TECHNICAL BULLETIN NO. : CHF-5

Bamboo for sustainable development of Bundelkhand

A K Pandey

M J Dobriyal

Rani Lakshmi Bai Central Agricultural University, Jhansi 284 003

Correct citation Bamboo for sustainable development of Bundelkhand

Compiled by : **A.K. Pandey & M.J. Dobriyal**

Assistance: **R. P. Yadav, Ghan Shyam Abrol & Garima Gupta**

First Print : **2021**

Address: Dean

College of Horticulture ad Forestry

Rani Lakshmi Bai Central agricultural University

Jhansi-284003

Published by **Rani Lakshmi Bai Central Agricultural University, Jhansi – 284 003**

TECHNICAL BULLETIN NO. : CHF-5

Bamboo for sustainable development of Bundelkhand

A K Pandey

M J Dobriyal

2021

Rani Lakshmi Bai Central Agricultural University,
Jhansi 284 003

दारा सिंह चौहान
मंत्री
वन, पर्यावरण एवं जन्तु उद्यान
उत्तर प्रदेश।

मंत्री
उत्तर प्रदेश

मुख्य भवन, कक्ष संख्या-67,68
उ0 प्र0 सचिवालय, लखनऊ
कार्यालय : 0522-2238104
सी0 एच0 : 0522-2213630
आवास : 0522-2238160

संदेश

मुझे यह जानकर अत्यन्त प्रसन्नता हुई कि उद्यान एवं वानिकी महाविद्यालय, रानी लक्ष्मी बाई केन्द्रीय विश्वविद्यालय, झाँसी द्वारा विगत 18 सितम्बर, 2021 को अंतर्राष्ट्रीय बांस दिवस के अवसर पर बुन्देलखण्ड के सतत् विकास में बांस की उपयोगिता विषय पर संगोष्ठी का आयोजन किया गया, जिसमें बड़ी संख्या में विश्वविद्यालय के छात्र-छात्राओं एवं प्राध्यापकगण के अतिरिक्त बड़ी संख्या में क्षेत्र के किसानों ने भाग लिया।

हमारे देश में लगभग 156.90 लाख हेक्टेयर बांस आच्छादित क्षेत्र है। 148 बांस की प्रजातियों के साथ भारत में बांस की जैव विविधता के क्षेत्र में विश्व में दूसरा स्थान पर है। देश के उत्तर पूर्वी पर्वतीय क्षेत्र के राज्यों में बांस की सर्वाधिक विविधता देखने को मिलती है तथा 90 से अधिक बांस प्रजातियों की पहचान की गयी है, जिनमें 41 स्थानीय प्रजातियाँ हैं। बांस के विविध उपयोग के कारण इसे कल्पवृक्ष से लेकर "ग्रीन गोल्ड", "गरीब की लकड़ी", "कैंडल टू काफिन टिम्बर" की संज्ञा दी जाती है। आज दुनिया भर में 250 करोड़ से अधिक लोग बांस का व्यापार या उपयोग करते हैं। बांस हस्तशिल्प मनुष्य के ज्ञान की सबसे प्राचीनतम् शिल्पों में से एक है और भारतवर्ष में बांस शिल्प लाखों व्यक्तियों के लिए पूर्णकालिक रोजगार भी है। हमारे देश में बांस से निर्मित 1,500 से अधिक जन उपयोगी वस्तुओं की पहचान की गयी है। हस्तशिल्प वस्तुओं के अतिरिक्त बांस आधारित घरेलू कागज-लुगदी उद्योग 80 हजार करोड़ रूपये का है। वर्तमान में हमारे देश में प्रति व्यक्ति कागज की खपत 14 कि0ग्रा0 प्रतिवर्ष है और यह खपत वर्ष 2024-25 में बढ़कर 17 कि0ग्रा0 प्रतिवर्ष होने की उम्मीद है।

यद्यपि बांस टैक्सोनामिक रूप से धान कुल का एक घास है, लेकिन इसे कानूनी रूप से भारतीय वन अधिनियम, 1927 के तहत वृक्ष के रूप में परिभाषित किया गया था। हमारी केन्द्र सरकार ने एक ऐतिहासिक निर्णय के द्वारा गैर वन क्षेत्रों में उगाये गये बांस को वृक्ष/पेड़ की परिभाषा से मुक्त करने के लिए भारतीय वन (संशोधन) अधिनियम, 2017 को प्रख्यापित किया गया, जिससे इसके आर्थिक उपयोग के लिए कटाई या परमिट की आवश्यकता को समाप्त कर दिया गया है। गैर वन भूमि पर बांस की खेती के लिए यह एक बहुत बड़ी बाधा थी तथा केन्द्र सरकार के इस कदम से बांस की खेती को अब और अधिक बढ़ावा मिलेगा जिससे रोजगार के नए अवसर सृजित होगें तथा किसानों की आय दोगुनी करने में मदद मिलेगी।

मैं "बुन्देलखण्ड के सतत् विकास में बांस की उपयोगिता" नामक तकनीकी पुस्तिका के उत्कृष्ट प्रकाशन हेतु शुभकामनाएं देता हूँ तथा कार्यक्रम से जुड़े विश्वविद्यालय के कुलपति एवं सभी अधिकारियों को बधाई देता हूँ।

(दारा सिंह चौहान)

रानी लक्ष्मी बाई केन्द्रीय कृषि विश्वविद्यालय
ग्वालियर रोड, झांसी 284 003 (उत्तर प्रदेश) भारत
Rani Lakshmi Bai Central Agricultural University
Gwalior Road, Jhansi 284 003 (U.P.) India

डॉ अरविन्द कुमार
कुलपति
Dr Arvind Kumar
Vice-Chancellor

Phone : 0510-2730777
E-mail : vcrlbcau@gmail.com
Website : www.rlbcau.ac.in

FOREWORD

Bamboo's plethora of essential uses has led to the use of terms such as "Green Gold", "Poor Man's Timber", "Bamboo, Friend of The People", and "Cradle to Coffin Timber". India has an immense diversity of bamboo genetic resources after China. About 25 per cent of bamboo species of the world are found in India and distributed widely in almost all the states. A total of approximately 148 species in 29 genera of bamboos are currently occurring in India. The North-eastern hilly states of India harbour nearly 90 species of bamboos, 41 of which are endemic to the region.

Worldwide, approximately more than 2.5 billion people trade-in or use bamboo. Bamboo handicrafts are amongst the oldest crafts known to man. The Bamboo craft is a full-time employment for thousands of individuals in India, and about 1,500 traditional bamboo applications have been documented in India so far. While most bamboo resources are natural, more emphasis has been dedicated to the establishment of planted bamboo in the recent past. Further, there is a need to change the 'forestry mindset' to the 'farming mindset' and create awareness about the species' commercial viability and profitability. Considering the importance of bamboo, in 2017, the Government of India removed bamboo from the definition of forest to stimulate bamboo production so that bamboo is no longer confined to its designation as a tree. After this amendment, harvesters do not have legal intervention in extracting bamboo, and it can be harvested and sold effortlessly. Therefore, there is a significant potential for the domestic bamboo market in India at competitive prices.

The major constraints in expansion of the area, production and productivity of bamboo include legal issues, overexploitation, poor regeneration, low productivity, variety management and lack of quality planting materials, baseline data deficiencies, capital intensive production process, fragmented nature of the industry, undeveloped markets, poor quality perceptions and low level of awareness etc.

I appreciate the efforts of the authors to compile the information on various aspects of this miraculous plant and bring out a comprehensive technical bulletin entitled" Bamboo for sustainable development of Bundelkhand". I am sure that this technical bulletin, apart from serving the need of the region's bamboo growers, will serve the purpose of forestry students, extension workers, and all those who are directly or indirectly associated with the holistic aforestation drive programme of the country.

(Arvind Kumar)

Camp Office: Room No. 213, KAB-II, Pusa, New Delhi 110 012 *Ph*: (O) 011-25846034

PREFACE

Bamboo is a major source of resilient, adaptable, and highly renewable natural resources. Bamboos offer enormous wood replacement potential. It's plethora of essential uses has led to the use of terms such as "Green Gold", "Poor Man's Timber", "Bamboo, Friend of The People" and "Cradle to Coffin Timber". Bamboos have socio-economic and ecological value and their management can provide benefits on a local, national and global level through livelihood, economic and environmental security of rural people. India has abundant diversity of bamboo genetic resources after China. About 25% of bamboo species of the world are found in India; widely spread in almost all the states. Bamboo occurs almost ubiquitously in the country up to 3000 m above MSL except in Kashmir. In India, bamboos are distributed in five geographical zones- Western Himalaya, Eastern Himalaya, Northeast India, Peninsular India and Andaman and Nicobar Islands. Over half of the bamboo species occur in Eastern India, viz., Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura and West Bengal. According to FSI (2019), the total bamboo bearing area of the country is estimated to be 16.00 million hectare.

Bamboos have socio-economic and ecological value and their management can provide benefits on a local, national and global level through livelihood, economic and environmental security for millions of poor people of rural India. At present, we are able to harness only 10% of our capacity whereas we have 30% of the world's resources related to bamboo production. The country is importing half of our bamboo requirement from other countries especially from China. Considering the immense importance of bamboo in our country, Government of India has removed bamboo from definition of forest to stimulate bamboo production, so that bamboo is no longer a tree. After this amendment, harvesters do not have legal intervention in extraction of bamboo, and it can be harvested and sold easily. So now there is a significant potential of domestic bamboo market in India at competitive prices. While the majority of bamboo resources are natural, more emphasis has been given to the establishment of planted bamboo in recent years. In 2006-07, the Government of India established a Centrally Sponsored National Bamboo Mission (NBM) in India to promote bamboo in the country. The Cabinet Committee on Economic Affairs (CCEA), on April, 2018, restructured National Bamboo Mission. The Mission plans to foster holistic growth in the bamboo industry by adopting a regionally differentiated strategic approach and to expand the area under bamboo farming and marketing.

In Bundelkhand, under network project on bamboo (National Bamboo Mission) *Bambusa vulgaris, B. tulda* and *Dendrocalamus strictus* were introduced and evaluated for their growth and productivity under agroforestry system. Results reveal that bamboo has immense scope for boosting the economy of resource poor farmers in the semi-arid conditions of Bundelkhand region. It starts yielding commercial culms after 4–5 years of establishment, which can be harvested annually till flowering occurs (35–50 years). Bamboo can be used in farming systems by farmers of Bundelkhand to create sources of income, restore waste lands and avert the repercussion of climatic changes. The present compendium covers almost all aspects of bamboo like diversity of bamboo, bamboo based agro-forestry, cultivation, conservation and identification of different species through Bambusetum, disease and pest management in bamboo etc. This compendium will be very much useful for students, teachers, scientists, researchers, policy makers and professional engaged in the field of forestry, agroforestry and other related disciplines.

Dec.01, 2021
Jhansi

A. K. Pandey
M. J. Dobriyal

Content

Contributors

A.K. Pandey Dean, College of Horticulture and Forestry, RLBCAU, Jhansi **Email**: pandey.ajai1@gmail.com	**A. Singh** Assistant Professor, Biotechnology and Crop Improvement, RLBCAU, Jhansi **Email**: asinghrajkumar@gmail.com
Amey Kale Assistant Professor, Forest Products and Utilization, RLBCAU, Jhansi **Email**: amey.iwst@gmail.com	**Dipika Ayate** Teaching Associate, Tree Improvement, RLBCAU, Jhansi **Email**: daayate@gmail.com
Garima Gupta Teaching Associate, Silviculture and Agroforestry, RLBCAU, Jhansi **Email**: garima811@gmail.com	**Gaurav Sharma** Associate Professor & Head, Horticulture, RLBCAU, Jhansi **Email**: gauravhort@gmail.com
Ghan Shyam Abrol Assistant Professor, Postharvest Technology, RLBCAU, Jhansi **Email**: ghanshyamabrol@gmail.com	**M. J. Dobriyal** Professor & Head, Forestry, RLBCAU, Jhansi **Email**: manmohanjrdobriyal@gmail.com
Pankaj Lavaniya Teaching Associate, Silviculture and Agroforestry, RLBCAU, Jhansi **Email**: drkumarpankaj2010@gmail.com	**Pavan Kumar** Assistant Professor, Wild Life Biolo, RLBCAU, Jhansi **Email**: pawan2607@gmail.com
Pavithra B S Assistant Professor, Forest Protection, RLBCAU, Jhansi **Email**: pavithrabs24@gmail.com	**Prabha Singh** Scientist, ICAR-Indian Grassland and Fodder Research Institute, Jhansi **Email**: Prabha.Singh@icar.gov.in
Prabhat Tiwari Assistant Professor, Silviculture and Agroforestry, RLBCAU, Jhansi **Email**: prabhatbhu033@gmail.com	**Priyanka Sharma** Assistant Professor, Floriculture and Landscaping, RLBCAU, Jhansi **Email**: priyankafls@gmail.com
R.S. Tomar Teaching Associate, Biotechnology and Crop Improvement, RLBCAU, Jhansi **Email**: rsstomar81@gmail.com	**Swati Shedage** Assistant Professor, Forest Biology and Tree Improvement , RLBCAU, Jhansi **Email**: shedageswati85@gmail.com
Venkatesh Y N Scientist, Central Agroforestry Research Institute, Jhansi **Email**: venkatesh.yn@icar.gov.in	**Yumnam Bijilaxmi Devi** Assistant Professor, Natural Resource Management , RLBCAU, Jhansi **Email**: bijilaxmiyumnam@gmail.com

Chapter 1

Prospects of Bamboo Plantation in Bundelkhand Region

A. K. Pandey, M. J. Dobrial, and Pankaj Lavania
College of Horticulture and Forestry, RLBCAU, Jhansi

Bundelkhand lies between the Indo-Gangetic Plain to the north and the Vindhya Range to the south. It is a gently sloping upland, distinguished by barren hilly terrain with sparse vegetation, although it was historically forested. The plains of Bundelkhand are intersected by three mountain ranges, the Vindhya, Fauna and Bander chains, the highest elevation not exceeding 600 meters above sea-level. Beyond these ranges the country is further diversified by isolated hills rising abruptly from a common level, and presenting from their steep and nearly inaccessible scarps eligible sites for forts and strongholds of local kings. The principal rivers are the Sindh, Betwa, Shahzad River, Ken, Bagahin, Tons, Pahuj, Dhasanand Chambal. The Kali Sindh, rising in Malwa, marks the western frontier of Bundelkhand. Parallel to this river, but further east, is the course of the Betwa. The Yamuna and the Ken are the only two navigable rivers. Notwithstanding the large number of streams, the depression of their channels and height of their banks render them for the most part unsuitable for the purposes of irrigation, which is conducted by means of ponds and tanks.

Climate

Bundelkhand is a hot and semi-humid region. Minimum temperature varies from around 6^{o}C in Chhatarpur to 12^{o}C in Sagar. Maximum temperature varies from 38^{o}C in Sagar to 43^{o}C in Banda. Generally hottest days are in May and coldest days in December or January. Actual local temperatures are much higher, due to local conditions such as lack of fog and radiation from rocky soils or outcrops. Banda is considered as one of the hottest places in India,. The cloud of dust can be so thick that it becomes dark even during the day.

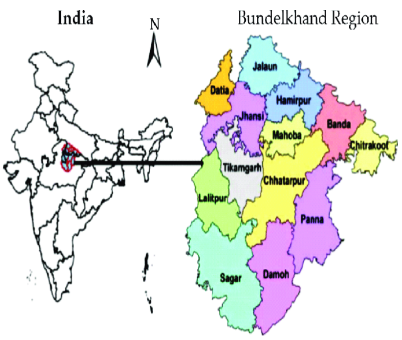


Fig.1.1. Bundelkhand region

Demography

As per Census, 2001, Bundelkhand has a population of around 15. 5million, the total population of UP Bundelkhand districts was around 8.2 million and the population of MP Bundelkhand districts was around 7.3 million. The largest population was found in Sagar district (20.2 lakhs) and lowest population was found in Datia district (6.2 lakhs). The region is marked by low population density. By Census 2001 figures, the population density of UP Bundelkhand as a whole works out to 280 persons per sq km which is less than one third of the state average. The region has both low population density as well as low level of urbanization. In all the districts of Bundelkhand, except Jhansi and Sagar, over three-fourths the population are living in rural areas (Census, 2001). In Chitrakoot district, less than 10% of the population resided in the urban areas. There is a clear variation in intra-regional distribution of population. There is higher population density in the Bundelkhand Plain areas (particularly in Jalaun and Banda), and Bundelkhand Intermediate region areas (particularly in Jhansi and Tikamgarh), and lower population density in Bundelkhand Upland (particularly in Panna and Chhatarpur) and the southern Damoh and Sagar plateaus. Urbanization (UP): 22.4% (compared to India's 31%). Between 2001&2011, urbanization in Bundelkhand rose from 22% to just 22.4%. Child sex ratio (UP + MP): 899, declined from 914 in 2001. Per capita income in agriculture (both states) has been worked out as Rs 7,173 which is 13.4% of national per capita income (2010-11) where as in UP-Bundelkhand, is Rs 7,658 for agriculture.

NATURAL RESOURCES OF BUNDELKHAND REGION

a) **Mineral Resources:** The Bundelkhand region is an important source for some of country's rare mineral deposits. The Panna district of Madhya Pradesh was world renowned for its diamond reserves, especially in the medieval period, but has since faded into obscurity. Nowadays Bundelkhand is more important for the availability of stone for construction and is famous for the gigantic blocks of medium to coarse-grained varieties of pink, red and grey granite found in Jhansi, Lalitpur, Mahoba, Banda, Datia, Chhatarpur, Panna and Sagar districts. Two varieties called Jhansi Red and Fortune Red are mined in Chhatarpur and are unique to this region. Different colored sandstone like white, buff, cream, pink and red sandstone are found scattered across Panna and Sagar districts. Sandstone being soft in nature can be chiseled to create exquisite designs and architectures; for example found in the famous sculptures of Khajurao temple in Chhatarpur district. Lalitpur is known for sandstone varieties called Lalitpur Grey and Lalitpur Yellow. Stone of lower value is crushed and used for road and building construction. Sagar, Damoh and Panna districts are known for their limestone and dolomite reserves. Excluding granite, the most precious resource of UP Bundelkhand is silica sand found in Mau tehsil of Chitrakoot. The deposits are said to be the best source of glass sands in India. Lalitpur is important for low grade iron ore as well as rock phosphate which is an essential part of fertilizer industry. The districts of Datia, Panna and Tikamgarh provide clay needed in different industries. Agate pebbles found in some places in the gravel of Ken River are used for making artifacts and trinkets (Gupta *et al*., 2014)

b) **Water Resources:** Bundelkhand region is drained by a number of rivers of the Yamuna river system. The main rivers are the Yamuna in north, Ken in east and Betwa and Pahuj in the west. The river Yamuna flows from west to east and its first order tributaries – the Betwa, Ken, Pahuj, Baghain, and Paisuni flow from south to north. Numerous second order tributaries of the Yamuna such as the Dhasan, Jamni, Birma, Sonar, Katne, Bewas, and Kopra drain the area. Also flowing along the west is the Sindh and Chambal rivers, with the Narmada flowing in the south. The region of Malwa and Udaipur Gwalior forms the southern section of Bundelkhand. The Betwa contributes around 50% of the water available in Bundelkhand Upland and Bundelkhand Plain sub-regions; the Ken contributes around 25 per cent. The rivers flow through both the states of UP and Madhya Pradesh. The Betwa, Ken, Pahuj and Dhasan are very important for irrigation in the region. Their seasonal fluctuations however, are very large. For example, the average annual discharge of river Ken is around 800 cusecs, but in winter it is reduced to around 300 cusecs and dwindles to practically nothing in May. Such fluctuations undermine the security of irrigation. Historically the need for security of water was recognized and Bundelkhand is known for its water bodies including the Pahuj reservoir, Barwasagar, Barwarlake, Aiaori Lake, Pachawara lake, Dakwan and Parichha reservoirs. A host of smaller tanks and ponds (tals) are found near Mahoba and Yikamgarh is famous for its tanks such as the Madansagar, Nandwara, Birsagar and Arjan lakes. In Chhatarpur district, the important tanks include the Jagatsagar, Goratal, Gangau reservoirs and the post independence period tanks such as Matatila, Lalitpur and Saprar reservoirs (Gupta *et al*., 2014)

WRG (2030) has initiated commissioned a comprehensive mapping of water reservoirs in the Jhansi District of Bundelkhand. The study uncovered an encouraging fact with proper restoration; the storage capacity of reservoirs in the region can be increased by five folds. Based on the mapping analysis, 2030 WRG is now developing a project to integrate resources and initiatives from government, private sector, philanthropic foundations, and civil society. This project aims to rejuvenate water reservoirs in Bundelkhand, starting with the Jhansi District. The plan is to scale up this initiative to include all seven districts in Bundelkhand. When completed, these reservoirs would enable storage of surface water for dry seasons and recharge aquifers and nearby drinking water sources. With the support of it stakeholders, the MSP is now one step closer to addressing Bundelkhand’s water challenge.

c) **Forest Resources in Bundelkhand:** Bundelkhand region currently occupies 9947.15 sq km area under forest covers, counting roughly 15.63 percent cover of total geographical area of the region. Bundelkhand region of Uttar Pradesh comprising 07 districts viz., Chitrakoot, Banda, Hamirpur, Mahoba, Jalaun, Jhansi and Lalitpur cover 2217.96 sq km area under different types of forest cover accounting 7.54 percent of the total geographical areas of the region. Among all the 07 districts of Bundelkhand region of UP, Chitrakoot maintains significant edge over other districts in maintaining the maximum area under the dense forest(81.0 km) as well as maximum percentage of geographical area of the district under forest cover(18.23%). Bundelkhand region covering 07 districts of neighboring state Madhya Pradesh accounts 22.60 per cent forest cover of total geographical areas of all 07 districts (Table 1.2). Districts Chhatarpur and Panna are having substantial dense forest covers of 184.06 km and 83.01 km, respectively. Among all the districts of Bundelkhand region of Madhya Pradesh, Panna covers the maximum area under forest covers (38.44%) of the total geographical area of the district followed by Damoh district (35.41%). The minimum forest covers (6.97%) have been reported in Datia district followed by Tikamgarh (7.66%). Distribution of forest cover of Bundelkhand region of Uttar Pradesh has been given in the table while forest cover of Bundelkhand region of Madhya Pradesh has been given in table (1.1).

Forest wealth of the region went through major deforestation during the colonial times. Recently the forest cover has improved relatively and the menace of timber collection has decreased in comparison to earlier.

Table (1.1).Forest area in Bundelkhand Region of Uttar Pradesh

Sl No.	District	Geographical Area (GA)	*Forest area in km*			Total	% of GA
			Very Dense Forest	Mod. Dense Forest	Open Forest		
1.	Banda	4,408	0.00	46.00	55.91	101.91	2.31
2.	Chitrakoot	3,216	81.00	319.00	186.40	586.40	18.23
3.	Hamirpur	4,021	0.00	80.00	147.00	227.00	5.65
4.	Mahoba	3,144	0.00	21.00	149.00	170.00	5.41
5.	Jalaun	4,565	0.00	60.58	186.73	247.31	5.42
6.	Jhansi	5,024	0.00	42.00	262.05	304.05	6.05
7.	Lalitpur	5,039	0.00	128.89	452.40	581.29	11.54
	Total	**29,417**	**81.00**	**697.47**	**1439.49**	**2217.96**	*7.54*

Source: FSI (2019).

Table(1.2). Forest area in Bundelkhand Region of Madhya Pradesh

Sl No.	District	Geographical Area (GA)	*Forest area in km*			Total	% of GA
			Very Dense Forest	Mod. Dense Forest	Open Forest		
1.	*Chhatarpur*	8,687	184.06	817.52	756.97	1,758.55	20.24
2.	*Tikamgarh*	5,048	1.00	89.96	295.68	386.64	7.66
3.	*Damoh*	7,306	2.00	845.79	1,739.39	2,587.18	35.41
4.	*Sagar*	10,252	1.00	1,141.57	1,651.97	2,794.54	27.26
5.	*Datia*	2,902	0.00	92.11	110.17	202.28	6.97
6.	*Panna*	7,135	83.01	1,478.26	1,181.44	2,742.71	38.44
	Total	**34,195**	**188.06**	**2986.95**	**4554.18**	**7,729.19**	*22.60*

Source: FSI (2019).

Looking the comprehensive need of the region emphasis has to be given on afforestation on hill slopes, in catchment areas of rivers, lakes and reservoirs and on semi-arid, and desert tracts. Strategic importance has been laid on afforestation, social-forestry and farm-forestry. Under the forestry section 4.2.3, it is noted that village and community lands, including those on foreshores and environs of tanks, not required for other productive uses, should be taken up for the development of tree crops and fodder resources. As regarding the troubles related to mining it has been stated under the section 4.4.2 that beneficiaries who are allowed mining and quarrying in forest land and in land covered by trees should be required to repair and re-vegetate the area in accordance with established forestry practices. No mining lease should be granted to any party, private or public, without appraised from the environmental angle.

Major Agrarian Problem of Bundelkhand

In Bundelkhand a small section of the rural population depends upon nonagricultural occupations for their livelihood but these occupations are also indirectly related to the Agriculture. Farmers of the villages perform various agricultural activities for which they need the cooperation of other members of the villages. Besides the several government programme for community development of the region still the population in the rural areas are poor, live in scarcity and prone to migration.

Table (1.3) State wise distribution of bamboo area in recorded forest area State/UT Bamboo bearing area (sq km)

Sl. No.	State/UT	Bamboo bearing area (sq km)	Bamboo bearing area (sq km) as per ISFR,2017	Change in Are with respect to ISFR, 2017
1.	Andhra Pradesh	7,003	7,578	-575
2.	Arunachal Pradesh	14,981	15,125	-144
3.	Assam	10,525	8,955	1,570
4.	Bihar	1,116	1,004	132
5.	Chhattisgarh	11,255	11,060	195
6.	Goa	418	382	36
7.	Gujarat	3,392	3,544	-151
8.	Haryana	72	21	51
9.	Himachal Pradesh	650	540	110
10.	Jharkhand	4,123	4,470	-347
11.	Karnataka	10,181	10,442	-261
12.	Kerala	2,849	3,484	-635
13.	Madhya Pradesh	20,867	18,167	2,700
14.	Maharashtra	15,408	15,927	-519
15.	Manipur	9,903	10, 687	-784
16.	Meghalaya	5,410	5,943	-533
17.	Mizoram	3,476	3,267	209
18.	Nagaland	4,428	6,025	-1,741
19.	Odisha	11,827	12,109	-282
20.	Punjab	255	44	211
21.	Rajasthan	1,874	1,976	-102
22.	Sikkim	1.176	553	623
23.	Tamil Nadu	4,357	4,154	203
24.	Telengana	5,438	4,778	660
25.	Tripura	3,783	3,617	166
26.	Uttar Pradesh	1,235	936	299
27.	Uttarakhand	1,489	1,078	411
28.	West Bengal	855	942	-87
29.	A&N Island	1, 814	0	1,814
	Total	1,60,037	1,56,808	3,229

Source: FSI (2019), Note: data for Chandigarh, Dadra and Nagar Haveli, Daman and Diu, Delhi, Lakshadweep, J&K and Pondicherry is not included.

A peculiar problem in the Bundelkhand region is the '*Chutta jaanwar*' (i.e., stray animals). A large number of cattle particularly cow when these are unproductive in terms of milk, or when their masters lack resources and capacity to sustain their maintenance due to losses in agriculture or other livelihood interventions. These stray animals further affect the vegetation – saplings, crops and crop yields in the forms besides causing a menace on the traffic.

Diversity Status of Bamboo in India

India has abundant diversity of bamboo genetic resources after China. About 25% of bamboo species of the world are found in India distributed widely in almost all the states. In India, bamboos are distributed in five geographical zones- Western Himalaya, Eastern Himalaya, Northeast India, Peninsular India and Andaman and Nicobar Islands (Bedell, 1997). They are found distributed as an under storey in southern hilltop tropical evergreen forests, west coast semi evergreen forests, southern moist deciduous forests and dry bamboo brakes (Champion and Seth, 1968). Mehra and Sharma (1975) reported that bamboos grow from the coastal plains to elevations of 3700 meters in the Himalayas. Biswas (1988), Rai and Chauhan (1998) reported that bamboos were particularly abundant in the Western Ghats and North-East India. Varmah and Bahadur (1980) reported about 19 principal genera of bamboos in India. Sharma (1987) reported about 130 species belonging to 24 genera of bamboos from India out of which 20 are indigenous and four are of exotic origin. Tewari (1992) described 23 genera and 128 species in India. Seethalakshmi and Kumar (1998) reported 123 species and 18 genera of bamboos in India which include 87 naturally occurring and 41 introduced or cultivated species. Naithani (2008) reported presence of 20 genera and 115 species of bamboos in India. Kumar (2011) reported 136 species of bamboos belonging to 29 genera in the country out of which 96 species are native bamboos and 40 species are cultivated ones. Sharma and Nirmala (2015) reported 148 species and 4 varieties belonging to 29 genera are found in India (both wild and cultivated).

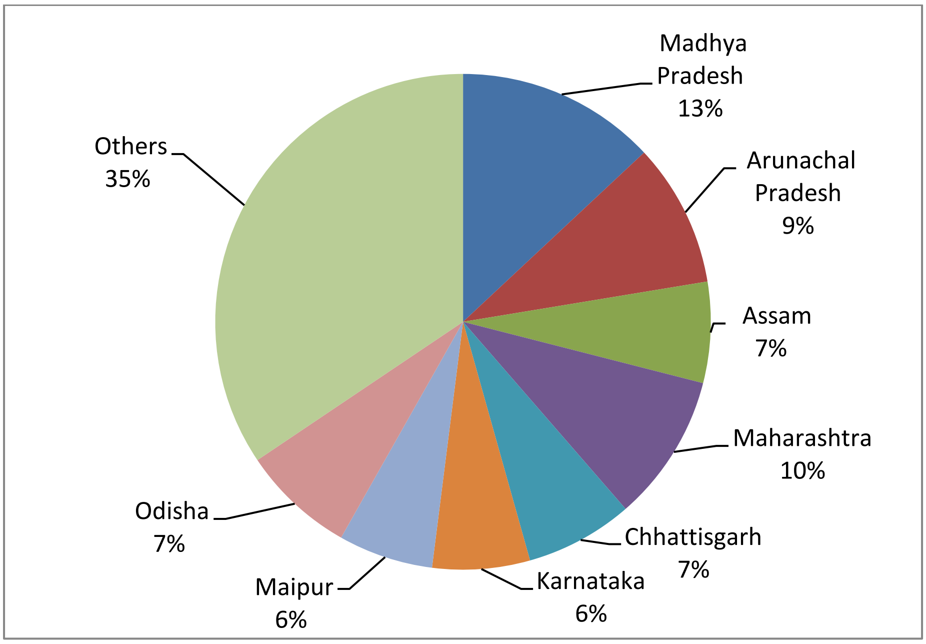


Fig.2. Leading bamboo producing states

Bamboo – National Scenario

According to FSI (2019), the total bamboo bearing area of the country is estimated to be 16.00 million hectare (Table 1.3). Madhya Pradesh has maximum bamboo bearing area of 2.09 m ha followed by Maharashtra (1.54 m ha), Arunanchal Pradesh (1.49 m ha) and Odisha (1.18 m ha). As per FSI report (2019) there has been change in current area as per compared to data compiled in 2017. NE states occupy the substantial are under bamboo, however, some decline in the areas of bamboo in NE states like Arunachal Pradesh, Manipur, and Nagaland.

State Scenario of Bamboo in Uttar Pradesh

In Uttar Pradesh, bamboo is grown in approximately 1,235 Sq km area (FSI, 2019). As per estimate of data collected during 2017, there is improvement in acreage and additional 299sq km area has been added (Table 1.4). Thus, Uttar Pradesh covers almost 0.77 per cent total country's growing bamboo stock.

Table(1.4). Growing Stock of Bamboo in Uttar Pradesh

Growing Stock (GS)	*Particular*	**% of Country's GS of Bamboo**
Bamboo bearing area inside RFA/Green Wash	1,235 (in sq km)	0.77
Total number of culms(in millions)	236	0.60
Total equivalent green weight	974 (000' tonnes)	0.35

Source: FSI (2019).

Quantified estimation of Dependence of People living in forest fringe villages on forests in Uttar Pradesh

Through a nation-wide study, FSI has done estimation of dependence of people living in the villages close to forest for fuel wood, fodder, small timber and bamboo in quantified terms for each State & UT of the country .The estimated quantities of the four produce for Uttar Pradesh is given in the table (1.5)

Table (1.5). Estimation of Dependence of People in Forest Fringe Villages on Forests in Uttar Pradesh

Fuelwood (tonnes)	**Fodder (tonnes)**	**Bamboo (tones)**	**Small Timber (tones)**
51,40,777	5,93,35,092	1,09,512	1,59,587

Source: FSI (2019).

State Scenario of Bamboo in Madhya Pradesh

In Madhya Pradesh, bamboo is grown in approximately 20,867 Sq km area (FSI, 2019). As per estimate of data collected during 2017, there is improvement in acreage and additional 2700 sq km area has been added (Table 1.4). Thus, Madhya Pradesh covers almost

13.04 percent total country’s growing bamboo stock, equivalent to 14,088 (000' tonnes) green weight table (1.6).

Bamboo Plantation in Bundelkhand Region

Smart Agro-techniques

Most of the bamboo species can be grown in a wide range of agro-climatic zones in the country but a suitable matching of the species with the site is crucial to maximize the benefits. Based on the natural range of the species and past experience with the exotics, some species have been identified that perform better under specific conditions. Selection of the species should be based on the suitability of agroclimatic conditions of the particular region. Thus, *Bambusa vulgaris* var. *striata* and *B. vulgaris* are tolerant of salinity in coastal soils. *Dendrocalamus strictus* is hardy and withstands arid climate well but productivity is improved under good management. *B. balcooa* has gained popularity many parts of the country since it is easy to propagate through vegetative means as well as tissue culture, carries no risk of gregarious flower and responds well to inputs. The exotic species *Guadua angustifolia* introduced recently from South America is found to grow well in the early years of planting in areas with good rainfall and therefore might be a good candidate for plantations. The bamboo reed (*Ochlandra* species) has performed quite well in introductions to the North Eastern States and *Melocanna baccifera* which is native to the area has performed well in Karnataka and Kerala.

Table (1.6). Growing Stock of Bamboo in Madhya Pradesh

Growing Stock (GS)	*Particular*	**% of Country's GS of Bamboo**
Bamboo bearing area inside RFA/Green Wash	20,867	13.04
Total number of culms(in millions)	3595	9.11
Total equivalent green weight	14,088 (000' tonnes)	5.08

Source: FSI (2019)

Soil

Bamboo comes up in a variety of soils; however productivity will be the best if the soils are of alluvial type of soil which is well drained. Care should be taken to see that a minimum soil depth of 45cm is available. This is mainly because bamboo is a surface feeder with a shallow but tardy root system. At times bamboo can be invasive and can compete with adjacent crops for moisture and nutrition hence care should be taken to see that site selection is done meticulously keeping in mind the active spreading habit of the plant. Bamboo requires open sunshine and hence planting bamboo under other trees may lead to failures in plantation establishment. Optimum temperature range is between 20 to 38°C and rain fall between 900 to 4000 mm for luxuriant growth of bamboo. The altitudinal range in which bamboo can be grown economically is 500 to 4000 MSL. Water logged areas are to be avoided for planting bamboo as the rhizome growth will be affected due to poor air circulation in the soil.

However, if the objective is only to stabilize the water logged area; soil can be made in to mounts and clumps planted above the mount. It is not advisable to plant bamboo in very steep slopes due to the possibility of the clumps toppling down due to heavy wind or rain is high.

Propagation

By Seeds: In species that set seeds usually after gregarious flowering at long intervals of 30 - 60 years, huge quantities of seeds are produced. Seeds have short viability of few months unless stored under reduced humidity and temperature. Even under the best conditions seed viability declines after 1- 2 years and production of seedlings no longer becomes practical.

Macroproliferation: This is a common method of producing bamboo planting material in the seedling nursery long after seed viability is lost. After a year of growth in the nursery bamboo seedlings have several tillers (culms) each with a rhizome formed below the soil. It is feasible to produce planting stock by dividing (splitting) the seedling into tillers each with a rhizome. The process can be repeated in the same manner every year and if proper nutrients, water and maintenance are provided in the nursery this method can ensure continuous production of planting material. The other advantage of the method is that the size of the plant produced remains the same as the seedling and thus facilitates transport from nursery to field.

Vegetative propagation through rhizome transplants: When seeds or seedlings are not available, bamboo can be propagated vegetatively by extracting and transplanting the rhizome along with a small portion of the previous year's culm or sometimes the entire culm and the rhizome. Since the rhizome has a store of food and is capable of growing into the culm and establishing itself, this method has a good rate of success although removal and transport if the bulky material is a limitation. However, this method of propagation can't be followed in the larger areas due to strenuous work of rhizome separation and further a requirement of a large quantity of planting materials.

Vegetative propagation thorough culm cuttings: This method is perhaps the most practical of large scale vegetative propagation methods. The method involves preparing culm cuttings (each with a single node or more effectively with two nodes each), and if found necessary, use of rooting hormones. Either the cuttings are dipped in a hormone solution or in the case of the species with large and hollow internodes the hormone solution is poured into the cavity and place in the propagation beds in the nursery or ropagation chamber. Each node produces shoots and roots and can be transplanted into bags and hardened in the nursery. The propagule that results is often bulky for transport. The advantage is that a single culm can produce several plants.

Micropropagation (Tissue culture): Through tissue culture we can produce plants on a very large scale using small plant parts. The tissue culture method requires trained personnel and specialized facilities for maintaining sterile and controlled environment. Propagation protocols including specific nutrient media are also required to be standardized through research. High multiplication rates and sterile conditions ensure that uniform, small and disease and pest free propagules can be produced throughout the year. Guidelines have been issued by the NBM aims at ensuring that plantations of bamboo in the country is raised only through certified superior planting stock produced through a network of certified high-tech bamboo nurseries. The superior clones of different bamboo species have been identified and rhizome banks are being established as source of mother plant for mass production of quality planting stock. In the interests of improving productivity bamboo growers are advised to ensure that plantations in future be established as far as possible with superior planting stock.

Bamboo Nurseries and Tissue Culture Laboratories

With a view to expand the cultivation of bamboo plantations and enhance the post-harvest management and marketing activities of the bamboo-based products, the Ministry of Agriculture and Farmers Welfare has implemented the Authorization of Bamboo Nurseries, Tissue Cultural Laboratories and Certification of Quality Planting Materials Programme. The programme aims at increasing the cultivation of bamboo by supplying Quality Planting Materials and encouraging the industries to set up new nurseries and boost the growth of the already ones. Agroforestry Centers of ICAR like State Agricultural Universities (SAUs), All India Coordinated Research Projects (AICAR), ICAR and ICFAR initiate to supply certified seeds and planting materials of both vegetative and tissue culture to the States to establish accredited nurseries to provide Quality Planting Materials to the farmers and industries.

Objective of the Program

The program which is implemented through the National/State Bamboo Mission aims at achieving the following objectives:

- Framing out an organizational framework to ensure the availability of certified planting materials of various bamboo species.
- Establishing accredited bamboo nurseries with advanced infrastructure, quality control measures, and technical skill
- Setting up procedure for the documentation of complete information about the planting stocks such as the name of the species, clonal identity, geographical descent and demonstrated quality lineage
- Expanding the quality planting materials accredited in the nurseries
- Educating Quality Product Material producers and farmers about the quality elements of the planting materials
- To evaluate, assess and accredit the planting materials with paper trails right from the production of the mother plant to the supply of planting materials to the farmers and the industries.

- Supervising the operations of the accredited nurseries and quality of planting materials through consistent inspections and renewal of accreditation of the nurseries
- Encouraging the accredited nurseries to utilize the superior clonal material produced through advanced and multiple techniques

Activities Covered under the Program

The activities covered under the program are as follows:

- Accreditation of Tissue Culture Laboratories involved in Micropropagation of bamboo plants
- Accreditation of Nurseries engaged in the production of Quality Planting Materials which are ready for use by the farmers
- Certification of planting materials bred in the accredited nurseries

Accountabilities of the Bamboo Nursery Owners

The National and State Bamboo Mission have set out predetermined principles for the accredited nursery members and the other agencies involved in the production of Quality Bamboo Stock. They are as follows:

Recognition of bamboo species and clones

- Identifying the superior bamboo species with the introduction of DNA barcoding techniques
- Collecting the certified specimens of Quality Bamboo Materials such as leaves sheath, inflorescence and seedlings
- Involving the experts in recognizing and selecting the superior clones of bamboo plant stocks
- Depositing the best-found specimens at the authorized herbariums and research organizations.
- Coordinating with the executives of the State Bamboo Mission in obtaining geo-tagging the plus clumps and species-wise locations of the clusters
- Maintaining a proper record of geo-tagged species as determined by GPS instruments and marking on a map with the recognizable landmarks
- Being a part of the quality control process by undergoing genetic fidelity tests for the Tissue Culture plants
- Obtaining Intellectual Property Rights for the species in order to avoid the mixing up of clones and
- Increase the mother stock of the clones

Clonal planting material

- Maintaining vital details of the parent plus clumps to set up species identity of the accredited nursery stock and keeping up the chain of ownership of the documents prepared

- Labeling all the nursery stocks carefully to avoid mixing up of the batches
- Establishing genotypic stability for the nursery stocks and get the materials tested for clonal trials at multiple locations

Maintenance of Clonal Banks

- Preserving the mother plants in the clonal banks from any kind of disease and infections under the phyto-sanitary settings
- Maintaining the Nursery Log Book to record the treatment schedules and supervise the progress
- Ensuring the quality of the bamboo stock during the certification process

Quality of Planting Materials

- Following a determined process in the nurseries to guarantee the quality of bamboo stocks
- Cultivating the healthy planting materials with the developed rhizomes and tillers with green and healthy leaves
- Rigoursly following the rules laid down by the National Certification System for Tissue Culture Plants (NCS-TCP) of the Department of Biotechnology while determining the quality of shoots, rhizomes and root system in the nursery

Micro-propagation of Tissue Culture

- Specifying the mode of plantlet regeneration approved by the Tissue Culture Lab
- Properly recording the batch sizes of the planting stock and the number of cycles after which it was regenerated
- Undergoing the Genetic Fidelity Testing for the Tissue cultured plantlets through any recognized Government Institutions
- Maintaining the Documentation of Nursery on Chain of Custody (CoC)
- Maintaining the transparent record of the transfer of the planting materials from the source nursery to the plantation sites
- Obliging Good Laboratory Practices (GLP) as per the guidelines of the (NCS-TCP).

Planting time and spacing: Best time for bamboo planting is during the pre-monsoon showers so that establishment during the monsoon is successful and requires less watering. The seedling/cutting is placed in the pit and the polybag is removed with a sharp blade taking care not to disturb the roots and rhizome of the plant. Soil around the plants should be consolidated tightly by pressing with feet. The surface of the pit, after filling should be slightly sloped to one side so as to promote moisture retention. Generally, three weeding in the first year, two in the second and one in the third year has to be carried out. According to the clump size, species can be classified to small (5-15 m tall with a clump diameter of 1-3 m), medium (15-20 m tall with a clump diameter of 3-5 m) and large (20-30 m tall with a clump diameter of 5-8 m) clumps. Higher densities (closer spacing) are appropriate for small-sized bamboos, and lower densities (more spaced) are appropriate for larger bamboos. Depending on the parent clump size, 3-4 m, 5-6 m and 8- 10 m. spacing can be provided in the range of 4 X 4m, 5 X 5m (e.g. *Thyrsostachys oliverii*), 7 m X 7m (e.g. *Dendrocalamus hamiltonii*) or even 10 X10 m (e.g. *Dendrocalamus giganteus*).

Mounding: The network of rhizomes and the root system is what anchors the tall and heavy culms to the soil. The tendency of rhizomes in sympodial bamboo is to grow horizontally under the soil and only the newly emerging culms grow upwards. Roots emerging from below the new culms need soil to establish. However, as the clump gets older the rhizome system tends to gets exposed above the ground. This usually happens when the soil is eroded and the mulch is minimal. In such a clump, rhizomes are likely to be retarded in growth if it gets exposed to the sun and the overall availability of nutrients and moisture tends to be reduced. Exposed rhizomes are also likely to lead to clumps that are top heavy and when lacking sufficient anchorage, leading to toppling in wind or rain. When the rhizomes are seen exposed in a clump, usually after several years of establishment, soil mounding may be considered. Loosen the soil surrounding the bamboo culm; apply five baskets (≈30 kg of manure/compost/ash), and if available, an additional 500 g of NPK. Mix the fertilizer with loosened soil, carryout soil mounding at the base of the clump and trench around the clump.

Irrigation: During the first year of planting watering helps obtain higher survival rates especially in areas where the dry period is longer than two months. Irrigation generally helps to increase the productivity at least by three times. Natural water conservation methods like ditches or crescent shaped trenches and use of mulch help in moisture conservation. Reports from Karnataka show that yield was increased to three fold when plantations of *Dendrocalamus strictus* were irrigated. However the requirement of irrigation will vary with the local climatic conditions and microenvironment. In water scarce areas drip irrigation has been found cost-effective, but that requires technology and investment during site preparation. Considerable savings in water will be achieved when drip irrigation is used and should be preferred where water resources are scarce. The drip irrigation system further can be strengthened with the provision of fertigation.

Trenching: In drier locations or semi-arid regions, rainfall is relatively scanty. Trenches can be created to collect and store more water to increase soil moisture by collecting the run-off generated.

Pruning: Some of the bamboo species like *Bambusa bambos*, *B. balcooa*, *B. nutans* and *Dendrocalamus hamiltonii* has a tendency to produce large number of branches at the base of the clump thus producing a congestion. This indirectly can affect the development of new sprouts. In order to prevent the congestion it is advisable to prune these branches when the clump is two to three years old and continue every year preferably during the months of November to February. Cleaning of the clump is done by removing the dead and dying culms from the clump and thinning the clump by removal of weaker culms and this will facilitate proper growth of new shoots. Removal of the upper part of the culm is also recommended in areas prone to heavy wind and frost.

Productivity Status: The present yield per hectare is very low compared to other countries such as Japan, China, Taiwan and Malaysia. As compared to China and Taiwan, India's productivity is one fourth to one fifth. In Odisha, productivity from homestead areas was an average of 5-6 MT per hectare per annum, much above the productivity level of bamboo in forest areas. In fact, the Odisha Bamboo Policy acknowledged that there was a need to enhance the productivity up to 20–25 MT per ha per annum through scientific cultivation, superior clones and species change. Correspondingly, in Maharashtra from homestead areas, the average productivity was 3-4 MT per hectare per annum, which also was much above the productivity level of bamboo in the forest areas. Similarly, the yield in Andhra Pradesh was 7 MT per hectare per annum from forest plantations, while in the managed plantations it was found to be 12 MT per hectare per annum (FRI 2014; Haque, 2007).

Demand and Supply: In country, 10 million people depend solely on bamboo for survival. The current demand of bamboo for various purposes estimated to 26.69 million tonnes as against supply of 13.47 million tonnes in the country as reported by Salam (2013). The share in global bamboo trade and commerce is only 4% though it possesses 45% of global bamboo growth.

Issues in Bamboo Sector: Despite its well known characteristics and potential for multiple uses, bamboo sector suffers from technology constraints both in plantation technology and management and its various uses in terms of lack of application of known scientific methods in plantation and post harvest treatment and technology for product development. To utilize the full potential of bamboo plants and its multiple uses following issues need to be addressed:

- **Lack of awareness:** Despite the high economic potential of bamboo and huge utility of bamboo for the rural areas, bamboo has not been able to find its desired place in the rural economy due to lack of awareness about the economic potential and utility of bamboos. There is a need for changing the 'forestry mindset' to the 'farming mind set' and creating awareness on the commercial viability and profitability of the species (Mishra *et al.*, 2014). Research results available in the public and private domain do not regularly reach the farmers due to lack of a dedicated extension system. In this regard, extensive awareness and capacity building programmes are required at all levels viz. farmers, extension workers, village level societies, tree growers' cooperative societies etc.
- **Limited choice of species and non-availability of quality planting stock:** Choice of the species is one of the major constraints in the ravine region of India. So far, two species viz., *D. strictus* and *B. bambos* are dominating the plantations. These species though hardy have lower productivity as compared to commercial. New species of bamboos, having proven track record of higher yield which could grow successfully under different climatic and edaphic conditions thus need to be screened for higher yield. Research conducted under NMBA sponsored project has revealed that *D. hamiltonii*, *B. balcooa*

and *B. vulgaris* have higher productivity in sub-tropical conditions of the country (Kaushal *et al*., 2014).

- **Lack of database:** Lack of reliable data on growth, biomass, productivity, growing stock and area is adversely impacting the resource strengthening initiatives in the country. Majority of growth and biomass data available is only on one or two species i.e. *Dendrocalamus strictus* or *B. bambos* and *Melocana baccifera*. Further, the available data is largely based on the inferences drawn from the bamboo sale data maintained by the state forest departments. Thus, there is urgent need of data management based on actual removals of bamboo from forests both by right holders for domestic consumption and by the forest departments for commercial purposes. Efforts are also required to adopt uniform unit for recording bamboo harvest and sale data (Tewari *et al*., 2019)
- **Lack of quality planting stock and genetic improvement**: Quality planting material is not available for bamboos. Due to gregarious nature of flowering, seed is not easily available and has to be procured from suppliers whose quality is not known. Majority of plantation in India is being raised from seed obtained from unknown sources with no mechanisms to certify the productivity credentials of its source (FRI, 2014). Vegetatively propagated plants are also not easily available. There is immediate need to screen and develop genetically superior germplasm for commercial bamboo species and make them available on mass scale through developing protocols by macro and micro propagation methods. Genetic and breeding research to improve productivity through selection of superior clones is the need of the hour. Inter-varietal, inter-specific and inter-generic hybridization methods thus need to be taken up on urgent basis.
- **Harvesting and transport restrictions:** The full potential of the bamboo sector in the past was not utilized due to the problems being faced by the cultivators like restrictive regulatory regime, requirement of permission for felling, transit and processing, export restrictions, royalty and transit fee on the products etc. However, recently Government of India cleared an ordinance amending Indian Forest Act, which omits bamboo grown in non-forest areas from the definition of trees thereby exempting bamboo grown in non-forest areas from the requirement of felling/transit permit. This move will allow free movement of bamboo and would generate the demand for raw material leading to planting of bamboo trees on non-forest land, provide employment and encourage the growth of small and medium industries in the villages and smaller towns and reduce dependence on imports. Bamboo grown in forest areas however, shall continue to be governed by the Forest Conservation Act, 1980,
- **The need of value addition**: Most of the handicraft sector in bamboo is traditional due to which the production level is low. For production of bamboo handicrafts, huge quantity of splits, sticks and semi-processed raw materials of various specifications are required which presently are obtained by manual processing of whole bamboos by artisans which results in more wastage and reduce the quality of the end product. Therefore, there is an immediate need to provide ready to use raw material including housing material, improved tools, machinery/skill development so that production can be enhanced without compromising with the quality.

- **Policy for promotion of bamboo plantation in degraded ravine lands:** A large portion of degraded lands, which could be profitably used for raising bamboo, are under the control of the Revenue Department/ Forest Department. Such lands are neither being developed by the Department nor leased away to the interested entrepreneurs for development. These lands can be economically utilized for promoting bamboos. Further, statutory ceiling limits on agricultural land holdings for wastelands should be liberalized. Plantation of bamboos should be treated on par with plantations of commercial crops like rubber, tea, coffee, etc. Long term finance, fiscal incentives and tax benefits should be provided to promote technology based reforestation and farm forestry projects. For encouraging the growth of bamboo sector in the country, Import Duties also need to be rationalized.
- **Capacity building:** Bamboo is generally viewed as a group of plants having vast potential for improving the socio economic condition in rural areas in the country through its use in craft. There is, however, a need to create the capacity of the people to develop high value bamboo articles. It was recommended that wide-ranging national programs to build the capacity of the rural artisans in bamboo craft be initiated towards developing bamboo based cottage industry in the country and enhancing cash incomes of the rural artisan (Tewari *et al.*, 2019)

References

1. Bedell, P.E. (1997). Taxonomy of Bamboos. ABC Publications, New Delhi, 150.
2. Biswas, S. (1988). Studies on bamboo distribution in Northeastern region of India. Indian Forester 114, 514–531
3. Champion, H.G. and Seth, S.K. (1968). A revised survey of the forest types of India. Govt. of India Press, New Delhi.
4. FRI, (2014). Proceeding of National Seminar "Bamboo Productivity in Forest and Non – Forest Areas" 30th to 31st January, 2014. Bamboo Technical Support Group. Indian Council of Forestry Research and Education. Forest Research Institute, Dehradun.
5. FSI, (2017). India State of Forest Report 2017. Forest Survey of India. Ministry of Environment and Forests. Government of India. Dehradun. Available from http://fsi.nic.in/ isfr2017/isfr-forest-cover-2017.pdf.
6. FSI, (2019). India State of Forest Report 2019. Forest Survey of India. Ministry of Environment and Forests. Government of India. Dehradun.
7. Gupta, A. K., Nair, S.S., Ghosh, O., Singh, A. and Dey, S. (2014). Bundelkhand Drought: Retrospective Analysis and Way Ahead. National Institute of Disaster Management, New Delhi, Page 148.
8. Haque, M.S., 2007. Bamboo for ecological security and prosperity. Research paper, National bank for Agriculture and Rural Development. India.
9. Kaushal, R., Tewari, S. and Chaturvedi, O.P. (2014). Bamboo growth and productivity outside forest area. In: Proceeding of National Seminar "Bamboo Productivity in Forest and Non – Forest Areas" 30th to 31st January, 2014. Bamboo technical support group. Indian Council of Forestry Research and Education. Forest Research Institute, Dehradun.
10. Kumar, M. (2011). Grasses and Bamboos. (Part- II), Bamboos of Peninsular India, All India coordinated Project on Taxonomy (AICOPTAX). KFRI Research Report No, 399, 140.

11. Mehra, P.N., and Sharma, M.L. (1975). Cytological studies in some central and eastern Himalayan Grasses V. The Bambuseae Cytologia, 40, 463–467.
12. Mishra, P.K., Kurothe, R.S., and Krishna Rao, B. (2014). Bamboo Productivity in Degraded Gullied Lands of Major Ravine Systems of India. In: Proceeding of National Seminar “Bamboo Productivity in Forest and Non–Forest Areas” 30th to 31st January, 2014. Bamboo Technical Support Group. Indian Council of Forestry Research and Education. Forest Research Institute, Dehradun.
13. Naithani, H.B. (2008). Diversity of Indian bamboos with special reference to North-east India Indian Forester, 134, 765–788.
14. Naithani, H.B. and Bennet, S.S.R., (1991). New combinations for Burmese bamboos. Indian Forester, 117, 67–68.
15. Rai, S.N. and Chauhan, K.V.S. (1998). Distribution and growing stock of bamboos in India. Indian Forester,124, 89–97.
16. Salam, K. (2013). Connecting the poor : Bamboo (Problems and prospect). https://www.jeevika.org %2Fbamboo%2F2g-article-fornbda.docx&usg=AFQjCNGuk5Z-4cNeLPhqL8d3A8Ntz4Z7bw(Accessed on 6 May 2013).
17. Seethalakshmi, K.K. and Kumar, M. (1998). Bamboos of India- a compendium. BIC India, Kerala Forest Research Institute, Peechi and International Network for Bamboo and Rattan, New Delhi, India, 342.
18. Sharma, M.L. and Nirmala, C. (2015). Bamboo diversity of India: an update. Proceedings of the 10th World Bamboo Congress, Korea. Available from www.proceedings. com/28028.
19. Sharma, Y.M.L. (1987). Inventory and resource of bamboos. In: Rao, A.N., Dhanarajan, G., Sastry, C.B. (Eds.). Recent Research on Bamboos. Proceedings of the International Bamboo Workshop. Hangzhou, China, IDRC, 117.
20. Tewari, D.N. (1992). A monograph on bamboo. International Book Distributors, Dehradun, India, 498.
21. Tewari, S., Negi, H. and R. Kaushal, R.(2019).Status of Bamboo in India. International Journal of Economic Plants, 6(1):030-039.
22. Varmah, J.C. and Bahadur, K.N. (1980). India - a country report. In: Lessard, G., Chouinard, A. (Eds.), Bamboo Research in Asia. Proceedings of a Bamboo Workshop, Singapore. IDRC. IUFRO, 1946.
23. *WRG (2030). Water Resources Group is a public, private, civil society multi-donor trust fund hosted by the World Bank Group.*

Chapter 2

Diversity of Bamboo Species in India- an over view

A.K.Pandey, M.J. Dobrial and Garima Gupta
College of Horticulture and Forestry, RLBCAU, Jhansi

A total of approximately 148 species in 29 genera of bamboos are currently thought to occur in India (both wild and cultivated). The maximum concentration of species is found in the deciduous and semi evergreen regions of North-east and the tropical moist deciduous forests of North and South India (Sharma and Nirmala, 2015). The North-eastern hilly States of India harbour nearly 90 species of bamboos, 41 of which are endemic to that region. There are 3 large genera (*Bambusa*, *Dendrocalamus*, and *Ochlandra*) of bamboos in India with more than 10 species each. Together, these three genera represent about 45% of the total bamboo species found in India. On the other hand, there are some genera which are represented by only one species each e.g. *Ampelocalamus*, *Sarocalamus*, *Chimonobambusa*, *Pseudostachyum*, and *Stapletonia*. Bamboos in India show a great diversity in both their habitat and habit of growth. They occur in different forest types, ranging from tropical to sub-alpine zones. Some species are found only in cultivated state in few gardens. Endemism in Indian bamboos is of very high order. More than 50% of the bamboos found naturally occurring in India (71species) are endemic to the country. This projection is however tentative, since more than a dozen species have been described as new species from India in the recent years and their presence in other geographical regions remains unexplored. Substantial studies have been made on Himalayan bamboo, classified in subtribes and genera with a key to the genera. The systematic treatment begins with six tropical and subtropical genera which all have iterauctant inflorescences and 6 stamens. *Bambusa* and *Dendrocalamus* are in the subtribe Bambusinae Agardh, having solid styles. *Melocanna*, *Cephalostachyum*, *Teinostachyum*, and *Pseudostachyum* have elongated hollow styles and are in the subtribe Melocanninae Reichenbach (Stapleton, 1994).)

Table (2.1). A list of various genera (with number of species in parenthesis) and species of bamboos found in India

Sl.No.	Genera	No. of species and varieties reported in India
1.	*Ampelocalamus*	01
2.	*Bambusa*	37 +2 var.
3.	*Cephalostachyum*	08
4.	*Chimnobambusa*	01
5.	*Chimonocalamus*	04
6.	*Dendrocalamus*	18
7.	*Dinochloa*	02
8.	*Drepanostachyum* (including *Himalayacalamus*)	06
9.	*Gigantochloa*	07
10.	*Indocalamus*	* 2+1 var.
11.	*Melocalamus*	05

12.	*Melocanna*	03
13.	*Neohouzeaua*	02
14.	*Neomicrocalamus*	02
15.	*Ochlandra*	11+1 var
16.	*Oxytenanthera*	05
17.	*Phyllostachys*	05
18.	**Pleioblastus*	01
19.	**Pseudosasa*	01
20.	*Pseudostachyum*	01
21.	*Sarocalamus*	01
22.	*Schizostachyum*	05
23.	**Shibataea*	01
24.	*Stapletonia*	01
25.	*Teinostachyum*	02
26.	*Thamnocalamus*	04
27.	*Thyrsostachys*	02
28.	*Yushania*	09
29.	*Borinda*	01

Source: Sharma and Nirmala (2015)

State–wise distribution of bamboos in India (wild and cultivated)

Although bamboo grows naturally in every state, its frequency varies in different regions, primarily due to variations in climatic conditions. The state–wise distribution of bamboos in India is not completely known for all states. While such a study has recently been undertaken in some states, particularly in the North-eastern region, the information is lacking on the bamboo species present in those states where bamboo has as yet not been adopted in the social forestry or agroforestry system (Sharma and Nirmala, 2015). State–wise distribution of bamboos species in India is given in table (2.2)

Table (1.2).State–wise distribution of bamboos species in India

Sl. No.	**State/UT**	**No of Bamboo Species**	**References**
1.	Andhra Pradesh	02	https://www.kfri.res.in ›
2.	Arunachal Pradesh	47	Sharma and Nirmala (2015)
3.	Assam	38 + 2var	Sharma and Nirmala (2015)
4.	Bihar	19	Sharma and Nirmala (2015)
5.	Chhattisgarh	09	Sharma and Nirmala (2015)
6.	Goa	2	Sharma and Nirmala (2015)
7.	Gujarat	2	Sharma and Nirmala (2015)
8.	Haryana	2	Sharma and Nirmala (2015)
9.	Himachal Pradesh	8	Sharma and Nirmala (2015)
10.	Jharkhand	10+1var	Sharma and Nirmala (2015)
11.	J&K	2	Sharma and Nirmala (2015)
12.	Karnataka	10	Sharma and Nirmala (2015)
13.	Kerala	22+2var	Sharma and Nirmala (2015)

14.	Madhya Pradesh	8	Sharma and Nirmala (2015)
15.	Maharashtra	7+1 var.	Sharma and Nirmala (2015)
16.	Manipur	40+1 var.	Sharma and Nirmala (2015)
17.	Meghalaya	46-50	Sharma and Nirmala (2015)
18.	Mizoram	33	Sharma and Nirmala (2015)
19.	Nagaland	32	Sharma and Nirmala (2015)
20.	Odisha	12+1var.	Sharma and Nirmala (2015)
21.	Punjab	4	Sharma and Nirmala (2015)
22.	Rajasthan	2	Sharma and Nirmala (2015)
23.	Sikkim	29-30	Sharma and Nirmala (2015)
24.	Tamil Nadu	17	https://www.agricultureinindia.net
25.	Tripura	19+1var	Sharma and Nirmala (2015)
26.	Uttar Pradesh	7	Pathak *et al.* (2015)
27.	West Bengal	32	Sharma and Nirmala (2015)
28.	A&N Island	22+2 var.	Sharma and Nirmala (2015)

Source: Sharma and Nirmala (2015)

Description of important species

1. ***Ampelocalamus petalaris***

Description: A rather soft, evergreen, caespitose bamboo. Culms 7-10 m. tall, 2-5-3-75 cm. in diameter, dull green, striate; nodes marked by a projecting, softly hairy ring; internodes 30-45 cm. long, whitish below the nodes; walls thin. Culm-sheaths long persistent, 25-30 cm. long, 7-5 cm. broad at the base, sparsely covered with appressed, brown, stiff hairs outside, glabrous within, attenuate at the top; margins membranous, laciniate; imperfect blade lanceolate, 15 cm. long, usually recurved; ligule long, fimbriate. Leaves variable, 20-40 cm. long by 2-5-10 cm. broad, unequal at the base, shortly petioled, terminating above in a twisted scabrous point, smooth above, rough below, scaberulous on the margins; leaf-sheaths striate, keeled, fringed on the margins; ligule very long, long fimbriate. Inflorescence a huge compound panicle with spicate branches bearing distant distichous heads, heads 1.25-2.5 cm. in diameter, supported by hard shining bracts, manyspiculate; rhachis dull greenish brown, rough, fistular. Spikelets dark brown, depressed, 10 mm. long. Empty glumes 1 or 2, many-nerved, membranous; florets 2-3, usually all fertile; lemmas orbicular, cuspidate, ciliate on the edges and densely tomentose within, 9-11 nerved; palea much shorter, ovate-lanceolate, ciliate on the keels, 2-nerved between the keels, densely tomentose within; rhachilla prolonged, bistle-like. Lodicules 0 or 2, narrow linear-lanceolate, long ciliate. Stamens exserted; anthers purple, tip conical, hairy, apiculate. Ovary broadly ovate, hairy above; stigmas 3, short, plumose. Caryopsis rounded, shining, hairy above.

Global Distribution: India: Assam, Meghalaya; Temperate Regions

2. Genus *Bambusa*

Approximately 157 species from the genus *Bambusa* are documented throughout the world. The distribution varies tropically and is native to countries like Pakistan, India, Sri Lanka, Nepal, Bhutan, Bangladesh, Burma, Thailand, Laos, Kampuchea, Vietnam, China, Japan, Malaysia, Singapore, Indonesia, Philippines, Papua New Guinea, Australia, and Madagascar (Schröder, 2010; Sarojam, 1996). The genus *Bambusa* is found throughout tropical Asia, comprising about 37 species, where 37 species and 2 varieties have been reported in India (Sharma and Nirmala, 2015**).**

Table (2.3).List of the species under the genus *Bambusa* reported in India

Sl.No.	Species
1.	*Bambusa affinis* Munro;
2.	+*B. Bambusa alemtemshii* Naithani;
3.	*Bambusa assamica* Barooah and Borthakur
4.	*Bambusa atra* Lind.;
5.	*Bambusa balcooa* Roxb.;
6.	*B. bambos* Voss;
7.	+ *Bambusa bambos var. gigantea* Bennet and Gaur;
8.	*Bambusa barpatharica* Borthakur and Barooah;
9.	*Bambusa binghamii* Gamble
10.	*B. burmanica* Gamble;
11.	*Bambusa.cacharensis* Majumdar
12.	*Bambusa comillensis* Alam
13.	+ *Bambusa dampaeana* Naithani
14.	*B. garuchokua* Barooah and Borthakur
15.	* *Bambusa glaucescens* (Willd.) Sieb.ex Munro
16.	*Bambusa griffithiana* Munro
17.	*Bambusa. jaintiana* Majumdar
18.	*Bambusa khasiana* Munro
19.	*Bambusa kingiana* Gamble
20.	*B. majumdarii* Kumari and Singh
21.	+ *Bambusa manipureana* Naithani and Bisht
22.	+*B. mizorameana* Naithani
23.	*Bambusa memberanacea* (Munro) Stapleton
24.	+ *Bambusa mohanramii* Kumari and Singh
25.	*Bambusa multiplex* (Lour.) Raeusch ex Schult. and Schult.f.;
26.	+ *Bambusa nagalandeana* Naithani
27.	*Bambusa nairiana* Kumari and Singh
28.	+ *Bambusa nutans* Wall. ex Munro
29.	*Bambusa oliveriana* Gamble
30.	*Bambusa pallida* Munro
31.	*Bambusa polymorpha* Munro
32.	*Bambusa pseudopallida* R. Majumdar
33.	+ *Bambusa rangaensis* Barooah and Borthakur
34.	*Bambusa salarkhanii* Alam
35.	*Bambusa teres* Ham. ex Munro
36.	*Bambusa tulda* Roxb
37.	*Bambusa vulgaris* Schrad. ex Wendl
38.	*Bambusa vulgaris var. vittata* A. and C. Riviere
39.	*Bambusa wamin* Camus

*Only cultivated. + Endemic to India.

Bambusa bamboos can be easily distinguished from other bamboos based on their characteristics and habitat. The significant characteristics obviously seen among Bambusa bamboos are they are closely tufted, culms erect, hollow with relatively thick walls and usually glabrous. Branch complement of several branches with the middle branch dominant and producing branches at each node. Culm sheaths usually covered with dark hairs, as well as with welldeveloped auricles; blades erect, usually triangular. Inflorescence borne on branches of leafless culms (Dransfield, 1991). Other particular characteristics differ in each species. Distributions and habitat of *Bambusa* bamboos vary tropically (Pai and Diao, 2014).They are usually found growing in open areas in the lowlands or on hill sides, on various types of soil, but are found abundantly in moist places like river banks (Khan and Hemalatha, 2015).

Description of some important species under the genus *Bambusa*

2.1 *Bambusa affinis* Munro

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect; 500-600 cm long; 25-35 mm diam.; woody; without nodal roots. Culm-internodes terete; 30-60 cm long; light green, or light green and white; concolorous, or striped; striate; distally pubescent. Culm-nodes pubescent. Lateral branches dendroid. Culm-sheaths 10-15 cm long; 1 times as long as wide; yellow; glabrous, or pubescent; hairy throughout; with tawny hairs; convex at apex; without auricles. Culm-sheath blade lanceolate; reflexed; 2.5-5 cm long; 7-12 mm wide; pubescent. Leaves cauline. Leaf-sheaths striately veined; pubescent; hairs tawny. Leaf-sheath oral hairs lacking. Leaf-sheath auricles absent. Ligule an eciliate membrane. Collar with external ligule. Leaf-blade base with a brief petiole-like connection to sheath; petiole 0.5 cm long. Leaf-blades lanceolate; 15-25 cm long; 25-35 mm wide; glandular. Leaf-blade midrib conspicuous. Leaf-blade venation with 12-16 secondary veins. Leaf-blade surface scabrous; rough abaxially; glabrous. Leaf-blade margins scabrous. Leaf-blade apex acuminate; antrorsely scabrous.

Distribution: Asia-tropical: Indo-China.

2.2 ***Bambusa assamica***

Description : Caespitose, perennial. The rhizomes are short and clumped together. Culms are 500–1200 cm in length, erect and 15–30mm in diameter. The culm-internodes are hollow, terete, mid-green, 15–40 cm in length and distally pruinose. The lateral branches are dendroid. On the lower part of the culm the buds and branches are present. The culm-sheaths are 1.3 times as long as the width, smooth, 8-16 cm in length, auriculate and with 10mm high auricles. The culm-sheath ligule is entire and 0.5–1mm in height. Culm-sheath blade is 6–15 cm in length, triangular, pubescent, acuminate and 50-80mm in width. The leaf-sheaths are smooth or covered with hairs on the surface and pruinose. Leaf-sheath oral hairs are pale, 10–16mm in length and setose. Leaf-sheath auricles are falcate. The Ligule is erose and an enciliate membrance. The collar is with an external ligule. The leaf-blade is with a brief petiole like connection to the sheath and asymmetrical.

Leaf-blades are deciduous at the ligule and persistent, lanceolate, 25–40 mm in width and 10–24 cm in length. The leaf blade midrib is consipicuous. There are 16–20 secondary veins in the leaf blade. The leaf-blade margin is scabrous. Leaf-blade apex is attentuate. Flowers specimens are presently unknown (Barooah & Iftikher Ahmed , 2014)

Global Distribution: India: Throughout; China, Indonesia, Java, Myanmar, Sri Lanka, Thailand, Introduced In West Indies

2.3 *Bambusa atra*

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

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

B. atra has several relatives which are also found in the eastern part of Indonesia and throughout New Guinea and the Solomon Islands, such as *B. amahussana* Lindley, *B. forbesii* (Ridley) Holttum, *B. hirsuta* Holttum and *B. solomonensis* Holttum. They share similar features such as large leaf blades, inflorescences terminating leafy branches, laterally compressed spikelets and lemmas with long, curved, pointed tips. A critical investigation is needed to find out the taxonomic relationships of these species. It is difficult to differentiate species using herbarium specimens, but in the field they can readily be distinguished from each other (Widjaja, 2016).

2.4 *Bambusa arundinacea* (*B. bambos*)

B. bambos is a tough, vigorous and widespread multipurpose bamboo of South Asia but with limited value for high-value products due to its thick culm internodes that do not enable easy splitting and its thorny nature. Brief description—thorny bamboo with culms erect up to 30 m tall, to 18 cm in diameter, thick walled up to 15 cm, nodes up to 40 cm long and slightly swollen. Lower branches bear recurved spines, forming dense, often impenetrable, thicket. B.

bambos clumps are variable with some races almost thorn-less and others very straight culmed.

Distribution: Native to India, Bangladesh, Myanmar, Thailand and China. Grows at up to about 1,200 m altitude and can tolerate 2 C. Introduced to Nepal, Indonesia, Vietnam, Philippines and elsewhere. Propagation—Seed and offsets.

Lifecycle: clumps can often be found in flower either whole clumps or a portion of the culms—and produce copious quantities of seeds which exhibit high levels of diversity in the next generation.

Uses: *B. bambos* is planted for land rehabilitation and riverbank stabilisation and is used locally for handicrafts and low-value construction. Culms are often used for pulp and supplies 20 % of India's bamboo pulp demand.

2.5. *Bambusa balcooa*

B. balcooa is used for construction as well as agricultural implements, round-pole furniture and pulp but is not used for high-value products.

Brief description: culms are up to 24 m tall and 15 cm in diameter; new culms are grey-green to light white bloom, nodes 30–45 cm long and thick walled up to 2.5 cm.

Native to N.E. India and Bangladesh. Introduced to Indonesia and Australia. Propagation—offsets and seed.

Uses : construction and farm use.

2.6. Bambusa binghami

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect; woody; without nodal roots. Culm-internodes terete. Lateral branches dendroid. Leaves cauline. Leaf-sheaths striately veined; smooth; glabrous on surface. Leaf-sheath oral hairs scanty. Leaf-sheath auricles absent. Ligule an eciliate membrane. Collar with external ligule. Leaf-blade base with a brief petiole-like connection to sheath; petiole 0.1-0.2 cm long. Leaf-blades lanceolate; 7-15 cm long; 10-15 mm wide. Leaf-blade midrib evident. Leaf-blade venation with 10-12 secondary veins. Leaf-blade surface smooth. Leaf-blade apex acuminate; smooth.

Distribution: Asia-tropical: Indo-China.

2.7. *Bambusa blumeana*

Large, thorny bamboo with limited commercial value but often used locally. Brief description—densely tufted, culms 15–25 m tall, up to 20 cm diameter, internodes 25–60 cm long, green and glabrous with prominent nodes. Young shoots with yellowish-green sheaths and blades.

Distribution: Believed to be native to Sumatra, Java, Lesser Sunda Islands and Borneo. Introduced to Papua New Guinea, Peninsular Malaysia, Thailand, Vietnam, Philippines and southern China.

Life cycle: gregarious flowering perhaps once in 20–30 years. Sporadic flowering is also known.

Propagation: culm cuttings, rhizome cuttings, layering and marcotting. Seeds/ caryopses are not available.

Uses and value: Good for rehabilitating degraded lands and as borders to agricultural areas. Used locally for low-quality furniture, chopsticks, handicrafts and, occasionally, shoots are used after processing.

2.8.*Bambusa barpatharica* Borthakur & Barooah

Description:

This plant has short rhizomes, grows in clumps and for a prolonged period. Their rhizomes clump with each other unlike the running morphs. These grow to great lengths measuring at times from 1500–2000 cm long with a width of 80–100 mm in diameter and woody in characteristics. The internodes are cylindrical, hollow, 30–50 cm in length, display an appearence where they are covered with a white powdery appearence and dark green in color. The branches are dendroid in appearence. Branches and buds are present on the lower quarter of the culm. The culm sheaths are deciduous, 12–22 cm in length, 0.9 times as wide, having no similar growth, hairy on the shoulders and pointed. The culm sheath ligule is about 2mm high. The blade is triangular, cordate and pointed. The leaf sheath is curved like a sickle. The ligule is hairy and 0.5mm long. The collar has an external ligule. There is a petiole like connection to the sheath and it is 0.4 cm long. The lead blades are deciduous or persistent at the ligule. They are lanceolate, 16–22 cm in length and 20–30mm in width. The mid-rib in the leaf blade is prominent. The leaf becomes thinner as you reach the apex (Barooah, and Ahmed, 2014)

Global Distribution: India: Arunachal Pradesh, Assam, Bihar, Manipur, Meghalaya, Nagaland, Tripura, Uttar Pradesh, West Bengal; Bangladesh, Indonesia, Australia

Indian Distribution: Throughout Assam

2.9. *Bambusa burmanica*

Description: Culm erect, 15-20 m tall, diameter 8-10 cm, thick-walled; internodes about 30 cm long. Culm sheath green, tinged with yellow along the margins, covered with dark brown to golden-brown hairs on the back; blade broadly triangular, erect; auricles relatively large, with long bristles. Leaf blade 25-30 cm × 3-5 cm. Inflorescence borne on leafless branches; pseudospikelets about 2 cm long, in groups of 2-5 at the nodes. *B. burmanica* is related to *B. tulda* Roxb. and *B. polymorpha* Munro by its large auricles of the culm sheath. In Burma (Myanmar) it is found on dry hill slopes. Potentially, it might also be of interest for other countries in South-East Asia (PPROSEA, 2016)

2.10. *Bambusa polymorpha*

Description: A medium to large bamboo. Brief description—densely tufted bamboo with culms 15–25 m tall and up to 15 cm in diameter, relatively thick walls of 1 cm, occasionally solid. **Distribution:** native to Myanmar, extending to Bangladesh, India and Thailand. Introduced to germplasm collections elsewhere but not known to be cultivated outside its distribution area.

Life cycle: flowering after 50–60 years. Propagation—cuttings, rhizome cuttings, branch cuttings, layering and marcotting.

Uses and value: locally used for building and structural uses and for baskets and low-quality furniture. The shoots are edible.

2.11. *Bambusa dampeneana*

Description: Perennial; caespitose. Rootstock evident. Rhizomes short; pachymorph. Culms erect; 800 cm long; 70 mm diam.; woody; with aerial roots from the nodes. Culm-internodes terete; thin-walled; 35-45 cm long; light green. Lateral branches dendroid. Culm-sheaths 30-55 cm long; hispid; with appressed hairs; with dark brown hairs; auriculate; with 4 mm high auricles; setose on shoulders; shoulders with 5-7 mm long hairs. Culm-sheath ligule dentate. Culm-sheath blade triangular; cordate; 12-27 cm long; 80-100 mm wide; with ciliate margins; acuminate. Leaves cauline. Leaf-sheaths striately veined; glabrous on surface; outer margin hairy. Ligule an eciliate membrane; brown; obtuse. Collar with external ligule. Leaf-blade base with a brief petiole-like connection to sheath; petiole 0.1-0.2 cm long. Leaf-blades lanceolate; 15-35 cm long; 20-55 mm wide; glandular. Leaf-blade midrib conspicuous. Leaf-blade venation with 24-26 secondary veins; without cross veins. Leaf-blade surface scabrous; rough on both sides. Leaf-blade margins scabrous. Leaf-blade apex acuminate.

Distribution: Asia-tropical: India.

2.12. *Bambusa garushwkoa*

Description: *Bambusa garushwkoa* is sporadically cultivated all over Assam, nowhere found in wild state. This bamboo is seldom used because of its undurable culms. Therefore,it is less known even among the common people(Barooah et Borthakur,2003).Since the common users have traditional idea on this bamboo species that it is not hard and durable bamboo, hence it is utilised in secondary uses.

2.13. *Bambusa khasiana* Munro

Description: Perennial; culms solitary. Rhizomes elongated; pachymorph. Culms erect; 1000-1500 cm long; 25-30 mm diam.; woody; without nodal roots. Culm-internodes terete; thin-walled; 13-38 cm long; dark green; distally glabrous, or pubescent. Lateral branches dendroid. Culm-sheaths 13-15 cm long; 1.2 times as long as wide; pubescent; hairy throughout; with appressed hairs; with tawny hairs; truncate at apex; without auricles. Culm-sheath blade triangular; acuminate. Leaves cauline. Leaf-sheaths striately veined; glabrous on surface. Leaf-sheath oral hairs setose; deciduous. Leaf-sheath auricles absent. Ligule an eciliate membrane; 1-2 mm long; obtuse. Collar with external ligule. Leaf-blade base with a brief petiole-like connection to sheath; petiole 0.5-0.7 cm long. Leaf-blades lanceolate; 10-23 cm long; 25-35 mm wide. Leaf-blade midrib conspicuous. Leaf-blade venation with 12-16 secondary veins. Leaf-blade surface glabrous. Leaf-blade apex acuminate; hairy

2.14. Bambusa majumdarii P.Kumari & P.Singh

Description: Culm-sheaths shorter than internodes, deciduous, triangular, broader than long, yellowish-brown, young ones whitish green with white stripes; sheath proper 19 – 20 cm long, 35 – 36 cm broad at base, attaining into 18 – 19 cm wide convex top, brown-blackish hairs appressed in patches on outer surface, smooth shining on inner surface; imperfect blade persistent, erect, triangular, c. 7 cm long and 12 cm broad at rounded base, continuing with auricles, terminating into incurved, pointed apex, striate, glabrous on both surfaces except few cilia at apex on inner surface, margins ciliate at base; ligule c. 2 mm long, unevenly serrated, ciliate at mouth, with few short hairs in groups at base underneath imperfect blade; auricles somewhat unequal, dissimilar, c. 1 cm high, 2.5 – 3.5 cm broad, wavy, pubescent on outer surface, fringed with c. 5 mm long, dense ciliolate bristles Culms c. 10 m high, 5 – 8 cm in diameter, light green with whitish pruinose deposition; nodes even; internodes 30 – 45 cm long, thick-walled; nodal bud oval; branching in triple pattern with one dominating and subsequent smaller branches, present on all nodes except few lower ones

2.15. *Bambusa textilis*

Description: A delicate thin-walled bamboo ideal for weaving. Brief description—medium-sized bamboo with straight culms and long internodes. Culms are up to 15 m tall, 3–5 cm in diameter, internodes up to 60 or more cm long and culms are thin walled. Cultivars and varieties—there are three botanical varieties that are widely grown in China: cv Albo striata, var glabra and var gracilis.

Distribution: southern China. Introduced to other provinces of China. Life cycle—not known to flower gregariously. Propagation—offsets and seed are the two most common methods of propagation.

Uses and value: *Bambusa textilis* culms split easily and very finely, providing high-quality bamboo for woven items. B. textilis and some of its varieties are also often used for landscaping. Shoots are edible but small.

2.16. *Bambusa tulda*

Description: culms are up to 30 m tall, usually 20 m, 5–10 cm diameter, internodes 40–70 cm long, culm walls to up 1 cm thick.

Distribution: India, Bangladesh, Myanmar and Thailand. Introduced to Nepal, Indonesia, Vietnam and Philippines. Life cycle—reports of flowering after 25–40 years.

Propagation and cultivation: culm cuttings, marcotting, rhizomes and macroproliferation.

Uses and value : multiple uses. Culms are used structurally, for furniture, pulp and handicrafts.

2.17. ***Bambusa vulgaris***

Description: vigorous medium-large bamboo with relatively open clumps. Culms are up to 20 m tall, internodes 25–35 cm long, 5–10 cm diameter, walls up to 1.5 cm thick. Culms are not straight, internodes often zigzagging.

Cultivars and varieties: *B. vulgaris* var vulgaris (Yellow culms very widely grown as an ornamental plant) and *B. vulgaris* cv Wamin (Bhudda's belly bamboo, very widely grown as an ornamental plant).

Distribution: global tropics. *B. vulgaris* is known as the only pan-tropical bamboo. Life cycle—gregarious flowering not seen, sporadic flowering occurs only very rarely.

Propagation and cultivation: culm cuttings, rhizomes, branch cuttings, layering and marcotting. *B. vulgaris* is one of the easiest bamboos to propagate and is extremely vegetatively vigorous. Uses and value—widely used for local purposes including construction, furniture and handicrafts, but its non-straight culms limit its uses. Good for pulping. In Brazil, it is grown for pulp in large plantations and harvested mechanically on a 3-year rotation.

2.18. ***Bambusa cacharensis*** R. B. Majumdar.

Description: A. Species in the home garden. B. Culm with culm sheaths. C. Culm sheath: close up. D. Full blooming culm. E. Died culm after full bloom. F. Partially blooming culm. G. Spikelets before opening. H. Spikelets after opening showing drooping versatile anthers. I. Strong, healthy culm in vegetative stage. J. Culm arising from weakened clump after blooming. K. Felling of the species by the local villagers after flowering.

3. Genus *Cephalostachyum*

Cephalostachyum is a genus of Asian and Madagascan bamboo in the grass family (William 1868). The plants are of small to medium size compared to most other bamboo. Their choice habitats are mountain to lowland forests. Under this genus 08 species have been reported for their occurrence in different parts of the India (Sharma and Nirmala, 2015).

Table (2.4).Species under the genus *Cephalostachyum* reported in India

Sl.No.	***Species***
1.	*C. capitatum* Munro;
2.	*C. flavescens* Kurz.;
3.	*C. fuchsianum* Gamble;
4.	*C.latifolium* Munro;
5.	*C. longwanum* Naithani;
6.	*C. mannii* (Gamble) Stapleton and Li;
7.	*C. pallidum* Munro;
8.	*C. pergracile* Munro.

Description of important species under the genus *Cephalostachyum*

3. 1.*Cephalostachyum pergracile*

Description: medium-sized bamboo with straight culms that keep the culm sheaths. Up to 30 m tall, thin walled, internodes up to 45 cm.

Distribution: N.E. India, Myanmar, Northern Thailand, Yunnan province and S.W. China also cultivated in botanic gardens. Introduced to southern China, Java.

Life cycle: *C. pergracile* is not known to flower gregariously.

Propagation: offsets and seed are the two most common methods of propagation. Seedlings can be collected from the forest. Offsets are taken from 1 to 2-year old culms, keeping 1–1.5 m of the culm and planted directly in situ.

Uses and value: light construction, basketry. Outer layer can be split very finely and used for handicrafts. Attractive, ornamental with glaucous culms and brownish sheaths

3.2. *C. capitatum* Munro;

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms leaning, or scandent; 400-1000 cm long; 25-30 mm diam.; woody. Culm-internodes terete; thin-walled; 60-100 cm long; yellow, or mid-green. Lateral branches dendroid. Culm-sheaths 15-30 cm long; 3-4 times as long as wide; chartaceous; pubescent; with appressed hairs; with tawny hairs; concave at apex, or truncate at apex; auriculate. Culm-sheath ligule entire, or ciliate. Culm-sheath blade lanceolate; erect, or reflexed; pubescent. Leaf-sheaths glabrous on surface. Leaf-sheath oral hairs scanty; deciduous. Ligule an eciliate membrane. Leaf-blade base asymmetrical; with a brief petiole-like connection to sheath; petiole 0.5-0.8 cm long. Leaf-blades lanceolate, or ovate; 10-20 cm long; 25-50 mm wide; light green. Leaf-blade midrib conspicuous. Leaf-blade venation with 8-20 secondary veins; without cross veins. Leaf-blade surface glabrous. Leaf-blade margins scabrous. Leaf-blade apex acuminate; filiform; antrorsely scabrous.

Distribution: Asia-tropical: India.

3.3. Cephalostachyum flavescens Kurz

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect; 300-600 cm long; 25-38 mm diam.; woody. Culm-internodes terete; thin-walled; yellow, or dark green; smooth. Lateral branches dendroid. Culm-sheaths 10-35 cm long; 1 times as long as wide; glabrous, or hispid; with appressed hairs; with tawny hairs; auriculate; setose on shoulders; shoulders with curved hairs; shoulders with 2-5 mm long hairs. Culm-sheath ligule entire, or dentate. Culm-sheath blade ovate, or triangular; cordate; erect; 2.5-9 cm long. Leaf-sheaths striately veined. Leaf-sheath oral hairs scanty; deciduous. Leaf-sheath auricles erect. Ligule an eciliate membrane. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades linear; 7-19 cm long; 10-20 mm wide. Leaf-blade midrib evident. Leaf-blade venation with 8-12 secondary veins. Leaf-blade surface glabrous, or pilose; sparsely hairy; hairy abaxially. Leaf-blade margins scabrous. Leaf-blade apex acuminate; antrorsely scabrous.

Distribution: Asia-tropical: Indo-China.

3.4. Cephalostachyum latifolium

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms leaning, or scandent; 200-300 cm long; woody. Culm-internodes terete; thin-walled; dark green. Lateral branches dendroid. Culm-sheaths 15-22 cm long; 3 times as long as wide; chartaceous; concave at apex; auriculate; with acute auricles. Culm-sheath blade lanceolate; 10-12.5 cm long; 8-12 mm wide. Leaf-sheaths striately veined; outer margin hairy. Ligule an eciliate membrane; 3-6 mm long. Leaf-blade base asymmetrical; with a brief petiole-like connection to sheath; petiole 0.7-1 cm long. Leaf-blades lanceolate, or ovate; 25-40 cm long; 25-100 mm wide. Leaf-blade midrib conspicuous. Leaf-blade venation with 16-36 secondary veins; without cross veins. Leaf-blade apex acuminate; filiform; antrorsely scabrous.

Distribution: Asia-temperate: China. Asia-tropical: India and Indo-China.

3.5. *C. mannii* (Gamble) Stapleton and Li;

Description: Perennial. Rhizomes short; pachymorph. Culms scandent; slender; 1000 cm long; 8 mm diam.; wiry and woody. Culm-internodes 90 cm long. Lateral branches dendroid. Culm-sheaths tardily deciduous; 30-40 cm long; hispid; with dark brown hairs. Culm-sheath blade linear; as wide as sheath at base; 25 cm long; mucronate. Leaf-sheaths striately veined; glabrous on surface. Leaf-sheath oral hairs scanty. Leaf-sheath auricles falcate. Ligule an eciliate membrane. Leaf-blade base with a brief petiole-like connection to sheath; petiole 0.5 cm long. Leaf-blades lanceolate; 20 cm long; 20 mm wide; chartaceous; glaucous. Leaf-blade venation with 10 secondary veins; with obscure cross veins. Leaf-blade surface pubescent; hairy abaxially. Leaf-blade margins scabrous. Leaf-blade apex attenuate; filiform.

Cephalostachyum mannii is a tall, graceful scandent bamboo with solid culms. Sharma *et al.* (2021) carried out to investigate radial and vertical variations in anatomical and physical properties in the culms of this bamboo species. The mature culms (3-4 years old) were selected from forests of Amkassar Amlarem village, West Jaintia Hills District, Meghalaya, India. The selected internodes of culms were radially divided into outer, middle and inner zones, and vertically bottom, middle and top positions. The vascular bundles were of Type II and well developed in middle zones of both bottom and middle positions. The number and size of vascular bundles increased from inner to outer zone and decreased from bottom to top. Vessel length and vessel diameter decreased both radially and vertically. Among fibre characteristics, fibre wall thickness increased, while fibre length, fibre diameter, and fibre lumen diameter decreased significantly in both radial and vertical directions. Among physical properties, density increased, and moisture content decreased in both radial and vertical directions. Radial shrinkage was higher than tangential shrinkage. Both radial and tangential shrinkage decreased significantly from bottom to top. The fibres were long, thick-walled and highly rigid, and the derived indices do not satisfy the requirement as a superior fibrous raw material for pulp and paper making. However, this bamboo species has the potential for making good quality handicrafts and basketry.

Distribution: Asia-temperate: China. Asia-tropical: India. Sharma *et al.* (2021) reported that this species is distributed in Arunachal Pradesh, Meghalaya, Mizoram, and Nagaland states of Northeast India.

3.6. *Cephalostachyum pallidum* Munro

Description: Culms 6–12 m, 1.5–2.5 cm in diam., subscandent; internodes 50–80 cm, smooth; wall thin; nodal ridge not prominent; sheath scar prominent. Branches many, clustered at each node, subequal. Culm sheaths deciduous, yellow, oblong-lanceolate, 15–20 cm, thickly papery, abaxially appressed ciliate, apex truncate; ligule short; blade reflexed, narrowly lanceolate, 5–10 × 1–3 cm. Leaf sheaths pubescent; ligule conspicuous; blade ovate-lanceolate, 15–25 × 2–4 cm. Inflorescence capitate, solitary at tip of leafy branch, 1.5–2.5 cm in diam., subtended by many bractlets. Pseudospikelet 1.2–1.7 × 0.3–0.4 cm. Glumes ovate, long mucronate or awned; lemma similar to glumes; palea thin; lodicules 3, apex ciliate. Ovary ovoid-coniform; stigmas 2. Caryopsis ovoid, apex with persistent style base.

4. Genus Chimonobambusa

Chimonobambusa is an East Asian genus of medium-sized, shade loving, running bamboos, consisting of about 40 species. For the most part, they are native to China, Japan, Myanmar and Vietnam. They are also found in the foothills of the Himalayas. Despite having running rhizomes, they are not as fast-spreading as other varieties, like *Phyllostachys*. They are most notable for their unusual culms and knobby nodes. The most popular species for ornamental cultivation are Walking Stick bamboo (*C. tumidissinoda*) and Square bamboo (***C.*** *quadrangularis***).** Members of the genus *Chimonobambusa* are native to East Asia, mostly coming from China, Japan, Vietnam, Tibet and parts of the Himalayas. So unlike the tropical and subtropical bamboos, primarily indigenous to places like Indonesia, South East Asia and Central or South America, *Chimonobambusa* is far more tolerant to cold temperatures. Though not as hardy as some varieties of *Phyllostachys*, which can survive temperatures as low as -20º F, *Chimonobambusa* can definitely withstand freezing winters. The most common species are cold hardy to about 10º or 15º F. In fact, they are more particular about heat, preferring at least some partial shade, especially in the warmer climates. So for only one species i.e., *Chimonobambusa callosa* (Munro) has been reported in India (Sharma and Nirmala , 2015)

Description of species under the genus *Chimonobambusa*

4.1.Chimonobambusa callosa (Munro)

Description: Perennial. Rhizomes elongated; leptomorph. Culms erect; 400-700 cm long; 12-25 mm diam.; woody; with root thorns from the nodes. Culm-internodes terete; thin-walled; 12-25 cm long; grey; smooth. Culm-nodes swollen. Lateral branches dendroid. Culm-sheaths 1 length of internode; chartaceous; pubescent; hairy at the base; hairy on margins;

truncate at apex; ciliate on shoulders. Culm-sheath ligule 2 mm high; fimbriate. Culm-sheath blade linear; 1.2-2.5 cm long; pubescent. Leaves cauline. Leaf-sheaths pubescent; hairs tawny; outer margin hairy. Leaf-sheath oral hairs setose. Ligule a ciliolate membrane. Collar with external ligule. Leaf-blade base with a brief petiole-like connection to sheath; petiole 0.2-0.7 cm long. Leaf-blades deciduous at the ligule; lanceolate, or oblong; 20-33 cm long; 17-32 mm wide. Leaf-blade midrib conspicuous. Leaf-blade venation with 10-16 secondary veins; with distinct cross veins. Leaf-blade surface scabrous; rough adaxially; pubescent; hairy abaxially. Leaf-blade margins scabrous. Leaf-blade apex acuminate; antrorsely scabrous

Distribution: Asia-tropical: India.

5. Genus *Chimonocalamus*

It is a genus of Asian bamboo in the grass family. It is native to China, the eastern Himalayas, and northern Indochina. Some of the species are aromatic and grown as ornamental plants. Under this genus total 04 sppecies have been reported in India (Sharma and Nirmala, 2015)

Table (2.5) Species under the genus *Chimonocalamus*

Sl.No.	***Species***
1.	*C. griffithianus* (Munro) Hsuch and Yi;
2.	*C. longiusculus* Hsueh and Yi;
3.	*C. nagalandianus* (Naithani) M.L. Sharma c*omb. nov.*;
4.	*C. lushaiensisi* (Bor) M.L.Sharma c*omb. nov.*

Description of species under the genus *Chimonocalamus*

***5.1.C. longiusculus* Hsueh and Yi;**

Mao and Bhaumik, (2010) collected this species during Plant exploration tour to Apatani Plateau, Lower Subansiri district in Arunachal Pradesh in October 2008. The plant sample was collected from the hills of 'Luro Poliyang' near Ziro town, the head quarter of Lower Subansiri district. A clump of yellowish green bamboo with long internodes, was spotted, growing inside the subtropical forest at an altitude of c. 1715m. On approaching the bamboo clump, the local guide told that the bamboo's internodes contain clear water which is aromatic and nice for drinking. On cutting one of the bamboo culms, to the suprise it was found as told by the local guide. A single internode contains about 25-50 ml of the sweet aromatic liquid. It was also observed that the freshly cut and split bamboo when kept in a room gives a strong swet aroma for about a week. The plants appear to be rare as there were only a few clumps found in the whole hill during the survey. On close examination along with studies confirmed that the plant was reported as endemic to China (Dezhu & Stapleton 2006; Hsueh & Yi 1979).

6.Genus *Dendrocalamus*

The genus *Dendrocalamus* consists of tropical, clumping bamboos, primarily native to Southeast Asia, India and the Indonesian archipelago. These are some of the world’s biggest bamboos, including *Dendrocalamus sinicus*, the largest bamboo species of all, with culms well over 100 feet in height and more than 12 inches in diameter. They are known to shoot up more than three feet a day in the growing season. Certain *Dendrocalamus* species are especially important economically, widely used for building and construction. Farmers around the world are currently examining their potential as a cash crop, based on their remarkable size, growth rate and versatility.

Dendrocalamus are probably the largest bamboos in the world. Their sheer size and incredible rate of growth have amazed the people of Southeast Asia for millennia. With its practically supernatural properties, it's no wonder we have so many myths and legends surrounding the origins of this gigantic bamboo. Most species of *Dendrocalamus* grow 50-60 feet tall, and 4 or 5 inches in diameter, but some grow much larger. Like most bamboo varieties in the tribe Bambuseae (a subdivision of the bamboo family), *Dendrocalamus* are tropical and clumping by nature. Truly tropical, they will not survive if the winter temperatures commonly fall below 30º F. Unlike the running the bamboo varieties, these species do not spread aggressively and invasively. Yes, the individual culms can grow to astronomical proportions, but the plant itself tends to reach a maximum size with a limited footprint, usually about 10-15 feet across.

In addition to their massive size, many species of *Dendrocalamus* also have very thick culm walls. This makes them extremely hard and resistant to cracking. In other words, they provide a superior building material. And compared to how long it takes to grow a 100-foot-tall tree, the benefits over traditional lumber are obvious. Culm internodes on *Dendrocalamus* are usually relatively short, just a few inches apart, especially closer to the base of the plant. The culms also produce ariel roots around the nodes at the bottom few feet. Higher nodes will produce multiple branches, usually with one larger, dominant branch. Often the branches are thorny. So for in India 18 species have been reported (Table12.6)

Table (2.6): Species under genus *Dendrocalamus*

Sl.No.	***Species***
1.	*D.asper* (Schult.) Backer;
2.	*D. brandisii* (Munro) Kurz.;
3.	*D. calostachyus* (Kurz) Kurz ;
4.	*Dendrocalamus collettianus* Gamble;
5.	**D. copelandii* (Gamble exBrandis) Xia and Stapleton;
6.	*D. giganteus* Munro;
7.	*D. hamiltonii* Nees and Arn. ex Munro
8.	*D. hookeri* Munro;
9.	*D. latiflorus* Munro;
10.	*D. longifimbriatus* Gamble;
11.	*D. longispathus* Kurz ;
12.	*D. manipureanus*Naithani and Bisht;
13.	*D. parishii* Munro;
14.	*D. sahnii* Naithani and Bahadur;
15.	*D. sericeus* Munro;
16.	*D.sikkimenis* Gamble;
17.	*D. somdevai* Naithani;
18.	*D. strictus* (Roxb.) Nees

*Only cultivated. _______+ Endemic to India.

Description of Important Species under the genus *Dendrocalamus*

6.1.*Dendrocalamus asper*

Description: Large bamboo culms up to 20–30 m tall, internodes 20–45 cm long with a diameter of 8–20 cm and thick walls up to 2 cm.

Distribution: N.E. India, Nepal, Bangladesh, Myanmar, northern Thailand, Laos and Vietnam. Introduced to southern China, Malaysia, Indonesia and Philippines. Cultivars—six are known including cv betung wulung, cv Tahi green and cv Phai Tong Dam.

Life cycle: gregarious flowering not known.

Propagation: culm and branch cuttings and offsets.

Uses and value: *D. asper* is a multipurpose bamboo with a wide range of uses. Structural use bamboo with large and strong culms, and a very useful bamboo for construction in rural areas with durable culms. Shoots are edible and are good, tasty and sweet. Plantation for bb shoots established of this bamboo in Thailand. Used for good quality furniture, musical instruments, chopsticks, household utensils and handicrafts.

6.2. *D. brandisii* (Munro) Kurz.*;*

D. brandisii is a perennial sympodial bamboo having hexaploid chromosome (chromosome number: n= 36, 2n= 72) (Sobita Devi and Sharma, 1993). It primarily grows in wet evergreen tropical forests, chiefly on calcareous rocks up to an altitude of 1300m (Dransfield and Widjaja, 1995). Its native area extends from north-eastern India (Jiribam, Manipur), Myanmar, to northern Thailand, Indo-China, China (Yunnan Province) and in the Andamans. This species was widely introduced in Coorg, Karnataka between 1913-24 (Seethalakshmi and Mukteshkumar, 1998).

Description: Culms are erect and tapering towards the top, reaching up to even 30m height, 13-30cm diameter with wall thickness of 2.5 - 4.0cm, more at the base and gradually less towards the tip. The mature culm is smooth ashy-gray to greenish-gray coloured, loosely spaced and thornless. The culms are hollow with internodes 30-38cm long and nodes slightly swollen with aerial roots in lower half of culm. Culm sheaths of mature clumps are broad and long, usually 30-35cm broad to 40–60cm long, thick, leathery with pubescence on the back, rounded and depressed at the top. Ligules of sheath are 1-2 cm high, deeply lacerate with small and plaited auricles (Seethalakshmi and Mukteshkumar, 1998). Leaves are 20-30cm long, 2.5-5.0cm broad, oblong to lanceolate in shape with a glabrous petiole. Leaf sheaths are striately veined and pubescent. Base of the leaf blade may have a brief petiole like connection to sheath. The blades are lanceolate or oblong and pubescent (Seethalakshmi and Mukteshkumar, 1998).

This species usually flowers sporadically as well as gregariously. Flowering cycle is reported to be 45-50 years. Gregarious flowering was reported from Coorg, Karnataka during 1961-62 and from Manipur in 1987-88. After the next cycle of 45 years, gregarious flowering of Burma bamboo in Coorg started 2010 and is still continuing. During the on-set of gregarious flowering the entire clump flowers profusely and dies within a period of 2-3 years after seed setting. Inflorescence is synflorescence and bractiferous mostly clustered at the nodes in globose formation. Spikelets are 1-1.5 cm long, dense, 2.5-4 cm between clusters and with glumaceous subtending bracts and with axillary buds at base of spikelet. Fertile spikelets sessile, comprising 2-4 fertile florets. Spikelets are ovate, 5-7.5 mm long, laterally compressed. Glumes several, persistent with 1-2 empty glumes, sometimes shorter than spikelet. Upper glume ovate, acuminate apex without keel. Lemma hairy above with puberulous surface and ciliate margins and acute apex. Palea 3 - veined, 2-keeled ciliate. Flowers are also veined and ciliated. Anthers yellow, 6 in number, with apiculate tip. Filaments united in a tube with 1-2 plumose stigmas. Ovary ellipsoid, hairy, style short, stigmas ending in a thick, club-shaped or divergent, plumose stigmas. Seed is an ovoid caryopsis, 2.5-4 mm, hairy above, tipped with the persistent style and crustaceous pericarp.(Seethalakshmi and Mukteshkumar, 1998).

Dendrocalamus brandisii (Munro) Kurz., synonym *Bambusa brandisii* Munro, locally known as 'Burma bamboo' was first introduced in Coorg District, Karnataka in 1913 as per records. It has since then been preferred for cultivation in homesteads by enterprising farmers mainly due to its large size, straight growth habit and thornless nature in sharp contrast to other local bamboo species like *D.strictus* and *B.bambos.* In addition to traditional uses such as for ladders and for basket weaving, this species is currently used widely as fencing poles for ginger cultivation in upland paddy fields (Viswanath *et al*., 2013)

***6.3. Dendrocalamus calostachyus* (Kurz) Kurz**

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect; 2000-2500 cm long; woody. Culm-internodes terete; 30-40 cm long; distally pubescent. Lateral branches dendroid. Culm-sheaths pubescent; with appressed hairs; with tawny hairs; truncate at apex. Culm-sheath ligule entire. Leaf-sheaths striately veined; outer margin hairy. Ligule an eciliate membrane; entire, or erose; truncate. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades lanceolate; 22-30 cm long; 30-65 mm wide. Leaf-blade venation with 18-26 secondary veins. Leaf-blade surface pubescent; hairy abaxially. Leaf-blade margins scabrous. Leaf-blade apex acuminate.

Distribution: Asia-tropical: India and Indo-China.

6.4.D. copelandii (Gamble exBrandis) Xia and Stapleton*;*

Description: Sympodial bamboo. Culms straight and erect, about 15–30 m long, 8–20 cm in diam., with relatively thin walls, about 1–2 cm thick, culm tips more or less arching; internodes 20–48 cm long, lower ones without hairs, covered with copious white wax when young; nodes not swollen, lower ones without verticils of roots. Branches several a each node, the primary one dominant, without aerial roots. Culm-sheaths tardily deciduous to persistent, coriaceous, 28–46.5 cm long by 42–55 cm wide, top convexly horizontal, covered with golden brown to dark brown hairs, occasionally glabrous; blades lanceolate, erect to spreading, 10–25.5 cm long, ca 5 cm wide near the base, hairy near the adaxial base; auricles continuing from the base of culm-sheath blade as fleshy, crisped lobes, 2–5 mm tall/wide, 10–40 mm long, margin wavy or pleated, glabrous; ligule 3–10 mm high, margin dentate to subentire, fringed with cilia up to 0.5 mm long. Leaf blades 10–27 cm long by 2.4–4 cm wide, hairy below, apex acuminate, base rounded to acute, pseudopetiole 2–10 mm long; auricles absent; ligule 1–1.2 mm high, margin dentate, fringed with cilia 0.1–0.2 mm long. Inflorescences iterauctant, borne on leafless branches, spikelets congested, forming stellate clusters subtended by a 1-keeled prophyll and a 1-keeled matching bract, axis hairy, internodes 1.5–2.5 cm long. Pseudospikelets ovate-oblong to ovate-lanceolate, laterally compressed, 20–28 mm long by 5.5–7.3 mm wide; transitional (empty) glumes 2– 9, shorter than the lowest lemma, 7–35-nerved; fertile florets 5–6, terminal vestigial floret present, shorter than florets; rachilla internodes between florets short, not disarticulating below each floret; lemmas chartaceous, 12–25 mm long, minutely pubescent on the back, 23–37-nerved, apex acute to pointed; paleas membranous, 9.2–22 mm long, 2-keeled on the back, keels and edges long-fringed, the uppermost one not keeled, outside minutely pubescent, inside sparsely and minutely pubescent to glabrous, apex shortly bidentate, 2– 3(–5)-nerved between keels, edges very narrow, not nerved; lodicules usually 3, occasionally none, hyaline, pubescent; stamens 6, filaments free, anthers 5–11 mm long, yellow, tips pointed, usually with minute spines; ovary umbonate, summit hairy, with long slender style, stigma 1, slightly plumose. Caryopsis 12–16 mm long, contracted towards the apex, almost bottled-shaped, slightly grooved on one side; pericarp rather thick and loose (Sungkaew *et al*., 2017)

6.5. *Dendrocalamus giganteus*

Description: large, sometimes huge bamboo, culms 25–60 m green to dark bluish green, internodes 40–50 cm long, 10–20 cm in diameter and thick walls of 2.5 cm.

Distribution: southern Myanmar and northern Thailand. Introduced to India, Sri Lanka, Bangladesh, Nepal, Thailand, Vietnam, China, Indonesia, Malay Peninsular, Philippines and Kenya. Life cycle—not known to flower gregariously.

Propagation: culm cuttings, rhizome planting, branch cuttings, layering, marcotting and macroproliferation.

Uses and value: tructural bamboo, strong, for building and for bamboo boards. Also for pulp and for household items. Used for furniture too, and shoots are of good quality.

6.0 Dendrocalamus hamiltonii Nees & Arn. ex Munro

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect, or arching; 1200-2000 cm long; 100-185 mm diam.; woody; with root dots on the nodes. Culm-internodes terete; thick-walled; 30-50 cm long; dark green, or grey; distally pubescent. Lateral branches dendroid. Buds or branches absent from lower quarter of culm. Culm-sheaths 35-45 cm long; 2 times as long as wide; antrorsely scabrous; glabrous, or hispid; with dark brown hairs; truncate at apex. Culm-sheath ligule entire. Culm-sheath blade lanceolate, or narrowly ovate; narrower than sheath; 15-30 cm long. Leaf-sheaths keeled; hispid; hairs white. Ligule an eciliate membrane. Leaf-blade base asymmetrical; with a brief petiole-like connection to sheath. Leaf-blades lanceolate; 20-37 cm long; 20-40 mm wide. Leaf-blade venation with 12-34 secondary veins. Leaf-blade surface scabrous; rough abaxially; glabrous. Leaf-blade margins scabrous. Leaf-blade apex acuminate.

Distribution: Asia-temperate: China. Asia-tropical: India and Indo-China.

6.7.Dendrocalamus hookeri Munro

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect; 1500-2000 cm long; 100-150 mm diam.; woody. Culm-internodes terete; thick-walled; 40-45 cm long; dark green; distally pilose. Lateral branches dendroid. Buds or branches absent from lower quarter of culm. Culm-sheaths 20-30 cm long; 0.5-0.75 times as long as wide; hispid; with dark brown hairs, or black hairs; ciliate on shoulders. Culm-sheath ligule 5-7 mm high; dentate. Culm-sheath blade triangular; 8-18 cm long. Leaf-sheaths striately veined; pilose (below). Leaf-sheath oral hairs scanty, or lacking. Ligule an eciliate membrane; truncate. Leaf-blade base asymmetrical; with a brief petiole-like connection to sheath. Leaf-blades oblong. Leaf-blade midrib conspicuous. Leaf-blade venation indistinct; with 16-32 secondary veins. Leaf-blade surface scabrous; rough abaxially; glabrous. Leaf-blade margins scabrous. Leaf-blade apex acuminate.

6.8. *Dendrocalamus latiflorus*

Description: medium-sized bamboo 14–25 m tall, internodes 20–70 cm long, 8–20 cm diameter and walls 0.5–3 cm.

Cultivars: cv Meimung in China.

Distribution: Myanmar, South China and Taiwan. Like high rainfall. Introduced to Philippines, Indonesia, Thailand, India, Vietnam and Japan. Life cycle—D. latiflorus is not known to flower gregariously.

Propagation and cultivation: culm cuttings, layering and marcotting. Uses and value—structural uses of medium quality; very good for shoots, also for high-quality furniture, crafts, baskets, pulp and thatching; leaves are used to wrap rice for cooking.

6.9. D. longispathus

Description: Culm up to 20 m tall, diameter 8-12 cm, wall 12 mm thick, glaucous green when young; internodes 25-60 cm long; nodes slightly swollen, bearing aerial roots. Culm sheath with dark brown hairs on the back; blade lanceolate, reflexed; ligule toothed with brown bristles; auricles membranaceous, bearing bristles along the edge. Leaf blade 20-30 cm × 1.5-3 cm. Inflorescence borne on leafless or leafy branches; pseudospikelet up to 6 cm long. Caryopsis ovoid. Found in mixed and disturbed forest, on rather fertile soil and along riversides. Propagation by culm cuttings of 1-year-old culms gives the best results. Fibre length of the culm is 2.70 mm, diameter 15.02µm, lumen diameter 3.39µm. Potentially, *D. longispathus* is also of interest for the rest of South-East Asia

Distribution: Northern Thailand, Burma (Myanmar), Bangladesh and India.

6.10. Dendrocalamus sericeus Munro

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect; 700-1700 cm long; woody. Culm-internodes terete; solid. Lateral branches dendroid. Culm-sheaths hispid; hairy on margins. Culm-sheath blade triangular; acute. Leaf-sheaths keeled; pilose. Ligule a ciliate membrane. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades lanceolate; 12-40 cm long; 17-25 mm wide. Leaf-blade midrib prominent beneath. Leaf-blade venation with 12-14 secondary veins. Leaf-blade surface pubescent; hairy on both sides. Leaf-blade margins scabrous. Leaf-blade apex acuminate.

Distribution: Asia-tropical: Indo-China.

6.11.*Dendrocalamus sikkimensis*

Description: *Dendrocalamus sikkimensis* is commonly found in Sikkim, West Bengal, Arunachl Pradesh, Nagaland and Meghalaya. The culms are dark green reaching a height of 17-20 meters with 12-20 cm diameter. The internodes are 40-45 cm long with a rough nature. The species is used mainly for fencing, posts, huts, ropes, boxes, water pipes, Chungas for carrying milk and for manufacturing paper.

6.12. *Dendrocalamus strictus*

Description: medium-sized bamboo culms are 8–20 m tall, internodes 30–45 cm long, 2.5–8 cm diameter, thick walls but slightly zigzag.

Distribution: India, Nepal, Bangladesh, Myanmar and Thailand. Introduced to many countries in SE Asia but is of limited value outside these regions. Life cycle—report indicates 20–40 years flowering cycle.

Propagation: culm cuttings, rhizome planting, layering, marcotting and macroproliferation of seedlings. Culm cuttings can be used for propagation when seeds are not available. About 40 to 70 per cent of rooting can be obtained in culm cuttings depending on the period of collection, age of culm and treatment with growth regulating substances. Cuttings treated with NAA 100 ppm during February and March may give maximum rooting (Surendran and Seethalakshmi, 1985). Seasonal variation in rooting response is reported and it is attributed to the variation in nutrient contents in the culm (Gupta and Pattanath, 1976). Tissue culture using nodes, seeds, seedlings, shoots, excised embryos and other methods like multiple shoot production, rooting and in vitro flower induction are reported (Zamora, 1994).

Uses and value: Structural uses, medium to light quality, edible shoots but of poor quality. Pulp use, thick walled and ok for boards, agricultural implements and household utensils. *D. strictus* is suitable for reclamation of ravine land and is extensively used as raw material in paper mills and also for a variety of purposes such as construction, agricultural implements, musical instruments, furniture etc. Decoction of leaves, nodes and the silicious matter is used in traditional medicine.

7.*Genus Dinochloa*

It is a genus of tropical clumping high-climbing bamboos in the grass family (Hendrik, 1854)). These species bear zigzag culms and fleshy fruits. They are found in the hill forests and lowland dipterocarp forest of southern China, Southeast Asia, and the eastern part of the Indian subcontinent. Under this genus 02 species viz., D. andamanica Kurz. a nd D. nicobariana Majumdar have been reported to be found in the Andaman and Nicobar island of India (Sharma and Nirmala, 2015)

Table (2.7). Species under the genus *Dinochloa*

Sl.No.	***Species***
1.	+*D. andamanica* Kurz.;
2.	+ *D. nicobariana* Majumdar.

*Only cultivated. _______+ Endemic to India.

Description of species under the genus *Dinochloa*

7.1. *D. andamanica* Kurz.;

Description: Plants with long, green, glossy, creeping culms. Culms single, creeping along the ground, and rooting at the nodes or climbing over tall trees usually to a height of 35 m; branches geniculate, single, as long and stout as the culms; branchlets slender, numerous, in whorls, hanging with dense foliage; nodes swollen, marked by the base of fallen culm-sheath; internodes 23-46 cm long, 2.5 cm diameter, walls thin. Culm-sheaths green, less than one-fourth of the length of the internodes, with a fugacious white bloom; imperfect blade leafy, deciduous, nearly as broad as sheath. Leaves 23-30 cm long and 5-7.5 cm broad, ovate-lanceolate, attenuate at the base into a very short petiole, apex setaceous, smooth on both surfaces, scabrous on the edges, midrib prominent, secondary veins 7-9 pairs, transverse veinlets conspicuous owing to pellucid dots; leaf-sheaths appressed hairy when young, glabrous when old, ending in a callus and rounded mouth with white cilia; ligule broad, truncate, ciliate, fimbriate **(**Anonymous, 1874).

Rhizomes short; pachymorph. Culms prostrate, or scandent; zigzag; 2000–3000 cm long; 25 mm diam.; woody; rooting from lower nodes. Culm-internodes terete; thin-walled; 23–46 cm long. Culm-nodes swollen. Lateral branches dendroid. Branch complement several; with 1 branch dominant; as thick as stem. Culm-sheaths deciduous; 0.25 length of internode. Culm-sheath blade triangular; as wide as sheath at base. Leaf-sheaths glabrous on surface, or pubescent. Leaf-sheath oral hairs ciliate. Leaf-sheath auricles falcate. Ligule a ciliolate membrane. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades lanceolate; 23–30 cm long; 50–75 mm wide. Leaf-blade midrib conspicuous. Leaf-blade venation with 14–18 secondary veins; with distinct cross veins. Leaf-blade surface smooth. Leaf-blade margins scabrous. Leaf-blade apex attenuate; filiform.

7.2. D. nicobariana Majumdar

Description: A climbing bamboo. Branches smooth and nodes with a ring formed by the base of fallen sheaths. Culms green, hairy, scandent over the trees; branchlets numerous from the nodes, slender; nodes marked by prominent nodal rings; internodes up to 30 cm long. Culm-sheaths green, long, having white dense tomentum, imperfect blade leafy, deciduous, nearly as broad as sheath. Leaves 5-12 cm long and 0.6-1 cm broad, lanceolate, attenuate to the base with very short petiole, apex setaceous, smooth on both surfaces; midrib narrow, secondary veins 4-5 pairs; leaf sheaths appressed, hairy. Inflorescence a large compound panicle; spikelets clustered, 0.2-0.4 cm, strawcoloured, one- flowered; empty glumes 2, 2.5-3.5 mm broad, obtuse; flowering glume similar to empty glume, 2.5 mm long; palea long, convolute, 2.5 mm long. Stamens 6, included, free, acute tip, filament short. Ovary oval ending in a thick style; stigmas three, plumose. Caryopsis not known. This species has been collected in flower for the first time from 16 km, Nicobar during 1993. World Distribution: India: This species is distributed in Car Nicobar and Great Nicobar (A & N Islands).

8.0. Genus *Drepanostachyum*

A genus of beautiful, medium sized, clumping, Himalayan bamboos. Culms arch in upper part and many thin branches half encircle each node. Shoots in the spring. Under this genus 06 species have been reported in India by Sharma and Nirmala (2015).

Table (2.8). Species under the genus Drepanostachyum

Sl.No.	***Species***
1.	.+*D. falcatum* (Nees) Keng f.
2.	+ *D. falconeri* (Munro) D.C. McClint.
3.	*D.hookerianum* (Munro) Keng f.
4.	+ *D. intermedium* (Munro) Keng f.
5.	*D. kurzii* (Gamble) Majumdar
6.	+*D. polystachyum* (Kurz.ex Gamble) Majumdar

*Only cultivated. _______+ Endemic to India.

Description of important species under the genus Drepanostachyum

8.1.*Drepanostachyum falcatum*

Description: It is an evergreen, clump-forming bamboo with woody stems that can be around 200 - 350cm tall and 7 - 15mm in diameter. The plant is harvested from the wild for local use as a food and source of materials. Baskets and other products made from the canes are often sold in local markets. It is often planted within its native range, both to provide material for basket making and also to stabilize the slopes of terraces etc. It is also often grown as an ornamental.

Himalayan Weeping Bamboo is a lovely soft dandy drooped leaf bamboo. Does really well in cooler climates like Victoria, and will tolerant moist shaded areas. Prefers morning sunny positions with shelter from strong hot winds. Easy to grow in the right conditions, Can be pruned in to shape and grows well indoors with filtered sun.

8.2. *D. intermedium* (Munro) Keng f.

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect; 250-400 cm long; 10-12 mm diam.; woody. Culm-internodes terete; thin-walled; 12-25 cm long; grey. Lateral branches dendroid. Branch complement many; with subequal branches. Culm-sheaths 20-25 cm long; 5-8 times as long as wide; chartaceous; glabrous; truncate at apex; ciliate on shoulders. Culm-sheath ligule 3-5 mm high. Culm-sheath blade linear; reflexed; 1.2-5 cm long. Leaf-sheaths striately veined; glabrous on surface, or hispid. Leaf-sheath oral hairs setose; deciduous. Leaf-sheath auricles falcate. Ligule an eciliate membrane. Leaf-blade base with a brief petiole-like connection to sheath; petiole 0.2-0.3 cm long. Leaf-blades deciduous at the ligule; linear, or lanceolate, or oblong; 7.5-20 cm long; 12-25 mm wide; light green; glandular. Leaf-blade midrib conspicuous. Leaf-blade venation with 6-14 secondary veins; with obscure cross veins. Leaf-blade surface scabrous; rough adaxially. Leaf-blade margins scabrous. Leaf-blade apex attenuate; filiform.

Distribution: Asia-tropical: India.

9.0 *Genus Gigantochloa*

Gigantochloa is a tropical Asian and Papuasian genus of giant clumping bamboos in the grass family. It is found in southern China, Southeast Asia, the Indian subcontinent, and New Guinea. Under this genus a total of 07 species have been spotted in India (Sharma and Nirmala, 2015).

Table (2.9). Species under the genus *Gigantochloa*

Sl.no.	*Species*
1.	*G. albociliata* (Munro) Kurz ;
2.	*G. andamanica (*Kurz.) Kurz;
3.	*G. apus* (Bl. ex Schult.f.) Kurz *;*
4.	**G. atroviolacea* Widjaja*;*
5.	+*G.bastareana* Naithani and Pal;
6.	*G. macrostachya*Kurz ;
7.	**G. pseudoarundinacea* (Steud.) Widjaja

*Only cultivated. _______+ Endemic to India.

Description of Important Species under genus *Gigantochloa*

9.1.*Gigantochloa apus*

Brief description: large bamboo 8–30 m, culms 4–13 cm diameter, strongly tufted, internodes 35–45 cm long, wall thickness 1.5 cm and flexible culms.

Distribution: Myanmar, Thailand, Indonesia and Malaysia. Known to survive in drier areas. Introduced to N.E. India. Life cycle—not known to flower gregariously.

Propagation: culm cuttings, offsets.

Uses and value: structural uses of medium quality, and for furniture of medium and good quality, also for handicrafts, musical instruments, utensils and baskets. Shoots are edible but are of poor quality, very bitter in taste.

9.2. *Gigantochloa levis*

Brief description: large bamboo, culms up to 30 m tall, 5–16 cm in diameter, walls 1–1.2 cm thick and internodes up to 45 cm long.

Distribution: origin unknown, cultivated in Philippines, Eastern Indonesia, Northern and Western Kalimantan, east Malaysia, China and Vietnam. Common in the homesteads and gardens of the Philippines.

Life cycle: gregarious flowering not known.

Propagation: culm cuttings and offsets.

Uses and value—structural, shoots are edible and of good quality, also for utensils, furniture, craft paper, fencing and other subsistence uses.

9.3. *Gigantochloa pseudoarundinacea*

Description: culms 7–30 m tall, internodes 35–45 cm, 5–13 cm diameter, medium to think wall of 2 cm, strong.

Distribution: native to Java, cultivated in Java and Sumatra. Introduced to China, Malaysia, India and Vietnam.

Life cycle: gregarious flowering not known. Propagation and cultivation—culm cuttings and branch cuttings.

Uses and value: structural, water pipes, handicrafts, good quality furniture, household articles, chopsticks and toothpicks; good quality edible shoots.

10. *Genus Indocalamus*

It is a genus of about 35 species of flowering plants in the grass family (Poaceae), native to China, Vietnam and Japan. They are quite small evergreen bamboos normally up to 2 m (6.6 ft) in height, initially forming clumps and then spreading to form larger thickets. They have thick, glossy leaves. *Ruo leaves* use to wrap foods like rice during dragon boat festival, originate in fujian refer to *Indocalamus longiauritus* originally but now are nonspecific to just about any leaf wrap. Three species have been reported in India (Sharma and Nirmala, 2015)

Table (2.10). Species under the genus *Indocalamus*

Sl.No.	Species
1.	*I. walkerianus* (Munro) Nakai;
2.	+*I. wightianus* (Munro) Nakai;
3.	+*I. wightianus* var. *hispidus* (Steud) Nakai

*Only cultivated. _______+ Endemic to India.

11. Genus *Melocalamus*

Description: (after Clayton et al. 2008): Perennial. Rhizomes short, pachymorph. Culms sympodial, scandent, 1.2–2.5 cm diam, bud complement 1, branch complement several in a horizontal line, 1 branch dominant, lateral branches dendroid, internodes and branches usually long. Culm sheaths persistent, stiff, base usually swollen, internodes hollow, auricles absent or falcate, then with setose oral hairs, blades wedge-shaped, reflexed. Ligules membranous. Leaf blades with a short pseudo-petiole, with obscure cross-venation. Inflorescences indeterminate, paniculate, a complex of partial inflorescences and intervening foliar organs, spikelet-bearing axes capitate, bractiferous with axillary buds, prophyllate below the lateral spikelets. Pseudospikelets small, laterally compressed, breaking up at maturity above the glumes. Glumes persistent, 2–4, subequal, shorter than the spikelet, awnless. Florets 2 or 3, the lower one or two bisexual, the upper one sterile, without proximal incomplete florets. Fertile lemma 3- or 5-nerved. Rachilla internodes suppressed. Lodicules 3, ciliate. Stamens 6. Ovary with a conspicuous, broadly conical, fleshy apical appendage. Styles 2 or 3. Fruits fleshy, spherical, pericarp thick, free, endosperm evanescent (Nguyen and Tran, 2010). Under this genus following 05 species have been spotted in India (Sharma and Nirmala, 2015)

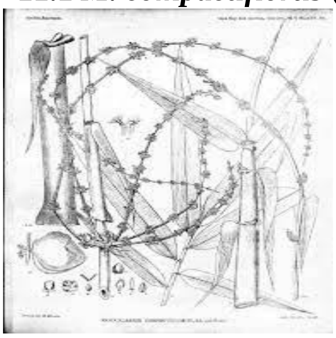
Table (1.11). Species under the genus *Melocalamus*

Sl.No.	***Species***
1.	.*M. compactiflorus* (Kurz) Benth.;
2.	*M. gracilis* Majumdar;
3.	+*M. indicus* Majumdar*;*
4.	*M. maclellandii* (Munro) Naithani;
5.	+*M. mastersii* (Munro) Majumdar.

*Only cultivated. ________+ Endemic to India.

Description of species under the genus

11.1 *M. compactiflorus* (Kurz) Benth.;



Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms scandent; 500-850 cm long; 15-25 mm diam.; woody. Culm-internodes terete; thin-walled; 30-60 cm long. Lateral branches dendroid. Bud complement 1. Branch complement several; in a horizontal line; with 1 branch dominant. Culm-sheaths persistent; glabrous, or pubescent. Culm-sheath blade lanceolate, or ovate; reflexed; 5-15 cm long. Leaf-sheath oral hairs setose. Leaf-sheath auricles falcate. Ligule an eciliate membrane. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades oblong; 15-25 cm long; 25-50 mm wide. Leaf-blade venation with obscure cross veins. Leaf-blade apex acuminate.

Distribution: Asia-temperate: China. Asia-tropical: India and Indo-China.

11.2 *M. indicus* Majumdar*;*

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms scandent; pendulous at the tip; 600-3000 cm long; 100-200 mm diam.; woody. Culm-internodes terete; solid; 40-50 cm long; distally mealy. Lateral branches dendroid. Branch complement several; with 1 branch dominant; as thick as stem. Culm-sheaths deciduous but leaving a persistent girdle; 20-25 cm long; 4-6 times as long as wide. Culm-sheath blade linear; reflexed. Ligule an eciliate membrane. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades lanceolate.

12.0 Genus *Melocanna*

Melocanna is a genus of tropical clumping bamboo (tribe Bambuseae of the family Poaceae). It comprises 3 species, found in East Asia. The genus is similar to Bambusa. The 48-year cycle of *M. baccifera* in northeastern India is responsible for the mautam phenomenon of bamboo flowering, followed by a plague of rats and famine.

Table (2.12). Species under the genus *Melocanna*

Sl.No.	*Species*
1.	*M. arundina* Parkinson;
2.	*M. baccifera* (*Roxb*.) Kurz;
3.	+*M. clarkei* (Gamble ex Brandis) Kumari and Singh

*Only cultivated. _______+ Endemic to India.

Description of species under the Genus *Melocanna*

12.1 *Melocanna baccifera* (Grove Forming)

Description: Culms to 10–20 m tall, very open, thin walls of 0.5–1.2 cm, internodes 20–50 cm long, 5–7 cm in diameter, culm tips are pendulous**.**

Distribution: *M. baccifera* covers huge swathes of northeast India and adjoining parts of Myanmar and Bangladesh. Introduced to Indonesia and China.

Life cycle: 48 years.

Propagation and cultivation: fruits and culm cuttings.

Uses and value: roofing, thatching, matting, pulp, paper and rayon; shoots are locally eaten and used for preparing liquor.

13.0 *Genus Neohouzeaua*

Neohouzeaua is a genus of Asian bamboo within the grass family (Camus, Aimée Antoinette. 1922). These species have culms growing in large tufts, often somewhat scandent. *Neohouzeaua* is sometimes included in the genus *Schizostachyum*. Species found under this genus have been given in table ().

Table (2.13). Species under the genus *Neohouzeaua*

Sl.No.	*Species*
1.	*N. dullooa* (Camus) Gamble*;*
2.	*N. helferi* (Munro) Gamble.

14.0 Genus *Neomicrocalamus* P. C. Keng

Description: Climbing or scrambling bamboos. Rhizomes short necked, pachymorph. Culms unicaespitose, scrambling, slender, hollow to solid; internodes terete, long, very smooth; nodes level to slightly raised with persistent sheath-base collar. Branches many, central dominant, approaching size of culm, others short and subequal. Culm sheaths deciduous after branching, narrowly triangular, basally very tough, apically papery; ligule inconspicuous, auricles and oral setae absent; blade erect, acicular, short. Leaves broadly linear-lanceolate, small, venation indistinct, apex acicular. Inflorescence bracteate, lateral spikelets subtended by a bract and basally prophyllate. Prophyll and glumes not subtending buds. Spikelets sessile, several flowered, followed by a terminal incomplete floret. Rachilla disarticulating and florets separately deciduous. Glumes 1, or absent in terminal spikelets; lemma glabrous. Palea 2-keeled, usually equal in length to lemma. Lodicules 3. Stamens 6; filaments free. Ovary oblong or ovate, upper portion pubescent or glabrous; style 1; stigmas

3. Caryopsis shortly terete, grooved. Under this genus 02 species have been identified in India (Sharma and Nirmala, 2015)

Table (2.14). Species under the genus *Neomicrocalamus*

Sl.No.	*Species*
1.	*N. andropogonifolius* (Griffith) Stapleton;
2.	+*N. prainii* (Gamble) Keng f.

*Only cultivated. ________+ Endemic to India.

15.*Genus Ochlandra*

Ochlandra is a genus of shrubby, clustered, reed-like, running bamboo that grows in India, particular in the region of the Western Ghat mountains. Ochlandra species typically have papery culm-sheaths that do not fall off in maturity (persistent.) Under this genus a total 11 species and 1 variety have been reported in India (Sharma and Nirmala, 2015). List of the species and variety have been given in the table (1.15).

Table (2.15). Species under the genus *Ochlandra*

Sl.No.	*Species*
1.	+*O. beddomei* Gamble;
2.	+*O. ebracteata* Raizada and Chatterji;
3.	+ *O.keralensis* Muktesh, Ramesh and Stephen;
4.	+*O. scriptoria* (Dennst.) Fischer ;
5.	+*O. setigera* Gamble ;
6.	+*O.sivagiriana* (Gamble) Camus;
7.	+ *O. soderstromeana* Muktesh and Stephen ;
8.	+*O. spirostylis* Muktesh, Seetha. and Stephen;
9.	+*O. talbotii* Brandis;
10.	+ *O. travancorica* var. *travancorica* Benth. and Hook. f.;
11.	+*O. travancorica* var. *hirsuta* Gamble;
12.	+ *O. wightii* (Munro) Fischer.

*Only cultivated. ________+ Endemic to India.

Description of important species under the genus *Ochlandra*

15.1 *O. travancorica* var. ***hirsuta*** Gamble;

Description: Tall reed-like grasses; rootstock rhizomatous, branched; culms to 5 m tall, densely clumped, hollow, covered with culm sheaths; culm sheaths with small limbs. Leaves scattered, 20-40 x 5-10 cm, oblong-lanceolate, base truncate, or cuneate, glabrous; sheaths tubular, mouth with stiff bristles; ligule short. Panicles large, spicate. Spikelets in verticils, 3-9 together, sessile, 5-6 cm long; glumes 2-5, unequal, to 5 cm long, lanceolate, mucronate, smooth; florets one, bisexual; lemmas 5 cm long, elliptic-oblong, muticous; palea membranous, stamens 20-40, filaments monadelphous; style long; stigma 4-6; fruit ovoid, 2-3 x 1.5 cm, beaked, smooth (Sasidharan, 2021).

15.2 *O. wightii* (Munro) Fischer.

Description Erect shrubby bamboo; culms 6-7.5 m tall, 1.5-2 cm diameter, nodes prominent with grayish bands on both sides, average internode length 50 cm; culm-sheath 8-15 cm long excluding the blade, 5 cm broad, covered with appressed, light brown subulate hairs; blade 6 cm long, 1-1.5 cm broad, lanceolate, acuminate. Leaves 18-36 x 3.5-7.5 cm, oblong-lanceolate, acuminate, attenuate at the base, glabrous on both surfaces, whitish beneath, margins cartilaginous, smooth, mid-vein prominent; secondary veins 10-14 pairs; sheath striate ending in a smooth rounded callus with two short auricles and a few stiff deciduous bristles; ligules very long. Inflorescence terminal spikes, rachis thick. Spikelets several in the verticels in the axils of bracts, glabrous, 2.3-2.8 x 0.4-0.6 cm, conical steriate; sterile glumes 4, basal, 0.6-2 cm long in flowers, 09-1.5 cm in fruits, outer two thicker and ovate-truncate with a subulate point; the inner two ovate-acute, mucronate; fertile glumes thin, membranous, 1.8 cm long in flowers, 2.5-3 cm long in fruits, many veined; palea 1.8 cm long in flowers, 3.5 cm long in fruits, narrow. Lodicule 1, 1.3 cm long, many nerved, serrate at apex. Stamens up to 60; filaments narrow, long, apiculate. Ovary glabrous, perigynium thickened and enclosing the style; stigmas 5, plumose. Caryopsis 5.5 x 1.8 cm, fleshy (Sasidharan, 2021)

16. Genus *Oxytenanthera*

Shrub or small tree. Culms woody. *Inflorescence of dense spherical clusters of spikelets*, at the tips of leafy branchlets, the clusters sometimes confluent. Spikelets subtended by several short papery bracts, 1-2-flowered, 1(-2) upper florets bisexual, the lower barren; glumes round on the back, 17-30-nerved, 2-4 persistent plus 1-2 deciduous with fl; lemmas 26-32-nerved, the tip pungent. Stamens 6. Fruit a caryopsis. Under this genus 5 species have been reported in India (Sharma and Nirmal, 2015).

Table (2.16). Species under the genus *Ochlandra*

Sl. No.	***Species***
1.	*O. abyssinica* (A. Rich.) Munro;
2.	+*O. bourdillonii* Gamble;
3.	*O. monadelpha* (Thw.) Alst.;
4.	+*O. ritcheyi* (Munro) Blatter and Mc Cann.;
5.	+ *O. stocksii* Munro.

*Only cultivated. _______+ Endemic to India.

Description of species under the genus Oxytenanthera

16.1. *Oxytenanthera abyssinica*

Description: Clump-forming bamboo with a robust rhizome up to 10 cm in diameter; clump dense, typically consisting of 20–100 stems; stems (culms) erect, ascending or leaning outwards, 5–10(–15) m tall and 3–8(–10) cm in diameter, internodes 15–30(–40) cm long, the basal ones solid, the distal ones thick-walled, glabrous at maturity; young shoots grey-green, densely silky hairy. Leaves alternate, simple; sheath up to 15 cm long, with 2–5 mm long bristles at top; ligule short, c. 0.5 mm long; blade linear-lanceolate to oblong, 5–20(–26) cm × 1–5 cm, base tapering into a short false petiole, apex long-acuminate and pungent, somewhat glaucous, with numerous longitudinal veins. Inflorescence a dense star-shaped cluster 4–9 cm in diameter, with 10–20 spikelets. Spikelets sessile, narrowly lanceolate, 1.5–4.5 cm long, pungent, 1–4-flowered with upper floret bisexual and lower florets male or sterile; lower glume 5–8 mm long, upper glume 8–10 mm long, lemma narrowly lanceolate, the lowest 12–20 mm long, the uppermost about as long as spikelet, tapering into a rigid spine up to 7 mm long, palea narrowly lanceolate, somewhat shorter than lemma; floret with 6 stamens, filaments united into a tube, and a glabrous ovary extending into a hollow style terminating in 3 stigmas. Fruit a spindle-shaped caryopsis (grain) 10–15 mm long. Seedling with a short mesocotyl and a loose coleoptile, the first leaves without lamina; primary root a pale taproot bearing short lateral roots (Inada and Hall, 2008).

Uses: The stems are widely used for construction, fencing, furniture and fish-traps. They are also used for stakes, trellises, tool handles, household implements and arrow shafts. The use of dry stems as fuel is widespread and they are sometimes made into charcoal. The stems have some potential as raw material for paper making. Split stems are used for basketry. Sap from the plant is collected for wine making in Tanzania and Malawi, the fresh or dried leaves are used as fodder, and the seeds and young shoots as famine food. *Oxytenanthera abyssinica* is used in shelterbelts and windbreaks, and as a complementary crop in plantations of *Cordia africana* Lam., *Eucalyptus microtheca* F.Muell. and *Khaya senegalensis* A.Juss. in Sudan, for erosion control in land rehabilitation in Sudan and Tanzania, and as an ornamental plant.
The rhizome is used in the treatment of dysentery and the leaves are marketed for treating diabetes, colic and rheumatism. In Ethiopia the root is applied in the treatment of skin diseases on the head. In Senegal leaf decoctions are taken to treat polyuria, oedema and albuminuria (Inada and Hall, 2008).

17. Genus *Phyllostachys*

This genus of bamboo is indigenous to Asia, with most species originating somewhere in Southern or Central China. Based in these climates, most *Phyllostachys* are **temperate bamboos**, meaning that they can tolerate cold winters. Many of them are able to survive temperatures well below 0º F. This makes the *Phyllostachys* especially popular in colder climates, like USDA zones 5 and 6. But most *Phyllostachys* are adaptable to warmer weather as well. So you can really find them flourishing all over the world. In fact, they are some of the most widespread and commonly cultivated bamboo species across North America, and also Europe and Australia.

Species distribution under the genus *Phyllostachys in India*

Sharma and Nirmal (2015) have reported that under the genus *Phyllostachys* following 05 species are found in India:

17.1 *Phyllostachys aurea*

The common forms of *P. aurea* are easily identified by their characteristic compressed internodes in the lower part of the canes which have a tortoise shell-like appearance. This internodal compression result in shorter heights (25 ft) and thicker cane diameters (relative to height) than many other *Phyllostachys* species. The canes turn yellow in full or partial sun, and deepen into a gold-orange color as the plant matures. Branching and foliage tend to start lower to the ground than many other *Phyllostachys* species, but some prefer to cut off lower branches to show off the interesting 'tortoise shell' lower part of the canes

17.2 *Phyllostachys bambusoides*

Phyllostachys bambusoides is a "running" (monopodial type) evergreen bamboo which can reach a height of roughly 20 m (66 ft) and a diameter of 10 cm (3.9 in). The culms are dark green, with a thin wall that thickens with maturity, and very straight, with long internodes and two distinctive rings at the node (Moore and Bibi,2001).The species is thin-skinned, easily split lengthwise, has long fibres, and is strong and highly flexible, even when split finely. Leaves are dark green, and the sheaths are strong and hairless. New stalks emerge in late spring and grow at a rate of up to 1 m (3 ft 3 in) a day; one specimen produced culms growing a remarkable 120 cm (47 in) in 24 hours. The flowering interval of this species is very long, lasting roughly 120 years.

Madake (*Phyllostachys bambusoides* S. et Z.) bamboo stands in Japan underwent gregarious flowering during the 1960's to 1970's suffering a deadly blow for a time (Watanabe,1983). In Asia, *Phyllostachys bambusoides*, known in Japan as *madake*, is one of the preferred bamboos for construction and furniture manufacture. Its properties also make it useful in a number of traditional Japanese arts and crafts.

17.3 *Phyllostachys edulis* (Moso)

One of the more elegant and extraordinary bamboos, this is the world's largest hardy bamboo. Only a few tropical bamboos grow larger. In it's native environment, it can grow over 3' (1m) in one day. An extremely tall and very thick bamboo, it is recommended for large lots or gardens. 'Moso' is derived from the chinese words 'Mao Zhu', meaning hairy bamboo. In China, it grows as forests and covers vast areas of land. The culm wood is thick and widely used to make tools, utensils and for construction.

Description: Perennial. Rhizomes elongated; leptomorph. Culms erect; 1000-3500 cm long; woody. Culm-internodes semiterete; thin-walled; 35-50 cm long; yellow, or light green; distally pubescent. Lateral branches dendroid. Branch complement two. Culm-sheaths deciduous; coriaceous; hispid; with red hairs; setose on shoulders. Culm-sheath blade linear; reflexed; pubescent. Leaves cauline. Leaf-sheaths glabrous on surface, or puberulous. Leaf-sheath oral hairs ciliate; deciduous. Ligule a ciliolate membrane; pubescent on abaxial surface. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades lanceolate; 8-10 cm long; 8-10 mm wide. Leaf-blade venation with 8 secondary veins; with distinct cross veins. Leaf-blade margins scabrous. Leaf-blade apex acuminate.

Distribution: Asia-temperate: Caucasus, China, and eastern Asia. Asia-tropical: Indo-China.

17.4. *Phyllostachys mannii*

Phyllostachys mannii is an evergreen bamboo that can grow 8 - 12 metres tall; the erect, woody culms are 40 - 60mm in diameter with thin-walled internodes 30 - 42cm long. The rhizomes are elongated, the plant having a running habit that can produce new canes some distance from the main clump, especially in warm climates. This tendency to run, however, is somewhat curtailed in cooler climates, where new shoot production can be rather reduced. The plant is harvested from the wild for use as a food and a source of materials. It is cultivated in central and southern China for this purpose, and also has considerable economic importance in northeast India, where the plant supplies material for the local handicraft industry

Phyllostachys mannii is native to the subtropical regions of the Indian and Myanmar Himalayas, but is also often cultivated in the temperate to warm temperate regions of southern China. Succeeds in full sun and in partial shade. Species in this genus generally tolerate a wide range of soils and sites, though they prefer a damp humus-rich soil in sun or semi-shade.They grow best in a position sheltered from cold winds. Plants are generally not very tolerant of dry conditions. Bamboos have an interesting method of growth. Each plant produces a number of new stems annually - these stems grow to their maximum height in their first year of growth, subsequent growth in the stem being limited to the production of new side branches and leaves. In the case of some mature tropical species the new stem could be as much as 30 metres tall, with daily increases in height of 30cm or more during their peak growth time. This makes them some of the fastest-growing species in the world. Bamboos in general are usually monocarpic, living for many years before flowering, then flowering and seeding profusely for a period of 1 - 3 years before usually dying. This pattern can vary - sometimes flowering is sporadic, with plants flowering annually and not dying; at other times it is gregarious with all the plants in a specific species coming into flower at the same time.

17.5 Phyllostachys nigra (Loddiges ex Lindley) Munro,

Phyllostachys nigra, commonly known as black bamboo, is a species of bamboo, native to Hunan Province of China, and is widely cultivated elsewhere.

Description: Culms 4–8(–10) m, to 5 cm or more in diam.; internodes green or gradually developing purple-brown to black spots or turning uniform purple-brown or black, 25–30 cm, initially white powdery, densely puberulent; wall ca. 3 mm thick; nodal ridge slightly more prominent than or equaling sheath scar; sheath scar initially brown hairy on margin. Culm sheaths red-brown, sometimes tinged with green, unmarked or densely extremely minutely and imperceptibly dark brown spotted, spots aggregating into a distal dark brown patch, thinly white powdery, brown strigose; auricles and oral setae well developed, purple-black; ligule purple, arcuate to acutely so, long ciliate; blade erect or gradually deflexed, green or tinged with purple on both sides, triangular to triangular-lanceolate, navicular, ± wavy. Leaves 2 or 3 per ultimate branch; auricles weak or absent; oral setae deciduous; ligule slightly exserted; blade thin, 7–10 × ca. 1.2 cm. Flowering branchlets shortly spicate, 3.5–5 cm, scaly bracts 4–8. Spathes 4–6, glabrous or puberulous; auricles absent; oral setae few or absent; blade usually subulate or ovate-lanceolate, small. Pseudospikelets 1–3 per spathe. Spikelets lanceolate, 1.5–2 cm; florets 2 or 3. Glumes (absent or)1–3, abaxially ± distally pubescent; rachilla pubescent; lemma 1.2–1.5 cm, densely pubescent; palea shorter than lemma. Anthers ca. 8 mm. Stigmas 3. New shoots late Apr, fl. May (FOC).

3. *Genus Pleioblastus*

Description: It is a genus of running bamboo native to East Asia but naturalized throughout the world, which includes roughly two dozen species. Unlike some of their better known and more colossal cousins, many varieties of *Pleioblastus* will only get to be 2 or 3 feet tall, with culms thinner your little pinkie finger. Perhaps not as impressive as the grand specimens of timber bamboo, these dwarf bamboos can add great interest to a garden. Their diminutive size makes them ideal as ground covers, or accents alongside larger plants and trees. Its striped leaves bring an extra dimension of beauty to greenery.

Under this genus of *Pleioblastus* only one species ie., *P. viridistriatus* (Regel) Makino has been reported in India (Sharma and Nirmala, 2015)

20. Genus *Pseudosasa*

Description: Plants shrub-like, spreading and densely clumped; rhizomes leptomorph, tillering. Culms 0.5–13 m tall, to 4 cm in diam., self-supporting, erect or nodding, pluricaespitose; internodes mainly terete, only slightly flattened immediately above the branches, glabrous, with light wax below nodes; nodes not or slightly swollen, supranodal ridge not evident. Branches initially 1–3 branches, erect to arcuate, often short; central dominant, basal nodes compressed, lateral branches arising either from basal nodes (P. japonica) or from more distal nodes, branches fully sheathed, sheaths and prophylls more or less glabrous, persistent, tough; buds tall, closed at front, 1 to 3 initials visible within, prophylls 2-keeled. Culm sheaths coriaceous and very persistent; blades erect or reflexed, narrowly triangular to strap-shaped. Leaf sheaths persistent; blade tessellate, medium to large for size of culm, without marginal necrosis in winter, arrangement random. Synflorescence an open raceme or panicle; branching subtended by much reduced or quite substantial bracts. Spikelets 2–20 cm, with 3–30 florets, rhachilla sinuous; disarticulation below the florets. Glumes 2, shorter than the first lemma; lemmas to 1 cm; stamens 3; stigmas 3; paleas 2-keeled. Name after the exclusion of the first species published from the similar but 6-stamened genus *Sasa*.

Around 36 species are currently assigned to *Pseudosasa*, originating in Japan, China, and Korea. The Japanese type species, *P. japonica* differs from the rest of the genus (Subgenus *Sinicae*) by having very persistent culm sheaths and a solitary spreading branch at each node rather than 3 very erect branches.

21. Genus *Sarocalamus*

It is a small genus of approximately 4-6 species, native to the E Himalayas and SW China. They are morphologically closest to *Arundinaria*, a genus now restricted to species native to N America, and among the Asian genera considered rather similar to *Bashania*. Distinguished from *Bashania* by the lack of compressed basal branch internodes, leading to fewer branches at the base of the complement, and the smaller, thinner leaves, and distinguished from *Arundinaria* by the narrower spikelets and glabrous pedicels. Note that *Gelidocalamus* is a very different genus, not closely related to *Sarocalamus* or *Bashania*.

Rather than having few major branches with many branchlets and many leaves, it has many branches with few branchlets and few leaves.

22. Genus *Schizostachyum*

It is a tall or shrub-like tropical genus of bamboo. They are natives mostly of tropical Asia and Papuasia, with a few species in Madagascar and on certain islands in the Pacific. A few have become naturalized in other tropical regions (Soreng, 2000). Occurrence of its 05 species have been documented by Sharma and Nirmala (2015)

Table (2.17). Species under the genus *Schizostachyum*

Sl.No.	*Species*
1.	*S. andamanicum* Kumar and Ramesh;
2.	+ *S. kalpongianum* Kumar and Ramesh;
3.	*S. kurzii* (Munro) Majumdar;
4.	+*S. rogersii* Brandis;
5.	+*S. seshagirianum* Majumdar

*Only cultivated. _______+ Endemic to India.

22.1 *S. andamanicum* Kumar and Ramesh;

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms arching; 300-400 cm long; 12-18 mm diam.; woody. Culm-internodes terete; thin-walled; 18-22 cm long; yellow, or light green; distally pubescent. Culm-nodes swollen; glabrous. Lateral branches dendroid. Branch complement many; with subequal branches. Culm-sheaths 13-16 cm long; 3 length of internode; green; hispid; with tawny hairs; auriculate; with 2 mm high auricles; setose on shoulders; shoulders with curved hairs. Culm-sheath ligule 2 mm high. Culm-sheath blade lanceolate; erect; 5-7 cm long; 4-8 mm wide; pubescent; acuminate. Leaf-sheaths glabrous on surface. Leaf-sheath oral hairs scanty. Leaf-sheath auricles falcate; 1 mm long. Ligule an eciliate membrane. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades lanceolate; 8-22 cm long; 26-48 mm wide. Leaf-blade surface glabrous.

Distribution: Asia-tropical: Indo-China.

23. Genus *Shibataea*

Description: They are unique shorter bamboos with dark green leaves. This genus is more closely related to the genus *Phyllostachys* than other small bamboos. Excellent as tall groundcover or short hedges, they are especially suited to climates similar to the Pacific Northwest since they dislike dry climates. They not do well with alkaline or water-logged soil. They need acidic conditions to prevent leaf burn. They are sometimes called ruscus-leaved bamboo, as the shape of the leaves resembles that of the genus *Ruscus*. These bamboos are very resistant to bamboo mites. They are used to make canes.

Under this genus only one species ie., *S. kumasasa* (Zoll. ex Steud.) Makino ex Nakai. Has been reported for its cultivation in India by Sharma and Nirmala (2015)

Description of Species under the Genus *Shibataea*

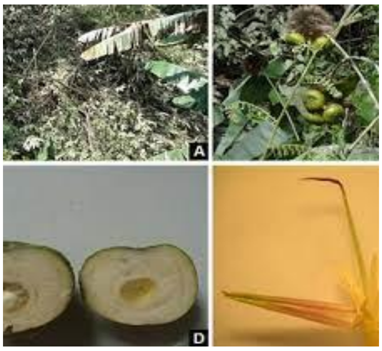
23.1.*S. kumasasa* (Zoll. ex Steud.)

Description: Perennial. Rhizomes elongated; leptomorph. Culms erect; zigzag; 50-150 cm long; 3-5 mm diam.; woody. Culm-internodes semiterete; thin-walled; 3-10 cm long. Culm-nodes swollen; with distinct supra-nodal ridge. Lateral branches suffrutescent. Branch complement two, or three, or several; with subequal branches; thinner than stem. Culm-sheaths deciduous; chartaceous; without auricles; ciliate on shoulders. Culm-sheath blade linear. Leaves cauline; 1(-2) per branch; with sheath almost obsolete. Ligule an eciliate membrane. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades lanceolate, or ovate; 5-11 cm long; 20-25 mm wide. Leaf-blade venation with distinct cross veins. Leaf-blade surface pubescent; hairy abaxially. Leaf-blade margins scabrous.

24.0 Genus *Stapletonia*

Description of Species

24.1.*Stapletonia arunachalensis* (H.B.Naithani) P.Singh, S.S.Dash & P.Kumari



Description: Culms 10-15 m high, 6-7 cm in diameter, at first erect then branches pendulous, dark green when young turning yellow with age; nodes swollen, with a ring of fallen culm-sheath base and c. 1 cm broad ring of thick, brown deciduous hairs; internodes terete, at base c. 20 cm long and up to 1.5 m or more long above, smooth, hollow, walls 5-10 mm thick; bud oval, rounded at apex; branches 6 (4, 2 cm in girth). Culm-sheaths deciduous, shorter than internodes, brownish, thick crustaceous; sheath proper covered with yellow-brown hairs on outer surface, glabrous inside, 15-26 cm long, 12-14 cm broad at base, sides more or less parallel with 10-11 cm broad obliquely round top; one margin completely ciliate, another usually at top only, cilia c. 2 mm long, dense, dark brown; imperfect blade shorter than sheath proper, 10-25 cm long, 9-11 cm broad, triangular, one side longer than the other, rounded at base, acute at apex, erect, transversely veined, minute hirsute at somewhat wrinkled base on outer surface, scanty appressed hairy on inner surface, margins ciliate at base, smooth upwards; ligule narrow, entire. Leaf-blades oblong-lanceolate, up to 48 cm long and 18 cm broad, obliquely attenuate at base, acuminate at apex with c. 2 cm long, incurved, twisted setaceous apex, minutely hirsute on abaxial surface; midrib raised, prominent, glabrous, secondary veins 12-18 pairs, tertiary 5-7(8), pseudopetiole 1- 1.5 cm long; leaf-sheaths striate, thin keeled, puberulous, ending above in a thin callus, densely ciliate at margins; ligule narrow; auricles oblong-conical, extending along margins up to c. 1.5 cm length, long fringed, fringes c. 1 cm long, deciduous. Inflorescence a dense, globular, terminal or subterminal head, 6-10 cm in diameter consisting of fertile spikelets among majority of empty aristate bracts or sterile spikelets. Fertile spikelets c. 4 cm long, glabrous; empty glumes 6-8, 1.2 - 3 cm long, ovate at base, long scabrous-aristate above, glabrous, striate, 5-7 nerved. Lemma 2.5 - 3.5 cm long, shortly aristate, rosy pink. Palea 2-3 cm long, rosy pink, narrowly 2-keeled. Rhachilla extension c. 0.5 cm long, hairy in lower half. Lodicules 3, c. 1.3 cm. long, lanceolate, papillate hairy on inner surface, glabrous outside, ciliate on margins, rosy pink, white near base. Stamens c. 5 cm long; anthers c. 1 cm long; filaments free, thread like. Pistil stipitate, c. 3 cm long; style long, hollow; stigma bifid, hairy. Fruit c. 5 cm across, globose, slightly depressed at top with elongated persistent, acicular style when young Dash *et al.*, 2009)

25.Genus *Thamnocalamus*

Thamnocalamus is a genus of clumping bamboo in the grass family. These species are found from the Himalayas as well as Madagascar and Southern Africa. Thamnocalamus is closely related to Fargesia. Under this genus species have been reported in India by Sharma and Nirmala (2015).

Table (2.18).Species under the genus *Thamnocalamus*

Sl.No.	*Species*
1.	+*T. aristatus* (Gamble) Camus;
2.	*T. longispiculatus* (Majumdar) M.L.Sharma
3.	+ *T. spathiflorus* (Trin.) Munro. *;*
4.	*T. occidentalis* Stapleton.

*Only cultivated. _______+ Endemic to India.

Description of species under the genus *Thamnocalamus*

25.1. *T. spathiflorus* (Trin.) Munro.

Description: Rhizome neck 3.5–6 cm, 7–20 mm in diam. Culms 3–4 (–5.5) m, 1–2 cm in diam.; internodes terete or slightly flattened above branches, 15–18 cm, grooved, ridged, initially densely white powdery, glabrous; wall 2–3(–4) mm thick; nodes slightly to distinctly swollen; sheath scar prominent, with persistent remains of sheath base. Branches (1–)3–6, erect or deflexed, densely white powdery, glabrous. Culm sheaths deciduous, narrowly rounded or narrowly triangular-rounded, equal to or slightly longer than internodes, leathery, white powdery, glabrous or densely setose, margins yellow-brown ciliate, longitudinal ribs conspicuous; auricles absent or falcate, oral setae absent or prominent; ligule arcuate, ca. 1 mm, glabrous, margins fissured; blade erect, gray or gray-brown, triangular or linear-lanceolate, glabrous, margins usually rolled, serrulate. Leaves 2–5(or 6) per ultimate branch; sheath glabrous; auricles absent or prominent, oral setae absent, or many and readily deciduous, gray, 1–1.5 mm; ligule truncate, ca. 1 mm, margins puberulous; blade narrowly lanceolate, 4.5–9 × 0.5–1 cm, glabrous, secondary veins 2-paired, transverse veins distinct, base broadly cuneate or nearly rounded, margins serrulate. Inflorescence unknown from China. New shoots May–Jun (WFO, 2021)

26. Genus *Thyrsostachys*

The name Thyrsostachys was first mentioned by Gamble (1894: 1) based on the collection of T. oliveri Gamble by J.W. Oliver in Myanmar (Sungkaew *et al.,* 2021). Based on morphological data, Thyrsostachys is closely related to Bambusa Schreb. and Dendrocalamus Nees but differs by its thyrsoid paniculate, bracteate inflorescence and its paleas which are keeled and bifid in the lower florets and are not or hardly keeled in the upper ones (Gamble, 1894; 1896; Holttum, 1958; Bennet, 1988; Goh et al., 2018). Its grouping within the subtribe Bambusinae of the Palaeotropical and Austral woody bamboo clade is supported by both morphological and molecular phylogenetic studies, but relationships within the subtribe are still largely unresolved (Holttum, 1946; 1958; Grosser & Liese, 1973; Clayton & Renvoize, 1986; Ohrnberger, 1999; Loh et al., 2000; Sungkaew et al., 2009; BPG, 2012; Zhou et al., 2017; Goh et al., 2018; Liu et al., 2020).

Description: Arborescent, unarmed bamboo. Rhizomes pachymorph with short necks, forming a clump usually with very dense culms. Culms erect, tips erect to slightly arched; internodes terete, lower ones usually solid or nearly so, otherwise hollow; lateral branch buds at each node solitary. Branches developing from the upper quarter of the culm upwards. Midculm branch complement several to many branches at each node, in a horizontal line, with 1 branch dominant, thinner than the mother culm. Culm leaves tardily deciduous to persistent; ligules short, membranous; auricles absent or inconspicuous, margins ciliate;

blades usually erect, linear or triangular. Foliage leaves shortly pseudo-petiolate; ligules very short; auricles absent or inconspicuous, margins ciliate; blades lanceolate, cross-veins present. Synflorescences fully bracteate, paniculate, usually on leafless branches, inflorescence units iterauctant (indeterminate), composed of pseudospikelets. Pseudospikelets laterally compressed, 1.2–2.5 cm long; empty glumes 1–4, shorter than the spikelet; fertile florets 1–6(7), sometimes plus a barren rachilla extension, falling together, not disarticulating below each floret; rachilla internodes between the florets short. Florets with lemmas similar to glumes; paleas 2-keeled but the uppermost without keels; lodicules absent to 3; stamens 6, filaments free; ovary umbonate, short-stalked, hairy to glabrous, style 1, stigmas 1–3, feathery. Caryopses basic, terete, smooth, glabrous, with persistent style base.

The genus includes two species, Thyrsostachys oliveri and T. siamensis Gamble, with a natural distribution in Myanmar, Thailand and Indochina; both species were introduced to India and seeded there (Gamble, 1896; Bor, 1941, Sharma and Nirmala, 2015).

Table (2.19).Species under the genus *Thyrsostachys*

Sl.No.	***Species***
1.	*T. oliveri* Gamble;
2.	**T. regia* (Munro)Bennet.

*Only cultivated. _______+ Endemic to India.

Description of species under the Genus *Thyrsostachys*

26.1 *Thyrsostachys oliveri*

Description: Culms 10–20(–25) m tall, 5–7.5 cm in diameter, covered with appressed white hairs when young, becoming glabrous when mature; internodes initially bright green, becoming dull green, 30–60 cm long; walls rather thick, particularly from lower internodes; nodes slightly prominent. Culm leaves relatively persistent, ca ¾ as long as the internodes, chartaceous; culm-leaf sheaths 20–35.5 × 10–25.5 cm, apex somewhat truncate or rounded to convex, 2–9 cm wide, back covered with appressed white to pale brown hairs; ligules 0.5–2.5 mm high, margin ciliolate; culm-leaf blades erect to slightly arched, deltoid to linear-lanceolate, 7.5–25 × 1.5–8 cm, base ca ½–⅔ width of the sheath apex, pubescent. Foliage leaves 5–7 per branchlet; pseudo-petioles 0.05–0.5 cm long; foliage-leaf sheaths 3–5.5 cm long, abaxially hairy to glabrous, margins ciliate; auricles absent, fimbriae and oral setae absent; ligules short, ca 0.5 mm high, margin ciliolate; foliage-leaf blades linear-lanceolate, (10–)12–22.5 × (0.7–)1–1.8 cm, adaxially scaberulous and hairy abaxially, to glabrous on both sides, base somewhat obliquely cuneate, apex acuminate. Pseudospikelets 1.5–2.5 cm long; bracts subtending prophyllate bud 2 or 3; empty glumes 1 or 2, rarely 3, 0.5–1.2 cm long, apex acute, margins entire or ciliolate towards the apex, chartaceous, 11–21-nerved, back pubescent to glabrous. Fertile florets 2–6(–7); rachilla internodes between fertile florets 1–3 mm long, scantly hairy to glabrous; lemmas similar to the glumes, 0.9–2.5 cm long, apex acute, margins ciliolate towards the apex, 9–29-nerved, abaxially slightly pubescent to glabrous; paleas membranous to thinly chartaceous, hairy abaxially, usually as long as or slightly shorter than the lemmas, apex obtuse to bifid for ¼–⅓ of its length, 2-keeled, keels ciliate, 5–7-nerved between keels and 2–4-nerved between each keel and the ciliate and involute margin; lodicules 2 or 3, conspicuous, membranaceous, ovate to lanceolate, 1–1.2

mm long, margin ciliate; anthers 5–6 mm long, apices acute to apiculate, glabrous; ovaries hairy to glabrous, style ca 1.5 cm long, stigmas 3. Caryopses ca 1 cm long, glabrous (Sungkaew *et al*., 2021).

26.2. ***Thyrsostachys siamensis*** Gamble

Description: Culms 5–15 m long, 1.5–6 cm in diameter, covered with appressed white hairs

when young, becoming glabrous when mature; internodes initially green, becoming gray-green, 15–30 cm long; walls very thick to solid or nearly so, particularly from lower internodes; nodes slightly prominent, with a white waxy ring below. Culm leaves very persistent; 3/4–1 as long as internodes, chartaceous; culm-leaf sheaths 10–20 × 5–15 cm, apex somewhat truncate or rounded to convex, 2–3 cm wide, abaxially covered with appressed white to pale brown hairs; ligules 0.5–2.5 mm high, margin ciliolate; culm-leaf blades erect to slightly arched, deltoid to linear-lanceolate, 3.5–15 × 1–2 cm, base ca ½–⅔ width of the sheath apex, pubescent. Foliage leaves (3–)5–7 per branchlet; pseudo-petioles 0.05–0.15 cm long; foliage-leaf sheaths 2.5–3.5 cm long, abaxially hairy, margins ciliate; auricles absent, fimbriae and oral setae absent; ligules short, ca 0.5 mm high, margin ciliolate; foliage-leaf blades narrowly linear, 5–15 × 0.3–0.7 cm, adaxially scaberulous only on lateral veins near the margin and near the midrib or glabrous, abaxially hairy, base somewhat truncate to cuneate or acute, apex acuminate. Pseudospikelets 1.2–1.4 cm long; bracts subtending prophyllate bud 2 or 3; empty glumes (1–)2 or 3, 0.75–1.2 cm long, apex acute, margins entire or ciliolate towardsthe apex, chartaceous, 8–15-nerved, back hairy, especially near the base, or glabrous. Fertile florets 1–3; rachilla internodes between fertile florets 1–2 mm long, scantly hairy to glabrous; lemmas similar to the glumes, 1–1.4 cm long, apex acute, margins ciliolate towards the apex, 14–29-nerved, abaxially slightly pubescent only near the base and the tip, otherwise glabrous; paleas membranous to thinly chartaceous, hairy to glabrous abaxially, usually as long as or slightly shorter than the lemmas, apex usually bifid for 1/10–½ of its length, 2-keeled, keels ciliate, 2 or 3-nerved between keels and 0 or 1-nerved between each keel and the ciliate and involute margin; lodicules (2–)3, rarely absent; anthers ca 3.5 mm long, apices acute to mucronate, glabrous; ovaries usually glabrous, style ca 1 cm long, stigmas 1–3. Caryopses 0.5–0.8 cm long, glabrous (Sungkaew *et al*., 2021).

27. Genus *Yushania*

Yushania is a genus of medium sized, clumping mountain bamboos from Taiwan, the Himalayas, and Africa. They are particularly frost-tolerant and grow in spreading thickets. Shoots in the spring. *Yushania* is a temperate to subtropical genus that currently contains around 80 species, occurring from the NW Himalayas to Taiwan and the Philippines. The genus differs from *Borinda* principally in having long-necked rhizomes that enable the plants to spread further, giving a semi-running, pluricespitose habit under suitable conditions. The species are mainly of little utility, and several species are even considered invasive weeds. They form good screening but can be rather invasive in warmer sites.

Description: Plants shrub-like, spreading to form diffuse and/or dense clumps; rhizomes pachymorph with variable necks up to (0.3–)0.5(–2) m long. Culms pluricespitose, 1.5–5 m tall, 0.5–3 cm thick, basally erect; internodes 15–40 cm, terete, often scabrous, distally more densely so, usually not ridged, often waxy at first, usually grey-green, remaining matt; nodes scarcely to moderately raised. Branches 5–7(–15) per mid-culm node at first, above promontory, subequal, initially erect, becoming deflexed, lateral branch axes lacking subtending sheaths; buds at mid-culm lanceolate, with 2 often very tall, single-keeled bracts, open at front, 3–9 initials visible within. Leaf sheaths persistent; blades usually thickened, usually glossy above, venation tessellate, persistent in winter and not deciduous. Synflorescence ebracteate, semelauctant; branching paniculate, often deflexed, often with pulvini but with little or no fasciculation; branches subtended by minute sheath remnants or rings of hairs. Spikelets with 4–10 florets, glumes tight or loose, rarely subtending reduced non-viable buds. Stamens 3. Stigmas 3. Named after Yu Shan (Jade Mountain), the highest mountain in Taiwan (called Niitakayama by the Japanese), on which the type species, *Y. niitakayamensis* is found.

Under this genus diversity of 05 species have been reported in India by Sharma and Nirmala (2015).

Table (2.20).Species under the genus *Yushania*

Sl.No.	***Species***
1.	*Y. densifolia* (Munro) Majumdar;
2.	*Y.elegans* (Kurz.) Majumdar;
3.	+*Y. hirsutea* (Munro)Majumdar;
4.	+*Y. jaunsarensis* (Gamble) Yi;
5.	*Y. maling* (Gamble) Majumdar;
6.	+*Y. microphylla* (Griffith) Majumdar;
7.	+*Y. pantlingii* (Gamble) Majumdar;
8.	+ *Y. rolloana* (Gamble) Yi;
9.	*Y. yadongensis* Yi.

*Only cultivated. _______+ Endemic to India.

27.1 *Y. hirsutea* (Munro)Majumdar;

Description: Perennial; caespitose. Rhizomes short; pachymorph. Culms erect; 200 cm long; woody. Culm-internodes terete; thin-walled; 15 cm long; scaberulous; distally hirsute. Lateral branches dendroid. Branch complement one, or two. Culm-sheaths 10-15 cm long; 4-6 times as long as wide; chartaceous; hispid; with tawny hairs; convex at apex; auriculate; setose on shoulders. Culm-sheath ligule ciliolate. Culm-sheath blade linear; reflexed. Leaf-sheaths striately veined; hispid. Leaf-sheath oral hairs setose. Ligule a ciliolate membrane. Leaf-blade base with a brief petiole-like connection to sheath. Leaf-blades deciduous at the ligule; lanceolate; 7-12 cm long; 12-16 mm wide. Leaf-blade venation with 8-12 secondary veins; with distinct cross veins. Leaf-blade surface pilose; hairy abaxially. Leaf-blade margins scabrous. Leaf-blade apex attenuate.

Distribution: Asia-tropical: India.

28.0* Genus *Borinda

A recently created genus of clumpers and "open clumpers" from the mountainous regions of Asia, composed of several species that had been previously assigned to other genera, such as Fargesia, Yushania, Arundinaria, Thamnocalamus, and Himalayacalamus.

Classification of these bamboos has been problematic. Shooting season is variable. It is a temperate to subtropical genus that currently contains about 20 species. Many species have high local economic value and great horticultural potential. They are often indigenous to dwindling forest areas or individual mountain tops, and are thus potentially threatened with extinction as forests are cleared and climate change pushes species up the mountains

Description: Plants shrub-like to subarboreous, usually densely clumping; rhizomes pachymorph, necks similar in length, up to 30 cm. Culms in a single dense to loose clump (unicespitose), to 7 m tall and 3.5 cm in diam., erect or curving at base, apically nodding to pendulous; internodes to 50 cm, terete, usually finely ridged, without fine purple spots, usually blue-grey with light persistent wax, matt or becoming glossy, usually partially setose or pubescent, especially at top; nodes scarcely to moderately raised. Branches 3--7 per mid-culm node at first, above promontory, subequal, deflexed, or basally erect but arching out, lateral branch axes lacking subtending sheaths; buds at mid-culm lanceolate, with 2 often very tall, single-keeled bracts, open at front (closed at culm base), 3--9 initials visible within. Culm sheaths usually long-triangular, papery and deciduous (rarely oblong, thickened and persistent); blades long, reflexed, deciduous. Leaf sheaths usually persistent; blade usually matt, thin, venation distinctly tessellate, either persistent or deciduous in winter. Synflorescence ebracteate, semelauctant; branching paniculate, erect, never unilateral, usually long-exserted from narrow subtending sheath, often fasciculate in dense panicles. Spikelets several-flowered; glumes basally loose, and frequently subtending reduced non-viable buds. Stamens 3. Stigmas 3. Named after Norman L. Bor, forester and grass taxonomist of the Indian Forest Service and the Royal Botanic Gardens Kew.

Only one species ie., B. grossa (T.P.Yi) Stapleton has been reported from India by Sharma and Nirmala(2015)

28.1. *B. grossa* (T.P.Yi)

Description: Perennial; caespitose; clumped densely. Rhizomes short; pachymorph. Culms erect; drooping at the tip; 500-1000 cm long; 20-45 mm diam.; woody; without nodal roots. Culm-internodes terete; thin-walled; 25-50 cm long; ridged; distally pruinose, or glabrous. Culm-nodes flush with internodes. Lateral branches dendroid. Bud prophyll 1-keeled. Branch complement three; subtended by a bare patch above the node; with subequal branches; thinner than stem. Culm-sheaths persistent; 26 cm long; 2 times as long as wide; hispid; with dark brown hairs; without auricles; setose on shoulders; shoulders with straight hairs; shoulders with 3-8 mm long hairs. Culm-sheath ligule 1-2 mm high; ciliolate. Culm-sheath blade lanceolate; deciduous; erect; 3.5-7 cm long; 20 mm wide; hispid. Leaf-sheaths glabrous on surface, or pubescent. Leaf-sheath oral hairs setose; 3-5 mm long. Ligule an eciliate membrane; 15-25 mm long; truncate. Collar pilose. Leaf-blade base with a brief petiole-like connection to sheath; petiole pubescent. Leaf-blades lanceolate; 4.5-18 cm long; 5-20 mm wide. Leaf-blade venation with distinct cross veins. Leaf-blade surface glabrous, or pilose; sparsely hairy; hairy adaxially.

Distribution: Asia-temperate: China. Asia-tropical: India.

Conclusion :

None of the wild species of Indian bamboos is known with certainty to have a threatened conservation status. This opinion may be due to the lack of data on exploitation or decline, and lack of systematic studies on distribution and assessment of threat to these plants, compounded by profound taxonomic uncertainties. In India, most of the cultivated bamboos are less vulnerable, and are already conserved in various Gardens or Bambuseta located in different parts of the country. It will be holistic approach to plant most of the bamboo species in botanical gardens and bambusetum at different scientific institutions so that student and people having interest in bamboo taxonomy may get opportunity to visit the side and trace the treasure of nature.

References:

1. **Anonymous *(1874). Dinochloa andamanica*** Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 42 (4), 1874: 253.
2. Bamboo Phylogeny Group (BPG). (2012). An Updated Tribal and Subtribal Classification of the Bamboos (Poaceae: Bambusoideae). Bamboo Science and Culture: The Journal of the American Bamboo Society 24(1): 1–10.
3. Barooah, C. and I Ahmed, I. (2014). Assam Science Technology and Environment Council. Widjaja, E.A. (2016). Bamboos (PROSEA)
4. Benton, A. (2015). International Network for Bamboo and Rattan (INBAR), 8, Futong Dong Da Jie, Wangjing, Chaoyang District, P. O. Box 100102-86, Beijing 100102, P. R. China e-mail: andrew@inbar.int, http://www.inbar.in
5. Camus, Aimée Antoinette. (1922). Bulletin du Muséum National d'Histoire Naturelle 28(1): 100-102 descriptions in Latin, commentary in French, line drawings on page 102
6. Clayton, W.D., Harman, K.T. and Williamson, H. (2008). GrassBase – The online world grass flora. http://www.kew.org/data/grasses-db.html.
7. Clayton, W.D. and Renvoize, S.A. (1986). Genera Graminum: grasses of the world. Kew Bulletin Additional Series 13. Her Majesty’s Stationery Office, London, England, 389 pp
8. Dash, S. S., Kumari, P., and Singh, P. (2009). Notes on flowering in *Schizostachyum arunachalensis* HB Naithani (Poaceae: Bambusoideae). *Nelumbo*, *51*, 241-244.
9. Dransfield, S. (1991). The Bamboos of Sabah. Sabah Forest Record No. 14. Sabah Forestry Department; 11-94.
10. FOC (2008). Flora of China Vol. 22: 54, 55 in eFloras.org, Missouri Botanical Garden. Accessed Nov 12, 2008.
11. FOC (Flora of China) Vol. 22 Page 164, 166, 175
12. Gamble, J.S. (1894). A handsome new Burmese Bamboo. Indian Forester 20(1): 1.
13. Gamble, J.S. (1896). The Bambuseae of British India. Annals of the Royal Botanic Garden, Calcutta 7: 1–133, plates 131–119
14. Goh, W.L., Sungkaew, S., Teerawatananon, A., Ohrnberger, D., Xia, N.H., Chan, K.S., How, Y.X. and Wong, K.M. (2018). The hybrid origin of Phai Liang, a bamboo of recent introduction into horticulture in Southeast Asia, and a new nothogenus, ×*Thyrsocalamus* (Bambuseae: Bambusinae). Phytotaxa 362 (3): 271–281.
15. Grosser, D. and Liese, W. (1973). Present status and problems of bamboo classification. Journal of the Arnold Arboretum 54: 293–308.
16. Gupta, B.N., Pattanath, P.G. (1976). Variation in stored nutrients in culms of Dendrocalamus strictus and their effect on rooting of culm cuttings as influenced by the method of planting. Indian For. 102(4): 235-241.
17. Hendrik, B.L. (1854). Plantae junghuhnianae: enumeratio plantarum, quas, in insulis Java et Sumatra 387-388 in Latin
18. Holttum, R.E. (1958). Thebamboos of the MalayPeninsula. Gardens’ Bulletin Singapore 16: 1–135
19. Holttum, R.E. (1946). The classification of Malayan bamboos. Journal of the Arnold Arboretum 27: 340–346.
20. Hsueh, C. J. and Yi, T. P. (1979). Two new genera of Bambusoideae from S.W. China. Acta Botanica Yannanica 1(2): 74-84.
21. https://www.agricultureinindia.net
22. https://www.kfri.res.in ›

23. Inada, T. & Hall, J.B., 2008. Oxytenanthera abyssinica (A.Rich.) Munro. [Internet] Record from PROTA4U. Louppe, D., Oteng-Amoako, A.A. & Brink, M. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands. <http://www.prota4u.org/search.asp>. Accessed 7 September 2021.
24. Khan, K.K. and Hemalatha, E. (2015). A Review on the genus *Bambusa* and one particular species *Bambusa vulgaris* in Sabah (Malaysia). Int. Res. J. Pharm. 6 (9):580-584
25. Li, D. and Stapleton, C. (2006). *Chimonocalamus* Hsueh & Yi. In: Flora of China 22: 103-105.
26. Liu, J.X., Zhou, M.-Y., Yang, G.Q., Zhang, Y.X., Ma, P.F., Guo, C., Vorontsova, M.S. & Li, D.-Z. (2020). ddRAD analyses reveal a credible phylogenetic relationship of the four main genera of *Bambusa- Dendrocalamus-Gigantochloa* complex (Poaceae: Bambusoideae). Molecular Phylogenetics and Evolution 146: 106758.
27. Loh, J. P., Kiew, R., Set, O., Gan, L. H., and Gan, Y. Y. (2000). A study of genetic variation and relationships within the bamboo subtribe Bambusinae using amplified fragment length polymorphism. *Annals of Botany*, *85*(5), 607-612.
28. Mabberley D. J. (2008) . Plant-Book, A portable dictionary of plants, their classification and uses (3rd edn.). 179. Cambridge.
29. Mao, A. A., and Bhaumik, M. (2010). *Chimonocalamus longiusculus* Hsueh & TP Yi (Poaceae: Bambusoidae) a New Record for India. *Nelumbo*, *52*, 150-151.
30. Moore, N. and Bibi, W. (2001). *Bamboo in Japan* (1st ed.). New York: Kodansha International. p. 34.
31. Muktesh kumar, M.S. (2011) .All India Coordinated Project on Taxonomy (Aicoptax) Grasses & Bamboos Project Completion Report (April 2000- March 2011) Bamboos Of Andaman And Nicobar Islands Part-I. Final report of the Research Project No. KFRI 358/2000
32. Nguyen, H. N. and Tran, V. T. (2010). Six new species of Melocalamus (Gramineae: Bambusoideae) from Vietnam. *Blumea-Biodiversity, Evolution and Biogeography of Plants*, *55*(2), 129-138.
33. Ohrnberger, D. (1999). The bamboos of the world: annotated nomenclature and literature of the species and the higher and lower taxa. Elsevier Science, Amsterdam, 585 pp.
34. Pai, P. and Diao, S. (2014). Isolation, structural characterization and potential applications of hemicelluloses from bamboo : A review. Carbohydrate Polymers., 112:701-720.
35. Pathak, P. K., Kumar, H., Kumari, G., & Bilyaminu, H. (2015). Biomass production potential in different species of bamboo in Central Uttar Pradesh. *The Ecoscan*, *10*(1), 41-43.
36. Sarojam, N. (1996). Bamboo Information Centre-India: Bamboos of South and South-East Asia: an annotated bibliography. Bamboo Information Centre-India, Kerala Forest Research Institute,
37. Sasidharan, N. (2021). (Dr. B P Pal Fellow), Kerala Forest Research Institute, Peechi, Indian Biodiversity , Portal
38. Schröder, S. (2010). Guadua Bamboo. Bambusa. [updated 2010 Jauanry 31; cited 2015 August 9]. Available from: http://www.guaduabamboo.com/genera/bambusa.
39. Seethalakshmi, K.K. and Muktesh Kumar, M.S. 1998. Bamboos of India – a Compendium. KFRI, Peechi. Pp 342.
40. Sharma, C. L., Sharma, M., Lamare, D. M., Wangkhem, M., & Pangging, G. (2021). Anatomical and physical characteristics of *Cephalostachyum mannii* (Gamble) Stapleton–an endemic scrambling bamboo of northeast India. *Indonesian Journal of Forestry Research*, *8*(1), 99-110.
41. Sharma, M.L. and Nirmala, C. (2015). Bamboo diversity of India: an update. Proceedings of the 10th World Bamboo Congress, Korea. Available from www.proceedings. com/28028.
42. Sobita Devi, T. and Sharma, G. J. (1993). Chromosome number in some bamboo species of Manipur. BIC- India Bulletin, 3 (1): 16-21.
43. Soreng, R. J. (2000). *Schizostachyum*. In Catalogue of New World Grasses (Poaceae): I. Subfamilies Anomochlooideae, Bambusoideae, Ehrhartoideae, and Pharoideae. Contributions from the United States National Herbarium 39: 112
44. Stapleton, C. M. A. (1994). The bamboos of Nepal and Bhutan. Part I: Bambusa, Dendrocalamus, Melocanna, Cephalostachyum, Teinostachyum, and Pseudostachyum (Gramineae: Poaceae, Bambusoideae). *Edinburgh Journal of Botany*, *51*(1), 1-32.

45. Sungkaew, S., Stapleton, C. M., Salamin, N., and Hodkinson, T. R. (2009). Non-monophyly of the woody bamboos (Bambuseae; Poaceae): a multi-gene region phylogenetic analysis of Bambusoideae ss. *Journal of plant research*, *122*(1), 95-108.
46. Sungkaew, S., Suddee, S., Wong, K. M., & Teerawatananon, A. (2021). Thyrsostachys (Poaceae: Bambusoideae) in Thailand: taxonomy, lectotypification and natural distribution. *Thai Forest Bulletin (Botany)*, *49*(1), 49-56.
47. Sungkaew, S., Teerawatananon, A., Korawat, W., & Hodkinson, T. R. (2007). *Dendrocalamus copelandii* (Poaceae: Bambusoideae), a new giant bamboo record for Thailand. *Thai Forest Bulletin (Botany)*, (35), 94-97.
48. Surendran, T., Seethalakshmi, K.K. (1985). Investigations on the possibility of vegetative propagation of bamboos and reeds by rooting stemwood cuttings. KFRI Res. Report 31. Kerala Forest Research Institute, Peechi 47p.
49. Viswanath, S., Chethan, K., Srivastava, A., Joshi, G. Sowmya. C. and Joshi, S. C. (2013). *Dendrocalamus brandisii*. (Munro) Kurz. An ideal bamboo species for domestication in humid tropics. IWST Technical Bulletin No. 12, A Publication of Institute of Wood Science & Technology, Bangalore.
50. Watanabe, J. (1983). On the Productivity of a *Phyllostachys bambusoides* Stand in Recovering from Flowering* Masatoshi. Jap. For. Soc. 65(3):89-93
51. 'WFO (2021): Thamnocalamus spathiflorus (Trin.) Munro. Published on the Internet;http://www.worldfloraonline.org/taxon/wfo-0000903472. Accessed on: 08 Sep 2021'
52. William. M. (1868). Transactions of the Linnean Society of London 26(1): 138-141
53. Zamora, A. B. (1994). Review of Micropropagation Research on Bamboos. In Constraints to Production of Bamboos and Rattans. INBAR Technical Report No.5. International Network for Bamboo and Rattan, New Delhi: 45-100.
54. Zhou, M.Y., Zhang, Y.X., Haevermans, T. and Li, D.Z. (2017). Towards a complete generic-level plastid phylogeny of the paleotropical woody bamboos (Poaceae: Bambusoideae). Taxon 66: 539–553.

Chapter 3

Establishing Bambusetum for Identification, Conservation and Characterization of Valuable Genetic Wealth of Bamboo at RLBCAU, Jhansi

Pankaj Lavania, A K Pandey, M J Dobriyal, Pawan Kumar, R S Tomar and Garima Gupta

College of Horticulture and Forestry, RLBCAU, Jhansi

"Bambusetum" means a garden having a collection of bamboo plants. Bamboo is the regarded as the 'Emperor' among the grasses and commonly called poor man's timber. It is extraordinary & unique plant that is sustainable, productive and fastest growing plant in the world. It belongs to family Poaceae and sub family Bambusoideae distributed in humid tropical, sub tropical and temperate region of the world. "The Green Gold" of the 21st century is available at much lower price compared to wood and is as strong as strongest wood. It has new applications as an alternative source of depleting and costly wood resources (Nirmala *et al.*, 2017). The important gerera of bamboos are *Arundinasia*, *Bambusa*, *Cephalostachyum*, *Dendracalamus*, *Guadua*, *Gigantochloa*, *Melocanna*, *Ochlandra* etc. (Bahadur and Jain, 1981). There are approximately 1500 species under 87 genera of bamboo worldwide (Ohrnberger, 1999). India is the second richest country in bamboo genetic resources, after China. India is the rich source of genetic diversity of bamboo with 136 species of bamboo in 23 genera spread (natural & planted) over an around 11.4 million ha in 28 states and union territories, which constitute 16.7 percent of total forest area in the country (Nirmala *et al*,. 2012). The Western Ghats harbour 23 taxa belonging to 8 genera, of which 9 species are considered to be rare or threaten (Goyal *et al.*, 2017).Living collections of plants maintained in a botanic garden attract and excite human minds. They provide botanical, environmental and ecological education and facilitate sustainable utilization of plant genetic resources for human welfare (Sutherland *et al.*, 1999) Most of all, they help in conservation of plants for future options. Thus, botanic gardens across the world are intended main1y to conserve the gene pool of plant diversity and to tap this reservoir for the benefit of all (Sutherland *et al*., 1999)

Historical background

Bambusetum may form part of a botanic garden or an arboretum. It is an important feature of a modern botanic garden. It is an area, small or large, where a living collection of bamboos is kept for display, education, conservation and related studies (Wong, 2004). World's largest living bamboo collections are in China where there are more than 20 botanic gardens and bambuseta such as Anji Bamboo Botanic Garden, Hanzhon Botanic Garden, Hainan Bamboo Botanic Garden, Hunan Botanic Garden and Xishuangbannna Botanic Garden each holding over 100 species. Of these, Anji Bamboo Botanic Garden and Hunan Botanic Garden together harbour more than 300 species of barnboos (Fu Maoyi, 1999).

In India, the first known bambusetum was at the Acharya Jagadish Chandra Bose Indian Botanic Garden (AJCBIBG), formerly well-known as **Indian Botanic Garden,** established in 1787 in Howrah, West Bengal. Roxburgh (1814) reported the existence of seven bamboo species at the time of his assuming charge as the first superintendent of the Garden in 1794. The Forest Research Institute (FRI) in Dehra Dun, Uttarakhand is the pioneer institution in bamboo research, where an exceptional barnboo collection is maintained (Bennet &Gaur, 1990 a&b; Biswas, 1999). Many bambuseta were established in India during 1979 - 1989.The one at Van Vigyan Kendra (VVK), Chessa, Arunachal Pradesh was established in 1981 with a live collection of 35 species (Beniw al & Haridasan, 1988). Bambuseta at AJCBIBG, FRI and VVK, all located in th e North-western and Eastern region of India, together hold 68 species, of which 35 are native (Biswas, 1999). Kerala harbours two major bambuseta, one at Kerala Forest Research Institute (KFRI), Peechi in Tluissur district and the other at JNTBGRI, Palode in Thiruvananthapuram district. The KFRI Bambusetum started in 1982holds 63 species at two centers, 55 at Velupadam in Thrissur and 8 at Devikulam in Munnar (Surendran *et al.,* 1991; KFRI, 2005). Started in 1987, the JNTBGRJ Bambusetum harbours 68 species (Koshy, 2010). Live collections are also maintained at centers like Rain forest Research Institute (RFRI), Jorhat, Assam (34 species), Arunachal Pradesh Centre Bamboorium at Basar, West Siang district (31 species); Manipur University, Imphal (22 species), Botanical Garden of Punjab University, Chandigarh (20 species); Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, Tamil Nadu (26 species), and Kerala Forest Department at Begur, Wayanad 12 species (Sharma,1997;Subramanian, 1998 and Singh, 2009).

Knowing the correct identity of a plant is basic to the understanding of the plant's characteristics and uses. In forestry, identification is of fundamental importance in vegetation analysis, inventory of existing stands of trees and other plants, management of protected areas, biodiversity assessment, pest and disease management, food chain studies and many more. This is the reason why a course in dendrology or plant taxonomy is always included in the baccalaureate curricular programs of forestry colleges throughout the world. In several other fields, plant identification is likewise given much importance. In the area of herbal medicine, for instance, experts agree that identification is of crucial importance because human lives can be seriously endangered if the wrong species or variety is used. Similar consequences may also occur when incorrectly identified plants are used for food or as livestock feeds. The development of a vegetative key for the identification of bamboos would be of great help to the following: 1) bamboo scientists who conduct studies on the propagation, ecological and physiological requirements, culture, properties and utilization of different species of bamboo; 2) instructors of botany subjects; 3) private individuals engaged in the production of planting stocks of different species whether for plantation development or for landscaping purposes; and 4) foresters engaged in the development and management of bambuseta, botanical gardens, theme parks and plantations. The key for identification is based entirely on vegetative characters for one important reason - most species of bamboo do not produce flowers annually. In fact, flowering occurs at irregular intervals and for some, the interval may be as long as 25 to more than a hundred years. On the other hand, vegetative characters can be determined almost throughout the year.

The RLBCAU-Bamboosetum was established during 2020-21. 20 different species of bamboos are present in the Bambusetum .The valuable information on clump development, Culm production and growth parameters like culm length, culm girth, etc. are being gathered, computed and analyzed for productivity of these valuable Bamboos. Effect of management practices like weeding, soil working, selective cutting etc. on the production potential of each of these species is being closely monitored.

AIM

- The RLBCAU-Bamboosetum aims to have an exhaustive collection of Sympodial bamboos that can be grown in a typical agro-climatic zone and to gather valuable scientific information on bamboo growth in state.
- The Bamboosetum also serves as genetic resource for future crop improvement programme and for forest managers and farmers.
- Identification and multiplication of suitable planting material of bamboo species for Bundelkhand region.
- Assessment the growth behaviour of different bamboo species in given same site.
- It helps to the students in identification of different bamboo species, use as instructional block.
- Develop the best nursery technique & plantation technology, helpful for farmer and industrialist.
- Reclaimation of wasteland through bamboo plantation.
- To promote the bamboo based small scale industries.

Key for the identification of different bamboo genera

A. Member species with sympodial, clump-forming type of rhizome. All species with thorns **..... Guadua**

B. Some member species with thorns; back of culm sheaths with dark brown hairs or glabrous; culm sheath blades are erect; culm sheath auricles are distinct, rounded with bristles **..... Bambusa**

C. Member species without thorns, very big in height and diameter, young culms are covered with light to dark brown, velvety to rough hairs

D. Culm sheath auricles are thick, young culms of member species are covered with light to dark brown velvety hairs, node is prominent with aerial roots ..... **Dendrocalamus**

D. Culm sheath auricles are low, firm, distinct, rim-like or small and inconspicuous

E. Culm sheath auricles are low, firm, rim-like; back of culm sheath has dark hairs; young culms of member species are covered with light to dark brown rough hairs; node is not prominent ..... **Gigantochloa**

E. Culm sheath auricles are small or inconspicuous, leaf blade is glabrous, back of culm sheaths has short appressed light hairs ..... **Thyrsostachys**

C. Member species are medium to small in size; thin to thick walled culms, green, with or without purplish to brown lines or covered with yellowish stiff hairs; have many branches of unequal sizes; leaves are big and wide to very narrow

F. Member species are medium in size; thin-walled, young culms are green, purplish to brownish, especially on the basal portion; branches many of unequal sizes ...... **Nastus**

F. Member species are medium to small in size; thin to thick walled; young culms are green, covered with whitish waxy powder or yellowish stiff hairs; branches many of unequal sizes; leaves are big and wide or very narrow

G. Member species are medium in size; thin to thick-walled; young culms are green, covered with whitish waxy powder or yellowish stiff hairs; branches many of unequal sizes; leaves are green, big and wide to long and narrow with striations

H. Member species are medium in size, thin to thick walled, green, covered with whitish waxy powder or yellowish stiff hairs; branches many of unequal sizes; leaves are green and medium sized

I. Culm sheaths have 1 or 2 transverse corrugations at the top portion, culm sheath blade is erect, culms are loose ..... **Melocanna**

I. Culm sheaths do not have corrugations, culm sheath blades are erect or reflexed, culm blades are erect or reflexed, culms are densely tufted ..... **Schizostachyum**

H. Member species are medium in size, thick-walled, culm sheath and leaves have striations ..... **Sasa**

G. Member species are generally small, culms are green, with or without striations; culm sheath with or without striations; leaves are small or big with or without striations; leaf sheath is light green to pinkish with light brown bristles

J. Culms are green; leaves are small to very narrow, green or with striations; leaf sheaths are light green to pinkish

K. Culms are green; leaves are green, linear or with striations; leaf sheath is light green with light brown bristles ..... **Arundinaria**

K. Culms are green, leaves are green and very narrow, leaf sheath is pinkish ..... **Otatea**

J. Culms have white striations, culm sheath has striations, leaves are big with prominent striations ... **Hibanobambusa**

A. Member species with monopodial, non-clump-forming or running type of rhizome L. Internodes flattened or grooved at one side, in line with the branch complement; branches two of unequal sizes ..... **Phyllostachys**

L. Internodes not flattened, branches more than one, some thicker than the culms M. Branches 4-8, culm sheath persistent and longer than the internodes; leaves linear lanceolate ..... **Pseudosasa**

M. Branches typically three; culm sheath deciduous, not longe than the internodes; leaves broadly lanceolate to lanceolate

N. Leaves 3-4, green, broadly lanceolate to lanceolate, pubescent beneath to glabrous on both sides

O. Leaves 3-4, green, broadly lanceolate, face different from part to part, pubescent beneath ..... **Shibataea**

O. Leaves 3-6, green, lanceolate, glabrous on both sides, sometimes have white striations ..... **Chimonobambusa**

N. Leaves 3-4, light green, rough on the surface and chartaceous, 13.5 - 23.5cm long, 4.5 - 5.6cm wide ..... **Indocalamus**

(Source- Handbook on Erect Bamboo Species Found in the Philippines, written by Roxas, C. A. 2012)

1-Genus *Bambusa* Schreber

The rhizomes of bamboo species under genus *Bambusa* are typically sympodial or clump-forming. Their culms are erect. The culm sheath blades erect or tardily reflexed, triangular to ovate lanceolate; and the auricles are typically lobe-like and bristly at the margins. The branch complement has a dominant primary branch, one to several secondary branches and branchlets form its base. The leaf blades are typically obtuse at the base.

Table (3.1). Species under the genus *Bambusa* and their identification

Bamboo genus and Species	Identification
BAMBUSA *Bambusa merillian*	• Culms with thorny branches especially at the basal portion. • Branches and branchlets at the base are only partially thorny or sometimes without thorns
Bambusa blumeana	• Culms with thorny branches especially at the basal portion. • Branches and branchlets at the base are densely set with more or less strong recurved thorns
Bambusa tuldoide	• Culms without thorny branches • Culm internodes are inflated near the base or nodes and constricted. • Culm sheath is glabrous to slightly hairy at the back, culm sheath is only up to 5mm high
Bambusa vulgaris	• Culms without thorny branches • Culm internodes are inflated near the base or nodes and constricted. • Culm sheaths are thickly hairy at the back, culm sheath auricle is larger up to 2cm high.
Bambusa multiplex f. alphonso- karri	• Culm internodes are more or less cylindrical Culms have diameter up to 2cm • Culms are yellowish with green stripes to burgundy red when exposed to sunlight.
Bambusa multiple	• Culms are generally green, occasionally with narrow white stripes. • Culms are green, sometimes white-waxy; leaves are dark green.
Bambusa multiplex f. variegata	• Culms are generally green, occasionally with narrow white stripes . • Culms are pale green; leaves are pale green with white striped striations
Bambusa vulgaris var. striata	• Culms have diameter more than 2cm Culms are yellow with unequal width of green stripes
Bambusa maculata	• Culms are generally green, occasionally with narrow yellow stripes when young and glabrous, purplish to black with dark-brown spots when old Culms are green with yellow stripes and turn purple to black or dark brown spots appear when it matures Culms are green with yellow stripes and dark brown spots on mature ones
Bambusa lako	• Culms are green with yellow striations, there are no brown spots, becomes glabrous when old and turns purplish to black Culms are green, young ones have yellow stripes and turn

	purple to black when old
Bambusa dolichomerithalla	• Culms are green without any yellow stripe; culm sheath is glabrous or with whitish to dark brown hairs; • sheath blade is erect, corrugated, linear to narrowly triangular to linearlanceolate to broadly ovate lanceolate • Culm sheath is glabrous; sheath blade is triangular and somewhat corrugated; leaves are linear lanceolate.
Bambusa atra	• Culm sheath has whitish to dark brown hairs; sheath blade is narrowly triangular to broadly ovate to oblong lanceolate; leaves are linear lanceolate to lanceolate. • Culm sheath has whitish hairs at the back, sheath blade is broadly ovate lanceolate; leaves are linear-lanceolate to oblong lanceolate
Bambusa vulgaris	• Culm sheath has whitish to dark brown hairs; sheath blade is narrowly triangular to broadly ovate to oblong lanceolate; leaves are linear lanceolate to lanceolate. • Culm sheaths have dark brown hairs at the back; sheath blade is narrowly triangular; leaves are linear-lanceolate

2-- Genus *Dendrocalamus* Nees

Rhizomes under this genus are sympodial or clump-forming. Culm sheath blades are either erect or variously at angle with the axis. The auricles are either lobe-like or bristly on the margin, low or distinct. There is a branch complement at the middle portion of the culm with a dominant primary branch and one to several secondary branches with usually smaller branchlets coming from its bases.

Table (3.2). Species under the genus *Dendrocalamus* and their identification

Bamboo genus and Species	Identification
Dendrocalamus strictus	• Culm diameter at breast height is generally below 10cm. • Culm sheath blade is erect, abaxial side is slightly hairy towards the top, leaf blade small 10-17cm long and 1.5-2.5cm wide. • Culm wall is solid to almost solid near the base
Dendrocalamus brandisii	• Culm sheath blade is spreading to reflexed, without hairs on the abaxial side, leaf blades are long, 15-50cm long and 2.5-7.5cm wide. • Culm sheath is usually densely hairy with brownish hairs outside toward the upper half when young; the sheath blade is usually shorter than half of the culm sheath length
Dendrocalamus membranaceus	• Culm sheath is entirely densely hairy with brownish hairs outside; the sheath blade is usually longer than half of the culm sheath length
Dendrocalamus asper	• Culm diameter at breast height is usually over 10cm. Internodes at the basal portion are thickly covered with brown velvety hairs; the nodes are raised and usually densely set with aerial roots
Dendrocalamus latiflorus	• Internodes at the basal portion are green, sometimes thickly white-waxy when young; the nodes are thinly set with aerial roots

3. Genus *GUADUA* Kunth

The rhizomes of the species under the genus are sympodial or clump-forming. The culms are erect, internodes are cylindrical or sometimes deeply sulcate above the point of insertion of a bud or a branch complement and hollow. Branch buds at culm nodes are typically solitary. Branches at the lowest nodes of the culms are typically thorny in all species. Currently more or less, there are 27 species confined in the New World (i.e., from Mexico to all countries of the Central and South America, except Chile).

Table (3.3). Species under the genus *Gaudua* and their identification

Bam *Bamboo genus* and Spec species	**Identification**
Gaudua angustifolia	• Culms are close together forming a clump. • Culms are erect, broadly arching above reaching 30m high. Internodes are open, 2-9cm in diameter, the wall is 0.4-2.5cm wide at the upper and inner internodes. • Culm sheath is densely hairy outside; the blade is roughly triangular; the auricles are inconspicuous. • Branches are usually solitary and spiny, rarely three with one dominant at the center.

4. Genus Phyllostachys Siebold & Zuccarini

Phyllostachys is a genus native to China and Japan. It grows well in cool climates. The rhizomes of the species under this genus are monopodial or running. Culms are erect, widely spread, arising laterally from the slender, cylindrical, typically hollow rhizomes. Internodes are flattened or grooved at one side in line with the branch complement. There are usually two branches of unequal size. Culm sheath is papery to subcoriaceous and spotted outside.

Table (3.4). Species under the genus Phyllostachys and their identification

Bamboo genus and Spe species	**Identification**
Phyllostachys pubescens	• Culm internodes are covered with velvety white hairs when young
Phyllostachys nigra	• Culm internodes are different from the one described above. Culms are yellow with or without green striations on the hollow portion; the auricle has dark brown to purplish bristles. Culm internodes are dark green to purplish, glabrous and do not have velvety hairs
Phyllostachys aureosulcata f. spectabilis	• Culms are yellow with or without green striations; the auricle has purplish to dark brown bristles Culms are yellow with green striations; the auricle has purplish bristles.
Phyllostachys vivax f. aureocalis	• Culms are yellow without green striations; the auricle has dark brown bristles
Phyllostachys praeco	• Culms are green; culm sheath is yellow green or yellowish with or without dark brown spots or covered with white hairs; the auricle has dark brown to purplish bristles. • Culms are green; culm sheath is yellow green; sheath blade is

	erect or reflexed, glabrous or covered with white hairs Culms are green; culm sheath is yellow green; sheath blade is erect and glabrous
Phyllostachys aurea	• Culm is green; culm sheath is yellow green covered with white hairs; sheath blade is reflexed and glabrous .....
Phyllostachys bambusoide	• Culms are green; culm sheath is yellowish to brownish with dark brown spots; and the auricle has dark brown to purplish bristles Culms are green; culm sheath is yellowish with dark brown spots; the auricle has dark brown bristles
Phyllostachys dulcis	• Culms are green; culm sheath is brownish with dark brown spots; the auricle has purplish bristles .....

5. Genus Pseudosasa Makino

The genus Pseudosasa has a monopodial type of rhizome. They are found spontaneously growing on remote islands of the South of Japan and China. One branch can be found on one node on the upper part of the culm. The node is not prominent. The culm sheaths are persistent and longer than the internodes

6. Genus *Sasa* Makino & Shibata

The rhizome of the species under the genus is sympodial or clump-forming. The culms are erect, dwarf but those on the valleys are taller, 20cm to 4m high; and its leaf has cross veins. Culm sheath is persistent. Auricles and ligules are conspicuous and well-developed. It is widely distributed on the main island of the Japanese archipelago.

Table (3.5). Species under the genus *Sasa* and their identification

BAMBOO SPECIES	Identification
Sasa kurilensis f. Kikan-shiroakebono	• Culm branches and culm sheath are yellow green to yellowish in color. Leaves are small, milky white in color especially when starting to open due to long and short white striations.
Sasa kurilensis f. Takara	• Culms, branches and culm sheaths are green in color with whitish striation. Leaves are big, green with wider whitish striations. The yellow green background in the leaves turns into white.

7. Genus *Schizostachyum* Nees

The rhizome of the species under this genus is sympodial or clump-forming. The culms are erect. Internodes have pale appressed hairs all over and a white-waxy zone just below the node. Culm sheaths have blades that are either erect, spreading or reflexed. Auricles are lobe to rim-like with bristles on the margin. There is a branch complement at the middle part of the culm with a cluster of slender, sub-equal branches. There are about 45-50 species under this genus. It came from South China through Southeast Asia to the Pacific islands.

Table (3.6). Species under the genus *Schizostachyum* Nees and their identification

BAMBOO SPECIES	Identification
Schizostachyum lima	• Culm sheath blades are erect at first then reflexed, linear lanceolate Culm diameter is 2-4cm, the wall is more or less 2mm thick.

Schizostachyum lumampao	• Culm diameter is 4-8cm, the culm wall is 4-10mm thick
Schizostachyum brachycladum (yellow form)	• Culm sheath blades are stiffly erect, tardily reflexed, narrow Culm internodes are yellow orange with green striations

List of Selected bamboo species in Bambusetum at RLBCAU, Jhansi

At RLBCAU, Jhansi in ist phase of establishment of Babusetum following species have been planted (Table 3.7)

Table (3.7). List of the bamboo species in Bambusetum at RLBCAU, Jhansi

S.No	Bamboo species	S.No	Bamboo species
1	*Bambusa bamboos,*	12	Dendrocalamus giganteus,
2	*Bambusa balcooa Roxb*	13	*Dendrocalamus hamiltonii,*
3	*Bambusa valgaris (Green)*	14.	Dendrocalamus longispathus,
4	*Bambusa valgaris (wamin)*	15.	Dendrocalamus strictus,
5	*Bambusa valgaris (yellow)*	16	*Guadua angustifolia,*
6	*Bambusa nutans,*	17	*Oxytenanthera parviflora,*
7	*Bambusa pseudopallida.*	18	*Oxytenanthera stocksii ,*
8	Bambusa tulda	19	*Phyllostachys nigra*
9	*Bambusa cacharensis,*	20	*Pseudosasa japonica,*
10	*Dendrocalamus asper*	21	*Sasa fortune*
11	*Dendrocalamus brandisii*	22	*Schizostachyum dulloa*

In the year 2020-21 study was conducted on Establishment and Growth performance of different bamboo species was recorded. The height of *Dendrocalamus strictus, Bambusa valgaris green* and *Bambusa valgaris* yellow were recorded 145cm, 129.17 cm and 120.83 cm respectively and least growth in height (46.67 cm) was found in *Bambusa vulgaris-wamin.*

CONSERVATION OF BAMBOO GERMPLASM

Conservation of bamboos assumes great importance on account of their irregular flowering and seeding nature. The strategy for conservation of rare and threatened bamboo species can be broadly classified in two ways:

(*1) In-situ conservation :* involves prevention measures against the exploitation of edible shoots, culm extraction of rare species, fencing of area in seeding year, restriction on clear felling and declaration of bamboo sanctuary for lesser known species. This method helps in preserving of inter-specific and intra-specific genetic variability. Therefore, areas rich in species diversity need to be marked for taking conservation measures of economically important, rare and vulnerable species

(2*) Ex-situ* conservation: this involves seed banks, clone banks, bamboo gardens and cryopreservation. Several botanical gardens and arboreta in the tropics are maintaining rich collection of bamboos for botanical conservation and study. Fine collections of bamboos exist at Royal Botanic Garden, Paradeniya (Sri Lanka), Botanic Garden, Bogor (Indonosia), Peching Botanic Garden, Hopei (China), Botanic Garden of Tokyo (Japan), Bangladesh

Forest Research Institute, Chittagong and a number of botanic gardens in India. The Forest Research Institute, Dehradun has the good collection of over 32 species. Similarly, the establishment of a bambusetum at State Forest Research Institute, Itanagar (Van Vigyan Kendra, Chessa, Arunachal Pradesh) has given the leading role in bamboo research with a collection of over 50 species. Indian Botanic Garden, Calcutta; Tropical Botanic Garden, Trivandrum and Kerala Forest Research Institute, Peechi are maintaining good exotic and indigenous collections. A large collection of about 60 species of bamboos has been established at Regional Plant Resource Centre, Bhubaneswar. Dr. Y.S. Parmar University of Horticulture and Forestry, Solan and its Regional Research Stations, have been able to introduce over 30 species in bambusetum. In addition to this there are many institutes and organizations including the state forest departments in India viz., constituent institutes and centres of Indian Council of Forestry Research and Education (ICFRE), Dehradun; research wings of the different States and some universities like Tripura University, Agartala which are maintaining inter and intra species collection of bamboos as per the regional priority so that they can conserve the resources and promote their use in that region. The intra-species cohorts of bamboos raised from the seeds of clumps which have flowered at different periods by maintaining a proper record will serve as useful gene pool for planting those areas which will flower gregariously in the days to come

Bamboo germplasm in Bambusetum at RLBCAU, Jhansi

Bambusetum at RLBCAU, Jhansi

***Bambusa vulgaris* –yellow**

***Bambusa vulgaris* -green**

Dendrocalamus strictus Ness

Dendrocalamus hamiltonii

Bambusa pallida Munro

Bambusa nutans

Bambusa vulgaris (Wamin)

Bambusa vulgaris Var. vulgaris Schrad exWendle

***Bambusa vulgaris* (Green)**

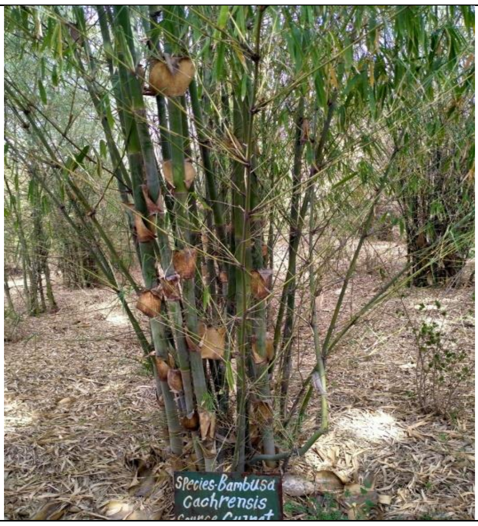
***Bambusa balcooa* Roxb.**

Bambusa balcooa

Bambusa nigra

Dendrocalamus brandisii

Dendrocalamus asper



Bambusa cachrensis

Bambusa tulda Roxb

Oxytenenthera stocksii

Pseudosasa japonica

Sunder koya

Bambusa Nutan

***Guadua angustifolia* Kunth**

Bambusa bambos

Conclusion

Living collections of plants maintained in a bambusetum attract and excite human minds. They provide botanical, environmental and ecological education and facilitate sustainable utilization of plant genetic resources for human welfare. Bamboos (Poaceae, Bambusoideae, Bambuseae), the fastest growing plants on earth and found as an important renewable resource of the tropics. They are used in manufacturing various household articles, pulp, paper and fabrics. Most bamboos flower once in lifetime after a prolonged period of vegetative phase ranging from 30 to 60 or up to 120 years. They complete their life cycle long after the retirement of the persons who planted them. This endorses the fact that the study of bamboos is a continuous process stretching over several generations. This continuity is possible only at R & D centers and botanic gardens where living collections of bamboos in bambusetum, arc scientifically maintained. Being giant and woody, bamboos do not lend themselves to represent in herbaria, especially rhizomes, culms and culm sheaths. In such cases living collections function as the best reference materials

The establishment of bambusetum, Germplasm bank and culm production activities at will be beneficial for students, farmer, forest department, Non govt. organization and also bamboo based industries in Bundelkhand will be benefited having the diverse bamboo species and their different hereditary lines along with records of their phonological process such as growth, flowering, fruiting, death and details on progenies. This chapter concern to be bambusetum history and an inventory of its collection (20 Species under 7 Genera) with the identification and conservation of Valuable Genetic Wealth of Bamboo in Bundelkhand.

References

1. Bahadur, K.N. and Jain, S. S. (1981). Rare bamboos of India. Ind. J.For.4(4):280-286
2. Beniwal, B.S and Haridarsan, K. (1988) Study on bamboos through establishment of Bambusetum in Arinachalpradesh. Indian Forester, 114:650-655.
3. Bennet, S. S. R. and Gaur, R. C. (1990a). Nomenclature of Burmese bamboo, *Melocanna humilis* Kurz. Indian Forester, 116: 648- 649.
4. Bennet, S. S. R. and Gaur, R. C. (1990b). Thirty Seven Bamboos Growing in India. Forest Research Institute, Dehra Dun:100p. Bisen, S.S.; Luxmi Chauhan; Rao, R.V. and Sharma, B.L. 1989. Epidermal features of the culm of Indian bamboo - Part 1. *Dendrocalamus*. Journal of Tropical Forestry, 5: 76-85
5. Biswas, S. A. S. (1999). Bamboo diversity and conservation in India,In A.N.RAO and V.R.RAO(ends) A conservation, Diversity, Ecogeography, Germplasm, Resource Utilization workshop,10-17 May 1998, Kunming and Xishuangbanna, Yunnan, Malaysia.
6. Goyal, A. K., Ghosh. P.K., Dubey . Kumar. Ajay and Sen, A. (2012) Inventorying bamboo biodiversity of North Bengal: A Case Study, Int. J. Fundamental Applied Sci. 2012, 1(1) , 5-8
7. KFRI. (2005) Three decades of research in KFRI: new technologies and information,pp.220-221.Kerala research Institute, Peerchi
8. Koshy.K.C(2010). Bamboos at TBGRI, Tropical Botanical garden and research institute,Palode, Thiruvananthapuram, Kerala
9. Mauyi, F. U. (1999) Bamboo resource and Utilization in China. In: RAO, A conservation, Diversity, Ecogeography, Germplasm, Resource Utilization workshop,10-17 May 1998,Kunming and Xishuangbanna, Yunnan, Malaysia.
10. Nirala, D.P., Nirbhay, A. and Kumari. P. (2017). A review on distribution of bamboos. Life Sciences Leaflets , Online & Print Volume No. 92 , 70 to 78
11. Ohrnberger, D. (1999). The Bamboos of the World: Annotated Nomenclature and Literature of the species and the higher and lower Taxa. Elsevier, Amsterdam.
12. Roxas, C. A. (2012). Handbook on Erect Bamboo Species Found in the Philippines. Pub. Ecosystems Research and Development Bureau, Department of Environment and Natural Resources, College, Lagun,1-132
13. Roxburgh, W. (1814). Hortus Benghalensis or a catalogue of the plant in hororable east India campany Botanic Garden at Calcutta,Serampore.
14. Sharma, G.J.(1997).Survey, collection and utilization of bamboo resources.ENVIS.Bul5(1)7-8

15. Singh. O. (2009) Genetic improvement and conservation of bamboo in India. VIII. world Congress Procedings4:15-24.
16. Subramaniam, K.N. (1998) Bamboo genetics resource in India, Vevekanandan, K , A.N.Rao and V.R. Rao (eds)Bamboo and rattanGenetic resources in India.pp-33-61.IPGRI-APO,Serdang.Malaysia
17. Surendran,T., Chacko, K.C, Nair, N.G. and Muhammad, E. (1991). Establishment of a bamboosetum, KFRI Research Report 84 Forest Research Institute, Peechi.
18. Sutherland, Lucy A., Abraha,T.K., and Thomas, Jacob(1999). The Power for Change Botanic Gardens as Centres of Excellence in Education for Sustainability, Proceedings of the 4th International Congress On Education in Botanic Gardens, 8-12 November 1999 Hosted by the Tropical Botanic Garden and Research Institute, Thiruvananthapuram, Kerala, India.pub. Botanic Gardens Conservation International Descanso House, 199 Kew Road Richmond, Surrey TW9 3BW U.K.
19. Tripathi, S.K and Singh, K.P. (1994). Productivity and nutrient cycling in recently harvested and mature bamboo savannas in the dry tropics. Journal of Applied ecology,31,109-124
20. Watt, George (1889) Dictionary of the economic products of India, 1:37
21. Wong, K.M.(2004). Bamboo- The Amazing Grass- A Guide to the diversity and study of bamboos in southeast Asia, International Plant Genetic Resources Institute (IPGRI) and University of Malaya, First edition:1-98

Chapter 4

Bamboo-Based Agroforestry for Enhancing Productivity and Sustainable Livelihoods

Garima Gupta, M.J. Dobriyal, Prabhat Tiwari and Pankaj Lavania
College of Horticulture and Forestry, RLBCAU, Jhansi

Bamboo is a major source of resilient, adaptable, and highly renewable natural resources. India is one of the richest country in bamboo population with about 130 species belong to 25 genera of the total 1250 species under 75 genera found in the world. Bamboo occurs almost ubiquitously in the country up to 3000m above MSL except in Kashmir. Over half of the bamboo species occur in Eastern India, viz., Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura and West Bengal. It occurs mostly in moist deciduous, semi-evergreen, tropical, subtropical and temperate areas of forest. The bamboo has several purposes, including fodder, pulp, timber, building work, charcoal, edible shoot, cottage, etc. These are known to be the fastest growing woody plants with a growth rate ranging from 30 – 100 cm per day in growing seasons. It can grow up to a maximum height of more than 36 m with a diameter of 1 – 30 cm. The increasing rate of tropical deforestation makes the search for alternative natural resources important. Bamboos offer enormous wood replacement potential. It's plethora of essential uses has led to the use of terms such as "Green Gold", "Poor Man's Timber", "Bamboo, Friend of The People" and " Cradle to Coffin Timber" (Seethalakshmi and Kumar 1998; Tewari *et al*., 2015; Akwada and Akinlabi, 2016). Bamboos have socio-economic and ecological value and their management can provide benefits on a local, national and global level through livelihood, economic and environmental security for many millions of rural people. Due to rapid biomass accumulation and effective fixation of solar energy and carbon dioxide, the carbon sequestration ability of bamboo is very high. According to an estimate, one quarter of the biomass in tropical regions and one-fifth in subtropical regions comes from bamboo. At present we are able to utilize only 10% of our capacity whereas we have 30% of the world's resources related to bamboo production. We are importing half of our bamboo requirement from other countries especially China.

Bundelkhand falls under semi arid climate and it is a hot spot of water scarcity and frequent crop failure. In Bundelkhand, under network project on bamboo (National Bamboo Mission) introduced *Bambusa vulgaris*, *B. tulda* and *D. strictus* and evaluated for its growth and productivity under agroforestry system. Results shows under such circumstances, bamboo the green gold has shown ray of hope in the semi-arid conditions of Bundelkhand. It starts yielding commercial culms after 4–5 years of establishment, which can be harvested annually till flowering occurs (35–50 years). Bamboo can be used in farming systems by farmers of Bundelkhand to create sources of income, restore waste lands and fight the climate crisis (CAFRI, 2020).

While the majority of bamboo resources are natural, more emphasis has been dedicated to the establishment of planted bamboo in recent years. Keeping in consideration, the importance of bamboo, in 2017 the Government of India has removed bamboo from definition of forest to stimulate bamboo production, so that bamboo is no longer a tree. After this amendment harvesters do not have legal intervention in extraction of bamboo, and can be harvested and sold easily. So now there is a significant potential of domestic bamboo market in India at competitive prices. In 2006-07 the Government of India established a Centrally Sponsored National Bamboo Mission in India to promote bamboo in the country. To meet current and future demand, bamboo expansion in non-forestry through agroforestry will be a sustainable way of expanding the bamboo region and of improving the livelihoods of small and marginal farmers. The Cabinet Committee on Economic Affairs (CCEA), on 25-04-2018, restructured National Bamboo Mission (https://nbm.nic.in/Home). The Mission plans to foster holistic growth in the bamboo industry by adopting a regionally differentiated strategic approach and to expand the area under bamboo farming and marketing.

2. Agroforestry

Trees were always considered as an integral part of the Indian culture which is supported extensively by ancient writings and historical records. The loss of forests and cutting of trees was widely believed to cause famine circumstances, whilst the planting and preservation of trees were seen to be noble gestures (Prasad, 2003). Indeed, so much has been written in our ancient literature that people planted tree in ancient times on their own farm. In recent centuries, forests were gradually exploited to meet growing need for fuel, fodder and timber because of a burgeoning population and widespread imbalance between demand and supply. To deal with this enormous strain on existing forests we need to consider alternate measures to supply the growing demand for forest products, the manufacturing of such products must also take place outside the boundaries of forest. Consequently, the concept of the utilization of land with multifunctional trees has become extremely significant in the context of ever-increasing demand. In such scenario, it is important to adopt and promote agroforestry, which is a multifunctional land-use system. It is an interface between agriculture and forestry and covers mixed practices on land use.

The International Centre for Research in Agroforestry (ICRAF, 1997) defines agroforestry as a dynamic, ecologically based, natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for all land users at all levels. National Agriculture Policy, (2000) has clearly recommended that agroforestry should be promoted to enhance the income and livelihood security of Indian farmers. Planning Commission, GOI, 2001 for promoting agro forestry, has recommended that the commercial agroforestry should be used in irrigated districts of the country instead of adopting a common strategy for the country as a whole. A unique strategy for environmental safety, sustainable agriculture and food accessibility should be devised for rainfed areas. *Acacia nilotica*, species of bamboo, *Casuarina equisetifolia*, species of Eucalyptus, *Populus* *deltoides* and *Prosopis cineraria* may include suitable for commercial agroforestry for diverse climatic, edaphic or agricultural situations.

In Indian Agricultural systems there are challenges, such as climate change characterized by a high incidence of extreme events including frequent drought with increasing frequencies of high drought, longer-term dry spells, changing growing-duration, temporal and geographical variation in rainfall and temperature stress. Agricultural systems are particularly vulnerable to rainfed agriculture in the semi-arid tropics because of numerous sorts of climate shocks and socio-economic pressures. In such circumstances integrated agriculture and agro-forestry initiatives will leverage and enhance desirable development by increasing their capacity to handle the inherent drought conditions and so reduce their negative consequences on crop yields and ultimately on livelihood. Agroforestry in underdeveloped countries has garnered substantial attention to tackle numerous difficulties and give a range of economic, environmental and economic benefits in particular since the UN Framework Convention on Climate Change Protocol on Kyoto (UNFCCC).

Agroforests can play a beneficial role in reducing vulnerability, improving farm resilience and protecting households against harsh climatic conditions (Dhyani 2014). Projection of decreased area under agriculture and increased demand for food grain and fuel (2 times), fodder (1.5 times) and timber production (3 times) is further increasing the importance of agroforestry (Dhyani and Handa, 2014). Agroforestry meets almost half of the demand of fuelwood, 65 % small timber, 70–80 % wood for plywood, 60 % raw material for paper pulp and 9–11 % green fodder requirement of livestock, in addition to its environmental benefits (NRCAF 2013). Agroforestry provides a variety of ecosystem services such as food, fuelwood, fodder, timber, poles, and so on (provisioning), hydrological benefits and microclimatic alterations (regulatory), and nutrient cycling (Tengnas 1994; Leakey 1998; Unofia *et al.* 2012). At present in India, agroforestry is practiced between 17.45 million ha (Rizvi *et al*,. 2014) to 25.32 million ha. (Dhyani *et al*., 2013). Rizvi *et. al*. (2014) estimated the area under agroforestry through using the geo-spatial technologies and ranked Uttar Pradesh (1.86 m ha), Maharashtra (1.61 m ha) and Rajasthan (1.55 m ha) as first, second and third, respectively.

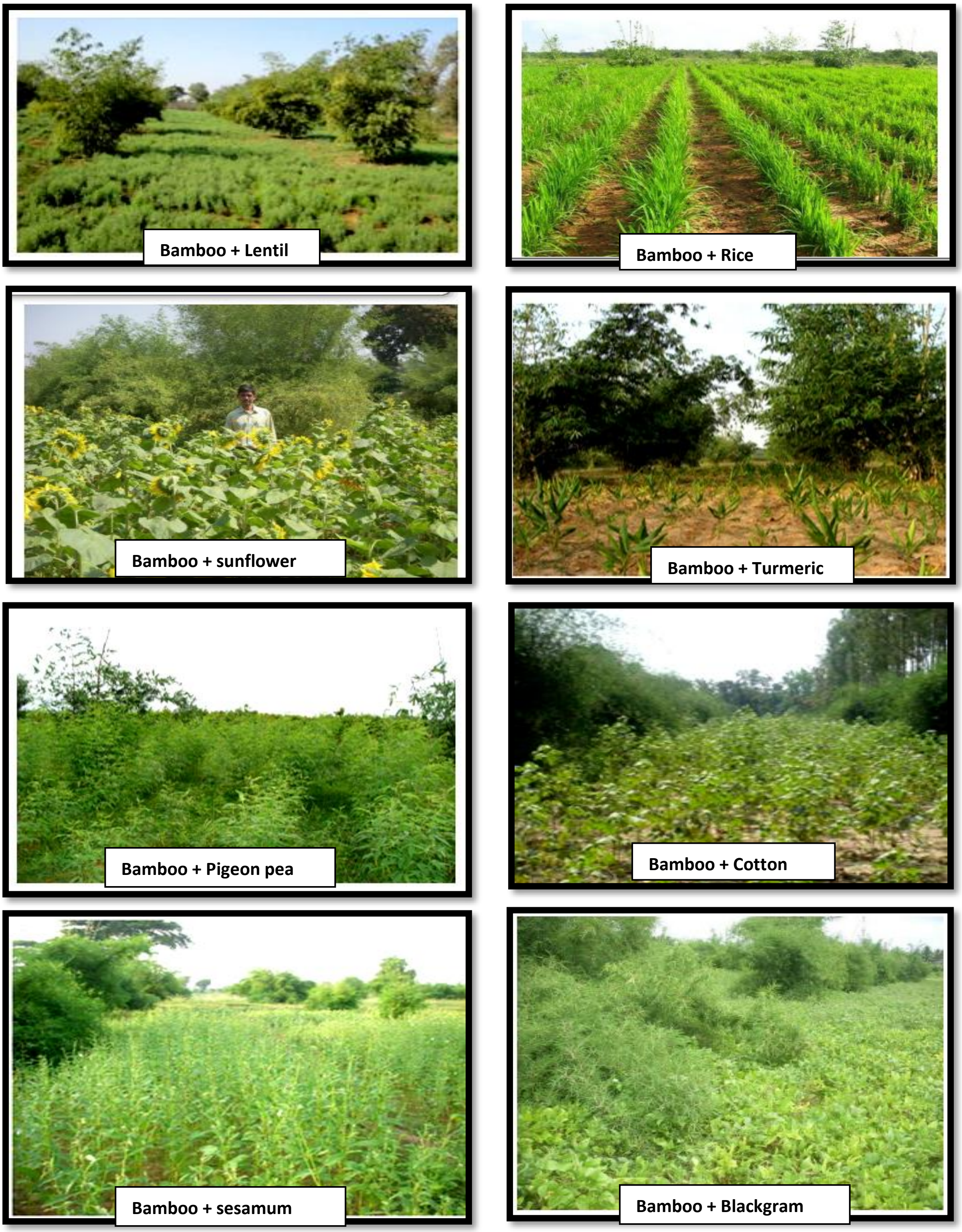
Bundelkhand region of Uttar Pradesh is prone to drought and is the hotspot of water scarcity, land degradation, poor permanent vegetal cover and miserable socio-economic status. Farmers are moving away from agriculture due to lower remuneration and a significant risk of weather variations. Agroforestry is acknowledged as a land use choice in the drought-prone Bundelkhand region for the sustainability of the farming sector as they provide food, forage, fuel and wood. They control land and water deterioration by means of increased carbon sequestration and fight against climate change.

Agroforestry systems in Bundelkhand Aonla, Bael, Ber, Gvava are relatively widespread Agrihorticultural system. In agrisilviculture system Eucalyptus, Babul, Teak, Bamboo based Agroforestry system is prominent in the region. Silvipasture system refers to rehabilitation of non arable lands by planting grasses and forest trees together. Such trees could be fodder or timber trees. Subabul, Ber, Babul, Bamboo alongside forage grasses have been found very successful in Bundelkhand Region. Other Agroforestry systems may include fish + acquatic plants + trees on surroundings. These solutions for agriculture provide food, fodder, fuel and timber for the sustainable use of farmers in Bundelkhand regions. Minor forest products are a source of nourishment from these plants. They promote alternative livelihood systems (gum & raisin, honey, basket, mat broom making industry), source of nutrients and provide employment. (Tripathi, 2015).

3. Potential of Bamboo Based Agro forestry for enhancing produtivity

Biomass production by bamboos, there is a wide variation depending on species and region of cultivation. Even within the same region, production potential varies due to clump densities, mode of plantation and silvicultural management adopted. The different agroforestry models with bamboo as a potential forestry component that has been reported in the Indian context reported by Nath *et al.* (2009). Agroforestry based on bamboo showing that the safest choice among agroforestry species is made up of indigenous vegetation with an experience of adaptability to regional regimes of precipitation. Bamboo is also benefited by a share of resources such as irrigation, abundance of fertiliser, and weeding with intercrops under the agroforestry, resulting in a considerably better quantity and quality of bamboos than monculture and unmanaged plantations.

In agroforestry, the scope for bamboo is particularly vast due to variable weather conditions and increased labor costs. Bamboo, when managed appropriately, may be cultivated under the agrislviculture, silvipastoral, agrisilvipastoral and agrisilvi systems. If bamboo produced from offsets, bamboo takes four to five years for the first crop to be grown, far earlier than other wood species. The first harvest is acquired after 7 years when grown from the seedling. At first three to four years can be used sustainably in order to raise intercrops and increase the farmers' sustainability and profitability. In India, bamboo plantations are normally raised at spacing of 6 X 6 m to meet the increasing demand for bamboo products. Balaji (1991) reported that the scope of bamboo in agroforestry is very wide because of the uncertain climatic condition and increasing cost of labour involved in agriculture these days In order to restore degraded agricultural lands in central India, Behari (2001) developed successful seven agroforestry models with three bamboos (B. bamboos, B. nutans and D. strictus). The inter crops are: Soybean Glycine max), Niger (Guizotia abyssinica), Moong (*Phaseolus aureus*), Wheat (*Triticum aestivum*), Urad (*Phaseolus mungo*), Pigeon pea (*Cajanas cajan*) and Mustard (*Brassica campestris*). Shanmughavel and Francis (2001 & 2002) recommended intercropping of Pigeon pea, Soybean and Turmeric in bamboo (*B. bambos*) plantations based on comparative growth and yield. The land equivalent value (LEV) i.e., the land area in sole system required to produce the same yield as in one ha of intercropping, for bamboo-turmeric system is 1.2. However, pigeon pea and soybean provided most benefits in terms of productivity (Shanmughavel and Francis, 2001). Intercropping ginger under three fertilized edible clump forming bamboos was beneficial for



Bamboo with different inter-copping (Source: NRCAF, 2014)

both the components under degraded soil condition of N E India (Jha and Lalnunmawia, 2004). The feasibility of bamboo (*D. brandisii*) in abandoned paddy fields in Coorg, Karnataka have shown that bamboo at 6m x 6m spacing intercropped with ginger had the highest NPV (net present value) and LEV (Land expectation value). This may be attributed to low input costs associated with bamboo farming and higher market value of the produce over a longer period (Viswanath, Dhanya, and Rathore, 2007). Likewise, since bamboo forests are an integral component of most of the tropical forest ecosystems and adaptive to adverse site conditions, they can be planted in degraded tropical forests (Sohel et al. 2015; Ling et al. 2016; Qin et al. 2017).

Gangopadhyay (2003) surveyed the home garden in 13 sample villages in five districts of MP in India and reported that about 15.13 percent of families were having *D. strictus* on their fields. In less moist to semi drier parts of Bihar, U.P., M.P. and Maharastra, *B. bamboos* and *D. strictus* are commonly cultivated along with *B. balcooa*, *B.tulda* and *B. nutans*. They can be grown on marginal land and regenerate annually through an extensive rhizome system, and they lend themselves to soil stabilization, reducing erosion, increasing slope stability, and contributing significantly to the restoration of degraded lands, which are essential to combat desertification (Zhou et al. 2011; Ling et al. 2016). Bamboos are adaptive to adverse site conditions and can be planted in degraded tropical forests (Sohel et al. 2015; Qin et al. 2017). Thus, in the face of global climate change, deep-rooted poverty, fast degradation of land resources, and other environmental hazards, bamboo-based agroforestry is indeed a viable option for enhancing productivity, resource conservation, and sustainability As literature sources indicate (Viswanath et al. 2007; Nath and Das 2008; Banerjee et al. 2009; Kittur et al. 2016; Tangjang and Nair 2016), bamboo-based agroforestry has been widely practiced in Asia continent than other bamboo-growing parts of the world. Bamboo-based agroforestry systems have been integrated on farmlands, homesteads, degraded lands, and riparian filter (Tewari et al. 2015). Table(4.1) shows that some examples of greater B: C ratio (>1) under different agroforestry systems.

Table (4.1): Economy of Intercropping with Bamboo

Agroforestry System	Intercrop	Bamboo Species	Spacing	BCR	Reference
Silvipasture	Napier	*B. vulgaris*	5x5m	4.4	Puran et al. 2018
	Sudan	*B. vulgaris*	5x5m	2.6	
	Guinea	*B. vulgaris*	5x5m	3.74	
Agrisilviculture	Maize Cassava, Cowpea,	*B. balcooa*	5x5m	1.2 1.2 1.24	Akoto et al. 2020
	Sesamum indicum	*Dendrocalamus strictus*	10x10	3.1	Dev et al. 2017
	Sesamum indicum	*Dendrocalamus strictus*	10x12	2.59	Dev et al. 2017
	Sesamum indicum	*Dendrocalamus strictus*	10x10	2.6	Dev et al. 2017
	Sesamum indicum	*Dendrocalamus strictus*	10x12	2.7	Dev et al. 2017
	Pigeon pea	*B. balcooa*	9 ×9 m	1.81	Kumar et al. 2015

	turmeric and maize				
	Pigeon pea turmeric and maize	*B. vulgaris*	9 ×9 m	1.17	Kumar et al. 2015
	Pigeon pea turmeric and maize	*Dendrocalamus strictus*	9 ×9 m	1.09	Kumar et al. 2015
	chickpea	*Dendrocalamus strictus*	10x10	2.05	Ahlawat, et al., (2008)
	chickpea	*Dendrocalamus strictus*	10x12	2.86	
	Ginger	*Dendrocalamus brandisii*	6x6	3.10	Viswanath et al. 2007
	Ginger	*Dendrocalamus brandisii*	6x10m	2.71	
Agrisilvipasture (Home Garden)	Mixed cropping	*Bambusa bambos*	-	2.83	Krishnankutty (2004)

There have been reports on the attempts to cultivate agricultural crops in bamboo plantations. As Mailly *et al.* (1997) noted, the integration of bamboo on croplands is confirmed a suitable approach for increased productivity of food crops and non-food biomass in many parts of Asia. The agrisilviculture, silvipastoral, agri-silvipastoral, and agri-silvihorticultural system and bamboo in home gardens are some of the agroforestry models in which bamboos are grown (Nath and Das, 2008; Banerjee *et al*., 2009; Tewari *et al*., 2015).

Thus it could be seen that, there have been evidences of development of performing agroforestry models incorporating bamboo as a tree component across different parts of the country. These models could potentially address the issues of inclusive development, rural food security as well as building up the required resilience in the landscape based production systems in the context of the climate change (Kumar *et al*., 2014).

Potential of Bamboo Based Agro forestry for socio-economic benefits

Bamboo-based agroforestry can play an important role in enhancing productivity, sustainability, and resource conservation of developing countries in the tropics (Kittur et al. 2016). In agroforestry systems, the bamboos play important role in the livelihoods of rural people by providing employment, energy, nutritious foods, and a wide range of goods and also balancing ecosystems. Bamboo has played a leading role in human culture since time immemorial and contribute to subsistence across Asia, Latin America and Africa for people living in the tropical and subtropical region (Devi 2013). As Table 1 shows Bamboo offers a wide range of advantages and can be used in various ways such as food, medicines, drinks, side dishes, clothing, and building materials sources. In most countries the pattern of use of bamboo shoots also shows that it can be consumed as raw, canned, dried, cooked, fermented or medicinal in various manners. (Basumatary et al., 2017).

Table (4.2). Sociocultural benefits of bamboo products.

Types (parts)	Uses	Sources
Bamboo shoots	Health food (high proteins, amino acids, carbohydrates, many important minerals, and vitamins) and make up for dietary deficiencies of nutrients in the diet	Liu et al. (2016), Thakur et al. (2016), Devi (2013), Nirmala et al.(2011), Anusriti et al. (2017)
Bamboo fibers	Common ingredient in breakfast cereals, fruit juices, bakery and meat products, sauces, shredded cheeses, cookies, pastas, snacks, frozen desserts	Chongtham et al. (2011), Felisberto et al. (2017)
Value-added products and traditional drinks and medicine	Bamboo shoots are consumed in raw, canned, boiled, marinated, fermented, frozen, liquid, and medicinal forms for food, medicine, and both traditional and modern drinks	Choudhury et al. (2011), Thakur et al. (2016), Satya et al. (2010), Shukla et al. (2012), Karanja et al. (2015)
Construction materials and home appliance	Cost effective, easy to bend and lithe, easy availability, process ability	Patil and Mutkekar (2014), Nurdiah (2016), Boran et al. (2013), Nwoke and Ugwuishiwu (2011)
Enterprises and employment	Employment generation and sustainable livelihoods in rural communities	Swamy (2011), Alamgir (2007)
Bamboo fiber and starchy pulp	For clothing and cellulose fiber for pulp	Saravanan and Prakash (2007), Sowmya et al. (2016)

Source: Solomon, 2021

The agro-forestry system based upon bamboo is currently being promoted as a potential land-use option to reduce timber, fuel wood, and construction materials' dependency on natural forests. Cultivation and maintenance cost of *D. strictus* is very low as compared to short rotation trees species like poplar, eucalyptus, leucaena etc. It starts yielding commercial culms after 4–5 years of establishment, which can be harvested annually till flowering occurs (35–50 years) (Dev et al. 2017). Due to their vital role in improving the socioeconomic status of rural populations (Asha et al. 2018). Therefore, bamboo-based agroforestry systems are one of the important components to improve socioeconomic status of people as well as conservation and sustainability of the environment (Diwakar et al. 2018). Dev et al. (2017) studied on Dendrocalamus strictus + Sesamum indicum based agroforestry to find out the suitability of bamboo based agroforestry system (AFS) in the semi-arid region of bundelkhand and found highest B:C ratio of 2.83 was observed in 10m×10m bamboo +

sesame followed by 2.59 (10m×12m bamboo + sesame) and 1.43 (pure sesame) at harvest stage of bamboo (5th year). He suggested that bamboo based AFS has economic and environmental advantages over the sole crop and due to this, the system could be one of best alternative livelihood options for farmers of semi-arid tropics.

Agroforestry can be used to diversify and intensify farming systems through the integration of indigenous trees producing marketable timber and non-timber forest products. It is described in terms of an agroecological succession, in which climax agroforests are biodiverse, highly productive, and profitable (Leaky, 1999). Seshadri (1985) noted that soybean cultivation is technically feasible and economically profitable as a bamboo intercrop for the first six years. He also reported that the intercropping interval may be extended further when the bamboo culms are wider and bamboo canopy is handled carefully. While bamboo cultivated in mixed cropping home gardens in Kerala, bamboo (*Bambusa bam*bos), and holds the second position in terms of profitability (Benefit-Cost ratio) among the crop groups (Krishnankutty, 2004). Bamboo had a high B/C ratio because of poor inputs and low farm prices. Study was done by Paul et al. 2017 to evaluate the pools and fluxes of bamboo culms in Aizawl and its value added products obtained in the study area. Data were collected among the bamboo entrepreneurs in the local markets using PRA and survey was conducted in three strata viz. retailer, industry and consumer level. The study also reveals that bamboo culms markets provide employment for 27 male and 25 female that gives a total of 52 persons in the study area. Bamboo is recognized as the most profitable among plants investigated, with cassava, nut and mango placed next to bamboo, in an analysis on systemic bamboo plantings intercropped with mango, cassava nut, jack fruit, kokum and rubber in the Konkan region of Karnataka (Wagh and Rajput, 1991). Agroforestry based on bamboo are one major component of improving socio-economic status, stakeholder's annual revenue and an environmentally-friendly environment. Due to rapid growth and straightness and paired with their short maturities and multi-functioning characteristic, the addition of bamboos, multifunctions in the agroforestry system received increasing attention. Therefore, the traditional uses of bamboo are recognized by rural people in support of their livelihoods, including the edible bamboo and bamboo shades for homes and domestic farm utilities.

Potential of Bamboo Based Agro forestry for resource conservation and climate change mitigation

Climate change is generally recognized as one of the greatest challenges for humankind and practices needed to effectively integrate the objectives of climate change mitigation and adaptation with sustainable forest management (SFM) and biodiversity protection (Bodegom et al. 2009). Biological characteristics of bamboos make it a perfect tool for solving many environmental problems such as erosion control and CO_2 sequestration. On account of extensive rhizome-root system and accumulation of leaf mulch, bamboo serves as an efficient agent in preventing soil erosion, conserving moisture reinforcement of embankments and drainage channels etc. (ZHOU *et al*., 2005). The adaptive capacity and conserving potential of the nutrients and waters of bamboos enable them in the eco restructuring of degraded countries as forerunners (Mishra *et al.*, 2014). Because of the fast-growing nature and the dense foliage of bamboos, they are able to maintain the thick layer of litter (INBAR 2010a). This litter layer maintains microclimate in the understory and soil moisture, the most important factors for the restoration of degraded lands (Sharma *et al*., 2018; Buckingham 2014). The bamboo represents invaluable plant species for adapting and mitigating climate change. They are characterized by rapid growth and a complex network of rhizome-root system (Lobovikov *et al*., 2009; INBAR 2010a), which enable them to sequester more carbon than fast-growing tropical and subtropical trees under comparable conditions (Lobovikov *et al.*, 2012; Li *et al*., 2016; Thokchom and Yadava, 2017). Furthermore, bamboo diversifies the landscapes, providing food and habitat for numerous species of insects, birds, and animals (FAO and INBAR 2018).According to FAO and INBAR (2018), recently, an increasing number of countries have begun to identify and explicitly include bamboo as high-priority species for use in landscape restoration. Cameroon, China, Ethiopia, Kenya, Ghana, India, Madagascar, the Philippines, and Vietnam are some of the countries that include bamboo in their sustainable land management programs. Some small scale studies of bamboo restoration have shown promises (Rebelo and Buckingham, 2015; Sharma *et al*., 2018). For example, the Organization of African Bamboo is preparing nurseries for large-scale restoration of degraded land with bamboo (Partey *et al*., 2017). The Eco Planet Bamboo has been active in Nicaragua, restoring 5000 ha of degraded pastureland in Latin America (Eco Planet Bamboo 2014). Likewise, in India, the INBAR completed a prize-winning bamboo restoration project which turned a degraded mining area into a green and productive land (Benton 2014). The study conducted by FAO and INBAR (2018) shows how a degraded mining area exhibited a remarkable recovery after planting bamboos. The study indicated that farm crops and trees had been added to the bamboo landscape and that the groundwater table had grown by 10 meters in 20 years. Due to its effectiveness, the initiative has been extended to 100,000 hectares of degraded land in over 600 villages and to over one million people for their economic and social benefit. In Nepal, a similar plantation helped reduce soil erosion and flood damage (FAO and INBAR 2018). As Sharma *et al.* (2018) noted, recently countries like China, India, and the Philippines have incorporated bamboo in their national restoration plans.

The characteristics of bamboo make it a perfect solution for the environment and social consequences of tropical deforestation. Rapid biomass accumulation and effective fixation of CO_2, bamboo has a high carbon sequestration capacity. Over and above the high biomass carbon storage, bamboo also has a high net primary productivity (12-26 Mg ha-1 yr-1) even with regular selective harvesting, thus making it a standing carbon stock and a living ecosystem that continues to grow (Nath *et al*., 2015a). Bamboo harvesting does not remove the entire plant, therefore, preventing the release of CO2 at post-harvest period (Nath *et al*., 2015a, b; Ling et al. 2016). Consequently, to date, bamboo is widely regarded as an ideal plant to sequester carbon and expected to play a bigger role in mitigating the impact of future climate change (Song et al. 2011). The International Network of Bamboo and Rattan (INBAR) had shown the roles that bamboo plays in fighting climate change in different ways. It combats climate change by sequestering carbon in its biomass, reducing carbon release by offering alternative highly renewable sources of biomass energy. Adaptation by the rapid establishment and growth of bamboos reduces the exposure to disaster, and it restores the degraded lands with friendly property to the soils and livelihood diversification. Bamboo's fast growth, ability to grow on varied soils and climate, renewability, and positive socioeconomic impacts make them an excellent species for combating climate change (Mohit and Neelu, 2012). Bamboo's carbon sequestration rate can equal or surpasses that of fast-growth trees over short time periods in a new plantation, but only when bamboo is properly harvested and managed (Yiping *et al*., 2010). Studies have shown that appropriately managed and regularly harvested bamboo can sequester more carbon than bamboo in natural state (Thokchom and Yadava, 2015). Cost-effective managed ecosystems that can substantially remove atmospheric CO2 while providing essential societal benefits are important (Nath et al. 2015a, b). A study by Yuen et al. (2017) reported the comparative study results about the importance of bamboos with other tree species on the carbon sink, mitigating the effect of climate change, and its ability to provide key ecosystem services for humans including stabilizing hill slopes from accelerated soil erosion, improving soil fertility, and providing food and construction materials. According to carbon density of bamboo forest ecosystems in China, the estimated global bamboo carbon stock is about 4 Pg (1 Pg ¼ 1015 g; 1 Tg ¼ 1012 g; 1 ton ¼ 106 g), accounting for 0.43–0.61% of total global forest carbon stock (Mei 2017).

Bamboo helps us all mitigate and adapt the effects of climate change by absorbing and storing carbon; protecting forests and watersheds; insulating environments against extreme weather; providing low-cost greenhousing and infrastructure; providing cleaner biofuels; and providing renewable, sustainable resources for generating incomes (Thibbotuwawa 2019). Thus, the innovative use of bamboo by incorporating in the form of agroforestry in climate smart agriculture could give multifaceted benefit. Therefore, the enhanced protection and management of natural ecosystems and more sustainable management of natural resources and agricultural crops can play a critical role in climate change adaptation strategies (INBAR 2010a, b; World Bank 2010). Despites its high potential in carbon storage and sequestration and its important role in livelihood of millions of rural poor's worldwide, prospects of bamboo ecosystems in CDM (Clean Development Mechanism) and REDD (Reduced Emission from Deforestation and Forest Degradation) schemes remain to be explored. Thus, there is an urgent need to recognize ecosystem services that woody bamboo provides for well-being of rural communities and nature conservancy (Nath *et al*., 2015).

Constrains and Strategies for Promotion of Bamboo-Based Agroforestry in Bundelkhand

Worldwide, approximately more than 2.5 billion people trade in or use bamboo (Puran et al. 2018). The major constraints reported include legal issues, over exploitation, poor regeneration, low productivity, variety management and biodiversity conservation, lack of market information, base line data deficiencies, labour availability, capital intensive production process, fragmented nature of the industry, undeveloped markets poor quality perceptions and low level of awareness etc. Lack of silvicultural intervention in the bamboo cultivation results in the profuse uniformly dense mat of regeneration preventing the formation of bamboo clumps (Chaubey et al. 2013). For the success of bamboo based agroforestry, there has to be a known source of seedlings for planting, and one of the sources for the seedling could be bamboo flowering (Zhu et al. 1994).

At present semi-arid circumstances of Bundelkhand bamboo based agroforestry have not been promoted yet as per expectation after implementation of NBM because of several factors, such as the adaptation of relatively few species of bamboo in semi-arid conditions. Secondly there is no availability of abundant planting stock to the farmers due to unavailability of bamboo seeds every year. In addition, the market link in Bundelkhand is inadequate due to the lack of wood industry. Along with this, bamboo has fastest spreading behavior, making them more competitive in comparison to other tree species in agroforestry. Farmers also do not have knowledge of the suitable species according to the purpose which is a matter of trouble for the bamboo based agro forestry. Agroforestry Centers of ICAR like State Agricultural Universities (SAUs), All India Coordinated Research Projects (AICAR), ICAR and ICFAR initiate to supply certified seeds and planting materials of both vegetative and tissue culture to the States to establish accredited nurseries to provide Quality Planting Materials to the farmers and industries.

The National Bamboo Development Policy also envisages comprehensive development of bamboo resources as a marketable commodity with linkage of bamboo farmers with bamboo artisans (NABARD, 2013). As per the estimates of the Planning Commission of India, the market potential for value added bamboo products has been estimated at Rs.4463 crores against the current market size of Rs. 2403 crores (Planning Commission, 2013) with 8.6 million people in India depend upon bamboo resources for their livelihoods. However, reports suggest that, the bamboo value chain in India is suffering from different challenges at different levels of the value chain. The other business aspects such as market accessibility, cost effectiveness, economies of scale, etc. also are reported to affect the market attractiveness of the bamboo industry. Nevertheless, with the growing market access, institutional and financial arrangements in place in the national scenario, the market prospects could be expected to provide more buoyancy to the industry by involving different production business models in the ecosystem. Bamboo-based agroforestry is currently being promoted as a viable option for social, economic, and environmental benefits. Well-managed bamboo in agroforestry has tremendous potential to contribute to sustainable development and to a greater economy.

Resource competition in bamboo based Agroforestry system can be checked by giving due consideration to the plant population and geometry of planting. Root management practices like trenching can also be useful in reducing the belowground competition. For Agroforestry bamboos should be planted 8 - 9 meter away. Trenching, 30- 40 cm wide and 50 -70 cm deep should be done in case of boundary plantation, So that, new culm should not pass to the nearby field. Therefore canopy reduction treatment such as pruning and thinning are appropriate to overcome intra-specific competition. Pruning up to a height of 1.5 m above the ground is recommended in plantations of 4 year and above. Removal of dry and dead culms from the centre of the clump to reduce conjunction is also recommended. There is an urgent need for screening the species of bamboo which are high yielding. The soil plant water interaction in bamboo based Agroforestry also need to be studied for reducing competition.

Conclusion

Bamboo is a perfect economic investment for farmers which can be used in numerous ways but which also has huge potential to alleviate many problems. India can have even higher benefits from usage of bamboo in agro-forest systems, as its bamboo goods barely hold 4 per cent of the global market, while being the second largest bamboos manufacturer in the world. This implies that if India invests more in agro-forestry bamboo systems, it might exploit significantly greater potential. The integrated approaches for enhancing bamboo production through multiple strategies including positioning of agroforestry in the production context is expected bridge the demand supply gap in domestic market as well as to promote inclusive development in the context of climate change with multiplayer impacts on employment generation and food security in Bundelkhand. Though agroforestry based bamboo production models help to bridge the supply gap in the bamboo trade and market to certain extent , there need to be further solid strides taken in the areas of market development, integration, value chain management, skill development, insurance etc in the production and utilization domains.

References

1. Ahlawat S P, Kumar R V, Gupta V K, and Dhayni S K 2008. Scope of bamboo based agroforestry system in India. In proceeding of national conference of “Bamboo management, conservation, value addition and promotion” Held at TFRI Jabalpur, India, 89pp.
2. Akoto, D.S., Partey, S.T., Denich, M. *et al.* Towards bamboo agroforestry development in Ghana: evaluation of crop performance, soil properties and economic benefit. *Agroforest Syst* **94,** 1759–1780 (2020). https://doi.org/10.1007/s10457-020-00493-7
3. Alamgir M, Mezbahuddin M, Jashimuddin M (2007) Role of bamboo-based cottage industry ineconomic upliftment of rural poor of Chittagong, Bangladesh. J Bamboo Rattan 6:157–164.
4. Anonymous, (2001). Report of the task force on greening India for livelihood security and sustainable development. Planning commission, GOI.
5. Asha P, Malik MS, Oroan PR, Abhay K (2018) Study on growth and economics of bamboo basedsilvipastoral system. Int J Curr Microbiol App Sci 7:4273–4277.
6. Banerjee H, Dhara PK, Mazumdar D (2009) Bamboo (Bambusaspp.) based agroforestry systemsunder rainfed upland ecosystem. J Crop Weed 5(1):286–290
7. Basumatary A, Middha SK, Usha T, Basumatary AK, Brahma BK, Goyal AK (2017) Bambooshoots as a nutritive boon for Northeast India: an overview. 3 Biotech 7:169.
8. Benton A (2014) .Greening red earth: restoring landscapes, rebuilding lives, vol 76. INBARWorking Paper, pp 16–17.
9. Bodegom, A.J. van, H. Savenije, and M. Wit. (2009). Forests and Climate Change: adaptation and mitigation. European Tropical Forest Research Network 50.
10. Boran S, Çavdar A, Barbu M (2013). Evaluation of bamboo as furniture material and its furnituredesigns. Pro Ligno 9(4):811–819. ISSN 2069-7430, ISSN-L 1841-4737, https://www.researchgate.net/deref/http%3A%2F%2Fwww.proligno.ro%2F

11. Buckingham K (2014) Bamboo: the secret weapon in forest and landscape restoration? Worldresources institute blog.
12. C. N. Krishnankutty. (2004). Benefit–cost analysis of bamboo in comparison with other crops in mixed cropping home gardens in Kerala State. India. J. Bamboo and Rattan, Vol. 3, No. 2, pp. 99–106
13. Chaubey OP, Sharma A, Prakash R (2013) Eco-silvicultural interventions for rehabilitation of gregariously flowered bamboo forests with special reference to dendrocalamus strictus (Roxb)Nees. Global Journals Inc. (US) 13 (13). Online ISSN: 2249-4626 and Print ISSN: 0975-5896
14. Chongtham N, Bisht MS, Haorongbam S (2011) Nutritional properties of bamboo shoots: potential and prospects for utilization as a health food. Inst Food Technol 10:153–169
15. Choudhury D, Sahu JK, Sharma GD (2011) Value addition to bamboo shoots: a review. J Food SciTechnol 49(4):407–414. https://www.researchgate.net/deref/https%3A%2F%2Fdoi.org%2F10.1007%2Fs13197-011-0379-z
16. Dev Inder, Asha Ram, S. P. Ahlawat, D. R. Palsaniya, Ram Newaj, R K Tewari, Ramesh Singh, K. B. Sridhar, R P Dwived, M Srivastava, O. P. Chaturvedi, R V Kumar and R. S. Yadav. (2017). Bamboo (*Dendrocalamus strictus*) + sesame (*Sesamum indicum*) based agroforestry model: A sustainable livelihood option for farmers of semi-arid region Indian Journal of Agricultural Sciences 87 (11): 1528–34,
17. Devi YR (2013) Bamboo forest resources of India and its role in food security–a review. Agric Rev34(3):236–224
18. Dhyani SK and Handa AK (2014). Agroforestry in India: Current scenario, Indian Farming 63(11) 6–8
19. Dhyani SK(2014). National Agroforestry Policy 2014. and the need for area estimation under agroforestry, Current Science, 107(1) 9-1
20. Dhyani SK, Handa AK, and Uma (2013). Area under agroforestry in India: An assessment for present status and future perspective, Indian Journal of Agroforestry 15(1) 1-11.
21. Diwakar PN, Jai K, Sarfaraz A, Phallo K (2018) Bamboo-based agroforestry system for livelihoodand ecological security in North Chhotanagpur division of Jharkhand. J Pharmacol PhytochemSP1: 1996–1999
22. Eco Planet Bamboo (2015) Restoring land and reducing deforestation.
23. FAO and INBAR. (2018). Bamboo for land restoration. INBAR policy synthesis report 4. INBAR,Beijing.
24. Felisberto MHF, Miyake PSE, Beraldo AL, Clerici MTPS (2017). Young bamboo culm: potentialfood as source offiber and starch. Food Res Int 101:96–102
25. Gangopadhyay, P.B. (2003). Bamboo Resources as a Rural Livelihood Option in Madhya Pradesh, India. Paper submitted to XII World Forestry Congress, Quebec City, March 2003.
26. Hibbotuwawa M (2019). Bamboo for sustainable development, climate adaptation and mitigation.Stakeholder workshop on bamboo sector road map/country action/strategic plan development.Saman Kelegama Auditorium, IPS. http://planning.up.nic.in/Go/BOOK-2/PDF-Agriculture/1.10-RK%20Tripathi.pdf
27. Jha L. K., Lalnunmawia F (2004) Agroforestry with bamboo and ginger to rehabilitate degraded areasin North East India. J Bamb Ratt 2(2):103–109

28. Karanja PN, Kenji GM, Njoroge SM, Sila DN, Onyango CA, Koaze H, Baba N (2015) Composi-tional characteristics of young shoots of selected bamboo species growing in Kenya and theirpotential as food source. J Food Nutr Res 3(9):607–612.
29. Kittur BH, Sudhakara K, Kumar BM, Kunhamu TK, Sureshkumar P. (2016). Bamboo-basedagroforestry systems in Kerala, India: performance of turmeric (Curcuma longaL.). In: Thesubcanopy of differentially spaced seven-year-old bamboo stand. Agrofor Syst 90:237–250
30. Krishna kutty, CN. (2004). Benefit –cost Analysis of bamboo in comparison with othercrops in mixed ropping home garden in Kerele state, India. Journal of Bamboo and Rattan. 3(2): 99-106
31. Kumar, H., Mehera, B., Lal, S.B. and Umrao, R. (2015). The potential of bamboo cultivation as a way forward inimproving livelihood: a case study In: Proceedings ofWorld Forestry Congress at Durban, South Africa Sept7-11, 201
32. Kumar, R. S., Binu, N. K., Nishant, N., Buxy, S. and Sinha, G. N. (2014). A review of bamboo based agroforestry models developed in different parts of India, productivity and marketing aspects, , pp. 45–52.
33. Leakey RRB (1998). Agroforestry for biodiversity in farming systems. In: Collins WW, Qualset CO(eds) Biodiversity in agroecosystems. Publishers CRC, New York, pp 127–145
34. Leaky RRB (1999) Agroforestry for biodiversity in farming systems. In: Collins WW, Qualset CO(eds) Biodiversity in agroecosystems. CRC Press, New York, pp 127–145
35. Li M, Li C, Jiang H, Fang C, Yan J (2016) Tracking bamboo dynamics in Zhejiang, China, usingtime-series of Landsat data from 1990 to 2014. Int J Remote Sens 37:1714–1729
36. Ling M, Christensen M, Donnison A, Belmonte KD, Brown C (2016). Scoping study to inform theglobal assessment of bamboo and rattan (GABAR). Environment World Conservation Moni-toring Centre, Cambridge
37. Ling M, Christensen M, Donnison A, Belmonte KD, Brown C (2016) .Scoping study to inform theglobal assessment of bamboo and rattan (GABAR). Environment World Conservation Moni-toring Centre, Cambridge
38. Liu Y, Tang Q, You Y, Zeng S, Li Y, Chen D, Liu A, Feng C, Li C, Chen D (2016). Evaluation ofthe bamboo shoots'development status and nutrition in sichuan, china. International conferenceon education, sports, arts and management engineering (ICESAME). Atlantis Press, pp 531–534
39. Lobovikov M, Lou Y, Schoene D, Redinoja W (2009). The poor man's carbon sink. FAO workingpaper No, 8. Rome, Italy.
40. Lobovikov M, Schoene D, Yping L (2012.) Bamboo in climate change and rural livelihoods. MitigAdapt Strategy Glob Change 17(3):261–276.
41. Mailly D, Christanty L, Kimmins JP (1997). without bamboo, the land dies: nutrient cycling andbiogeochemistry of a Javanese bamboo talun-kebun System. For Ecol Manag 91:155–173
42. Mei T (2017). Bamboo for climate change mitigation. Zhejiang A and F University, China
43. Mishra G, Giri K, Panday S, Kumar R, Bisht NS (2014). Bamboo: potential resource foreco-restoration of degraded lands. J Biol Earth Sci 4(2):130–136
44. Mohit G, Neelu G (2012) .Bamboos: importance for mitigation and adaptation to climate change.Thefifth assessment report of IPCC
45. Nath AJ, Das AK (2008). Bamboo resources in the home gardens of Assam: a case study from BarakValley. J Trop Agric 46:46–49

46. Nath AJ, Lal R, Das AK (2015a). Ethnopedology and soil quality of bamboo (Bambusasp.) basedagroforestry system. Sci Total Environ.
47. Nath S, Das R, Chandra R, Sinha A (2009). Bamboo based agroforestry for marginal lands withspecial reference to productivity, market trend and economy. Agroforestry in Jharkhand, EnvisJharkhand News, Jharkhand, pp 80–96 .
48. NBAR (2010a). Bamboo and climate change mitigation: a comparative analysis of carbon seques-tration. INBAR Technical Report No. 32. Beijing
49. Nirmala C, Madho SB, Sheena H (2011). Nutritional properties of bamboo shoots: potential andprospects for utilization as a health food. Comp Rev Food Sci Food Safety 10:153–169.
50. NRCAF. 2013. Vision 2050. National Research Centre forAgroforestry, Jhansi.
51. NRCAF. 2014. Final report of Development of bamboo agroforestry systems for six agroclimatic ones. Jhansi NRCAF. Available at: http://nbm.nic.in/Reports/ICAR _Jhansi. Pdf)
52. Nurdiah EA (2016) The potential of bamboo as building material in organic shaped buildings.Procedia–Social and Behavioral Sciences, pp 30–38
53. Nusriti B, Sushil KM, Talambedu U, Amit KB, Birendra KB, Arvind KG (2017). Bamboo shootsas a nutritive boon for Northeast India: an overview. Biotech 7(169).
54. Nwoke OA, Ugwuishiwu BO (2011). Local bamboo and earth construction potentials for provisionof affordable structures in Nigeria. Int J Sustain Constr Eng Technol (ISSN: 2180-3242), pp17–31
55. P. SHANMUGHAVEL¤ and K. FRANCIS. (2001). Intercropping trials of four crops in bamboo plantations J. Bamboo and Rattan, Vol. 1, No. 1, pp. 3–9
56. Partey ST, Sarfo DA, Frith O, Kwaku M, Thevathasan NV (2017). Potentials of bamboo-basedagroforestry for sustainable development in Sub-Saharan Africa: a review. Agribiol Res 6(1):22–32.
57. Patil S, Mutkekar S (2014). Bamboo as a cost-effective building material for rural construction. JCivil Eng Environ Technol 1(6):35–40. https://www.researchgate.net/deref/http%3A%2F%2Fwww.krishisanskriti.org%2Fjceet.html
58. Paul Lalremsang , David C. Vanlalfakawma , S. K. Tripathi. (2017). Volume 143, Issue 9,Wagh, R.; Rajput, J.C. 1991. Comparative performance of Bamboo with the Horticulture crops in Konkan. In: 4th International Bamboo Workshop on Bamboo in Asia and Pacific, Chiangmai, 27-30 Nov. 1991. Proceedings. Thailand, an International Development Researh Centre.pp.5-86.
59. Prasad K.(2003). PROSPECT OF AGROFORESTRY IN INDIA. XII World Forestry Congress, Quebec City. http://www.fao.org/3/XII/0931-B5.htm#P28_106.
60. Puran Asha, M. S. Malik, P. R. Oroan and Abhay Kumar. (2018). Study on Growth and Economics of Bamboo Based Silvipastoral System *Int.J.Curr.Microbiol.App.Sci. Special Issue-7: 4273-4277.
61. Qin H, Niu L, Wu Q, Chen J, Li Y, Liang C, Xu Q (2017). Bamboo forest expansion increases soilorganic carbon through its effect on soil arbuscular mycorrhizal fungal community and abun-dance. Plant Soil. https://doi.org/10.1007/s11104-017-3415-6
62. R. K. Tripathi. (2015) .Scope and Prospects of Agroforestry in Bundelkhand Region
63. Rebelo C, Buckingham K (2015). Bamboo: the opportunities for forest and landscape restoration. In:Lapstun S (ed) Forest and land scape restoration. Unasylva No. 245, 66.
64. Rizvi RH, Dhyani SK, Newaj R, Karmakar PS, and Saxena A (2014). Mapping agroforestry area in India through remote sensing and preliminary estimates, Indian Farming 63(11) 62-64

65. Saravanan K, Prakash C (2007) .Bamboo fibbers and their application in textiles. The Indian TextileJournal 117:33–36
66. Satya S, Bal ML, Singhal P (2010). Bamboo shoot processing: food quality and safety aspect(a review). Trends Food Sci Techn 21:181–189
67. Seshadri, P.(1985). Intercropping of Bamboo *(D. stritus)* with soyabean An agroforestry study. Ph.D. Thesis . Tamil Nadu Agriulture University, Coimbatore 480p.
68. Shanmughavel P, Francis K (2002). Bambusa bambos–An afforestation trial. In: 12th World Forestry Congress, FAO, Quebeck City, Canada. 23–29
69. Sharma R, Wahono J, Baral H (2018) Bamboo as an alternative bioenergy crop and powerful allyfor land restoration in Indonesia. Sustainability 10:4367.
70. Shukla R, Sumit G, Sajal S, Dwivedi PK, Mishra A (2012) Medicinal importance of bamboo. Int JBiopharm Phytochem Res 1(1):9–15.
71. Sohel MSI, Alamgir M, Akhter S, Rahman M (2015). Carbon storage in a bamboo (Bambusavulgaris) plantation in the degraded tropical forests: implications for policy development. LandUse Pol 49:142–151. https://doi.org/10.1016/j.landusepol.2015.07.011
72. Song X, Zhou G, Jiang H, Yu S, Fu J, Li W, Wang W, Ma Z, Peng C (2011) Carbon sequestrationby Chinese bamboo forests and their ecological benefits: assessment of potential, problems, andfuture challenges. Environ Rev 19:418–428.
73. Sowmya RN, Raaja V, Prakash C (2016) Investigation of relationship between blend ratio and yarntwist on yarn properties of bamboo, cotton, polyester, and its blends. J Nat Fibers. https://www.researchgate.net/deref/https%3A%2F%2Fdoi.org%2F10.1080%2F15440478.2016.1193087
74. Swamy C (2011). Employment generation by bamboo resource development and its impact on ruralcommunities. Int J Rural Stud (IJRS) 18(1):1–6
75. Tangjang S, Nair PKR (2016). Integrated bamboo + pine home-gardens: a unique agroforestrysystem in Ziro valley of Arunachal Pradesh, India. Int J Environ Agric Res 2(2):25–34.
76. Tengnas B (1994). Agroforestry extension manual for Kenya. International Centre for Research inAgroforestry, Nairobi.
77. Tewari S, Banik RL, Kaushal R, Bhardwaj DR, Chaturvedi OP, Gupta A (2015). Bamboo basedagroforestry systems. ENVIS. Centre on agroforestry systems.
78. Thakur K, Rajani CS, Tomar SK (2016) Fermented bamboo shoots: a riche niche for beneficialmicrobes. J Bacteriol Mycol 2(4):87-93. https://doi.org/10.15406/jbmoa.2016.02.00030
79. Thokchom A, Yadava PS (2017). Biomass, carbon stock and sequestration potential ofschizostachyum pergracilebamboo forest of Manipur, North East India. Trop Ecol 58:23–32
80. Unofia SI, Owoh PW, Ukpong EE, Ekpo IE (2012). Assessment of plant species of socio-economicimportance conserved in homegarden of nsit ubium local government area of Akwa Ibom state,Nigeria. Niger J Agric Food Environ 8:99–108.
81. Viswanath S, Dhanya B, Rathore TS (2007). Domestication ofdendrocalamus brandisiiin uplandpaddyfields in Coorg, Karnataka. J Bam Ratt 6(3–4):215–222
82. World Bank (2010). Convenient solutions to an inconvenient truth, the international bank forreconstruction and development.
83. Yiping L, Yanxia L, Buckingham K, Henley G, Guomo Z (2010). Bamboo and climate changemitigation. Technical Report 32, INBAR, Beijing

84. Yuen JQ, Fung T, Ziegler AD (2017). Carbon stocks in bamboo ecosystems worldwide: estimatesand uncertainties. For Ecol Manag 393:113–138
85. Zhu S, Ma N, Fu M (1994). Compendium of Chinese bamboo. China Forestry Publishing House,Beijing, pp 8–9.
86. Zou, B. Z., M. Y. Fu, J. Z. Xie, X. S. Yang & Z. C. Li.(2005). Ecological functions of bamboo forest: research and application. Journal of Forestry Research 16(2): 143–147. In Chinese

Chapter 5

Harnessing the potential of Bamboo Resources for Sustainable Growth in Agriculture

Yumnam Bijilaxmi Devi and A. K. Pandey
College of Horticulture and Forestry, RLBCAU, Jhansi

Natural resources have been depleting at a higher rate due to various factors including overpopulation, deforestation etc. In order to maintain the ecological balance of nature, various solutions have been introduced/developed. Among this, bamboo can be a one of the biggest assets in bringing out the ecosystem services to the ecosystem. Bamboo is a very fast growing, renewable resource which is very easy to grow (Akwadaand Akinlabi, 2018). It has multiple uses including construction, medicine, furniture, clothes, food, fuel etc.Bamboo belongs to Poaceae family and the Bambusoideae subfamily (Wu *et al.*,2009; Ruiz-Sanchez *et al.*,2019).Around 1662 species of bamboo under 121 genera have been identified, out of this, 14% *i.e* 232 species have been found worldwide irrespective of their native place (Canavan *et al.*,2017). According to their rooting structures, bamboo have been classified monopodial (diffuse or tree like), sympodial (clumping) and amphodial (mixed) (Buckingham2014). Depending on flowering, bamboos can also be classified as annual flowering like *Indocalamuswightianus, Ochlandra* spp., sporadic or irregular flowering like *Chimonobambusa* species, *Dendrocalamushamiltonii,* gregarious flowering like *Bambusabambos, Dendrocalamusstrictus* (Yeasmin *et al.*,2015). Bamboo has the characteristics of grasses *i.e* they grow, flower, produce seeds and then die which is a consistent character to spread or continue its new generation (Paudyal*et al.,* 2019). Bamboo is found extensively in tropical and subtropical regions *i.e* in Africa, Asia, South and Latin America (Yeasmin*et al.*,2015; Bitariho and McNeilage, 2008). The economic resource from bamboo may be explored for this area. The potential of bamboo to impact livelihood of people and geographical areas is well known but its potential is partially exploited. Now is the time to harness the true potential of bamboo in enriching the ecosystem as well as social development. Bamboo can play a significant role in the restoration and rejuvenation of rural and national economies through its cultivation (Akwada & Akinlabi, 2016).

Bamboo in enriching the ecosystem

Bamboo forests promote human well-being by providing various goods and services which is regarded as ecosystem services, this may include landscape restoration, prevention of soil and sediment loss, food supply, domestic and industrial raw materials, release of oxygen and carbon sequestration (Zhou *et al.,* 2005; Yiping *et al.,* 2010; Sohel*et al.,* 2015). Overall, bamboo generate sociocultural, economic and ecological values to local as well as global communities (Shinohara *et al.*,2014). Sociocultural connects the forest and people with spiritual significance for local people, economic values are related with raw materials provided by bamboo for local and industrial uses and lastly ecological values relates the maintenance of ecosystem by carbon stocking or sequestration.

Ecosystem services provided by bamboo makes it one of the important components of agroforestry system like extensive rhizome system helps in reducing erosion thus conserving the soil in areas where run off water moves due to steep slopes, riverbanks or degraded lands. The strong root system protects the soil from damaged or fragile riverbanks where earthquakes and mudslides are common. If proper harvesting is done, the roots of bamboo remain intake and starts growing again when feasible climate prevails, so this helps in conserving the top soil from loss (AkwadaandAkinlabi, 2016). The extensive root system and dense litter floor with uniquely shaped leaves gives the stem flow rate and canopy intercept 25% of the normal rate thus, bamboo presents massive erosion by reducing the runoff rate drastically (Pandey and Shyamasundar, 2008). The example of well-known capacity of bamboo to control erosion was reported from Phillipines, Kenya and Andes region. In Punjab, India also, clumps were stubbed in 1980 to control 311 ha of embankments from erosion (Chandrashekara, 1996; Andeam, 1995).This practice gave an annual benefit of around U$ 70,000.

Being an evergreen plant, bamboo with the thick canopy and thick litter fall reduces the splash erosion and improves infiltration (Alfonso, 1987). As bamboo's culms are elastic, they do not break during high wind speed but bends so bamboo may be used as windbreaks to protect the cash crops in coastal areas where winds are havoc (Pandey and Shyamasundar, 2008). So, planting bamboo will help in enriching the ecosystem with these services besides other multiple uses. Bamboo may even help in restoring the degraded land more efficiently than the normal rate by improving the soil health in terms of nutrient status along with physical property of soil. Soil damaged by overgrazing and poor agricultural practices may also be restored with bamboo (Pandey and Shyamasundar, 2008). Bamboo also provides various environmental services like protecting traditional houses from strong winds, raw material for house construction and fuelwood purposes etc. (Nath *et al.,* 2015, 2018; Partey*et al.,*2017). Furthermore, bamboo helps in rehabilitation of degraded land, as a timber substitute to hard woods and watershed protection (INBAR, 2006).The assessment of ecosystem services may serve many purposes like clarifying the importance of bamboo to policymakers, investors, environmental protection workers and local communities. This will also improve the link the opportunities of bamboo farming to markets by including in the preference of decision makers of the country(Gu *et al.*,2019) and this will also show the potentiality of bamboo plantation in the restoration of degraded lands(UNEP,2019).

Table (5.1): Ecosystem services provided by bamboo in various aspects (Paudyal *et al.*, 2019)

Services	Description	References
Food	More than 200 species of bamboos provide food (edible and palatable shoots) from wild and cultivated areas throughout the world	Xu *et al.,*2018
Forage production	Bamboo supplies forage that is popular for local livestock development everywhere	Partey*et al.,*2017

Timber	Many bamboo species provide construction timber and are used for building raw materials, modern engineered bamboo products, composite panels and boards.	van der Lugt*et al.*,2018 Ahammad*et al.*,2019
Raw materials	Bamboo provides raw materials for various types of enterprises from traditional domestic to industrial uses such as different types of bamboo housing, flooring, crafts and fiber for pulp, paper and clothes	Sharma *et al.*,2016 Dai *et al.*,2017
Bioenergy	Bamboo has traditionally been used as a source of domestic energy and substitute for wood charcoal and mineral coal. Biogas and oil can also be produced from bamboo. Bioenergy can replace fossil fuel and decrease the carbon footprints	Sharma *et al.*,2018 Yusuf *et al.*,2018
Medicinal resources	Traditional and indigenous medicine derived from bamboo products	Panee,2015 Yeasmin*et al.*,2015
Fresh water provision	Bamboo forests contribute significantly to water source protection and helps in supplying freshwater	Sun *et al.*,2006 Liu *et al.*,2018
Landscape restoration	Restoration of degraded land through planting bamboo	Rebelo and Buckingham,2015
Sediment retention	Bamboo forests stabilize the slope and prevent soil erosion, which improves the condition of land and controls floods and landslides. These phenomena reduce the deposition load downstream	Tardio*et al.*,2017, 2018 van der Lugt*et al.*,2018
Carbon sequestration	Bamboo grows faster and can sequestrate carbon from the atmosphere at a faster rate than many tree species	Lobovikov*et al.*,2009 Song *et al.*,2011
Carbon stock	Increased bamboo biomass indicates a higher amount of carbon storage	Li *et al.*,2015 Teng *et al.*,2016
Air quality and local climate regulation	Bamboo forests filter the air and remove odors, pollutant gases (nitrogen oxides, ammonia, sulfur dioxide and ozone) and dust particles out of the air through the action of leaves and bark. Improved air quality makes the local climate better	Troy Mera and Xu,2014
Floods/ landslides control	Bamboo forests control floods and landslides by holding soil particles together through a complex network of roots and rhizomes in the field	Lin *et al.*,2017 van der Lugt*et al.*,2018
Groundwater recharge	The increased area of bamboo forests reduces the runoff rate and assists water percolation	Yeasmin*et al.*,2015
Maintenance of biological diversity	Bamboo forests maintain and/or enhance biodiversity by promoting different varieties of bamboo species and providing habitat for wild animals	Sharma and Nirmala,2015 Yeasmin*et al.*,2015
Recreation and ecotourism	Bamboo forests provide opportunities for ecotourism and recreational activities through the promotion of greenery and landscape beautification	Troy Mera and Xu,2014

Cultural/ religious values	Bamboo materials have been used from the cradle to the grave in many countries because of religious and cultural values associated with bamboo	van der Lugt*et al.*,2018

Benefits of Bamboo

Bamboo has been used for everything from food to bridge building for millennia. Among the countless benefits, here are some which is stated below

1. **Renewable resource:** Compared to other tree species, bamboo is an important renewable resource as it can be harvested in one to five years depending on the species (ABS, 2002). The high frequency in harvest of bamboo contributes more in market area as a substitute for hard woods which gradually reduces the deforestation. Deforestation is one of the major problems which is causing environmental deterioration and thus global warming. Use of bamboo products will ease the dependence on hard woods which takes time to grow and mature.
2. **Faster growth**: The growth rate of bamboo is incomparable to other plant species; it is way faster (AkwadaandAkinlabi, 2018). Some species of bamboo grow more than three feet a day. After harvesting the bamboo, it can regenerate itself with a new shoot from its extensive root system without planting additionally or cultivating it again.
3. **Versatility:** Bamboo is flexible in any kind of materialistic use starting from flooring, furniture, paper, charcoal, building materials etc. Bamboo fibres are stronger than the wood fibres and has the ability to adapt in changing climate.
4. **Not much waste**: Bamboo has been used as food, soil enriching mulch, from making small chopsticks to beautiful furniture, every part of it can be used for one or other purpose. North east Indian people eats small shoots growing out near the matured plants.
5. **Releases more oxygen to the atmosphere**: Comparing to the hardwood trees, bamboo absorbs 35% more oxygen to the atmosphere and absorbs carbon dioxide at a higher rate which is one of the major greenhouse gases. With its ability to grow fast, bamboo have a high carbon stock potential (Yiping *et al.*,2010), especially when the harvested culms are used as durable products (Nath *et al.*,2009).
6. **No chemicals required for growth:** Compared to cash crops, bamboo does not require fertilizers, pesticides or herbicides to grow, it can thrive well in any condition and attains optimum growth from the soil nutrient itself. On top of this, bamboo also enriches the soil with nutrients like nitrogen by fixing the nitrogen from atmosphere (Lobovikov*et al.*,2007). Inorganic chemicals have caused numerous health hazards and pollution to environment, so this will be halt in case of bamboo cultivation.
7. **Soil protection**: Soil erosion is the loss of fertile soil by water and wind when soil is not covered with vegetation. Hardwood forests are burned or cut down for various purposes, but bamboo have strong root system which remain intake even after harvesting and start growing again when climate is prevalent (Pandey and Shyamasundar, 2008). This will improve the physical condition of soil and prevent soil from erosion losses which otherwise would have clogged rivers, streams beside deteriorating soil health.

8. **Wide variation of climate**: Bamboo can grow widely in various climatic conditions specially drought where other crops fail to grow. The roots remaining intake even after harvesting stores enough moisture for vital growth. Bamboo can grow from low wetlands to higher elevations in the mountains. Bamboo could also grow from sea level to as high as 300 meters elevation and it attains its full growth within 2-4 months (Adekoya, 2003).
9. **Economic Development**: In a developing country like India, unemployment is one of the major problems. Growing multipurpose bamboo in large scale will open opportunities for job and will improve social and economic stability (Cho *et al.,* 2011).Bamboo is a competent component in rural farming system and helps in rural economy by sustaining the livelihoods of people. Bamboo enterprises are the main source of income for sustaining livelihoods (Partey *et al.*,2017)

Conclusion

Bamboo plantation promotes human well-being by providing various goods and services which is regarded as ecosystem services. Bamboo generate sociocultural, economic and ecological values to local as well as global communities. It provides multiple uses which has the potential to enrich ecosystem through its ecosystem services. The overall potential of bamboo in providing the services to humanity and the environment may be highlighted if the assessment of ecosystem services is carried out. This is also one of the reasons that this article is emphasising on the potential of bamboo in enriching the ecosystem. Qualitatively, agro-ecosystem services provided by bamboo is numerous, but its assessment statistics are poor, so future studies should also focus on assessment. Plantation of bamboo should be emphasized as it helps in enriching the agri-ecosystem resulting in sustainable growth of agriculture.

References

1. [INBAR] (International Bamboo and Rattan Organisation). (2006). The partnership for a better world— strategy to the year 2015. Beijing, China: International Bamboo and Rattan Organisation (INBAR).
2. [UNEP] (United Nations Environment Programme). (2019). New UN Decade on Ecosystem Restoration offers unparalleled opportunity for job creation, food security and addressing climate change. https://www.unenvironment.org/news-and-stories/press-release/newun-decade-ecosystem-restoration-offers-unparalleled-opportunity
3. ABS American. Bamboo Society, ABS, (2002). General bamboo information. www.bamboo.org/GeneralInfo.htmI.
4. Adekoya, J. A. (2003). Environmental effect of solid minerals mining. *Journal of Physical Sciences, Kenya, 8*, 625-640.
5. Ahammad, R., Stacey, N., & Sunderland, T. C. (2019). Use and perceived importance of forest ecosystem services in rural livelihoods of Chittagong Hill Tracts, Bangladesh. *Ecosystem services, 35*, 87-98.
6. Akwada, D. R., andAkinlabi, E. T. (2016). Economic, social and environmental assessment of bamboo for infrastructure development. In *5th International conference on infrastructure development in Africa July in Johannesburg, South Africa*.

7. Akwada, D. R., andAkinlabi, E. T. (2018). Bamboo application in infrastructure development of Ghana. In *Conference on infrastructure development and investment strategies for Africa*.
8. Alfonso, D.J., 1987. Let's plant bamboo. Agribusiness weekly, 1(19): 25
9. Andeam, C.J, 1995. Production and utilization of bamboo in the Philippines. Philippine Technical Journal, 20(2); 59-72.
10. Bitariho, R., &McNeilage, A. (2008). Population structure of montane bamboo and causes of its decline in Echuya Central Forest Reserve, South West Uganda. *African Journal of Ecology*, *46*(3), 325-332.
11. Buckingham, K. (2014). Bamboo: the secret weapon in forest and landscape restoration?
12. Canavan, S., Richardson, D. M., Visser, V., Le Roux, J. J., Vorontsova, M. S., & Wilson, J. R. (2017). The global distribution of bamboos: assessing correlates of introduction and invasion. *AoB Plants*, *9*(1).
13. Chandrashekara U.M. Krishnan kutty, C.N. and Sankar, S. (1996). Strategies for promotion of cultivation, sustainable management and use of bamboo. In: *ProceedingNational Seminar on Bamboo,* Bangalore. Bamboo society of India, Bangalore Pp.76-82.
14. Cho, E., Um, Y., Yoo, S. K., Lee, H., Kim, H. B., Koh, S., ... & Lee, Y. (2011). An expressed sequence tag analysis for the fast-growing shoots of Bambusa edulis Murno. *Journal of Plant Biology*, *54*(6), 402-408.
15. Dai, E. F., Wang, X. L., Zhu, J. J., & Xi, W. M. (2017). Quantifying ecosystem service trade-offs for plantation forest management to benefit provisioning and regulating services. *Ecology and evolution*, *7*(19), 7807-7821.
16. Gu, L., Wu, W., Ji, W., Zhou, M., Xu, L., & Zhu, W. (2019). Evaluating the performance of bamboo forests managed for carbon sequestration and other co-benefits in Suichang and Anji, China. *Forest Policy and Economics*, *106*, 101947.
17. Li, P., Zhou, G., Du, H., Lu, D., Mo, L., Xu, X., ... & Zhou, Y. (2015). Current and potential carbon stocks in Moso bamboo forests in China. *Journal of Environmental Management*, *156*, 89-96.
18. Lin, W., Yang, F., Zhou, L., Xu, J. G., & Zhang, X. Q. (2017). Using modified Soil Conservation Service curve number method to simulate the role of forest in flood control in the upper reach of the Tingjiang River in China. *Journal of Mountain Science*, *14*(1), 1-14.
19. Liu, W., Hui, C., Wang, F., Wang, M., & Liu, G. (2018). Review of the resources and utilization of bamboo in China. *Bamboo-Current and Future Prospects*, 1-10.
20. Lobovikov, M., Lou, Y., Schoene, D., &Widenoja, R. (2009). The poor man's carbon sink: bamboo in climate change and poverty alleviation. *Non-Wood Forest Products Working Document*, (8).
21. Lobovikov, M., Paudel, S., Ball, L., Piazza, M., Guardia, M., Ren, H., ... & Wu, J. (2007). *World bamboo resources: a thematic study prepared in the framework of the global forest resources assessment 2005* (No. 18). Food & Agriculture Org.
22. Nath, A. J., Lal, R., & Das, A. K. (2015). Managing woody bamboos for carbon farming and carbon trading. *Global Ecology and Conservation*, *3*, 654-663.
23. Nath, A. J., Sileshi, G. W., & Das, A. K. (2018). Bamboo based family forests offer opportunities for biomass production and carbon farming in North East India. *Land use policy*, *75*, 191-200.
24. Nath, S., Das, R., Chandra, R., & Sinha, A. (2009). Bamboo based agroforestry for marginal lands with special reference to productivity, market trend and economy. *Agroforestry in Jharkhand, Envis Jharkhand News*, 80-96.

25. Pandey, C. N., &Shyamasundar, K. (2008). Post-harvest management and storage of bamboo culms. In *Proceedings of the International Conference on Improvement of Bamboo productivity and marketing for sustainable livelihood. 15th-17th April* (pp. 47-58).
26. Panee, J. (2015). Potential medicinal application and toxicity evaluation of extracts from bamboo plants. *Journal of medicinal plant research*, *9*(23), 681.
27. Partey, S. T., Sarfo, D. A., Frith, O., Kwaku, M., &Thevathasan, N. V. (2017). Potentials of bamboo-based agroforestry for sustainable development in Sub-Saharan Africa: a review. *Agricultural Research*, *6*(1), 22-32.
28. Paudyal, K., Adhikari, S., Sharma, S., Samsudin, Y. B., Paudyal, B. R., Bhandari, A., ... &Baral, H. (2019). Framework for assessing ecosystem services from bamboo forests: Lessons from Asia and Africa (Vol. 255). CIFOR.
29. Rebelo, C., & Buckingham, K. (2015). Bamboo: The opportunities for forest and landscape restoration. *Unasylva*, *66*(245), 91.
30. Ruiz-Sanchez, E., Sosa, V., Ortiz-Rodriguez, A. E., &Davidse, G. (2019). Historical biogeography of the herbaceous bamboo tribe Olyreae (Bambusoideae: Poaceae). *Folia Geobotanica*, 1-13.
31. Sharma, M. L., & Nirmala, C. (2015). Bamboo diversity of India: an update. In *Proceedings of the 10th world bamboo congress, Damyang, Korea* (pp. 17-22).
32. Sharma, P., Saikia, P., &Sarma, K. (2016). Diversity, uses and in vitro propagation of different bamboos of Sonitpur District, Assam. *Journal of Ecosystem &Ecography*, *6*(2), 1-9.
33. Sharma, R., Wahono, J., &Baral, H. (2018). Bamboo as an alternative bioenergy crop and powerful ally for land restoration in Indonesia. *Sustainability*, *10*(12), 4367.
34. Shinohara, Y., Kume, T. O. M. O. N. O. R. I., Ichihashi, R., Komatsu, H., &Otsuki, K. (2014). Moso-bamboo forests in Japan: what are the effects of their area expansion on ecosystem services? *Journal of the Japanese Forest Society*, *96*(6), 351-361.
35. Sohel, M. S. I., Alamgir, M., Akhter, S., & Rahman, M. (2015). Carbon storage in a bamboo (*Bambusa vulgaris*) plantation in the degraded tropical forests: Implications for policy development. *Land Use Policy*, *49*, 142-151.
36. Song, X., Zhou, G., Jiang, H., Yu, S., Fu, J., Li, W., ... & Peng, C. (2011). Carbon sequestration by Chinese bamboo forests and their ecological benefits: assessment of potential, problems, and future challenges. *Environmental Reviews*, *19*(NA), 418-428.
37. Sun, Y. H., Zhang, H. J., Cheng, J. H., Wang, Y. J., Shi, J., & CHENG, Y. (2006). Soil characteristics and water conservation of different forest types in Jinyun Mountain. *Journal of Soil and Water Conservation*, *20*(2), 106-109.
38. Tardio G, Mickovski SB, Rauch HP, Fernandes JP and Acharya, MS. (2018). The use of bamboo for erosion control and slope stabilization: soil bioengineering works, bamboo current and future prospects. *IntechOpen*. doi: 10.5772/intechopen.75626
39. Tardio, G., Mickovski, S. B., Stokes, A., &Devkota, S. (2017). Bamboo structures as a resilient erosion control measure. *Proceedings of the Institution of Civil Engineers-Forensic Engineering*, *170*(2), 72-83.
40. Teng, J., Xiang, T., Huang, Z., Wu, J., Jiang, P., Meng, C., ... & Fuhrmann, J. J. (2016). Spatial distribution and variability of carbon storage in different sympodial bamboo species in China. *Journal of environmental management*, *168*, 46-52.
41. Troya Mera, F. A., & Xu, C. (2014). Plantation Management and Resource Economics of Bamboo in China. *Ciencia y Tecnología (1390-4051)*, *7*(1).

42. van der Lugt P, Long TT and King C. (2018). Carbon Sequestration and Carbon Emissions Reduction through Bamboo Forests and Products. Beijing, China: International Network for Bamboo and Rattan (INBAR).
43. Wu, F. H., Liu, N. T., Chou, S. J., Shen, S. C., Chang, B. C. H., Pan, C. Y., & Lin, C. S. (2009). Identification of repressed gene transcript accumulation in three albino mutants of *Bambusa edulis* Munro by cDNA microarray analysis. *Journal of the Science of Food and Agriculture*, *89*(13), 2308-2316.
44. Xu L, Shi Y, Zhou G, Xu X, Liu E, Zhou Y, Zhang F, Li C, Fang H and Chen L. (2018). Structural development and carbon dynamics of *Moso bamboo* forests in Zhejiang Province, China. *Forest Ecology and Management* 409:479–88.
45. Yeasmin, L., Ali, M. N., Gantait, S., & Chakraborty, S. (2015). Bamboo: an overview on its genetic diversity and characterization. *3 Biotech*, *5*(1), 1-11.
46. Yiping, L., Yanxia, L., Buckingham, K., Henley, G., &Guomo, Z. (2010). Bamboo and Climate Change Mitigation: a comparative analysis of carbon sequestration. *International Network Bamboo and Rattan*.
47. Yusuf, S., Syamani, F. A., &Fatriasari, W. (2018). Review on Bamboo Utilization as Biocomposites, Pulp and Bioenergy. In *IOP Conference Series: Earth and Environmental Science* (Vol. 141, No. 1, p. 012039). IOP Publishing.
48. Zhou, B. Z., Fu, M. Y., Xie, J. Z., Yang, X. S. and Li, Z. C. (2005). Ecological functions of bamboo forest: Research and application. *Journal of Forestry Research* 16:143–47.

Chapter 6

Edible Bamboo- Nutritional Importance and Value addition

Ghan Shyam Abrol, A.K. Pandey, Priyanka Sharma and Gaurav Sharma
College of Horticulture and Forestry, RLBCAU, Jhansi

Though bamboo shoot is not a popular food commodity in the Indian sub-continent, it is a delicacy in the north-eastern states being used in fresh and fermented forms. Bamboo shoots have high content of proteins, carbohydrates, minerals, fibre and vitamins and are even richer in nutrient components than some of the commonly used vegetables (Bajwa *et al*., 2019). They are endowed with health enhancing properties due to the presence of phenols, phytosterols and fibre (Behera and Balaji, 2021). However, this highly nutritious vegetable is being neglected and replaced by other food items and its usage in local households is gradually diminishing. Very few people are aware of the nutritive value of the shoots and with the passage of time, it is becoming neglected as other indigenous plants like finger millet, buckwheat, taro, amaranth etc. and considered as food of the tribal's and poor people. Concerted efforts need to be taken up to utilize this natural resource not only to meet the increasing demand of food and food security in the region but also to encounter malnutrition widely prevalent in the country and provide income generation for the local people (Awuchi *et al*., 2020). Despite the enormous production of bamboo shoots in the country, processing and packaging of the shoots is in its infancy with only a few units being operational. Taking into account the increasing demand of bamboo shoots worldwide, and the enormous economic potential, development programs need to be framed for utilizing the vast resource to generate employment opportunities for the weaker sections of the society and help in their social and economic prosperity.

Bamboo shoot as a Health Food

Soft juvenile bamboo shoots of all most all species are used as food by all tribes and ethnic groups of the north eastern region. However, there are some species like *Bambusa balcooa, B. bambos, B. tulda, Dendrocalamus giganteus, D. hamiltonii, Melocanna baccifera, Chimonobambusa callosa, D. hookerii, D. giganteus, D. sikkimensis*, etc. which are preferred. The young shoots are either used fresh or fermented and dried for later use. In terms of yield, it is *Dendrocalamus species (D. hamiltonii, D. sikkimensis, and D. giganteus*) which are harvested maximum for shoots (Rai and Chauhan, 1998). Every tribe or ethnic groups of the region have their own methods of fermentation and use of bamboo shoots as food (Nimachow *et al*., 2010). The Khasi people in Meghalaya mainly ferment shoots in plastic or glass bottles filled with water, whereas Meiteis of Manipur ferment bamboo shoots in black clay pots or in bamboo baskets. Generally bamboo shoots, fresh or fermented are used for making pickles, curry like Soibum (by Meiteis) or prepared with pork (by Khasis) (Madhab, 2003). However, these cuisines are traditional followed for generations and may not be palatable to all. Hence, new cuisines should be developed taking into account the changing food habits of the modern world. There is a need to develop new food items from bamboo shoots to popularize it as an important health food as well as a solution for food security in the region. In developed countries, bamboo shoots are an ingredient of food items such as cookies, dairy and meat products, beverages, ketchups etc. and because these are popular food items, they are readily consumed by people (Choudhury *et al*., 2012).

Though bamboo shoots have been a popular food commodity for generations in the region, with changing trends in the food habit, it has become a neglected food item. Younger generations are not aware of the nutritional value of the shoots (Chongtham *et al*., 2011). It is generally despised as tribal or village food and do not find any place in the plates of city people. Very few people know that worldwide bamboo is listed third out of six most healthy foods. Also people in the region are not aware that phytosterols present in bamboo shoots have the cholesterol lowering activity and it is termed as appetizer due to presence of high cellulosic content in it (Chongtham *et al*., 2020). The fiber content in the bamboo shoots which ranges from 3-5 g/100 of fresh weight helps in lowering cholesterol in blood and bamboo shoots are known to protect neurons from oxidative stress and have anti-fatigue activity. Bamboo shoots have many amino acids and minerals like potassium, phosphorus, sodium, magnesium, calcium, etc which are absent in many common vegetables that people take in the region. Bamboo shoots have many medicinal benefits from preventing cardiovascular diseases, cancer and weight loss to improve digestion. Due to high potassium content in shoots, bamboo is considered as heart protective vegetable.

Nutritional Importance

Bamboo is one kind of idle vegetable for its being pollution free, low in fat, high in edible fibre and rich in mineral elements (Bhatt *et al*., 2005). Bamboo shoot is brittle, tender, delicious and nutritive. It is shown by chemical determination that fresh shoot contains about 88.8 % of water, over 3.9% of protein, 17 amino acid. Amino acid content of bamboo is much higher than found in other common vegetable such as cabbage, carrot, onion and pumpkin. Eight kinds of amino acids that are not synthesized in the human body have to be supplied from food items and almost all these are available in bamboo shoots. Bamboo shoots contain 17 different types of enzymes and over ten kinds of mineral elements such as Chromium, Zinc, Manganese, Iron, Magnesium, Nickel, Cobalt, Cupper etc. and particularly Selenium content is very important because, lack of this element in the body can cause 40 sorts of diseases (Nongdam and Tikendra, 2014). Another important thing is bamboo shoot content Germaclinum, which can activate human body.

Be it fresh, dried, shredded or pickled, bamboo shoots have formed a part of the traditional cuisine in most parts on India. Since bamboo shoots are high in fibre content, they help in preventing chronic constipation and promoting healthier bowel movements. The shoots help in removing stomach worms and reduce LDL (bad) cholesterol in the body. Since they are low in calories, bamboo shoots prove to be perfect for obese persons, who are trying to reduce weight. Being an excellent source of potassium, the shoots help in lowering high blood pressure. A good source of phenolic acids, with anti-oxidant and anti-inflammatory properties, bamboo shoots reduce the risk of various chronic diseases including heart disease. They also help in curing toxemia (internal poisoning). The shoots contain phyto-chemicals that are potent antioxidants and have anti-cancer, anti-bacterial and anti-fungal properties.

Nutrition status of Bamboo:

Shoots: Bamboo shoots are low in fat and calories. One cup of half-inch long slices contains a mere 14 calories and half a gram of fat. The shoots are a good source of fibre. The same serving size provides about 2.5 grams of fibre; which is approximately 10% of the recommended amount needed in a day. Fibre helps keep cholesterol levels in check and plays a role in preventing colon cancer (Nirmala *et al*., 2001). Bamboo shoots are also a good source of potassium. One cup provides 640 milligrams, which is 18% of the daily recommended amount. Potassium is a heart-healthy mineral. It helps to maintain normal blood pressure and a steady heart beat. When it comes to photochemical, natural substances found in plants, bamboo shoots hold promise. They contain lignans and phenolic acids. Lignans, a component of fibre, exhibit a number of important related to health benefits (Nirmala *et al*., 2011). Lignans appear to have anticancer, antibacterial, antifungal and antiviral activity. Phenolic acids have mild anti-inflammatory properties and are potent antioxidants. Antioxidants help prevent cancer and the blood vessel injury that can start atherosclerosis.

Table (6.1): Nutritional Value of Bamboo Shoot (Total Weight of Bamboo Shoot: 120 g)

Nutrients	Amount	Nutrients	Amount
Water	115 g	**Vitamins**	
Ash	1.0 g	Riboflavin	0.1 mg
Proteins	1.8 g	Niacin	0.4 mg
Calories		Vitamin B6	0.1 mg
Total Calories	13.2	Foliate	2.4 mcg
Calories From Carbohydrates	6.5	Pantothenic Acid	0.1 mg
Calories From Fat	2.2	**Minerals**	
Calories From Proteins	4.5	Calcium	14.4 mg
Carbohydrates		Magnesium	3.6 mg
Total Carbohydrates	1.8 g	Phosphorus	24.0 mg
Dietary Fibre	1.2 g	Potassium	640 mg
Fats & Fatty Acids		Iron	0.3 mg
Total Fat	0.3 g	Sodium	288 mg
Saturated Fat	0.1 g	Zinc	0.6 mg
Poly-saturated Fat	0.1 g	Copper	0.1 mg
Omega-3 Fatty Acids	18.0 mg	Manganese	0.1 mg
Omega-6 Fatty Acids	99.6 mg	Selenium	0.5 mcg

Source: Nirmala *et al*., 2007; Nirmala *et al*., 2011; Chongtham *et al*., 2011

Edible Bamboo Shoots: Of the 1575 known bamboo species worldwide, 110 species are recorded to have edible shoots. Edible meaning a satisfactory to delicious taste, because even though some bamboo shoots are classified as edible, they must be carefully prepared and boiled before consuming. Bamboo shoots may contain significant, potentially very toxic amounts of cyanogenic glycosides (Padilla-González *et al*., 2021). Various reports even place bamboo shoots amongst the most potentially toxic plant materials, exceeding apricot, bitter almond stones and considerably exceeding that of cassava. However, the cyanogenic glycoside in bamboo is in fact taxiphyllin. Taxiphyllin is unusual amongst other similar compounds in the sense that it degrades readily in boiling water. Thus, boiling bamboo shoots or cooking bamboo shoots should remove any problem.

Table (6.2): Nutrient content of different shoots of some important bamboo species

Nutrients	***B. bamboos***	***B. nutans***	***B. polymorpha***	***B. tulda***	***B. vulgaris***	***D. asper***	***D. giganteus***
Amino acids (g/100 g)	3.98	3.89	3.42	3.65	3.57	3.12	3.96
Protein (g/100 g)	3.57	2.84	3.64	3.69	3.64	3.59	3.11
Carbohydrate (g/100 g)	5.42	5.47	5.44	6.92	6.51	4.90	5.10
Fats (g/100 g)	0.50	0.40	0.46	0.48	0.50	0.40	0.39
Fibres (g/100 g)	4.49	2.28	3.81	3.97	4.24	3.54	2.60
Vitamin C (mg/100 g)	1.90	1.19	2.60	1.42	4.80	3.20	3.28
Vitamin E (mg/100 g)	0.61	0.47	0.49	0.61	0.52	0.91	0.69
Calcium (mg/100 g)	0.36	1500	180.69	1300	320	5.51	26.93
Phosphorus (mg/100 g)	30.12	900	15.06	700	220	40.95	12.57
Iron (mg/100 g)	3.00	-	1.53	1.57	-	3.37	1.06
Sodium (mg/100 g)	10.10	-	-	12.96	400	10.14	3.64
Potassium (mg/100 gm)	-	30.0	-	20.0	920	464	275
Magnesium (mg/100 gm)	5.38	40.0	-	40.0	100	10.14	9.57

Source: Nirmala *et al*., 2007; Nirmala *et al*., 2011; Chongtham *et al*., 2011; Padilla-González *et al*., 2021

Fresh harvest of bamboo shoots: Bamboo is a member of the grass family. Bamboo shoots are young, new canes that are harvested for food before they are two weeks old or one-foot tall. Bamboo shoots are crisp and tender, comparable to asparagus, with a flavor similar to corn. They are used frequently in Asian cuisine. Commercially canned bamboo shoots are common, but fresh, locally grown bamboo has far better flavor and texture (Pandey *et al*., 2012).

Storage: Fresh bamboo shoots can be stored in the refrigerator for up to two weeks. A bitter taste develops if kept longer than this, or if the shoots are exposed to sunlight. Store whole, unpeeled bamboo shoots in the crisper drawer of the refrigerator. Fresh shoots can also be cooked then frozen (Pandey *et al*., 2012).

Uses of Bamboo Shoots for cooking: Raw shoots are bitter tasting and can be hard to digest. Bamboo shoots need to be peeled and cooked before using (Pandey and Ojha, 2014). Do not eat bamboo shoots raw as they are bitter tasting and can be hard to digest. Trim the roots, peel the outer leaves (sheath leaves), and remove any tough flesh of the shoots before cooking (Madhab, 2003). Tender leaves can be left attached and eaten. The shoots should be cut across the grain into one-eighth inch slices. If very tender, the shoot can be cut into any pattern. Cook bamboo shoots in boiling water in an uncovered pan for 20 minutes. Leaving the pan uncovered allows the compounds that cause bitterness to dissipate into the air. If there is any bitter taste to the shoots after cooking, boil them in fresh water for 5 more minutes. Bamboo shoots can also be micro waved, in an uncovered shallow pan of water for four minutes. Shoots will still be crisp and crunchy after cooking, and methods of cooking the bamboo shoots are as:

- Serve as a vegetable side dish with a bit of butter and pepper or soy sauce.
- Add to salads, soups, vegetable combination dishes or stir-fry.
- Stir-fry in a wok and serve with soy sauce and rice.
- Marinate in rice vinegar, sesame oil and soy sauce for several hours.
- Try one of the following delicious recipes

Impact of Food-based Cyanide on Humans: Cyanide can and does cause significant health problems at sub-lethal levels. Some of the cassava-eaters in Africa have suffered harmful effects to the nervous system, including weakness of the fingers and toes, difficulty walking, dimness of vision, and deafness. Some children who ate large quantities of apricot stones, which naturally contain cyanide as part of complex sugars, had rapid breathing, low blood pressure, headaches, and coma, and some died.

Removal of Cyanide from Bamboo Shoots: The cyanogen in bamboo is taxiphyllin and therefore one of the few cyanogenic compounds that decompose quickly when placed in boiling water (Zhong *et al*., 2020; Padilla-González *et al*., 2021). Bamboo becomes edible because of this instability. Boiling bamboo shoots for 20 minutes at 98°C removes nearly 70% of the HCN while all improvements on that (higher temperatures and longer intervals) remove progressively up to 96%. Thus, significant higher quantity of cyanide found in bamboo shoots would be detoxified after cooking them for 2 hours.

References

1. Awuchi, C. G., Victory, I. S., Ikechukwu, A. O., and Echeta C. K. (2020). Health benefits of micronutrients (vitamins and minerals) and their associated deficiency diseases: A systematic review. International Journal of Food Sciences, 3(1), 1-32.
2. Bajwa, H. K., Santosh, O., Koul, A., Bisht, M. S., and Nirmala, C. (2019). Quantitative determination of microelement and microelement content of fresh and processed bamboo shoots by wavelength dispersive X- ray fluorescence spectrometry. X- Ray Spectrometry, 48, 637-643. http://doi.org/10.1002/xrs.3048
3. Behera, P., and Balaji, S. (2021) Health Benefits of Fermented Bamboo Shoots: The Twenty-First Century Green Gold of Northeast India. Appl Biochem Biotechnol 193, 1800–1812. https://doi.org/10.1007/s12010-021-03506-y
4. Bhatt B. P., Singh K., and Singh A. (2005). Nutritional values of some commercial edible bamboo species of the North Eastern Himalayan region, India. *Journal of Bamboo and Rattan* 4(2):111–124. doi: 10.1163/1569159054699317.
5. Chongtham N., Bisht M. S., Haorongbam S. (2011). Nutritional properties of bamboo shoots: potential and prospects for utilization as health food. Comprehensive Reviews in Food Science and Food Safety. 10(3):153–168. doi: 10.1111/j.1541-4337.2011.00147.x.
6. Chongtham, N., Bisht, M. S., Bajwa, H. K., Santosh, O., and Indira, A. (2020). Mineral elements in Bamboo shoots and Potential role in Food Fortification. Journal of Food Composition and Analysis, 103662. doi:10.1016/j.jfca.2020.103662
7. Choudhury, D., Sahu, J. K., and Sharma, G. D. (2012). Value addition to bamboo shoots: a review. Journal of food science and technology, 49(4), 407–414. https://doi.org/10.1007/s13197-011-0379-z
8. Madhab, J. (2003). The Green Gold: Under Exploited Wealth of the North-East India. Dialogue, 5 (2), 45-52.
9. Nimachow, G., Rawat, J. S. and Dai, Y. (2010). Prospects of bamboo shoot processing in North-East India. Curr. Sci, 98, 288.
10. Nirmala, C., Bisht, M.S., and Sheena, H. (2011). Nutritional Properties of Bamboo Shoots: Potential and Prospects for Utilization as a Health Food. Comprehensive Reviews Food Science Food Safety, 10, 153-165.
11. Nirmala, C., David, E. and Sharma, M.L. (2007). Changes in nutrient components during ageing of emerging juvenile bamboo shoots. International Journal of Food Science and Nutrition, 58: 345-52.
12. Nirmala, C., Madhoo, S.B. and Sheena, H. (2001). Nutritional Properties of Bamboo Shoots: Potential and Prospects for Utilization as a Health Food. Comprehensive Reviews in Food Science and Food Safety, 10:153-169.
13. Nongdam, P., and Tikendra, L. (2014). The Nutritional Facts of Bamboo Shoots and Their Usage as Important Traditional Foods of Northeast India. *International Scholarly Research Notices*, 2014, 679073. https://doi.org/10.1155/2014/679073
14. Padilla-González, G. F., Sadgrove, N. J., Rosselli, A., Langat, M. K., Fang, R., and Simmonds, M. S. J. (2021). Cyanogenic Derivatives as Chemical Markers for the Authentication of Commercial Products of Bamboo Shoots. Journal of Agricultural and Food Chemistry, 69(34), 9915–9923.
15. Pandey A.K., Ojha V. and Choubey S.K. (2012). Development and Shelf-life Evaluation of Value Added Edible Products from Bamboo Shoots. American Journal of Food Technology, 7: 363-371.

16. Pandey, A. K., and Ojha, V. (2014). Precooking processing of bamboo shoots for removal of anti-nutrients. Journal of Food Science and Technology, 51(1), 43-50. DOI: 10.1007/s13197-011-0463-4
17. Rai, S.N. and Chauhan, K.V.S. (1998). Distribution and growing Stock of Bamboo in India. Indian Forester, 124(2):89-98.
18. Santosh, O., Bajwa, H. K., Bisht, M. S., and Nirmala, C. (2019). Functional biscuits from bamboo shoots: Enrichment of nutrients, bioactive compounds and minerals in bamboo shoot paste fortified biscuits. International Journal of Food Science and Nutrition, 4(1), 89-94.
19. Satya, S., Bal, L.M., Singhal, P., and Naik, S.N. (2010). Bamboo shoot processing: food quality and safety aspect (a review) Trends Food Sci Technol., 2(4):181–189. doi: 10.1016/j.tifs.2009.11.002.
20. Wróblewska, K. B., C.S. de Oliveira, D., Tereza Grombone-Guaratini, M., and Roberto H. Moreno, P. (2019). Medicinal Properties of Bamboos. Pharmacognosy - Medicinal Plants. doi:10.5772/intechopen.82005
21. Zhong, Y., Xu, T., Chen, Q., Li, K., Zhang, Z., Song, H., and Lu, B. (2020). Development and validation of eight cyanogenic glucosides via ultra-high-performance liquid chromatography-tandem mass spectrometry in agri-food. Food Chemistry, 127305. doi:10.1016/j.foodchem

Chapter 7

Harnessing the Potential of Bamboo as Alternative to Wood

Amey Kale

College of Horticulture and Forestry, RLBCAU, Jhansi

Bamboo is one of the most utilised material, for construction purpose by mankind. Traditionally the native tribes have been using bamboo for various purposes. For tribal people, bamboo, is a mainly rich source of nutritious food. Tribal of North East India, Odisha, Bengal Western Maharashtra, Kerala & Tamil Nadu; bamboo is widely used material for number of purposes. Humans are using bamboo for making Shelters, ropes, clothing, bridges, rafts, boats & agricultural implements. The forest dwellers have been using bamboo for making bow and arrow for hunting; of course now a days hunting is prohibited but even though bow and arrows made from bamboo are used for sports in villages. Bamboo is a very versatile material it can support the load, in load bearing applications as well as it is used for making handicrafts. Bamboo is very strong material that it can compared with the solid wood and other man made constructional material like Steel. It is used in aquaculture, fishing nets; in submerged conditions in salt water as well as in fresh water. For paper and pulp industry, it is widely sought raw material for pulping. Bamboo fibres are long, strong and bamboo contains less amount of Lignin in it compared to other raw material used in pulping. Thus it reduces the cost in bleaching the material. Bamboo is used for charcoal making and for cooking purposes also by non-urban population of India.

Table (7.1): Economically important bamboo species in India

Sr. No.	Species	Sr. No.	Species
1	*Bambusa bambos*	10	*D. hamiltonii*
2	*B. nutans*	11	*D. stocksii*
3	*B. pallida*	12	*D. strictus*
4	*B. polymorpha*	13	*D. asper*
5	*B. tulda*	14	*Guadua angustifolia*
6	*B. vulgaris*	15	*Meloconna baccifera*
7	*B. balcooa*	16	*Ochlandra travancorica*
8	*Dendrocalamus brandisii*	17	*Schizostachym dullooa*
9	*D. giganteus*	18	*Phyllostachys bambusoides*

The Handicrafts of Bamboo is one among the oldest crafts better-known to man. In trendy days, numerous types of decorative things are created out of cane and bamboo. The Bamboo craft is full time employment for thousands of individuals in India (www.handicrafts.nic.in). About 1,500 traditional bamboo applications have been documented in India.

Several types of biomasses are used in rural area for meeting energy needs (Sims *et* *al.* 2006). Among them bamboo is potential raw material for bioenergy. The total growing stock of bamboo in India is around 180 $\times 10^6$ tons, including bamboo grown in forested and non-forested areas. India is the second major bamboo producing country with 16 MHa (22.46 %) of a total forest area out of a total of 71.2 MHa (FSI, 2019).Bamboo forests cover almost 15.69 million ha area in India (ISFR 2017). Being fast growing plant, Bamboo produces more biomass per ha than wood and has the potential to substitute wood in many ways (singh 2008). The calorific value of bamboo ranges between 18.7–19.6 $MJ \cdot kg^{-1}$ and fuel value index ranges between 586–2120 (Kumar 2014). Bamboo is alternative solution to ever increasing need of fuel wood, reducing the pressure on existing forests. Utilization of bamboo for power production is achieving success in many countries (Qisheng Z 2002). Bamboo produces excellent charcoal for domestic purpose as well as fuel for gasifiers (Saikia et al. 2007). In India, many northeastern states like Assam, Manipur and Mizoram are establishing bamboo based power plants for electricity production.

Bamboo as alternative source

Bamboo as we all know, is called as the 'poor man's timber.' It is said so for many reasons; right from its multidimensional utility to its vast variability and plenty of availability. According to National Forest Policy 1988, the felling of timber from the natural forest is banned. Hence, the Indian timber industry is heavily relying on the imports. Marginal need of the wood industry are fulfilled by the wood obtained from the plantations, Agroforestry or from trees felled in developmental projects, like road construction, Industrial developments etc. Scarcity of the solid wood, opens up door for the bamboo. Solid bamboo as we know it, is traditionally used for construction purpose, because of its good strength properties; which are comparable to other construction material like wood and steel. GoI encourages the more and more use of bamboo in round or the other forms. By the launch of National Bamboo Mission (NBM) in year 2006-2007, bamboo plantation on Government and private lands in increasing. This is helping in supplementing farm income and contribute towards resilience to climate change as well as availability of quality raw material requirements of industries. India is also contributing member in International Bamboo and Rattan Organisation, since 1998. Bamboo and rattan are astounding resources with unique potential to combat poverty and natural resources challenges. Since its founding in 1997, it's making significant contribution and making a real difference to the lives of millions of people using bamboo and bamboo products; making resilient bamboo construction & restoring degraded land.

Fair bit of efforts are made during the last few decades, in evaluating the properties of the bamboo and value addition. Bamboo is a short rotation crop. The bamboo clumps can be harvested within 3-4 years of plantation. Many bamboo species have been explored, for their potential applications in furniture making as well as bamboo based composites. The natural durability of bamboo is being main research focus in using solid bamboos. Depending upon the species and end use, natural durability of the bamboo varies anywhere between 2 to 36 months, because of fast deterioration due attack of insects, rotting and staining fungi. The degradation of bamboo components is amplified by the moisture and climatic conditions.

Split bamboo strips are more vulnerable to weather conditions than the solid round bamboo.

The alarming rates at which our natural forests are disappearing, foresters are paying more attention towards short rotation forest trees, catering the needs of wood and wood based industries. In view of shrinking supply of timber form the natural forests, lot of attention is being paid on the utilization of bamboo, seen as the replacement to solid wood. Bamboo the versatile grass, have immense capacity to produce maximum biomass per unit area, compared to other woody material. With advancement in wood science and technology, bamboo can be made more robust and more serviceable in the modern world. It is truly said that "bamboo-friend of the people" and "the cradle to coffin species"

Bamboo physical properties

There about 136 species found in India. The abundantly available material has to be used in efficient manner. The vast resource material like bamboo can have great impact on environment and economy of the country. Since advent of the 20th century, bamboo has established itself a potential raw material for composites such as, particleboard, medium density fiberboard, hard fibreboard, laminated composites, oriented strand, board, zephyr board, inorganic-bonded board, wood plastic composites etc. Similar to wood, bamboo is a heterogeneous and anisotropic material. Therefore, its mechanical properties are extremely variable and closely dependent on the anatomical characteristics, culm height, culm location and density. Bamboos are having very specific properties, easy workability and low cost of production. The bamboo culm developments and maturity of culms is faster (within 3-4 years). Culm straightness, toughness, strength, easy to cut and split, light weight even though its tough material. Culms are useful to mankind in every step of life, making it 'green gold' to villagers. Straight, Long and soft bamboo fibers are comparable to wood fibers. Some bamboo species are hollow in nature, some are characterized as solid bamboo as *Dendrocalamus stocksii*, *Dendrocalamus strictus.* The strengths of many bamboo species are at par with some of the timber species. The partitioning walls between the internodes of the bamboo make it very strong as compared to wood, and very hard to bend. Bamboo are having smooth, shiny and clean surface, creating some difficulties in treating them with preservative solution. Freshly felled, green bamboo have higher amount of sap content. Bamboos can be easily cut and split in required lengths strips to make number of items. Thin strips are very flexible in nature and can be used for making mats, baskets, woven sheets etc. When we say that bamboo is potential alternative to replacing the wood, teak is gold standard for wood. If we look at the mechanical properties of the some of the bamboo species compared with teak, bamboo is as good as teak.

Table (7.2): Comparison of strength properties of bamboo with teak

Species	Specific gravity	MOR (kg/cm^2)	Max crushing stress (kg/cm^2)
Dendrocalamun stocksii	0.691	620	386
Bamboosa nutans	0.603	529	456
B. bambos	0.584	836	572
D. strictus	0.631	734	359

Tectona grandis	0.604	959	532

Rao *et al*. 2004.

In general, bamboo is stronger than wood in bending strength, compression strength parallel to grain and is similar in shear strength parallel to grain. The strength of bamboo along the direction of grains is extremely high, especially modulus of rupture (MOR) and modulus of elasticity (MOE). Table 2 shows the comparison of strength properties of spruce wood, steel, and bamboo. Bamboo possesses higher compressive and tensile strengths when compared with spruce wood, but lower when compared with steel.

The data indicate (Table 3) that bamboo is stronger in bending than timber, and its strength-to-weight ratio (expressed as MOR/specific gravity) is greater than that of all materials listed except carbon fiber. Not only is bamboo fast-growing, but it is also highly efficient in comparison to other raw structural materials.

Table (7.3): Comparison of Bending Properties of Bamboo to Other Common Building Materials

Building materials	Specific gravity	MOE (GPa)	MOR (MPa)	MOR to specific gravity ratio (MPa)
Giant timber bamboo*	0.52	10.7	102.7	197.5
Other bamboo*	—	9.0–20.7	97.9–137.9	—
Loblolly pine^	0.51	12.3	88	172.5
Douglas-fir^	0.45	13.6	88	195.6
Cast iron$	6.97	190	200	28.7
Aluminum alloy$	2.72	69	200	73.4
Structural steel$	7.85	200	400	50.9
Carbon fiber$	1.76	150.3	5,650.00	3,205.10

* Lee et al. 1998, ^Forest Products Laboratory 1999, $Rittironk and Elnieiri 2007.

The main characteristics of bamboos arte listed here –

- Size availability
- Straight culm
- Light weight
- Average density and minimum shrinkage
- Good tensile & flexural strength
- Short rotation age
- Sustainable renewable material
- Suitability to replace the wood in many ways
- Easy handling
- Cost effective

Chemical composition of bamboo and Bamboo fibers:

Wood and bamboo are similar in chemical composition. Table 4 shows the chemical composition of the bamboo. The main constituents of bamboo culms are cellulose, hemi-cellulose and lignin, which amount to over 90% of the total mass. The minor constituents of bamboo are resins, tannins, waxes and inorganic salts. Compared with wood, however, bamboo has higher alkaline extractives, ash and silica contents (Tomalang *et al.* 1980; Chen *et al.* 1985).

Yusoff *et al.* (1992) studied the chemical composition of one, two, and three year old bamboo (*Gigantochloa scortechinii*). The results indicated that the holocellulose content did not vary much among different ages of bamboo. Alpha-cellulose, lignin, extractives, pentosan, ash and silica content increased with increasing age of bamboo. Bamboo contains other organic composition in addition to cellulose and lignin. It contains about 2-6% starch, 2% deoxidized saccharide, 2-4% fat, and 0.8-6% protein. The carbohydrate content of bamboo plays an important role in its durability and service life. Durability of bamboo against mold, fungal and borers attack is strongly associated with its chemical composition. Bamboo is known to be susceptible to fungal and insect attack. The presence of large amounts of starch makes bamboo highly susceptible to attack by staining fungi and powder-post beetles (Mathew and Nair 1990). Silica content is the highest in the epidermis, with very little in the nodes and is absent in the internodes. Higher ash content in some bamboo species can adversely affect the processing machinery.

Table (7. 4): Chemical composition of the bamboo

Lignin (%)	26.1
Cellulose (%)	49.1
Pentosan (%)	27.7
Ash (%)	1.3
Ethanoltoluene Extractives (%)	4.6

The chemical composition of bamboo fibre constitutes mainly cellulose, hemicelluloses and lignin. These components are actually same high-glycans, and make about 90% of total weight of bamboo fibre. The other constituents are protein, fat, pectin, tannins, pigments and ash. These constituents play important role in physiological activity of bamboo and they are found in cell cavity or special organelles. The chemical composition of the bamboo fibre is given in Figure 1 (Wang *et al.*, 2010). Usually the chemical content of bamboo changes with age of the bamboo, particularly cellulose content keeps on decreasing while age of bamboo is increased so directly it directly affects the chemical composition of bamboo fibre.

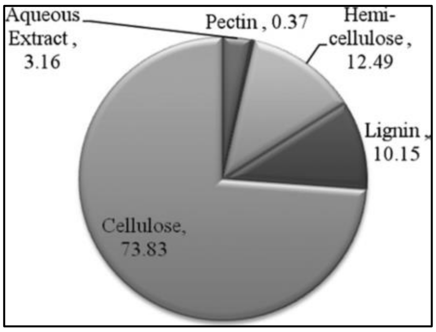


Figure 1: Chemical constituents of Bamboo fibre (Source: Wang 2010, Li 2010)

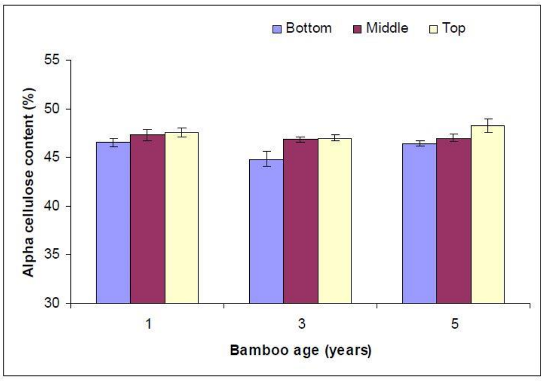


Figure 2: Alpha-cellulose content of bamboo at different age and height location (Source: Li, 2004)

Analysis has shown that Analysis of variance showed that age had no significant effect on alphacellulose content (Li 2004). In general, the alpha-cellulose content in bamboo is 40-50%, which is compatible to the reported cellulose content of softwoods (40-52%) and hardwoods (38- 56%). Cellulose contents in this range make bamboo a suitable raw material for the paper and pulp industry.

Bamboo anatomy

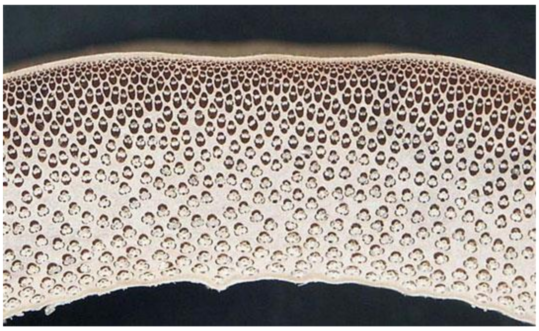


Figure 4: Microstructure of Bamboo (Source: Shukla, 2020)

The structure of a bamboo culm transverse section is characterized by numerous vascular bundles embedded in the parenchymatous ground tissue. The culm tissue consists of two cell types: parenchyma cells and vascular bundles. The parenchyma cells are mostly thin-walled and connected to each other by numerous simple pits. Pits are located predominantly on the longitudinal walls. The horizontal walls are scarcely pitted. The size of the vascular bundle is large in the inner and middle layer but smaller and denser in the outer layer (Li 2004). Outer most layer of culm is about 0.25 mm thick, smooth and shiny, containing silica to protect plant. Vessels take care of the transport of liquids during the life of the bamboo. Bamboo, does not have any rays.

The bamboo culm comprises about 50% parenchyma, 40% fibers and 10% vessels and sieve tubes. The fibers contribute 60-70% of the weight of the total culm tissue. They are long and tapered at their ends. The ratio of length to width varies between 150:1 and 250:1. Fiber length has showed considerable variation within species. Mean values are: *Bambusa tulda* 3 mm, *B. vlgaris* 2.3 mm, *Dendrocalamus giganteus* 3.2 mm, *Guadua angustifolia* 1.6 mm, *Phyllostachys edulis* 1.5 mm. Generally, the fibers are much longer than those from hardwoods (1-1.5 mm) (Liese 1987, 1995). Fibers in bamboos are grouped in bundles and sheaths around the vessels.

Bamboo based composites

The demand for the industrial round wood is ever increasing in India. India is one of the leading importers of round wood in world. According to data provided by the International Tropical Trade Organization (ITTO), in the year 2020, India has imported around 130574.95 thousand m^3 of industrial round wood. Bamboo is potentially seen as the way to put some curbs on the huge imports and replace the wood to some extent. Apart from use of solid bamboo in construction and other applications, bamboo composites made form bamboo particles, strands, husk and bamboo fibres combined with cement, plastics is being used extensively.

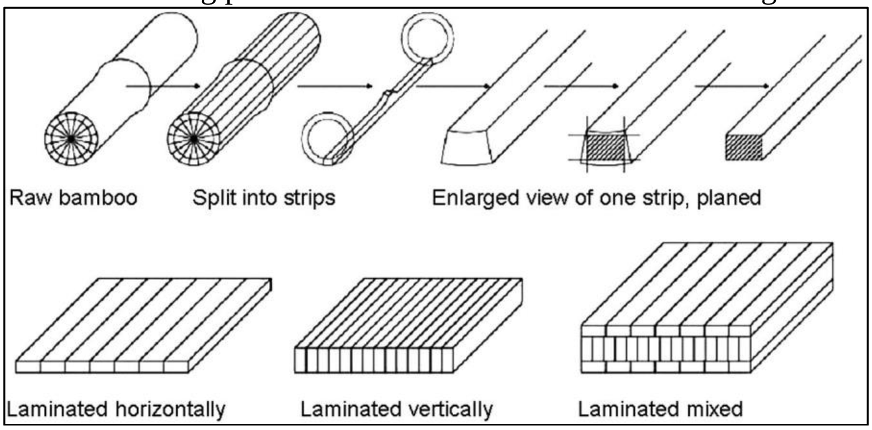
Development of bamboo strip based panel products such as bamboo timber, bamboo lumber, bamboo laminates are gaining importance as these products resemble with wood when used in a particular fashion as in parallel laminates. Bamboo based composites are durable, stable and environmental friendly. Synthetic resin adhesives are used for bonding bamboo strips. These laminates will have superior physical and mechanical properties and suitable for structural and other specialized applications. Bamboo can be processed into various engineered composite materials like Laminated Bamboo Lumber (LBL) and Bamboo Strand Lumber (BSL) through various modern technological interventions. Institute of Wood Science and Technology (IWST) and Indian Plywood Industries research & Training Institute (IPIRTI) both located at Bangalore are actively involved in developing bamboo based composites and improving the service life of the bamboo culms.

Table 7.5: Important Indian Standards (IS) related to bamboo

BIS Code No.	Title of IS Standard
IS 6874:2008	Method of Tests for Bamboo
IS 8242:1976	Method of Tests for Split Bamboo
IS 1902:1993	Code of Practice for Preservation of Bamboo and Cane for non structural purposes
IS 9096:1979	Code of Practice for Preservation of Bamboo and Cane for Structural purposes
IS 14588:1999	Specification for Bamboo Mat Veneer Composite for General Purposes
IS 13958:1994	Specification for Bamboo Mat Board for General Purposes
IS 8295:1976	Specification for Bamboo Chicks ; Part 1 Fine, Part 2 Coarse
IS 7344:1974	Specification for Bamboo Tent Pole
IS 15476: 2004	Specification for Bamboo Mat Corrugated Sheets

The LBL is an engineered composite which utilizes processed bamboo strips or splits whereas the BSL is produced with crushed bamboo strands bonded with structural grade adhesives like phenol formaldehyde (PF). LBL maintains the inherent strength properties of bamboo while additionally addresses the drawbacks which occur in the processing and utilization of round bamboo. The LBL provides a material with regular cross sections which has numerous opportunities for its utlization in load bearing applications.

Figure 3: Manufacturing process of laminated bamboo lumber using bamboo strips



The LBL can be manufactured into various sizes and shapes depending upon the availability of processing equipments. However, the performance of engineered bamboo composites is highly dependent on the processing parameters used for the production.

Bamboo Mat Boards, is also one of the composite developed by the IPIRTI. Bamboo mats are woven from bamboo slivers manually. Women bamboo mats are dipped in modified phenol formaldehyde resin mixed with a preservative to increase resistance to termite and decay. After application of glue mats are aligned one over the other and hot pressed in hot pressing machine.

Figure 4: Bamboo Mat Board

Investigations were also carried out by the Forest Research Institute, Dehradun and IPIRTI to develop the Corrugated Bamboo Mat Sheet (BMCS). Extensive experiments were carried out using woven bamboo mats of *Melaconna bambusoides* & *Ochlandra travancorica* that were dipped in phenol formaldehyde resin and pressed under temperature and pressure. Sheets made were subjected to rigorous testing for evaluating bond integrity. BMCS thus produced were subjected to performance tests like load bearing capacity, water permeability test, resistance to boiling water and weather ability and found to process excellent load bearing capacity. Institute has developed after extensive research has resulted in the development of Bamboo Mat High Density Panel (Compreg), Bamboo Mat Moulded Skin Board (BMMSB), Bamboo Mat Ridge Cap (BMRCS), Bamboo flattened board and Bamboo laminated lumber.

IWST, has developed the lingo-cellulosic thermoplastic composites a new age composite material. Shredded bamboo fibres are used as reinforcing material with thermoplastics such as polypropylene (PP), Polyethylene (PE), High density Polyethylene (HDPE), etc. for making such bio-fibre reinforced composite materials. Over the years natural fibres like jute, flax, wheat straw, kenaf, hemp, bamboo, coir, bagasse etc. have been explored by the researchers. Blending of polymers with fillers is a powerful way to produce newer materials with a desirable combination of properties unavailable with a single component. Typical desired properties are improved stiffness, thermal stability, tensile and bending strength, reduced shrinkage of molded parts and reduced wear due to usage and environmental factors. But the challenging part in making such composites, is that the surface energies of the polymer and fibres is different; also polymers are hydrophobic in nature and fibers are hydrophilic in nature. Institute has undertaken a systematic study to improve the interfacial adhesion between natural fibers and matrix materials.

Products development and utilization for different applications requires efforts not only form government organizations but private industries contribution is also needed. KONBAC a non-profit organization is a leading innovator in the Bamboo sector and is dedicated to promoting Bamboo as a Sustainable Material and as an alternative to current limited planetary resources like wood. Spectalite, a bio-composite material manufacturing company, makes use of fast renewable material like bamboo and agricultural crop waste material to manufacture truly sustainable products across industries like automotive, housewares, toys, packaging & disposables. Recently

Bamboo based composites are suitable for not only for construction & panelling purpose, but they are also employed in making light weight, economical and yet robust boats.

Water Transport & Mobility at Akvotransiro Tech Pvt Ltd. is in process of making river boats making use bamboo composites in Assam. Under this project, one proof of concept river boat using the stitch and glue technique as a demonstration model for the replacement of the fleet of accident-prone leaky wooden country boats that currently ply the Indian waterways, is being made. 70% of it's hull and deck construction material will be locally produced. (www.linkedin.com).

Source: Spectalite

Dias made from bamboo composite

Pen stand made from Bamboo thermoplastic composite by IWST

Conclusion

Bamboo has huge potential in making number of products, and India has large amount of bamboo resources available. According to FSI 2019, India has 16 MHa of bamboo Forest, which is more than that of China. Hence the promotion and development of bamboo and bamboo based products is need of the hour. The focus of the Indian Bamboo industry should be on manufacturing the products of international standard, exporting them and improving the Indian economy, giving employment options to the urban and rural youths.

References:

1. Chen, Y.D., W.L. Qin, et al.. 1985. The chemical composition of Ten Bamboo Species. In: (A. N. Rao, et al., eds.). Recent research on bamboo. Proceedings of the International Bamboo Workshop, Hangzhou, China, 6-14 October. Chinese Academy of Forestry, Beijing China; International Development Research Center, Ottawa, Canada. pp. 110- 113.
2. Forest Products Laboratory. 1999. “Wood handbook: Wood as an engineering material.” FPL-

GTR-113, U.S. Dept. of Agriculture, Forest Service, Madison, WI.
3. FSI, 2019. Indian State of Forest Report 2019 Chapter 8 - Bamboo Resources of the Country. 16th ed. Dehradun – 248195, Uttarakhand, India.
4. India State of Forest Report, 2017. Forest Survey of India. https://fsi.nic.in › forest-report-2017
5. Kumar, Ritesh and Chandrashekar, N. 2014. Fuel properties and combustion characteristics of some promising bamboo species in India. Journal of Forestry Research; 25(2): 471− 476.
6. Lee, A. W. C., Bai, X., and Bangi, P. 1998. "Selected properties of laboratory-made laminated bamboo lumber." Holzforschung, 52, 207–210.
7. Li LJ, Wang YP, Wang G, Cheng HT, Han XJ. 2010. Evaluation of properties of natural bamboo fibre for application in summer textiles. Journal of Fiber Bioengineering and Informatics;3:94–9.
8. Li, Xiaobo. 2004 Physical, chemical, and mechanical properties of Bamboo and its utilization potential for Fiberboard manufacturing. Masters Thesis. Louisiana State University.
9. Liese, W. 1987. Anatomy and properties of bamboo. In: (A.N. Rao, G. Dhanarajan and C.B. Sastry eds.). Recent Research on Bamboos. Chinese Academy of Forestry, China and International Development Research Centre, Canada. pp. 196-208.
10. Liese, W. 1995. Anatomy and utilization of bamboos. European Bamboo Society Journal
11. Mathew, G. and K.S.S. Nair. 1990. Storage pests of bamboos in Kerala. In: (R. Rao, R. Gnanaharan, and C. B. Sastry, Eds.). Bamboos: Current Research. IV. Proc. International Bamboo Workshop, KFRI/IDRC. pp. 212-214. May 6. pp. 5-12.
12. Qisheng Z, Shenxue J, Yongyu T. 2002. Industrial utilization on bamboo. International network for bamboo and rattan, technical report No. 26.
13. Rao R V., S. K. Sharma, P. Kumar, S. Shashikala, R. Sudheendra and Maddurappa. 2004. Wood Quality parameters for improving planting stock of Bambusa arundinacea, Dendrocalamus strictus and Pseudooxytenanthera stocksii. (Project Report IWST/WPU-009)
14. Rittironk, S., and Elnieiri, M. 2007. Investigating laminated bamboo lumber as an alternate to wood lumber in residential construction in the United States. Proc., 1st Int. Conf. on Modern Bamboo Structures, Taylor & Francis, Abingdon, U.K., 83–96.
15. Saikia P, Kataki R, Choudhury PK, Konwer D. 2007. Carbonization of eight bamboo species of northeast India. Energy Sources, 29: 799−805
16. Shukla, S. R. 2020. Training Manual on value-addition - bamboo technologies for Bamboo Artisans and Master Craftsmen. BTSG-ICFRE.
17. Sims REH, Hastings A, Schlamadinger B, Taylor G, Smith P. 2006. Energy crops: current status and future prospects. Global Change Biology, 12(11): 2054−2076.
18. Singh O. 2008. Bamboo for sustainable livelihood in India. Indian Forester, 134 (9): 1193−1198.
19. Tomalang, F. N., A.R. Lopez, J. A. Semara, R.F. Casin, and Z.B. Espiloy. 1980. Properties and utilization of Philippine erect bamboo. In: (G.Lessard and A. Chouinard, eds.). International Seminar on Bamboo Research in Asia. Singapore, May 28-30. Singapore: International Development Research Center and the International Union of Forestry Research Organization. pp. 266-275.
20. Wang YP, Wang G, Cheng HT. 2010. Structures of bamboo fibre for textiles. Text Res J; 84:334–43.
21. www.handicrafts.nic.in/themecrafts/NaturalFiberEFC.aspx accessed on 17th August, 2021.
22. www.linkedin.com/pulse/project-overview-building-lightweight-economical-robust-ravi-deka/ accessed on 17th August, 2021.

23. Yusoff, M.N.M, A. Abd.Kadir, and A.H. Mohamed. 1992. Utilization of bamboo for pulp and paper and medium density fiberboard. In: (W.R.W. Mohd and A.B. Mohamad, eds.). Proceeding of the seminar towards the management, conservation, marketing and utilization of bamboos, FRIM, Kuala Lumpur. pp. 196-205.

Chapter 8

Bamboo flowering: phenomenon and consequences

Swati Shedage and Dipika Ayate
College of Horticulture and Forestry, RLBCAU, Jhansi

Bamboo is an economically and ecologically important species with a high biomass yield due to its fast growth. The bamboos belong to the Poaceae family and subfamily bambusoidae. Bamboos are monocarpic (Species produce seed once in the life cycle) or semelparous and perennial. It is one of the most prominent flowering plant families. There are about 88 genera and 1642 species found worldwide (Voronstova *et al*., 2016). The flowering behavior in bamboo is not fully understood, but most of the research in flowering focuses on periodicity. Bamboos have a long vegetative phase, and their asexually propagating capability is good (Zheng *et al.*, 2020). Contrary to popular myth, all bamboo does not always die after flowering. Only some species of bamboo would be the example of this myth. The flowering is infrequent and dramatic; flowering can weaken the clump of bamboo but can be recovered with proper management. Bamboos have peculiar flowering behavior, which is under genetic control; it is like a genetic clock. Due to this, irregular flowering bamboo seeds cannot be available at regular intervals. In general, bamboo plants flowers in three different ways: gregarious, sporadic, and annual.

Gregarious flowering: This is one of the impressive flowering patterns exhibits in bamboos. In this entire bamboo, plants start flowering at once. Flowering could happen at any interval of 60-120 years, but whenever it happens, it happens simultaneously. In this type of flowering, growing bamboo spends all the energy on flowering and seed-producing. This flowering behavior exhausts the plant, and it takes its life. This type of flowering exhibits all over the world irrespective of its geographical location. Verma and Bahadur (1980) reported the flowering cycle of *Dendrocalamus strictus* is about 20-65 years.

Sporadic Bamboo Flowering: This type of flowering depends on environmental factors and not on genetic factors. In this type, bamboo flowers intermediately and not on a mass scale. Parent plant remains healthier even after the flowering.

Annual flowering: In Northeastern part of India, a number of bamboo species are there, and most of them are herbaceous. Continuous flowering was observed on herbaceous and some woody bamboos. This species keeps successive flowering year after year without impacting its parent plants, but the seed produced annually is significantly less viable. Besides this, some species of bamboos can flowers sporadically as well as gregariously.

Table (8.1). Flowering cycle of some important bamboo species

S. N.	Species	Flowering cycle (year)
1.	*Bambusa balcooa*	32-45
2.	*Bambusa bamboos*	16-52
3.	*Bambusa nutans*	25-35
4.	*Bambusa polymorpha*	35-80
5.	*Bambusa spinosa*	20-100
6.	*Bambusa teres*	35-60
7.	*Bambusa tulda*	15-60
8.	*Bambusa vulgaris*	80-150
9.	*Dendrocalamus asper*	30-120
10	*Dendrocalamus giganteus*	40-76
11	*Dendrocalamus hamiltonii*	25-44
12	*Dendrocalamus hookeri*	117
13	*Dendrocalamus latiflorus*	10
14	*Dendrocalamus longispathus*	20-32
15	*Dendrocalamus membranaceus*	18-20
16	*Dendrocalamus strictus*	7-70
17	*Drepanostachyum polystachyum*	30
18	*Fargesia denudate*	50-63
19	*Gigantochloa nigrociliata*	30-50
20	*Himalayacalamus falconeri*	20-38
21	*Himalayacalamus hookerianus*	30-35
22	*Kuruna wightiana*	Annual
23	*Melocalamus compactiflorus*	7-50
24	*Melocanna baccifera*	7-50
25	*Oxytenanthera abyssinica*	7-30
26	*Phyllostachys aurea*	13-29
27	*Phyllostachys dulcis*	42-43
28	*Schizostachyum lumampao*	20-40
29	*Thamnocalamus spathiflorus*	10-20

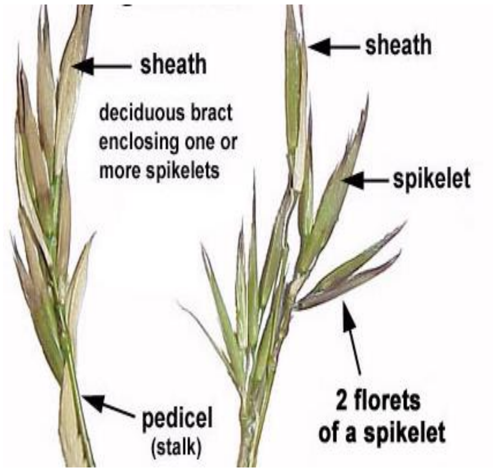
Table (8.2). Flowering cycle of some species of bamboo in North-East India

Species name	Cyclicity (Years)
Dendrocalamus longispathus	16-17
D. strictus	25-65
D. hamiltonii	30-40
Bambusa tulda	30-60
B. polymorpha	35-60
Melaconna baccifera	40-45
B. bambusoides	40-45

Pseudostachyum polymorphum	48
Phyllostachys bambusoides	60

Source: Shridhara and Rajendran (2010)

Bamboo Flower Structure: Information on the floral biology of bamboos is scanty because of its occurrence after long intervals. Based on available data like other grasses, bamboo also produces tiny inflorescence with large branchy panicles with dense and rounded heads. Spikelets are hairy. Florets are a mixing of fertile and sterile ones. Six long stamens are exerted (*Dendrocalamus strictus*). Woody bamboo flowers are always bisexual, while unisexual flowers are found in the herbaceous bamboos (Judziewicz *et al.*, 1999). Anthers are yellow and pointed at the end. Ovary of *Dendrocalamus strictus* is stipitate. The style is long, and the stigma is divided into two equal lobes with feathery appearance and purple (Nadgauda *et al*., 1993). In some species, both androecium and gynoecium mature simultaneously, e.g., *B. arundinacea*, but they heterostyly. In *D. strictus* androecium and gynoecium mature at a different time (dichogamy), protogyny in nature. Bamboo produces wind-pollinated flowers and cross-pollinated. Bamboo clumps height facilitates wind pollination (Shridhara and Rajendran, 2009). Sanchez *et al*. (2017) documented insect visits to the flowers of bamboo, insects visiting *Guadua paniculata* and *G. inermis* flowers were collected in the field. Scanning electron micrographs were taken of the visiting insects. Four species of bees, three from tribe Meliponini (*Geotrigona acapulconis*, *Plebeia frontalis* and *Trigona fulviventris*) and one from tribe Apini (*Apis mellifera*), along with a syrphid fly (*Toxomerus teligera*) were found visiting bamboo flowers.



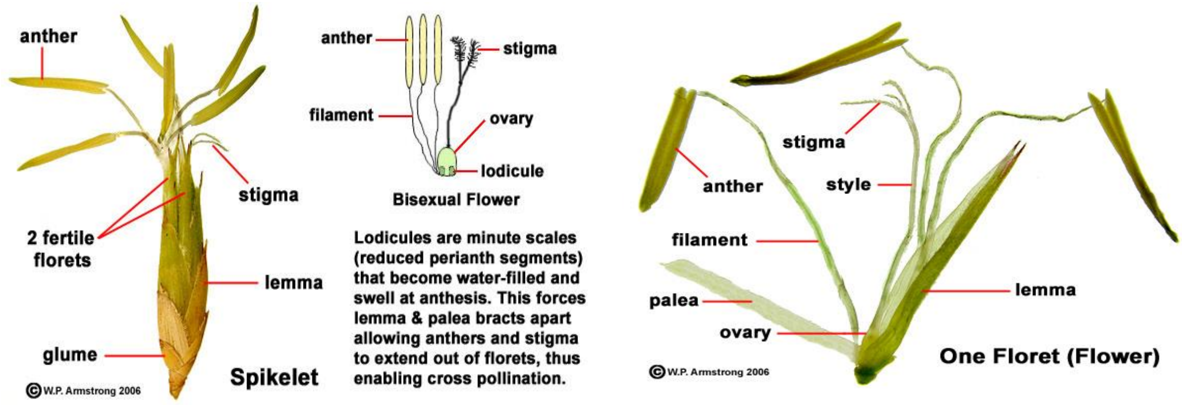


Fig 8.1. Flower Structure of bamboo

Flowering behaviour:

Flowering is one of the most important events in the evolution of land plants. Variation exists in flowering time worldwide, ranging from annual flowering to 120 years of vegetative phase (Janzen 1976). He was the first scientist who gave the interesting theory of the evolution of mast seeding. Generally, flowering in a favorable environment is decided by some complex regulatory mechanisms like photoperiod, vernalization, autonomous, hormonal, and age factors. These all pathways follow in the majority of bamboo species. A number of studies have been done and going on the gene sequencing to know the secret of flowering mechanism in bamboos. In one study on flowering and fruiting of bamboos in Yunnan China, observed that it was 61 species of bamboo possess flowering tendency. The study showed flowering and fruit-bearing phenomena of bamboos are closely related to their living state (wild or cultivated) and connected with their taxonomic position at the genus level (DuFan *et al*., 2000). Park *et al.* (2017) reported that some bamboo culms are simultaneously blooms and die regardless of environmental factors; it may be due to specific genes expressed by the biological clock. Waikhom *et al*. (2014) based on their scanning electron microscopy study of pollen development of *Bamboosa vulgaris* and *Dendrocalamus manipureanus*, provided evidence that genus specificity exists in the development of woody bamboo pollen structure. Rai and Dey (2012) carried out a program to identify programmed cell death-related genes in bamboo (*Bambusa arundinacea)* and identified specific genes of fundamental importance, which could play a vital role in elucidating an underlying mechanism involving programmed cell death in bamboos. *Melocanna baccifera* is a gregarious flowering bamboo in Mizoram during their reproductive phase; in some patches not flowered that escapes the inevitable death, this phenomenon is locally called as 'Mauhak (Sadananda *et al*., 2010).

Consequences:

Bamboo is a predominant under-story species in several Asian forest ecosystems. This understory is has bad influence after flowering in bamboos. Lia Montii *et al.* (2011) conducted a study in a neotropical forest of Argentina; they studied the effect on the ecosystem processes after mass flowering in bamboo *Chusquea ramosissima* and found that there was short term effect on understorey regeneration during the flowering period due to low light interception and rapid colonization of herbaceous plants was observed after flowering period due to significant increment in light availability and affected on the growth of understorey tree sapling. A similar finding also reported in the report of Marchesini *et al.* (2009).

Massive flowering in bamboos could be a natural disaster for Giant pandas (IUCN listed vulnerable species). According to Zhao Xue *et al.* (2019) reported the possible impact of bamboo flowering on giant pandas, there may be food shortage to pandas and their habitats also on high risks. They suggested that there is a need for management of long-term risk for Giant pandas and other species from the bamboo flowering phenomenon. A similar investigation was carried out by Wang *et al.* (2009) and they reported that during bamboo flowering events, many habitats in the area are no longer suitable for pandas, so it was suggested that there is a necessity of strengthening the protection and research on potential habitats, restoring them to suitable habitats.

Soil fertility changes is another important phenomenon observed after bamboo flowering. After mass flowering and death, nutrient uptake by bamboo is stopped and large amount of dead organic matters added to the soil. Very scanty studies found to investigate whether soil fertility declines or improve due to release of nutrients from decomposing organic matter. After analyzing soil from the upper layer (0-10 cm) of mass flowered and dead bamboo site and from living bamboo site, it was revealed that flowerings degrade soil nutrient status, makes the soil acidic and also lower the concentration of exchangeable Ca, Mg and soil Nitrogen (Masamichi *et al*., 2007; Rai, 2009).

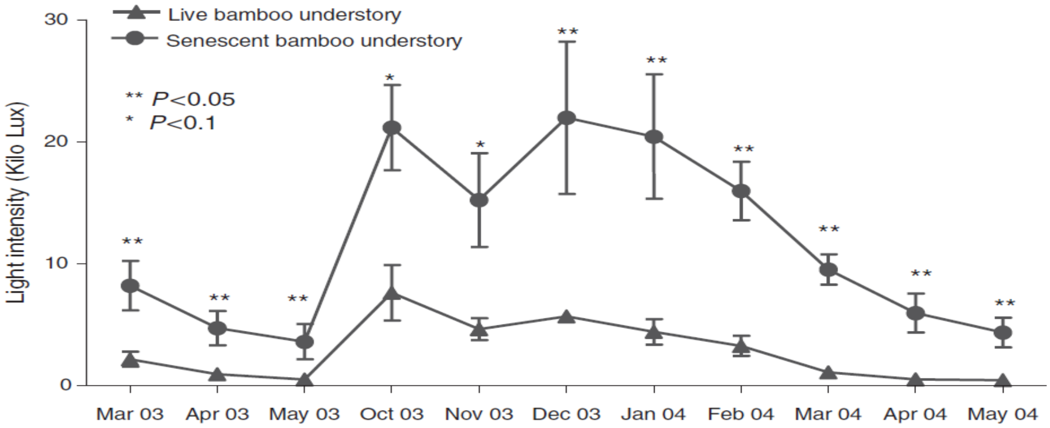


Fig-8.2. Understory growth live bamboo and senescent bamboo

The popular belief is that the gregarious flowering of bamboo resulted in famine. After the flowering and seeding, the bamboo ‘clumps' die. But rodents that feast on bamboo seeds multiply their numbers and start attacking agricultural crops once the bamboo plant perishes after flowering (Maitreyi, 2010). When the flowering cycle of *Bambusa tulda*, *Dendrocalamus longispathus* and *Melocanna bambusoides* [*M. baccifera*] is reported as the cause of famines known as 'Mautam' and 'Thingtam' in Mizoram (Pathak and Kumar, 2000). No Me Htwe (2010) reported an outbreak of rodents from 2007 to 2009 in upland rice cultivation areas in Myanmar after a massive flowering event. This was the first time clear documented evidence of the direct association between flowering and rodents widespread. Similar findings were reported by many Asia scientists (Aplin and Lalsiamlian, 2010, Belmain *et al*., 2010, Douangboupha *et al*., 2010, Ahaduzzamen and Sarker 2010). The phenomenon of the outbreak of rodent population in the northeastern region of India was also investigated by Chauhan (2003) reported that during the period of flowering of *Bambusa tulda* (1976–79), five major species of wild rats and mice occurred in the study area. *Rattus rattus brunneusculus* was the most common rat in Mizoram and *Rattus nitidus* in Manipur and Nagaland. The populations of these rats were high in crop fields and caused extensive damage to paddy crops. Pre-harvest crop damage caused by rodents was assessed during the bamboo flowering phase (2005–2007) in two major states of northeastern Himalaya by Thakur *et al.* (2012) in Meghalaya, rodent damage in upland paddy, lowland paddy, maize, pineapple, and groundnut was found to be 14.33, 16.31, 13.69, 17.36, and 16.02%, respectively. Relatively more serious damage was recorded in Mizoram, where jhum rice and maize losses were 42.7–46% and 23.41–47.65%, respectively. Shridhara and Rajendran (2009) also reported evidence of rodent outbreak after bamboo blooming. Dhananjoy *et al*.

(2012) linked to changes in the gene sequences in rat due to heterochromatinization or by pericentric inversion. Obviously, the chemicals in bamboo may lead to changes in chromosomal as well as DNA sequences. The occurrence of *Rb* fusion shows that the chemical might cause nicking of DNA and fusion at the centric region, but the cut segment cannot be detected.

Table(8.3). Gregarious flowering events in Madhya Pradesh

Area	Year of flowering			Physiological cycle (Years)
	First	**Second**	**Third**	
Balaghat	1916	1963	-	47
Bastar	1948	1981	-	33
Betul	1940	1968	-	28
Bilaspur	1895	1860	-	65
Jabalpur	1930	1965	1985	27
Khandwa	1910	1954	-	44
Mandla	1900	1921	1946	23
Raipur	1924	1960	-	36
Seoni	1921	1939	1964	21
Shahdol	1909	1984	-	75

Source: Dwivedi (1988)

Table (8.4). Gregarious flowering events in Mizoram

Species	Year of flowering
B. tulda; D. longispathus	1880-84
Melocanna baccifera	1910-1912
B. tulda; D. longispathus	1928-1929
Melocanna baccifera	1958-1959
B. tulda; D. longispathus	1976-77
Melocanna baccifera	2007-2010

Source: Singh (2019)

Tabl (8.5). Flowering period, nature of flowering and location in bamboo species

S. N.	Species	Period	Nature of flowering	Place	Reported by
1	*Arundinaria arista*	1900	-	Darjeeling,West Bengal	Rogers, 1900
2	*A. maling*	1951	Gregarious	Darjeeling, West Bengal	Ray, 1952
3	*Bambusa bamboos*	1901	-		Ponnambalam Pillai, 1901
4	*Bambusa nutans*	1980	Gregarious	FRI, Dehradun	Bahadur,1980
5	*Bambusa tulda*	1867-68, 1872 & 1884	Gregarious	Bengal	Troup, 1921
6	*Bambusa vulgaris*	1995	-	Tripura	NMBA, 2009
7	*Cephalostachyum capitatum*	1830,1835,1850	-	Khasi hills, Meghalaya	Gamble,1896

8	*Dendrocalamus asper*	2011	Sporadic	FRI, Dehradun	Thapliyal, 2011
9	*Dendrocalamus giganteus*	1974	Sporadic	Kurseong, West Bengal	Lahiri,1974
10	*Dendrocalamus hamiltonii*	1894	Gregarious	Sikkim and Dehradun	Gamble, 1896
11	*Dendrocalamus hukeri*	1967	-	Shilong, Meghalaya	Gupta, 1968
12	*Dendrocalamus sikkimensis*	1917	-	Kalimpong,North Bengal	NMBA, 2009
13	*Dendrocalamus strictus*	1939	-	Angul Forest Division, Odisa	Sen Gupta,1939
14	*Melocanna baccifera*	2008	Gregarious	Bajali area of Indo-Burma hotspot region, Assam	Sarma *et al.*, 2010
15	*Neomicrocalamus prainii*	2008	-	Anjaw District, Arunachal Pradesh	Taj *et al.*, 2009
16	*Oxytenanthera nigrociliata*	1961	-	Bastar, Madhya Pradesh	NMBA, 2009
17	*Phyllostachys bambusoides*	1985	-	Sikkim	Majumdar and Banerjee, 1985
18	*Schizostachyum capitatum*	2004	Sporadic	Kameng district, Arunachal Pradesh	NMBA, 2009
19	*Schizostachyum dulloa*	1962	-	Cachar, Assam	Nath, 1962
20	*Teinostachyum helferi*	1940	-	Garo Hills, Meghalaya	De, 1940

Source: Thapliyal *et al.* (2015).

Bamboo seeds:

Bamboos are naturally propagating both sexually and asexually from seeds and rhizomes. Seeds produced are viable only for 2-3 months which is a very short time period and vegetative propagation in bamboos is practiced through offsets, but these rhizomes are cumbersome (Singh *et al.*, 2017). A high percentage of germination (80-100) is obtained if seeds are sown soon after collection under shade. The germination period is four to twenty days in orthodox seeds, while for recalcitrant seeds of *Melocanna and Ochlandra,* it may be less. Germination in fresh seeds of bamboo is high, like 90-95 percent in *B. bambos*, up to 75 per cent in *D. strictus*, 55- 90 percent in *Ochlandra spp*. The use of growth regulators like IBA and GA had a significant influence on germination and vigour of seeds of

D. hamiltonii while IAA, IBA, and NAA on *D.strictus (*Gopi Chand and Sood, 2008*).* Bamboo seeds need to be collected immediately before rains set in as seeds lose viability rapidly on exposure to excess moisture. Most bamboo seeds lose viability within a short period. The deterioration of seed quality depends on two environmental factors – relative humidity that regulates seed moisture content and temperature and both influence by affecting the metabolic rate of seeds (Bhumibhamon, 1980). Lakshmi *et al*. (2018), investigated the influence of seed storage conditions and germination media on the germination of a priority bamboo species, (*Dendrocalamus brandisii)* and reported that seed viability of *D. brandisii* could be extended by reducing moisture content up to a critical level (8%) before storage. Fluctuations in moisture content play a significant role in seed deterioration and decrease in seed germination.

Some indigenous communities in India, Kani tribes of Kanyakumari district, southern Western Ghats use *Bambusa arundinacea* Willd. as a means to sustenance. The Kani tribes believe that the seeds of *Bambusa arundinacea* enhance the fertility, so that there is great demand of seeds of this species in the pharmaceutical industry to manufacture drugs to improve fertility (Kiruba *et al*., 2007).

Conclusion

The flowering of bamboos is an intriguing phenomenon because it is a unique and very rare occurrence in the plant kingdom. The long flowering intervals remain largely a mystery to many botanists. According to studies, mass flowering may be a genetic instinct. Different scientists postulate several theories. Mass flowering attracts predators of rodents. But rodents that feast on bamboo seeds multiply their numbers and start attacking crops once the bamboo plant perishes after flowering. So flowering phenomenon may trigger the famine fear in the community. The major limitation of propagation of bamboos by seed is their short shelf life. So the development of appropriate storage methods and use of suitable germination medium will assure the use of large quantity of quality seeds produced during gregarious flowering to raise seedling nurseries in subsequent years.

References

1. Ahaduzzamen, S.K. M.and Sarker, S.K. (2010). Chittagong story:regional damage assessment during rodent population outbreak. In GrantR. Singletons, Steve R. Belmein, Peter R. Brown and Bill hardy (Ed.) *Rodent Outbreaks:Ecology and Impact* (pp.65-78), IRRI-International Rice Research Institute.
2. Aplin, K.P. and Lalsimlian, J. (2010).Chronical and impact of 2005-2009 mautam in Mizoram. In GrantR. Singletons, Steve R. Belmein, Peter R. Brown and Bill hardy (Ed.) *Rodent Outbreaks: Ecology and Impact* (pp.13-48), IRRI-International Rice Research Institute.
3. Bahadur, K. N. (1980). A note on *Bambusa nutans*. *Indian Forester*. 106(4) : 314-316
4. Belmain, S.R., Chakma N., Sarker N.J., Sarker S.U, Sarker, S.K., and Kamal N. Q. (2010). The Chittagong story:Studies on the ecology of rat floods and bamboo masting. In GrantR. Singletons, Steve R. Belmein, Peter R. Brown and Bill hardy (Ed.) *Rodent Outbreaks: Ecology and Impact* (pp.49-64), IRRI-International Rice Research Institute.
5. Bhumibhamon, S. (1980) Seed testing. In: Regional Training Course in Forest Tree Improvement, Thailand, 21 April-31 May, 1980. BIOTROPICA/KU/RFD.

6. Chauhan, N. P. S. (2003). Observations of bamboo flowering and associated increases in rodent populations in the northeastern region of India. In Grant R. Singletons, Lyn A. Hinds, Charles J. Krebs, Dave M. Spratt (Ed.) *Rodent Rats, mice and people: rodent biology and management* (pp.267-270), Australian Centre for International Agricultural Research.
7. De, R. N. (1940). Flowering of *Teinostachyum helferi*, Gamble climbing bamboo. *Indian Forester*. 66 (6) :383
8. Dhananjoy, Ch., Laishram J.M., Brajendra1, N., Singh C. B., and Jiten S. (2012). Chromosomal abnormalities in rats after bamboo flowering in Manipur, India, *International Journal of Basic and Applied Medical Sciences*, 2(3):252-256.
9. Douangboupha, B., Singleton G.R.,Brown, P. R. and Khamphoukeo, K. (2010). Rodent outbreaks in upland of Lao PDR. In Grant R. Singletons, Steve R. Belmein, Peter R. Brown and Bill hardy (Ed.) *Rodent Outbreaks: Ecology and Impact* (pp.99-112), IRRI-International Rice Research Institute.
10. Du Fan ; Xue JiaRong , Yang YuMing , Hui ChaoMao and Wang Jing (2000). Study on the bamboo flowering phenomenon and its types in Yunnan in the past fifteen years. Scientia Silvae Sinicae. 36(6):57-68.
11. Dwivedi, A.P. (1988). Gregarious flowering of *Dendrocalamus strictus* in Shahdol (Madhya Pradesh) - Some Management Considerations. Proceedings of the Bamboo Workshop, Nov 14-18, pp.87-89.
12. Gamble, J. S. (1896). The Bambuseae of British India. Calcutta, Bengal Secretariat Press. 133p.
13. Gopi Chand and Sood, A. (2008). The influence of some growth regulators on the seed germination of *Dendrocalamus strictus* Nees. *Indian Forester*, 134(3): 397-402.
14. Gupta, K. K. (1968). Flowering of the bamboo *Dendrocalamus hookeri* in Shillong during 1967. *Indian Forester*, 98 (2) : 209
15. Janzen, D. H. (1976). Why bamboos wait so long to flower. *Annu. Rev. Ecol. Syst*. 7, 347–391.
16. Judziewicz, E.J., Clark, L. G, London˜o X, Stern, M. J. (1999). American bamboos. Smithsonian Institution, Washington.
17. Kiruba, S. Jeeva, S., Sam Manohar Das & Kannan, D (2007). Bamboo seeds as a means to sustenance of the indigenous community, *Indian Journal of Traditional Knowledge*, 6(1):199-203.
18. Lahiri, A. K. (1974). Sporadic flowering of *Dendrocalamus giganteus*, Munro in Bamonpokhri, Kurseong Forest Division. *Indian Forester*, 105 (8): 532.
19. Lakshmi, C.J., Seethalakshmi, K.K. and Jijeesh, C. M. (2018). Influence of seed storage and germination media on the germination of a priority bamboo species, *Dendrocalamus brandisii* (Munro) Kurz. *Journal of Tropical Agriculture,* 56 (2): 191-196,
20. Lía Montti, Paula, I., Campanello, M., Genoveva Gatti, Cecilia Blundo, Amy, T. Austin, Osvaldo E. Sala, Guillermo Goldstein (2011). Understory bamboo flowering provides a very narrow light window of opportunity for canopy-tree recruitment in a neotropical forest of Misiones, Argentina, *Forest Ecology and Management*, 262 (8):1360-1369.
21. Maitreyi, M. L. M. (2010). Gregarious bamboo flowering triggers famine fears. The news article in The hindu Date 19 April 2010. https://www.thehindu.com/news/cities/Hyderabad/lsquoGregarious-bamboo-flowering-triggers-famine-fears/article16371124.ece
22. Majumdar, R. B. and Banerjee N. C. (1985). First report of the flowering *Phyllostachys bambusoides* Siebet Zucc in Sikkim with a note on allied species. *Indian Forester*, 111(8) : 630-633

23. Masamichi Takahashi, Hitomi Furusawa, Pitayakon Limtong, Vanlada Sunanthapongsuk, Dokrak Marod & Samruan Panuthai (2007). Soil nutrient status after bamboo flowering and death in a seasonal tropical forest in western Thailand. *Ecological Research* 22:160–164.
24. Marchesini, V. A., Sala, O. E., & Austin, A. T. (2009). Ecological consequences of a massive flowering event of bamboo (*Chusquea culeou*) in a temperate forest of Patagonia, Argentina. *Journal of Vegetation Science, 20(3), 424–432.* doi:10.1111/j.1654-1103.2009.05768.x
25. Nadguada, R. S., John, C. K. and Mascarenhas, A. F. (1993). Floral biology and breeding behavior in the bamboo *Dendrocalamus strictus* Nees. *Tree Physiology* 13:40l-408.
26. Nath, G. M. (1962). Flowering of dalu bamboo, Assam. *Indian Forester*, 97 (8) : 498
27. NMBA(National Bamboo Mission Application). (2009). Flowering records – The mission is establishing a 'Flowering Reporting System', a part of its collate and disseminate knowledge about bamboo and the sector. New Delhi NMBA. (Available at: http://www.bambootech.org/subsubTOP.asp? Subsubid=&subid=23&name=BAMBOO)
28. No Me Htwe, Grant R. Singleton, Ye Mint The and Yee Yee Lwin (2010). Rodent population outbreaks associated with bamboo flowering in china state Myanmar. In GrantR. Singletons, Steve R. Belmein, Peter R. Brown and Bill hardy (Ed.) *Rodent Outbreaks: Ecology and Impact* (pp.79-98), IRRI-International Rice Research Institute.
29. Park, S.G., and Choi, S.H. (2017). Why Does Draft Bamboo Bloom Once in a Lifetime on a Large Scale and then Die? *Korean Journal of Environment and Ecology*, *31*(6):564–577. https://doi.org/10.13047/kjee.2017.31.6.564
30. Pathak K. A. and Kumar, D.K. (2000). Bamboo flowering and rodent outbreaks in North-Eastern region of India, *Indian Journal of Hill Farming*, 13(.1/2):1-7.
31. Ponnambalam Pillai, T. (1901). Flowering of the bamboo in Travancore. *Indian Forester*, 27 (8):429
32. Rai, P.K. (2009). Comparative Assessment of Soil Properties after Bamboo Flowering and Death in a Tropical Forest of Indo-Burma Hot Spot, *Ambio*, 38 (2):118-20.
33. Rai V. and Dey Nisringa (2012). Identification of programmed cell death related genes in bamboo. *Gene*, 497:243-248.
34. Ray, P. K. (1952). Gregarious flowering of common hill bamboo *Arundinaria maling*. *Indian Forester*, 78(2) : 89-90
35. Rogers, G. (1900). Flowering of bamboos in the Darjeeling district. *Indian Forester*, 26 (7): 331-332
36. Sadananda, C. , Dilip, S. , Singha, L. B. , Khan, M. L. (2010). 'Mauhak' –yet another mystery in the dictionary of bamboo flowering. *Current Science*, 99 (6):714-715.
37. Sanchez, Eduardo Ruiz, Peredo, Luis C. Santacruz Jezabel B. Ricardo Ayala-Barajas (2017). Bamboo flowers visited by insects: do insects play a role in the pollination of bamboo flowers?, *Plant Syst. Evol*. 303:51–59, DOI 10.1007/s00606-016-1351-1
38. Sarma, H., Sarma, A., Sarma, A. and Baroh, S. (2010). A case of gregarious flowering in bamboo, dominated lowland of Assam, India: Phenology, regeneration, impact on rural economy and conservation. *Journal of Forestry Research*, 21 (4): 409.
39. Sen Gupta, M. L. (1939). Early flowering of *Dendrocalamus strictus.* Indian Forester, 65 (8): 583-585.
40. Shridhara S. and Rajendran T. P. (2009). Bamboo Flowering and Rodents outbreaks, Scientific Publisher, Jodhpur.

41. Shridhara S. and Rajendran T. P. (2010). Gregarious Bamboo Flowering and Rodent Outbreaks – An Overview, Proc. 24th Vertebr. Pest Conf. (R. M. Timm and K. A. Fagerstone, Eds.) Published at Univ. of Calif., Davis. Pp. 228-234.
42. Singh G., Richa and Sharma, M. L. (2017). A review article - bamboo seed viability. *International Journal of Current Advanced Research*, 6(1):1690-1691.
43. Singh, A.P. (2019). Bamboo Flowering and Its Consequences in North East India. In Naresh R..K. (Ed.) *Advances in Agricultural Sciences* (pp. 67-78), AkiNik Publications, New Delhi.
44. Taj, R. K. , Tayeng, Geeta, Thungdok, D. K., Gab, R., Norbu T. and Sinha, G. N. (2009). Bamboo flowering and its monitoring in Arunachal Pradesh (2004-2009). SFRI bulletin No. 31.
45. Thapliyal, M. (2011). Flowering in *Dendrocalamus asper* in FRI, Dehradun. (Unpublished)
46. Thapliyal, M., Joshi, G. and Behera F. (2015). Bamboo: Flowering, seed germination and storage, In Kaushik, S., Singh, Y. P., Kumar, D. Thapliyal M., and Barthwal, S. (Ed) *Bamboos in India* (pp.89-108), ENVIS, Center on Forestry, FRI.
47. Troup , R. S. (1921). The silviculture of Indian Trees. Vol. 3 Oxford, Clarendon Press.
48. Thakur Azad, N.S., Firake, D.M. and Kumar, D. (2012) An appraisal of pre-harvest rodent damage in major crops of northeastern Himalaya, India, Archives of Phytopathology and Plant Protection, 45:11:1369-1373, DOI: 10.1080/03235408.2012.674711
49. Varma, J.C. and Bahadur, K.N. (1980). Country report and status of research on bamboos in India. Indian. Res. (N.S.) Botany 6:1-28.
50. Vorontsova, M. S., Clark, L. G., Dransfield, J., Govaerts, R., and Baker, W. J. (2016). *World Checklist of Bamboos and Rattans*. Beijing: Science Press.
51. Waikhom, S.D., Louis, B., Roy, P. I. (2014). Scanning electron microscopy of pollen structure throws light on resolving *Bambusa–Dendrocalamus* complex: bamboo flowering evidence. *Plant Syst Evol* **300,** 1261–1268. https://doi.org/10.1007/s00606-013-0959-7
52. Wang Ying, Ran Jiang-hong,Ling Lin and Du Bei-bei (2009). Bamboo Flowering and its Effects on Giant Pandas in North Minshan Mountains, https://en.cnki.com.cn/Article_en/CJFDTotal-SCDW200903013.htm.
53. Zhao Xue TianXuehua LiuZhiyong FanJianguo LiuStuart L. PimmLanmei LiuClaude GarciaMelissa SongerXiaoming ShaoAndrew SkidmoreTiejun WangYuke ZhangYoude ChangXuelin JinMinghao GongLingguo ZhouXiangbo HeGaodi DangYun ZhuQiong Cai (2019). The next widespread bamboo flowering poses a massive risk to the giant panda, *Biological Conservation*, 234:180-187.
54. Zheng, X., Shuyan, L. Huajun, F. Yawen, W. and Yulong, D. (2020). The bamboo flowering cycle shed light on flowering biodiversity. *Frontier in plant science*. 11:1-14.

Chapter 9

Major pest and diseases of Bamboo and their management

Pavithra B S[1] and Venkatesh Y N[2]

[1]Rani Lakshmi Bai Central Agriculture University, Jhansi-284003

[2]Scientist, Central Agroforestry Research Institute, Jhansi-284003

Bamboos are fast-growing, versatile plant species with multiple end-uses. For centuries, bamboos have been closely related to the agriculture, cottage industries, arts, culture and day-to-day life of more than half of the world's population. Recently, bamboos have also entered highly competitive markets in the form of pulp for paper and rayon, parquet, boards, ply bamboo, charcoal, and as a canned vegetable. Bamboo has tremendous potential for economic and environmental development. In the afforestation and reforestation programmes of many Asian countries, bamboo has assumed considerable importance to meet industrial and rural requirements and also as a means to combat climate change through carbon sequestration, bioremediation for soil erosion and also to reverse land degradation. Bamboo suffers from diseases caused mainly by fungi, which attack the rhizome, roots, culms, foliage, flower and seeds. More than 1,100 fungal species have been described and recorded on bamboos, which comprise about 630 Ascomycetes, 150 Basidiomycstes, and 330 mitosporic taxa (100 Coelomycetes and 230 Hyphomycetes) from the world (Hyde *et al*., 2002; Arjun *et al.* 2016). Diseases have been reported on bamboo seedlings in nurseries and clumps in plantations, village groves, homesteads and natural stands. Deterioration and decay of culms during post-harvest storage and use have also been reported (Mohanan, 2017). From Asian countries, more than 800 insect species have been recorded on bamboos but their impact on bamboo industry has been recognized only in a few countries. In India, nearly 180 insect species were found to be associated with bamboos (Varma and Sajeev, 2015), of which the sap feeders *Antonina* sp., *Ceratovacuna silvestrii* and *Palmicultor lumpurensis*, the defoliators *Psara licarsisalis*, *Pyrausta coclesalis*, *Hexacentrus unicolor* and *Discophora sondaica* were categorized as major pests. Defoliating pests were found high during the month from May to August and the sap sucking pests were found high during the month of January to March.

Table (10.1). Major insect pests and diseases of bamboo and their Symptoms

SI. No.	Insect pests	Symptoms
Defoliators		
1.	Leaf roller, *Pyrausta coclesalis* Walker (Pyraustidae:	The larvae tie the leaves together as leaf cases and feed on the upper tissues of the leaves.

	Lepidoptera)	
2.	*Discophora sondaica* (Boisduval) (Pyraustidae: Lepidoptera)	The larva feeds the tender as well the matured leaves and cause defoliation.
3.	*Psara licarsisalis* Wlk. (Pyraustidae: Lepidoptera)	The larva rolls up green leaves and feeds on the inner leaves.
4.	*Hexacentrus unicolor* Serville (Tettigoniidae: Orthoptera)	Nymphs and adults feeds the tender as well the matured leaves.
Sap Feeders		
5.	*Ceratovacuna silvestrii* Tak. and *Myzus obtusirostris* David, Narayanan & Rajesh (Aphididae: Homoptera)	Aphids suck the sap of the leaves and tender shoots. Leaves often yellow, curl or drop and new growth may emerge distorted where aphids have been feeding. Aphids produce sooty mold colonies and interfere with photosynthesis.
6.	*Antonina* sp. and *Palmicultor lumpurensis* Tak. (Pseudococcidae: Homoptera)	The mealy bugs will suck the sap of the tender shoots. Sucks the juices from the bamboo culms or hollow shafts and can cause culms to become deformed.
Culm borer		
7.	*Estigmen chinensis* Hope (Coleoptera; Chrysomelidae)	They damage the tender culm shoots during the rainy season. The larvae completely devour the soft tissues of the young shoots, leaving only the culm sheaths. Due to the damage of the terminal buds, the juvenile culms may die completely.
Root Feeders		
8.	*Microtermes* spp. and *Odontotermes* spp. (Termitidae: Isoptera)	Termites attack on the roots of germinating seedlings and rhizomes of bamboos.
9.	*Holotrichia consanguinea* Blanchard (Coleoptera: Scarabaeidae)	Grubs feeds on the developing rhizomes resulting in the death of the seedlings.
Seed Pests		
10.	*Udonga montana* Distant (Hemiptera: Penatomidae)	Bugs feed on the developing seeds on the flowered culm as well as the seeds which have fallen on the ground, thereby, affecting the regeneration process in nature.
Diseases in bamboo nurseries		
11.	Damping-off:	The seed decay and pre-emergence damping-off are

	Rhizoctonia solani (Kuhn)	characterized by the rotting of well-filled viable seeds and also the newly emerged radical. Post-emergence damping-off is characterized by the development of water-soaked greyish brown lesions on the emerging plumule near the soil level. The lesions spread and become necrotic, resulting in the collapse of the plumule.
12.	Seedling leaf rust: *Kweilingia divina* (Syd.)	The small flecks coalesce and form spindle-shaped dark brown pustules surrounded by a pale area. Necrosis and withering of leaves occur from rust infection.
13.	*Bipolaris* Leaf Blight: *Bipolaris maydis* (Nisikado and Miyake)	Minute, spindle-shaped, water-soaked lesions appear on both young and mature leaves and later turn dark brown to dull violet, with greyish brown centres. Lesions coalesce and form large necrotic areas.
14.	Seedling Rhizome Rot: *Rhizostilbella hibisci* (Pat.)	The disease manifest as general wilting of seedlings, rolling up of juvenile foliage, yellowing of more mature leaves and finally premature defoliation. The affected seedling shows dark yellowish brown discolouration and decay of the growing portion of the rhizome, especially around the rhizome buds.
Diseases in bamboo stands		
15.	Culm brown rot *Fusarium solani (Mart.)*	Severe infestation can be seen in high rainfall areas. Dark brown lesion on the outer culm sheath and rotting of emerging shoots
16.	Branch die back *Fusarium pallidoroseum* (Cooke)	Drying of branches during December –January. Infection occurs on foliage later spreading to the entire lamina, resulting in leaf necrosis; withering and premature defoliation takes place. Severe infection causes die back of the branches and culm tip.
17.	Witches' broom *Balansia* spp. and *Phyllostachy* spp.	Shortened internodes, affected culm and shoots looks like witches' broom.
18.	Blight *Sarocladium oryzae* (Sawada)	Premature death of the culm sheath and partial collapse of the fragile apical region and sequential die back of culm seen.
19.	Little leaf disease: *Phytoplasma aurantifolia*	The disease is characterized by the development of numerous, highly reduced, abnormal bushy shoots from the nodes of newly emerged culms and culm branches. Foliage develops from these shoots, showing prominent size reduction and needle like appearance. Profuse development of such abnormal shoots from each node of the developing culm and their subsequent growth give rise to a massive bushy structure around each node.
20.	Bamboo Mosaic virus	Foliar mosaic and stripe, brown internal streaking of the shoots and culms and culm abortion (Lin and Chen, 1991) can be seen. Culms are poorly developed with shortened internodes and the newly emerging shoots are hard in texture, thereby, depleting their quality for eating and canning

A study showed that at least 25% of the standing culms of *Dendrocalamus strictus* were damaged by shoot and Culm boring beetle (Singh, 1990). Bamboos are prone to attack by various groups of insects during their growth, *viz*., (1) defoliators (2) leaf rollers (3) sap-suckers and (4) shot and culm borers. The shoot and culm borers cause more damage to bamboo clumps as compared to other groups of insects.

1. Leaf roller*: Pyrausta coclesalis*

Leaf rolling with excreta **Larva** **Adult**

Management:

- Spray Spinosad, 45% SC at 0.4ml/l / Navaluran 10 EC at 1ml/l / Profenophos 50 EC at 0.9ml/l
- Spinosad 45 SC 0.12 ml/l Flubendiamide 39.35 SC 0.075 ml/l Lambda-cyhalothrin 5 EC 0.5 ml/l

2. Common duffer: *Discophora sondaica*

Management:

- Spray Lambda-cyhalothrin 5 EC 0.5 ml/l, Fenvalerate 10 EC 0.5 ml/l, Emamectinbenzoate 5 SG 0.4 g/l, Flubendiamide 480 SC 0.075 ml/l / Indoxacarb 14.5 SC and Chlorantraniliprole 18.5 SC @ 0.2 ml/l.

3. Aphids: *Myzus obtusirostris*

Management:

- Spray azadirachtin 1 EC @ 2 ml/l, Imidocloprid 17.8SL 0.3 ml/l / Thiamethxam 25WG 0.3g/l / Flonicamid 50 WG 0.3g/l.

4. Armoured Bamboo Scale: *Kuwanaspis pseudoleucaspis*

Management:

- Spray azadirachtin1EC @ 2 ml/l.
- Imidocloprid 17.8SL 0.3 ml/l / Thiamethxam 25WG 0.3g/l / Flonicamid 50 WG 0.3g/l.

5. Bamboo Borer: *Estigme*

Management:

- Removal and destruction of dead and severely affected trees.
- Spray or inject any fumigants like Malathion or Profenophos 50 EC at 1ml/lit.

6. Termites: *Microtermes* spp. and *Odontotermes* spp

Management:

- Locate termite mounds in and around the field and destroy it along with the queen.
- Drench / pour the termite mounds with solution of chloropyriphos 20 EC @ 3ml/l.
- Irrigate the crop regularly to reduce the incidence.
- Drench the soil with chloropyriphos 20 EC @ 2-3 litre per acre mixed in 500-1000 litre of water.

7. Damping-off: ***Rhizoctonia solani***

Management:

- Excessive watering and dense shading should be avoided.
- Low sowing rate -500 g seeds per standard seedbed is preferable.
- Pre-sowing seed treatment (overnight soaking of bamboo seeds in water).
- Seedbed soil solarization and seed dressing with fungicides such as Thiram 75 WP (@ 2 g/kg), Captan 75 WP (@2g/kg) and seed coating with spores of antagonistic fungi such as *Trichoderma harzianum* and *T. viride* are suggested to minimize the disease incidence (Mohanan, 2001).

8. Leaf rust: *Kweilingia aıvına*

Management:

- Application of fungicide (Plantavax 0.01% a.i.) on rust affected seedbeds.
- Sulphur-based fungicides can also be employed (dusting).

9. Bamboo Blight:*Sarocladium oryzae*

Management:

- Silvicultural measures recommended for controlling the disease include: cutting and removing of blighted bamboo culms, burning the debris of clumps in situ and addition of new soil to clumps.
- Weeds and bushes around the clump should be removed as these act as retainers of moisture, which is considered favorable for causing infection (Jamaluddin and Gupta 1996).
- Application of Carbendazim combined with Mancozeb (Carbendazim 0.15% 40 a.i. + Mancozeb 0.3% a.i.) or with Fytolan (Carbendazim 0.25% a.i.+ Fytolan 0.3% a.i.) is recommended.
- Drenching the soil around the bamboo clumps with Copper oxychloride and Mancozeb is also desirable to check the disease (Rahman, 1988).
- Selection of planting stock from disease-free clumps has also found helpful in reducing the infection.

10. Witches'-broom: *Aciculosporium sasicola*

Management:

- Spraying with Carbendazim or Triazolone dust achieved 99% disease control.
- Spraying with Carbendazim and Triazolone three times at 7-day intervals has a control effect of 100% (Lou *et al.* 2001).
- Improving the ventilation in the stands, cutting old and weak culms and clearing diseased clumps and burning them outside the

forests have been suggested for disease management.

11. Bamboo mosaic virus:

Management:

- The infected stock should be isolated and only virus free planting material be used for further propagation of the nursery stock.
- Cultivation of bamboos resistant to mosaic disease should be promoted in disease prone areas.
- For managing the disease as well as checking the spread of the disease, preparation and use of vegetative propagules from diseased clumps should be avoided.
- Meristem tip culture technique is being used for the production of virus free bamboos, but for such plants also, it is necessary to know whether the material is virus free.
- Pruning of diseased plants should be done carefully and blades must be sterilized between each use to minimize dissemination of the disease from infected to the healthy plants.
- Strict quarantine measures against the movement of infected planting materials within the growing areas also should be practiced.

General Management practices of bamboo insect pests and diseases

1. Silvi-cultural measures should be taken to manage most of the insect and diseases.
2. Physically removing and burning the infected culms and withes' brooms.
3. Rhizome or culms from diseased clumps should not be used for vegetative propagation.
4. Many broad-spectrum pesticides would have been recommended wherever some outbreak of defoliators or sap-suckers occurred.
5. Sap sucking pests can be managed by spraying of dimethoate or imidacloprid and defoliators can be managed with chlorpyrifos or profenofos or pyrethroids.
6. Soil drench of chlorpyrifos has been shown to destroy termites and other root feeder.

7. Blight: application of carbendazim combined with mancozeb (carbendazim 0.25% a.i. + mancozeb 0.3% a.i.) or with Fytolan (0.3% a.i.) is recommended.
8. Application of carbendazim (@0.2% a.i.) or mancozeb (@ 0.3% a.i.) recommended for the control of culm rot.

Post-harvest pests and Diseases of Bamboo and their Management

A study carried out by Forest Research Institute (FRI), Dehradun, reported that nearly 40 per cent of stored bamboo was damaged severely by borer attack which resulted to almost a loss of 40 million rupees to the forest department (Thakur and Bhandari, 1997). Similar reports from the storage yards and on finished products made out of bamboos have also been reported from Kerala (Paduvil, 2008). Termites and shot hole borers are known to cause severe damage to the post-harvest bamboos. Major borers namely, *Dinoderus* spp., *Lyctus africanus, Heterobostrychus aequalis, Stromatium barbatum, Chlorophorus annularis, Cryptotermes dudleyi, Coptotermes heimi.*

Bamboo also often succumbs to fungal decay and bio-deterioration during storage. The severity of decay and bio-deterioration depends on the duration of storage, bamboo species and environmental and storage conditions. During storage for up to 12 months, about 20-25% damage of culms has been reported in India (Varma and Bahadur, 1980). In India, the decay fungi recorded on stored bamboos are *Rigidoporus lineatus*, *Fomes tenuiculus, Favolus grammocephalus, Polystictus steinheilianus, Oxyporus cervinogilvus, Antrodia rhizomorpha, Pleurotus sp., Trametes elegans, Nigroporus durus, Fomes hypoplastus, Schizophyllum commune, Stilbella fimetaria, Tubercularia lateritium, Tetraploa aristata, Thelephora palmata, Earliella scabrosa, Tremella fuciformis, Gloeophyllum striatum, Cyathus limbatus, Sphaerostilbe bambusae, Sporidesmium nilgirense, Ellisembia leptospora, Cribaria intricate, Gymnopilus dlipes, Arthrinium arundinis, Lacellina graminicola, Phellinus gilvus* (Mohanan, 1994a).

Management of post-harvest pests

1. Bamboo should be dried thoroughly under the sun.
2. Bamboos harvested during dry season and before flowering are highly susceptible to borer attack, while those harvested during wet season are comparatively resistant and those harvested after flowering were completely resistant to borer attack.
3. After felling, immerse felled culms in water, it can significantly improve their resistance to borers as well as to fungi (XuTiansen, 1983).
4. Coat wood surface with paraffin wax, varnishes and paints to avoid egg laying by the adult borers.
5. Treat bamboo with a mixture of 2 kg of boric acid + 2 kg of borax +500 gm of sodium dichromate in 100 liters of water (available as Tim-bor or SoluBor). Bamboo can be impregnated, submerged or sprayed with this chemical.
6. Treating culm splits by immersing them in 0.2% phoxim for 3 minutes and can protect the treated split from attack for over 1 year (Zhou Huiming, 1987).
7. Soaking in an aqueous solution of 2% boric acid, 0.5% pentachlorophenate and 5%

alcohol can treat bamboo rind and similar semi-finished products.

8. Treat Bamboo with cypermethrin and permethrin insecticides (Varma *et al.*, 1988).
9. Fumigation in closed chambers or storehouses with sulphuryl fluoride @ 30 to 50 g/m³ of timber for 24 hours (Li Yanwen *et al.*, 1996; Chen Zhilin *et al.*, 2000).
10. Treat unfinished bamboo wood, plywood, particle board with "Boracare" by sprayed, brushed or foamed.
11. Treat bamboo structure with UV blocking polyurethane but need to re-coat it every year in moderate climates and re-coat every 6 months in heavily rainy climates.
12. The use of borates (disodium octaborate tetrahydrate) for the control of termites results in eliminating existing infestations.
13. Treat soil round the storage logs with cypermethrin, fipronil, fenvalerate, imidacloprid and permethrin to prevent termite attack (Randall, 2000).
14. Preservation near Sea water: Dry bamboo thoroughly under the sun. Then soak them in the sea for 2 months. Bamboo easily absorbs the salt of the sea. It protects from termites, borers and fungi. It's widely used in Asia and also used for wood treatment.

Management of post-harvest diseases

1. Culms should be stacked horizontally over raised walls to facilitate water drainage and air circulation.
2. Bamboo culms are treated during or immediately after extraction and before stacking in the storage yard.
3. Curing should be done; it involves leaving harvested culms, with branches and leaves intact, in open air.
4. Smoke the bamboo culm over fire; this is considered an effective treatment against insects and fungi.
5. Painting of culm with lime is widely used and said to ward off fungal attack. Often, culms are painted with a mixture of tar and sand or plaster, cow dung and lime, to prevent fungal and insect attacks.
6. Submerge the culms in either stagnant or running water or mud for several weeks.
7. Various chemical treatments recommended for increasing the service life of fresh (green) bamboo include: steeping, sap displacement, diffusion process and boucherie process. Treatments for dry bamboo culms include soaking in a preservative solution, hot-cold process and pressure treatment.
8. Reed bamboos used for mat weaving can be stored effectively even up to 8 months by keeping them under water (running or stagnant), or a disinfectant solution (bleaching powder or potassium permanganate) or preservative chemical solution (copper sulphate or boric acid) of very low concentration.

References

1. Arjun Shukla, Aradhana Singh, Deepa Tiwari, Bhoopendra Kumar, K.A., 2016. Bambusicolous fungi: A reviewed documentation. *International Journal of Pure & Applied Bioscience*. **4**(2): 304-310.
2. Chen Zhi-Lin, XieSen, Li Guo-Zhou and Lin Chao-Sen, 2000.Occurrence of Bostrychidae in house buildings and its control. *Entomological Knowledge*, **37**(4):220-222.
3. Hyde, K.D., Zhou, D.Q. and Dalisay, T., 2002. Bambusicolous fungi. *Fungal Diversity*, **9**: 1-14.

4. Jamaluddin and Gupta, B. N,. 1996. Outbreak of bamboo (Bambusa nutans) blight disease in Orissa, India. Impact of diseases and insect pests in tropical forests. Proceedings of the IUFRO Symposium, Peechi, India, 23-26 November 1993, Kerala Forest Research Institute (KFRI), Peechi, Kerala, India, 199-208.
5. Li Yanwen, Yin Qin and Tang Jindeng, 1996. Major pests infesting bamboo woods and their control. *Journal of Jiangsu Forestry Science & Technology*, **23**(41):55-56.
6. Lin, N.S. and Chen, C.C., 1991. Association of bamboo mosaic virus (BoMV) and BoMV specific electron-dense crystalline bodies with chloroplasts. *Phytopathology*, **81**(2): 1551-1555.
7. Lou Jun Fang, Hu Guo Liang, Yu Cai Zhu, You Long De and Ye Yu Zhu, 2001. Control of *Balansia* take damaging shoot bamboo forests. *Journal of Zhejiang*, Forestry College, **18** (2): 177-179.
8. Mohanan, C., 1994a. Diseases of bamboos and rattans in Kerala. KFRI Research Report No. 98. Kerala Forest Research Institute, Kerala, India.120 pp.
9. Mohanan, C., 2001. Biological control of damping- off in forest nurseries in Kerala. KFRI Research, Report No. 214. Kerala Forest Research Institute, Peechi, Kerala.
10. Mohanan, C., 2004. Witches' broom disease of reed bamboo in Kerala, India.*Forest Pathology*, **34** (5):329-333.
11. Mohanan,C., 2017. Diseases of Bamboos in Asia: An Illustrated Manual. *INBAR.*1-170pp.
12. Paduvil Raju, 2008. Post-harvest damage by *Dinoderus* beetle in Bamboos and its Management. *Ph.D. thesis*, FRI University, Dehradun, 105 p.
13. Rahman, M.A. 1988. Perspective of bamboo blight in Bangladesh. *Indian Forester*, **114**(10): 726-736.
14. Singh, P. 1990. Current status of pests of bamboos in India. In "Bamboos Current Research" 90-194. Rao, I.V.R, Gnanaharan, R. and 9 Sastry, C.B. (eds.) Proc. International Bamboo Work-shop.
15. Thakur, M.L. and Bhandari, R.S. 1997. Recent trends in protection of harvested bamboos from ghoon borer. *Indian Forester*, **123**(7):646-651.
16. Varma, J.C. and Bahadur, K.N. 1980. Country report and status of research on bamboos in India. Indian Forest Records (Botany), **6**: 28 pp.
17. Varma, R.V. and Sajeev, T.V., 2015. Insect Pests of Bamboos in India. Edi. Shailendra Kaushik, Yash Pal Singh, Dinesh Kumar, Manisha Thapliyal, Santan Barthwal: Bamboos in India). *ENVIS Centre on Forestry*, 227-246.
18. Varma, R.V., Mathew, G., Mohanadas, K., Gnanaharan, R. and Nair, K.S.S., 1988. Laboratory evaluation of insecticides for the control of the bamboo borers, *Dinoderusminutus* and *D. ocellaris* (Coleoptera: Bostrychidae). *Material und Organismen*, **23**(4):281-288.
19. XuTiansen, 1983. Integrated measures for control of insect pests on post-harvest bamboo. *Journal of Subtropical Forestry Science and Technology*, **3**:50-53.
20. Zhou Huiming, 1987. Studies of reasonable application of insecticide to control and cure the bamboo and bamboo wares damaged by *Dinoderus minutus. Journal of Nanjing Forestry University*, **4**:48-51.

Chapter 10

Bamboo germplasm improvement and micropropagation

R. S. Tomar[1]*, Prabha Singh[2], Pankaj Lavaniya[1], Pavan Kumar[1], A. Singh[1], M. J. Dobriyal[1] and A. K. Pandey[1]

[1]College of Horticulture & Forestry, Rani Lakshmi Bai Central Agricultural University, Jhansi-284003

[2]ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284003

Bamboo is the perennial, evergreen, dendroidal member of the grass family (i.e., Poaceae) and it constitutes a single subfamily *Bambusoideae* (Kigomo 1988). The subfamily includes herbaceous bamboo or *Olyreae* tribe and woody bamboos or *Bambuseae* tribe (Ramanayake et al., 2007). The two differs based on the presence and absence of abaxial ligule (Zhang and Clark 2000). The area and distribution of bamboos on earth varies from 51N latitude in Japan (Island of Sakhalin) to 47S latitude in South Argentina. Approximately, 1,400 bamboo species are found all over the world. It can grow well in an altitudinal range which extends from just above the sea level up to 4,000 m (Behari 2006). A total of 14 million hectares of the earth surface is covered by bamboos with 80 percent in Asia (Tewari 1992). The major species richness is available in Asia-pacific than by South America, with least number of species in Africa (Bystriakova et al., 2003) (Fig. 1 & 2). According to survey by FAO in 2005, the total area under bamboo cultivation is 11,361 ha. Out of this around 1,754 ha is owned by private owners. The habitat of bamboo include from hot, humid rainforests to cold resilient forests. It can grow in extreme temperature of about -20ºC and bear excessive precipitation ranging from 32 to 50 inch. annual rainfall (Goyal et al. 2012).

After China, India is the second richest country in bamboo genetic resources (Bystriakova et al. 2003). It has been reported by several studies like Bahadur and Jain (1983) stated 113 bamboo species, while others from 102 (Ohrnberger 2002) to 136 (Sharma 1980). The area under bamboo plantation in India is about 12.8 % of the total forest area with approximately 9.57 million ha (Sharma 1980). It is greatly influenced by human interruptions (Boontawee 1988). According to Gamble (1896), the distribution of bamboo in India is associated with rainfall. However, Varmah and Bahadur (1980) reported the preferential distribution of various bamboo species with respect to agroclimatic zones. The alpine region embraces *Arundinaria* and *Thamnocalamus,* these two genera also grow in the temperate region along with *Phyllostachys. Arundinaria, Bambusa* and *Dendrocalamus* grow well in the subtropical region, whereas the tropical moist region for *Bambusa, Dendrocalamus, Melocanna, Ochlandra* and *Oxytenanthera*; grows well in the dry tropical region (Ahmed 1996)

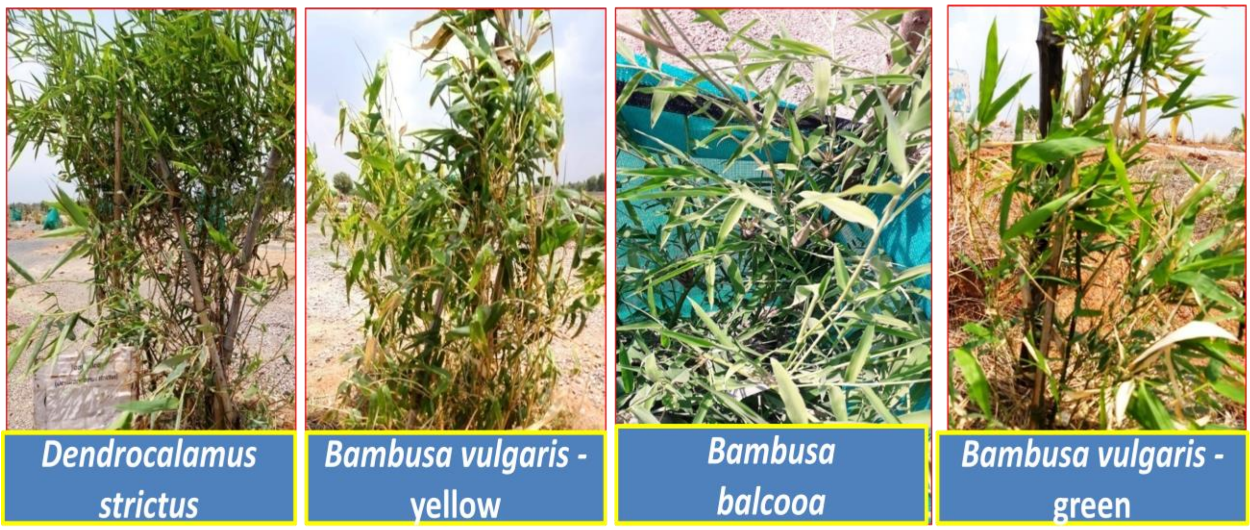


Fig.1. Diverse bamboo germplasm grown at Bhojla farm, RLBCAU, Jhansi

Fig. 2. Bamboo germplasm grown at Notghat Bamboo Farm, Niwadi, Madhya Pradesh

Bamboo genetic composition

Bamboo is the giant member of grass family (Kigomo 1988). In general, the chromosome number of bamboo is 12 (x = 12), while for herbaceous bamboo it is 11 (x = 11) (Grass Phylogeny Working Group 2001). Two different polyploidy groups are present in woody bamboo. The tropical woody bamboo is hexaploid (2n = 6x = 72) and the temperate woody bamboo is tetraploid (2n = 4x = 48) (Clark et al. 1995). The variation in the chromosome numbers for some species of *Bambusa* and *Dendrocalamus* has been reported by Ruiyang (2003). The cytometric flow analysis has revealed that genomic DNA content of tropical woody bamboo is larger than that of the temperate woody bamboo (Gielis et al. 1997). The flow cytometric analysis of tetraploid bamboo *Phyllostachys heterocycla* var. *pubescens* has found its genome size to be 2.075 Gb (Peng et al. 2013). The total of number of 3,087 ESTs and 17,789 nucleotide sequences of bamboo deposited till November 2009 which is about 0.1 % of the total sequences from grass family (Peng et al. 2013). The moso bamboo genome contains 43.9 % GC and 59.0 % transposable elements (Peng et al. 2013).

Bamboo and its usage

Bamboo is a major export item for the global market and is a major source of raw material for the paper and pulp industry. In addition, it is extensively used in house construction, basket malting, manufacturing of agricultural implements, containers, water and milk vessels etc.

In this way, bamboo is poor man's timber with the material needs of people (Mukherjee et al. 2010). Just like cattles are available in nature and play vital role in growth and development of the man in a similar way bamboo is also one of those providential developments in nature (Porter –field 1933). It plays significant role in daily rural life or human life. As it plays an important role in cultural, artistic, industrial, agricultural, construction and household needs of human beings (McNeely 1995). The use of bamboo shoots and leaves vary from pickle preparation (Khatta and Katoch 1983) to preparation of traditional medicine. Bamboo has significant medicinal values too and widely used in ayurveda. The solvent extraction of *P. pubescens* and *P. bambusoideae* show strong antioxidant activity (Mu et al. 2004) whereas mature bamboo leaves contain phenolic acids and root contains cyanogenic glycosides (Das et al. 2012). The culm of adult bamboo leads to high-quality charcoal (Park and Kwon 1998). The rich tradition of South East Asia involves initiation of life of newborn with a knife made of bamboo as of the umbilical cord is cut by it (McNeely 1995). *B. balcooa* is generally chosen for construction purposes and fiber-based mat board and panel manufacture (Ganapathy 1997), but for its mechanical strength it is also utilized to produce quality paper pulp (Das et al. 2005). Bamboo is known as ''green gold'' because of its economic importance and several end uses in human life (Bhattacharya et al. 2009). It is widely utilized in making musical instruments like flutes are made up of hollow bamboo (Kurz 1876). Bamboo is widely utilized for construction purposes. It has manifold application in construction of house such as making pillars, floors, doors and windows, room separator, rafters etc. (Das et al. 2008). It is also utilized for making guard wall of water bodies and river bank. Bamboo is an efficient agent for preventing soil erosion and conserving soil moisture (Christanty et al. 1996; Kleinhenz and Midmore 2001).

Bamboo and biodiversity

In addition to the several direct human uses, it plays an important role in many other ways; as it is well known habitat of large number of bird species living in forest. The other animals like Elephants (*Elephas maximus*), wild cattle (*Bos gaurus* and *B. javanicus*) and various species of deer (*Cervidae*) and primates (including *macaques Macaca* and leaf monkeys *Presbytis*), pigs (*Suidae*), rats and mice (*Muridae*), porcupines (*Hystricidae*) and squirrels (*Sciuridae*) are subsidiary feeders on Asian bamboos. The world's second smallest bat (*Tylonycteris pachypus*, 3.5 cm) nests between nodes of mature bamboo (*Gigantochloa scortechinii*), which it enters through holes created by beetles. The Asian giant panda (*Ailuropoda melanoleuca*), red panda (*Ailurus fulgens*) and the Himalayan black bear (*Selenarctos thibetanus*) are heavily dependent on bamboo for their feed (Bystriakova et al. 2003). The Red Panda (*A. fulgens*) is recently listed as endangered in the Red Data Book of IUCN. Red Panda mainly lives on bamboo leaves and the destruction of bamboo forest is one of the main reasons for its extinction from the wild (redpanda.network).

Bamboo plant propagation

In present time plant tissue culture is the advanced technique that can be used to solve the problems of speedy and mass propagation of the bamboo species. For the conservation of bamboo and to fulfill the growing demand of the markets, micropropagation is the alternative method that provides rapid mass multiplication of bamboo along with disease-free plants as well as the same clone (Arya et al. 2008; Singh et al. 2013). Micropropagation is not only ensuring the supply of quality planting material regularly but it also helps in conserving of germplasm of bamboo (Arya et al. 2008). Some of the bamboo trees take more than 100 years in flowering. This makes breeding difficult in bamboo. To solve this problem and facilitate breeding, bamboo micropropagation using controlled tissue culture techniques will be highly significant. Different types of explants viz. seed, seedlings, inflorescences, root, culm, mature clumps, nodal segment, meristem domes or leaves, etc are used for bamboo micropropagation. In bamboo, both juvenile and mature plants can be considered as explants. The nodal segments containing is considered as more effective explants for *in vitro* culture because of resumed food materials. Due to the presence of highly active meristematic tissue in nodal segments, it develops into new plantlets. The response of explants depends on the physical condition of plants, the health of mother plants, collection of the season from field and size of explants, and its position in mother plants. Using nodal explants for organogenesis reduces the chance of somaclonal variation. There is so much research conducted on micropropagation of bamboo through nodal explants. However, the developed protocols are either insufficient or not applicable because the protocols are only limited to the research which is not applicable for industrial mass production. It is intended to explore the suitable protocols on the micropropagation technique for mass bamboo propagation.

Plant tissue culture (PTC) exploits the totipotent nature of bamboo plant cells and the phenomenon of regenerating entire plants from any single cell is known as totipotency of cells. Micropropagation comprises of different stages viz. creation of a dedifferentiated cell from well differentiated tissue under specific culture conditions; proliferation of dedifferentiated cells for a number of generations and; its subsequent redifferentiation and regeneration in to whole plant. In other words, one imposes a period of essentially dedifferentiated cell proliferation between an explant and the next plant generation. The source of explants may be different plant parts including leaves, stems, petiole, embryos, roots, microspores and protoplasts. The ease and efficiency with which such manipulations can be made varies enormously from species to species.

Haberlandt in 1902 for the first time gave the concept of plant tissue culture where he worked on the culture of single cells. The actual tissue culture though was reported by Gautheret (1939) where he developed a method for *in vitro* growth of carrot tissues. Tissue-culture techniques have subsequently been developed and established for a lot of plant species. The major breakthrough in plant tissue culture leading to commercial scale tissue culture however begun after the discovery of artificial medium by Murashige and Skoog in 1962. Micropropagation is an important tool in both basic and applied studies, as well as in commercial application.

Propagation of bamboo plants through micropropagation has become an established and popular technique to reproduce otherwise difficult to propagate conventionally by seed and/or vegetative means. Until the last decade, the tissue culture of bamboo received very less attention (Huang and Murashige, 1984). The regeneration of bamboo plantlets through embryo culture was reported by Alexander and Rao (1968). But the real progress in bamboo tissue culture came after 1980s. Mehta (et al., 1982) gave complete protocol on micro-propagation of bamboo through seeds. Micropropagation in bamboo offers many unique advantages over conventional propagation methods of propagation, such as rapid multiplication, expeditious release of improved varieties, production of disease-free plants, non-seasonal production (round the year), germplasm conservation and international exchange. Through the use of micropropagation the production of secondary metabolites is considerably accelerated. In spite of its widespread applications, plant tissue culture still has limitations such as cost of production, choice of crops which is restricted to species with well-established and reproducible micropropagation protocols etc. As tissue culture raised plants are grown in aseptic, highly protected environment, they need to be hardened or acclimatized in nurseries before transfer to the field. Advances in commercialization of plant tissue culture and acceptance of tissue cultured plantlets by the commercial sector have led to continued exponential growth within the industry in terms of number of new units as well as number of plants produced by these units. The factors for each of the bamboo species such as season and stage of explant collection, cultivars/genotypes/ecotypes, process of surface sterilization, culture media and process of hardening and acclimatization need to be standardized. Nodal segments from some species of bamboos such as *B. balcooa, B. bambos, B. tulda, B. nutans* have been developed and highly efficient. There are different techniques used for micropropagation of plant material. *In vitro* propagation can be achieved either through organized and unorganized culture approaches. Apart from tissue culture and generation plantlets, the major bottleneck is rooting, acclimatization and survival under field conditions. Rooting in bamboo plants can be effectively induced when clusters of three to four shoots were used as compared to individual shoots. Maximum rooting (92.5%) was recorded in *B. balcooa,* whereas, a minimum of 80 per cent rooting was recorded in *D. asper*.

Regeneration through callus/Indirect regeneration

A method in which plant regeneration is achieved through intervening callus culture and subsequent regeneration of callus to give rise to organs (organogenesis) or entire embryos (somatic embryogenesis) de novo, and it is called as indirect regeneration or callogenesis, respectively. Under *in vitro* cultures, the meristematic cells undergo dedifferentiation to become parenchyma cells and which further divides and re-divides to form unorganized mass of cells called callus. These callus cells later undergo redifferentiation thereby regenerating into entire organs or plants.

Naturally the unorganized growth is observed very rarely, but it is frequently observed under *in vitro* culture conditions. The resulting unorganized cell typically lacks any recognizable structure and contains only a limited number of the many kinds of specialized and differentiated cells of plant parts (Fig. 3 & 4). A differentiated cell is one that has developed a specialized morphology and/or function. The formation of differentiated cell types can only be partially controlled in culture medium. It is not possible, for example, to maintain and multiply a culture composed entirely of epidermal cells. By contrast, unorganized tissues can be increased in volume by subculture and can be maintained on semisolid or liquid media (suspension cultures) for long periods.

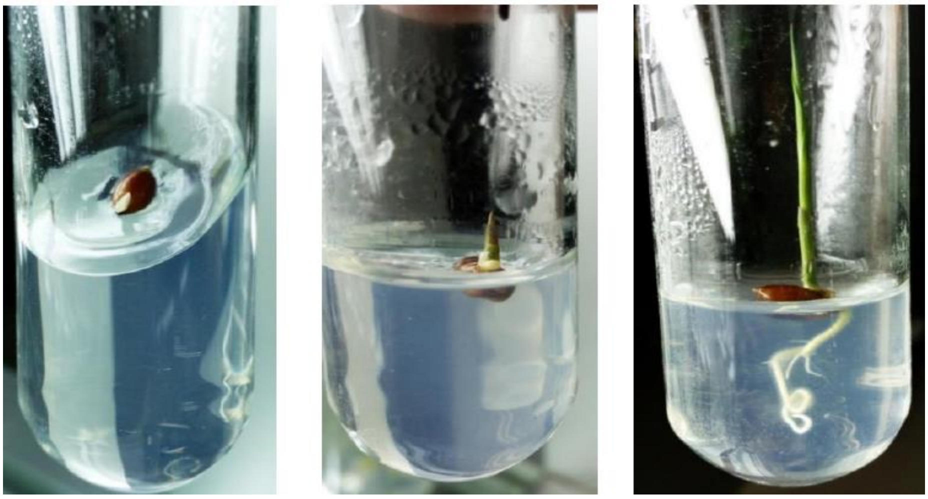


Fig. 3. Stages of seed germination and shoot development (Source: Hossain *et al*., 2018)

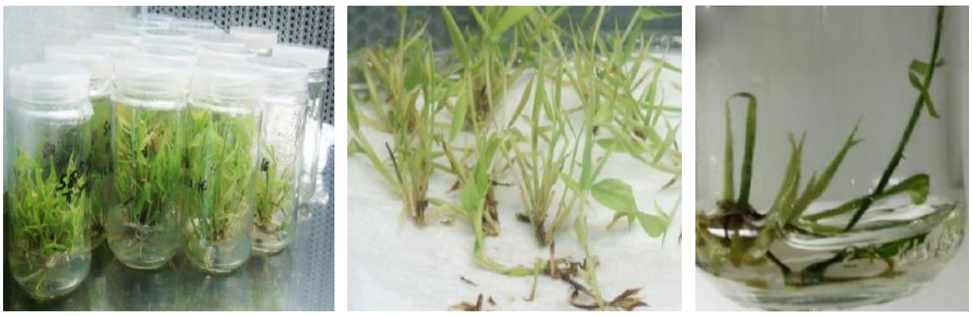


Fig. 4. Bamboo seedlings developed from tissue culture based techniques (Source: Hossain *et al*., 2018).

The micropropagation technique has both advantages as well as disadvantages. It includes advantages like

i. Explant is required in the beginning of the experiment.
ii. The rate of propagation is higher in macropropagation and large number of plants can be produced in short time enabling newly selected varieties quickly and widely.
iii. Production of disease free plants assures higher productivity, as a major commercial application of plant tissue cuture.
iv. With its application clones of rare species/genotypes, and also plants that are otherwise slow and difficult (or even impossible) can be propagated vegetatively.
v. Production can be continued all the year round and is more independent of seasonal changes.
vi. Vegetatively-reproduced material can often be stored over long periods.

Limitation

i. The cost of propagules is usually relatively high due to the requirement of sophisticated tools and techniques required to maintain stringent aseptic environment and also cost medium requirements is also high.
ii. In order to survive *in vitro,* explants and cultures have to be grown on a medium containing sucrose or some other carbon source.
iii. As they are raised within glass or plastic vessels in a high relative humidity, and are not usually photosynthetically self-sufficient, the young plantlets are more susceptible to water loss in an external environment.
iv. Further undesirable consequence of using *in vitro* adaptations is that the plantlets obtained are initially small and sometimes have undesirable characteristics caused by somaclonal variation. It can be a serious limitation in commercial tissue culture practices, and it can be occurring both during *in vitro* propagation and in the field conditions. The main objective of the clonal propagation is regeneration of phenotypically identical individuals, but in contrast it is often not the case in practice. One of the popular examples of adverse effect of somaclonal variation is the mantled floral phenotype in oil palm which affects ~5% of regenerated palms. Causes of somaclonal variations are genetic and epigenetic changes induced in response to micropropagation.

Molecular marker approach

A molecular genetic marker determines the differences in nucleotide sequence at the corresponding position of the homologous chromosomes (physical position) and it shows Mendelian pattern of inheritance. Molecular markers, including DNA based genetic markers have found their applications in almost all areas of biology, more so in evolutionary biology, genetics and breeding in order to identify a particular sequence of

DNA in a pool of unknown DNA. For many applications, DNA markers are preferred over other molecular markers since DNA is stable within an organism over time and among stages of development whereas other molecules are dynamic. Variations in DNA across genotypes are substantial in any species and all DNA variations are essentially due to single nucleotide polymorphisms (and additions and deletions), chromosomal aberrations and copy number variations. Diversity within a species is a result of these sequence variations and interaction between them and the environment. Since the former is inherited across generations, it is worthwhile to identify and employ these variations in DNA for both basic (e.g. phylogeny and diversity analysis, molecular tagging of traits of interest) and applied studies (e.g. marker assisted selection, fingerprinting, genetic fidelity testing). There is array of molecular markers developed to identify these variations all of which rely either on hybridization or PCR based approaches. Most commonly used molecular markers in biological sciences include Random Amplified Polymorphic DNAs (RAPDs), Restriction Fragment Length Polymorphisms (RFLPs), Amplified Fragment Length Polymorphisms (AFLPs), Cleaved Amplified Polymorphic Sequences (CAPS), DNA Amplification Fingerprinting (DAF), Simple Sequence Repeats (SSRs) or Sequence Tagged Microsatellite Sites (STMS), Sequence Tagged Sites (STS), and Microsatellite Primed-PCR (MP-PCR), Inter simple Sequence Repeats (ISSR), Inter-Retrotransposon Amplified Polymorphism (IRAP) and Retrotransposon-Microsatellite Amplified Polymorphism (REMAP).

Tissue culture based rapid multiplication technique has proved to be very promising in various plant species and including bamboo plants also. Therefore, by optimizing and efficiently using this *in vitro* multiplication protocol will increase the social, environmental and economic benefit derived from these plant species. Such work was will provide in vitro regeneration of bamboo plants for mass clonal propagation which can be used in domestic as well as industrial purposes. The use of molecular markers such as RAPD and ISSR for genetic diversity analysis and identification of bamboo will further help in germplasm improvement. It can lead to identification and establishment of a profiling system to estimate genetic diversity and gene bank which can be further used for other bamboo germpasm improvement programs.

References

1. Ahmed MF (1996) In: Keynote address: proceedings of the National seminar on bamboo, Bangalore, 28–29 Nov, pp 6–8
2. Alexander MP, Rao TCR (1968). *In vitro* culture of bamboo embryos. Current Science, 37 (14) :415
3. Arya S, Satsangi R, Arya ID. (2008). Large scale plant production of edible bamboo Dendrocalamus as per through somatic embryogenesis. Bamboo Science & Culture. 1:21(1)
4. Bahadur KN, Jain SS (1983) Rare Bamboos of India. In: Jain SK, Rao PR (eds) An assessment of threatened plants of India. Botanical survey of India, Howrah, pp 265–271
5. Behari B (2006) Status of Bamboo in India. Compilation of papers for preparation of national status report on forests and forestry in India. Survey and Utilization Division, Ministry of Environment and Forest, 109–120
6. Bhattacharya S, Ghosh JS, Das M, Pal A (2009) Morphological and molecular characterization of Thamnocalamus spathiflorus subsp. spathiflorus at population level. Plant Syst Evol 282:13–20

7. Boontawee B (1988) Status of bamboo research and development in Thailand. In: proceedings of the International Bamboo workshop held in Cochin, India, 14–18 Nov, Kerala Forest Research Institute.
8. Bystriakova N, Kapos V, Lysenko I, Stapleton C (2003) Distribution and conservation status of forest bamboo biodiversity in the Asia-Pacific region. Biodiversity Conserv 12:1833–1841
9. Christanty L, Mailly D, Kimmins JP (1996) ''Without bamboo, the land dies'': biomass, litterfall, and soil organic matter dynamics of a Javanese bamboo talun-kebun system. For Ecol Manag 87:75–88
10. Clark LG, Zhang W, Wendel JF (1995) A phylogeny of the grass family (Poaceae) based on ndhF sequence data. Syst Bot 20:436–460
11. Das M, Bhattacharya S, Pal A (2005) Generation and characterization of SCARs by cloning and sequencing of RAPD products: a strategy for species- specific marker development in bamboo. Ann Bot 95:835–841
12. Das S, Rizvan Md, Basu SP, Das S (2012) Therapeutic potentials of Bambusa bambos Druce. Indo Global J Pharma Sci 2:85–87
13. Das M, Bhattacharya S, Singh P, Filgueiras TS, Pal A (2008) Bamboo taxonomy and diversity in the Era of molecular markers. Adv Bot Res 47:225–268
14. Gamble JS (1896) The Bambuseae of British India. Ann R Bot Gard Calcutta 7:1–133
15. Ganapathy PM (1997) Sources of non wood fiber for paper, board and panels production: status, trends and prospects for India. In: Asiapacific forestry sector outlook study working paper series, Working Paper No. APFSOS/WP/10. Forestry Policy and Planning Division, Rome Regional Office for Asia and the Pacific, Bangkok, 1–59
16. Gautheret, R. (1939). Sur la possibilité de réaliser la culture indéfinie des tissues de tubercules de carotte. C. R. Soc. Biol. Paris 208 118–120.
17. Gielis J, Everaert I, De Loose M (1997) Genetic variability and relationships in Phyllostachys using random amplified polymorphic DNA. In: Chapman GP (ed) The bamboos, vol 19., Linnaean Society SymposiumAcademic, London, pp 107–124
18. Goyal AK, Ghosh PK, Dubey PK, Sen A (2012) Inventorying bamboo biodiversity of North Bengal: a case study. Int J Fund Appl Sci 1:5–8
19. Grass Phylogeny Working Group (2001) Phylogeny and sub-familial classification of the grasses. Ann Mo Bot Gard 88:373–457
20. Hossain MA, Bayezid MK, Uddin MA, MM Rahman (2018). In vitro Propagation of the Giant Bamboo *Dendrocalamus giganteus.*
21. Huang, LC Murashige, T (1984). Tissue culture investigation of bamboo I. Callus culture of Bambusa, Phyllostachys and Sasa. Botanica Bulletin of Academia Sincia, 24 (1) :31-52.
22. Khatta V, Katoch BS (1983) Nutrient composition of some fodder tree leaves available in sub-mountainous region of Himachal Pradesh. Ind For 109:17–24
23. Kigomo BN (1988) Distribution, cultivation and research status of bamboo in Eastern Africa. KEFRI Ecol Ser Monogr 1:1–19
24. Kleinhenz V, Midmore DJ (2001) Aspects of bamboo agronomy. Adv Agron 74:99–145
25. Kurz S (1876) Bamboo and its use. Ind For 1:219–269
26. Mehta, U, Rao, IV, Mohan Ram HY (1982). Somatic embroyogeneis in bamboo. In:5th International Congress of Plant Tissue Culture, Maruzen, 11-16 July, 1982. Plantt tissue culture 1982: Proceedings edited byA. Fujiwara.Japan, Japanese Association of Plant Tissue Culture. Pp109-110
27. McNeely AJ (1995) Bamboo, Biodiversity and conservation in Asia. Bamboo, people and the environment. In: Proceedings of Vth International bamboo workshop and the IV international bamboo congress, Ubud, Bali, Indonesia
28. Mu J, Uehara T, Li J, Furuno T (2004) Identification and evaluation of antioxidant activities of bamboo extracts. For Stud China 6:1–5
29. Mukherjee AK, Ratha S, Dhar S, Debata AK, Acharya PK, Mandal S, Panda PC, Mahapatra AK (2010) Genetic relationships among 22 Taxa of Bamboo revealed by ISSR and EST-Based random primers. Biochem Genet 48:1015–1025

30. Murashige, T. and Skoog, F. (1962) A Revised Medium for Rapid Growth and Bio Assays with Tobacco Tissue Cultures. Plant Physiology, 15, 473-497.
31. Ohrnberger D (2002) The bamboos of the World. Second impression. Elsevier, Amsterdam Park
32. SB, Kwon SD (1998) Development of new uses of bamboos (II): development of carbonization kiln and schedule investigation for bamboo charcoal making. FRI J For Sci 59:17–24
33. Peng Z et al (2013) The draft genome of the fast- growing non- timber forest species moso bamboo (Phyllostachys heterocycla). Nature
34. Genet 45:456–463
35. Porter-field WM (1933) Bamboo, the universal provider. Scientific Mon 36:176–183
36. Ramanayake SMSD, Meemaduma VN, Weerawardene TE (2007) Genetic diversity and relationships between nine species of bamboo in Sri Lanka, using random amplified polymorphic DNA. Plant Syst Evol 269:55–61
37. Ruiyang C (2003) Chromosome Atlas of Major Economic Plants Genome in China. Chromosome Atlas of Various Bamboo Species, 4th edn. Science Press, Beijing, p 646
38. Sharma YML (1980) Bamboos in the Asia Pacific Region. In: Lessard G, Chorinard A (eds.) Proceedings Workshop on bamboo research in Asia, Singapore, 28–30 May, 1980. International Development Research Centre, Ottawa, Canada, pp 99–120
39. Singh SR, Singh R, Kalia S, Dalal S, Dhawan AK, Kalia RK. Limitations, progress and prospects of application of biotechnological tools in improvement of bamboo-a plant with extraordinary qualities. Physiology and Molecular Biology of Plants. 2013 Jan 1;19(1):21-41. https://doi.org/10.1007/s12298-012-0147-1
40. Tewari DN (1992) A monograph on Bamboo. International Book Distributors, Dehradun
41. Varmah JC, Bahadur KN (1980) In: Lessard G, Choulnard A (eds.) Country report: India, Bamboo research in Asia, proceedings of a workshop in Singapore, 28–30 May, pp 19–46
42. Viswanath S. (2013). *Dendrocalamus stocksii* (Munro.): A potential multipurpose bamboo species for Peninsular India. Institute of Wood Science and Technology
43. Zhang W, Clark LG (2000) Phylogeny and classification of the Bambusoideae (Poaceae). In: Jacobs SWL, Everett JE (eds) Grasses: systematics and evolution. CSIRO Publishing, Collingwood, pp 35–42

WORLD BAMBOO DAY

18 September 2021

Time:-3pm onwards

Rani Lakshmi Bai Central Agricultural University, Jhansi

College of Horticulture and Forestry
Is Organising

National Workshop
on
"Harnessing Bamboo Resources in Buldelkhand Region for Sustainable Livelihoods and Climate Change Mitigation"

Chief Patron

Prof. Arvind Kumar
Vice Chancellor,
RLBCAU, Jhansi

Patron

Dr. A. K. Pandey
Dean, College of Horticulture
& Forestry, RLBCAU, Jhansi

Chief Guest

Shri Devendra Kumar
IFS(Retd)/ Ex PCCF
EFCC Dept. UP

Special Guest

Dr. A. Arunachalam,
Director, ICAR-CAFRI, Jhansi

Special Guest

Dr. Amrish Chandra
Director, ICAR-IGFRI, Jhansi

Organizing Secretary

Dr. M. J. Dobriyal, Prof and Head, Forestry,
RLBCAU, Jhansi

CO-Organizing Secretary

Dr. Gaurav Sharma and Dr. R. P. Yadav
Associate Prof, RLBCAU, Jhansi

Organizing committee

- Dr. Rakesh Kumar (Asst. Prof.)
- Dr. Swati Shedge (Asst. Prof.)
- Dr. Vinod Kumar (Asst. Prof.)
- Dr. R.S. Tomar (Teaching Associate)
- Dr. Dipika Aayate (Teaching Associate)
- Dr. J. Bhatt (Teaching Associate)
- Dr. Abhishek (Teaching Associate)

Bamboo Project Team

A. Bambusetum

- Dr. Pankaj Lavania (Teaching Associate)
- Dr. A.S. Kale (Asst. Prof.)
- Dr. Pavan Kumar (Asst. Prof.)

B. Bamboo based Agroforestry

- Dr. Prabhat Tiwari (Asst. Prof.)
- Dr. Garima Gupta (Teaching Associate)
- Dr. Y. Bijilaxmi Devi (Asst. Prof.)

Technical Report Writing Team

- Dr. Ghanshyam Abrol (Asst. Prof.)
- Dr. Alka Jain (Asst. Prof.)
- Dr. Pavithra B.S (Asst. Prof.)

National Workshop
on
"Harnessing Bamboo Resources in Bundelkhand Region for Sustainable Livelihoods and Climate Change Mitigation"

September18, 2021

Programme: 3.00PM

• Welcome Address	:	Dr. A. K. Pandey, Dean Hort.& Forestry
• Ecological aspects of Bamboo Cultivation in Bundelkhand Region	:	Dr. A. Arunachalam, Director, ICAR-CAFRI, Jhansi
• Address by Guest of Honour	:	Dr. Amresh Chandra, Director, ICAR- IGFRI, Jhansi,284003
• Inaugural Address by the Chief Guest	:	Shri Devendra Kumar IFS, EX PCCF, EFCC, UP.
• Presidential Remarks	:	Prof. Arvind Kumar, Hon'ble Vice Chancellor, RLBCAU, Jhansi
• Vote of Thanks	:	Dr. M. J. Dobrial, Prof. & Head, Forestry, COHF, RLBCAU, Jhansi

MOC: Y. Biji Laxmi Devi, Asstt Prof, NRM, COHF, RLBCAU, Jhansi

Plantation of Buddha Bamboo in Bambusetum by Hon'ble Vice Chancellor, RLBCAU, Jhansi





Rani Lakshmi Bai Central Agricultural University, Jhansi 284 003