# Distribution, Diversity and Prospects for Propagation of Industrially Suitable Bamboo Species in India

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**Abstract**: Among the bamboo species growing in India, about twenty species show promise as suitable for modern industrial uses and trade on the basis of existing practices of utilization, wide occurrence in the different 15 Agroclimatic Zones (ACZ) and their comparative ease of propagation. The majority of commercial bamboo species have been either growing naturally or cultivated satisfactorily from the ACZ 2 to ACZ 10 (throughout northeast, north including Terai, eastern, and central part of India). The paper examines the distribution and occurrence of 20 major industrially important bamboo species in the different ACZ of the country. The clump phenotypes and diversity of flowering behavior in these bamboo species are highlighted along with the prospects in selection for production of quality planting material and diversified industrial utilization. The success rate of different propagation techniques of the 20 industrially suitable bamboo species are also presented.

*Keywords*: flowering behavior, Industrial Bamboos of India, morphological diversity, propagation

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## Introduction

Bamboo is one of the most useful multipurpose plant species. It is a main construction material for about 70 to 90 percent of the rural housing in different countries in South and Southeast Asia. The famous Accra walls of houses in Bhutan, Assam, Manipur and other eastern States of India are made of bamboo mats plastered with mud or cement. Such buildings last long and has the potential to withstand earthquakes. The excellent ability of bamboos to produce slivers when split enables its use in a wide range of applications, such as construction, basket making, furniture and in novelty items. Split and plaited bamboo are used for walls, ceilings, and roofs. Bamboo has become a strategic natural resource that provide energy-saving, low-carbon and environmentally friendly material thanks to it fast growth rate and high cellulose content. The net calorific value of bamboo is comparable or higher than other wood species like beech, spruce, eucalyptus and poplars and is in the range of 18.3-19.7 MJ/kg (Janssen, 2000). With developments in technology and design, utilization of bamboo for various modern industrial products such as, bamboo-based panel products, bamboo-wood (bamboo lumber), bamboo charcoal, bamboo textile, paper and pulp, furniture, etc. have become important commercial commodities in both local and global market. The UN ComTrade database (2016) estimates the world exports of bamboo and rattan products at US$ 1,830 million in 2014. Bamboo and Rattan (BR) are mainly traded within

and between Asia and Europe. In 2016, the export value of BR products from Asia reached US$ 1,482 million, indicating that the continent accounted for 88 percent of the world's exports. The BR products mainly include engineered bamboo products, woven bamboo and rattan products, furniture/seats, raw materials and bamboo shoots. Engineered bamboo products were the major products exported in 2014, with an export value of US$ 548 million, accounting for 30 percent of the total. China accounted for 68 percent of the world export of BR products in 2016 with a value of US$ 1,162 million. China's bamboo industry total output value in 2016 reached US$ 31.8 billion and by 2020 the figure will reach US$ 48 billion, and the employment increased to 10 million. Trade of bamboo shoots account for US $ 285 million, which is about 16 percent of the global market for bamboo based products (UN ComTrade data base, 2016). The Indian domestic market for bamboo shoots is valued at INR 48 million (1 US$ =64 INR) only (Vanlalfakawma, 2014).

INBAR (2016) lists the top 15 countries like China, Vietnam, Indonesia and Philippines, that have been pioneering in the BR trade sector. India with its huge bamboo resources however does not find a place in the list of the global BR trade market, pointing to the need for efforts to be taken to earn dividends from this sector. One of the major weakness is the lack of information about the suitable local bamboo species to support the various bamboo-based industries in the country. Thus, an attempt is made in the present paper to develop an information base on the distribution and occurrence of bamboo species with industrial potential that are growing naturally or being cultivated in the different Agro Climatic Zones (ACZ) of India, by reviewing the relevant literature and from field observations. An attempt is also made to examine the utility of existing morphometric and flowering diversity in some of these industrially suitable bamboos of the country and to look at the propagation possibilities to evaluate the prospects of production of quality planting materials (QPM).

## Industrially Suitable Bamboo Species in India

### Major industrial practices and bamboo species

The properties of bamboo culms determine their potential uses. For the point of view of utilization, species selection is commonly made based on culm diameter, internode length, wall thickness, and culm height. The structural (both morphological and anatomical) and chemical composition of the culm of a bamboo species provide numerous possibilities for utilization (Liese and Tang, 2015). The composition varies according to species, the conditions of growth, the age of the culm, and the part of the culm under consideration. Structural and chemical properties influence the physical and mechanical properties and these in turn determine the type of utilization of a bamboo species. For bamboo to be used as an engineering material in structural applications, data on mechanical properties (density, modulus of rupture, modulus of elasticity, etc.) should be gathered. Studies show that some of the mechanical and physical properties of bamboo species (*B. bambos, B. nutans, B. tulda* etc.) collected from different zones (populations) of India varies significantly (Tewari, 1992). The main chemical constituents of the culm tissues are cellulose, hemicelluloses, and lignin. The parenchyma cells at the outer culm wall, the cortex, contain silica, which influence pulping and processing, as well as strength and durability. The amount of silica varies between species, influenced by age, site and may differ among the populations (Thulsidas *et al*., 2013). A bamboo species or any of its populations having low silica content are preferred raw material for paper and pulp manufacture or for furniture. *Bambusa vulgaris* has low silica content, while *Schizostachyum* spp. has a higher one (Tamolang *et al*., 1980). Culms of *D. strictus* sourced from 8 states (Assam, Bengal, Bihar, MP, Maharashtra, Tamil Nadu, Orissa, and UP) showed variation in silica, lignin, cellulose and pentose content and thus influenced the quality and quantity in pulp production (Bhargava, 1945). Intra-species variability observed in end-use linked chemical composition having high range of lignin content (25.64 - 29.46 percent) in *B. nutans* and that of holocellulose (70.7 - 75 percent) in *B. tulda* (Thakur *et al*., 2015). Some locally grown bamboo species and their current major industrial utilization are mentioned below:

a) Building and Structural Applications: *Bambusa balcooa, B. bambos, B. nutans, B. tulda, B. vulgaris,*

*D. brandisii, D. giganteus, D. hookeri, D. latiflorus, D. sikkimensis, D. strictus, D. stocksii (syn. Pseudoxytenanthera stocksii), T. oliveri, T. siamensis*. etc.

b) Mats, handicrafts and novelty items: *Bambusa cacharensis, B. jaintiana, B. nutans, B. polymorpha, B. tulda, D. hamiltonii, D. longispathus, Melocanna baccifera, Ochlandra travancorica, O. setigera, Schizostachyum dullooa*. However, species like Dev Ringal, *Himalayacalamus falconeri* (Syn. *Thamnocalamus falconeri*), *Pseudostachyum polymorphum* and *Schizostachyum pergracile* have limited distribution in a few states but with significant local demand.

c) Furniture/Engineered products (Laminates, bamboo lumber, Veneer, Ply, Particleboard, Fiberboard, Panels, etc.): *B. balcooa, B. bambos, B. cacharensis, B. nutans, B. pallida, B. polymorpha, B. tulda, B. vulgaris, M. baccifera, Dendrocalamus brandisii, D. giganteus, D. hamiltonii, D. latiflorus, D. stocksii, D. strictus, T. oliveri, T. siamensis* etc.

d) Pulp, paper and fiber: *B. balcooa, B. bambos, B. tulda, B. vulgaris, D. hamiltonii, D. longispathus, D. strictus, M. baccifera, Ochlandra spp.* Additionally other wild species with scattered distribution of *Chimonobambusa, Schizostachyum* are also occasionally utilized.

e) Making Incense sticks/ chops sticks: *B. cacharensis, B. nutans, B. polymorpha, B. tulda, D. hamiltonii, D. longispathus* etc.

f) Edible shoot : *B. balcooa, B. polymorpha, B. tulda, D. hamiltonii, D. latiflorus, D. longispathus, M. baccifera* etc.

The consumption of bamboo edible shoots, in India, is largely restricted to indigenous tribes in North East India. About 426.8 tonnes of shoots are harvested every year in the north eastern states alone (Choudhury *et al*., 2012) and hence the production and trade of bamboo shoot could be hugely enhanced through increasing the awareness of culinary potential of these species in the rest of the country and examining the potential for export.

g) Bio-energy: Bamboo, with it fast grown, renewable lignocellulosic biomass, has great potential to be used as a suitable energy source by conversion into solid, liquid and gaseous fuel (Chin *et al*., 2017). To utilize bamboo as an energy crop resource, high yielding species with a stable supply is required. *B. balcooa*, with high productivity is suited to this because of its lower ash content which also indicates its suitability of bioenergy and gasification process (Viswanath *et al*., 2021). The calorific value (CV) of *B. balcooa* was at 19.6 MJ $kg^{-1}$, higher than those of *B. bambos* (19.2 MJ $kg^{-1}$), *D. brandisii* (19.1 MJ $kg^{-1}$), *D. stocksii* (18.7 MJ $kg^{-1}$), and *D. strictus* (18.8 MJ $kg^{-1}$) (Kumar and Chandrashekar, 2014).

**Distribution and occurrence of species**

Kumar (2011) lists 136 species of bamboos from India. Most grow naturally in the forest, but some (about 20-30 percent) species are preferred by the farmers for various uses and have been in cultivation since ages. Farmers in the different Agro-climatic Zones (ACZs) of the country have selected bamboo species on the basis of site-species suitability, utilization requirement and market demand. An ACZ is a land unit in terms of major climates, suitable for a certain range of crops and cultivars. Based on Khanna (1989) and Ghosh (1991) categorizes 15 broad ACZs in India, taking into account mainly the physical attributes (e.g., temperature, rainfall, terrain and soils, etc., Table 1) prevailing in the regions (states and part of state).

Distribution and occurrence of the major industrially suitable bamboo species growing in different ACZs of India yields important information on the availability of raw material to initiate plans for establishing the bamboo-based industries in the country. On the basis of species-site suitability and field experience, farmers have selected and optimized the cultivation of bamboo species in different parts of the country. With innovation of utilization technologies more species can be selected and brought in to cultivation to serve as raw materials for furniture and engineered bamboo products.

Based on the review of literature and observations from the field, the occurrence and distribution of industrially suitable bamboo species has been recorded and arranged under the 15 different Agro-climatic Zones (ACZ) of India (Table 2). The number of industrially suitable species has been kept to a minimum to bring focus on future studies on

**Table 1.** The broad Agroclimatic zones ( ACZ) in India based on temperature, rainfall, and soil characteristics

| sl No | Broad Agro-climatic Zones of India | Temperature 0C (Mean varies) | | Rainfall cm (Avg. varies) | Soil character and terrain | States and regions included |
|---|---|---|---|---|---|---|
| | | July | January | | | |
| 1 | Western Himalayan Region | 5-30 | 5-(-5) | 75-150 | Alluvial in valley, brown in hills & silty loam | HP, Jammu & Kashmir, hill regions of UK |
| 2 | Eastern Himalayan Region | 25-30 | 10-20 | 200-400 | Red-brown soil, hilly | North east India, West Bengal (Darjeeling) |
| 3 | Lower Gangetic Plain Region | 26-41 | 9-24 | 100-200 | Alluvial to Sandy-loam | West Bengal(except hills), Eastern Bihar |
| 4 | Middle Gangetic Plain Region | 26-44 | 9-24 | 100-200 | Alluvial plain | Uttar Pradesh (South), Bihar |
| 5 | Upper Gangetic Plain: Region | 26-41 | 7-23 | 75-150 | Sandy loam | Western UP, Hardwar, UdhamNagar of UK |
| 6 | Trans-Gangetic Plain Region | 25-40 | 10-20 | 65-125 | Alluvial | Chandigarh, Haryana, Delhi, Punjab, Rajasthan |
| 7 | Eastern Plateau & Hills Region | 26-35 | 10-27 | 80-150 | Red, Yellow, with patches of laterites alluvium | Chhattisgarh, Jharkhand, M P, Maharashtra, Orissa, West Bengal |
| 8 | Central Plateau & Hills region | 26-40 | 7-24 | 50-100 | Mixed red. yellow& black | Madhya Pradesh, Rajasthan, UP |
| 9 | Western Plateau & Hills Region | 24-41 | 6-23 | 25-90 | Regur (black) | MP (Decan Plateau), Maharashtra |
| 10 | Southern Plateau & Hills Region | 25-40 | 10-20 | 50-100 | Red, lateritic, black alluvio-colluvial | AP, Karnataka, Tamil Nadu upland, |
| 11 | East Coastal Plains & Region | 25-30 | 20-30 | 75-150 | Alluvial,loam,clay, Alkalinity problem | AP, Orissa, Pondicherry |
| 12 | West Coast Plains & Ghats Region | 25-30 | 18-30 | More than 200 | Laterite & coastal alluvial | Goa, Karnataka, Kerala, Maharashtra,Tamil Nadu |
| 13 | Gujarat Plains & Hills Region | 30 | 25 | 50-100 | Regur in plateu, in coast alluvium, red &yellow in Jamngar | Gujarat, Dadra & Nagar Haveli, Daman,& Diu |
| 14 | Western Dry Region | 28-45 | 5-22 | Less than 25, desertic | Sandy, saline, alkali -ne & calcareous. Clay, loamy, black | Rajasthan |
| 15 | Island Regions | 30 | 25 | Less than 300 | Sandy to clayey loam | Andamans &Nicobar islands, Lakshadweep |

States & Regions in India:HP= Himachal Pradesh, UK= Uttarakhand, UP= Uttar Pradesh, MP=Madhya Pradesh, AP= Andhra Pradesh

resource management and improvement. The 20 industrially suitable bamboo specie that are either naturally growing and /or widely cultivated and utilized in the country has been listed (Table 2). Lesser-known species are not included in the list.

The majority of commercial bamboo species have been either growing naturally or in cultivation from the ACZ 2 to ACZ 11. The highest species diversity is found in the Eastern Himalayan Region (ACZ 2), Lower Gangetic Plain Region (ACZ 3), and Middle Gangetic Plain Region (ACZ 4) including humid hills to sub-humid plains, that is Upper Gangetic Plains (ACZ 5). Farmers in the moist humid zones – north-east India (ACZ 2 to ACZ 3: Tripura, Assam, Manipur, Nagaland, Meghalaya, West Bengal, Orissa) have been commonly cultivating *B. balcooa, B. tulda, B. vulgaris, B. nutans, B. cacharensis, B. polymorpha* and *D. hamiltonii*, in the homesteads, farms and waste lands. These species have been growing in most of the soil types (except desert, black and saline soil) of India including that of the greater Terai region of the Himalayas but prefers heavy textured soil with good drainage. *B. polymorpha* is extensively cultivated in Tripura, commonly in Manipur and sporadically in other parts of India. However, *B. balcooa, B. tulda, B.vulgaris* are the most common bamboos in the homesteads of north-east (all over Tripura, Assam, Meghalaya, etc.) and also in parts of north (eastern Uttar Pradesh) and eastern part of India (West Bengal, parts of Orissa, Bihar, Jharkhand, Chhattisgarh). *B. balcooa* and *B.vulgaris* are known only known in cultivation and no natural vegetation has ever been reported. Additionally, in Tripura *Thyrsostachys oliveri* and *B. cacharensis* are cultivated mainly as important raw material for furniture industry. Among them *B.cacharensis,B. tulda* and *D. hamiltonii* grow naturally in the forests and farmers also cultivate in the homesteads in some of the north-eastern States. A major naturally distributed bamboo, *Melocanna baccifera*, covering 70-80 percent of total bamboo forest of north east India has been extensively used in housing, matting, incense stick making, pulping industries and for edible shoots. A large tufted bamboo, *D.hookeri*, commonly used in construction, has been growing in the hill forests of Eastern Himalayas, Khasi, Jaintia and Nagahills (600-1500 m) and also in cultivation in Arunachal, Sikkim, Duars and western Himalayas (Varmah and Bahadur, 1980). Another densely tufted tall bamboo *D.latiflorus*, found to grow sporadically in Manipur and Nagaland has been much used as edible shoot and also in construction (Naithani, 2011). *Himalayacalamus falconeri* (Syn. *Thamnocalamus falconeri*), a shrubby bamboo locally known as Dev Ringal grows naturally between 1900-2750m as in the western Himalayas, Kumaon and Garhwal hills, is most preferred for making crafts, baskets and mats of high market demand (Varmah and Bahadur, 1980).

Both *B. bambos* and *D. strictus* are common naturally or in cultivation in most of the ACZs (throughout main land India - north, central, and western part) including less moist to semidrier parts like Bihar, Uttar Pradesh, Chhattisgarh, Madhya Pradesh, Maharashtra and have great impact on socio-economy of people. The distribution of *B. bambos* is further extended up to Konkan and Western Ghat regions.

A comparatively lower bamboo species diversity is observed in Chandigarh, Haryana, Delhi, Punjab, Rajasthan ( ACZ 14), Deccan Plateau, Pondicherry, Gujarat (ACZ 6, 9, 10, 11); West Coast Plains, Gujarat Plains & Hills (ACZ 13 and Island regions (ACZ 15) of the country (Table 2). However, *D. brandisii* and *D. stocksii* have been growing from sea level to an altitude of 800 m in Central Western Ghats and is widely cultivated in Goa, southern Karnataka, northern Kerala and Konkan region of Maharashtra (ACZ 12,13) and has been used for furniture and construction industries (Kumar, 2011). A number of reed bamboo species under genus *Ochlandra* grow in southern India (ACZ 12) and has utility in housing, weaving, matting, and pulping (Kumar, 1988). These bamboo species are not found in any other part of India.

**Diversity in major bamboo species and their possible utilization**

The diversity in clump phenotypic characters and flowering nature of a bamboo species may be utilized profitably for specific type of industrial use.

**Diversities in clump phenotype:** The clump phenotypic characters that are usually considered for commercial purpose of utilization are straight

**Table 2.** Occurrence and distribution of industrially suitable major bamboo species in the Agroclimatic zones of India

| Species | Agroclimatic Zones (ACZ) in India | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1. *B. balcooa* | + | +++ | +++ | +++ | ++ | + | +++ | ++ | + | + | + | - | - | + | + |
| 2. *B. bambos* | + | + | + | +++ | ++ | + | ++ | ++ | + | ++ | ++ | ++ | ++ | + | - |
| 3. *B. cacharensis* | - | +++ | + | + | - | - | + | - | - | - | - | - | - | - | - |
| 4. *B. nutans* | + | +++ | ++ | + | + | - | + | - | + | + | + | - | - | - | - |
| 5. *B. polymorpha* | - | ++ | + | - | - | - | + | - | - | + | - | - | - | - | - |
| 6. *B. tulda* | + | +++ | +++ | ++ | ++ | - | ++ | + | + | - | + | + | - | + | - |
| 7. *B. vulgaris* | + | ++ | +++ | ++ | ++ | + | + | + | + | + | + | + | - | + | + |
| 8. *D. brandisii* | - | + | - | - | - | - | - | - | - | - | - | ++ | ++ | - | - |
| 9. *D. giganteus* | + | + | + | - | + | - | + | - | + | - | + | + | - | - | - |
| 10. *D. hamiltonii* | ++ | +++ | + | + | + | + | + | + | + | - | - | - | - | - | - |
| 11. *D. hookeri* | - | +++ | ++ | + | + | - | - | - | - | - | - | - | - | - | - |
| 12. *D. longispathus* | + | +++ | + | + | - | - | + | - | - | - | - | + | - | - | - |
| 13.*D. latiflorus* | - | ++ | + | - | - | - | - | - | - | - | - | - | - | - | - |
| 14. *D. strictus* | ++ | + | + | ++ | ++ | ++ | + | +++ | +++ | + | ++ | + | ++ | ++ | - |
| 15. *D. stocksii* | - | - | - | - | - | - | - | - | - | + | - | +++ | ++ | - | - |
| 16. *H. falconeri* | +++ | + | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 17. *M. baccifera* | - | +++ | ++ | + | + | | + | - | - | - | - | - | - | - | + |
| 18. *O. travancorica* | - | - | - | - | - | - | - | - | - | ++ | - | +++ | + | - | - |
| 19. *S. dullooa* | - | ++ | ++ | + | | - | + | - | - | - | - | - | - | - | - |
| 20. *T. oliveri* | - | ++ | ++ | + | + | - | + | - | - | + | - | - | - | - | - |

Note: Qualitative expression of occurrence of species:( +++ )= Extensively, ( ++ ) = Commonly, (+ ) Sporadic to isolated, (-) not found or absent.

erect culms, culm height, diameter, wall thickness, and internode length (Banik, 1993). The consideration of plant habit like compactness of clump is also advantageous for management and harvesting operations. Both *B. bambos* and *D. strictus* are the most common forest bamboo which is also cultivated extensively in central, southern, northern and some parts of eastern India. A number of populations of these species have clump phenotypes that could influence selection for specific uses. Additionally, *B. balcooa* and *B. vulgaris* (green type) are important commercial bamboo, extensively cultivated throughout the sub-continent. No natural populations of *B. balcooa* have been reported and it is only known in cultivation. *B. vulgaris* is quite pantropic in distribution (McClure, 1966) that one cannot establish with certainty the region to which it is native (Soderstrom and Calderon, 1979). *B . tulda, B. nutans* and *D. hamiltonii* too are widespread, found in forest and commonly cultivated in India in a region extending from Himachal, Uttarakhand, UP, along Terai, to all regions of northeast, covering about 4000 km including Nepal, Bhutan and Bangladesh. Such wide distribution in the natural forests and extensive cultivation might have evolved a number of phenotypic variations in the clumps of these important bamboo species and provide opportunities to select suitable populations/cultivars for specific industrial uses.

Two major growth forms is the tall form and the dwarf form have been recognized in *B. bambos*. The tall (24 -30 m), handsome clump having large diameter culms (8-12 cm) are naturally grown and cultivated in South India mainly for construction, making fences in the rural farms, as raw materials in pulp mills and also used to make engineered bamboo

products (e.g. laminated bamboo lumber, bamboo veneer, ply bamboo, particle boards, etc.). Clumps of largest size are also found in the hills of Circars, especially around the river Godavari, on the hill ranges of the eastern and southern scarps of the Mysore plateau and in the Nilgiris. The Dwarf form (6-10 m), with very thorny, thickly interlaced branches and small crooked and knotty culm type is often found on the low hills of Orissa, lower Bengal, south eastern part of Bihar, Jharkhand, Chhattisgarh, and Uttar Pradesh (UP); and across to Myanmar (Banik, 2016). The densely interlacing thorny branches and branchlets make this type a closed, almost impenetrable hedge, thus it has been largely planted in 3-4 rows at close spacing (3x3 m) in the periphery or in boundary as a protective live fences in the rural farm lands and homesteads in those areas. Gamble (1896) wrote "against such a hedge nothing but explosives would be of much effect".

In *D. strictus*, three stable growth forms are recognized in India (Deogun, 1937) and their place of occurrence with specific type of utilization practices.

A) Common type – i) Clump of ordinary form producing medium-sized culms with moderately thick wall, and widely distributed. ii) Culms hollow with relatively thin walls, generally found in moist depressions, on cooler aspects. iii) Culms solid or nearly so, usually found on ridges and on hotter aspects.

B) Large type – It grows within the forests of Nauri, Lansdowne Division in Uttar Pradesh, and is cultivated in north Bihar and Orissa. The culms are big with long, with straight and smooth internodes and is widely used for structure, construction work, as stakes to support sugarcane in north India and for making furniture, mats, baskets and novelty items. It is one of the most suitable raw materials for the pulp and paper industry.

C) Dwarf type – This is of a small size and only rarely forms clumps. It is typically found in Balaghat division of Madhya Pradesh where it is known as Karka, and to a limited extent elsewhere. Considering the wide phenotypic variations, McClure (1966) termed *D. strictus* as a polymorphic species. The type C and sometimes type B of this bamboo is widely cultivated as shelterbelts in drier areas in India and for the consolidation and support of embankment (Pande *et al*., 2012). In the terai of Nepal, a form of *D. strictus* with small-stature, solid culms and strong branching is quite common.

*Dendrocalamus stocksii* has solid, 12-16 m tall, erect culms having very little side branches, a diameter of 25-40 mm with 20-38 cm long internode (Kumar, 2011). It is commonly used for structural and construction works. Based on strength properties (MOR), *D. stocksii* is comparable with *D. strictus* and is better than *B. nutans* (Viswanath *et al*., 2013b). At present, excellent buildings, prefabricated housing components and furniture have been extensively produced with this bamboo in Sindhudurg, Maharashtra (Karpe, 2019) and also having high demand in local market. A few populations having clumps with better growth forms, erect culm, 18-20 m tall, 52-65 mm diameter and 22-46 cm long internode were observed at the lower slopes and valleys in the Western Ghats which may be selected and grown for higher yield and heavier construction works. Among the 10 populations studied in Western Ghats region, the Sirsi population had comparatively better culm diameter and internode lengths followed by Ratnagiri and Sindhudurg populations. The clumps from Chandged region were solid upto 7.06 m from the base while rest of the populations had solid culms ranging from 3-5 m from the base (Rane *et al*., 2019) which may have a demand in construction industry.

During the long history of cultivating *B. balcooa* and *B. vulgaris* since long, a number of `cultivars` have been recognized/ developed by farmers for different purposes. Two such distinct types (cultivars`), locally known as Shilbarua/ Sil barak / Hilbarak and the other as Nol/Telibarak (Banik, 2000, 2016; Karmakar *et al*., 2013) have been reported in *B. balcooa*. The Shilbarak type is common in upper Assam, Tripura and Sylhet and has thick walled culms, with many shorter internodes, swollen and elevated nodes. This type is very much preferred for making post or pillar essentially for load bearing purposes like house roof, bridge panels etc. and is one of the best and strongest bamboo for construction and scaffolding. It is also preffered for making frames for rickshaw hood, platform of bullock cart and boats, electric poles, lad-

**Table 3.** Seed characters of some commercial bamboo species

| Species | Seed shape and weight |
|---|---|
| *Bambusa balcooa* | Do not produce seed |
| *B.bambos* | Small, like wheat grain, 745 seeds per 10 gm. |
| *Shorter and more spiny species (Bambusa bambos var. spinosa ?)* | Small, like wheat grain, 1,325 seeds per 10 gm. |
| *B. longispiculata* | Like wheat grain, 145 seeds per 10 gm. |
| *B. nutans* | Like wheat grain, 100 seeds per 3 gm. |
| *B. polymorpha* | Small, like wheat grain, 1,250 seeds per 10 gm. |
| *B. tulda* | Like wheat grain, 150 seeds per 10 gm. |
| *B. vulgaris* | Do not produce seed. |
| *Dendrocalamus brandisii* | 100 seeds=2.78g with husk; 2.58g without husk (Viswanath, *et al*., 2013a). |
| *D. giganteus* | Ovoid to oblong, hairy at the upper-end, 200 seeds per 10 gm. |
| *D. hamiltonii* | Small, broadly ovoid, rounded at the base 264 seeds per 10 gm. |
| *D. hookerii* | Caryopsis (seed) not known (Gamble, 1896; Tewari, 1992). |
| *D. latiflorus* | Ovoid to oblong, tip with minute stiff beak. 166 seeds per 10 gm. |
| *D. longispathus* | Small, coriander like seed, 1,350 seeds per 10 gm. |
| *D. strictus* | Small shinycoriander like seed, grain ovoid to sub-globose, 515 seeds per 10 g (Chittagong, Bangladesh); 258 seeds/ 10g (Chhindwara- Madhya Pradesh (MP)), 223seeds/10g (Betul-MP), 244seeds/10g (Hosangabad of M P), 265 seeds/10g (Bilaspur of MP). |
| *D. stocksii* | Do not produce seed |
| *Melocanna baccifera* | Very large and obliquely ovoid, fleshy pear/onion-shaped and the apex terminating in a curved beak, green with smooth surface and not covered with glumes. Weight of a seed varies from 7.0 to 150 g, length from 35 to 110 mm, and diameter from 22 to 60 mm. 45 to 70 seeds per kg |
| *Thamnocalamus spathiflorus* | Small oblong, grain like. |
| *Ochlandra travancorica* | Large, 5 cm long, 2-3 cm broad, brown, oval-oblong, wrinkled, with 4-5 cm long stiff beak, pericarp fleshy enclosing, the whole surrounded by persistent glumes and palea.40seeds per kg (Seethalakshmi and Kumar 1998). |
| *O. scriptoria* | 640 fruits per kg (Seethalakshmi and Kumar, 1998). |
| *Schizostachyum dullooa* | Narrow, elongated grain-like, somewhat broader and flat base with cylindrical top terminating in a long beak formed by the persistent base of the style, deglumed seeds are blackish brown, 393 to 410 seeds per10 gm. |
| *Thyrsostachys oliveri* | Small paddy like grain, 40 seeds per 0.62-0.73 gm. |
| *T. siamensis* | Small paddy like grain, 248-490 seeds per 10 gm. |

(Source: Banik,2015)

ders, furniture, fencing, including agricultural and fishing implements. In the other type, Nolbarak/ Telibarua, the culms and branches are comparatively thin walled, with long internodes and have been used for simple light constructions and occasionally making incense-stick in Tripura State. Stapleton (1994) had described the culm sheath of a form of *B. balcooa* from Nepal and Bhutan where it is mainly used as pillars and beams, in which the imperfect blade edges are wavy, culms thick walled, and not so wide in diameter unlike the cultivated one in Tripura and Assam. Another sporadically grown 'cultiva' Kanta Barak clump seen in Nayanimura of west Tripura (Banik, 2004), and in homesteads of eastern and northern parts of Bangladesh has tall strong durable culms, hard to cut and commonly used as pillars for house, bridges and other heavy structural works. The clump is compact, so densely branched towards the base that it is difficult to move inside, has culm sheaths more or less similar type of *B. balcooa*.

In *Bambusa vulgaris* also a number of cultivars/ variety (Holttum, 1958; McClure, 1966, Laurence, 2007) are known, and widely cultivated. Green type (*B.vulgaris* var. *vulgaris*) is common in naturalized populations, much used for construction works, props, scaffoldings, bridge making, and also as raw material in pulp and paper industries. Other types, such as the yellow type culms with green striation (*Bambusa vulgaris* var. *vittata A. Riviere; B. vulgaris* var. *striata* (Lodd. ex Lindley) Gamble).

Buddha's Belly with swollen internodes (*B. vulgaris* cv. `Wamin` Brandis ex Camus); Maculata with green culms mottled with black, turning mostly black with aging; and Wamin *striata*: grows up to 5m tall with light green striped in dark green , with swollen lower internodes; have been cultivated mostly in parks, gardens as ornamental plants. A population of *B. vulgaris* has been recognized (Banik, 1994a) as short and bushy type, with culms 7-15 m tall, 4-7 cm in diameter; and branching throughout. This type, generally cultivated in coastal cyclone prone areas in Orissa, West Bengal and in Cox's Bazar and south of Bangladesh near Bay of Bengal (where it is known as "Kenta Bizzya bans") are hardy against cyclonic storms and is rarely infected with blight disease.

The cultivated clumps of *B. tulda* in homesteads are comparatively strong, tall, big sized culms with thicker walls, fewer branches at the lower parts of the culms and very useful as raw material for roofing and construction as well as other industrial applications. The species is comparatively durable in water and is hence used for making fish traps and roofing of boats (Banik, 2016). The variations in internodal length, culm girth and number of culms per clump contribute the total genetic diversity of *B. tulda* (Singh, 1993). Populations of two types – those with loose or compact clumps are observed in cultivation. Three growth forms have been recognized in this species: (a) normal- 9-15 m tall, 2.5-4.5 cm diameter, glabrous, mostly thin walled (b) large with thicker culms, and (c) medium with large cavity and thin wall (Banik, 1994a). The Nalbari district of Assam is well-known for cultivating the erect, very tall (27-30 m), straight type clumps of *B. tulda*. This elegant bamboo having a pipe-like smooth culm (in local language pipe is `nal` so Nalbari means 'home of nal') with an internode length of 40-75 cm, diameter of 8-10 cm, finds use for making the traditional Assamese hat (Jhapi) of high market demand, quality round incense sticks and novelty items. Cultivation of this type is also popular in the neighboring Barpeta district and in lower Assam. *B. tulda* culm is not known to have swollen nodes (Gamble, 1896), however, the feature was observed in 14 populations in various districts of West Bengal (Bhattacharya *et al*., 2006) and found to be preferred for use as load bearing posts or pillars house and bridges. Crooked culms with the internode bulging on one side are observed in clumps of a few populations in cultivation in Kokrajhar Assam, west Tripura (Banik, 2016) and West Bengal (Bhadreswar, Srerampore, Kalayani) (Bhattacharya *et al*., 2006). These culms may find use in furniture making. The *B. tulda* clumps in the adjacent natural forests in many parts of North east India, Manas Reserve, lower Terai, Chittagong Hill Tracts and Sylhet are thin walled and not so tall.Towards the western end of its range in the Terai, *B. tulda* becomes progressively shorter with heavier branching, smaller leaves, and more crooked culms. Small populations of *B. tulda* may have culms with yellow striations on the 1-3 basal internodes, with comparatively thicker walls and which has a high demand for making sliver and

mat veneer have been seen in some locations inside Khowai Teliamura)/Subalshing forests of Tripura and southern part of Sylhet forest.

*Bambusa nutans* is a species with moderate- sized clumps, culms of which are straight and strong, branched on the upper side, thick walled at bottom and occasionally used as poles in small construction works, furniture making and as raw material for pulp and paper industries. Since the branches are small and the poles split easily, the species is also used for weaving baskets, mats and making agricultural implements. The intraspecific variation of six morphological characters-culm height, diameter at breast height, wall thickness, internode length, culm sheath length and culm sheath breadth in *B. nutans* has been studied in Central Nepal by Adhikari and Shrestha (2008) who reported that the culm wall thickness showed highly significant difference among the populations and argued that the variation among the plants might be of genetic origin.

There is substantial variation within *Dendrocalamus hamiltonii* and several distinct varieties are known (Stapleton, 1994). Across the six populations of *D. hamiltonii* in east Khasi hills, the morphological variability in 120 sampled clumps was significant ($p \leq 0.05$) for culm internode length and culm lumen diameter (Pattanaik and Hall, 2014). Similarly longer internodes and thin walls characterize the populations at Naga Hills and Tamenglong Hills in Manipur. Clumps growing in lower slopes and valleys on the hills of Mizoram generally produce taller (19.6m -23.9m) culms having longer internodes but with narrow diameter (7.8cm – 11.7cm) and a lower number of culms with fewer branches. The culm tips are thin and of drooping nature and may set intermingled with each other as observed in the forests of the high rainfall areas of Meghalaya and north Sylhet (Banik and Das, 1996). Such a form was also seen near Bejnath area of Palampur, Himachal. The clumps of *D. hamiltonii* growing in northern India (Himachal and west Uttarakhand) generally produce tall culms with thicker wall than those from northeast-India (Mizoram) and Sylhet forest of Bangladesh. At Molichak village in Banuri, about 5 km from Palampur in Himachal Pradesh, a productive and healthy population of *D. hamiltonii* has been observed in cultivation. A CPC was selected, having 54 culms, of which 21 was produced in year of study. The clump showed superior culms characteristics is conserved at the Bamboo Clone garden of GBP Agricultural University, Pantnagar (Banik, 2016). The populations growing in Arunachal, Manipur (Tamenglong, Jiribam), Nagaland, Mizoram, Darjeeling hills and Sikkim produce tasty edible shoot and very much liked by the local people.

Apparently three different growth forms of *Bambusa cacharensis* are seen in cultivation. i) The *normal common type* has culms 18-24 m tall, a diameter of 5-8 cm, branching always in the upper third of the culm height and with smaller size leaves. It has long internodes (42 - 95 cm) and smooth nodes and is commonly cultivated in Tripura, Southern Assam (Barak Valley, Cachar district), at Pasadwar and Umkiang, Jaintia Hills (Meghalaya) and Sylhet. Locally the species is known as Bethua, Bom, Moral bansh, etc. Due to the creamy colour and smooth surface, the bamboo is used for making chopsticks, spoons and tooth picks, and also used for making incense sticks in Tripura. ii) *Tall and straight type* (local people call this type as Jati Bom), has elegant loosely growing clumps with culms that are 25-29 m in height, a diameter of 9-11 cm and less branching below. This type is observed at Kanchanmala, Bibeknagar (Amtali) in Sepahijola and West Tripura districts, Tripura. Poles of this species are commonly used in furniture and novelty items. In recent times it used to manufacture bamboo flooring tiles (Mutha Industries Pvt. Ltd. Bodhjungnagar, Tripura). iii) *Shorter, compact type* locally called as 'Pecheebom' with culms 10-16 m tall, smaller diameter (3-5 cm) and thick walled, commonly used for small construction works and fencing.

*Bambusa polymorpha*, found mostly in cultivation in homesteads, is a durable bamboo, now in popular use to make attractive fibre boards and sometimes as raw material for agarbatti sticks and chopsticks. The bamboo artisans in Melaghar block of Tripura are well known for their skill in making bamboo crafts, finer toys, and attractive handicrafts. The young shoots are edible and considered tasty. A number of phenotypic variations are observed in the species especially with respect

to compactness of clumps and colour variations in newly emerging shoots. A shrubby clump type of the species, locally referred to as 'pencil/straw bamboo', have been found to grow naturally inside the Sepahijala Wildlife Sanctuary and adjacent areas of Veshwaj Uddyan (Brajapur), near Rotia Bill, and Amrit Sagar in Sipahijala district in Tripura and also reported from the nearby natural reserve forests of Rema, Kalenga, south Sylhet of Bangladesh (Banik, 2000).The culms are erect and 3.2 - 5.5 m tall and do not have any branches at the nodes of basal third of the culm height. The culm diameter at basal end is 2.1 - 1.98 cm, at middle of culm around 0.62-1.79cm, and at apical internodes, diameter around 0.33- 0.53 cm. The internodes are thin-walled (0.1- 0.38 cm), smooth and pipe-like and are locally used as straws for drinking tender coconut water and soft drinks. A dwarf growth form about 25-35 cm tall with numerous grassy shoots has been reported (Banik, 2016) and has been maintained in that form for the last 27 years, as`bonsai` bamboo.

*Melocanna baccifera*, occasionally display clumps that are 5-8 m tall with several small diameter (1-3 cm at mid culm zone) and comparatively thick-walled culms in forests of Tripura, Cachar, and Sylhet and locally known as *tengramuli or nali or bazali*. Those with basal curved rhizomes has high demand in making umbrella handle and walking sticks (Banik, 2010a). Most clumps of *M. baccifera* produce young shoots with a yellowish culm-sheath which are preferred as edible shoots but there are others with deep brown sheaths are not favoured as food due to bitter taste (Banik 1994a). Local tribal people are of opinion that edible shoots of *M. baccifera* and *D. longispathus* collected from Ambassa, Tripura taste better than those from other localities of the state.

**Diversity in flowering behavior and potential for utilization:** A majority of Indian bamboo species produce flowers and seeds gregariously after 30-65 years (depending on the species), and die simultaneously within 12-18 months of blooming and thus the clumps exhibit complete flowering nature. Occasionally some populations of the same species also exhibit sporadic flowering, in addition to normal gregariously flowered clumps. There are also instances where a bamboo species flowers gregariously at one location but not at an adjacent location revealing a distinct flowering population (Banik, 1995a). Reports of more than one flowering period within a species viz. short, medium and long intervals of inter-mast periods are seen in *B. bambos, B. cacharensis, B. tulda, B. nutans, D. strictus, M. baccifera* (Banik, 2010, 2015). Populations in *B. bambos* seeded after 30-35 years in central India (Tewari, 1992), and south India (Brandis, 1906), 40 years at Orissa (Das, 1969); and 47-52 years at north and NE India (Gupta, 1982). *D. strictus* seeded after 24-28 years in south India (Kadambi, 1948), 35 years in Eastern India, 40-44 in central India (Gupta, 1952) and after 65 years in the drier western India (Mathauda, 1952). Similarly, different populations of *M. baccifera* exhibited 30-35, 45-50 and 60 year inter-seeding periods at locations in Chittagong Hill Tracts (CHT), NE India, and Myanmar forests (Kurz, 1876, Gamble, 1896, McClure, 1966). *B. tulda* frequently flowered sporadically but also occasionally gregariously after 20-30 years in Bangladesh (Hasan, 1973) and eastern India (Bhattacharya, 2006) and at 45-50 years interval at Terai and NE India (Lalnuntluanga *et al*., 2003). Only one out of four clumps of *B. tulda* flowered sporadically in 2003 at Dighra, Hooghly, India. Out of a total of ten culms in this clump, only two flowered. The number of fertile nodes recorded was six in one culm and eight in another (Bhattacharya, 2006). Like in *B. tulda*, frequent sporadic flowering is not uncommon in *B. cacharensis*, and *D. hamiltonii*. In *B. cacharensis*, there were occasions where in small populations could exhibit partly flowering nature i.e. flowering was completed part by part in 36-45 months. followed by death of clumps, was observed. In cultivated population of *B.cacharensis, B. tulda, B. nutans* and *D. longispathus*, a few culms( irrespective of age) of a clump may flower and die partly in the first year, while the remaining culms may complete flowering within next 2-3 or more years and then die exhibiting part flowering behaviour (Banik, 1986). Such cultivated village groves of *B. tulda* and *B. nutans* were rarely seen to flower gregariously and isolated or partly flowering nature was more common. In adjacent natural forests the clumps of these bamboos are comparatively short and thin-walled. Though rare there were also instances where a few branches in

some clumps of *B. nutans* and *B. longispiculata* continue to flower for 17 and 22 years, exhibiting continuous flowering nature but without any death of clumps (Banik, 1997, 2015).

*B.balcooa* and *B. vulgaris* are common homestead bamboo species of Indian sub-continent rarely seen to flower. Flowering occurs mostly in isolated clumps without any seed yield and it has been shown that 70-92 percent pollen are sterile (Banik, 1997). However, in *B. vulgaris* a few clumps have been observed which exhibited part flowering nature for 3-5 years and then revived growth after flowering ceased. Such 'genotypes' are suitable for selection and utilization for cultivation (Banik, 1994 a). Another commonly cultivated bamboo *D. stocksii* in Konkan, Sindhudurg, Maharastra is rarely seen to flower and mostly in isolated clumps without any seed set (Banik, 2008). *D. giganteus* often flowers in isolated clumps, sporadically in 30 years (Munro, 1868), 76 years (Janzen, 1976) and also after a long period of 85-90 years (Banik, 2000) and is presumed to have more than one flowering population showing sporadic and isolated clump flowering. The villagers at Myanaung in the Irrawadi delta Burma, raised plantation of *D. giganteus* in 1876-77 over 20 acres alluvial soil within half a mile of river bank, by planting offsets from different sources in the gaps formed from time-to-time death of the clumps due to flowering. The raised plantation could be maintained indefinitely for uninterrupted resource supply, since the young offsets so planted would complete the whole span of life before flowering (Troup, 1921). It was possible as the species exhibited sporadic flowering in isolated clumps and had populations of different flowering cycles. Additionally, some clumps are part flowering and a few are also complete flowering in nature. *D. hookeri* is also another species reported to flower after a long interval of 117 years (Janzen, 1976). So such bamboo species having long flowering interval, and such genotypes (cohorts/populations) that rarely flower or have part flowering, where all clumps do not die at a time after flowering, should get preference in cultivation since they have the potential for longer vegetative period of growth and thereby give better support to the industry.

**Propagation Prospects of Industrially Suitable Bamboo Species**

The Bamboo Planting Material (BPM) may be seeds (direct sowing in case of *M. baccifera*), seedlings, rooted culm- and branch-cuttings or offsets.

**Propagation with seeds and seedlings**

The seed character, shape and weight of bamboos varies from species to species, and even within population (location) as presented in Table 3. Such information about a bamboo species are a prerequisite for raising successful seedling nursery of industrial plantations. Generally, grain like seeds are soaked in water for overnight and sown in the germination bed having a mixture of sand, soil and FYM/cowdung at ratio of 2:1:1. The medium should be moist, well drained, but not waterlogged and temperature around 25-35$^0$C. Also, it needs overhead partial shade (50% shade net) as bamboo seeds are negatively photoblastic in nature (Banik, 1991). In most of the bamboo species seeds germinate within 3-7 days of sowing. Sun-dried seeds of *Thamnocalamus spathiflorus* (an important Himalayan bamboo) were stored at room temperature (20-25°C) for four years and viability was 90-93 percent for the entire period (Bag *et al*., 2013). But generally, bamboo seeds are short lived. The seed longevity and storage techniques of a number of species have been described (Banik, 1987, 1994b; Ramyarangsi, 1988; Seethalakshmi, 2006).

Wildlings of bamboo, often seen as a thick mat on the ground just below the flowering mother clumps, compete for survival and also prevent the regeneration of other plant species. Thinning of bamboo seedlings besides promoting natural regeneration, could be successfully utilized as planting materials (Banik, 1988). At four to six-leaved stage of the bamboo wildlings can be collected during rains and transplanted to polythene bags containing soil, sand and mixed with FYM/cowdung (2:1:1). Seedlings have to be maintained initially under shade-net (50-60 percent) with fogging for a week for hardening and healthy growth, and thereafter with regular weeding and daily watering (misting) in the nursery.

**Table 4.** Practices and success rate of various techniques of propagating some industrially suitable bamboo species in India.

| Bamboo species | Seed/Seedling | | Vegetatively Propagated planting materials | | | |
|---|---|---|---|---|---|---|
| | Seed | Macropro -liferation | Offset/ Rhizome | Part*- Clump | Culm- cuttings | Branch Cuttings |
| *Bambusa balcooa* | No | only cuttings used | ●●● | NA | ●●● | ●●● |
| *B. bambos* | ●●●● | ●●●● | ●● | NA | ●● | ●● |
| *B.cacharensis* | ●●● | ●●●● | ●●● | NA | ●● | ●● |
| *B.nutans* | ●● | ●● | ●●● | | ●● | ●● |
| *B. polymorpha* | ●● | ●● | ●● | NA | ●● | ● |
| *B. tulda* | ●●● | ●●●● | ●● | NA | ●● | ● |
| *B.vulgaris* | No | only cuttings used | ●●● | NA | ●●● | ●●●● |
| *Dendrocalamus brandisii* | ●●● | ●● | ●● | NA | ●● | ●● |
| *Dendrocalamus giganteus* | ●●● | ● | ●● | NA | ●● | ●●● |
| *D. hamiltonii* | ●●● | ●●●● | ●●● | NA | ●●● | ●●● |
| *D.latiflorus* | | | | | | |
| *D. longispathus* | ●●● | ●●● | ●● | NA | ● | ● |
| *D.hookeri* | NK- | -NA | ●●● | NA | ●●● | ●●● |
| *D. strictus* | ●●●● | ●●●● | ●● | NA | ●●● | ●●● |
| *D.stocksii* | No | only cuttings used | ●● | NA | ●● | ●● |
| *DeoRingal(shrubby bamboo)* | ●●●● | ●●●● | | | | |
| *Melocanna baccifera* | ●●●● | - | ● | ●● | No | No |
| *Ochlandraspp* | ●●● | - | ●● | ●● | ● | ● |
| *Schizostachyum dullooa* | ●●● | ●● | ●● | ●● | ● | ● |
| *Thyrsostachys oliveri* | ●● | ●● | ●●● | NA | ●● | ●● |

Note: ●●●●: Very successful (85-95 %), and widely practiced,●●● :Successful (60- 80%), and commonly practiced,●●: Limited success (40-above 50%) and rare in practice, ● : Poor success (20-35%).NA: Not applicable, NK: Not known

Juvenile selection for better growth: Seedling populations of a bamboo species usually exhibit different types of growth-forms like, grassy, grassy-erect, erect and very erect. The erect and very erect (but not lanky), and the vigorously growing type of seedlings of any bamboo species should be selected (juvenile selection) from the total mass of seedling population raised in the nursery and used for planting for realizing the maximum growth potential (Banik 1980, 1997, 2015; Tewari 1992). The grassy seedlings with many thin shoots and bushy appearance are of value as ornamentals particularly for marketing as potted “bonsai”.

**Vegetatively propagated planting materials**

The planting material of bamboo should be produced or collected from the clumps with desired phenotypic characteristics (discussed in Section Diversities in clump phenotype) of known sources to enhance the productivity in plantations. For producing Quality Planting Material (QPM), the guideline mentioned below may be followed:

- Mother clumps that are selected should be healthy (free of disease or pests)and at the adult stage (usually 8-10 years old) so that all characters are expressed.
- Clumps should be high yielding i.e. those that produce more number of culms of desirable height and diameter per year with desired internodal length and other characters of importance (e.g. low or no congestion, etc.).
- A higher number of Candidate Plus Clump (CPCs) have to be selected for each of the desired bamboo species, for maintaining wider genetic base in raised BPMs.

In most bamboo species cultivated in homestead gardens and farms, characters like clump orientation – showing either loose or compact nature, optimum clump expansion with height and diameter of culms and number of culms produced per year; rate of juvenile culm mortality, etc. usually express optimally at around 8-10 years. Farmers consider these growth traits when they select from such full grown adult clumps for use a planting material for new plantations. Flowering cycles cannot be predicted in such plantations since generally the clumps cultivated by farmers are not raised from seeds and are not frequently flowering. The homestead gardens are thus a treasure trove of high yielding quality mother clumps as the farmers have already domesticated the desired and superior types of each commercial bamboo spp of the country. These stock populations which have exhibited proven performance in the field make the selection process shorter and quicker than through exploration from natural forests.

The species-wise success of rooting in different types of vegetative propagation techniques (branch cuttings, culm cuttings, offsets, part clump and macroproliferation) for common industrial bamboos of India have been developed (Banik, 1980, 1985, 1994b, 1995b, 2008, 2010b, 2016; Viswanath *et al*., 2013a, 2013b, Seethalakshmi *et al*., 1988) and most of the selected species exhibit 50 to 95 percent rooting success (Table 4). Thin-walled species like *D. longispathus, M. baccifera, Ochlandra spp*, and *S. dullooa* show poor success (20-35 percent) in rooting. However, excepting *B. balcooa, B. vulgaris* and *D. stocksii*, all other bamboo species produce fertile seeds and germinated well (Table 3 & Table 4). Rhizome offsets and part-clump (consisting of a rhizome assembly having 2-3 offsets connected with each other), have to be collected during spring and maintained for 3-4 months in a sand media propagation bed Transit nursery before out planting during rainy season.

All the above mentioned industrially suitable bamboo species can therefore be successfully propagated to produce Bamboo planting material (BPM) for enhancing raw material resources. Moreover, Tissue Culture Plants (TCP) of a number of bamboo species are available in market. Cloning of bamboo species should be from as many Plus Clumps as possible for maintaining wide genetic base in the BPM. Except for few species, like *M. baccifera, Ochlandra* spp. it is very difficult to identify the bamboo species by the morphology of seeds, seedlings, culm and branch cuttings or Tissue Culture (TC) plants. Therefore it is of prime importance that origin of the BPM and the propagation method adopted is properly documented and diligent labelling ensured in the nursery to avoid mixing of species.

## Conclusion

India has a number of bamboo species with industrial potential growing naturally or cultivated in respective agroclimatic zones of the country. The phenotypic diversities available in the different bamboo species may be utilized for selection of specific types to generate BPM for mobilization of resources for industrial use. It is also important to conserve the germplasm for future improvement and utilization of bamboo genetic resources. A bamboo species may have variation (short or long or both) in intervals of seed availability. The variation in seed characters, germination capability and juvenile selection of seedling are important considerations in raising quality seedling. The species wise information on the success of different techniques of vegetative propagation are important for producing QPM of bamboo. Studies are necessary to know the culm properties (morphological, physical, mechanical and chemical, etc.) of major bamboo species of different populations for determining suitable specific industrial uses in India.

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