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Global Priority Species of Economically Important Bamboo

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INBAR
INTERNATIONAL BAMBOO AND RATTAN ORGANIZATION

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About the International Bamboo and Rattan Organization

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

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Elizabeth A. Widjaja (page 148, *Schizostachyum zollingeri*, page 166, *Gigantochloa atter,* page 168, *Gigantochloa levis*);

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Introduction

Bamboo has come of age in recent times. For thousands of years, it has been the mainstay of many rural economies with a long and widespread tradition of use for buildings, household and farm implements and as food. It is now recognised as a valuable industrial raw material that can be converted to value-added products. The distinct advantage of bamboo lies in the fast growth and rapidly renewing lignocellulosic biomass. Bamboo fibre is now used in a range of products and processes representing sustainable alternatives to conventional materials like timber, steel, and plastic.

More than 1642 species of bamboo have been recorded (Vorontsova et al., 2016). The species are distributed mainly across Asia, Africa and South and Central America. Fewer than one hundred are cultivated in significant quantities. Historically, bamboo has mainly been extracted on a small scale from forests and homesteads with no attempt at scientific resource management or large-scale cultivation. Except for a few species, most bamboos have no history of domestication. Consequently, there has been little effort expended to develop optimal cultivation procedures, propagation methods or genetic improvement. Nevertheless, the importance of bamboo for rural economies has been widely recognised even as natural resources continued to be exploited.

Earlier efforts at priority species selection

The INBAR-IBPGR Consultative Meeting on the Selection of Priority Species of Bamboo and Rattan in 1993 marked the beginning of efforts to select species based on the economic importance and potential for large-scale cultivation. The publication that resulted, "Priority species of bamboo and rattan" (Williams and Rao, 1994) listed 19 priority species of bamboo and an additional list of 18 other important species that required attention at an international level for utilisation and conservation of genetic resources. In 1998, IPGRI and INBAR brought out a second edition of Priority Species of Bamboo and Rattan (Rao et al., 1998) in which new information was incorporated, including recommendation by national programmes. At the time, INBAR membership comprised only 11 countries, and bamboo research and development were still in its infancy in many parts of the world. For this reason, emphasis was placed on the Asian region for both these efforts, where many INBAR Member States were situated.

The priority species of bamboo selected by the experts in the 1998 report included the following 20 species and an additional 18 of secondary importance (Rao et al., 1998). This publication builds on and extends this previous work to give an updated list (Chapter 4) of 44 priority species, 18 additional species, and specific regional lists of priority species for Africa, Asia (South and Southeast Asia, China), and Latin America.

Priority species

1. *Bambusa balcooa*
2. *Bambusa bambos*
3. *Bambusa blumeana*
4. *Bambusa polymorpha*
5. *Bambusa textilis*
6. *Bambusa tulda*
7. *Bambusa vulgaris*
8. *Schizostachyum pergracile*
9. *Dendrocalamus asper*
10. *Dendrocalamus giganteus*
11. *Dendrocalamus latiflorus*
12. *Dendrocalamus strictus*
13. *Gigantochloa apus*
14. *Gigantochloa levis*
15. *Gigantochloa pseudoarundinacea*
16. *Guadua angustifolia*
17. *Melocanna baccifera*
18. *Ochlandra spp.*
19. *Phyllostachys pubescens*
20. *Thyrsostachys siamensis*

Additional species

1. *Arundinaria sp*
2. *Bambusa atra*
3. *Bambusa heterostachya*
4. *Bambusa nutans*
5. *Bambusa oldhamii*
6. *Bambusa pervariabilis*
7. *Lingnania chungii*
8. *Dendrocalamus brandisii*
9. *Dendrocalamus hamiltonii*
10. *Dendrocalamus hookerii*
11. *Dendrocalamus membranaceus*
12. *Gigantochloa albociliata*
13. *Gigantochloa atroviolacea*
14. *Gigantochloa balui*
15. *Gigantochloa hasskarliana*
16. *Oxytenanthera spp.*
17. *Phyllostachys glauca*
18. *Schizostachyum spp.*

Need for revision of priority species

The potential for use of bamboo for economic and environmental development is tremendous given its fast, renewable nature and ability to conserve soil, water and rapidly sequester carbon. While there are several bamboo species that are used in significant quantities, it is no longer sustainable to collect it from forests without large-scale degradation of ecosystems and degradation of genetic resources. Cultivation in plantations, agroforestry systems and homesteads is the only solution to ensure sustained supply of bamboo for these emerging industrial uses. Given the diversity of available species and the range of agroclimatic conditions in which they can be cultivated in different regions of the world, it is feasible to increase the area of bamboo available globally. This includes in areas where bamboo does not grow natively, but where climatic and other factors are conducive to its growth.

Within this context, a revision of the list of priority species of bamboo is attempted here. Earlier efforts described above, although commendable, were focussed primarily on Asian species. The prospects of the American and African species were not explored. This report takes a fresh look at bamboo species biodiversity from the perspective of the wider range of products and applications for bamboo available today. The purview is thus extended to include other regions that was omitted earlier (notably Africa and the Latin American countries). The emphasis is on the potential for large-scale cultivation of bamboo in different climatic and soil conditions to meet the requirements for all major uses.

Criteria for selection of priority species

There have been 1642 species of bamboo documented worldwide (Vorontsova et al., 2016). In order to identify the most useful, a set of criteria for selection must first be defined. Principle among these is the potential for largescale cultivation. This in turn is based on potential for utilisation of the species for various products and processes that would create a demand for raw material. Bamboo has a wide range of uses around the world and has traditionally been used for household and agricultural purposes and as edible shoots in rural areas. These traditional uses are important, but modern industrial uses will require significantly more volume of raw material. Current industrial uses of bamboo include engineered bamboo products like laminates, particle boards and bamboo scrimber/ lumber; feedstock for bioenergy applications like charcoal, syngas, bioethanol; and as a biorefinery for producing a host of industrial chemicals. While biomass from any bamboo is adequate for some of the uses, for many others the culm dimensions and the physical, chemical, and mechanical properties are important. These properties differ widely across species.

For the present revision, the species were first selected based on existing uses in different defined product categories. Then, priority species were further refined based on the potential for profitable, largescale cultivation, given the different agroclimatic factors prevalent in potential bamboo-growing areas. Over the last two decades, there has been a rapid increase in information and research on bamboo available in scientific journals, technical reports, and books. The availability of data on important morphological, climatic and physicochemical parameters

also contributed to the process of selection of priority species, with preference given to species on which a large amount of good quality data is available.

To avoid regional bias and to overcome the skewed distribution of publications across the different continents, at least 10 species of importance to each of the three main bamboo-growing regions of Africa, Asia and the Americas were selected. A significant extent of temperate leptomorph (running) bamboo, both in species diversity as well as in distribution and area under cultivation, occurs in China, along with several important sympodial species. We have therefore dealt with China as a separate region from rest of Asia, which includes South and Southeast Asia. Likewise, in the American continent, since the diversity of species and area under cultivation occurs predominantly in countries referred to as Latin America, we refer to Latin America as one of the regions. Consultation with bamboo experts in the respective regions was carried out to broaden the perspective and to avoid any bias that information from publications alone would bring.

Emphasis was given to native species of the respective regions that had potential for largescale cultivation in plantations. It was assumed that these species are better adapted to local climate and soil conditions, and that suitable propagation methods have already been standardised, so planting material in adequate quantities can be made available.

The selected bamboo species have been grouped into two categories:

Category I: Widely cultivated species already used in significant quantities. These species are therefore prime candidates to be promoted as global priority species. In most cases, the information available on various parameters for these species is adequate.

Category II: Additional species which have enormous potential for plantation but are currently limited in distribution/cultivation to a single region. In many cases, adequate information on many of the key parameters is not available for these species.

It is recognised that there are several important species for local communities and economies that nevertheless do not have a high potential for cultivation in other parts of the world. Local efforts to promote plantations, conservation of germplasm, standardisation of cultivation practices and development of value chains for utilisation are justified and valuable. However, such species do not fall in the purview of the present priority list.

Layout of datasheets for priority bamboo species

Datasheets are structured according to the key information and parameters described above. This report uses the World Geographical Scheme for Recording Plant Distributions to describe the geographic distribution of the priority bamboo species. This classification system is not designed to specifically match politically recognised regions, but instead to accurately describe geographical distributions based on convenience, botanical tradition or phytogeography. Level 2 (Region) is first given, then more specific Level 3 classifications (Botanical Country) are listed after the Level 3 designation. If no more specific information is known, then only the Level 2 classification is given. If known, Level 4 regions are given in square brackets. If available, a brief narrative description of the distribution of the species is given before the region and country codes.

Where information is missing, the datasheets are left empty or “none reported” or "no data available" is mentioned.

Updated priority list of economically important bamboo species by category

Category I (Global priority list of bamboo species)

1. *Bambusa balcooa*
2. *Bambusa bambos*
3. *Bambusa multiplex*
4. *Bambusa nutans*
5. *Bambusa oldhamii*
6. *Bambusa polymorpha*
7. *Bambusa rigida*
8. *Bambusa spinosa (B. blumeana)*
9. *Bambusa textilis*
10. *Bambusa tulda*
11. *Bambusa vulgaris*
12. *Chimonobambusa quadrangularis*
13. *Chusquea culeou*
14. *Dendrocalamus asper*
15. *Dendrocalamus barbatus*
16. *Dendrocalamus brandisii*
17. *Dendrocalamus giganteus*
18. *Dendrocalamus hamiltonii*
19. *Dendrocalamus latiflorus*
20. *Dendrocalamus longispathus*
21. *Dendrocalamus membranaceus*
22. *Dendrocalamus sikkimensis*
23. *Dendrocalamus strictus*
24. *Gigantochloa apus*
25. *Gigantochloa atroviolacea*
26. *Gigantochloa scortechinii*
27. *Guadua aculeata*
28. *Guadua angustifolia*
29. *Guadua chacoensis*
30. *Melocanna baccifera*
31. *Ochlandra travancorica*
32. *Oldeania alpina*
33. *Otatea acuminata*
34. *Oxytenanthera abyssinica*
35. *Phyllostachys aurea*
36. *Phyllostachys edulis*
37. *Phyllostachys nigra*
38. *Phyllostachys violascens (P. praecox)*
39. *Phyllostachys vivax*
40. *Pseudoxytenanthera stocksii*
41. *Schizostachyum pergracile*
42. *Schizostachyum zollingeri*
43. *Thyrsostachys oliveri*
44. *Thyrsostachys siamensis*

Category II (Additional list of bamboo species)

1. *Bambusa cacharensis*
2. *Bambusa chungii*
3. *Chimonobambusa tumidissinoda*
4. *Chimonobambusa utilis*
5. *Dendrocalamus somdevae*
6. *Dendrocalamus farinosus*
7. *Gigantochloa atter*
8. *Gigantochloa levis*
9. *Guadua paraguayana*
10. *Guadua amplexifolia*
11. *Guadua trinii*
12. *Phyllostachys glauca*
13. *Phyllostachys nidularia*
14. *Phyllostachys propinqua*
15. *Pseudoxytenanthera madhavii*
16. *Schizostachyum dullooa*

List of priority species by region

A. Africa

1. *Bambusa balcooa*
2. *Bambusa multiplex*
3. *Bambusa vulgaris*
4. *Dendrocalamus asper*
5. *Dendrocalamus giganteus*
6. *Dendrocalamus hamiltonii*
7. *Dendrocalamus membranaceus*
8. *Dendrocalamus strictus*
9. *Guadua angustifolia*
10. *Oldeania alpina*
11. *Oxytenanthera abyssinica*
12. *Phyllostachys aurea*
13. *Phyllostachys edulis*

B. Asia: South and Southeast Asia

1. *Bambusa balcooa*
2. *Bambusa bambos*
3. *Bambusa cacharensis*
4. *Bambusa multiplex*
5. *Bambusa nutans*
6. *Bambusa oldhamii*
7. *Bambusa polymorpha*
8. *Bambusa spinosa (B. blumeana)*
9. *Bambusa textilis*
10. *Bambusa tulda*
11. *Bambusa vulgaris*
12. *Dendrocalamus asper*
13. *Dendrocalamus barbatus*
14. *Dendrocalamus brandisii*
15. *Dendrocalamus giganteus*
16. *Dendrocalamus hamiltonii*
17. *Dendrocalamus latiflorus*
18. *Dendrocalamus longispathus*
19. *Dendrocalamus membranaceus*
20. *Dendrocalamus sikkimensis*
21. *Dendrocalamus somdevae*
22. *Dendrocalamus strictus*
23. *Gigantochloa apus*
24. *Gigantochloa atroviolacea*
25. *Gigantochloa scortechinii*
26. *Melocanna baccifera*
27. *Ochlandra scriptoria*
28. *Ochlandra setigera*
29. *Ochlandra travancorica*
30. *Phyllostachys violascens (P. praecox)*
31. *Phyllostachys edulis*
32. *Phyllostachys edulis var bambusoides*
33. *Pseudoxytenanthera madhavii*
34. *Pseudoxyteneanthera ritcheyi*
35. *Pseudoxytenanthera stocksii*
36. *Schizostachyum dullooa*
37. *Schizostachyum pergracile*
38. *Schizostachyum zollingeri*
39. *Thyrsostachys oliveri*
40. *Thyrsostachys siamensis*

C. Asia: China

1. *Bambusa intermedia*
2. *Bambusa rigida*
3. *Bambusa vulgaris*
4. *Chimonobambusa quadrangularis*
5. *Chimonobambusa tumidissinoda*
6. *Chimonobambusa utilis*
7. *Dendrocalamus giganteus*
8. *Dendrocalamus hamiltonii*
9. *Dendrocalamus latiflorus*
10. *Dendrocalamus membranaceus*
11. *Phyllostachys aurea (P. bambusoides)*
12. *Phyllostachys edulis (P. pubescens)*
13. *Phyllostachys violascens*
14. *Phyllostachys nidularia*
15. *Phyllostachys glauca*
16. *Schizostachyum pergracile*
17. *Schizostachyum funghomii*
18. *Schizostachyum zollingeri*

D. Latin America

1. *Bambusa multiplex*
2. *Bambusa oldhamii*
3. *Bambusa vulgaris*
4. *Chusquea culeou*
5. *Dendrocalamus asper*
6. *Guadua aculeata*
7. *Guadua amplexifolia*
8. *Guadua angustifolia*
9. *Guadua chacoensis*
10. *Guadua paraguayana*
11. *Guadua trinii*
12. *Otatea acuminata*
13. *Phyllostachys aurea*
14. *Phyllostachys edulis*

Action needs for priority species

Selection of economically important priority species is important because it allows research and development to be focussed on species that will produce dividends. This section highlights priority action needs for bamboo species that are further detailed in the datasheets in this report. The current state of work is first summarised in each subsection, and recommendations are then given for next steps in these fields.

1. Survey, collection, and conservation of germplasm

Collecting information pertaining to different bamboo species for this book presented a significant challenge. This brought to the fore that despite the vast areas of bamboo present in the world's forests and in many cases under cultivation, not much work has been undertaken to study, acquire and conserve genetic diversity of bamboo species. Descriptions of the morphological characteristics of bamboo are found in taxonomic reports, which are insufficient for providing data on parameters of silvicultural importance. For example, parameters such as clump form (open/compact, bushy/tall, nature of branches, presence of thorns, etc.) and culm character (diameter and wall thickness from base to top, prominence of the node, internode length, smoothness of culm wood, etc.) are particularly important for selecting species for profitable utilisation and developing clump management schedules. This information is not always found in taxonomic reports.

Generating a database of specific species for different agroclimatic zones is also necessary. The extent of genetic variability occurring in wild populations is not known for many of the important species. This means that the bamboo community is not able to fully profit from this variability to select for desirable traits. There is also a prevalent risk of genetic resources being lost forever due to degradation or loss of habitat from human development and climate change.

As emphasised by Rao et al. (1998), conservation of bamboo genetic resources is of paramount importance. This is particularly so because many economically important species occur outside primary forests and are subject to threat of habitat loss and genetic erosion. There have been few comprehensive programmes to survey and study wild populations of bamboo species and to conserve the germplasm, whether in situ in nature reserves or ex situ in live collections. Unlike with important forestry species, no specific efforts aimed at conservation of bamboo genetic resources in their natural habitat have been initiated. Some work has been done to survey and collect germplasm for ex situ germplasm banks and bambuseta, and some exchange of species as planting material for plantations has been carried out between countries. However, these efforts are made in a fragmented manner and leave open a huge gap in conservation for most species. Establishment of bambuseta, with a collection of a few individuals of each species, serves the purpose of increasing awareness and enabling research, but it does little to conserve genetic variability within the species.

Only a comprehensive survey, collection of accessions from throughout the native and cultivated range of each species, and establishment of *ex situ* live germplasm collections will allow genetic resource availability to be conserved. National level programmes for comprehensive surveys across the full range of the natural habitat and collection of sufficient accessions representing the major populations need to be carried out for at least the top priority species. National agencies responsible for the bamboo sector will do well to incorporate this into their respective strategies.

2. Genetic improvement

Genetic improvement of economically important bamboo using conventional approaches is severely limited by the unique semelparous (monocarpic) flowering behaviour. This behaviour is characterised by long inter-mast periods and simultaneous gregarious flowering followed by death of the entire flowering cohort in most species. The long flowering cycles and its unpredictable nature imposes a hurdle in planning any breeding programme. Except for a few species, bamboo has not been domesticated long enough for us to understand the genetic structure and the

distribution of variability in wild populations. Bamboos are predominantly outcrossing species. Seeds therefore do not breed true. Use of seeds to generate planting stock will result in a genetically heterogenous population. Selection of superior individuals will be possible only after 3–5 years, when clumps have matured, although juvenile (seedling) selection based on seedling vigour is also practiced (Banik, 1997). The use of molecular methods is sure to hasten and improve our understanding of genetics and enable early selection, but for the present this practice is still under development. Meanwhile, bamboo genetic improvement will have to depend on an alternative trialling and clonal propagation strategy, summarised below:

i. Survey and assessment of genetic variability available in natural populations or in farmers' fields of the economically important bamboo species.
ii. Collection of accessions within each species representing the intra-specific genetic variability and their conservation as part of in situ and ex situ germplasm collections.
iii. Characterisation of the accessions at the morphological, physicochemical, and genetic levels based on parameters relevant to important applications.
iv. Selection of superior accessions in economically important species that match current requirements for traditional and industrial applications and emerging ones.
v. Field testing of selected accessions in multilocational field trials to assess performance and to enable site-species and site-clone matching.
vi. Mass clonal propagation of the selections to enable their use in multilocational testing.
vii. Make the high performing clones available for operational planting in commercial bamboo plantations.

Farmers have a long tradition of having carried out selections of clumps with traits of economic or silvicultural interest. This process must be hastened by researchers through systematic research to bring the full benefit of improved planting material in newly established plantations around the world.

3. Production of quality planting material

Much of the planting of bamboo in plantations is still done with bulk seed material obtained from gregarious flowering events and the seedlings derived from those seeds. While this helps maintain some genetic variability in bamboo plantations, it does little to improve productivity.

There is an urgent need to identify and select quality mother clumps (known as candidate plus clumps, CPC) of useful bamboo species to serve as the source of vegetative material for clonal propagation. This material, including rhizomes, offsets, branches, culm segments, and buds, can be used to produce quality planting material. The clumps must be selected at an adult stage, usually 6–8 years old, so that the phenotype (morphological and physicochemical characteristics) is adequately expressed. The selected clumps should be of desirable form, free of diseases and pests, and high yielding with a high annual culm production rate or total biomass/hectare. Selection, when carried out from populations across the natural range of the species, provides for a larger number of CPCs for a wider genetic base in plantations of the future.

4. Propagation

Seeds are the natural means of propagation of a vast majority of bamboo species, except for the few which are known to be sterile. While seeds are available in great quantities at the end of the gregarious flowering cycle, due to the relatively short period of viability, plant production through germination is limited to about a year, even under the best storage conditions.

Despite this limitation, mass propagation methods have been standardised for several species and many of them are being commercially produced in significant numbers, contributing to the ease of availability of quality planting material. Several types of vegetative propagation methods have been the mainstay of bamboo propagation in species which are naturally sterile, these methods are the only means of propagation.

The simple method of macroproliferation (Banik, 1987; Kumar and Pal, 1994) is an elegant way of overcoming the limitation of short seed viability. Due to the propensity of germinated seeds of bamboo to form a new rhizome during every growing season, it is feasible to separate the tillers in such a manner that at least one rhizome is retained with each shoot. Proliferation can be carried out for successive generations of the rhizomes and the size of the culms kept to a manageable size for handling in nursery beds. Macroproliferation is a cloning method, but no genetic improvement by traditional selection is feasible since, in this case, seedlings have undergone no selection. Juvenile selection for some traits has been reported to be successful (Banik, 1997). Through clonal propagation of vegetative material from mature clumps that have been tested for higher productivity or other quality traits, genetic improvement is possible.

Another common method is the use of rhizome offsets, which consists of removing the rhizome along with a part of the culm consisting of a few nodes with viable axillary buds. This is almost exclusively the method used by farmers for most species due to its simplicity and high rate of success when carried out in the right season. Rooting of culm or branch cuttings is another method which is successful to varying degrees depending on species, age and position on the culm from which the cutting is taken. Often it is the two or three node cuttings taken from 1- to 2-year-old culms and the lowermost nodes on the culm that give the best results. In recent times, treatment of cuttings with plant hormones like naphthalene acetic acid or indole-3-butyric acid have improved the success rates of obtaining rooted cuttings. Air layering with whole culms or branches and use of pre-rooted branches have been used for some, bamboo species but not as a largescale procedure. The limitation of all these vegetative methods is the slow multiplication rate and the restriction imposed by the quantity of vegetative material that can be collected from each bamboo clump.

Plant tissue culture of bamboo has also become standardised in several important species since the 1980s. Beginning with procedures for propagation from germinated seeds, it has now been successfully standardised for tissues collected from mature clumps (Muralidharan, 2002; Sandhu, 2018). While many major commercial species have been successfully micropropagated on a large scale, there are several important species for which procedures are currently limited to laboratory-scale procedures. Tissues taken from field-grown bamboo of these species show high levels of microbial contamination, low multiplication rates and inadequate rooting. These issues present major constraints to scaling up the practice. In other species, bushy vegetative growth, precocious flowering, and high mortality of plants derived through micropropagation remain problems that need solutions.

Improved efficiency of micropropagation and reduction of cost of production are areas of research that will contribute to wider application of micropropagation to mass production of quality planting material. Contemporary trends like photoautotrophic micropropagation and use of automated systems like bioreactors hold great promise but have not been tested in the case of bamboo.

5. Genetic transformation

Given several decades of *in vitro* culture research on bamboo, it is surprising that procedures for *in vitro* culture amenable to genetic transformation have not been widely adopted. Somatic embryogenesis and organogenesis have both been successful in several bamboo species yet reports of genetic transformation are few. To keep pace with the developments in other crops, including forest trees, it is of strategic importance to develop efficient *in vitro* systems that can support genetic engineering of bamboo. Genetic transformation could facilitate achievement of many promising objectives, including increased productivity, the ability to engineer lignin and cellulose pathways to achieve desirable proportions, control of gregarious flowering behaviour, and increased tolerance to environmental stresses.

6. International collaboration

Throughout the history of agriculture, horticulture, and forestry, numerous plant species have travelled across continents and become naturalised and well established as important crops in their new habitats. This has been the case with bamboo species such as *B. vulgaris*, *D. strictus*, *G. angustifolia*, and *P. edulis*. Exchange of specific germplasm accessions between countries so that bamboo could be cultivated successfully in regions with similar

agroclimatic conditions is an important goal. Limitations to the free exchange of germplasm are the biodiversity and quarantine laws of the nations involved as donors and recipients. Potential dangers including the introduction of invasive species and transfer of pest and diseases are serious enough to exercise extreme caution when seeds or vegetative material are exchanged. The use of tissue cultures as a means of exchange is of great advantage, since the material transferred is maintained in a sterile condition and free of potential pest and diseases. Micropropagated plants, if maintained under phytosanitary conditions, represent the next best means of transfer of germplasm. As with any plant variety, the question of intellectual property rights (IPR) and protection of plant varieties apply to bamboo species. This is especially true of varieties that have been in cultivation for long in some communities and developing a protocol for protection of their IPR and right to benefit sharing would be ideal.

Multidisciplinary approach to find solutions for common problems would require a platform for bringing together researchers in disciplines. INBAR can provide such a forum either through the current Task Forces or constituting a special one on each major theme. Organisations that foster international collaboration in forestry such as CGIAR, the Food and Agriculture Organization of the United Nations, the International Tropical Timber Organisation, International Fund for Agricultural Development and the International Union of Forest Research Organizations also could play a role in such interactions.

Emerging industrial uses of bamboo

Bamboo forests and plantations bring multiple benefits in terms of livelihood and ecosystem services. Bamboo forests have influenced the livelihood of rural people in a substantial manner for centuries and continues to play an important role in the economy of many countries. In addition to traditional uses, newer applications and products are emerging as improved technologies permit innovative uses and applications of bamboo. This report identifies priority species for many of these emerging and established uses. This section summarises the uses and applications considered central during the species selection process. These uses require in-depth knowledge of the anatomical and mechanical properties of the specific bamboo used. Not all applications are suitable for all species.

In brief, bamboo biomass is used in the form of whole culm, splits, strips and total biomass for building, furniture, engineered bamboo and for second generation biofuel and paper/pulp feedstock. Growing bamboo is one of the fastest means of producing wood lignocellulosic biomass available to us. Due to this potential as a rapidly renewing, sustainable source of biomass, there is increasing interest in the use of bamboo for applications that replace conventional materials like plastics, steel, or cement. Early industrial applications in which bamboo was used included paper making and viscose (rayon). Other well-known uses of bamboo are as a building material in its round pole form and in the form of engineered bamboo products like matboards, laminates and bamboo lumber. It is also a raw material for second-generation biofuels and a host of valuable chemical by-products that are formed when it acts as a biorefinery (He et al., 2014).

Bamboo plantations sequester carbon both in aboveground biomass (AGB) component consisting of the culms, branches, and litter and in the below ground rhizomes, roots, and soil. Through judicious conversion to long lasting products, bamboo can be a carbon sink. Bamboo has been used as a tool for forest landscape restoration (Donfack, 2020; FAO and INBAR, 2018) and it has been widely used to improve soil properties and stabilise slopes, riverbanks, and areas prone to soil erosion (Sujatha et al., 2002; Kaushal et al., 2021). Bamboo has also shown potential for commercial wastewater treatment using the root zone treatment technology where aerobic bacteria residing in the profuse root system of bamboo help in the oxidisation (Fuke et al., 2021).

Species datasheets for priority economic bamboo species contain references to traditional uses, industrial uses, and potential uses, reflecting the dynamic state of the field.

Research and information requirements

While many uses of bamboo are derived from similar uses of timber and agricultural residue, further research is required to characterise the structure, chemical composition, and physical properties of different bamboo species to assess the potential and select the most suitable species for each application. This includes lesser-known species, which could find additional markets based on such a physicochemical characterisation. This section summarises the current state of research and data availability in several key fields relating to priority bamboo species and makes recommendations for further research.

1. Physicochemical characterisation

The various uses of bamboo lignocellulosic biomass described in the previous section require raw material to be standardised to enable efficient utilisation. Use of appropriate species and part of biomass matched to the specific application will encourage plantations of specific species in the region and optimise performance, enable mechanisation and reduce wastage. This requires an understanding of the anatomical, physical, and mechanical properties of the bamboo species.

Understanding the extent of the variability in characteristics between species, within species and in different parts of the plant is important when considering different applications and uses. Properties may vary under different growing conditions, within the culm from base to top and in the radial direction from outer to the inner layer. Mechanical properties vary across species and depend on the environmental conditions in which it is grown (Hidalgo, 2003). Studies show that some mechanical and physical properties of bamboo species (*B. bambos, B. nutans, B. tulda* etc.) collected from different zones (populations) of India vary significantly (Tewari, 1992). Properties also vary with the anatomy of the culm part, such as the node and the internode. It was demonstrated in the early part of the 20th century that the middle part of culm is stronger in tensile strength and the top part is stronger in compressive strength (Uno, 1932) and that the tensile and bending strength of the outer layer of the culm is much higher than that of the inner layer (Baumann, 1912).

The properties of bamboo are often measured in the green state and in the air- and oven-dried state. The air-dried sample generally matches the state in which bamboo is most used. Other key parameters include the density, or Specific gravity, which has a bearing on the use of bamboo for laminates, ply, and composites as well as in feedstock for biofuels and biorefinery. The dimensions and properties of the fibre itself are relevant to the paper, pulp, and natural fibre textile industries and to their use as reinforcement for composites.

The chemical composition of the bamboo biomass is also an important factor than influences the choice of species for industrial applications. The cellulose and lignin levels in bamboo are important for the paper and viscose industry. Silica content is mainly found in the outer layer of the culm and gives protection from mechanical stress and insect damage but contributes to wear and tear of machinery and fouls up walls of kilns used for pyrolysis. The ash content in bamboo adversely affects the chemical recovery of alkaline pulping liquor (Yuan et al. 2017). Chemical composition also helps predict the pyrolysis products. Wang et al. (2015) studied the variation in chemical composition within the bamboo culm and paved the way for the use of bamboo biomass in a more appropriate and efficient manner and with less wastage. The availability of high throughput methods such as Fourier transform near-infrared spectroscopy enable rapid assessment of many of these chemical parameters.

To bring uniformity in data generation and to encourage comprehensive testing for all important parameters, it is desirable to introduce a standardised protocol for physicochemical characterisation. The parameters cover the range of anatomical, chemical, and mechanical properties that are pertinent to the important applications. Datasheets report as many of the below properties as can be identified by the authors of this report:

a. Specific gravity or density (specify whether in air-dried, oven-dried, green condition)
b. Bulk density

c. Cellulose content % Holocellulose, α-cellulose, Hemicellulose
d. Lignin % Acid soluble, Klason lignin (acid insoluble)
e. Silica content %
f. Ash content %
g. Modulus of Elasticity (MOE)
h. Modulus of Rupture (MOR)
i. Compression or shear strength parallel to grain
j. Fibre length
k. Fibre diameter
l. Kappa value
m. Runkel ratio
n. Starch content
o. Extractives (pyrolysis-gas chromatography-mass spectrometry)

While many of the parameters are measured for bamboo as they are for wood, there are a few notable differences. Bamboo's usually hollow culms, the presence of nodes, the variation in longitudinal and radial planes and the presence of the hard, dense silica rich outer layer are all unique. The ISO standard ISO 22157 (ISO, 2019) describes the testing methods for determination of the physical and mechanical properties of bamboo culms.

There are some important points to note. For engineered bamboo, it is standard practice to carry out tests with the finished product rather than to ascertain bulk density and specific gravity with the compressed product. This is relevant when measurements are taken to determine a product's characteristic for its use as biomass converted into pellets and briquettes, and for strength when used as structural elements. Measurements taken with air-dried bamboo are applicable to most uses, but standardisation would also involve measurements with oven-dried samples for consistency. Lastly, an important goal for research is to test all parameters with samples from representative locations in different agroclimatic zones where the species is cultivated in significant quantities. This will allow areas to be identified where bamboo of specific species with optimal characteristics for different applications could be cultivated.

2. Germplasm characterisation

As in any species of economic importance, the genetic variation existing in nature is a valuable resource from which useful traits can be selected for crop improvement. Conserving genetic variation is therefore an important goal. This requires an understanding of the populations of each species across its natural habitat and necessitates extensive surveys and collection of representative accessions. Besides *in situ* conservation in their natural habitat, the germplasm is typically assembled in *ex situ* collections. The presence of landraces among some bamboo species that have been cultivated for a long period is apparent in their specific uses based on morphological features or mechanical properties.

Characterisation of germplasm accessions to understand the diversity of morphological, anatomical and physicochemical variation is an urgent research need that should follow on from the survey and collection of these accessions described in Section 8.1 of this report. While mean values for many of the parameters like height, diameter and internode length is available for many species, data availability is often insufficient to be able to match the various parts of the culm to different uses. The variation in diameter and wall thickness, for example, varies significantly from base to top of the culms and these parts are utilised for totally different types of products. Variation in parameters like cellulose, lignin, silica, and starch content with culm age can also be expected.

Molecular methods have advanced to a stage where a range of molecular markers are available for rapid and inexpensive genetic variability assessments. Such methods can assess the interspecific and intraspecific variation to enable precise identification of species and characterise clones or proprietary germplasm. DNA barcoding markers have been described for some regions, but a universal barcode for all bamboo is has not yet been

generated (Dev et al., 2020a). DNA fingerprinting, on the other hand, is well established. Bamboos are amenable to be fingerprinted to confirm homogeneity in clonally propagated plants and prevent stock mixups in the nursery.

3. Soil preferences

The relevance of soil preferences of bamboo species has been noted by Williams and Rao (1994). The adaptability of some bamboo species, like *B. vulgaris, B. balcooa and D. strictus,* has been shown by its cultivation across a wide range of climates and terrains. However, it remains unproven how other species will perform in soils different from their Native habitat. Along with the soil type or texture, the pH and nutritional status of the soil is relevant, since productivity in terms of quality and quantity will eventually decide preferences for the large-scale cultivation of a particular bamboo species against competing land uses. Information is not available for these parameters for many of the species in our list and research into experimental plantations around the world would do well to focus on generating this data.

4. Climatic preferences

Historically, bamboo has been collected from wild populations and from the few clumps that were domesticated in the vicinity of human habitations and in homesteads. With increasing industrial use, some bamboo species have been planted outside their Native habitats in plantations. A few species have even been taken to other continents and successfully cultivated there. Such species have demonstrated that many bamboos can adapt well to a wide range of climatic conditions. However, there are many other species that are well adapted to narrow ecological conditions and are apparently limited by altitude, temperature, and moisture requirements. Species that are adapted to very arid climates or areas prone to flooding or salinity may find use for plantations in other parts of the world where such conditions exist and are a limitation for native species. Only trials conducted in multiple agroclimatic zones will demonstrate the adaptability and performance of such species. Increased demand for bamboo around the world demands that bamboo cultivation be undertaken on a variety of landscapes, often on degraded lands. An evaluation of the climatic factors influencing performance of different bamboo species is therefore of great relevance.

5. Carbon sequestration

Data pertaining to biomass production and carbon storage in bamboo are available for several bamboo species. While some excellent examples of thorough studies are available (Isagi et al., 1997; Nfornkah et al., 2021), most other studies carried out do not conform to a standard protocol. Data on annual productivity of biomass on a unit area basis are more appropriate to compare species and for calculations of carbon sequestration. Many studies focus only on aboveground biomass (AGB) while there is the need to look at the belowground biomass and litter and soil carbon to evaluate the potential for bamboo plantations to be used in carbon trading. With cultivated bamboo being utilised for an increasing diversity of products that vary in their life cycle and their role as carbon sinks or otherwise, data pertaining to bamboo's different post-harvest value should be studied and generated.

Datasheets on global priority bamboo species

1. *Bambusa balcooa* Roxb.

Subspecies/variety/clone: C585, RFRI/BBL/03 RFRI/BBL/04 RFRI/BBL/14, RFRI/BBL/21 (India)

Synonyms (Vorontsova et al., 2016): *Arundarbor balcooa* (Roxb.) Kuntze; *Bambusa capensis* Rupr.; *Bambusa vulgaris* Nees.; *Dendrocalamus balcooa* Voigt.

Common names (Language/area in parenthesis): *Baluka, Sil borua* (Assam, India); *Balku bans* (Bengal, India); *Boro bans* (Duars, India); *Wamnah, Beru* (Garo, India); *Barak* (Tripura, India), *trelồ ô* (Viet Nam).

Description: This evergreen, densely tufted bamboo has short-necked pachymorph rhizomes and culms reaching height of 15 to 31 m with arching top (Banik, 2016). The diameter of mature culms ranges from 8–15 cm with wall thickness of 2.7–3.2 mm (base), 1.2–2.0 mm (middle), 0.3–0.7 mm (top) (Banik, 2016). Length of internodes varies between 15.5–35 cm (base), 38.0–41.0 cm (middle), 30.0–36.0 cm (top) (Banik, 2016). This sturdy species has prominent nodes and strong branching with thornlike branchlets at lower nodes.

Distribution

a. Native range: Indian Subcontinent: Bangladesh, India, Nepal, Assam.
Indo-China: Laos, Myanmar, Viet Nam.

b. In cultivation/naturalised in:
Indian Subcontinent: Eastern Himalaya.
West-Central Tropical Africa: Gulf of Guinea Islands.
Southern Africa: Cape Province, KwaZulu-Natal, Northern Provinces.

Climatic parameters: *B. balcooa* tolerates a temperature range of -5–20.3 °C but can survive up to 30.5 °C (Nath and Das, 2012; Banik, 2016) and precipitation in the range of 2500–5000 mm. This species commonly grows at altitudes from 1000–1250 m but is also successfully cultivated at lower elevation and even at sea level (Banik, 2016).

Soil: *B. balcooa* prefers heavy textured soil with good drainage such as alluvial clay, sandy loam, deep, loose and fertile sandy loam (Banik, 2016) and sandy clay loam (Nath, 2008). Soil organic carbon in this area ranges between 0.87–1.39 % with a pH of 5.11–7.5 (Nath, 2008; Banik, 2016).

Native habitat: This species grows abundantly on flat lands and valleys in moderate to high rainfall zones (Banik, 2016).

Propagation

a. Natural: The flowering cycle of this species is reported as 30–45 (Kumari and Singh, 2014) and 40 ± 5, 90 ± 5 and 130 ± 5 years (Banik and Alam, 1987; Banik, 2000). It only produces sterile flowers.

b. Clonal propagation: Banik (2016) reported a 70 % success rate with rhizome offsets. Banik (2016) reported a 70–75 % success rate with two-node cuttings taken from 1- to 2-year-old culms while Seethalakshmi et al. (1988) used 2- to 3-year-old culm cuttings with hormone treatment. Pre-rooted branch cuttings gave a success of 65–70 % (Banik, 2016) and Seethalakshmi et al. (1988) obtained a 40 % success with branch cuttings. Ground layering was also successful with 1- to 2-year-old culms (40–50 %) (Banik, 2016).

c. Tissue culture: Plantlet production through axillary bud proliferation (Mudoi and Borthakur, 2009; Rajput et al. 2020; Das and Pal, 2005; Islam and Rahman, 2005; Sharma and Sharma, 2011) as well as somatic embryogenesis (Gillis et al., 2007; Muralidharan et al., 2008) has been reported.

Cultivation

a. Plantation: This species is grown in block plantations, high density plantations, agroforestry plantations and strip plantation (Banik, 2016).

b. Spacing: The species is usually grown in 4x4 m spacing in low rainfall areas but 5x5 m spacing in high rainfall areas (Banik, 2016) but for intercropping, a wider spacing (7x7 m, 9x9 m) is usually adopted (Banik, 2016).

c. Other potential species for mixed plantation: Agroforestry with horticultural tree crops like mango, cashew, jackfruit, *Garcinia indica*, rubber (Malik and Raj, 2014); Upland paddy, peanut, cowpea, okra, pigeon pea, turmeric, maize, and yam (Baruah and Borah, 2019); *Aegle marmelos,* Citrus, *Artocarpus heterophyllus,* moringa, neem, and silk cotton tree (Banik et al., 2008).

d. Years to maturation for harvesting: 3–5 (Banik, 2016).

e. Shooting season: May–November (Banik, 2016).

Productivity

a. Culm production : Seethalakshmi and Muktesh Kumar (1998) reported a production of 1200-1600 culms/ha from Bangladesh whereas 7–19 culms/clump/yr was observed by Banik (2016). An average of 7799 culms/ha. was reported at plantation age of 7 years by Jijeesh (2014).

b. AGB : Estimates of 21.36 Mg/ha/yr (Nath and Das, 2012) and 18.57 Mg/ha during the sixth to seventh year (Jijeesh, 2014) have been reported.

c. Allometric equations :

India 1 (Nath et al., 2009)	log Biomass=2.476+0.997*(log(DBH))
India 2 (Nath et al., 2009)	log Biomass=2.368+2.214*(log(DBH)) log Biomass=2.085+2.432*(log(DBH)) log Biomass=1.868+2.716*(log((DBH)^(1)) (Globallome Equation No. 39249)
Viet Nam 1 (Hung et al., 2012)	Biomass=0.0164*((DBH)^(1.7734))
Viet Nam 2 (Hung et al., 2012)	AGB = 0.1006×D2.2220 (Bamboo forest) AGB = 0.0644×D1.9696H0.3426 (Bamboo forest)

Mechanical properties

a. Specific gravity : 0.79–0.85 oven-dried from base to top (Kabir et al., 1991); 0.79 (base), 0.84 (middle), 0.85 (top) (Sattar et al., 1991) oven-dried.

b. Basic density : Krishnakumar et al. (2017) reported a value of 0.46 oven-dried.

c. Cellulose/lignin/silica content : Cellulose (54.6 %); lignin (25.2 %) (Vena et al., 2013).

d. Modulus of Elasticity (MOE) : 9.3–12.7 kN/mm^2 (air-dried) (Kabir et al., 1991); 93 (base), 108 (middle), 127 (top) 1000kg/cm^2 (air-dried) (Sattar et al., 1991).

e. Modulus of Rupture (MOR) : 92.6–69.6 N/mm^2 (air-dried) (Kabir et al., 1991); 926 (base), 787 (mid), 696 (top) kg/cm ^{2} (air-dried) (Sattar et al., 1991).

f. Fibre length : 2.8 mm (Seethalakshmi and Muktesh Kumar, 1998), 2.9 mm (Vena et al., 2013).

Genetic diversity and conservation status: Clumps with compact, strong, straight, thick-walled culms with swollen and elevated nodes and higher number of leafless thorn-like branches at the lower nodes of the culms (S*hil barua/ Sil barak/Hil barua or Hil barak*) have been identified in Upper Assam, India (Banik, 1994). Another form (*Nol barak/Teli barua*) with thin-walled culms and branches and longer internodes also have been identified (Banik, 2016).

Germplasm collections, selection and multilocational trials have been carried out by the Indian Council of Forestry Research and Education (ICFRE). Some of the promising selections are C585, RFRI/BBL/03, RFRI/BBL/04, RFRI/BBL/14, RFRI/BBL/21) (Ginwal, 2021).

B. balcooa, produced on large-scale through micropropagation by M/s Growmore Biotech, India has been popularised among farmers as '*Bheema bamboo*" especially for biofuel plantations.

Uses

a. Traditional: Handicrafts, whole culms in construction (Kumari and Singh, 2014), edible shoots, fodder, agricultural implements (Kumari and Singh, 2014), incense sticks, soil erosion control and flood control (Banik, 2016).
b. Industrial: Strand woven lumber, paper pulp (Banik, 2016; Das and Pal, 2005); laminated bamboo (Biswas et al., 2011).
c. Potential: Commercial plantations for fibre, biofuel, biorefinery and charcoal.

Key ecosystem service values: This species is grown in many countries across the world and due to its ease of propagation has enormous potential for large-scale plantations for water conservation, erosion control etc. The species has the added advantage of being a sterile species and therefore without risk of gregarious flowering and death of entire population. Since the biomass productivity is high in suitable locations, the potential for carbon trading is also promising.

Research gaps: Precise and extensive information on the extent of genetic variability is not available in the species. Survey, characterisation, and selection of useful and superior traits can be done from all areas of its current cultivation, to widen the genetic base.

Information Gaps: Additional data on many mechanical and chemical parameters is needed to explore other potential applications, especially for its use as biorefinery.

Habit

Culm and branching pattern

New shoot

Culm sheath

2. *Bambusa bambos* (L.) Voss

Subspecies/variety/clone: *Bambusa bambos var. spinosa* Camus (Banik, 2016)

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 parenthesis):Thorny bamboo (English), *Kotoha bah* (Assam-India); *Wakynta (*Garo-India); *Kanta bau*ns (Orissa-India); *Illi , Mula , Pattill* (Kerala-India); *Bidduru , Gatte* (Karnataka-India); T*oncur* (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* (Lao PDR); *Russei khlei , Russei prei* (Cambodia); *Tre Ng, Tre Gai* (Viet Nam); *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 and tall, erect, or gently arching culms that reach a height of 6–10 m (Banik, 2016). Culm diameter is 5–8 cm (Seethalakshmi and Muktesh Kumar, 1998), wall thickness 1–1.5 mm and the internode length 20–40 cm. The culms have stout thorny branches all over and nodes are prominent (Seethalakshmi and Muktesh Kumar, 1998).

Distribution

a. Native range: Indian Subcontinent to Southeast Asia.
   Indian Subcontinent: Assam, Bangladesh, India [Orissa, Madhya Pradesh, Goa, Karnataka, Jharkhand, Bihar, Chhattisgarh, Tamil Nadu], Sri Lanka.
   Indo-China: Cambodia, Laos, Myanmar, Thailand, Viet Nam.

b. In cultivation/naturalised in:
   Western Indian Ocean: Seychelles.
   Indian Subcontinent: Maldives, India (Naithani, 2007).
   Malesia: Java, Malaya, Molucca, Philippines.
   Central America: Costa Rica, El Salvador, Honduras, Nicaragua, Panama.
   Caribbean: Cuba, Windward Islands.

Climatic parameters: *B. bambos* is found distributed from sea level to up to elevations of 1200 m (Rao et al.,1998; Banik, 2016) receiving nearly 2000–2500 mm annual rainfall. Mean maximum temperature is 28.5–36.7 °C.

Soil: This bamboo grows well in laterite, red-to-brown coloured and sandy loam soil with pH 7.4–7.8.

Native habitat: This species is native to humid tropical climate and grows best along riverbanks, in river valleys and in other moist sites (Banik, 2016). It is found in moist and dry deciduous forests, degraded forests associated with many tree species.

Propagation

a. Natural: A flowering cycle of 30–49 years has been estimated for the species. The species flowers gregariously and different flowering populations often overlap in India. Seed are therefore always available. Seed weight is estimated as 99 seeds/gram (Banik, 2016). 50–80 % germination is obtained.

b. Clonal propagation: Seedling macroproliferation is practiced widely (Kumar and Pal, 1994). Rhizome offsets taken from 1- to 2-year-old culms lead to 65–75 % establishment (Banik, 2016). Culm cuttings with hormone treatment gives a success rate of 50–60 % rooting (Banik, 2016). Branch cuttings with hormone treatment gives 45–65 % success (Banik, 2016). Air layering is also possible (Banik, 2016) but not commonly practiced.

c. Tissue culture: Plant regeneration is reported in the species through both axillary bud proliferation (Arya et al., 2002) and somatic embryogenesis (Mehta et al., 1982).

Cultivation

a. Plantation type: Block plantation, live fencing (Banik, 2016).

b. Spacing: 5x5 m, 6x6 m; 3–4 rows at close spacing for live fencing.

c. Possible species mixed: teak.

d. Years to maturation: 3–5.

e. Shooting season: June–September.

Productivity

a. Culm production : 16 culms/clump at six years after planting (Shanmughavel and Francis, 1996).

b. AGB : 17.5 kg to 70.1 kg between two and six years after planting (Shanmughavel and Francis, 1996); 8527 kg/ha. in three years (Rao et al., 1991).

c. Annual C sequestered : 76.5 Mg/ha (Yuen et al., 2017); 83.3-103.8 Mg/ha (Das and Chaturvedi, 2006).

d. Allometric equations :

India (Kumar et al., 2005)	Y =-3225.8+1730.4 DBH (R^2 = 0.83; n=8; p<0.001) ln Y = 4.298 + 2.647 ln DBH (R^2 = 0.82; n=8; p<0.001) Y =-12.23+37.281 DBH (R^2 = 0.80; n=106; p<0.0001) (Biomass in kg.)

Mechanical properties

a. Specific gravity : 0/641–0.664 (Tewari, 1992).

b. Density : 0.48–0.75 (Kaur et al., 2016).

c. Cellulose/lignin/silica content : Lignin (24.2 %); Lignocellulose (4.77–5.05 %); lignin (21.5–26.5 %) (Kaur et al., 2016).

d. MOE : 31.6–134.5 (Tewari, 1992).

e. MOR : 482–975 (Tewari, 1992).

f. Fibre length : 0.7–4.2 mm (Pande, 2009); 2.7 mm (Liese, 1980).

g. Fibre diameter : 6–18 µm (Pande, 2009).

h.	Other	:	Lumen diameter 7.44 µm (Seethalakshmi and Muktesh Kumar, 1998); Wall thickness 5.37 µm (Seethalakshmi and Muktesh Kumar, 1998); Kappa No.27.4. (Guha and Bhola, 1976).
i.	Starch	:	2 % (Kaur et al., 2016).

Genetic diversity and conservation status: Survey and collection of germplasm has been carried out in India and selections made by ICFRE. Thornless and straight culm varieties have been selected (Ginwal, 2021). Several phenotypes are available in nature with variations in stature, branchiness, hollowness, etc. The potential for selection is high. Grassy, grassy erect, erect and very erect types of seedlings are found with the last two types being more vigorous (Kondas, 1982).

Uses

a. Traditional: Handicraft, weaving, round culm construction, edible shoots, thorny branches for fencing, clumps for live fencing (Banik, 2016), medicinal amorphous siliceous deposits (Tabashir) (Banik, 2016).
b. Industrial: Laminated bamboo, strand woven, paper pulp, refinery, charcoal.
c. Potential: Biorefinery, bioenergy and ecological restoration.

Key ecosystem service values: Water and soil conservation, food for wildlife (elephants).

Research gaps: Genetic variability within and between populations, physicochemical characterisation.

Habit

Culm and branching pattern

New shoot

Culm sheath

3. *Bambusa multiplex* (Lour.) Raeusch. ex Schult.f.

Subspecies/variety/clone: 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*).

Synonyms (Vorontsova et al., 2016): *Arundo multiplex* Lour., *Bambusa glaucescens* f. *variegata* (E.G. Camus) Muroi & Sugim., *Arundarbor multiplex* (Lour.) Kuntze, *Bambusa argentea* Nehrl., *Bambusa multiplex* var. *normalis* Sasaki, *Bambusa argentea* var. *vittata* Nehrl., *Leleba multiplex* (Lour.) Nakai, *Bambusa dolichomerithalla* Hayata, *Ludolfia glaucescens* Willd., *Leleba dolichomerithalla* (Hayata) Nakai, *Arundinaria glaucescens* (Willd.) P. Beauv., *Bambusa liukiuensis* Hayata, *Bambusa glaucescens* (Willd.) Merr, *Leleba liukiuensis* (Hayata) Nakai, *Bambusa nana* Roxb., *Bambusa nana* f. *viridistriata* Makino ex I. Tsuboi, *Arundarbor nana* (Roxb.) Kuntze, *Bambusa floribunda* f. *viridistriata* (Makino ex I. Tsuboi) Nakai, *Bambusa nana* var. *normalis* Makino & Shiras, *Leleba floribunda* f. *viridistriata* (Makino ex I. Tsuboi) Nakai, *Bambusa nana* var. *typica* Makino ex I.Tsuboi , *Bambusa multiplex* f. *viridistriata* (Makino ex I.Tsuboi) Muroi, *Bambusa multiplex* var. *nana* (Roxb.) Keng f., *Bambusa glaucescens* f. *viridistriata* (Makino ex I. Tsuboi) Muroi & Sugim., *Ischurochloa floribunda* Buse in F.A.W.Miquel, *Bambusa* nana f. *vittateargentea* Makino ex I.Tsuboi, *Leleba floribunda* (Buse) Nakai , *Bambusa shimadae* Hayata, *Bambusa glaucescens* var. *floribunda* (Buse) Hatus., *Bambusa multiplex* var. *shimadae* (Hayata) Sasaki, *Bambusa aurea* Siebold, *Leleba shimadae* (Hayata) Nakai, *Arundarbor aurea* Kuntze,, *Bambusa glaucescens* var. *shimadae* (Hayata) L.C.Chia & P.P.H.But, *Bambusa sterilis* Kurz ex Miq., *Leleba amakusensis* Nakai, *Bambusa caesia* Siebold & Zucc. ex Munro, *Leleba elegans* Koidz., *Triglossum arundinaceum* Gamble, *Bambusa multiplex* var. *elegans* (Koidz.) Muroi, *Bambusa alphonse-karrii* Mitford ex Satow, *Bambusa glaucescens* f. *elegans* (Koidz.) Muroi & Sugim., *Bambusa nana* f. *alphonse*-karrii (Mitford ex Satow) Kawam., *Bambusa multiplex* var. *riviereorum* Maire, *Bambusa nana* var. *alphonse*-karrii (Mitford ex Satow) Kawam., *Bambusa glaucescens* var. *riviereorum* (Maire) L.C. Chia & H.L. Fung, *Bambusa multiplex* f. *alphonse-karrii* (Mitford ex Satow) Nakai., *Bambusa multiplex* f. *solida* Muroi & Maruy. in J. Sugimoto, *Bambusa glaucescens* f. *alphonso*-karrii (Mitford ex Satow) Hatus., *Bambusa glaucescens* f. *solida* (Muroi & Maruy.) Muroi & Sugim., *Bambusa nana* f. *albovariegata* Makino, *Bambusa glaucescens* f. *albostriata* Muroi & Sugim., *Bambusa glaucescens* f. *albovariegata* (Makino) Muroi & Sugim., *Bambusa glaucescens* f. fu-*komachi* Muroi & Sugim., *Bambusa multiplex* f. *albovariegata* (Makino) Muroi,, *Bambusa glaucescens* f. *midori* Muroi & Sugim,, *Bambusa nana* var. *gracillima* E.G.Camus, Bambusa *glaucescens* f. *gimmei* Muroi & Kasahara, *Bambusa multiplex* var. *gracillima* (E.G.Camus) Sad.Suzuki, *Bambusa glaucescens* f. *kimmei-suhou* Muroi & Kasahara, *Bambusa nana* var. *variegata* E.G.Camus, *Bambusa glaucescens* f. *midori-beni* Muroi & H.Hamada,*Leleba multiplex* f. *variegata* (E.G.Camus) Nakai, *Bambusa glaucescens* f. *shirosuji* Muroi & H.Okamura, *Bambusa multiplex* f. *variegate* (E.G.Camus) Hatus., *Bambusa glaucescens* f. *tukushi-komachi* Muroi & Yu.Tanaka.

Common names (Language/area in parenthesis): *xiao shun zhu* (China), Chinese dwarf bamboo, hedge bamboo, Oriental bamboo.

Description: Densely clumped bamboo with pachymorph short-necked rhizome and arching tips. The height of the culm reaches to 2.98–8.27 m with culm diameter of 1–2.9 cm. The internodes are 28.95–46.15 cm long and the wall thickness is 0.3–0.8 mm. Nodes are slightly prominent with branching throughout the culm.

Distribution

a. Native range: China: China South Central, Hainan, China Southeast.
Eastern Asia: Taiwan.
India Subcontinent: East Himalaya, Nepal.
Indo-China: Laos, Myanmar, Viet Nam.

b. In cultivation/naturalised in:

Western Indian Ocean: Mauritius, Madagascar, Seychelles.
Western Asia: Iraq.
Eastern Asia: Nansei-shoto.
Indian Subcontinent: Bangladesh, Pakistan, Sri Lanka.
Indo-China: Cambodia.
Malesia: Malaya.
Papuasia: Bismarck Archipelago.
New Zealand: New Zealand North.
Southeastern U.S.A: Florida.
Mexico: Mexico Southeast.
Caribbean: Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Windward Islands.
Western South America: Colombia, Ecuador.
Brazil: Brazil Southeast.

Climatic parameters: *B. multiplex* grows at a wide range of temperatures from -10–42 °C, in areas with annual rainfall of 800–2500 mm and at elevations of 5–1000 m.

Soil: The species prefers medium (loamy) and heavy (clay) and well-drained soils. Soil organic carbon of 0.80–1.50 % and pH 4.3–7.1 is preferred.

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

Propagation

a. Natural: The species is rarely in flower and has not been reported to set seeds.
b. Clonal propagation: Rhizome offsets, culm and branch cuttings are widely used propagation methods for this species.
c. Tissue culture: Ara et al. (2020) describe procedures for multiplication using shoot meristems and through somatic embryogenesis (Yuan et al., 2010) but commercial methods are not known.

Cultivation

a. Plantation type: Live fencing, strip plantation, block plantations, Agroforestry, high density plantation.
b. Spacing: 1x1 m (fencing), 4x4 m, 5x5 m.
c. Years to maturation: 3.
d. Shooting season: June-August.

Productivity

a. Culm production : 2500–3000 culms/ha (Yuan et al., 2010).
b. AGB : 15-20 t/ha/yr. (Yuan et al., 2010).
c. Allometric equations :

India 1 (Kumar et al., 2005)	Y =-3225.8+1730.4 DBH (R^2 = 0.83; n=8; p<0.001) ln Y = 4.298 + 2.647 ln DBH (R^2 = 0.82; n=8; p<0.001) Y =-12.23+37.281 DBH (R^2 = 0.80; n=106; p<0.0001) (Biomass in kg.)
India 2 (Agarwal and Purwar, 2010)	Y=(-0.16)+(0.07)b_1+(4.41)b_2+(-2.54)b_3 (Fresh wt.) Y=(0.055)+(-0.035)b_1+(-0.20)b_2+(3.27)b_3 (Dry wt.) (Biomass in kg)

Mechanical properties

a. Density : 897–938 kg/m^3 (Dransfield and Widjaja, 1995).

b. MOE : 49.0–62.0 N/mm^2 (Dransfield and Widjaja, 1995).

c. MOR : 57.0–71.0 N/mm^2 (with nodes), 78.0–98.3 N/mm^2 (without nodes) (Dransfield and Widjaja, 1995).

Genetic diversity and conservation status: The wide distribution of the species indicates adaptability to a wide range of climatic conditions. The genetic variability within the species is seen in the number of varieties that are cultivated as ornamentals. No systematic study on physicochemical properties of all the varieties is known.

Uses

a. Traditional: Live fencing, soil erosion control and flood control, handicrafts.

b. Industrial: Laminated bamboo, paper pulp; horticulture; drinking straws.

c. Potential: Soil stabilisation and erosion control, ornamental, composite fibre, charcoal.

Key ecosystem service values: Due to the manageable size and dense nature of the clump it is useful for planting as live fences and as a barrier to noise and dust pollution along roads and for erosion control in riverbanks and water bodies.

Research gaps: Studies of genetic variability of populations is required to avoid narrow genetic base of plantations established through clonal methods. The species is difficult to propagate by vegetative and tissue culture methods and research into improved methods are need.

Habit

Culm and branching pattern

New shoot

Culm sheath

4. *Bambusa nutans* Wall. ex Munro

Subspecies/variety/clone: *Bambusa nutans* Wallich ex Munro subspecies nutans *Bambusa nutans* subspecies cupulata.

Synonyms (Vorontsova et al., 2016): *Arundarbor nutans* (Wall. ex Munro) Kuntze; *Bambusa crinita* Thomson ex Munro; *Bambusa falconeri* Munro.

Common names (Language/area in parenthesis): *Tharu bans* (Kathmandu, Nepal), *Sate bans* (Pokhara, Nepal).

Description: A large erect bamboo species with short-necked pachymorph rhizomes. Culms reach a height of 10–20 m (Banik, 2016). The culms are solid at the base in most locations and hollow at the higher internodes. The internode length can vary from 25–45 cm (Banik, 2016). The culms are much branched at the higher nodes and have slightly raised nodes.

Distribution

a. Native range: Himalaya to Indo-China.
Indian Subcontinent: Nepal, West Himalaya [Himachal Pradesh], India [Uttar Pradesh].

b. In cultivation/naturalised in:
East Himalaya: Sikkim, Bhutan (Banik, 2016).

Climatic parameters: The species is found growing well in areas with a precipitation of 700–4500 mm and at elevations from sea level to 1700 m (Adhikari and Shrestha, 2008) although it prefers 700–1500 m (Banik, 2016). The species grows at 10–32 °C.

Soil: Well-drained sandy loam to clay loam soils with pH of 6–7 is preferred (Banik, 2016). Soil organic carbon of plots with *B. nutans* is estimated at 57.28 t /ha (Tariyal, 2014).

Native habitat: The species is found in the lower hills to plains and is associated often with teak forests (Banik, 2016). It prefers well-drained moist site with moderate shade (TIS, 2004; Stapleton, 1994).

Propagation

a. Natural: Propagation in nature is through seeds which form in part flowering of clumps that occurs from 30–65 years of age (Banik, 2016). Seed weight is 133.3 seeds/gram (Banik, 2016). Germination of 56 % is obtained in 3-7 days and seeds remain viable for 45 days (Banik, 2016).

b. Clonal propagation: Banik (2016) reports success with a variety of clonal methods. Seedling macroproliferation is possible with seedlings after 6 months of growth in nursery. Rhizome offsets taken from 1- to 2-year-old culms give 40–65 % success and two-node culm cutting (40–55 %) and branch cuttings taken during May–June (40–45%) are also possible with addition of hormones.

c. Tissue culture: Plant production through axillary bud proliferation (Negi and Saxena, 2011; Chaudhary et al., 2016) and through somatic embryogenesis (Mehta et al., 2011) has been successful.

Cultivation

a. Plantation type: Block plantations, boundary planting.

b. Spacing: 5x5 m is ideal, 3x3 m is also adopted (Ranga Plantations, Jabalpur, India).

c. Possible species mixed: teak, shorea, gmelina.

d. Years to maturation: 3-5.

e. Shooting season: May-August.

Productivity

a. Culm production : 3–7 culms/year;15–40 culms at full growth (Banik, 2016).

b. AGB : 171.76–281.71 t/ha (Tariyal, 2014).

c. Annual C sequestered : 24.2 t /ha (Choudhury et al., 2015).

d. Allometric equations :

Nepal (Oli and Kandel, 2015)	W = 1.426 + 0.0091 * (D^2 L). "W" is the weight, kg, "D" is the diameter at 15 cm, "L" is the veritical length of the culm. r^2=90%

Mechanical properties

a. Specific gravity : 0.673–0.758 (Tewari, 1992).

b. Density : 0.2 (Kaur et al., 2016).

c. Cellulose/lignin/silica content : Lignocellulose (51.6 %); Lignin 26.2 % (Kaur et al., 2016).

d. MOE : 62.8 to 124.4 (1000 kg/cm^2) (Tewari, 1992).

e. MOR : 524 to 869 (kg/cm^2) (Tewari, 1992).

Genetic diversity and conservation status: Adhikari and Shrestha (2008) studied the intraspecific variation of *Bambusa nutans* subspecies *nutans* among populations in Central Nepal and found variation in the phenotypic traits characters which were significantly correlated with each other.

Uses

a. Traditional: weaving, whole culms in construction, furniture (Banik, 2016), fodder (Bhandari et al., 2015).

b. Industrial: paper, pulp, shelter for tea plantations (Banik, 2016), charcoal.

c. Potential: bioenergy, biorefinery and engineered bamboo.

Key ecosystem service values: The species adapts well to drier areas and therefore has potential for use in ecological restoration projects.

Research gaps: Physicochemical characterisation needed to explore the scope for utilisation. Germplasm collection and selection of superior selection are needed to improve the plant stock.

Habit

Culm and branching pattern

New shoot

Culm sheath

5. *Bambusa oldhamii* Munro

Synonyms (Vorontsova et al., 2016): *Arundarbor oldhamii* (Munro) Kuntze, *Leleba oldhamii* (Munro) Nakai, *Sinocalamus oldhamii* (Munro) McClure, *Dendrocalamopsis oldhamii* (Munro) Keng f., *Bambusa atrovirens* T.H.Wen, *Dendrocalamopsis atrovirens* (T.H.Wen) Keng f. ex W.T.Lin, *Bambusa oldhamii* f. *revoluta* W.T.Lin & J.Y.Lin, *Dendrocalamopsis oldhamii* f. *revoluta* (W.T.Lin & J.Y.Lin) W.T.Lin,*Neosinocalamus revolutus* (W.T.Lin & J.Y.Lin) T.H.Wen, *Sinocalamus oldhamii* f. *revolutus* (W.T.Lin & J.Y.Lin) W.T.Lin,, *Bambusa revoluta* (W.T.Lin & J.Y.Lin) N.H.Xia, R.H.Wang & R.S.Lin.

Common names (Language/area in parenthesis): Giant timber bamboo, Oldham's bamboo, green bamboo (English), *lü zhu* (China); *Ryoku-Chiku* (China).

Description: *B. oldhamii* is a densely clumped bamboo with short-necked pachymorph rhizomes. The erect culms grow up to 10–16 m tall. Culm diameter ranges from 3–9 cm with wall thickness of 4–12 mm. The thin-walled internodes are 17–20 cm long. The nodes are flat and with dendroid branches (Flora of China, 2006).

Distribution

a. Native range: Southeast China to Hainan.
China: Hainan, China Southeast.

b. In cultivation/naturalised in:
Caribbean: Puerto Rico.
Central America: Honduras.
Eastern Asia: Nansei-shoto, Taiwan.
New Zealand: New Zealand North.
Mexico: Mexico Southeast.
Western South America: Colombia, Ecuador, Peru.

Climatic parameters: The species tolerates temperatures down to-7 °C and thrives at an annual mean temperature of 19 °C. The species comes up in areas with an elevation of about 1600 m and with average rainfall of 2350 mm/year.

Soil: The species prefers highly porous, dark-coloured soils known as andosol soils.

Propagation:

a. Natural: Flowering has not been reported in the species.
b. Clonal propagation: Culm cuttings including the basal first to fifth nodes taken from 1-year-old culms in March was found to be optimal (Sirikulyanon et al., 1997).
c. Tissue culture: Propagation through axillary bud proliferation (Lin et al., 2007a) and somatic embryogenesis (Yeh and Chang, 1986) have been reported.

Cultivation

a. Plantation type: Block plantation.
b. Spacing: 4.5x6 m.
c. Years to maturation: 3–5.
d. Shooting season: May–November.

Productivity

a. Culm production : 10.0–11.7 t ha/yr (Maoyi, 2007); 15.82 g ha/yr (Castaneda-Mendoza et al., 2012).
b. AGB : 103.9 Mg from seven-year-old plantation (Castaneda-Mendoza et al., 2005).

c. Annual C sequestered : 51.98 Mg/ha (Castañeda-Mendoza et al., 2005); 27.53 Mg/ha (Rojas et al., 2013); 46.91 Mg/ha (Elizondo- Briceño et al., 2016).

d. Allometric equations :

Mexico (Castañeda-Mendoza et al., 2005)	ln Y ln (6.85)+1.24 (1st yr.) ln Y ln (5.75)+1.84 (2nd yr.) ln Y ln (5.07)+2.23(3rd yr.) ln Y ln (6.02)+1.64 (4th yr.) (Biomass in Mg)

Mechanical properties

a. Cellulose/lignin/silica content : Holocellulose 71.1 %; Lignin 23 % (Cao et al., 2014).

b. Fibre length : 2.39 mm (Cao et al., 2014).

c. Fibre diameter : 12.31 µm (Cao et al., 2014).

d. Runkel ratio : 2.37 (Cao et al., 2014).

Genetic diversity and conservation status: The species has been introduced into several regions where it grows well. The genetic diversity of the populations and conservation of land races is to be studied.

Uses

a. Traditional: edible shoots, furniture.

b. Industrial: paper pulp.

c. Potential: bioenergy, biorefinery, engineered bamboo.

Key ecosystem service values: This species is already introduced to Africa which indicates the potential of this bamboo to grow in a wide range of climates. Therefore, this species can be used for restoration programmes to meet various United Nations Sustainable Development Goals.

Research gaps: Being thin-walled, the scope of the species for use in matboard manufacture can be explored.

Information Gaps: Information on type of plantations and other associated species with this bamboo is not available. Information on flowering cycle as well as data on seed germination is not available.

Habit

Culm and branching pattern

New shoots

Culm sheath

6. *Bambusa polymorpha* Munro

Synonyms (Vorontsova et al., 2016): *Arundarbor polymorpha* (Munro) Kuntze; *Bambusa cyanostachya* Kurz ex Gamble.

Common names (Language/area in parenthesis): *Hui gan zhu (China); Jama betwa (Assam-India); Faura (Tripura-India), Wakobor (ADC Dukli, DebBarma-Tripura*); *Kyanthung - wa* (Myanmar); *Pharua* (Sylhet, Bangladesh), *Mascumba, Burma, Rangoon bans* (Chittagong, Bangladesh); Pai *Hom* (Thailand).

Description: Large evergreen densely tufted bamboo species having pachymorph rhizomes with very short neck. The erect culms reach a height of 10–25 m (Kumari and Singh, 2014; Banik, 2016) and have a diameter of 5–15 cm (Banik, 2016; Kumari and Singh, 2014). Culms have a wall thickness of 1.5–2 mm (Kumari and Singh, 2014); 0.2 -0.3 mm (top), 0.6-0.9 mm (mid) and 1.6- 2.2 mm (base) (Banik, 2016); Branching in the species is from mid-culm upwards. Nodes are slightly prominent.

Distribution

a. Native range: Bangladesh to Yunnan and Southeast Asia.
   China: China South-Central.
   Indian Subcontinent: Bangladesh.
   Indo-China: Laos, Myanmar, Thailand.
   Malesia: Jawa.

b. In cultivation/naturalised in:
   Indian Subcontinent: Assam, Eastern Himalaya, Sri Lanka. India [Tamil Nadu, Kerala, and Karnataka] (Kumari and Singh, 2014).
   Caribbean: Cuba, Puerto Rico.
   Western South America: Ecuador.

Climatic parameters: *B. polymorpha* grows between the temperature range of 3–35 °C (Banik, 2016) but tolerates down to –3 °C and up to 53 °C (Durai and Long, 2019). The species grows well in areas with a precipitation of 3000–6000 mm (Banik, 2016) and at elevations of 300–500 m (Kumari and Singh, 2014).

Soil: *B. polymorpha* prefers deep, rich well-drained fertile loam soils (Banik, 2016).

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

Propagation

a. Natural: The species has a flowering cycle of 35–60 years (Kumari and Singh, 2014). Seed weight is 0.038 seeds/gram and gives a germination rate of 40 % (Dransfield and Widjaja, 1995).

b. Clonal propagation: Seedling macroproliferation is feasible with seedlings after 6 months of germination in nursery beds. Rhizome offsets with two-year-old culms give 100 % success (Dransfield and Widjaja, 1995; Benton, 2015). Culm cuttings are the best method for clonal propagation in this species (Banik, 2008). Branch cuttings also gives 90 % success (Benton, 2015). Air layering has been reported to give 80 % success (Benton, 2015; Durai and Long, 2019).

c. Tissue culture: Detailed procedures for tissue culture are not available but the species is listed among species that are commercially propagated.

Cultivation

a. Plantation type: Homestead cultivation (Banik, 2004).
b. Spacing: 4x4 m (Dransfield and Widjaja, 1995).
c. Possible species mixed: Teak.
d. Years to maturation: 3–5.
e. Shooting season: June–September (Banik, 2016).

Productivity

a. Culm production : 22 t/ha of air-dried culms in a three-year rotation.
b. AGB : 15.3 Mg C/ha (Yuen et al., 2017).
c. Allometric equations :

Myanmar 1- Total Aboveground Biomass (Chan et al.,2013)	0.189*(DBH)^1.956 (Globallome Equation No. 55249)
Myanmar 2- Leaf Biomass (Chan et al., 2013)	0.038*(DBH)^1.452 (Globallome Equation No. 56297)
Myanmar 3- Culm Biomass (Chan et al., 2013)	0.111*(DBH)^2.147 (Globallome Equation No.56308)
Myanmar 4- Branch biomass (Chan et al., 2013)	0.0312*((DBH)^1.6) (Globallome Equation No.56363)
Myanmar 5- Culm biomass (Fukushima et al., 2007)	0.0522*((DBH)^2.58) (Globallome Equation No.56364)
Myanmar 6- Branch biomass (Chan et al., 2013)	0.028*(DBH)^1.551 (Globallome Equation No.58742)
Myanmar 7- Leaf biomass (Fukushima et al., 2007)	0.0363*((DBH)^1.36) (Globallome Equation No.58806)

Mechanical properties

a. Density : 659 kg/m^3 (air-dried bamboo) (Dransfield and Widjaja, 1995).
b. Cellulose/lignin/silica content : Cellulose 54–62 %; lignin (21-22 %); Silica 0.3 % (Dransfield and Widjaja, 1995); Holocellulose 64.10–66.70 %, 23.46–27.08 %; ash 1.62–2.84 % (Thirunirai Selvan, 2017).
c. MOE : 4315 N/mm^2 (Dransfield and Widjaja, 1995).
d. MOR : 34.8 N/mm^2 (Dransfield and Widjaja, 1995).
e. Fibre length : 4.19 mm (Qing et al., 2008); 2.4–2.5 mm (Dransfield and Widjaja, 1995).
f. Fibre diameter : 16–23µm (Dransfield and Widjaja, 1995).

Genetic diversity and conservation status: No germplasm collections exist.

Uses

a. Traditional: whole culms in construction, edible shoots, agricultural implements, landscaping, stick based products (Durai and Long, 2019).
b. Industrial: paper pulp, incense sticks, edible shoots.
c. Potential: engineered bamboo.

Key ecosystem service value: The species is ideal for agroforestry systems and can serve as windbreak and protect against soil erosion.

Research gaps: No conservation efforts for the species are known. The scope of the species in agroforestry systems is to be studied.

Habit

Culm and branching pattern

New shoot

Culm sheath

7. *Bambusa rigida* Keng & Keng f.

Synonyms (Vorontsova et al., 2016): *Bambusa stipitata* W.T. Lin.

Common names (language/area in parenthesis): *ying tou huang zhu* (China).

Description: A medium sized bamboo with a short-necked pachymorph rhizome, erect culms arched apically attaining a height of 5–12 m culm, and a diameter of 2–6 cm. The culms have a wall thickness of 1–1.5 mm and internodal length of 30–40 cm (Flora of China, 2006). The species branches from base upwards and culms are with prominent nodes (Flora of China, 2006).

Distribution

a. Native range: China: China South-Central [Sichuan].
b. In cultivation/naturalised in: No data.

Climatic parameters: No data.

Soil: No data.

Native habitat: Cultivated along riversides and around villages (Flora of China, 2006).

Propagation

a. Natural: No reports of seed formation have been found (Flora of China, 2006).
b. Clonal propagation: Rhizome offsets: No reports known but feasible as with similar species by use of 1- to 3-year-old culms with rhizomes, culm/branch cuttings with or without hormone treatment.
c. No reports of propagation by tissue culture are available.

Cultivation

Cultivated along riversides and around villages (Flora of China, 2006).

a. Plantation type: No data available.
b. Spacing: No data available.
c. Possible species mixed: No data available.
d. Years to maturation: No data available.

Productivity

a.	Culm production	:	No data available.
b.	AGB	:	No data available.
c.	Annual C sequestered	:	No data available.
d.	Allometric equations	:	No data available.

Mechanical properties

e.	Density	:	Basic density 542–808 kg/m^3(Huang et al., 2018).
f.	MOE	:	11.46–18.35 Gpa (1.168–1.871 Kg/cm^2) (base to top) (Huang et al., 2018).
g.	MOR	:	153.26–221.13 Mpa (1562.2 to 2254.89 (base to top) (Huang et al., 2018).

h. Fibre length : 1362–1848 mm (Huang et al., 2018).

i. Fibre diameter : Not reported.

Genetic diversity and conservation status: Not known.

Uses

a. Traditional: handicrafts (Huang et al., 2018), whole culm in construction, agricultural implements (Huang et al., 2018).

b. Industrial: strand woven lumber (Huang et al., 2018).

Key ecosystem service values: Not known.

Research gaps: Data on cultivation and productivity still to be generated.

Information Gaps: Data on several parameters to be collected.

Habit

Culm and branching pattern

New shoot

Culm sheath

8. *Bambusa spinosa* Roxb.

Subspecies/variety/clone: *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 parenthesis): 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); *Wei-fang Lin* (Taiwan); *le zhu* (China).

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

Distribution

a. Native range: Jawa to Maluku.
Malesia: Borneo, Java, Lesser Sunda Islands, Maluku, Philippines.

b. In cultivation/naturalised in:
China: China South-Central, China Southeast.
Eastern Asia: Nansei-Shoto, Taiwan.
Indian Subcontinent: Bangladesh.
Indo-China: Cambodia, Laos, Thailand, Viet Nam.
Malesia: Malaya.
Caribbean: Puerto Rico.

Climatic parameters: The species grows at 18–32 °C but can tolerate 8–37 °C. It prefers a mean annual rainfall of 1500–4000 mm but tolerates 1000–5000 mm (Ecocorp, 2021). Grows at elevations up to 1000 m.

Soil: Grows on heavy soils and on marginal land. 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 in mixed dry deciduous forest and semi-evergreen forest. Grows well along riverbanks, hill slopes and freshwater creeks. The species tolerates flooding (Dransfield and Widjaja, 1995).

Propagation

a. Natural: A flowering cycle of 20–30 years and sporadic flowering is reported but without any seed set (Dransfield and Widjaja, 1995).

b. Clonal propagation: 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).

c. Tissue culture: No reports of micropropagation procedure.

Cultivation

a. Plantation type: Block plantation.

b. Spacing: 8x8m or 10x10m (Dransfield and Widjaja, 1995).

c. Years to maturation: 5.

d. Shooting season: During rains.

Productivity

a. Culm production : 8 culms/year (800–1200/ha) in managed plantations, 5 (500–750/ha) in unmanaged plantations; 960–1600 culms/ha/year in natural stands (Dransfield and Widjaja, 1995).

b. AGB : 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 (Uchimura, 1978); 9 t/ha/yr of paper pulp (Dransfield and Widjaja, 1995).

c. Annual C sequestered : 72 Mg C/ha (Uchimura, 1978); 93.0 Mg C/ha (Philippines) (Yuen et al., 2017).

d. Allometric equations :

North Malaysia- Perlis & Kedah (Mohamed et al., 1991)	15469.6+(466.1177*W)

Mechanical properties

a. Density : 500 kg/m^3 (Dransfield and Widjaja, 1995).

b. Cellulose/lignin/silica content : Holocellulose 67.4 %; lignin 20.4 %; ash 4.8 %; silica 3.4 % (PROSEA, 1995); Holocellulose 81.6 %; lignin 27.2 %; ash 4.7 % (Ratanophat, 2004).

c. MOE : Green: 2.83–5.8x1000 MPa (Mohmod et al., 1993).

d. MOR : 4.68–10 x10 MPa (Mohmod et al., 1993).

e. Compression strength parallel to grain : 19.8–28.85 MPa (Mohmod et al., 1993).

f. Shear strength : 3.99–4.96 MPa (Mohmod et al., 1993).

g. Fibre length : 2.02–2.47 mm (1-3 years) (Mohmod et al., 1993); Green: 1.99 mm (base), 2.00 mm (mid), 1.85 mm (top), 1.95 mm (mean) (Mohmod et al., 1990); 1.95–2.56 mm (Dransfield and Widjaja, 1995).

h. Fibre diameter : 15–20 µm (Dransfield and Widjaja, 1995); Green: 21 µm (base), 17 µm (mid), 21 µm (top), 20 µm (mean) (Mohmod et al., 1990).

i. Runkel ratio : 1.52 (Nordhalia et al., 2019).

Genetic diversity and conservation status: Germplasm collection of *B. spinosa (B. blumeana* has been established in Lampung (Sumatra) and the Indonesian Ministry of Forestry. Selection of superior genotypes will allow improvement of the species, which does not produce seeds.

Uses

a. Traditional: Weaving, whole culms in construction, household implements, edible shoots (preferred), windbreaks and live fences (Dransfield and Widjaja, 1995).
b. Industrial: Laminated bamboo, paper pulp, chopsticks, furniture, flooring tiles (Dransfield and Widjaja, 1995; Tesoro and Espiloy, 1988).
c. Potential: Bioenergy, biorefinery, engineered bamboo.

Key ecosystem service values: The species is planted along riverbanks for control of soil erosion.

Research gaps: Optimal techniques for cultivation, especially management of the thorny culms, is to be developed. Scope for other possible applications is a research gap. To improve the crop, it is recommended to collect germplasm from all areas where it grows or is cultivated.

Habit

Culm and branching pattern

New shoot

Culm sheath

9. *Bambusa textilis* McClure

Subspecies/variety/clone: var *albo striata,* var *glabra* and var *gracilis.* (Benton, 2015); *Bambusa textilis* 'Maculata' and *B. textilis* 'Purpurascens' (Flora of China, 2006).

Synonyms (Vorontsova et al., 2016): *Bambusa textilis* var. *glabra* McClure, *Bambusa textilis* var. *gracilis* McClure, *Bambusa textilis* var. *maculata* McClure, Bambusa *textilis* var. *pubescens* B.M. Yang, *Bambusa textilis* var. *purpurascens* N.H. Xia, *Bambusa textilis* f. *purpurascens* (N.H. Xia) T.P. Yi, *Bambusa minutiligulata* W.T. Lin & Z.M. Wu, *Bambusa annulata* W.T. Lin & Z.J. Feng, *Bambusa glaucescens* var. *annulata* (W.T. Lin & Z.J. Feng) N.H. Xia, *Bambusa varioaurita* W.T. Lin & Z.J. Feng.

Common names (Language/area in parenthesis): Weavers' bamboo, *Ging pi zhu* (China).

Description: A medium sized thin-walled bamboo with short-necked pachymorph rhizomes. The culms are erect with drooping apex and attain a height of 8–15 m (Flora of China, 2006; Benton, 2015). The culm diameter is 3–5 cm (Benton, 2015) and wall thickness 2–5 mm (Flora of China, 2006). The internode length is 40–70 cm (Benton, 2015; Flora of China, 2006). Branching is from mid-culm upwards, and the node is not prominent.

Distribution

a. Native range: Anhui, Guangdong, and Guangxi to Viet Nam.
China: China Southeast.
Indo-China: Viet Nam.

b. In cultivation/naturalised in:
Caribbean: Puerto Rico.
Western South America: Colombia.

Climatic parameters: The species can tolerate temperatures as low as -10 °C. It grows well in dry areas to those with 1000 mm annual rainfall.

Soil: The species comes up in moderately rich soils.

Native habitat: *B. textilis* is usually found growing on hills and cultivated along riversides, around villages and at low elevations.

Propagation

a. Natural: This species flowers sporadically (Flora of China, 2006) but seed formation is rare. Fresh seeds have 50–60 % viability which drops to 0 % within one year (Zhang, 2000).

b. Clonal propagation: Rhizome offsets can be used for propagation (Benton, 2015). Propagation through culm cuttings is not reported but expected to be feasible using two-node cuttings from 1- to 3-year-old culms.

c. Tissue culture: Listed as a commercially propagated species (Bambu Nusa Verde, Indonesia). Published protocols not known.

Cultivation

a. Plantation type: Block plantations, border planting, ornamental use, and landscaping.

b. Spacing: 3x3 m; 5x5 m.

Productivity

a. Annual C sequestered : 26.2 Mg C /ha (Yuen et al., 2017).

b. Allometric equations :

China (Yang et al., 2011)	Tb=-7360.122 + 3933.155D + 41.158D^2- 93.171D^3

Mechanical properties

a.	MOE	:	18.5 (air-dried).
b.	Compression strength parallel to grain	:	83.3 (split, air-dried), 83.7 (whole culm, air-dried).
c.	Shear strength parallel to grain between columns	:	13.3 (air-dried) (Rao et al., 1998).
d.	Fibre length	:	2.29 mm (Su et al., 2005).
e.	Fibre diameter	:	8.17–28.21 µm (Azzini and Caramello, 1971).

Genetic diversity and conservation status: The species has been cultivated around the world as an ornamental. Several varieties have been identified: var *albo striata,* var *glabra,* var *gracilis.* (Benton, 2015), *Bambusa textilis* 'Maculata' and *B. textilis* 'Purpurascens' (Flora of China, 2006). Each has specific characteristics for uses such as weaving, edible shoots etc.

Hybrids have been produced by crosses with *Bambusa pervariabilis* and *Dendrocalamus latiflorus* (Rao et al., 1998). Hybrids such as *B. pervariabilis* × (*D. latiflorus* + *B. textilis*) No. 1, and 7, and *D. latiflorus* × *D. hamiltonii* No. 1 were selected successfully (Zhang, 2000). A superior line was generated using culture and field tests.

Uses

a. Traditional: Handicrafts (Flora of China, 2006) woven materials (Benton, 2015; Flora of China, 2006), whole culms in construction (Flora of China, 2006), edible shoots (but small in size) (Benton, 2015), landscaping (Benton, 2015; Flora of China, 2006), furniture (Flora of China, 2006), fodder.

b. Industrial: Furniture.

c. Potential: Natural fibre, oriented fibreboard.

Research gaps: The potential uses of the various varieties are to be explored after physicochemical characterisation. Superior selections for various end use other than ornamental requires study of anatomical and physiochemical properties.

Information Gaps: Information on use of the species in agroforestry is needed.

Habit

Culm and branching pattern

New shoot

Culm sheath

10. *Bambusa tulda* Roxb.

Subspecies/variety/clone: *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 parenthesis): *Jati bah* (Assam, India), *Mitinga/Mirtenga* (Tripura, India, Bangladesh), *Taleda/Taral/Telda* (West Bengal, Odisha, India), *Wati (Owati)* (Garo), Raw thing (Mizoram, India), *Thaik-wa* (Myanmar), Bengal Bamboo, *fu zhu* (China), Calcutta cane/East India Brown Bamboo/Bengal Bamboo, *Longmi, Auoti, Tsuntsan, Rotha, Khoprei Beking, Biurang, Gunyon, Apishe, Api, Apiba, Chera, Vuzhe, Throngjak, Shixu, Hauh, Haoh, Longmi, Ngat, Jati- Gunyon, Meking, Nyet (*Naithani, 2011).

Description: An evergreen clumping bamboo with short-necked pachymorph rhizomes. The culms are erect and apically drooping, flexuous (zig-zagged) at lower nodes (Flora of China, 2006). The culms grow to a height of 8–30 m (Dransfield and Widjaja, 1995; Singh et al., 2010; Benton, 2015). Various estimates of culm diameters are: 5 cm (Singh et al., 2010); 7.8 cm (base), 8.13 cm (mid), 7.06 cm (top) (Salzer et al., 2018); 7.3 cm (Mohmod et al., 1993); 8.7 cm (Espiloy, 1992); 10 cm (Singh et al., 2010); 10.3 cm (base), 10.9 cm (mid), 9.65 cm (mid), 0.7.6 (top) (Latif and Tamizi, 1992); 9.0 (bottom), 8.4 (middle), 5.31 (top); 0.85 (bottom), 0.87(mid), 0.81 (top).

Estimates of wall thickness vary depending on location, including 7–15 cm (Singh et al., 2010); 7.1–14.6 cm (Mohmod et al., 1993); 1.92–2.74 cm (base), 0.76–1.40 cm (mid) and 0.62–0.76 cm (top) (Salzer et al., 2018); 1.46 cm (base), 1.03 cm (mid), 0.82 cm (top) (Latif and Tamizi, 1992). Internode length ranges from 18–35 cm (Mohmod et al., 1993); or 30–60 cm (Singh et al., 2010) depending on source. Branching occurs from the 4th node upwards (Flora of China, 2016) and nodes are slightly prominent.

Distribution

a. Native range: Himalaya to China (Yunnan) and Southeast Asia.
   China: China South-Central, Tibet.
   Indian Subcontinent: Assam, Bangladesh, East Himalaya, India, Nepal, West Himalaya.
   Indo-China: Laos, Myanmar, Thailand, Viet Nam.

b. In cultivation/naturalised in:
   Western Asia: Iraq.
   Caribbean: Puerto Rico.
   Western South America: Columbia, Ecuador.
   Brazil: Brazil Southeast.

Climatic parameters: *B.* tulda grows in areas with the temperature range of 4–37 °C (Banik, 2016) or 5.6–43.3 °C (Srivastava et al., 2012) and precipitation of 1246–1400 mm (Srivastava et al., 2012). It grows well at 4000–6500 mm. The species grows at elevations of 600–1500 m (Banik, 2016; Singh et al., 2010).

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

Native habitat: Along 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). Found in association with *Shorea robusta* (Sal) and in mixed deciduous forests.

Propagation

a. Natural: The species shows both sporadic and gregarious flowering (Srivastava et al., 2012). Estimates of flowering cycle varies between 15–30 (Kumari and Singh, 2014), 25–40 (Benton, 2015) and 25–30 years (Nautiyal et al., 2008).

b. Seed weight is estimated at 15 seeds/gram (Banik, 2000), 23.7 (Suraj and Nath, 2011) and 23.69 seeds/gram (Srivastava et al., 2012). Germination figures of 97 % (Srivastava et al., 2012), 75 % (Sarma et al., 2010) and 92 % (Ahlawat et al., 2002) in 9-30 days have been reported. Viability under proper storage conditions is three months.

c. Clonal propagation: Seedling macroproliferation is feasible in this species (Kumar, 1991). Rhizome offsets taken from 1- to 2-year-old culms is successful (Singh et al., 2010). Culm cuttings from mid to lower nodes have been successfully used for propagation (Banik, 2008). Branch cuttings and air layering is also successful (Benton, 2015).

d. Tissue culture: Plant production through axillary bud proliferation has been reported by Saxena and Bhojwani (1991) and Mishra et al. (2008).

Cultivation

a. Plantation type: Block plantations, agroforestry.

b. Spacing: 5x5 m.

c. Possible species mixed: teak, sal, agroforestry species.

d. Years to maturation: 3–4 (Singh et al., 2010).

e. Shooting season: May–August.

Productivity

a. Culm production : 1088 culms/ha (Majumdar et al., 2016).

b. AGB : 100.29 Mg/ha (Devi and Singh, 2021); 41.84 Mg/ha (Majumdar et al., 2016); 14132 Mg/ha (Devi and Singh, 2021); 73.58 to 127 Mg/ha (Devi and Singh, 2021) for plantations older than three years.

c. Annual C sequestered : 27.79 Mg/ha (Devi and Singh, 2021); 20.92 Mg/ha (Majumdar et al., 2016); 15.17 Mg/ha (Devi and Singh, 2021).

d. Allometric equations :

Myanmar 1 (Chan et al., 2013)	$W=0.131*D^{2.351}$
Myanmar 2 (Fukushima et al., 2007)	$W=0.141*D^{2.48}$

Mechanical properties

a. Density : 0.79 kg/m^3 (Kaur et al., 2016).

b. Cellulose/lignin/silica content : Lignocellulose 56.2 %; lignin 24 % (Kaur et al., 2016).

c. Fibre length : 2.02–2.47 mm (Mohmod et al., 1993.

d. Starch : 1.8 (Kaur et al., 2016).

Genetic conservation and ecosystem services: The species shows tremendous variability, and 19 genotypes are recognised (Singh, 1993). Survey germplasm collections and selection of superior genotypes for propagation has been done by ICFRE throughout Native habitats in India (Ginwal, 2021).

Uses

a. Traditional: Handicrafts (Benton, 2015), basketry, whole culms in construction (Benton, 2015), edible shoots (preferred species for fermented shoots known as soibum, which are culturally important in Manipur, India) (Benton, 2015; Singh and Singh, 1994), incense sticks, furniture (Benton, 2015), mats, baskets, fishing rods and flutes.

b. Industrial: Laminated bamboo (Benton, 2015), strand woven board (Mohmod et al., 1993), paper pulp (Tesoro and Espiloy, 1988).

c. Potential: Bioenergy and biorefinery; carbon trading.

Key ecosystem service values: A common species in flood-prone areas of Northeast India and therefore important in soil erosion control. The species also comes up well in drier tracts and has potential for use in ecological restoration.

Research gaps: *B. tulda* is a popular species in India for plantations. It shows tremendous variability and a comprehensive survey and germplasm collection from its native range and from homesteads. Characterisation and conservation are needed to improve the prospects of plantations.

Information Gaps: The extent of plantations and differences in productivity of the species in different agroclimatic zones of India, Bangladesh and other countries is not available. Assessment of resource availability for industry is difficult.

Habitat

Culm and branching pattern

New shoot

Culm sheath

11. *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 parenthesis): *long tou zhu* (China) *Jai borua* (Assam, India).

Description: *B. vulgaris* is a tufted bamboo with erect culms and short-necked pachymorph rhizomes. The loosely clumping, erect culms with drooping tips are slightly bent at the base and grow to a height of 8–15 m with a diameter of 5–9 cm, wall thickness of 7.3–15 mm and internodal length of 20–30 cm (Flora of China, 2016). Branching occurs from lower nodes upwards, and nodes are with slightly prominent nodes.

Distribution

a. Native range: China: China South-Central.
Indo-China: Cambodia, Laos, Myanmar, Thailand, Viet Nam.

b. In cultivation/naturalised 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.
Middle Atlantic Ocean: Ascension.
Western Indian Ocean: Aldabra, Chagos Archipelago, Madagascar, Rodrigues.
Eastern Asia: Nansei-shoto.
Indian Subcontinent: Assam, Bangladesh, Eastern Himalaya, India, Maldives, Sri Lanka.
Indo-China: Andaman Islands.
Malesia: Java, Malaya, Maluku.
Papuasia: Bismarck Archipelago, New Guinea.
Southwestern Pacific: Tonga, Wallis-Futuna Islands.
North-Central Pacific: Hawaii.
Southeast USA: Florida, South Carolina.
Mexico: Mexico Central, Mexico Northeast, Mexico Gulf, Mexico Southwest, Mexico Southeast.
Central America: Costa Rica, El Salvador, Honduras, Nicaragua, Panama.
Caribbean: Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, Leeward Islands, Puerto Rico, Trinidad-Tobago, Windward Islands.

Western South America: Columbia, Ecuador, Peru.
Brazil: Brazil West-Central, Brazil Northeast, Brazil Southeast, Brazil South.

Climatic parameters: *B. vulgaris* grows at elevations of up to 870 m in areas with annual rainfall of 1364.3–2585 mm and mean annual temperatures of around 25 °C.

Soil: This species is widely grown in vertisols and ferralitic soils, sandy, silty, hydromorphic and sandy volcanic soils, and andosol at a depth of 4.5–6 m (Nfornkah et al., 2020).

Native habitat: The species is found on riversides and in open forests in Yunnan (Flora of China, 2016).

Propagation

a. Natural: It is a sterile species which is rarely in flower and produces no seeds.
b. Clonal propagation: pre-rooted rhizome and culm cuttings are used. The species is easy to propagate by culm and branch cuttings. Results are enhanced by use of hormones and mist propagation. Vegetative propagation using ordinary water is also reported (Seethalakshmi and Muktesh Kumar, 1998). Cuttings taken from 1- to 2-year-old culms planted in the summer months gave maximum sucess (Banik, 1984); Ground layering and air layering are also successful. Marcotting with polyacrylamide gel has been successful (Cariño, 1990).
c. Tissue culture: Micropropagation through axillary bud proliferation has been achieved by Nadgir et al. (1984); Arya and Arya (2009). Propagation of B. *vulgaris f. striata* (Ramanayake et al., 2006) and B. *vulgaris f. wamin* (Arshad et al., 2005) has also been successful.

Cultivation

a. Plantation type: Block plantation.
b. Spacing: 6x6 m, 8x8 m, 12x12 m.
c. Years to maturation: 3.
d. Shooting season: Variable, depending on water availability; May-September in India.

Productivity

a. Culm production : 10 t/ha/year (Seethalakshmi and Muktesh Kumar, 1998); 2296 culms/ha) (Nfornkah et al., 2020).
b. AGB : 63.02 t/ha (Nfornkah et al., 2020); 50.44 t C/ha (Sohel et al., 2015).
c. Annual C sequestered : 29.70 t c/ha (AGC); 108.7 t CO_2 equivalent (Nfornkah et al., 2020).
d. Allometric equations :

Philippines1- culm dry biomass (Uchimura, 1978)	log (Cb) = 0.77024 log D^2H – 1.24067
India 1- Branches biomass (Nath et al., 2009)	log Biomass=1.404+2.073*(log((DBH)^(1)) (Globallome Equation No.38222)
India 2- AGB (Nath et al., 2009)	log Biomass=2.281+2.149*(log((DBH)) (Globallome Equation No.44044)
India 3- Leaf Biomass (Nath et al., 2009)	log Biomass=1.756+1.462*(log((DBH)) (Globallome Equation No.45932)
Indonesia (Prayogo et al., 2021)	$Y=1.3553*DBH^{1.3378}$ $Y=0.0268*H^{2.7716}$ where Y is dry weight, in kg

Mechanical properties

a.	Specific gravity	:	510 (base) 550 (mid), 570 (top) (Mohmod et al., 1990) (Green).
b.	Density	:	904.76, 727.10 (basic density oven-dried) (Sulaiman et al., 2018).
c.	Cellulose/lignin/silica /Ash	:	Holocellulose 66.5/26.9/1.5/2.4 % (Tesoro and Espiloy, 1988); lignin 67.8–69.6 %; silica 22.7–23.9 %; ash 1.8–2.1 % (Latif and Liese, 1995; Liese and Tang, 2015).
d.	MOE	:	Green: 6.70 (base) 6.10 (mid) 8.08 (top) 6.96 (mean) 1000MPa (Mohmod et al., 1990); 25218.25 N/mm^2 (Sulaiman et al 2018); 6100 Mpa (Liese, 1986).
e.	MOR	:	Green: 78.41 (base) 58.14 (mid) 46.15 (top) 60.90 (mean) Mpa (Mohmod et al., 1990); 179.65 N/mm^2 (Sulaiman et al., 2018); 62.3 Mpa (Liese, 1986).
f.	Fibre length	:	3.76 mm.
g.	Fibre diameter	:	170 µm.

Genetic diversity and conservation status: No assessment of the genetic variability of this species where propagation is solely through clonal means. Any available variation needs to be conserved and made available for planting stock for plantations.

Uses

a. Traditional: Handicraft, weaving, whole culms in construction, edible shoots, cultivated for edible shoots in Malaysia (Naithani, 2011).
b. Industrial: Particle board (Calegari et al., 2007; Gauss et al., 2019), laminated bamboo (Biswas et al., 2011), paper pulp, charcoal, engineered bamboo.
c. Potential: Biofuel, biorefinery.

Key ecosystem service values: *B. vulgaris* is a truly 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 ecological restoration programmes with good success.

Research gaps: Allometric equations for biomass estimations are needed for this important species. Productivity estimates from different agro-climatic zones are needed.

Habit

Culm and branching pattern

New shoot

Culm sheath

12. *Chimonobambusa quadrangularis* (Franceschi) Makino

Subspecies/variety/clone (if any): *Tetragonocalamus quadrangularis var. sotaroanus Muroi.; Tetragonocalamus quadrangularis f. sotaroanus (Muroi) Muroi.; himonobambusa quadrangularis f. sotaroana (Muroi) T.H.Wen.; Tetragonocalamus quadrangularis f. albostriatus Muroi & H.Okamura; Chimonobambusa quadrangularis f. albostriata (Muroi & H.Okamura) T.H.Wen; Tetragonocalamus quadrangularis f. aureostriatus Muroi & H.Okamura; Chimonobambusa quadrangularis f. aureostriata; Tetragonocalamus quadrangularis f. castillonis; Tetragonocalamus quadrangularis f. nagamineus H.Okamura; Chimonobambusa quadrangularis f. nagaminea; Tetragonocalamus quadrangularis f. suow; Chimonobambusa quadrangularis f. suow; Chimonobambusa quadrangularis f. purpureiculma; Chimonobambusa quadrangularis f. cyrano-bergeraca; Tetragonocalamus quadrangularis f. gimmei; Tetragonocalamus quadrangularis f. tatejima.*

Synonyms (Vorontsova et al., 2016): *Bambos sikaktake* Siebold.*; Bambusa sikaktake* Zoll.*; Bambusa quadrangularis* Franceschi.*; Arundinaria quadrangularis (*Franceschi*)* Makino.*; Phyllostachys quadrangularis (*Franceschi*)* Rendle.*; Tetragonocalamus quadrangularis (*Franceschi*)* Nakai.

Common names (Language/area in parenthesis): *Bambu kimono* or *bambu krisik* (Indonesia) (Tjitrosoedirdjo et al., 2016); *U-sparbah* ((Khasi, India) (Kumari and Singh, 2007); *fang zhu* (Flora of China, 2006), square bamboo (English).

Description: A much spreading, shrubby, erect bamboo with leptomorph rhizomes (Damayanto and Muhaimin 2017). The culms are erect and quadrangular at base and cylindrical in the upper parts and reach a height of 4–8 m and diameter of 2–5 cm. Wall thickness is 2–8 mm and internodal length is 8–25 cm (Kumari and Singh, 2007; Taihui, 1994; Damyanto and Muhaimin, 2017; Flora of China, 2006). The nodes are characteristic with prominent spines.

Distribution

a. Native range: Southeastern China to Viet Nam and Taiwan.
   China: China Southeast.
   Eastern Asia: Taiwan.
   Indo-China: Viet Nam.

b. In cultivation/naturalised in:
   New Zealand: New Zealand North.
   Eastern Asia: Japan.
   North America, Europe (Flora of China, 2006).

Climatic parameters: The species occurs in areas with an annual temperature and rainfall of 16.3°C and 2266 mm respectively. It is cold tolerant (up to -12°C, but not lower (PFAF, 2021a). It grows at elevations of 1450–1900 m (Kumari and Singh, 2007; Taihui, 1994) in moist locations.

Soil: Suitable for light (sandy), medium (loamy) and heavy (clay) soils. Prefers mildly acid, neutral and mildly alkaline soil (PFAF, 2021).

Native habitat: *C. quadrangularis* is a short-day plant that can grow well under trees in the forest (Taihui, 1994).

Propagation

a. Natural: The species is not known to flower.
b. Clonal propagation: No reports.
c. Tissue culture: No reports.

Cultivation

a. Plantation type: Block plantations, ecological restoration.
b. Spacing: not spaced (running bamboo).
c. Shooting season: August-December/January (Kumari and Singh, 2007; Taihui, 1994).

Productivity

a. AGB : Not reported.
b. Annual C sequestration : 11.1 Mg C/ha (Yuen et al., 2017).
c. Allometric equations :

Japan (Inoue et al., 2019)	Culm: Wc = 85.863 $D^{2.258}$ (r^2 = 0.955); Whole AGB: W = 180.970 $D^{1.883}$ (r^2 = 0.908)

Mechanical properties

a. Specific gravity : Not reported.
b. Density : Not reported.
c. Cellulose/lignin/silica /Ash : Not reported.
d. MOE : Not reported.
e. MOR : Not reported.
f. Fibre length: : 1463.6 µm (corner) 1452.7 µm (side) (Jiang et al., 2021).
g. Fibre diameter: : 12.3 µm (corner) 12.8 µm (side) (Jiang et al., 2021).

Genetic diversity and conservation status: The inclusion of *C. quadrangularis* in the IUCN Red List is surprising, considering its wide distribution (Flora of China, 2006).

Uses

a. Traditional: Handicrafts, whole culms in construction, edible shoots (lalapan, fresh or boiled shoots in Indonesia) (Widjaja, 2001), ornamental (Taihui, 1994).
b. Potential: Ecological restoration of degraded land, polysaccharides (from bamboo shoot residue) (Chen et al., 2019).

Key ecosystem service values: Risk of turning invasive; invasive in Jawa, Sumatra, and Hawai (Damayanto and Muhaimin, 2017; Bystriakova et al., 2003).

Research gaps: Development of protocols for management of this running bamboo for developing plantations is needed to mitigate its invasive nature.

Information Gaps: information on many physicochemical properties is not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

13. *Chusquea culeou* É. Desv.

Subspecies/variety/clone: *Chusquea culeou* var. tenuis D.C. McClint.

Synonyms (Vorontsova et al., 2016): *Chusquea breviglumis* Phil.

Common names (Language/area in parenthesis): Chilean feather clumping bamboo, Chilean bamboo (English), *caña coligüe*, *colihue* (Spanish).

Description: This is an evergreen bamboo with pachymorph short-necked rhizomes forming clumps of about 1–4 m in diameter. The woody culms attain a height of 1–8 m with diameter of 5.7–21.47 cm with short (10–12 cm), thick, and solid internodes (Pearson et al., 1994). The nodes are flat without nodal roots and have clusters of branches.

Distribution

a. Native range: Central and South Chile to Northwest Argentina.
Southern South America: Argentina South, Chile Central, Chile South.

b. In cultivation/naturalised in: No recorded.

Climatic parameters: *C. culeou* grows at altitudes of 765–1160 m and in areas with annual precipitation of 1300–4000 mm (Pearson et al., 1994). It is tolerant to drought.

Soil: This species prefers light (sandy), medium (loamy) and heavy (clay) soils, mildly acid, neutral and basic (mildly alkaline) soils. It can grow in semi-shade such as in light woodland (Pearson et al., 1994).

Native habitat

It occurs both in pure stands in the open and beneath the dense canopy of *Nothofagus* forests. Often grows in association with *Berberis* sp., *Ribes* sp. *Gaultheria* sp., *Ovidia pillo-pillo*, grass, herbs *Nothofagus pumilio N. dombey* and *Myrceugenia chrysocarpa* (Pearson et al., 1994).

Propagation

a. Natural: Flowering in C. *culeou* is sporadic and gregarious with a cycle of 15–15 years (Pearson et al., 1994). This plant seems to be self-sterile with only 2 % of spikelets containing seeds.

b. Clonal propagation: No information on artificial propagation, including on tissue culture, is available.

Cultivation

a. Plantation type: No information on the species being cultivated is available.

b. Years to maturation: 4 (Pearson et al., 1994).

c. Shooting season: November-early December.

Productivity

a.	Culm production	:	10 t/ha/yr; 12 m^3/ha/yr (Poblete et al., 2009). 179 t/ha/yr (Pearson et al., 1994).
b.	AGB	:	162 kg dry weight of 10 clumps (Pearson et al., 1994).
c.	Annual C sequestered	:	AGC: 80.8 Mg C/ha (Yuen et al., 2017).
d.	Allometric equations	:	

Argentina (Pearson et al., 1994)	Dry weight (mg) = 3.4-0.019X + 0.0047X^2, where X is length of the foliage leaf blade in mm; r = + 0.94.

Mechanical properties

a. Specific gravity : 0.631 g/cm^3 and 0.685 g/cm^3 (nodes); 0.549 g/cm^3 and a maximum value of 0.616 g/cm^3 (internodes) (Poblete et al., 2009).

b. Density : 1.2 g/cm^3 (10 fresh culms) (Pearson et al., 1994).

c. Cellulose/lignin/silica content : Holocellulose: 73.1 (node), 71.9 (internode); Cellulose: 51.4 (node), 51.5 (internode); Lignin: 22.3 (node), 23.0 (internode) (Poblete et al., 2009).

d. MOE : 7.326 N/mm^2 (node), 6.638 N/mm^2 (internode) (Poblete et al., 2009).

e. MOR : 59.9 N/mm^2 (node), 61.9 N/mm^2 (internode) (Poblete et al., 2009).

f. Fibre length : 1.68–1.74 mm (Poblete et al., 2009).

g. Fibre diameter : 0.96 µm and 1.02 µm (Poblete et al., 2009).

Genetic diversity and conservation status: No systematic effort at survey, collection, and conservation of the germplasm of the species seems to have been done. The uniqueness of this solid species adapted to the arid conditions justifies such efforts to domesticate and utilise the valuable resource.

Uses

a. Traditional: used to make the musical instrument known as *trutruca.*

b. Industrial: construction.

c. Potential: substitute for large diameter rattan in furniture; excellent species for land restoration programmes due to its drought tolerant property and an appropriate raw material for the pulp and paper production.

Key ecosystem service values: Frost-tolerant and widely cultivated in temperate regions. A keystone species which can control patterns of forest dynamics by impeding regeneration of tree species.

Research gaps: Genetic diversity studies and collection and conservation of germplasm.

Habit

Culm and branching pattern

New shoot

Culm sheath

14. *Dendrocalamus asper* (Schult.f.) Backer ex Heyne

Subspecies/variety/clone: *Betung wulung*, cv Tahi green and cv Phai Tong Dam (Benton, 2015) cv. Thai green, cv. Phai Tong Dam, *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 (Language/area in parenthesis): *Buong* (Vietnamese), *ma lai tian long zhu* (Taiwan).

Description: This is a large tufted, erect bamboo with short-necked pachymorph rhizomes. Culms attain heights of 15–30 m (Flora of China, 2006; Benton, 2015). Culm diameter ranges between 6–20 cm (Flora of China, 2006; Benton, 2015) and wall thickness of 1.1–2 cm (Benton, 2015, Banik, 2016). Culms have an internode length of 30–50 cm (Flora of China, 2006; Benton, 2015) and branches form from the 9th node upwards (Flora of China, 2006).

Distribution

a. Native range: Bangladesh to Taiwan and Malesia.
   China: China South-Central, China Southeast.
   Eastern Asia: Taiwan.
   Indian Subcontinent: Bangladesh.
   Indo-China: Andaman Islands, Laos, Myanmar, Thailand, Viet Nam.
   Malesia: Borneo, Java, Lesser Sunda Islands, Malaya, Maluku, Philippines, Sulawesi, Sumatra.
   Papuasia: New Guinea.

b. In cultivation/naturalised in:
   Caribbean: Puerto Rico.
   Indian Subcontinent: Sri Lanka.
   Papuasia: Bismarck Archipelago.
   Western South America: Colombia, Ecuador.
   Brazil: Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central.

Climatic parameters: The species is found growing in area with an average temperature of 27 °C and precipitation of 217 mm at elevations of around 600 m.

Native habitat: Not known, but the species is planted or naturalised at low elevations up to 1500 m.

Soil: *D. asper* will grow in any type of soil, but it grows better on heavy soils with good drainage. In Thailand, the species will grow well on sandy and rather acidic soils.

Propagation

a. Natural: Seed weight is 36.9 seeds/gram (Hanjiang, 2019). Germination is 36.5 % after 18 months at 5 °C (Banik, 2015a).

b. Clonal propagation: Seedling macroproliferation is feasible in nurseries at intervals of six months. Rhizome offsets give a success rate of 70–80 % (Banik, 1995).

c. Tissue culture: Propagation 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

a. Plantation type: Block plantations; plantations for edible shoots.
b. Spacing: 5x5 m, 6x6 m.
c. Possible species mixed: none recorded.
d. Years to maturation: 3–5.
e. Shooting season: May–June (Thailand).

Productivity

a. Culm production : 10–11 t (Malanit et al., 2009); 660–1070 kg/ha/year (Air dried) three- to four-year-old plantation (Tesoro and Espiloy, 1988).

b. AGB : 16 t culms/ha/year (Pungbun, 2000); 74.5 Mg C/ha (Yuen et al., 2017).

c. Annual C sequestered : 215.48 t /ha (Prayogo et al., 2021).

d. Allometric equations :

Indonesia (Prayogo et al., 2021)	Y= 1.2974 X $^{1.3512}$ (X=DBH, cm) Y= 0.0028 X $^{3.0625}$ (X=Hight of bamboo stem, m) Y=Dry weight, kg

Mechanical properties

a. Specific gravity : 0.766 (Malanit et al., 2009).

b. Density : 0.55–0.90 g/cm^3 from base to top (Malanit et al., 2009).

c. Cellulose/lignin/silica content : Cellulose 61.3 %; lignin 25.5 %; silica 2.4 % (Tamolang et al., 1980); cellulose 49 %; hemicellulose 22 %; lignin 23 %; extractives 7.1 %; ash 3.3 % (Bremer et al., 2012).

d. MOE : 15,363 Mpa (air-dried) (Malanit et al., 2009).

e. MOR : 11,953.7 (with nodes), 9433.6 (without nodes) (Prawirohatmodjo, 1990); 198.52 MPa (air-dried) (Malanit et al., 2009); 92-100 MPa (Royal Forest Dept., 2003).

f. Compression strength perpendicular to grain : 14.39 MPa (air-dried) (Malanit et al., 2009).

g. Compression strength (parallel) : 8.4 to10.0 MPa (Royal Forest Dept., 2003).

Genetic diversity and conservation status: The species is widely cultivated in plantations in India, all derived through propagules produced through tissue culture. This has very narrow genetic base and run a risk of pest and disease build up. Introduction of new germplasm from the native region is therefore important. Germplasm collections have been made in Sumatra (Banik, 2016).

Uses

a. Traditional: Handicraft, whole culms in construction, edible shoots.
b. Industrial: Laminated bamboo (Malanit et al., 2009), oriented strand board (Febrianto et al., 2012; Malanit et al., 2011); Parquet flooring (Tesoro and Espiloy, 1988).
c. Potential: Bioenergy, biorefinery.

Key ecosystem service values: As a species with good performance around the world multiple uses it can play a role in ecorestoration programmes with livelihood development. The soil binding role and formation of a good leaf litter mulch has been seen in plantations in India.

Research gaps: Performance of the different varieties of the species should be tested in other regions of the world to bring about more diversity in plantations.

Habit

Culm and branching pattern

New shoot

Culm sheath

15. *Dendrocalamus barbatus* Hsueh & D.Z.Li

Subspecies/variety/clone: *Dendrocalamus barbatus* var. *internodiiradicatus* Hsueh & D.Z.Li.

Common names (Language/area in parenthesis): *Phai sang chin, phai sang khiao, phai tong chin* (Thailand), *Luong bamboo* (Viet Nam, English).

Description: A large densely clumped bamboo with short-necked pachymorph rhizome. The culms attain a height of 15–20 m and a diameter of 10–15 cm. Thick-walled culms have internodes of 26–32 cm with aerial roots from the nodes.

Distribution

a. Native range: China: China Central, China South-Central (Yunnan).
b. In cultivation/naturalised in: Indo-China: Thailand, Viet Nam.

Climatic parameters: This species grows at an elevation of 300–1100 m, at temperatures of about 20 °C and with annual rainfall of 1600–2000 mm (Do et al., 2000).

Soil: *D. barbatus* grows well on sandy loam to clay loam or silty clay, yellow, and moisture-retentive to moist soil with pH~4.5 and 2.3 % organic material (Tran, 2010).

Native habitat: The main distribution areas of the species have a warm, moist climate with dry winters and rainy summers. *Dendrocalamus barbatus* is light-demanding, so it cannot grow under the canopy of other plants (Le, 2000).

Propagation

a. Natural: Flowering of this species was reported in 2017 in Thailand with seed weight of 32–34 seeds/gram. The germination potential was 30–35 %.
b. Clonal propagation: Seedling macroproliferation is expected to be feasible but not reported. The stump digging or rhizome offsets are successfully transferred for propagation (Tran, 2010). Branch cuttings and air layering are also reported as a successful method (Tran, 2010).
c. Tissue culture: Shoot cultures and callus induction have been successfully established from seeds by He et al. (2011) and Wang et al. (2012).

Cultivation

a. Plantation type: Block plantations.
b. Spacing: 5x10 m.
c. Possible species mixed: None recorded.
d. Years to maturation: 4.
e. Shooting season: None recorded.

Productivity

a. Culm production : 42 million culms/yr (Trieu et al., 2020).
b. AGB : 36.1 ton/ha (Trieu et al., 2020).
c. Annual C sequestered : 17.5 ton/ha (Trieu et al., 2020), 26.6 MgC/ha (AGB) (Yuen et al., 2017).
d. Allometric equations :

Viet Nam (Phuong et al., 2012)	AGB = $0.1726*D^{2.0545}$

Mechanical properties

a. Specific gravity : Not reported.

b. Density : Not reported.

c. Cellulose/lignin/silica content : Cellulose 48.62 %; lignin 27.96 % (Qing et al., 2008).

d. MOE : 179.2 N/mm^2 (Tran, 2010).

e. MOR : 99.9 ± 2.9 N/mm^2 (Tran, 2010).

f. Fibre length : 4.52 mm (Qing et al., 2008).

g. Fibre diameter : 20.13 µm (Qing et al., 2008).

Genetic diversity and conservation status: Not known.

Uses

a. Traditional: Shoots for food; culms for construction.

b. Industrial: Pulp, paper, activated charcoal, edible shoots.

c. Potential: Wood-based panels, strand woven flooring panels, bamboo matboard.

Research gaps: Assessments of genetic diversity and efforts at selection and conservation of superior genotypes are needed.

Information Gaps: Physicochemical properties are not available, nor is the scope of large-scale propagation methods.

Habit

Culm and branching pattern

New shoot

Culm sheath

16. *Dendrocalamus brandisii* (Munro) Kurz

Synonyms (Vorontsova et al., 2016): *Bambusa brandisii* Munro; *Arundarbor brandisii* (Munro) Kuntze.

Common names (Language/area in parenthesis): *Bulka*, *Wanan*, Burma bamboo (India); *Bo shi tian long zhu* (China); *Kyalo*-wa, *wabo* (Myanmar); *hôk* (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 19–33 m (Seethalakshmi and Muktesh Kumar, 1998; Flora of China, 2016). Culm diameter is 13–20 cm (Seethalakshmi and Muktesh Kumar, 1998), wall thickness 1.7–3 mm (Viswanath et al., 2007) and internode length, 30–43 cm (Seethalakshmi and Muktesh Kumar, 1998; Viswanath et al., 2007; Flora of China). Branching is mostly mid-culms upward and nodes are not prominent, but aerial roots are present.

Distribution

a. Native range: China: China South-Central.

b. In cultivation/naturalised in:
Indian Subcontinent: Bangladesh.
Indo-China: Andaman Islands, Laos, Myanmar, Thailand, Viet Nam.

Climatic parameters:

a. Temperature: Not reported.

b. Precipitation: Not reported.

c. Altitude: 1300 m.

d. Soil: In Myanmar, the species is frequently found on limestone, but it also grows well on well-drained loamy soils.

Native habitat: *D. brandisii* grows in wet, evergreen tropical forest at elevations of up to 1300 m.

Propagation

a. Natural: Flowering cycle is 40–50 years (Viswanath et al., 2013). Seed weight is 100 seeds/gram (Viswanath et al., 2013). Germination of up to 90 % is obtained within 90 days of collection (Viswanath et al., 2013).

b. Clonal propagation: Seedling macroproliferation 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).

c. Tissue culture: Micropropagation through axillary bud proliferation (Mukunthakumar et al., 1999; Chetan, 2012; Muralidharan and Seethalakshmi, 2017) and through somatic embryogenesis using zygotic embryo as explant (Vongvijitra, 1988; Nadgauda et al., 1990; Zamora, 1994; Muralidharan and Seethalakshmi, 2017).

Cultivation

a. Plantation type: Block plantations, Agroforestry planting.

b. Spacing: 5x5 m, 6x6 and 6x10 m (Viswanath et al., 2013).

c. Possible species mixed: Agroforestry intercrops (Ginger) (Viswanath et al., 2007).

d. Years to maturation: 3–4.

e. Shooting season: June–September.

Productivity

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

b. AGB : Not reported.

c. Annual C sequestered : AGC- 74.5 Mg C/ha (Yuen et al., 2017).

d. Allometric equations : Not reported.

Mechanical properties

a. Cellulose/lignin/silica content : Holocellulose 72.69 %; acid insoluble lignin 26.9 %; acid soluble lignin 3.23 %; ash; silica 0.94 %.

b. MOE : Laminated boards: mean MOE of 11594 N/mm (Appiah-Kubi et al., 2014).

c. MOR : Laminated boards: mean MOR of 99.73 N/mm (Appiah-Kubi et al., 2014).

d. Fibre length (in mm) : 2.02–2.47 mm, 2.52 (Wang et al., 2016); 2.08 (top), 2.76 (middle), 2.72 (bottom) (Wang et al., 2016).

e. Fibre diameter (in µm) : 17.63 (Wang et al., 2016), 16.05 (T) 20.88 (M) 15.95(B) (Wang et al., 2016).

f. Runkel Ratio : 3.98 (Wang et al., 2016).

Genetic diversity and conservation status: No efforts at studying and conserving the genetic diversity appears to have been done.

Uses

a. Traditional: Handicraft, weaving, whole culms in construction, edible shoots.

b. Industrial: Laminated bamboo, strand woven, paper pulp, composite fibre, edible shoots.

c. Potential: Bioenergy, biorefinery.

Key ecosystem service values: The species is suited for stabilisation of hilly terrain in humid tropics.

Research gaps: Studies on ecological requirements, cultivation methods, management, propagation, physicochemical properties are needed. Live germplasm collections and selection of superior genotypes for planting stock production are urgently needed (Dransfield and Widjaja, 1995).

Habit

Culm and branching pattern

New shoot

Culm sheath

17. *Dendrocalamus giganteus* Munro

Synonyms (Vorontsova et al., 2016): *Sinocalamus giganteus* (Munro) Keng f.; *Bambusa gigantea* Wall.

Common names: (language/area in parenthesis) 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'* (Lao PDR); *phai-po, phai-pok* (Thailand); *m[aj]nh t[oo]ng to* (Viet Nam).

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

Distribution

a. Native range: West Bengal, India to Yunnan, China.
   Indian Subcontinent: Assam, Eastern Himalayas, India.
   China: China South-Central.
   Indo-China: Laos, Myanmar.

b. In cultivation/naturalised in:
   Indian Subcontinent: Bangladesh, Nepal, Sri Lanka.
   Western Indian Ocean: Mauritius, Madagascar, Seychelles.
   Eastern Asia: Taiwan.
   Indo-China: Cambodia, Thailand, Viet Nam).
   Malesia: Jawa, Malaya, Sumatra.
   Caribbean: Puerto Rico, Trinidad-Tobago.
   Western South America: Ecuador.

Climatic parameters: The species is found at elevations of up to 1200 m.

Soil: The species prefers rich alluvial soils.

Native habitat: The species is found naturally in mid tropical highlands, at up to 1200 m altitude but can grow in tropical lowlands and is found in natural teak forests in Thailand (Dransfield and Widjaja, 1995).

Propagation

a. Natural: The species has a flowering cycle (gregarious) of 30–60 years (Dransfield and Widjaja, 1995; Kumari and Singh, 2014) but sporadic flowering/part flowering is common. The seed weight is 20 seeds/gram and germination success rate 60-75 % obtained in 3–7 days (Banik, 2016).

b. Clonal propagation: Seedling macroproliferation is possible after about 6 months of transplanting in nursery bed/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 in 60–70 days. Mid-culm nodes are found to be best, whereas branch cuttings give 60–70 % rooting in 45–55 days (Banik, 2008). Branch cuttings gave 63.33 % rooting without any treatment (Razvi et al., 2015).

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

Cultivation

a. Plantation type: Block plantations.

b. Spacing: 10x10 m.

c. Possible species mixed: Teak.

d. Years to maturation: 7 but full culm size is reached only in 15 (Dransfield and Widjaja, 1995).

e. Shooting season: June–September (India).

Productivity

a. Culm production : 200 culms and 200 young shoots/ha/yr (Dransfield and Widjaja, 1995); 20 to 30 t/ha (Guadua Bamboo 2021) *.

b. Annual C sequestered : 15.5 Mg C /ha (Yuen et al., 2017).

c. Allometric equations :

China (Tang et al., 2011)	For 1 year old, Tb = $0.226D^{1.925}$ For 1–2 years old, Tb = $0.398D^{2} - 2.709D + 8.046$ For 2–3 years old, Tb = $0.275D^{1.955}$

Mechanical properties

a. Specific gravity : 0.71 (Dransfield and Widjaja, 1995).

b. Density : 765 kg/m^2 (Sint et al., 2008).

c. Cellulose/lignin/silica content : Not reported.

d. MOE

i. Static bending : 6656 N/mm^2 (Sint et al., 2008).

ii. Compression parallel to grain : 2117 N/mm^2 (Sint et al., 2008).

iii. Shear : 13.32 N/mm^2 (node), 14.41 (w/o node) (Sint et al., 2008).

e. MOR : 179 N/mm^2 (Dransfield and Widjaja, 1995).

f. Fibre length : 2.650 (Pande, 2009), 0.82 to 6.42 mm (Wang et al., 2016); 1.4–4.6 mm (Dransfield and Widjaja, 1995).

g. Fibre diameter : 13 µm (Pande, 2009); 26 µm (Dransfield and Widjaja, 1995).

Genetic diversity and conservation status: The species is planted in botanical gardens and bambuseta in several countries, but germplasm collections are not known. Survey and collections representative of populations in the native range is needed to broaden the genetic base of plantations.

Uses

a. Traditional: Handicrafts, whole culms in construction, wall, flattened culms for ceiling and floorboards edible shoots, furniture, ornamental (landscaping), water pipes, sheath made into hats.

b. Industrial: Laminated bamboo, paper pulp.

c. Potential: Flooring tiles, disposable plates from culm sheath.

Key ecosystem service values: The large sizes attained of the species and difficulty in obtaining planting material makes it underutilised for landscaping and ecological restoration projects, where it has some potential.

Research gaps: Physicochemical characterisation of the species and productivity data for culms and edible shoots are needed to explore the scope of the species of wider applications and assess potential for commercial plantations.

Information Gaps: Comparison with other species with similar climatic requirements with regard to productivity data are required to assess potential for plantations.

* Secondary and unverified source of information.

Habit

Culm and branching pattern

New shoot

Culm sheath

18. *Dendrocalamus hamiltonii* Nees & Arn. ex Munro

Subspecies/variety/clone: *Dendrocalamus hamiltonii var. edulis* Munro; *Dendrocalamus hamiltonii var. hamiltonii*.; *Dendrocalamus hamiltonii var. undulatus* Stapleton.

Synonyms (Vorontsova et al., 2016): *Sinocalamus hamiltonii* (Nees & Arn. ex Munro) T.Q. Nguyen.

Common names (Language/area in parenthesis): *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, Muyipru, Remhuh, Luhg, Woa, Talua, Waeng, Hepai, Vongnyu* (Nagaland, India) (Naithani, 2011); *Tama, Choya bans* (Nepal); Thailand: *phai-nual-yai, pai-hok* (North, Thailand), *waa-klu* (Karen, Thailand); *manh tong nua* (Viet Nam); *ko hoe, hôk* (Lao PDR).

Description: A large evergreen bamboo with short-necked pachymorph rhizomes. Culms are erect but slightly zig zag in appearance with drooping (pendulous) top that attain a height of 12–24 m (Naithani, 2011). Wall thickness is 1.2–2 mm and internodal length 30– 50 cm. Stout branches occur from base (Naithani, 2011).

Distribution

a. Native range: Nepal to China (Yunnan) and Southeast Asia.
China: South Central China.
Indian Subcontinent: Assam, Bangladesh, Eastern Himalayas, Nepal.
Indo-China: Laos, Myanmar, Thailand, Viet Nam.

b. In cultivation/naturalised in:
Indo-China: Cambodia.

Climatic parameters: The species grows in areas with annual mean temperature above 16 °C with 900–2000 mm annual rainfall and about 70 % annual mean relative humidity (Zhan et al., 2016). It is found at elevations of 300–2000 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 banks of streams and in valleys, often forming dense thickets, in evergreen and moist forests (Banik, 2016). The species seems to be light-demanding and is rarely seen under the tree canopy. The species does not tolerate biotic interference (Banik, 2016).

Propagation

a. Natural: Flowering cycle is reported to be 30–40 years (Kumari and Singh,2014) and the seed weight is 26.4 seeds/gram (Kumari and Singh, 2014). Germination of 80–85% seeds occur in 3–7 days. Viability is only up to 25 days without proper storage.

b. Clonal propagation: Seedling macroproliferation is feasible (Kumari and Singh, 2014). Rhizome offsets are successful (60–70 %) for propagation (Banik, 2016). Culm cuttings (70–80 %) and branch cuttings (70–75 %) as well as pre-rooted and pre-rhizomed branch from 1.5–2-year-old culms give good results (Banik, 2008; Banik, 2016).

c. Tissue culture: Propagation through axillary bud proliferation (Arya et al., 2012; Sood et al., 2002; Agnihotri and Nandi, 2009) and somatic embryogenesis (Godbole et al., 2002) have been demonstrated.

Cultivation: The species is suitable for block planting and for river side planting. A spacing of 4x4 m (Banik, 2016) is ideal. Intercropping with turmeric has been successful (Banik, 2016). It takes 3–5 years for maturation when established from rhizomes. New shoots emerge from June–August.

Productivity

a. AGB : 71.76 kg/Clump (Alemayehu et al., 2015).

b. Annual C sequestered : 70.8 Mg C/ha (Yuen et al., 2017).

c. Allometric equations :

Laos (Xayalath et al., 2019)	AGB=1.2130 $DBH^{1.2249}$ (r^2=0.4688) AGB=0.6252 (DBH^2 H) $^{0.4600}$ (r^2=0.5196) AGB is in kg, DBH is in cm, H is culm length, m.

Mechanical properties

a. Specific gravity : 0.64–0.8 (oven-dried) (Banik, 2016).

b. Cellulose/lignin/silica content : Cellulose 64.8–77.6 %; lignin 21.2–27.1 %; silica 1–3.4 %; ash 1.9–2.5 %; Extractives 0.7–2.3 % (Zhan et al., 2016).

c. Static Bending : 18860 N/mm^2 (Sint and Myint, 2008).

d. Compression parallel to grain : 3404 N/mm^2 (Sint and Myint, 2008).

e. Shear strength : 15.3 N/mm^2 (node): 15.06 N/mm^2 (w/o node) (Sint et al., 2008).

f. Fibre length : 3.2 mm (Pande, 2009); 3.36mm (Qing et al., 2008)

g. Fibre diameter : 13 µm (Pande, 2009).

h. Slenderness ratio : 157.99 (Zhan et al., 2016).

Genetic diversity and conservation status: Pattanaik and Hall (2014) have studied the patterns of morphometric variability in populations of the species across East Khasi Hills, Northeast India. Meena et al. (2019) have developed suitable molecular markers that would serve to assess the genetic diversity of population. Survey and collection of accessions and conservation of germplasm in *ex situ* collection have been done in India by ICFRE (Ginwal, 2021). A selection, DH001/Ml/HP, with superior culm traits has been identified at Pantnagar, India (Banik, 2016).

Uses

a. Traditional: Handicraft, whole culms in construction, edible shoots, incense sticks (Banik, 2008), wind break in tea plantations (Naithani, 2011), pickled leaf (Hiyup) in Arunachal, India (Pal, 1984), fodder.

b. Industrial: Paper Pulp (Naithani, 2011; Zhan et al., 2016).

c. Potential: Bioenergy, biorefinery, engineered bamboo.

Key ecosystem service values: The species is adapted to hilly slopes and can play a role in stabilising the soil and preventing landslips. It plays a significant role as source of food for wild animals in its natural habitat.

Research gaps: The species performs well in areas outside its Himalayan range. Performance trials for other agroclimatic zones and for agroforestry is needed. There is scope for extensive survey of natural populations across the large distribution range with potential for great genetic diversity.

Habit

Culm and branching pattern

New shoot

Culm sheath

19. *Dendrocalamus latiflorus* Munro

Subspecies/variety/clone: cv Meimung in China (Benton, 2015); Subconvex' (*D. latiflorus* Munro var. *lagenarius* Lin) (Dransfield and Widjaja, 1995).

Synonyms (Vorontsova et al., 2016): *Sinocalamus latiflorus* (Munro) McClure; *Dendrocalamus latiflorus* var. *lagenarius* W.C. Lin, *Sinocalamus latiflorus* var. *magnus* T.H. Wen, *Dendrocalamus latiflorus* var. *magnus* (T.H. Wen) T.H. Wen.

Common names (Language/area in parenthesis): *ma zhu* (China), *Diem truc* or *Bat do* (Viet Nam).

Description: This large species of bamboo has short-necked pachymorph rhizomes. The culms are erect with pendulous tips (Naithani, 2011) and attain a height of 14–25 m. The culms have a diameter of 5–20 cm (Flora of China, 2006; Naithani, 2011) and a wall thickness of 0.5–3 mm. The internodes have a length of 20–70 cm. The nodes of the species are flat, and branching occurs from mid-culm upwards.

Distribution: Myanmar to Southern China and Taiwan.

a. Native range: China: China South-Central, Hainan, China Southeast.
   Indo-China: Cambodia, Myanmar, Viet Nam.
b. In cultivation/naturalised in:
   Eastern Asia: Japan, Nansei-Shoto, Ogasawara-Shoto, Taiwan.
   Malesia: Jawa.
   Caribbean: Cuba.
   Brazil: Brazil Southeast.
   Indo-China: Myanmar, Thailand, Viet Nam, Japan, Philippines, Indonesia.

Climatic parameters: The species tolerates temperatures as low as -4 °C, prefers areas with high rainfall and at elevations of 100–1000 m.

Soil: This species grows best in moist, sandy loam and fertile soils. In the tropics it can be cultivated in lowlands as well as in the highlands, but heavy clay, gravel alkaline or acidic soils are not suitable for the production of edible shoots (Guadua Bamboo, 2021)*.

Native habitat: Subtropical regions of Taiwan. It is cultivated in the lowlands and highlands of other countries in Southeast Asia.

Propagation

a. Natural: The species is not known to flower gregariously and sporadic flowering with seeds is reported. 90 % of the seeds germinate within two weeks (Dransfield and Widjaja, 1995).
b. Clonal propagation: Seedling macroproliferation has not been reported but is expected to be successful. Rhizome offsets and culm cuttings are routinely used for propagations (Dransfield and Widjaja, 1995). Culm cuttings with two-noded cuttings are preferred (Dransfield and Widjaja, 1995; Benton, 2015). Air layering is also successful (Benton, 2015).
c. Tissue culture: Propagation through Inflorescence culture has been reported (Lin et al., 2007b).

Cultivation

a. Plantation type: Block plantations.
b. Spacing: 5x5 m, 4x4 m and 2x4.5 m.
c. Possible species mixed: Not reported.
d. Years to maturation: 3–5.
e. Shooting season: Not reported.

Productivity

a. Annual C Sequestration : 14.2 Mg C/ha (Yuen et al., 2017).

b. Allometric equations :

China 1- Total Dry biomass (Feng et al., 2010)	$Tb = -9.175 + 2.419\ D - 0.002\ D^3$ $Tb = 18.579 - 1.923\ H + 0.08\ H^2$ $Tb = -7.522 + 2.028\ Bd - 0.02\ Bd^2$
China 2 (You, 2002)	$W = 0.1478244 * D^{1.815716} * H^{0.1221029}$ (1 yr, dry wt, kg) $W = 1.078253 * D^{1.306463} * H^{0.1478039}$ (2 yr, dry wt, kg)

Mechanical properties

a. Cellulose/lignin/silica content : Holocellulose 80.15%; lignin 24.76% (Dransfield and Widjaja, 1995).

b. MOE : 92.63 MPa (top), 139.52 MPa (mid), 159.95 MPa (base) (Acma, 2017).

c. MOR : 98.67 MPa (top), 76.85 MPa (mid), 43.2 MPa (base) (Acma, 2017).

d. Fibre length : 3.01 mm (Dransfield and Widjaja, 1995).

e. Fibre diameter : 18.1 µm (Dransfield and Widjaja, 1995).

Genetic diversity and conservation status: Germplasm collections of *D. latiflorus* are available in China (Guangdong), Taiwan, Indonesia (Lampung, Sumatra) and the Philippines. Promising hybrids have been developed from crossings with *B. pervariabilis* (for paper-making material and edible shoots), *B. textilis* (for culm production) and *D. minor* (for culm production) (Dransfield and Widjaja, 1995).

Uses

a. Traditional: Handicraft, whole culms in construction, edible shoots, furniture (Benton, 2015), agricultural implements, water pipes, basketry, rafts, weaving, furniture, chopsticks, hats from leaves, cooking utensils for rice.

b. Industrial: Bamboo boards, paper making.

c. Potential: Bioenergy, biorefinery.

Research gaps: Potential for expanding plantations in other countries with similar agro-climatic zones should be explored.

Information Gaps: Data on several parameters need to be collected.

* Secondary and unverified source of information.

Habit

Culm and branching pattern

New shoot

Culm sheath

20. *Dendrocalamus longispathus* (Kurz) Kurz

Synonyms (Vorontsova et al., 2016): *Bambusa longispatha* Kurz.

Common names (Language/area in parenthesis): *Orah, Khag bansh* (Bangladesh); *Rupai, Wamlik, Rawnal, Siejlong* (India); *Orah, Wanet, Waya, Talagu* (Myanmar), Long sheath bamboo (English).

Description: *D. longispathus* is a densely clumped bamboo with pachymorph short-necked rhizomes. Culms attain a height of 10–18 m with culm diameter of 4–10 cm and wall thickness of 2–18 mm. The internodal length is 12.5–38.2 cm (base), 48–65 cm (mid) and 6.5–16 cm (top) (Banik, 2016). Culms have flat nodes and branches emerge from mid-culm nodes upwards.

Distribution

a. Native range: Indian Subcontinent: Assam [Tripura, Nagaland, Mizoram], Bangladesh (Banik, 2016).
Indo-China: Laos, Myanmar, Thailand.
Malesia: Malaya.

b. In cultivation/naturalised in: Indian Subcontinent: India [Kerala].

Climatic parameters: This species grows well in moist lowland tropical and subtropical region with temperature of 20–27 °C and it can tolerate up to 11 °C. It occurs at elevations up to 1000 m with annual rainfall of 1800–6000 mm (Dransfield and Widjaja, 1995; Banik, 2016).

Soil: No information available.

Native habitat: It grows along streams in the most fertile loamy soil and partially shaded fringes of the forest, and in moist deciduous forests without closed canopy cover (Banik, 2016). Associated with Albizzia sp., *Aphanamixis polystachya*, *Anthocephalus* chinensis, *Artocarpus* sp., *Dipterocarpus* sp., *Duabanga* sp., *Gmelina* arborea, Syzygium sp., *Terminalia* sp. *Melocanna baccifera*, *Bambusa tulda*, rarely with *S. dulloa, D. hamiltonii* (Banik, 2016). It grows in the regions of Rakhain, Bago, Thonze, Konbilin forests and Tungoo, Arakan and Tenasserim in Myanmar and Sylhet and Chittagong in Bangladesh.

Propagation

a. Natural: Flowering cycle is estimated to be 29–45 years (Kumari and Singh, 2014; Banik, 2016). Seed weight is 135 seeds/gram (Banik, 2016) and 76.4 % germination under shadenet (50 % sunlight) (Banik, 2015b). Viability of seeds is retained only for 55 days.

b. Clonal propagation: Seedling macroproliferation has a success rate of 70-85 % (Banik, 1995). Rhizome offsets offer 60–75% success (Banik, 1995). Culm cuttings of two-noded culm segments treated with hormones have a success rate of 30–45 % (Banik, 1995). Branch cuttings have a success rate of 25–40% with hormone treatment (Banik, 1995).

c. Tissue culture: Micropropagation through axillary bud proliferation (Saxena and Bhojwani, 1991; Haque, 2010) and somatic embryogenesis (Saxena and Bhojwani, 1993) have been successful.

Cultivation

a. Plantation type: Block plantations; edible shoot production in Bangladesh (Banik, 1998).

b. Spacing: 4×4 m or 5×5 m (Banik, 2016).

c. Possible species mixed: Intercrops of *Glycine max*, *Sesamum* sp, *Cajanus cajan, Erygium foetidum*), rice (Jhum variety), *Hibiscus esculentus*, local chillies. After 4–5 years: *Curcuma longa, Ananus comosus* (Banik, 2016) and *Zingiber officinale.*

d. Years to maturation: Up to 3; attain full size in 10 (Banik, 2016). 3–4-year-old culms are to be cut selectively to obtain sustainable yield (Banik and Islam, 2005).

e. Shooting season: April–November (Banik, 2016).

Productivity

a. Culm production : 4–9 culms/year.

b. AGB : 15 to 150 Mg/ha for 1- to 3-year-old plants (Devi and Singh, 2021); 16.66 t/ha (Puangchit et al., 2019).

c. Annual C Sequestration : 50.11 to 65.16 Mg C/ha (Devi and Singh, 2021).

d. Allometric equations :

India (Rawat et al., 2018)	Y=-3.53+0.71*DBH+0.33*ht
Myanmar (Puangchit et al., 2019)	y=3.579 DBH0.762

Mechanical properties

a. Specific gravity : 0.80 (top), 0. 76 (mid), 0.71 (base).

b. Cellulose/lignin/silica content : Cellulose 65.42 % (Lalduhsanga et al., 2013).

c. MOE : 277 (top) 196 (mid) 199 (1000 kg/cm^2) (base) (Sattar et al., 1992).

d. MOR : 551 (top) 700 (mid) 905 (kg/cm^2) (base) (Sattar et al.,1992).

e. Fibre length : 3.51 mm, 1.0–5.50 mm (Pande, 2009).

f. Fibre diameter : 6–28 µm (Pande, 2009).

Genetic diversity and conservation status: No information available.

Uses

a. Traditional: Handicrafts, weaving, whole culms in construction, edible shoots, craft paper.

b. Industrial: Paper pulp (Banik, 2016) curtains, round sticks.

c. Potential: Kite frames.

Key ecosystem service values: The species prefers moist locations and is therefore suited for control of soil erosion in riverbanks and near streams and water bodies.

Research gaps: Survey, collection and characterisation of superior germplasm and conservation efforts are needed.

Habit

Culm and branching pattern

New shoot

Culm sheath

21. *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 with pendulous tips (Flora of China, 2006; Durai and Long, 2019). Culm diameter is 7–12 cm and internode 34–42 cm long (Flora of China, 2006; Durai and Long, 2019). Branching occurs from base to top and the nodes are not prominent (Flora of China, 2006).

Distribution

a. Native range: Bangladesh to China (South Yunnan) and Southeast Asia.
   China: China South-Central [Yunnan].
   Indian Subcontinent: Bangladesh.
   Indo-China: Cambodia, Laos, Myanmar, Thailand, Viet Nam.

b. In cultivation/naturalised in:
   Malesia: Sumatera.
   Caribbean: Puerto Rico.
   Indian Subcontinent: India.

Climatic parameters: *D. membranaceus* grows in the temperature range of 22–33 °C (Durai and Long, 2019), in areas with precipitation of ~1000 mm (Durai and Long, 2019). The preferred altitude for the species is 1150 m but is found growing from 50–1400 m (Durai and Long, 2019).

Soil: Prefers a moist laterite or black limestone soil, but plants can tolerate arid and barren conditions (Seethalakshmi and Muktesh Kumar, 1998). Light (sandy), medium (loamy) and heavy (clayey) soils, prefers well-drained soil and can grow in nutritionally poor soil with mildly acid, neutral, and basic (mildly alkaline) pH (PFAF, 2021b)*.

Native habitat: The species is found in river valleys to hilly forested areas (Flora of China, 2006) in mixed deciduous or monsoon forests (Durai and Long, 2019) as pure bamboo forest or mixed with broad-leaved trees (China).

Propagation

a. Natural: The flowering cycle is 19–20 years and germination of 38 % seeds is obtained (Seethalakshmi and Muktesh Kumar, 1998). Seed weight is 25 /g (Hanjiang, 2019).
b. Clonal propagation: Seedling macroproliferation is not reported but expected to be feasible. Rhizome offsets and culm and branch cuttings hare reported be successful (Durai and Long, 2019).
c. Tissue culture: Micropropagation through axillary bud proliferation has been reported by Arya et al. (2002).

Cultivation

a. Plantation type: Block Plantations, Agroforestry.
b. Spacing: 5x5 m.
b. Years to maturation: 3–5.
c. Shooting season: May–September.

Productivity

a. Culm production : 6250 culms/ha (Komiya et al., 2001).

b. AGB : Not reported.

c. Annual C sequestered : 23.8 Mg C/ha (Yuen et al., 2017).

d. Allometric equations :

North Viet Nam (Komiya et al., 2001)	$Y= aX^b$ Y stands for dry weight (kg) or height (rn) and X is DZH (di·m) or DBH (cm), a and b are constants determined with applying least square method.
Laos (Xayalath, et. al., 2019)	AGB (kg)=0.3634*$DBH^{1.9938}$ (r^2=0.9360) DBH in cm.

Mechanical properties

a. Specific gravity : 0.55–0.65 (Narasimhamurthy et al., 2013).

b. Density : 702 ± 0.05 kg/m^3(Chitbanyong and Puangsin, 2017).

c. Cellulose/lignin/silica content : Holocellulose 74. 3 %; alpha-cellulose 67.9 %; acid-insoluble lignin 27.6 %; ash 0.02 % (Chitbanyong et al., 2018).

d. MOE : 6414 MPa (base), 7458 MPa (mid) and 6609 MPa (top) (Narasimhamurthy et al., 2013).

e. MOR : 127.7 MPa (base), 97.3 MPa (mid) and 102.3 MPa (top) (Narasimhamurthy et al., 2013).

f. Fibre length : 2.16±0.04 mm (Chitbanyong and Puangsin, 2017).

g. Fibre diameter : 36.89±0.62 mm (Chitbanyong and Puangsin, 2017).

Genetic diversity and conservation status: Threatened by cultivation, loss of germplasm, conservation efforts required (Yang et al., 2012). Although not a threatened species its main distribution in the south of Yunnan includes one of the habitats of the wild Asian elephant (Xie et al., 2016) in *situ* conservation measures for all populations in Yunnan and collecting sufficient samples for ex situ conservation is recommended. the conservation area to be extended to its main natural habitats, the Lancang-Mekong River Valley (Yang et al., 2012).

Uses

a. Traditional: Whole culms in construction (Yang et al., 2012; Durai and Long, 2019), edible shoots (Yang et al., 2012; Durai and Long, 2019), furniture (Yang et al., 2012).

b. Industrial: Laminated bamboo (Durai and Long, 2019), paper pulp (Yang et al., 2012, Durai and Long, 2019), fibre board, chopsticks.

a. Potential: Bioenergy plantations and biorefinery.

Key ecosystem service values: The natural forest of this species is habitat for wild Asian elephants (Yang et al., 2012).

Research gaps: Assessment of genetic variability across the distribution range and collection of germplasm accession for selection of superior ones for future plantations.

Information Gaps: Data on several parameters is not available.

* Secondary and unverified source of information.

Habit

Culm and branching pattern

New shoot

Culm sheath

22. *Dendrocalamus sikkimensis* Gamble ex Oliv.

Synonyms: None.

Common names (Language/area in parenthesis): *Annung, Wakap, Gunyin, Vuyo, Ming* (Nagaland, India) (Naithani, 2011*), Wadah* (Garos); *Pugriang* (Lepcha, India); *Rawami, Sangau* (Mizoram, India) (Seethalakshmi and Muktesh Kumar, 1998); *xi jin long zhu* (China) (Flora of China, 2006); *Bhalu-ban*s (Nepal) (Seethalakshmi and Muktesh Kumar, 1998).

Description: This large erect clumping bamboo has short-necked pachymorph rhizomes. The culms reach a height of 10–22 m (Naithani, 2011; Flora of China, 2006). Culm diameter ranges from 10–18 mm (Flora of China, 2006; Naithani, 2011). The culms have a wall thickness of 1–3.5 cm (Flora of China, 2006; Naithani, 2011) and internode length of 45–56 cm (Flora of China, 2006; Naithani, 2011). Branching in the species occurs from mid-nodes upwards (Naithani, 2011).

Distribution

a. Native range: East Himalaya to China (S. Yunnan).
China: China South-Central.
India Subcontinent: Assam, East Himalaya.

b. In cultivation/naturalised in:
Central America: Honduras.
Caribbean: Cuba, Puerto Rico.
Indian Subcontinent: Kerala.

Climatic parameters: The species occurs at elevations of 100–1800 m (Flora of China, 2006; Naithani, 2011).

Soil: No information is available.

Native habitat: No information is available.

Flowering Cycle (in years): Not reported.

Propagation

a. Natural: Germination of 90 % has been reported by Jijeesh et al. (2012).
b. Clonal propagation: Seedling macroproliferation is feasible at 6-month cycles. Rhizome offsets are used successfully for establishing plantations. Culm cuttings and branch cuttings are also feasible.
c. Tissue culture: Not reported.

Cultivation

a. Plantation type: Block plantations, border plantations, agroforestry.
b. Spacing: 5x5 m.
d. Years to maturation: 3–5.
e. Shooting season: May–July (Kerala, India).

Productivity

a. Culm production : 6250 culms/ha (Komiya et al., 2001).
b. AGB : 21.3 Mg/ha (Yuen et al., 2017).

c. Annual C sequestered : 23.8 Mg C/ha (Yuen et al., 2017).

d. Allometric equations : None reported.

Mechanical properties: No published information available.

Genetic diversity and conservation status: No information is available.

Uses

a. Traditional: Whole culms in construction (Seethalakshmi and Muktesh Kumar, 1998), edible shoots, fodder, milk/water containers (Seethalakshmi and Muktesh Kumar, 1998).

b. Industrial: Paper pulp (Holstrom, 1993), engineered bamboo.

c. Potential: Bioenergy, biorefinery.

Key ecosystem service values: Not reported.

Research gaps: Data on productivity and physicochemical characterisation are needed to explore scope for other applications.

Information Gaps: Data on several parameters to be collected.

Habit

Culm and branching pattern

New shoot

Culm sheath

23. *Dendrocalamus strictus* (Roxb.) Nees

Subspecies/variety/clone: Three ecotypes found in India: Common (medium-sized, dense clumps with solid culms); Large (loose clumps with straight culms and smooth internodes): and *Karka*, a dwarf type found in Madhya Pradesh, India.

Synonyms (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 parenthesis): 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, Kurathi mula (Haridasan and Tewari, 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 length ranges from 30–40 cm with the 5th to 6th internode being the longest (Naithani, 2011). Culms are slightly zig-zagged at times, have slightly prominent nodes and branching is seen from base to mid-culm.

Distribution

a. Native range: Indian Subcontinent: Assam, India, Nepal, Pakistan, West Himalaya.
Indo-China: Andaman Islands, Laos, Myanmar, Thailand, Viet Nam.

b. In cultivation/naturalised in:
Brazil: Brazil Southeast.
Caribbean: Bahamas, Cuba, Puerto Rico, Trinidad-Tobago, Windward Islands.
Central America: Honduras.
China: China Southeast.
Eastern Asia: Taiwan.
Malesia: Jawa, Malaya.
Southwestern Pacific: New Caledonia.
West Tropical Africa: Togo.
Western Indian Ocean: Madagascar, Seychelles.

Climatic parameters: The optimum mean temperature for the species is 20–30 °C, but species 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 between 1000–3000 mm with 300 mm/month during the growing season. The species can also tolerate abnormal drought conditions (Banik, 2016).

Soil: The species prefers well-drained soil and sandy loams on hilly ground. It grows on loamy sand in Punjab, India (Singh et al., 2018). Soil pH of 5.5–7.5 (Banik, 2016); 8.2–8.4 (Singh et al., 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 form, Kerala) found the moist areas. *Karka*, a dwarf type found in Madhya Pradesh, India. The species is associated with teak in many locations in India.

Propagation

a. Natural: The species flower gregariously on an estimated 25–45-year cycle (Kumari and Singh, 2014), but more commonly sporadically. Seed weight is 51.5 seeds/gram (Kumari and Singh, 2014). Seed viability remains only up to 30–35 days after collection under normal storage (Banik, 2016) but 59 % germination was obtained after 34 m of storing at 3–5 °C after reduction of its moisture content to 8 % (Varmah and Bahadur, 1980).

b. Clonal propagation is possible through seedling macroproliferation (Banik, 1987), rhizome offsets, culm cuttings, branch cuttings and air layering (Banik, 1995; Benton, 2015).

c. Tissue culture propagation has been reported through axillary bud proliferation (Chaturvedi et al., 1993; Ravikumar et al., 1998) and through somatic embryogenesis (Saxena and Dhawan, 1999; Reddy, 2006).

Cultivation: Block Plantations with a spacing of 4x4 or 3x4 m (Durai and Long, 2019) or 1x1; 1.8x1.8; 3x3 m (Patil et al., 2008) have been established. Intercrops of leguminous crops, turmeric, ginger, and vegetables are feasible for the first three years. Dev et al. (2020b) found intercrops with sesame and chickpea gave better culm yield at 10x12 m and 10x10 m. Shooting season is May–September and shoots take two years to mature.

Productivity

a. Culm production : Not reported.

b. AGB : 91.35–103.70 Mg/ha (Singh et al., 2004); Leaf litter: 4.08–7.18 Mg/ha (Tripathi and Singh, 1994).

c. Annual C sequestered : 21.9 Mg C/ha (Yuen et al., 2017); 18.08 kg/m^3 (Lubina et al., 2019).

d. Allometric equations :

Myanmar1 (Chan et al., 2013)	Culm Biomass: 0.021*(DBH)^1.87 (Globallome Equation no.: 55250)
Myanmar2 (Chan et al., 2013)	Branch Biomass: 0.076*(DBH)^1.455 (Globallome Equation no. 555251)
Myanmar3 (Chan et al., 2013)	Leaf Biomass: 0.034*(DBH)^1.364 (Globallome Equation no. 55252)
Myanmar4 (Chan et al., 2013)	Total AGB: 0.308*(DBH)^1.767 (Globallome Equation no. 56446)

Mechanical Properties

a. Specific gravity : 0.45 (oven-dried) (Singh et al., 2018); 0 .799.

b. Density : 0.67–0.83 (g/cc) (Kaur et al., 2016).

c. Cellulose/lignin/silica content : Lignocellulose (53.4-53.6 %); lignin (25–27 %) (Kaur et al., 2016).

d. MOE : 87.6–213.8 (1000 kg/cm^2) (air-dried) (Tewari, 1992).

e. MOR : 941–1498 (kg/cm^2) (air-dried) (Tewari, 1992).

f. Fibre length : 1.1–5.6 mm (Pande, 2009); 2.4 mm (Liese, 1980).

g. Fibre diameter : 7–33 µm (Pande, 2009); 25 µm (Singh et al., 2018).

h. Starch : 2.5–4.5 % (Kaur et al., 2016).

Genetic diversity and conservation status: Survey, collection of germplasm accessions and selection of superior genotypes have been carried out by ICFRE, India (Ginwal, 2021). The tall, hollow ecotype from the moist areas have not been popularised in plantation.

Uses

a. Traditional: Handicrafts, whole culms in construction, household implements, tool handles, ladders, fencing and partitions, walking sticks, batons. The shoots are edible, but of poor quality (Benton, 2015).
b. Industrial: Paper pulp and charcoal.
c. Potential: Bioenergy, biorefinery, ecological restoration.

Key ecosystem service values: Found success in ecological restoration in arid regions of northern India where the water table was restored in a degraded area mined for brickmaking.

Research gaps: Survey and collection of germplasm accessions on a wider scale is needed to cover the large distribution range of the species.

Information Gaps: Data on several parameters to be collected.

Habitat

Culm and branching pattern

New shoot

Culm sheath

24. *Gigantochloa apus* (Schult.f.) Kurz

Synonyms (Vorontsova et al., 2016): *Bambusa apus* Schult.f., *Schizostachyum apus (*Schult.f.) Steud., *Arundarbor apus* (Schult.f.) Kuntze., *Oxytenanthera apus* (Schult.f.) E.G. Camus, *Gigantochloa kurzii* Gamble.

Common names (Language/area in parenthesis): Tabashir bamboo, String bamboo, *Pring Tali, Watho, Bambu tali* (Indonesia), *Awi tali* (Sundanese), *Pring tali, Pring apus* (Javanese).

Description: An open-tufted, sympodial bamboo with short-necked pachymorph rhizomes. Culms reach a height of 8–30 m with a diameter of 3.33–8.92 cm and wall thickness of 4.59–14.36 mm (Nurmadina and Bahtiar, 2017). The internodes are 32.78–67.25 cm long. Culms branch from 8th to the 11th node with many clustered branches and one large dominant branch. Nodes are slightly swollen (Nurmadina and Bahtiar, 2017).

Distribution

a. Native range: Assam to China (Guangdong) and W. Malesia.
China: China Southeast.
Indian Subcontinent: Assam, Bangladesh.
Indo-China: Laos, Myanmar, Thailand.
Malesia: Borneo, Jawa, Lesser Sunda Islands, Malaya.

b. In cultivation/naturalised in:
Brazil: Brazil West-Central, Brazil Southeast.
Caribbean: Puerto Rico.
Malesia: Sulawesi, Sumatera.

Climatic parameters: This species grows well in tropical climate with annual rainfall ranging from 2000–2500 mm and annual temperature from 18–30 °C.

Soil: *G. apus* prefers to grow in sandy or clayey soils.

Native habitat: The species is found in the tropical humid lowlands, but also occurs on hill slopes in open areas, disturbed forest and on river sides.

Propagation

a. Natural: A 50–60-year flowering cycle has been reported (Dransfield and Widjaja, 1995).
b. Clonal propagation: Rhizome offsets consisting of young rhizome bearing 1- or 2-culm nodes are widely used for the propagation of this species (Dransfield and Widjaja, 1995). Use of single-node culm cuttings (Sutiyono, 1990) has been found to be successful.
c. Tissue culture: No available reports.

Cultivation

a. Plantation type: Block Plantation.
b. Spacing: 5x5 to 7x7 m.
c. Possible species mixed: not recorded.
d. Years to maturation: 3.
e. Shooting season: November-April.

Productivity

a. Culm production : 1744 /ha (Sujarwo, 2016).
b. AGB : 11.27 Mg/ha (Sujarwo, 2016); 83.51–234.99 t/ha (Nadapdap and Purwanto, 2013).

c. Annual C sequestered : 5.64 ± 0.60 Mg/ha (Sujarwo, 2016); 41,23–116,23 t/ha (Nadapdap and Purwanto, 2013).

d. Allometric equations :

Indonesia (Nadapdap and Purwanto, 2013)	Ct= 0.008(D^2H)1.003 (r^2=0.929).

Mechanical properties

a. Density : 312.585 kg/m (Nurmadina and Bahtiar, 2017).

b. Cellulose/lignin/silica content : Holocellulose 63.23 %; lignin 22.41 %; Silica 1.8–5.2 % (Sugesty et al., 2015).

c. MOE : 183069 kg/cm^2 (Nurmadina and Bahtiar, 2017).
24.0 N/mm (green, with nodes); 23.5 N/mm^2 (green, without nodes); 37.5 N/mm^2 (air-dried, with nodes); 33.9 N/mm^2 (air-dried, without nodes) (Dransfield and Widjaja, 1995).

d. MOR : 686.7 mm (Nurmadina and Bahtiar, 2017).
102.0 N/mm (green, with nodes); 71.5 N/mm (green, without nodes); 87.5 N/mm (air-dried, with nodes); 74.9 N/mm^2 (air-dried, without nodes) (Dransfield and Widjaja, 1995).

e. Fibre length : 4.89 mm.

f. Fibre diameter : 14.54 µm.

Genetic diversity and conservation status: A germplasm collection of *G. apus* has been established in Lampung, Indonesia (Dransfield and Widjaja, 1995).

Uses

a. Traditional: Handicraft, weaving, whole culms in construction, furniture, cooking utensils, fishery tools, furniture, ropes or strings, basketry, edible shoots (though bitter) (Dransfield and Widjaja, 1995).

b. Industrial: Strand woven, building material for roofing, walls, scaffolding and bridges

c. Potential: Bioenergy, biorefinery.

Key ecosystem service values: *G. apus* and *G. ava* protect the Pengalipuran Village bamboo forest in Indonesia from soil erosion and support efforts for water conservation, land rehabilitation and provide carbon sequestration (Sujarwo, 2016).

Research gaps: Genetic variability in natural populations needs to be studied and selection for superior traits carried out to improve planting material. Large scale propagation methods are yet to be developed.

Information Gaps: Information on parameters useful for plantations is to be collected.

Habit

Culms and branching pattern

Emerging shoot

Culm sheath

25. *Gigantochloa atroviolacea* Widjaja

Subspecies/variety: *Gigantochloa atter var. nigra* Gamble.

Common names (Language/area in parenthesis): Black bamboo, *Bambu Hitam, Awi hideung, Awi wulung* (Sundanese); *Pring wulung* (Javanese).

Description: *G. atroviolacea* is a loosely clumped tufted bamboo with short-necked pachymorph rhizomes. The culms are straight and grow up to 8–16 m (Khotimah et al., 2015; Maulana et al., 2021). The culm diameter is 4.8 (top) 6.2 (middle) and 6.5 cm (bottom) with wall thickness 4.4 (top), 6.2 (middle) and 9.4 mm (bottom) (Maulana et al., 2021). The internodes are 30–50 cm long (Khotimah et al., 2015). Branching begins from mid-culm and nodes are not prominent.

Distribution

a. Native range:
   Malesia: Jawa.
b. In cultivation/naturalised in:
   Indian Subcontinent: Bangladesh, India.
   Malesia: Sumatera.

Climatic parameters: *G. atroviolacea* grows well at temperatures from 20–30 °C, with annual precipitation of 1500–3700 mm and at elevations up to 1000 m.

Soil: This species thrives in red and reddish-brown latosols, lateritic soils, and drier limestone soils in areas without waterlogging (Roxas, 2012).

Native habitat: This bamboo grows in the per humid lowland tropics (Roxas, 2012). It is native to West Java, especially Banten and Sukabani District, and Central Java (Seethalakshmi and Muktesh Kumar, 1998).

Propagation

a. Natural: Not reported. Flowering cycle is not reported.
b. Clonal propagation: Rhizome offsets are the cheapest and most efficient propagation method. The propagules are transferred to polybags after 4–5 months for improved survival. Culm cuttings with four internodes are widely used for propagation. Cuttings treated with growth regulators (Somen et al., 2011) and taken from 1.5–2-year-old culms (Roxas, 2012) have seen success.
c. Tissue culture: Micro propagation through axillary shoot proliferation has been reported (Bisht et al., 2010).

Cultivation

a. Plantation type: Block plantations, landscaping.
b. Spacing: 8x6 m or 210 clumps/ha, 2 x 7 m in contour (Khotimah et al., 2015); 8x7 m (Dransfield and Widjaja, 1995).
c. Species mixed: Not reported.
d. Years to maturation: 4–5 (Dransfield and Widjaja, 1995).

Productivity

a. Culm production : 2520 culms/ha (Seethalakshmi and Muktesh Kumar, 1998); 20 culms/3 years old (or with 200 clumps/ha, about 4000 culms/ha every 3 years (Dransfield and Widjaja, 1995).
b. AGB : 42.6 t/ha at 7 years old (Seethalakshmi and Muktesh Kumar, 1998).

Mechanical properties

a.	Specific gravity	:	0.82 (Seethalakshmi and Mukteshkumar, 1998); 0.65 for oven-dried (Dransfield and Widjaja, 1995).
b.	MOE	:	237.4 N/mm^2 (Prawirohatmodjo, 1990).
c.	MOR	:	35.74 kN/mm^2 (Prawirohatmodjo, 1990).
d.	Fibre length	:	2.462 mm (Maulidyawati et al., 2018); 3.6 mm (Dransfield and Widjaja, 1995).
e.	Fibre diameter	:	20.82 µm (Maulidyawati et al., 2018); 25.9 µm (Dransfield and Widjaja, 1995).

Genetic diversity and conservation status: Great variation among the population of *G. atroviolacea* such as culms with large diameter with thick-walled, small diameter with thin-walled has been identified and propagated by local farmers in Java. No conservation efforts for this species are known except through botanical gardens and experimental plots.

Uses

a. Traditional: Weaving, whole culms in construction, furniture, water pipes, edible shoots, chopsticks, musical instruments.
b. Industrial: Paper pulp, cement fibre board, knock down furniture.

Key ecosystem service values: Widely planted for landscaping and hence can serve for the purpose of soil erosion controls.

Research gaps: Mass clonal propagation methods to be standardised. Genetic variability to be assessed and germplasm conservation efforts initiated. Superior selection to be used for plant propagule production. Carbon sequestration potential should be analysed.

Information gaps: Information on performance of the species in different agroclimatic zones is to be collected.

Habit

Culm and branching pattern

New shoot

Culm sheath

26. *Gigantochloa scortechinii* Gamble

Common names (Language/area in parenthesis): *Buluh semantan*, *Buluh Galah*, *Buluh Telor* (Malay); Common Giant Bamboo.

Description: *G. scortechinii* is a densely tufted bamboo with pachymorph short-necked rhizomes. The culms of this species attain a height of 10–20 m with diameter of 6–12 cm. Internodes reach a length of 40 cm and culm wall thickness is 6.5 mm (Hisham et al., 2006).

Distribution

Native range: Penninsular Malaysia.
Malesia: Malaya, Sumatera.

Climatic parameters: This species is found at elevations of 300–1700 m, at temperatures ranging from 26–34 °C and annual rainfall between 400–1600 mm.

Soil: *G. scortechinii* grows on well-drained sandy to clay loam soils with slightly acidic conditions (soil pH of 5.0–6.5).

Native habitat: This species spreads on the riverbanks and pond shores and in ravines, gullies and logged-over areas and is quite aggressive once it is exposed to sunlight.

Propagation

a. Natural: A germination rate of around 70–75 % can be expected from the seeds of this species.
b. Clonal propagation: *G. scortechinii* rhizome offsets survived up to 85 % about 30 months after planting (Azmy, 1992). Marcotting with palm oil mill effluent gave better results for this species during rhizome propagation (Azmy, 1992). Culm cuttings from the mid-culm portion planted horizontally was the best for propagation (Othman, 1992). Branch cuttings treated with hormones are a successful method of propagation.
c. Tissue culture: No reports are available.

Cultivation

a. Plantation type: Block plantation.
b. Spacing: 3x6 m on a contour hill.
c. Possible species mixed: Rubber.
d. Years to maturation: 3.5. X shaped harvesting recommended (Othman et al., 2012).
e. Shooting season: Not reported.

Productivity

a.	Culm production	:	40–50 t/ha (Dransfield and Widjaja, 1995).
b.	AGB	:	86.7 kg (Othman et al., 2012); 86.2 t/ha(plantation) and 71.9 t/ha (natural stand) (Othman, 1994).
c.	Annual C sequestered	:	20.9 Mg C /ha (Yuen et al., 2017).
d.	Allometric equations	:	

North Malaysia-(AGB): Perlis & Kedah (Mohamed et al., 1991)	-2086.12+(1364.44*W) (Globallome equation no. 56737)
North Peninsular Malaysia (Azmy et al., 2011)	Height (3yr.): Y= 4.47962 + 1.31436x (r^2 =0.56) Culm weight (3 yr.): Y =-21.1764 + 5.09095x (r^2 =0.79) Volume (3 yr.): Y = 9.276 + 48.519x (r^2 =0.72)

Mechanical properties

a. Density : 680 Kg/m^3 (6.5 years old) (Hisham et al., 2006).

b. Cellulose/lignin/silica content : Cellulose 67.4 %; lignin 26.4 % (Mustafa et al., 2011); Homocellulose 82.3 %; Cellulose 64.4 % (Hisham et al., 2006); lignin 29.0 % (Hisham et al., 2006).

c. MOE : 1678.94 MPa (bottom), 449.24 MPa (bottom) 1778.74 MPa (middle top), 2346.13 MPa (top) (Jusoh et al., 2013).

d. MOR : 69.02 MPa (top), 57.16 MPa (middle), 48.26 MPa (bottom) (Awalluddin et al., 2018).

e. Fibre length : 17.4527 mm (Mustafa et al., 2011).

f. Fibre diameter : 17.26 µm (Mustafa et al., 2011).

Genetic diversity and conservation status: No germplasm collections are established for the conservation of this species. Genetic variability studies should be conducted**.**

Uses

a. Traditional: Handicraft, weaving, edible shoots (although with a slightly bitter taste), whole culms in construction, scaffolding, chopsticks, toothpicks, skewers, blinds, joss sticks, large baskets and poultry cages.

b. Industrial: Laminated bamboo, paper pulp.

c. Potential: Bioenergy, biorefinery.

Key ecosystem service values: Stabilisation of hillsides (Othman, 1989) and as a windbreak.

Research gaps: Development of management and sustainable harvesting measures for natural stands is required.

Habit

Culm and branching pattern

New shoot

Culm sheath

27. *Guadua aculeata* E. Fourn.

Subspecies/variety/clone: *Guadua aculeata* var. *liebmanniana* E.G. Camus.

Synonyms (Vorontsova et al., 2016): *Bambos aculeata* (E. Fourn.) Hitchc.

Common names (Language/area in parenthesis): Mexican guada; *Tarro, Otate* (Central America); Guadua, *Cafta brava, Cafta mansa, Garipa* (Columbia and Ecuador); *Marona, Ipa* (Peru); *Juajua, Puru puru* (Venezuela).

Description: *G. aculeata* is a loosely clumped thorny bamboo with short-necked pachymorph rhizomes. The culms are 10–15 m long and 10–25 cm in diameter. The internodes are 20–30 cm and wall thickness of 2–5 mm.

Distribution

a. Native range: Mexico (Veracruz to Chiapas) to C. America.
Mexico: Mexico Central, Mexico Gulf, Mexico Southeast.
Central America: Nicaragua, Panamá, Costa Rica, El Salvador, Guatemala, Honduras.

Climatic parameters: *G. aculeata* grows in a warm humid region with temperature of 9–29 °C and rainfall of 2000–4000 mm and at an elevation of 50–2200 m (Londono, 2001).

Soil: This species is widely distributed in soils of compact sandy, clay or loam texture with a pH of 4.5–7.58 and 1.99 % organic content.

Native habitat: *G. aculeata* grows in lowland rainforest, lower montane rainforest, semideciduous forest, deciduous forest, savanna and with secondary shrub vegetation and mountain mesophilic forest. *Andira inermis, Carapa nicaraguensis, Dialium guianense, Depteryx panamensis, Luehea seemanii, Terminalia amazonia* etc found as associated vegetation in lowland rainforests.

Propagation

a. Natural: The flowering cycle is unknown and information on the seed setting associated with sporadic or gregarious or annual flowering is not available. Data on germination percentage and seed viability are not available. Seedlings are collected from the forest and used for macroproliferation (Sanchez et al., 2016).
b. Clonal propagation: No methods available but the conventional methods of rhizome offsets, culm and branch cuttings are expected to be successful to varying degrees.
c. Tissue culture: No data available.

Cultivation

a. Plantation type: Land restoration.
b. Spacing: 5x5 m.
c. Years to maturation: 3–5.

Productivity

a.	Culm production	:	150,000 t/ha.
b.	AGB	:	not reported.
c.	Annual C sequestered	:	54 m t/ha over six years (Ecoplanet Bamboo, 2015).
d.	Allometric equations	:	Not reported.

Mechanical properties

a.	Density	:	0.429 (basal) 0.653 (upper) (Ordóñez-Candelaria and Bárcenas-Pazos, 2014).
b.	MOE	:	15.1 to 24.1 GPa (Zaragoza-Hernández et al., 2015).
c.	MOR	:	51.9 to 79.6 MPa (Zaragoza-Hernández et al., 2015).
d.	Fibre length	:	2152 mm (Zaragoza-Hernández et al., 2015).
e.	Fibre diameter	:	13.68 µm (Zaragoza-Hernández et al., 2015).

Genetic diversity and conservation status: No studies on genetic diversity of the species are known. However, Pérez- Alquicira et al. (2021) have developed microsatellite markers for other *Guadua* species which can be used to assess the genetic variability of *G. aculeata* populations.

Uses

a. Traditional: Whole culms in construction, furniture, live fences or shade, pipe for drinking water, fishing rods and cradles, crates, cages.
b. Industrial: Charcoal.
c. Potential: Biomass for biofuel and refinery.

Key ecosystem service values: A project launched in Nicaragua in 2011 used *G. aculeata* to restore 6500 ha of highly degraded land into commercial plantations and provide more than 250 permanent jobs. The project also stimulated local economies by providing an alternative fibre for international carbon and charcoal markets (Ecoplanet Bamboo, 2015).

Research gaps: Studies on durability of culms and suitable methods for management and harvest of the thorny culms is needed to improve the scope for utilisation of the species. Performance trials for understanding the scope of the species in commercial plantations and for agroforestry is required.

Information Gaps: Information on propagation methods and carbon sequestration potential of the species needs to be generated.

Habit

Culm and branching pattern

Culm sheath

28. *Guadua angustifolia* Kunth

Subspecies/variety/clone (if any): *Guadua angustifolia* var. bicolor Londoño*; Guadua angustifolia* var. nigra Londoño.

Synonyms (Vorontsova et al., 2016): *Bambusa guadua* Bonpl.; *Nastus guadua* (Bonpl.); *Arundarbor guadua* (Bonpl.); *Bambusa acul*eata Caldas; *Bambusa inermis* Caldas; *Guadua intermedia* E. Fourn.

Common names (Language/area in parenthesis): Colombian timber bamboo, American narrow-leaved bamboo, vegetal steel.

Description: Loosely spaced culms in open clumps with leptomorph, long-necked rhizomes. Culms attain a height of 16.7–30 m (Riaño et al., 2002) with average diameter of 11.15 cm (basal) 11.05 cm (middle) and 5.84 cm (apical) (Londoño et al., 2002; Marulanda et al., 2002). Wall thickness ranges from 182 mm (basal), 132 mm (middle) to 89 mm (top) with internodal length of 33.38 cm (apical) to 20.25 cm (basal) (Londoño et al., 2002) with flat nodes.

Distribution

a. Native range: Venezuela to N. Peru.
   Northern South America: Venezuela.
   Western South America: Columbia, Ecuador, Peru.

b. In cultivation/naturalised in:
   Brazil: Brazil Southeast, Brazil South.
   Northern South America: Guyana.
   Southern South America: Argentina Northeast, Argentina West, Paraguay, Uruguay.

Climatic parameters: The optimum growth conditions for this species is 500–1800 m with temperature and precipitation of 18–24 °C and 1200–2500 mm (Riaño et al., 2002).

Soil: Alluvial soils that are rich in volcanic ash with a moderate fertility and good drainage.

Native habitat: Tropical life zones, very humid lower montane and very humid subtropical forests. Associated with coffee (in plantations) (Marulanda et al., 2005a).

Propagation

a. Natural: No data available for seed weight and germination.
b. Clonal propagation: No data available for rhizome offsets. Culm cuttings: whole Culm Technique (Banik, 1995). Culm cuttings treated with IBA 2500 ppm in sand led to >80 % rooting in six weeks (Somashekar et al., 2004). Branch cuttings of leafy stem cuttings reported (apical shoot and nodal branch segment) (Manzur, 1988). Air layering of side branches using dry *Sphagnum khasinum* moss as substrate has been carried out (Verma et al., 2013).
c. Tissue culture: Axillary bud proliferation has been reported (Gutiérrez et al., 2016; Jiménez et al., 2006; Nadha et al., 2012; Marulanda et al., 2005b; Daquinta et al., 2007).

Cultivation

a. Plantation type: Block plantations, Soil erosion control.
b. Spacing: 5x5 m for timber, 3x3 m for soil conservation (Viswanath et al., 2012).
c. Possible species mixed: No data is available.
d. Years to maturation: 3–4.
e. Shooting season: Not reported.

Productivity

a. Culm production : 3000–8000 culms/ha. (Riaño et al., 2002).

b. AGB : At 5 years old: mean AGB: 161.18 kg/clump & BGB: 7.27 kg/clump; at 4 years old: 152.65 kg and 6.0 kg (5x5 m) (Viswanath et al., 2012).

c. Annual C sequestered : >50 metric tons CO_2/ha during six years of growth (Riaño et al., 2002).

d. Allometric equations :

Colombia (Garcıa and Kleinn, 2010)	V_{net} = 0.001059 + 0. 2840. V_{app}; (R^2_{adj} = 0.9398 MSE = 1.5824E-05).

Mechanical properties

a. Specific gravity : 730 kg/m^3 (Lorenzo et al., 2020).

b. Density : 686.3 at 5th year after planting (Correal and Arbeláez, 2010).

c. Cellulose/lignin/silica content : Cellulose 52.6 %; hemicellulose 19.7 %; lignin 27.6 % (Ardila et al., 2020).

d. MOE : 18.480 Mpa (Lorenzo et al., 2020); 14.59 GPa (average) (Ghavami and Marinho, 2005).

e. MOR : 12 M Pa (Lorenzo et al., 2020); 86.96 Mpa (average) (Ghavami & Marinho, 2005).

f. Fibre diameter : 236.431 µm (Espitia et al., 2018).

Genetic diversity and conservation status: No data is available.

Uses

a. Traditional: Weaving, whole culms in construction, furniture, water pipes, edible shoots, handicrafts.

b. Industrial: Laminated bamboo, strand woven lumber, paper pulp, composite fibre, charcoal.

Research gaps: Studies on status of conservation and efforts to collect germplasm are required.

Information gaps: Data on propagation through seeds and rhizomes are not available. Increased data availability on performance of the species in other agroclimatic zones will be useful.

Habit

Culm and branching pattern

New shoot

Culm sheath

29. *Guadua chacoensis* (Rojas Acosta) Londoño & P.M. Peterson

Subspecies/variety/clone: *Guadua angustifolia subsp. Chacoensis (*Rojas Acosta).

Synonyms (Vorontsova et al., 2016): *Bambusa chacoensis* Rojas Acosta.

Common names (Language/area in parenthesis): *Tacuara, Takuaruzu* (Paraguay); *Tacuarembó, Bambú, Guadua* (Bolivia).

Description: A loosely clumped bamboo with short-necked pachymorph rhizomes. The culms are straight and thorny with height of 10–20 m (Londono and Peterson, 1992) that arch apically. The diameter of the culm is 8–10 cm (base), 6–8 cm (middle) and 3–4 cm (top) (Panizzo et al., 2016), with wall thickness of 2.2 cm and internode length of 23 cm (Campos, 2013).

Distribution

a. Native range: Bolivia to S. Brazil and N. Argentina.
Brazil: Brazil West-Central, Brazil South.
Southern South America: Argentina Northeast, Argentina Northwest, Paraguay.
Western South America: Bolivia.

Climatic parameters: *G. chacoensis* grows well at temperatures from 12.5–22.5 °C and tolerates severe frost every year during the winter (IAPAR, 1994). The species grows in areas with annual precipitation of 1500–2000 mm, at elevations of 890–950 m and on slopes of 3–20 % (Maack, 1981).

Soil: This species thrives on clayey and sandy soil rich in litter organic content with C/N ratio 11.3/15.7 and pH 5.7–6.5.

Native habitat: *G. chacoensis* grows in tropical forests, most commonly near rivers (Londono and Peterson, 1992). It grows in almost pure associations in marginal forests and riparian forests. It is found together with *G. trinii* in Iguazú National Park.

Propagation

a. Natural: Sporadic and gregarious flowering are reported in this species (Londono and Peterson, 1992). Flowering cycles of 31 and 28 years have been reported by Guerreiro (2014) and Vega and Hernández (2008) respectively. Seed germination rates are reported as higher than other *Guadua* species.
b. Clonal propagation: Clonal propagation methods are not reported with this species.
c. Tissue culture: Axillary bud proliferation has been reported by Ornellas et al. (2019) and Polesi et al. (2019).

Cultivation

a. Plantation type: The species is not yet in wide cultivation but can be expected to be similar to *G. angustifolia* in features and performance except for its thorny nature.
b. Years to maturation: 7 (Lindholm and Palm, 2007).
c. Shooting season: March–October.

Productivity

a. Culm production : No reports.
b. AGB : No reports.

c. Annual C sequestered/ha. : No reports.

d. Allometric equations : No reports.

Mechanical properties

a. MOE : 94 MPa (Lindholm and Palm, 2007); For laminated bamboo with different glues (N/mm^2): PVA- 6629 (747); FWC-7787 (1137); 5PU-7861 (872) (Appiah-Kubi et al., 2014).

b. MOR : 25 Mpa (Lindholm and Palm, 2007); For laminated bamboo with different glue (N/mm^2); PVA: 78.2 (17.09) FW: 81.26 (12.93); 5 PU: 80.25 (18.12) (Appiah-Kubi et al., 2014).

Genetic diversity and conservation status: The diversity of *G. chacoensis* has not been studied but molecular markers (SSR) which will facilitate the understanding of the genetic structure of populations have been developed by Rozzarola et al. (2020).

Uses

a. Traditional: Handicraft, weaving, whole culms in construction, manufacture of boards, construction of framework for the roofing of rustic houses, valued as an ornamental and as fences.

b. Industrial: Laminated bamboo (Appiah-Kubi et al., 2014), charcoal (Alchouron et al., 2019).

c. Potential: Biochar, leaves as fodder, construction (houses and bridges), furniture manufacturing, bioenergy/biorefinery.

Key ecosystem service values: Like *G. angustifolia, G. chacoensis* to can play a significant role in ecological restoration programmes especially of the riparian zones.

Research gaps: Data on physicochemical characterisation and productivity of this species is to be generated. Potential of this species for pulp and fibre and bioenergy/biorefinery must be evaluated.

Information Gaps: This species grows abundantly in its native habitat, but the potential for plantations and agroforestry, carbon trading land restoration programmes must be explored.

Habit

Culm and branching pattern

New shoot

Culm sheath

30. *Melocanna baccifera* (Roxb.) Kurz

Synonyms (Vorontsova et al., 2016): *Bambusa baccifera* Roxb.; *Melocanna bambusoides* Trin.; *Beesha baccifera* (Roxb.) Kunth; *Nastus baccifera* (Roxb.); *Beesha rheedii* Kunth.

Common names (Language/area in parenthesis): Berry bamboo (English); *Muli (*Tripura, West Bengal, India); *Watrai* (Garo, Meghalaya, India); *Lahure bans* (Bhutan); *Usylli* (Khasi Meghalaya), *Wathwi* (Kokbarok- Tripura); *Usylli* (Khasi Meghalaya); *Tyrlaw* (Jaintia Meghalaya-India); *Saneibi, Moubi* (Manipuri- India); *Rieng* [Rongmai Naga-Tamenglong (Manipur)]; *Turiah* (Nagaland- India); *Mautak mau* (Mizo- India); *Tador dort* (Arunachal-India); *Lahure bans* (Nepal, Bhutan); *Muli, Nali, Tengra muli, Paiya, Bazali* [Bengali; Chittagong Hill Tract, Sylhet and Mymensingh forests, Bangladesh].

Description: An open diffuse clumping bamboo with long-necked pachymorph rhizomes (Banik, 2016). The erect culms arise well separated (up to 1 m) and reach a height of 8–22 m (Banik, 2016), a diameter of 3–22 cm and wall thickness of 0.16–2.3 mm. The internodes are long, 10–60 cm in length and with a dense tuft of 25–40 slender, thin subequal branches at each mid-culm node developing after 6–9 months of emergence (Banik, 2016).

Distribution

a. Native range: Indian Subcontinent to Myanmar.
Indian Subcontinent: Assam, Bangladesh, East Himalaya, Nepal.
Indo-China: Myanmar.

b. In cultivation/naturalised in:
Brazil: Brazil Southeast.
Caribbean: Jamaica.
Malesia: Jawa.
Western South America: Colombia, Ecuador.

Climatic parameters: *M. baccifera* stands a wide range of temperature of 5–37 °C. This species grows at elevations up to 1400 m with annual precipitation of 2500–6000 mm (Banik, 2016).

Soil: This species grows in a wide range soil such as moist sandy, clay loam alluvial soils, well-drained residual soils, sandy rough slopes, the apices of hills etc with pH of 4.5–6 (Banik, 2016). Soil organic content ranges between 2.8–3.1 % in the rhizosphere of 2–10-year-old plants (Hauchhum and Tripathi, 2017).

Native habitat: Hill forests are the native habitat of *M. baccifera* (Banik, 2016). The species grows as undergrowth under many tree species like *Tectona grandis, Gmelina arborea*, *Lagerstroemia speciosa, Albizia* spp, *Terminalia* spp, *Toona iliate, Dipterocarpus turbinatus*, etc. and forms a pure stand due to the aggressive nature of its underground rhizome in areas after burning. This bamboo species does not grow well under shade but springs up readily in gaps (Banik, 2010).

Propagation

a. Natural: Flowering cycle in *M. baccifera* reported as 30–60 years. The large fleshy fruits are known as becca. The seed weight is 7–150 g/fruit. 60–70 % germination is obtained within 3–7 days (Banik, 2016).

b. Clonal propagation: A cluster of rhizomes with 3–4 noded culms separated during March–April for rooting in a sand bed with adequate watering has been reported as successful (Banik, 2010).

c. Tissue culture: Immature embryos from developing fruits and branch nodes with buds has been used for micropropagation of *M. baccifera* (Banik, 1991).

Cultivation

a. Plantation type: Block plantation, homesteads.

b. Spacing: A spacing of 2×2 m, 3×3 m is reported for block plantations while a spacing of 9 m with line gap of 10/12/15 m is recommended for intercropping with tree species (Banik, 2016).

c. Possible species for mixed plantations: Cultivating the legume crops (*Cajanus cajan*, lentil, *Sesbania* sp., *Glycine max*, tapioca, *Dioscorea* and other vegetable crops like ginger, chilli, etc. is possible at the early stage before developing a closed canopy. Tree species like *Acacia, Albizzia* spp, *Gmelina arborea, Tectona grandis, Toona ciliata* and *Areca catechu* also used for intercropping *with M. baccifera* plantations (Banik, 2010).

d. Years to maturation: 3–5 (Banik, 2016).

e. Shooting season: May–August (Banik, 2016).

Productivity

a. Culm production : Banik (2010) reported a production of 5500 culms/ha in 3rd year after planting and 7700 culms/ha in the eighth year after planting.

b. AGB : Estimates of 27.31 Mg/ha and 74.17 Mg/ha. For the second and third year after planting. have been reported (Devi et al., 2018).

c. Annual C sequestered : Devi et al. (2018) reported carbon sequestration of 44.71 Mg/ha in a 3-year-old plantation.

d. Allometric equations :

India (Rawat et al., 2018)	Y=-1.09+0.60*DBH+0.07*ht

Mechanical properties

a. Density : 0.75 (top), 0.71 (middle), 0.70 (base) (Banik, 2016).

b. Cellulose/lignin/silica content : α-cellulose 95.0 %; β-cellulose 4.0 % (Banik, 2016).

c. MOE : 281 MPa (top), 228 MPa (middle), 188 MPa (base) (Banik, 2016).

d. MOR : 687 MPa (top), 700 MPa (middle), 782 MPa (base) (Banik, 2016).

e. Fibre length : 2.78 mm (Banik, 2016).

f. Fibre diameter : 15.6 µm (Banik, 2016).

Uses

a. Traditional: Handicraft, weaving, whole culms in construction, edible shoots.

b. Industrial: Matboard, paper/pulp, scrimber flooring.

Key ecosystem service values: *M. baccifera* protects the forests of the north-eastern states of India on steep slopes and alleviates it from the effects of many activities like slashing, burning, sowing, weeding, and harvesting.

Research gaps: The potential of the species, which is a major bamboo species in many states in Northeast India and in Bangladesh, for plantations for biofuel and biorefinery needs to be further explored.

Information gaps: Information on genetic variability of populations is not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

31. *Ochlandra travancorica* (Bedd.) Gamble

Subspecies/variety/clone: *Ochlandra travancorica* var. hirsuta Gamble**;** *Ochlandra rheedei* var. sivagiriana Gamble; *Ochlandra scriptoria* var. sivagiriana (Gamble) C.E.C. Fisch.

Synonyms (Vorontsova et al., 2016): *Beesha travancorica* Bedd.; *Melocanna travancorica* F. Muell.; *Ochlandra sivagiriana* (Gamble) E.G. Camus; *Ochlandra soderstromiana* M. Kumar & Sequiera.

Common names (Language/area in parenthesis): Etta, Kar-etta, Vai (Malayalam); Vaate bidiru (Kannada); Eral, Era-katti, Nanal, Odai (Tamil); Elephant grass of Travancore; Reed bamboo.

Description: Reedlike, shrubby or arborescent bamboo with pachymorph short-necked rhizomes. The species reaches a height of 2–6 m (Banik, 2016) with clump diameter of 105 m in 36 months (Sujatha et al., 2002). Culms have a diameter of 2.5–18 cm and a wall thickness of 2–3 mm (Banik, 2016). Internodes are long and 45–150 cm in length (Seethalakshmi and Muktesh Kumar, 1998) with swollen nodes and thin subequal branches (Banik, 2016).

Distribution

a. Native range: Southern India.
   Indian Subcontinent: India [Kerala, Tamil Nadu].
b. In cultivation/naturalised in:
   Caribbean: Puerto Rico.

Climatic parameters: This species grow well in area with altitude of 450–600 m and precipitation of 2500–5000 mm (Sujatha et al., 2004).

Soil: *O. travancorica* grows well in dark brown, acidic, sandy loam with granular structure, high porosity, good aggregate stability and with high water holding capacity (Sujatha et al., 2004).

Native habitat: Western Ghats region in Kerala and Tamil Nādu States of India**.** Occurs widely as undergrowth in low-level evergreen and semi evergreen forests, along the riversides and stream banks in wet evergreen and semievergreen forests (Sujatha et al., 2004) in association with *Hopea parviflora, Cullenia exarillata, Canarium strictum, Dipterocarpus indicus* etc (Banik, 2016).

Propagation:

a. Natural: Flowering cycle of this species is reported as 7–15 years (Banik, 2016) with the production of 45–57 fruits/kg (Seethalakshmi and Muktesh Kumar, 1998) or 24–32 g/fruit (Banik, 2016). These fruits are viable only for 45 days (Seethalakshmi and Muktesh Kumar, 1998).
b. Clonal propagation: Propagation through rhizome offsets is found to be very successful with this species (Sujatha et al., 2002). Two-node culm segments are made from two- to three-year-old culm and treated with hormones to give 50 % rooting (Sujatha et al., 2002).
c. Tissue culture: Axillary bud proliferation with nodal segments from *in vitro* seedlings and somatic embryogenesis using Isolated embryos from mature seeds (Philip, 1997; Bejoy et al., 2012).

Cultivation

a. Spacing: 5x5 m; 9x9 m (Sujatha et al., 2004).
b. Possible species mixed: No data available.
b. Years to maturation: 4 (Banik, 2016).
c. Shooting season: June-August.

Productivity

a. Culm production : 62 culms/clump in 3.5 years (Raveendran et al., 2010).

b. AGB : No data available.

Mechanical properties

c. Specific gravity : No data available.

d. Density : No data available.

e. Cellulose/lignin/silica content : Cellulose 61.8 %; lignin 26.9 %; silica 2.1 % (Seethalakshmi and Muktesh Kumar, 1998).

f. Fibre length : 9 mm (Seethalakshmi and Muktesh Kumar, 1998).

g. Fibre diameter : 16.7 µm (Seethalakshmi and Muktesh Kumar, 1998).

Genetic diversity and conservation status: A germplasm collection of about 350 accessions, representing all major populations has been established at Velupadam, Thrissur by Kerala Forest Research Institute. The accessions have been well characterised in chemical and anatomical properties with low lignin, low silica and high cellulose selections undergoing multilocational trials. Many of the populations grow in protected areas but others are vulnerable to overexploitation by industry or habitat loss to hydroelectricity projects.

Uses

a. Traditional: Handicraft, mats, flutes, umbrella handles, walking sticks, whole culms in construction, furniture, water pipes, edible shoots, fodder for elephants.

b. Industrial: Matboard (bamboo ply), laminated bamboo, strand woven lumber, paper pulp.

c. Potential: Biofuel, biorefinery feedstock.

Key ecosystem service values: A very suitable species to arrest land degradation through soil erosion and to improve soils.

Research gaps: Mechanical properties of the species have not yet been studied. Efficient mechanical tools for selective harvesting of culms are to be developed. Carbon sequestration potential should be evaluated.

Information gaps: The productivity of natural stands/plantations from the biofuel/biorefinery point of view is to be ascertained.

Habit

Culm and branching pattern

New shoot

Culm sheath

32. *Oldeania alpina* (K. Schum.)

Synonyms (Vorontsova et al., 2016): *Arundinaria alpina* K. Schum., *Yushania alpina* (K. Schum.), *Sinarundinaria alpina* (K. Schum.), *Arundinaria fischeri* K. Schum., *Arundinaria tolange* K. Schum., *Oxytenanthera ruwensorensis* Chiov.

Common names (Language/area in parenthesis): *Mirangi* (Kikuyu), *Techani* (Pokot), *Tegek* (Kipsigis), *Tekek* (Sebei), *Modi* (Luo), *Mianzi/Mwanzi* (Kiswahili), African alpine bamboo, Highland Bamboo, Mountain bamboo, Babou Creux (French), *Anini* (Agew); *Kerkeha*, *yedega kerkeha* (Amharic); *Kias* (Gamu); *Shineto /Shinato* (Kefigna); *Lemmen*, *Shimela* (Afan Oromo); *Shenbek'wa* (Welayita); *lema* (Konso, Kembata, Sodo Gurage and Sidamo); *werye/shikaro / shinato* (Kefa); *lewu* (Nuwer).

Description: *O. alpina* is a bamboo occurring as open stands with widely spaced erect green culms (Stapleton, 2013) and pachymorph long-necked rhizomes. The culms reach a height of 13–20 m with diameter of 5–12 cm. Wall thickness ranges from 2 cm at the bottom to 0.3 cm at the top with internodal length of 30–70 cm and slightly prominent nodes.

Distribution

Native range: Ethiopia to Zambia.
East Tropical Africa: Kenya, Tanzania, Uganda.
Northeast Tropical Africa: Ethiopia, Sudan.
South Tropical Africa: Malawi, Zambia.
West-Central Tropical Africa: Burundi, Cameroon, Congo, Rwanda, Zaire.

Climatic parameters: Rainfall is seasonal, with 3–6 dry months (mean rainfall less than 50 mm) in eastern Africa, but only 2 dry months in Cameroon. Annual totals vary from 800 mm in Tanzania to 1400-2000 mm in Ethiopia and 3000 mm in Cameroon.

Soil: Prefers well drained sites; 45–60 % slopes on ravine areas produce maximum performance. It also grows in flat to slightly sloping (5–15 %) and steep slopes up to 45 % with pH 5.92–6.26 and soil organic content of 5.41 %. Rooting depth of 90–119 cm is found for varied landforms (Mulatu, 2012).

Native habitat: On the slopes of mountains; slopes of ravine areas are highly preferred sites.

Associated vegetation: Monodominant 'bamboo zones' (van der Hoek et al., 2019); situated in high forests with *Podocarpus* in upland and with Juniperus in drier forest.

Propagation

a. Natural: Flowering cycle has been reported as 15–40 years (van der Hoek et al., 2019). Seed weight is 15.4 seeds/gram and up to 70 % germination is obtained for fresh seeds.
b. Clonal propagation: Seedling macroproliferation is feasible. Rhizome offsets four nodes and six nodes is successful (Kebede et al., 2017). Culm cuttings: Whole culm propagation produces a high number of shoots with reasonable size at the bottom, middle and top positions (Mulatu and Fetene, 2014). Branch cuttings and air-layering do not perform well.
c. Tissue culture: Not reported.

Cultivation

a. Spacing: 5x5 m.
b. Years to maturation: More than 10 if established from seedlings; From offsets, it takes about 5.
c. Shooting season: May–June.

Productivity

a. Culm production : 10 t/ha (Endalamaw, 2015).

b. AGB : 95.4 ± 1.5 t/ha (Nigatu et al., 2020); stock reaches 117 t/ha.

c. Allometric equations :

Ethiopia (Mulatu and Fetene, 2011)	TDW (<1 year) =exp(0.185*DBH); R^2=0.835, SE=0.44; TDW (1-3 year) =exp(0.323*DBH); R^2=0.95, SE=0.366; TDW (>3 year) =exp(0.147*DBH); R^2=0.749, SE=0.461

Mechanical properties

a. Specific gravity : No data available.

b. Tensile strength : 179.7–246.1MPa (Muche and Degu, 2019).

c. Cellulose/lignin/silica content : Cellulose 46.76 % ±1.09%; lignin 25.27 % ± 1.52%; hemicellulose 12.18 % ± 1.01% (Tsegaye et al., 2020).

Genetic diversity and conservation status: This species has high variability in its morphological appearance, applications, and management. Different landraces have been identified in Ethiopia. The species is promoted on farmers' lands for diverse needs. Mass flowering and mass death is a big challenge especially on natural forests which are under the ownership of the state.

Uses

a. Traditional: Weaving, whole culms in construction, furniture, water pipes, edible shoots.

b. Industrial: Laminated bamboo, strand woven, paper pulp, charcoal, syngas ethanol production (Tsegaye et al., 2021), stick-based product lines, including curtains, incense sticks, toothpicks, matchsticks and other stick-based products.

c. Potential: Bamboo lumber.

Key ecosystem service values: Catchment rehabilitation, regulation of water flow, and erosion control.

Research gaps: Characterisation of landraces and taxonomic studies in different areas is needed to address the probability of coming up with new species or clearly defined varieties. Physicochemical characterisation of the species is needed.

Information Gaps: Information on propagation technique such as tissue culture is not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

33. *Otatea acuminata* (Munro) C.E. Calderón ex Soderstr.

Subspecies/variety/clone: *Otatea acuminata* subsp. *aztecorum* (McClure & E.W.Sm.).

Synonyms (Vorontsova et al., 2016): *Arundinaria acuminata* Munro; *Otatea aztecorum* (McClure & E.W.Sm.); *Yushania acuminata* (Munro) McClure; *Yushania aztecorum* McClure & E.W.Sm.

Common names: Mexican weeping bamboo.

Description: An evergreen bamboo with short-necked pachymorph rhizomes and compact thin, narrow, and long light-green leaves. Dense thickset clumps with mid-sized culms 2–10 m in height and 1–5 cm in diameter (Ruiz-Sanchez et al., 2018). Internodes are 9.5–24 cm in length with wall thickness of 2–4 mm. Depending on location, sometimes culms are solid (Ruiz-Sanchez et al., 2018). Branches consists of three subequal and ascending branches/nodes (Ruiz-Sanchez, 2012).

Distribution

a. Native range:
   Mexico: Mexico Central, Mexico Northeast [Chuhuahua, Durango], Mexico Gulf, Mexico Northwest [Sinaloa, Sonora], Mexico Southwest [Guerrero, Jalisco, Michoácan, Nayarit].
b. In cultivation/naturalised in:
   Central America: Costa Rica, Honduras.

Climatic parameters: *O. acuminata* and *Otatea acuminata* subsp. *aztecorum* grows at an average annual temperature of 22 °C and a minimum temperature of -5 °C. This species is found distributed at elevations of 150–2000 m and precipitation of 1350 mm (Ruiz-Sanchez et al., 2018).

Soil: This species grows on thin and stony soils usually derived from calcareous rocks with pH of 6–7.8 (Guzmán et al., 1984).

Native habitat: Widely distributed in tropical dry forests, dry oak forests and xerophytic scrubs in association with *Acacia* spp. and *Lysiloma* spp.

Propagation

a. Natural: A flowering cycle of 30 years has been reported (Ruiz-Sanchez et al., 2011). Sporadic flowering also occurs in some populations (Vázquez-López et al., 2004).
b. Clonal propagation: Clusters of rhizomes with culms separated from the mother clump have been widely used for the propagation of this species.
c. Tissue culture: Somatic embryogenesis from zygotic embryo explants has been reported for the subspecies *Otatea acuminata* subsp. *aztecorum* (Woods et al., 1992).

Cultivation

a. The species is widely grown as an ornamental plant and used for ecological restoration, but commercial plantations are not known.
b. Spacing: 4.7x6 m, 6x9 m, 9x12 m have all been reported as suitable for this species.
c. Years to maturation: 3–4.
d. Shooting season: July–September (Vázquez-López et al., 2000).

Productivity

a. Culm production : 1430 juvenile culms/ha (Vázquez-López et al., 2004).

b. AGB : 7–8 t/ha (Vázquez-López et al., 2004).

c. Allometric equations : Not reported.

Mechanical properties (*Otatea acuminata* subsp. *Aztecorum*):

a. Density : 879.67 kg/m^3 (Rodríguez López, 2020).

b. MOE : 645.85 Mpa (Rodríguez López, 2020).

c. MOR : 13,322 Mpa (Rodríguez López, 2020).

Genetic diversity and conservation status: Except for *ex situ* species collection there are no reports of conservation efforts for the species, which is entirely utilised by extraction from wild populations.

Uses

a. Traditional: Handicraft, weaving, basket making, fencing, furniture, joinery, culms widely used for construction, house walls in the bahareque style, tool handles or stakes in agriculture. Highly prized ornamental species.

b. Industrial: None.

c. Potential: Ecological restoration, particularly of drier regions.

Key ecosystem service values: This species plays an important role in regenerating the forest, restoring, and maintaining fertility and productivity of land, conserving soil moisture and reducing and preventing erosion and flood risks (Vázquez-López et al., 2004). It is more tolerant of drier climates which makes it a useful plant for land restoration, and it is widely used in land rehabilitation.

Research gaps: Since this is an endemic species with high diversity, germplasm collection and genetic variability studies are required. For exploiting the potential of this species to grow in wider climatic zones such as coastal regions and dry deciduous regions, an optimal method for large-scale production of propagules is also required. Proper planning for management and harvesting should be designed. A controlled management program must be required to regulate harvesting practices for *Otatea acuminata* subsp. *Aztecorum* (Olvera-Vargas, 2000).

Information Gaps: Information on carbon sequestration potential of this species is not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

34. *Oxytenanthera abyssinica* (A. Rich.)

Synonyms (Vorontsova et al., 2016): *Bambusa abyssinica* A.Rich.; *Bambusa schimperiana* Steud.; *Oxytenanthera macrothyrsus* K.Schum.; *Oxytenanthera braunii* Pilg.; *Oxytenanthera borzii* Mattei, Boll.; *Houzeaubambus borzii* (Mattei) Mattei.

Common names (Language/area in parenthesis): Lowland bamboo, West African bamboo, savanna bamboo (English); Shemel/Shimel (Amharic); Gagu, Enta, Shimalla (Welaytinya or Affan Oromo); Elta, Bindura bamboo (Senegal region); Arkay (Tigrinya); o-kadjié, u-hátyè (Senegal): kebe, kewal (The Gambia); souguê, djame (Guinea-Bissau); Kô-Tatami (Guinea); Thong (Sierra Leone); Temui (Liberia); Bσ (Mali); Buna (Upper Volta); Pamploo (Ghana); Téma (Dahomey); Káálá (Niger); Òcyácyọ̄ (Nigeria); Lekwê (West Cameroon).

Description: A medium-sized, densely clustered bamboo with pachymorph short-necked rhizomes. The culms are mostly erect and arch over at the top (Fanshawe,1972). Culms attain a height of 3–13 m and diameter of 5–10 cm (Gurmessa et al., 2016). The culms are solid (Gurmessa et al., 2016) with internode length of 16.5–28.6 cm (Elbasheer and Raddad, 2013) Branches are produced alternately from the nodes, but the main branches all lie in one plane (Fanshawe, 1972).

Distribution

a. Native range: Tropical and Southern Africa.
   Northeast Tropical Africa: Chad, Eritrea, Ethiopia, Sudan, Kenya, Tanzania, Uruguay, Angola, Malawi, Mozambique, Zambia, Zimbabwe.
   Southern Africa: Northern Provinces.
   West-Central Tropical Africa: Burundi, Central African Republic, Cameroon, Congo, Equatorial Guinea, Gulf of Guinea Islands.
   West Tropical Africa: Benin, Burkina, Gambia, The, Ghana, Guinea-Bissau, Guinea, Ivory Coast, Mali, Nigeria, Senegal, Sierra Leone.

b. In cultivation/naturalised in:
   Indian Subcontinent: India [Kerala].

Climatic parameters: The species occurs in areas with a temperature of 20–27 °C and an annual precipitation rate of 500–1800 mm (Gebrewahid et al., 2020) at an elevation of 1100–1800 (IBC, 2014).

Soil: The species grows well in very acidic sandy soils, deeply humus stained (poorly aerated) and poor in nutrients, with pH 5.5–6. Soil organic carbon content of areas with *O. abyssinica* is 3.4–5.3 %.

Native habitat: The species is abundant on disturbed termite mounds in full light. It grows in savanna woodland, usually in river valleys, and is often found on very poor soils with an association of *Lonchocarpus laxiflorus, Combretum* sps and *Entada abyssinica.*

Propagation

a. Natural: Flowering cycle in this species is reported as 30–35 years (Abere et al., 2020). Seed weight is 8.3 seeds/gram (Bahru et al., 2015) and germinate in 9–12 days in soil (65.8 %) (Dereso, 2019). A survival rate of 56.25 % has been reported for direct seed sowing (Gebretsion and Abay, 2019).

b. Clonal propagation: A success rate of 43.75 % for seedling macro-proliferation has been reported (Gebretsion and Abay, 2019). Survival rates of 59.32 % and 17.42 %, for rhizomes with two nodes and rhizomes without nodes respectively, was also recorded by Abere et al. (2020). Whole culms used for propagation gave a 22.2 % survival rate (Abere et al., 2020). Two nodal culm cuttings taken from basal and middle positions planted horizontally showed significantly higher survival rates (Gebrehiwot et al., 2016).

c. Tissue culture: Propagation through axillary bud proliferation with nodal explants from 12-month-old seedlings (Diab and Mohamed, 2008).

Cultivation

a. Plantation type: Homestead cultivation, agroforestry systems and commercial plantations.
b. Spacing: 5x5 m.
c. Possible species mixed: Cash crops and hardwood trees.
d. Years to maturation: 7 years (For culms developed from seeds) (Abere et al., 2020).
e. Shooting season: June–August.

Productivity

a. Culm production : Up to 5921 culms/ha from two-year-old forest (Abere et al., 2020).
b. AGB : 140.11 ± 2.55 Mg/ha (Abere et al., 2020).
c. Annual C sequestered : Mean biomass carbon: 83.2 ± 1.5 Mg C/ha; soil organic carbon: 70 ± 1.7 Mg C/ha; total bamboo forest: 152.5 ± 2.5 Mg C/ha to 559.8 ± 9.0 ton CO_2/ha (Abebe et al., 2021).
d. Allometric equations :

Western Ethiopia (Gurmessa et al., 2016)	TAGB= -1.073+0.067*BA+(-0.064*D_{10}) +0.206*Height+0.653*DBH, R^2=0.866 TAGB=-1.157+0.058*BA+0.203*Height+0.624*DBH, R^2=0.865 TAGB=-1.392+0.234*Height+0.766*DBH, R^2=0.84 DHB is diameter at breast ehight; D_{10} is basal diameter at 10 cm abover ground; BA is basal area of individual culm

Mechanical properties

a. Density : 1.077, 0.9845, 0.9787 g/cm^3 (Hankun et al., 2019); 0.493 g/m^3 (Abdalla et al., 2014).
b. Cellulose/Lignin/silica content : Cellulose 52.06 %; lignin 22.47 % (Tolessa et al., 2017); Cellulose 60.1–62.3 % lignin 21.2–25.1 % (Abdalla et al., 2014).
c. MOE : 11,140 MPa (Seyoum, 2009).
d. MOR : 146 MPa (Seyoum, 2009).
e. Fibre length : 1.83 mm–2.04 mm (Abdalla et al., 2014).
f. Fibre diameter : 30.32–30.83 µm (Abdalla et al., 2014).

Genetic diversity and conservation status: Natural bamboo forests containing *O. abyssinica* are under threat of deforestation and degradation (Nfornkah et al., 2020). Genetic diversity and population structure analysis of *O. abyssinica* have been carried out. The data show a clear diversity among the population based on their geographical locations (Oumer et al., 2021).

Uses

a. Traditional: Weaving, whole culms in construction, furniture, water pipes, edible shoots, fodder (leaves), fencing material, arrow shafts, walking sticks.
b. Industrial: Charcoal.
c. Potential: Pulp, bioenergy.

Key ecosystem service values: A potential species for carbon sequestration and climate change mitigation. The species has been used for reclamation of degraded mined sites in Ghana (Peprah et al., 2014).

Habit

Culm and branching pattern

New shoot

Culm sheath

35. *Phyllostachys aurea* (André) Rivière & C. Rivière

Subspecies/variety/clone: *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 parenthesis): 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; *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 (Roxas, 2012) and average diameter of 1.1–9 cm with extremes of up to 15 cm, with wall thickness of 2–8 mm (Roxas, 2012). The internodes are long, 8–20 cm in length, with branches that are borne at the middle of the culm with unequal thickness (Roxas, 2012). The species has prominent nodes with a white powdery wax below. The lower nodes are often irregularly short and swollen, while the upper are distant and horizontal (Roxas, 2012). Branches occur in uneven pairs with sulcus (Gucker, 2009). The stems and branches of *P. aurea* are green when they are young and turn golden yellow at maturity (Rickel and Rojas- Sandoval, 2017).

Distribution

a. Native range: Fujian and Zhejiang to Viet Nam.
China: China Southeast.
Indo-China: Viet Nam.

b. In cultivation/naturalised in:
Australia: New South Wales, South Australia, Queensland.
Caucasus: Transcaucasus.
Central America: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua.
Eastern Asia: Nansei-shoto.
Europe: Spain.
Indian Subcontinent: East Himalaya.
Malesia: Jawa, Lesser Sunda Islands, Sumatera.
Mexico: Mexico Central, Mexico Northeast.
New Zealand: Kermadec Islands, New Zealand North.
Northwestern U.S.A: Oregon.
Southeastern U.S.A.: Alabama, Arkansas, Florida, Georgia, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia Southwestern.
Southwestern U.S.A.: California.
South-Central U.S.A.: Texas West-Central.
Tropical Africa: Cameroon.
Western South America: Bolivia, Colombia, Ecuador, Peru.
Brazil: Brazil Southeast, Brazil South, Brazil West-Central.

Climatic parameters: *P. aurea* tolerates a wide range of temperature of -15–26 °C and sometimes as low as -20 °C (Rickel and Rojas-Sandoval, 2017). This species grows at elevations of 700–2000 m with annual precipitation of 1000 mm (Rickel and Rojas-Sandoval, 2017).

Soil: Sandy soils with drainage and rich nutrients are optimum for the wild growth of this species. *P. aurea* cannot withstand water-logged conditions (Rickel and Rojas-Sandoval, 2017).

Native habitat: An invasive plant in undisturbed habitats including along stream edges and riparian corridors (Rickel and Rojas-Sandoval, 2017). Dense litter fall prevents other species from thriving.

Propagation

a. Natural: Both sporadic and gregarious flowering has been reported with this species. Flowering cycles may occur in 7–12 years (Miller, 2003) with no seed settings.
b. Clonal propagation: *P. aurea* spreads rapidly by underground rhizomes in all directions. Clump parts, 0.5–1.0 m long, with both a rhizome and roots are also commonly used for large scale planting with 100 % success (Roxas, 2012).
c. Tissue culture: Somatic embryogenesis has been found to be successful with this species (Huang and Huang, 1993).

Cultivation

Shooting season: Each spring (Gucker, 2009).

Mechanical properties

a. Density : 783 ± 28 kg/m (Armandei et al., 2015); 0.77 g/cm^3 (Panels) (Armandei et al., 2015).
b. MOE : 9.49 +1.46 Gpa (Armandei et al., 2015); 210.0 MPa (Cruz, 2002); 69.0 MPa (Cruz, 2002).
c. MOR : 4.0 MPa (Cruz, 2002).

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

Uses

a. Traditional: Handicrafts, weaving, bamboo pipes, walking sticks, umbrella and fan handles, popular garden ornamental and hedges.
b. Industrial: Charcoal, briquettes, and pellets for bioenergy.
c. Potential: Being a rapidly growing species, there is a great potential for cultivation on degraded lands for restoration and carbon sequestration with proper containment measures.

Key ecosystem service values: No data available.

Research gaps: Allometric equations for biomass and estimates of annual C sequestered are needed.

Information Gaps: Cultivation practices and information on productivity are not known.

Habit

Culm and branching pattern

New shoot

Culm sheath

36. *Phyllostachys edulis* (Carrière) J. Houz.

Subspecies/variety/clone (if any): *Phyllostachys heterocycla var. pubescens* (Pradelle) Ohwi; *Phyllostachys heterocycla f. pubescens* (Pradelle) D.C.McClint.; *Phyllostachys mitis var. heterocycla* (Carrière) Makino; *Phyllostachys pubescens var. heterocycla* (Carrière) J.Houz.; *Phyllostachys edulis var. heterocycle*; *Phyllostachys pubescens var. biconvexa*; *Phyllostachys edulis f. heterocycle*; *Phyllostachys edulis f. subconvexa*; *Phyllostachys heterocycla f. subconvexa*; *Phyllostachys pubescens f. aureovariegata*; *Phyllostachys heterocycla f. aureovariegata; Phyllostachys edulis f. aureovariegata; Sinarundinaria pubescens f. nabeshimana; Phyllostachys heterocycla f. nabeshimana; Phyllostachys pubescens var. nabeshimana; Phyllostachys edulis f. nabeshimana; Phyllostachys pubescens f. nabeshimana; Sinarundinaria pubescens var. bicolor; Phyllostachys heterocycla f. bicolor; Phyllostachys pubescens f. bicolor; Phyllostachys edulis f. bicolor ; Phyllostachys macroculmis var. edulis; Phyllostachys edulis f. aureostriata K; Phyllostachys pubescens var. taokiang; Phyllostachys heterocycla f. taokiang; Phyllostachys heterocycla f. gimmei; Phyllostachys edulis f. gimmei; Phyllostachys pubescens f. grammica; Phyllostachys pubescens f. purpurescens; Phyllostachys edulis f. purpurescens; Phyllostachys pubescens f. rigida; Phyllostachys edulis f. rigida; Phyllostachys pubescens f. huamozhu; Phyllostachys heterocycla f. huamozhu; Phyllostachys edulis f. huamozhu; Phyllostachys pubescens f. gracilis; Phyllostachys pubescens f. lutea; Phyllostachys edulis f. lutea; Phyllostachys pubescens f. luteosulcata; Phyllostachys edulis f. luteosulcata; Phyllostachys pubescens f. viridosulcata T.; Phyllostachys heterocycla f. viridosulcata; Phyllostachys edulis f. viridisulcata; Phyllostachys heterocycla f. obliquinoda; Phyllostachys edulis f. obliguinoda; Phyllostachys heterocycla f. ventricose; Phyllostachys edulis f. ventricose; Phyllostachys pubescens f. obtusangula; Phyllostachys heterocycla f. obtusangula; Phyllostachys edulis f. obtusangula; Phyllostachys pubescens f. quadrangulate; Phyllostachys heterocycla f. quadrangulate; Phyllostachys edulis f. quadrangulate; Phyllostachys pubescens f. tubiformis; Phyllostachys heterocycla f. tubiformis; Phyllostachys edulis f. tubiformis; Phyllostachys edulis f. gracilis; Phyllostachys heterocycla f. oboro; Phyllostachys edulis f. albovariegata; Phyllostachys heterocycla f. oboro; Phyllostachys edulis f. albovariegata; Phyllostachys pubescens f. holochrysa; Phyllostachys edulis f. epruinosa; Phyllostachys edulis f. venusta; Phyllostachys heterocycla f. anjiensis; Phyllostachys edulis f. purpureoculmis; Phyllostachys edulis f. purpureosulcata ; Phyllostachys pubescens f. quadrangulata* S.Y.Wang.

Synonyms (Vorontsova et al., 2016): *Bambos moosoo* Siebold; *Bambusa edulis* Carrière; *Bambusa mitis* Carrière; *Bambusa pubescens* Pradelle; *Phyllostachys pubescens* (Pradelle) Mazel ex J. Houz.; *Sinarundinaria pubescens* (Pradelle) Muroi; *Bambusa heterocycla* Carrière, Rev.; *Phyllostachys heterocycla* (Carrière) Matsum.; *Phyllostachys bicolor* Crouzet.

Common names (Language/area in parenthesis)**:** *Mao zhu* (Chinese), *Moso, Mosochiku* (Japan); Edible bamboo, Tortoise-shell bamboo.

Description: A large bamboo with long-necked leptomorph rhizomes and straight culms that attain a height of 10–35 m. The diameter of the culm ranges from 19–20 cm with internodes of length up to 45 cm and wall thickness of 14.04 mm (base), 10.21 mm (middle) and 9.04 mm (top) (García et al., 2012). Nodes are with prominent nodal ridges and branches are only found at the top of the culms.

Distribution

a. Native range:

China: China South-Central, China Southeast.
Eastern Asia: Taiwan.

b. In cultivation/naturalised in:

Indo-China: Viet Nam.
Southern, South-eastern and Western Brazil.
Japan (including the Ryukyu Islands), Korea.
The Philippines
South-eastern U.S.A (Georgia, South Carolina).

Climatic parameters: *P. edulis* grows at a temperature range of -13–41 °C and precipitation in the range of 800–1800 mm. The species commonly grows at elevations of 100–700 m but is occasionally grown at higher elevations up to 1000 m.

Soil: It will grow in well drained acidic or neutral purple and yellow soil, and reddish yellow soil with pH 4.73–4.82 (Wu et al., 2018) and soil organic content 90.6 Mg/ha (Zhuang et al., 2015).

Native habitat: Mountain slopes; below 1600 m in elevation.

Propagation

a. Natural: Flowering cycle of 67 years has been reported in *P. edulis*. Incidence of sporadic flowering also occurs regularly in pockets. Treatment with GA_3 resulted in 100 % seed germination (Sood et al., 2014).
b. Tissue culture: Auxillary bud proliferation (Sood et al., 2014) and somatic embryogenesis (*Phyllostachys heterocycla* var. *pubescens*) (Yuan et al., 2013).

Cultivation

a. Years to maturation: The harvest age depends on its use. 7 for timber, 4 for pulp and paper.
b. Shooting season: April–July.

Productivity

a. Culm production : 8–15 t /ha (with full irrigation plus rainfall) and 0–8 t /ha with reduced irrigation (Kleinhenz et al., 2003).
b. AGB : 14.07 Mg/ha (Zhang et al., 2014); 16.24–163.41 kg/culm and 23.7–572.29 Mg/ha (Chen et al., 2009).
c. Annual C sequestered : 0.451–0.531 g C/g (culms); 105.07 t/ha(soil) (Liu et al., 2010); 6.74 Mg/ha (Zhang et al., 2014).
d. Allometric equations :

China 1 (Gao et al., 2015)	Total biomass (kg) = $0.24*DHB^{1.87}$ (R^2=0.93)

Mechanical properties

a. Specific gravity : 0.553 to 1.006 (Yu et al., 2008).
b. Density : 0.68 g/m^3 (Berndsen et al., 2013).
c. Cellulose/lignin/silica content : Cellulose 64.54 % (inner layer); 82.99 % (outer layer); 80.89 % (middle layer) (Yoshizawa et al., 1991); lignin; 29.88–35.36 % (Internode), 19.66–29.93 % (Node) (Yoshizawa et al., 1991); α-cellulose: 42 % (Thomas, 1977).
d. MOE : 13.719 Mpa (Berndsen et al., 2013).
e. MOR : 167 Mpa (Berndsen et al., 2013).
f. Fibre length : 1.56 mm (Liese, 1998).
g. Fibre diameter : 13 µm (Liese, 1998).

Genetic diversity and conservation status: Not reported.

Uses

a. Traditional: Handicraft, weaving; whole culms in construction; furniture; edible shoots.

b. Industrial: Laminated bamboo; paper/pulp; Charcoal
c. Potential: Biorefinery.

Key ecosystem service values: *P. edulis* has excellent carbon sequestration potential and performs well against soil erosion.

Research gaps: *P. edulis* is of interest around the world being the mainstay of a huge industry in China. Information on the range of climatic and soil parameters that permit cultivation of the species in other suitable regions is needed.

Information Gaps: None reported.

Habit

Culm and branching pattern

New shoot

Culm sheath

37. *Phyllostachys nigra* (Lodd. ex Lindl.) Munro

Subspecies/variety/clone: *Phyllostachys puberula* var. *nigra* (Lodd. ex Lindl.) J. Houz.

Synonyms (Vorontsova et al., 2016): *Bambusa nigra* Lodd. ex Lindl.

Common names (Language/area in parenthesis): Black bamboo, Timber bamboo.

Description: Large bamboo with rapidly forming loose clumps with leptomorph long-necked rhizomes. The culms grow up to 2.7–7 m with a diameter of 1–5.7 cm with arching tips. The internodes are 25–30 cm long with wall thickness 3 mm (Flora of China, 2016) which are greenish when young and turn blackish or purplish-black at maturity. The nodes are banded with horizontal rings and the internodes are grooved lengthwise between the nodes.

Distribution

a. Native range: South Hunan.
China: China Southeast [Hunan].

b. In cultivation/naturalised in:
Australia: New South Wales, Queensland.
Brazil: Brazil Southeast.
China: China South-Central, China North-Central, China Southeast.
Central Europe: Austria.
Eastern Asia: Japan, Korea, Nansei-shoto.
Indo-China: Viet Nam.
Malesia: Jawa islands, Philippines.
New Zealand: New Zealand North.
Northeast U.S.A: West Virginia, South Carolina.
Northern Europe: Great Britain.
North-Central Pacific: Hawaii.
South-eastern U.S.A.: Georgia, Tennessee, Virginia.
Western Indian Ocean: Seychelles.

Climatic parameters: This species grows well at an elevation of 1100–1200 m with annual rainfall and temperature of 1200–1700 mm and 10–18 °C.

Soil: Sandy loamy soil, and sometimes clay soil. Soil with soil organic content of 1.74 % and pH 4.5–6.6.

Native habitat: Open forests on slopes and in valleys with Masson pine and China fir with some cypresses.

Propagation

a. Natural**:** The flowering cycle in the species is 40–50 years (Lin et al., 2010) but seeds are rare.
b. Clonal propagation: Rhizome offsets are a widely used method for cultivation.
c. Tissue culture: Renyi et al. (2009) hold a patent for micropropagation of the species through axillary bud proliferation. Ogita (2005) reported plantlet regeneration through somatic embryogenesis.

Cultivation

a. Plantation type: Line planting, potted (ornamental).
b. Spacing: 1–1.5 m.
c. Years to maturation: 2–4.

d. Shooting season: April–May.

Productivity

a. Annual C sequestered : 43.2 Mg C /ha (Yuen et al., 2017).

b. Allometric equations :

Japan (Inoue et al., 2018)	$S = 187.66D^{1.70}$ $S = 2.08DH$

Mechanical properties

a. Specific gravity : 907 (0.02) kg/m^3 (Akinbade et al., 2019).

b. Cellulose/lignin/silica content : Cellulose 46.6 %; hemicellulose1 5.67 %; lignin 32.43 % (Depuydt et al., 2019).

c. MOR : 45.2 (0.13) MPa (Akinbade et al., 2019).

d. Fibre length : 2.2 mm (Jeon et al., 2018).

e. Fibre diameter : 167–180 µm.

Uses

a. Traditional: Food, musical instruments, ornamental uses.

b. Industrial: Lumber, food.

Key ecosystem service values: As a popular plant for uses as a live fence, the species can be used as an effective windbreak and as a soil binder.

Research and Information gaps: Information of genetic variability and conservation efforts are not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

38. *Phyllostachys violascens* Rivière & C. Rivière

Subspecies/variety/clone: *Phyllostachys praecox f. notata* S.Y. Chen & C.Y. Yao; *Phyllostachys praecox f. prevernalis* S.Y. Chen & C.Y. Yao; *Phyllostachys praecox f. viridisulcata* P.X. Zhang & W.X. Huang.

Synonyms (Vorontsova et al., 2016): *Bambusa violascens* Carrière; *Phyllostachys praecox* C.D. Chu & C.S. Chao.

Common names (Language/area in parenthesis): *Lei* bamboo, early bamboo, violet bamboo.

Description: The species is a loosely packed, evergreen bamboo with long-necked leptomorph rhizomes. The straight culms attain a height of 8–10 m (Molari et al., 2020) and have inclined top. The thin walled (4.53 mm) culms have the diameter ranging from 4–6 cm with an average of 5.11 cm (Molari et al., 2020). The internodes are long, 15–25 cm in length (Molari et al., 2020). Lateral branches grow in threes with one dominant branch.

Distribution

a. Native range: SE. China.
China: China Southeast [Anhui, Fujian, Hunan, Jiangsu, Jiangxi, Zhejiang].

b. In cultivation/naturalised in:
China: China South-Central [Yunnan], China Southeast [Anhui, Fujian, Hunan, Jiangsu, Jiangxi, Zhejiang].

Climatic parameters: *P. violascens* grows in the warm temperate and subtropical regions of southern China. This species withstands temperatures as low as -15 °C for short periods (an average of 132 frost days). The annual precipitation of this area is 1420 mm, and the annual average temperature is 15.9 °C, with a maximum of 41.9 °C and minimum of-13.4 °C (Guo et al., 2014).

Soil: The species grows well in medium loam soil with good drainage. This soil is ferrosol and derived from granite (Guo et al., 2014). Soil organic content of this soil is 36.67–42.72 g/kg (Gai et al., 2021) with pH 4.0–6.69.

Native habitat: *P. violascens f. prevernalis* occurs on plains and low mountains (Yue et al., 2004).

Propagation

a. Natural: Sporadic flowering has been reported in this species. Seeds are rarely available and germinate at about 20 °C soon after collection.

b. Clonal propagation: Rhizome offsets and clump divisions are the most common methods used *in P. violascens* for clonal propagation.

Cultivation

a. Plantation type: *P. violascens* is under wide cultivation for edible shoots. They are popular due to early shoot production.

b. Possible species mixed: Bamboo farming in association with chicken in China (Zhang et al., 2021).

c. Years to maturation: This species cultivated mainly for its edible shoots which are collected on the 4th day of emergence from the soil (Neményi et al., 2015).

d. Shooting season: Two shooting seasons are prevalent in this species, the first is induced with mulching (March–April) and the normal season is April–May (Flora of China, 2006).

Productivity

a. Culm production : 16500 culms/ha (Guomo et al., 1998); 19500, 18900 and 18060 stalks /ha respectively under control, 3-year mulching and 6-year mulching conditions in 3-, 2-, and 1-year-old plantations (Guo et al., 2014).

b. AGB : Estimates of 1.18 + 0.12 kg in *P. violascens f. prevernalis* grown in 100 % relative light intensity (Yue et al., 2004).

Mechanical properties

c. Density : 743 kg/m^3 (Molari et al., 2020).

d. Cellulose/lignin/silica content : 45.65 % dietary fibre content (Yang et al., 2021).

e. MOE : 148.91 MPa Tension (Molari et al., 2020).

f. MOR : 59.5 Mpa (Molari et al., 2020).

Uses

a. Traditional: Edible shoots, crafts.

b. Industrial: Edible shoots.

c. Potential: Biofuel.

Research gaps: Studies on the carbon sequestration potential of this species are required. Potential of this species for bioenergy production should be studied.

Information Gaps: Information on AGB and other ecosystem services are not available with this species or its varieties.

Habit

Culm and branching pattern

New shoot

Culm sheath

39. *Phyllostachys vivax* McClure

Subspecies/variety/Clone (Vorontsova et al., 2016): *Phyllostachys vivax f. huanguenzhu, Phyllostachys vivax f. vittate, Phyllostachys vivax f. aureocaulis, Phyllostachys vivax f. viridivittata*.

Common names (Language/area in parenthesis): Chinese timber bamboo, Running giant bamboo, Golden Chinese Timber Bamboo *(Phyllostachys vivax aureocaulis*).

Description: An evergreen running bamboo with leptomorph long necked rhizomes and tall culms of height 5–11.7 m. The average culm diameter of this species is 5.7 cm and the average wall thickness 10.7 mm. The internodes are up to 35.2 cm long and nodes have asymmetrical ridges. The older culms turn yellow at maturity.

Distribution

a. Native range: East China.
China: China North-Central, China Southeast.

b. In cultivation/naturalised in:
China: China North-Central [Shandong], China South-Central [Yunnan], China Southeast [Fujian, Henan, Jiangsu, Zhejiang].

Climatic parameters: *P. vivax* thrives in regions with annual mean temperature and precipitation of 15.9 °C and 1157 mm respectively but can survive at temperatures as low as-15 °C.

Soil: *P. vivax* grows on sandy soil with pH of 7.97–8.15. Soil should be moist with good drainage.

Native habitat: This species grows well in humid environments and also in coastal saline areas.

Propagation: The species does not set seeds, so propagation is only through vegetative means. Rhizome offset method is the method adopted.

Cultivation

a. Plantation type: Block plantations, strip plantations.
b. Spacing: Block plantations: 6x21 m (Temmerman et al., 2005).
Strip plantation: 3x51 m (Temmerman et al., 2005).
c. Possible species mixed: *Phyllostachys aureosulcata* 'spectabilis' and *Phyllostachys praecox*. for strip plantations in Belgium (Temmerman et al., 2005).
d. Shooting season: March–June.

Productivity

Culm production	:	Dry matter: 10–13 t /ha/yr (Temmerman et al., 2005).

Mechanical properties

a.	Cellulose/lignin/silica content	:	Cellulose 56.8 %; hemicellulose 12.1 %; lignin 31.15 % (Depuydt et al., 2019).
b.	Fibre length	:	1.38 mm (Haun et al., 1966).
c.	Fibre diameter	:	1.02 µm (Haun et al., 1966).

Genetic diversity and conservation status: No efforts to conserve the species or carry out selections for improvement are known.

Uses

a. Traditional: Edible shoot production, some cultivars for ornamental purpose, woven articles, handles for farm tools.
b. Industrial: Pulp industry, edible shoots.
c. Potential: Ecosystem services.

Key ecosystem service values: *P. vivax* grows well in coastal regions, and it has been shown that this species can be used to protect coastal areas from erosion and in restoration programmes on land with a high saline content (Li et al., 2021).

Research gaps: Potential of this species for carbon sequestration should be studied. Studies on genetic variability and largescale propagation including tissue culture are needed.

Information Gaps: Information of flowering cycle, seed production and propagation methods are not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

40. *Pseudoxytenanthera stocksii* (Munro) T.Q. Nguyen

Synonyms (Vorontsova et al., 2016): *Oxytenanthera stocksii* Munro; *Pseudotenanthera stocksii* (Munro), *Gigantochloa stocksii* (Munro) T.Q. Nguyen, *Dendrocalamus stocksii* (Munro).

Common names (language/area in parenthesis)*: Saeme bamboo, Manga Bamboo* (Goa, India) *Konda*, *Oor-shema*, *Maarihal* (Karnataka, India)*; Chivari*, *Mes* (Maharashtra, India).

Description: *P. stocksii* is a medium-sized, loosely clumped bamboo with pachymorph short-necked rhizomes. The grey-green culms grow up to 8–9 m high with a diameter of 2.5–5.8 cm. The internodes are long (15–30 cm) with a solid base (usually up to the 6th node) and wall thickness of 12.18 mm (middle) and 7.12 mm (top) (Kaushal et al., 2021). The nodes are flat with a pubescent ring and self-pruned branches up to the 5th or 6th node from the base (Viswanath et al., 2013).

Distribution

a. Native range: India, Viet Nam.
   Indian Subcontinent: India.
   Indo-China: Viet Nam.

b. In cultivation/naturalised in:
   Indian Subcontinent: India [Karnataka].

Climatic parameters: This species grows well in an elevation of 19–2000 m with an extreme maximum of 9000 m. Annual rainfall should be 3000–4000 mm and mean temperature 24°C.

Soil: *P. stocksii* requires a well-drained, deep, loamy soil with pH 5.35–6.14. The soil organic carbon of this species' growing area is 1.91–4.47 mg/cm^3 (Kaushal et al., 2021, Lubina et al., 2019). The natural distribution of this species is in humid tropics with lateritic soil type. It has a wide adaptability and comes up well in sub humid and semi-arid conditions on black and red soils.

Native habitat: *P. stocksii* is known only in cultivation. This bamboo is mostly confined to the banks of streams and mostly found in homesteads and cultivated area such as arecanut gardens and paddy fields. It is native to the Western Ghats region of India and found cultivated in the coastal belt of Karnataka and Himalayan foothills of India.

Propagation

a. Natural: Sporadic and gregarious flowering have been reported in this species (Beena et al., 2007) with no seed setting.

b. Clonal propagation: Splitting of rhizomes (Reddy and Yekanthappa, 1989) is found to be a very efficient propagation method. Two-node culm segments (from 1.5/2-year-old culms) with viable healthy buds at the nodes are used with hormone treatment (Banik, 2016). Pre-rooted branches from culm nodes have also been used successfully in this species (Banik, 2016).

c. Tissue culture: Micropropagation is successful through axillary bud proliferation (Sanjaya et al., 2005; Vidya, 2019) and somatic embryogenesis (Vidya and Muralidharan, 2013, Somashekar et al., 2018). Commercial micropropagation is also well established.

Cultivation

a. Plantation type: Home gardens or as pure block plantations; commonly planted as live fences or on farm boundaries.

b. Spacing: 5x5 m or 4x4 m for dense plantations (Viswanath et al., 2013).

c. Possible species mixed: Finger millet, areca nut, pepper.

d. Years to maturation: 5.

e. Shooting season: June–August.

Productivity

a.	Culm production	:	11.8 culms/clump and 6018 culms /ha at the sixth year after planting (Subbanna and Viswanath, 2018).
b.	AGB	:	Not reported.
c.	Annual C sequestered	:	Not reported.
d.	Soil Organic Carbon	:	1.91–4.47 mg/cm^3 (Kaushal et al., 2021; Lubina et al., 2019).
e.	Allometric equations	:	Not reported.

Mechanical properties

a.	Specific gravity	:	0.691 (Banik, 2016).
b.	Density	:	1.52 ± 0.083 Mg/m^3 (Kaushal et al., 2021).
c.	MOE	:	386 kg/cm^2 (Banik, 2016).
d.	MOR	:	610 kg/cm^2 (Banik, 2016).
e.	Fibre length	:	3.4 mm (Rao et al., 2004).
f.	Fibre diameter	:	16.6 µm (Rao et al., 2004).
g.	Runkel ratio	:	1.9 (Viswanath et al., 2013).

Genetic diversity and conservation status: Due to poor seed setting and the non-gregarious nature of this bamboo, genetic diversity could be highly restricted and continuous vegetative propagation from a narrow genetic base could have serious implication for conservation of the species. Extensive survey and collection of germplasm, establishment of live germplasm collections (BSKKV, Dapoli; College of Forestry, Sirsi and IWST, Bangaluru) and trials and selection of superior genotypes have been carried out.

Uses

a. Traditional: House construction, scaffolding, basketry, crafts, tools, edible shoots, stakes in agriculture, umbrella handles, walking sticks, as a navigation tool in country boats.

b. Industrial: Modern construction, pulp and paper, furniture making.

c. Potential: Substitute for cane and rattan in the bamboo-based furniture industry.

Key ecosystem service values: This species has great potential for social forestry, agroforestry, and coastal zone forestry.

Research gaps: The potential of this species for carbon sequestration has not been evaluated. Multilocational trials and agroforestry trials should be carried out since the species has tremendous potential as a commercial species.

Information Gaps: The species has been planted in several states of India outside in native range but information on its performance in these areas needs to be collected.

Habitat

Culm and branching pattern

New shoot

Culm sheath

41. *Schizostachyum pergracile* (Munro) R.B. Majumdar

Synonyms (Vorontsova et al., 2016): *Cephalostachyum pergracile* Munro; *Oxytenanthera aliena* McClure.

Common names (language/area in parenthesis): *xiang nuo zhu* (China), *Bhalan bans; Madang; Wootang; Latang; Dangi* (India) *Pungsangl*, *Gulhang/Goekhang* (India).

Description: *S. pergracile* is a medium-sized bamboo with straight culms and short-necked pachymorph rhizomes. Culms are apically drooping and have a height of 7–20 m with an average of 9 m (Flora of China, 2006; Durai and Long, 2019). Culm have a diameter of 5–7 cm, internodal length of 30–45 cm (Flora of China, 2006; Benton, 2015) and the nodes are flat.

Distribution

a. Native range: India to South Yunnan in China.
China: China South Central.
Indian Subcontinent: Assam [Manipur, Nagaland], Bangladesh, Eastern Himalaya [Arunachal Pradesh], India [Andhra Pradesh, Bihar, Chhattisgarh, Madhya Pradesh, Maharashtra, Orissa] (Naithani et al., 2010).
Indo-China: Laos, Malaya.
Malesia: Java.

b. In cultivation/naturalised in:
China: China South-Central [Yunnan] (Benton, 2015).
Indo-China: Myanmar, Thailand.

Climatic parameters: This species grows profusely at 50–1200 m elevation (Flora of China, 2006). Durai and Long (2019) reported its distribution up to 1500 with ideal of 500–1200 m. S*. pergracile* tolerates -6 °C and prefers normal temperature of 22–23 °C with annual precipitation of 800–1000 m (Durai and Long, 2019).

Soil: The species is most common in well drained, loamy soils in Myanmar (Durai and Long, 2019) but is also suitable for sandy, heavy clay and red soils (Guadua Bamboo 2021)*; Soil organic content of this area is 1.38–1.52 % with pH 5.5–6.4 (Thokchom and Yadava, 2017). This bamboo thrives in well-drained loamy soils.

Native habitat: This species is found on lower hills, in mountain valleys, and in mixed deciduous forests near streams up to an altitude of 1000 m (Guadua Bamboo 2021)*. It widely grows in semi-humid to semiarid regions in association with trees such as *Phoenix sylvestris, Terminalia citrina, Castanopsis hystrix, Curcuma augustifolia* and *Smilax* sp. (Thokchom and Yadava, 2017). In moist deciduous forests it co-exists with teak, *Bambusa polymorpha* or *Dendrocalamus membranaceus*, but in the drier forests, where it is found with *Dendrocalamus strictus*, it is stunted in growth (Guadua Bamboo 2021)*. In central India the species is associated with *B. tulda* and *B. bambos.*

Propagation

a. Natural: Flowering in the species is more commonly sporadic without seed set, but gregarious flowering occurs at intervals of 7–15 years (Guadua Bamboo, 2021) *.

b. Clonal propagation: Seedling macroproliferation. Rhizome offsets from 1- to 2-year-old culms are used for propagation (Benton, 2015; Durai and Long, 2019). Culm cuttings have also been used successfully (Seethalakshmi and Muktesh Kumar, 1998; Durai and Long, 2019).

c. Tissue culture: Only one report (Prutpongse and Gavinlertvatana, 1992) without much detail, is available for the species.

Cultivation

a. Plantation type: Block plantation, agroforestry, ornamental.
b. Spacing: 3x3, 4x4 m; 8x8 m (Seethalakshmi and Muktesh Kumar, 1998).
c. Possible species mixed: *B. tulda, B. nutans*, teak, agroforestry with pulses, vegetables.
d. Years to maturation: 3–4.
e. Shooting season: June–August.

Productivity

a. Culm production : 61.85 Mg/ha (Thokchom and Yadava, 2017); 7 t/ha of air-dried culms/year (Guadua Bamboo 2021)*.
b. AGB : 143.1 to 202.62 Mg/ha (Thokchom and Yadava, 2017).
c. Annual C sequestered : Vegetation: 64.65–91.48 Mg/ha; Soil: 53.25 Mg/ha (Thokchom and Yadava, 2017).
d. Allometric equations :

Myanmar (Fukushima et al., 2007)	$Cb = 0.089\ D^{2.35}$ Cb = culm dry biomass (kg), D = diameter at breast height (cm)

Mechanical properties

e. Cellulose/lignin/silica content : Lignin 24.9 %.
f. Fibre length : 2.1–2.48 mm (Seethalakshmi and Muktesh Kumar, 1998).
g. Fibre diameter : 16.46 µm (Seethalakshmi and Muktesh Kumar, 1998).
h. Kappa No. : 28.2 (Singh and Bhola, 1978) cited by (Seethalakshmi and Muktesh Kumar, 1998).

Genetic diversity and conservation status: No information is available on the genetic diversity of the species and any efforts on conservation.

Uses

a. Traditional: Handicraft, weaving (Benton, 2015), whole culms in construction, edible shoots (Long and Durai, 2019), ornamental, lacquerware (Seethalakshmi and Muktesh Kumar, 1998), mats (Seethalakshmi and Muktesh Kumar, 1998; Durai and Long, 2019), containers for cooking rice.
b. Industrial: Paper pulp (Seethalakshmi and Muktesh Kumar, 1998).
c. Potential: Engineered bamboo, ecological restoration, bioenergy.

Key ecosystem service values: The species is adapted to drier areas with low rainfall and therefore can be ideal for ecological restoration programmes.

Research gaps: Physicochemical characterisation of the species is needed to explore the scope for other value chains.

Information Gaps: Data to be collected for several parameters.

* Secondary and unverified source of information.

Habitat

Culm and branching pattern

New shoot

Culm sheath

42. *Schizostachyum zollingeri* Steud.

Synonyms (Vorontsova et al., 2016): *Melocanna zollingeri* (Steud.) Kurz ex Munro.

Common names (Language/area in parenthesis): *Buluh kasap, Buloh nipis, Buloh dinding, Buloh telo* (Malaysia); *Pring Rampal* (Malang); *Mai hea* (Japan); *Phai-miangfai* (Thailand); *Bambu lampar* (East Java), *Buluh telor, Buluh nipis* (Sumatra, Indonesia).

Description: A non-tufted bamboo with pachymorph short-necked rhizomes and slender, straight culms with drooping whip-like tips. The inflexible culms attain a height of 6–22 m (Rahayu and Ervianti, 2020; Abdulla Siam et al., 2019) and a diameter of 2–8 cm with an average of 5.4 cm at DBH (Mohamed et al., 1991). The internodes are long, 46.5–79.4 cm, and wall thickness reaches to 4.6–3.9 mm (Mohamed et al., 1991). Branches are typically borne at the middle of the culm, with a cluster of slender subequal branches (Rahayu and Ervianti, 2020).

Distribution

a. Native range:
   Indo-China: Laos, Viet Nam.
   Malesia: Borneo, Jawa, Malaya, Sumatera.

Climatic parameters: *S. zollingeri* grows in a temperature range of 25–34 °C and precipitation in the range of 400–4220 mm. The species commonly grows at elevations of 50–200 m but is also successfully grown at higher elevations of up to 400 m (Dransfield and Widjaja, 1995).

Soil: It will grow in any well-drained soil but prefers sandy loams or clay loams (Dransfield and Widjaja, 1995). The species grows on soils with soil organic content of 7.07–15.31 % and pH of 3.9–4.7. This species can survive long drought.

Native habitat: *S. zollingeri* is distributed in dense forest but more often in disturbed areas such as forest edges and forest clearings (Rahayu and Ervianti, 2020). It is often found growing together with *Gigantochloa ligulate* in Peninsular Malaysia.

Propagation

a. Natural: Sporadic flowering is seen in the species in every year but annual gregarious flowering during dry season also reported. Abundant seed were produced after the gregarious flowering with more than 80 % germination retained after 1 month and 50 % after 2 months of collection (Dransfield and Widjaja, 1995).
b. Clonal propagation: Rhizome cuttings have been found to be successful for propagation in this species (Dransfield and Widjaja, 1995). Culm cuttings from the top and middle portions are commonly used for large-scale planting with a success rate of 100 % (Dransfield and Widjaja, 1995).

Cultivation

a. Plantation: This species is not commonly under cultivation.
b. Spacing: It is usually grown in 4x4 m or 6x6 m (Dransfield and Widjaja, 1995).
c. Years to maturation: 3–5.
d. Shooting season: June–September.

Productivity

a. Culm production : According to the Tropical Plants Database (2021), this species produces 2000–3200 culms/ha.

b. AGB : Estimates of 17–27 tons/ha have been reported (Tropical Plants Database, 2021).

c. Allometric equations :

Malaysia (Mohamed et al., 1991)	y =- 53.1224+ 976.808 x y is volume (cm3); x is weight (kg); (r^2=93.08%)

Mechanical properties

d. Density : 355 (Abdulla Siam et al., 2019).

e. Cellulose/Lignin/ silica content : Cellulose 71.6 %; lignin 21.4 %; (Nor Aziha and Azmy, 1991).

f. MOE : 9717 N/mm^2 (Abdulla Siam et al., 2019).

g. MOR : 143 N/mm^2 (Abdulla Siam et al., 2019).

h. Fibre length : 2.32 mm (Abdulla Siam et al., 2019).

i. Fibre diameter : 14.8 µm (Abdulla Siam et al., 2019).

Genetic diversity and conservation status: A small germplasm collection of *S. zollingeri* has been established in Lumpung, Sumatra.

Uses

a. Traditional: Handicrafts, satay sticks, basketry, toothpick, water container, skewer sticks.

b. Industrial: Toothpick, skewer sticks, paper pulp.

c. Potential: Matboard and oriented strand board.

Key ecosystem service values: Not reported.

Research gaps: *S. zollingeri* is a variable species without any breeding programmes, so establishment of more germplasm collections and selections of superior clones are necessary. Development of various large scale propagation methods such as tissue culture are required. The strong flexible screens made from its long culms has great potential that needs to be developed.

Information Gaps: Details of cultivation practices are not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

43. *Thyrsostachys oliveri* Gamble

Synonyms: Nil.

Common names (Language/area in parenthesis): Oliver bamboo; *Kanak Kaich, Busai, Nusai* (Northeast India); *Nala bauns* (Odisha, India); *Keirakwa* (Manipur, India); *Lathi mula* (Kerala, India); *Rupai*, *Rangoon bans* (Bangladesh); *Phai ruak dam* (Thailand); *Thanawa* (Myanmar).

Description: *T. oliveri* is a seasonal deciduous bamboo with tightly packed culms and short-necked pachymorph rhizomes. The straight culms attain height of 15–25 m (Banik, 2016) and have a slight drooping at the tip. The diameter of the culms ranges from 2.5–6 cm with an average of 4.24 cm. The wall thickness of the species is between 26.1–1.5 mm from base to top and an internodal length of 30–55 cm (Banik, 2016). Branches are produced only from the upper nodes of the culm. Nodes are hardly prominent but have persistent culm sheath.

Distribution

a. Native range:
   China: China South-Central.
   Indo-China: Laos, Myanmar, Thailand.

b. In cultivation/naturalised in:
   Indian Subcontinent: Assam, Bangladesh, East Himalaya [Arunachal Pradesh], India [Kerala, Tamil Nadu, Uttar Pradesh] (Banik, 2016).

Climatic parameters: *T. oliveri* prefers to grow in areas with mean annual temperatures about 20°C and annual rainfall exceeding 1500 mm. The distribution of this species found at elevations of 700–1300 m.

Soil: *T. oliveri* grows well on moist sandy clay loam, alluvial soils and on well-drained residual soils. The species' growing area has soils of pH 6–8 on plains and pH 4.5–5.5 on the hills.

Native habitat: The species is commonly distributed in the mixed deciduous forests and found in association with teak (Banik, 2016).

Propagation

a. Natural: Flowering cycle of *T. oliveri* is reported as 47–50 years (Banik, 2016). This species produces seeds of weight varying from 0.62–0.73 g for 40 seeds (Banik, 2016) with 100 % germination soon after collection (Seethalakshmi and Muktesh Kumar, 1998).

b. Clonal propagation: Rhizome offsets planted at the spacing of 2.7x1.8 m produced the highest percentage of shoot responses, with an average number of shoots of 30.6/culm (Debbarma et al., 2014). Banik (2016) reported that propagation through culm cutting with two- to three-node segments collected from 20- to 30-month-old culms gave a success rate of 40–45 %. Branch cuttings and air layering also gave 30–50 % success in this species (Banik, 2016).

c. Tissue culture: Plantlet production through axillary bud proliferation (Islam and Rahman, 2005) has been reported.

Cultivation

a. Plantation type: This species cultivated in block plantation as well as strip plantations.

b. Spacing: A spacing of 5×5 m or 6×6 m is reported for block plantations (Banik, 2016) whereas 0.75x0.75 m or 1x1 m is typically adopted for live fences.

c. Possible species for mixed plantations: Plantations of bamboo are intercropped with kokum, jack fruit, mango, cashew nut and rubber in the southern regions of India (Jayasankar et al., 1997). In a widely spaced (5×5 m) plantation, intercropping was successfully carried out with ginger, pineapple, turmeric, cowpea, peanut, maize and mustard (Banik, 2016).

d. Years to maturation: 3–5 (Banik, 2016).
e. Shooting season: May–August (Banik, 2016).

Productivity

a.	Culm production	:	Jijeesh (2014) reported the production of 3725 culms/ha seven years after planting.
b.	AGB	:	Appraisals of 44.11 ± 4.96 and 50.04 ± 14.13 Mg/ha during the sixth and seventh year respectively (Jijeesh and Seethalakshmi, 2020) have been reported.
c.	Annual C sequestered	:	Jijeesh and Seethalakshmi (2020) reported data on carbon sequestration as 20.92 ± 2.12 and 23.92 ± 6.14 Mg/ha during the sixth and seventh year respectively.
d.	Allometric equations	:	Not reported.

Mechanical properties

a.	Specific gravity	:	0.758 (of air-dry bamboo) (Banik, 2016).
b.	Cellulose/lignin/silica content	:	Cellulose 60 %, Lignin 27 % (Seethalakshmi and Muktesh Kumar, 1998).
c.	MOE	:	12.2 kN/mm^2 (Banik, 2016).
d.	MOR	:	917.7 kg/cm^2 (Banik, 2016).
e.	Fibre length	:	2.50 mm (Seethalakshmi and Muktesh Kumar, 1998).
f.	Fibre diameter	:	15.47 µm (Seethalakshmi and Muktesh Kumar, 1998).

Genetic diversity and conservation status: The Forestry Master Plan of Bangladesh implemented an *in situ* conservation of bamboo stands of *T. oliveri* in natural ecosystem with two zones, i.e., core zones and buffer zones. The buffer zones can be utilised by the people of adjacent village for their own needs whereas the core areas consist of permanent plots for bamboo.

Uses

a. Traditional: Handicrafts, weaving, whole culms in construction, water pipes, basket and mat making, roof thatching, edible shoots, fodder.
b. Industrial: Javelin, fishing rod, range of furniture such as table, chair, sofa sets, cot, room partitions, handicrafts etc. charcoal.
c. Potential: Commercial plantations for fibre, biofuel, biorefinery, charcoal etc.

Key ecosystem service values: The preference for the species by farmers for agroforestry due to the erect clusters of culms and small canopy as well as its graceful foliage used as fodder encourages its widespread use as a soil binder and stabiliser of streams and ponds.

Research gaps: A great variation has been reported on this species and hence a detailed genetic diversity and variability analysis is required. An accelerated decline of natural stands of *T. oliveri* erode the genetic resources of this species and therefore, there is an urgent need to conserve genetic resources of bamboo both in their natural habitat (*in situ*) and in *ex situ* conservation plots.

Habit

Culm and branching pattern

New shoot

Culm sheath

44. *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 parenthesis): *Pai Ruak* (Thai); Monastery bamboo, Umbrella-handled bamboo, Thai bamboo (English); *Shamu dake* (Japanease); *Bambu Jepang, Bambu Payung* (Indonesian); *Tam Vong* (Viet Nam); *Tiyowa, Kyaung-Wa* (Myanmar).

Description: A seasonal, deciduous, tightly clustered species with short-necked pachymorph rhizome. The culms reach a height of 8–16 m (Narasimhamurthy et al., 2013) and are mostly erect or gently arching with weeping tops. Culm have a diameter of 3–8 cm (Benton et al., 2011). The culms are solid at base but with 8.89 mm wall thickness at the top (Sompoh et al., 2013). The internodes are 15–38 cm long (Benton et al., 2011; Narasimhamurthy et al., 2013). Branches grow from mid-culm nodes upwards (Roxas, 2012). Nodes are flat with a sheath (Roxas, 2012).

Distribution

a. Native range:
   China: China South-Central.
   Indo-China: Laos, Myanmar, Thailand, Viet Nam.

b. In cultivation/naturalised in:
   Indian Subcontinent: Bangladesh, Sri Lanka.
   Malesia: Malaya.

Climatic parameters: This species prefers an altitude of 300–1000 m with annual precipitation of 100–2000 mm and temperature of 23–30 °C.

Soil: *T. siamensis* grows well in a wide range of soils, especially sandy loam to clay loam, provided it is not waterlogged. The soil organic content of this bamboo is 58.96 Mg/ha (Pibumrung et al., 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 and under canopy in association with *Anomianthus dulcis, Bauhinia malabirica, B. scandens, Ceasalpinia sappan, Zollingeria dongniaensis, Xylia xylocarpa* and *Homalium tomentosum* (Chaiyarat, 2018) and *Tectona grandis*.

Propagation

a. Natural: Sporadic and gregarious flowering cycles are reported in this species. Sporadic flowering is reported every November-February in Thailand. Seed weight is 10–82 seeds/gram with germination potential of 7–86 % (Banik, 2016) depending on the seed size.

b. Clonal propagation: Propagation with rhizomes of 1-year-old culms is the widely accepted method which has been found to be very successful (Banik, 2016). Both culm (two-noded segments) and branch cuttings with hormone treatment gave improved results for propagule production (Banik, 2016).

c. Tissue culture: Plantlet production through axillary bud proliferation (Banik et al., 1993) and somatic embryogenesis (Obsuwan et al., 2019) have been reported.

Cultivation

a. Plantation type: This species is ideal for strip plantation on roadsides at closer spacing of two to three rows (Banik, 2016) and block plantations (Benton et al., 2011).

b. Spacing: The optimum spacing for block plantations is 4×4 m (Benton et al., 2011).

c. Other potential species for mixed plantation: Intercropping with timber trees such as teak (Dransfield and Widjaja, 1995).

d. Years to maturation: 3–4.

e. Shooting season: May–July.

Productivity

a. Culm production : An average of 28 culms/clump in a three-year-old seed-raised plantation (Dransfield and Widjaja, 1995), 1500 culms/ha. (Scurlock et al., 2000).

b. AGB : 11 to 54 t/ha. (Scurlock et al., 2000); 26.98 (culm) and 4.22 (leaf and branch) t/ha (Chaiyo et al., 2011) have been reported.

c. Allometric equations :

North-eastern Thailand (Leksungnoen, 2017)	logY = 1.072 X + 2.180 (culm) logY = 0.717 X + 1.784 (leaf)
Laos (Xayalath et al., 2019)	AGB(kg)=0.0685*$DBH^{2.6746}$ (r^2=0.9131) AGB(kg)=0.0285*$(DBH^2H)^{0.9144}$ (r^2=0.9280)
Reunion Island (Piouceau et al., 2014)	y = 1015(1052 bx^a 2320) R^2(%) =91.6∗ y = Total above ground fresh biomass (g); x = Basal diameter (mm).

Mechanical properties

a. Specific gravity : 0.73 (Sompoh et al., 2013); 718 (base) 712 (middle) 450 kg/m^3 (top)-node (Narasimhamurthy et al., 2013); 654 (base) 541 (middle) 415 kg/m^3 (top)-internode (Narasimhamurthy et al., 2013).

b. Basic density : 845 kg/m^3 (Sompoh et al., 2013); 0.41(base), 0.46 (middle), 0.62 g/cm^3 (top) (Hoang and Tang, 2007).

c. Cellulose/lignin/silica content : Cellulose 63.8 %, Lignin 29.2 % (Ho, 2011).

d. MOE : 177 MPa (Sompoh et al., 2013); 7091 Mpa (Narasimhamurthy et al., 2013); 6575 MPa (Hoang and Tang, 2007).

e. MOR : 131 Mpa (Sompoh et al., 2013); 124.2 Mpa (Narasimhamurthy et al., 2013); 68 MPa (Hoang and Tang, 2007).

f. Fibre length : 3.14 mm (Dransfield and Widjaja, 1995).

g. Fibre diameter : 17.1µm (Dransfield and Widjaja, 1995).

Uses

a. Traditional: Handicrafts, whole culms in construction, baskets, chopsticks, umbrella and broom handles, handicrafts, fishing rods, ornamental plants, windbreak, and edible shoots.

b. Industrial: Laminated bamboo, paper pulp, charcoal and as fuel.

Key ecosystem service values: *T. siamensis* is widely cultivated in many countries for its ornamental and religious value. It is of significance for land restoration programmes, where it can provide many ecosystem services such as water conservation, erosion control etc.

Research gaps: No germplasm collections or breeding programmes are known for *T. siamensis* and therefore the narrowing of genetic variability under clonal propagation is a risk. Due to its high potential for culms and edible shoots, establishment of plantations are required to avoid overexploitation of natural stands. Proper studies on efficient cultivation and management of this species are also highly recommended.

Information Gaps: Additional data on many mechanical and chemical parameters are required to explore other potential applications.

Habit

Culm and branching pattern

New shoot

Culm sheath

Additional list of economically important bamboo species

1. *Bambusa cacharensis* R.B. Majumdar

Common names: *Bom bans, Pechee* (West Tripura-India); *Bethua* (North Tripura, Cachar-India), *Ba* (Jaintia, Meghalaya-India), *Moral*, *Sonarati*, *Bethua* (southern Meghalaya-India); *Bethua* (Sylhet-Bangladesh).

The species is a large evergreen loosely clumping species with short-necked pachymorph rhizomes. Culms of the species reach 15–29 m in height and 3–11 cm in diameter. Internodes are 42-95 cm long and culm wall thickness 0.2–1.5 cm. Nodes are slightly prominent and lower nodes have root hairs. Branching is seen in the upper nodes (Banik, 2016).

The species is native to Assam and Bangladesh in the Indian Subcontinent and is commonly cultivated in home gardens in Meghalaya and other states of Northeast India and in Bangladesh. The species grows in humid tropics in river valleys and in mixed moist deciduous to semi-evergreen forest. It grows in moist and well-drained soils and at elevations of 20–300 m and prefers red soil with good humus content (Banik, 2016).

Flowering cycle is estimated to be 30 yr., but sporadic flowering with survival of clumps appears to be more common. Propagation through seeds (50–70 %), seedling macroproliferation (80–90 %), rhizome offsets (40–75 %), two-noded culm cuttings from one- to two-year-old culms (50-55 %) and through branch cuttings (45–55 %) has been reported to be successful (Banik, 2015a). Tissue culture methods are available. Cultivation in plantations is done at 4x4 m or 5x5 m spacing (Banik, 2016). New shoots emerge from May-October. On average, 4–7 culms are produced annually per clump (Banik, 2016).

Soil carbon stock (26–35 Mg C/ha) and sequestration rate (0.28–0.59 Mg C/ha/year) (Nath et al., 2015). Sattar et al. (1992) have studied the mechanical properties of the species. The specific gravity of oven-dried culms is 0.79–0.84. The MOE of air-dried culms ranges from 60–96 1000 kg/cm^2 and the MOR from 556–414 kg/cm^2 from base to top.

Three types are recognised (Banik, 2016): The common type with 18-24 m tall culms with diameter of 5-8 cm and smaller leaves always in the upper 1/3 of the height. (ii) “Pechee bom” bash that have compact clumps with shorter (10–16 m) and slender culms (3–5 cm diameter) and (iii) ‘Jati Bom’ type with less branched clumps that have tall loosely clustered culms (25–29 m) with a diameter of 9–11 cm.

The species is used for weaving mats, ceilings, and walls in in traditional construction, chopsticks, spoon and toothpicks, for manufacture of flooring tiles, for its edible shoots and for fodder (Banik, 2016).

Research and information gaps: Data on productivity and genetic variability are needed to explore scope for other applications.

Habit

Culm and branching pattern

New shoot

Culm sheath

2. *Bambusa chungii* McClure

Synonyms: *Lingnania chungii* (McClure) McClure; *Lingnania chungii* var. *petilla* T.H. Wen; *Bambusa chungii* var. *petilla* (T.H. Wen) Ohrnb.9; *Lingnania chungii* var. *barbellata* Q.H. Dai; *Bambusa chungii* var. *barbellata* (Q.H. Dai) Y.M. Lin & Q.F. Zheng (Vorontsova et al., 2016).

Common names: Emperor's Blue bamboo, *fen dan zhu* (China) *phai chung, phai chungyi* (Thailand).

B. chungii is a medium sized clumping bamboo with short-necked pachymorph rhizomes. Culms are erect and reach a height of 5–18 m and diameter of 3–7 cm. The internodes are 30–45 cm, sometimes even up to 100 cm in length.

B. chungii occurs naturally in China (South-Central and Southeast) and Indo-China (Viet Nam). The species grows at elevations of 100–500 m in lowland hilly areas (Flora of China, 2006). Grows in sandy loam to clay loam soils with a pH range of 5.5–6.5 with good drainage. Young shoots emerge March–September.

Three-year-old culms contain 71.70 % holocellulose, 22.70 % lignin and 1.50 % ash (Fei et al., 2016). The species is used for paper making, basketry and for weaving. It is grown for ornamental use.

Research and information gaps: Information of physicochemical properties, genetic variability and cultivation practices is not available.

Habit

Culm and Branching pattern

3. *Chimonobambusa tumidissinoda* Ohrnb.

Synonyms: *Chimonobambusa tumidinoda* T.H. Wen; *Qiongzhuea tumidinoda* Hsueh f. & T.P. Yi; *Qiongzhuea tumidissinoda* (Ohrnb.) Hsueh f. & T.P. Yi (Vorontsova et al., 2016).

Common names: *fang zhu, qiong zhu* (Chinese).

A medium sized shrubby running bamboo with diffuse culms and leptomorph rhizomes. Culms reach a height of 2.5–6 m and a diameter of 1–3 cm. Internodes are 15–25 cm in length and nodes are swollen and prominent with a disc shape. Nodes are nearly solid at base (Taihui, 1994; Flora of China, 2006).

The species is naturally distributed in China (Sichuan and Northeast Yunnan). The species grows on hilltops at elevations of 1400–2600 m in broadleaf forests. The annual rainfall in the area is 1400 mm and humidity 80–90 %. New shoots form in April and produce fleshy fruit (bacca) (Taihui, 1994; Flora of China, 2006).

The species is used for handicrafts, walking sticks, umbrella handles, construction, as ornamentals and for its edible shoots (Taihui, 1994).

Research and information Gaps: Information on propagation, cultivation, productivity, and mechanical properties are not available. Studies on the genetic variability and conservation of germplasm are also needed.

Habit

Culm and branching pattern

New shoot

4. *Chimonobambusa utilis* (Keng) Keng f.

Synonyms: *Oreocalamus utilis* Keng (Vorontsova et al., 2016).

Common names: *jin fo shan fang zhu* (China).

C. utilis is a medium sized running bamboo with leptomorph rhizomes. Culms are quadrangular at the lower nodes and reach a height of 5–10 m and diameter of 2–6 cm. Internodes are 20–30 cm long with wall thickness 6–8 mm and slightly prominent nodes with short spines (Taihui, 1994; Flora of China, 2006).

The species is naturally distributed in China (NE. Yunnan, Sichuan, Guizhou). It grows in areas with an average annual temperature of ~8.5 °C but tolerates low temperature of -14.1 °C. It grows at elevations of 1400–2250 m and at an average annual rainfall of I444–1800 mm in soil pH of 7 (Taihui, 1994).

The flowering cycle is about 40 years, and fruits are fleshy (bacca). The new shoots appear from July–October. Shoot production is 750–2250 kg/ha and growth is better under forest cover (Taihui, 1994).

C. utilis is used for handicrafts and ornamental articles. It is a preferred species for edible shoots.

Habit

Culm and branching pattern

New shoot

5. *Dendrocalamus somdevae* H.B. Naithani

Common name: *Magar* (India).

A large evergreen clumping bamboo with short-necked pachymorph rhizomes. Culms are erect and reach a height of 12–20 m and diameter of 6–7 cm. The internodes are 15–40 cm long and 2.5–3 mm thick. Nodes are prominent.

The species is naturally distributed in Western Himalaya and India (Uttarakhand, Himachal Pradesh). The species is very similar to *D. hamiltonii* in morphology and uses. It is used in construction, basketry and provides excellent fodder.

Eight selections of *D. somdevae* have made at FRI, India and five of them: FRI-HDS-2, FRI-HDS-6, FRI-HDS-7, FRI-HDS-8, FRI-HDS-9 propagated for further trials (Ginwal, 2021).

Research and information gaps: Information on propagation methods, cultivation practices, physicochemical properties are required.

Habitat

Culm Sheath

new shoot

culms and branches

6. *Dendrocalamus farinosus* (Keng & Keng f.) L.C. Chia & H.L. Fung

Synonyms: *Sinocalamus farinosus* Keng & Keng f. *Lingnania farinosa* (Keng & Keng f.) Keng f., Neosinocalamus *farinosus* (Keng & Keng f.) Keng f. & T.H. Wen, *Dendrocalamus farinosus* f. *flavostriatus* T.P. Yi, *Neosinocalamus farinosus* f. *flavostriatus* (T.P. Yi) Ohrnb., *Dendrocalamus ovatus* N.H. Xia & L.C. Chia. (Vorontsova et al., 2016).

Common names: *da ye ci* (Chinese) *phai paeng chin tai* (Thai).

D. farinosus is a medium sized clumping bamboo with short-necked pachymorph rhizomes. Culms are erect and reach a height of 7–12 m and diameter of 4–8 cm. Internodes are 10–45 cm long and thin walled (4–10 mm). Branching is from mid-culm upwards.

Distribution of the species is from South-Central and Southeast China to Viet Nam. It has been introduced into Ecuador successfully. The species tolerates up to-5 °C and grows at elevations of 500–1700 m.

Seed weight is 28-31 seeds/gram and seed germination rate is low (<40 %) (Bamboos of Thailand, 2022). Clonal propagation through rhizome offsets, culm and branch cuttings is practiced. Propagation through tissue culture is also feasible (Hu et al., 2011). A somaclonal mutant No.30 with high cellulose and lignin content, long fibre cells and high length-to-width ratio of fibre cell has been developed and characterised at a molecular level (Wand et al., 2017).

Yao et al. (2016) have estimated holocellulose (72.70 %), lignin (22.18 %) and ash content (1.24 %). The average module of elasticity (MOE) of single fibres is 26.93 GPa and the average tensile strength is 1.06 GPa (Yang et al., 2015). Fibre length is estimated at 2.25 mm and the fibre diameter, 13.96 µm (Fei et al., 2016).

The species is used traditionally for weaving, making farm tools, as edible shoots and as an ornamental. It has also been used in paper making.

Research and information gaps: Information on genetic variability, productivity in plantations is needed.

Habit

Culm and branching pattern

New shoot

Culm sheath

7. *Gigantochloa atter* (Hassk.) Kurz

Subspecies/variety/clone: *Bambusa thouarsii* var. *atter Hassk*.

Synonyms: *Bambusa atter* Kurz (Vorontsova et al., 2016).

Common names: Sweet bamboo, Giant atter (English); *Bambu ater, Bamboo Temen, Legi bamboo, Parring Bamboo,* Javanese bamboo (Indonesian); *Kayali* (Philippines); *Pring legi* (Javanese); *Pring keles* (Madurese); *Buluh jawa* (eastern Indonesia).

G. atter is a densely tufted, sympodial bamboo with pachymorph short-necked rhizome. The culms grow up to 15–22 m height with a diameter of 5–10 cm (Rifai, 1995). The internodes are 40–50 cm long with ~8 mm wall thickness. The nodes are prominent with aerial roots (Rifai, 1995).

The species is native to Indo-China (Laos, Viet Nam), Malaysia (Borneo, Jawa, Maluku, Philippines, Sulawesi, Sumatera) and Papua Sia (New Guinea). The species grows in regions from sea level to 1400 m with 1000-2500 mm rainfall and temperature range of 19–30 °C (Rifai, 1995). The species prefers latosols but can be grown also on alluvial, limestone, and sandy loam soils (Rifai, 1995) with pH 5.9-6.10.

Flowering cycle of this species has been reported as 50–60 years by Benton (2015).

Propagation with single nodal culm cuttings (Sutiyono, 1990) and branch cuttings in the field (Paembonan et al., 2019) have been reported. A successful tissue culture method has been developed by García-Ramírez et al. (2015).

G. atter is cultivated at a spacing of 7-8x7 m (Rifai, 1995). The mature culms are harvested at the year of 2nd or 3rd year of emergence. Annual culm production has been reported as 1200–1400 culms/ha (Rifai, 1995). Prayogo et al., 2021 have estimated the annual C sequestered to be 103.60-ton C/ha.

Allometric equations for estimating biomass is available:

Indonesia 1 (Baharuddin and Daud, 2013)	W= 0.348D$^{1.830}$ (Biomass) CS = 0.171 D$^{1.830}$ (Carbon)
Indonesia 2 (Prayogo et al., 2021)	Y= 1.0668 X $^{1.3539}$, where X =Diameter, in cm. (R^2 = 0.5029) Y= 0.0121 X $^{2.7886}$, where X = Height of bamboo culm, in m, (R^2 = 0.9198) Y=Dry weight, kg

Mechanical properties: The density of 40-month-old culms has been estimated by Marsoem et al. (2015) as 400 (base), 660 (mid) and 710 g/cc (top). They also report fibre length of 2.41 mm and diameter of 13.20 µm in the species. MOE of culms is reported to be 16.68 GPa (Abdullah et al., 2017) and the average MOR of air-dry culms 117.7 to 127.7 N/mm^2 (Prawirohatmodjo, 1990).

This species is widely used in for construction, handicraft, weaving and furniture industries. The young shoots are widely used as edible shoots. The species is suitable planting in buffer zone in ecological restoration programmes.

Research and information gaps: Status of genetic diversity, germplasm collections and conservation is not known.

Habit

Culm and branching pattern

New shoot

Culm sheath

8. *Gigantochloa levis* (Blanco) Merr.

Synonyms: *Bambusa levis* Blanco., *Gigantochloa scribneriana* Merr., *Dendrocalamus curranii* Gamble., *Gigantochloa heteroclada* Stapf, J. Linn, *Arundarbor levis* (Blanco) Kuntze (Vorontsova et al., 2016).

Common names: *Bulo semilang, Buloh seremai, Bolo* (Philippines); *Beting* (Malay); *Poring* (Dusun); *Buluh betung* (Brunei); *Buluh suluk* (Indonesia).

G. levis is a densely tufted clumping bamboo with short-necked pachymorph rhizome. Culm reach a height of 15–30 m and diameter of 5–16 cm. Internodes are 20–45 cm long and culm wall 1–1.2 mm thick. The nodes are prominent and with aerial roots (Roxas, 2012; Akinlabi et al., 2017).

The species is distributed naturally in China (China South-Central, China Southeast Yunnan, Guangdong), Indo-China (Viet Nam), Malesia (Borneo, Malaya, Philippines, Sulawesi, Sumatera) and is in cultivation in Taiwan.

This species grows well at an altitude of 500–1000 m along the riversides and valleys in red and yellow latosols and podzolic soils.

Propagation has been successful with rhizome offsets (Roxas, 2012), culm cuttings (Akinlabi et al., 2017) and branch cuttings (Othman, 2005). In tissue culture plant regeneration through somatic embryogenesis from zygotic embryos (Zamora et al., 1988) and axillary bud proliferation in nodal culture (Othman, 2005) has also been reported in this species.

AGB production was evaluated in the species comparing tissue culture raised plants (136.7 kg/ha) and those produced through culm cuttings (143.7 kg/ha) by Othman (2005). 73.4 Mg C/ha of C sequestration in AGB was estimated by Yuen et al. (2017).

Wahab et al. (2013b) have estimated the specific gravity at 0.75 and 85.08% holocellulose, 33.80 % α cellulose and 26.5 % lignin in the species. Estimates of MOE of 117.31 kg/cm^2 and MOR of 3793.31 have been reported (Wahab et al., 2013a). Zakikhani et al. (2017) reported a fibre length of 1.6–3.2 mm and a fibre diameter of 290.34–375 µm.

The use of the species includes artefacts or handicrafts, for construction and architectural works, furniture, walls, for household utensils, pulp, and paper. The species produces edible shoots good quality.

Research and information gaps: No Information on genetic diversity, germplasm collections or conservation is or on cultivation practices is available.

Habit

Culm and branching pattern

New shoot

Culm sheath

9. *Guadua paraguayana* Döll

Synonyms: *Bambusa paraguayana* (Döll) Bertoni (Vorontsova et al., 2016).

Common names*: Picana, Picanilla, Tacuara ganchosa* (Argentina); *Taquarembó´* (Bolivia) and *Picanilla* (Paraguay).

This is a clumping bamboo with short-necked pachymorph rhizomes with culms that reaches 13–18 m height. Internodes are solid and with a diameter 2–4 cm (Lizarazu et al., 2013). The nodal ridges have a clear sheath scar and claw shaped spines at the lower nodes.

The species is distributed naturally in south America from Bolivia to SE. & S. Brazil and NE. Argentina and Paraguay. It grows at a temperature range of 13.0–24.0 °C and 1400 and 1600 mm of rainfall. The natural habitat is banks of the rivers (Lizarazu et al., 2013).

Propagation is naturally through seeds and a flowering cycle of 38 years has been reported (Guerreiro, 2014) but data on propagation through germination is not available. Neither are any clonal propagation or tissue culture methods reported.

Galvão et al. (2012) report an annual C sequestration of 2800 kg/ha/year.

Brazil (Galvão et al., 2012)	Y = 0.0003x- 0.2568x + 97.13 with a correlation coefficient (R) of 0.9132. $Y = -0.8934x^2 + 2.9261x + 0.2446$, where Y is the amount of root (dry weight) in kg/m^3

The species finds use as posts, fences, flooring and decorative work, construction of traditional buildings (Lizarazu et al., 2013) and as edible shoots (Judziewicz et al., 1999). It is a species that is ideal for planting in wetlands.

Research and information gaps: No data on mechanical properties or on its status of genetic variability and conservation efforts is available.

Habit

Culm and branching pattern

New shoot

Culm sheath

10. *Guadua amplexifolia* J. Presl

Synonyms: *Arundarbor amplexifolia* (J.Presl) Kuntze; *Bambusa amplexifolia* (J.Presl) Schult.f.

Common names: Guadua, Colombian Timber Bamboo, Colombian Giant Thorny.

G. amplexifolia is a large evergreen clumping bamboo with pachymorph short-necked rhizomes. The culms grow up to 10–20 m and have a diameter of 6–10 cm. It has thick-walled or solid internodes of 5–20 cm length. Nodes have thorny branches with prominent white band (Pérez-Alquicira et al., 2021).

The species is naturally distributed from Mexico (Mexico Gulf, Mexico Southwest, Mexico Southeast), Central America (Costa Rica, El Salvador, Honduras, Nicaragua, Panamá), Northern South America (Venezuela) and Western South America (Colombia).

This species grows at elevations of 500–1500 m with tropical or subtropical climate and in areas with up to 2000 mm annual rainfall, in well drained alluvial soil. It grows along the riversides as a narrow but continuous band and occurs in open forest as pure stand or mixed trees and shrubs.

G. amplexifolia has a flowering cycle of 32–35 years but details of propagation through seeds are not available. Clonal propagation through culm cutting has been reported by Marquez de Hernandez and Marin (2011). The species is cultivated at a spacing of 200–500 plants/ha.

Mechanical and chemical properties:

a.	Cellulose/lignin/silica content	:	Cellulose 47.8 %, Hemicellulose 26.3 %, Lignin 21.5% (Salas-Enríquez et al., 2016).
b.	MOE	:	13,811.5 MPa (basal), 18,179.4 MPa (mid), 23,108.7 MPa (top) for fresh culm (Ordóñez-Candelaria, 1999).
c.	MOR	:	73.3 MPa (base), 92.63 MPa (mid), 103. 82 MPa (top) for fresh culm (Ordóñez-Candelaria, 1999).

Uses: *G. amplexifolia* is traditionally used for posts, fences, flooring and decorative work and as edible shoots. The culms have been used as frames of the roofs of rustic buildings (Lizarazu and Vega, 2012) and as edible shoots (Judziewicz et al., 1999). It is a potential species for activated charcoal production (Salas-Enríquez et al., 2016).

Research and information gaps: Genetic diversity and conservation status of the species is not known. Data on productivity as well as carbon sequestration potential are not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

11. *Guadua trinii* (Nees) Rupr.

Synonyms: *Bambusa trinii* Nees, Arundarbor *trinii* (Nees) Kuntze, Guadua *trinii* var. *scabra* Döll, *Bambusa tacuara* Arechav., Guadua *ribbentropii* Herter, Guadua *tomentosa* Hack. & Lindm., *Bambusa tomentosa* (Hack. & Lindm.) McClure, *Bambusa riograndensis* Dutra, *Guadua riograndensis* (Dutra) Herter, *Bambusa ribbentropii* Herter (Vorontsova et al., 2016).

Common names: *Tacuaruzú, Tacuara brava*, *Cañabrava, Yatevó, Tacuara* (Argentina); *Tacuara brava, Taquaruçu, Taboca, Taquara, Taquara-assú, Tacuarussú, Yatevo* (Brazil) (Judziewicz et al., 1999).

This is a densely clumped bamboo with short-necked pachymorph rhizomes with culms reaching a height of 8–10 m. The hollow culms have a diameter of 3–5 cm, wall thickness of 5–7 mm and internodal length of 50–55 cm (Lizarazu et al., 2013).

The species is native to Southeast and South Brazil to Northeast Argentina and Uruguay. It is naturally found on riversides in Atlantic forests, prefers sandy to silty, clayey soil and comes up well in areas with precipitation greater than 1000 mm and average temperatures of 16–18 °C.

Flowering cycle is reported as 30–33 years by Guerreiro et al. (2020). No information on propagation methods is available, including seed germination potential. This species is not under cultivation and therefore data on productivity, carbon sequestration potential and other parameters are also not available.

Prado Gárate et al. (2021) report a density of 0.53 g/cm^3, fibre length and diameter 1.044 mm and 24.4 µm respectively. The timber contains 23.9 % lignin and 65.6 % carbohydrates (Prado Gárate et al., 2021).

Traditionally the species is used to build huts, to make musical instruments, for rural construction. It has also been used in the paper industry. Information on ecosystem service values, genetic variability and conservation are not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

12. *Phyllostachys glauca* McClure

Subspecies/variety/clone: *Phyllostachys glauca var. variabilis* J.L. Lu; *Phyllostachys glauca f. yuozhu* J.L. Lu (Vorontsova et al., 2016).

Common names: Leopard bamboo, hedge bamboo.

This is a woody, perennial, and evergreen bamboo with leptomorph rhizomes. Culms of the species have brown spots and blotches and attain a height of 5–12 m and diameter 2–5 cm. Internodes are long and with a length of 40 cm and wall thickness of 3 mm. Nodes are slightly prominent.

P. glauca grows in China South-Central, China North-Central, China Southeast and is cultivated in the Eastern Himalayan region of the Indian Subcontinent. The species prefers to grow at a temperature range of 12–26 °C, precipitation of 800–1600 mm and grows well in alkaline soil.

Flowering cycle is reported as 50–60 years or 120 years by Zheng et al. (2020) but information on propagation, cultivation and productivity are not available.

Jiang (2016) report fibre length and diameter in the species as 1.11 mm and 9.79 µm respectively and 74.67 % cellulose content, 22.76 % of lignin and 0.18 % silica. This species is traditionally used for weaving, water pipes, furniture, for construction, as an ornamental and as edible shoots.

Research and information gaps: Large-scale propagation methods need to be standardised and physicochemical properties and carbon sequestration potential need to be assessed.

Habit

Culm and branching pattern

New shoot

Culm sheath

13. *Phyllostachys nidularia* Munro

Subspecies/variety/clone: *Phyllostachys nidularia f. farcta; Phyllostachys nidularia f. vexillaris; Phyllostachys nidularia f. glabrovagina; Phyllostachys nidularia f. mirabilis; Phyllostachys nidularia f. speciosa; Phyllostachys nidularia f. sulfurea.*

Synonyms: *Phyllostachys subulata, Phyllostachys cantoniensis* (Vorontsova et al., 2016).

Common names: Nidularia, Big-Node Bamboo, Broom bamboo.

P. nidualaria is running bamboo with a leptomorph rhizome and culms that reach a height of 4.4–6 m and diameter of 4 cm. The internodes are solid to nearly solid (3 mm) with 30–36.5 cm length (Stokes et al., 2007). Nodal ridge conspicuously elevated.

P. nidularia is native to Central and South China and is cultivated in the Wolong nature reserve, China. It grows well at altitude of 1800–2000 m region with temperature of 12.3–32.7 °C and precipitation of 1300–1450 mm. It grows on red clay soil accompanied by brown forest soil in mountainous regions at depth of 0.5–1.3 m (Stokes et al., 2007).

Frequent sporadic flowering was reported without seed production (Zheng et al., 2020).

Successful propagation through rhizome offsets was reported by Stokes et al. (2007). Cultivation details such as plantation type, possible species mixed, harvesting period etc are not available with this species.

Annual AGB of 38 t/ha (Zhang et al., 1996) and annual C sequestered of 26.7 Mg C/ha (Yuen et al., 2017) have been reported.

Jiang (2002) report Hemicellulose (21.91 %), Lignin (20.20 %), α-Cellulose (58.55 %) in the species. Jie et al. (2021) have elucidated the complete chloroplast genome of a solid form of the species.

The species is traditionally used for construction, furniture, water pipes. The shoots are a main food of giant panda. It is also used in paper industry. It is a suitable species for erosion control but as pure stand it is ineffective in preventing landslides (Stokes et al., 2007).

Research and information gaps: Data on physicochemical and mechanical properties in the species is needed. The genetic diversity and allometric equations for this species is not available.

Habit

Culm and branching pattern

New shoot

Culm sheath

14. *Phyllostachys propinqua* McClure

Synonyms: *Phyllostachys propinqua f. lanuginose.*

Common names: Beijing Bamboo, zao yuan zhu (Chinese).

This species is a medium sized running bamboo with culms attaining a height of 6 m and culm diameter of 3–4 cm. The internodes are 20 cm long and the wall thickness of 4 mm. The nodal ridges are slightly elevated and prominent as sheath scar.

It is a native of Southern China but cultivated in other parts of China. *P. propinqua* prefer sites with a warm, moist climate and the average annual temperature is 17.3 °C but tolerates extremes of 41. 0 °C and-11.4 °C. The annual average precipitation is 1621.9 mm The species is found growing on river sides and on red soil in hilly areas in clayey, barren soil or saline-alkali soil with pH 4.5–7.5 and soil organic matter is 43 g kg^{-1}.

Information on propagation methods is not available.

It is cultivated as block plantation at 900 plants/ha (Chen et al., 2005) and is used for ecological restoration planting. Culm production of 2970 fresh culms/ha in second year (Chen et al., 2005). New shoots form in late mid-season (McClure, 1957).

The species is traditionally used for weaving and for making tool handles but appears to have great potential for use in ecological restoration projects since it has good eco-adaptability for land restoration and erosion control (Chen et al., 2005).

Research and information gaps: Information on physicochemical properties, large-scale propagation methods and on the genetic diversity in the species or efforts at conservation is needed.

Habit

Culm and branching pattern

New shoot

Culm sheath

15. *Pseudoxytenanthera madhavii* sp.nov.

Common names: *Mes* (Maharastra, India).

P. madhavii is a deciduous gregarious loosely clumped bamboo with short-necked pachymorph rhizomes. The culms are erect and reach a height of 9–16 m and diameter of 6–10 cm (DBH of 8.5 cm). The internodes are 22–70 cm long, solid at base up to one meter and culm wall thickness ranging from 0.9–1.9 cm higher up. Branching is mid-culm upwards, and nodes are slightly swollen.

The species is found naturally and in cultivation in Pune and Satara districts of Maharashtra, India. It is native to moist and dry deciduous forests. The species grows on well-drained loamy soil.

Flowering in the species is sporadic and no seed set has been reported (Tetali et al., 2021). The species is propagated through rhizome offsets. Branch cuttings and tissue culture methods have not been standardised.

P. madhavii is cultivated as block plantations or as an agroforestry planting. A spacing of 4x4 m or 5x5 m is adopted. Intercropping with vegetable crops and agroforestry with tree crops such as mango and jackfruit are commonly practiced.

The species is used in construction. It has good potential for furniture and housing industry due to smooth surface, good mechanical strength, slivering, and strip making qualities.

The species is suited for stabilisation of hilly terrain in the humid tropics.

Research and information gaps: Studies on large scale propagation, physicochemical properties are required. Live germplasm collections and selection of superior genotypes for planting stock production are urgently needed.

Habit

Culm and branching pattern

New shoot

Culm sheath

16. *Schizostachyum dullooa* (Gamble) Majumdar

Synonyms: *Teinostachyum dullooa* Gamble; *Neohouzeaua dullooa* (Gamble) A. Camus (Vorontsova et al., 2016).

Common names: *Dullu* (Assam, Tripura, India); *wadlok* (Kokbarok, Tripura); *pogslo* and *puksalu* (Lepcha, India); *shlu* and *siej la* (Khasi, Meghalaya, India); *tarang* (Jaintia, Meghalaya, India); wadrow (Garo, Meghalaya, India); *unap* and *unal*, (Manipuri, Manipur, India); *guh* [Rongmai Naga, Tamenglong (Manipur)]; *rawthla* (Mizoram, India); *dalu bans* (CHT, Chittagong, Sylhet); *tokhre bans* (Nepal, Bhutan); *wa- byauk*, *gya-wa* and *thai-kwaba* (Myanmar); *lakhra* (Kachin).

The species is a medium-sized, evergreen, densely clumping bamboo with very short-necked pachymorph rhizomes. The culms are erect or scandent and reach a height of 8–22 m thin walled and a diameter of 3–7 cm. The culms have long internodes of 50–150 cm and with thin walls of 2–5 mm. Branches occur from mid-culm upwards.

The species is distributed from East Himalaya to Indo-China and mainly in Assam, Bangladesh, Myanmar and Viet Nam. *S. dullooa* is commonly found in moist semievergreen forests of the Northeast region of India. Moist and shady valleys are preferred sites for the species. It occurs as understory in the deciduous forests (Banik, 2016). The species prefers an average temperature range of 5–35 °C and annual rainfall of 3000–6000 mm and grows at elevations of 1200–2000 m (Banik, 2016). The species is seen on well-drained soil with low pH (4.5–6.5) and on soils originating from sandstones and capable of growing on the coarse-textured soil provided there is moisture (Banik, 2016).

The species has a flowering cycle of 35–47 years (Banik, 2016). Seed weight is 39–41 seeds/gram. Viability of seed is very short. Transplanting of wildlings (1–3 months old) from forest is recommended. Clonal propagation with one-node cutting and use of hormones is reported (Banik, 2016) and tissue culture are available for this species. The species is cultivated in plantation. Spacing of 3×3 m is recommended by Banik (2016) to obtain erect culms.

S. dullooa is considered as a threatened bamboo species of Northeast India and nearby Bangladesh forests (Banik, 2000); however, no efforts at conservation or study of genetic variability are known.

The species is traditionally used for making water containers, umbrella sticks, flutes, mats, baskets, and incense sticks. It has potential for manufacture of matboard.

The species provides an ideal habitat for voles, water rats, field mice, rodents, and pythons (Banik, 2016). Due to its adaptability to shady areas and understory of forest and gullies it has potential for ecological restoration of river and stream sides.

Research and information gaps: Studies on physicochemical and anatomical properties are needed to explore potential uses. Large scale clonal propagation methods would be useful for raising plantations.

Habitat

culm sheath

New shoot

branching pattern

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