NATIONAL MISSION ON BAMBOO APPLICATIONS
Technology Information, Forecasting, and Assessment Council (TIFAC)
Department of Science and Technology (DST)
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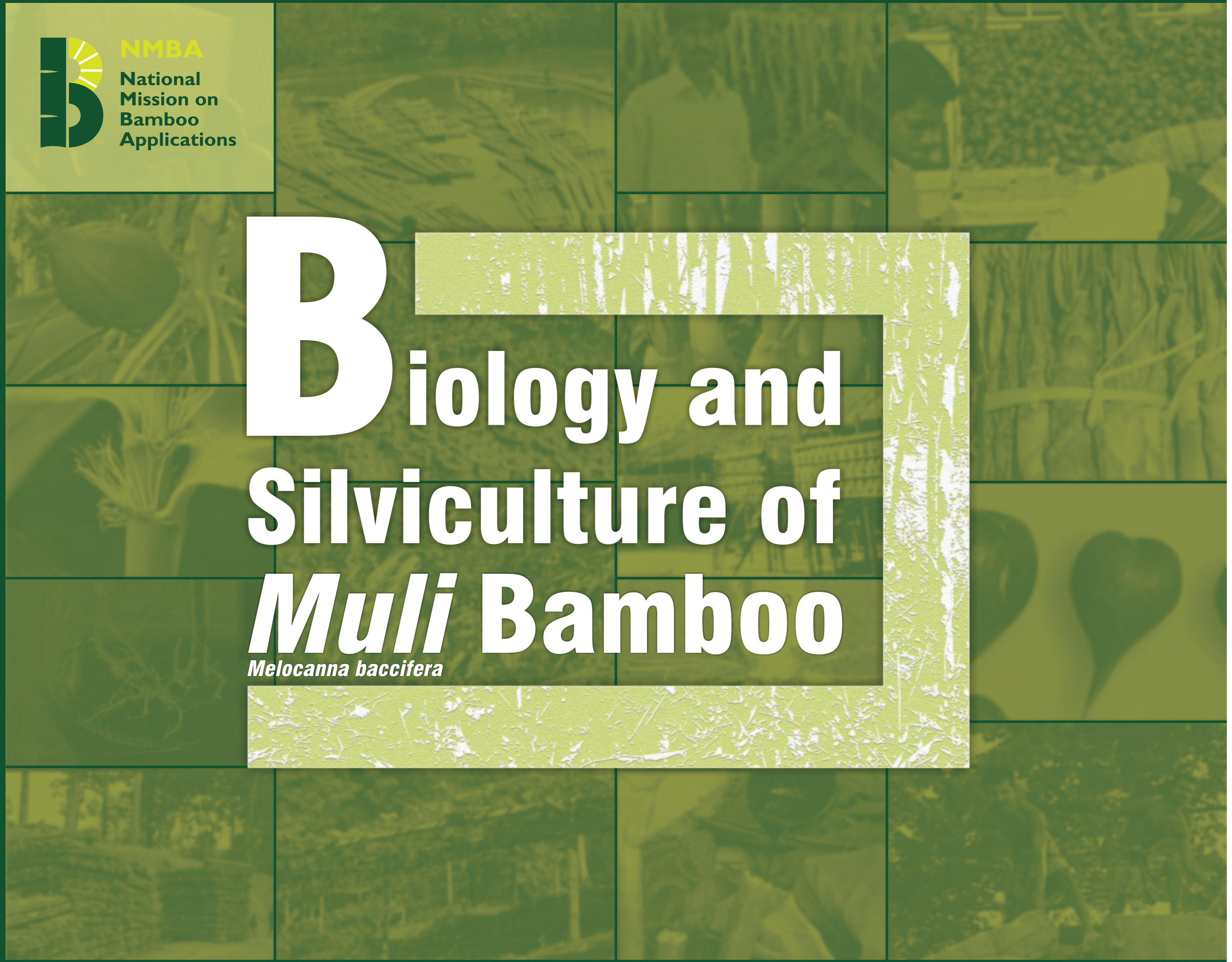

Biology and Silviculture of *Muli* Bamboo

Melocanna baccifera

BIOLOGY AND SILVICULTURE OF

Muli BAMBOO

Melocanna baccifera

(Roxb.)Kurz

Dr. Ratan Lal Banik

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The National Mission on Bamboo Applications (NMBA) has been established by the Department of Science and Technology (DST), Government of India. Implemented by the Technology Information, Forecasting, and Assessment Council (TIFAC), the Mission is tasked with providing a new impetus and direction to the bamboo sector.

It supports technological upgradation, develops indigenous capacities and enterprise, provides linkages with markets, functions as a platform for exchange of knowledge and technology and encourages association and cooperation amongst sectoral constituents and stakeholders.

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FOREWORD

India has the largest area under bamboo in the world, which is estimated around 11.36 million hectares. It is also the second richest country globally in terms of bamboo genetic resources, after China, and around two-thirds of the growing stock of bamboo in the country is found in the North Eastern States. Broadly speaking, the two bulk species are Dendrocalamus strictus and Melocanna baccifera (muli) with 53% and 16% share respectively.

Muli plays a major socio-economic role in the livelihoods of millions of families in the north eastern states as it is used extensively for housing, fencing, matting, basket making, agricultural implements, and freshly emerging shoots as food. The wide spread mortality after the recent gregarious flowering in its zone of distribution (even extending into the adjoining countries), and its deleterious impact on the socio-economic fabric of the resource dependent communities has drawn widespread attention of not only the affected communities but also of the scientists, foresters, administrators and community based organizations.

It was a coincidence that around this time, Dr. Ratan Lal Banik, a renowned bamboo expert in the South Asia region, with more than three decades of experience of working in the field with muli bamboo in the Indian subcontinent, offered to write a compendium on its biology and silviculture of muli, and management options, in the wake of mass mortality over large areas cutting across the states (even international) boundaries. National Mission on Bamboo Applications (NMBA), which is dedicated to provide a dynamic knowledge platform for Indian bamboos, offered to support

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publication of an authoritative compendium titled " The Biology and Silviculture of Muli Bamboo", as the inaugural issue of its technical monograph series. Dr. Banik has successfully and ingeniously collated in this book his lifetime field experience relating to the said species and its impact on the hill ecosystem and the people resident therein. Moreover, the book has been profusely illustrated with drawings and relevant photographs. The monograph also includes available past and present flowering records and estimated seeding cycles in Melocanna baccifera.

Shri Sudhir Kumar Pande, the ex-DG of Forest of India & Advisor of NMBA, has made fruitful suggestions in critically reviewing the text of the monograph. I would like to make a special mention of the hard work put in by Ms. Tajinder Kaur of the NMBA in editing the draft and readying it for publication.

It is hoped that the monograph will help better understanding of the morphology, flowering and propagation, growth habits, culm properties, harvesting requirements, utilization and management regimes of muli bamboo. I also take this opportunity to sincerely thank Dr.Banik for offering this treatise to the NMBA for publication.

Sanjiv Nair

Mission Director

National Mission on Bamboo Applications

PREFACE

Melocanna baccifera plays an important socio-economic role in the livelihoods of millions of families in the Indian subcontinent. This species alone covers almost 70 to 95 per cent of bamboo forests in the hills of northeast India, Sylhet, Chittagong Hill Tracts and Arakans (Mynmar), where it grows naturally and has been valued as the life blood of local indigenous people. About 150 million people of this region including both tribal and non tribal (mainly *Bengalis* in north eastern part of Bangladesh, Tripura, Lower Assam and north of West Bengal) have been depending on this bamboo species for their housing, fencing, matting, basketries, making agricultural implements, etc. including harvesting the shoots for food. Within recent decades, intensive biotic interference due to increasing population pressure and urbanization, including road, dam and building construction has razed many hills and fragmented populations. Furthermore, gregarious flowering has led to wide spread mortality of the bamboo.

I have been fortunate to be able to work in the forests of the eastern part of the sub-continent where I have observed *M. baccifera* closely in its natural habitat. Here I attempt to bring all the knowledge that I have garnered together from my studies and various sources into this single monograph. I believe, this monograph will be interesting and useful to researchers, foresters, farmers, environmentalists, bamboo lovers, and bamboo based Industries in the Sub Continent.

I express my deep gratitude to Shri Raju Sharma, former Mission Director, NMBA for agreeing to publish this book under the aegis of NMBA as it is first in the series of technical monographs on bamboos.

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I gratefully acknowledge the support received from Shri Sudhir Kumar Pande, IFS (retd.) ex- DG of Forests of India and currently Advisor, National Mission on Bamboo Applications (NMBA) in critiquing, and also editing, the manuscript. I also deeply acknowledge the sincere efforts of Ms. Tajinder Kaur of NMBA, for editing, corrections and making the draft in to a published book.

My special thanks go out to Mr. Suneel Kumar Pandey, Senior Vice President, BILT, New Delhi for his inspiration and support during my works and writing the book.

Sincere thanks are due to Mr. Ajay Kumar Mission Coordinator, and Ms. Manju Arya, NMBA; Dr I.V.Ramanuja Rao, Programme Director, INBAR, China; Mr Sanjeev Vasudev, Director STADD, New Delhi; Dr K. Haridasan, Joint Director of FRLHT, Bangalore; Mr. S.T.S Lepcha, CEO, UBFDB, Uttarakhand, Mr V.G. Jenner, Director, TBM of Tripura; Mr Angshuman Dey, D.S of Ministry of M.S &M.E, Govt of India; Mr Selim Reza of TRIBAC, Tripura; Mr P. Nehamia Of TAMBAC, Tamenglon (Manipur); and Prof Salil Tewari and Dr Rajesh Kaushal of GBP University of Agriculture & Technology, Pant Nagar for inspiration while preparing the manuscript.

My heart felt appreciation also goes to my wife Shikha for her encouragement and uncomplaining support during my work.

This book is dedicated to the wisdom and bamboo love of indigenous people staying in the hills of Northeast and Chittagong Hill Tract.

(**Ratan Lal Banik**)
New Delhi
(January, 2010)

CONTENTS

1 Introduction

1.1 General Information

Melocanna baccifera (Roxb.) Kurz
Synonym: *Melocanna bambusoides* Trin.

Roxburgh (1814, 1819) presented the original description and illustration of the species, as *Bambusa baccifera* Roxb. Trinius (1821) first described the genus *Melocanna* and named as *Melocanna bambusoides* Trin. On the basis of *Bambusa baccifera* Roxb. the correct binomial was published by Kurz (1875) as ***Melocanna baccifera*** (Roxb.) Kurz.

1.1.1 Vernacular and Local names

Berry bamboo (English); *Muli* (Tripura, West Bengal-India); *Wathwi* (Kokbarok-Tripura); *Watrai* (Garo-Meghalaya-India); *Usylli* (Khasi Meghalaya); *Tyrlaw* (Jaintia Meghalaya-India); *Tarai, Muli, Wati* (Assam-India); *Saneibi, Moubi* (Manipuri -India); *Rieng* [Rongmai Naga-Tamenglong (Manipur)]; *Turiah* Nagaland- India); *Mautak mau* (Mizo-India); *Tador dort* (Arunachal-India); *Lahure bans* (Nepal, Bhutan); *Muli, Nali, Tengra muli, Paiya, Bazali* [Bangali-Chittagong Hill Tract (CHT), Sylhet and Mymensingh forests-Bangladesh]. Various tribes inhibiting CHT have different names for *Melocanna baccifera.* The *Bawm* tribe calls the species as *Mautak maau*, Chakma tribe- *Ekuzha banz, Egojya bansh;* Lusai- *Mau hrau*, Marma- *Kaiang waah*. Muraong- *Kawoo thum*, Tanchan-gya-*Paba baith*, and Tipara- *Hruthui yeaha*. The Magh tribe of Myanmar calls the species as *Kayoung Wa* (Banik 1998a). Thus it appears local ethnic people have been identifying bamboos by in their own 'binomial'—one 'generic' and other is 'species' name. However, the name *muli* is widespread common and well known to most of the hill-tribe people and plain land Bengalis in northeast India, West Bengal and Bangladesh (Chittagong Hill Tract, Sylhet, north Mymensingh).

1.1.2 Natural distribution and Habitat Ecology

The natural distribution of *Melocanna baccifera* is restricted to the forests of north eastern India (Assam, Garohills of Meghalaya, mainly Tamenglong of Manipur, Mizoram, Nagaland and Tripura) towards the Sylhet and Chittagong Hill Tracts (located in Bangladesh territory) and move southeast to Arakan, Yoma hills crossing from Pathein and Pye in to Rakhine State of Myanmar (Figure 1) covering the hills either continuously over large areas or in pure patches as well as mixed vegetation (Banik 1989, 1994a). In fact, the species is not seen occurring in Arunachal Pradesh. The migrated Chakma tribe from Chittagong Hill Tract (CHT) is seen to cultivate the species in Manabhum Reserve Forest under Lohit district in Diyun circle and also in Changlang district, southern part of Arunachal Pradesh. In Megalaya the species is commonly found in East, West and South Garo Hills and West Khasi Hills. In East Khasi Hills, Jaintia Hills and Ri-Bhoi Districts, it is rarely planted by the local people. There is also gregarious distribution of this species from east Sikkim and northern part of West Bengal.

Taking bamboo, bamboo with miscellaneous species and shfting cultivation stratum, the bamboo resource base in Tripura extends over 2391 km^2 of forests (as per State Forestry Action Plan) and 109 km^2 in small holding of farmers outside the forests (Sharma 2008).

In Tripura, *muli* is the most important bamboo species, while all other forest–grown bamboo species contribute only 5-7 percent of the total production. The bamboo resource heads in the state have been categorized based on the resource flow from the point of origin to the primary market. It has been observed that the rivers act as a supply heads of bamboo from the upper catchments and reach the downstream market place.

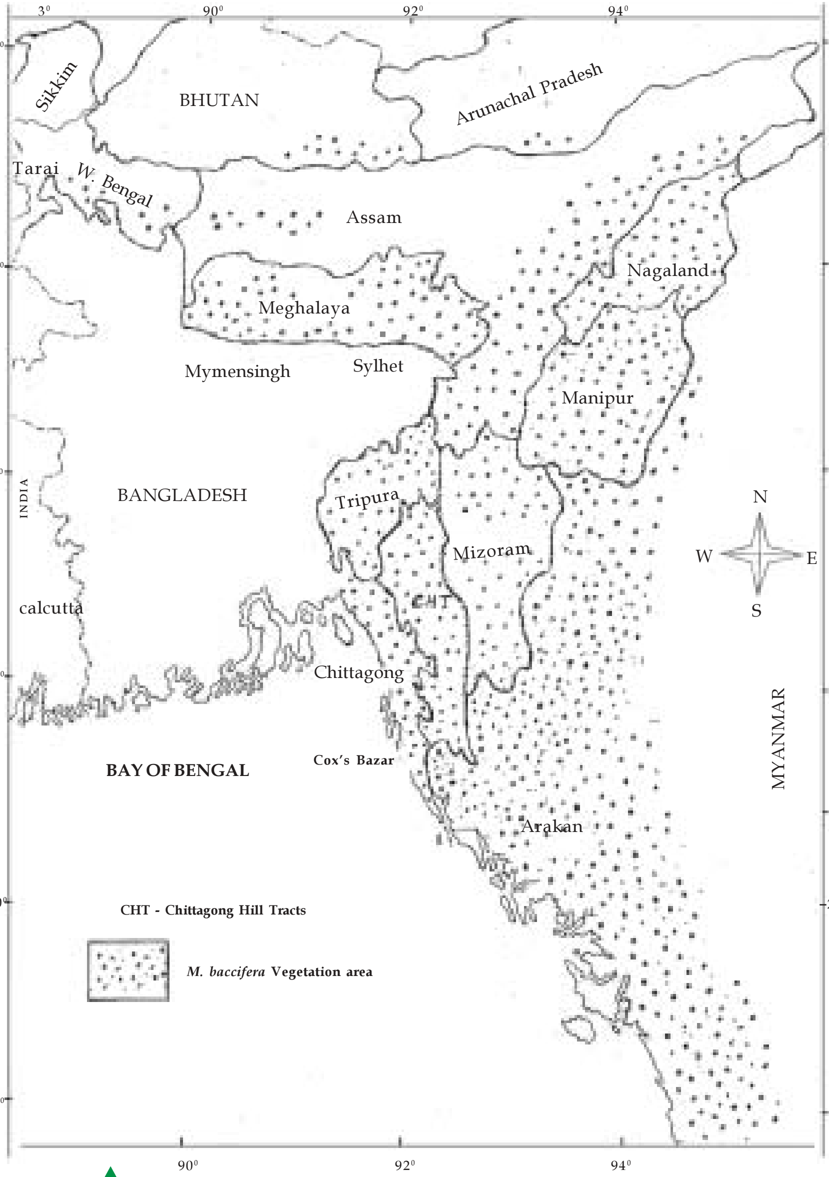


Figure 1:

Map showing geographical distribution of natural *muli* bamboo (*Melocanna baccifera*) forest [Source: Banik,R.L.(2000)]

These are:

a) The Kumarghat bamboo resource head on river Manu,

b) The Chakmaghat bamboo resource head on river Khowai,

c) The Maharani bamboo resource head on river Gumti,

d) The Kalashi bamboo resource head on river Muhuri.

Apart from these four river bamboo catchment, there are also river Feni bamboo catchment, river Dhalai catchment and Mohanpur areas.

In North Tripura and Dhalai, the Kumarghat Bamboo Resource Head – River Manu catchment basin, is the second largest river system in Tripura with 1923 km^2 of bamboo.

In west Tripura, the Chakmaghat bamboo resource head on the river Khowai acts as a bamboo resource head. The total river catchment is about 1328 km^2 out of which 1025 km^2 is hilly. The upstream of Khowai Reserve Forest (RF) catchments, Kulai RF Extension, Attaramura RF, Chakmaghat RF, Teliamura RF, Nunnachara RF, and other forest areas have the natural bamboo vegetation where *muli* is the most predominant species. Out of this 770 km^2 lies in the West District and about 255 km^2 in Dhalai district upstream of Chakmaghat. The *muli* vegetation is also occurring in Uttar Baramura Debtamura RF catchments and Paschim Kalajhari Reserve including Udaipur, Amarpur, and Maharani bamboo forests.

In south Tripura Baramura Debtamura RF (22800 ha.) contains some bamboo brakes in the upstream, majority of which is *muli* bamboo. The Kalashi *chara* joins Muhuri river at Kalashi area. The western ridges of Baramura Debtamura reserve forms the resource catchment and the eastern side of the ridge forms the catchment river Feni.

Manipur has about 3268 km^2 pure bamboo brake where *muli* is the major and dominant bamboo species.

In Tamenglong of Manipur, *muli* is the predominant bamboo species and occupies about 85 to 95 per cent land of the bamboo forest.

The bamboo forest cover in Mizoram is about 6446 sq. km, which is 31 per cent of the total geographical area of the state. Major natural bamboo resource of Mizoram *Melocanna baccifera* (locally known as *Mautak*) occupies about 95 per cent of the bamboo forest. Here people give highest priority to this resource as "*Mau, Hausakna Hnuk*" meaning "Bamboo, the ultimate resource for prosperity." The species grows profusely in the drainage areas of Twlang, Tut, Teirei, Lagaiah and Barak rivers in west Aizwal (Anon 2001). The extent of bamboo vegetation is highest in Lunglei district followed by Aizwal district and lowest in Chhimtuipui district. However, large tracts of bamboo forest are seen in Aizwal district. Under this, *muli* is the most dominant bamboo species. About 70 per cent of the vegetation in the Kolasib district is bamboo and it is seen in all parts of the district. The bamboo resources are located throughout Kolasib with the catchments of the rivers Serlui and Twlang having the most resources, from the ridge apices to the bottoms of the valleys. The areas adjoining the river Twlang which flows along the west of Kolasib district and forms the border between Kolasib and Mamit districts have been found to have about 95 per cent *muli* and the rest are *Dendrocalamus longispathus*, *D. hamiltonii* and *Bambusa tulda.* In the Twlang catchment there is more human pressure on the bamboo resources than other areas compared to the River Serlui catchment and also the River Twlang catchment has more *Jhum* areas. The presence of human settlements on the eastern ridges of the River Twlang along the Highway (The National Highway 54 which runs north-south and splits the district into East and West) have more influence on the resources because the bamboos are frequently clear felled for *Jhum* cultivation. Also on the western side of Kolasib the bamboo resources have been a source of raw material for the Cachar paper mills, due to the regions proximity and the convenient transportation (the river Twlang passing through Pachgram and National Highway 54). The River Serlui catchment has limited human settlements and thus has less *Jhuming* and resource extraction for the paper mills or for other uses. The vast hillsides of River Serlui catchment are under mostly unexploited *muli* and *D. hamiltonii.* Natural stocks of *D. longispathus* are also seen in exposed lower slopes and valleys in limited areas.

Melocanna baccifera dominates in Mizoram where as *Dendrocalamus hamiltonii* is a very common species in the hills of north Cachar. Though the three localities, i.e. North Cachar, Cachar and Mizoram are contiguous, this disparity in distribution could probably be attributed to differences in underlying geological formation. The geological formation of north-south wave-like corrugated structures, whereas the Borail and north Cachar hill ranges consist of east-west monoclinal folds. According to the Working Plan for Bamboo Working Circle for the Barak Valley the growing stock of bamboo was estimated as 469224 MT AD (in Cachar 242000, Karimganj 120646, Hailakandi 106578 MT AD), of which *muli* constitute about 72 percent. So in the valley alone 0.72 x 469224 = 337841 MT AD of *muli* bamboo growing stock exists (Yadava 2002).

The ‘natural home‘ of *muli* is believed (McClure 1966) to be in Chittagong Hill Tracts (CHT) where this species grows gregariously covering large tracts, and from there it is likely to spread to north east and other parts of the subcontinent. The bamboo jungles of CHT are very important to the sustenance and livlihood of local people. The Kassalong, Rankhiang, Sangoo and Matamuhuri reserves are the main bamboo producing areas in CHTs. According to 1984 forest inventory report, Kassalong has 164446, Rankhiang has 77104 and Sangu and Mathamuhuri has 74500 hectare of bamboo forests (De Milde *et al.* 1985). Drigo *et al.* (1988) inventoried the forest resources of southern Sylhet Forest Division and reported that bamboos were found to occur in 13,933 ha of forestland, of which *muli* constitutes 80-85 per cent of the growing stock.

Encroachment, illicit felling, over-exploitation, unscientific management, gradual conversion of bamboo forests into plantations through clear felling and burning, gregarious flowering and other different biotic interference including shifting cultivation have markedly reduced the areas of bamboo vegetation. As a result, in many forest areas of northeast India and Chittagong, yield of *muli* bamboo has been decreasing. Interestingly Troup (1921) reported that in CHT the weight of a *muli* bamboo culm was about 2.20 kg, but in repeat measurements in 1984 the average weight in Kaptai, Banderban, Rankhiang was found to about 1.5 kg (Banik 1992, 1994a). Intensified biotic interference is the main reason for such biomass degradation of this species. It has been estimated that the annual loss of bamboo area has been 2.53 percent at Kassalong and 2.83 percent at Rankhiang reserves. The annual loss of bamboo area is relatively low (around 0.93 percent) in Sangu and Matamuhuri areas (Banik 1992, 1994a). So the average annual loss of bamboo forest area is 2.6 per cent. However, in the some of the hills of Mizoram and Manipur (Tamenglong) bamboo has been growing with fewer disturbances and hence the *muli* clumps possess vigorously growing healthy culms.

During forest felling, incendiary fires are also not uncommon and usually cause damage to *muli* bamboo groves and trees. These are mostly in the form of ground fire set by sungrass cultivator in the 'sunkholas' (Sungrass, Savanna area).

Muli also occurs as undergrowth to many tree, species like *Tectona grandis, Gmelina arborea, Lagerstroemia speciosa, Albizia* spp., *Terminalia* spp., *Toona ciliata*, *Dipterocarpus turbinatus*, etc. and also forms a pure stand due to the aggressive nature of its underground rhizome in areas after burning. This bamboo species does not thrive well under shade, but springs up readily in gaps.

It is believed that *muli* is introduced to Nepal and Bhutan from adjoining *muli* areas. This distinctive bamboo is commonly planted in south-eastern *Tarai* part of Nepal and occasional in other areas such as Palpa district. This bamboo has also been cultivated on the lower hills near the southern border of Bhutan (Stapleton 1994a, 1994b).

However, the clumps of *muli* have been seen to grow naturally in the lower hill slopes by the side of the road leading to Panbang from Mathanguri along the bank of river Manas along the southern Bhutan border with India.

This bamboo species occasionally cultivated even in Andaman islands and has also been introduced in botanical and private gardens all over the world, including, Hong Kong, Indonesia, Taiwan and South America. During mid-nineties the author assisted in introduction of *M. baccifera* in the Botanical Gardens of Singapore and Philippines (Los Benos) through the seeds collected from CHT.

1.1.3 Required Climatic and Soil condition

Melocanna baccifera thrive satisfactorily on moist sandy, clay loam alluvial soils, well-drained residual soils, sandy rough slopes and the apices of hills. The species can also grow on highly weathered deep clay soil to shallow, to very deep loamy soil, having pH 4.5-6.0. The species naturally thrive well and grows luxuriantly in area (northeast India, CHT and Arakan, Pegu) having annual rainfall of 2500-6000 mm, and average temperature maximum 37.0 °C, minimum 5.0 °C with a long dry season each year from November to March. The species grow quite well on the hills of Tamenglong, Manipur even up to 1600m height. Moreover, a number of introductory field trial through seeds of *muli* have shown very satisfactory growth in areas far away from its natural habitat in India, such as Uravu, Wyandu (Kerala), Sindhudurg (Konkan) and Dehradun.

The culms are very healthy and tall when grown in the lower slopes and valleys with rich moist soil as observed in Mamit and Lunglei areas of Mizoram.

The species has rarely been cultivated in the homesteads of plain tract of Assam, Tripura and Bengal due to its non-tolerance to flood, as the species cannot survive flooding for more than two weeks (Banik 2000). Besides the farmers generally avoid growing *muli* bamboo in their homestead gardens as the species out numbers other crops and trees due to its aggressive (running) nature of culm production and clump expansion behaviour. Except in a few hilly villages at CHT and north east India *M. baccifera* has rarely been tried for domestication in the homesteads of plains and as such most of the populations of the species are found in wilderness.

2 Morphology and Plant Data

2.1 Clump and Culm Character

2.1.1 Clump behaviour

The young clumps (upto 3-4 years of age) of *Melocanna baccifera* are usually densely caespitose at first, becoming more open on the periphery as they develop and getting old. Mature, well developed clumps are diagnostically open and diffuse in nature (Figure 2). The species is an arborescent bamboo of moderate size. It is more or less an evergreen bamboo species having open clump with many single culms arising 0.5 to 2 m apart from a ramifying underground rhizome system.

2.1.2 Culm height and nature

The culms of *muli* bamboo are upright, erect, arising singly in a variety of distance from a common creeping rhizome and attain height of 9 to 18 m. Clumps growing on the hill top and steep slope generally do not produce big size culms while on valleys they are very tall even up to 24 m. *The young culms* (4-5 months old) are completely unbranched, thin at apical part with persistent straw colour culm sheaths on the nodes clearly visible from a distance (Figure 3), and within a few months (November to April) the thin drooping tips produce 4-6 leaves.

2.1.3 Nodes and Internode

The *internode* is cylindrical and glabrous, 10-60 cm long with maximum elongation at mid culm zone and nodes are not raised (Figure 4). The species has a series of more or less equal internodes in the mid-culm zone and therefore, the internode curve is broad and somewhat flat at the middle (Plate 1). In some cases the culm internodes are found to be more elongated, up to 90–110 cm, with comparatively thin walls in clumps, growing as understorey with the trees and also on shady slopes of the hills

(Figure 5). Such long internode culms of *M. baccifera* when harvested and sold in the market can be confused with the highly priced culms of *Schizostachyum dullooa,* commonly known as *dalu* bamboo. Characteristically the culms of *S. dullooa* have elongated internodes and commonly used in making superior quality mat and kite frames. Now-a-days *dalu* bamboo is rarely found in the forest due to the destruction of its habitat and large scale clump death as a result of flowering. The *muli* culms having long internodes are some times used in making kite frames as substitute for *dalu* culm, and are useful for making thin mats.

The *muli* bamboo culm nodes are usually marked by a thin sheath scar (Figure 4), which is an important feature of the species. The sheath scar is a transverse circumaxial thin and inconspicuous offset in the surface of culm, marking the circumaxial locus of insertion of the culm sheath (McClure 1966).

2.1.4 Culm diameter

The culm diameter commonly varies from 3-7 cm. In Manipur one can observe healthy culms (7–11 cm diameter at breast height, 7-18 cm tall) on hills both the sides of the river Barak while going to Aziuram from Tamenglong. Such big size bamboos are available mostly along the river banks of Barak, Jiri, Makru, and Irang in Manipur. Such big diameter culms are also found in pure *Melocanna* forests around Lunglei in Mizoram.

2.1.5 Culm wall thickness

The *muli* culms are smaller in size than those of many common *Bambusa* or *Dendrocalamus* species. The culms are hollow, thin walled, average thickness at mid-culm zone is 0.3 cm, and very thin (0.16 cm) at top part but thick-walled (2.3 cm) to solid in the basal 2-4 nodes.

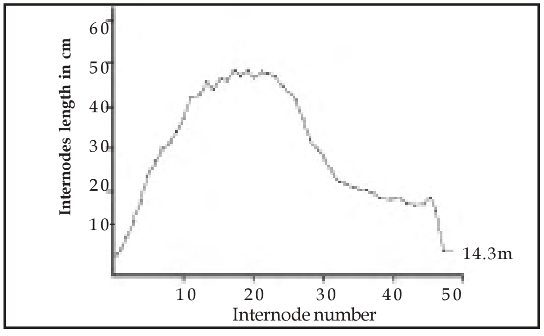
Figure 2:

A well developed clump of *Melocanna baccifera* diagnostically open and diffuse in nature

Figure 3:

The young culms (4-5 months old) are completely unbranched, thin at apical part with persistent straw colour culm sheaths on the nodes clearly visible from a distance, and within a few months the thin dropping tips produce 4-6 leaves

PLATE 1: *Melocanna baccifera*: the culm internode length presented in a curve. The curve is broad and somewhat flat at the middle.



2.1.6 Culm weight

Investigation on the weight of a 3-year old culm (excluding leaves and branches) of *muli* bamboo from the clumps growing in some places of northeast India and CHT shows that it varies from 1.00–2.75 kg; the weight of a culm being more dependent on its length than the diameter. Generally small diameter culms

Figure 4:

Melocanna baccifera culm nodes are not raised, usually marked by a thin sheath scar and normally produces 10-60cm long internodes

Figure 5:

M. baccifera: Culms produce 90–110 cm elongated nodes when clumps grow as understorey with the trees and also on shady slopes of the hills

are found in the disturbed jungles where there is no control over repeated felling and burning, but these culms have thicker walls.

2.1.7 Culm sheath

Fairly large, 10-15 cm long, yellowish-green when young and yellowish-brown when old, brittle, felted; symmetric, narrow; auricle prominent, blade arising from a concave depression. Culm sheaths are covered with white hairs at first, knee shaped ridge present on the outside of the sheath where the blade is attached; blade narrow, usually 15-30 cm long, 2-3 cm broad, sword-shaped and longer than sheath. *Ligule*: serrate, 1-2 mm tall. In young shoots ligule horse-shoe shaped, blades flagellate (Figure 6).

2.1.8 Bud dormancy and Branching habit

After 6-9 months of culm emergence culm-sheaths start dislodging basipetally and bud break progress up to one-third of the culm confined from mid to upper

Table 1: A comparative data (average value) on wall thickness (Wt), diameter (Dia) measurement at three different culm position of *Melocanna baccifera* along with other species growing in some places in North-eastern part of the subcontinent.

Species	Base		Mid		Top	
	Dia (cm)	Wt (cm)	Dia (cm)	Wt (cm)	Dia (cm)	Wt (cm)
B. balcooa	9.15	2.82	7.82	0.92	1.24	0.36
B. tulda	5.75	1.17	4.52	0.41	1.02	0.21
B. vulgaris	8.32	1.72	7.65	0.62	0.70	0.22
D. giganteus	18.72	3.45	11.00	0.70	0.42	0.10
D. strictus	6.52	3.34	5.00	0.54	0.63	0.22
M. baccifera	4.05	2.28	3.25	0.29	0.60	0.16
G. andamanica	4.01	0.96	3.04	0.31	0.69	0.10
S. dullooa	2.87	0.68	2.65	0.24	0.86	0.12
Th. oliveri	4.61	2.21	4.63	1.32	0.67	0.15

Genus: *B.=Bambusa, D.=Dendrocalamus, G. = Gigantochloa* , S. = *Schizostachyum Th. = Thyrsostachys*

part of the culms. The degree of precocious branching is very pronounced, and the branch complement emerges from a single primary branch axes at node. Prophyllum is a sheathing organ, which surrounds the branch primordium at node. In *muli* bamboo primary branch is indistinguishable in size from the subsequent order of axes, and the result is a dense tuft of thin, widely radiating, numerous, subequal 25-40 branches arises from the culm node (Figure 7). Such array of branches is called as *branch complements*. The branches at mid-culm nodes radiate from a common point, which is the locus of insertion of the primary branch primordium. Such thin branches generally do not develop root primordia and therefore branch and culm cuttings in *muli* bamboo fail to induce roots.

Sheaths persist on the lower two-third of culm and sheath-blades are loosely fitted. In the next year culm-sheaths further dislodge, bud break and branching continue up to two-third portion of the culm. Nodes in the lower half to two-third of the culm usually are without buds or branches in plants of mature stature. Most of the time nodal buds remain dormant on lower one-third portion (basal 3-7 nodes) of culm with persistent culm-sheaths.

Figure 6:

M. baccifera: Culm sheath is felted; symmetric, auricle prominent, long and narrow, sword-shaped blade arising from a concave depression

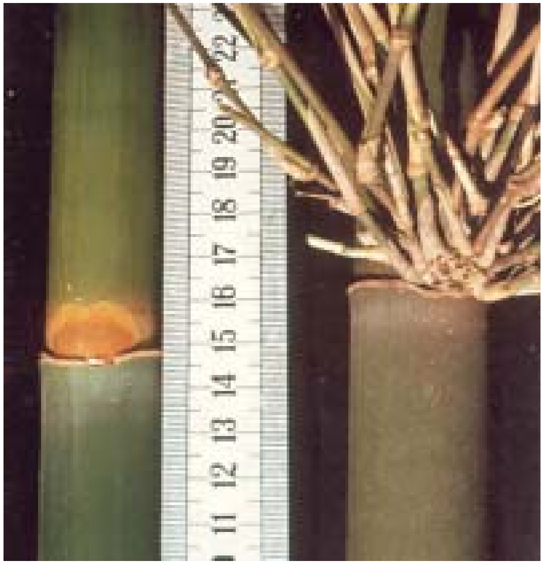


Figure 7:

M.baccifera: (left) Bud on the culm-node is flat and appressed, thin wing like growth present on both left and right of the margin of the bud; (right) dense tuft of thin, widely radiating, numerous, subequal branches (branch complement) arise from the culm node

2.1.9 Leaves

The plant is mostly evergreen in nature. The leaves are 15-30 cm long, 2.5-5.0 cm broad, oblong-lanceolate, apex acuminate, base oblique or somewhat truncate, adaxial surface glabrous, abaxial surface glabrous or sometimes sparsely pubescent, margins finely ciliate. Transverse veinlets, called as "pellucid glands", sometimes apparent on both surfaces, especially in young leaf blades, obscure in older ones. Leaves start developing within 2-4 weeks from the developing branches. *Leaf sheath* is thick, glabrous, smooth, ending in a pointed auricles bearing 10 to 12 or more, prominent, 8-25 mm long erect wavy deciduous bristles always in seedling (Figure 8); the ligule short, petioles narrow.

Figure 8

Leaf sheath is thick, glabrous smooth, ending in a pointed auricles with 10 to 12 or more, whitish, prominent, 8-25 mm long erect wavy bristles

2.2 Underground morphology

2.2.1 Rhizome system

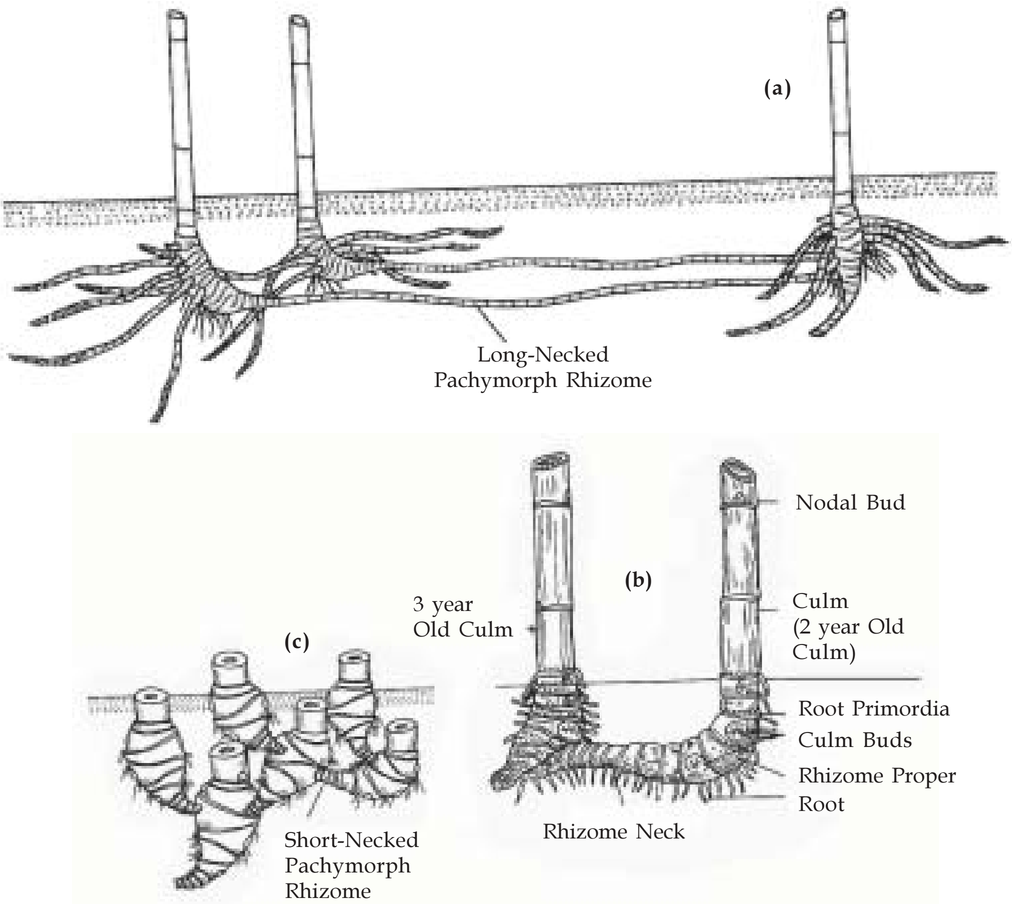
Melocanna baccifera clump has *open* and *diffuse* type of *pachymorph* long (1.0-2.0m) necked rhizome system (McClure 1966) below the ground (Plate 2a). Due to the woodiness of the rhizome system it has been also termed by Watanabe (1986) as the *woody- pachymorph-diffuse* type. The morphological characteristics, absence of any buds at each node of long necked pachymorph rhizome, differ from those of leptomorph type. And, the portion of existing large buds at the thick rhizome proper connected under the culm base, is typical of pachymorph type in particular. By the development of a long necked rhizome, the distribution of standing culms shows a real diffuse form

Figure 9:

Melocanna baccifera : A portion of the clump having vigorously growing rhizome system with elongated underground rhizome necks


Dr. R.L. Banik

PLATE 2: Growth form of rhizome system in bamboo species: **a)** *M. baccifera:* a non clump forming species with *woody-pachymorph-diffuse* type rhizome system; **b)** a typical short-necked rhizome of *B. vulgaris* resulted in clump forming species; (**c)** compact caespitose clump with pachymorph rhizome.



Growth form of rhizome system in clump forming bamboo species: (a) "Woody-pachymorph-diffuse type" rhizome system with long rhizome neck in *Melocanna beccifera* arising single culms in a clump. (b) A typical short-necked rhizome of *B. vulgaris* resulted in (c) Compact cespitose clump.

inside the clump. (Figure 9) and as a result this species produce net like massive ramifying rhizome system. Probably due to this reason local people call *M. baccifera* as '*muli*', in Sanskrit '*mul*' means strong root like structures that are very prominent in underground part of this species.

The other common tropical and sub-tropical clump forming bamboos have short rhizome necks with very thick swollen rhizome proper at the base of the culms (Plate 2b, 2c).

2.2.2 Cytogenetics

The cytology of most species of bamboo is not well studied. Like most of the tropical bamboo species *Melocanna baccifera* possess 72 numbers of somatic chromosomes (Janaki Amal 1959).

2.3 Specific field characters for identification of *Muli* bamboo (*M. baccifera*) in the field

1) The Clumps are open and diffuse, with culms erect, arising singly in a well separated distances (0.5-2 m apart) from the ramification of an underground rhizome system. (Plate 2a).
2) Rhizome necks are greatly elongated even up to 2.5 m. (Figure 9).
3) Bud on the culm-node is flat and appressed with the culm wall. Thin wing like growth present on both left and right upper margin of the bud. (Figure 7).
4) Culm sheaths have ridge on the outside of the sheath where the narrow sword-shaped blade (longer than the sheath proper) is attached. (Figure 6).
5) Young shoot yellowish-brown to brown, sheath margin and top pinkish, ligule horse-shoe shaped,

blades flagellate and glabrous. (Figure 27).

6) Leaf is oblong-lanceolate, no cross-veins, larger leaf blade in seedlings than adult plants. (Figure 20b).

7) Leaf sheath glabrous, auricle bearing long white to ash colour 8-25 mm long hairy bristles. (Figure 8).

8) Branching usually confined from mid to upper part of culm. Tufts of sub-equal thin branches 25-40 are developed from each node. (Figure 7).

9) The florets are prominent and has elongated purple coloured stigma clearly visible from apart. (Figure 11c)

10) Fruits, big size pear to mango shaped with a beak, smooth surface, fleshy, green, 7-150 g per fruit. (Figure 13b).

3 Flowering and Propagation

3.1 Flowering Nature in *Melocanna baccifera*

Like most other bamboo species *M. baccifera* is also semelparous, i.e. the life cycle of the plant ends with flowering. Most of the commercially important bamboo species of the sub-continent are of gregarious flowering nature, that is, majority of the plants in the population flower simultaneously or close to it after a specific period of time and then die. In respect of flowering *M. baccifera* (*muli*) behave also similarly. The clumps of *muli* generally flower once in their life time and take almost one year, very rarely more than one year, to complete flowering and then die. The documented flowering dates (years) were mostly on the basis of reports made by ones who might have observed flowering at any time during the wave of a flowering incidence.

A flowered culm of *muli* is brittle in nature and as a result it easily breaks even with light wind pressure. Kitamura (1975) observed a significant reduction of specific gravity and strength properties in a flowered bamboo culm of *Phyllostachys heterocycla* var. *pubescens* which could explain the breakage of such flowered culms in *muli* also.

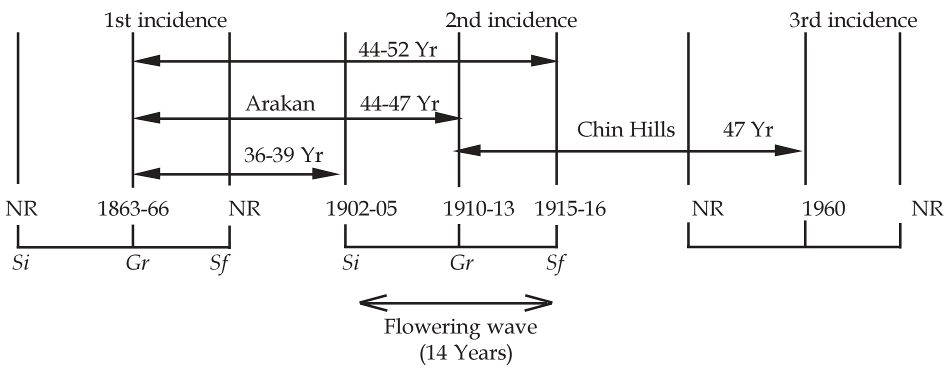
3.1.1 Flowering wave with Phase wise sporadic and gregarious flowering

The flowering in *muli* was first documented and reported to occur, as late as 150 years back, during 1863-1866, in the subcontinent (Myanmar, Assam) by William Munro (1868) in his book "*A Monograph of the Bambuseae*" and also during 1865 in Chittagong south, Chittagong north and Chittagong Hill Tracts (Gamble 1896, Brandis 1899, Troup 1921). After that, the species had been reported to start flowering again in the area in 1902 and completed in 1916 (Appendix I). The flowering continued like a "wave" for 14 years (1902-1916) spreading over the whole forest area (Plate 3a). Regarding *Melocanna* flowering in Myanmar, Raitt (1929) mentioned "the flowering is not concentrated into one season; it may be spread over 12 years". In some locations the 'flowering wave' may continue even for 17 years (Plate 3e). Thus, initially flowering may take place over a comparatively small area and spread like a wave in a definite direction, taking few years to extend over hundreds of square kilometers. During this time the species flowered in Chittagong Hill Tracts (CHT) like a wave covering an area of about 10,000 sq. miles in four (1957-1961) years time (Hasan 1973). A clump does not continue to flower in the wave for 14 or 12 or 17 years, each year many new clumps flower and within this period flowering successively spread over the whole forest area like a wave. So one can have fruits every year from different clumps flowered in successive years.

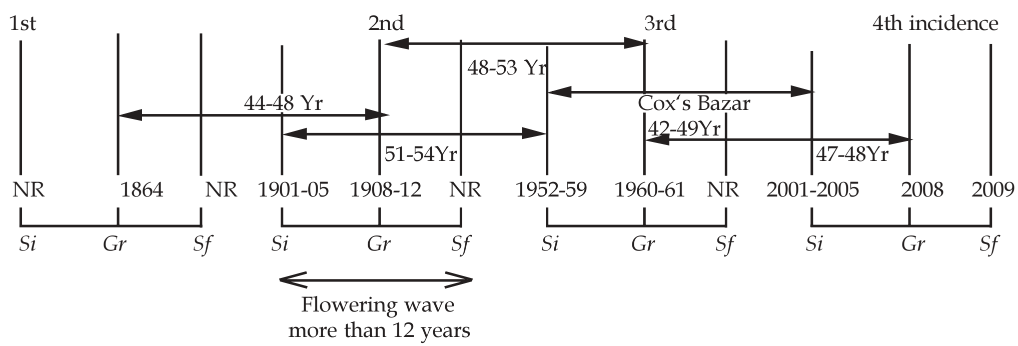
The flowering in *M. baccifera* usually takes place in three phases (Troup 1921); *preliminary* or *initial sporadic flowering*, *gregarious flowering* and *final sporadic* flowering of the remaining clumps (Plate 3). At the beginning of flowering period in a population about 10-20 percent clumps flower scatteredly and die, known as *Initial Sporadic flowering* (may be designated as *Si*-phase). The *Si*-phase usually continues for 4-8 years. Then *gregarious* (*Gr*-phase) flowering starts and more than 80 percent clumps flower and die completely within 3-5 years in a population. After gregarious flowering and mass scale death, remaining some of the clumps in the population flower sporadically and die in *final sporadic phase* (*Sf*-phase), continue to do so for 2-4 years and then all remaining members die. In early part of twentieth century, during 14 years time the flowering in *muli* bamboo in Myanmar was initially sporadic (*Si*-phase) for 4 years (1902 1905) which gradually became gregarious (*Gr*-phase) during 1910-1913, and then again turned into final sporadic (*Sf*-phase) for the last two (1915-1916) years (Plate 3a). Such 3 phase flowering nature has also been exhibited by *muli* in north-east India and Chittagong Hill Tracts of Bangladesh. In Chittagong south the last flowering was reported to occur in 1952 which was sporadic for 8 years up to 1958 or 1959 (Hossain 1962). There after a gregarious flowering took place and continued for two years during 1960 and 1961 (Plate 3b). The date of final sporadic (*Sf*-phase) was not available. The duration of each phase may vary considerably, and the first phase is usually so prolonged as to include the second, which may not be very marked. During present time, in most of the states of northeast India, the *initial Sporadic* flowering occurred from 1995-2003, *gregarious* flowering started in 2003 in different localities and spread throughout the region up to 2008, and in a few areas up to 2009. The *final Sporadic* flowering phase is going on now (2009) in many areas of *muli* forests. Thus, it is evident that the major flowering phases (both initial sporadic and gregarious) in *muli* bamboo forests are already over in most of the part of the region. The final sporadic flowering may continue for next 2-4 years upto 2012.

PLATE 3: Estimation of flowering cycle in *Melocanna baccifera* from the illustration of number of incidences of flowering in the different localities of India-Bangladesh-Myanmar region during last 150 years. (Note: 3-phase flowering nature: *Si* = initial sporadic flowering, *Gr* = gregarious flowering, *Sf* = final sporadic flowering. NR = flowering date not reported).

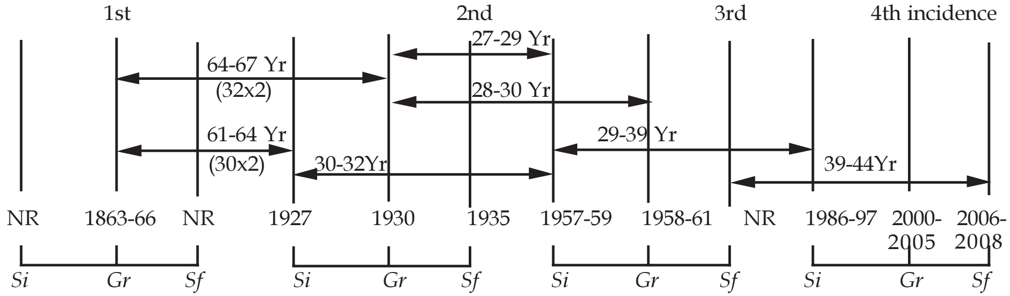
(a) Myanmar (Arakan) : Three flowering incidences each one having 3-phase flowering wave.



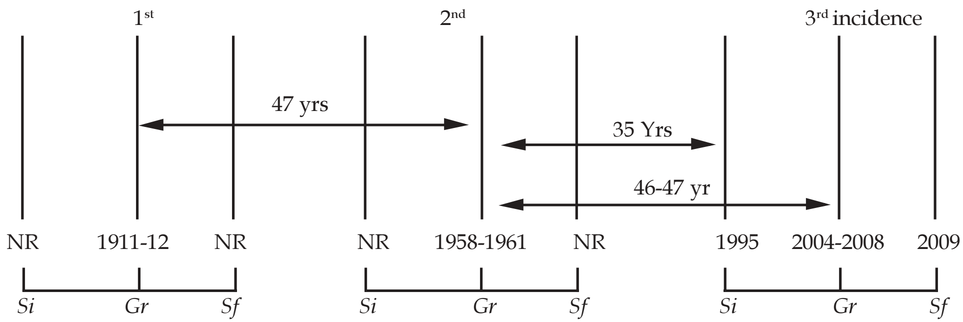
(b) Bangladesh (Chittagong south and Cox's Bazar): Four flowering incidences each one having 3-phase flowering wave.



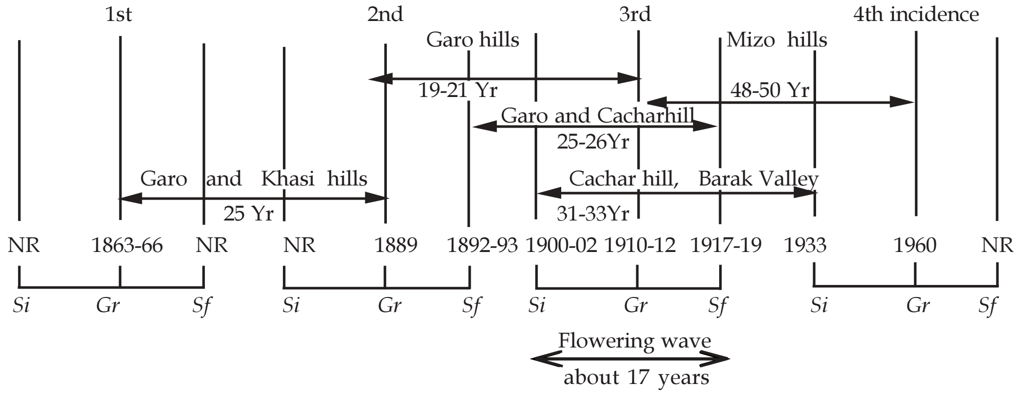
(c) Bangladesh (Chittagong Hill Tracts and Chittagong north): Four flowering incidences each one having 3-phase flowering wave.



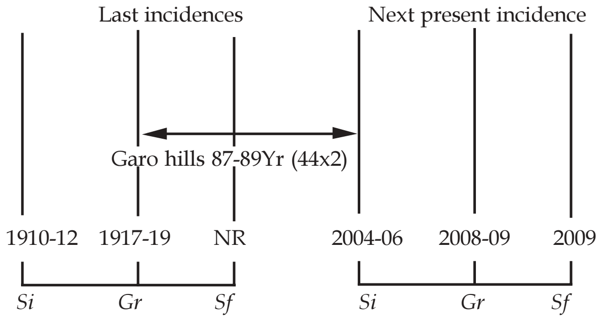
(d) India (Tripura) : Three flowering incidences each one having 3-phase flowering wave.



(e) India (Assam, Tarai, Garo and Khasi hills, Mizo hills, Lushai hills) : Four flowering incidences each one having 3-phase flowering wave.

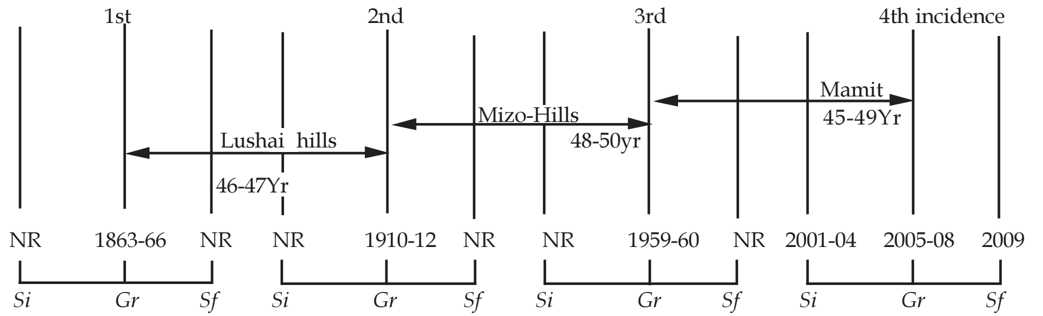


(f) India (Assam, Garohills) : Two flowering incidences each one having 3-phase flowering wave.

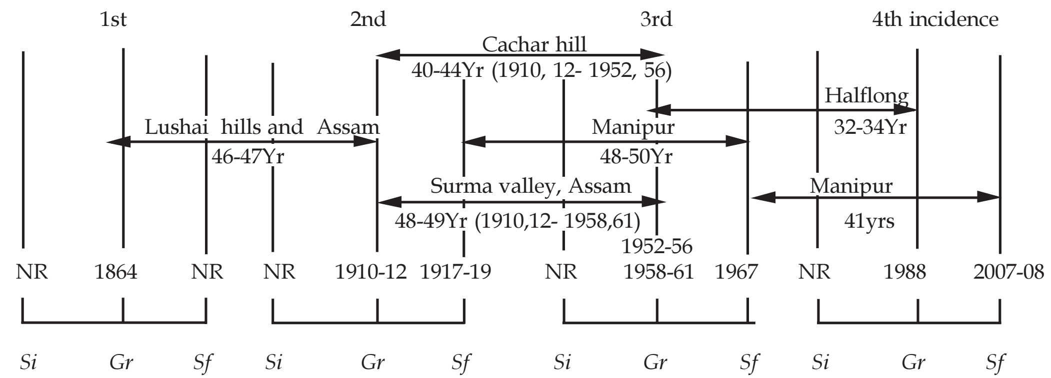


N.B. : It seems that one flowering incidence is between the "last" and "present" has gone unreported and hence the estimated interseding period of about 87-89 years; a multiple of 44 years.

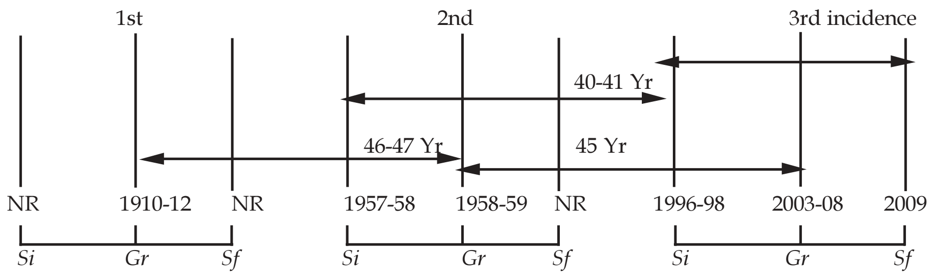
(g) India (Mizoram- Mamit, Lushai hills, Mizo hills) : Four flowering incidences each one having 3-phase flowering wave.



(h) India (Lushai hills, Surma valley, Manipur, Halflong, Cachar hills) : Four flowering incidences each one having 3-phase flowering wave.



(i) Bangladesh (Sylhet) : Three flowering incidences each one having 3-phase flowering wave.



3.1.2 Flowering populations (cohorts) with diverse duration of flowering cycles

In Myanmar (Arakan) the estimated flowering cycle in *muli* bamboo is about 44-47 years (Appendix-I; Plate 3a, *Gr* phase to *Gr* phase). No records are available on the dates of present flowering in this species. However, from present flowering incidences in north-east India and Chittagong Hill Tracts (CHTs) it may be assumed that the species has also flowered simultaneously in Arakan and neighbouring areas of Myanmar.

In Chittagong south the flowering cycles seems to be long and estimated as 45-53 years (Banik 1991a, Hossain 1962, McClure 1966, Parry 1931, Troup 1921). During present flowering the *muli* forests of this area showed sporadic flowering from 2001-2004, later flowered gregariously in the year 2005-2008. The species in further southern part of Bangladesh (Cox's Bazar) and neighbouring area of Myanmar (Arakan, Yoma, etc.) appears to exhibit similar longer, (44-53 years, or about 59-60 years) flowering cycle (Appendix-I; Plate 3b, 3c). In some parts of Arakan and south Chittagong the estimated cycle was about 60 years (Appendix-1; Raitt 1929, McClure 1966).

During current flowering of *muli* bamboo in the region, the first available report of flowering was in 1986 from north CHTs (Banik 1989). The initial (1986-1997) sporadic flowering of *muli* bamboo in different localities of northern Chittagong and CHTs (Bangladesh - Kamalchari, Fatikchari, etc.) was during 1986 and had been moving gradually like 'waves' towards the area of Fatehabad, Nazirhat, etc.; within 1997 covered about 400 sq.miles (Banik1989, 2000, Plate 3c).

In Chittagong Hill Tracts (CHT) and neighbouring areas (Chittagong north), the species is reported to flower during 1863-66, 1927, 1930, 1935 and 1957-1960. During present time it has started flowering since 1986 and from the past records, it appears that the species exhibits comparatively shorter duration of flowering cycle of 30-35 years in the area (Appendix-I; Plate 3c) similar to the estimated cycle reported by Kurz (1876), Gamble (1896), and Gupta (1988). Later during 2000-2008 the species has been flowering gregariously covering different parts of Tripura, northern Chittagong and CHTs. On the contrary, during this period the species has been reported to start flower only sporadically with a very few gregarious spots in Chittagong south and Cox's Bazar. Thus the species flowered earlier (1985) in Chittagong north and CHTs than to Chittagong south, Cox's Bazar (2005) forests (Bangladesh) bordering to Myanmar.

It was mentioned in the Annual Administrative Report of the Government of the *Maharaja* of Tripura state, that a 'Bamboo Plague' happened due to gregarious flowering during the year 1911-1912 (Sharma 2008). The next recorded gregarious flowering of *muli* bamboo in Tripura was in the years 1958 and 1961. On the southeast of Tripura border across the river Feni, the Hyanko forests of CHT (Bangladesh) where many *muli* clumps seeded during 1990-1998. Simultaneously, since 1995, *M.baccifera* have been flowering sporadically in south Tripura particularly at Sabroom (Bagafa, south Tripura) partitioned by the Feni

River and nearby forest area. Thus flowering started nearly ten years earlier in the neighbouring forests of north CHT and moved north like a `wave` towards south Tripura state of India. Then gradually the flowering wave moved to west central Tripura and further towards north. Simultaneously another flowering wave from Halflong (Assam) [that flowered during1990s] and from Kolasib [Mamit areas of Mizoram flowered in 2003-2008] might have moved towards northern Tripura. It appears in Tripura *Initial Sporadic* flowering occurred from 1995-2002 (Banik 2004), *Gregarious* flowering started in 2003 at different localities and spread throughout the State till 2008, and in a few areas up to 2009. The *Final Sporadic* flowering phase is now (2009) going on in many areas of *muli* forests in the state. Thus, it is evident that the major flowering phases (both initial sporadic and gregarious) in *muli* bamboo forests are already over in Tripura. In north Tripura the initial sporadic flowering started in 1999-2004. Further, it seems that the flowering wave has been moving gradually from south Tripura to north and west districts and exhibited cycle of 35 years in south and 46 years in some localities of north (Appendix-1, Plate 3d).

Earlier reports showed that *muli* bamboo flowered in Assam, Garo and Khasi Hills, Mizo hills and Manipur in 1863 then in 1889-93, 1910-12, 1917-1919,1933, 1967 and presently in 2000–2008 (Plate 3e, 3f, 3g, 3h). The species also started flowering in Assam (Halflong area) in 1985 (Gupta 1988, Plate 3h) along with northern Chittagong and CHT (Bangladesh) during 1986-88. It was also estimated to be 30-40 years in Halflong areas of Assam (Plate 3f; Appendix-1). The estimated cycle of 25-33 years is same to that of most parts of Assam, Tarai and Mizo hills (Plate 3; Appendix-I). In most of the areas of Assam including Garo and Khasi hills the species exhibited short duration (19-21, 25, 26-30, 27-29, 31-33 years) of flowering cycle (Plate 3e;

Appendix-I). It is evident from the past records (Plate 3, Appendix-I) that the species flowered in some areas at a time but not in all the areas of the region.

In Cachar hills, Surma valley, Manipur and Lushai hills the species exhibited longer intervals 40-44, 48-49, 48-50, 46-47 years respectively (Table 1, Plate 3e, 3f, 3g). In a few areas of Lushai hills, however, the species also exhibited *short duration* (19-21, 25 years) of flowering cycle. The flowering has moved as 'waves' towards the southem part of Sylhet forests (Bangladesh- Dholaichara, Kurma) in 1996. Presently, during 2004-2008, the species has been flowering sporadic to gregariously in these localities (Plate 3i). Thus the estimated flowering cycle is 40-41 and 46-47 years in Sylhet forests of Bangladesh bordering to the neighbouring areas of Cachar hills and Surma valley of India (Plate 3h, 3i; Appendix-I).

The old records of Forest Department show that this species flowered gregariously during 1815 in Mizoram (then known as Lushai Hills, and part of Assam) and Barak Valley during 1912 (Lalnuntluanga et al 2003, Yadava 2002). It was further reported that the gregarious flowering of *M.baccifera* in Mizoram in 1958 caused widespread damage from 1961 through 1965 covering an area of 21000 sq. km. (12482 sq.miles) and affecting a population of more than 7000,000 (Bagala 2001). During present time *muli* clumps in Kolasib area of Mizoram showed sporadic flowering in the year 2003 and the flowering wave also might have moved from north eastern part of CHT. It appears that in some areas of Mizohills (Mamit) and south Garohills the species also exhibited longer (48-50 years) flowering interval (Plate 3e, 3f, 3g; Appendix-I).

Reports also indicated that the species exhibited mostly long flowering cycle in Meghalaya (Garo and Khasi hills) and the bordering north Mymensingh areas

(Foothills of Garohills) of Bangladesh (Appendix-I).

The geographical position of Sylhet, Cachar hills, Manipur and north Mymensingh including south Garohills are not same as the Arakan, Yoma and Prome districts of Myanmar. Sylhet, north Mymensingh and Manipur are located within latitude 24° to 26°N, whereas Arakan, Yoma, Prome districts of Myanmar and Cox's Bazar, Chittagong south of Bangladesh are situated towards south within that of 17.5°N to 21°N. So, obviously, there exists some climatic variation, even though most of the *M. baccifera* population flowered synchronously in these two regions.

A 'flowering population' may be described as a cohort, characterized by some geographical position, where individuals are established in a particular year/period following either a gregarious or sporadic flowering and may have closely allied genetic make up. A cohort may consist of a number of individuals (clumps) that are half sib in nature (only one parent is common) and due to this genetic proximity the biological clock runs almost synchronously in all the plants in the cohort (Pattanaik et al 2002). So, all the individuals in a cohort are expected to flower and die simultaneously. Geographically distant populations flowering simultaneously thus should be regarded as one cohort.

However, few individuals in a flowering population may differ in the flowering periodicity and behaviour from the rest. It is not uncommon to find few clumps of *M. baccifera* remains with green leaves without any flowers growing in small patches inside a vast majority of gregariously flowering population covering a large tract of land (Figure 10). Accordingly one may observe such non flowering clumps of *muli* in scattered patches or populations (locally known as *Mau-Hak* in Mizoram) inside the gregariously flowering area on the hills

Figure 10:

Melocanna baccifera: A few clumps remain with green leaves without any flowers growing in small patches (*Mau-Hak*) inside a gregariously flowering population covering a large tract of land on the hills of Mizoram

of Mizoram, Tamenglong, and Chittagong Hill Tracts. Be that as it may, though the majority of clumps of the species growing in a locality flowered gregariously at a time, some clumps isolatedly or in patches may not flower synchronously and constitute a separate population (cohort). It was observed that the clumps of *M. baccifera* growing on the lower hills at Panbang - Mathanguri area of southern border of Bhutan did not flower till 2008 and also not showed any symptoms of flowering even in next year 2009 though the species have been flowering gregariously for last 10 years in the neighbouring different areas of Assam and Meghalaya in India. Thus, the *M.baccifera* population in southern Bhutan seems to be a separate cohort. From the foregoing discussions it is clear that a number of gentic populations of *muli* exist in the region.

Adaptive significance of differences of flowering behaviour and movement of 'flowering wave' needs to be understood by analyzing the population structure on a given tract of land.

3.1.3 Importance of Cohort diversities

It appears from the flowering records (Appendix-I) and distribution map (Plate 4:Map) of flowering (reproductive) populations that *Melocanna baccifera* exhibits more than one flowering cycle (interseeding period) in different localities of Bangladesh-India-Myanmar region and they might be isolated from each other by flowering and reproduction time (Plate 4).The species exhibits long (40-50 years) duration of interseeding period in northern Tripura and bordering bamboo forests of south east Sylhet, and southern Nagaland. The population in southern Tripura bordering to CHTs, northern Chittagong and a few parts of western Mizoram appears to have shorter duration (30-35 years) of interseeding periods. Thus it is evident that there exist mainly two distinct large populations (cohorts), one with short interval of 30-35 years and the other with 40-50 years of long interval flowering cycle (Plate 4). In the boundary areas of two, however, populations are likely to overlap with each other and some of the clumps may flower in further shorter and others after longer periods or in between (Plate 4). In fact, few small populations (cohorts) of the species seem to exhibit further longer interseeding period (55, 60, 65 years) in Arakan (McClure 1966), southern Chittagong and Cox's Bazar (Appendix -1). In some areas of Assam, Mizoram and Chittagong Hill Tracts shorter intervals (7-10, 10-13, 19-21, 22-23, 25, 28 years) of flowering cycles were also reported by Chatterjee (1960), Hossain (1962) and Banik (1998b). The past flowering reports of *M. baccifera* in the region (Appendix-I) also support the view. The existence of a number of cohorts with diverse duration of seeding cycles seems a buffering mechanism of at a time death of all clumps.

Due to such diversities in flowering cycle enormous genetic variabilities are expected within this vast natural habitat and each of these flowering populations may be regarded as a different cohort. *Melocanna baccifera* being a cross pollinating bamboo species, covering a vast geographical region, there must exists variations in population(s), or cohorts, with diverse flowering intervals (cycle) and enormous genetic variability (Banik 1998b).

3.1.3.1 Mapping cohort populations

When flowering occurs the exact area coverage should be marked, identified and a map using Geographic Information System (GIS) be prepared. Cohort mapping would help in estimating the interseeding periods and predicting future flowering dates in various cohorts located in different areas of the region. This information would be vital in systematic management of issues arising out of gregarious flowering of *M.baccifera* covering vast region of the sub-continent.

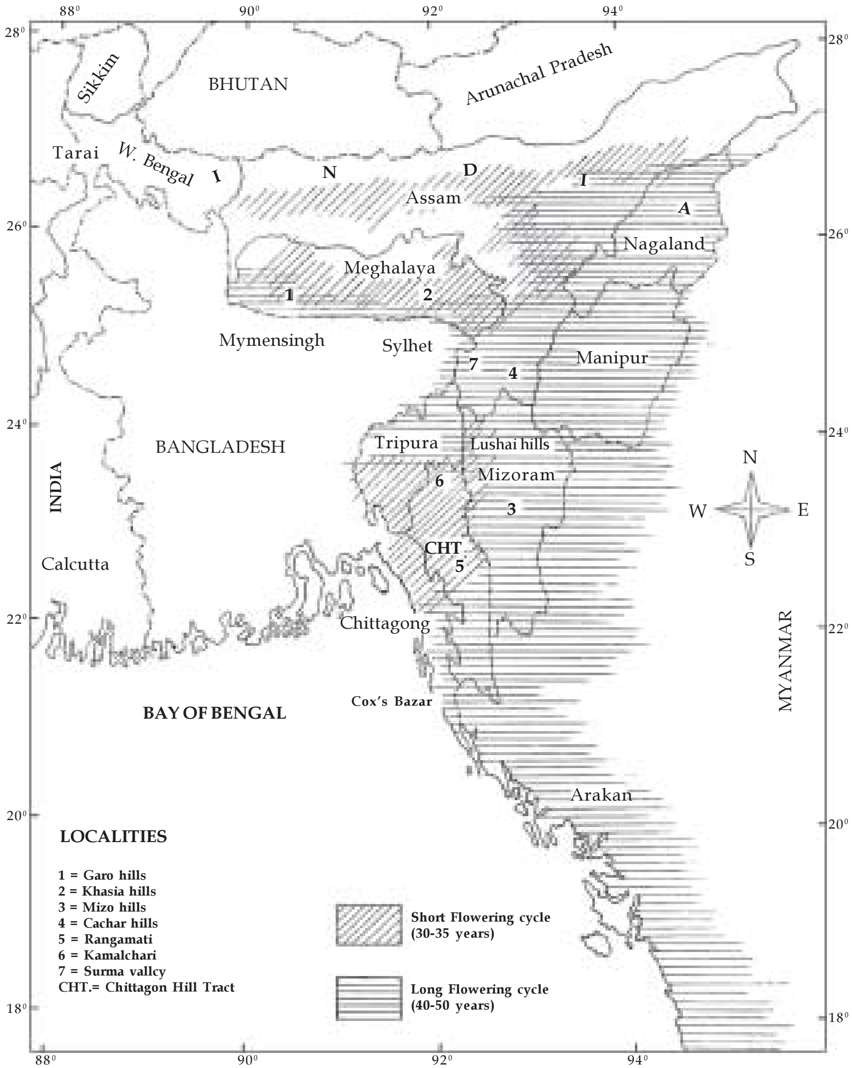
3.1.3.2 Cohort Seed Orchards

Delimiting of cohort population of *muli* bamboo open up challenging opportunities in mitigating the severe adverse socio-economic impacts of gregarious flowering. It is important to collect seeds and seedlings from each of the identified cohort located in different parts of the region and their year wise labelled collation in areas through raising plantations (minimum of 100 plants) in blocks. These cohorts are likely to flower and seed block by block during next flowering cycle. Such centralized plots serve as "seed orchard" or "seed stands" of *Melocanna baccifera* (Banik 1995a, 1997a, 2008). Plantations raised from different cohort sources would not flower, and die, at a time in future. Such diverse flowering populations (cohorts) also offer opportunities for selection of candidate plus clumps and improvement of the species (Banik 1997a).

Besides the presence of different flowering cohorts, it is likely that in the vast populations of *M. baccifera* there might exist some clumps that escape death after flowering without setting much seeds as observed in other bamboo species like *B.vulgaris* (Banik 1979), *Pseudoxytenthera stocksii*, and *Dendrocalamus giganteus*. In some occasions a few individual inside the population may flower a few years early in between normal flowering year or late but not synchronously. So, a few clumps of the species sometimes may flower without following any known period of flowering cycle. Such 'out of phase flowering' could be due to a certain pedigree originating from different interseeding periods (Banik 1980, Watanabe and Hamada 1981). Through extensive exploration in this vast *muli* growing region it is not unlikely that a few individual clumps may be discovered that flower but do not die after seeding or die partly and rejuvenate.

The genetic variability is also likely to initiate considerable phenotypic variation

PLATE 4: A tentative distribution map of major flowering populations of *Melocanna baccifera* in different localities of Bangladesh-India-Myanmar Region.



among the population. Exploration, identification and selection of desired phenotype(s) are needed for the improvement of *muli* to enhance productivity. Accordingly locating and mapping of these areas may be regarded as "hotspots" for genetic-diversity conservation and improvement research in *M. baccifera*. Keen field observations, and systematic documentation of phase wise flowering reports, along with localities are important in this regard.

3.2 Floral Characteristics and Seed Production

3.2.1 Inflorescence

All culms in a clump of *muli* do not always flower synchronously, some clumps may have culms in two or more different phenological states. During a flowering year, culms in a clump start producing floral shoots always at the apex of thin leafy branches (Figure 11a) generally in the month of September to October (Banik 1998b, Table 2). These

Table 2. Floral shoot appearance, flowering and seeding period in *M. baccifera.*

Species	Floral shoot		Flowering date	Shoot to flowering (period)	Seed ripen (date)	Flowering to seed (period)
	Initiation date	Length (cm)				
Melocanna baccifera	Sep. 2nd week	12-60	Nov. 2nd week - January	7 weeks	April –Sept.	7-8 weeks

floral shoots with flower-buds are leafless, slightly brown and 12-45 cm or may be 60 cm long. After about two and a half months the floral shoots start blooming during November to December or January. The flower buds are borne at nodes along one side of the axis of a floral shoot and thus the pseudospikelets are produced on one side of the branches (Figure 11b).

About two and half month later, that is in last part of November to mid January, blooming starts on the floral shoots.

The inflorescence is a large compound panicle, usually remains drooping in nature. The *spikelet* is cylindrical and about 40-60 mm long. *Palea* is convolute, mucronate and 7 veined. *Lodicules* 2 and fimbricate. The number of *florets* on the spikelet is 3-8, out of which 1-2 are fertile and 1-7 are sterile.

The *ovaries* in florets are *diagnostically prominent, visible and have elongated styles*. The ovary is ovoid and narrowed upward into an elongated style which is divided into 2-4 hairy, recurved **purple** coloured *stigmas*, the major portion of which is exposed (Figure 11c). *Stamens* are 5-6, filaments short, free, and 7-9 mm long. *Anther* is **yellow**, obtuse, and 2-4 mm long, not much exposed or emerged out. The pollen grains are globose having wide variation in diameter size, from 41-86 microns.

Figure 11 (a)

Melocanna baccifera: Clump starts producing floral shoots always at the apex of thin leafy branches

Figure 11 (b)

Melocanna baccifera: The floral buds borne at nodes along one side of the axis of a floral shoot and thus the pseudospikelets are produced on one side of the branches;

Soon after blooming in the apical floral shoot, all the leaves below to it on the branches turn yellow and gradually wither. The buds on the axils of the withered leaves then start producing short panicles, both flowering and fruiting take place simultaneously (Figure12). Accordingly within a few weeks the main and secondary branches become leafless and form a large compound panicle. Thus finally all branches on the culms become leafless and produce flowers. All the leafless flowering culms in a clump look like a giant inflorescences.

The clumps of *M. baccifera* take almost one year to complete flowering and then die. Complete flowering clumps of *M. baccifera* do not produce any culms in the current year of flowering. All the flowering clumps under study (1990-1991) at Chittagong Hill Tracts did not produce any new culms or produce a very few numbers of culms. However, in the

Figure 12

After blooming in the apical floral shoot, all the leaves below to it on the branches turn yellow and gradually wither; produced short panicles, both flowering and fruiting in leafless flowering culms in a clump and look like a giant inflorescences.

Figure 11 (c)

Melocanna baccifera: The *ovaries* in florets are diagnostically prominent, visible and have elongated styles with short recurved *purple* coloured *stigma*, the major portion of which is exposed.

previous years of flowering year, i.e. during 1989, 1988 and 1987 (1, 2, 3 preceding years of flowering) the average culm production per clump was 8.0, 17.0 and 12.0 respectively (Banik 1991a). Thus it appears that flowering clumps usually do not produce any new culm, but in the immediate preceding year culm production decreases significantly. Similar situation was observed in Mamit area of Mizoram where flowering started sporadically in 2006 and gregariously during 2007-2008. Before flowering in 2005, the culm number of more than 3-year old, 3-year old, 2-year old, 1-year old and current year per hectare was found as 11100 (in 2001), 2850 (in 2002), 5660 (in 2003), 4500 (in 2004), and 4310 (in 2005) respectively. In 2006 the number of new culms decreased to 3000 only per hectare and all of them were very thin, 1.0 to 2.0 cm in diameter (Shibata et al 2008). The culms of various age groups including 9-12 months old young culms also flowered at a time in the same clumps (Figure 13a).

3.2.2 Anthesis and pollination

The florets of *M. baccifera* mostly open in the morning up to 10 a.m. Generally upper floret opens first and the lower floret opens after 2 to 5 days (Banik 1998b). Anthers come out in the morning and burst in the afternoon at 3 p.m to 5 p.m. Some may come out in the afternoon and burst in the morning of next day. Dehiscence starts from the apex and moves longitudinally down the anther. However, in most of the other bamboo species (*Bambusa bambos, B. glaucescens, B. tulda, Dendrocalamus longispathus*) opening of flower and pollen discharge take place only in the morning 6a.m to 9a.m (Banik 1986).

Blooming of florets is random in the branches which could stimulate greater movement of wind between inflorescences and different flowering clumps. As the filaments are short, anthers do not emerge out much or exposed, where as style is much elongated, and the major portion is exposed, so that more pollen from the wind can be trapped to favour cross pollination and more production of viable fruits.

Minute fruit is visible within a week of pollination. Pollination, fruit setting and maturation take place within four to five months, by April and May. However, *caryopsis* (fruit) maturation is quicker in early part of seeding season. Both flowering and fruiting in a clump are simultaneous. Often as many as 6 or 10 fruits may be found hanging in clusters round each node down the whole length of the culm.

3.2.3 Seed characters

Melocanna baccifera is widely known as the bamboo with large, thick-walled fruit commonly referred as "like a pear" in size and shape, unlike other common bamboo species which have grain like fruit (McClure 1966). Kurz (1876) described the fruit of *Melocanna baccifera* as "a large pear-shaped and fleshy" and "berry like". Later the fruits of this species has been termed as "*bacciform caryopsis*" or "*bacoid caryopsis*" (Tsvelev 1976). In Botanical Latin '*bacca*' means a berry, "*bacciformis*" means shaped like a berry and '*bacciferous*' means bearing berries. Fruits are green with smooth surface, large, obliquely ovoid, some what mango shaped, thick and fleshy at stalk-end, apex terminating in a curved beak not covered with any glumes (Banik 1991a, Figure 13a).

The fruit is not solid but possesses a seed-cavity towards the swollen stalk-end. It has thick (7-13 mm) white cream colour fleshy fused pericarp and mesocarp filled with starch, and the thickness is as great as the diameter of the seed cavity (Figure 13c). At the swollen end the cavity has endosperm, much reduced embryo with relatively large scutellum containing starch grains, and therefore germination takes place at this end. This necessitates that the swollen end of the seed should always be under the soil surface to have higher percentage of germination and seedling survival (Figure 14a).

Variations in size and weight exist among the fruits of a population. In a sample of 10000 fruits the length, diameter and weight varied from 35-110 mm, 22-60 mm, 7-151g respectively (Banik 1991a). However, a field forester usually terms the fruit (caryopsis) as "seed". In one case in-

Figure 13 (a)

Melocanna baccifera: Young culms, 9-12 months old having persistent culm sheath also flowered simultaneously along with other age-group culms in clumps;

Figure 13 (b)

Melocanna baccifera: Fruits or "*Bacciform caryopsis*" are green with smooth surface, large, obliquely ovoid, onion-shaped, thick and fleshy at stalk-end, apex terminating in a curved beak not covered with any glumes;

Figure 13 (c)

Melocanna baccifera: the longitudinal section of a fruit showing the presence-a seed-cavity towards the stalk-end with thick white cream colour fleshy fused pericarp and mesocarp.

dividual fruits weighed 300g. The mean seed size and weight drop signifcantly towards the later part (September) of the seeding season. Study show that the seeds produced in May-June were comparetively bigger (length 6.9 ± 0.3 cm, diameter 4.1 ± 0.2 cm) and heavier (weight 55.3 ± 5.46g) and also germinated with higher rate (79.8 ± 6.5 per cent) than produced in September. Seeds produced in September were small (length 5.2 ± 0.5 cm, diameter 3.3 ± 0.4 cm), light in weight (17.8 ± 2.6g) and had poor germination capability (46.6 ± 11.4 per cent).

3.2.4 Seed production

Seed production is poor in sporadic flowering conditions where possibility of cross pollination is very low. Gregarious flowering over a large tract of land facilitates cross pollination resulting higher production of viable "seeds." Often as many as 8 or 10 fruits may be found hanging in clusters from the node of a culm. One medium sized full grown clump usually produces 5-7 kg "seeds" in one flush and 25-40 kg within whole flowering period before dying.

In a field study of a ten year old *muli* plantation, nearly 23,300 culms were found to be growing per hectare. Considering the average number of fruits per culm to be 100, during the entire fruiting period, with an average seed weight of 50 gms, one hectare of *muli* plantation will yield 10-12 tonnes of fruits.

In general, "seed" production is high during May-June and poor from later part of August-September.

3.2.5 Seed dispersal

The mature "seeds" usually drop near the mother clumps and may also disperse far away from mother clumps by rolling over the hill slopes. They are also naturally dispersed widely covering a large areas along the flow of rain water through streams.

The seeds, are eaten heavily by rats, wild boars, porcupines, deers and other animals. The *muli* "seeds" are also edible (Holland 1919) to human being and it was reported that in 1930 seeds were even sold in the local hill markets in CHT (Nath 1930). The local hill-tribes also eat the fleshy "seed" as vegetable and some times the seed cavity which contains sweet fluid is eaten raw. The comparison of nutrient contents of *muli* bamboo fruit/kernel and other food items is given in Table 3. (Lalnunmawia 2008). The creamy colour white embryo of *muli* bamboo seeds is taken as medicine by the tribal people. According to James Lalsiamliana, Assistant Plant Protection Officer, Mizoram Agriculture Department, who has been specially assigned by the state government to keep track of rodent population during the present bamboo flowering. "A hundred grams of bamboo seeds contains 60.36g of carbohydrate and 265.6 K Calorie of energy. This amount of carbohydrate and energy can easily make any living being active.... even in sex". However, scientists are yet to accept that these seeds can increase the fertility of rats or enhance human libido.

3.2.6 Seed collection

Muli seeds can be collected both from the clumps and from the ground easily due to their big size. The seeds have to be collected by plucking directly from the plant or by shaking the culms gently, so that the mature seeds fall on the ground (Banik 1998b). As an extra advantage, this also reduces the availability of seeds to the rats, porcupines and wild bores on the ground. Thereby it assists in controlling the population increase of such animals. Collection of *M. baccifera* seeds should be started from later part of May and may be continued up to August. The best time of seed collection is from April-July. It can also be collected in the months of August-September but with poor capability of germination.

Table 3. A comparison of nutrient contents of different cereal food grains, tubers and *Melocanna baccifera* seeds.

Food	Moisture (%)	Protein (g)	Crude Fat (g)	Available Carbohy-drates (g)	Fibre(g)			Crude ash (g)	Energy (Kcal)
					Dietary	Water insoluble	Lignin		
Brown rice	14.0	7.3	2.2	71.1	4.0	(2.7)	(0.1)	1.4	384.0
Wheat	14.0	10.6	1.9	61.6	10.5	(7.8)	(0.6)	1.4	375.0
Maize	14.0	9.8	4.9	60.9	9.0	(6.8)	(0)	1.4	396.0
Potato	77.8	2.0	0.1	15.4	2.5	(1.9)	(0)	1.0	70.0
Cassava	63.1	1.0	0.2	31.9	2.9	(2.2)	(0)	0.7	133.0
Yam	71.2	2.0	0.1	22.4	3.3	(2.6)	(0)	1.0	98.0
Melocanna baccifera (Fruit)	37.11	5.16	0.3	53.14		1.61		2.68	235.9
Melocanna baccifera (Kernel)	87.75	2.29	6.11	2.84		0.05		0.96	75.5

(Source: Lalnunmawia 2008)

3.2.7 Seed processing

In the forest, seeds of *M. baccifera* start germinating with the first heavy showers of the rainy season. As the seeds of *muli* are big and not covered with glumes, they can be separated easily from debris and unwanted materials. The collection bags should be kept open, and in shade to prevent heat build up as it affects the viability of seeds. If seed collection continues for more than a day, a temporary storage prior to return to the station is recommended. The seed should be kept in shade in well ventilated conditions.

3.2.8 Seed viability and storage

As *muli* seeds are fleshy '*baccaform*' in nature, these can be sacked in gunny bags having slightly moist sand (need aeration, not desiccation) for transportation. However for storage, even for a period of two months, the material should be kept in air conditioned rooms. The '*bacca*' type *Melocanna* seeds are sensitive to desication (exhibit *recalcitrant* behaviour), while the grain like seeds (caryopses) of other bamboo species (*Bambusa* sp, *Dendrocalamus* sp., *Gigantochloa* sp., *Schizostachyum* sp, *Thyrsostachys* sp, etc.) can tolerate desiccation (*orthodox* behaviour). Storage conditions also affect seed viability as seeds stored at a low temperature (at 15-17 ^{0}C) have higher germination ability than those stored at a normal room temperature.

3.2.9 Seed Sowing position and germination

Occasionally some nurseries experience poor rate of germination due to improper sowing position of *muli* seeds in the soil (Figure 14a). The seed should be sown at least 0.5-1.0 cm below the soil surface. When swollen portion of the seed is above the soil surface, chances of root and shoot desiccation is very high, oppositely when the swollen portion is placed vertically at dip in the soil (that is, the narrow beak portion is up). The plumule (shoot) need to bend and move upright for piercing through the ground and in such situation may die before reaching above the soil. Placing the seeds below the soil surface either horizontally is the ideal way of sowing position in *muli* bamboo (Figure 14b).

The collected ripen fresh “seeds” germinate immediately (Banik 1991a). Generally the mature seeds germinate well (80-85 per cent) under diffused light usually within 3-7 days of sowing. The germination is very low (30-36 per cent) under direct sunlight. The seeds in the collected lot will continue to germinate for 35 days from the date of collection, but with higher rate in the first 10-15 days (Banik 1991a). During germination a thick (4-6 mm) soft, tender green plumule with pointed tip, usually one and sometimes 2-4 in number and fleshy roots are produced from thick end of the fruit (Figure 14c). Most of the seedlings germinated from big and heavy seeds (51g and above) produce 2 or more number of shoots (57 percent), while small and light seeds produce 15-39 per cent only. Seedlings raised from light seeds produce mostly 1 shoot seedling (56-77 per cent).

In *M. baccifera* seedling survival is a maximum (70-80 per cent) when raised from the seeds heavier than 50 g, but it drops (50 percent) when raised from light weight (7-16 g) seeds. Different types of abnormalities (Figure 14d), such as, rootless plumules, stunted radicles and radicles growing upward etc. are not uncommon (Banik 1991a) in the seedlings produced from light weight (4-10g) and some times too big and heavy (more than 150g) seeds. So, medium to big size seeds should be selected and collected for raising plantation. The germination percentage is significantly low mostly with abnormal seedling.

During later part of flowering season, September-November, few “seeds” were found in germinating stage even on the flowering culms (vivipary germination) (Figure 14e).

Figure 14 (a)

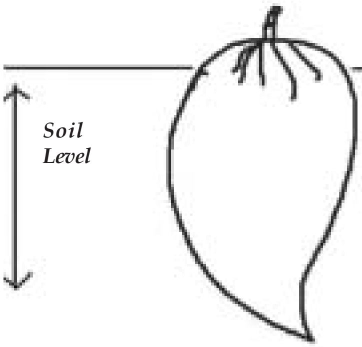
Melocanna baccifera seed germination: Improper sowing positions of seeds- the swollen portion of seed is above the soil surface

The seeds collected from isolated clumps in some occassions may produce albino seedlings (Figure 15a). Such albino seedlings are very rare when germinated from heavy seeds while it could be about 13 per cent when raised from small and light seeds. As these seedling are devoid of chlorophyll, they can not manufacture their food and ultimately die within a few weeks when the stored food in the seeds is exhausted.

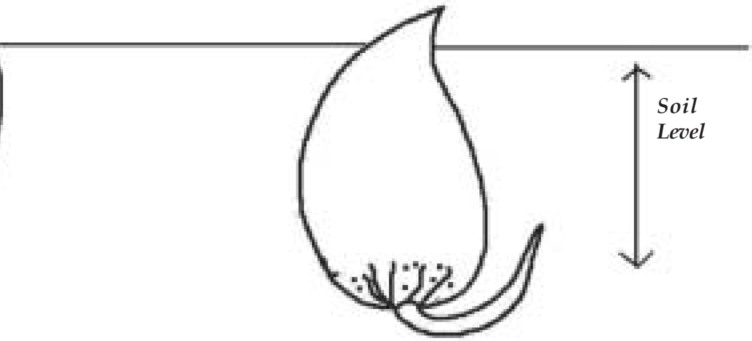
Figure 14 (b)

The improper and proper position of sowing of *muli* seeds for obtaining better germination and normal seedlings

A) Seeds sown vertically upright or upside down position above the soil surface.

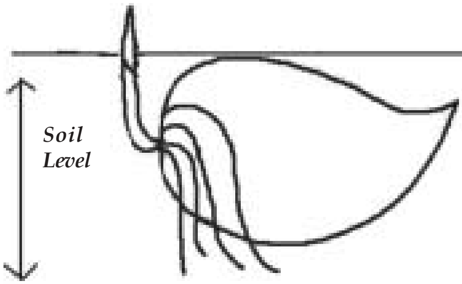


a. The swollen portion of the 'seed' is above the soil level.
The roots and shoots are getting dried, mostly die.

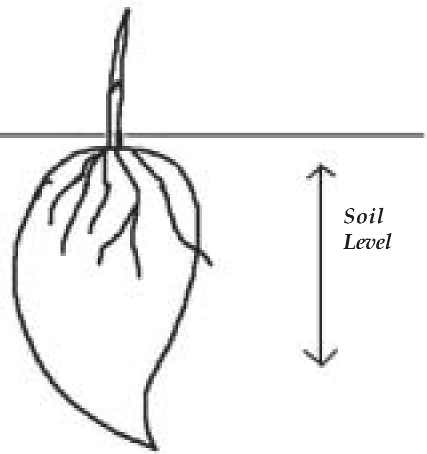


b. The swollen protion of 'seed' is at the dip of the soil.
The shoots bends and trying to reach above the soil.
Most cased die.

B) Seeds swon below the soil surface.



c. Seed placed horizantally, during germination, roots went down to the soil and shoot (plumule) easily developed straight above the ground.



d. Seeds placed vertically and the swollen portion is below the soil surface, germinating without any chance of root drying.

3.2.10 Handling of freshly germinated seeds and maintenance of seedling at nursery

The newly elongated shoots (plumule) are soft and tender; as a result these get damaged or injured due to careless handling. Care should also be taken to protect germinating radicles from being

Figure 14 (c)

Seed germinated with vigorously growing plumule and radical

Figure 14 (d)

Different types of abnormalities- rootless plumules, stunted radicles, radicles growing upward and albino character

Photograph Courtsey: Dr. Sasikumar IFS, FD, Tripura

Figure 14 (e)

Seed also germinate while on the culm (viviparous germination) desiccated. Therefore, seeds should be carefully carried and handled during loading, transportation and unloading. Seeds when carried with slightly moist sand in the jute bags during long distance transportation the damage are minimum and retain the viability in movement. After reaching the destination, the collected seeds should be immediately spread on seedbed in a nursery shed under partial light and well-ventilated condition. The details of seedling management are being discussed under Chapter 5 (Section 5.2.4).

3.3 Synchronized death of flowering clumps and Precocious Flowering in seedling

It is believed that the reserve food material left in a flowering clump left behind in the rhizome, if any, was not fit to be utilized for developing leafy shoots but for flowering and seeding, possibly due to the absence of enzymes required to reconvert the reserve material into a suitable form for the production of leafy shoots. It is suggested that during flowering, most of the monocarpic plants convert all of their undeterminate meristems that continued vegetative growth to determinate flower forming meristems (Salisbury 1963). It has been observed that a flowering bamboo clump does not die until all the vegetative buds (leaf buds) are transformed into flower buds (Ueda 1960). The water demand of the bamboo and its upward movement, becomes markedly restricted during flowering time due to absence of leaves, and as a result the plant dies.

However, in monocarpic species, death of the whole plant is closely connected with reproduction and is evidently 'genetically programmed' (Wareing and Phillips 1978, Numata 1987) at this stage in the life cycle. According to Janzen (1976) an internal physiological calender might set the timing of seeding or ripeness to flower in bamboo and he concluded that flowering in bamboo is

Figure 15 (a)

Melocanna baccifera: Albino seedlings

Figure 15 (b)

Seeds germinated in May 1989, seedlings flowered precociously at the age of 10 months (March 1990), then transferred to a big container (a drum) for further study

without doubt a genetic trait. Precocious flowering was also reported in *M. baccifera* seedling (Banik 1998b). Among 10,000 seedling population raised during May 1989 from the seeds collected from Hyanko (Chittagong Hill tracts), 4 seedlings started flowering precociously at the age of 10 months (March 1990) and another seedling at 12 months (May 1990) of age (Figure 15b). In total 5 seedlings (parental generation) flowered and all produced seeds. But some seeds from two mothers germinated and developed into seedlings. These seedlings (first generation) again flowered and produced seeds and seedlings similar to the report of Banik (1980) on *Bambusa tulda.* Unlike adult flowering clump, the precociously flowering seedling produced new culms simultaneously and did not die within one year. These seedlings, however, died within 30 to 36 months of age. One seedling of 3rd generation had been surviving and again started producing floral shoots in the month of March 1997 and fruited in August 1997 in the Nursery and finally died in 1998 at the age of 5 years. Such flowering behaviour in bamboo seems to be genetically controlled and the responsible gene(s) is (are) segregated and expressed in each subsequent generation (Banik 1980, 1987, Watanabe and Hamada 1981).

3.4 Implication of *Muli* Bamboo flowering in the Hills of the region

The possible impact of recent (since 1985 to date) flowering of *Melocanna baccifera* in northeast India and other parts of the sub-continent are discussed in the following segments.

3.4.1 Socioeconomic Effect

Such widely occuring flowering in bamboo vegetation may have grave socio-economic implications. The flowering and death of bamboo forest result in marked shortage and has in the past caused following problems:

a) ***Localized famines:*** The history says that when *muli* bamboo flowers in its native habitat around the Bay of Bengal (Bangladesh, Myanmar and North-eastern part of India) once every 30-35, or 45 years, its flowering and fruiting can lead to disaster. The flowering and death of bamboo forest result in marked shortage of raw material for housing, cottage industries and pulp and paper mills. Like other bamboo species, the fruits of *muli* are also eaten heavily by rats, pigs, porcupines, elephants, bison, rhinoceros, deer, cattle, and other animals. Excessive accumulation of bamboo fruits brings on a rapid increase in the rodent population, which begin devouring grains/ seeds and stored food as well may create shortage of food grains, thus created a localized famine. Such localized famines resulted in the region after each gregarious flowering in *Muli* bamboos. Famines due to *muli* flowering during 1815, 1863, 1911 and 1959 are locally known as "Mautam" in Mizoram, and in the past the state experienced serious socio-economic unrest due to this (Lalnuntluanga et. al 2003). `*Mau*` refers `Mautak` bamboo meaning *Melocanna baccifera* and `*Tam*` meaning famine. Massive flowering of bamboo in Mizo hills led to an explosion in the population of rats. These devoured the grain in the field and in village ware-houses, causing scarcity of food for humans created a famine in the area. A Mizo National Famine Front was formed, which found the State's response wanting. Deeply affected by the famine, later a Mizo National Front (MNF) was created under the leadership of a one–time accountant named Laldenga (Guha 2007).

It is observed that during (since 2005-2008) recent gregarious flowering of *muli* bamboo in different localities of Mizoram state, the population of *Ochrophora montana*, a bug locally known as '*thangnang*` also swarmed in Sabual, Zamaung, Kawrthah (near Mamit) and other areas where these bugs were not seen in normal non-flowering years. These bugs might feed on nectar and pollen grains of *muli* flowers and thus population increased during gregarious flowering. These bugs are collected by the local people from the bamboo jungle and used as food. First bugs are cleaned thoroughly, macerated in a wooden mortar into paste then mixed with water and boiled slowly, fat oil floats on the top of the hot mixture, collected and preserved for ceremonial uses (Figure 16 a-d). People treat the bug-oil as precious material as available once in a fifty years.

Figure 16 (a-d)

Bugs locally known as '*thangnang*` are available in huge number during gregarious flowering of *muli* bamboo in different localities of Mizoram state; and used as food, macerated in a wooden mortar into paste
and boiled for extracting fat oil

Figure 16 (b)

Figure 16 (c)

Figure 16 (d)

Figure 16 (e)

The local people in Mizoram have been using different types of trap, to kill the rodent for minimizing the crop damage

Both rodent and bug population have been destroying the paddy, maize and sugarcane crops. In flowered areas local farmers are showing reluctance to cultivate paddy and other crops in jhum lands.

The local people of villages- Chhawrtui, Puilo, Dulte in Mizoram has been using different types of trap, locally known as 'Vaithang', 'Mangkhawng' and 'Thangchep' to kill the rodent for minimizing the crop damage (Figure 16e). A total of 54,030 tails of rats were collected by killing them in the traps only in these villages during the month of October and November 2006 (Anon. 2007). It was further reported that a total number of 2,21,636 rats were killed from Champhai and Serehhip districts alone in year 2006. Thus, this gregarious flowering of *M. baccifera* has developed a belief that flowering in bamboo is a sign of bad days coming ahead.

Some opinions are there that bamboo culms may be felled one or two years before flowering from the area to avoid production of seeds. But field observations are that *cutting down clump* which is about to flower does not prevent flowering; in such a case a profuse mass of flowers and seeds appears on the stumps of the cut culms and small shoots developed from the base of the clump (Figure 17). If

Figure 17

A profuse mass of flowers and seeds appears on the stumps of the cut culms. Some nodes on the culm stumps also produced many big-size leaves (juvenile leaves). Cutting down and burning the clump of *M. baccifera* which is about to flower could not prevent flowering

the bamboos are cut in the cold weather when about to flower, they flower from dwarf shoots next year. By *cutting the culms down* in April - May when the fruits are almost ripe, however, the *rhizomes are killed* and the great majority of the *fruits are destroyed* and thus predators get deprived off the substantial amount of fruits.

b) ***Diseases:*** Local people has a belief that flowering in bamboo is a sign of bad days ahead. In the past the explosion of rodent population consumed food grains and initiated different diseases such as typhus, typhoid, and bubonic plague, which reached epidemic proportions.

c) ***Death and Shortage of Bamboo:*** Wide occurrence of such gregarious flowering has serious economic implications. The flowering and death of bamboo forest result in marked shortage of raw material for housing, cottage industries and pulp and paper mills. In the past whenever there was gregarious flowering in the *muli* forest, all the clumps died covering a large tract of land that created shortage and scarcity of bamboo resources in different parts of India, Bangladesh and Myanmar (Brandis 1906, Janzen 1976, McClure 1966, Troup 1921). In Chittagong Hill Tracts and most north-eastern states of India, next to agriculture; it is bamboo-based economic activities that generate a large amount of employment. The large tribal population that inhabits this region depends on forest of bamboo, which spells ready cash for them. The entire standing stocks of *muli* bamboo crop are eliminated within 2-3 years. Processing industries and local weavers lose their source of raw materials very rapidly and pass very difficult time to remain in business. Many parts of the hills became exposed resulting in increased amount of soil erosions, landslide etc. and alarming situation for local people as there are little or less availablity of edible shoots, very few bamboo based works and employment.

d) Shortage of edible shoot production: Some animals, like monkey, porcupines, buffalo and wild boar depend partly or wholly on tender shoots and young rhizomes of bamboos for their food. Recent flowering and large-scale death of *M. baccifera* and *D. hamiltonii* in the North East, including sporadic death of *B. tulda, S. dullooa,* results in scarcity of these food items and has an adverse effect on their health and survival. Local tribal communities have been consuming the tender shoots as one of the major food items during rainy season. Large scale death of *Melocanna* vegetation would drastically cut down the availability of edible shoots, and thus influence the nutritional level and health condition of local hill people.

3.4.2 Some approach to address the situation

To overcome and minimize these problems the suggested strategy is:

- Local utilization of seeds in natural regeneration as well as in plantation raising to minimize the predation.
- Harvesting, storing and value added utilization of dead bamboos.

a) Minimization of Predation by immediate utilization of seeds through involvement of local communities: The Tripura Forest Department has started Joint Forest Management (JFM) with the local indigenous people to raise bamboo plantations in the hills. These JFM Committees can be effectively utilized in collection and plantation of *muli* bamboo. Maximum numbers of communities are to be involved in collecting and marketing the seeds, thus bamboo seeds would become *a selling commodity.* Then the local people will protect, collect and preserve the *M. baccifera* seeds like other selling commodities. It is observed that local people residing in bamboo seeding areas have been collecting and selling the seeds as commodities with the increase in demand of raising bamboo planting stocks (Figure 18 a).

b) Seeds as commodities: During earlier flowering incidences least amount of seeds were used to be collected by human being for raising bamboo plantations, as the nursery technology was unknown for most of the bamboo species. In those days seed collection was also very difficult due to lack of road communication and wilderness of the forests. As a result in the past huge amount of seeds used to remain in the forest floor and attracted the wild animal. But in recent years of seeding in a number of bamboo species in south Asian countries, the situation has changed. The availability of *muli* seeds have to be advertised to other countries of Asia, Africa and South America through electronic media and internet facilities. The attracted exotic customers would buy the seeds, if find suitable, either for raising experimental plantations or large scale resource plantations.

c) Seed selling, handling during long distance transportation: During 2002-2007, the seeds of *M. baccifera* were collected from different flowering areas of Tripura with the assistance of local communities. The seed was purchased from them with the cost of each from Rupees (Rs.) 0.50 to 1.00 at collection point. On the basis of demand, the specified amount of seeds were sold and transported to a number of organizations located in different parts of the country where the species has been not in flowering stage or not growing naturally. In the subsequent years with the enhanced demand of planting materials the price of a seed, during 2008, increased up to Rupees 1.50. The seeds were mostly transported by truck (Figure 18 b-d). However, in few cases small amount of seeds were also sent by aeroplane. During long distance transportation, say up to Dehra Dun, a 7–10 cm thick layer of sand/ sandy soil was spread on the floor of the truck and moistened (no water stagnation was allowed) by spraying water. Both germinated and non germinated seeds were placed carefully on the moist sand/ sandy soil medium so that radicle / plumules did not get damaged due to jerking of truck during transportation. While moving occasionally slight watering was done to seeds and overhead cover was also removed for cooling and air movement. Most of the seeds germinated while in transportation. After arrival at the destination seeds were unloaded carefully by picking them up one by one (not sweeping all together) from the truck floor and simultaneously spread (placed) on moist sandy loam soil (not waterlogged/wet) in a nursery shed under partial light and well ventilated condition. These were hardened for a few days and gradually transferred in open nursery bed under the overhead partial shade.

Figure 18 (a)

Melocanna baccifera: seeds are used as commodities Local boys and girls are collecting (plucking) seeds from the clumps

Figure 18 (b)

Collected seeds are stored in the house

Figure 18 (d)

Transporting to the nursery site by truck load

Figure 18 (c)

Loading in gunny bags

Now-a-days *muli* bamboo seed has been treated as one of the selling commodity, and as result in most cases these are no longer left in the forest and so not easily available to the rodents, rats and wild boars as food. Therefore, intensity of predation is reducing year after year. In recent years *muli* bamboo seeds have been treated as precious planting material for raising man made bamboo plantation, as a highly renewable and eco-friendly wood substitutes. Plantations of *muli* bamboo have been raised, experimentally, in different parts of India by seeds. The popularity of seeds as planting materials has been gaining, and thus, demand of seeds has increased manifold. Seeds are being purchased and have monetary value as commodity to the local people.

3.4.3 Future Restocking of *Melocanna* vegetation:

Some important activities are mentioned below:

a) *Local utilization of seeds*: It is estimated that the gregarious flowering of *M. baccifera* will occur in an area of around 18,000 Sq. Km in the states of Mizoram, Manipur, Tripura, Assam and Meghalaya and almost all the flowered clumps in this area will die creating a denuded condition in the hills (Goala and Borthakur 2002).

Accordingly restocking of the entire flowering area either by direct seed sowing or/ and by planting seedlings is urgently needed. Such Aided Natural Regeneration (ANR) through specific silvicultural practices have already been started in most forest divisions of Tripura, Assam, Manipur (Tamenglong), and Mizoram. There is a need of establishing bamboo nursery to support the activity.

b) *Formation of Nursery Entrepreneurs:* Different self help groups (SHG) and JFMC can be encouraged and trained to raise bamboo nurseries near the flowered area. Training may be given on seed collection, processing and storage, bed preparation, seed sowing, germination, seedling raising and nursery management, seedling selection and finally their transplantation at fields.

c) *Indigenous Community Employment for Maintenance and aiding the Natural regeneration*: Members of JFMC and SHG need to be employed for *weeds control, fire protection* and *grazing* to assist *the seedling survival* and *successful establishment* of natural regeneration.

d) *Raising Mosaic Plantations of diverse flowering populations*: The members of

JFMC and SHG may be engaged in raising *mosaic plantation* with a mixture of two or more different flowering populations of *M. baccifera*. All these populations raised in a *mosaic plantation* will flower after different interval of times in the next flowering time, and so all the *muli* clumps are not likely to flower and die at a time making sudden shortage of resources and denudation of hills.

The following activities may be undertaken through total collaboration of local people of bamboo areas. This would also generate employment for them.

3.4.4 Harvesting and Storage of dead bamboo

The present gregarious flowering in *muli* bamboo (*M. baccifera*) will make available about 26 million tons of bamboo due to the large scale death of flowering clumps, of which only 10 million tons are in accessible areas of Northeast India (Goala and Borthakur 2002). Efforts should also be made to harvest a substantial amount of such huge quantities of dead bamboos from the inaccessible areas. The State government of Tripura, Mizoram and Meghalaya (from Garo hills), Manipur (from Tamenglong) may take a policy to allow extract and export of bamboo from the flowered areas even to neighbouring countries for the best resource utilisation.

- ***Careful harvesting of dead bamboo*** even from inaccessible areas and marketing them.
- ***Good storage practices for huge amount of harvested dead bamboos:*** Storage of the huge quantity of bamboo for a long period result in damage by microorganisms and as a result bamboo deteriorates rapidly. Bamboos may be protected against deterioration by giving prophylactic treatment by spraying dilute preservatives like, Sodium Pentachlorophenate (1 percent solution), Boric acid + Borax (1:1) 2 per cent solution.
- ***Maximizing utilization of available huge dead culms:*** As mentioned earlier, the dead flowered bamboos are fragile in nature and are not suitable for any

construction works. Bamboo is a good substitute for fossil fuels in the form of charcoal briquettes. Such dead bamboo can be best utilized for generating electric power through a bamboo-based biomass gassifier. By this process, the energy present in the biomass is converted into a gaseous combustible, or chemical energy. Gas products are easy to handle and can be used in combustion engine or gas turbines. The combustion is clean and less polluting. Further discussion is made in the Chapter-8 under heading: *Power generation through bamboo gasification*. However, establishment of micro-enterprise for producing agarbatti sticks, chop sticks, tooth-picks, bamboo made pencils and charcoal etc. may be carried out so that the indigenous people can also earn livlihoods and tide over the difficult period till the *muli* areas regenerate, or before.

3.5 Propagation of *M. baccifera* by Vegetative means

3.5.1 Macro-propagation (vegetative propagation)

When seeds are available, the huge number of planting materials of *muli* (*M. baccifera*) bamboo may be produced with no difficulty. The details of seed processing, handling and germination have been discussed above.

However, during non-seeding time the species can be multiplied with great difficulty by vegetative propagation. The success in rooting of culm and branch cuttings in *muli* bamboo is very rare as the species has little or no, root primordia at branch bases and nodal buds. Generally the thin-walled species like *Schizostachyum dullooa* and *Melocanna baccifera*, in which the culm wall is very thin and branches are not stout, usually *do not respond well to the branch* and *culm cutting method.*

***a) Part-clump*:** The most convenient method of vegetative propagation is clump division (part-clump method) (Banik 1995b). These should be made from the young culms, while the lateral buds of the rhizome are still dormant. Most of the culm, and the long slender rhizome neck, may be discarded for convenience and easy handling of materials with less injury. *Part-clump or rhizome assembles with 2-3 offsets connected with each other* have to be collected as a unit during March–April for further rooting in sand bed nursery with adequate watering. The individual rhizome in a part-clump propagule should not be separated or damaged during the time of collection from the soil. The culm part of each of the member rhizome should have 3-4 nodes, with viable branch buds.

During transportation much care should be taken against any damage and injury of the rhizome parts. Planting has to be made during rainy season for obtaining the optimum success. As the propagules contain more than one rhizome, the planting pit should be wider (preferably 70-80 cm wide) in size. As soon as monsoon starts in May/June these part-clumps are to be transplanted in the field for better survival and successful result.

3.5.2 Micro-Propagation (Tissue culture)

The contamination free culture of *M. baccifera* were developed by sterilizing the explants with the prior treatment of 0.1 per cent benomyl solution, and then soaking in 0.075 per cent mercuric chloride for 10 minutes. Explant showed growth only on MS medium supplemented with 4 per cent sucrose and vitamin of B5 medium. The explant type branch nodal segments with buds sprouted 70–80 per cent within 7-12 days of culture on 2,4-D 10mg/*l*,with 10 per cent coconut milk (CM). Plantlets are produced after subsequent 6th transfer culture with 25-30 days of interval. Apparently, tissue survived and grow in higher concentration of growth regulator (2,4-D 10mg/*l*, and BAP 5.0 mg/*l*) after successive transfer. At the final transfer on to the medium supplemented only with BAP 5.0 mg/*l* and NAA 1.0mg/*l*, the explant developed in to a complete plantlet with fully developed root system (Figure 19 a-d and Table 4). The time requirement for the complete development of a plantlet from the branch nodes was about 6-7 months from the date of first inoculation.

Immature embryo of the species also produced both shoot and root with 15 days of culture when the modified MS medium was supplemented with 2, 4-D (1.0–0.05 mg/*l*) and BAP (0.1–3.0 mg/*l*).

Benzylaminopurine was found to be the most effective cytokinin to induce and continue growth in the tissue.

Shoot were usually long (7–9 cm) and required taller and larger glass bottles or larger test tubes for good culture growth. It was possible to produce viable plantlets after adequate hardening.

Table 4: Tissue culture protocol for *Melocanna baccifera*

Explant type	Medium (mg/l)	Results	References
Embryo from 'seed'	MS + 2,4-D (1.0-5.0) +BAP (0.1 – 3.0)	Shoot and root produced	Banik (1991 b)
Node with bud	MS + 2,4-D (10)+BAP(0.5) +CM (10%)	Shoot produced	Banik (1991 b)
	MS+BAP (5.0) NAA(1.0)	Shoots rooted	

Note: MS = Murashige and Skoog medium; 2,4-D = 2,4-dichlorophenoxyacetic acid; BAP = Benzylaminopurine; CM = Coconut milk, AC= Activated charcoal; NAA= Naphthalene acetic acid.

* The stated protocol is developed by author in lab scale conditions. However for commercial production, some modifications may require.

Figure 19 (a)

Tissue culture in *M. baccifera*: sprouting explant / embryo

Figure 19 (b)

Shoot and root development

Figure 19 (c)

Shoot elongation and profuse rooting

Figure 19 (d)

Plantlet planted in polythene bag containing mixture of sand and soil

4 Growth Habit

4.1 Above ground Growth and Morphometric Expression of a Clump

4.1.1 Seedling Growth

The *Melocanna baccifera* seedlings show vigorous growth of thick (4-6 mm) plumule (primary culm) with pointed tip from the germinating seed (Figure 14c). More commonly secondary culms may develop by tillering (shooting) before leafy branches appear. Such precocious emergence of additional shoots from the primary one, sometimes up to eight may occur in this species. Study showed that about 5 per cent seedlings germinated from heavy seed (more than 45g) produced 4 or more number of living shoots during germination (Banik 1991a). New shoots are bigger and taller than the older ones. This apparently is related to the abundance of stored food in the fruit as compared to that found in the small grain like seeds (caryopses) of most other bamboo species. However, the precocious emergence of additional shoots is very rare in other bamboo species. All the plumules shoots do not develop into stems, mostly die in the juvenile stage, usually 1-2 ultimately develop and form 1-2 stems (culm). Within four weeks, the plumule elongates rapidly (80-100 cm) into a small stem bearing 2-3 big size leaves alternating at the nodes without any branches (Figure 20a, 20b). The seedling stem remains soft tender and unbranched up to 8-9 months of age.

Soon after 15–21 days of germination fibrous roots develop from the base of the young shoot.

Rhizome formation starts after 30-40 days of seedling age. Usually two long (15-25 cm) stout rhizome bodies are formed from the base of primary shoot (Figure 21a). The rhizome body of *M. baccifera* seedling is covered with comparatively thick tough sheaths fitted

Figure 20 (a)

Melocanna baccifera : A seedling with seed at the base, leaves produced directly on the node of unbranched stem

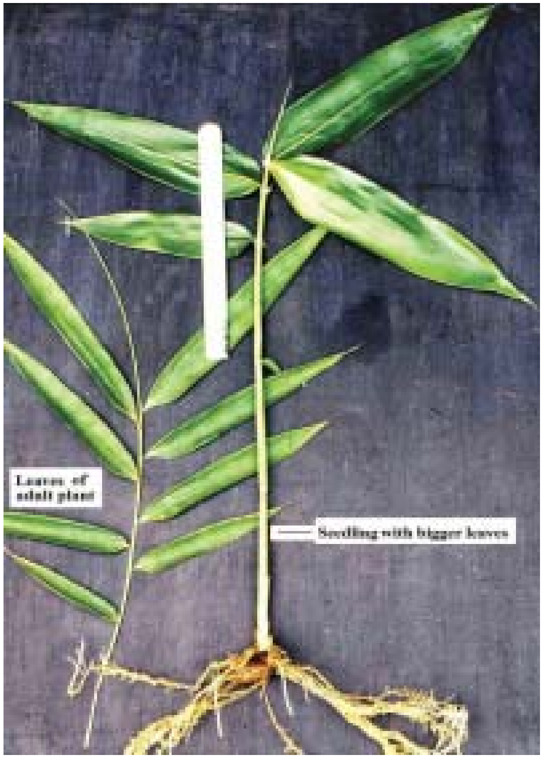


Figure 20 (b)

Leaves are bigger, one and half times more in size on the *M.baccifera* seedlings than those of adult clumps

imbricately one above the other up to the pointed tip, the 4-6 cm long rhizome proper. Generally in the seedlings of *muli* bamboo at least up to 6 months of age no new shoots emerge, except the primary shoot(s) which are produced directly from the germinating seeds. Older thin shoots die and allow the new bigger shoot to emerge vigorously. New shoots are bigger and taller than the older ones. Within 11–12 months a tufted young plant is formed by the production of successive pointed shoot buds on the aggressively developing young rhizome system (Figure 21b).

A comparative nature of growth and biomass production in the seedlings of *Melocanna baccifera* and a true caespitose clump forming bamboo (e.g; *Bambusa tulda*) was studied (Banik 1991a) and mentioned below (Table 5). Both green and oven dry weight of different organs of seedlings of *M. baccifera* was found higher than those of *B. tulda* at the initial stage of growth and development.

Long rhizome necks develop from the seedling of *M. baccifera* but no roots were produced (along individual) rhizome neck. As a result allocation of biomass to

Table 5: A comparative biomass measurement (average value) *Melocanna baccifera* and *Bambusa tulda* seedling at different age and season in the nursery.

Species	Age in Months (Obs. Date)	Green weight (g)			Oven dry weight (g)		
		Culm & leaves	Rhizome	Root	Culm & leaves	Rhizome	Root
Melocanna baccifera	**3 (Nov.)**	**60.14 ± 9.98**	**11.11 ± 5.32**	**12.63 ± 5.49**	**16.75 ± 3.36**	**2.81 ± 1.09**	**5.09 ± 1.80**
B. tulda	3 (Sep.)	10.71 ± 2.11	1.27 ± 0.43	6.78 ± 1.76	4.01 ± 0.71	0.32 ± 0.09	1.95 ± 0.44
M. baccifera	**6 (Feb.)**	**43.59 ±10.06**	**35.40 ±10.39**	**13.28 ± 6.96**	**19.87 ±5.22**	**12.38 ±5.24**	**7.90 ±5.14**
B. tulda	6 (Dec.)	44.20 ± 6.50	6.83 ± 1.42	49.40 ± 30.10	18.52 ±3.70	1.72 ±0.21	14.90 ±3.42
M. baccifera	**10 (May)**	**86.76 ± 31.40**	**38.05 ± 8.17**	**14.00 ± 6.80**	**43.59 ±16.58**	**16.42 ±10.01**	**5.05 ±2.16**
B .tulda	10 (Mar.)	87.05 ±10.50	18.70 ± 9.65	49.40 ± 25.01	42.08 ±6.28	10.63 ±5.31	27.47 ±17.39

(Source: Banik 1991a)

Figure 21 (a)

Melocanna baccifera seedling: Two long (15-25 cm) stout rhizome bodies formed from the base of primary shoot and covered with tough sheaths fitted imbricately one above the other up to the pointed tip

Figure 21 (b)

Pointed shoot buds on the aggressively developing rhizome system of yound seedling

rhizome production was higher than root production. On the other hand in case of *B. tulda* the rhizome necks were very short and most of the root system come out from the rhizome itself. Therefore, the root production was higher in *B. tulda*.

The biomass growth of culm with leaves, rhizome and roots gradually increased as the *Melocanna* seedling became older (Table 5). The green weight of culm and leaves was 60.14 g at 3 months of age, but it decreased (43.6 g) at 6 months and again increased (86.7 g) when seedling became 10 months old. However, the oven dry weights of culm and leaves at 6 months of age were not lower than those of 3 months old. The higher green weight of culm and leaves at 3 months of seedling age was mainly due to the higher amount of water content in the plant body in early juvenile stage. Probably that is why in *M.baccifera* the young culms of a seedling remain soft and tender. The data indicates that the biomass content of culm, rhizome and roots of both species reduced while it increased in rhizomes from wet to dry season. The biomass of rhizome developed 4-5 times from 3-6 months growth. Stored photosynthate in the underground rhizome system is being utilized in initiation and development of new shoots (culms) and leaves in the next growing season (moist and warm season). Thus, it appears that the growth of different parts (culms, rhizomes, roots) of *muli* seedlings were inter related and also influenced by seasonal changes. Leaves of *M. baccifera* seedlings are around, one and half times bigger in size than those of adult clumps (Figure 20b, Table 6). The leaves chronologically produced in the seedling become smaller with the age. After about 10 months the leaves produced by the seedlings have attained more or less similar size to that of adult clumps.

Table 6. Comparative average leaf size (Length, mid width, cm) in the seedlings and fifteen years old adult plants of *Melocanna baccifera* and *Bambusa tulda*

Age	*M. baccifera*				*B. tulda*			
	Seedling Leaf		Adult plant Leaf		Seedling Leaf		Adult plant Leaf	
	Length	Mid width	Length	Mid width	Length	Mid width	Length	Mid width
3 month	32.31	8.76			11.18	2.58		
6 month	28.68	6.57			17.91	3.24		
10 month	21.30	3.94			19.5	3.61		
About 15 years old			23.74	3.26			21.11	3.05

However, at about 15 years of age the leaf size become elongated by 2.0 cm and slightly less in mid width than that of 10 months old plant.

4.1.2 Nature of young clump

By the end of the first season of planting, the germinating seeds would usually produce about four to five shoots, of which the youngest may be as much as 3.0–3.5 m high; these shoots are crowded together in a caespitose type of clump (Figure 22a).

During second season more shoots are produced, the clump expands somewhat, and it is not until later that they are spaced out with the gradual elongation of rhizome necks.

Young clumps are extremely dense, the rhizomes being closely interlaced. After three years of age, the clumps start expanding and spread to a visible extent by its vigorously elongated under ground rhizome necks (Figure 22b).

Figure 22 (a)

Melocanna baccifera: Young, 1-2 years old clump is extremely dense with crowded emergence of shoots

Figure 22 (b)

After 3-5 years of age, the clumps expand and spread to a visible extent where culm start emerging loosely


Yr-I
Yr-II
Yr-III

4.1.3 Culm emergence periodicity in adult clump

The culm emergence in a clump of *M. baccifera* may start any time between May to mid-November (Table 7). The maximum number of culms emerge from July to mid-September, similar to those of other bamboo species growing in North-east, and Chittagong Hill tracts. The emergence is primarily influenced by both soil and air temperatures and moisture condition of the area (Banik 1993a). During the month of November-April, the culm emergence stops as the period is comparatively dry with lower soil and air temperatures as compared to the period (July-November) when maximum culm emergence takes place (Table 7).

During the initial stage of emergence period, food storage is high in the underground rhizomes, resulting in the highest number of culm emergence. As time passes, food supply gets exhausted and results in gradual decrease in the culm emergence in the following months. Field studies revealed that for culm emergence in *Melocanna baccifera* and as well as other bamboo species, 28°C soil (50-200cm soil depth), 26°C air temperature, above 60 per cent mean relative humidity and monthly mean total rainfall within 100-800 mm seem to be the optimal requirement (Banik 1993a).

It was further observed that one of the most important climatic factors influencing the emergence of new culm was the rainfall and its seasonal distribution. If the monsoon arrives on time, the rainfall is sufficient in amount and is well distributed, the production of new culms is good. But if the monsoon is delayed , or there is a break after the first heavy showers, the production of new culms is adversely affected. In general, years of plentiful rainfall produce larger numbers of shoots than the years of deficient and scanty rainfall. Shingematsu (1960) also reported that rain prompted the shoot emergence and culm growth in all Japanese bamboos.

Table 7. The average number of culm emerged in different months from the clumps of nine bamboo species growing in eastern part of sub continent in relation to monthly climatic condition.

(Source : Banik 1993a)

Species	**Months**												EmrgPerd
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(mth)
B.bal	0	0	0	0	0.2	0.9	0.5	0.3	0.1	0.3	0.2	0	7
B. nut	0	0	0	0	0	0.7	1.4	0.5	0.5	0.6	0	0	5
B. pol	0	0	0	0	0	0.7	0.9	0.9	0.6	0.7	0	0	5
B.tul	0	0	0	0	0.07	0.5	0.7	0.6	1.2	1.1	0.6	0	7
B. vul	0	0	0	0	0	0.7	0.9	1.0	0.3	0.3	0.07	0	6
D. gig	0	0	0	0	2.6	3.8	4.2	0.6	0	0	0	0	4
D. str	0	0	0	0	0	0.1	0.8	1.0	0.4	0.7	0.3	0	6
M.bec	0	0	0	0	0.1	0.7	1.7	3.7	2.2	0.9	0.2	0	7
S.dul	0	0	0	0	0.2	0.6	1.8	2.8	1.2	0.09	0	0	6

Climatic Conditions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Soil temp(ST) °C in different depth												
50cm	20.8	22.4	26.5	29.2	29.7	29.3	29.0	29.0	29.1	29.6	25.9	21.7
100cm	22.1	22.8	25.3	28.3	29.1	28.9	28.7	28.6	28.5	28.5	26.5	23.5
200cm	24.2	23.8	24.9	26.9	28.2	28.3	28.5	28.6	28.6	28.7	27.7	25.3
Average ST °C	22.3	23.0	25.5	28.1	29.0	28.8	28.7	28.7	28.7	28.9	26.7	23.4
Air temp°C	18.5	20.9	25.3	26.6	26.9	26.6	26,0	26,5	25.3	25.5	20.9	16.2
Relative Hum %	56.5	55.5	55.3	62.2	65.1	67.4	70.8	67.2	66.0	66.0	63.1	55.9
Total rain fall mm	17.9	12.7	33.6	117.5	375.6	566.3	783.0	426.1	321.6	247.1	95.1	13.6

Species: B.bal = *Bambusa balcooa*, B. nut =*B. nutans* , B. pol.= *B. polymorpha,* B.tul = *B. tulda*, B. vul = *B. vulgaris*, D. gig =*Dendrocalamus giganteus*, D.lon = *D. longispathus*, D. str = *D. strictus,* M.bec = *Melocanna baccifera*, S.dul = *Schizostachyum dullooa*

Emrg Perd (mth) = Emergence period (month). *Relative Hum* % = Relative Humidity %

The shoot in a clump of *M.baccifera* starts to emerge from the soil mostly at the beginning (May) of rainy season and the emergence continues till the end of October (later part of the growing season). The emerged number of culms decreases, when the number of rainy days is few and average total rainfall is also comparatively low. Thus, the culm emergence period in *muli* bamboo was found to be 7 months, May-November with maximum emergence peak in August (Table 7).

4.1.4 Juvenile mortality of emerging culm

The natural mortality of emerging culm is common feature of a bamboo clump. Some of the emerging culm die naturalty during the process of elongation and thus, known as juvenile culm mortality. By nature, *M. baccifera* forms open diffuse type of clump, but at the initial (3-4 years of ages) stage the clump is somewhat compact and congested one. The clump congestion is also seen when culm felling is not regular or is discontinued for several years. Such juvenile mortality of culms was found to be about 9 per cent in *M. baccifera* and mostly seen in congested clumps culm mortality (Banik 1983).

4.1.5 Culm elongation and growth in the adult clump

The height growth of the culm is due to elongation of internodes. The internodal elongation begins at the basal portion of the culm and then gradually proceeds to top. More specifically, elongation is mainly due to the intercalary meristem present at the node. In intercalary growth, the immature axis increases in length by the elongation of cells in zones of secondary meristems each located just above the node. In the elongating segmented axes of a *muli* bamboo plant the locus of each zone of intercalary growth is just above the locus of insertion of a sheath (Figure: 23a).

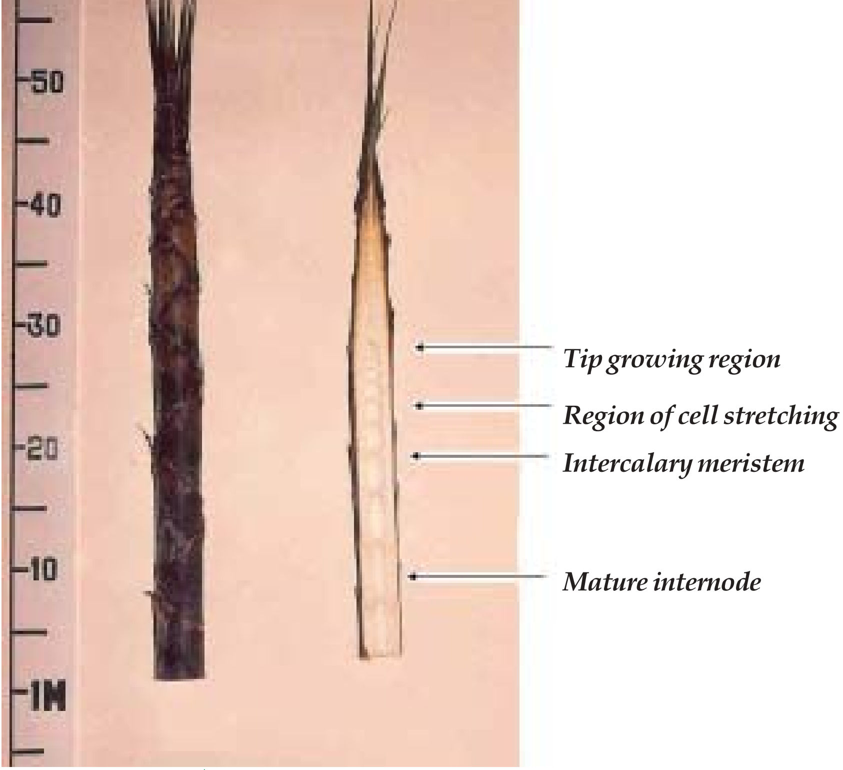


Figure 23 (a)

Longitudinal section of a young elongating shoot of *M.baccifera*; showing the stages of development— first basal internodes expanded so wider than the upper ones, and zone of intercalary growth

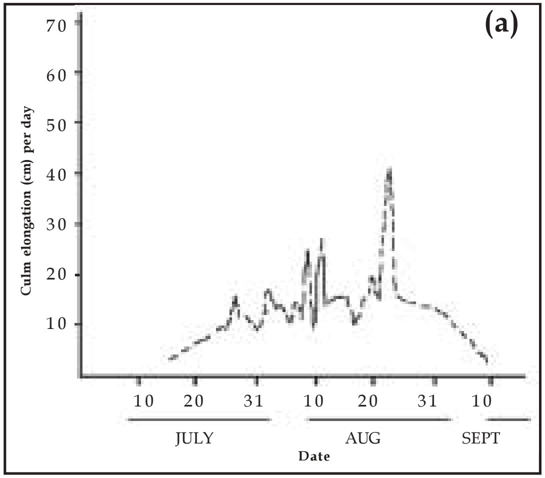
Figure 23 (b)

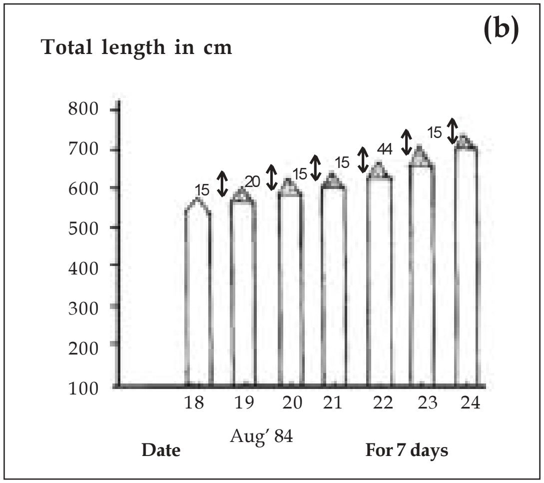
The newly emerged culms also simultaneously start developing rhizome neck(s) below the ground from the rhizome

Soon after emergence, culms elongate very slowly up to 1.0-1.5 m within 20 days and then gradually gain speed until they attain the optimum size and thereafter the rate of elongation slows down quickly. The average extension growth usually varies from 10-30 cm per day (24 hours), but may peak up to 44 cm after 30-40 days of emergence (Banik 1993a). Such rapid rate of elongation was observed during second half of the complete culm elongation period. The total culm elongation period height growth is achieved in 55-60 days in *M. baccifera* (Plate 5).

The culm elongation in *M. baccifera* happens mainly during the night. The daily growth of culm is the total of the daily elongation (extension growth) of the internodes. The cell division in the internodes of upper part of culm is weaker than that in the mid part. Further, it was observed that everyday only the mid-culm internode elongated maximum and moved gradually in successive order from the base to the tip (Banik 2000). This can be explained as: say an elongating culm is 2.10 m long, so the mid segment of the culm is around 1.05m. The existing internode at this point (1.05 m) is approximately 9.0 cm long. In the next morning it is observed that the culm attained a length of 2.32 m; that is, it elongated by 22 cm in a day (24 hours) of which mid internode expansion accounted for 20 cm (9-29 cm) while all

PLATE 5: a) The total culm elongation period is recorded to be 55-60 days in *Melocanna baccifera.* The average extension growth usually varies from 10-30 cm per day (24 hours). **b)** Daily maximum elongation rate up to 44 cm after 30-35 days of emergence during its total elongation period.





other internodes elongated by only 2.0 cm.

The diameter with which culm emerge remains unchanged throughout its life but they continue to change in density and strength properties. The culm does not show any diameter increment during or after the elongation period. Thus, it seems that the size of the diameter of a culm is determined by the size and vigour of the bud present in the mother rhizome from where it originates. Therefore maintenance of health of underground rhizome along with culm buds is a very important management procedure for producing healthy big size culm in the *muli* forests. Maintenance of adequate soil moisture, aeration and good organic matter in the soil is essential for proper culm elongation and healthy growth.

The action of reserve nutrients must be considered as one of the factors that influences the growth of bamboo culm and rhizome. Generally in bamboo clump the reserve of starch in 1-year old culms is highest till it produce a new sprout. The starch reserves in the rhizome system decreases most during the period of growth and increase after it is completed (Uchimura 1980). In other words, the consumption of the reserve starch in the rhizome is higher during the emerging, elongating and growing period for 1-year old culms. The amount of nutrients reserve in the rhizomes declines during growing period and start increasing from the end of October and attains peak in winter (December-January), that is, during the period of non-growth.

Within next 20-25 days of complete elongation (end of July to mid-August) of culm, sheaths at the apical nodes, partially dislodge and the culm starts producing leaves directly at these 4-6 apical nodes. In the next, 90-95 days (mid-August to November) no further growth (such as, bud break, branch and leaf production) are observed in the culm while underground rhizome neck elongates steadily in horizontal manner

(Figure 23b). After August, up to next February, the climatic conditions gradually become dry and cold and the above ground growth season ends (Table 7). The culm sheath remains persistent on the node for 5-7 months after the cessation of culm elongation till the bud below it completes the growth and development. Then each of the well developed buds on the culm node activate and sprout piercing through the culm sheath. The initiation of branch buds and root primordial on any segmented axis always takes place within a zone of intercalary growth, before the tissue lose their meristematic potential, and while the subtending sheath is still living (McClure 1966). Transverse thickening of nodes, that is, "supra nodal ridges" are lacking or inconspicuous through out the culms of *M.baccifera.* At the lower part of the culms nodes that do not bear buds or branches, such thickening is absent.

4.1.6 Culm Production and clump expansion behaviour

A study on ten clumps of *M. baccifera* showed that the average number of full grown (FG) culms produced in the first year was 2.5 and from third year the number increased rapidly to 12.5 (Table 8). The increase of FG culm production further accelerated in the subsequent years reaching 35.7 after 10th year of clump age (Banik 1988a).

Table 8: Average annual production of full-grown (FG) culm and gradual expansion of clump girth up to 10 years of clump age in *Melocanna baccifera*.

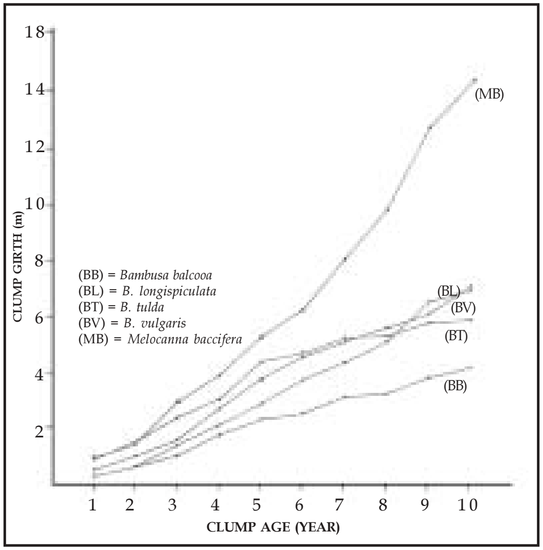
	Clump age (year)									
	1	2	3	4	5	6	7	8	9	10
FG Culms (nos.)	2.5 ±0.5	5.6 ±1.7	12.5 ±2.5	16.4 ±4.2	23.6 ±7.2	25.3 ±4.6	26.6 ±8.7	25.1 ±6.2	31.1 ±8.0	35.7 ±13.3
Clump girth (cm.)	92.2 ±20.5	145.9 ±23.2	301.0 ±42.0	395.4 ±53.3	529.3 ±105.6	624.3 ±115.2	805.4 ±146.1	980.6 ±170.5	1268.0 ±247.0	1432.3 ±281.0

In the first 2-3 years of planting, the species forms compact clump, after that period clump starts gradual rapid expansion and takes the characteristic form of open diffuse clump with the production of 35-40 culms per year. However, some clumps have been found to produce 62-78 culms annually. It has been observed that a clump of *M. baccifera* can produce large number of culms even at very young age of 3 years. A clump of *M. baccifera* in favourable environment may produce up to 80 or more culms annually even from the age of three. During May, 2002 a few seeds of *M. baccifera* was collected from Arundhuti Nagar, Western Tripura (India) and sown in the campus of INBAR supported Bamboo Development Project office on the hilltop at Agartala town (Capital Complex). Every year the number of FG culms produced in the clump was recorded during December. One of the clumps produced 6 culms in 2002 (age: Year 1), 35 in 2003 (Year 2), 79 in 2004 (Year 3) and 121 in 2005 (Year 4). Newly produced culms are more in the peripheral zone and they possess long necked slightly swollen elongated rhizomes below the ground and thus expand and march rapidly covering more new land annually.

Troup (1921) made an enumeration in natural habitat of this bamboo forests at Arakan in two separate plots of 1 acre (1 ha equals to 2.471 acre). Each plot gave 10,575 culms weighing 27,404 lb., and 6,855 culms weighing 33,248 lb (1lb equals to 0.4536 Kg) respectively. The average weight of a culm in the plot-1 was calculated as 1.17 Kg and 2.20Kg in plot-2.

Similarly the clump expansion is rapid from 3 years of clump age and after 5–6 years the rate of expansion of clump girth rapidly increases every year (Plate: 6; Figure 22b). Probably, a 4-5 years old clump of *Melocanna* accumulates sufficient amount of photosynthetic reserves for producing elongated rhizome necks.

PLATE 6: The rate and pattern of clump expansion in *M. baccifera* are more or less similar to those of other clump-forming bamboo species up to 3 to 5 years of clump age, after that period the expansion of clump girth rapidly increases every year.



4.1.7 Longevity and senescence of culm

In a clump, all culms of same age group do not die at a time rather these remain alive for several years (the death-years). It has been seen that the longevity of culms in the clump varied from species to species. Culms started dying at 5 years of age in *M. baccifera, D. longispathus,* and *Gigantochloa andamanica* (Syn *Oxytenanthera nigrociliata.*), whereas death started at 10 and 11 years of age in *D. giganteus* and *B. balcooa* respectively. So depending on the species nature, living culms of different age groups, from 1-10 or even 14 years old, can be found in a bamboo clump, if left unharvested (Banik 2000). However, in case of *M. baccifera* the felling cycle should be 3-4 years.

It was observed (Banik 1983) that in a *M. baccifera* clump 4.2 per cent culms died naturally at 5-years of age, 11.0 per cent at 6-years age, 14.1 per cent at 7-years of age, 73.2 per cent at 8-years of age, 88.8 per cent at 9-years of age, 96.7 per cent at 10 years of age and 100 per cent at 11 years of age. It appeared that culm life in the clumps of *muli* bamboo, was comparatively shorter than that in the clumps of thick walled cultivated species. Depending on the species 4 to 33 per cent culms started dying at the beginning of death years (usually at 4-5 years of culm age) and the remaining culms died gradually within next 4-7 years. The stem quality depends on the age. According to Kasahara (1981) this is an ageing cycle of organs or tissue and varies with environment.

More often culms among the same age group that are at the centre of a clump die earlier than those emerge on the periphery. Death symptoms start from the upper portion of the culm by drying up of tip, branches and leaf buds. When most of the leaves on the culm start shedding, the symptoms of ageing rapidly accelerate by complete yellowing of the culms from tip downwards. Such natural deterioration due to ageing, that accompanies senescence, ultimately lead to the death of culm in a clump. Thus, it appears that the reduction in photosynthetic surface on the older culms limit the supply of energy to the different metabolic activities necessary for the life support proceses. Moreover, when a culm attains the age of 6-7 years, its fibrous roots and root hairs through which the essential nutrients are absorbed, gradually reduced in numbers. Therefore, it is likely that the food reserve in the older culms gradually get reduced leading to the loss of culm vitality. It is evident that culms in the clump should not be left unharvested for a long time. Life period of individual culms of a bamboo species might be an important criterion for fixing the upper limit for the felling cycle (Seth and Mathauda 1959).

4.1.8 Culm age determination

A farmer usually distinguishes between “mature” and “immature” culm by flipping or tapping with fingers. From the sound he can identify the group. Sometimes the colour of the culm is also considered. This is a skilled job and depends on field experience. The presence or absence of culm sheath and nodal root-rings, bud break and branching pattern, and colour were found to be diagnostic morphological characters varying with the culm age. Lately, Banik (1993b) identified some morphological field characters for determining the age of culms in bamboo clumps. (Table 9).

Table 9. Morphological characters for determining the culm-age in a clump of *M.baccifera* (Source : Banik 1993b, 2000)

Year (age)	Culm character of *Melocanna baccifera*
1st Year	*Culm sheath*: All nodes of the culm covered with culm sheath excepting thin tip. *Bud break and branches*: No bud break on the culm node, 2-4 tip buds on the culm produce drooping large leaves directly on the nodes, no branches. *Culm*: Green, branchless straight culm with drooping tips having 2-4 leaves.
2nd Year	*Culm sheath*: Sheath persist on the lower two-third culm, blade of the sheath is loosely fitted. *Bud break and branches*: Buds on the one-third upper portion of the culm nodes break and produce many thin branches in assembly. *Culm*: Green.
3rd Year	*Culm sheath*: Persist loosely only on basal one-third portion of culm (3-5 internodes), mostly black colour, blade of the culm sheath shed off. *Bud break and branches*: Further buds break upto two-third of the culm and many thin branches are produced in assembly with comparatively less number of leaves. *Culm*: Dull dark green.
4th Year	*Culm sheath*: Absent. *Bud break and branches*: Buds mostly dead on the basal culm nodes. Some branches in the branch assembly die mostly on the upper portion of the culm. Leafy branches are less, dead leaves scars present on the branches. *Culm*: Light green to yellowish straw colour.

However, a laborious technique to record the yearly growth has also been developed in which different colour paint (red, black, white, etc) is marked on the culm internode to denote the year of culm emergence, or mark year wise number of ring of only one colour (Waheed Khan 1962, Banik 1988b).

4.1.9 Bud dormancy and leaf fall

In *Melocanna baccifera* culm-sheaths start dislodging besipetally and bud break progress up to one-third of the culm. Simultaneously many thin branches are also produced in assembly from each culm bud. Leaves start developing within 2-4 weeks from the developing branches.

Sheaths persist on the lower two-third of culm and sheath-blades are loosely fitted. In the next year culm-sheaths further dislodge, bud break and branching continue up to two-third portion of the culm. Most of the time nodal buds remain dormant on lower one-third portion (basal 3-7 nodes) of culm with persistent culm-sheaths.

Annually the amount of leaf fall from adult clumps of *Melocanna baccifera* is 6.0 ton per hectare (Hassan and Islam 1984). These leaves fall to about 10–15 cm thickness per year and help absorb the impact of the rain drops during monsoon. Such thick leafy litters act as mulch assisting the earth to absorb rain water and maintain ground temperature more effectively, and retained moisture have been recharging the springs and streams. The blanket of fallen leaves is also effective mulch to retain the moisture and also serves as an organic fertilizer to rejuvenate the soil. Bamboos growing in flatland site and in valleys usually accumulate litter fall twice as much as the hill side. Leaf-decomposition starts in June-July and humification reaches its peak in October-November. It is further reported that this bamboo species contributes more litter than *B. tulda* and *G. andamanica*, major two forest species, and about 20 kg per ton of organic matter to the soil more or less similar to other broad-leaved tree species (*Hevea brasilensis, Syzygium grande,* etc.).

Due to the scarcity of fuel wood now-a-days, people collect dry bamboo leaves every year from the ground and use these as fuel. This practice gradually depletes the organic matter and also lowers moisture content of the soil, resulting in poor annual yield and growth of bamboo culms per clump.

4.1.10 Leaf production in relation to culm age

The clumps of *Melocanna baccifera* are not always true evergreen in nature, shed a substantial amount of leaves when grown on the steep slopes during drier and cold months. Most of the clump-forming types in the tropical regions shed their leaves in winter when it is dry and renew the leaves simultaneously in a short time. Different age group of culms in the clumps of *M. baccifera* may not have similar amount of leaf production. Ueda (1960) measured the fresh weight of leaves collected from 1, 2, 3-years old culms of a clump of *Melocanna baccifera* in Assam and observed higher production of leaf biomass (1.10 Kg per culm) in 2-years old culms than those of 1-year (0.70 Kg) and 3-years (0.60 Kg) old culms.

Thus it appears that in *Melocanna baccifera,* felling of culms may be started after 3rd-4th year of age as concluded from the similar study for *D. longispathus* clumps (Banik and Islam 2005). It is further observed that irrespective of culm age, leaf contains about 50 per cent moisture to its fresh weight. The abundant leaf fall and rhizome growth in the continuous vegetation of *M. baccifera* covering vast tract of land on the hills serves to ameliorate soils in the top-soil layer. Ueda (1960) found that the fresh weight of total leaves roughly equals the total fresh weight of new culms that develop annually from a *Phyllostachys* bamboo clump.

4.2 Growth of Underground Organs

4.2.1 Periodicity of rhizome growth

The growth periodicity of rhizome in a 15 year old adult clump of *M. baccifera* has been studied and is discussed in the following segments (Banik 1999). It was found that each of the several buds on the basal part of culm under the ground enlarged from the end of autumn in the previous year, and grew into rhizomes in the spring. One of the rhizomes protrudes out of the soil and develops into a culm from May-July, while in the remaining rhizomes growth ceases. The newly emerged culms also simultaneously start developing rhizome neck(s) below the ground from the rhizome (Figure 23b; Banik 1999). As a culm may emerge in the clump any time during May-November the production of rhizome neck is also goes on in this period of the year. At the beginning, rhizome neck elongation is slow and then move slightly geotropically and horizontal. During the horizontal movement (elongating) of rhizome neck if it is touched, especially the tip or disturbed by soil excavation, the plant senses it and stops the process of elongation.

While an emerging culm continues to elongate and attains the optimum height growth within 55-60 days the movement (elongation) of underground rhizome neck is more or less slowed down. Within next 20-25 days (end of July-mid August) culm sheaths at the apical nodes partially dislodge and culm start producing leaves directly at these 4-6 apical nodes. In the next, 90-95 days (mid-August-November) no further growth (such as, bud break, branch and leaf production) are observed in the culm but underground rhizome neck elongates steadily in horizontal manner. The climatic condition after August up to next February gradually becomes dry and cold, and during the winter all buds on the culm nodes remain dormant and are somewhat completely covered with persistent culm-sheaths, but rhizome neck elongates more or less slowly and usually do not stop its horizontal elongation below the ground (Banik 1999). After that the rhizome necks elongate rapidly (90-110cm, 1-2 cm per day) during the next 55-60 days (March-May) as with the rising temperature and moisture content in surrounding soil and atmosphere.

It is evident that during cold and dry season the growth was diverted towards the ground rhizome neck elongation. So it appears that the movement and elongation of rhizome neck of *M. baccifera* goes on either actively or slowly throughout the year below the ground even in winter and dry season, rapidly in spring, irrespective of seasonal variation (Banik 1999). The annual growth periodicity of underground rhizome system and culm above the ground is interrelated and seems to be alternating with each other in *M. baccifera*. New rhizomes start developing from the tip buds of the mother rhizome necks any time during May-August and within 2-3 weeks bent upward (negative-geotropic) at right angle piercing the soil and appear above the ground producing daughter culms. The knowledge of rhizome growth periodicity is essential for developing a scientific management system for optimizing the yield of *muli* bamboo forests. It is also apparent that any deep soil work in the *Melocanna* forest might interrupt the normal elongation of neck and growth of rhizome proper which would adversely influence the culm production and clump health (Banik 1999).

4.2.2 Distribuion of rooting zone

In the seedling stage, the primary root (developed from the radicle) is a slender, unsegmented axis and cylindrical or nearly so. The distal end of the newly produced rhizome develop into rhizome proper and proximal part into neck. The tip of rhizome proper bends upward and finally produce new shoot that appear above the ground piercing through the soil. After the part elongation of shoots the rhizome proper starts producing new roots to anchor and support the growth (Figure 23b).

In a well developed adult *muli* bamboo clump the rhizomes are distributed horizontally under the ground and laid up to the depth of 25.0–65.0 cm anchoring and supporting the culms in clump. Sometimes the dorsal side of the whole rhizome system is visible within 1.0–5.0 cm of the soil surface. Thus in a pure *muli* forests several thousands of clumps have been growing side by side forming continuous rhizome networks just below the surface of the soil. About 70.0 per cent of root and other plant material was present in the upper 33 cm of soil, 24.0 per cent in 33-66 cm, 5.0 per cent in 66-100cm and remaining 1.0 per cent between 100 and 150 cm deep from the surface (Table 10). It is further observed that the root diameters usually vary from 0.04 cm-0.48 cm.

4.3 Above and Underground Growth Ratio

The regenerating seedlings in the first year produce thick, tender, soft (not woody) culms rapidly elongate up to 150-180 cm within 3 months of age. Therefore, the crown structure of *M. baccifera* is predominantly herbaceous at the first 12 -18 months of naturally regenerated vegetation after gregarious flowering. During this phase of development the above ground biomass is more than double to that of below ground part of the clump (Table 5). As the age increased the canopy starts closing due to the production of more number of culms. More amount of underground biomass start producing after third years of clumps age due to the formation of comparatively

Table 10. Distribution of Root Biomass of a well-developed clump of *Melocanna baccifera* at different soil depth.

Soil depth from surface to bottom (cm)	Average root biomass (gm) per 10 cubic cm	Percentage
0 -33	19.94	70.38
33-66	6.74	23.80
66-100	1.25	4.41
100-150	0.40	1.41
Total	**28.33**	**100.00**

elongated rhizome necks. The above ground biomass was found to be maximum (73.28 per cent) in 17 years to any time below 25 years of clump age and showed highest value of above-ground/ below-ground ratio (2.74) of biomass (Table 11). Thus it seems the canopy architecture of *M. baccifera* showed maximum plasticity during this period of clump age (17-24 years).

Another fairly common clump forming bamboo species, *Neohouzeua dullooa* (*S.dulloa*), growing in the forest of north east India and CHT has some what similar (height and diameter) looking culms to that of *Melocanna baccifera*, also showed maximum total standing biomass per clump in a 15 years old fallow (Rao and Ramakrishnan, 1988). At the end of 25 years *M. baccifera* clumps became thickly populated with more number of culms and due to the reduction in space and light canopy assume a cylindrical form with culms having shorter branches mostly in the upper part. As a result the allocation of biomass started building up (32.52 per cent) at below-ground (rhizome) portion and also due to the production of optimally elongated solid rhizome necks. Therefore, at 25 years of clump age the above - ground/ below-ground ratio of biomass started declining to 2.07.

Table 11. Above-ground (culm, leaves, branches) and below-ground (rhizomes, roots) oven dry biomass and ratio of *Melocanna baccifera* bamboo at 3 months to 25 years of clump age.

Age of plant (Clump) (months/years)	Biomass (kg)			Above-ground/Below-ground ratio of biomass
	Above-ground	Below-ground	Total	
3 months (Nov.) Oven Dry at 102^{0}C	4 culms = 0.170 kg	0.08 kg	0.25	2.13
10 months (May) Oven Dry at 102^{0}C	6 culms = 0.436 kg	0.215 kg	0.651	2.03
24 months (2years) Oven Dry at 102^{0}C	6 old+35 new culm = 41 (0.44 + 7.38 kg = 7.82)	3.32 kg	11.14	2.35
3 years, a whole of clump (Air Dry value)	41 old + 79 new culms = 20 (7.82 + 27.26 kg = 35.47)	14.73 kg	50.20	2.41
4 years, a whole of clump (Air Dry value)	120 old+121new culms = 289 (35.47 + 83.25 kg = 118.72kg)	48.13 kg	166.85	2.46
5 years, a whole of clump (Air Dry value)	289 old + 187 new culms = 466 (118.72 +128.67kg = 247.39kg) (71.52%)	98.53 kg (28.48%)	345.92	2.51
17 years (approx.), from 5x5m plot at CHT forest flowered in 1957-61. Data collected in 1978 (Air Dry value)	57 old + 34 new culms = 91 (150.15kg)(73.28%)	54.76 kg (26.72%)	204.91	2.74
25 years (approx), from 5x5m plot at CHT forest flowered in 1957-61. Data collected in 1986. (Air Dry value)	63 old + 24 new culms = 87 (137.46kg) (67.48%)	66.25kg (32.52%)	203.71	2.07

Note: * CHT = Chittagong Hill Tract

5 Natural and Artificial Regeneration, Plantation Management and Yield

5.1 Natural and Aided Natural Regeneration (ANR) of *Muli* Bamboo Forests

As mentioned earlier gregarious flowering starts at some point in the *muli* bamboo zone and gradually spreads in waves, covering the whole area in up to 3-4 years. In flowering area the natural regeneration of *muli* seedlings occurs profusely after each gregarious flowering. The ripe seeds fall on ground from mother clumps, germinate and the seedlings (wildlings) start growing naturally. Past records suggest that the new seedlings grow vegetatively usually for the same length of time as parents and repeat the process (McClure 1966, Janzen 1976), and thus a new generation of bamboo vegetation starts again after the mass scale death of mother bamboo forests due to gregarious flowering. This has been happening from times immemorial.

Due to flowering, almost all the clumps of *muli* bamboo die and simultaneously create an acute scarcity of the resource and imbalance in the hill ecosystem. In fact *muli* bamboo has been treated as live blood of indigenous people. Thus the incidence of flowering and simultaneous large scale death of *muli* vegetation is very important to the people and foresters of the region. During earlier recorded flowering time (1863-1864, 1909-1912, 1955-1961) there were less human population in the hills where *muli* vegetation exits. Also these hills were mostly inaccessible with little road connectivity. As a result human interference was minimum in the *muli* forest areas and establishment of natural regenration from abundant seedling was certain. On the contrary, currently these areas has also come under heavy biotic interference due to population pressure and urbanization like; construction of more roads and infrastuctures, oil fields and water storage dams etc. All these have been adversely affecting the success of natural regeneration of bamboo forests. Therefore, it is necessary to protect the wild seedlings by providing them favourable condition for survival and assisting it through human intervention in areas where it is lacking/failing to ensure restocking of bamboo forests after such mass scale death.

5.1.1 Factors and Related Activities in aiding the Natural Regeneration process

At the initial stage (from year 1 to 3) the wild seedlings of *muli* bamboo need proper care and nursing for survival in the process of obtaining the successful natural regeneration. The following aiding operations have been found essential for ensuring the success of natural regeneration (Aided Natural Regeneration) into a bamboo forest again (Banik 1988b).

a) Identification of gregariously flowered areas and demarcation of regeneration site**:** The flowered areas have to be identified through a number of field visits and demarcated. This is important to know the site condition and topography of the area for site specific interventions of ANR (Aided Natural Regeneration) works. First of all a survey should be done in the month of March-April to get acquainted with the topography and extent of area under seeding. A site map may be drawn for systematic monitoring and evaluating the regeneration process. During first 3 years it is necessary to make checking, resurvey and evaluation of the area at the end of July-September to assess the success of regeneration in the field.

At the initial stage during *first year* of natural regeneration process, huge quantity of mature seeds falls randomly on the ground from the newly seeded mother clumps that germinate profusely with the onset of rains and start growing. As a result many wild bamboo seedlings (wildlings) are usually seen on the ground just below and near the mother clumps. They are particularly numerous on bare or freshly exposed soils. Seedlings could also be seen in slopes and mostly in valleys far below the clumps where the seeds roll with gravity or are washed down by rain and get accumulated.

b) ***Removal of weeds and vines that are suppressing the regenerating bamboo seedlings*****:** The seeded mother clumps are mostly dead and devoid of leaves. Thus the forest floor becomes exposed to the sun that induces man invasion of weeds and vines on the forest floor. These weeds and climbers quickly start suppressing the regenerating seedlings of *muli* bamboo and as a result many seedlings die (Figure 24a). The common weeds and climbers are *Eupatorium odoratum* Linn, *Mikania scandense* Willd., *Streblus asper* Lour, *Desmodium trifolium* DC, *Imperata cylindrica* Beauv., etc. (Banik 1998b). Besides, bamboo seedlings also face intense competition with the weeds and even nearby bamboo seedlings for sun light, soil nutrients and space required for their survival, growth and development. As a result many seedlings die during the process of regeneration. It has been further observed that the bamboo seedlings exhibited better growth under partial shade than under full weeds and complete shade condition. Under complete shade, almost *muli* seedlings tend to become lanky and weak and eventually degenerate. It has been observed in Chittagong Hill Tract that proper weeding including vine cutting and maintenance of the seedlings ensured survival and enhanced the growth. Within 4–5 years these seedlings developed into merchantable clumps, whereas it took 10–12 years in the natural condition if the regenerating areas are left unattended. In such sites the regenerating population became thin and bamboo areas get squeezed. Long ago in Myanmar, Kurz (1877) also observed similar weed problems for natural regeneration of bamboo seedlings and surmised that it was not certain whether the next generation may not be a pure bamboo jungle as areas with bamboo population could be squeezed by more agressive and profuse weed growth.

To minimize weed suppression, weeding and vine cutting have to be carried out from the beginning of rainy season (May-June) in the *muli* regenerating area and weeds have to be taken out from the site. The, second weeding and vine cutting have to be started from August and finished by September. However, in the third year, during June-August one thorough weeding and vine cutting have been found to be very useful.

c) *Protection of regenerating bamboo seedlings from grazing:* The tender leaves and rhizomes of the *muli* bamboo seedlings are very delicious fodder to the animals like- cow, goats, porcupines, deer, buffalo, wild bore, etc. and thus remain vulnerable to the grazing and trampling. Further when animal eats up the shoots of young bamboo it pulls up the whole plant and kills it. Severe, grazing is capable of wiping out the natural regeneration of bamboos almost entirely. So, in the regenerating area, during April–May, a fence may be made to protect the bamboo seedlings. In heavily grazed areas seedlings do manage to survive inside the dead bamboo clumps, contrary to what happens in case of fire, and eventually grow up into clumps if given a chance. So there is a need of block fencing and the extent of fencing would depend on the extent of area to be protected from grazing and its intensity. Depending on the grazing intensity, fencing may require maintainance at least up to third year.

d) ***Gap filling by seed sowing and planting*****:** The seed fall may not be evenly distributed throughout the regenerating area and as a result some areas are likely to remain very thinly populated or barren. These gaps are to be filled up by direct sowing of *muli* seeds (2 seeds per pit) in pits, during the month of June-August or by seedling planting to even out spacing. This practice is essential for obtaining evenly distributed plant density during the process of regeneration. Simultaneously thinning of wild seedlings of *muli* should be done carefully to minimize the inter-seedling competition. The thinned out germinating seeds/ seedlings may be transferred to a nearby temporary nursery for a few weeks for hardening. These seedlings can then be utilized for regenerating and afforesting new sites.

e) ***Proper Inspection and monitoring*****:** In the early part of regeneration process during first year, it is necessary to undertake frequent visits and monitor the success of regeneration in the field during the year. As the *muli* seedlings attain the height above the grazing level (1.5-2.5 m height) and produce strong rhizome system within 12 months of age, they are comparatively less vulnerable to grazing in the subsequent second and third year of regeneration process. However, depending on the field situation number of visits may be reduced for second and subsequent years.

In the first year (during April-May) it is useful to make 1-meter wide inspection path to facilitate access to regeneration areas. The path is laid out, as far as possible, diagonally to the tract so that one can visit and inspect maximum portion of the area. In the next two years the path may be cleared of weeds and other obstructions at the end of rainy season i.e; November.

f) ***Protection from fire*****:** During winter and dry months of December-April, there is always a chance of fire in the forest floor that may kill the regenerating bamboo seedlings (Figure 24b). So it is safer to lay out fire line to control firing and fire watcher may also be engaged from JFMC. However, inspection paths may also serve as fire lines. The burning and/or harvesting of dead culms is detrimental to regeneration process by killing almost all bamboo seedlings. At the same time the presence of dead culms increases the risk of fire hazards during dry months. So firing should be prevented and harvesting of dead culms should be delayed in the early stage of regeneration (at least 3-4 months) to obtain higher survival and establishment of wild bamboo seedlings. Within this time period the *muli* seedlings develop dependable rhizome systems which help them to revive even after death of above ground shoots due to fire.

Therefore awareness campaign has to be made among the local hill people against the possible fire hazards, animal predation of *muli* seeds and grazing. The local Joint Forest Management Committee (JFMC) members are to be involved in all the above mentioned management activities to obtain success of the regneration process.

Gradually in two or three years time clusters begin to form, and eventually in fifth year or more the area carries a healthy homogeneous crop of more or less equally spaced young clumps of bamboo. Thus a new forest of *muli* starts developing again.

5.2 Raising Plantations of *Melocanna baccifera*

As an annually growing resource, bamboo provides woody material for several subsistence uses of the community, which if these were to be replaced with only wood, would lead to a severe and rapid degradation of forests and forest cover. Since 1985, *Melocanna baccifera* has been flowering in different parts of north east India, Chittagong Hill Tracts sporadically at the beginning and now (from the year 2005, onwards) gregariously and as a result large

Figure 24 (a)

Regeneration of *M. baccifera* seedlings after gregarious flowering - weeds suppressing the seedlings

Figure 24 (b)

Bamboo seedlings killed by fire

number of clumps are dying in recent years creating shortage in supply of this bamboo. Thus, it is necessary to raise plantations of this bamboo species (Figure 25) particularly in the degraded areas, logged over forests and of denuded hills. In this regard direct collaboration of the members of local Joint Forest Management Committee (JFMC) and

Month wise summary of ANR activities in different year of regeneration

Activity Item	Working months in each year		
	First Year	Second Year	Third Year
i. Identification of gregariously flowered area and demarcation of the regenerating site.	March-April	-	-
ii. Removal of weeds vines from and near the regenerating bamboo seedlings	May-June and September-October	May-June and September-October	June-July
iii. Fencing the vulnerable entry side in the area so that cattle can not enter and graze.	April-May	April-May	April-May
iv. Find out the gap area, fill up the gaps by seed sowing/seedling planting to even out spacing.	June-August	June-August	July
v. Proper inspection, monitoring and evaluation of the regeneration process. If needed, may make an inspection path.	August, May-December, January-April	July, September, November, January-May	June, September, December, January-May
vi. Making/repairing inspection path	April-May	November-December	November-December
vii. Protection against fire, may engage fire watcher, if any.	November-May	November-May	November-May

local foresters are essential for obtaining better establishment of seedlings through protection and management. Due to flowering large amount of seeds and seedlings are being produced curently every year. Direct seed sowing and/or seedling planting should be done in the rainy days, June-August.

5.2.1 Site selection and field preparation

Generally for raising plantations of *M. baccifera*, the suitable sites are mentioned below.

- Denuded hills and degraded areas,
- On the bank of the hilly stream,
- Gullies and hill slopes, and

Figure 25

M. baccifera: One year old plantation raised on the hill slope in north Tripura

- River catchment soil water conservation areas.

The following factors need to be considered in selecting the sites for bamboo plantation.

(i) The planting sites should be surveyed to assess the topographic condition and land area. Bamboos do not survive under deep shade. The *muli* seed may also be sown in the well thinned or widely spaced forest plantation of timber trees.

(ii) Lower slopes of the hills are good planting sites; upper slopes have to be avoided. It requires gentle terrain sites, with deep, loose, and fertile sandy loam. Dry and barren site, rocky or clay soils are not suitable to be selected for planting bamboos. However, *muli* being a hardy species can grow fairly on the hill tops and steep slopes.

(iii) Planting site should be well drained, moist and preferably rich in organic matter. Bamboos do not survive in saline habitats or water logged conditions. New canal banks can also be selected. The jungle should be cut and cleaned in the planting sites.

5.2.2 Production of planting materials

Both seeds and seedlings can be best utilized as planting materials for raising large scale plantations. To popularize the man-made bamboo plantation, *muli* bamboo seeds and seedling need to be distributed among the people of nearby villages. It is advisable to germinate the seeds in the seedbed first and then transfer the germinated seeds to the pits or in the poly bags for raising seedling nursery. One or more seedbed may be prepared under partial shade (50 per cent light only) and well-ventilated condition near the planting site closer to the available water sources. The size of a seedbed may be 1.25 m wide, 10 cm deep and 5 to 7 m long. However, the bed length may be decreased and increased depending on the availability of space in the nursery. The preferable seed germinating medium in the seedbed is sand or sandy loam soil, which should be moist but not waterlogged. Too much watering will result in rotting of seeds. The germinating seeds need to be hardened for 1-2 days by placing on the seed beds under partial shade.

Collection of *M. baccifera* seeds should be started from later part of May and continued up to August. The fresh seeds give better germination rate. Whenever seeds are collected from the forests, these should be transported to the nursery for immediate sowing in the seed beds. All the seeds are then immediately spread horizontally below the surface of the medium of seed beds in a nursery shed. Regular light watering is essential for obtaining better germination and survival (80-85 per cent). Batch-by-batch fresh *muli* seeds should be collected and sown simultaneously in the nursery bed. One should not wait to receive at a time all the seeds collected in different time and batches for best results the dibbling of *muli* seeds should be done fresh but not beyond 48 hours of collection.

5.2.3 Transfer and direct sowing of germinating seeds for raising plantation

In the sites having no problems of predations, direct sowing of germinating seed in the pits would reduce the plantation cost. This would cut down the cost of nursery making, purchasing of polythene bags, and management of seedlings in the nursery. The seedbeds have to be visited and observed, regularly germinated seeds need to be identified and carefully taken out from the beds batch-by-batch in the early morning and carried immediately to the planting sites for direct sowing in to the pits for raising plantation.

Thus day by day collection and transplantation of germinated seeds are to be made for raising successful *muli* plantation.

i) ***Pit making and seed sowing*****:** In the barren hills and scrub forests, close planting is suggested for quick regreening of the land, and the planting pits are to be dug at 3m x 3m spacing, so 1111 pits per ha. The planting pit size may be 30 cm x 30cm x 30cm. The dug out soil is kept in two parts, one part containing the 20 cm top layer soil and other part with inner rest 10 cm layer soil.

To take care of any causality due to possible damage in handling of seeds, 2 seeds may be sown in each pit along the contour lines in hills. Thus for raising *muli* plantation in one hectare of land 2222 germinated seeds are required. To obtain the above number of germinated seeds one needs 2778 seeds (considering germination rate 80 per cent), say 2780 seeds to be sown in the seed beds.

Compact block or line plantations of *muli* bamboo in close spacing (2x2m, 3x3m) helps minimizing soil erosion on the hill slopes to reduce siltation or prevent soil cutting from riverbanks, which are perhaps the major cause in reduced carrying capacity of rivers, and flooding during peak rainy season. Therefore, creation of continuous green cover of *muli* bamboo vegetation to a large extent is a synonymous with environmental protection on the hills.

However, in normal case the planting space may be 5mx5m, or may be 7mx7m; and in between the rows arhar (*Cajanus cajan*) may be planted as intercrop. This would serve as and nurse crop. The dead arhar plants would serve as fuel wood to the local people reducing demand from the other forest areas.

ii) Sowing and refilling of pits: During sowing, the seeds should be placed horizontally at least 0.5-1.0 cm below the soil surface. After sowing the seeds in the pits, it should be carefully covered with dug out top layer soil (fertile humus soil) for better nutrition and protection. The dug out soil should be refilled making small mound to avoid water stagnation during heavy rain as this will rot the seeds.

iii) Protection of germinating seeds: The planted *muli* seeds in the pits need to be protected against the herbivore animals like wild bore, porcupines, cattle, and monkey for the survival of germinating seedlings, and subsequent establishment of clumps, for successful reforestation. However, seed can be treated with environment friendly chemicals (seed coated with neem formulations, etc.) before sowing to protect against the predation from animal and insects.

5.2.4 Seedling raising and management

The planting of *muli* seedlings will overcome the problem of seed predation and ensures better stocking in a plantation. Although it involves time and money to produce bamboo seedlings and after caring them for 9 to 12 months in a nursery but it pays in raising successful bamboo forests/farms. Every afternoon the germinating seeds are to be collected from the seed beds and transferred to polythene bags filled with a growth mixture (sandy loam soil 3 part and FYM 1 part). The seedlings in the polythene bags need to be harden for 2-4 days by placing under partial shade (50 percent shade) and humid conditions (Figure 26a). After that period, seedlings in the polythene bags are to be transferred gradually to the open nursery under the sun, regularly irrigated and weeded; and maintained in the nursery till planting in the field.

i) Seedling management in the nursery: The *muli* seedlings should be raised at the nursery in early season (April-May) and become ready for field plantation during July-August (Figure 26b) of the same year. When seedlings are raised during June-August it is not recommended to transplant them in the field during the same rainy season, as they need at least 3-6 months to produce well developed rhizome system. Thus it become necessary to keep the seedling at nursery up to 9–12 months before planting in to the field in the next rainy season. During this period, some parts of rhizome system pierce the polythene bags due to its vigorous growing nature. After piercing out from the polythene bags the developing rhizomes get anchored in to the ground below or penetrate the neighbouring polythene bags of other seedlings creating *intermingled seedlings root and rhizome mass* (Figure 26c). As a result considerable injury is done to root and rhizome during uplifting and transportation of seedlings from the nursery. To overcome such problem the seedlings *need to be shifted from one bed to another* after 6 months of age at 30-45 days of interval. This practice would help in minimizing the rhizome and root anchorage of seedlings.

Unlike seedlings of other bamboo species, the stems of 3 months old *muli* seedlings are comparatively taller, soft and tender. As a result they usually break and get damaged during handling and transportation. Such injury and damage not only affect the performance of the

Figure 26 (a)

Melocanna baccifera: Germinating seeds are placed in the polythene bags under moist and partial shade condition for hardening

Figure 26 (b)

Vigorously growing seedlings are in the nursery bed

Figure 26 (c)

Roots and rhizomes of seedlings intermingled

Figure 26 (d)

Chopping of seedling tip activated buds on the remaining stem-nodes from tip to base and produced branches and leaves

seedlings but also create frustration and doubt in the mind of planters about the survival of plants and ultimate success of the plantation. Therefore, it is useful to maintain the seedling height at the limit of 90-100 cm by chopping the stem tip above the 5^{th} nodes. Within 15-20 days of chopping, buds on the remaining stem-nodes start activating from top to base and produce branches and leaves; and stem become comparatively strong and somewhat woody in nature (Figure 26d, Banik 1991a). The buds on underground rhizome system also starts activating for producing more rhizome parts and shoots. These truncated height seedlings with more active buds, show about 90-95 percent survival and establish early in the field. Normal (tip not cut) seedlings of this bamboo species produce branches only after 9-10 months of age.

Like common nursery practices weeding, watering and protection of *muli* seedlings have to be done regularly for maintaining the good health.

***ii) Planting of seedlings for raising muli plantation*:** Site selection, land development, spacing and pit making are to be done as described in earlier segments. The planting pit size should be bigger (60x60x60 cm) than those used for direct sowing of seeds, to accommodate the well developed rhizome systems of 10-15 months old *muli* seedlings. The field planting of seedlings has to be started in June with onset on rains and may continue upto August.

5.3 Raising Mosaic Plantation of *muli* bamboo

5.3.1 By mixing different cohorts of *muli* bamboo

While raising a *muli* bamboo plantation efforts have to be made to use the seeds from different available sources having diverse duration (short flowering cycles 30-35 years, long flowering cycles 45-50 years, and others) of interseeding periods (cohorts). The seeds of same cohort (having same duration of interseeding period) should not be planted continuously covering large tract of land, rather plantation be raised in patches. However, seeds or seedlings of both short and long interseeding populations may not be available always in the same year. The short duration population (30-35 years of interseeding period) started flowering earlier in late eighties. The seeds or seedlings of that short interseeding cohort might have already been planted in the forests. At present the long interseeding populations (45 years) are also in flowering state and the available seeds or seedlings of this cohort may be collected and planted nearer to those short interseeding cohort. The seeds/seedlings of dissimilar cohort (flowering population) may be planted side by side in patches or blocks covering the gap areas. Thus, the said locality would have mosaic plantation with a mixture of two or more different cohorts (flowering populations) of *M. baccifera* (Banik 2004). In the next flowering time all these populations raised in a mosaic plantation will flower at different intervals of time, and so all the *muli* clumps will not flower and die at a time exposing a vast tract of land and creating sudden shortage of resources.

The existence of diverse duration of interseeding populations would also offer possibilities of frequent availability of seeds in *muli* bamboo in the next flowering time. Keen observations on seeding along with localities and their documentation are important in this regard. Further, such *muli* plantations, having diverse populations, would maintain a wide range of genetic base.

5.3.2 By mixing different bamboo species with *muli*

Mosaic plantations of *muli* may also be raised by mixing with other local bamboo species. At present (2002-2009) some bamboo species like *Dendrocalamus hamiltonii*, *Gigantochloa andamanica*, *Schizostachyum dullooa, Bambusa tulda, B. cacharensis,* etc. have been flowering in different areas of northeast (Assam, Nagaland, Manipur, Mizoram, Meghalaya, Tripura). These species can also be planted in small blocks mixing with *muli* bamboo on the hill tops, slopes, valleys, and riverbanks. But, specifically, the seedlings of *Schizostachyum dullooa* should be strategically planted in gullies and along the shady stream bank. Other locally available big size clump forming useful bamboo species, like *Bambusa vulgaris, B.balcooa, B.polymorpha, Thyrsostachys oliveri* are also good choice for raising Mosaic Plantations of *muli* nearer to the human habitation (in scatteredly formed small villages hamlete on the hills). As these species are presently not in seeding stage and, especially *B.balcooa* and *B.vulgaris* do not produce seeds after flowering, can be planted with cuttings or any other vegetative planting materials. In the next flowering time this mixed mosaic bamboo vegetation will not flower and die at a time because the clumps of *B. balcooa, B. vulgaris* flower rarely.

5.4 Aftercare and Plantation Management for culm production

Immediately after raising the plantation of *Melocanna baccifera* either by direct sowing of seeds or by planting seedlings, proper nursing and management of the plants are essential to maintain desired good stocking (survival) and their growth.

5.4.1 Management operations

The common silvicultural practices are mentioned below:

a) Weeding**:** Cutting and cleaning of vines and weeds around the planting pits is essential for maintaining the competition free condition for germinating seedlings. After planting in June-August, three times weeding and vine cuttings are done in the first year, and two in the second year. Afterwards only one weeding has to be done every year around the planted clump. In the second year, ring (0.5m radius) weeding is to be done once in April-May, and other in July-August.

b) Mulching: It is important to make sure that the bamboo does not dry out during the first summer after planting. The signs of drying out are apparent when the bamboo leaves roll up like cigarette papers and become very narrow. To reduce the loss of moisture due to evaporation from the planting pits, organic materials like fallen tree leaves, barks, bamboo leaves, rice or wheat stalk and chaff or hay, cut grass, leaves of legume pulses, etc., alone or mixed are placed as mulch around the stems (clumps) of the bamboo plant covering the exposed ground of the pit. The mulches are, usually, placed as 7.0–10.0cm thick layer and spread to 1.0-1.5 m radius around the plant. At the end of rainy season proper soil work has to be done around each of the planted seedling/ cuttings. Immediately after that mulching is needed up to completion of annual drought period (December-March). Mulching conserve moisture in the pit, maintain underground temperature and checks the weed growth around the bamboo plant.

c) Application of fertilizer and soil mounding: The knowledge about the requirements of a bamboo for inorganic nutrients is indispensable for cultivating bamboos. It was observed (Ueda 1960) that in a mature culm (3-years old) of *M. baccifera* every portion showed more amount of inorganic substances, suggesting a decrease in the rate of consumption than 1-year old young culm (Table 12). In this bamboo the nodes from mid-culm to upper portion have branches and in growing season produce leaves while the nodes on the basal portion of culm do not produce any branches and leaves and so consume lesser rate of inorganic substance (Table 12).

Less amount of reserve of inorganic substances in young developing culm (1-year culm) indicates the higher requirement of these materials at this stage mainly for growth and development. So adequate amount of fertilizer application in the field is essential for better growth of bamboo culms and clumps in *muli* plantation.

Table 12. Amount of inorganic substances of the culm, leaves and rhizome of *M. baccifera.*

A mature culm		Inorganic substances (% on air dry matter)			
		Total-Nitrogen	Total-P_2O_5	Total-K_2O	Total-Ash
Mid-culm	1-yr culm	0.20	0.08	0.26	0.30
	3-yr culm	0.24	0.11	0.69	1.55
Basal part of culm	1yr culm	0.17	0.08	0.35	0.40
	3-yr culm	0.23	0.12	1.14	1.13
Leaves	1yr culm	2.08	0.36	1.02	8.40
	3-yr culm	2.21	0.44	1.28	11.95
Rhizome	1yr culm	0.34	0.16	0.66	1.13
	3-yr culm	0.41	0.25	1.57	1.38

Fertilization improves the growth of the plant by producing more elongated shoots with maximum number of leaves. Study showed that in fertilized plot and control (unfertilized) plot of *M. baccifera,* the mean culm height and number of leaves per plant were 1.26m, 70.7 and 1.12m, 74.2 respectively. Similarly the plants of *D. longispathus* grown in fertilized plots produced 1.43m, 72.0 and in control plot 1.18m, 61.3. NPK may be applied in the form of Urea, Super phosphate, and Muriate of Potash at the rate of 60, 40, and 40gm per plant in three split doses at intervals of three months (Jha and Marak 2004).

After fertliser application mounding or heaping fresh, lose soil around and over the base of the plant in 10 and 15 cm height has to be carried out during second year in the month of May-June. Thus underground rhizomes remain covered and emerging shoots are protected.

d) Grazing and fire protection**:** The seedlings of *muli* bamboos are susceptible to grazing and firing. However, grazing is very common as the neighbouring local tribal people maintain domestic cattle. Seedlings can not survive when grazing is severe. Block fencing may be done to protect the seedlings from grazing and the extent of fencing would depend on the intensity of grazing and the extent of area to be protected. Only one fire incidence is alone capable of wiping out the bamboo seedlings entirely. Protection against fire is ensured by making fire line including its maintenance throughout the dry season.

e) Irrigation**:** Adequate amount of water is essential for survival and growth of bamboo plants. During first two years of plantation especially, in the dry season, plants may need to be watered. It is advisable to water the plant once a week during the dry months. However, in forest plantations, it may not be feasible.

f) ***Intercropping***: As *muli* plantations are, generally, raised in the hilly lands, (slope, valley and tops), intercroping with traditional agricultural crops has not been in vogue. The seedlings of *muli* bamboo exhibit some what caespitose clump forming nature up to 3 years of planting and after that clumps start expanding in all direction and within a few years cover the space between the plants (See: Chapter-4). So weeding may be avoided by cultivating the legume crops (*Cajanus cajan*, lentil, *Sesbenia* sp etc.) in early ages of plantation. The inter cropping of soyabean (*Glycine max*) was found to improve the soil condition and influenced the bamboo growth. At the early stage before developing a close canopy, intercropping can be done with tapioca, *Dioscoria* and other vegetable crops like ginger, chilly, etc. In order to reclaim the degraded *jhum* land of North-west part of Zemabawk in Mizoram, two major economic and edible bamboo species viz, *Melocanna baccifera* and *Dendrocalamus longispathus* were planted in bamboo based agroforestry system (Jha and Marak 2004). The moisture content and amount of organic carbon in the degraded *Jhum* land increased from 12.1 to 19.1 per cent and 0.315 to 0.375 per cent after one year of intercropping. The yield of soybean was also better 2284.375 kg per ha in *M. baccifera* plot and 2231.375 kg per ha in *D. longispathus* field. Additionally intercropping reduces the weeding problem and thereby cut down the plantation cost.

When timber tree species (*Acacia, Albizzia* sp, *Gmelina arborea, Tectona grandis, Toona ciliata*, etc.) are grown as intercrops in between the planting rows, the bamboos have to be planted in wide spacing (bamboo seedling spacing 9.0 m; line to line gap 10.0 m, 12.0 m, 15.0 m). One can find a number of successful plantation plots having extensive teak and *muli* bamboo plantations raised by Joint Forest Management Committee (JFMC) at East Khopilong Panchayat area under

Udaipur Forest Division of Tripura. The fast growing deciduous tree species would be better choice so that they provide partial shade and can quickly attain the height before the *muli* clumps spread over the inter planting space. *Areca catechu* is also a good intercrop on the hills, especially when grown near to the tribal villages due to its light narrow crown.

Regular visits and inspections are very important to monitor the after care and evaluate the success of plantations.

5.4.2 Production Yield

As bamboo is a fast growing and quick harvesting crop, the output of the plantations will be apparent 3-5 years after afforestation and reforestation activities. In the case of *Melocanna* species, about 15 culms are produced per clump in the first year of harvest (five years after plantation). As the plantation has been raised at 3 m x 3 m spacing, so 1111 plants exist per ha of land. Within first 5 years of plantation period on an average one clump can produce a total of 15 culms, or 16665 culms per ha. Based on felling in three year rotation, 5555 culms can be harvested annually from one hectare at the first year (at the 5th year of plantation) of harvesting. After 6-7 years of plantation *Melocanna* clumps start producing 2-3 more culms per year, and thus on the basis of following calculation about 7700 culms per hectare can be harvested in the 8th year (Table 13). After 13-15 years of age clump productivity becomes more or less steady. The culm density in a natural forest of Mizoram, (in Mamit area), before flowering during 2005, was estimated about 30000 culms per hectare. The productivity (mostly in weight) can be improved 10-15 per cent by proper clump management for sustainable harvest.

It has been estimated that in Tripura forests, *Melocanna* bamboo contributes 93 per cent by weight and 95 per cent by number out of the total bamboo

Table 13: An estimate on plantation yield (culms/ha/annum) of *M. baccifera* after five years of plantation at 3 years rotation and also expected annual income

	Year After Plantation					
Species	5	6	7	8	9	10
M. baccifera (a Thin-walled sp)	**16665/**3yr **=5555** (15 culms/ clump)	**18887/**3yr **=6296** (17 culms/ clump)	**21109/**3yr **=7036** (19 culms /clump)	**23331/**3yr **=7777** (21culms /clump)	**25553/**3yr **=8518** (23 culms /clump)	**27775/**3yr **=9258** (25 culms /clump)
	5555 (x Rs1) = Rs 5555.0	6296 (x Rs1.5) = Rs9444.0	7036 (x Rs 1.5) Rs 10554.0	(7777 x Rs 2)= Rs 15554 .0	8518 (x Rs2) = Rs17036.0	9998 (x Rs2.5) = Rs23145.0

Note: Cost assessment year 2003.

production. The average per hectare stocking of this species is about 18 times higher by number and 13 times by weight than those of other clump forming bamboo species. In Cachar district of Assam *M. baccifera* shows a growing stock of 20 to 24 tonnes per ha, yielding a cut of 5 tonnes (dry) annually per unit area of a working circle, while in case of *Bambusa tulda*, a compact clump forming bamboo species, the best areas yield is 12.5 tonnes (dry) per ha on a 4 year cycle, or only 3.1 tonnes per unit area of a working circle (Varma and Bahadur 1980, Tewari 1992). So it appears that productivity of *muli* bamboo is higher than most of the other naturally growing bamboo species of this region. In Myanmar the density of *muli* culm was about 25000 culms per one acre of land, that means the distance between them is approximately 45 cm (Htun 1999).

5.5 Management of *Melocanna* forest for edible shoot production

In the vast region of northeast India and Chittagong Hill tracts the major supply of edible shoots comes from the bamboo species like *Melocanna baccifera* and next to it *Dendrocalamus hamiltonii* and *D. longispathus*. Having largest area coverage, *M. baccifera* provides bulk quantity of shoots for household consumptions and local market. The people have been collecting edible bamboo shoots. Almost 95 per cent of the annual consumption of bamboo shoots in the region is taken out from the existing natural bamboo forests, with only 5 per cent coming from homestead grown bamboo species like, *Bambusa balcooa, B. vulgaris* and others. Out of 95 per cent about 70 per cent edible shoots are sourced from natural *muli* forests in Tripura, Mizoram, Assam and in other places of northeast India. Moreover, *muli* shoots are much favoured by the Chakma, Lushai, Maugh, Tipra, Garo, Tanchangya Tribal people in the Chittagong Hill Tract.

In forest conditions, the production potential of clumps is not fully utilized because of combination of several factors like over exploitation both for culm and shoot, cattle browsing, low fertility status of the soil, absence of soil working and low moisture availability during the critical period of bud breaking. Besides other essential clump management practices like periodical weeding, fertilizing, irrigation, pest control and mulching for optimizing the shoot production are not being practiced in the natural bamboo forests. Except harvesting the shoots, no other operations have been practiced in the natural *muli* bamboo forests.

5.5.1 Harvesting of all shoots

The effect of complete harvesting of all new shoots continuously for seven years has been studied in the clumps of different bamboo species including

M. baccifera (Banik 1997c). It was observed that the shoot production both by number and weight per clump increased in the first, second and third year after which it declines, if continuously harvested for several years. After six years of continuous harvest clumps did not produce any shoot or could produce a few shoots with poor weight. In a clump, all the culms have rhizomes, and they are connected with each other by necks forming a underground rhizome system. There are 4-5 culm buds present on each side of a rhizome, totaling 8-10 buds per rhizome. Among the buds present on a rhizome of a 1-2 years old culm, only 1-2 vigorous ones normally activate and emerge out of the ground to grow into shoots during hot rainy season. If these elongating shoots (culms) are damaged or removed the next 1-2 culm buds (out of the remaining 7-9 buds) activate and emerge above the ground as new shoots. The continuous harvesting of all shoots from a clump during the first and second year is likely to activate the remaining culm buds on the underground rhizomes, resulting in the emergence of an increased number of new shoots in the third and fourth year. It was further observed that the continuous harvesting of all shoots from a clump for more than 3-4 years hampers new bamboo production in a clump, and therefore continuous harvesting of all shoots more than 4 years from a clump should be discouraged and selective harvesting in every year has been advised.

From a preliminary ethnobotanical study on bamboos in Chittagong Hill Tracts it was observed (Banik 1997c, 1998a) that the local tribal people usually do not harvest all the shoots continuously for more than 2-3 years from a bamboo clumps. After 3-4 years they move from the harvested clump to a new clump. However due to certain of market demands in most cases, small wise traditional practices are being ignored by the younger generation.

5.5.2 Selective harvesting

The local tribal people in the north east India practice selective harvesting of about 50 to 60 per cent of the available prodution of shoots in the forest from the crowded portions of shoots emergence. The traditional extraction method is to dig out the shoots by sharp knife when these are 10-15 cm long and then immediately cover the rhizome by soil. The *Selective harvesting of shoots* from a bamboo clump, as practiced by the local people, may be an important procedure for bamboo grove management. In fact, the ethnobotanical knowledge of bamboo grove management for shoot production supports the research result of adverse effect of continuous harvest of all shoots from a clump. Therefore, the casual statement made by some people that harvesting of edible bamboo shoots is an important reason for declining the bamboo resources in the hills is not always factually correct. What is required is sustainable harvest (around 50 per cent) than no harvest.

There are two different colours of *muli* shoots seen in the nature. In one type, shoots possess a yellowish culm-sheath and are usually preferred as edible shoots. In the other, the sheaths are comparatively deep brown and not usually favoured as food due to their bitter and astringent taste (Figure 27).

When a *muli* bamboo plantation is raised with the primary objective of shoot production a grower must give special attention to the following factors for obtaining the optimum production of shoot from plantation.

i) ***Weeding*****:** Generally in the *muli* forests weeds in the forest floor are not so heavy due to extended coverage of clumps on the ground. However, in many occasion weeds like *Mikania scandens* and *Eupatorium odoratum*, *Lantana camera*, etc are commonly occuring in the *muli* forests. The presence of weeds not only retards the culm growth but also prevents sunlight to enter in the ground level. As a result the shoots production from the

Figure 27

Bundles of edible bamboo shoots, *Melocanna baccifera*: One type shoots possess a yellowish culm-sheath and are usually preferred as edible shoots. In the other, the sheaths are comparatively deep brown and not usually favoured as food due to their bitter and astringent taste

clumps decreases due to severe competition. Therefore, vine cutting and weeding is essential for better yield.

ii) ***Grazing*****:** Animals like monkey, porcupine, wild bore relish eating tender *muli* shoots, so needs protection.

iii) ***Timely application of appropriate fertilizer*****:** A shoot stand consumes more mineral nutrients from the soil than a timber stand and, hence, the application of organic or chemical fertilizers is important. In the case of chemical fertilizer, NPK fertilizers (without silicon) should be used. The ratio of N, P and K will vary with site conditions. In the north east hilly region potassium content in the soil is generally high, the NPK ratio could be 4:3:1 or 5:2.1. Up to 1.5 tons per hectare of NPK fertilizer will be needed annually during the time of soil loosening and addition of soil to the base of clump. Shoot emergence and vigour are dependent on the activation of culm buds on the rhizomes and the amount of stored food in the mother rhizome.

iv) ***Watering*****:** "The vegetable bamboo" likes water but can not stand water stagnation. Watering is needed in the dry season for survival of newly planted bamboo, rhizome expansion and shoot bearing in older bamboos. In the high rainfall zone ditches should be dug to drain out the excess water in valley areas for protecting the rhizome from rotting. Time to time watering to the clump minimize the juvenile mortality of young shoot and improves the health and weight.

v) ***Mulching*****:** The organic materials like fallen leaves, barks, rice or wheat stalk and chaff or hay, cut grass, etc., alone or mixed, are to be laced around the stems (clumps) of the bamboo plant covering the exposed ground of the pit. Qungen et al (1996) observed that mulching would make early shoots emergence and also prolonged the shooting period in *Phyllostachys praecox* stands. It has been reported that mulches increased soil temperature to varying degrees (2 to 5^{0}C), notably during winter December–January and conserves moisture in the soil. The increased soil temperature boosted the physiological activity of underground rhizomes of bamboo plants and stimulated the sprouting of shoots. This would benefit the local people in producing edible shoots

vi) Effect of light: Rhizomes grow vigorously beneath the soil surface, finally breaking into shoots. However, exposure to sunlight leads to the production of chemicals that are bitter and hastens shoot elongation by stimulating development of a very woody base. So, partial shade may be provided to maintain culm density and selective felling of culm.

5.6 Performance of *Muli* bamboo in other States of India through recent Seed introduction from North east

In the past attempts were made to collect fruits or rhizomes of *M. baccifera* (*muli* bamboo) from its natural habitat of northeast India-Bangladesh-Myanmar and introduced to other agroclimatic zones of the sub-continent and other continent of the globe.

Troup (1921) reported that "Mr T. D. Turner of Hurbanswala, Dehradun obtained seeds from Assam in 1912, of which six germinated successfully, and produced strong plants, which grew and spread rapidly on moist fertile ground." However, nursery trials made in Florida with plants of *M. baccifera* from fruits introduced by the U.S. Department of Agriculture early in the 20th century were unsuccessful (McClure 1966).

In the recent flowering years, *muli* seeds were collected in Tripura and depending on the request these were sent to few organization/persons in different parts of India (Table 14) mostly by truck. However, in a few cases small amount of seeds were sent by air (Also mentioned under Chapter-3, 3.4.2c *Seed selling, handling during long distance transportation*).

Some of the organizations that have brought *muli* seeds from Tripura and raised nursery, and experimental plantations in far away places, are mentioned in Table 14.

Table 14: Some of the places in India where *muli* bamboo seeds were transported from recent flowering at Tripura.

Date of seed collection	**Seed collection source**	**Sold and Transported to Organization and locality**	**No.s of seed Or in weight**
July15-26 2003	Chikan cherra of Kumarghat	Uttaranchal Bamboo and Fiber Development Board (UBFDB) Dehradun, UA.	40,000
01.5.2004	Tulakona, Agartala, Tripura	NBPGR Regional Station, Barapani, Meghalaya (through Dr.Datta of ICAR NEH Region, Tripura Center, Lembucherra).	1000
09.6.2004	Tulakona, Tripura	Delhi GTZ office for raising plantation in Himachal GTZ.	7800 (550kg)
15.6.2004	Indranagar, Agartala, Tripura	Delhi University.	1500(98 kg)
15.6.2004	Indranagar, Tripura	Jharkhand.	700 (50kg)
24.6.2004	Tulakona, Tripura	KFRI,Peechi, Kerala.	42, 955
24.6.2004	Tulakona, Tripura	Jalandar University.	1500 (90Kg)
9.7.2004	Tulakona, Tripura	Uttaranchal FRI Dehradun.	14000
9.7.2004	Indranagar, Tripura	Nagpur Oriental Enterprise.	150
14.7.2004	Indranagar, Agartala, Tripura	ICAR Research Complex, Umiam, Shillong.	400 (25 kg)
16.7.2004	Indranagar, Tripura	Bhuvaneshwar, Oriental Enterprises.	150 (10Kg)
19.72004	Tulakona, Tripura	Plantation & Rawmaterial, Jk Papermill, Visakhapatnam.	3000 (200kg)
21. 7.2004	Tulakona, Tripura	Uttaranchal, DheraDun, C/o INBAR, 200 Jorbagh, New Delhi.	7150 (520Kg)
24.7.2004	Tulakona, Tripura	IHBT (CSIR), Palam-pur, Himachal.	5400 (380kg)
June 2005	Tulakona, Tripura	KONBAC, Kudal, Konkan, Maharasthra.	1500
May-June, 2007	South Tripura	DCF Chennai.	2160Kg
June 2007	South Tripura	KFRI.	10Kg
June 2007	Anadanagar, Dukle,	KONBAC, Kudal, Konkan, Maharasthra.	115(10Kg)
August 2007	Anadanagar, Dukle,	Institute of Forest Productivity, Lal Gutwa, Ranchi, Jharkhand.	20 seeds/ seedlings
May, 2008	Attaramura	Bidhan Chandra KrishiVishwa Vidhalya (BCKV), Kallayani, WB.	25 seeds/ seedlings

Source : TRIBAC Office, Tripura.

Figure 28 (b)

Clump raised at Kudal, Konkan-Maharashtra by sowing germinated seeds in 2005 and observed in August 2007

Figure 28 (a)

Melocanna baccifera: Germinated seeds were brought from Tripura, **a)** planted at Dehradun in August 2003 and the raised clump was observed in March 2007

Except damage of plantation in few areas due to grazing/fire, the planted seedlings have been performing well in most of the states (Kerala - Uravu, Wyandu, Maharashtra - Konkan, Uttaranchal - Dehradun, Himachal, Jharkhand etc. (Figure: 28a, 28b.)

6 *Melocanna* Vegetation and Hill Ecology

The principle bamboo genera met within different countries of the Indian Sub-continent are *Bambusa, Cephalostachyum, Dendrocalamus, Dinochloa, Gigantochloa, Melocanna, Schizostachyum,* and *Thyrsostachys.* The bamboo species belonging to these genera, except *Melocanna*, are purely clump forming in nature where culms are produced in cluster and more or less densely formed (caespitose type) tufts. But *Melocanna baccifera* is a non-clump forming bamboo species where culms are not clustered and tufted rather emerged very loosely. In respect of density and occurrence *M. baccifera* is a major naturally growing gregarious bamboo species in the North Eastern hills of the sub-continent (Banik 1997b). One can have panoramic view of pure *Melocanna* forest devoid of any trees extending as far as the vision of horizon covering hill after hills forming bamboo sea (Figure 10, Figure 29) in some parts of north east India (Tamenglong of Manipur, Dhalai of Tripura, Patharia reserve of Assam, Kolasib of Mizoram, etc.), Kassalong and Rankhiang reserves of CHT, and Surma and Champarai reserves of Sylhet forests. It has been estimated that in northeast India nearly 2.31 million ha of land is under bamboo vegetation (Kulkarni and Rao 2002) of which about 70-95 per cent area (varies from State to State, 1.6-2.2 million ha) is covered only with *M. baccifera.* Similar to north-east India the species also forms pure and scattered bamboo vegetation extending over 90,000 ha in the forests of Chittagong, CHT and Sylhet (Banik 1992); and as pure stands over 5059.3 Km^2 in Rakhine Yoma area of Myanmar (Htun 1999). Specifically, in Mizoram, Tripura and Manipur, *muli* is the predominant bamboo species and occupies about 85-95 per cent land of the bamboo forest.

It is but logical to enquire what are the possible inherent biological characters of *M. baccifera* that has made it a major dominant natural bamboo species over vast tract of hilly lands and its ecological importance. In this context it is imperative to understand the clump form and growth periodicity, including natural system of regeneration of the species, that provide aggressive ability in rapidly colonizing land and role on hill ecosystem. Though the species characters have already been discussed, earlier, some of the relevant points are, however, elaborated further in the following sections to find the answer of the above quarries.

6.1 Plant behaviour related to rapid colonization of the hills

6.1.1 Acclimatization in wider Topographic variation

Melocanna baccifera seems to be both partial shade tolerant and full light demander, grows luxuriantly on well-drained valley, gentle to steep slopes having moist organic very deep loamy soil, and satisfactorily on highly weathered deep clay soil to shallow sandy soil on the drier hill slopes. The clumps can grow as undergrowth in high forests as well as also spring up in practically pure stands after clear felling and burning of natural forests. As regards the altitudinal distribution, *M. baccifera* is common from sea level to 1200m altitude and may also occur naturally up to 1600m (observed on the hills near the Barak river catchments area of Tamenglong district in Manipur). It indicates that *M. baccifera* is some what hardy in nature and has wide ecological amplitude. Most of the natural bamboo species of the region have

Figure 29

A view of *Melocanna baccifera* vegetation, like a bamboo sea, on the hills of Mizoram. Many different clumps of the species intermingle with each other in the forest and usually impossible to demarcate the boundary of a clump

been growing in very narrow and specific type of habitat condition. Species like, *Schizostachyum dullooa* grows only in the moist gully areas near the streams; *Bambusa tulda* on the flat alluvial deposits along the hilly streams inside the forests and also along the banks of the dry water courses; and *Dendrocalamus hamiltonii* and *D. longispathus* mostly along the streams in the most fertile loamy soil and partially shaded fringes of the forest covers. These species are very rarely seen on hill-tops, drier slopes and under the close canopy cover; whereas *M. baccifera* grows in all the habitat conditions.

6.1.2 Some tolerance to biotic interference

In many forest areas of northeast India and Chittagong Hill Tracts (CHT) continuous overexploitation, habitat destruction and frequent fires repeatedly destroy the above ground photosynthetic parts (culms including leaves and branches) and as a result bamboo clumps get little time to manufacture and store foods to recover the growth. The bamboo species like, *Dendrocalamus hamiltonii, D. longispathus, Schizostachyum dullooa,* etc. has little or no tolerance to such habitat destruction and may disappear when the burning and other biotic disturbances are severe and repeated. However, the bamboo species like *M. baccifera* can survive in such degraded areas and develop small sized clumps with some what thick walled, small diameter (1-3 cm at mid culm zone) culms. Such small sized stunted and less diffuse clumps seem to be a morphological adaptation of *M. baccifera* to tolerate intensive grazing, repeated cutting, burning, and grazing; there by enabling the species to regenerate successfully even in heavily deforested and *jhumed* areas. This type of naturally degenerated clumps of *M. baccifera*, could be a bioform, locally known as *tengra muli/nali/bazali* in CHT and Sylhet forest (Banik1994a), and as *rua muli/wai muli* in Tripura and southern Assam. Thus, it is evident that the rhizomes of *M. baccifera* are remarkably tenacious, and has ability to survive the burning of culms, leaves, and branches (Banik 1994a). The vitality of the rhizomes is well demonstrated in the natural forests of this bamboo by the difficulty experienced in eradicating it on ground, cleared for cultivation, and the areas unvariably regenrate thickly with *Melocanna* by the vigorously growing green twigs and big size leaves produced from the stumps (Figure 17). On this account local people in the hill are said to prefer flowered areas for making the clearings to cultivate crops because within a 2-3 years of flowering the above ground parts (culms, twigs, etc.) get dry and ultimately die. However, part of the underground rhizome system still remain alive for next 1-2 years and directly produce flowers and fruits (Figure 17).

6.1.3 Reaction with *Jhum* agriculture

The hill tribal people of northeast India, Chittagong Hill tracts (CHT) and Myanmar region have been practicing *Jhuming* (shifting cultivation) since pre historic age. In the cultivation process jungle is cut and fire is set to burn the debris and clean the hill site for cultivating agricultural crops. Such fires are set annually with little soil work on the hilly terrain, which decrease soil moisture and depletes the lands of organic matter. In addition, the clear felling of high forest has also been a common forestry practice prior to starting any plantation activities in this hilly region. Such deforestion, results in considerable set back to ecological conditions and in many cases may even result in failure of man made plantations. In repeatedly burnt sites with other biotic disturbances, the plants having strong underground rhizome systems can withstand the repeated depredation while most other species disappear. Due to increased pressure on land, *jhum* cycles have reduced considerably, thereby bringing more high forest under seral conditions. A typical recuperation cycle in such areas (in parts of Cachar and North Cachar) has been estimated at more than 60 years encompassing stages such as weeds (typically *Imperata cylindrica*, and *Macaranga dendiculata*) to bamboos (typically *Melocanna baccifera*) to shrubs and trees (Rao and Ramakrishnan 1987). Repeated fire and destruction of vegetation (clear felling, firing and *Jhuming*) progressively also destroy the rhizome systems of naturally growing different grasses, and finally bamboo species, like *Melocanna baccifera,* with its underground strong rhizome system generally invade the abandoned fields. The unhurt underground rhizome systems rapidly regenerate into pure bamboo forests covering wide areas as a *fire climax* and form bamboo forests as secondary vegetation. It can be seen in the hills of northeast, CHT and Arakan and Karen hills of Myanmar that *Jhumed* clearings have mostly grown up with bamboos that become harvestable within 7-10 years. Thus *M. baccifera* expands its area by the *jhum* agriculture and it is believed that the *jhumed* areas regain productivity from bamboo ash. In fact, the *M. baccifera* vegetation dominate in *Jhum* areas because of high capacity of regeneration after burning. However, in the case of tufted bamboos (like species of *Bambusa, Dendrocalamus, Gigantochloa*, etc.) this effect of shifting cultivation, in producing large tract of pure bamboo, is not generally so marked, since the new culms produced after the clump is cut, are smaller and less vigorous for the first few years than in the case of loosely-stemmed spreading clumps of *M. baccifera.* Troup (1921) stated that "*Melocanna bambusoides* is a gregarious bamboo, and occupies extensive tracts of country in the Chittagong and Arakan hills, where the destruction of tree growth by shifting cultivation has covered considerable areas and produced a veritable sea of bamboos".

Figure 30

Melocanna baccifera: A part of rhizome system, each individual isolated standing culm conects with long necked (1.0-2.0m) pachymorph rhizome

Dr. R.L. Banik

6.1.4 Diffuse nature of clump architecture with open type of rhizome system

The excavated underground rhizome part of a *M. baccifera* clump shows that individual standing culms are connected with each other at the base through short, thick swollen rhizome having very much widely elongated rhizome necks (Figure 30). In this long necked-pachymorph-diffuse special type of rhizome the necks are slender, 1.0-2.0 m long, circular in cross section progressively from one end to the other, and smallest at the proximal end (obterete), except near the distal end, where it expands in to a rhizome proper (Figure 30). With the development of a long necked rhizome, the distribution of standing culms shows a real diffuse form of clump. As a result emerged culms have been standing solitarily, 3 cm to 200 cm gap in between, not clustered, making the formation of loose, open and diffuse clump. No buds are present on any node of the long necked pachymorph rhizome and bear some roots only in a few spots, but large buds existing on the nodes of thick rhizome proper connected under the culm base (Plate 2a). While enumerating the culm production in *M. baccifera* vegetation (of 25 years old) 24 number of young culms were found in a 5.0m x 5.0m clump area, of which 14 occurred towards the periphery (58.3 per cent) and remaining 10 grown (41.7 per cent) in the central part. While in all local caespitose clump forming bamboo species (*Bambusa, Dendrocalamus, Gigantochloa, Schizostachyum,* etc.), the annual culm production per adult clump is far less in number may vary with the species, from 5 to 35. Fresh culms mostly emerge towards the periphery, compactly, due to clustering of culms from underground short stalked (neck), about 5 to17 cm long, pachymorph rhizome system (Plate 2b, 2c). As these bamboo species possess compact nature of clump, it does not provide much room for the emergence of new culms.

6.1.5 More culm production with rapid rate of clump expansion

A ten year study on culm production, growth and clump expansion behaviour of *Bambusa balcooa, B. longispiculata, B. tulda, B. vulgaris,* and *M. baccifera* have shown that on an average only one to three full-grown (FG) culms were produced per clump in the first year after plantation (Banik 1988a). The number of FG culms emerged in the clumps of different *Bambusa* species increased in the subsequent years and became a maximum (8-12) in the fifth to seventh year of clump age and then gradually become stable.

On the contrary, in *M. baccifera* the average number of FG culms produced

Table 15. A comparison of annual production of full-grown (FG) culm and expansion of clump girth upto 10 years (1973-1982) of clump age in *Melocanna baccifera* and some other bamboo species.

Clump age (Year)	*B. balcooa*		*B.longispiculata*		*B.tulda*		*B.vulgaris*		*M. baccifera*	
	FG Culm (nos.)	Clump girth (cm.)	FG Culm (nos.)	Clump girth (cm.)	FG Culm (nos.)	Clump girth (cm.)	FG Culm (nos.)	Clump girth (cm.)	FG Culm (nos.)	Clump girth (cm.)
1	1.2	28.5	1.8	30.0	3.0	87.0	1.6	50.0	2.5	92.2
2	2.3	66.2	2.7	66.5	3.8	153.0	2.8	105.0	5.6	145.9
3	1.7	102.0	4.1	140.2	8.2	243.0	3.2	162.6	12.5	301.0
4	2.7	177.0	6.2	222.0	5.7	307.0	5.3	273.4	16.4	395.4
5	3.2	232.0	7.0	286.4	8.8	439.3	5.2	378.0	23.6	529.3
6	2.2	250.0	6.7	372.0	4.5	464.0	3.6	456.3	25.3	624.3
7	2.4	312.5	5.0	430.0	4.9	520.1	3.2	508.3	26.6	805.4
8	1.8	320.5	6.6	507.6	3.7	527.2	3.2	555.0	25.1	980.6
9	2.2	376.0	5.8	648.3	4.8	571.0	2.6	603.0	31.1	1268.0
10	2.2	414.2	5.7	690.0	2.7	586.7	2.8	705.0	35.7	1432.3

Source: Banik (1988a)

in the first year was 2.5 and from third year the number increased rapidly to 12.5. and continued to increase further in the subsequent years reaching 35.7 by the tenth year of clump age (Table 15). Accordingly clump expanded rapidly after every year and continued thereafter even upto the tenth year of the study (Banik 1988a). At the early stage, the clump area of *M. baccifera* is small and thus can produce only fewer fresh FG culm, like other true clump-forming (caespitose) bamboo species. From third year onward, *M. baccifera* clump start expanding rapidly by producing elongated rhizome necks (Table 15), and as a result the clumps open with more room available to produce and accommodate larger number of culms annually. Gradually from about fifteenth to twenty-fourth years of clump age, the rhizome system expresses maximum morphometrical development (Table 11) with fully elongated rhizome necks. Thus in *M. baccifera* a diffuse and open type of clump expanded in all directions, provides the room required for emergence of the increasing number of FG culms. Probably due to this architectural habit, the rate and pattern of clump expansion in *M. baccifera* is very rapid and higher than other bamboo species (Table 15) growing in the region. Moreover, in a clump forming bamboo species the expansion of clump is limited due to its short-necked pachymorph rhizome system and thus can not form continuous crown cover. With its structural advantages of long-necked rhizome system *M. baccifera* can, therefore, quickly invade and cover the exposed hilly areas. Due to rapid clump expansion ability many different neighbouring adult clumps overlap and intermingle with each other forming a pure bamboo vegetation with interwoven extended rhizome network below the ground-and make impossible to demarcate the boundary of each clump of *muli* bamboo in forest (Banik 1994a).

Figure 31 ▶

M. baccifera clump: Marching towards the upper direction of the hill slopes

Due to the aggressive spreading nature *Melocanna baccifera* bamboo constitutes 70-90 per cent of the total bamboo resources present in the different hill forests of northeast and eastern part of India, CHT and Arakan range of Myanmar. It is interesting to note that while *M. baccifera* clump expanding it also has a tendency to move even across the hill slopes by producing new culms (Figure 31a).

Once the hills are heavily deforested, it becomes difficult to create green cover, but *M. baccifera* can be successfully grown. Closer spacing of even 2-3m may be opted for creating green cover quickly in the denuded hills and river banks.

6.1.6 Longer growth periodicity of rhizome system

Most of the tropical clump forming bamboo species exhibit seasonal movement and growth of rhizomes only in the spring. The development of daughter rhizome starts from the base of a culm only after it completes elongation and becomes at least of 12-15 months old. In contrast to that, a clump of *M. baccifera* while producing a new culm simultaneously also start developing the rhizome neck(s) below the ground from the rhizome of the emerging culms (Figure 23b, Banik 1999). Study shows that the movement and elongation of rhizome neck of *M. baccifera* goes on, either actively or slowly throughout the year, even in winters, irrespective of season (Figure 23b, Banik 1999). However, the rhizome neck elongation slows only when mother culm exhibits growth and produces branches and leaves. In contrast to *M. baccifera,* most of the tropical clump forming species of *Bambusa* and *Dendrocalamus,* with compact pachymorph rhizome systems (short 3-10 cm rhizome neck, Plate: 2b and 2c), exhibit only seasonal (primarily during February-August) movement and growth of rhizomes in a year. In these genera development of daughter rhizome starts from the base of culm only when it is at least of 11-15 months of age. As these clump forming bamboo species do not produce long rhizome necks and therefore no such large net like structures are formed and each clump covers only a small surface area and thus, unable to develop continuous bamboo vegetation like *M. baccifera*. Therefore, preference may be given for selecting *M. baccifera* in reforesting the denuded and degraded hills (Banik 1997b).

6.1.7 Longer period of culm emergence with less juvenile mortality

Each species of bamboo, in general, has definite periodicity for culm emergence. The culm emergence takes place in adult clumps of *M. baccifera* at the advent of rainy season in the month of May and may continue up to beginning of dry winter November, about 7 months long emergence period (Banik 1993a). Most of the other naturally grown bamboo species in the forests of north-east, CHT, Myanmar have shorter period of culm emergence of 4-6 months only (Table 7).

All emerging culms in a clump do not always develop into full-grown culms. Some of them die naturally during the process of elongation, which is known as juvenile culm mortality. Such mortality behaviour was studied by Banik (1983) continuously for three years (1978-1980) on a number of bamboo species and observed that it was low around 8-10 per cent; in *M. baccifera*, in comparison to 30-70 per cent, in tall and thick walled bamboo species (*Bambusa balcooa, B. longispiculata, B.nutans, B. vulgaris,* and *Dendrocalamus giganteus*). Sharma (1982) also observed 60 per cent culm mortality at elongation stage in a clump of *Gigantochloa levis,* a common clump-forming thick walled tall bamboo species of south east Asia. In all the above mentioned species, except *muli*, the death of a emerging culms was observed within the average height of 22.0 cm and within the distance of 27.0 cm to the nearest older culm. The emergence of large number of culms within the distance created congested clump condition. Generally, the dead culms in *muli* were taller (35.0 cm) than others and their emerging distance are also within 78.0cm to the nearest older culm. The length of rhizome neck and the nature of rhizome movement control the distance of emerging culm from the nearest older culm.

In the above mentioned caespitose clump forming bamboo species most of the culms emerge within a short distance due to short-necked sympodial rhizome systems and often a congested condition is created if not regularly harvested. This leads to intensive competition for survival among the developing culms increasing mortality amongst young developing culms. Kondas (1981) and Sharma (1982) also opined that congestion could be a factor for death of emerging culms. Due to a more open and diffuse type of clump architecture, the problem of congestion is not acute in *M. baccifera* and consequently the emerging culms face less competition for space, food and light than other caespitose clump forming bamboos. Besides, as a practice local indigenous people in many areas of north east (Tripura, Mizoram, Assam, Garo hills, etc.) and Chittagong Hill Tracts harvest large number of emerging culms (shoots) from *Melocanna* forests for edible purposes and earning cash through marketing. Such thinning of culms further decreases the competition and juvenile mortality of *muli* culms and as a result the species get advantage over other bamboo species in invading the hills.

6.1.8 Efficiency in dispersal of fruits

Unlike the seeds of other bamboo species where seeds are usually small and grain like, the seeds of *M. baccifera* are green, heavy and big and pear like (Figure 13b). *Melocanna* seeds are dispersed over the hill slopes far away from the mother clumps by rolling due to its weight, smooth surface and somewhat round shape. As a result the species was found springing up in new hill-sides and valleys, where it did not exist before. According to Stapf (1904) during 1867, a surveyor reported that in a 6000 square mile patch the pear sized seeds of *M. baccifera* were falling so thickly that he had to give up work because he could not place his plane table and theodolites on the ground. During 1915-1916 fruiting in Arakan the species was also observed to spread, owing to the rolling of the heavy fruits down the hill slopes, to places where it did not exist before, and was found springing up on savannahs and in beds of streams (Troup 1921). Thus after each gregarious flowering the seeds and seedlings of the species are dispersed widely and usually cover a large tract of land resulting quick invasion and natural re-greening of hills, if the natural regeneration is nursed are protected adequately.

6.1.9 Vigorous growth nature of seedling

The *Melocanna baccifera* seedlings, unlike most of other bamboo species, make vigorous growth from the commencement (Figure 14c, Figure 26b). More commonly secondary culms may develop by tillering before leafy branches appear. The precocious emergence of such additional shoots is very rare in other bamboo species. In the seedling, formation of a sound rhizome system starts at early age, about 4-6 weeks of germination (Figure 21a, 21b). The rhizome body is covered with comparatively thick tough sheaths fitted imbricately one above the other up to the pointed tip, the 4-6 cm long rhizome proper. Such thick sheath coverage help the tender seedling rhizomes to tolerate abrasion in penetrating and spreading inside the rough soil. A comparative study on the nature of growth and biomass production in the seedlings of *Melocanna baccifera* and a true caespitose clump forming bamboo (e.g; *Bambusa tulda*) show that both green and oven dry weight of different organs of seedlings of *M.baccifera* are higher than those of *B.tulda* at the initial stage of growth and development (Banik1991a, Table 5).

The amount of rhizome biomass in *M. baccifera* seedling increased 4-5 times from 3-6 months growth showing the faster growth nature of the species. A comparatively longer rhizome system is developed in *M. baccifera* within 11-12 months of seedling age, move strongly geotropically and travel deep up to 10-15 cm, produce successive pointed shoot buds on the aggressively developing young rhizome system, the tip become phototropic that curve upwards and emerge as new culms (Figure 21b). On the other hand *B. tulda* seedlings have a lighter rhizome system with very short rhizome necks. Thus a *Melocanna* seedling from its early stage of life possesses some what long-necked heavy rhizomes which have the ability to produce big culms than the seedlings of other clump forming bamboos (e.g; *B. tulda*).

M. baccifera seedlings produce big size leaves than those of adult clumps (Figure 20b) and as well as from other clump-forming bamboo species, e.g; *B.tulda* (Table 6). Such big leaves trap more sunlight for producing more food required for supporting the vigorous growth of seedlings. Besides a germinating seed remain attach to the seedling for 2-3 months to support the initial vigorous growth (Figure 20b). The leaf area reduces to normal size with the age. It is evident from the study that *Melocanna baccifera* grows faster from the seedling stage itself and thus possesses inherent aggressive nature of growth compared to other local species of bamboo.

6.2 The role of continuous vegetation of *Melocanna* on hill ecosystem

6.2.1 Maintains water catchment

The pure vegetation of *Melocanna baccifera* stretches on the hills and maintains a continuous green cover in air and thick layer of leaf liters on the forest floor. On the ground of *M. baccifera* forest the dorsal sides of rhizomes are observed within 1.0–5.0 cm from the soil surface and below that the whole rhizome system distributed horizontally and laid up approximately to the depth of 25.0–75.0 cm (Table 10). Besides, about 94 per cent of root and other plant materials are also present within 66 cm depth of soil below the clump of *M. baccifera* (Table 10). Thus the species exhibits a compact rhizome net with shallow fibrous root system.

As already mentioned earlier, *M. baccifera* has been growing over large continuous patches and also merge into continuous vegetation covering several thousand hectares in the sub-continent (in the hills of north-east India, Chittagong Hill Tracts and north western Myanmar). This region of the globe has very high annual rainfall (3000-6350 mm) with 5–6 months draught period (commonly from November to Mid April). It is also seen that the species has also been growing dominantly in even higher rain fall zone (6000-10,000 mm) of Tangmang area at Cherrapunjee, in southern Meghalaya. These regions have sandy to clay loam alluvial soils on the hilly terrain with moderate to steep slopes that are extremely vulnerable to soil erosion during monsoon. During drought period the top soil gets dry and dusty. With the onset of such monsoonal heavy rainfall the big rain drops impact the ground hard and render the hilly region extremely vulnerable to soil erosion and land slides. Every year the blanket of fallen leaves and twigs up to 10-15 cm thickness act as somewhat spongy pad on the forest floor and buffer the direct hit of monsoon raindrops.

Annually the amount of leaf fall from adult clumps of *M. baccifera* is 6.0 ton per hectare (Hassan and Islam 1984). The thick litter is effective mulch and also absorbs rain water and the retained moisture gradually gets released through the underground rhizome net in the continuous vegetation of *M. baccifera* covering vast tract of land on the hills. Every year portions of old rhizome nets and roots die and decay thereby leaving many finer and some broader tunnels under the soil surface of the hill slopes. The rain water stored inside the micro tunnels of dead roots (root diameter varies from 0.04 cm-0.48 cm) below the ground recharge the springs and streams originating in the water catchment areas (Banik 1989, 1997b). In addition, the evergreen foliage crown takes the punch off the fierce tropical rains and softens their impact on the ground. Also the upstream bamboo vegetation provides opportunities to increase the recharge of aquifers and facilitates seepage for equable year round water flow in the streams. However, during last two to three decade, the continuous vegetation cover has been destroyed for urbanization of the areas (Figure 31b). Numerous roads, dams, buildings etc. have been constructed by razing down the hillsides and cutting away of the vegetation. As the underground rhizome and root parts of *muli* bamboo vegetation is mostly within the depth of upto 65cm, the ripping of under ground continuous rhizome network leads to soil erosion and land slides.

Figure 31b

Raising of hills for making road and urbanisation have been dstroying bamboo forests

6.2.2 Controls soil erosion and flash flood

The continuous bamboo vegetation along with other plants prevents sudden water flow and immediate water runoff in the downstream channels. The vastly spread, branched and inter-connected ramifying underground rhizome networks (Figure 9, Figure 30) also bind (bamboo reinforced) the soil and thus prevent the soil erosion or landslide in the hills. Preliminary study show that such wide spreading rhizome system, accumulation of dense litters on the forest floor, the stem flow rate and canopy intercipt is about 25 per cent which means the compact and continuous green crown cover of this bamboo greatly reduces the rain water run off and conserves more water on the ground and for subterrarian flows. As a result, the siltation in the downstream is minimized and flash floods are mitigating in the valleys and plains. The dense natural vegetation mostly of *Melocanna baccifera* in the hills, thus, have been maintaining the steady flow of water in the river Jiri, Makru, and Irang in Tamenglong (Manipur) including the Barak valleys; river Khowaii, Manu in Tripura; river Serlui, Twlang, and Lagaiah in Mizoram and river Karnafully and Sangu in Chittagong Hill Tracts covering large tract of water catchment areas. Collection and burning of dry leaves/twigs (litter) exposes the surface of the hilly ground, the ensuing monsoon shower directly hits the ground accelerating the soil erosion, especially, on the slopes. Allowing thick layers of litters to decompose on the ground is an important practice in scientific management of *Melocanna* forest for preserving watershed attributes, controlling erosion and maintainence of soil nutrition levels. It is relevant to mention that an INBAR supported research project in China conclusively proved that the canopy and leaf litter of temperate bamboo stands can intercept rainfall much higher than those for conifer and pines (Rao Ramanuja 2004).

6.2.3 Acting as Carbon sink

Generally bamboos are harvested regularly from a clump and thus the above-ground biomass is utilized. The below-ground biomass allocation gets higher as the clumps become older (Table 11) and each year several tons of new woody biomass of rhizomes are produced. The clump forming bamboos has limited expansion of rhizome system and accordingly the above ground crowns of several clumps could not form a compact vegetation cover like *M. baccifera*. Thus the existing *Melocanna* vegetation extended over large tract of land in the region have been serving as store house of a huge amount of organic matter inside the rhizome network than other bamboo species of short necked rhizome system.

6.2.4 Possible effect of monocarpic death of *Melocanna* vegetation due to gregarious flowering

Due to the recent (1990-2008) sporadic to gregarious flowering and simultaneous large scale death of *Melocanna* vegetation, the hill surface gets exposed and the underground rhizome nets covering vast hilly lands also start disintegrating and weaken the soil binding thereby creating adverse conditions enhancing soil erosion, land slide and increased run offs in the catchment areas. The gregarious mortality of *M. baccifera* also drastically reduces litter fall on the ground not only deminishing water recharge but also soil nutrition levels. The rotting and decaying of underground rhizome nets weaken the soil binding and thus create serious problems of land slide and soil conservation. The exposed denuded hills are likely to enhance siltation in river beds and also create unpredictable floods in the plains, navigation problem and aquatic fish lives. This, in turn, would reduce the agricultural productivity on the hills and valleys.

Therefore, it would be logical to say that the nature might have selected this aggressive *M. baccifera* as a dominant species only for this high rainfall region probably for maintaining the fragile hill ecosystem by reducing the soil erosion and regulating water flows (Banik 1989, 1997b). Thus, from ecologic, social and economic viewpoints, *Melocanna baccifera* is an important multipurpose bamboo resource in north eastern hills of South Asia.

7 Harvesting Practices

Harvesting of bamboo is the main or only management activity being practised in natural bamboo forest. However scientific harvesting of vast natural forests is beset with many difficulties primarily for want of close supervision and the consequent failure to ensure correct treatment to the forest in germinated individual clumps in particular. The important factors for consideration in harvesting of bamboo forest are felling cycle, intensity of felling and method of felling.

7.1 Some Important factors considered during felling

7.1.1 Season and harvesting age

Bamboos are usually not harvested in growing season. Generally, bamboos harvested during summer deteriorate more rapidly than those felled after the rainy period. Flowered bamboo has a higher resistance to beetles because the starch is depleted when bamboo flowers. But these bamboos are also brittle.

It was observed that in the clump of *M. baccifera* 3-years old culms possessed less (0.60 Kg) amount of leaves than 1 and 2 years old culms (Ueda 1960). Subsequently fewer amounts of leaves remain in 4-5 years old culm, and therefore it is likely that it has little contribution in photosynthesis and over all health of the clump. Thus it appears that in *M. baccifera* clumps felling of culms may be started after 3-4 years of age.

In the forests, the bamboos are not allowed to be harvested for three months from June to mid-September. These three months are the maximum shoot emergence period and, therefore, closed to harvest. The harvesting of bamboos has been done in dry and winter season of year, during Hindu calender months *Kartik* to *Poush* (November-March).

In northeast India, generally bamboos (*Melocanna baccifera* is 60-90 per cent out of total bamboo forest) are worked on a 4-year cycle, and felling rules prohibit cutting one year, two years old and a few older ones left scatteredly in the clump. The 'Harvestable Growing Stock' means the stock found in the areas which can be harvested as per norms laid by the Government of India, i.e. not falling within 500 m of major river, stream, steep slopes and above 1000 m altitude (Yadava 2002).

7.1.2 Selection felling and clear felling

In the forestry practice only 3 years or older culms are harvested from the clumps as selection felling. In some occasions, especially in Jhumed areas, clear felling of all the culms are practiced by the local hill people. The rate of recovery of *muli* bamboo after clear felling was also found to be satisfactory, but during first year the emerged culms are very thin, short with profuse number of big size leaves which attract animals for grazing and remain vulnerable to fire damage during dry season. Clumps require initial 4–6 years to produce merchantable size culms, if not disturbed further. In case of gregarious flowering when clumps die in large numbers clear felling is carried out to remove the dead and dry bamboos.

7.1.3 Felling processes and step

The felling process is purely manual using a sharp tool (bill hook or *dao*) for cutting bamboos from the clump. The *dao* is 0.3-0.6 m long and 4-5 cm wide flat iron knife. People also use *dao* for constructing their house, as agriculture implement and also protecting themselves from any attack of wildlife. Bamboos are never cut after leaf fall. Bamboos are found not durable if harvested in March/ April/ May as they contain more starch and moisture. However, for temporary use like repairing of house in emergency, bamboo can be harvested in off-season also.

For construction purpose only the mature bamboos are cut from the clump. Local people can identify the ripe/mature bamboo by hearing the sound by beating the back side of *dao* on the bamboo stem. Young bamboos, usually 12-18 months old, are not harvested. People can also identify the ripe bamboo from some morphological characters. These are smooth culm surface with light yellowish colour and absence of culm sheath.

There is a belief that if bamboos are felled in the first day of new moon, it will be more durable and resistant to *ghoon*.

7.2 Felling Practices of *muli* bamboo in some places of the region

***a) Tripura*:** A case study at Tripura forest has been made on the different steps of *muli* bamboo harvesting and transportation that has been narrated below:-

Both males and females of Reangs, Debermas and a limited population of Munda and Molsom tribes, who inhabit in the upstreams, are actively involved in bamboo extraction. The tribes mostly extract naturally grown bamboos such as *Muli* (*Melocanna baccifera*), *Mirtinga* (*Bambusa tulda*), *Dalu* (*Schizostachyum dullooa*) and *Rupai* (*Dendrocalamus longispathus*) are the major amongst them. The *muli* bamboo constitutes the major portions of all extracted bamboo which is more than 90 per cent. The major livelihood in the upstream is *jhumming* for subsistence and bamboo extraction for generating cash money. The maximum extraction is done near the water courses for ease in transportation by floating with the water current. In the inaccessible areas on the hills the felling is done rarely and as a result *muli* clumps are congested with below average growth and yield. Regular felling is necessary for making room for culm emergence and proper growth.

From the hilltops, bamboos are collected by making access paths. Bamboos are cut at the hilltops and brought to the bottom of the hills through sliding on the walking paths and stacked there.

Harvesting of bamboos include a series of operations broadly divided into three phases as follows:

- The felling of bamboo stems 0.3-0.45 meters above the ground, their trimming and cutting into pieces for bundling and extraction as shoulder load.
- Transportation of bamboo includes bunching and rafting through river water/ streams.
- Stacking of bamboos on the river side depots for loading into trucks for transporting to the local district markets and beyond.

In Tripura there are four major bamboo resource heads namely, Chakmaghat near Teliamura on Khowai river, Sonamura on Gumati river, Kalashi on Muhuri river, and Kumarghat on Manu river. A five step process is involved from the point of extraction to transportation of bamboo through water ways to temporary local village market, Agartala market, capital town of Tripura, by road.

Chakma Ghat, (Teliamura): It is a big *muli* bamboo market in Tripura. The bamboos are brought here from Attaramura range through river Khowai. The supply chain of bamboo from harvesting to marketing involves a number of steps :

Step: I – Bamboos are harvested from the forests of Juri, Ghanga nagar, and along the stream bank of Jial cherra, Nona cherra, Poma cherra, Tetua cherra, Guli cherra, Balu cherra, Tekorma cherra, Bashkara cherra. Bamboo pole extraction, clearing from forest, trimming, sizing it accordingly. Bundle them into 12 numbers of bamboo and carry it up to stream or river point. Bamboo cutting is generally carried out in two phases - roadside cutting and cutting on the hills and rolling the felled culms to the nearby water ways (river/ streams). In roadside cutting, cutters cut bamboo along the road extending to an average lead of 90-150 m. Bamboos are often cut 1.0-1.5 m above ground level; chop off the upper narrow portion 1.5-2.0 m, only harvesting the mid portion. The basal 1.0-1.5 m is heavier and has more biomass and the upper portion of the culm has longer fibre length much desired for pulp production. In most of the cases these portions (productive raw materials for pulp and paper mill) are left in the forest and not harvested. It is estimated that nearly about 50 per cent of the total length of the harvested bamboo is left on the forest floor. After felling, the bamboos are pulled out of the clump, then limbed and trimmed for handling and cut into pieces of 1.7-3.0 m in length for road transport by trucks. Sizing bamboo in the poles is done at cutting spots. Generally, 5.5–6.5m, sometimes 8.0 m long pieces are transported through waterways streamlets of Baskarachara, Nonachara, Pomachara, Tetuachara, Beluchara, Tekomachara, Jialchara which act as link to river Khowai. The felled and trimmed bamboo poles are tied with *doga* (newly emerged soft bamboo strings) in to bundles of 5-10 pieces each, so that these can be carried individually on shoulders. For water ways transportation, the bamboos are commonly bundled in 12, 16 or 24 pole (to round up 96) of 12 ft (3.66m), 15 ft (4.57m,) or mostly 18 ft (5.5m) length. These are tied to make a bundle. The practice of bundling 96 culms has its roots in the days of the Kings. The four culms from 100 were used to be paid as royalty to the king. This practice has been considered as an ethnic way of conserving the bamboo resource.

The local tribal villagers themselves cut bamboo from the forest, sometimes labourers are also engaged. The existing practise of bamboo cutting is a piece rate job, irrespective of age, size and quality. On an average, a labourer can cut, trim, carry and stack 40-50 bamboos per day that is equivalent to about 100-125 kg of *muli* bamboo poles up to river or any water ways (before rafting). So only for extracting 1 ton about 10 people, for 1 million ton 10 million people need to be employed. Out of expected 26 million ton dead *muli* bamboo, say 20 million ton could be harvested and for conducting this work 200 million man-days will be required. Taking as Rs.100.00 per person per day, Rs.20000 million of money is involved. Hill communities themselves have been conducting the whole process of harvesting and transportation. But in the marketing they have little role to play, rather in most cases the plain land people act as middleman and control the marketing. Thus the hill people who have been managing, protecting, harvesting and transporting to the local river side depots get deprived of proper price of the harvested bamboo culms. Harvesting to marketing of bamboo is done by the members of Joint Forest Management Committee (JFM) and Self Helf Groups (SHGs), in collaboration of the respective Forest Department. Involvement of individual contractors should be discouraged and at the same time government needs to provide all logistic supports to the local people for controlling the business. This would bring out a new partnership model of joint natural resource management that benefit the people, environment and economy.

Step: II - The bamboos are tied into a rafts by the person who rafts it down stream usually employed by the trader who buys the bamboo at Chakmaghat, and ties them into *challis* which has usually 300 poles. When the smaller bundles of bamboo poles reach the river they are retied into *Chalis* and usually about 10 to 15 *challis* together form a raft by tribes who are skilled and only engaged in rafting bamboos. Thus, a raft will usually have 3000 to 5000 poles (Figure 32a).

Step: III - The bamboos are rafted up to Chakamaghat from various places starting from Ganganagar and the rafts are anchored there by local tribal people. Bamboo transportation from Ganganagar to Chakmaghat market usually takes 2-3 days depending on water level and water current in the river.

It has been understood from an interview with a bamboo rafter that one person can earn Rs.150-200 for rafting 1000 poles through river Khowai up to Chakmaghat point (cost in year 2003). It was further learnt that about 10 per cent of total harvested bamboos are lost/decay in one year inside the forests stack. In general out of 1000 bamboos about 45 are lost or damaged in the monsoon floods in narrow streams or rain during waterways transportation. In the river, the bamboo *challis* are untied and each bundle is carried to the road side of NH-44 (Assam-Tripura Road) and assembled by the tribal and Bengali labours in Chakmaghat (Figure 32b). The bamboo bundles are untied and rebundled consisting of a right mix of bamboos, again 12 in numbers for loading in trucks by the local/tribal and Bengali labourers in Chakmaghat. The bamboos are loaded in truck for transporting to the destination mostly to Agartala.

It is estimated that around 16 million man-days anually of employment is generated on account of management and extraction of bamboos (State Bamboo Policy 2001, FD, and Government of Tripura).

Step: IV- The extracted bamboos are often sold to the bamboo traders at the major river transportation points near to major roads (Chakmaghat on river Khowai, Sonamura on river Gumati, Kalashi on river Muhuri). At the Chakmaghat point the bamboos are sold at Rs.4-5 per pole (Cost in the year 2006-07). Thursday is the market day in Chakmaghat.

Step: V- The bamboos are loaded in trucks for transporting to the destination mostly to Agartala and partly to Assam through road NH-44 (Figure 32c).

The bamboo resources in Teliamura forest division are from the bamboo resource head at Chakmaghat which originated from the Khowai river catchments in Dhalai and West Tripura

Figure 32 (b)

In the river the bamboo *challis* are untied and each bundle is carried on the road side of NH-44 and assembled by the tribal and bengali labourers in Chakmaghat, Tripura

Figure 32 (c)

The bamboo from Chakmaghat are transported in trucks to the retail market at Agartala Town

district, also some resources from the Baramura hillocks. In this section the bamboo extracted from the Teliamura forest division from its various collection points and among them the Chakmaghat accounts for more than 80 per cent of all bamboo extracted within the division, other places of collection points are Teliamura, Baramura etc.

The bamboo based economy of the Teliamura forest division is mainly on the intensity of the bamboo extraction, which forms a major livelihood option of the Tribal people. The major local bamboo depot in this area is the Chakmaghat on the bank of river Khowai on the national highway 44 and every Saturday large numbers of bamboo rafts arrive here, and from this point the bamboos are marketed to traders the Plains. The major secondary and retail market is Agartala town. The bamboos from here are transported in trucks to the retailer in Agartala (Figure 32c).

As per rule, bonafide householders and cultivators who are the inhabitants in

Figure 32 (a)

Melocanna baccifera: A raft usually has 3000-5000 bamboo poles transported through the river Khowai to Chakmaghat depot, Tripura

Tripura villages entirely surrounded by reserved forest are allowed free permits for harvesting bamboo to the extent of 250 numbers per family between the month of January and March.

Gumati river bank bamboo market at Tripura: Muli bamboo culms are tied in bundles and then into rafts. Each bundle may contain 12, 16, or 24 number of 15 ft (4.57m) long culms. The Government royalty per 100 bamboos is Rs.15. These bamboos are purchased from Pitha cherra, Killa beat at Rs.5-6 per pole, and 100 culms sold at this market roughly Rs.520-620 [Rs.15 (royalty) + Rs.2.25 (income tax 15 per cent) + Rs.0.27 (12 per cent surcharge) + Rs.0.6 (4 per cent VAT)= Rs.18.12 (revenue)] However, the price for 20-21 ft (5.10 m - 5.40 m) tall bamboo is from Rs.820 to 930. Bamboos are also transported from Killa to Sunamura through Gumati river and it takes more than 8–9 hours. The market days are only on Monday and Friday. Bamboos are harvested from Amarpur and Maharani, Ranicherra and Ganga cherra and brought at the *Kakraban Bamboo raft market* through the river Gumati. Here the price of one 16 ft tall *muli* bamboo was Rs.5-6 just before gregarious flowering. At *Belonia bazaar Bamboo depot*, the major types of bamboo are *muli*, and a few are *bari* (*B.vulgaris*) and *barak* (*B.balcooa*) upto 2003. At *Sonamura Ghat* point on the bank of Gumati river the price of 1000 *muli* bamboo was Rs.8000-9000. The price of a *bari* and *barak* bamboo was Rs.50 and Rs.70 respectively. All the above mentioned selling rates are from the observation of the year 2007-08. Now-a-days the muli bamboo is rarely available and if found the cost of a *muli* bamboo has gone up to Rs.10-15 at *ghat* point due to large scale mortality post of gregarious flowering.

It is often observed that a substantial quantity of *muli* bamboo moves further down to Comilla and Noakhali (Bangladesh territory) through the river Gumati, Fani and Mohuri, mostly in the night.

***b) Lower Assam* (*Badarpurghat*)**: In lower Assam (Barak valley- Cachar, Karimganj, and Hailakandi), *muli* bamboo is harvested from the hills and brought down by leaseholder who sells lengths of six-seven metres of bamboo in bundles of 1000 culms to a contractor. The contractor arranges to float the bamboo down the river to the cottage industry. A number of bundles of bamboos are tied together like a raft, and a team of labours live on the raft and navigate it to destination (Badarpur Ghat). The bamboo is taken out of the river and each culm is split in half along the length after the external nodal rings are cut off. The half culm is then flattened by hitting it along the length, particularly at the nodes. This is done with a wooden mallet or the back of a *dao*, a broad bladed knife, which causes the semi-circular cross-section of the culm to creak at various places, so that it lies flat. The internal nodal walls are chopped off, and then the board is split in two through the thickness so that one board has the outer skin of bamboo while the other has the inner surface of the culm. These are stored separately.

The single largest user of bamboo resources in the area is the Cachar Paper Mills, a unit of M/s Hindustan Paper Corporation Ltd. (HPC), Govt. of India undertaking. The unit is located at Panchgram in the Hailakandi district, and its raw material capacity is 250,000 Metric Tonne (MT) AD (Air dry ton) annually.

c) Mizoram: At present most of the extraction of the bamboo resources, which has predominant share of *muli* till 2009 (before gregarious flowering) takes place along the National highway to be transported by trucks and in river Tlawng up to the gate of Pachgram Cachar Papermill on the banks of the river Barak. The State of Mizoram has dual modes of leasing the bamboo resources for extraction by bamboo traders. In the Kolasib forest division the bamboo resources are managed by:

- *Mohal System*
- *Permit system*

The Mohal system is the main system of selling forest department bamboos. Harvesting rights are sold annually to *Mohaldars* (bamboo contractors) from Cachar part of Assam and they have rights to remove any quantity of bamboo (above 1 year old) from the forest. There are about 20 Mahals in seven forest divisions (Kolasib, Darlawn, Mamit, Champhai, Aizwal, and Tlabungi) covering an area of 1772 square kilometres. *Melocanna* accounted for 98 per cent of total standing stock with 725.684 million culms over one year old. Other bamboo species only accounted for 2 per cent of total bamboo stock. Although culms mature after three years, regulations exist to limit cutting to four-year old culms to provide some safeguards for future culm availability. The steep terrain makes the harvesting very difficult.

Under *mohal system* the bamboo resources are identified by the forest division and demarcated by area in case of Kolasib mostly on the 800 meters of either side of the river are given to a Mohaldar (selected bidder of the mohal) for a specified duration of the year. Local people have no rights to harvest bamboo in a Mohaldar's forest and must pay the Mohaldar if they wish to take any culms. Most of the bamboo harvested by the Mohaldars is supplied to HPC at Panchgram in Karimganj district of Assam. Rivers are preferably used for bamboo transportation to HPC through Barak river. Seven of the major rivers in the State flow north to Assam, five flow south and three flow towards the west. The river Karnafuli flows north and then enters Chittagong Hill Tracts (Bangladesh) and the Chhimtuipui (Kolodyne) flows south to Myanmar. Both the rivers are navigable and are potential water ways, so may be used as potential export routes to the sea port of

Chittagong (Bangladesh) and Myanmar. Major roads are also used for transporting bamboos within and out side the State. The national highway, NH-54 connects the state to Silchar (Assam), NH-150 connects Imphal (Manipur) and Kohima (Nagaland) and NH-40 to Tripura.

Extraction from the village forest land or private land is based on the permission from the village council or the individual owner.

Under the *Permit system*, in Mizoram a permit fee at the rate of Rs.8 per 100 poles and 100 per cent monopoly fee (Rs.8) is collected. Mostly road sides bamboo forests along the NH-54, Bairabi-Kolasib highway, are leased under this system.

According to an estimate, at present in Mizoram, only a small percentage of bamboo resources, 28,315 Metric Ton (MT) per year are harvested for the purpose of local construction, tiny handloom and handicraft production.

While the total bamboo yield works out to be 32,37,689 MT/Year in Mizoram, the annual aggregate consumption figures at 28,315 MT/Year, resulting an annual bamboo surplus of 32,09,374. Present bamboo resources extracted accounts for 1 per cent of the total yield and thus 99 per cent of the surpulus bamboo yield in Mizoram remains unutilised. Thus, there is a huge surplus of 32,09,374 MT/Year annually, which can be scientifically and gainfully utilised for generating huge financial resources to the State.

Development of rope ways in the hills would be very important for easy and cost effective extraction of bamboo from inaccessible areas. Paper mills in association with respective forest departments may initiate the work. The deplorable conditions of National Highways and other state and district roads including narrow roads on the hills are to be maintained and improved for the better transportation of bamboo resources.

d) Manipur **(*Tamenglong*):** According to the accepted local practice, October-January is the best season for harvesting of *muli* bamboo from the forest. Bamboos harvested in March/ April/May are not found durable. However, for temporary use bamboos are harvested during off-season also. Village like Paobam, Wangkhul, Rangkhung, Khongsung of Tamenglong district have plenty annual supply of the harvested bamboo.

Harvested bamboos are transported mainly through road, NH-53, to Imphal and Silchar. It is transported to local markets in Imphal, Giribam, Tamenglong by truck through temporary road inside the deep bamboo jungle. Sometimes in the villages people carry bamboo as head load to nearer local markets. Felled culms of *muli* bamboo are hardly transported through the Irang river. Some are also transported through river Jiri and Makru down to Barak river and ultimately to Badarpur. In the year 2002, at Namtiram part-II village the price of 20 kg bamboo shoots was Rs.50 where as in Tamenglong it was Rs.70.

The costs of bamboo pole in the year 2003-04 was about Rs.2200 per truck load (600–700 culms) from Namtiram part-II to Tamenglong. The villagers themselves cut bamboo from the forest, sometimes labourers are also engaged. The cost of a labour is Rs.60–70 per day. A labourer can cut 15-20 ft. (or 4.6-6.1 m) long 50-60 bamboos per day. Five numbers of big size (12" or 30 cm girth) or medium size (8-9" or 23 cm girth) ten number bamboo poles are carried as one head load. Sizing of bamboo in to poles is done at cutting spots.

e) Chittagong Hill Tracts and Sylhet **(*Bangladesh*):** In Sylhet and Chittagong Hill Tracts harvesting of bamboos (of which 70-90 per cent is *muli*) from the forests have also been practiced by *Mohal* and *Permit System* respectively. In the Chittagong Hill Tracts, bamboos are mostly sold through a permit system issued by the local officers, specifying the quantity, area and the time limit. The royalty for the quantity of bamboos is paid at the time of issuing the permit. After the completion of the harvesting, rafts are checked by the Forest officer and royalty realized for excess numbers of bamboos taken out. The entire system is a manual operation and is mostly located along the bank of river Sangu, Karnafuli, Matamuhuri or stream bank for ease of extraction. Under this system bamboo is rarely cut beyond 1.6-3.2 km of the floating stream banks. Such bamboos are rafted or taken by boat by the permit holder to important selling centres. Bamboos are mostly felled, procesed, rafted by Chakma, Lushai and Morong tribes and sold at Kaptai, Dohazari, Chiringa and the local markets near the forests of the Chittagong and Cox's Bazar Forest Divisions. At Kaptai, Karnafuli Paper Mills (KPM) purchases a substantial quantity of the bamboos extracted by the permit holders. This is the cheapest method of bamboo harvesting but, due to the change of hands, the prices go up to accommodate the profit of the different parties. This method only harvests bamboo in the accessible areas along the stream and riverbanks.

KPM also carries out extraction of bamboos by employing contractors using hired labourers. The major working areas for KPM are in the Kassalong and Rankhiang Reserve Forests of Chittagong and Chittagong Hill Tracts. The harvesting of bamboos is done on three year rotation using selection felling. Normally, felling starts in October and lasts for about 120 days in a season. The three months from 16th June-15th August is a closed season for harvesting.

Bamboo cutting is generally carried out in two phases - roadside cutting and ropeway cutting. In roadside cutting, cutters cut bamboo along the road extending to an average lead of 90-150 m. In ropeway cutting, cutters cut bamboo extending to an average lead of

90 m on each side of the ropeway. A rope way system consists of endless moving cables which are suspended at about 2.5-3.0 m above the ground at an interval of 18-25 m on trees or other supports. The cable is operated at a slow speed of 1.0 m /sec by a 20-25 hp petrol /diesel engine. Maximum load given is 30-35 kg (green) at an interval of 12-15 metre. Tractors with trailers are used for the transportation of bamboo extracted by ropeways as well as those cut along walking paths.

On an average 11 per cent of total harvested bamboos decay in one year in the forests stacks and 7-19 per cent get lost in the monsoon floods in narrow streams or rain. In wider watercourses the bamboo rafts may be torn apart by storms and high waves (Banik 2000). Thus bamboos are being transported from Kassalong and Rankhiang to Chandraghona KPM site.

Sylhet Pulp and Paper Mills Limited (SPPM) conducts major harvesting operation in the Sylhet forest. Both pure and mixed bamboo vegetation are found throughout the southern part of the Sylhet Forest Division in Rajkandi, Patharia, Hararganj Reserve Forests (RF) and Prithimpasha Acquired Forests (AF). These Reserves and AF are divided into bamboo *mahals* that represent the area units under bamboo extraction every four years. Bamboo *mahals* identify the catchment areas of the water courses (or *charas*) that are used for the bamboo extraction and after which they are named such as *Surmachara Mahal* and *Dholaichara Mahal.* Sylhet Pulp and Paper Mill's (SPPM) allotment is 12150 ha in the Sylhet bamboo forests. Every year after getting allotment of bamboo *mahals* from the Bangladesh Forest Department (BFD), the Mill authority appoints a harvesting contractor through tender. The permission for harvesting bamboos remain valid from 1st January-31st December, with a gap of three months from 16th June-15th August. This gap period is a closed season for harvesting. Cutting procedures are also similar to those practiced in the Chittagong and Chittagong Hill-tract. The size and number of the felled bamboos are then checked and verified by the SPPM and Forest Department officials. These are then transported by waterways on a particular day of a week to the base depot on the bank. A long distance of over 300 km is to be covered to the mill site at Chattak. Part of this distance bamboo has to be transported against the river current.

Shoulder load transportation up to the river bank, extends 3.5 km in some cases, are done by the labourers due to the absence of extraction forest roads. As the cutting and extraction is done on a piece rate basis, the workers have tendency to cut more bamboos in the accessible areas, and also immature (less than one year old) bamboos ignoring the prescribed cutting rules (Banik 2000). Bamboo extracted by purchasers in the Sylhet Forest Division is often sold to the bamboo traders at the major transportation points, mostly located near the railway stations. The average price in 1984 for *muli* bamboo at Juri station was Taka 3,000 to Taka 3,500 depending on the quality. During 1990-91 the price had gone up and according to Juri Range officer, the price of average size *muli* bamboo was about Tk 5,000 to Tk 5,500 per 1,000. In the case of quality *muli* bamboo (3 years old, 6.5 m long, 15-17 cm girth at base), the price is Tk 6,000 to Tk 7,500 per 1,000 (Banik 2000). However, present scarcity of *muli* bamboo due to gregarious flowering has increased the price TK 15,000-20,000 per 1000 poles.

Long distance transportation even up to Dhaka, Barisal, Patuakhali and Khulna is carried out mostly through rivers and taken to these areas in big rafts. However, now-a-days rail and truck also transport a substantial amount of bamboos. Sometimes bamboos are converted into *tarjas* (flats) and transported by bundles in trucks or on railway wagons.

f) ***Myanmar*****:** Htun (1999) reported that *muli* bamboos are harvested at 3-5 years cycle from the bamboo forests mainly through river ways. The overall system of extraction is more or less similar to the practices followed in Chittagong Hill tracts.

The age old practice of transportation of harvested bamboo through water ways from the forests of north east India, Chittagong hill tracts and Myanmar is an example of intelligence and wisdom of local indigenous people. In this region every year several millions of bamboo poles are being transported through water and marketed without any cost of fuel and machines. In some cases bamboos are transported for more than 150 Km in 4-5 weeks time, the rower and rafts man stay on the raft full time and navigate safely along the water current to the destination market. Such transportation practices have a number of benefits - first it is environment friendly as no fuel or any machines are used, and bamboo poles become treated while conveying on water for a few weeks.

8 Culm Properties and Utilization

8.1 Physical Properties and Mechanical Properties of culm

Information on the physical and mechanical properties of bamboo is necessary for assessing its suitability for various end products. Study on the physical and mechanical properties of one to five years old *muli* culms have shown (Sattar et.al 1991) that the moisture content changed significantly with the culm height and age. The younger culms possess higher amount of moisture and it gradually decreases with the age. The moisture content is highest (111 percent) in butt, 95 per cent in middle and 82 per cent in top position of a 1-year old culm, while it is 97, 84 and 78 per cent respectively in the above positions of a 5 year old culm. The younger culms, however, show higher percentage of moisture content.

The specific gravity of *muli* was studied in both green and oven dry volume at butt, middle and top position of culms. The age was found to have direct relation with the specific gravity. The younger bamboos were less dense than the older ones. The maximum value was observed in the case of 3 year old culm. After three years there was no increase in the value of specific gravity in the culm. The recorded values were 0.55-0.70 at butt, 0.60-0.71 at middle and 0.64-0.75 at top position of three years old (green to oven dry) culm. The value increases from the butt to the top position based on both green and oven dry volumes. The higher specific gravity at the top of the culm may be due to the presence of higher portion of sclerenchyma tissue per fibrovascular bundle at this position.

Anatomical study shows that a fully developed culm of *muli* bamboo contains parenchyma, fibres and conducting tissue at the percentage of 43, 50 and 7 respectively. The fibre content in most of the other bamboo species is within 37-45 per cent. Therefore products made of *muli* bamboo wood are usually difficult to make smooth and polished.

The conducting tissue consists only of two small vessels and a few sieve tubes with their companion cells. The vascular bundles immediately below the cortex are circular in transverse section. Towards the middle of the culm wall, the vascular bundles become large and more widely spaced. The large diameter metaxylem vessels in bamboo are the main channel for solution to penetrate along the longitudinal direction, and its size is the most important factor that affects the permeability property. The average vessel diameter of the species is 96.7 ì m more or less similar to the value of *Phyllostachys pubescens* (95.5 ì m). The inner side of the vessel wall is covered by a warty layer. The warts are distinguishable from remnants of cytoplasm debris or remnants of starch granules. With a size of 110–370 ì m, they are generally smaller than those in various cell types in bamboos. Warts remain in the lignin skeletons of the cell wall, indicating their composition of lignin-like materials (Liese 1998).

Unlike wood, bamboo shrinks right from the beginning of drying. The highest shrinkage was recorded in butt portion of culm. The shrinkage (in percentage) in wall thickness (bottom-9.5, middle-5.6, top-4.8) and in diameter (bottom-5.4, middle-4.1, top-2.9) shows decreasing tendency from the bottom to top from green to 12 per cent moisture content. This may be related to the variation in distribution of moisture content in different height positions of culm.

The mechanical properties viz., modulus of rupture (MOR, kg/cm^2), modulus of elasticity (MOE 1000 kg/cm^2), and compressive strength varied significantly with the height and age of the culm in both green and air dry conditions (Sattar et.al 1991). The bottom is found to be the strongest in MOR while the top exhibits the lowest values for the species. There was gradual increase of the strength from the culm of 1 year to 3 years (Table 16). The maximum bending strength was observed in the 3 years old bamboo. In comparison to other common bamboo species of northeast India and CHT *muli* shows the highest value of elasticity. The butt of three years old was the strongest in MOR 728 - 782 Kg/cm^2 while the top showed the lowest value 622 - 687 Kg/cm^2 both in green and air dry condition respectively. Above 3 years strength values declined. The MOE and compression parallel to grain increase along the culm from butt to the top. The highest values were 460-647 Kg/cm^2 noted at the top position in both green and air dry condition. However, the 4-years old culm showed maximum compressive strength. The culm age has been found to be an important factor

Table 16. Some physical and mechanical properties of *Melocanna baccifera* at different culm height position and ages.

Properties	Culm age	Culm Butt		Culm Middle		Culm Top	
		Green	Airdry	Green	Airdry	Green	Airdry
Modulus of Rupture (MOR) (Kg/cm^2)	1	570.00	658.00	503.00	547.00	478.00	544.00
	2	594.00	679.00	566.00	633.00	505.00	556.00
	3	728.00	782.00	647.00	700.00	622.00	687.00
	4	653.00	751.00	579.00	672.00	570.00	682.00
	5	635.00	728.00	506.00	644.00	542.00	666.00
Modulus of Elasticity (MOE) (1000kg/cm^2)	1	128.00	154.00	141.00	175.00	165.00	238.00
	2	128.00	156.00	147.00	178.00	226.00	239.00
	3	178.00	188.00	191.00	228.00	237.00	281.00
	4	129.00	166.00	172.00	205.00	284.00	280.00
	5	139.00	169.00	149.00	185.00	220.00	275.00
Compressive Strength Value (kg/cm^2)	1	384.00	380.00	393.00	430.00	434.00	489.00
	2	366.00	456.00	414.00	495.00	430.00	522.00
	3	370.00	464.00	421.00	479.00	442.00	551.00
	4	391.00	575.00	419.00	611.00	460.00	647.00
	5	363.00	468.00	415.00	517.00	473.00	525.00

influencing the strength properties.

8.2 Some Uses and Socio-economy

Melocanna baccifera occurs mainly in the uplands (hills) that are inhabited mostly by tribal people. It, therefore provides direct benefits to them in creation of livelihood, food (edible shoots) and shelter. Further various benefits have been flowing from the species to the indigenous hill people in generating employment from harvesting the bamboos, their transportation to urban market depots and utilizing in local housing, making handicrafts and agarbatti sticks, mats, baskets, agricultural implements, etc. It is much used as a material for fences, bamboo mats, baskets, flat forms on the bridges, a great variety of agricultural implements, and poles for navigation and other small utility items in day to day usage especially by the tribal people. The State governments also earn revenue by selling the raw bamboo to Pulp and Paper Industries. Both the uplanders and lowlanders have been getting socio-economic benefits from the industrial processing and trading of *muli* bamboo in the region.

Housing: Although thin-walled, *M. baccifera* is strong and naturally durable, and has an inherent advantage of being straight with only slight knots. Therefore this bamboo is much used for roofing, thatching and matting in house construction in north east India, Bangladesh and Myanmar. It has been estimated that 80 per cent rural houses in this vast tract are made of bamboo, and about 90 per cent of house construction is with *muli* culms. In this context, Gamble (1896) described this species as "one of the most universally used for building purposes." He further reports "Major Lewis says that white ants (termites) do not touch it."

To the hill people, bamboo is a traditional building material, in which *muli* bamboo contributes more than 80 per cent (Figure 33a, b). Due to the presence of

Figure 33 (a)

Some uses of *M. baccifera* bamboo in construction of a houses

Figure 33 (b)

Basket

silica *muli* is not preferred by insects and thereby inhibits diseases, it makes strong, hygienic houses; suitable for hilly regions. Most of the agricultural implements, domestic utensils, mats, storage baskets, hats, homestead garden fencing, garden stakes and supports are only a few of the important uses of *muli* bamboo in rural economy and life style and also in some parts of urban areas. About 82.4 per cent

Figure 33 (c)

Mats

Figure 33 (d)

Food grain containers

houses in Tripura are "kuccha houses", i.e, made of bamboos (Tripura Bamboo Mission, INBAR Mission Report 2002). Out of total extracted quantity of bamboos, major portion (73.09 percent) is being used for construction of local houses, barricading and fencing in Tripura State (Source: State Bamboo Policy 2000, Forest Department, Govt. of Tripura.).

Similarly in other states like Assam, Mizoram, Meghalaya - Garohills, Manipur-Tamenglong and in CHT *muli* bamboo has been used as a major house construction bamboo. In Kolasib, Mizoram, limited bamboo based houses are used by the nomadic Reang tribes as temporary shelter.

The houses are built entirely of bamboo, raised from 1.5 - 2 m from the ground by means of bamboo or some times wooden supports. The floor and walls are made of bamboo split and flattened out and then woven together. The frame-work of the roof is also made from bamboo, with cross-pieces of wood, the whole securely fastened together with strips of rattan cane or by *doga* bamboo (young bamboo slivers). Sometimes the roof is thatched with local wild palm leaves called "Krook pata", cane leaves or grass. The first named material makes the most lasting roof. If there is any roof leak, the remedy is simple. A piece of bamboo is split in two, the knots removed, making a clear and smooth channel; this is then fastened under the leak with the end projecting through the nearest side wall; the water runs down the bamboo-channel and get outside the house. The space between the ground and the floor of the house is usually used for shelter to the domestic animals–pig, cow and goat. They usually store fire woods and bamboos in the space. The raised houses also protect the inhabitant from the ferocious wild animals. There is no value addition, as bamboos have been used in raw state, without any preservative treatment or processing and finishing. Such a large quantity of bamboo resource used in housing can be gainfully processed and produced into quality roofing and structural materials for construction. Large coarse bamboo matting is made from flattened bamboo boards and used as prefabricated walls and roofs, particularly in the bamboo frame Assam type houses in Assam, Tripura and Sylhet. Small labour intensive cottage industries make this type of matting and two or three such industries are located at Badarpur, Assam on the banks of the Barak River. When the culms are split in half and the nodes are removed, they are used as structure of fence. At the cottage industry level, a number of people employed by contractor convert the culms to flattened board. Some trader from Kolkatta buy in smaller quantities for varied purposes such as bamboo mats, kite sticks, some sorts of fencing.

Although urban Khasis give more emphasis on the modern technologies and synthetic building materials, yet bamboo houses are still a common sight in rural Khasi and Jaintia Hills. Bamboo, a naturally pre-finished material is still the favoured material from which the traditional rural houses are built. Even today, the house of the *Syiem* (The King) in Smit, is made of bamboo with thatched roof. Split and flattened culms are used for flooring and for wall panelling. Bamboo's intrinsic strength with silica and stability make it ideal for flooring.

Matting: The *muli* bamboo has great demand in cottage industries especially in making of mats.The bamboo poles are split into slats for weaving into mats (Figure 33c). They are easy and cheap to make and can last long provided some preservative is applied and proper maintenance is taken care of. The bamboo is brought out of the river and each culm is split in half along the length after the external nodal rings are cut off. The half culm is then flattened by hitting it along the length, particularly at the nodes. These are stacked and stored separately.

The slivers are also commonly used to make food grain containers (Figure 33d) in Bengal and Assam. The same indigenous application of bamboo is also carried for furniture, fences, cages, mats, farming implements, and blinds (Figure 34a).

Coarse mats made of split bamboo skins (by vertically splitting the bamboo thickness), woven in a variety of designs, are also used to cover wall gaps and are supported by 6 x 2 cm wooden battens which are placed on both sides and tied with bamboo skins. Mats made with skins from the outside of the bamboo are generally used for the exterior wall after applying a coat of coal tar on the outer surface for protection against rain.

Different types of mats and sheets of varying width and thickness are also made by interweaving strips. For house construction and for drying agricultural crops, mats used should be big and strong and hence wider and thicker strips are needed. Strips used for making sleeping mats and packing sheets should be smaller and thinner. As for weaving fancy articles such as pictorial curtains and screens, lady fans, vase or cup slipcovers, etc., only the outer part of culms is selected and then split into wirelike strips of amazing uniformity and fineness.

Basket making: The *Khasis* make different types of bamboo baskets (*Ki khoh*) which are used either as 'carrier' or as 'container'. The baskets, used for different purposes, are of different sizes and of varying shapes. But generally they all conform to the conical shape, broad and round at the top, narrowing gradually towards the bottom. The conical shape is definitely related to the topography of the region and also suitable from the technical point of view and ergonomic considerations. With loads in their baskets on their back, they can walk up and down the hills without any hassle and pressure on their body. They can climb up the hilly terrain bending forward and at the same time keeping both their hands free. Another feature is that it is very convenient to carry commodities and even potful of water. The 'conical shape' prevents water from accumulation and also allows any fallen water to trickle down slowly and gradually. These are carried on the back, suspended by a head cane strap. The *Khasis* use the baskets for carrying loads, for marketing, and for other purposes. *Khoh wanly* with wide interstices is usually used for carrying scroll of betel leaves. A special kind of basket – *Khoh trop* woven out of bamboo has a cover to protect the contents from the rain. This has a special utility in the long journey. Oranges are also carried in these baskets. *Khoh kwai*, the large cylindrical bamboo baskets are used for keeping areca nuts in the curing ponds. *Khoh kit briew*, a conical structure with a seat provided is used for carrying sick person or traveller. It looks like an enfolded chair with legs, foot rest and a cover on its top.

Artistic baskets known as *meghum khoks* are made in the Garo Hills, and are used by tribals to store valuable items including clothes. It is important to note that mats are often purchased by the outside traders from the Garo cane and bamboo workers. The trade of handicrafts from different states of northeast Indian region to different places is through the middlemen and agents. These two sources of marketing technique constitute about 62.04 per cent and 23.41 per cent respectively. The handicrafts are also sold directly in the markets and these constitute around 11.39 per cent while through the Government agencies it is only 3.61 per cent (Khaund 1984).

The internodes are also used as container by the local people for carrying the material, like molasses, curd, etc. from one place to other (Figure 34b).

Betel leaf cultivation: The demand of *muli* bamboo is very high among the cultivator of betel leaves in the Bagafa area of southern Tripura (Figure 34c), Assam and across the border to Bangladesh. Some local traders provide money in advance to the local poor people to collect bamboo from the Tekka Tulsi RF at a rate of government royalty of 10 paise, whereas the traders get Rs.1.50 per *muli* bamboo pole (Ramani Tripura 2005). Thus, for long past the villagers were being exploited by some wily traders. Recently, during 2004, a Bamboo Collection and Trade Centres have been established and managed by a Self Help Group of beneficiaries under JFMC named Sib Shankar SHG. The Tripura Forest Department took a pro-active role here and this SHG was given a Forest Trade Licence to carry out the trade.

People in the hills construct bamboo platforms and supports for cultivating the vegetables like cucurbit *Momordica cochinchinensis* (Bangla name: *Kakrol*) beans, and also paan leaves (*Piper betel*) (Figure 34 c-d).

Figure 34 (a)

Some uses of *M. baccifera* bamboo in construction of fencing

Figure 34 (b)

Internode cylinder uesd as container

Pulp and Paper: Muli bamboo is one of the major raw materials for pulp and paper and rayon mills in north east India, Sylhet and CHT (Bangladesh), and Myanmar. About eighty years ago Raitt (1929) documented the possibility of making pulp from *M.baccifera* and also enclosed a sample piece as an exhibit in The Indian Forest Records. The fibre characteristics, the pulp and paper making properties of the wood of *muli* bamboo are given in (Varmah and Bahadur 1980) Table 17.

Figure 34 (c)

Betel leaf cultivation

Figure 34 (d)

Supports for cultivating the cucurbit vegetable

Table 17: The fiber characteristics and properties of pulping and paper making of *M. baccifera* wood.

Fibre characteristics		Pulping properties		Paper making properties			
Fibre length (mm)	Fibre diameter (µm)	Lumen diameter (µm)	Alkali used (%)	Screened - pulp yield (%)	Breaking length (m)	Burst factor	Tear factor
2.78	15.60	3.55	25	43.8	5480	40.0	210.7

Oye and Mizuno (1967) applied a prehydrolysis sulfate process to *M. baccifera* and produced quality rayon-grade pulp with á-cellulose 95.0 per cent, â-cellose 4.0 per cent, pentosan 3.0 per cent, extracts 0.03 per cent, ash 0.068 per cent, CaO+ MgO, 0.24 per cent, with brightness 91.

About 9 per cent of total bamboo extracted in Tripura (about 16.51 million number; Source: State Bamboo Policy 2000, Forest Department, Govt. of Tripura) is sent to the paper mills situated mostly in Assam. It has also been estimated that each year, about 1.2 million tons of bamboo is smuggled across the international border as raw material in paper mills (Tripura Bambo Development, INBAR Mission Report 2003). So, annually in total about 17.72 million (16.51 + 1.2 million) number of bamboo are going out from Tripura only to feed paper mills. In Mizoram, the bamboo usage from Kolasib district is mostly for Cachar Paper Mills. The single largest user of this bamboo resource in the Barak valley is the Cachar Paper mill, a unit of M/S Hindustan Paper Corporation Ltd., Govt. of India undertaking. The unit is located at Panchgram in the Hailakandi district, and its raw materials capacity is 2,50,000 MT AD. About 50 and 15 million culms are being used annually for the production of pulp and rayon respectively in Bangladesh and mostly coming from CHT and Sylhet forests (Banik 1992).

However, bamboos solely used for pulp and paper are not profitable, as the mills generally pay a low royalty, which is even lower than the cost of the other value added products like, making mats, mat board, mat moulded articles, agarbatti sticks, some fine handicrafts and novelty items, etc.

Edible young shoots: In the hilly areas of northeast (Tripura, Mizoram, Assam, Tamenglong, Garo hills of Meghalaya) India, Chittagong Hill Tract and Arakan of Myanmar specially the tribal people

Table 18 : Measurement of tender edible shoots of *Melocanna baccifera*

Basal dia-meter (cm)	Fresh weight %		Edible portion (meat)			
	Sheath	Edible part	Taste	Flavour	Colour	Texture
4.7	44.2	55.8	S.Bt - Sw	Sw - As	Cw	Cr - Tn

Note: Taste and Flavour: S = Slight, Bt = Bitter, Sw = Sweet, As = Astringency; Colour: Cw = Creamy white.; Texture: Tn = Tender, Cr = Crisp.

collect *muli* shoots from the natural forests and have been using them as one of the major food items during rainy season. It is estimated that 708MT of bamboo shoots are annually being extracted for local consumption from the forests and 68 MT from private land in Tripura State, of which *muli* constitute about 80-85 per cent. In the past edible bamboo shoots extraction for market sale was spread over only about 3-4 months, but now people continue to harvest for 6-7 months due to increasing market demand and price.

The shoots of *Melocanna baccifera* are yellowish green to yellowish brown, sheath margin and top pinkish, ligule horse-shoe shaped, blades flagellate and glabrous; and somewhat slightly bitter to sweet in taste and pleasant flavour in raw state (Banik 1997c). The weights of sheath cover and edible portions of *muli* shoot along with other edible characters are described in Table 18.

It is observed that a *muli* bamboo shoot usually contains 85-95 per cent water in respect of its total weight. Fairly acceptable taste and easy availability of shoots of *M. baccifera* made the species most common bamboo vegetable for the tribal people of north-east and CHT. Moreover, the smoothness or fewer amounts of hair on the sheaths of this species is an advantage, since the varieties with hairs are difficult to handle. The hair often tend to stick in the fingers as the sheaths are removed from the shoots. It appears that in *M. baccifera* two types of clumps exist in nature judged on the basis of emerging shoot characters. One type shoots possess a yellowish culm-sheath and are usually preferred as edible shoots. In the other, the sheaths are comparatively deep brown and not usually favoured as food due to their bitter and astringent taste (Banik 1994b; Figure 27). With two changes of water in cooking, the unpleasant taste is practically dispelled, and ordinary seasoning with salt (2 per cent of solution) and butter made the bamboo agreeably palatable.

During rainy season, shoot emergence time, the shoots of *muli* bamboo are often sold in both temporary and permanent vegetable markets. Local tribal people have been selling freshly collected *muli* bamboo shoots in the village market. Recent (2004-08) large scale death of *Melocanna* vegetation due to gregarious flowering has created an acute shortage of supply of the edible bamboo shoots. While the author was traveling to North East in 2008 many tribal people in Tripura, and Garohills lamented and expressed their agony of scarcity of bamboo shoots saying " what we will eat during present rainy season".

In the beginning of the shoot production season the price of shoots per kg was found to be Rs.15-20. During on-season of the production the price falls to Rs.8-12 per kg at Agartala town market and at the end of the season price rises even to Rs.20-25 per kg. During the fresh shoot harvest period from June-August, shoot base are kept dry for 3-7 days and then covered tightly with soil to avoid possible micro-organism infection. After removing the sheaths the inner tender portion or meat of the shoots is thoroughly washed in water and then cut into pieces. The pieces are usually consumed as vegetable ingredients in curry or soup by mixing with fish or meat, and also as pickle. Shoots are also sliced and dried for preserving them. These dried shoots are eaten in off-season. Occasionally people preserve them for

Figure 35

Culm segments of *rua muli/nali* are stacked at road (NH-44) side for marketing

some time wrapped with banana leaves in earth-pits until they become soft and tasty. Modern processing and packaging technologies have developed new dimension and markets for bamboo shoots.

Umbrella handle: The small, short internode and narrow diameter (1-2 cm at mid culm zone) culms with comparatively thicker wall (locally known as *rua/wai muli* in Tripura and *tengra muli/nali/bazali* in Patharia and Sylhet forest) have high demand for making handles in umbrellas and bags. These are collected by the local people, usually chopped into 100-110cm long pieces, and exported to Kolkata and other parts of the country (Figure 35).

As musical instrument: Bamboo musical instruments especially the flutes are known to almost every tribes. Flutes, the musical blown instruments, are usually made by one internode. *Mro* prople call the bamboo flute as *Plu*. In Marma language this type of flute is known as *"Wa-pre"*. Bamboo dance is popular amongst *Lushai / Mizo* tribe. A number of similar size 1.5-2.0 m long bamboo stems of *M. baccifera* or *D. longispathus* are used for dancing purpose.

Pot plant sticks: About 30 cm long and 4-5 mm in diameter bamboo sticks are sold in bundles at different local markets in the hills of CHT. One bundle has 500 sticks and price is Rs.25-40 each. Monthly 10 million pieces are sold in the local market and purchased by some Bangalee traders and exported to the European countries. One person can make 6 bundles per day. About 500-600 families are economically dependent on the bamboo stick business. It is learnt that the sticks are used for supporting the pot plants abroad. The bamboo sticks are usually made from *M. baccifera* bamboo.

Agarbatti sticks (*Incense Sticks*): *Agarbatti* is a perfume stick used in houses, temples, mosques, churches, graveyards and other public places as air freshener and / or mosquito repellent. The demand for *agarbatti* is increasing everyday both in domestic and export market. The major raw materials used in *agarbatti* enterprise are bamboo (commonly, *Melocanna baccifera, Bambusa vulgaris, B.balcooa,* etc.), wood charcoal and *Jiggat*. The *Jiggat* is adhesive like substance made from powdered bark of a tree, commonly known as *Mandhai / Chang Pichaala*) [*Litsea glutinosa (Lour.) C.B. Rob.*]. All these materials are abundantly found in Tripura and Assam. One pole of *muli* bamboo can yield 1.0-1.3 kg incense sticks. At present there is scarcity of bamboo due to large scale mortality of *muli* bamboo consequent upon recent (2003-08) gregarious flowering. As a result, people are mostly using *B. tulda* for producing incense sticks.

Charcoal is also produced by burning unutilised bamboo / bamboo waste. The charcoal is grinded to powder and like wise the bark of *Jigat* plant is also made into powder form (trade name *Jiggat* powder). The *jiggat* powder and charcoal powder is mixed and a paste (*doubh*) is made by adding water to it. Finally, this paste is hand rolled around the bamboo sticks and subsequently dried-up under sun. This semi-finished product is called non-scented raw *agarbatti*. Then the sticks are dipped it in a mixture of oil and perfume for adding the desired fragrance (Figure 36a). Finished products are then packed and marketed.

Presently the national market for *agarbatti* industry is almost Rs.1000 crores. Interestingly, 90 per cent of the industry's bamboo sticks requirement is met from Tripura (Dutta 2006). On an average around 100 truck loads of raw bamboo sticks are supplied from Tripura to various destinations of India (Karnataka, Gujarat, Andhra Pradesh, Bihar and West Bengal) annually (Figure 36b). On analysis, it is found that the raw bamboo sticks constitute one third of the total weight of the *agarbatti* stick.

In Tripura, production of *agarbatti* sticks is the most important traditional small

Table 19: Different grades of incense sticks made of *M. baccifera* bamboo

Grade qualities	Specification	Nos. per Kg	Cost(Rs.)/Kg.*
SP = Special	Thin, clean & light	8000 & above	6.50
SM = Super Medium	Slightly thicker than SP	6500-7000	5.75
FM = Fine Medium	Slightly thicker than SM	5000-6000	4.75
MD = Medium	Slightly thicker than FM	4000-4500	4.75

Length of sticks = 8-9 inch, actually found 7.5 inch, Sticks made of *Muli* bamboo.
*prices are of year 2002

Figure 36 (a)

Melocanna baccifera: *Agarbatti sticks* (Incense Sticks) making

Figure 36 (b)

Truck loads of Raw Bamboo Sticks are supplied from Tripura and transported to various destinations of India

scale cottage industrial business in the state involving several thousand rural people. "*Agarbatti* villages" in Tripura are: (a) in north: Kanchanpur, Radhagar, Sripur, Rajkandi (Ganganagar), Nepal tilla, Manu, Chamanu; (b) in west Melaghar, Bishalgarh, Udaypur. Different grade qualities of *agarbatti* sticks are available in the trade. The *agarbatti* sticks are usually 20-23 cm long and 1.5-2.7 mm in diameter (Table 19).

Tripura has two *Agarbatti* Trade Centres; one at Kumarghat and other at Nalchar.

Except the stick making, there has been

Raw Bamboo sticks: a. Cost of one truckload (9MT) : Rs.50000.00 assuming cost of 1 kg Raw stick Rs.5.50 in 2009 it is Rs. 20 due to the scarcity of *muli* bamboo (gregarious flowering).	Since *agarbatti* stick constitute one third of the total weight of *Agarbatti*, so, from one truckload i.e, 9 ton of raw bamboo stick, 27 ton of non-scented raw agarbatti can be produced. Cost of 1 Kg Raw *Agarbatti* Rs.22.00+4% CST: Rs.0.88 The total costs= Rs.22.88
Revenue Earning of Government: b. Purchase tax- Rs.1300.00 c. Forest Royalty Rs.3000.00 d. (b+c)=Rs.4300.00	Revenue Earning of Government: From one Kg = Rs.0.88 From 27000 kg = Rs.23760.00 + (Purchase Tax Forest Royalty) Rs.4300 Total Revenue: Rs.28060.00

(Source: Dutta 2006)

hardly any activity in the field of manufacturing of non-scented raw *agarbatti* or finished perfumed *agarbatti* in Tripura, which could have brought more revenue to the government and more income generation in the rural sector especially among unskilled and unorganized sector through value addition. A comparative analysis vis-a-vis revenue generation by value -addition to raw bamboo *agarbatti* sticks is shown below:

A Small Scale Industries (SSI) unit based at Kailashar in North Tripura viz, M/s Trideep Dhupbati Industries, has undertaken the job of manufacturing non-scented raw *agarbatti* sticks by employing women artisans from the nearby villages. Presently the said enterprise is providing employment to around 500 women artisans in those villages. Of late, Tripura Bamboo and Cane Development Center (TRIBAC) has been imparting necessary skill development training to the women folks in various villages of West Tripura. TRIBAC is presently marketing three branded finished *agarbatti*-named as *Neermahal, Rangamati* and *Longtari* with different fragrances. The marketing has been gradually developed through SHGs and unemployed youth. Thus *Melocanna baccifera* and some other bamboo species are instrumental in providing employment to a substantial section of rural people, particularly women, mainly to Tripura and Assam in manufacturing *agarbatti* sticks.

The main constrains are availability of *Jigat* bark for adhesive preparation and adequate funds support to the communities.

Power generation through bamboo gasification: In a gasification process biomass (woods, leaves twigs etc.) is burnt at very high temperature, between 700^{0}C and 900^{0}C in presence of air (gas). Bamboo has an advantage over other biomass in as much as it has high calorific or heating value, low ash content and alkali index (Pandey 2008). Tamenglong Bamboo and Cane Development Centre (TAMBAC) at Tamenglong, Manipur has tested the suitability of bamboo biomass for electricity generation. To ascertain the power yield, 500 kg of *Melocanna baccifera* was sent to Netpro at the Indian Institute of Science (IISc), Bangalore. The tests and analysis conducted by Netpro have shown that 1.2 kg of bamboo biomass can generate 1 KW of electricity. The National Mission on Bamboo Applications (NMBA) has demonstrated commercial viability of bamboo based gasification system through units of HPC Jagi Road and Silchar (1MWe Thermal), Agartala (4 units of 25 KW) Kolasib (80 KW), Arunachal (25 kw), Madhubani (25 KW). In most of the places *muli* bamboo biomass has been used in maximum amount.

Charcoal Production: *Muli* bamboo, being a highly renewable biomass with a maturity cycle of 3-4 years, has excellent potential for charcoal production to meet rural energy needs for heating and cooking, as industrial fuel, and to make high value added products like activated carbon. Presently huge amount of culms are available due to recent (2004-2008) large scale death of *muli* bamboo clumps as a result of gregarious flowering in northeast India. These dead bamboos are comparatively dry and suitable for producing charcoal. As charcoal is a biomass based product, bamboo with 3-4 years maturity, when it attains maximum biomass, should be used for charcoal production. To get maximum yield in charcoal production, moisture content of bamboo should be around 20-25 per cent, accordingly freshly cut bamboo should be stored for 15-20 days to lower down the moisture content. The activated carbon prepared from various bamboo samples was analyzed for surface area, pore volume etc. (Table 20); and show the comparative results of two bamboo species which are capable of giving high quality activated carbon.

Bamboo culms should be sized to about 2.5 m and stacked horizontally in the kiln from the door at the bottom. All available lops and tops of the bamboo plants can be used for charcoal production. Moisture content in waste bamboo is also lowered to a large extent during processing and it can directly be used for charcoal production without waiting for further drying. All bamboo-processing units generate waste to the extent of more than 50% of bamboo used in the processing. The door should be closed with bricks and mud after loading of feed. The feed is then fired from the top opening. The openings in the wall of the kiln should be kept open during firing to create a flow of light air. Once ignition starts, these openings are regulated (closed/opened) to create and maintain a temperature of 400–500^{0}C so that the product is uniformly carbonized and the yield is optimised. A temperature below 350^{0}C would give unconverted product and above 500^{0}C the product would be completely burnt to ash. The carbonization time is between 2-3 days. At the end of three days, all air inlets are closed and the product is allowed to cool for about 2 days. Care should be taken to prevent entry of air

Table 20: Properties of various activated carbons analyzed by BET (Burnauer, Emmett, and Teller) apparatus.

Sr. No.	Parameters	Standard activated carbon. (Activated Carbon comp.)	Assam bamboo samples		
			Melocanna baccifera	*Bambusa tulda*	Not Specified
1.	Surface area (m^2/g)	1100	1220	1350	1280
2.	Pore volume (cc/g)	0.73	0.4995	0.9614	0.5057
3.	Avg.Pore diameter (A)	-	16.5278	16.6322	16.19
4.	Bulk density (gm/cc)	0.48	0.213	0.237	0.28
5.	Volatile matter	-	21.3	21.3	21.3
6.	Ash content	3.00	3.38	3.38	3.38
7.	Iodine No. (ASTM _4607)	900-1100	950-1050	950-1100	950-1100

during this time as otherwise the charcoal will catch fire. The cycle time is usually 5-7 days. Apart from being used as a solid fuel by hotels, *dhabas* (local low budget eateries), *dhobis* (washerman) and for cooking in rural areas and barbequing in elite homes. It also finds use in space heating, manufacture of activated carbon and in forging and metal works as fuel. Depending upon the properties and availability, the price of charcoal varies from Rs.5 – Rs.12 per kg.

Medicinal use: '*Tabashir*', also known as banslochan, occurs as a siliceous deposit in the lacuna of the culm of *Melocanna baccifera*, *Bambusa bambos* and *Dendrocalamus* spp. It appears as loose lumps of porous silica, lying on top of the diaphragm inside the internode. First a thick liqiuid is formed and then it becomes solid. *Tabashir* may be chalky or transparent, off white or bluish-white in colour. It has been used for centuries in traditional *Ayurvedic* medicine. It is thought to clear away the heat, eliminate phlegm and reduce fever. It is used as a cooling tonic, to draw poison out of wounds and as an aphrodisiac. Because of its porous structure *tabashir* absorbs large quantities of fluid and adheres strongly to the tongue with a severe taste (Jones et al 1966, Shor 1992). It also has interesting technical properties as a catalyst. It is highly prized by collectors, who shake the standing culms for the tell-tale rattling noise that reveals tabashir's presence. The reason for the origin of such enormous amount of silica in the lacuna remains obscure.

Paste prepared from the tip of very young culm of *muli* bamboo is applied to a wound from animal bite. Moreover if, there is a deep cut/injury, the green *muli* bamboo skin is lightly scurf and put on the injured spot and covered with a bandage. Patient is asked to drink water sufficiently, as it helps in stopping the bleeding and joining the cut without any stitch. The *Tipra* people call it *yeaha thia uchua.*

Basic Consideration in Handling and Transportation of Seeds and Seedling of *Muli* Bamboo *(Melocanna baccifera)*

A. Seed Collection Time

- Seeds collected in Mid April to Mid June are healthy, comparatively bigger in size and give better percentage of germination (70-85 %), so this is the best time for collection.
- One can also collect during July-August, and may be in September but the success in germination is less (20-40%).

B. Characterization of good seeds

- Seed should be green colour, fresh looking, surface should be smooth, and not shrinked.
- Slightly black colour seeds are not good and germinate poorly
- Collect average size seeds (length 6.9±0.3 cm, diameter 4.1±0.2 cm, weight 55.3±5.46 g), one kg good quality seed contains about 15 to 40 number of seeds.
- Small (length 3-6 cm, diameter 2-4cm, weight 5-10 g) and too big seeds (80g and above) do not germinate well, only 5 to 20 per cent.
- Seed should not be damaged or partly eaten.

C. How to Collect Seed (Collection Procedure)

- The seeds need to be collected by plucking directly from the plant or by shaking the culms gently so that the mature seeds fall on the ground.

- However, one can collect the seeds fallen on the forest floor; but collect only fresh one. Do not sweep and collect all.
- As the seeds of *muli* are big and not covered with glumes, they can be separated easily from debris and unwanted materials.
- The bag containing seeds should be kept open and in shade to prevent heat build up inside the bag which affects the viability of seeds, as many seeds start germinating at a time in the storage
- One should not wait to receive at a time all the seeds collected in different time and batches.
- Batch-by-batch fresh *muli* seeds should be collected and brought to the nursery.
- If seed collection continues for more than a day, temporary storage facilities should be there in the field prior to return to the station.

D. Seed germination

- The freshly collected ripen "seeds" germinate immediately
- While bringing to the Nursery, some seeds may start germinating.
- After arriving in Nursery, Place them carefully immediately on the floor in the nursery shed under partial shade (50 percent light only) and well-ventilated condition.
- The preferable seed germinating medium in the nursery is sand or sandy loam soil, which should be moist but not waterlogged.
- The mature seeds germinate well (80 - 85 per cent) generally better under partial shade condition
- The germination is very low (30 - 35 per cent) under direct sunlight.
- The seeds in the collected lot will continue to germinate for 35 days from the date of collection, but with higher rate in the first 10 to 15 days.

- Nursery floor or the seedbeds have to be visited and observed regularly, germinated seeds need to be identified and carefully taken out from the floor or beds batch-by-batch.

E. Transplanting of germinating seeds in to poly bags for raising seedlings

- Every afternoon the germinating seeds are to be collected from the Nursery floor or the seedbeds and transferred with care(so that tender and soft plumule of in the germinating seeds are not damaged) to polythene bags filled with a soil mixture (sandy loam soil 3 part and FYM 1 part).
- Initially the germinating seeds (seedlings) in the polythene bags need to be maintained for 1 month by placing under partial shade (50 percent shade net) and humid conditions, after that gradually shift them carefully in the open nursery.

F. Seed viability and storage

- *Muli* Seed life is 35 days, can be stored placing in a bag having slightly moist sand (need aeration, not desiccation), storing the bag in air conditioned room for 65-70 days. *Muli* seeds are sensitive to desiccation (exhibit recalcitrant),
- Storage conditions also affect seed viability as seeds stored at a low temperature (at 15-17^{0}C) have higher germination ability than those stored at a normal room temperature.

G. Transportation of seeds

Immediately after collection of seeds at Nursery, get ready to transport the seeds to other places located far away.

- The plumule height of the germinated seeds should not be more than 3cm, if it is long it will break during handling and transportation.
- Select newly germinated seeds along with fresh seeds which are likely to germinate.

- On a Truck/Van floor take big Gunny bag, place a layer (say, 5cm thick) of slightly moist sand at the bottom, then on it place selected seeds; place another layer of sand and seeds on it and repeat this till fill the bag, close the bag loosely keeping a gap above the top layer. Do all this operation on the truck to avoid carrying the loaded bag from the nursery floor to truck
- About 700- 1000 seeds may be carried in one such bag, and 35-40 bags may be transported in one consignment depending on the size of the truck.
- Move the truck, mostly in night, and reach within 24 hr to the destination, may travel for 7-10 days and in that case sand layer between the seeds should be 10cm.
- After reaching the destination carefully unload the bag from the truck and open the bags by tearing the stitch from tip to the bottom on the side,
- Now the bag will open in two halves and all seeds with sand will fall automatically on the nursery floor.
- Take out/ separate the seeds carefully from the sand mass fallen on the ground.
- In the mean time the nurserymen at the received-end should be ready with the poly bag half filled soil mix (sandy loam soil 3 part and FYM 1 part).
- After separating the seeds from the sand get a dip in water and then place horizontally on the soil inside the poly bag. Cover the seeds and fill the upper part of polybag with soil mix.
- Unload and take out all seeds and accordingly place them in poly bags.
- Keep all the poly bags with seeds under partial Shed-Net condition of nursery.
- Maintain and take care by watering regularly.
- All the germinated seeds will produce seedlings and remaining good non-germinated seeds that were brought

mostly also (say70%) germinate and produce seedlings.

Advantage: Can carry many germinated seeds at a time with least possible damage.

Limitation: Needs careful handling of germinated seeds so that plumules on the seeds are not damaged.

H. Transportation of seedlings carrying in Poly bags

- If need to transport, better to do it when seedlings are short within 2 month of age.
- Load the poly bags with seedlings and place on the truck floor.
- If seedlings are tall, chop off the top above the 5th node; and seal the expose tips by cowdung or wax.

Advantage: Transported materials are all (100%) living planting material

Limitation: Can carry a limited number, say 600-800 seedling, in a truck in one assignment.

I. Transportation of bare rooted seedlings

- It is possible and has been done in some places, but need sincere effort and skill.
- When the seedlings are 4-6 months old they will have an underground rhizome system, at this stage seedling are to be taken out from poly bags, wash the soil by dipping and shaking in water. Also to minimize the height of the seedlings chop off the top above the 5th node; and seal the expose tips by cowdung or wax.
- Place thoroughly wet gunny bags or jute sheets/ canvas sheet on the truck floor, lay down the bare rooted seedlings (with chopped off tops) on it. Cover all these seedlings by wet gunny bags or jute sheets/ canvas sheet and place another layer of bare rooted seedlings on it and do it again. In this way 7-9 layers of seedlings may be carried.

- Nurserymen at the received-end should be ready with the poly bag one-third filled with soil mix (sandy loam soil 3 part and FYM 1 part).
- Quickly unload the seedlings, get a dip in water and then place upright in the poly bag, pour soil mix and fill up the polybags, water adequately but should not be water logged.
- Place the poly bag with seedlings under Shed-Net Nursery.

Advantage: Can carry maximum number of seedlings in one consignment

Limitation: All the procedural works mentioned above are to be done with the time in a short duration. Any delay in movement in the way or negligence will kill all the seedlings.

Appendix

APPENDIX-I: Available past and Present flowering records and estimated seeding cycle in *Melocanna baccifera*

Country *States / Provinces*	Flowering date (Calender year)	Estimated Flowering Cycle (years)	References
MYANMAR: *Arakan*	1863-1866 (Greg.),1900, 1902,1904-1905(Spor.)	30-35; 36-39 (1863,66-1900, 02)	Kurz (1876), Brandis (1906), Troup(1921)
Arakan, Yoma	1910-1913 (Greg.)	44-47	
Prome, Henzada		(1863,66-1910,13)	Troup(1921)
Arakan	1915-1916 (Greg.) 1909-1916	44-52 (1863-1909, 16) 45-51(1864 -1909,16)	Troup (1921) Raitt (1929)
Arakan(some part)	upto 1928 not flowered	About 60 (1866-1928)	Raitt (1929)
Rakhine	1933		Htun (1999)
Chin Hills	1915-16, 1960	44-45 (1915,16-1960)	Htun (1999)
Locality not mentioned	1900 1957-1959 (Greg.)	About 60 (1900-1959)	McClure(1966)
All over country	upto 1998 not flowered	More than 41 (1957, 60–1998)	Htun (1999)
BANGLADESH: ***Chittagong (south)***	1864 (Greg.) 1901-1905 (Spor.) 1908-1912 (Greg.)	44-48 (1864 -1908, 1912)	Troup(1921)
	1952 (Spor.), 1958-1959 (Spor.)	51-54 (1901,05-1952, 59)	Hossain(1962)
	1957-1959 (Greg.) 1960-1961 (Greg.) 2002-2007 (Spor./Greg.)	48-52 (1908, 12-1960,61) 46 (1961-2007)	McClure(1966), Hasan(1973) Author observed
Cox's Bazar	1908-1912 (Greg.) 1959-1960 (Spor.) 1960-1961 (Greg.) 2001-05 (Spor./Greg.)	48-53 (1908,1912-61) 45 (1960, 61- 2004, 06)	Troup (1921), Hossain(1962) Hossain(1962) Author observed

Chittagong (north)	1863-1866 (Greg.) 1901-1905 (Spor.)	35-38 (1863, 66-1901, 05)	Kurz (1876), Gamble (1896), Brandis (1906)
Hathazari, Nazirhat Fatehabad	1988-1997 (Spor.)	28-32 (1960, 61-1988, 97)	Banik (1998)
Chittagong Hill Tracts (CHT)	1863-1866 (Greg.) 1927 (Spor.)	61 or (30x2) = (1866-1927)	Kurz (1876), Brandis(1899) Hossain(1962)
Rangamati	1930 (Greg.) 1935 (Spor.)	64 or (32x2) = (1866-1930)	Nath (1930), Hossain (1962)
Kassalong	1958-1959 (Spor.) 1959-1960 (Greg.)	31 (1927-1958) 30 (1930-1960)	Hossain (1962) Hasan (1973)
BANGLADESH: (continued) ***Chittagong Hill Tracts (CHT) north***	 1957-1958 (Spor.) 1958-1961(Greg.) 1998 (Spor./Greg.) 2005-2007 (Greg.)	 36 (1961-1998)	 Hossain (1962) Banik (2000) Author observed
Kamalchari, Hyanko Haludia, Fatikchari Naranhat, Shisak	1986-1997 (Spor.)	29-39 (1957, 58-1986, 97)	Banik (1989, 2000)
INDIA: *Tripura* (south) Bagafa- Sabrum (Border CHT north-Hyanko), Silachari Killa, Matabari	1911-1912 1958-1959 (Greg.) 1995-2003, 2002-07 (Greg.) 2007-08 (Greg.)	 35 (1959-1995) 43 (1959-2003)	 Sharma (2008) Banik (2004)
Mid-Tripura Agartala, Shekarkot Bogla khal, A D nagar Indranagar, Narshing Gar Tulakona, Anadanagar, Dukle, Jampui JalaKamalghat, Mohanpur	 2000-2005 (Spor./Greg) 2002- 2003 (Spor) 2004-07 (Greg.) 2005-07 (Greg.) 2006-08 (Greg.)	 40-47 (1959-2000, 03, 05, 07, 08)	 Banik (2004) Author observed
Khowai, Kalyanpur Teliamura, Nunachara	2003, 2006-07 (Greg.)	44 (1959-2003)	Author observed Banik (2004)

North-Tripura			
Ambasa, Kumarghat	2004-2006 (Spor./Greg.)	45 (1959-2004)	Banik (2004)
Kanchanbari,	2004-2006 (Spor./Greg.)		
Ratacherra Rajkandi,			
PecharthalSunaimuri,	2006-2008 (Greg.)		
Panisagar,		47 (1959-2006)	Author observed
Attaramura-Longtrai			
Assam	1863-1866 (Greg.)	27-29	Gamble (1896)
	1892-1893 (Spor.)	(1863, 66-1892, 93)	Brandis (1899)
Jorhat	2000-2001(Spor)		Tripathi (2002)
			Pathak (2002)
Lushai hills, Assam	1864 (Greg.)	25 (1864-1889)	Brandis (1906)
Garo and Khasi hills	1889 (Greg.)		Troup (1921)
	1900, 1902 (Spor.)		Parry (1931)
Garo hills,	1910-1912 (Greg.)	19-21 (1889-1910, 12)	Hossain (1962)
Cachar hill			
Lushai hills, Assam	1917-1919 (Spor.)	26 (1892, 93-1917,19)	Hossain (1962)
Meghalaya			
Garohills (south)	1917-1919 (Spor.)	88 or (44 yr x 2)	
	2004-2008 (Spor./Greg.)	(1919 - 2007)	Author observed
Cachar hills,	1952-1956 (Greg.)	40-44(1910,12-1952,56)	Gupta (1988)
Halflong	1967 (Spor.)		
Halflong	1988 (Greg.)	32-36 (1952,56-1988)	Gupta (1988)
Barak valley	1912, 1958 (Greg.)	46 (1958-1912)	Yadava (2002),
	1997, 2002(Spor.)	39, 44 (1958-1997, 2002)	Author observed
Surma valley	1958-1961 (Greg.)	48-49	Hadfield (1958),
		(1910, 12-1958,61)	Nath(1959,1960, 62)
Lushai hills	1911-1912 (Greg.)	46-47(1864 -1911, 12)	Troup(1921),
(presently Mizoram)	1958 (Greg.)	46-47 (1911, 12-1958)	Yadava (2002)
Mizo hills, *Cachar hills*	1815	42-46 (1815-1863, 66)	Lalnuntluanga et. al
Assam (Famine due to	1863-1866 (Greg.)	26-30 (1863, 66-1892, 93)	(2003)
gregarious flowering	1892-1893 (Spor.)		Chatterjee (1960)
of *Muli* is called	1900-1902 (Spor.)		Troup(1921)
Mautam, and*Tam*	1910-1912 (Greg.)	47 (1863 - 1910, 12)	
means Famine)	1933 (Spor.)	31-33(1900,02-1933)	Chatterjee (1960)
	1959-1960 (Greg.)	48-50 (1910,12 -1960)	

Mizoram (*Mautam*) Kolasib Sabual, Mamit	1959-1960 (Greg.) 2001- 2004 (Spor.) 2005- 2008 (Greg.)	 45-49 (1959, 1960-2004, 08)	Chatterjee (1960) Author observed Anon.(2007), Author observed
Manipur Tamenglong (near Barak valley)	1967 (Spor./Greg.) 2003-07 (Spor./Greg.)	48-50 (1917-1967) 40-44 (1958, 67-2003, 07)	Nath (1968) Author observed
Dehra Dun: New Forest (Seeds introduced in 1892; reported by Gamble 1896)	1958- 1960 1991-1992	 31-34 (1958,60- 1991,92)	Gamble (1896), Vaid (1972), Sharma(1992)
West Bengal: *Siliguri* (Sebak, Kochbihar, Duras)	1960 2006-08	 46 (1960-2006)	Chatterjee (1960) Author observed
Calcutta Botanic garden (Introduced date not known)	1863-1866		Gamble (1896)
BANGLADESH: ***Sylhet***	1910-1912 (Greg.) 1957-1958 (Spor.) 1958-1959 (Greg.)	 46-47 (1910,12-1957, 59)	Troup (1921), Hossain (1962), Hasan (1973)
Sylhet: Dholaichara, Madhav CharaPutijuri (Border of Ambassa, *Tripura*)	1996 (Spor.), 1997 (Spor.), 2003–2008 (Spor./Greg.)	40-41 (1957-1996, 97)	Banik (1998, 2000) Author observed
Mymensingh: North Forest. Range Rasulpur (Border to south *Garohill, Meghalaya*)	1974 (Spor.) 1975 (Spor.)	63-64 (32x2) (1911, 12 of Garo hills 1974, 75)	Hasan (1973) Banik (1998b)

Note: Spor. = sporadic flowering; Greg. = gregarious flowering

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Glossary

A

Abaxial : The side facing of the plant *Syn*. Dorsal, opp. Ventral.

Acre : An area of land measuring 43560 square feet or 0.405 hectares.

Acuminate : Having long, slender, sharp point with concave sides, margin straight to convex.

Adaxial, adaxial surface : The side towards the axis, the surface of a leaf that faces the stem during the development, e.g. the upper side of the leaf.

Adventitious roots : Roots arising at the nodes of rhizomes and culms and not from the initial (primordial) root.

Air-dry : Bamboo in a condition that has been dried through exposure to natural conditions to a level approximately in equilibrium with atmospheric conditions.

Air-dry Metric Tonne (AD MT) : This unit of weight is used for pulp pricing. At the time of manufacture each bale has a somewhat different moisture content, usually not exactly 10 per cent, 1 Air Dry tonne of pulp contains exactly 900 kg of bone dry fibre and 100 kg of water, in other words it has a 10 per cent moisture content.

Alluvial soil : Soil, usually rich in minerals, deposited by water as in flood plains.

Anther : In a flower, the terminal part of a stamen in which the pollen grains are produced.

Anthesis : The period during which a flower is fully open and functional.

Apical dominance : In some plants, the lateral bud located in the axil of each leaf does not grow to form branches, especially at first; this condition is known as apical dominance.

Appressed organ : Closely or flatly pressed against the entire length of an organ part.

Arborescent : Tree like form

Auricle : Ear-shaped lobe or extension at the top of a sheath on each side; this extension can be enlarged towards the outer end. A pair of auricles is found on each culm sheath or leaf.

Axes : Plural of axis.

Axis : An imaginary central line around which organs are developed.

B

Bamboo brakes : Distinct pure stands of bamboos.

Basipetally : Progressing toward a base.

Blade : Especially a leaf of grass or the broad portion of a leaf as distinct from the petiole or the equivalent section at the top of a culm sheath.

Binomial : As the word "binomial" suggests, the name of a species is made by using two words: the genus and species.

Biomass : Total weight of the plant in a given area.

Bract : Modified leaf associated with a flower or inflorescence.

Branch : The limb arising from the culm; sub-branches are branches arising from the branches.

Branch complement : The set of branches that develop at any one culm node.

Branch sheath : The sheathing organs borne singly at each node of an aerial vegetative branch of any order, excluding the neck sheaths and the leaf sheaths.

Bristles : Stiff and erect hairs.

Bud : A vegetative or reproductive organ containing embryonic meristems in the earliest stage of development which later develop into flowers, stem or leaves and enclosed in protective specialized leaves termed bud scales.

B5 medium vitamins : The B5 medium established by Gamborg et al ; [Ref: Gamborg, O.L. et al., Exp. Cell Res., 50:151-158 (1968).]. The medium contains macro and micronutrient chemicals and vitamins. The amount (mg /L) of vitamin content (myo-Inositol, Nicotinic Acid, Pyridoxine-HCl, and Thiamine-HCl) in the B5 medium is higher by 2- 10 times than those in other common tissue culture medium.

C

Caespitose : Matted, Growing in tufts or small dense clumps, plants forming a cushion.

Canopy : Layer or multiple layers of branches and foliage at the top of a bamboo plant system.

Caryopsis : The fruit of a grass, in which the outer layer [testa] of the seed proper is fused to the ovary wall, a one seeded, dry, indehiscent fruit, the grain of fruit of grasses.

Cellulose : A polysaccharide compound of hundreds of cellulose units (composed of two glucose molecules combined in inverted structure) arranged in a chain like pattern; main compound of cell wall.

Cilia : Hairs along the edge.

Ciliate : Fringed with fine hairs.

Climber : A herbaceous or woody plant that climbs up trees or other support by twining round them or by holding on to them by tendrils, hooks, aerial roots or other attachments.

Clump : The whole bamboo plant, consisting of many culms grouped in a cluster, is called a clump.

Compressive strength : The ability of a material to resist a force that tends to crush.

Coriaceous : Of leathery texture.

Cortex : Outer part of a culm or rhizome, between the epidermis and the ground tissue.

Cross-veins : Short veins running across the leaf seen when looking through a leaf held up to the light.

Culm : Segmented aerial axis that emerges from the rhizome and forms the above ground stem. The stem or stalk of a grass plant, Most clearly identified as 'bamboo', it is the pole or stem that extends from the rhizome, growing vertically. The aerial axis of the bamboo plant, divided into nodes and internodes.

Culm internode : Part of the culm between two successive nodes.

Culm sheath : The modified tubular leaf in a bamboo culm, inserted at a node and covering part of the culm, it generally consists of a blade, a large sheath, ligule and two auricles. It is also called as *Culm Leaf*.

Cutting : A section or part of the plant that can be placed in soil or water to root.

Cytokinin : A class of plant growth substances (plant hormones) that promote cell division. They are primarily involved in cell growth.

D

Deciduous : Falling off of parts at a particular stage of growth (opposite of persistent); usually applied to structures (leaves, culm sheath, branches , etc.) that fall off rather quickly.

Dehiscence : Opening of anther.

Density of wood : Defined as its *mass* per unit *volume*. The symbol of density is *ñ* (the Greek letter rho).

Diffuse clump : Evenly spaced culms rather distant from each other.

Dormancy : Seeds or other organs in sleeping posture.

Durability : The natural ability of the material to be resistant against insect and fungal attack without any other measure.

E

Entire : Continuous and smooth in outline; usually describes the margin or edge of a relatively flat structure such as the leaf blade, ligule or auricle.

Erect : Standing upright.

Evergreen : Never entirely without green foliage, leaves persisting until a new set has appeared. Plants that do not shed all leaves at one time and hence appear green throughout the year.

Exotic : Not native to the area in question.

Explants : Small parts of the bamboo plant excised to become the source of tissue cultured material.

F

Farm Yard Manure (FYM) : Agro and animal waste and residues used to enrich soil.

Felted : Hair to interlace and cling to gether to make into felted.

Fertilizer : Organic or inorganic plant foods in either liquid or granular form, used to amend the soil in order to improve the quality or quantity of plant growth.

Fibre : Long cells with lignified walls, generally dead, providing mechanical support for the culm as fibre sheath or fibre bundle.

Fibrovascular bundles : A unit strand of the vascular system in stems and leaves of higher plants consisting essentially of xylem and phloem.

Filament : Slender stalk that supports the anther.

Fimbricate : Margins fringed, with long and coarse hair.

Flagellate : Whip-like

Floret : The unit of spikelet that consist of a single flower.

Flowering : A phenomenon by which a cluster of highly specialized leaves grows with the specific aim of participation in reproduction.

Foliage leaves : Leaves of woody bamboos with well-developed green blades and small sheaths produced in complements on culm branches genus (genera) taxonomic category; smallest natural group (groups) containing different species.

Fungi : Filamentous organisms that are devoid of chlorophyll and derive their food from organic matter.

G

Genus : Taxonomic category; smallest natural group (groups) containing different species, a group of similar species with the same generic name. *e.g. Bambusa*.

Genotype : The internally coded and inherited information carried by all organisms; this is used for building and maintaining a living creature

Glabrous : Smooth and without hairs as in the "skin" of a tomato or apple.

Globose : Spherical

Glume : Modified leaf or dry membranous bracts at the base of the grass spikelet or pseudospikelet or caryopsis (fruits) of bamboo.

Gregarious flowering : When all the culms in a clump and about 90 to 80 per cent clumps in a population flower at a time and subsequently die after seed setting, the phenomenon is called as gregarious flowering.

Ground Tissue : The tissue that forms the culm, consisting of parenchyma cells and vascular bundles.

Growth plasticity of clump : Increase and completion of clump growth as with the change of climate and age.

Gynoecium : Flower organ consist of ovary, style, and the stigma.

H

Habit : Characteristic appearance or pattern of growth of a plant.

Habitat : The natural range of distribution of a species. Natural environment of a plant or organism; the place where it is usually found.

Hectare : An area of land measuring 100 square metres or 2.47 acres.

Hotspot : The precise location of something; a spatially limited location; where everything is centralized. Commonly used for *in situ* conservation site of genotypes having enormous variability.

I

Internode : The section of a culm between two nodes.

Interseeding period : The gap period between two seeding incidences of a bamboo population.

Imbricate : With regularly arranged, overlapping edges, as fish scales.

Immature culm : A young culm in which the process of lignification is not yet complete.

Indehiscent : Remaining closed at

maturity, used in the context of fruits.

Indigenous : Native to a specified area or region; not introduced

Inflorescence : An aggregation of flowers.

Intercalary meristem : A meristem that is forming between regions of permanent or mature tissue. It is capable of cell division and allow for rapid growth and regrowth, located at the base of the internode in monocot stems.

Intercropping : Growing more than one crop at one time on a given area of land.

Internode : The part of the bamboo culm- or rhizome-that lies in between two successive nodes.

Irrigation : Artificial application of water to the soil for the benefit of growing crops.

No technical/ scientific words used starting with J

K

Kernel : Inner edible part of the fruit.

L

Lanceolate : Lance-shaped, wide at the base and tapering towards the apex, as in bamboo leaves.

Leaves scars : Marks left on a branch by the separation of leaves or leave fall.

Lemma : Bract-like sheath that subtends a grass flower.

Leptomorph rhizome : A termed coined especially to designate a slender, elongated type of rhizome and indeterminate growth.

Lignification : Formation of a polymer wall that gives strength to the culm.

Lignin : A complex amorphous polymer that contributes to the rigidity of cell walls.

Ligule : Membranous outgrowth on upper surface of culm sheath or leaf, at the junction of the sheath and blade; a projecting tongue where sheath and blade meet, visible at the ventral side of the culm sheath; may also be represented by a ridge or by a line of hairs; elongated , flat, strap-shaped.

Linear : Long and narrow, with the sides nearly parallel.

Loam : A soil composed of sand, silt and clay in such proportions that properties of the soil are not dominated by any one of them.

Lodicule : One of two or three minute hyaline scales of the base of stamens of most grasses; perianth segment (petal) with a scale-like structure.

M

Mat : Mats are woven from bamboo slivers of thickness ranging from 0.6 mm to 1.00 mm, done manually and dried in air to moisture around 15 %.

Mature : A stage the culm has reached after three years at which stage the cell wall development and lignification has nearly been completed.

Meristem : A body of tissue in which cell division and differentiation are active or potential.

Modulus of elasticity : is a measure of the *stiffness* of an *isotropic* (uniformity in all directions) elastic material (such as, wood, bamboo, etc.) can be calculated by dividing the *tensile stress* by the *tensile strain*; [is the ratio of *stress* (which has units of *pressure*) to *strain* (which is *dimensionless*)] Stress is a measure of the average force per unit area of a surface within a deformable body on which internal forces act. Strain or deformation is the change in the metric properties of a continuous body.

Modulus of Rupture : A measure of the ultimate load-carrying capacity of a wooden or bamboo beam; equal to the ratio of the bending moment at rupture to the section.

Monocarpic : Plants that flower [and fruit] once in their life time and then die.

Monopodial [Leptomorph] : A form of branching in which lateral branches usually originate at some distance from the apex of the main axis. In bamboos, a primary axis which continues its original line of growth from the same apical meristem to produce successive lateral branches. Where one axes is dominant and secondary axes are develop from it, having indeterminate branches.

Monopodial bamboo : Bamboos that thrive in temperate conditions, occasionally enduring below freezing temperatures; characterized by lengthy rhizomes with symmetrical internodes, more long than broad; individual culms tend to be free-standing and not clumped.

Morphology : The science of the form and structure of organisms.

Morphometric : Defined as the determination of relationships based on continuous characters, especially linear measurements; observable or measurable characteristics of plants. Taxonomic analysis using measurements of the form of organisms.

Mould : Type of fungi growing on the surface in damp conditions producing coloured spores.

Mucronate : Possessing a short, straight point.

Mulch : Any loose material or coarse organic matter such as leaves, placed over soil to control weeds and conserve moisture.

N

Native: Naturally occurring (not cultivated or introduced).

Neck : The constricted basal part, characteristic of all, or most, of the segmented vegetative axes (such as, rhizome) of a bamboo plant.

Node : A segmentation of the culm or rhizome, from where branches or roots originate. At the node, a diaphragm divides the culm, from a node the culm sheath, foliage leaves, branches or flowers arise.

Nodal line : The prominent line below the nodal region.

Nodal region : Region that bears roots, buds and branches, between the nodal line and supranodal ridge.

Nutrients : Elements necessary for growth and reproduction of plants; primary plant nutrients are nitrogen, phosphorus and potassium.

O

Oblique : Slanted; with unequal sides oblong much longer than broad, with nearly parallel sides.

Oblong : Refers to a shape which resembles a rectangle or ellipse (oval shaped).

Obovoid : Somewhat egg-shaped (the reverse of ovoid).

Obterete : Circular in cross section, tapering progressively from one end to the other, and smallest at the proximal end (for example, a rhizome neck).

Obtuse : Blunt or rounded at the tip, not pointed.

Offset : The rhizome along with the culm, used for vegetative propagation.

Orbicular : More or less circular in outline or shape.

Ovoid : Oval in outline.

P

Pachymorph : Type of rhizome system characterized by shortened, thick and fleshy stem, produced many branched clumps having closely packed culms.

Palea : Upper or inner of a pair bracts that subtends the floret panicle type of indeterminate branched inflorescence in which all the flowers are pedicellate (stalked) and borne by the secondary axis.

Panicle : A determinate inflorescence with branches of more than one order.

Parallel Venation : Numerous veins (bundles of vascular tissue) run through the blade of the leaf, serving to bring water and to collect the products of photosynthesis; in some plants, the larger veins all run the length of the blade with smaller veins branching off and interconnecting them and is called parallel venation.

Parenchyma : Brick-shaped, generally living cells, primarily for the storage and distribution of carbohydrates.

Perennial : A plant that lives for a number of years.

Pericarp : Wall of a fertilized ovary; sometimes differentiated into distinct layers such as exocarp, mesocarp and endocarp (outer, middle and inner carps).

Permeability : A measure of the ease of liquid penetration into bamboo tissue.

Persistent : Remaining attached even after the attainment of maturity, like the culm sheath in certain species of bamboos.

pH : A measure of the amount of lime (calcium) contained in the soil; pH values of 0 to 6.5 indicate acidic conditions, a pH value of 7.0 indicates neutral conditions and pH values greater then 7.0 indicate alkaline conditions.

Phenology/ Phenological : Studies of periodic biological phenomena, such as bud break, branch and leaf development, flowering, seeding, etc., with relation to climate, especially seasonal changes. Phenological records of the dates on which seasonal phenomena occur also provide important information on how climate change affects ecosystems over time.

Plantation : A plot of land on which intensive cultivation is practiced using scientific principles of management.

Plumule : The germinating embryo shoot of a seed or young shoot, or plumule, is said to be negatively geotropic, because it moves away from the soil.

Preservative : Toxic chemicals that prevent the development and/or growth of wood destroying organisms.

Prophylactic treatment : Prevention or short term protection against insect and fungal attack.

Prophyll : First leaf of a branch; a kind of sheath found at the first node of a branch or scale-like appendage.

Prophyllate bud : A bud with a prophyll.

Proximal : Basal; situated at or near the base of an axis or an organ;--designates loci of insertion, or structures, so situated.

Pruning : Removal of branches to divert nutrients for the growth of new culms and to prevent congestion.

Pseudospikelet : Spikelet - like inflorescence; unlike a true spikelet, it has bracts at its base each of which bears a prophyllate bud.

Pubescent : Covered with hairs (especially soft and short ones).

Pulp : Dry fibrous material prepared by chemically or mechanically separating fibres from bamboo, wood, fibre crops.

R

Raceme : Inflorescence with single order of branches.

Rachilla : A secondary axis of a spikelet in any gramincous plant.

Rachis : The primary axis of an inflorescence; --- its position is terminal to the peduncle.

Radicle : It is the first part of a seedling (a growing plant embryo) to emerge from the seed during the process of germination; that develops into a root. The radicle, which normally grows downward into the soil from a seed, is said to be positively geotropic.

Rayon : In the production of rayon, purified cellulose is chemically converted into a soluble compound to form soft filaments that are then converted or "regenerated" into almost pure cellulose. Because of the reconversion of the soluble compound to cellulose, rayon is referred to as a regenerated cellulose fiber. The rayon fibre is highly absorbent, soft and comfortable, and easy to dye.

Recurved : Bent or curved downward or backward.

Rhizome : An underground stem or portion of a stem with nodes and internodes, bearing scale leaves and usually rooting at the nodes.

Rhizome sheath : The husk like sheathing organ inserted at each node of a rhizome proper.

Rhizome Neck : Constricted portion of the rhizome which links the thicker portions.

Root primordium : Root in its initial stage of development.

Running bamboos : Monopodial bamboo; The culms are spaced out since they arise along the running rhizome such that the plant looks.

S

Scale leaf : Leaf-like sheathing organ for the protection of the rhizome.

Sclerenchyma tissues : Composed of cells (sclerenchyma cells) that have extremely hard, thick walls. Sclerenchyma is commonly described as a simple, dead, mechanical tissue.

Scutellum : A shield-shaped structure, such as the cotyledon, by which a grass embryo absorbs the endosperm.

Secateur : A specialized cutting tool.

Seral : A *seral* community (or sere) is an intermediate stage found in *ecological succession* in an ecosystem advancing towards its climax community. A *seral* community is the name given to each group of plants within the succession. Each of these stages can be referred to as a *seral* community.

Serrate : With a saw toothed edge or margin notched with tooth like projections.

Sheath : A sheathing organ, the basal part of which, the sheath proper, completely surrounds the vegetative axis on which it is borne.

Sheath scar : A mark left on a stem by a separation of a sheath.

Shoot : Young culm at an early stage of its development, before it elongates and turns woody.

Slivers : Strips of bamboo of thickness less than 1mm, which are used for weaving into mats.

Spacing : The distance between the bamboo plants put out in a plantation.

Species : Basic unit of classification of living things; consists of all individuals that are closely related such that they appear very similar and often interbreed to produce offspring.

Specific gravity : A measure of the amount of wood substance present in a sample.

Spike : A simple indeterminate in florescence with stalk less flowers along a single axis; the youngest are at its tip while the older ones are towards the base.

Spikelet : A secondary spike.

Stacking : Arranging bamboo culms in a pile.

Stem : The principal axis of a plant from which buds and shoots are developed.

Stigma : The uppermost sticky part of the female reproductive organ of the plant; receives the pollen grains and aids in reproduction.

Storey : A horizontal stratum or layer of canopy in a plant community.

Style : Narrow prolongation of the ovary which terminates in a branched or unbranched stigma.

Subtend : Extending under

Swollen : Enlarged, bloated

Symmetry : Exact correspondence of parts on either side of a straight line or plane, or about a centre or axis: balance or due proportion: beauty of form, disposition of parts

Symmetric : Having symmetry

Sympodial [Pachymorph] : Where each axis becomes dominant and develops determinate branches. Branching in which the growing point in an inflorescence or in rhizome bodies, growth being continued by a new lateral growing point.

T

Taper : The decrease in diameter of the culm from the base to upwards.

Tensile strength : Resistance to forces that tend to pull the wood apart.

Terminal : At or produced from the tip of the axis.

Thinning : Removal of some culms in a clump to improve the vigour and quality of the remaining culms, reducing culm density and competition

Tillering : Throwing out of stems from the base of a stem. Proliferation of culm from its basal (subterranean) buds, without the intercalation of a rhizome proper.

Truncate : A base or apex which ends abruptly, that looks cut off.

U

Understorey : An underlying layer of vegetation, especially the plants that grow beneath a forest's canopy.

V

Veins : These are the vascular tissue, looks like the skeleton marks on the leaf blade; *veinlets* are the further ramification of veins. The veins are made up of: *Xylem*: tubes that brings water and minerals from the roots into the leaf and *Phloem*: tubes that usually move sap, with dissolved sucrose, produced by photosynthesis in the leaf, out of the leaf.

Vessels : Large cells arranged in axial series for water conduction through the culm.

Viability : The potential capacity of a seed to germinate

W

Weathering : Process of degradation due to atmospheric factors such as light, wind, moisture.

Weed : Any unwanted plant that interferes or tends to interfere with the growth of individuals of favoured plants.

Windbreak : Planting of trees, bamboo or vegetation designed to protect soil, crops, homes or structures from wind.

No technical/ scientific words used starting with X, Y, Z.