AEZs) and to note the morphological variation, level of management, and productivity. The objective was to help stakeholders identify the bamboo species precisely and match the species to the most suitable AEZs in Uganda, based on the information available on their performance.

Conventional taxonomy depends on characters of the floral parts, which imposes a severe restriction in the case of bamboo since most species flower only once in their lifetime; thus, for most of the intervening period, identification must depend solely on vegetative characters. To overcome this serious limitation, a field key to the identification of the species based on the vegetative morphological features was developed, which is suitable for the layman.

The report of the study gives a full description of the selected exotic species, including taxonomic information, morphological features, the habitat and climatic parameters ideal for the species, propagation and cultivation methods available, and potential uses. Each description includes a set of photographs showing the nature of clumps, the culms and branching pattern, the appearance of new shoots, and the culm sheath, which, along with the taxonomic key, helps in the identification of species in the field.

Based on observations made during field visits and the characteristics of the exotic species in their native habitat, the suitability of selected species to the different AEZs of Kenya was ascertained.

*Bambusa bambos* and *Bambusa spinosa* (*B. blumeana*), the thorny bamboo species, were found to be most suited to low to mid-elevations with moderate to high rainfall found in Lake Victoria Crescent and West Nile.

*Bambusa multiplex*, a small-sized species widely cultivated around the world, was found suitable to areas of low to high elevation with moderate or high rainfall in Lake Victoria Crescent and West Nile.

Similarly, *Bambusa vulgaris*, a pan-global species commonly cultivated in Africa, has a wide range of preferred habitat suitability, from low to mid-elevations and in areas of moderate rainfall in Lake Victoria Crescent, West Nile, and Southwestern Highlands.

The mid-sized bamboo species *Bambusa polymorpha* and *Bambusa tulda* prefer the low to mid-elevations with low to moderate rainfall and are ideal for the Lake Victoria Crescent and West Nile regions.

Among the large-sized bamboo species, *Dendrocalamus asper* was found most suited to the locations in the low to mid-elevations in Lake Victoria Crescent and West Nile that receive moderate rainfall.

*Dendrocalamus brandisii* prefers higher rainfall and comes up well in the low to mid-elevations found in the Lake Victoria Crescent region. *Dendrocalamus giganteus*, the largest bamboo species, is better adapted to higher elevations and is suited to the high rainfall areas of the Lake Victoria Crescent and the Eastern and Southwestern Highlands. The same locations are also suitable for *Dendrocalamus hamiltonii*, a medium-sized species.

*Dendrocalamus membranaceus* and *Thyrsostachys siamensis* prefer low to mid-elevations and tolerate low to moderate rainfall; thus, they are ideal for the Lake Victoria Crescent and West Nile regions.

*Dendrocalamus strictus*, a small-sized bamboo, is well adapted to drier locations and low to mid-elevations and therefore suitable to the Southern Drylands, West Nile, and low rainfall areas of the Southwestern Highlands.

*Phyllostachys aurea* is a running bamboo that is suitable for higher elevations and tolerates the moderate rainfall in the Eastern and Southwestern Highlands.

The study offers recommendations for steps to be taken before large-scale bamboo plantations are established in the different AEZs of Uganda to ensure that best scientific practices are adopted to optimize productivity. The introduction of suitable germplasm of the selected species from the native regions and the carrying out of trials to demonstrate the best spacing and agronomic practices will help realize the full potential of the bamboo species. It is also recommended that agroforestry be encouraged so that farmers retain the benefits of the agricultural practices of the region, along with deriving additional economic resources from the annual harvest. The standardization of propagation methods for the large-scale production of quality planting material (QPM) in bamboo nurseries under a national certification scheme is also suggested to cater to the anticipated demand for planting material. The report also suggests a few additional exotic species that are expected to perform well in the AEZs and can be included in future programs for the testing of species.

## 1. Introduction

Bamboo, a woody perennial grass, has in recent times attained importance primarily as a source of rapidly renewable wood biomass for a range of applications that contribute to sustainable development. The benefits of bamboo lie in its contributions to the environment and the economy, either directly from the plant in its natural or cultivated form, which is used in construction, in handicrafts, and as food, or in its processed or engineered form as an alternative to timber, steel, and plastics or a viable bioenergy feedstock.

Bamboo is found in three major geographic regions with tropical and subtropical climates – South and Southeast Asia, Africa, and Central and South America (Latin America). All three regions have their native species, several of which have been brought into large-scale cultivation. Introduction to other regions has also been attempted with varying levels of success. Southeast Asia and China have an extraordinary richness in species diversity and, not surprisingly, a comparatively larger number of species from the region have been in cultivation.

### **The challenges**

The introduction of exotic species of bamboo into the country without appropriate documentation has resulted in confusion regarding the identity of the introduced species, as well as the origins of the planting material. The later introductions were part of trials carried out in various locations, and the expectation was that growth performance would generate information that could inform future plantation programs. However, the absence of proper management of clumps in trials has resulted in suboptimal performance.

A better understanding of the taxonomy of bamboo species, especially exotic species, would be advantageous to their cultivation and utilization. The identification of bamboo from planting material cultivated in nurseries is fraught with the danger of misidentification. Field visits were made to the major locations of species trials and bamboo plantations in various AEZs to observe the morphological variation so as to create an identification key and come up with recommendations on species–site matching based on our observations and cross-referencing literature and experiences from other countries.

Conventionally, taxonomists study the reproductive parts of plants to delineate species. The challenge with bamboo is the semelparous nature of most bamboo species and their unusually long life cycles. Identification in the field is therefore difficult, since the chances of obtaining a

plant in flower are relatively few. Although species discrimination of bamboo has been carried out by experts using descriptions of the reproductive parts, identification in the field can also be conducted based on the morphological features of vegetative parts. In such identification, as is to be expected, vegetative morphological traits are often prone to environmental variation.

## 2. Methodology

Several exotic bamboo species were introduced into Uganda since the 1990s as experimental species trials and plantations undertaken by farmers at various locations. Proper records of these introductions are not available and hence details of the species, the origin and type of the planting material used are not known in all the cases. Many of these early trials were not very successful and the reasons for poor performance or suitability is not known. To understand the status of exotic bamboo species and their growth performance, it was found necessary to make field visits to the various agroecological zones (AEZs) across the country to collect information first hand to confirm the species.

From the documentation that could be traced in official records, the history of exotic bamboo species was pieced together as best as possible. The team made field visits to various parts of Uganda in the first week of December 2022. Due to constraints of time and logistics it was not feasible to visit all of the plantation sites or to carry out observations across different seasons.

In the field, bamboo clumps were observed closely to identify morphological features that could help in identification and assessment process. Since the visits were not at the time of emergence of the new culms, only a part of the morphological features of the culms were available for identification of the species. Other details provided by the farmers or officials were also used to estimate the age of the plantations and the management practices adopted. Microclimatic parameters in the plantation were also considered along with the general climatic factors to arrive at conclusions on the influence of such factors on growth.

Information on taxonomic descriptions, local names, climatic parameters, propagation methods, productivity and traditional as well as industrial uses were collected from scientific literature and interaction with the enterprises. The species descriptions have mainly been taken from the INBAR publication on Global Priority Species of Economically Important Bamboo (Muralidharan and Shankar 2023). Suitability of a particular species to the potential sites across the different agroecological zones in Uganda was assessed and potential for commercial plantations determined with the information collected.

### 3. Agro-ecological zones of Uganda

Uganda is divided into nine AEZs based on climatic variations. Five of these support the growth of bamboo and have either farmer who have taken up cultivation or species trials that have been undertaken in the past. The five zones are Lake Victoria Crescent, Southern Drylands, Southern Highlands, Eastern Highlands, and West Nile.

These AEZs reflect the diversity of landscapes and climatic and soil parameters across the country, which render them suitable for a variety of agricultural activities. The same parameters that influence the agricultural and horticultural species are of relevance to bamboo since it is a woody grass, albeit with a wide range of adaptability. Hillary et al. (2022) identified the five AEZs in Uganda as having potential for the cultivation of bamboo based on the performance of introduced exotic species (Table-1).

**Table 1.** Potential of agro-ecological zones (AEZs) for cultivation of bamboo in Uganda

Agro-ecological zone	Altitude (m)	Annual temperature (°C)	Annual rainfall (mm)	Soil type
Lake Victoria crescent	1,000–1,400	18–28	Bimodal 1,200–1,450	Sandy clay loams with medium to high productivity.
West Nile	600–1,600	23–30	Unimodal 1,500–1,700	Sandy loam, acidic soils
Southern Drylands			<900	Sandy clay
Southwestern Highlands	1,000–3,500	10–25	Bimodal 1,250–1,500	Volcanic
Eastern Highlands	1,000–4,320	22–25	Bimodal 1,250–1,800	Volcanic

## 4. Exotic bamboo species of Uganda

Uganda's government and development partners have worked together for the past one decade to introduce 14 or 15 different kinds of exotic bamboo across the country's many agroclimatic regions. Field offices of the National Forestry Authority and the research institute, University which included CBOs and corporate partners, meticulously monitored the species at selected trial plantation locations. The following exotic species were documented and field-observed for assessment and identification (Table-2).

**Table 2.** Exotic bamboo species found in Uganda

<i>Bambusa bambos</i>	<i>D. brandisii</i>
<i>B. multiplex</i>	<i>D. giganteus</i>
<i>B. polymorpha</i>	<i>D. hamiltonii</i>
<i>B. spinosa</i>	<i>D. membranaceus</i>
<i>B. tulda</i>	<i>D. strictus</i>
<i>B. vulgaris</i>	<i>Phyllostachys aurea</i>
<i>Dendrocalamus asper</i>	<i>Thyrsostachys siamensis</i>

#### 4.1. *Bambusa bambos* (L.) Voss

**Synonyms** (Vorontsova et al., 2016):

*Arundo bambos* L., *Bambos arundo* J.F.Gmel., *Arundo excelsa* Salisb., *Bambusa indica* André, *Arundarbor bambos* (L.) Kuntze, *Bambusa bambusa* Huth, *Bambos bambos* (L.) W.F.Wright, *Arundo arborea* Mill., *Bambos arundinacea* Retz., *Bambusa arundinacea* (Retz.) Willd., *Bambos quinqueflora* Stokes, *Nastus arundinaceus* (Retz.) Sm., *Arundarbor arundinacea* (Retz.) Kuntze, *Arundo agrestis* Lour., *Bambos agrestis* (Lour.) Poir., *Bambusa agrestis* (Lour.) Steud., *Arundarbor agrestis* (Lour.) Kuntze, *Arundo bambu* Lour., *Arundo indica* Noronha, *Arundo maxima* Lour., *Bambos maxima* Poir., *Bambusa maxima* (Poir.) Steud., *Gigantochloa maxima* (Poir.) Kurz, *Arundarbor maxima* (Poir.) Kuntze, *Bambusa orientalis* Nees, *Ischurochloa arundinacea* var. *orientalis* (Nees) Buse, *Arundarbor orientalis* (Nees) Kuntze, *Bambusa arundinacea* var. *orientalis* (Nees) Gamble, *Bambusa arundo* Wight ex Steud., *Bambusa neesiana* Arn. ex Munro, *Bambusa arundinacea* var. *gigantea* Bahadur, *Bambusa bambos* var. *gigantea* (Bahadur) Benn. & R C Gaur, *Bambusa bambos* f. *gigantea* (Bahadur) S.S.Jain & S.Biswas.

**Common names** (Language/Area in parentheses):

Thorny bamboo (English); *Kotoha bah* (Assam–India); *Wakynta* (Garo–India); *Kanta bauns* (Orissa–India); *Illi*, *Mula*, *Pattill* (Kerala–India); *Bidduru*, *Gatte* (Karnataka–India); *Toncur* (Gujarat–India); *Bongu veduru*, *Mulla veduru* (Andhra Pradesh–India); *Mungil* (Tamil Nadu–India); *Nal bans* (Punjab–India); *Kanta bans*, *Behor bans* (West Bengal–India), *Kanta bans* (Bangladesh); *Kante bans* (Nepal); *Katu Una* (Sri Lanka); *Cha-kat-wa*, *Kyakat-wa* (Burmese); *Phai Paak*, *Phai Namm* (Thailand); *Rai-sai* (Khmer); *May Phaipa*, *Phaix pa* (Laos); *Russei khlei*, *Russei prei* (Cambodia); *Tre Ng*, *Tre Gai* (Vietnam); *Bambu duriori* (Indonesia); *Pring ori* (Java–Indonesia); Indian bamboo (Philippines); Spiny bamboo, *Bambú espinoso* (Cuba); *Banbu cafi a de indios* (Spain); *Bambus*, *Dorniger* (Germany); *Bambou épineux* (French).

**Description:**

A large clumping evergreen bamboo with short-necked pachymorph rhizomes. Culms are erect or gently arched. Culms are 6–10 m high (Banik, 2016), with a diameter of 5–8 cm, wall thickness of 1–1.5 mm, and internode length of 20–40 cm. Branches armed with stout thorns are a characteristic feature of this species (Figure 1).

**Culm sheath:**

Wide and triangular with pointed tip, 16–18 cm long, and 16–18 cm wide. The adaxial surface is glabrous or sparsely minutely hairy in stripes. The abaxial surface is glabrous, with glabrous margins, hyaline, and filmy. In the median region of the sheath, the upper margin extends slightly upward. The ligule is coriaceous and small, and indistinct from the auricle.

**Distribution**

**A. Native range:**

Indian subcontinent to Indochina.

Indian subcontinent (Assam, Bangladesh, India, Sri Lanka);

Indochina (Cambodia, Laos, Myanmar, Thailand, Viet Nam);

India (Orissa, Madhya Pradesh, and Konkan, and on the Western Ghat Range; Jharkhand, Bihar, Chhattisgarh, Deccan, and Nilgiris).

**B. In cultivation/naturalized in:**

Western Indian Ocean (Seychelles);

Indian subcontinent (Maldives);

Malesia (Java, Malaya, Molucca, Philippines, and Sumatra);

Central America (Costa Rica, El Salvador, Honduras, Nicaragua, and Panama);

Caribbean (Cuba, Windward Island);

India (Rongrenggiri areas of the East Garo Hills, the Angratoli Reserved Forest, and the South Garo Hills [Naithani, 2007]).

**Climatic parameters:**

The native habitat of *B. bambos* extends from sea level up to elevations of 1,200 m (Banik, 2016) receiving nearly 2,000–2,500 mm annual rainfall and with mean maximum temperatures of 28.5°C to 36.7°C.

**Soil:**

This bamboo grows well in red- to brown-colored sandy laterite loam soil with a pH of 7.4–7.8.

**Native habitat:**

This species is native to humid tropical regions in moist and dry deciduous forests and degraded forests along riverbanks, river valleys, and other moist sites (Banik, 2016).

**Propagation:**

*B. bambos* flowers gregariously in cycles of 30–49 yr. Seed weight (number per 1 g) is estimated as 99 (Banik, 2016), and 50%–80% germination is obtained. Clonal propagation through macro-proliferation is widely practiced (Kumar, 1994). Rhizome offsets of 1–2-year-old culms yield a 65%–75% success rate (Banik, 2016). Hormone-treated culm cuttings yield 50%–60% rooting, and branch cuttings are successful 45%–65% of the time (Banik, 2016). Air layering is also feasible (Banik, 2016) but not commonly practiced. Propagation through tissue culture is reported in this species through both axillary bud proliferation (Arya et al., 2002) as well as somatic embryogenesis (Mehta et al., 1982).

**Cultivation:**

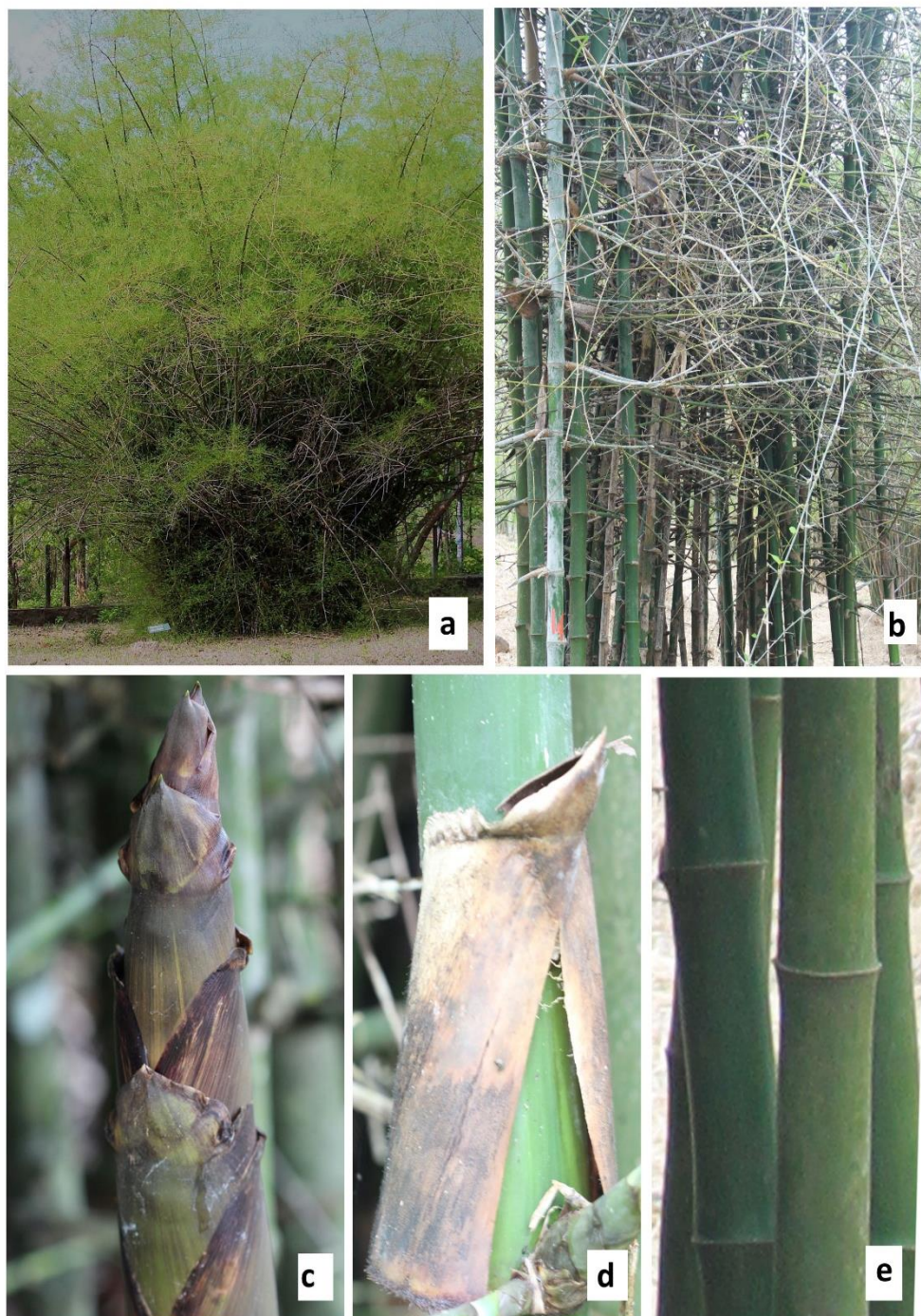
Spacing of 5 x 5 m and 6 x 6 m is used for block plantations, while 3–4 rows at close spacing are suitable for live fencing. Intercropping with species such as teak is possible (Banik, 2016).

**Productivity:**

Culm production: 16 culms/clump at the end of six years after planting (Shanmugavel and Francis, 1993). Aboveground biomass (AGB) of 17.5 kg to 70.1 kg from 2<sup>nd</sup> to 6<sup>th</sup> year (Shanmughavel, 1995). Yields 8,527 kg/ha in three yr. (Rao et al., 1991).

**Uses:**

Traditionally used for handicrafts, weaving, construction (the culm), and edible shoots; the thorny branches are used for fencing and clumps for live fencing (Banik, 2016). There are also medicinal amorphous siliceous deposits (Tabashir) (Banik, 2016). It has good potential for industrial use in laminated bamboo, woven strands, paper pulp, biorefinery, and charcoal. Other uses include water and soil conservation and food for wildlife (elephants).



**Figure 1.** *Bambusa bambos*: a) Clump habit; b) Culms and thorny branches; c) New shoot; d) Culm sheath; e) Culm surface

## 4.2. *Bambusa multiplex* (Lour.) Raeusch. ex Schult.f.

### Subspecies/varieties/clones:

Fern leaf; Alphonse-Karr; *B. multiplex* var. *multiplex* (*xiao shun zhu* or *yuan bian zhong*), *Bambusa multiplex* var. *incana* B.M.Yang (*mao feng huang zhu*), *Bambusa multiplex* var. *riviereorum* Maire (*guan yin zhu*), *Bambusa multiplex* var. *shimadae* (Hayata) Sasaki (*shi jiao zhu*).

### Common names (Language/Area in parentheses):

*xiao shun zhu* (China), Chinese dwarf bamboo, clumping bamboo, hedge bamboo, Oriental bamboo.

### Description:

Densely clumped bamboo with short-necked pachymorph rhizome and arching tips. The height of the culm reaches 3–10 m, with a culm diameter of 1.5–3 cm. The internodes are 30–45 cm long, and the wall thickness is 0.3–0.8 mm. Nodes are slightly prominent with branching throughout the culm. Culms and branches are green striped with green or yellow, with branches at culm nodes from the base to the top (Figure 2).

### Distribution

#### A. Native range:

China (South Central China, Hainan, Southeast China);  
Indian subcontinent (the Eastern Himalayas, Nepal);  
Indochina (Laos, Myanmar, Viet Nam).

#### B. In cultivation/naturalized in:

Western Indian Ocean (Mauritius, Madagascar, Seychelles);  
Western Asia (Iraq);  
East Asia (China);  
Indian subcontinent (Bangladesh, Pakistan, Sri Lanka);  
Indochina (Cambodia);  
Malesia (Malaya);  
Papuasias (Bismarck Archipelago);  
New Zealand (New Zealand, North Island);  
Southeastern United States (Florida);  
Mexico (southeastern Mexico);

Caribbean (Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Windward Islands);  
Western South America (Colombia, Ecuador);  
Brazil (Southeast Region).

**Climatic parameters:**

*B. multiplex* grows at a wide range of temperatures, from -10°C to 42°C, in areas with annual rainfall of 800–2,500 mm and at elevations of 500–1,000 m.

**Soil:**

The species prefers medium (loamy), heavy (clay), and well-drained soils. A soil organic carbon level of 0.80%–1.50% and a pH of 4.30–7.10 are suitable for the cultivation of this species.

**Native habitat:**

The species is found wild and under cultivation in low hills, mountains, fields, and along riversides.

**Propagation:**

The species flowers rarely and has not been reported to set seeds. Clonal propagation through rhizome offsets and culm and branch cuttings is widely used. Tissue culture procedures for multiplication using shoot meristems (Shirin and Rana, 2007) and somatic embryogenesis (Yuan et al., 2009) have been reported.

**Cultivation:**

The species is commonly planted for ornamental and landscaping purposes. Planting is done in live fences, strip plantations, and block plantations in agroforestry systems in 4 x 4 m or 5 x 5 m spacing or 1 x 1 m (for fencing).

**Productivity:**

Culm production of 2,500–3,000 culms/ha (Yuan, 2010) and an AGB of 15–20 t/ha/yr. (Yuan, 2010) have been reported.



**Figure 2.** *Bamusa multiplex*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) Culm surface

### 4.3. *Bambusa polymorpha* Munro

**Synonyms** (Vorontsova et al., 2016):

*Arundarbor polymorpha* (Munro) Kuntze; *Bambusa cyanostachya* Kurz ex Gamble

**Common names** (Language/Area in parentheses):

*Hui gan zhu* (China); *Jama betwa* (Assam, India); *Faura* (Tripura, India); *Wakobor* (ADC Dukli, Deb Barma, Tripura, India); *Kyanthung-wa* (Myanmar); *Pharua* (Sylhet, Bangladesh); *Mascumba*, *Burma*, *Rangoon bans* (Chittagong, Bangladesh); *Pai Hom* (Thailand).

**Description:**

Densely tufted bamboo species with pachymorph rhizomes with a very short neck. Culms are erect and attain a height of 10–25 m (Kumari and Singh, 2014; Banik, 2016) and a diameter of 5–15 cm (Banik, 2016; Kumari and Singh, 2014). Culms have a wall thickness of 1.5–2 mm. The length of the internodes varies from 40–95 cm (Kumari and Singh, 2014; Banik, 2016). Branching in the species is from mid-culm upward. Nodes are slightly prominent (Figure 3).

Culm sheaths are persistent, 20–25 cm long and 30–35 cm wide, broader at the base and rounded at the top, and covered on the back with densely and closely appressed brown to dark-brown deciduous hairs. The ligule is narrow, irregularly dentate, and ciliate. The auricles are unequal, falcate, continuous with a sheath, and with deciduous bristles. The blade is 6–10 cm long, reflexed, and deciduous. The base is triangular-cordate, and the apex acuminate, with an abaxial surface with brown pubescence and an adaxial surface felted with dark hairs; the margins are ciliate. Young shoots are brownish-green with a sheath of light brown or sometimes greenish or golden yellow, covered with dark brown hairs. The blades are greenish with dark brown hairs; the lower half margin has whitish or yellowish cilia and is boat shaped. At the tip of the shoot, the auricles are biseriate and are prominent and wavy with whitish or yellowish cilia. The leaves are linear-lanceolate, 7–18 cm long, and 1–2 cm wide.

**Distribution**

**A. Native range:**

Bangladesh to China (Yunnan) and Indochina.

China (South Central China);

Bangladesh;

Indochina (Laos, Myanmar, Thailand);

Malesia (Java, Myanmar, Thailand).

**B. In cultivation/naturalized in:**

Indian subcontinent (Assam, Eastern Himalaya, Sri Lanka);

Caribbean (Cuba, Puerto Rico);

Western South America (Ecuador);

India (Tamil Nadu, Kerala, and Karnataka) (Kumari and Singh, 2014).

In Uganda, it is grown in Kalagala-Mpigi (AEZ-Lake Victoria Crescent). Introduced in 2018 from seeds from India.

**Climatic parameters:**

*B. polymorpha* grows in a temperature range of 3°C to 35°C (Banik, 2016) but tolerates up to -3°C and up to 53°C (Long and Durai, 2019). The species grows well in areas with precipitation of 3,000–6,000 mm (Banik, 2016) and at elevations from 300–500 m (Kumari and Singh, 2014). In Uganda is grown in locations at 1227 m a.s.l, mean annual rainfall of 1600mm and mean annual temperature of 22.2°C,

**Soil:**

*B. polymorpha* prefers deep, rich, well-drained fertile loam soils (Banik, 2016). In Uganda it grows on medium to rich soils (clay with sand).

**Native habitat:**

The species is found on the borders of mixed subtropical evergreen forests and prefers a moist, shady habitat (Kumari and Singh, 2014). It is found particularly on lower slopes and in well-drained valleys and is often associated with teak in moist mixed deciduous forests. It prefers tall trees (Banik, 2016). It is also associated with *Cephalostachyum pergracile* in moist soils.

**Propagation:**

The species has a flowering cycle of 35–60 years (Kumari and Singh, 2014). The seed weight (number per 1g) is 0.038 and has a germination rate of 40% (PROSEA, 2016). Clonal propagation is successful with seedling macro proliferation after six months of germination in nursery beds. Rhizome offsets from 2-year-old culms have a 100% success rate (PROSEA, 2016; Benton, 2015). Culm cuttings are the best method for clonal propagation of this species (Banik, 2008), but branch cuttings also enjoy 90% success (Benton, 2015) and air layering 80% success (Benton, 2015; Long and Durai, 2019).

**Cultivation:**

Homestead plantation at a spacing of 4 x 4 m is adopted.

**Productivity:**

Culm production: 22 t/ha of air-dried culms in a three-year rotation

**Uses:**

Traditionally used in construction, for its edible shoots, stick-based products, and agricultural implements for landscaping (Long and Durai, 2019). The potential is high for paper/pulp and engineered bamboo. The species is ideal for agroforestry systems and can serve as a windbreak and protection against soil erosion. In Uganda culms are used for construction.



**Figure 3.** *Bamusa polymorpha*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath

#### 4.4. *Bambusa spinosa* Roxb.

##### Subspecies/varieties/clones:

*Bambusa blumeana* Schult.f., *Bambusa blumeana* var. *luzonensis* Hack.

##### Synonyms (Vorontsova et al., 2016):

*Arundo spinosa* (Roxb.) Oken, *Ischurochloa spinosa* (Roxb.) Buse, *Arundarbor spinosa* (Roxb.) Kuntze, *Bambusa arundinacea* var. *spinosa* (Roxb.) E.G.Camus, *Bambusa bambos* var. *spinosa* (Roxb.) S.S.Jain & S.Biswas, *Bambusa spinosa* Blume ex Nees, *Bambusa blumeana* Schult.f., *Schizostachyum durie* Rupr., *Arundarbor blumeana* (Schult.f.) Kuntze, *Bambusa pungens* Blanco, *Arundarbor pungens* (Blanco) Kuntze, *Bambusa teba* Miq., *Arundarbor teba* (Miq.) Kuntze, *Bambusa stenostachya* Hack., *Ischurochloa stenostachya* (Hack.) Nakai, *Bambusa blumeana* var. *luzonensis* Hack.

##### Common names (Language/Area in parentheses):

Spiny bamboo or thorny bamboo (English); *buluh duri*, *buluh sikai* (Malaysia); *anoo*, *batakan*, *baugin*, *dugian*, *baugin cana espina*, *kauayan*, *kauayan ng bayog*, *kauayan totoo*, *kauayan gid*, *kauayan potog*, *kabugauan*, *kauyang siitan*, *kawayang tinik*, *lamnuan*, *marurugi*, *pasingan*, *paua*, *rugian*, *cana espina* (the Philippines); *Tre gai*, *tre lá ngắn* (Viet Nam); *Bamboo duri*, *haur cucuk*, *pring gesing* (Indonesia); *Russei rollick* (Cambodia); *Phaix ban: nz* (Lao PDR); *Phai see suk*, *Waa me bo* (Thailand); *le zhu* (China).

##### Description:

A densely tufted erect bamboo with spiny branches and short-necked pachymorph rhizomes. The culms grow to a height of 15–25 m (Mohmod et al., 1993). The average culm diameter is 7.3–8.7 cm (Mohmod et al., 1993): 7.8–10.3 cm at the base, 8.13–9.65 cm in the middle, and 7.06–7.6 cm at the top (Salzer et al., 2018). Internodes are 18–60 cm long, and the wall thickness is 0.7–1.5 cm (Mohmod et al., 1993; Dransfield and Widjaja, 1995). Nodes are prominent (Dransfield and Widjaja, 1995). Branching starts from the base upward, forming a thick interlacing thicket (Figure 4).

##### Distribution

###### A. Native range:

Jawa to Maluku.

Malesia (Borneo, Jawa, Lesser Sunda Islands, Maluku, and the Philippines).

**B. In cultivation/naturalized in:**

China (South Central China, Southeast China);  
Indian subcontinent (Bangladesh);  
Indochina (Cambodia, Laos, Thailand, Viet Nam);  
Malesia (Malaya);  
Caribbean (Puerto Rico).

**Climatic parameters:**

The species grows at 18°C to 32°C but can tolerate 8°C to 37°C. It prefers a mean annual rainfall of 1,500–4,000 mm but tolerates 1,000–5,000 mm (Ecocorp, 2021). Grows at elevations of up to 1,000 m.

**Soil:**

Grows in heavy soils and on marginal land. The optimum pH is 5–6.5. The species does not tolerate salinity (Dransfield and Widjaja, 1995).

**Native habitat:**

Mixed moist deciduous forest, and not less commonly mixed dry deciduous forest and semi-evergreen forest. Grows well along riverbanks, on hill slopes, and along freshwater creeks. The species tolerates flooding (Dransfield and Widjaja, 1995).

**Propagation:**

A flowering cycle of 20–30 yr. and sporadic flowering is reported but without any seed set (Dransfield and Widjaja, 1995). Clonal propagation using 2–3-noded culm cuttings taken from the middle portion of 1–2-year-old culms and 3-noded cuttings from branches, up to 1.5 cm in diameter, from 1–2-year-old culms with hormone treatment is reported to be successful (Dransfield and Widjaja, 1995). There are no known reports of micropropagation procedures.

**Cultivation:**

Block plantation with spacing of 8 x 8 m or 10 x 10 m (Dransfield and Widjaja, 1995).

**Productivity:**

Culm production of eight culms/yr. (800–1,200/ha) in managed plantations and five culms/yr. (500–750/ha) in unmanaged plantations, whereas 960–1,600 culms/ha/yr. in natural stands have been reported by Dransfield and Widjaja (1995). Standing crop production (dry weight)

is estimated at 143 t/ha (120 t for culms, 18 t for branches, 5 t for leaves) (Dransfield and Widjaja, 1995); 143 Mg/ha (Uchimura, 1978); and 9 t/ha/yr. of paper pulp (Dransfield and Widjaja, 1995).

**Uses:**

Traditionally used for weaving, construction, household implements, edible shoots (a preferred species), windbreaks, and live fences (Dransfield and Widjaja, 1995). Industrial uses include laminated bamboo, paper pulp, chopsticks, furniture, and flooring tiles (Dransfield and Widjaja, 1995; Tesoro and Espiloy, 1988). The potential is high for bioenergy, biorefinery, and engineered bamboo. The species is planted along riverbanks to control soil erosion.



**Figure 4.** *Bamusa spinose*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) Thorny branches

#### 4.5. *Bambusa tulda* Roxb.

##### **Subspecies/varieties/clones:**

*Bambusa tulda* Roxb. var. *tulda*, *Bambusa tulda* Roxb. var. *gamblei* P.Kumari & P.Singh var. *nov.*

##### **Synonyms** (Vorontsova et al., 2016):

*Dendrocalamus tulda* (Roxb.) Voigt, *Bambusa macala* Buch. Ham. ex Munro, *Bambusa trigyna* Roxb. ex Munro.

##### **Common names** (Language/Area in parentheses):

*Jati bah* (Assam, India); *Mitinga/Mirtenga* (Tripura, India; Bangladesh); *Taleda/Taral/Telda* (West Bengal, Odisha, India); raw thing (Mizoram, India); *Thaik-wa* (Myanmar); Bengal bamboo, *fu zhu* (China); Calcutta cane/East India brown bamboo/Bengal bamboo.

##### **Description:**

Medium-sized clumping bamboo with short-necked pachymorph rhizomes. The culms are erect and apically drooping. The culms attain a height of 8–30 m and zigzag at times in the lower part. The culm diameter ranges from 5–10 cm and the wall thickness from 0.75–2.75 cm. The internode length ranges from 18–35 cm. Branching occurs from 4<sup>th</sup> node upward (FOC), and nodes are slightly prominent (Figure 5).

##### **Distribution**

###### **A. Native range:**

Himalaya to China (Yunnan) and Indochina.

China (South Central China, Tibet);

Indian subcontinent (Assam, Bangladesh, East Himalaya, India, Nepal, West Himalayas);

Indochina (Laos, Myanmar, Thailand, Viet Nam).

###### **B. In cultivation/naturalized in:**

Western Asia (Iraq);

Caribbean (Puerto Rico);

Western South America (Columbia, Ecuador);

Brazil (Southeast Region).

**Climatic parameters:**

*B. tulda* grows in areas with a temperature range of 4 °C to 43.3 °C and rainfall of 1,200–1,400 mm. It grows particularly well at 4,000–6,500 mm. The species grows at elevations of 600–1,500 m.

**Soil:**

The species prefers fine-textured, moist alluvial soil in rainfall areas with good rainfall (semi-evergreen forests) (Seethalakshmi and Muktesh Kumar, 1998; Anon, 2005; Nautiyal et al., 2008; Singh et al., 2010) and flat alluvial deposits (Banik, 2016).

**Native habitat:**

Along the borders of evergreen forests and foothills in humid tropical and subtropical regions (Seethalakshmi and Muktesh Kumar, 1998; Anon, 2005; Nautiyal et al., 2008; Singh et al., 2010). It is found in association with *Shorea robusta* (Sal) and in mixed deciduous forests.

**Propagation:**

The species shows sporadic and gregarious flowering (Srivastava et al., 2012). Estimates of the flowering cycle vary from 15–40 yr. (Kumari and Singh, 2014; Benton, 2015). The seed weight (number per 1 g) has been estimated at 15 (Banik, 2000), 23.7 (Suraj and Nath, 2011), and 23.69 (Srivastava et al., 2012). Germination rates of 97% (Srivastava et al., 2012), 75% (Sarma et al., 2010), and 92% (Ahlawat et al., 2002) in 9–30 days have been reported. The viability period under proper storage conditions is three months.

Clonal propagation through seedling macro-proliferation is feasible in this species (Kumar, 1994). Rhizome offsets taken from 1–2-year-old culms (Singh, 2010) and culm cuttings from mid- to lower nodes have been successfully used for propagation (Banik, 2008). Branch cuttings and air layering have also been successful (Benton, 2015). Propagation via tissue culture through axillary bud proliferation was reported by Saxena and Bhojwani (1991) and Mishra et al. (2008).

**Cultivation:**

Plantation type: block plantations and agroforestry plantations at a spacing of 5x5 m; interplanting with trees like teak, *Shorea* and other agroforestry species is feasible. It has a culm production of 1,088 culms/ha (Majumdar et al., 2016), and the AGB has been estimated at 100.29 Mg/ha (Devi and Singh, 2021).

The species shows tremendous variability, and 19 genotypes are recognized (Singh, 1993). Surveys, germplasm collection, and the selection of superior genotypes for propagation have been conducted by the ICFRE throughout the native habitats in India (Ginwal, 2021).

**Uses:**

Traditionally used for handicrafts, basketry, construction (Benton, 2015), edible shoots, incense sticks, furniture (Benton, 2015), mats, baskets, fishing rods, and flutes.

Industrial uses include laminated bamboo (Benton, 2015), strand woven board (Mohmod et al., 1993), paper, and pulp (Tisero and Espiloy, 1998). The potential exists for bioenergy, biorefinery, and carbon trading.

It is a common species in the flood-prone areas of northeast India, where it is important for soil erosion control. The species also comes up well in drier tracts and has the potential for eco-restoration.



**Figure 5.** *Bambusa tulda*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath

#### 4.6. *Bambusa vulgaris* Schrad. ex J.C.Wendl.

##### **Subspecies/variety/clone:**

Three varieties—green, yellow (“Striata”), and Buddha’s Belly (“Wamin”).

##### **Synonyms** (Vorontsova et al., 2016):

*Leleba vulgaris* Schrad. ex J.C.Wendl. *Arundo mitis* Lour., *Bambos mitis* (Lour.) Poir., *Bambusa mitis* (Lour.) Steud., *Phyllostachys mitis* (Lour.) Rivière & C.Rivière, *Arundarbor mitis* (Lour.) Kuntze, *Nastus thouarsii* Raspail, *Bambusa thouarsii* (Raspail) Kunth, *Nastus viviparus* Raspail, *Bambusa striata* Lodd. ex Lindl., *Arundarbor striata* (Lodd. ex Lindl.) Kuntze, *Bambusa vulgaris* var. *striata* (Lodd. ex Lindl.) Gamble, *Leleba vulgaris* var. *striata* (Lodd. ex Lindl.) Nakai, *Bambusa mitis* Blanco, *Bambusa monogyna* Blanco, *Arundarbor monogyna* (Blanco) Kuntze, *Bambusa humilis* Rchb. ex Rupr., *Bambusa surinamenis* Rupr., *Arundo fera* Oken, *Bambusa fera* (Oken) Miq., *Arundarbor fera* (Oken) Kuntze, *Bambusa blancoi* Steud., *Arundarbor blancoi* (Steud.) Kuntze, *Bambusa sieberi* Griseb., *Bambusa auriculata* Kurz, *Gigantochloa auriculata* (Kurz) Kurz, *Oxytenanthera auriculata* (Kurz) Prain, *Bambusa madagascariensis* Rivière & C.Rivière, *Bambusa vulgaris* var. *vittata* Rivière & C.Rivière, *Bambusa vulgaris* f. *vittata* (Rivière & C.Rivière) McClure, *Bambusa vulgaris* var. *latiflora* Balansa, *Bambusa latiflora* (Balansa) T.Q.Nguyen, *Bambusa nguyenii* Ohrnb., *Bambusa wamin* E.G.Camus, *Bambusa vulgaris* var. *aureovariegata* Beadle, *Bambusa vulgaris* f. *waminii* T.H.Wen.

##### **Common names:**

(Language/Area in parentheses): *long tou zhu* (China), *Jai borua* (Assam, India)

##### **Description:**

Large tufted bamboo with short-necked pachymorph rhizomes. The loosely clumping erect culms with drooping tips are slightly bent at the base. Culms are 8–15 m high and have a diameter of 5–9 cm and wall thickness of 7.3–15 mm. Internodes are deep green with a length of 20–30 cm (Flora of China, 2016). Branching occurs from the lower nodes upward; the nodes are slightly prominent (Figure 6).

The culm sheaths are deciduous with the apex arched below blades and concave below auricles. The auricles are conspicuous, ascending, nearly equal in shape and size, and oblong or reniform (8–10 mm). The oral setae are curved and fine. The ligules are 3–4 mm, serrate, very short, white, and ciliolate. The blades are deciduous, erect or deflexed, broadly triangular

to triangular, with a base that is slightly rounded and ca. ½ the width of the sheath apex. The abaxial surface is sparsely covered with stiff, dull brown hairs; the adaxial surface is densely covered with stiff, dull brown hairs between veins; and the apex is involute and sharply apiculate. The leaf blade is narrowly lanceolate, 10–30 x 1.3–2.5 cm. Both surfaces are glabrous.

## **Distribution**

### **A. Native range:**

China (South Central China);  
Indochina (Cambodia, Laos, Myanmar, Thailand, and Viet Nam).

### **B. In cultivation/naturalized in:**

Northern Africa (Libya);  
West Tropical Africa (Benin, Burkina, Ghana, Guinea, Ivory Coast, Nigeria, Sierra Leone, Togo);  
West-Central Tropical Africa (Cameroon, Gulf of Guinea islands, Rwanda, Zaire);  
Mid-Atlantic Ocean (Ascension);  
Western Indian Ocean (Aldabra, Chagos Archipelago, Madagascar, Rodrigues);  
Indian subcontinent (Assam, Bangladesh, Eastern Himalaya, India, Maldives, Sri Lanka);  
Indochina (Andamans);  
Malesia (Java, Malaya, Maluku);  
Papuasias (Bismarck Archipelago, New Guinea);  
Southwestern Pacific (Tonga, Wallis and Futuna Islands);  
North Central Pacific (Hawaii);  
Southeastern USA (Florida, South Carolina);  
Mexico (Central Mexico, Northeast Mexico, the Gulf of Mexico, Southwest Mexico, Southeast Mexico);  
Central America (Costa Rica, El Salvador, Honduras, Nicaragua, Panama);  
Caribbean (Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, the Leeward Islands, Puerto Rico, Trinidad and Tobago, the Windward Islands);  
Western South America (Columbia, Ecuador, Peru);  
Brazil (Central-West Region, Northeast Region, Southeast Region, South Region).  
In Uganda it is cultivated in AEZ-LM2, AEZs; Lake Victoria crescent, and Southern Highlands Mpigi, Wakiso, Buikwe and Mityana.

**Climatic parameters:**

*B. vulgaris* grows from sea level to 870 m altitude in areas with annual rainfall of 1,364.3–2585 mm and an average temperature of around 25 °C. In Uganda the species prefers a mean annual temp 22°C and grows best in low altitudes. It tolerates a mean annual rainfall range of 700 - 4,500 mm but prefers 1,200 - 2,500mm.

**Soil:**

This species is widely grown in vertisols, andosols, ferralitic soils, and sandy, silty, hydromorphic, and sandy volcanic soils at a depth of 4.5–6 m (Nfornkah et al., 2020). In Uganda it grows in wide range of soils but prefers moist alluvial soil and also well drained sandy and clayey soils.

**Native habitat:**

This species is found along riversides and in open forests in Yunnan (Flora of China, 2016).

**Propagation:**

*B. vulgaris* is a sterile species that rarely flowers but sets no seeds. Clonal propagation through pre-rooted rhizomes or culm and branch cuttings is the most common means of propagation. Ground layering and air layering are also successful. Micropropagation through axillary bud proliferation has also been achieved (Nadgir et al., 1984; Arya and Arya, 2009; Ramanayake et al., 2006; Arshad et al., 2005).

**Cultivation:**

Block plantation at spacings of 6 x 6 m, 8 x 8 m, or 12 x 12 m.

**Productivity:**

Culm production: 10 t/ha/yr. (Seethalakshmi and Mukteshakumar, 2002); 2,296 culms/ha (Nfornkah et al., 2020);

**Uses:**

Traditionally used for handicrafts, weaving, construction, firewood as an ornamental and edible shoot. Industrial uses include particle board (Calegari et al., 2007; Gauss et al., 2019), laminated bamboo (Biswas et al., 2009), paper pulp, charcoal, and engineered bamboo. The potential for biofuel and biorefinery feedstock is high. *B. vulgaris* is a truly pan-global bamboo

species and has adapted well to a range of climatic conditions. It is drought as well as salinity tolerant and can therefore be used for eco-restoration programs with good success.



**Figure 6.** *Bambusa vulgaris*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) *B. vulgaris* var. *striata*

#### 4.7. *Dendrocalamus asper* (Schult.f.) Backer ex Heyne

##### **Subspecies/varieties/clones:**

*Betung wulung*, cv. Thai green, cv. *Phai Tong Dam* (Benton, 2015), *Dendrocalamus asper* f. *niger* Hildebrand., *Betung Hitam* (Rao et al., 1998).

##### **Synonyms** (Vorontsova et al., 2016):

*Arundo piscatoria* Lour., *Calamagrostis piscatoria* (Lour.) Steud., *Bambusa aspera* Schult.f., *Arundo aspera* (Schult.f.) Oken, *Gigantochloa aspera* (Schult.f.) Kurz, *Sinocalamus flagellifer* T.Q.Nguyen, *Bambusa bitung* Schult.f., *Schizostachyum bitung* (Schult.f.) Steud., *Arundarbor bitung* (Schult.f.) Kuntze, Revis., *Bambusa flagellifera* Griff. ex Munro, Trans., *Dendrocalamus flagellifer* Munro, *Schizostachyum loriforme* Munro, *Dendrocalamus asper* f. *niger* Hildebr.

##### **Common names:**

*Buong* (Vietnamese), *ma lai tian long zhu* (China)

##### **Description:**

This is a large, tufted, erect bamboo with short-necked pachymorph rhizomes. Culms attain heights of 15–30 m (Flora of China, 2016; Benton, 2015). Culm diameter ranges from 6–20 cm (Flora of China, 2016; Benton, 2015) and wall thickness between 1.1–2 cm (Benton, 2015; Banik, 2016). Culms have an internode length of 30–50 cm (Flora of China, 2016; Benton, 2015), and branches form from the 9<sup>th</sup> node upward (Flora of China, 2016) of culm (Figure 7).

##### **Distribution**

###### **A. Native range:**

Bangladesh to China and Malesia.

China (South Central China, Southeast China);

Indian subcontinent (Bangladesh);

Indochina (Andamans, Laos, Myanmar, Thailand, Viet Nam);

Malesia (Borneo, Java, Lesser Sunda Island, Malaya, Maluku, the Philippines, Sulawesi, Sumatra);

Papuasias (New Guinea).

###### **B. In cultivation/naturalized in:**

Indian subcontinent (Sri Lanka);

Papuasias (Bismarck Archipelago);

Caribbean (Puerto Rico);

Western South America (Colombia, Ecuador);

Brazil (West-Central, Northeast, Southeast, North, and South Regions).

In Uganda it is found cultivated in Luzira-Prizon Kamengo-Mpigi (AEZ-Lake Victoria crescent)

#### **Climatic parameters:**

The species is found growing in areas with an average temperature of 27°C and precipitation of 217 mm at elevations of around 600–1,500 m. In Uganda it is cultivated in mean annual temperature of 18-22.2°C but found to withstand frost and cool temperature up to -4°C. It prefers a mean annual rainfall in the range 954 - 3,600mm, but tolerates 1,200 - 4,500mm.

#### **Soil:**

*D. asper* will grow in any type of soil, but it will grow better in heavy soils with good drainage. In Thailand, the species grows well in sandy and rather acidic soils. In Uganda it prefers heavy and well drained soils like loamy soil and clay with sand.

#### **Propagation:**

Natural propagation occurs through seeds. A germination rate of 36.5% is obtained after 18 months of storage at 5°C (Banik, 2015). Clonal propagation through seedling macro-proliferation is feasible in nurseries at intervals of six months. Rhizome offsets give a success rate of 70–80% (Banik, 1995). Micropropagation through axillary bud proliferation (Arya et al., 2002; Singh et al., 2011; Banerjee et al., 2011) is successful and has been commercialized in India.

#### **Cultivation:**

Block plantations and plantations for edible shoots are planted at spacing of 5 x 5 m and 6 x 6 m.

#### **Productivity:**

Culm production of 10–11 t (Malanit et al., 2009) and 660–1,070 kg/ha/yr. (air dried) from a 3–4-year-old plantation (Tesoro and Espiloy, 1988) has been reported.

**Uses:**

Traditional uses include handicrafts and construction. The species is much sought after for edible shoots. Industrially, it is used for laminated bamboo (Malanit et al., 2009), oriented strand board (Febrianto, 2010; Malanit, 2011), and parquet flooring (Tesoro and Espiloy, 1988), and has good potential for bioenergy production and biorefinery. As a species with good performance around the world, its use in eco-restoration programs is ideal since livelihood development programs are also possible. The other advantages include its soil binding ability and the formation of leaf litter mulch and industrial utility.



**Figure 7.** *Dendrocalamus asper*. a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) Culm surface

#### 4.8. *Dendrocalamus brandisii* (Munro) Kurz

**Synonyms** (Vorontsova et al., 2016):

*Bambusa brandisii* Munro, *Arundarbor brandisii* (Munro) Kuntze.

**Common names** (Language/Area in parentheses):

*Bulka*, *Wanan*, Burma bamboo (India); *Bo shi tian long zhu* (China); *Kyalo-wa*, *wabo* (Myanmar); *hók* (Lao PDR); *phai-bongyai phai-sangyen* (Thailand).

#### **Description:**

The species is a large, tall evergreen bamboo with erect culms and short-necked pachymorph rhizomes (Banik, 2016). Culms attain a height of 19–33 m (Seethalakshmi and Muktesh Kumar, 1998; Flora of China, 2016). The culm diameter is 13–20 cm (Seethalakshmi and Muktesh Kumar, 1998), and the wall thickness is 1.7–3 mm (Viswanath et al., 2007), with an internode length of 30–43 cm (Seethalakshmi and Muktesh Kumar, 1998; Viswanath et al., 2007; Flora of China). Branching mostly occurs mid-culm upward, and nodes are not prominent, although aerial roots are present (Figure 8).

#### **Distribution**

##### **A. Native range:**

China (South Central China).

##### **B. In cultivation/naturalized in:**

Indian subcontinent (Bangladesh);

Indochina (Andaman Islands, Laos, Myanmar, Thailand, Viet Nam).

#### **Climatic parameters:**

*D. brandisii* grows in well-drained loamy soils in wet, evergreen tropical forest at elevations of up to 1,300 m.

#### **Propagation:**

The flowering cycle is 40–50 years (Viswanath et al., 2013). Seed weight is 100 seeds/gram (Viswanath et al., 2013). A germination rate of up to 90% is obtained within 90 days of collection (Viswanath et al., 2013). Clonal propagation through seedling macro-proliferation is practiced at six-month intervals in nurseries. Rhizome offsets and culm cutting, treated with hormones, are used routinely for propagation (Somen et al., 2011). Rhizomatous branch

cuttings have a success rate of 70% (Somen et al., 2011). Micropropagation through axillary bud proliferation (Mukunthakumar et al., 1999; Chetan, 2012; Muralidharan and Seethalakshmi, 2017) and somatic embryogenesis using zygotic embryos as explant (Vongvijitra, 1988; Nadgauda et al., 1990; Zamora, 1994; Muralidharan and Seethalakshmi, 2017) have been reported.

**Cultivation:**

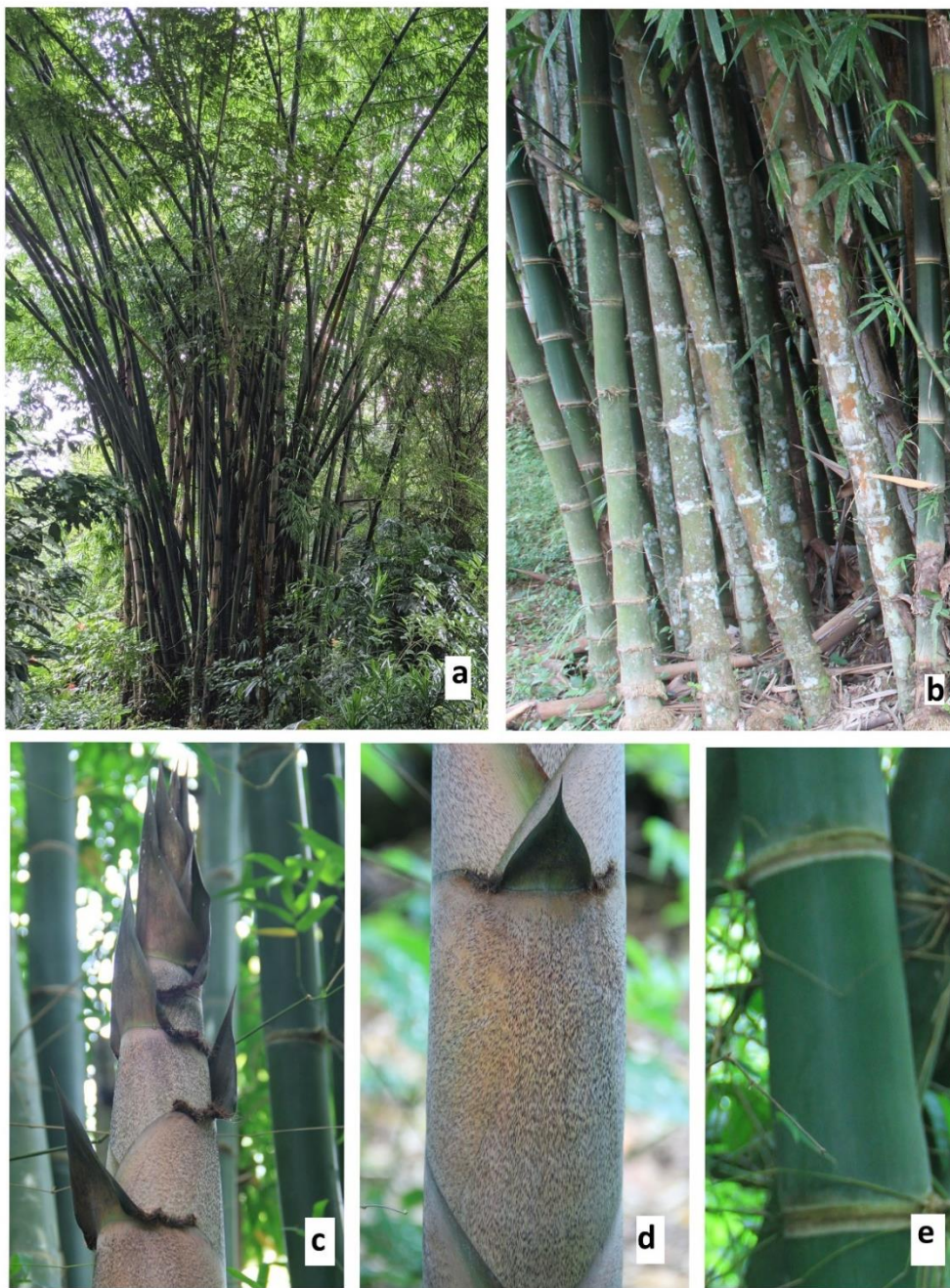
Block plantations: agroforestry planting employs spacing of 5 x 5 m, 6 x 6 m, and 6 x 10 m (Viswanath et al., 2013).

**Productivity:**

Culm production: annual fresh culms/clump: 2 (third year) to 10–40 (eighth year) (Viswanath et al., 2007); annual shoot production is 19.32–23.57 t/ha (Maoyi, 2007).

**Uses:**

Traditionally used for handicrafts, weaving, construction, and edible shoots. Industrial uses for laminated bamboo, strand woven board, paper pulp, composite fiber, and edible shoots. The potential is high for bioenergy and biorefinery feedstock.



**Figure 8.** *Dendrocalamus brandisii*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) Culm surface

#### 4.9. *Dendrocalamus giganteus* Munro

**Synonyms** (Vorontsova et al., 2016):

*Sinocalamus giganteus* (Munro) Keng f., *Bambusa gigantea* Wall.

**Common names** (Language/Area in parentheses):

Giant bamboo (English); *Maipo*, *Bhalo bans*, *Mari bol*, *Sadiya kako* (India) (Haridasan and Tiwari, 2008); *bambu sembilang* (Indonesia); *buloh betong*, *bambu sembilang* (Malaysia); *wabo*, *ban* (Myanmar); *russey prey* (Cambodia); *po'* (Laos); *phai-po*, *phai-pok* (Thailand); *m[aj]nh t[oo]ng to* (Viet Nam).

**Description:**

*D. giganteus* is among the largest bamboos. The species has short-necked pachymorph rhizomes and culms that reach a height of 24–30 m and has a diameter of 20–30 cm. The wall thickness is 2–3 cm, and the internodal length is 35–45 cm (Sint et al., 2008). The nodes are flat with branching only on the upper ones (Figure 9).

**Distribution**

**A. Native range:**

India (West Bengal) to China (Yunnan).

Indian subcontinent (Assam, Eastern Himalayas, and India);

China (South Central China);

Indochina (Laos and Myanmar).

**B. In cultivation/naturalized in:**

Indian subcontinent (Bangladesh, Nepal, Sri Lanka);

Western Indian Ocean (Mauritius, Madagascar, Seychelles);

East Asia (China);

Indochina (Cambodia, Thailand, Viet Nam);

Malesia (Java, Malaya, Sumatra);

Caribbean (Puerto Rico, Trinidad and Tobago);

Western South America (Ecuador).

In Uganda it is cultivated in Luzira-prizon, Katabi Entebbe and Kayunga (AEZ-Lake Victoria Crescent)

**Climatic parameters:**

The species is found up to elevations of 1,200 m a.s.l. In Uganda it grows well at 2070 m a.s.l, and in humid tropical highlands and in low lands with high humidity. It prefers a mean annual rainfall in the range 954 - 3,600mm, but tolerates 1,200 - 4,500 mm It prefers a mean annual temperature of 18-22°C but can tolerate up to -2°C.

**Soil:**

The species prefers rich alluvial soils, sandy, loam clay and loam soil,

**Native habitat:**

The species is found naturally in mid-tropical highlands up to 1,200 m in altitude, although it can grow in tropical lowlands and is found in natural forests with teak in Thailand (PROSEA, 1995).

**Propagation**

The species has a flowering cycle (gregarious) of 30–60 yr. (PROSEA, 1995; Kumari and Singh, 2014), although sporadic flowering/partial flowering is common. The seed weight (number per 1 g) is 20, and germination rates of 60%–75% are obtained in 3–7 days (Banik, 2016).

Seedling macro-proliferation is feasible after about 6 months of transplanting in nursery beds/containers. Rhizome offsets are successful but not very practical due to the large size of the culm and rhizomes. Culm cuttings have been used successfully (20%–40%) to produce rooted plants in 60–70 days; the mid-culm nodes were found to be best, whereas branch cuttings yield 60%–70% rooting in 45–55 days (Banik, 2008).

Tissue culture through axillary bud proliferation (Ramanayake et al., 2008; Arya et al., 2006) and organogenesis (Ramanayake and Wanniarachchi, 2003) have been successfully reported with this species.

**Cultivation**

Block plantations at spacing of 10 x 10 m is adopted. Intercropping with teak is feasible

**Productivity:**

Culm production: 200 culms and 200 young shoots/ha/yr. (PROSEA, 1995); 20–30 t/ha (Guadua Bamboo, 2021).

**Uses:**

Traditional uses of the species are for handicrafts, construction (walls, ceilings, and floorboards [flattened culms]), furniture, ornamentation (landscaping), water pipes, and the sheath is made into hats; edible shoots. Industrial uses include laminated bamboo, paper pulp potential for flooring tiles, disposable plates from the culm sheath.



**Figure 9.** *Dendrocalamus giganteus*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) Culm surface

#### 4.10. *Dendrocalamus hamiltonii* Nees & Arn. ex Munro

##### **Subspecies/varieties/clones:**

*Dendrocalamus hamiltonii* var. *edulis* Munro, *Dendrocalamus hamiltonii* var. *hamiltonii*.,  
*Dendrocalamus hamiltonii* var. *undulatus* Stapleton.

##### **Synonym** (Vorontsova et al., 2016):

*Sinocalamus hamiltonii* (Nees & Arn. ex Munro) T.Q. Nguyen

##### **Common names** (Language/Area in parentheses):

*Kako, Fonay, Pecha, Taqma, Unep, Wanoke, Pao, Phulrua, Maggar* (India) (Haridasan and Tiwari, 2008); *Vupa, Yiza, Watsa, Duling, Apo Khoguo, Hepai, Chentsu, Aghakhaub, Ratho, Apibo, Muiypru, Remhuh, Luhg, Woa, Talua, Waeng, Hepai, Vongnyu* (Nagaland, India) (Naithani, 2011); *Tama, Choya bans* (Nepal); *phai-nual-yai, pai-hok* (North, Thailand); *waa-klu* (Karen, Thailand); *manh tong nua* (Viet Nam); *ko hoe, h ok* (Laos).

##### **Description:**

A large evergreen bamboo with short-necked pachymorph rhizomes. Culms are erect but slightly zigzagged in appearance with a drooping (pendulous) top that attains a height of 12–24 m (Naithani, 2011). The wall thickness is 1.2–2 mm and the internodal length is 30–50 cm. Stout branches occur from the base (Naithani, 2011) of culm (Figure 10).

##### **Distribution**

###### **A. Native range:**

Nepal to China (Yunnan) and Indochina.

China (South Central China);

Indian subcontinent (Assam, Bangladesh, Eastern Himalayas, and Nepal);

Indochina (Laos, Myanmar, Thailand, and Viet Nam).

###### **B. In cultivation/naturalized in:**

Indochina (Cambodia).

##### **Climatic parameters:**

The species grows in areas with an annual mean temperature above 16 °C, with 900–2,000 mm of annual rainfall, and about 70% annual mean relative humidity (Zhan et al., 2016). It is found at elevations of 300–2,000 m (Das, 1990).

**Native habitat:**

The species is found in upland areas with moist, fertile soil, especially in hilly semi-evergreen to evergreen forests. It commonly occurs along the banks of streams and in valleys, often forming dense thickets, in evergreen and moist forests (Banik, 2016). The species seems to be a light demander and is rarely seen under the tree canopy. The species does not tolerate biotic interference (Banik, 2016).

**Propagation:**

The flowering cycle is reported to be 30–40 yr., and the seed weight (number per 1 g) is 26.4. The germination of 80%–85% of seeds occurs in 3–7 days. Viability is only up to 25 days without proper storage. Clonal propagation through seedling macro-proliferation is feasible (Kumari and Singh, 2014). Rhizome offsets have been successful (60%–70%) for propagation (Banik, 2016). Culm cuttings (70%–80%) and branch cuttings (70%–75%), as well as pre-rooted and pre-rhizomed branches from 1½–2-year-old culms yield good results (Banik, 2008, 2016). Propagation through axillary bud proliferation (Arya, Kaur and Arya, 2012; Sood et al., 2002; Agnihotri and Nandi, 2009) and somatic embryogenesis (Godbole et al., 2002) has been demonstrated.

**Cultivation:**

The species is suitable for block planting and riverside planting. A spacing of 4 x 4 m (Banik, 2016) is ideal. Intercropping with turmeric has been successful (Banik, 2016). It takes 3–5 yr. for maturation when established from rhizomes.

**Productivity:**

AGB: 71.76 kg/clump (Alameyhu et al., 2015).

**Uses:**

Traditional uses are for handicrafts, construction (culms), edible shoots, incense sticks (Banik, 2008), windbreaks in tea plantations (Naithani, 2011), pickled leaves (*hiyup*) in Arunachal, India (Pal, 1984), and fodder for cattle. Industrial uses include paper pulp (Naithani, 2011; Zhan et al., 2016). It has good potential for bioenergy, biorefinery and engineered bamboo.



**Figure 10.** *Dendrocalamus hamiltonii*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) Culm surface

#### 4.11. *Dendrocalamus membranaceus* Munro

**Subspecies/variety/clone:**

cv. Grandis

**Synonyms** (Vorontsova et al., 2016):

*Bambusa membranacea* (Munro) Stapleton & N.H. Xia, *Dendrocalamus longifimbriatus* Gamble, *Sinocalamus longifimbriatus* (Gamble) T.Q.Nguyen, *Oxytenanthera lacei* Gamble, *Dendrocalamus membranaceus* f. *fimbriligulatus* Hsueh & D.Z.Li, *Dendrocalamus membranaceus* f. *pilosus* Hsueh & D.Z.Li, *Dendrocalamus membranaceus* f. *striatus* Hsueh & D.Z.Li.

**Description:**

A large, evergreen clumping bamboo with short-necked pachymorph rhizomes and culms that reach a height of 8–25 m (Flora of China, 2016; Durai and Long, 2019). The culm diameter is 7–12 cm, and the internode distance is 34–42 cm (Flora of China, 2016; Durai and Long, 2019). Branching occurs from the base to the top, and the nodes are not prominent (Flora of China, 2016). The culm sheaths are deciduous, initially orange-green, elliptical to oblong, usually longer than the internodes, and papery with ciliate margins. The auricles are small, and the oral setae are short. The ligules are 8–10 mm and serrulate. The blade is reflexed, linear-lanceolate, and 30–40 cm x 2–3 cm of culm (Figure 11).

**Distribution**

**A. Native range:**

Bangladesh to China (S. Yunnan) and Indochina.  
China (South Central China);  
Indian subcontinent (Bangladesh);  
Indochina (Cambodia, Laos, Myanmar, Thailand, and Viet Nam).

**B. In cultivation/naturalized in:**

Malesia (Sumatera);  
Caribbean (Puerto Rico);  
Indian subcontinent (Peninsular India).

**Climatic parameters:**

*D. membranaceus* is found growing in a temperature range of 22 °C to 33°C (Durai and Long, 2019) in areas with precipitation of about 1,000 mm (Durai and Long, 2019). The preferred altitude for the species is 1,150 m, but it is found growing at altitudes of 50–1,400 m (Durai and Long, 2019).

**Soil:**

Prefers moist laterite or black limestone soil, although the plants can tolerate arid and barren conditions (Seethalakshmi and Muktesh Kumar, 2002). It also grows in light (sandy), medium (loamy), and heavy (clay) soils, prefers well-drained soil, and can grow in nutritionally poor soil with mildly acid, neutral, or basic (mildly alkaline) pH.

**Native habitat:**

The species is found in river valleys to hilly forested areas (Flora of China, 2016) in mixed deciduous or monsoon forests (Durai and Long, 2019) as pure bamboo forest or mixed with broad-leaved trees (China).

**Propagation:**

The flowering cycle is 19–20 yr., and a germination rate of 38% is obtained (Seethalakshmi and Muktesh Kumar, 2002). Clonal propagation through seedling macro-proliferation is not reported but is expected to be feasible. Rhizome offsets and culm and branch cuttings have been reported to be successful (Durai and Long, 2019). Micropropagation through axillary bud proliferation has been reported by Arya et al. (2002).

**Cultivation:**

Block plantations; in agroforestry, spacing of 5 x 5 m is adopted.

**Productivity:**

Productivity of 6,250 culms/ha was reported by Komiya et al. (2001). An AGB of 21.3 Mg/ha was reported by Yuen et al. (2017).

**Uses:**

Traditionally used for construction (Yang et al., 2012; Durai and Long, 2019), edible shoots (Yang et al., 2012; Long and Durai, 2019), and furniture (Yang et al., 2012). Industrial uses include laminated bamboo (Durai and Long, 2019), paper pulp (Yang et al., 2012; Durai and

Long, 2019), fiber board, and chopsticks. The potential is high for bioenergy plantations and biorefinery.



**Figure 11.** *Dendrocalamus membranaceus*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) Culm surface

#### 4.12. *Dendrocalamus strictus* (Roxb.) Nees

##### **Subspecies/varieties/clones:**

Three ecotypes are found in India—one common, medium-sized type found in dense clumps with solid culms; another found in large, loose clumps with straight culms and smooth internodes; and *Karka*, a dwarf type found in Madhya Pradesh, India.

##### **Synonyms:**

From the World Checklist (Vorontsova et al., 2016): *Bambos stricta* Roxb., *Nastus strictus* (Roxb.) Sm., *Bambusa stricta* (Roxb.) Roxb., *Bambusa tanaea* Buch.-Ham. ex Wall., *Bambusa pubescens* Lodd. ex Lindl., *Arundo hexandra* Roxb. ex Munro, *Bambusa glomerata* Royle ex Munro, *Bambusa hexandra* Roxb. ex Munro, *Bambusa verticillata* Rottler ex Munro, *Bambusa stricta* var. *argentea* Rivière, *Dendrocalamus strictus* var. *prainianus* Gamble, *Dendrocalamus prainiana* Varmah & Bahadur.

##### **Common names** (Language/Area in parentheses):

*Latare*, *Katli*, *Lathi*, *Dominee*, *Salia bauns*, *Tursing*, *Karka*, *Nakur bans*, *Kiri bidiru*, *Narvel*, *Kalmungil*, *Kallumula*, *Sadanapa Veduru*, *Karali*, *Lathi bans*, *Karail*, *Karka* (India); *Lathi* (Nepal); *Hmyin-wa* (Myanmar); *Bambu batu* (Indonesia) (Banik, 2016), *Lathi bans*, *Kanka kara*, *Sandapa veduru*, *Karal*, *Nakur bans*, *Kallan mula*, *Kurathi mula*, *Narvel*, *Salia*, *Kal mungil* (Haridasan and Tiwari, 2008); *Kirok*, *Oham Nget*, *Tephrie rie* (Nagaland, India) (Naithani, 2011).

##### **Description:**

A densely tufted, deciduous, sympodial bamboo with short-necked pachymorph rhizomes. The culms grow to a height of 6–15 m (Naithani, 2011) and, in some areas, up to 20 m (Benton, 2015). It attains a culm diameter of 2.5–7 cm (Naithani, 2011). The most common ecotypes have solid culms. Internode lengths range from 30–40 cm, with the 5<sup>th</sup>–6<sup>th</sup> internodes being the longest (Naithani, 2011). Culms zigzag slightly at times, have slightly prominent nodes, and branching is seen from the base to mid-culm. Culm sheaths are deciduous, orange-brown, ca. 3/4 as long as internodes, thickly papery, with ciliate margins, a rounded apex, and without auricles. They have a ligule of 1–3 mm, are serrulate, and have erect blades that are narrowly triangular. The leaf sheaths are initially sparsely hairy, becoming glabrous; the ligules are short and serrulate; and the blades are usually narrowly lanceolate (5–30 cm x 1–3 cm) of culm (Figure 12).

## Distribution

### A. Native range:

Indian subcontinent (Assam, India, Nepal, Pakistan, West Himalaya);  
Indochina (Andaman Islands, Laos, Myanmar, Thailand, and Viet Nam).

### B. In cultivation/naturalized in:

West tropical Africa (Togo);  
Western Indian Ocean (Madagascar and Seychelles);  
China (Southeast China);  
Malesia (Java, Malaya);  
Southwestern Pacific (New Caledonia);  
Central America (Honduras);  
Caribbean (Bahamas, Cuba, Puerto Rico, Trinidad and Tobago, Windward Islands);  
Brazil (Southeast Region).  
In Uganda it is cultivated in Entebbe

### Climatic parameters:

The optimum mean temperature for the species is 20°C to 30°C, but it can withstand extremes as low as 5°C and as high as 45°C (Banik, 2016). Mature plants are frost hardy, but young and tender culms are affected. Optimum rainfall is 1,000–3,000 mm, with 300 mm per month during the growing season. The species can also tolerate abnormal drought conditions (Banik, 2016). The species can grow from sea level to 1200 m a.s.l.

### Soil:

The species prefers well-drained soil, sandy loams, and hilly ground. It grows on loamy sand in Punjab, India (Singh et al., 2018). Soils of pH 5.5–7.5 (Banik, 2016), 8.2–8.4 (Singh, 2018), and 5.8–6.1 under cultivation in Thrissur, Kerala, India (Kittur et al., 2016) have been reported.

### Native habitat:

*D. strictus* is common in dry, deciduous forests and areas with low rainfall in many parts of India, Myanmar, and Thailand. The ecotype with tall, erect, and hollow culms ("*Dominee bans*" in Bihar and: "*Nadugani*" in Kerala) is found in moist areas. Karka, a dwarf type found in Madhya Pradesh, India, is associated with teak in many locations in India.

### **Propagation:**

The species flowers both gregariously in an estimated 25–45 yr. cycle (Kumari and Singh, 2014), but more commonly sporadically. Seed weight is 51.5 seeds per 1 g (Kumari and Singh, 2014). Seed viability is conserved only up to 30–35 days after collection under normal storage (Banik, 2016), but 59% germination was obtained after 34 months of storage at 3°C to 5°C after reduction of moisture content to 8% (Varmah and Bahadur, 1980). Clonal propagation is possible through seedling macro-proliferation (Banik, 1987), rhizome offsets, culm cuttings, branch cuttings, and air layering (Banik, 1995; Benton, 2015). Tissue culture propagation has been reported through axillary bud proliferation (Chaturvedi et al., 1993; Ravikumar et al., 1998) and somatic embryogenesis (Saxena and Dhawan, 1999; Reddy, 2006).

### **Cultivation:**

Block plantations with spacing of 4 x 4 m and 3 x 4 m (Long and Durai, 2019) or 1 x 1 m, 1.8 x 1.8 m, and 3 x 3 m (Patil et al., 2008) have been established. Intercropping of leguminous crops, turmeric, ginger, and vegetables for the first three years is feasible. Dev et al. (2020) found that intercropping with sesame and chickpea gave a better culm yield at 10 x 12 m and 10 x 10 m. The shooting season is from May to September, and shoots take two years to mature.

### **Productivity:**

Annual AGB/ha of 91.35–103.70 Mg/ha (Singh et al., 2004). Annual production of 3.5 t culms per ha. (Dransfield and Widjaja 1995)

### **Uses:**

Traditionally used for handicrafts, construction, household implements, tool handles, ladders, fencing and partitions, walking sticks, and batons. Industrial use has been for paper pulp and charcoal. The potential for bioenergy, biorefinery, and eco-restoration is high in low rainfall areas. In Uganda the species finds use in furniture, construction and basketry products. It is considered as suitable for fodder and for charcoal making.



**Figure 12.** *Dendrocalamus strictus*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath; e) Culm surface

#### 4.13. *Phyllostachys aurea* (André) Rivière & C.Rivière

##### **Subspecies/varieties/clones:**

*Phyllostachys bambusoides* var. *aurea* (André) Makino, *Phyllostachys reticulata* var. *aurea* (André) Makino, *Sinarundinaria reticulata* var. *aurea* (André), *Phyllostachys meyeri* var. *aurea* (André) Pilip., *Phyllostachys puberula* var. *flavescensinversa* J.Houz., *Phyllostachys aurea* var. *flavescensinversa* (J.Houz.) Nakai, *Phyllostachys aurea* f. *flavescensinversa* (J.Houz.) Muroi, *Phyllostachys bambusoides* f. *alternatolutescens* I.Tsuboi, *Phyllostachys reticulata* f. *alternatolutescens* (I.Tsuboi), *Phyllostachys aurea* f. *alternatolutescens* (I.Tsuboi) Makino & Nemoto, *Phyllostachys bambusoides* f. *albovariegata* Makino, *Phyllostachys reticulata* f. *albovariegata* (Makino) Makino & Nemoto, *Phyllostachys aurea* f. *albovariegata* (Makino).

##### **Synonyms** (Vorontsova et al., 2016):

*Bambos koteisik* Siebold., *Bambusa koteisik* Zoll., *Bambusa aurea* André, *Phyllostachys takemurae* Muroi in J. Sugimoto, *Phyllostachys breviligula* W.T.Lin & Z.M.Wu, *Phyllostachys formosana* Hayata.

##### **Common names** (Language/Area in parentheses):

Golden bamboo, fish-pole bamboo, stick bamboo, yellow bamboo, Castillon bamboo, hardy timber bamboo, *Madake*, giant timber bamboo, Japanese timber bamboo, fairyland bamboo (Australia); monk's belly bamboo (English), *Hotei-chiku*, *Pring uncue* (Indonesia).

##### **Description:**

A loosely clumping bamboo with leptomorph long-necked rhizomes. The culms attain a height of 2.5–12 m and a diameter of 1.0–5 cm, with a wall thickness of 2–8 mm. The internodes are long, between 8 and 20 cm, sulcate, with branches that are born at the middle of the culm with unequal thickness. There are prominent nodes with a white powdery wax below; the lower ones are often irregularly short and swollen, whereas the upper ones are distal and horizontal. Branches occur in uneven pairs with sulci. The stems and branches of the *P. aurea* are green when they are young and turn golden yellow at maturity (Figure 13).

The culm sheaths are yellow-green or pale red-brown, becoming straw-colored, with variably sized brown spots and the base edged with white pubescence. Auricles and oral setae are absent. The ligule is yellow-green, truncate or weakly convex at apex, very short, 1–2 mm, and the margin is longer, pale green, and ciliate. The blade is reflexed, green, with yellow margins, linear, and flat or crinkled in upper sheaths.

## Distribution

### A. Native range:

China (Fujian, Zhejiang) to Viet Nam.

China (Southeast China);

Indochina (Viet Nam).

### B. In cultivation/naturalized in:

Southwestern Europe (Spain);

West-Central tropical Africa (Cameroon);

Caucasus (Transcaucasus);

Indian subcontinent (East Himalayas);

Malesia (Jawa, Lesser Sunda Islands, Sumatera);

Australia (New South Wales, Queensland, South Australia);

New Zealand (Kermadec Island, North Island);

Northwestern U.S.A (Oregon);

Southwestern U.S.A. (California);

South-Central U.S.A.(Texas);

Southeastern U.S.A. (Alabama, Arkansas, Florida, Georgia, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia);

Mexico (Central Mexico, Northeast Mexico);

Central America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua);

Western South America (Bolivia, Colombia, Ecuador, Peru);

Brazil (Central West Region, Southeast Region, South Region);

In Uganda it is cultivated in Banda –wakiso (Lake Victoria Crescent)

### Climatic parameters:

*P. aurea* tolerates a wide range of temperatures from -15°C to 26°C and sometimes as low as -20°C (Rickel and Rojas-Sandoval, 2017). This species grows at elevations of 700–2,000 m with annual precipitation of around 1,000 mm (Rickel and Rojas-Sandoval, 2017). In Uganda it grows well up to 2056 m a.s.l and at a mean annual rainfall 1600-1800 mm and mean annual temperature of 18-19°C.

### Soil:

Sandy soils with drainage and rich nutrients are optimum for the wild growth of this species.

*P. aurea* cannot withstand waterlogged conditions (Rickel and Rojas-Sandoval, 2017). In

Uganda it tolerates a variety of soil types but grows best on rich, deep and well-drained sandy and loamy soils.

**Native habitat:**

It grows along stream edges and riparian corridors (Rickel and Rojas-Sandoval, 2017).

**Propagation:**

No seed setting has been observed in the species. Clonal propagation through rhizome offsets and clump parts 0.5–1.0 m long with a rhizome and roots are also commonly used for large-scale planting, with 100% success (Roxas, 2012). Tissue culture propagation through somatic embryogenesis has been found to be successful with this species (Huang and Huang, 1993).

This species is reported as an invasive in many countries. There are some cultivars of *P. aurea*, such as *P. aurea* 'Flavescens Inversa' (which has lower culms with a pale yellow stripe on the sulcus); *P. aurea* 'Holo-chrysa' with the common name 'golden golden' (of which the culms turn yellow/gold sooner than the type form; and random leaves have a yellow stripe); *P. aurea* 'Koi' (of which the culms turn yellow but the sulcus stays green, and random leaves have a yellow stripe); and *P. aurea* 'Takemurai' (of which the culms grow taller and lack the compressed internodes of the type form).

**Uses:**

Traditionally used for handicrafts, weaving, bamboo pipes, walking sticks, umbrellas, and fan handles. It is a popular garden ornamental and hedge plant. Industrial uses include charcoal briquettes and pellets for bioenergy. It has potential for cultivation in degraded lands for restoration and carbon sequestration.



**Figure 13.** *Phyllostachys aurea*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath

#### 4.14. *Thyrsostachys siamensis* Gamble

**Synonyms** (Vorontsova et al., 2016):

*Arundinaria siamensis* Kurz, *Arundarbor regia* (Thomson ex Munro) Kuntze, *Bambusa siamensis* Kurz ex Munro, *Thyrsostachys regia* (Thomson ex Munro) Bennet, *Bambusa regia* (Munro, 1868).

**Common names:** (Language/Area in parentheses):

*Pai Ruak* (Thai); monastery bamboo, umbrella-handled bamboo, Thai bamboo (English); *Shamu dake* (Japanese); *Bambu Jepang*, *Bambu Payung* (Indonesian); *Tam Vong* (Viet Nam); *Tiyowa*, *Kyaung-wa* (Myanmar).

**Description:**

It is a seasonal, deciduous, tightly clustered bamboo with a short-necked pachymorph rhizome. The culms attain a height of 8–16 m (Narasimhamurthy et al., 2013) and are mostly erect or gently arching with weeping tops. The diameter of the adult culm varies from 3–8 cm (Benton et al., 2011), with an average of 3.51 cm (Sompoh et al., 2013). The culms are solid at the base but with 8.89 mm wall thickness at the top (Sompoh et al., 2013). The internodes of the species are 15–38 cm long (Benton et al., 2011; Narasimhamurthy et al., 2013), mostly protected with persistent old culm sheaths. Branches grow from mid-culm nodes upward, with a dominant primary branch of 17–87 cm (Roxas, 2012) and several smaller branches without spines. Nodes are fragrant with a permanent sheath scar, but aerial roots and nodal ridges are absent (Roxas, 2012) of culm (Figure 14).

**Distribution**

**A. Native range:**

China (S. Yunnan) to Indochina;  
China (South Central China);  
Indochina (Laos, Myanmar, Thailand, Viet Nam);

**B. In cultivation/naturalized in:**

Indian subcontinent (Bangladesh, Sri Lanka);  
Malesia (Malaya).

**Climatic parameters:**

This species prefers an altitude of 300–1,000 m with precipitation of 100–2,000 mm and temperatures of 23°C to 30°C.

**Soil:**

*T. siamensis* grows well in a wide range of soils, especially sandy loam to clay loam, provided they are not waterlogged. The soil organic carbon concentration of this bamboo is  $58.96a \pm 8.48$  Mg/ha (Pibumrung, Gajasen and Popan, 2008) with a pH of 4.38–6.5.

**Native habitat:**

This species grows abundantly in open plains/slopes/valleys in dry, mixed deciduous, or semi-evergreen forest, as well as under canopy in association with *Anomianthus dulcis*, *Bauhinia malabirica*, *B. scandens*, *Ceasalpinia sappan*, *Zollingeria dongniaensis*, *Xylia xylocarpa*, *Homalium tomentosum* (Chaiyarat, 2018), and *Tectona grandis*.

**Propagation:**

Sporadic and gregarious flowering cycles are reported in this species. The number of seeds per gram is 10–82, with germination potential of 7%–86%, depending on the seed size (Banik, 2016). Clonal propagation with rhizomes of 1-year-old culms is a very successful method for this species (Banik, 2016). Culm cuttings with 2–3 nodal buds and branch cuttings with hormone treatment have also been reportedly successful (Azmy et al., 2009; Banik, 2016). Propagation through tissue culture has also been reported to be successful through axillary bud proliferation (Banik, Islam and Hadiuzzaman (1993)) as well as somatic embryogenesis (Obsuwan et al., 2019).

**Cultivation:**

The species is ideal for strip plantations for roadsides at closer spacing of 2–3 rows (Banik, 2016) and block planation (Benton et al., 2011), where a spacing of 4 x 4 m is suitable (Benton et al., 2011). Intercropping with timber trees, such as teak, is also promising (Dransfield and Widjaja, 1995).

**Productivity:**

An average of 28 culms per clump were obtained from a 3-year-old seed-raised plantation (Dransfield and Widjaja, 1995), and Scurlock et al. (2000) reported production of 1,500

culms/ha. Production of 11–54 t/ha (Scurlock et al., 2000), 26.98 t/ha of culms, and 4.22 t/ha of leaves and branches (Chaiyo et al., 2011) have also been reported.

**Uses:**

Traditionally used for handicrafts, construction, baskets, chopsticks, umbrellas, broom handles, fishing rods, ornamental plants, windbreaks, and edible shoots. Industrial uses include laminates, paper pulp, charcoal, and fuel.



**Figure 14.** *Thyrsostachys siamensis*: a) Clump habit; b) Culms and branches; c) New shoot; d) Culm sheath

## **5. Identification of bamboos based on vegetative morphological characters**

The identification of bamboo species in the field and in nurseries is generally considered difficult due to the limitation imposed by the lack of reproductive structures for most of the life cycle. The taxonomy of grasses relies greatly on flowers, and bamboos have therefore been ignored by botanical collectors since they are mostly not in flower. Preparation of herbarium specimens is also difficult due to the large size of the culms, the culm sheath, and inflorescence. Therefore, the identification of bamboo species in the field often has to be conducted based on morphological characters of the culm and the sheath. Field identification is further complicated by the rapid dehiscence, in many species, of the culm sheaths, which are of taxonomic importance. Many of the characters vary with the age of the culm and the sheath stretching from the bottom of the culm to the top.

Additional information, such as the natural habitat of native species and the history of the introduction of exotic species, is useful in narrowing down the list to those likely to be present in a particular region. The morphological keys to the identification of the bamboos of Uganda (given below) are based on morphological variations observed in exotic bamboo species introduced into the country and, therefore, may not be suitable for conducting identification in other regions where additional species might be present. The reader is advised to refer to taxonomic keys available in the literature for a wider set of species.

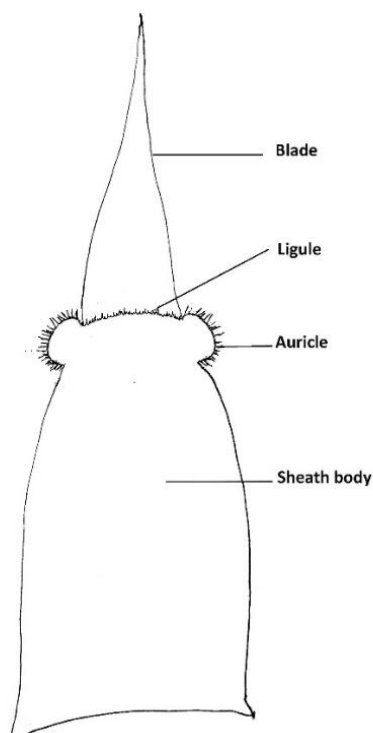
It should also be noted that the intraspecies variation is particularly significant, and so is the proclivity to exhibit variation when grown under different climatic conditions. Variations in culm diameter and color are commonly influenced by the prevailing conditions at the site.

### **5.1. Morphological characteristics of taxonomic importance**

Traditionally, reproductive structures have played an important role in plant taxonomy, and the description of flower parts is considered essential to describing a new species. However, because bamboo species are perennials with long life cycles and mostly semelparous (having a single flowering event in its life span), a commonly encountered difficulty in the identification of bamboo species in the field is the necessity of depending on vegetative characters. The following vegetative morphologic characters are useful for the identification of bamboo:

- **Culm sheath:** The shapes of various parts of the culm sheath are very useful for the purpose of identification. The features to be noted are the ligule, auricle, and blade. The persistence of the sheath on the culm and the nature of appendages, such as hair and cilia, are also useful in characterizing species.
- **The emerging shoot:** The morphology and color of the new shoot until it elongates to the final size is characteristic of a species.
- **The nodal region** on the culm also offers several features of taxonomic importance, such as the presence of rings of hair above or below, or the presence or absence of a prominent nodal ridge.
- **The nature of the rhizome**, especially the leptomorph or pachymorph types, and the length of the rhizome neck also provide valuable information for identification.
- **The surface of the culm:** The presence/absence of hairs, a waxy bloom, or color here is another useful identification feature.

The culm node in bamboo is characterized by the presence of a scar at the point of attachment of the culm sheath. A nodal ridge is present above the sheath scar, which may be prominent in some species (the supranodal ridge). The culm sheath is found in new culms and either falls off as the culms elongate or remains on the culm, but degrades gradually over months. The size and shape of the parts of the culm sheath are important taxonomic features. The earlike auricles on either side at the point of attachment of the blade and the shape and position of the blade with respect to the sheath body (erect, reflexed, or pendulous) are additional important features. Moreover, the color and texture of the culm surface, especially of young culms, are often characteristic of a species. The presence of a waxy bloom, downy hairs, or smooth surfaces are easily observed features that also help identify a species. Furthermore, branches are alternately arranged in culms, and the number of branches is of taxonomic significance.



**Figure 15.** Parts of the culm sheath

## 5.2. Morphological identification keys for bamboos of Uganda

1.
  - A. Rhizome leptomorph (thinner than culm diameter and running horizontally); culms solitary or in clusters separated from each other ..... *Phyllostachys aurea*
  - B. Rhizome pachymorph (thicker than culms); culms clump together loosely or tightly ..**2**
  
2.
  - A. Culms with spiny branches .....**3**
  - B. Culms without spiny branches .....**4**
  
3.
  - A. With white ring above node..... *Bambusa bambos*
  - B. Without white ring above node ..... *Bambusa spinosa* (*B. blumeana*)
  
4.
  - A. Culms with persistent sheaths, densely clustered..... *Thyrsostachys siamensis*
  - B. Culms without persistent sheaths .....**5**
  
5.
  - A. Young culms with white waxy bloom .....**6**

- B. Young culms without bloom .....7
  
- 6.
  - A. Large diameter hollow culms; culm sheath 40–45 cm long and 50–55 cm wide at base; ligule serrate in the middle ..... *Dendrocalamus giganteus*
  - B. Medium- to small-diameter culms .....8
  
- 7.
  - A. Small diameter culms (bright green rough surface, small leaves; culm sheath auricles very small or inconspicuous) ..... *Bambusa multiplex*
  - B. Medium- to large-sized culms .....9
  
- 8.
  - A. Culms solid at lower and middle internodes, sheath blade erect ..... *Dendrocalamus strictus*
  - B. Culms hollow, culm blade reflexed ..... *Dendrocalamus membranaceus*
  
- 9.
  - A. Prominent white ring above and below node ..... *Dendrocalamus hamiltonii*
  - B. White rings not present above node ..... 10
  
- 10.
  - A. Brownish-gray tomentose culms (lower nodes with rootlets, large leaves) ..... *Dendrocalamus asper*
  - B. Green/yellow with green striped culm with smooth surface ..... 11
  
- 11.
  - A. Cup-shaped culm sheath. Blades reflexed, culm sheaths have pale brown or white silky hairs ..... *Bambusa polymorpha*
  - B. Enlarged blades and large, unequal auricles; culm sheaths broadly triangular, length less than 1/2 the basal width; apex very broadly arched-convex or subtruncate; auricles ± horizontal ..... *Bambusa tulda*
  - C. Culm sheaths with stiff, dark brown hairs; auricles 0.8–1 cm; ligule 3–4 mm; leaf blade abaxially glabrous ..... *Bambusa vulgaris*

## 6. Bamboo species—site suitability

The history of bamboo introductions across the continents reveals that they adapt rather well to a wide range of climates and soil conditions, except for very arid regions and extremes of temperature. However, from the point of view of bamboo plantations as a commercial activity, it is essential to ensure that a satisfactory level of productivity is obtained to ensure that cultivation is rewarding to farmers and quality is enjoyed by the end users. To this end, it is vital that the species be chosen based on their growth performance under specific conditions and matched to the site.

Most important among the climatic factors that influence the survival and growth of bamboo is the temperature range, which is, in turn, influenced by the latitude and altitude of the location. Productivity is greatly influenced by the availability of moisture. In many of the sites visited, the growth of the bamboo clumps was affected by a lack of management, which had resulted in congestion and a decline in the quantity and quality of culms.

Bamboo plantations are established with commercial or environmental objectives. Productivity and the quality of bamboo culms in terms of length, diameter, straightness, and wall thickness are of prime concern, both from the point of view of better economic returns to the grower, as well as quality raw material for industries. Commercial plantations should therefore consider situations in which the scientific management of the clumps is feasible, to varying degrees, to ensure survival and optimum productivity. Moreover, competing land uses can result in marginal or degraded sites being preferred for planting, necessitating management interventions such as soil working, irrigation, mulching, fertilization, etc.

In the absence of well-planned field trials of bamboo species, the information available for decision making regarding appropriate species is limited to observations made in species trials, where the sample size is small and microclimatic conditions are not representative of the AEZ. Information from the literature on the performance of species in similar climatic areas in other countries is the next best guide to decision making. An allowance for improved growth performance under a better management regime is considered when the suitability of different species is recommended. It should also be remembered that since the choice of exotic bamboo species introduced to Uganda was not based on any systematic criteria, several other species with potential might be missing. Future plantation programs will benefit from species trials with a broader set of bamboo species chosen based on similarities in climatic parameters.

Based on firsthand observation of bamboo species during field visits at different sites in Uganda, Kenya, and other countries, as well as from information available in the literature, notably the INBAR reports (John et al., 2021; Hillary et al., 2022), recommendations for the suitability of bamboo species to various AEZs in Uganda (Table-3).

**Table 3.** Site-suitability of bamboo species to various AEZs in Uganda

Bamboo species	Suitable areas	AEZ for which the species is suitable
<i>Bambusa bambos</i>	Low to mid-elevations with moderate to high rainfall	Lake Victoria Crescent, West Nile
<i>Bambusa blumeana</i>	Low to mid-elevations with moderate to high rainfall	Lake Victoria Crescent, West Nile
<i>Bambusa multiplex</i>	Low to high elevations with moderate to high rainfall	Lake Victoria Crescent, West Nile
<i>Bambusa polymorpha</i>	Low to mid-elevations with low to moderate rainfall	Lake Victoria Crescent, West Nile
<i>Bambusa tulda</i>	Low to mid-elevations with low to moderate rainfall	Lake Victoria Crescent, West Nile
<i>Bambusa vulgaris</i>	Wide range of suitability, from low to mid-elevations and moderate rainfall	Lake Victoria Crescent, West Nile, Southwestern Highlands
<i>Dendrocalamus asper</i>	Low to mid-elevations with moderate rainfall	Lake Victoria Crescent, West Nile
<i>Dendrocalamus brandisii</i>	Low to mid-elevations with high rainfall	Lake Victoria Crescent
<i>Dendrocalamus giganteus</i>	Low to high elevations with high rainfall	Lake Victoria Crescent, Eastern and Southwestern Highlands
<i>Dendrocalamus hamiltonii</i>	Mid- to high elevations with moderate rainfall	Lake Victoria Crescent, Eastern and Southwestern Highlands
<i>Dendrocalamus membranaceus</i>	Low to mid-elevations with low to moderate rainfall	Lake Victoria Crescent, West Nile
<i>Dendrocalamus strictus</i>	Low to mid-elevations and low rainfall areas	Southern Drylands, West Nile, Low rainfall areas of Southwestern Highlands
<i>Phyllostachys aurea</i>	Higher elevations with moderate rainfall	Eastern and Southwestern Highlands
<i>Thyrsostachys siamensis</i>	Low to medium elevations with moderate rainfall	Lake Victoria Crescent, West Nile

## 7. Conclusions

Earlier studies on the performance of bamboo in Uganda (Hillary et al., 2022) were limited by the absence of mature plantations that could demonstrate the true potential of the exotic species. It was also observed during the field visits that management practices were suboptimal to minimal, which also project an incorrect picture of the potential of the species under interventions such as moisture management or decongestion.

To overcome the limitations described above and to confirm the suitability of species before embarking on large-scale plantations, especially for industrial applications that require quality culms rather than total biomass, proper trials are needed. These could take the form of management interventions to salvage clumps from existing trials or conducting fresh multilocational trials with control over some of the parameters. Two scenarios are possible: intensive management and minimal management. Intensive management involves larger pits at the time of planting, higher levels of manuring, regular irrigation, and soil working. Minimal management will involve at least irrigation in the summer to ensure survival and regular decongestion of clumps. Decongestion by removal of dead and overmature culms is mandatory at least every three years for both the management regimes.

Despite the lack of proper species trials, observations from the field indicate that several of the introduced species have potential, except in the most arid locations. As indicated in Table 3 above, the exotic species can be matched with multiple AEZs across Uganda. The potential for use of most of the exotic bamboo species in agroforestry systems is to be exploited since it permits the farmers to continue with their traditional crops but also to obtain additional income from bamboo clumps used either as intercrops or farm borders.

### **Potential for additional exotic bamboo species**

Introductions of exotic bamboo into Uganda carried out in the past, albeit in an unorganized manner without appropriate documentation, have resulted in preliminary information on the performance of the species in different zones. Judging from the available information, as well as the uses that the species are being put to in recent years, the question of the introduction of other similar species with potential for Uganda suggests itself. Most of the species introduced have been from South and Southeast Asia, which has a great diversity of bamboo species and a large number of sympodial species of economic importance. The recent publication, “Global Priority Species of Economically Important Bamboo,” by INBAR

(Muralidharan et al., 2023) lists several species that have potential for large-scale plantations and utilization.

- Moderate rainfall, low to mid-elevations: *Dendrocalamus barbatus*, *Pseudoxytenanthera stocksii*, *Pseudoxytenanthera madhavii*;
- Humid areas, mid-elevations: *B. balcooa*, *B. oldhamii*, *Dendrocalamus latiflorus*, *D. longispathus*;
- Low rainfall areas, low elevations: *Bambusa nutans*, *Pseudoxytenanthera ritcheyi*, *Schizostachyum pergracile*, *D. sikkimensis*.

It is to be emphasized that the performance of the species in each of the AEZs recommended above will depend on the level of management practices adopted, particularly the maintenance of the optimum culm density in the clumps by the timely removal of mature and dead culms. A common observation during visits to the species trial sites, and sometimes in the farmers' fields, was the lack of any form of clump management, resulting in tightly congested clumps with crooked and dead culms. A decline in the productivity and quality of the culms produced is to be expected under such conditions, leading to improper conclusions regarding the suitability of a species to the location.

### **Potential for value addition in Uganda**

An additional criterion when seeking species for large-scale planting would certainly be the potential applications to which the bamboo is suitable. Not only do these contribute to the economic returns that farmers can expect when the plantations mature, but the management practices and harvesting regime can also be modified to obtain the ideal quality for each application. The quality of culms, such as wall thickness, straightness, and taper, matters greatly to the engineered bamboo, construction, and furniture industries, for example.

The following applications are expected to develop in Uganda in parallel with the availability of bamboo:

### **Construction**

Bamboo culms, due to their favorable mechanical properties (especially their high strength-to-weight ratio, flexibility, tensile strength, fast renewability, and carbon sequestration capacity), are suited to environmentally friendly buildings. The aesthetic appeal of bamboo culms is ideal for ecotourism, earthquake- and tsunami-resistant buildings, disaster relief shelters, kiosks, waiting sheds, exhibition halls, etc.

### **Furniture**

Bamboo is a suitable raw material for furniture in contemporary designs to cater to the hospitality industry, promote competitiveness, and access upmarket clientele.

### **Food and fodder**

Bamboo shoots, which are traditionally used as an occasional food in the country, have the potential to be developed as a commercial product with the support of industrial processing facilities. Bamboo leaves are popular in Asia. The use of bamboo leaves for fodder, particularly to supplement conventional fodder in lean times, should be explored, particularly in agroforestry conditions.

### **Charcoal**

The conversion of bamboo culms and thinnings to charcoal shows promise, since it protects the natural forest from being exploited for firewood. Value addition in the form of pellets and briquettes will contribute to the local economy. Biochar for soil amendment also has tremendous potential for improvement of agricultural productivity in impoverished soils.

### **Engineered bamboo**

Various forms of engineered bamboo, in the form of composites and laminates, have come into use in recent times. They are fast becoming a replacement for conventional timber, steel, and plastic in construction, furniture, and household products. Large-diameter species, such as *D. asper*, *D. brandisii*, *D. giganteus*, and *B. vulgaris*, are suitable for such applications.

### **Landscape restoration**

Bamboos have a unique combination of features that make them ideal for use as landscape restoration devices. Not only are they suitable for the quick establishment of green cover, but their profuse root system and underground network of rhizomes prevent soil erosion, help retain water, and add organic matter to impoverished soils. The multiple uses to which bamboo is put, including replacement of timber, its use as food and fodder, applications of engineered bamboo, and bamboo as a biofuel, contribute to economic activity and livelihood development.

## 8. Recommendations

Based on the preliminary assessment of suitability of the introduced exotic species in various locations in Uganda, the potential of some bamboo species for commercial exploitation has become clear. To demonstrate their full potential under proper management practices before large-scale propagation and the establishment of plantations, the following steps are recommended:

- Introduce new planting material of the selected exotic species from their native regions to selected AEZs in Uganda that match in climate;
- Establish new demonstration trials to test the effects of spacing and standardize management practices for different types of bamboo plantations;
- Evaluate the agroforestry models appropriate for the dominant agricultural practices in each AEZ;
- Carry out extensive evaluation of variation in native species throughout the distribution range to identify suitable landraces for conservation and commercial exploitation for specific end uses;
- Standardize large-scale clonal propagation technology for the selected species for adoption by commercial nurseries; and
- Adopt a certification scheme for quality planting material (QPM) and nurseries.

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