

**BIOLOGY AND PROPAGATION OF BAMBOOS
OF
BANGLADESH**

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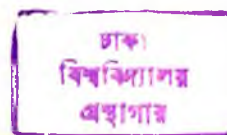
GIFT

Thesis submitted to the University of Dhaka
for the degree of Doctor of Philosophy
in the Faculty of Bio Science



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by



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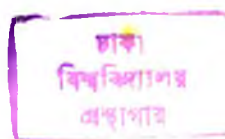
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Dedicated to the sweet memory of my

late father

Sri Paresh Ranjan Banik

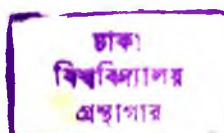
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C E R T I F I C A T E

This is to certify that this thesis contains the results of research on "Biology and Propagation of Bamboos of Bangladesh" and has been carried out by Mr. Ratan Lal Banik under my supervision. It is further certified that the work presented here is original and suitable for submission as a Ph.D. thesis.

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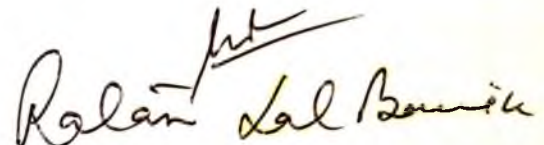
A handwritten signature in black ink, appearing to read 'Syed Hadiuzzaman'.

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D E C L A R A T I O N

I hereby declare that this thesis has been composed by myself and all the works presented herein are my own. I further declare that this work has not been submitted anywhere for any academic degree.

October, 1991


(Ratan Lal Banik)

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1.0 INTRODUCTION

Bamboo is a perennial member of the grass family (Gramineae) and belongs to the sub-family *Bambusoideae*. In this subfamily twelve hundred and fifty species under 47 genera are found in the world (Ueda 1960). Unlike other members of the grass family, this plant is unique in both of its sexual and vegetative characters. Bamboos are often referred to as giant woody grasses, generally having a tall aerial shoot (culm) with distinct nodes and internodes, the internodes being hollow and a complex underground rhizome system with a prominent sheathing organ at each node. The culms are the main parts of a bamboo plant utilized for various purposes by man since the prehistoric age. Both climate and soil of south and south-east Asia are favourable for the growth and development of bamboos. Thus hills of this region have vegetation of different bamboo species. Moreover, in the plains and villages people have been cultivating this plant from time immemorial for their day to day needs.

Bamboo has many inborn qualities, among which the following are remarkable:

- fastest growing plant (8.0-35.05 m within 2-3 months);
- highly elastic, allows to resist wind pressure and spring back when the stress is over;
- straight and cylindrical stem;
- light, hollow, but hard and strong;
- stems are of different diameter (1.0 cm - 25.0 cm) and wall thickness (less than 1.0 cm - 1.63 cm at mid culm);
- possesses long fibre with maximum amount of cellulose (2.3 mm - 3.6 mm is average range for bamboos of Bangladesh) and

- excellent splitting ability in straight lines.

Unlike woody trees the bamboos do not have a distinct bark. The outer layer or epidermis is quite heavily cutinized to prevent loss of water from the culms. In common with the culms of grasses, those of the bamboo have a hard, siliceous exterior which makes them more impervious to moisture and more durable than ordinary wood of the same weight. Cutinization of the outer wall increases the power to resist tearing as much as ten times over ordinary cellulose walls (Glenn 1950). High elastic strength of bamboo is of prime importance to its use as a reinforcing material in concrete (Glenn 1950). It is one of nature's strongest creations. Its cylindrical design, segmented by integral partitions, gives it amazing physical characteristics. Bamboo's strong, rigid structure makes it an ideal material of construction. In many parts of the world it is used as scaffolding, strong enough to withstand typhoons where steel scaffolding has collapsed.

It is the fastest growing plant species so far known and is rich in cellulose content. It is estimated that six or seven times as much cellulosic materials can be obtained per unit area from a bamboo forest compared to that of a pine forest (Sineath and Daugherty 1954).

Due to its excellent splitting ability bamboo has a wide range of use in construction, making basket, furniture and in novelty items. Bamboos are being used as a main construction material for about 90% of the rural housing in Bangladesh (Anon 1983). Bamboo materials knitted by thin split pieces of culm are commonly used for the support of muddy walls of rural houses of Bangladesh. Fencing with bamboo splits on the boundaries of agricultural fields are common picture in the countryside. Bamboo plantation also acts as wind break (Hsiung 1987) and helps in soil conservation and

flood control (White and Childers 1945), and therefore in Japan, bamboo cultivation was recommended since sixteenth century for the protection of river banks (Ueda 1960).

Besides all these versatile uses of bamboo, man probably from his ancient nomadic life, has been using this plant as one of his food items. Young shoots of several species of bamboos are important vegetable ingredients in the daily meals in China, Japan, Thailand, Burma, Korea and Philippines and are considered as gourmet item in the western world where these are available as imported canned products. All these countries earn huge amount of foreign exchange by exporting the bamboo shoots. During 1977, Taiwan exported nearly US\$ 25 million of bamboo shoots to the western world (Sharma 1980). In the hilly areas of Bangladesh specially the tribal people use to take bamboo shoots as one of their major food items.

Branches, twigs and leaves of bamboos are very common sources for fuel in Bangladesh. The calorific values of bamboos are within the range of 4600 -- 5400 cal/kg, that are higher than 3000-4000 cal/kg in woods (Shigematsu 1937). Thus bamboo, with its fastest growth rate and higher calorific value, is a potential alternative renewable energy to conventional energy source, in near future world.

Air pollution is now-a-days, a great problem in the industrialized countries of the world. Therefore, the demand of the activated charcoal may be more and more increased in the near future. The absorptiveness of gas by bamboo charcoal is stronger than that by wood charcoal, because bamboos can be said to be also suited to the resources for activated carbon (Ueda 1981).

Similar to other countries of tropics and subtropics bamboo grows naturally in the forest and is also cultivated in the village of Bangladesh. The major bamboo species in the forests of Bangladesh are *Melocanna baccifera* (Roxb.) Kurz

(local name: Muli), *Bambusa tulda* Roxb. (L.n. Mitinga), *Dendrocalamus longispathus* Kurz (L.n. Ora), *Oxytenanthera nigrociliata* Munro (L.n. Kali), *Neohouzeaua dullooa* Camus (L.n. Dalu), *Dendrocalamus hamiltonii* Munro (L.n. Pecha), and *Melocalamus compactiflorus* (Kurz) Benth. (L.n. Lata). These species are thin-walled, comparatively short and narrower in diameter than those which are being cultivated in the country side. The thin-walled species are mostly used for walling, partitions, ceilings by interweaving the splitted and flattened culms. The widely cultivated bamboo species in the villages of Bangladesh are: *Bambusa vulgaris* Schrad. (L.n. Baizya, Bashni, Bariala) *Bambusa balcooa* Roxb. (L.n. Barua, Baro, Barah), *Bambusa longispiculata* Gamble ex Brandis, (L.n. Talla, Bailla), and *Bambusa nutans* Munro (L.n. Makla, Mal). Sometimes *Dendrocalamus giganteus* Munro (L.n. Bhudum), *Bambusa arundinacea* Retz. (L.n. Kanta), *Bambusa polymorpha* Munro (L.n. Pharua, Bethua)) and *Dendrocalamus strictus* Nees (L.n. Lathi) are also cultivated sporadically in different villages of the country. Cultivated species are thick-walled and mostly used in structural works.

Bamboo is also an important raw material for cottage industries and agricultural implements. With the progress in industrialisation, the use of bamboo as raw materials for the pulp and rayon mills has added its importance to the national economy of Bangladesh. Of late bamboo is also being used in small scale irrigation works. During 1980-85 about 30 thousand bamboo shallow tube-wells (treadle pumps) were sunk in the crop field of north west part of the country. Bamboo in Bangladesh, therefore, is a most useful multipurpose plant.

Choudhury (1984) estimated the total consumption of 0.993 million air dry (A.D.) tons of bamboo in Bangladesh during 1980-81. Out of this total, the village groves contributed 0.803 million A.D. tons and the forest sources 0.19 million A.D. tons, the ratio being 4:1. He also

calculated that due to increasing population the requirement of bamboo per year in Bangladesh will stand at 1.407 million A.D. tons by the end of this century. He showed that due to over exploitation in the forests the harvesting numbers have decreased from 84.72 to 59.942 million since 1959 to 1983. Thus bamboos are progressively deteriorating in quantity and quality in almost all the forests of the country. Similarly the present village stock is also very insufficient to meet the demand. This reduction is putting an adverse socio-economic impact on the rural people due to increase in the price and lack of employment in harvesting and processing of the raw material for cottage industries.

Excepting homestead cultivation, bamboos have never been planted in the forests or marginal lands of Bangladesh. Thus people do not have any knowledge of bamboo afforestation or reforestation. Village farmers have very stray knowledge of bamboo cultivation in a limited scale mostly based on personal experiences but not on systematic scientific studies. The situation calls for immediate attention in the direction of its scientific cultivation and mass reproduction to meet the increasing demand.

2.0 OBJECTIVES OF THE STUDY

Bamboo being a very important forest produce for Bangladesh, needs a very intensive study and research. Due to its increased demand in the paper and pulp industries and also in village economy, bamboo has become the most important forest and homestead produce. The increasing demand for bamboo has opened up new trade channels and is providing greater employment opportunities for the rural people. In the past bamboos were considered a perpetual resource because of their vigorous vegetative regeneration. However, uncontrolled exploitation results in reduced yield and deterioration in quality. Considering both ecologic and economic importance Government of Bangladesh recently emphasized the need of bamboo plantation and management of resources in the forest and private lands.

The greatest impediment in the maximum production and utilization of this renewable resource is the difficulty in raising large scale plantations. Unlike other plants it is not possible to raise bamboo seedlings every year because of its long flowering interval. Moreover very little is known about bamboo seeds, their germination and seedling behaviour. Alternatively easy and mass macropropagation techniques are also not known for raising large number of propagules. Information on the flowering behaviour, seeding cycle, and natural regeneration of different bamboo species of the country are also scanty and therefore, it is difficult to predict the flowering years and is also a problem for proper management of natural regeneration.

Botanical identification of a bamboo species is also difficult because the usual way of classification depends on flowering and fruiting materials. Investigations on the availability of species and their distribution in different parts of the country are important to get an idea of the

bamboo-diversity of Bangladesh. This is basically required for the genetic improvement of the crop in future.

Unfortunately, proper management system could not be developed for the commonly growing bamboo species of Bangladesh due to lack of information on their culm production, pattern of elongation, and clump expansion behaviour as well as other related factors. Questions are often asked by farmers and field foresters ---- what are the interseeding periods in different species, is it possible to raise bamboo seedlings, how to produce other vegetative propagules, what are the planting techniques, and at which clump age culms attain optimum diameter and height growth, etc.

Therefore the objective of this treatise are:

- a) to study the various aspects of biological behaviour of bamboos,
- b) to develop techniques of mass propagation through seedlings and other vegetative means,
- c) to study the possibility of micropropagation in *Melocanna baccifera*(Roxb.) Kurz the most common species of Bangladesh, and
- d) to gather knowledge on the bamboo - diversity through collection and centralization of germplasm.

The knowledge, thus, generated in the present studies will ultimately help in formulating the silvicultural practices for bamboos of Bangladesh.

3.0 REVIEW OF LITERATURE

3.1 Biology

3.1.1 General ecology and distribution

Bamboo species and bamboo forests have very rarely been ecologically studied, except for agricultural (edible shoots), silvicultural (culms growth) and economic studies (Numata 1987). Sometimes bamboos are called "giant grass" (Campbell 1926) which have rhizomes. They are large plants consisting of canopy like trees, and their stands are called "bamboo forests" (Huberman 1959, Warming 1909). Depending on their physiognomy, they are sometimes called bushlands (Warming 1909) and bamboo brakes (Stamp 1926). In this respect, bamboo brakes are in the middle of forests and grasslands as a type of vegetation (Numata 1987). Soderstrom and Calderon (1979a) divided this group of plants into simply "bamboos" or "woody bambusoid grasses" and "herbaceous bambusoid grasses". However, physiognomically, they are classified into tall bamboos and dwarf bamboos (Numata 1987).

Geographical distribution: Bamboos are very unevenly distributed in the tropics, subtropics, and mild temperate regions of the world, from sea level to the snow line (Metcalf 1960). Some bamboos were recorded from latitude as far north as 46° and as far south as 47° and occurring at elevations as high as 4000 m (Soderstrom and Calderon 1979a). Marden (1980) has given a broad outline of the distribution of these plants in different continents of the world (Figure 1). According to McClure (1966) the great majority of bamboos are found in the southern and southeastern borders of Asia, from India through Japan to Korea. In the vast Eurasian continent north, west and northwest of China, no native bamboo has been found. The island of Madagascar is particularly rich

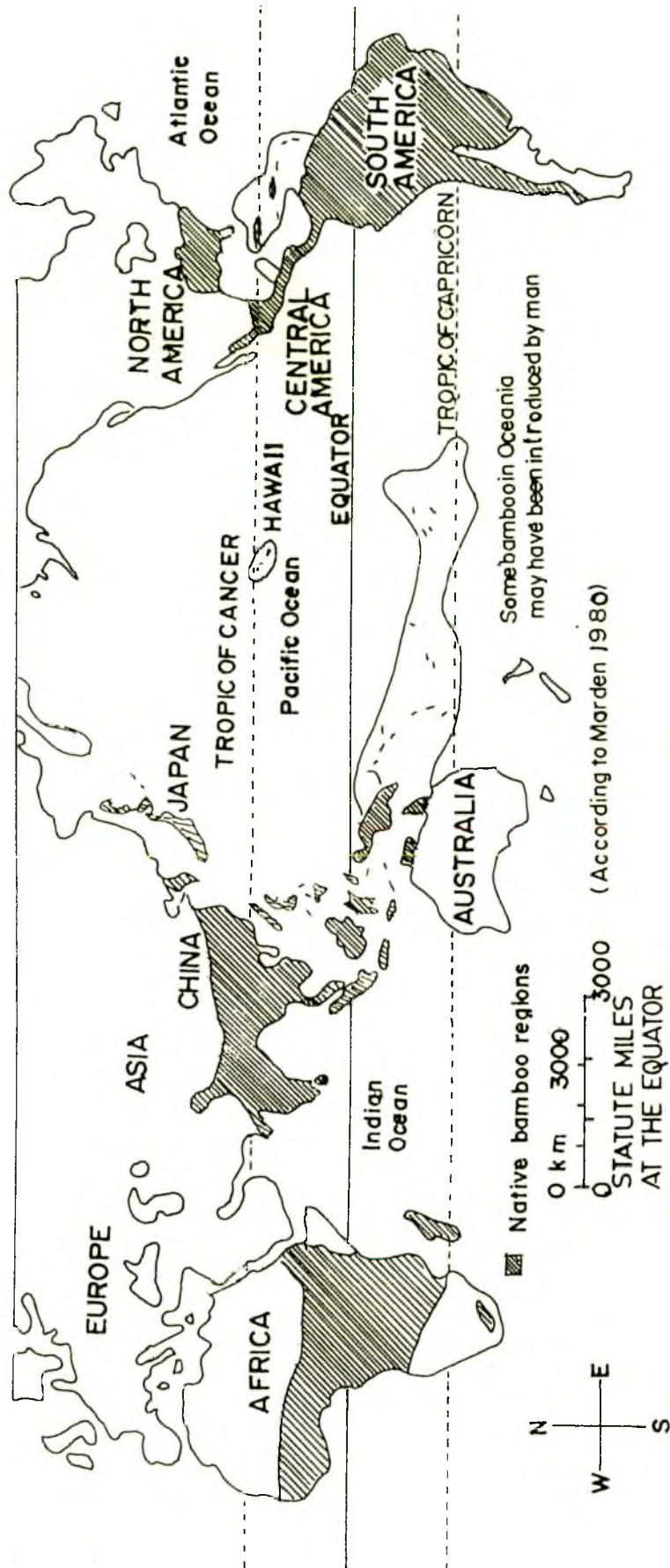


FIGURE 1. A broad outline of the native bamboo regions in different continents of the world .

in endemic genera and species, having more known kinds than all of Africa. Three endemic species have been described from Australia. In the Western Hemisphere, the known natural distribution of bamboos extends from $39^{\circ}25'$ N in eastern United States to $45^{\circ}23'30''$ S in Chile and even to 47° S in Argentina. In Asia the widespread distribution of some bamboo species parallel man's past migrations. Bamboos may also have travelled along the several ancient maritime spice routes between China, Indonesia, Sri Lanka and India. Man's long and close association with bamboo in Asia prompted Porterfield (1933) to say "Arecheologists would indeed be justified in incorporating in their historical outlines for tropical and sub-tropical Asia a definite *Bamboo Age* comparable with that of the Stone or Bronze". However, the distribution of bamboo is rich and gregarious in the areas of the Tropic of Cancer and the northern side and in the Tropic of Capricorn on the southern side, specially, for clump forming bamboos (Uchimura 1987). Bamboo species like *Bambusa*, *Dendrocalamus*, *Guadua* and *Schizostachyum* are the common genera belonging to this group. All these tropical bamboos growing in the forests are either in pure or mixed with trees; however, under the tropical rain forest condition the species possess luxuriant growth with vigorous underground rhizome system. In this zone clump forming bamboos exist in two categories (Uchimura 1987), namely, (i) bamboo forest in extensive areas, and (ii) in groups or colonies. Uchimura (1987) described that "the first category bamboos are more or less confined within $15-25^{\circ}$ of northern side, especially tropical monsoon Asia (India, Bangladesh, Burma, Thailand, Laos, Vietnam, etc). On the other hand only colonies of bamboo forests occur in other tropical America, tropical Africa and the rest of above tropical countries including both side of latitudes between Equator and 30 degrees. However, bamboo forests located in tropical

rainforest area where it is sandwiched between Equator and 15° both side of the latitude are mainly mixed with tree forests". Altitude also affects the distribution of bamboo with respect to form or type even in tropical region. Clump forming type is observed to predominate in low and medium altitudes, while the non-clump forming type occurs more abundantly at high elevation (Numata 1987, Uchimura 1987). Altitude and temperature are closely related and it is difficult to separate one from the other, for example, some species of *Phyllostachys* that grow at high elevation in tropics occur also at low elevation in the countries of temperate zone (Uchimura 1987).

Temperature: The majority of clump forming bamboos grow at temperature ranges from 7°C (sometimes 2-3°C) to 40°C. In general, high temperature accelerates the growth of bamboo and low temperature inhibits it. The clump forming types are generally present in the humid tropics mainly in places where the average temperature is higher than 20°C, and where the altitude is less than about 100 m above the sea level (Uchimura 1987).

Altitude: Non-clump forming type of bamboos are very seldom found to grow in areas higher than 1000 m above the sea level in the tropical region (Uchimura 1987). However, these groups are mostly confined in the temperate zones of the world. These species are characterized by monopodial rhizome and culms (McClure 1966) so that culms emerge sporadically and are widely spaced. Non-clump forming type such as *Phyllostachys*, *Semiarundinaria*, *Sinobambusa* and *Tetraganocalamus* are the common genera which grow in the temperate regions and sometimes in the high altitude of subtropical area (Uchimura 1987).

Bangladesh being a part of the subtropics has only clump forming bamboos. No temperate species that is non-clump forming bamboos are available in the country.

Rainfall and cyclones: Misawa (1950) discussed the parallelism of bamboo growth with rice and percimon production. Numata (1987) is in the opinion that high temperature and humidity requirement are common characteristics of plants originating in the monsoon areas of south east Asia. As the water requirement of bamboo is high, the amount of rainfall is also a limiting factor to distribution (Numata 1987). Rainfall is an important factor and 1000 mm seems to mark the minimum annual precipitation required. Gamble (1896) reported that distribution of bamboo in India was related to the rainfall, the most common range being 1270 mm to 4050 mm. The upper limit is not known but the species are found to grow in zones with over 6350 mm (Huberman 1959). The most common range is 1200 to 4000 mm per year.

The effect of cyclones on the growth and development of bamboos is not known. However, Shigematsu (1960) did some experiments on the effect of artificial vibration to the clumps of *Bambusa* sp. and *Phyllostachys* sp. and observed that vibration caused check in growth and confirmed the need for shelter from strong wind. Sites with more than 100 stormy days (with velocity $\geq 10\text{m/sec}$) cannot produce good quality bamboos (Numata 1987).

Topography: It has been reported that the occurrence and distribution of bamboo forests are clearly correlated with topographic features, on which the nature of soil formed is largely dependent (Huberman 1959). Most bamboos are found in well-drained, sandy-loam to clayloam soils, derived from river alluvium of flat or gentle slope area. *Bambusa polymorpha* and *B.arundinacea* grow on well drained and fertile soil under the

tree forest, while *B.tulda* and *Oxytenanthera albociliata* are suited to sandy soil. Furthermore *Dendrocalamus strictus* in India, *B.blumeana* in the Philippines and *B.multiplex* form *solida* in northern Malaysia have strong drought resistance capability (Uchimura 1987). Top soils that are suitable for bamboo vary in colour from yellow to brown-yellow, and heart soil colour are clear red, yellow-brown to blue-grey (Uchimura 1987). According to Uchimura (1987) soil pH about 5.0-6.5 is the most suitable for bamboo, some species may grow even at pH 3.5. Saline soil is not suitable for bamboo growth. Lyall (1928) stated that the geologically younger soils are more suitable for bamboo than the older soils. A wide range of textural variation and soil depth, however, do not interfere in the normal growth of bamboo provided the drainage, rainfall and temperature conditions are favourable (Qureshi et al. 1969). Usually bamboo prefers well drained and aerated soils but it can also grow in swampy or wet basin. According to Uchimura (1980) soils high in N, P_2O_5 , K_2O , CaO , and SiO_2 promote best growth of bamboo culm. He and Ye (1987) have investigated the physical and chemical properties of soil below *Phyllostachys pubescens* stands in Anji county and Zhejiang, and observed that soil N content was the most important factor affecting growth, but organic matter, texture, aeration, base exchange capacity and depth were also important. Treatment with N fertilizers has been recommended for stands of low productivity.

3.1.2 Bamboo systematics

Bamboos, the tree grasses are easy to recognise at sight, but they are more difficult to define botanically. According to Soderstrom and Calderon (1979a) the earliest comprehensive treatment of bamboos was that of 1839 by

Ruprecht based on herbarium specimens and the literature upto his time. This was followed by the studies of Munro (1868) whose excellent descriptions, notes and system of classification have been a basis for subsequent bamboo classification. During this period Kurz (1876, 1877) published field observations with some plates, and uses of the Indian and Malayan bamboos. Detail taxonomic descriptions and plates of many taxa of bamboos of Burma, India and Malaya were published by Gamble (1896) in his comprehensive monograph. In addition Bentham and Hooker (1883), Hooker (1897), Brandis (1899, 1906), Prain (1903), Camus (1913), Bor (1940), and Holttum (1956) published information on the systematic studies of the *Bambusoideae*. After a thorough revision of bamboo classification, Holttum (1956) proposed a system which was based on the structure of ovary with the following four divisions.

Classification system by Holttum (1956):

- A. Schizostachyum type
Melocanna, Ochlandra, Schizostachyum
- B. Oxytenanthera type
Oxytenanthera
- C. Bambusa - Dendrocalamus type
Melocalamus, Dinochloa, Thyrsostachys, Bambusa, Guadua, Dendrocalamus, Gigantochloa, Racemobambos
- D. Arundinaria type
Arundinaria

As because bamboo flowers after long interval (McClure 1966) field workers often face difficulties in identifying the species with the help of flower structures. Consequently, the same species may be described under different names, or the same name may be given to the quite different species (Liese 1985). Therefore, number of described

taxa varied from 500 to about 1250 species and from 30 to about 90 genera (Bahadur 1979, Hutchinson 1959, McClure 1966, Ueda 1960). It became apparent that earlier classifications emphasizing stamens, palea, keels and pericarp texture are unsatisfactory. Such a system was of little use for identification in the usual sterile condition, and many authors have turned to vegetative characters in addition to reproductive characters (Clayton and Renvoize 1986). Still there were great difficulties since most herbarium specimens consisted only of leafy shoots which were almost useless for taxonomy, and according to Clayton and Renvoize (1986) it was unfortunate that rhizomes, culm sheaths, and branch and bud complements have been consistently neglected by collectors. The subfamily *Bambusoideae* is markedly heterogenous, and thus Clayton and Renvoize (1986) have suggested to divide it loosely into 5 groups on the basis of both reproductive and vegetative characters:

1. *Bambuseae*
2. *Anomochloaeae, Streptochacteae*
3. *Olyreae, Parianeae, Phareae*
4. *Oryzeae, Phyllorachideae, Streptogyneae*
5. *Phaenospermatae, Ehrharteae,*
Diarrheneae, Brachyelytreae

Lately some identification devices have been developed by using the differences of size and pattern of culm-sheath (Chatterjee and Raizada 1963), and bud sheaths (Bahadur 1979). Calderon and Soderstrom (1973) have reported that leaf anatomy of different bamboos are distinctive type and can be used for identifying the species under lens. They also opined that the diverse patterns of branching in bamboos, at the vegetative and inflorescence level should be considered in any system of classification. Recently Alam (1982) has

published a field identification key for 18 bamboo species of Bangladesh mainly with the help of documented ideas of the previous workers. According to him bamboos occurring in Bangladesh were represented by 22 species under 9 genera as recorded by Gamble (1896), Hooker (1897), Prain (1903) and Brandis (1906). Presently, from the collection and centralization of bamboos at BFRI bambusetum, the number of taxa are regarded to be more (Banik 1980).

3.1.3 Phenology and growth habit

A bamboo plant has many jointed cylindrical hollow stem, called the culm. The stems are connected to a rhizome network that spreads out horizontally beneath the soil. The rhizome system constitutes the structural foundation of the plant (Liese 1985). Two major rhizome types are found in bamboos: *pachymorph* and the *leptomorph* (McClure 1966). The individual rhizome is a segmented axis of the total underground rhizome consisting typically of two parts: the rhizome proper and the rhizome neck. The neck is basal to the rhizome proper, generally shorter in length (clump-forming bamboos) and obconical in shape but in some cases (*Melocanna* sp.) it may be greatly elongated. Neck connects the new rhizome to the mother rhizome. All clump forming (*Bambusa*, *Dendrocalamus*, etc.) bamboo species have pachymorph rhizomes whereas all the non-clump forming species (*Arundinaria*, *Phyllostachys* spp.) of temperate zone have leptomorph rhizomes (McClure 1966, Ueda 1960). Pachymorph rhizomes are short, thick, subfusiform and usually more or less curved in shape, with a maximum thickness and usually somewhat greater than that of the culm into which they are always transformed apically. The rhizome internodes are broader than long, asymmetrical, and solid (Soderstrom and Calderon 1979b).

Shigematsu (1960) mentioned that the pachymorph rhizome is typically a summer sprouting type where mainly soil moisture and temperature play important role and the leptomorph is characteristically spring sprouting where temperature is the limiting factor. The growth of new culms is completely dependent upon the nutrition provided by the rhizome and the older culms (Liese 1985). Lateral buds of a pachymorph rhizome produce new rhizomes, but a culm originates only from the distal end of a rhizome axis. Leptomorph rhizomes are long and slender, cylindrical or subcylindrical, with a diameter usually less than that of the culms originating from them, the internodes are longer than broad, symmetrical or nearly so and typically hollow (Soderstrom and Calderon 1979b). Between the single-stemmed (leptomorph) and the densely clumped (pachymorph) forms, there are intermediate types (woody-pachymorph-diffuse) forming somewhat open clump (*Melocanna* sp.) (Watanabe 1986).

The shoot starts to emerge from the soil mostly at the beginning of rainy season. The shoot elongation continues both day and night; the genus *Phyllostachys* in Japan grows more during the day (Ueda 1960), whereas in the tropical regions, bamboos grow preferably during the night (Osmaston 1918). The daily (24 h) extension growth amounts to about 10-30 cm, but reaches 58 cm for *Dendrocalamus giganteus* (Osmaston 1918), and upto 121 cm for *Phyllostachys reticulata* (Ueda 1960). Bamboo being a member of monocotyledonous group do not possess any thickening due to a secondary growth, so that the emerging shoots have already attained their final diameter. An emerging culm reaches their full height within 2-4 months (McClure 1966, Ueda 1960). The height growth of the culm results mainly by the elongation of internodes. The internodal elongation begins at the basal portion of the culm and then gradually proceed to top. That is, elongation is mainly due to the intercalary meristem present at the node. An intercalary

meristem is directly derived from the apical meristem and is separated into a number of intercalary sections by successively formed nodes (Liese 1985, McClure 1966).

The clump height depends on the total length of the culm and it varies from 2-37 m depending on the species character (McClure 1966). The length of the culm internode increases gradually from base towards the middle portion of culm and decreases upwards. The growing culm is without branches, but branching begins either after culm has ceased growth or in the following growth season. Bud dormancy and the breaking of it vary with the nodal position (Banik 1980). Takenouchi (1931) was the first to call attention to the order of breaking of branch buds on the young culm. Banik (1980) reported the pattern of bud break on the culm node of different bamboo species of Bangladesh. In *Neohouzeaua dullooa* and *Melocanna baccifera*, the breaking of bud dormancy on the node of a culm was found to be in basipetal order, gradually moving towards the base and being completed in 3-4 years. Although, essentially, the same pattern was observed in *Bambusa vulgaris*, 5-10 buds around the middle of the culm remained dormant upto 3 years. After that, all opened except those in the 2-3 base nodes. In *B. tulda*, all the buds awakened at nearly the same time with the exception of a few at mid-culm or below. Most of the remaining buds started opening about age 1-2 years. Generally, in bamboos of Bangladesh, new leaves and branches start developing during March-April from the culm buds and branch buds after each defoliation. Bamboos are, however, not purely evergreen plants. Most bamboos, in Japan, change leaves in the period from spring to early summer; whereas clump forming type in the tropical region such as India, shed their leaves in winter when it is dry and renew the leaves in a short time (Ueda 1960). According to Banik (1980) buds are more active in March-April than at other time and he opined that this could be the best season of the year

for collecting the buds or branches as vegetative propagules. The buds on the culm nodes are protected by culm sheath on alternating sides. The size, shape, form and different parts of culm sheath are diagnostic for each species (Chatterjee and Raizada 1963). Culm sheath may be persistent or soon falls off from the culm internodes and this depends on the species nature.

While the culms of many bamboos are hollow and erect, in others they are solid and either erect, scandent, or climbing (Liese 1985). *Dendrocalamus strictus* growing in drier part of western India, generally, have solid culms (Kadambi 1949). The thickness of culm wall in one species may be less than 1 cm and in other species it may be upto 3 cm. Thus bamboos can be grouped into thin- and thick-walled species (Banik 1983a). Branches in some species may be thorny while majority are thornless (McClure 1966). Bamboo species belonging to the close clump type frequently have a crown of fine roots at the first lower node. The age of a culm is difficult to determine. Generally 3-5 years old culms are treated as "mature" and thus harvested (Huberman 1959). The "maturity" of a culm is a relative term. After completion of elongation, carbohydrates from the assimilating leaves are still transformed into cell wall material and deposited on existing walls of the culm (Liese 1985). According to him the evidence from chemical and technological tests regarding the beginning of "maturity" is still contradictory.

The diameter of the successively emerged culms increases with the age of the clump (Banik 1988a). In the first few years the culms are small and reach their maximum diameter after the fourth or fifth year. The mean diameter varies with the species but also influenced by environmental conditions. The knowledge on the growth behaviour of Indian bamboos are scanty. An elaborate management system has been developed (Seth 1954, Huberman 1959) only for *D. strictus* and a

few other clump forming bamboo species of the sub-continent as their growth habits were studied by Deogun (1937), Kadambi (1949), Sen Gupta (1952), Krishnaswamy (1956) and other workers. Recently Banik (1988a) has studied the growth habit of culm in the clumps of 5 different bamboo species of Bangladesh. He reported that full grown culm production gradually increased upto 5th year of planting in case of *Bambusa* species. After that period culm production gradually decreased, but the growth in diameter and height was more or less similar to those of previous years. Similarly clump girth expansion was rapid upto 5th and 6th year of plantation. Seth (1954) has developed felling system for *D.strictus* and a few other species, involving time of felling, height of culm cutting, number of culms to be cut, cleaning and improvement thinning. Cleaning operations relieve congestion in clumps and dense stands, promote regeneration and facilitate harvesting. According to Huberman (1959) and Kondas (1981) due consideration must be given to even spacing to relieve culm congestion.

3.1.4. Flowering and seeding behaviour

The flowering of bamboo is a strange phenomenon, which is not yet well understood. Attempts in the past were concentrated on determining the seeding cycles rather than flowering cycles so that seeding cycle could be predicted. Most of the bamboo species die after gregarious flowering (McClure 1966). The flowering and the death of bamboo forest result in marked shortage of raw materials. However, till now, no information on the dependable symptoms of flowering are known by which one could forecast the flowering year in bamboos atleast one year ahead (Banik 1986). Moreover, due to long intervals between flowering, it is very difficult to

conduct breeding and genetical experiments on this group of plants.

The duration of the vegetative state and the incidence of flowering in bamboo varies from one species to another (Arber 1934, Banik 1980, Janzen 1976, McClure 1966, Troup 1921, Ueda 1960).

On the basis of their flowering behaviour Brandis (1906) described three major groups of bamboos as follows:

1. Those that flower annually or nearly so;
2. Those that flower gregariously and periodically;
3. Those that flower irregularly.

However, a species may exhibit flowering behaviour in more than one of these groups (McClure 1966). *Dendrocalamus hamiltonii* for example, flowers sporadically almost every year (Rogers 1900) but may also flower gregariously at 30 years intervals (Cavendish 1905). A range of 25 to 35 years was regarded by Kurz (1876) as the general age at which the common kinds of Malayan and Indian bamboos belonging to the genus *Bambusa* and *Dendrocalamus*, come into flower. Intervals of flowering period in non-clump flowering bamboos (temperate types) were in the range of 60-120 years (Ueda 1960). Janzen (1976) analysizing the past reports on the flowering cycles in different bamboo species concluded that the flowering cycle ranges from 3 to 120 years; and most of them are between 15 and 60 years.

Almost all the past reports on bamboo flowering are based on speculation and estimation (Hasan 1973, Janzen 1976). The exact seeding cycle (from seed to seed) is known in a very few species. It has been possible, however, to determine the exact period of flowering cycles of some Indian species for those introduced into regions outside their natural habitat. The exact seeding cycle of *Dendrocalamus strictus* was 44

(Clement 1956) and 47 years (Wang and Chen 1971). For *Bambusa arundinacea* it was 31-32 years (Dutra 1938) and for *Thyrsostachys oliveri* it was 48 years (Bor 1941). The seeding cycle, in nearly all species, seems to be fixed. Recent analysis of flowering and sterile specimens in major herbaria indicated that Sino-Himalayan bamboos generally flower and die after vegetative periods which are integral multiples ($\times 1-8$) of 10-12.5 years or, in the west, 14-16.5 years (Campbell 1987).

Seeding generally attracts numerous birds, jungle-fowl and pheasant. In Burma it has been noticed that in the years of gregarious seeding of bamboos rats multiply freely, and when the seeding is over these pests commit great havoc among the neighbouring agricultural crops (Brandis 1899, Troup 1921). The fleshy fruits of *Melocanna baccifera* similarly attracts bison, deer, pig and other animals (Troup 1921).

Banik (1986) described the flowering nature, blooming pattern, pollination and seed yield of *Bambusa arundinacea* var. *spinosa*, *Bambusa glaucescens*, and *Dendrocalamus longispathus* which flowered during the period from 1977 to 1979 in the bambusetum of Bangladesh Forest Research Institute, Chittagong.

Flowering and death of bamboo clumps: The bamboos that flowered after a long interval were generally found to die within one to two years after flowering. On the basis of senescence behaviour in relation to flowering Ghinkul (1936) classified bamboo plants into three groups as follows:

1. Plants dying regularly after the first and only fruition.
2. Plants dying in part and renewing the dead parts after fruition.

3. Mostly small, whose life span is undetermined, flowering and bearing fruit repeatedly at short intervals without dying.

Most of the bamboo species of the Indo-Malayan zone and Japan fall under the first group (McClure 1966, Ueda 1960).

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). Salisbury (1963) thinks that during flowering time most of the monocarpic plants convert all of their undeterminate meristems to determinate flower forming meristems. Death becomes inevitable due to the lack in undeterminate meristems that continued vegetative growth. Ueda (1960) believes that 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. In describing the probable cause of death of the flowering clumps of *Bambusa arundinacea* Menon (1918) mentioned that the reserve 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 any enzyme required to reconvert the reserve material into a suitable form for the production of leafy shoots. However, in monocarpic species, death of the whole plant is closely connected with reproduction and is evidently 'genetically programmed' (Wareing & Phillips 1978, Numata 1987) at this stage in the life cycle. In explaining the mysterious flowering of *Phyllostachys bambusoides*, Soderstrom and Calderon (1976) hypothesized that all of the members of a bamboo species "know" when flowering time is at hand, seem to be in a genetically imprinted 'alarm clock'.

Generally the bamboos growing in a forest exhibit mostly gregarious flowering behaviour and die immediately

after flowering (Arber, 1934, Janzen 1976, McClure 1966, Troup 1921, Ueda 1960). In the natural habitat it seems that a small amount of reserve left after flowering would not be enough to maintain adult plant in the face of competition with large numbers of its own seedlings and other species (Janzen 1976).

Weak adults face disease and many herbivores are attracted by seeds (Janzen 1971, McClure 1966) and seedlings. In this context it is of interest that some species of bamboos could survive after flowering if they were free from normal forest competition and fertilized heavily (Ueda 1960).

Eco-physiology of bamboo flowering: According to Salisbury (1963) ripeness to flower must be a matter of capability of the plant to respond to photoperiod and or the synthesis of a flowering hormone. Flowering may be dependent upon the gradual accumulation of certain metabolites which must attain a certain threshold concentration (Wareing and Phillips 1978) before the initiation of flowering. In the flowering machinery, the right precursors must be available, the right enzymes must be there, the stimulus receptor pigment system must be coupled to the 'Clock' and to the florigen producing system in the proper way. The functioning of any or all of these processes could influence flowering (Salisbury 1963).

The existence of transmissible floral inhibitor(s) in some plant species has also been suggested (Bernier *et al.* 1981). Evans (1969) believes that in some cases floral initiation is essentially controlled by a balance between floral inhibiting and floral promoting substances. In fact, it has also been suggested that there might be a gene in some plant species which controls the production of floral inhibitor (Murrel & Reid 1973) and the activity of this gene decreases as the plant ages (Bernier *et al.* 1981). The timing of seeding or ripeness to flower in bamboo might be set by an internal physiological calendar (Janzen 1971, Janzen 1976).

The calender may be daily or annual accumulation or degradation of a photo-sensitive and temperature-insensitive chemicals (Janzen 1976). Days or nights and variation in seasonal temperature would seem appropriate to count the years.

Brandis (1899) reported that mutilated and injured clumps of *B.tulda* and *B.nutans* flowered before their time. The estimated flowering cycle of *Dendrocalamus strictus* in the dry western part of India was 65 years (Mathauda 1952) and 25 years in wet southern coast of India (Kadambi 1949). Nicholson (1922) also observed that on coarse grained dry soils this species generally flowered sporadically in isolated clumps and not in groups or gregariously flowering. On the other hand on moist soils gregarious flowering was not uncommon. Climate seems to influence the flowering since every dry year (famine years) is said to coincide with the flowering of bamboo and bamboo in exposed situation flowers earlier than a sheltered or cooler plaeces (Kadambi 1949). Lowe (1905) suggested that intensive heat, dry weather and low soil fertility cause flowering. However, Ueda (1960) studied that there is no experimental proof of the above statement. According to Troup (1921) instances of plentiful flowering in hot dry seasons have been recorded from time to time, but the influences which stimulate flowering, however, must act some time beforehand, while gregarious flowering repeatedly occurs in seasons which are not abnormal and in localities when drought is unknown. According to Campbell (1987) flowering in the Sino-Himalayan bamboos appears to be concentrated after droughts, which are related to 11- or 22-year sun spot cycles.

Ueda (1960) pointed out that all gregarious flowering types of bamboo flowered at the same stage and at the same time even though rhizomes of the same plant were separated and transplanted in different places having different latitude from their natural habitat. Transplanted

stocks of *Phyllostachys bambusoides* in England, Alabama and Russia, as well as their parental Japanese stock flowered at the same time in the late 1960's (Chen 1973, Soderstrom and Calderon 1976). Seeds of *Thyrsochachys oliveri* that flowered in Burma in 1891, were planted in Calcutta and at Dehra Dun which are 1500 km apart and the clumps at both the places flowered synchronously in 1940. Similar synchronised flowering of *Melocanna baccifera* was observed in 1961 in Garo Hills (Assam) and Dehra Dun which are more than 2000 km apart (Gaur 1987). Thus it seems that timing of flowering in many bamboo species was not disturbed or changed by shipment of seeds or rhizomes to different latitude and climates (Janzen 1976, Seifrizz 1923). Tanaka and Takimoto (1972) also failed to induce flowering in *Pleiochastus variegatus* by photoperiodic treatment.

Kawamura (1927) believed that some bamboos have special characteristics of periodical simultaneous flowering and this has no relation to climate, soil or any other external conditions. Janzen (1976) concluded that the internal calendar for flowering in bamboo is without doubt a genetic trait. One seedling of *B.tulda* at the age of 18 months flowered precociously at Forest Research Institute Chittagong though the species is said to flower normally in 20-30 years cycle (Banik 1980). Such flowering behaviour seems to be genetically controlled and the responsible gene(s) is segregated and expressed in each subsequent generation (Banik 1980, 1987b). Instances of precocious flowering in young seedlings of *D.strictus* have also been observed from time to time (Ahmed 1937, Brandis 1899, Sen Gupta 1939, Troup 1921). Recently Nadgauda *et al.* (1990) reported that they could induce precocious flowering and seeding in tissue-cultured shoots from bamboo seedlings of *B.arundinacea* and *D.brandisii*

on Murashige and Skoog (MS) medium supplemented with a cytokinin (6-Benzylaminopurine) and coconut milk after only three subcultures.

3.2 Propagation

3.2.1 Sexual propagation

Propagation of bamboo through seeds is not always possible due to long intervals between flowering resulting to inadequate supply of seeds (Anantachote 1987, Banik 1980, McClure 1966, Troup 1921, Ueda 1960). Moreover, it is impossible to predict the exact year or age at which bamboos will produce seeds (Banik 1986, McClure 1966). Anantachote (1987) reported that in Thailand, bamboo flowered every year involving different species and locations. In some locations, more than one species flowered and produced seeds. Therefore, he concluded that propagation through seeds would be the most promising methods in Thailand. However, both from the economic and genetic viewpoint seed is the best method of bamboo propagation and therefore be used whenever possible (Liese 1985). Rao (1920) in Akola Division and Andiappan and Wilson (1963) in Madras State, India, raised successful plantation of *B.burmanica*, *B.arundinacea* and *D.strictus* from seed. Dwivedi (1988) reported that in India, usually, there was a great demand for bamboo seeds from several sectors. In Korea, Sa and Joo (1970) have raised bamboo plantations by planting mother bamboo rhizomes, stalk with rhizomes, and bamboo seedlings. Though they obtained the same results in all types of planting stalks, they found that the use of bamboo seedlings was more economic than use of the other two methods. So far in Bangladesh, only the cultivated thick-walled bamboo species of villages were possible to propagate by vegetative means

(Banik 1987b). Moreover, the most common cultivated species, *B. balcooa* and *B. vulgaris* also do not produce seeds, therefore vegetative propagation remains as only method of cultivation (Banik 1979), Banik and Alam 1987, Banik 1987b). However, it has been observed that thin-walled bamboo species of the country were not amenable to any known vegetative methods (Banik 1980, Hasan 1977), therefore, for large scale afforestation or reforestation of those thin walled bamboo species mainly depend on seeds and seedlings (Banik 1987a).

Seeds of bamboos are very different, both in size and weight depending on the species (Anantachote 1987, Banik 1987a, McClure 1966). Banik (1980, 1987a) reported that *Bambusa* and *Oxytenanthera* spp. produce wheat-shaped seeds but in *Dendrocalamus* these are ovoid, sometimes seed may be like onions (e.g. *Melocanna baccifera*) or spherical like the shape of chestnut (*Melocalamus compactiflorus*) (McClure 1966). Bamboo produces one-seeded fruit with thin pericarp adnate to the seed coat, is known as *Caryopsis* covered with a number of persistent glumes (Gamble 1896, Gould 1968). Kurz (1876) described that the fruit of *M.compactiflorus* was "irregular globose, the size of a small wood-apple, the pericarp being thin and coriaceous". He and others (Hossain 1962, McClure 1966, Prasad 1948, Ueda 1960) described the fruit of *M.baccifera* as "a large pear-shaped and fleshy". However, in general, bamboo seeds are small and light excepting a very few species (Banik 1987a, Liese 1985). Grain like seed has a larger endosperm and small embryo (Liese 1985), excepting the fruit of *M.baccifera* where fleshy starch containing pericarp is present. The number of seeds per kilogram varies from 13-15 thousand depending on the species (Anantachote 1987, Banik 1987a, Liese 1985). Liese (1985) reported that 70 fruits gave 1 kg weight in case of *M.baccifera*.

It was found that the fresh seeds of *B.arundinacea* var.*spinosa*, *B.tulda*, and *D.longispathus* germinated better

than stored ones (Banik 1987a). The seeds have a short germinative power, which lasts only for 1-2 months. White (1947a) was able to preserve the seed viability of a bamboo species (*Phyllostachys* sp.) by storing the seed over calcium chloride at room temperature. Suret al. (1988) observed that for maintaining the vigour and viability of seeds of *D.strictus*, soaking-drying treatment with low concentration of disodium hydrogen phosphate (10^{-4} M) proved to be better than water. But how many days the seed viability could be maintained during the storage was not clearly stated. However, Varmah and Bahadur (1980) reported that *D.strictus* seeds could be stored over silica gel or anhydrous calcium chloride in a desiccator or at 3-5°C ambient temperature after reduction of its moisture content to 8%. Seed lots with 67% germination capacity were stored under these three conditions and exhibited 51, 54 and 59% germination respectively after 34 months. Similarly, Banik (1980) reported that it was possible to increase the seed longevity period of *B.tulda* upto 18 months by storing over silica gel in a dessicator.

3.2.2 Macro-asexual Propagation

Anatomical and structural basis of rooting in branches: In bamboo and other grasses, the meristematic zone is located only in isolated regions (McClure 1966). These are mainly the tip of every growing axis, the zone of intercalary growth just above each node of all actively elongating segmented axes, and dormant but viable bud and root primordia. The meristem of intercalary zones of actively growing segmented axes (rhizomes, culms, or branches) may give rise to root primordia or functional roots in addition to buds (rudimentary leafy axes) (McClure 1966). An elongating culm possesses all these meristematic zones. But soon after it

attains its maximum height and diameter (with 2-3 months of emergence), its meristematic zones become restricted to the buds and root primordia (Banik 1980).

Hasan (1980a) showed that the culm and branch bud has rhizome like structure consisting of root, rhizome and shoot primordia. The shoot primordia first become active and produce branches on the culm nodes. The other primordial structures (roots and rhizomes) of culm buds may remain dormant or active depending on, most probably, internal physiologic and environmental conditions (Banik 1980). As the buds are the only meristematic parts of the culm body, according to Banik (1980) studies in vegetative propagation should involve methods in transforming these innumerable buds into the planting materials as many as possible.

A complete bamboo plant consists of three morphologic structures - the aerial part (the culm) and the two underground parts (the rhizome and root). Success of rooted cuttings of dicots and gymnosperms depend only on the development of leafy axis and roots, but a bamboo propagule must develop all the morphologic structures - the leafy axis, rhizome and root, its failure in development of any of these phases leads to complete failure of a bamboo propagule (Banik 1980).

Due to the scarcity of seeds, bamboo is generally propagated by various vegetative methods. They are, however, associated with a high degree of failures (Liese 1985). McClure (1966) described different methods of vegetative propagation for various species of bamboos. These are:

- a) Clump divisions - offsets, rhizome;
- b) Whole culm cutting;
- c) Culm-segment cutting;
- d) Single branch cutting; and
- e) Layering.

a) **Clump division:** It is traditional, and perhaps the most generally prevalent, method of propagating bamboos vegetatively (McClure 1966). Clump divisions are generally done in two ways - offset planting, and rhizome planting.

i) Offset planting: The term "offset" was designated by Deogun (1937) for bamboo propagules each composed of the lower part of a single culm with the rhizome axis basal to it. According to Deogun (1937) 1- or 2-year old offsets of *Dendrocalamus strictus* gave better results, while propagules consisting of material 3 years or more in age gave progressively poorer results. Nearly a century ago, Peal (1882) reported that propagation of bamboos by offset planting was common in the villages of Assam and Bengal.

ii) Rhizome planting: Reports on the propagation of bamboos by rhizome planting are very meagre (McClure 1966). Dabral (1950) described it as "the best method", but he did not mention the name of the species and details of the method. Ahmed (1956) indicated that *Bambusa tulda* was successfully propagated by means of rhizome planting in situ condition. No details of the procedures (for example, age of material, preparation of propagules, season of planting, or type of care) were given. The use of rhizomes for propagating bamboo has been limited to non-clump forming species (Uchimura 1977). Generally rhizomes without culms are cut into 50 - 60 cm long with about 10-15 nodes including the roots in propagating the non-clump forming bamboo species (Ueda 1960). According to Ueda (1960), 2-3 year old rhizomes produced satisfactory results, but rhizomes over 5 years old were entirely unsuitable. He also reported that rhizomes were generally transplanted in spring.

While describing the general plantation technique of bamboo in Korea, Oh and Aoh (1965) mentioned that planting of rhizome cuttings, 40-50 cm long, 10 cm deep gave good results. In propagating *Schizostachyum lumampao*, an endemic species of

Philippines Uchimura (1977) obtained success only by planting of rhizomes or offsets. These were usually done with 1-year old culms that were excavated along with their root system. The culms were cut to about 1 meter high and planted during rainy season. McClure (1966) mentioned some problems in propagating clump forming bamboo through rhizomes. These were -- i) meagre development of roots, ii) decay of rhizomes, and iii) slowness of rhizome buds to break dormancy.

McClure (1966) opined that planting of rhizome might have advantage over offset being lighter and less bulky. However, he also mentioned that offsets could be physiologically more suitable for plantation as they have some foliage.

The disadvantage of offset method was mentioned by Hasan (1980b) and Uchimura (1977). According to them offsets or rhizomes are bulky and heavier (4-30 kg), and as a result the methods are expensive due to high cost of labour for excavation and transportation of the propagule. Moreover propagules are not available in large quantities. Use of these propagules are practicable only in cultivating a few clumps, particularly within a small accessible area (Banik 1987b).

b) **Whole culm cutting:** Kurz (1876) described this method as "by taking whole halms (culms) with their roots and burying them length-wise in the ground. By this process the alternating branch clusters send forth young branch shoots which gradually become transformed into stronger and stronger halms in the proportion as roots are formed". Pathak (1899) tried propagation of *Dendrocalamus strictus* using 3-5 year old culm cuttings. Although sprouting was good in the initial stages, the cuttings failed to establish during summer. McClure and Kennard (1955) did some experiments with

D.strictus and *B.tulda* and reported that 2-year old culms produced more propagules than 1-year old culms. The success was reasonable and the procedure was cumbersome.

c) **Culm- or Stem-cutting:** Propagation of bamboos through culm or stem segments is known as culm-cutting or stem-cutting technique (McClure 1966, Troup 1921). Generally culm segments of bamboos of 1, or usually 2-3 nodes bearing healthy buds or branches have been used for propagation (McClure 1966). The branches on each culm segments are generally pruned to a length of a few inches to a foot, no foliage is retained. Such cuttings are usually set upright or in an angle, with atleast one node well covered (McClure 1966).

Chinte (1965) made use of 1-year old culms cut into 3-node and 2-node sections, planting each cutting obliquely with two nodes and one node buried respectively. He reported a 60% survival for *B.vulgaris* and 28% for *Gigantochloa aspera*, whereas *B.blumeana* and *G.levis* failed to grow. Three node cuttings were found to survive better than 2-node planting stocks, and the basal sections were superior to the middle and top sections. Another study on *B.blumeana* showed a greater percentage of survival (60.8%) in culm cuttings planted unsplit (Cabandy 1957). For *G.levis*, unsplit cuttings also gave better results, and the middle and top portions of the culm were the best material for propagation (Burmalong and Tamolang 1980). Mabayag (1937) found that the basal portions of culm cuttings of *B.blumeana* were better than the middle and top portion of the culm. In a separate study 2-node split and unsplit (about 1-2 year old) culm-cuttings of 4 different bamboo species planted directly in the field showed better result (94%) after 3 months and poor results (11.7%) after 15 months of trial (Burmalong and Tamolang 1980). In all these species higher survival rates were observed with unsplit cuttings. Surendran and Seethalakshmi (1985) successfully

propagated *B.arundinacea*, *B.balcooa*, *D.strictus*, *Ochlandra travancorica* and *O.scriptoria* through culm-cuttings.

d) **Branch-cutting:** During the fifties White (1947b) reported that it was possible to propagate *Gigantochloa verticiliata* and *Sinocalamus oldhami* by branch cuttings. Later on Delgado (1949), McClure and Durand (1951) also propagated some bamboos by using branch cuttings, which were slow to form roots. Liese (1985) reported that 2-3 cuttings should be planted in each hole to ensure the success. Generally branch cuttings form good planting material in 30-36 months time depending upon the biological condition of the cuttings and the season of the year when the cuttings were taken (Hasan 1977). McClure and Durand (1951) pointed out that, in the matter of striking roots, the basal buds were slow to sprout and during this time the planted materials often die, with the result that the percentage of success became low.

Hasan (1977) described branches of bamboos as "miniature culms". According to him the basal portion of both branch and culm is swollen. In the case of culm the swelling is known as rhizome (McClure 1966), and in the case of branches it has been termed as "rhizomatous swelling" of branch bases. The swollen bases of the branches are morphologically and, under certain conditions, physiologically similar to the rhizome of a culm, and they can be made to function like it as well (Hasan 1980a).

Studies showed that in most of the bamboo species of Bangladesh normal branch cutting rooted well under mist tent but majority of them did not produce any new culm due to the failure of rhizome development (Hasan 1977). Such cuttings might survive upto 4-5 years only with the help of roots but without any further shoot production and clump formation (Banik 1980).

Banik (1980) successfully induced *in situ* rooting and rhizome at the branch bases of some thick-walled bamboo species of Bangladesh. Artificial induction was possible by chopping the culm tops and removal of newly emerging culms. He termed these branches as "prerooted and prerhizomed branch cuttings". Such cuttings performed better than normal branch cuttings (Banik 1987b).

e) **Layering:** Layering is a propagation method by which adventitious roots are caused to form a stem while it is still attached to the parent plant (Hartmann & Kester 1983). The layered stem when rooted is detached to become a new plant growing on its own roots. McClure (1966) described three layering procedures for bamboos. These are:

a) either a whole culm or only the branch bearing part of it was bent down to the ground and into shallow trench, and fastened in place by means of hooked or crossed stakes, and covering it with earth or any other suitable propagating medium;

b) the 1-2 node stumps of severed culms are covered with a suitable propagating medium; and

c) a culm was kept erect, and the base of each branch complement in the mid-culm range was surrounded with a suitable propagating medium, held in place by a suitable receptacle.

Each of the procedures were distinctly different from others and generally the first method has been termed as *ground or simple layering* (Hartmann and Kester 1983), the second one as *stump layering* (McClure 1966) and the third one as *air-layering or marcotting* (Hartmann and Kester 1983).

McClure (1966) found that 1-year old culms of *B. taxtilis* and *Guadua argustifolia* when bent down and covered with earth while still attached to the mother clump, satisfactorily produced little plants. According to him this

method was too cumbersome to be considered seriously except in unusual circumstances, such as dwarf cultivars of *B. mutiplex* var. *riviereorum*. Cabandy (1957) obtained a survival of 28% for *B. blumeana* by ground-layering 1-year old culms pruned of branches. The culms were half buried in the ground in such a manner that the buds along each side of the culm were in a lateral position. A lower survival rate was obtained when the entire culm was buried deeper and totally covered with soil. Abeels (1962) mentioned that "there are indications that the stem layering in bamboos may be successful if it is carried out *in situ* and the layered stem is not transported".

While studying the stump layering methods in *B. longispiculata* McClure (1966) obtained only 25% rooted branches, but it increased upto 54% when the stumps were treated with 200 ppm IBA. He also tried the same method with other species --- *B. textilis*, *B. tulda*, *B. tuldoidea*, and *D. strictus* and reported that either the plants died or did not produce any rooted propagules.

In exploratory studies, McClure (1966) tried air layering of matured branch components of 1-year old culms of *B. tuldoidea* and current year (developing) branch complements of *Semiarundinaria fastuosa* without achieving any success with either species. Cabandy (1957) obtained success (70%) in marcotting only with *B. blumeana*. However, Abeels (1962) in studying the air-layering in bamboos, mentioned that "cutting out of rooted parts is not easy and on planting them in the nursery, their survival is not definite".

Phytohormones and internal factors related to rooting in bamboos: White (1947b) studied the effect of the season of the year and of root-promoting substance on the rooting of branch cuttings of nine different bamboo species. His results showed that the average rooting percentage was maximum in December (15.8%) and the poorest success was in September (3.3%).

According to him no differences in rooting were found which could be associated with root-promoting substances. McClure (1966) later on critically analysed the experiment of White (1947b) and stated that variations in the success of rooting were due to seasonal differences prevailing in the physiological state of the material and might be related to stored nutrients, hormonal and enzymatic activity, and so forth, but mostly environmental.

However, Uchimura (1977) found that, of the three growth regulators (IAA, IBA and NAA), cuttings treated with 100 ppm of IBA for 24 hours gave better rooting percentage and formation of longer roots in *B.vulgaris*. In a similar study with *B.blumeana* using different concentrations of IAA, IBA and NAA, Burmalong (1977) observed that rooting amount was maximum with 600 ppm NAA, and the number of roots was also highest in 200 ppm NAA.

Suzuki and Ordinario (1977) obtained 45% survival of *B.blumeana* treated with IBA and 32% for controls; 80% for treated *B.vulgaris* and 75% for controls; 60% for treated *D.merrillianus* and 53.5% for controls. Their observation was mainly on the sprouting of the culm-cutting, nothing was reported on rooting percentage. In reporting the vegetative propagation of *B.arundinacea*, *D.strictus*, *Ochlandra travancorica*, *O.scriptoria* and *B.balcooa* through culm-cuttings, Surendran and Seethalakshmi (1985) reported that rooting and sprouting responses were significantly enhanced by the application of growth regulators. The success rate was 80% in *B.arundinacea*, 70% in *D.strictus*, 50% in *O.scriptoria* while treated with hormone in contrast to the control 40%, 50% and 10% respectively. In *B.balcooa* they obtained 40% success in branch cuttings, and 60% in culm-cuttings. Effective hormones were IBA and NAA. They also believed that the starch content and the levels of various nutrient in the cuttings might have influenced the rooting. In fact, Joseph (1958) and Gupta and

Pattanath (1976) observed seasonal variations in the amount of starch and N,P,K, Ca and Mg in *B.arundinacea* and *D.strictus* respectively. Joseph (1958) found high amount of starch content in culm cutting of *B.arundinacea* during February and March. According to Surendran and Seetalakshmi (1985) some species have rooted successfully without growth regulator. In reporting the success for culm cuttings, Banik (1987b) emphasized that preparation of culm segments in the month of April-May from the mid-zone of a young culm was critical for obtaining successful results. Palijon (1983) reported that cuttings treated with rooting hormones were higher in shoot production and the shoots were taller and wider in diameter than those of untreated cuttings, but there were no differences in survival rate at field level between them.

While reporting the success of branch cuttings in bamboo propagation, Delgado (1949) and White (1947b) pointed out that root promoting substances, normally do not have any effect. However, they did not mention any name of the root promoting substance.

Propagation condition for rooting of bamboo cuttings: There are only a few reports available about the effect of propagation conditions on rooting of bamboo cuttings. Mabayag (1937) found that *B.blumeana* culm-cuttings sprouted and survived better under direct sunlight than they did under full shade. However, studies of Delgado (1949) indicated that cuttings planted in shade rooted better than those in sunlight. Abeels (1962), while studying the propagation of *B.vulgaris*, *D.strictus*, *G.aspera* and *Oxytenanthera abyssinica*, observed that planting medium such as soil and sand of nursery beds or water logging did not affect rooting if the branch cuttings include basal swellings. He also noticed if the middle portion of the internode (culm-segment) was perforated and filled with water, to maintain high humidity in the culm

cavity, rooting was promoted vigorously. Rainfall in the preceding month of extraction of culm appears to be an important factor influencing rooting (White 1947b). Surendran and Seethalakshmi (1985) reported that culm-cuttings extracted and treated during summer months (February-May) gave better response than in other months. According to them this could be correlated with the high temperature and low precipitation prevailing during this period.

Multiplication of bamboo seedlings: Another interesting technique has been developed by Banik (1987b) for multiplication of seedling number through rhizome separation method. He termed the technique as macroproliferation. Later on, Kumar et al. (1988) also used the macroproliferation technique for multiplying the seedlings of *D.strictus*.

3.2.3 Micro-asexual propagation

Research on the tissue culture of bamboos was started by a preliminary study by Alexander and Rao (1968) to investigate the possibility of rescuing non-viable hybrids between *Bambusa* and *Saccharum* species. Alexander and Rao (1968) have standardised the growth requirements of bamboo embryo in artificial nutrient medium. They observed that mature embryos of bamboo grew satisfactorily on a medium containing 2% sucrose and Whites major and minor elements. After few years Tseng et al. (1975) reported successful isolation of protoplast from the leaves of *Bambusa* sp. in an enzyme-screening test.

The explant: Various explant tissues have been successfully used for regenerating the plantlets of different species of bamboo in *in vitro* condition. The explants which have been

used for callus induction in bamboo are mature embryos from seeds (Alexander and Rao 1968, Mehta et al. 1982, Rao et al. 1985), inflorescence (Yeh and Chang 1986a, 1986b, Nadgauda et al. 1990), leaves (Hassan and Debergh 1987, Prutpongse and Gavinlertvatana 1989), culm sheath base (Dekkers and Rao 1989), shoot tips (Huang and Murashige 1983, Huang 1988), and internodal section including the intercalary meristem (Dekkers 1989, Zamora et al. 1989). For direct development and proliferation of axillary shoots in different species of bamboos dormant culm buds (Banik 1987b), stem bud segments (Prutpongse and Gavinlertvatana 1989), and 10-15 mm one node segment from fresh lateral branches (Nadgir et al. 1984, Zamora et al. 1989, Dekkers and Rao 1989) were used. Banik (1987b) studied the capability of different explant tissues - young branch nodes, dormant culm buds, non-dormant culm buds, and emerging shoot (culm) tips in *in vitro* culture of *Bambusa glaucescens*. He observed that only the dormant culm bud explants grew, while other explants did not develop.

Tissue sterilization: Surface sterilization of explants is usually done with ethanol, dilute sodium or calcium hypochlorite, detergent, or a combination of these. The effectiveness of most sterilizing chemicals has been enhanced by adding a small amount of detergent, such as Tween 20 (polyoxyethylene sorbitan monolurate), into the sterilizing solution (Hughes 1981). The detergent helps in wetting the tissue surface and in allowing the chemical to penetrate and destroy the micro-organisms (Yeoman and Macleod 1977).

Young inflorescences of *Bambusa beecheyana* Munro var. *beecheyana* were excised and soaked in 0.01% Antiseptol (benzethonium chloride 10% and alkyl - arylpolyether alcohol 10%) for 3 hours, then wetted with ethanol for 1 minute, and finally rinsed thoroughly in sterile distilled water (Yeh and Chang 1986a). In culturing *Dendrocalamus strictus* Rao et al.

(1985) have washed the dehusked seeds in 2% Teepol solution on a magnetic stirrer for 5 minutes and finally washed the tissue in running tap water for 15-20 minutes followed by a rinse in distilled water. Finally sterilization was done by a 5 minute immersion of seeds in chlorine water (saturated chlorine water diluted 5 times with distilled water) followed by thorough washing in distilled water. Nadgir et al. (1984) have surface sterilized the nodal segments of *D.strictus*, *Bambusa arundinacea* and *B.vulgaris* with 0.1% mercuric chloride for 10 minutes for obtaining aseptic culture of the species. Zamora et al. (1989) have reported that for obtaining aseptic culture of *Dendrocalamus latiflorus* cv Machiku, the nodal sections were wiped with ethanol soaked cotton wads, washed in soapy water for 6 minutes, soaked in streptomycin (1 g/l) for 60 minutes and immersed in pure commercial bleach for 60 minutes. Sections were rinsed thrice with sterile distilled water. Leafsheaths were then removed and two internode sections, each approximately 2 mm long, were inoculated on to the culture media. Dekkers and Rao (1989) surface sterilized the base of young culm sheath with 80% ethanol for callus induction in *Bambusa ventricosa*, *Schizostachyum brachycladium* and *Thyrsoestachys siamensis*, whereas for disinfecting the nodal segments of the same species they have soaked the tissues in sodium hypochlorite (2%) for 20 minutes and rinsed three times in sterile distilled water. In disinfecting the dormant culm bud explants of *B.glaucescens*, Banik (1987b) has used 20-30% "Javex" (5-6% sodium hypochlorite) for at least 20 minutes.

Nutrient medium and growth regulator: During first part of eighties a team of scientist Mehta, Ramanuja, Rao and Mohan Ram (1982) first reported the success in *in vitro* culture of somatic embryos of *Bambusa arundinacea* by using seeds as explants. They have incorporated 2,4-D (3×10^{-5} M), BAP (5×10^{-6}

M) and polyvinylpyrrolidone (PVP) 250 mg/l into the medium. Within a few years similar findings on somatic embryogenesis in *Dendrocalamus strictus* was also reported by Rao et al. (1985). Both papers give an account of callus induction and the formation of plantlets. Huang and Murashige (1983) demonstrated that callus could be initiated from shoot tips of *Bambusa oldhamii*, *B.multiplex*, *Sasa pygmaea* and *Phyllostachys aurea* on MS medium, 3% sucrose, vitamins, glycine, 3 mg/l 2,4-D and 0.5% agar. Callus grew vigorously when incubated in darkness at $\pm 27^{\circ}\text{C}$. They have provided a detailed study of the organic requirement of the bamboo callus tissue. Inositol (100 mg/l), thiamin (1 mg/l) and nicotinic acid (0.5 mg/l) were found to be beneficial for callus growth. Seeds of *D.strictus* (Nadgir et al.1984), *D.brandisii* and *B.arundinacea* (Nadgauda et al.1990) were germinated in dark successfully on White's medium (White 1963) in order to obtain multiple shoots by transferring the explants from White's medium to MS medium supplemented with BAP and Coconut milk (CM). Production of number of shoots from the explant of *D.strictus* was influenced by the condition (liquid or solid) MS medium supplemented with different concentration of both K(0.2-0.5 ppm), BAP (0.5-10 ppm), IAA(0.05 ppm) or NAA (0.05 ppm) and CM (5-15%). Nimunuan Vasana et al. (1984) reported bamboo seeds germination and multiple shoot production *in vitro*. They were able to germinate the seeds of *B.arundinacea*, *Thyrsostachys siamensis* and *Gigantochloa hasskarliana* on MS medium supplemented with White's vitamins. Multiple shoots were developed from seedlings. Callus was initiated from young leaf of *B.flexuosa* which was cultured on MS medium supplemented with 3-6 mg/l 2,4-D whereas in *B.arundinacea* and *T.siamensis* 1-3 mg/l 2,4-D was required. They have further demonstrated that plantlets could be regenerated from callus by subculturing the same on media containing 2 mg/l BAP and 0.5 mg/l NAA. Zamora et al. (1989) reported that in *Dendrocalamus*

latiflorus cv Machiku 2,4-D (1-25 ppm) was effective in inducing callus from young internode tissue or shoot and plant regeneration, the important factors were the type of callus and the growth regulators, particularly BAP in the medium (1 ppm). The optimum concentration of sucrose that is commonly used for callus growth is 20-30 g/l. However, other authors used sucrose in much higher levels, 50 g/l (Mehta et al. 1982) or 60 g/l (Yeh and Chang 1986a, 1986b) of media.

Nadgir et al. (1984) have successfully demonstrated the development of multiple shoots (2-3 number) from the 80% of explants (nodal segments) collected from the mature clumps of *D.strictus*, *B.arundinacea* and *B.vulgaris* within 3-4 weeks after culturing on semisolid MS medium supplemented with K (0.2 ppm), BAP (0.5 ppm) and 10% CM. Rooting was poor even after transfer on fresh medium supplemented with IBA (1.0 ppm). Seedling - derived shoots could be rooted in liquid medium with the application of IBA. They further observed that activated charcoal (AC) was essential for root initiation from mature explant while it was not essential for seedling - derived shoots of *D.strictus*. Chaturvedi and Sharma (1988) incorporated phloroglucinol in the medium and kept the nodal explant in an inverted position to induce rooting in *D.strictus*. In the same species Dekkers (1989) also obtained multiple shoots from the embryo. However, only few of these shoots could be rooted on subsequent transfer to a rooting medium. Dekkers and Rao (1989) observed axillary shoot development from the nodal explant of *B.ventricosa* while placed on to the MS medium supplemented with 0.3-25 mg/l BAP. But rooting was not obtained in these shoots. Banik (1983b, 1987b) also obtained multiple shoots directly from the vegetative explants of *B.glaucescens* after culturing and followed by two successive transfer on to the modified MS medium supplemented with 4% sucrose, BAP (1.0 mg/l) and AC (3 g/l). According to him rooting of the shoots was possible

after transferring to the fresh medium supplemented with NAA (0.5 mg - 1.0 mg/l), and BAP (from 1.0 - 7.0 mg/l). The plantlets attained 12 cm height after 4 months of culture and then successfully transferred to the soil after 5 months. Rao et al. (1990) reported that the medium used for bamboo tissue culture has mostly been the MS medium and only embryo cultures were induced on other media such as B₅

Cultural condition: Mehta et al. (1982) reported that callus culture of *Bambusa arundinacea* was maintained under a 16-hr daily light regime (1500 lux from cool-white daylight fluorescent tubes) at $27 \pm 2^{\circ}\text{C}$. However, Yeh and Chang (1986b) reported no difference between continuous darkness and a 16/8 hr. day/night regime at $26 \pm 1^{\circ}\text{C}$ on callus development in *B. beecheyana*. Incubation in continuous darkness has been found to be effective for callus induction of some bamboos (Huang and Murashige 1983). Dekkers and Rao (1989) incubated cultures of *Shizostachyum brachycladium*, *T. siamensis* and *B. ventricosa* at $27 \pm 2^{\circ}\text{C}$ and exposed to a 12-hr photoperiod except for the callus induction phase during which the cultures were kept in the dark, whereas Rao et al. (1985) and Hassan and Debergh (1987) used continuous light. Direct axillary bud proliferation and plantlets production was achieved by incubating the explant of *B. glaucescens* in 28°C under 14-hr photoperiod (Banik 1987b).

Success of *in vitro* propagation of bamboo: The application of the methods of micropropagation is, however, still limited, since there has been partial success using nodes or other materials from mature, adult bamboo plants by which 'cloning' of these (making multiple, identical copies of the parent plant) could be achieved (Rao and Rao 1990). So far only about 4-10% of the shoots obtained from mature nodes (depending on the species) in culture can be induced to root.

Better success has been obtained with seedling material (Nadgir et al. 1984, Mascarenhas 1989) but this does not satisfy the objective of cloning mature and elite bamboos (Rao and Rao 1990). Somatic embryogenesis offers another easy method for mass propagation. But one limitation of this method at present is that somatic embryogenesis is possible only from juvenile tissue either from seed or seedling (Rao et al. 1990).

4.0 MATERIALS AND METHODS

The present investigations were made on two major aspects --- Biology and Propagation. Apart from this efforts were also made to collect and centralize the germplasm of different bamboo species available in the country. Details of germplasm collection and centralization has been discussed under 4.3.

All together 17 naturally grown and cultivated species of Bangladesh have been taken into consideration. These are:

Naturally grown:

Bambusa tulda, *Dendrocalamus hamiltonii*, *D.longispathus*, *Melocalamus compactiflorus*, *Melocanna baccifera*, *Neohouzeaua dullooa*, *Oxytenanthera nigrociliata*

Cultivated:

Bambusa arundinacea, *B.arundinacea* var.*spinosa*, *B.balcooa*, *B.glaucescens*, *B.longispiculata*, *B.nutans*, *B.polymorpha*, *B.vulgaris*, *Dendrocalamus giganteus*, *D.strictus*.

However, it was not possible to study all these species under each of the following parameters of biological and propagational investigations due to their non-availability in sufficient numbers and in flowering stage.

Most of the biological and propagational studies were conducted in the bamboo garden (*Bambusetum*) established in the Bangladesh Forest Research Institute (BFRI) campus Chittagong. The soil and climatic conditions and the maintenance procedure of bamboos in the *bambusetum* are given below:

Bambusetum: The bamboo garden or arboretum is known as the Bambusetum (Jain and Rao 1977). In the Bangladesh Forest Research Institute (BFRI) campus the bambusetum occupies on the west-east slope with hills on the north, south and west having a valley in between. The lower slope is towards the east of the valley. The total land areas of the bambusetum is approximately 0.25 ha.

Eroded, acidic, loams overlaying an unconsolidated sedimentary rock occur on steep slopes. Hill summits have an Aridic or Ustic (biologically dry for more than 90 consecutive days) soil moisture regime. Soils of the middle and lower slopes are deep. Soil moisture regime varies from Udic (biologically not dry for more than 90 consecutive days) to Ustic based on steepness of the slope (Hassan et al. 1988). According to Hassan et al. (1988) Oxic Dystropepts (brown forest soils) occur on the steep slopes (> 30%), Typic Tropudults (yellow-brown forest soils) occur on the middle and lower slopes and Dystric Tropaquepts (low humic glei soils) occur in the imperfectly drained valley, where the soils are coarse, loamy, acidic (pH around 5.5) having and Udic soil moisture regime.

The land of the bambusetum is under the influence of tropical monsoon climate having a range of annual air temperature 10-35°C, soil temperature 22-29°C at 50-200 cm depth, and total annual rainfall 2500mm-3000mm. Rainfall is high during the last part of May to August and dry months are mostly from November to March.

In the bambusetum different bamboo species have been planted in several lines since 1973-74. Culms produced in the clumps of each species were marked every year by different colour paints on the internodes to recognise the year of emergence.

The following colour and bands were used to mark the bamboos in the corresponding year of emergence.

<u>Marking on the internode</u>	<u>Emergence year</u>
A small tin plate	1974
One black band	1975
One white band	1976
One red band	1977
One yellow band	1978
One blue band	1979
Two red bands	1980
Two white bands	1981
Two yellow bands	1982
Two black bands	1983
Three red bands	1984
Three white bands	1985
Three black bands	1986
Three yellow bands	1987
One yellow band & a cross	1988
One red band & a cross	1989
One black band & a cross	1990

Weeding and maintenance (such as, adding of soil to the clump bases, clearing and cleaning of rotten bamboo shoots and twigs, etc.) operations have been carried out annually.

4.1 Biology: Efforts were made to study the distribution and site conditions, clump habit and appearance, periodicity of culm emergence, culm elongation, culm production and clump expansion behaviour, culm size and dimension, morphology of culm in relation to age, rhizome growth and development, juvenile and adult culm mortality, flowering cycle, flowering and seeding nature, precocious flowering, selection and collection of different "flowering genotypes", and natural

regeneration after flowering in different bamboo species of Bangladesh.

4.1.1 Clump habit and physical appearance

Ocular observations on the clump character of each of the bamboo species both from forest and village were made. The clump characters of each of the bamboo species when looked different were described. No details of the morphological characters were noted, only the diagnostic characters were described. Observations were made mainly in the BFRI Bambusetum. The natural habitat and/or cultivation in the rural areas are described from the observation under 4.1.2.

4.1.2 Distribution and preliminary assessment of ecological conditions and species composition in the forests and villages

Frequent visits were made in different forests and rural areas of the country. Qualitative assessments on the species compositions and observations on site conditions were recorded in the following forest localities:

Chittagong: Sitakunda Hills, Karerhat, Koilabeat, Andharmanik, Hazarikhil, Fatikchari, Bhomariaghona, Harbang-Dulahazara Road, Banshkhali.

Chittagong Hill Tracts: Ramgarh, Kaptai (East and West Range), Rajasthali, Bandarban (Chimbuk Hills), Alikadam, Ghagra, Rangamati-Chandraghona Road, Khagrachari-Kamalchari Road, Kassalong.

Cox's Bazar: Ramu, Rajarkul, Panerchara-Teknaf link road.

Sylhet: Lawachara, Adampur, Juri, Sagarnal, Kalenga, Rangunandan Reserve, Champarai. Khadimnagar, Tilagarh.

Dhaka-Mymensingh: Sal forest of Salna-Joydebpur, Madhupur, Rangtia, Gazni, foot of Garo Hill near Gazni, and Dinajpur sal forest.

Observations were made in different years mostly within 1987 to 1990. Site conditions were noted only from ocular observations. Information on the climatic conditions, wherever available, were collected. Occurrence of different bamboo species in the rural areas were recorded during occasional road travels and walking in the villages. Only qualitative observations were made on the occurrence of bamboo species from Dhaka, Tangail, Mymensingh, Faridpur, Pabna, Bogra, Jessore, Rajshahi, Kushtia, Barisal, Patuakhali, Khulna, Dinajpur, Rangpur, Comilla, Noakhali, Chittagong, Chittagong Hill Tracts and Sylhet.

4.1.3 Periodicity of culm emergence

Studies were undertaken on the adult clumps of the following species:

Bambusa balcooa, *B. glaucescens*, *B. longispiculata*, *B. nutans*, *B. polymorpha*, *B. tulda*, *B. vulgaris*, *D. giganteus*, *D. longispathus*, *D. strictus*, *Melocanna baccifera*, *Neohouzeaua dullooa*, *Oxytenanthera nigrociliata*

All *Bambusa* and *Dendrocalamus* species were planted through offset, whereas part-clump (a group of 3 offsets jointed by rhizome neck) planting were made for *Melocanna baccifera*, *Neohouzeaua dullooa* and *Oxytenanthera nigrociliata* during 1973-74 in the central Bambusetum of BFRI.

The soil temperature ($^{\circ}\text{C}$) at three different depths (50, 100, 200 cm), air temperature ($^{\circ}\text{C}$), and relative humidity (%) were measured and recorded daily at 8 am in each month of the year in Bambusetum during the study period. Monthly rainfall data were also collected.

Observations were made on the number of culm emerged per clump in each species at different months of the year after planting. The investigations were continued for 3 consecutive years on 10 clumps of each species.

4.1.4 Culm elongation

Investigations on the daily elongation of the emerging culms of the following three major bamboo species of Bangladesh were continued during growth period (June-October) of 1984. The species were *Bambusa balcooa*, *B. vulgaris*, and *Melocanna baccifera*.

The studies were conducted at the Bambusetum of BFRI on the nine years old clumps of each of the above mentioned species. Three culms of each species were studied.

Just after the appearance of newly emerged culms on the soil they were marked separately for each species. The heights of the elongating culms were recorded daily at 8 a.m. Day to day height measurement was easy at the beginning. But later on a digital measuring pole graduated in centimeter was used to measure the height of tall culms. Data recording was continued till the culms completed its elongation.

4.1.5 Natural mortality of emerging culms

The study was conducted at BFRI Bambusetum. Five years old clumps of 8 bamboo species, namely, *Bambusa balcooa*

B.longispiculata, *B.nutans*, *B.tulda*, *B.vulgaris*, *Dendrocalamus giganteus*, *D.longispathus* and *Melocanna baccifera* were studied for three years (1978-1980).

Number of dead and living culms out of total culms produced per clump of each species was recorded during the growing season of the year. The length of dead shoots was recorded to find out at which height maximum mortality occurred. The relative distance of dead culms from the nearest older culm was also noted.

4.1.6 Culm character -- internode length, wall-thickness and diameter ratio

The length, mid-diameter of each internode and culm-wall thickness at every fifth internode from base to tip of each of the following species were measured by slide caliper and a metric tape. The species were: *Bambusa balcooa*, *B.polymorpha*, *B.tulda*, *B.vulgaris*, *Dendrocalamus giganteus*, *D.longispathus*, *D.strictus*, *Melocanna baccifera*, *Neohouzeaua dullooa*, *Oxytenanthera nigrociliata*

The investigations were made at BFRI Bambusetum on the 3 years old culms. The culms were felled from the 10 year old clumps. For determining the age of full grown culm the paint marking on the internode at the year of emergence was considered. All the measurements were taken and recorded during December-January.

4.1.7 Culm production, growth and clump expansion behaviour

Studies were conducted on *Bambusa balcooa*, *B.longispiculata*, *B.tulda*, *B.vulgaris*, and *Melocanna baccifera*. Twenty clumps for each *Bambusa* species and 10 clumps of *Melocanna baccifera* were investigated.

All the clumps of *Bambusa* and *Dendrocalamus* species were raised through offset planting and those of *Melocanna baccifera* were raised through part-clump (a group of 3 offsets jointed by rhizome neck) planting. The species were planted in the BFRI Bambusetum in 1973. The full grown (FG) culms produced in all the clumps of the above species were marked every year by different colour paints for recognizing the age of both culm (year of emergence) and clump. Number of FG culms produced per clump were recorded. Culm diameter at breast height (DBH) was measured by slide caliper, and their length and annual increase of the girth of the clump were measured by a metric tape, each year after (1973) plantation.

Data were recorded every year at the end of the growth period (December) and these observations continued for subsequent ten years (from 1973 to 1982). During the study period all the clumps were allowed to grow in undisturbed conditions and no felling operations were practiced.

4.1.8 Natural senescence of culms

Studies on the natural longevity of the culm were conducted on 12-15 years old culms of the following species at BFRI Bambusetum. The species were: *Bambusa balcooa*, *B. longispiculata*, *B. polymorpha*, *B. tulda*, *Dendrocalamus giganteus*, *D. longispathus*, *Melocanna baccifera* and *Oxytenanthera nigrociliata*. All the clumps of the above species were raised through offset planting. Culms produced in the clumps were marked every year by colour paint to recognise the year of emergence and from that age of the culms in a clump were calculated. No felling operation was carried out from the clumps under study. Observations on the natural death of the culms in the clumps of each species were recorded during December-January. The number of dead and living culms

out of total full-grown standing culms from each age group (marked by separate colour) in a clump of each species were counted. The study was repeated in 10 clumps for each species excepting in *D.giganteus* and *O.nigrociliata*. Only one clump in each of these 2 species was investigated. Finally the percentage of dead culm in different age groups was estimated.

4.1.9 Morphological characters for culm age determination

Bamboo is a monocotyledonous plant and thus no secondary growth takes place in the culm and has no growth rings. Generally, a farmer makes distinction between "mature" and "immature" culm by flipping or tapping with fingers. From the sound he can distinguish the group. Sometimes the colour of the culm is also considered. The following morphological characters such as, presence or absence of culm sheath, branching intensity, presence or absence of adventitious roots on the basal nodes, and colour and surface of the culm were considered in the study.

Investigations were conducted on the five major bamboo species of Bangladesh. The species were: *Bambusa balcooa*, *B.longispiculata*, *B.tulda*, *B.vulgaris* and *Melocanna baccifera*

In each of the above species 10-15 clumps were planted in the BFRI bambusetum during 1974-1975. Every year new culms had emerged in each of the clump. The emerged culms were marked by separate colour paint. Different colour paint (as mentioned under Bambusetum) indicated the different year of culm emergence. The observation was made during 1980. The culms which emerged in 1975, 1976, 1977, 1978 and 1979 were 5, 4, 3, 2, and 1 year old respectively at the time of observation. All the above mentioned morphological characters were observed and recorded from the culm of 1, 2, 3 and 4 years of age group. The observations were confined upto 4 years old culm as

bamboos are believed to attain maturity (Liese 1985, McClure 1966, Ueda 1960) within 3-4 years of age.

**4.1.10 Rhizome growth and culm development in
*Melocanna baccifera***

Muli bans (*Melocanna baccifera*) has open and diffuse type of rhizome system with long (1-1.5 m) rhizome necke while other species in the country have very short rhizome necks forming clumps. It is not known when such long rhizome necks of *M.baccifera* starts growing and by how much time it completes its development before producing a new daughter culm. Therefore, to investigate the growth periodicity of daughter rhizome in *M.baccifera*, soil around 30 newly emerged culms were excavated carefully so that underground portion did not get any injury. Thus, the underground rhizome systems were exposed and the length of the rhizome neck was measured. Then soil along the paths of the rhizome necks were also dug for observing their movement pattern and measuring the distance travelled by the rhizome neck. The measurements were recorded at every week, upto the emergence of daughter culm in the next year. After each observation the rhizome necks were again covered loosely with soil. The study was undertaken in the BFRI bambusetum during 1987-1988.

The observations were recorded on initiation and movement of daughter rhizome necks from the mother rhizomes, and emergence of new culms in relation to time and seasons of the year. Time required for complete elongation of mother culms, initiation of bud break, branches and leaf development were also recorded.

4.1.11 Estimation of flowering cycle

Flowering dates of different species were collected from existing literature. Occurrence of flowering during last 20 years in Bangladesh was also recorded. Tabulating the consecutive flowering dates of each of the following species, the flowering interval/cycle was calculated. The studies were made on *Bambusa balcooa*, *B. polymorpha*, *B. tulda*, *B. vulgaris*, *Dendrocalamus longispathus*, *Melocalamus compactiflorus*, *Melocanna baccifera*, *Neohouzeaua dullooa*, *Oxytenanthera nigrociliata*.

4.1.12 Flowering biology

The following bamboo species flowered in the central bambusetum of BFRI during 1975-1990.

Bambusa arundinacea var. *spinos*a: Clump No. 39/1, 39/2, 39/3 (3 clumps flowered in 1980)

B. glaucescens: Clump No. 3/3 (1 clump flowered in 1977)

B. longispiculata: Clump No. 22/1, 22/2, 22/3, 22/5, 22/6 (5 clumps flowered in 1978)

B. tulda: Clump No. 27/1, 27/2, 27/3, 27/4, 27/5 (5 clumps flowered in 1984)

Dendrocalamus longispathus: Clump No. 26/1, 26/2, 26/3, 26/5, 26/6, 26/7, 37/16 (7 clumps flowered during 1977-1979)

While visiting Lawachara Silvicultural Research Centre at Sylhet, 5 more flowering clumps of *B.tulda* were also observed during 1978. Besides these 5 species, two other species also flowered within 3 miles of BFRI Chittagong. The species were:

B.vulgaris: Seven clumps flowered at Faridarpara (homestead of Mr. Kabir Contractor near Bardarhat, Chittagong) during 1979

Melocanna baccifera: Five clumps flowered at Fatehabad (homestead of Mr. Munshi Mia), near University Road, Chittagong during 1990.

All the flowering clumps of these 7 species were observed mainly on the following aspects.

- i) Inflorescence character: All the floral parts were described and measured whenever necessary.
- ii) Flowering nature and duration: Clumps those completed flowering within 1-year and then died, have been termed as *Complete-flowering*; those completed flowering within 2- or more years, then died or revived and stopped flowering, have been termed as *part-flowering*, and those in which flowering occurred every year, and did not complete flowering and also did not die have been termed as *continuous flowering*.
- iii) Blooming nature, anthesis and pollination behaviour: Time of blooming and anthesis were recorded. Two flowering branches from two different neighbouring clumps were brought together and then 10 unbloomed pseudospikelets from each branch bagged in the same bag to

facilitate cross pollination. Similarly ten pseudospikelets in the clumps were bagged separately to facilitate selfing. The seed yield in each of these two conditions (crossing and selfing) were counted and recorded. Studies were confined only on *B.arundinacea* var. *spinosa*, *B.glaucescens* and *D.longispathus*. Cross pollination study was not possible in *B.glaucescens* as only one clump flowered in the species.

- iv) Culm emergence and flowering: Culms present in the flowering clump were counted and their ages were identified from their colour marking. Finally number of culms produced in the current and preceding years of flowering in each clump were determined.
- v) Seeding season and adaptation: Seeding seasons of different bamboos that observed since 1974 were interpreted in relation to natural regeneration.

4.1.13 Precocious flowering

Observations were made on the flowering nature of different bamboo speices during 1974 to 1990. During this period seedling of *B.tulda* and *M.baccifera* flowered precociously. Different informations including flowering and monocarpic nature of the progenies of these species were recorded.

4.1.14 Selection and collection of "flowering genotypes"

It is evident from the the literature that both clump forming and non-clump forming bamboo species might have more than one "flowering genotypes", that is, all the clumps

of a species in a particular locality may not flower at a time and may show variation in interseeding period. Since 1974 efforts were made to locate, select and collect those "flowering genotypes" of the local species as much as possible whenever observed in the fields. Any sorts of propagules such as seeds, seedlings or vegetative parts were collected from those genotypes and centralized inside the central bambusetum of BFRI, Chittagong.

4.1.15 Natural regeneration after flowering and its maintenance

Many clumps of *Bambusa tulda* flowered and ultimately died during 1978-79 at Sagornal Block of Patharia Reserve of Sylhet forest, and also in 1983-84 at bambusetum of BFRI, Chittagong. Similarly *Dendrocalamus longispatus* flowered in Koila Block of Karerhat, Chittagong forest and at bambusetum of BFRI during 1972-73 and 1977-79 respectively.

Huge number of seedlings were produced naturally on the forest floor after the dropping of seeds from the flowering clumps of these two species.

Observations were made in the population density of bamboo seedlings of these two species by counting the seedling numbers at different months upto one year of age in the following habitat conditions: in full weed exposed, in less weed exposed, in partial shade and less weed, in complete shade and less weed.

No artificial shade was maintained. Plots which were under the shade of living bamboo clumps situated nearby were treated as complete shade. The partial shade condition was considered when the plots were under the shade of dead leafless flowering mother bamboo clumps.

For each species counting was made in ten quadrats of 10 x 10 cm, under above conditions at BFRI bambusetum. Growth of the seedlings (height and diameter of culms in each clump, culm produced per clump) were measured at 3, 6 and 12 months age only under the above conditions. Effect of burning due to jhuming and clear felling of the dead mother bamboo clumps on the establishment (number per 100 sq cm) of the regenerating bamboo seedlings at 1-3 months and 6-9 months of age were assessed in Koila Block and Sagornal Block of the natural bamboo forest.

To minimize the competition between the wild seedlings, these were thinned at 2-4 leaved stage (30-45 days age). Thinning or removal of seedlings was done in such a way so that only 13-14 seedlings were left per 100 sq m. The density and growth of the seedling were also counted in both thinned and unthinned plots under partial shade conditions.

4.2 Propagation

Studies on bamboo propagation were conducted on three major aspects --- sexual (seed), macro- and micro-vegetative propagation.

4.2.1 Sexual propagation

4.2.1.1 Seed morphology and germination

As per availability of flowering and seeding the species were selected for study. The name of the species, seed source and year of study are given below:

Species	Seed source	Seed collection and study year
<i>Bambusa arundinaceae</i> var. <i>spinosa</i>	Bambusetum BFRI	1980
<i>B. glaucescens</i>	Bambusetum BFRI	1972
<i>B. tulda</i>	Shishak CHT*	1977
	Adampur Syl*	1978
	Lawachara Syl*	1979
<i>Dendrocalamus</i> longispathus	Bambusetum BFRI	1978
<i>Melocanna baccifera</i>	Nazirhat	1989
	Hyanko	1989
<i>Oxytenanthera</i> nigrociliata	*Publakhali, CHT	1978

* CHT = Chittagong Hill Tracts, Syl = Sylhet

Bamboo fruit is one seeded and known as *caryopsis*. However, the term "seed" will be used instead of *caryopsis* as the word is commonly used by foresters.

Seeds were collected and brought to the Silviculture Genetics Division, BFRI, Chittagong. Observations were made on the seeds of all the above mentioned species.

At first seeds were qualitatively described. In each species, the measurements on size including length, width, breadth and diameter were recorded from 50 samples randomly drawn from the collected stock. As the pericarp and the seed

coat were fused, it was not possible to separate the seed from the fruit cover without any injury. However, the measurements were done with glumed (covered with glumes) and deglumed (glume removed) seeds. The measurements on weight of individual seed was taken only in the case of *M.baccifera* from 150 samples taken randomly. Both glumed and deglumed seeds of other 5 species were weighed on the basis of number of seeds present per 10 gm. Here measurements were repeated on 30 random samples. All the measurements were taken within 3-5 days of receiving the seed samples.

Excepting *M.baccifera*, glumed seeds of all other species were separated from debris and empty seeds by floating in water. Floated materials were thrown away and the seeds which sank, were used in studies. As the seeds of *M.baccifera* were big and not covered with glumes they could be separated easily from debris and unwanted materials. So floating test was not done for *M.baccifera*

Germination tests: At the beginning, both glumed and deglumed seeds of all the species (except *M.baccifera*) were sown on the moist blotting paper in petri dishes. However, fungal infection occurred in deglumed seeds, and therefore glumed seeds of each species were used in the following methods of germination tests.

(a) Petri dishes: In each test fifty glumed seeds were sown in petri dishes. For most of the times 6 replications were used.

(b) Polythene bags: Two hundred glumed seeds were directly sown in 200 polythene bags (10 x 15 cm) with 3 replications. Each bag contained hill soil and cowdung in the ratio of 3:1. Similarly randomly selected 200 seeds of *M.baccifera* were also sown in 200 polythene bags in 3 replications. The bags were placed in the sun and irrigated regularly.

Effect of light on the seed germination of *B.tulda*, *D.longispathus* and *M.baccifera* was investigated by placing the polythene bags both under nursery shed (diffused light) and open sky (sunlight). In each of these 3 species seeds were sown in 200 polythene bags with 3 replications. Big size (15 x 22 cm) polythene bags were used in case of *M.baccifera* as the species produced big size seeds.

c) **Nursery beds:** Germination response from broadcasting glumed seeds in nursery beds was studied only with *B.tulda* of Shishak source as sufficient amount of seeds were available. One kg of glumed seed (approximately 14000 in number) were sown in a nursery bed measuring 1.2 x 11.0 m (4' x 36') containing soil and cowdung in the ratio of 3:1. The experiment was repeated thrice. One hundred seeds of *M.baccifera* were also sown in a nursery bed prepared under open sky.

d) **Seed weight and germination:** As the seed weight in *M.baccifera* varied from 7.0 to 150.0 g, these were grouped into three grades - heavy (grade I, 51.0 g and above), medium (grade II, 26.0 - 50.0 g), and light (grade III, 1.0 - 25.0 g). Thirty seeds from each of the three grades (heavy, medium and light) were randomly sown in polythene bags under open sky in the nursery. The germination percentage was measured in each of the grades. Seedling nature and growth due to three different grades of seeds were also studied upto 3 months in the nursery.

All the germination trials were made during the months of May and June. Experiments stated under method (a) were carried out in room temperature (maximum 29.9⁰C, minimum 25.2⁰C) whereas other methods (b,c and d) were tested at the nursery of BFRI Chittagong. The average climatic conditions at the nursery during that time of the year were -- maximum temperature 31.1-29.8⁰C, minimum temperature 22.8-23.4⁰C, rel.humidity 64.7-68.6%, and total rainfall 278.0-800.0 mm.

4.2.1.2 Investigation on the seed longevity and storage technique

Depending on the seed availability studies were carried out on four bamboo species. These were *Bambusa arundinacea* var. *spinosa*, *Bambusa tulda*, *Dendrocalamus longispathus*, *Melocanna baccifera*. The seed source and seeding time of all these species have been described under 4.2.1.1

Just after collection seeds of *B. arundinacea* var. *spinosa*, *B. tulda*, *D. longispathus* were stored in small jute bags under normal room conditions. From the collected stock 50 glumed seeds were sown in petridishes at 10 days interval in 4 replications on different dates to determine the life span of stored seeds. The study was continued until germination had ceased (May-July). Average room conditions during the study period were as follows:

Month	Temperature °C		Relative humidity % (Avg.)
	Max.	Min.	
May	29.9	25.2	58.3
June	28.6	24.4	66.6
July	27.8	24.1	66.4

The amount of seeds collected for *B. glaucescens* and *O. nigrociliata* was not sufficient to conduct the study on these 2 species. In case of *M. baccifera* seeds were stored inside a jute bag at normal room temperature and sown in polybags under shade. Seeds were sown at different dates from the stock collection. On each date thirty seeds were sown.

About 0.25 kg glumed seeds of *B. tulda* were stored inside a desiccator containing Sorbisal Brand silica gel at room temperature. One hundred seeds were sown in petri dishes for germination test at an interval of 3 months from the

storage. It was not possible to determine the moisture content of seeds due to limited number of seeds. About 300 seeds of *M.baccifera* were stored in airconditioned room (temperature was about 21⁰C and humidity was about 60%), and 300 seeds inside dry sands in a jute bag kept in a room. Sand was selected as seed storing medium because Troup (1921) reported that when seeds were sent to a distance these were packed in dry sand. Thirty seeds from both these two conditions were taken randomly and sown after 15 days interval in a polythene bag till the ceasation of germination.

4.2.1.3 Seedling growth and management at nursery

a) Shoot emergence and growth, leaf size and rhizome development: The study was confined mainly to *Bambusa tulda* and *Melocanna baccifera*. These two species were representing two major genera of bamboos of Bangladesh. In each of these two species 1500 seedlings were raised in the polythene bags (15x25 cm) containing soil and cowdung in 3:1 ratio. The seedlings of *B.tulda* were raised from the seeds collected from Shishak during 1977 and the study was continued thereafter from 1977-1979, while in *M.baccifera*, the study was undertaken during 1989-1990 as the seedlings were raised at that time from the seeds collected from Hyanko forests.

The following observations were taken since the initiation of shoots in the seedlings:

I). The number of culm successively emerged and died in the seedling and their individual length and diameter at collar zone were recorded.

II). After subsequent 3,6,10, 14, 19 and 24 months of seedling age, randomly 10 seedlings were selected from the nursery population. Then the seedlings with ball of earth were taken out from the polythene bags and washed carefully under

tap water. Thus the rhizome systems of the seedlings were exposed. Both green and oven dry weight of culm with leaves, rhizome and roots of each of the seedlings of both species were recorded. The above data were recorded upto 10 months of age only in case of *M.baccifera* as the rhizome system of the species showed vigorous growth and had long rhizome necks and, therefore, in most of the cases some parts of the rhizome system come out from the polythene bags and anchored into the ground below.

III) As the seedlings and adults of these 2 species showed marked variation in leaf size, therefore, to quantify such variation the mid-length and mid-width of the leaves were measured at 3, 6 and 10 months of seedling age. At the same time similar measurements were also recorded from 100 leaves of adult 12 years old clumps of these 2 bamboo species to compare the leaf size to that of seedlings.

b) **Light effect on seedling management:** Studies were also undertaken on the seedlings of 2 species - *Bambusa tulda* and *Dendrocalamus strictus* and continued upto 3 months under three different light conditions, such as, under direct sunlight, partial shade and complete shade conditions. Three hundred (7-10 days old) seedlings of each of these two species were kept in the nursery. All the seedlings were raised in the polythene bags (15 x 25 cm) containing soil and cowdung in 3:1 ratio. The partial shade condition was maintained by placing alternately a number of 125 cm long and 2 cm width bamboo strips at 2 cm gap on the frame erected 2.5 meter above the seedlings. About 50% of total light (under the direct sun light) passed through the above structure to the seedlings below. Seedlings placed under nursery-shed were treated as under the shade condition. After 3 months of seedling growth under these light conditions the following observations were recorded.

- i. comparative count on survival,
- ii. number of shoots (culms) produced per culm,
- iii. collar diameter and total height of all the shoots present in a seedlings,

Data on (II) and (III) were recorded from 10 sample seedlings randomly selected in each of these 3 light conditions for both the 2 species. Survival (I) and shoot production (II) count were made on the total 300 seedlings of each species from three light conditions.

c) **Management of seedlings at nursery for easy and effective transportation:** In most of the cases some part of rhizome system in the seedlings of *M.baccifera* came out of the polythene bags due to its vigorous growth and anchored into the ground below or entered into the nearby polythene bags. As a result, during uplifting of seedlings from the beds they suffered from root and rhizome damage. But in case of *B.tulda* seedlings the problem was not so acute. However, to minimize such problems seedlings were time to time shifted from one bed to another. The polythene bags with seedlings were shifted at 3 months interval since the age of 6 months upto transplanting to the field (10-12 months seedling age).

During transportation and handling tall and soft shoots of *M.baccifera* seedlings usually break and thereby get damaged at large scale. To avoid and overcome such damage the seedling heights were shortened by chopping their tips. The shoots were cut at different heights (above 3, 5 and 7 nodes). The effect of chopping was also investigated by counting the new sprout from the rhizome, number of new branches produced due to bud break on the nodes below the cut. The observations were made on 30 seedlings from each group of cut and repeated three times.

4.2.1.4 Collection and utilization of wild seedlings for reforestation

Wild seedlings of *Bambusa tulda* and *Dendrocalamus longispathus* were collected from flowering localities as stated under 4.1.15. Seedlings at 2-4 leaved stage (30-45 days of age) with little soil (more or less bare rooted) were pricked out from the forest floor and brought to the nursery of Silviculture Genetics Division of BFRI and kept in the moist place (wash room) for 36 hours. During transportation bare-rooted seedlings were carried in bags under moist condition. From the collected stock 5000 seedlings from each species were transplanted in the polythene bags (15 x 10 cm) containing hill soil and cowdung in the ratio 3:1. In each species after 6 hours of collection 3000, and 36 hours of collection rest 2000 seedlings were planted in the bags. During the first 2-4 days these planted seedlings were kept under shade for hardening and then exposed to the sunlight. Necessary weeding and watering to the seedlings were practiced. At the age of 12-14 months 1300 seedlings of each of the two species were outplanted in the field station of Keochia at 4 x 4 m spacing (625/ha) covering a forest area of 4.05 hectare (10 acres) during the month of June and July. Survival of seedlings in the nursery as well as in the field (upto 3 years) were recorded and expressed in percentage. Quarterly weeding operation was carried out in the field upto 2 years of planting.

4.2.2 Macro-asexual propagation

4.2.2.1 Trials on offset planting and rhizome assembly

To optimise the success of offset planting for raising of small scale or homestead plantation the following trials were carried out.

a) Determination of offset survival in relation to their age collection and plantation time: Offsets of three different ages were selected for study. These are 1-year old offset (T_1), 2-year old offset (T_2), and 3-year old offset (T_3).

Offsets were collected and planted in two different times in 1975: 4th week of April (spring) and 1st week of June (rainy season).

The studies were conducted on 8 species --- *Bambusa balcooa*, *B. longispiculata*, *B. tulda*, *B. vulgaris*, *Dendrocalamus longispathus*, *Melocanna baccifera*, *Neohouzeaua dullooa*, *Oxytenanthera nigrociliata*

Offsets of all the *Bambusa* species were collected from the nearby village of BFRI, and planting was done in the BFRI bambusetum. The other remaining 4 species were collected and planted in Hazarikhil, Chittagong. Offsets of each age in each species were carefully excavated from the soil so that no bud on the underground rhizomes was not injured. The rhizome was separated from the mother clump by making a sharp cut at the neck. The above ground portion (culm) of the offsets were of 4-5 internodes with viable and healthy buds on the nodes. In each treatment 10 offsets (sample) were planted with 5 replication. The climatic condition of Bambusetum during field trial has been given in Table 1.

During plantation the cut-end of the offset was covered with a piece of banana leaf so that rain water (if any) could not remain inside the exposed internode. Offsets were planted as quickly as possible after collection inside the pits. The size of pits were dependent on the rhizome sizes of species. In general the pit size was 45 cm in diameter and 60 cm in depth. The trial was laid out in the field at Randomised Complete Block (RCB) design.

Table 1 : Climatic conditions of the Bambusetum of BFRI during 1975 and 1976.

Month	Air temp. °C	Rainfall (mm)			Rel. Humidity
	(avg.)	Total	Avg.	No. of days	(%)
April '75	26.6	113.2	3.8	10	62.2
May	26.9	360.0	11.6	15	65.0
June	26.6	346.0	11.5	25	67.4
July	26.0	963.4	31.1	29	70.8
August	26.5	243.0	7.8	24	67.2
September	25.3	330.8	11.0	22	66.0
October	25.5	381.4	12.3	17	66.1
November	20.9	123.1	4.1	7	63.1
December	16.2	0	0	0	52.9
January '76	15.6	0	0	0	54.3
February	18.3	6.0	0.2	1	58.3
March	22.7	30.5	1.0	1	59.8
April	25.3	50.8	1.7	6	59.6
May	25.5	255.3	8.3	12	63.5
June	24.3	1330.4	44.5	20	68.2

Hazarikhil is about 20.0 km from the BFRI. Therefore, it was assumed that the climatic condition of Hazarikhil and BFRI area were more or less similar.

Observation on the survival of offsets of different age group in each species was recorded after 6 months of outplanting.

The effect of age of offset and their interaction with the collection time on the survival was statistically analysed separately for each species.

(b) Planting of rhizome assembly: The success of single offset as a propagule in *M.baccifera*, *N.dulloo* and *O.nigrociliata* was either poor or nil. It was then thought to use offset in groups connected with rhizome system (rhizome assembly) as propagules for propagation studies in these three species.

The propagules were offset (T_1 control), two rhizome assembly with 2 culms (T_2), three rhizome assembly with 3 culms (T_3), more than three rhizome (4-5) assembly with similar number of culms (T_4). Excepting the offset (T_1) other propagules were also termed as part-clump planting materials.

All these materials were collected by excavating the soil as done in trial (a). Collection and planting of propagules were made in April 1976. Ten propagules in each treatment were planted in three replications. Trial was laid out at the Hazarikhil centre during the month of April 1976 in RCB design.

The observation was made on the survival of different types of offsets and was statistically analysed separately for above mentioned three species.

4.2.2.2. Trials on induction of *in situ* rooting and rhizome at the branch base

Attempts were made on the following two methods.

a) **Chopping of culm tops:** In some occasion, one may find the presence of spontaneous *in situ* rooting at the branch bases in a bamboo culm as previously observed by Chaturvedi (1947) and Cobin (1947). These rooted branches were found on the culms which were, generally, injured at the tops. Accordingly to induce such rooting at the branch bases the tops of the three current year old (less than one year) culms were chopped off by knife. The study was conducted on *Bambusa balcooa*, *B.nutans*, *B.polymorpha*, *B.vulgaris*, *Dendrocalamus giganteus*, and *Melocanna baccifera*.

Culms were selected from 3 clumps of the above bamboo (except *B.tulda*) species located at BFRI bambusetum. Chopping was done about 5 cm above the nodes of the upper part of the culms where diameters were 2-4 cm depending on the species during October. Observation was made, if any changes, such as, formation of aerial roots and rhizome at the branch bases in each species.

b) **Removal of emerging culm:** The study was conducted only on the clumps of *B.balcooa*, *B.nutans*, *B.polymorpha*, *B.vulgaris*, and *M.baccifera* depending on their limited availability in the BFRI bambusetum. Soil around the newly emerged culms was excavated and exposed emerging shoots were cut at the base and then dug out from the underground portion of the clumps. In each of these 5 species 3 clumps were selected for the study. Just after the culm removal, the soil around the treated clumps was placed again in position. Every day during the growing season clumps were inspected and whenever any new culms were seen emerging, these were removed.

The treatment had been continued at least for 3 years. Branches of the standing culms of the treated clumps were observed if there was any change, such as, formation of aerial roots and rhizome at their bases.

4.2.2.3 Rooting trial on normal branch and prerooted branch cuttings

Major rooting experiments with branch cuttings were conducted on *Bambusa balcooa*, *B. nutans*, *B. polymorpha*, *B. vulgaris*, *Dendrocalamus giganteus*

Both normal (T_1) and prerooted and prerhizomed (T_2) branch cuttings were collected from the mother culms/clumps of the above species studied under 4.2.2.2. These 2 types of branch cuttings were separated from the mother culms by a sharp hacksaw during the month of May (last week) and used as cuttings. Roots and rhizomes, if any, on such cuttings were not fully active and viable. Normal cuttings did not have any roots or rhizomes at their bases, and these were mostly selected from upper mid-portion to lower part of the culm.

Preparation of rooting medium: The rooting medium was made up of sand. The medium was 21.0 cm deep for providing necessary support to the bamboo branch cuttings. At the bottom of the rooting bed a 7.0 cm deep layer of coarse sand was placed above which medium coarse sand (7.0 cm deep) was added at the mid-layer and on the top finer sand to a depth of 7.0 cm was placed (Plate 1a). The length of the bed was prepared as per length of the different propagation frames. However, the width was always 1.4 meter. On the boundary of the bed, bricks were placed one above another to keep the sand in place. Before preparing the bed sands were washed thoroughly. These beds ran in a single row with a north to south orientation.

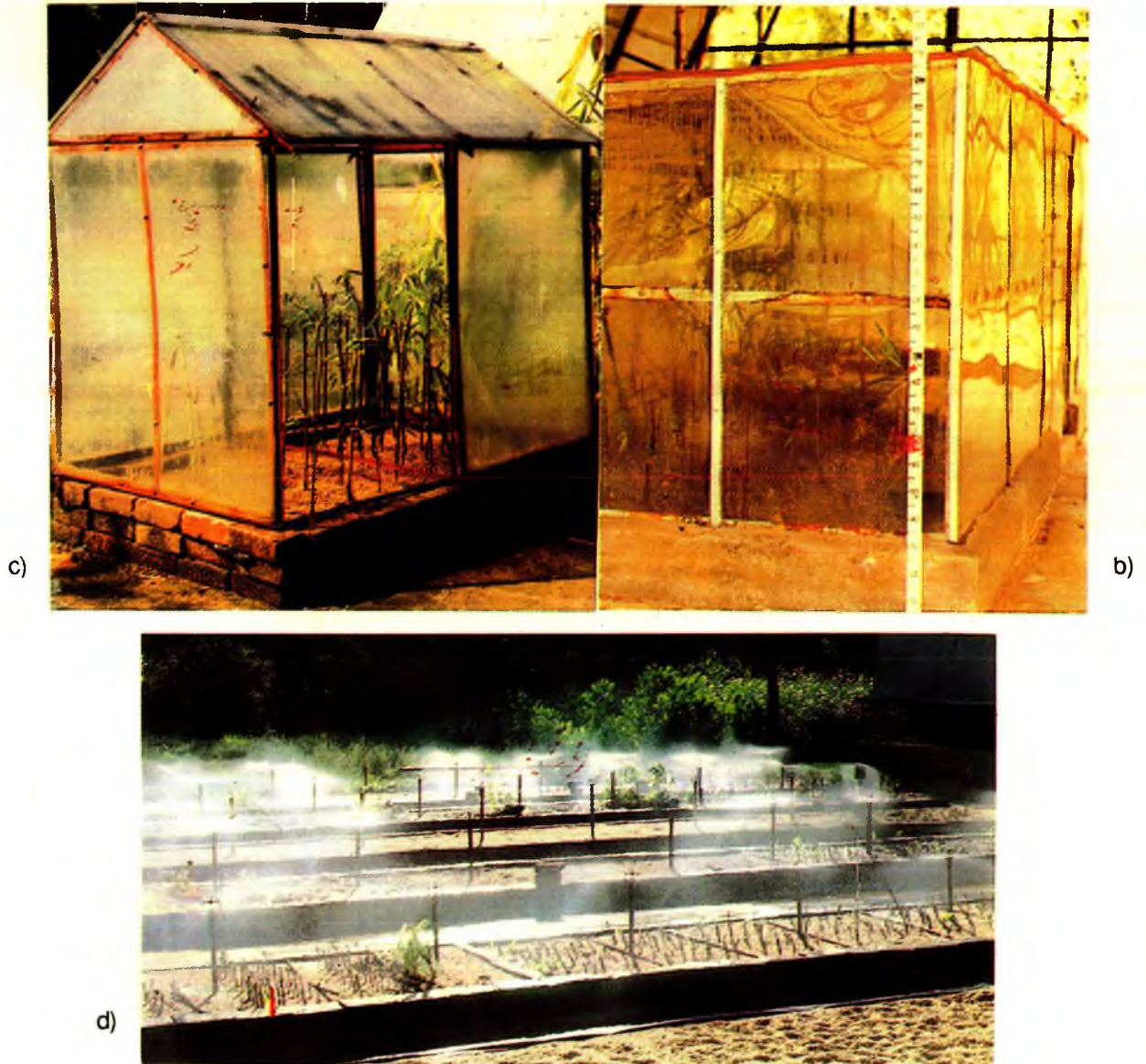
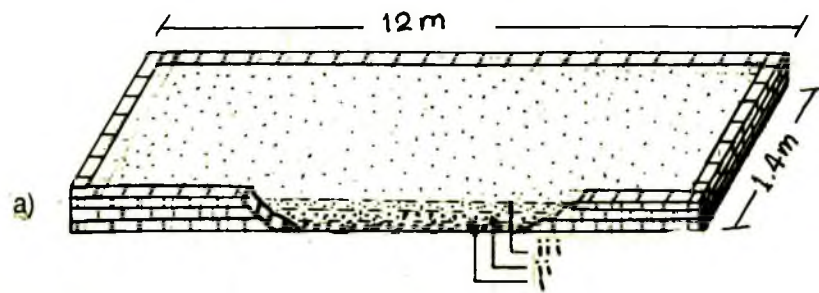


PLATE 1. : Rooting bed and propagation frames :

- a) sand rooting bed : i. Coarse sand, ii. medium coarse sand, and iii. finer sand
- b) big perspex tent,
- c) small perspex tent, and
- d) open intermittent mist bed.

Misting with nozzles: On rooting beds baffle-type nozzles spaced 80 cm apart were fitted on 90 cm long upright pipes, then pipes were connected with main feeder water pipeline running below the medium to distribute water on a pressure built by a small 1/4 horsepower pump. Generally 2 sprinklers were fitted along the centre of the rooting medium on a one meter long bed to mist the cuttings properly. The misting was intermittent for 30 seconds with a gap of 15 seconds. Time to time nozzles were cleaned for uninterrupted mist supply.

Propagation frame construction: The following mist propagation frames as described by Nelson (1961) for tree branch cuttings were used in the experiment.

a) Perspex tent (Plate 1b,c): It was a permanent box-like structure. It had four upright iron angle sides and a slopping roof. All the four sides of the structure was covered with perspex sheet (polyacrylic sheet) about 2 mm in thickness. The structure was 7.25 meter long and has 3.64 metre width with 1.8 meter height. The whole structure was fixed to an iron frame. At the front side of the structure, there was a door about 1.6 meter wide and 1.6 meter high. The panels of all sides were fitted and sealed properly to minimize the loss of internal heat and humidity. This propagation frame was built under the nursery shed covered with galvanised tin sheet. Therefore, the frame remained under the shade. Inside the tent rooting beds were prepared as described earlier. No misting facilities was provided in this bed, but at an interval of 2 days the bed was irrigated by a bucket of water. The door was always kept closed. Another small perspex tent was also constructed with or without misting facilities on the bed. These tents were portable (not fixed) and used for propagation out of doors. Each of the frame was 1.85 m long, 1.05 m broad and 76.0 cm in height. The

roof was placed in slanting manner lengthwise on both the side to prevent undesirable water drip on the cuttings (Plate 4.1b,c). So in total the following 3 types of perspex tents were used in the experiments:

- i) Big Perspex Tent without mist bed under shade (BPT-M/Sh)
- ii) Small Perspex Tent without mist bed under the sun (SPT-M/Sn)
- iii) Small Perspex Tent with intermittent mist under the sun (SPTM/Sn)

b) Open intermittent mist bed (Plate 1d): It has an open bed about 7.0 meter long and 1.40 meter broad with 18 cm height. The borders of the bed was made of bricks and the bed was filled up with sand rooting medium as described earlier. The bed had misting facilities. Two such beds were constructed as follows:

- i) Open intermittent mist bed under shade (OIM/Sh)
- ii) Open intermittent mist bed under the sun (OIM/Sn).

The basal swollen portion of the normal and prerooted and prerhizomed branch cuttings were inserted to a depth of approximately 7.0 cm of rooting medium. The cuttings were about 45.0 cm long from the base. Tip and small branches were trimmed off and set at 3.0 cm apart inside the 5 propagation frames in Randomized Complete Block Design (RCBD) with 3 replications. Cutting types, species and propagation frames have been considered as most important, less important and least important variables respectively. A split-plot analysis was done on the data collected and significant differences for the means were tested using LSD (Least Significant Difference) Test at 5% level, where f-tests show significant.

Data collection for statistical analysis: All the cuttings were checked time to time to observe root induction. When the rooting was profuse in the tested cuttings, the trials were taken as complete. Species wise following observations and results were recorded from each of the propagation frames. These were percentage of cuttings rooted, percentage of cuttings rooted and rhizomed, and amount of rooting (root biomass) on oven dry weight (g).

The time required for initial sprouting and rooting of the cuttings for each species under different propagation frames were also recorded.

4.2.2.4 Seedling multiplication by rhizome separation

Several methods of vegetative propagation are common in grasses like using tillers, culms, rhizomes or stolons (Langer and Ryle 1958). Like many other grasses, bamboo has the inherent proliferating capacity of producing new culms through rhizome development every year (McClure 1966). By utilizing the above natural principles the multiplication trial was initiated with the seedlings of *Bambusa arundinacea*, *Bambusa tulda*, *Dendrocalamus strictus*. The species were selected as they were in seeding stage and thus seedlings were raised during the time of experimentation.

In each species one thousand seedlings were raised in polythene bags (11 x 16 cm) containing soil and cowdung in 3:1 ratio during June-July. The seedlings of all the three species were maintained and nursed in the nursery of BFRI, Chittagong. As at 5 months of age (October) seedlings were generally 4-5 culm stage with well developed underground rhizome system, these were then selected for the study. Twenty five seedlings with 3 replications were randomly selected and taken out from the population of 1000 seedlings in each

species for the study. The polythene bags were removed from these selected seedlings exposing the soil. Seedlings with ball of earth then washed carefully either under tap or pond water to clean the soil so that underground rhizome and root system became clearly visible. After that the seedlings with naked roots and rhizome system were separated at the rhizome neck by a secateur in such a way that each 'piece' had roots, old and young rhizomes, and 1-2 shoots, if possible, with rhizome buds. Number of separated 'pieces' thus yielded from one seedling in each species were recorded and planted separately in polythene bags containing soil and cowdung 3:1 ratio. Then all these polythene bags with multiplied seedlings ("piece") were kept under nursery-shed (diffused sunlight) for 5-7 days and daily irrigation was ensured before shifting directly to the sunlight. In every month, since October, sample seedlings were collected and multiplied (first multiplication). The total multiplied stock of each month was again multiplied (second multiplication) after one year. The stock of the second multiplication was also multiplied similarly again after one year (third multiplication). However, studies were conducted for 2 years (1988-89, 1984-90) in *B.arundinacea*, 3 years (1984-85, 1985-86, 1986-87) in *B.tulda*, and *D.strictus*. Seedlings of the last two species were again multiplied at the sixth year from the first year stock. In each multiplication stage, number of propagules ('pieces') produced and their survival percentage were recorded.

4.2.2.5 Ground layering of seedling

A study was undertaken to induce rooting on the nodes of the seedlings of *Bambusa arundinacea*, *B.polymorpha*, *B.tulda* and *Melocanna baccifera* through ground layering.

Seedlings of these species were raised in the polythene bags (11 x 16 cm) at the nursery of BFRI in the year of 1988, 1984, 1984 and 1989 respectively. Nine months old seedlings in the polythene bags were placed horizontally on the sand rooting medium under the sun in such a way that only the culms were buried 2.0 cm deep inside the sand and the branches on the nodes were above the medium. The sand rooting medium was prepared as described under 4.2.2.3. At this age seedlings possessed 3-4 culms, each with 6-8 nodes.

Trials were started at the nursery during April and have been continued upto October of the same year. Thirty seedlings were tested in each of the species. Intermittent misting has been provided on the seedlings only in day time when there was no rain.

Observations on the rooting in each of the species were made by removing the sand cover above the buried culms from time to time. Appearance of roots in each node from base to tip was measured qualitatively as nil, poor, fair and maximum. Number of seedling rooted was expressed in percentage. The number of rooted branches with nodes were separated by secature and planted in polythene bags containing soil and cowdung mixed in 3:1. Finally the number of rooted nodes with branches yielded per seedling in each species and their survival percentage in polythene bags were calculated.

4.2.3 *In vitro* propagation

4.2.3.1 Tissue culture studies in *M.baccifera* (Roxb.) Kurz

A tissue culture propagation study, was conducted to develop a method of mass propagation with muli bamboo (*Melocanna baccifera* (Roxb.) Kurz by taking different types of tissues from the plant body as explants. The

experiments involved several types of media and explant handling techniques. This species was selected because it occurs predominantly in the natural forests of Bangladesh and widely used in the housing, cottage industries, paper and rayon making. Moreover the species is not amenable to any known vegetative propagation method excepting the conventional rhizome planting technique.

Explants used: The following explants were used: (a) nodal Segments with buds from branches (BN), (b) base of the culm sheath (SB), (c) soft culm wall (intercallary meristem zone) from the young 10-15 cm long developing shoot (YCW), (d) underground rhizome tip (RT), and (e) immature embryo (EM). All these explants were taken from 15 years old mature clumps. Length of the explants varied from 5-10 mm.

Sterilization of apparatus and materials: Glassware, inoculation bottles, distilled water, and nutrient media with different hormones (BAP, 2,4-D, Kn, NAA) were sterilized by autoclaving for 15 minutes at 1.46 kg/cm^2 (15 lbs) pressure and 120°C temperature.

All instruments, such as scalpels, blades, and forceps used for aseptic procedures were autoclaved and also dipped in 95% ethyl alcohol and passed through a flame followed by a dip into cold sterilized, distilled water prior to each use.

Sterilization of explants: The explants, after collection, were washed thoroughly in running tap water; and the leaf sheaths were carefully removed, wherever necessary; to expose the tissue. Different disinfectant chemicals, namely, calcium hypochlorite, 'clorox' (5.25% sodium hypochlorite), preparation of commercial bleach (Clorox Company, Oakland, CA, USA); and Mercuric chloride were tested

at various concentrations and for different time periods. Seventy percent ethyl alcohol was also used for 1 minute, alone and in combination with these chemicals. A surfactant, Tween 20 (Polyoxyethylene sorbitan monolaurate) was also added at a concentration of 2 drops/100 ml. After treatment with chemicals the explants were thoroughly washed 5 times with sterile distilled water. In some occasions, just after collection tissues were cleaned and sprayed with 0.1% benomyl solution and after 10 minute washed with distilled water before treating with above chemicals.

Larger explants, namely, branch nodes with buds, and rhizome buds, were stirred slowly with a magnetic stirrer in distilled water for 10-15 minutes before treating with the disinfecting chemicals to get rid of microorganisms.

From the flowering clump 'seeds' were collected and washed several times under running tap water. After that seeds were surface sterilized by dipping into 5% 'clorox' solution for 30 minutes. Then these were washed 3 times by sterile distilled water and brought under laminar flow cabinet. The embryos were, then extracted from the 'seeds' by dissecting with sterile knives. The white creamy coloured embryos (5-25 mm long) were either dipped into 0.1% benomyl solution and or directly treated with mercuric chloride for sterilization.

Nutrient media: The tested media were MS (Murashige and Skoog 1962), modified MS (Gamborg 1975), B₅ (Gamborg and Eveleigh 1968), and SH (Schenk and Hildebrandt 1972). MS, modified MS and B₅ were used because the previous workers (Banik 1983b, 1987b, Chaturvedi and Sharma 1988, Dekkers and Rao 1989, Huang 1988, Mehta *et al.* 1982, Nadgir *et al.* 1984, Rao *et al.* 1985, Rao *et al.* 1990) have demonstrated the suitability of these media in tissue culture of different bamboo species. The SH medium was also selected as it gave better result in orchard grass, compared to MS and B₅ medium

(Conger and Carabia 1978). The modified MS medium consisted of MS major and minor salts (Murashige and Skoog 1962) with vitamins of B₅ (Table 2). In selecting the suitable nutrient media for culturing all the different types of explants, the type of growth regulators such as (2,4-D and BAP were kept constant with variable concentrations of sucrose (Table 4.2).

Later on several experiments were conducted with BN, RT and EM explants grown only on modified MS (4% sucrose). Different growth regulators, namely, 2,4-dichlorophenoxyacetic acid (2,4-D), naphthalene acetic acid (NAA), benzylaminopurine (BAP), and kinetin (K) were added, either alone or in combinations, at various concentrations to the modified MS medium to determine their effect on culture.

In some experiments 10% coconut milk (CM) and in other experiments different percentage of casein hydrolysate (CH) was used in addition to the growth regulators.

Several transfer experiments were also conducted with the above mentioned growth regulator alone or in combinations.

Ten replicates were used for each of the treatment combination. However, in the transfer culture experiments each treatments were replicated in 5-10 times.

The media were adjusted to pH 5.8 with 0.2 N potassium hydroxide or 0.2 N hydrochloric acid whichever required prior to the addition of the agar.

In all the experiments 0.6% agar was added to gel the media. In almost all the experiments 2% activated charcoal (AC) was added to the culture medium.

Aliquots of 15 ml, 25 ml and 40 ml media were dispensed into 50 ml test tubes, 250 ml and 500 ml glass bottle with metal screw caps (Consolidated Bottle Co. Ltd., Toronto). The test tubes were sealed with cotton plugs wrapped with aluminium foil.

Table 2: Composition of modified MS media
(Gamborg 1975, Murashige and Skoog 1962)

Compound	Amount/l
a) Macronutrient	
NH_4NO_3	1.65 g
KNO_3	1.90 g
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	0.37 g
KH_2PO_4	0.17 g
Ferric EDTA	0.04 g
$\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ stock solution of 15g/100 ml	2.90 ml
(of B_5 medium)	
KI stock solution of 83 mg/100 ml	1.00 ml
b) Micronutrient	
H_3BO_3	6.2 mg
$\text{MnSO}_4 \cdot \text{H}_2\text{O}$	22.3 mg
$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	8.6 mg
$\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$	0.25 mg
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	0.025 mg
$\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$	0.025 mg
c) Vitamin (of B_5 medium)	
Nicotinic acid	1.0 mg
Thiamin HCl	10.0 mg
Pyridoxine HCl	1.0 mg
m-inositol	100.0 mg
Sucrose ^z	40.0 or 50.0 g
Glass-distilled H_2O	to volume
Agar (0.6%) ^{zz}	6.00 g

^z modified from 30.00g for culturing bamboo tissue

^{zz} modified from 7.00g for culturing bamboo tissue

Inoculation and transfer: One explants was inoculated into each glass bottle/test tube. The glass bottles were capped and sealed with 'Parafilm'. Inoculation and all transfer procedures requiring aseptic technique were carried out inside a laminar-flow cabinet.

Incubation: At the beginning, cultures were placed inside a growth cabinet with a temperature setting of 27⁰C (day) and 25⁰C (night) and 15-hour photoperiod , and a light intensity of 2 Klux at the specimen level from a combination of flurorescent and incandescent lamps installed inside a controlled conviron growth cabinet.

Data collection and analysis: Observations on the presence or absence of contamination, colour, and growth of explants were recorded in each treatment.

4.2.4 Field trials of different types of propagules

Studies were undertaken to test the performance of prerooted and prerhizomed branch cuttings (PrPz), seedlings (Sdl). Offsets (Off) and part-clump (Pc) after planting in the fields. Trials were initiated in different years on the following 8 bamboo species depending on the availability of types of propagules (Table 3).

The planting sites were BFRI bambusetum or Keochia field station, canal bank of Satkania Naya Khal of Chittagong, and homestead of Keochia, nandi gram, and Kelishahar villages of Chittagong (Table 3). Hassan et al(1980) reported that Keochia station has soil of coarse texture with low organic carbon content (0.17-0.87%), low total N-content (0.04-0.1%), total P-content 15.63-156/25 ppm, available Kn 0.1-1.7 ppm, and with strong acidic (pH 3.9-4.9) condition.

Table 3: Field trials of different types of propagules
of 8 bamboo species at 3 different sites.

Species	Propagules type	<u>Number of propagules planted at</u>		
		Forest (year)	Canal bank (year)	Homesteads (year)
<i>B. balcooa</i>	Off	25(1984)	12(1984)	13(1986)
	PrPz	15(1984)	10(1985)	30(1986)
<i>B. polymorpha</i>	Off	8(1973)	-	-
	PrPz	32(1984)	-	20(1986)
	Sdl	400(1985)	30(1985)	150(1986)
<i>B. nutans</i>	Off	10(1973)	-	-
	PrPz	15(1984)	-	-
<i>B. tulda</i>	Off	25(1984)	-	45(1986)
	Sdl	1300(1979)	25(1985)	250(1986)
<i>B. vulgaris</i>	Off	50(1981)	45(1985)	173(1986)
	PrPz	25(1984)	65(1985)	231(1986)
<i>D. giganteus</i>	Off	10(1972)	-	-
	PrPz	5(1984)	-	-
<i>D. longispathus</i>	Off	15(1974)	-	-
	Sdl	1300(1979)	-	-
<i>M. baccifera</i>	Pc	30(1984)	-	-
	Sdl	90(1990)	-	-

Observations were made on the survival of the propagules from outplanting upto establishment. The number of full grown (FG) culm produced per propagule per year were counted. The diameter of FG-culms at 70 cm above the soil level and their heights were measured every year during December-February. All the above mentioned data were collected and reported for the first 4-5 (1984-90 and 1985-90) years after plantation to maintain the conformity in the age. In case of *Melocanna baccifera* seedlings were planted in 1990 and data of only one year were presented. The number of propagules in each species under different sites were considered only for counting their survival rate. Among these number, only 5-25 individuals of each type of propagules were considered for collecting the growth data. Offsets and part-clumps of the corresponding species were planted in the field immediate after collection, whereas seedlings, prerooted and prerhizomed branch cuttings were planted in the field after one year maintenance in the nursery.

As the different propagules were planted in the different years and were not in uniform numbers, therefore, no statistical analysis was done on the collected data. Only the average value of the data were presented.

4.3 Germplasm collection and centralization

The morphological diversified characters, sometimes even in the same bamboo species, have made biological studies more difficult. Their *in situ* existences often are threatend due to the uncontrolled biotic interference and as a result bio-diversities among the species, even in individuals under a same species, have been diminishing. Therefore, it was felt necessary to centralize and conserve the different bamboo species and individuals for conducting studies on various

aspects of biology. Efforts were made to collect the propagules of such bamboo clump whenever found in any part of the country.

The collection and centralization of the species and their variants, if any, have been started since 1972-1973 inside the bambusetum of BFRI, Chittagong. The collected species have been planted in lines at 4 meter spacing in east-west direction. Infront of each line a permanent tin plate (30x15cm) has been fitted on a reinforce concrete pillar to mark the species. The line number, both scientific and local name of the species has been written on the plate. Each clump on the line was also numbered serially by tying a small tin plate to the plant. Each line were marked as line No.1, 2 and so on. Clumps in each line were also marked serially as Line 1/clump 1 or Line 1/1, Line 2/1 and so on.

5.0 RESULTS AND DISCUSSION

5.1 Biology

5.1.1 Clump habit and physical appearance

It has been observed that the different species of bamboos those have been growing and cultivated in Bangladesh are clump forming nature. Four major types, on the basis of clump habit, have been identified. These were, namely; clump not thorny, clump thorny, clump having openly growing single distant culms, and climbing culms in the clump.

The overall look and habit of clumps of the studied bamboo species are described below:

Clump nature and look	Species
1.0 Culm thickly growing and bushy, arising closely from short necked (4-10 cm) rhizome shorter than rhizome proper	
1.1 Clumps not thorny	
1.1.1 Shrubby, closely-growing hedges, 2-4 m long, culms diameter 1-3 cm, green when young, much branched from base. Cultivated in homestead boundary.	<i>Bambusa glaucescens</i> (Willd.) Sieb. ex Munro (l.n.: Tetua bans)

l.n.: Local name

- 1.1.2 Somewhat shrubby, 3-4 m long,
culms diameter 2-4 cm,
branching only on the upper
part. Culm is bright green
with whitish silky cover,
dull green or yellowish when
old, leaves smaller than
other species of the country.
Cultivated in the homestead. *Thyrsostachys sp.*
(l.n: Rangoon bans)
- 1.1.3 Closely growing clump,
small to medium size,
9-12m long, culm diameter
1-5 cm, dark green, lightly
vertical striation, black
cilia on the young stem,
less branching at the base.
Growing naturally in the
forests. *Oxytenanthera*
nigrociliata Munro
(l.n: Kali bans)
- 1.1.4 Clump medium to large size
10-15 m long, branching
mainly on the upper part of
of the culm and leaves only
on upper branches. Culm
glaucous-green when young,
greyish green when old.
Younger culm covered with
long persistent papery
sheaths; sheaths as long, or
even longer than the inter-
nodes. Nodes slightly swollen
usually cover with a ring of

2-5 mm long thick roots.

Growing naturally in
the forests.

Dendrocalamus
longispathus Kurz
(l.n: Ora, khag,
bans)

- 1.1.5 Clump medium to large size
10-25 m long, 3-8 cm in
diameter, dark green
branching excepting basal
of 5-8 nodes. Growing both
naturally in the forests
and also cultivated in the
villages.

Bambusa tulda Roxb.
(l.n: Mita, mitinga,
nitai, makla bans)

- 1.1.6 Clump has more or less
similar look to that of
B.tulda. Culms are not
closely placed rather
somewhat open, much
branched above, slightly
bluish green colour, not
shining, white ringed
below the nodes. Cultivated
in the homestead.

Bambusa nutans
Wall. ex Munro
(l.n: Peechle,
makal, makla,
keyitta bans)

- 1.1.7 Clump has more or less
similar look to those of
B.tulda and *B.nutans*.
Yellowish white vertical

striations are present on
the basal 2-4 nodes.
Cultivated in the
homestead.

Bambusa
longispiculata
Gamble ex Brandis
(l.n:Talla, bailla,
sakua, mahal bans)

- 1.1.8 Clump medium to large size,
10-35 m long. Culm glossy
green when young, yellowish
when old or exposed to sun,
prominent sulcation on the
internode just above the
bud or branch complement.
Slightly brown to whitish
ringed 5-7 mm roots usually
present on the lower nodes of
young culm, nodes little
raised usually covered with
fine brown hairs arranged in
a narrow rings. Culm diameter
5-10 cm, thick walled usually
branching throughout excepting
3-6 basal nodes. Clumps light
to yellowish green during dry
months, widely cultivated
in the villages.

Bambusa vulgaris
Schrad.ex Wendl.
(l.n: Bariala, bashni,
baijjya, jawa bans)

- 1.1.9 Clump is comparatively
smaller than *B.vulgaris*,
8-12 m long, stout.

Culms golden yellow,
green stripes along the
length of internode
alternating at each node,
diameter 3-7 cm with
prominent nodes. The green
stripes disappear on
drying. Sometimes
cultivated in the
villages.

B. vulgaris Schrad.
ex Wendl. var.
striata
(Lodd.) Gamble
(l.n: Sharna bansh)

- 1.1.10 Clump 15-23 m long, stout,
apical part of the culms
somewhat curved or hanged
centrifugally, culm diameter
8-15 cm, thick walled,
raised nodes having roots
maximum upto 3-4 nodes,
less upto 7 nodes. Culm deep
hookers green with silvery
brown pubescence on the
internode having somewhat
stout thick elongated
branches, branch nodes are
prominent, some auxiliary
leaf less branch recurved
like pointed spines
specially at the lower nodes.

Widely cultivated in the villages.

Bambusa balcooa
(l.n: Barua, sil
barua, telibarua,
barak, balku, bara
bans)

1.1.11 Clump large 15-24 m.

Culms usually in dense grouping, rarely open, 8-16 cm diameter, grey to greyish-green when young, at maturity covered with the whitish brown pubescence, half portion unbranched, much branching at above, curving outwards. Leaves linear lanceolate, smaller and narrower than those of the other species of *Bambusa* in the country.

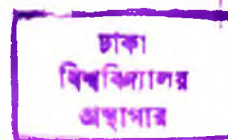
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Cultivated in the villages of Sylhet and Chittagong.

Bambusa polymorpha
Munro (l.n: Pharua,
bathua, burma bans)

1.1.12 Clump very large and

gigantic 20-35 m tall. Culm diameter 12-18 cm, closely emerged grey-green, covered with white waxy scurf when young, basal nodes marked with root scars, branching usually slender and limited to the upper part. Many small,



drooping branches on the
less than 1-year old culm,
after 1-year such branches
replaced by one stout
branch with 2-4 auxillary
branches. Cultivated in
the Buddhist temple.

Dendrocalamus
giganteus Munro
(l.n: Bhudum bans)

- 1.1.13 Clump densely tufted, medium
to large size 6-15 m. Culm
glaucous green when young,
dull green when old, often
rooting at lower nodes, short
and somewhat solid internode
at lower portion, diameter
3-9 cm, nodes prominent,
branching usually throughout
with upper drooping branches.
Cultivated in the drier part
of Bangladesh.

Dendrocalamus
strictus Roxb.
(l.n: Lathibans)

- 1.1.14 Clump large 10-30 m closed.
Culm greyish white when young
and dull green when old with
brown pubescence, sending out
apical part as flagellum,
sometimes intermingled with
each other, almost all nodes
have root rings or root scar,
diameter 5-14 cm, whitish
creamy coloured large and
broad ovate buds on the

nodes. Many small drooping branches on the less than 1-year old culm. Stout branches maximum in the upper part very much elongated 4-10 m, distinct semicircular bud in the branch node, no branching at below. Naturally growing in the forests of Sylhet.

Dendrocalamus
hamiltonii Munro
(l.n: Pecha)

- 1.1.15 Clump medium sized 5-12 m
Culm dark green covered with silvery white pubescence, internode very much elongated 30-120 cm and very thin walled (3-5 mm) compare to other bamboo species of the country, a glaucous ring below the node, diameter 3-7 cm, branching usually from mid culm to top. Naturally growing in the forests.

Neohouzeaua dullooa
(Gamble) Camus
(l.n: Dalu bans)

1.2 Clump thorny

- 1.2.1 Clump thorny, usually large 10-32 m. Culm dull to deep green, diameter 3-9 cm, root ring on nodes in young culm from base to mid culm zone, nodes prominent. Branching

throughout spreading, thorny.

Thorns strong, curved,

2.5-5 cm long. Cultivated

in the villages.

Bambusa arundinacea

(Retz.) Willd.

(l.n: Kanta bans)

1.2.1.1 Clump thorny, medium

sized 6-15 m dense. Culm

bright green, diameter

2-5 cm, much branched,

densely thorny. Thorn

smaller usually in 3s,

curved. Leaves

comparatively smaller.

Cultivated in drier

parts of Bangladesh.

B. arundinacea var.

spinosa Roxb.

(l.n: Bish kanta

bans)

2.0 Openly growing, single distant

culms arising from the long

necked (1-2.5m, 5-10 times longer

than rhizome proper) underground

ramifying rhizome system. Younger

culm (less than 12 months) has

persistent culm sheaths, completely

unbranched, apical thin part

drooping with 4-6 leaves clearly

visible from a distance. Growing

naturally in the forests.

Melocanna baccifera

(Roxb.) Kurz

(l.n: Muli, paiya,

bajali, nali bans)

3.0 Climbing, woody, spreading, clump-forming 3-8 m long, culm diameter 1-4 cm. No branches from 1-3 nodes, 2 branches from 4-12 nodes, 3 branches from 13 to the tip of the culm, internode upto 11 are more or less straight then gradually becoming scorpoid, this scorpoid habit is very prominent from 15 to onwards. Branches at the beginning arising perpendicularly from the culm nodes upto 1-2 branch node then making angle. Whitish pubescence band present at the base of the culm node upto 5th node from base, sometimes this band observed even at base of the few basal nodes of the branch. Naturally growing in the forests of Cox's Bazar.

Melocalamus
compactiflorus
(Kurz) Benth.
(l.n: Lata bans)

However, so far 33 bamboo species either have been seen in different parts of Bangladesh or reported in literature (Gamble 1896, Brandis 1906) were studied. Majority of them have been collected and planted in the bambusetum of BFRI Chittagong. Besides 19 species described above, the name of some other species along with their place of occurrence are given below:

Species name -----	Place -----
* 1. <i>Bambusa pallida</i> Munro (Local name: Makla)	Reported to occur in the foot hill of Khasia Jainta at northern Sylhet
2. <i>B. teres</i> Ham.ex Munro (l.n: Mirtinga)	Forests of Sylhet, Chittagong and Chittagong Hill Tract
3. <i>Bambusa</i> sp.(unidentified) (l.n: Kanakainch)	Cultivated in Comilla
4. <i>Bambusa</i> sp.(unidentified) (l.n: Tengra, tetua)	Cultivated in Sreemangal, Moulvibazar, Habiganj, Bramanbaria
5. <i>Bambusa</i> sp.(unidentified) (l.n: Bethua).	Cultivated in Sylhet, Moulvi-bazar, Sreemangal, and Nazirhat and Hathazari of Chittagong.
6. <i>Bambusa</i> sp.(unidentified) Looks like <i>B. vulgaris</i> (l.n: Kaldhapri)	Cultivated in the villages of Lahoria, Lohagara of Norail.
7. <i>Bambusa</i> sp.(unidentified) Very congested clump, culms are very thick walled, nodes somewhat spiny.	Cultivated in Dinajpur, Charkai, Khulna.
8. <i>Dendrocalamus</i> <i>membranaceus</i> Munro (l.n: Burma bans)	Cultivated in the villages of Chunati of Chittagong.

- | | |
|--|--|
| <p>* 9. <i>Dinochloa maclellandii</i>
 Gamble
 (l.n: not known)</p> | <p>Reported to occur in the
 forests of Chittagong and
 Cox's bazar.</p> |
| <p>*10. <i>Gigantochloa macrostachya</i>
 Kurz
 (l.n: not known)</p> | <p>Reported to occur in the
 forests of Chittagong Hill
 Tract.</p> |
| <p>*11. <i>Oxytenanthera albociliata</i>
 Munro.
 (l.n: Kali)</p> | <p>Reported to occur in the
 forests of Sylhet and
 Chittagong.</p> |
| <p>*12. <i>Teinostachyum griffithii</i>
 Munro.
 (l.n: Bajali)</p> | <p>Reported to occur in the
 forests of Sylhet, Chittagong
 and Chittagong Hill Tract.</p> |

* species were not seen

It is difficult to identify the bamboo species only by the local name, as more than one species might have the same local name. Field workers often have difficulties in identifying bamboos, because the essential flowering materials are not always available. Often different morphological variations, such as; branching habit, striation on internode, size of culm-sheath, buds on the culm node etc; were observed even in the same species. As for example, longitudinal yellow striations on the green internode of *B.tulda* culm was observed in the Bambusetum (Line No.14A, clump no. 1,2,6) of BFRI. Another clump of *B.tulda* (Line No.14A clump no.7) possessed tortoise shell shaped internode. but there was no such report in the original taxonomic description of *B.tulda* by Gamble (1896). Similarly in some clump (Line no 15B, clump no.2,4) of *D.longispathus* culm sheath did not fully cover the internode whereas in other clumps it completely covers the internode.

Most of the taxonomic descriptions on bamboos were based on herbarium specimen and have little information on the clump habit. The herbarium specimen were usually not collected adequately. Different structures such as leaves, buds, branch complements of young culms, and rhizomes - so important in documenting the plant - are mostly lacking in herbaria (Soderstrom and Calderon 1979b). As the flowering is not common in bamboo plants, therefore, detail description on different morphological structures seems to be very important for proper identification of the species especially at the field level. Thus it appears that the systematic study of the *Bambusoideae* lags far behind than that of other grasses.

5.1.2 Distribution and preliminary assessment of
 ecological condition and species composition
 in the forests and villages

Naturally grown species:

Habitats and Composition: Semi-evergreen and semi-deciduous forests in the hills of Chittagong Hill Tracts, Cox's Bazar, Sylhet and Northern Mymensingh of Bangladesh have different naturally grown bamboo species either as understory in association or pure stand. There are usually, but by no means always, scattered trees typical of the semi-evergreen to semi-deciduous climax standing singly or in groups over the bamboo especially in depressions. The shade cast by the bamboos is such that there is normally no undergrowth, but in the more open parts it is developed to a varying extent. Schimper (1895) said that most of the bamboo forests are secondary vegetation on abandoned fields. Bamboos generally invade abandoned fields after slash and burn agriculture (Jhuming), as can be observed in forest areas of Chittagong,

Chittagong Hill Tracts and Sylhet. The rhizomes of bamboo in a natural forest are left after jhuming and they rapidly regenerate into pure bamboo forests covering a wide areas as a fire climax (Numata 1987). No natural growth or regeneration of any bamboo species can be seen in the sal forests of Madhupur, Tangail, Mymensingh, Gazni and Dinajpur. This was very remarkably distinct that bamboo species such as, *M.baccifera*, *O.nigrociliata*, *B.tulda* were found to grow inside the semi-deciduous forest by the side of pure sal forest of Gazni, north-west of Mymensingh, near the border of Meghalaya Province of India. The major tree species of that semi-deciduous forest were *Artocarpus chaplasha*, *Mimosa* sp., *Caesalpinia digyna*, *Dalbergia rimosa*, *Ziziphus mauritiana*, *Mallotus* sp., *Glochidion* sp., *Acacia catechoids*, *Moringa* sp., *Syzygium* sp., *Leea* sp., and *Phyllanthus emblica*, *Toona ciliata*, *Bauhinia* sp., and *Albizia procera*. Similarly Waheed Khan (1960) reported that in Bilashpur forest of Madhya Pradesh where sal (*Shorea robusta*) is almost pure, bamboo is conspicuously absent. A proper scientific investigation is needed to identify the causes of such antagonistic relationship between pure sal forests and bamboo. Bamboos were also not naturally growing in the mangrove forests of Sundarbans (Fig. 2).

The average annual rainfall in Bangladesh varies from 1500 mm to 5500 mm which falls mostly between last part of May to August and period of dry months is from October to March. The relative humidity is also correspondingly high and ranges from 60 percent upwards. The atmospheric temperature ranges from 5-41°C. Bangladesh fullfills all the above climate requirements and thus a home of many different species of bamboos (Fig. 2). In most of the years country experience strong cyclonic winds but these do not seem to act as limiting factors to the occurrence or growth. Healthy growth of the clumps can be observed on the lower slopes of hills and near

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the valleys rich in organic matter. The favourable pH range is 5.0 to 6.5 for all the natural and cultivated species of Bangladesh. Almost all the species thrive well on moist but well-drained sandy loam to loam clay soils, derived from river alluvium from the underlying rocks. In the forest and hilly areas yellow, brownish yellow, or light reddish yellow are the soil colour most frequently encountered.

So far observed seven species of bamboos have been growing naturally in the forests of Bangladesh. Among them muli bans *Melocanna baccifera* is most common. Other species - - mitinga *Bambusa tulda*, orah *Dendrocalamus longispathus*, dalu *Neohouzeaua dullooa* and kali *Oxytenanthera nigrociliata* occur sporadically either in association with muli or in isolation forming small patches of pure vegetation. The other two species lata *Melocalamus compactiflorus* and pecha *Dendrocalamus hamiltonii* are localized only in limited areas of Chittagong and Sylhet forests respectively (Table 4).

Muli (*Melocanna baccifera*(Roxb.) Kurz) is the predominant and major species naturally growing in the different forests of Bangladesh (Table 4). Muli is more or less an evergreen with single culms arising at a distance of 1 to 2 meter apart from a ramifying underground rhizome. The branchless young (less than 1-year old) culms with drooping tips having a few leaves and nodes covered with persistent sheaths are the common views of the muli forests during October to April. It is typically a gregarious and handsome bamboo in the forest of Bangladesh. The natural distribution of this species, as described by Gamble (1896), is throughout eastern Bengal and Burma from the Garo and Khasia Hills to Chittagong and Arakan, and certainly in Chittagong this is the most common species. Scientists (Prasad 1948, McClure 1966) believe that the natural home of muli bamboo is in the Chittagong Hill Tracts, where it grows gregariously covering

large tracts of land. The above mentioned regions of the world are subjected to torrential monsoon climate having highest rainfall (3000 to 6350 mm), and it can be interestingly noted that occurrence of muli bamboo is confined to only these regions of the earth, probably, for protecting the soil from erosion by its long elongated ramifying intermingled rhizome system. Muli occurs as undergrowth in many of the tree crops and also forms pure stand in the disturbed areas due to shifting cultivation, burning or extensive clear-cutting. Thus it seems that muli can grow under the crown cover as well as in open hills. The long rhizome necks have the power of spreading and quickly cover the vacant space of the hills by producing culms within a short time provided the plant is not disturbed. Occasional forest fire kills the tree seedlings and other non-rhizomatous plants while the underground rhizomes of muli remain alive. Many new culms emerge from the living underground rhizomes and face a little or no competition from any other plants and thus form a pure muli vegetation. In the forest it is impossible to demarcate the boundary of a clump as the rhizomes of many different clumps intermingled with each other form underground network and make impossible for other plant species to invade the area. Overexploitation and frequent fire repeatedly destroy the culms resulting decrease in vigour and as a result clumps get little time for storing photosynthates to recover the growth. As a result, in many areas of Hill Tracts, Sitakunda Hills, Sylhet and Chittagong forest yield of muli bamboo has been decreasing. Present picture of degrading and diminishing muli bamboo in the hills of Sitakunda, and unclassed state forests of Hill Tracts is pitiful. Disappearance of muli and other bamboos from the forests were mainly due to the excessive exploitation and frequent firing in the hills. The plant have been thriving satisfactorily equally on the moist sandy clay loam alluvial soils and on the well drained residual soils consisting of

almost pure stands, even to the summits of low sand hills. As regards the topography muli is found to grow on the sandy rough slopes and the top of the hills indicating the hardy nature of the plant.

Mitinga (*Bambusa tulda* Roxb.) is another common bamboo growing naturally in the forest of Bangladesh. Mitinga is an evergreen or semi-deciduous clump-forming bamboo, branching freely from nearly all the nodes. The branches from the lower nodes being thin, nearly leafless and more or less horizontal. According to Prasad (1948) this species is native of Assam, Bengal, Northern Cachar, Chittagong and Burma. Mitinga is generally found to grow as undergrowth sporadically or in patches. Sometime it forms patches of pure to semi-pure vegetation as observed near Matamuhuri stream of Alikadam Range. In Adampur forest of Sylhet sometimes the species can be seen growing as pure stand. This bamboo frequently grows on the flat alluvial deposits along streams in the mixed deciduous forest and also along the banks of the dry water courses. The species is also being cultivated in the homesteads of Bangladesh.

Orah (*Dendrocalamus longispathus* Kurz) is a large tufted bamboo with leaves born only on the upper branches and easily recognizable by its long fragile papery sheaths covering the internodes of younger culms. The species has been naturally distributed in the eastern part of Bangladesh (Sylhet, Chittagong) and Burma (Arakan), chiefly along the streams and in the moist parts of the upper mixed forests, on moist fertile loam (Gamble 1896, Prasad 1948). The species is rarely seen on the hill tops and drier slopes. Under the close canopy cover the species are rarely seen, mostly grows in the moist and partially shaded fringes of the forest cover. Sometimes it forms pure patches as observed in koila block of

Ramgarh, Raingkhlang Reserves of Chittagong and Rajkandi Reserves of Sylhet.

Kali (*Oxytenanthera nigrociliata* Munro) is an evergreen semi-deciduous medium sized with comparatively smaller diameter tufted bamboo, usually darkgreen, nodes prominent, internodes and culm sheaths of younger culms mostly covered with blackish to brownish hairs. According to Gamble (1896), this species is naturally distributed from Orissa, Chittagong, Burma, Andaman Islands, Malaya Peninsula, extending to Sumatra and Java. Parker (1931) reported that the species could be seen gregariously on the flat ground and low elevations along the streams in the evergreen forests of Burma. Characteristically the species is plentiful and found as a congested clump in the fringes of moist semi-deciduous forest of Chittagong as observed in Kassalong valley and Sitapahar of Kaptai. One can also see the occurrence of this species on both the sides of Chittagong-Cox's Bazar Road near the fringes of Chunati and Harbang forests, and also in the Bhomariaghona forest. Kali is also distributed in isolated clumps on the disturbed scrubby and drier hills of Keochia, Bundarbans, Ramgarh, Kaptai and Rangamati. The species has capability to tolerate the repeated cutting while most of the other bamboo species fail to survive.

Dalu (*Neohouzeaua dullooa* A.Camus) is dark medium sized clump with culms growing in large tufts; culms are dark green covered with a few shiny whitish hairs, whitish below the nodes, glossy when dry. Nodes are little prominent. The species is easily distinguishable by its very long (0.3 to 1.2m) thin walled internodes covered with scattered shiny white appressed hairs. The species is much used for making mats. Leafy branches are switchy, in dense half-whorls at the nodes and less branching at the lower nodes. The natural

distribution of dalu is throughout northern and eastern Bengal and Burma, from Bhutan through the Assam and Sylhet valleys and the hills between them to Chittagong and upper Burma (Gamble 1896). The species generally occurs on the moist, well drained and fertile valleys as understory in the deciduous forests of Sylhet, Chittagong and Hill Tracts of Chittagong. Dalu prefers shade and is not available on drier, open and scrubby hills. Rao and Ramakrishnan (1988) have also reported that 'the species is more relatively shade tolerant and belong to the "periodic" growth - evergreen type'. Gamble (1896) reported that Hooker's collection from Sitakunda, near Chittagong were preserved in Kew herbarium. But at present, in 1989, one can seldom find a clump of dalu in Sitakunda Hills. Repeated cutting and fire have destroyed the forest and exposed the ground to direct sunshine. As a result land has become gradually drier and overhead shade due to trees has also been destroyed. Thus the habitat has become unfavourable for dalu bamboo. Similar situations were also observed in the different forests of Bangladesh. It appeared that *N.dulloo* has become a threatened species in the Bangladesh forests.

Pecha (*Dendrocalamus hamiltonii* Munro) a large clump forming bamboo, more often sending out its stems at an angle or curved downwards, as a result sometimes culm tips intermingle with each other. The natural distribution of the species is in North East-Himalaya, Assam valley, Khasia Hills, Sylhet, extending eastwards to upper Burma, and westwards to the Sutlej (Gamble 1896). The species is now most probably confined only to Patharia Reserve of Sylhet especially in the tea gardens.

According to Rao and Ramakrishnan (1988) *Neohouzeaua dulloo* and *D.hamiltonii* are light demanding early successional species, the former being more relatively shade tolerant. The present destruction of forests have decreased

the crown cover and the lands have become mostly exposed creating unfavourable conditions for these species. Based on the leaf characteristics they described *N.dulloo* as "periodic growth - evergreen type" whereas *D.hamiltonii* as "periodic growth - deciduous types".

Lata (*Melocalamus compactiflorus* Benth.) is an evergreen tufted bamboo with greyish-green, scandent spreading and arching culms climbing on the supporting trees. The stem has remarkable large buds at some of the nodes. The species is naturally distributed in Eastern Bengal and Burma, from Sylhet through Chittagong down to Martaban (Gamble 1896). At present, the distribution of lata is mostly confined to area of Teknaf forest of Cox's Bazar. The species thrives well near the banks of streams and moist valleys in the hills. Large scale monocarpic death of the species due to the flowering in 1975 in the area of Teknaf and Cox's Bazar has limited its availability in the forests.

Biotic influence on the natural existence: Biotic factors particularly the human influence have been found to be a major limiting factor for the natural distribution and growth of bamboos in the forest of Bangladesh. Fangming (1988) mentions that the main limiting factor of distribution of bamboo is found to be deficiency of water due to destruction of forests, soil erosion and meagre soils. In the hills of natural forests of Bangladesh tribal people practice an ancient form of cultivation, locally known as Jhum. Prior to the Jhum cultivation, jungle cutting, burning, little soil work on the hilly terrain decrease moisture and organic matter content in the substratum and also increase the rate of soil erosion due to the runoff of torrential rain water. Generally the area is cultivated for a year or two and then it is left fallow to allow natural regeneration of a forested cover. In

the hilly areas of north-eastern part of the subcontinent previously the cycle of Jhum was used to be approximately 30 years (Ramakrishnan and Toky 1983), but now-a-days the cycle has commonly become shortened to 4-5 years (Biswas 1988) due to population pressure and scarcity of land. As a result of successive short Jhum cycle, bamboos typical to the region are gradually degenerating in health and density.

Repeated exploitation and forest fire are the factors also influencing the presence and distribution of bamboos in the forests. Even 20 years before (late sixties) *lata* (*Melocalamus compactiflorus*) was a common bamboo species to be found in the forests of Teknaf and Cox's Bazar, but during 1978-80 large areas of these forests were clearfelled and slash burned for making plantation of oil palm and fast growing exotic tree species. As a result this species has been eliminated from most of these natural belts. The clumps of *D.hamiltonii* were rarely found inside the reserve forests and in the areas where human interference was not controlled. Tea gardens being a protected area might be a better site for regeneration of the species. The species occurred in moist places along streams and in valleys, often bending over and forming dense thickets. The species seems to be light demander, because clumps always occurred in the exposed condition rarely under the tree canopy. Rao and Ramakrishnan (1988) reported that *D.hamiltonii* was a light demanding early successional species with deciduous type of nature. Thus it appeared that both *M.compactiflorus* and *D.hamiltonii* which were common even two decades ago have now become threatened species in Bangladesh. Incendiary fires set by unscrupulous persons are not uncommon and usually cause damage to bamboo groves and trees in the forests. These are mostly in the form of ground fire. This is particularly the case in the sunkholas (Sungrass, Savanna area) which are burnt annually and the land gradually become poor to poorer in organic matter content. As

a result land become dry and unproductive. Such incendiary fires are set on the hills for obtaining the pure sungrass or sometimes for fodder grass for grazing cattle. Sungrass (*Imperata cylindrica*) hinders both bamboo and tree growth by its gregarious nature and strong spreading runner.

Village grown species:

Among the bamboo species cultivated in the different parts of Bangladesh, *B.balcooa*, *B.vulgaris*, *B.nutans*, *B.tulda* and *B.longispiculata* seem more common (Table 5). In ranking village grown species Barua or Bhalku bans (*B.balcooa*) and Bariala (*B.vulgaris*) bans are in the top of the list. The former being more common in the northern and western districts whereas the later one was frequently cultivated in the south and eastern part (Table 5). According to Gamble (1896) *B.balcooa* has been naturally distributed in Assam, lower Bengal (western) and Bihar and extending to Goruckpur. It is likely that this species has been commonly introduced in the long past by man nearing the border districts of Bangladesh from the place of naturally occurring areas of India. It was also seen that some of the cultivated species (*B.balcooa*, *B.vulgaris*, *B.polymorpha*, *B.longispiculata*, *B.nutans*) have been cultivated in small scale in the hills of Bandarban, Sitakunda, Chittagong, Cox's bazar, and Sylhet. These were mainly on the homestead. Thus it appears that these species can be cultivated in the plain land having pH 6-8, and in the hill soils of pH 4.5-5.5.

The bamboos grown in the flood plains can tolerate short seasonal floods. Flooding for a longer period are probably not favourable condition for many cultivated species. This is evident from the fact that neither the cultivated nor the natural species occurs in the seasonally or tidal flooded

Table 4: Distribution status of 7 bamboo species in different forest regions of Bangladesh.

Area/Species:	B.tul	D.ham	D.lon	M.bac	M.com	N.dul	O.nig
Ramgarh	2	0	2	2,3	0	1	2
Sitakund	1	0	1	2,3	0	1	1
Bandarban	1	0	2	2,3	0	1	2
Khagrachari	2	0	2	2,3	0	2	1
Kassalong	2,3	0	2	3,2	0	2	1
Kaptai-Sitapahar	2	0	2	3,2	0	1	1
Jaldi-Harbang	1	0	1	1	0	0	2
Cox'Bazar	1	0	1	1	1	0	1
Panerchara-	1	0	1	1	2	0	1
Teaknaf							
South Sylhet	2	1	2	3,2	0	2	1
North Sylhet	2	1	1	2,1	0	2	1
Sundarban	0	0	0	0	0	0	0
Dk-Mym sal	0	0	0	0	0	0	0
forest							
Dinajpur Sal	0	0	0	0	0	0	0
forest							

Status: 0 Absent, 1 Restricted to a very few localities but found foun in fair numbers, 2 Found in small numbers but occurring in several areas, 3 Occurring gregariously in pure form.

Dk-Mym : Dhaka-Mymensingh.

B.tul = *Bambusa tulda*, D.ham = *Dendrocalamus hamiltonii*,

D.lon = *Dendrocalamus longispathus*, M.bac = *Melocanna*

baccifera, M.com = *Melocalamus compactiflorus*, N.dul =

Neohouzeaua dullooa, O.nig = *Oxytenanthera nigrociliata*.

Table 5: Qualitative assessment on the cultivation of some bamboo species in different rural districts of Bangladesh.

	B.arn ¹	B.arn	B.bal	B.gla	B.lon	B.nut	B.pol	B.tul	B.vul	B.sp.	D.gig	D.lon	D.str	T.sia
District	spn													
Dhaka	0	1	3	0	1	2	0	2	2	1	0	0	0	1
Tangail	0	1	3	0	1	2	0	2	2	0	0	0	0	1
Mymensingh	1	1	3	0	1	2	0	2	2	0	0	0	0	0
Faridpur	0	1	3	0	1	1	0	2	2	0	0	0	0	0
Pabna	0	1	3	0	1	1	0	2	2	0	0	0	0	0
Bogora	0	1	3	0	1	1	0	2	2	0	0	0	1	0
Jessore	0	1	3	0	2	1	0	2	2	0	0	0	0	0
Rajshahi	0	0	3	0	1	1	0	2	2	0	0	0	1	0
Kushtia	0	0	3	0	1	1	0	2	2	0	0	0	0	0
Barisal	0	0	2	0	2	1	0	2	3	0	1	0	0	0
Patuakhali	0	0	2	0	2	1	0	2	3	0	0	0	0	0
Khulna	0	0	2	0	2	1	0	2	2	0	0	0	0	0
Dinajpur	1	0	3	0	3	2	0	2	2	0	1	0	1	0
Rangpur	1	0	3	0	3	2	0	2	2	0	1	0	1	0
Comilla	0	0	3	1	1	2	0	2	2	2	0	2	0	0
Noakhali	0	0	2	0	1	1	0	2	3	0	0	0	0	0
Chittagong	0	0	2	1	1	2	1	2	3	0	0	1	0	1
Hill Tracts	0	0	0	0	0	0	1	0	1	0	0	1	0	0
Sylhet	0	2	3	2	2	2	2	2	2	1	0	1	0	1

Ranking: 0 = not found, 1 = rarely cultivated, or cultivated in selected place,

2 = fairly cultivated, 3 = profusely cultivated

¹ B.arn. = *B. arundinacea*, B.arn. var. spn = *B. arundinacea* var. *spinosa*,

B.bal = *B. balcooa*, B.gla = *B. glauscens*, B.lon = *B. longispiculata*, B.nut = *B. nutans*,

B.pol = *B. polymorpha*, B.tul = *B. tulda*, B.vul = *B. vulgaris*, B.sp = *Bambusa* species,

D.gig = *Dendrocalamus giganteus*, D.lon = *D. longispathus*, D.str = *D. strictus*,

T.sia = *Thyrsostachys siamensis*

areas. Underground rhizome system in the water-logged condition might suffer from oxygen deficiency and thereby face problem in respiration.

Distribution of cultivated bamboo species in the plain districts seems to be related to the choice and liking of planters, utility values of the species and availability of planting materials.

5.1.3 Periodicity of culm emergence

It has been observed in 13 different bamboo species of Bangladesh that a clump start to produce culms generally either from the month of May or June and continue for 6 or 7 months ending either in October or in November (Table 6). The culm emergence periods were not the same for all the species under study. The species exhibited different duration of emergence periods varying from 4-8 months. *Bambusa nutans*, *B. polymorpha* and *Dendrocalamus giganteus* had 4-5 months culm emergence period whereas in *B. balcooa*, *B. glaucescens*, *B. longispiculata*, *B. tulda*, *B. vulgaris*, *D. longispathus*, *D. strictus*, *Melocanna baccifera*, *Neohouzeaua dullooa* and *Oxytenanthera nigrociliata* the periods were of 6-8 months (Table 6). It was personally observed in the villages of Sreemangal, Sylhet where rainfall was early, *B. vulgaris* started producing culms in the month of April, whereas in the BFRI bambusetum the species began sprouting in June. Thus it appeared that the period of culm emergence from the ground varied according to the species and environmental condition of the locality.

Both the soil (50-200 cm depth) and air temperature, during these months were about 28°C and 26°C respectively, and mean relative humidity was above 60%. The mean monthly total rainfall during these months were within 100-800 mm. In the

other months from December to April (excepting *D.longispathus*) all the species under study did not produce any culms. During this non-emerging period climate was comparatively dry and both soil and air temperature were also low in comparison to the period (May-November) of emergence (Table 6). Thus it appears that bamboos, in general, have a periodicity for culm emergence and most likely influenced by both soil and air temperature, and moisture condition of the climate. In this connection it is to be noted for future research that, during 1980-82 while conducting research on tissue culture in the University of Saskatchewan, Canada, the author grew two clumps of *Bambusa glaucescence* in big tubs inside the University green house. These two clumps produced culms during February by maintaining the soil temperature (25-26°C) and regular watering under 13 hour photoperiod. Thus it seems long photoperiod, i.e. 13 hours, in addition to the above mentioned other environmental conditions, might have activated the culm buds present in the rhizome. In fact day lengths are long during the productive months of culm emergence.

The number of culm emerged in each month of the emerging period for all the 13 species were summed up (Table 6) and interesting trend of shoot emergence was noted. The number of shoot emerged at beginning (April-May) of emerging period was low (0.4-4.5). After that it sharply increased (22.4-23.1) during June and July, and gradually decreased in the following months of August (21.5), September (15.2), October (8.2) and finally in November the emerging number was again low (3.2). According to Ueda (1960) the 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. Therefore, it was likely that activation of culm buds present on the underground rhizome was maximum in June-August due to the initial higher storage of the food materials and resulted

Table 6: The average number of culm emerged in different months of a year from the clumps of 13 bamboo species in relation to monthly climatic condition.

Species	Months												Culm emergence period (months)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
<i>Bambusa balcooa</i>	0	0	0	0	0.2	0.9	0.5	0.3	0.1	0.3	0.2	0	7
					± 1	± 3	± 3	± 1	± 0.7	± 1	± 1		
<i>B. glaucescens</i>	0	0	0	0	0.9	0.7	2.0	0.9	1.4	0.5	0.4	0	7
					± 3	± 4	± 9	± 3	± 5	± 4	± 3		
<i>B. longispiculata</i>	0	0	0	0	0	0.9	1.1	0.7	1.2	0.2	0.1	0	6
						± 3	± 1	± 3	± 2	± 1	± 1		
<i>B. nutans</i>	0	0	0	0	0	0.7	1.4	0.5	0.5	0.5	0	0	5
						± 2	± 3	± 1	± 3	± 2			
<i>B. polymorpha</i>	0	0	0	0	0	0.7	0.9	0.9	0.6	0.7	0	0	5
						± 2	± 2	± 2	± 2	± 2			
<i>B. tulda</i>	0	0	0	0	0.07	0.5	0.7	0.6	1.2	1.1	0.6	0	7
					± 0.7	± 2	± 3	± 2	± 3	± 3	± 3		
<i>B. vulgaris</i>	0	0	0	0	0	0.7	0.9	1.0	0.3	0.3	0.07	0	6
						± 3	± 2	± 4	± 1	± 2	± 0.7		
<i>Dendrocalamus giganteus</i>	0	0	0	0	2.6	12.8	4.2	0.6	0	0	0	0	4
					± 1.3	± 5.2	± 2.7	± 4					
<i>D. longispathus</i>	0	0	0	0.4	0.2	2.7	3.4	2.4	1.7	0.7	0.3	0	8
				± 3	± 1	± 0.9	± 1.4	± 1.0	± 6	± 2	± 2		
<i>D. strictus</i>	0	0	0	0	0	0.1	0.8	1.0	0.4	0.7	0.3	0	6
						± 0.09	± 4	± 2	± 2	± 0.7	± 1		

Table 6 continued ...

Species	Months												Culm emergence period (months)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
<i>Melocanna baccifera</i>	0	0	0	0	0.1	0.7	1.7	3.7	2.2	0.9	0.2	0	7
					± 0.7	± 2	± 5	± 7	± 6	± 3	± 0.8		
<i>Neohouzeaua dullooa</i>	0	0	0	0	0.2	0.6	1.8	2.8	1.2	0.09	0	0	6
					± 1	± 3	± 5	± 8	± 3	± 2			
<i>Oxythenanthera</i>	0	0	0	0	0.2	0.4	3.7	6.1	4.4	1.4	1.0	0	7
<i>nigrocialiata</i>					± 1	± 2	± 1.0	± 1.2	± 8	± 6	± 4		
Total	0	0	0	0.4	4.5	22.4	23.1	21.5	15.2	8.2	3.2	0	

Mean:

a) Soil temp °C

At 50-200 cm depth	22.0	22.8	25.6	28.3	29.1	28.9	28.6	28.8	28.5	28.5	26.2	22.4
- At 100 cm depth	22.1	22.8	25.3	28.3	29.1	28.9	28.7	28.6	28.5	28.5	26.5	23.5
b) Air temperature °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
c) Relative humidity%	56.5	55.5	55.3	62.2	65.1	67.4	70.8	67.2	66.0	66.0	63.1	55.9
d) Total rainfall mm	17.9	12.7	33.6	117.5	375.6	566.3	783.9	426.1	321.6	247.1	95.1	13.6

in highest number of culm emergence in these months. As time passed food supply became exhausted and thus resulted in gradual decrease in the culm emergence in the following months.

The knowledge of culm emergence periodicity might be useful in managing the bamboo clump. Uchimura (1980) reported that to improve the yield of a bamboo clump, fertilizers should be applied about a month before sprouting periods so that the effects appear at the time of sprouting and growth. Huberman (1959) also reported that felling of culms from the clumps should not be done during the culm emergence period.

5.1.4 Culm elongation

The elongation pattern of newly emerged culms of *Bambusa balcooa*, *B.vulgaris* and *Melocanna baccifera* are graphically represented by plotting the daily increase in length of the culm against the corresponding dates (Fig. 3). In all the three species the curves are usually steeper on the "east" side and more gently sloped on the "west" side. The curves indicate that just after the appearance of culms on the ground, they elongate very slowly upto 1-2 weeks and then gradually gain speed until they attain the optimum size and thereafter the rate of elongation quickly get slowed down (Fig. 3). The total culm elongation periods for *B.balcooa* and *B.vulgaris* were found to be 75-85 days, whereas it was 55-60 days in *Melocanna baccifera*.

The culm elongation curve of each of the species shows 2 distinct peaks, the first one being short and the second one is tall. These 2 peaks are due to the 2 rapid elongation phases exhibited by the culm in its total growth period. It is difficult to explain such behaviour of culm elongation in bamboos, and needs further studies. It was also

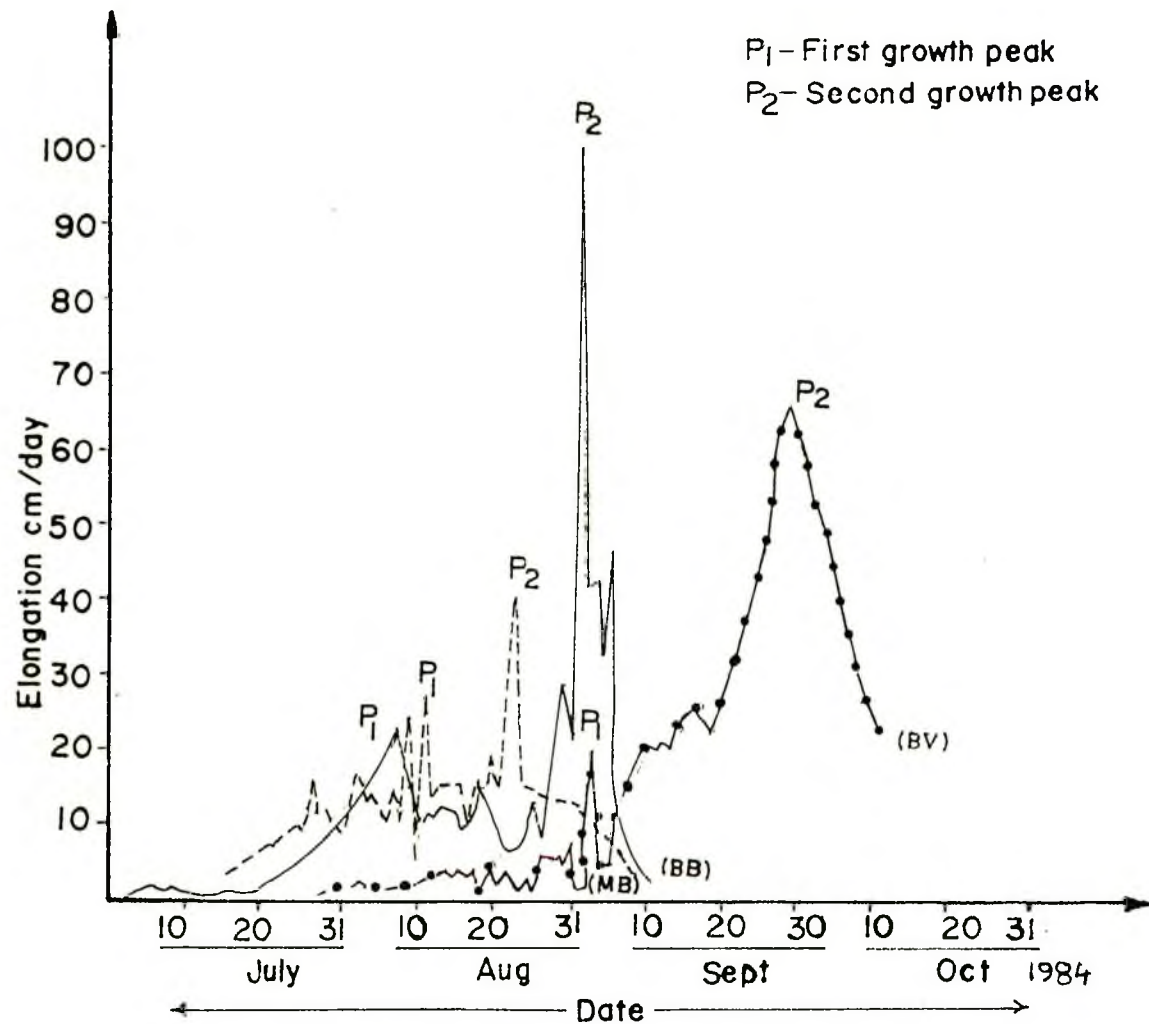


FIGURE 3. Elongation pattern of emerging culm: Bambusa balcooa (BB), B. vulgaris (BV), and Melocanna baccifera (MB).

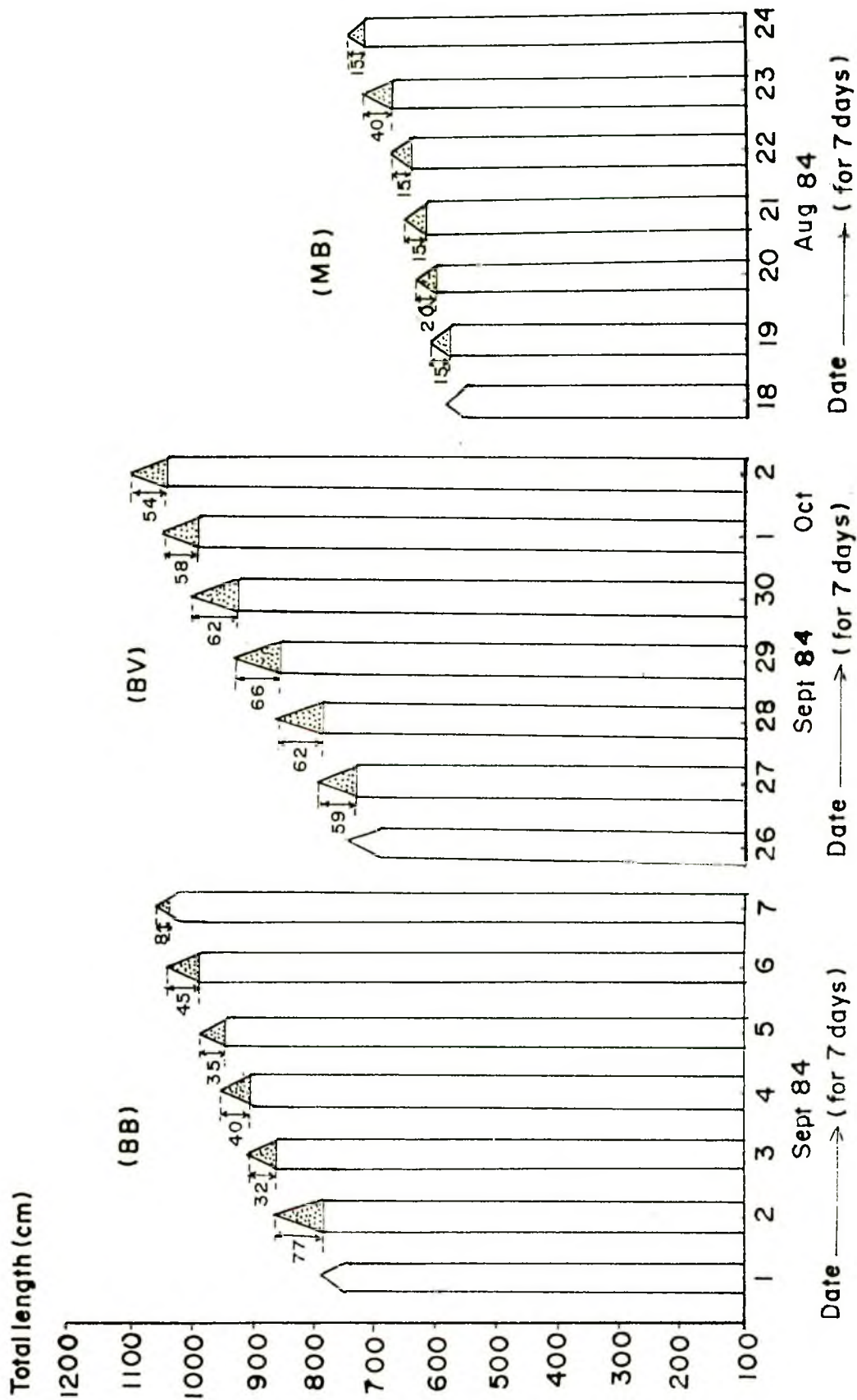


FIGURE 4. Daily maximum elongation rate of emerging culm: *B. balcooa* (BB), *B. vulgaris* (BV), and, *M. baccifera*(MB).

observed that culm did not show any diameter increament during or after the elongation period. The diameter with which it emerges remain unchanged throughout its life. 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.

The maximum elongation of culm of the 3 species have been elucidated by bar charts (Fig. 4). The maximum rate of elongation per day was observed in *B.balcooa* (77.0cm), and *B.vulgaris* (66.0cm), while it was comparatively low (40.0cm) in *M.baccifera*. Osmaston (1918) reported that in *Dendrocalamus giganteus* the daily elongation of culm was about 10-13 cm, but also raised upto 58 cm at the time of vigorous growth. Similarly Ueda (1960) also reported that the culms of *Bambusa arundinacea* elongated maximum of 91.3 cm per day. Such a remarkable growth could never be seen in any other species of plant kingdom (Ueda 1960). According to Kato (1963) it seems possible that gibberellins may play some part in mediating such rapid growth of bamboo culms. In fact Tamura *et al.* (1966) have first tentatively referred as bamboo gibberellin, and demonstrated its growth promoting effects on various plants. However, the effect of bamboo gibberellin on the growth of bamboos needs biochemical and physiological investigations.

5.1.5 Natural mortality of emerging culms

Mortality percentage of emerging culms at developing stage varies from species to species in bamboos. Variation was also high among the clumps within a species. Coefficient of variation in total culm production, survival, and death were within 50 to 137 percent in all cases (Table 7). All the clumps of each species under study were growing in the same

bambusetum and as a result the effect of environmental variations was considered negligible. The clumps of each species were of different clonal origin and brought to the bambusetum from different localities of Bangladesh. It is likely that each clone (clump) possesses specific genetic make up within the same species of bamboo and thus impart variability in culm production and mortality.

In all the species, excepting muli (*M.baccifera*), the death of the 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 this distance created a congested clump condition. Generally, the dead culms in muli were taller (35.0 cm) than others and their emerging distance were also within 78.0 cm to the nearest older culm (Table 8). Due to elongated rhizome necks muli has a more open type of clump than other clump forming bamboos which have short-necked sympodial rhizome system (Banik 1980). The distance of emerging culm from the nearest older culm is controlled by the length of rhizome neck and the nature of rhizome movement. Clumps having congested sympodial rhizome system produced most of the culms within a short distance (McClure 1966). Therefore, competition for survival among the developing culms had increased. This condition increased mortality percentage among the young developing culms in the species with short-necked sympodial rhizome system. On the other hand, the mortality percentage was lesser in muli where the clumps are open due to long-necked (1.0 to 1.5 m) sympodial rhizome system (Table 7). Kondas (1981) and Sharma (1982) had also opined that congestion could be a factor for death of emerging culms.

Generally, the culm mortality was higher in thick walled than in thin walled bamboo species (Table 7). Average mortality percentage varied from 28 to 69 in the case of thick walled, large dimension species, whereas, it was 9 to 37% in

the case of thin walled, small dimension species. Such high mortality in some thick walled bamboos were also reported by Sharma (1982). He reported 60% mortality in *Gigantochloa levis* and 70% in *B.vulgaris*. Elongation rate of an emerging bamboo culm, in general, can be grouped among the fastest growing ones of the plant kingdom (Ueda 1960, McClure 1966). To meet the requirements of such rapid rate of elongation mother rhizome has to supply sufficient food material to the developing culms. Uchimura (1980) reported that the amount of reserve food material in the rhizome declined during the culm growing period. Therefore, competition for food among the developing culms is not unlikely. It is likely that the food requirement in the species having larger culm dimensions is higher. Therefore, it is probable that the stored food in the rhizome of mother culm is not enough to meet the requirement of elongation of all the emerging culms in thick walled bamboo species. Inadequate food supply could be a reason for higher mortality in thick walled bamboo species. Ueda (1960) and Uchimura (1980) reported that survival rate of emerging culms can be increased by applying the fertilizer. Xianhui and Yuemei (1983) observed that transcription and translation losses of DNA and RNA prevent the synthesis of protein and force bamboo shoots to stop their growth resulting in degradation.

The culm emergence period, in most of the species, was during May to October (Table 6). It was observed that emerging culm mortality was higher (50-65%) in September and October (later part of the growing season) when the number of rainy days were few, and average total rainfall was comparatively low. Kadambi (1949) observed that, in general, years of plentiful rainfall produced large numbers of shoots than the years of deficient and scanty rainfall. Rain also prompted the shoot emergence and culm growth of all Japanese bamboos (Shigematsu 1960). Less and scanty rainfall are likely

	1978			1979			1980		
Species	Emerged total	Dead Nos.	Mortality (%)	Emerged total	Dead Nos.	Mortality (%)	Emerged total	Dead Nos.	Mortality (%)
Thick walled									
B.bal	2.9 $\pm$ 0.4 47	0.9 $\pm$ 0.2 60	31.0	3.8 $\pm$ 0.7 57	1.4 $\pm$ 0.3 69	36.8	3.5 $\pm$ 3.2 102	1.5 $\pm$ 0.5 105	42.9
B.lon	8.2 $\pm$ 0.1 45	2.4 $\pm$ 0.7 69	29.3	6.1 $\pm$ 1.8 64	1.7 $\pm$ 0.4 46	27.9	9.2 $\pm$ 1.8 45	3.0 $\pm$ 0.4 33	33.0
B.nut	8.1 $\pm$ 2.1 69	3.3 $\pm$ 0.9 72	40.7	7.3 $\pm$ 1.8 64	3.0 $\pm$ 0.7 58	41.1	9.1 $\pm$ 2.5 73	4.0 $\pm$ 1.0 64	43.9
B.vul	9.0 $\pm$ 1.2 52	6.1 $\pm$ 1.0 69	68.0	8.9 $\pm$ 1.5 65	6.2 $\pm$ 1.3 79	69.6	8.7 $\pm$ 1.5 67	5.9 $\pm$ 1.0 67	67.8
D.gig	7.0 $\pm$ 5.0 124	4.7 $\pm$ 3.7 137	67.0	11.7 $\pm$ 8.7 129	6.0 $\pm$ 4.5 130	51.3	11.0 $\pm$ 2.2 50	5.0 $\pm$ 1.5 40	45.5
Thin walled									
B.tul	12.6 $\pm$ 3.8 96	4.7 $\pm$ 1.6 109	37.3	3.6 $\pm$ 0.7 64	1.1 $\pm$ 0.3 100	30.6	6.8 $\pm$ 2.1 10	2.0 $\pm$ 0.9 145	29.4
D.lon	7.0 $\pm$ 2.1 84	1.5 $\pm$ 0.6 106	21.4	8.9 $\pm$ 2.6 84	2.1 $\pm$ 0.6 81	23.6	4.9 $\pm$ 1.6 99	1.4 $\pm$ 1.3 100	28.6
M.bec	2.9 $\pm$ 0.4 77	2.7 $\pm$ 0.7 80	10.3	25.5 $\pm$ 4.0 50	2.5 $\pm$ 0.4 54	9.8	33.2 $\pm$ 6.5 62	2.9 $\pm$ 0.7 79	8.7

Note: B.bal = *Bambusa balcooa*, B.lon = *B.longispiculata*, B.nut = *B.nutans*, B.vul = *B.vulgaris*,
D.giq = *Dendrocalamus giganteus*, B.tul. = *B.tulda*, D.lon = *D.longispathus*, M.bec = *Melocanna baccifera*,

Table 8: Average height of the dead culm of 8 different bamboo species and their average emerging distance from nearest older culm.

Species	Height (cm)	Distance (cm)
Thin walled		
<i>Bambusa tulda</i>	18.0	16.0
<i>Dendrocalamus longispathus</i>	18.5	15.0
<i>Melocanna baccifera</i>	35.0	78.0
Thick walled		
<i>Bambusa balcooa</i>	18.8	26.7
<i>B. longispiculata</i>	21.9	24.9
<i>B. nutans</i>	9.7	8.7
<i>B. vulgaris</i>	12.0	14.6
<i>Dendrocalamus giganteus</i>	13.0	20.0

to reduce turgescence, a condition essential for culm elongation and growth (Kramer 1959, Sharma 1982). Moreover, in the later part of the growing season stored food materials of the mother rhizome may become exhausted by supplying most of its food to the culms developed in the early part of the season.

During the study period soil was found eroded from some of the clumps of *B. vulgaris*, *B. balcooa*, and *D. giganteus* due to rains. Interestingly, mortality of emerging culms was much higher (70 to 92%) in such clumps of these species.

5.1.6 Culm character -- internode length, wall thickness and diameter ratio

Pattern of internode length: The march of increase and decrease in internode length, as measured from self-supporting bamboo culms of 10 different species are graphically represented by plotting the length of each internode against its serial number, beginning from the base to the tip. The graphs show the form of the profile of an asymmetrical mountain with a single acute or more or less rounded crest, or with two or more, usually less well-marked peaks in the median region (Fig. 5, 6 and 7). In all the 10 species the curves are usually steeper on the "left" side and more gently sloped on the "right" side. This indicates larger length increments in successive internodes from the lower to the middle parts and then internode lengths decrease gradually in the upper parts of the culm.

Among the four *Bambusa* species (Fig. 5) *B. polymorpha* and *B. tulda* have more elongated internodes at the mid-culm zones resulting in peaks in the median regions of the curves. Both *Bambusa balcooa* and *B. vulgaris* have a series of mid-culm internodes of more or less equal length. In each of the species, therefore, the curve of internode lengths is broad and has nearly flat middle section (Fig 5).

Among the three species of *Dendrocalamus* genus, *D. longispathus* possesses distinctly elongated internode in the mid-culm region represented by a sharp peak (Fig. 6). Both *D. giganteus* and *D. strictus* have series of more or less equal length internodes in the mid culm zones similar to *B. balcooa* and *B. vulgaris*.

Among three thin walled bamboo species of the forest, *Neohouzeaua dullooa* has very long internodes increasing succesively from the base to the mid-culm zone followed by sharp decrease in length towards the culm tip and

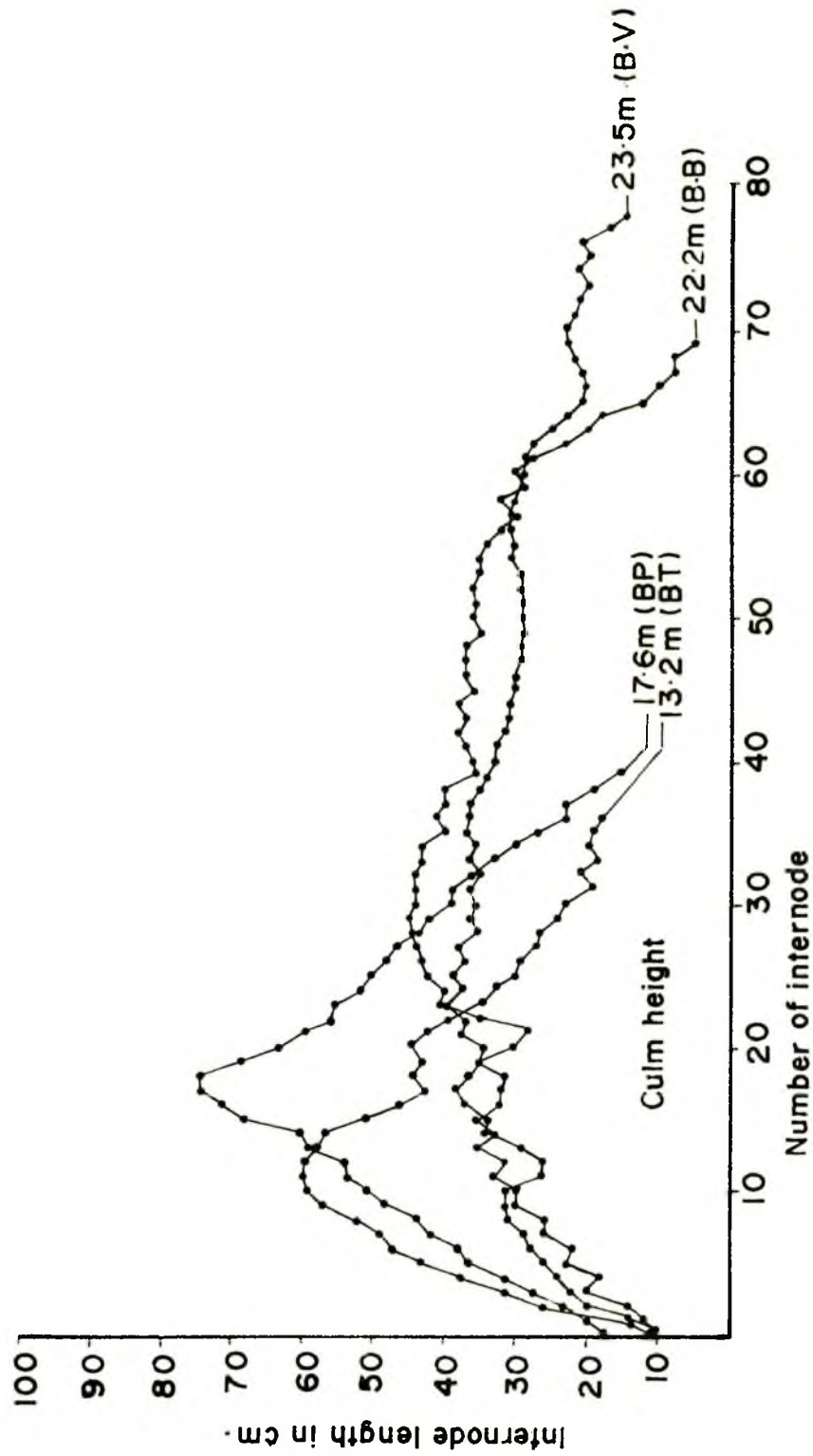


FIGURE 5. Pattern of increase and decrease in average internode length of a culm of same age group: Bambusa balcooa (B.B), B. Polymorpha (B.P), B. tulda (B.T), and B. vulgaris (B.V).

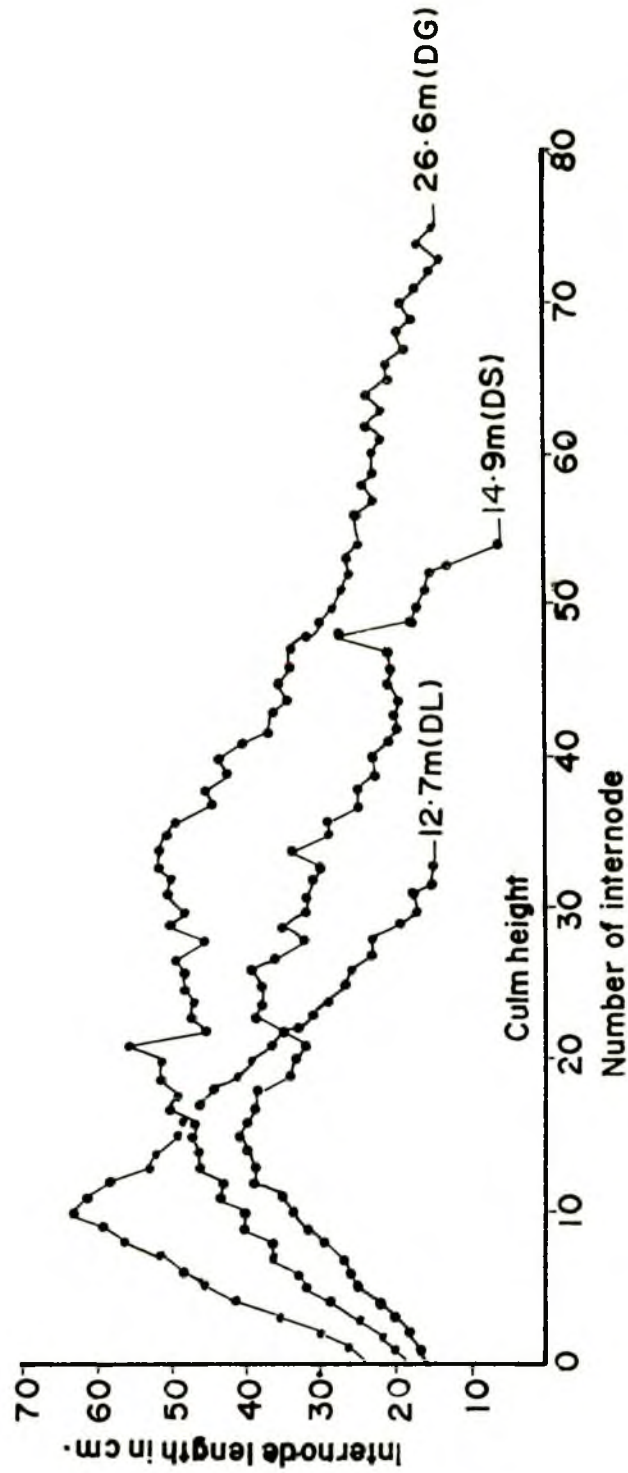


FIGURE 6. Pattern of increase and decrease in average internode length of a culm of same age group: Dendrocalamus giganteus (DG), D. Langispathus (DL), and D. strictus (DS).

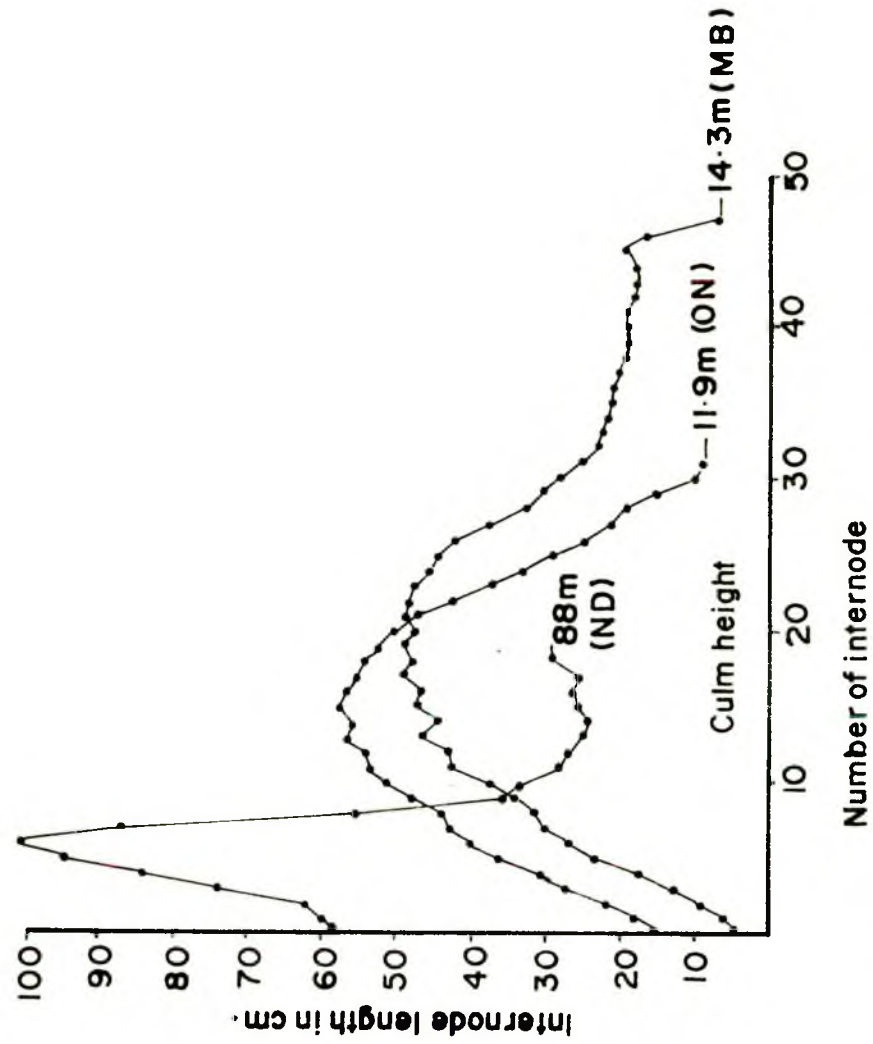


FIGURE 7. Pattern of increase and decrease in average internode length of a culm of same age group: Mclocanna baccifera (M B), Neohouzeaua dulloo (ND), and Oxytenanthera nigrociliata (O N).

is represented by a sharp peak in the middle of the internode curve (Fig. 7). On the contrary, *Melocanna baccifera* has a series of more or less equal internodes in the mid-culm zone and therefore, the internode curve (Fig. 7) is also broad and more or less flat at the middle. *Oxytenanthera nigrociliata* represents an intermediate pattern of internodal length in between *M. baccifera* and *N. dullooa*.

Presence of distinctly elongated internodes in the culms of *N. dullooa* and *D. longispathus* indicates that these species are more or less shade tolerant, and in fact in the forest they grow along the moist banks of streams, and associated with tree shades. The species are usually not found on the open hill tops. Rao and Ramakrishnan (1988) have also reported that *N. dullooa* is more relatively shade tolerant. Similarly *B. polymorpha* has also long internodes in the mid-culm zone and according to Troup (1921) the species grow naturally as an associate and understory of the *Xylia* (pynkado) forests of Burma. According to McClure (1966) the length of the internodes of bamboo culms varies from species to species and have a stable genetic basis.

Culm diameter and wall thickness ratio: Among ten bamboo species under study *D. giganteus* possesses widest diameter culms (Table 9). Other species such as, *B. balcooa*, *B. polymorpha*, *B. vulgaris* have also bigger diameter culms; while *M. baccifera*, *N. dullooa* and *O. nigrociliata* have small diameter culms. Culm diameters of *D. strictus*, *B. tulda* and *D. longispathus* suggest their grouping as intermediate type (Table 9). However, culm diameter may further increase or decrease depending on the site conditions and the age of the plant when culm is measured (Troup 1921, Ueda 1960).

In all the bamboo species under study wall thickness is maximum in the lower portion (base) of the culms and gradually decreases from base to top (Table 9).

Table 9: Ratio of wall thickness (wt)/diameter (dia) measurement at, base, mid and top - culm position in 10 different bamboo species.

Species	Base			Mid			Top		
	Dia	Wt	Ratio	Dia	Wt	Ratio	Dia	Wt	Ratio
B.bal	9.15	2.82	0.308	7.82	0.92	0.117	1.24	0.36	0.290
B.pol	9.25	1.19	0.128	7.78	0.74	0.095	1.35	0.22	0.163
B.tul	5.75	1.17	0.203	4.52	0.41	0.091	1.02	0.21	0.205
B.vul	8.32	1.72	0.206	7.65	0.62	0.082	0.70	0.22	0.314
D.gig	18.72	3.45	0.187	11.00	0.70	0.063	0.42	0.10	0.238
D.lon	5.30	1.79	0.337	4.10	0.36	0.088	0.88	0.19	0.215
D.str	6.52	3.34	0.512	5.00	0.64	0.130	0.63	0.22	0.350
M.bac	4.05	1.28	0.316	3.25	0.29	0.089	0.60	0.16	0.267
N.dul	2.87	0.68	0.237	2.65	0.24	0.090	0.86	0.12	0.139
O.nig	4.01	0.96	0.239	3.04	0.31	0.101	0.69	0.10	0.145

N.B: B.bal = *Bambusa balcooa*, 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.bac = *Melocanna baccifera*,

N.dul = *Neohouzeaua dullooa*,

O.nig = *Oxytenanthera nigrociliata*

Among them *D. giganteus*, *D. strictus*, and *B. balcooa* have maximum (3.45, 3.34 and 2.82 cm) wall thickness in the basal portion of the culms while *N. dullooa* and *O. nigrociliata* possess culms with thinnest wall (0.68 and 0.96 cm) (Table 9) However, when ratio between wall thickness and culm diameter is considered, the picture of so called grouping of "thick" and "thin" walled bamboos become different. Such ratio of *N. dullooa* and *O. nigrociliata* were higher than those of so called "thick" walled species like *B. vulgaris* and *D. giganteus* (Table 9). Among all the species *D. strictus* has the highest ratio

value between wall thickness and diameter at base, mid and top culm position. However, in all the 10 species the value of such ratio is found to be within 0.52. Thus it appears that the ratio between wall thickness and culm diameter might be an important consideration in classifying bamboos as "thick" and "thin" walled species. It is interesting to note that the value of ratio is found to be always lowest (0.06-0.13) in the mid zones than those of base and top culm portions of all the bamboo species under study (Table 9). This indicates that in relation to the diameter mid culm zones have thinnest wall thickness than those of basal and top portion of the culms. Presence of elongated internodes with lowest ratio values of wall thickness and diameter at mid culm zones might be an architectural adaptation in bamboos to provide more elasticity against severe stormy winds.

5.1.7 Culm production, growth and clump expansion behaviour

Culm production and clump expansion: It has been observed that all the five bamboo species (*B.balcooa*, *B.longispiculata*, *B.tulda*, *B.vulgaris* and *M.baccifera*) under study produced only one to three full grown (FG) culms per clump in the first year after plantation (Table 10). The number of (FG) culms gradually increased in the subsequent years and became more or less maximum (3.2 to 8.8) in the 5th year of clump age in the case of all four *Bambusa* species. To provide room for the increased number of culms the rate of clump girth expansion was also rapid upto the 5th year in the case of *B.balcooa* (avg. 232 cm) and *B.tulda* (avg. 439 cm) and 6th year in *B.vulgaris* (avg. 456 cm) and *B.longispiculata* (avg. 372 cm) after plantation (Table 10 and Fig. 8). Number of FG culm production in *Bambusa* sp. then slowly decreased

from the 6th year and were 2.2 to 5.7 in the 10th year of clump age. Cumulative total of FG culms produced in the clumps of these four *Bambusa* species upto the 5th and 6th year of age made crowded condition due to short (7-12 cm) neck pachymorph rhizome system. This crowded and congested condition created a scarcity of room for the new emerging culms and also increased competition among them for survival (Kondas 1981; Banik 1983b). Probably due to this reason culm production subsequently decreased from the 6th year in the clumps of *B.vulgaris*, *B.balcooa*, *B.longispiculata*, *B.tulda* (Table 10). Kondas (1981) observed in a clump of *B.vulgaris* planted in Dandeli, India that the culm production was higher upto the 4th year after planting and then decreased in the subsequent years. Decreased in culm production might have slowed down the rate of clump girth expansion after the 6th and 7th year in these four *Bambusa* species (Table 10 and Fig. 8). Sudden increase in the clump girth at the 9th year in the case of *Bambusa longispiculata* as shown in Figure 8 could not be explained. In the case of *Melocanna baccifera* the average production of FG culms was 2.5 in the first year and from third year the number increased rapidly to 12.5. Culm production also rapidly increased in the subsequent years reaching 35.7 after the 10th year of clump age (Table 10). Unlike other clump forming bamboos *M.baccifera* has underground pachymorph rhizomatous system with strongly elongated (1.0-1.5 m) neck (Banik 1980). Owing to this rhizome nature the species produces culms at varying intervals in all directions forming a diffuse and open type of clump (Watanabe 1986) which can accommodate the space required for the increased number of FG culm production in the subsequent years after plantation. Probably due to this reason the rate and pattern of clump girth expansion in *M.baccifera* are different from those of other four *Bambusa* species (Fig. 8). It can be seen from the Figure 8 that the rate and pattern of clump girth expansion

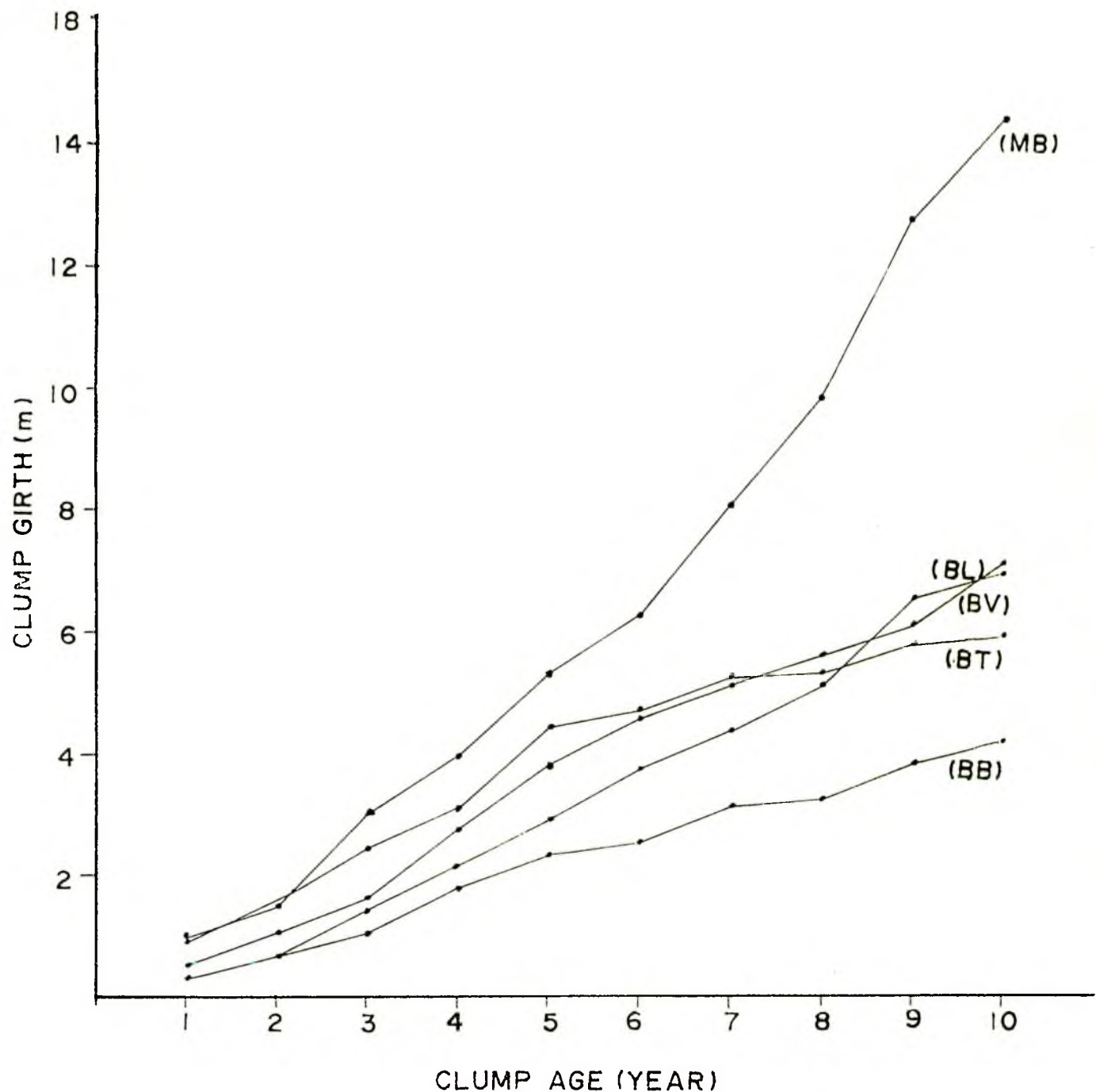


FIGURE 8. Rate and pattern of clump expansion at different age: *Bambusa balcooa* (B B), *B. Longispiculata* (B L), *B Tulda* (B T), *Bambusa vulgaris* (B V), and *Melocanna baccifera* (M B) .

in *M.baccifera* are more or less same as other *Bambusa* species for 4 and 5 years of clump age. After that period clump girth in *M.baccifera* increased rapidly every year and continued even upto the 10th years of the study. Therefore, in this species, it is difficult to prescribe any spacing distance for initial planting. In normal condition rhizome system of this species probably needs 4 to 5 years, to accumulate sufficient amount of photosynthetic reserves for producing elongated necks. As a result clump girth increased very rapidly only after that period of rhizome growth.

Culm height and diameter: Culms of all bamboo species complete their growth within 2 to 3 months after the emergence of sprouts from the ground. Their diameter and height do not increase after the growth is over (McClure 1966, Banik 1980, Ueda 1981). It has been observed that in all the five bamboo species the culms those emerged in the first year after plantation were short (1.5 m to 4.0 m) in length and narrow (0.7 cm to 1.6 cm) in diameter at breast height (dbh) (Fig. 9). Culms produced in subsequent years were distinctly taller and wider in diameter than those produced in the past years and such trend continued upto 5-6 years in *B.longispiculata* and *B.tulda*, and 7 years in the case of *B.vulgaris* and *B.balcooa*. After these periods clumps of these four *Bambusa* species did not produce any taller and wider culms in the subsequent years. The study also revealed that number of full grown culms emerged in the clumps of all the four *Bambusa* species increased upto the 5th year of age and then gradually decreased. Consequently to provide room for new culms, clump girth also expanded rapidly upto the 5th - 6th years of age of plantation. On the average clump girth varied between 232 cm and 456 cm within this period depending on the species. Considering the upper limit of clump girth expansion spacing between the planting stock may be kept at least 5 m in

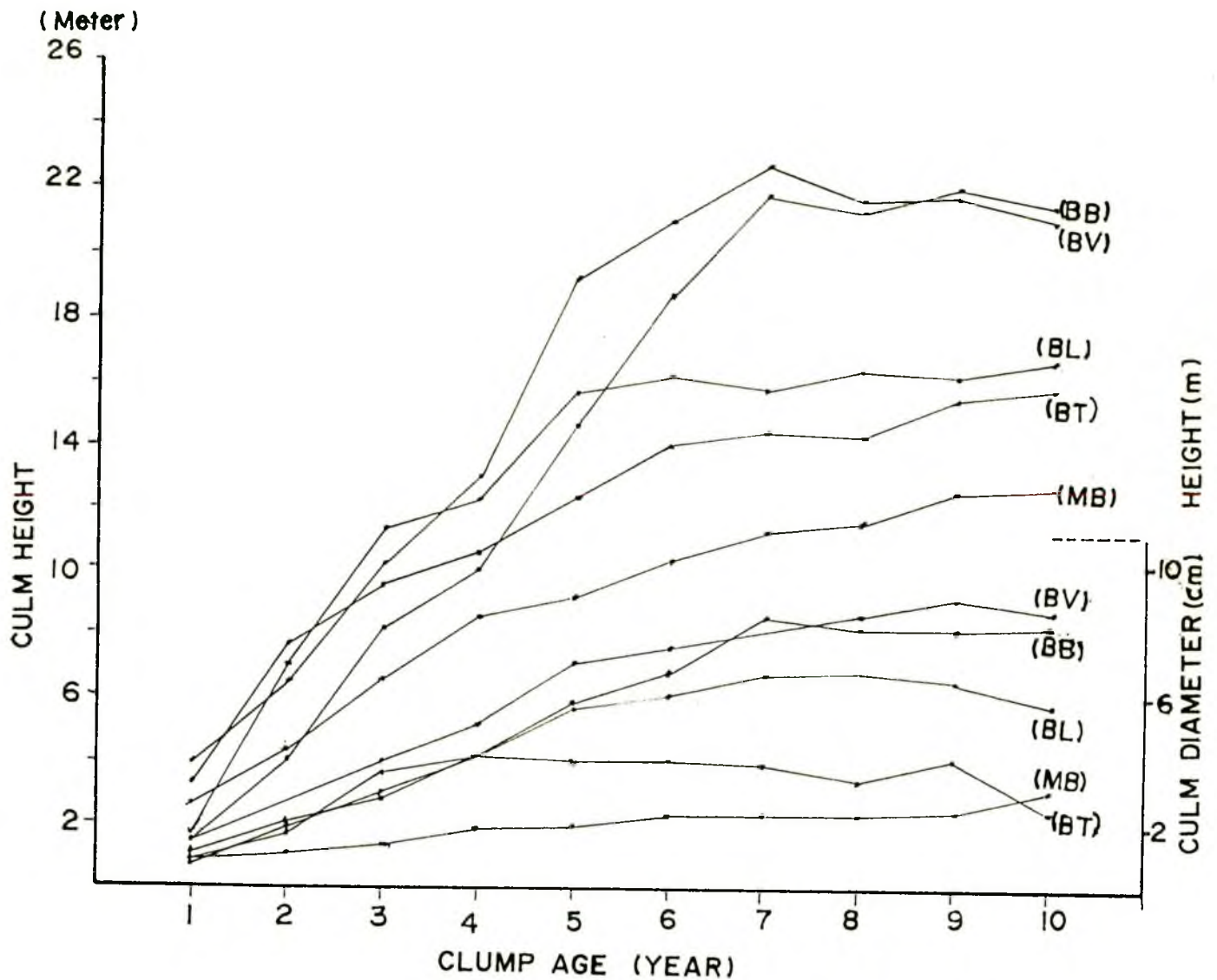


FIGURE 9. Growth rate of full grown culm produced at different age in a clump: *Bambusa balcooa* (B B), *B Longispiculata* (B L), *B Tulda* (B T), *Bambusa vulgaris* (B V), and *Melocanna baccifera* (M B).

Table 10: Annual production of full grown (FG) culm and gradual expansion of clump girth upto 10 years of clump age in 5 bamboo species of Bangladesh.

Clump age (year)	B.vul		B.bal		B.lon		B.tul		M.bac	
	FG	Clump	FG	Clump	FG	Clump	FG	Clump	FG	Clump
	culms (Nos.)	girth (cm)	culms (Nos.)	girth (cm)	culms (Nos.)	girth (cm)	culms (Nos.)	girth (cm)	culms (Nos.)	girth (cm)
1	1.6	50.0	1.2	28.5	1.8	30.0	3.0	87.0	2.5	92.2
(1973)	+0.2	+4.5	+0.2	+2.0	+0.4	+5.2	+0.5	+13.2	+0.5	+20.5
2	2.8	105.0	2.3	66.2	2.7	66.5	3.8	153.0	5.6	145.9
(1974)	+0.3	+10.0	+0.9	+13.5	+0.6	+13.6	+0.4	+16.6	+1.7	+23.2
3	3.2	162.6	1.7	102.0	4.1	140.2	8.2	243.0	12.5	301.0
(1975)	+0.7	+22.0	+0.2	+14.0	+0.6	+16.5	+1.3	+28.3	+2.5	+42.0
4	5.3	273.4	2.7	177.0	6.2	222.0	5.7	307.0	16.4	395.4
(1976)	+1.2	+35.5	+0.4	+22.6	+0.5	+24.7	+0.9	+36.5	+4.2	+53.3
5	5.2	378.0	3.2	232.0	7.0	286.4	8.8	439.3	23.6	529.3
(1977)	+1.7	+50.3	+0.8	+38.0	+1.3	+20.6	+2.3	+56.3	+7.2	+105.6
6	3.6	456.3	2.2	250.0	6.7	372.0	4.5	464.0	25.3	624.3
(1978)	+0.8	+62.1	+0.4	+29.4	+1.3	+28.2	+1.0	+51.0	+4.6	+115.2
7	3.2	508.3	2.4	312.5	5.0	430.0	4.9	520.1	26.6	805.4
(1979)	+0.6	+64.4	+0.5	+32.5	+1.0	+35.0	+1.2	+42.0	+8.7	+146.1
8	3.2	555.0	1.8	320.5	6.6	507.6	3.7	527.2	25.1	980.6
(1980)	+0.6	+75.8	+0.5	+24.0	+1.4	+66.6	+0.3	+61.6	+6.2	+170.5
9	2.6	603.0	2.2	376.0	5.8	648.3	4.8	571.0	31.1	1268.0
(1981)	+0.6	+58.0	+0.5	+53.7	+1.0	+109.6	+1.8	+57.6	+8.0	+247.0
10	2.8	705.0	2.2	414.2	5.7	690.0	2.7	586.7	35.7	1432.3
(1982)	+0.7	+114.5	+0.5	+58.3	+1.6	+132.3	+0.4	+207.8	+13.3	+281.0

* Clump raised through offset planting in 1972 left undisturbed upto 1983.

the case of these four *Bambusa* species. In these species both height and dbh of FG culm produced during 5 to 7 years of clump age were maximum and after that period these were more or less static. As the clumps were left undisturbed for a number of years a crowded and congested condition developed due to the cumulative production of culms leading to a decreased yield. Therefore, selective felling of older culms may be started in these *Bambusa* species after 5 to 7 years of planting.

New culms of *M.baccifera* emerged in each year after planting were taller and wider than those of the previous year. This trend was distinctly rapid upto the age of 4-5 years but after that (upto 10 years of study) the culms which emerged showed comparatively slower growth (Fig. 9). It has been observed that in *M.baccifera* culms with merchantable quality are produced after four years of planting and these bamboos die out generally within next 4 to 5 years due to senescence. If these bamboos are not harvested from the clump within this period (7 to 8 years of planting) the loss of resource would occur. Under the above considerations, it seems that felling of culms in *M.baccifera* may not be delayed at least beyond 7 to 8 years of planting.

However, further study is needed to find out the effect of felling on culm production and clump expansion.

5.1.8 Natural senescence of culm

Culms of different age groups, from 1-7 or even 14 year old, can be found in a clump if left unharvested (Table 11). It has been seen that the longevity of culms in the clump varied from species to species (Table 11). The life of culms in the clumps of *D.longispathus* and *O.nigrociliata* was 5-8, in

B.tulda 5-9, in *B.polymorpha* and *M.baccifera* 5-10, in *B.longispiculata* 6-8, in *D.giganteus* 10-12, and in *B.balcooa* 11-13 years. Similar to this observation Peal (1882) also reported that stem lived 10-14 years in Buluka (*B.balcooa*) bamboo at Assam. Ueda and Numata (1961) reported that culms of Japanese bamboos became mature in 3-4 years then gradually grew old and weak to death in 10 years or so. According to Kasahara (1981) this is an aging cycle of organs or tissue and varies more or less in accordance with the conditions of the environment. However, McClure (1966) reported that culms in some species were very short lived and more commonly persisted for 5-10 years.

Culms started dying at 5 years of age in *B.polymorpha*, *B.tulda*, *D.longispathus*, *M.baccifera* and *O.nigrociliata*, whereas death started at 10 and 11 years of age in *D.giganteus* and *B.balcooa* respectively (Table 11). In *B.longispiculata* death started when culms were 6 years of age. It appeared that culm life in the clumps of thinwalled forest species was comparatively shorter than those in the clumps of thick walled cultivated species. However, in a clump all culms did not die at the same year. Depending on the species 4-33% culms started dying at the beginning and the remaining culms died gradually within next 2-6 years (Table 11). That means from the same age group some culms died at 5 years and gradually remaining all died within 9 years (*D.longispathus*, *O.nigrociliata*), 10 years (*B.tulda*), and even within 11 years (*M.baccifera*, *B.polymorpha*) of age (Table 11). Death of the culms of same age group was completed within 4 years in *B.balcooa*, *B.longispiculata* and *D.giganteus* and within 5 years in *D.longispathus* and *O.nigrociliata*. But it took 6 years in *B.tulda* and 7 years in *B.polymorpha* and *M.baccifera*. This data indicate that death phenomenon is completed within 4-7 years and it varies from species to species.

Table 11: Natural life-period of culms in the clumps of 8 different bamboo species

Species		Age upto which 100% culm survived (years)	Mortality % of culm ($X \pm tSE$) in the following years after the age upto 100% survival						
			1-yr	2-yr	3-yr	4-yr	5-yr	6-yr	7-yr
B.bal	10	6.7	16.7	70.0	100	-	-	-	-
		± 18.5	± 29.3	± 34.0		-	-	-	-
B.lon	5	24.6	69.2	83.3	100	-	-	-	-
		± 27.8	± 34.5	± 14.5		-	-	-	-
B.pol	4	4.3	3.3	10.2	18.3	33.5	50.7	100	
		± 6.8	± 5.8	± 14.5	± 23.4	± 25.8	± 35.2	-	-
B.tul	4	9.3	19.7	37.6	70.4	97.9	100	-	-
		± 15.6	± 27.6	± 36.3	± 20.8	± 5.4	-	-	-
D.gig*	9	16.7	55.6	75.0	100	-	-	-	-
D.lon	4	6.6	45.4	62.0	85.4	100	100	100	
		± 11.2	± 39.0	± 34.9	± 14.2	-	-	-	-
M.bac	4	4.2	11.0	14.1	73.2	88.8	96.7	100	
		± 7.2	± 3.8	± 3.7	± 10.1	± 13.6	± 9.3	-	-
O.nig*	4	33.3	42.9	50.0	66.7	100	100	100	

Note: B.bal = *B.balcooa*, B.lon = *B.longispiculata*,
 B.pol = *B.polymorpha*, B.tul = *B.tulda*,
 D.gig = *D.giganteus*, D.lon = *D.longispathus*,
 M.bac = *M.baccifera*, O.nig = *O.nigrociliata*

* $\pm tSE$ not calculated as only 1 clump studied

More often culms among the same age group which were at the centre of a clump died earlier than those emerged on the periphery. Death symptoms started from the upper portion of the culm by drying up of tips, branches and leaf buds. When most of the leaves on the culm shed the symptoms of aging rapidly accelerated by complete yellowing of the culms from top towards the base. Such natural deterioration due to aging that accompany 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 process. 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 get reduced in number (Hossain 1962). 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 from the study that culms in the clump of a species should not be left unharvested for a longer time. Life period of individual culms of a species might be an important criterion for fixing the upper limit for the felling cycle as opined by Seth and Mathauda (1959).

5.1.9 Morphological characters for culm age determination

Some of the important morphological characters recorded from different age groups of culms under each bamboo species. Recorded characters in relation to culm age for some common bamboo species of Bangladesh are given below:

Age upto
(year)

Morphological description

Bambusa balcooa

- 1st year Culm sheath: Sheath may be present at 2-3 basal nodes.
- Bud break and branches: The large branch bud on the culm node breaks and produce a thick stout branch. Comparatively small and thin 1-2 branches are also produced from both the side of the main stout branch. Base of the branches along with some basal culm nodes are generally covered with straw coloured papery sheaths. Buds on the basal 3-4 nodes of the culm usually do not break and also not produce any branches.
- Culm: At young stage a brown to whitish pubescent ring is present on the basal 6-9 nodes, in addition to that usually basal 4-5 nodes possess a ring of adventitious roots. Nodes are prominent and ridged. Colour is dark glossy green. Basal 6-8 internodes are lightly covered with minute brownish hairs arranged in many vertical lines closely parallel to each other.
- 2nd year Culm sheath: Usually not present on the culms, sometimes may be present on the basal 1-2 nodes.
- Bud break and branches: Excepting 4-5 basal nodes almost all buds of the culm nodes developed thick stout branches. The auxillary branches upto basal 5-6 nodes transform into curved thorn like structure. Base of the branches sometimes may be covered with thin persistent sheath.
- Culm: Brown to whitish ring along with adventitious roots may be present on the basal

3-4 nodes. Colour is not so deep green and the basal internode are slightly covered with minute brownish hairs.

3rd year

Culm sheath: Absent

Bud break and branches: Usually buds on the basal 3-5 culm nodes are dead and rotten. Death is more on the congested clumps. Thin wirey auxillary branches up to 9-12 basal nodes shed their leaves and transform into curved thorn like structure.

Culm: Whitish ring on the basal nodes are usually not present, dead adventitious root rings may be present on the basal 2-3 nodes of the culm. Colour is deep bottle green (hookers green) and internodal surface is smooth.

4th year

Culm sheath: Absent

Bud break and branches: Branches having less number of leaves. Most of the auxillary branches and secondary branches of the two of main branches transform into curved thorn like structure. Many stout central branches on the basal nodes (upto 6) of the culm are usually dead, sheded and possess dead scar on the culm nodes.

Culm: Smooth surface having deep bottle green colour. Black rotten adventitious root ring may be present on the basal 1-2 nodes.

Bambusa longispiculata

1st year

Culm sheath: Generally absent. However, in some cases may be present on the nodes of upper

portion of the culm and at the 1-2 basal nodes.

Bud break and branches: Most of the branch buds on the upper and basal nodes break and produce branches. The buds on the lower mid culm zone (5-12 nodes) remain dormant and do not produce branches.

Culm: Deep glossy green. Vertical yellow striations are prominent on the 1-5 basal internodes. White bloom is present in the internode.

2nd year

Culm sheath: Absent

Bud break and branches: Excepting a few buds 2-4 at the mid culm zone all branch buds break and produce branches.

Culm: Dark green. Vertical yellow striations are also prominent. Amount of white bloom conspicuously reduced and comes off on fingers.

3rd year

Culm sheath: Absent

Bud break and branches: Almost all the branch buds in the culm nodes break and produce branches.

Culm: Dark green, but yellow colour striations are comparatively faded. White bloom is generally absent, in some internode it is scanty and greyish white in colour.

4th year

Culm sheath: Absent

Bud break and branches: Same as other years, but some main and thin branches at the base and upper portion of culm die and drop keeping black scars on nodes.

Culm: Uniformly dark green with no bloom on the internodes. Yellow colour striations are mostly faded.

Bambusa tulda

1st year Culm sheath: Usually not present on the culm, sometimes may be present on the basal 1-2 nodes and tightly fitted.

Bud break and branches: The branch bud on the culm node breaks acropetally producing stout branch, while 3-8 buds in lower mid culm zone remain dormant. Sometimes 3-5 branch buds may also remain dormant on the upper portion of the culm. Leafy branches are mostly confined to the top portion of the culm, smaller thin branches are present on the lower nodes. Branch bases and internodes cover the straw colour sheaths.

Culm: Dark green colour with slight whitish bloom on the internode and comes off easily with finger. Some times basal 1-2 nodes may have a ring of small adventitious roots. A brown to dark colour wooly band present just above the 1-3 basal nodes.

2nd year Culm sheath: Absent

Bud break and branches: Almost all the branch buds including dormant one of the first year on the lower mid zone and upper portion of the culm become active and produce branches.

Culm: Whitish bloom very slightly present, comes off with rubbing.

3rd year

Culm sheath: Absent

Bud break and branches: Generally branchy sprouts in a branch complement on the basal 1-4 nodes of culm become dead and shed off keeping the black scars. As a result the number of thin branches in the nodes especially at the basal portion of the culm get reduced.

Culm: Throughout green, excepting yellowish stain present at the lower part of each of the internode. Basal 1-3 internodes may not have this yellowish stain.

4th year

Culm sheath: Absent

Bud break and branches: Branches on the basal 3-7 nodes and in some cases on the upper portion of the culms (2-4 nodes) become dead and shed off keeping the black scars. More number of thin branches are dead.

Culm: Dark green. Yellowish stain at lower part of the internode is comparatively prominent.

Bambusa vulgaris

1st year

Culm sheath: Excepting basal 2-3 nodes no sheaths present.

Bud break and branches: One-third of culm top has leafy branches. Buds break producing central stout branches with small auxillary branches throughout culm except 3-4 basal nodes.

Culm: Bright grassy green, basal 3-4 nodes have adventitious white root rings.

2nd year Culm sheath: Light dark colour sheath may be present at 1-2 basal nodes.
Bud break and branches: More than half of the upper portion of the culm has leafy branches. Small axillary branches disappear.
Culm: Dull grassy green. Adventitious root rings on the basal nodes are drying out and turning black.

3rd year Culm sheath: Absent
Bud break and branches: Branches are more thick and stout with light green colour, leaves are few. Bud break start at basal 3-4 nodes but forms small thin wirey leafy branches.
Culm: Slightly yellowish green, no adventitious root rings on the node.

4th year Culm sheath: Absent
Bud break and branches: Thick stout branches are only on the upper one-third of the culm, leaves few but older and not deep green. Buds and branches on the basal nodes mostly dead leaving black scar.
Culm: Turning yellowish, smooth.

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 leaves.

- 2nd year Culm sheath: Sheath persist on the lower two-third culm, loose sheath blade.
Bud break and branches: Buds on the one-third upper portion of the culm break and produce branches, branches are many, thin and in assembly.
Culm: Green.
- 3rd year Culm sheath: Persist only on basal one-third portion of culm (3-5 nodes), mostly black colour, blade of the culm sheath shed off, persistent sheaths are comparatively loosely fitted on the internode.
Bud break and branches: Buds on the upper two-third of the culm break and produce thin but many branches in assembly. Leaves are comparatively less in the branches.
Culm: Dull dark green.
- 4th year Culm sheath: Absent.
Bud break and branches: Some branches in the branch assembly die mostly on the upper one-third portion of the culm. Leafy branches are less, buds mostly dead on the basal culm nodes, dead leaves scars present on the branches.
Culm: Light green to yellowish straw colour.

5.1.10 Rhizome growth and culm development of
Melocanna baccifera

The culm emergence and rhizome neck development in *M. baccifera* took place simultaneously. During May culm emerged in the clump and the rhizome neck also started growing simultaneously below the ground from the rhizome of the emerging culm. (Table 12). Thereafter, culm elongation continued and completed its maximum height within July while rhizome neck more or less slowed down its elongation. At the beginning rhizome neck elongation was slow and the movement pattern was slightly geotropic (Table 12). Within July to August, after completion of elongation culm started producing leaves at 4-6 apical nodes. From August to next mid-part of March culm nodes were more or less completely covered with culm-sheaths and did not produce any branches, but rhizome neck did not stop its elongation. The elongation was horizontal below the ground. The climatic condition after August upto next February was gradually becoming dry and cold and during that time rhizome did not stop its elongation whereas all buds on the culm were dormant. Thus it appeared that during cold and dry season all growth potentials were diverted towards the underground rhizome neck elongation. At the second week of March bud break started at nodes basipetally from the upper part of the culm and within June new branches initiated followed by leaf production.

Rhizome necks simultaneously showed rapid elongation during March to May. Development of new rhizome proper from the tip buds of the mother rhizome necks started during the end of May and might continue upto June. The rhizome then bent upward (negative-geotropic) at right angle piercing the soil and appeared at the ground producing daughter culms.

Table 12: Growth periodicity of culm and rhizome
in the adult clumps of *Melocanna baccifera*

Time of observation	Mother culm	Branch/leaves on culm	Daughter rhizome neck from the mother rhizome	Daughter culm
May, 6/11 to July, 31 (any time)	Emerged elongated 15±5 cm	No	Elongated 5 ± 2 cm (Geotropic)	No
May, 14/20 July, 12/15 (55-60 days)	Elongation completed 12.5±1.2 cm	No	Elongated slowly 12±2 cm	No
July, wk 4 to August 2nd wk (20-25 days)	No more elongation, culm sheath at the few apical node partially dislodged	Few tip node produced leaves alternatively, no branch	Elongated slowly 15±2 cm	No
August, wk 2 to Nov, wk 3 (90-95 days)	No growth	No further growth	Elongated normally 45±5 cm	No
Nov. wk 3 to March, wk 2 (110-115 days)	No growth	Bud break started in culm nodes besipetally end of March	Elongated slowly 45±10 cm	No
March wk 3 to May wk 2 (55-65 days)	No growth	Bud break was in progress	Elongated rapidly 90±10 cm	No
May wk 2 to June wk 3 (40-45 days)	No growth	New branch and leaves developed	Tip of the rhizome neck bent upward, pierced above the ground	New culm emerges

It appears that the movement and elongation of rhizome neck of *M.baccifera* was going on either slowly or actively throughout the year irrespective of seasonal variation. However, the rhizome neck elongation was slow only when mother culm exhibited growth and produced branches and leaves. But when (August to November and March to May) culm exhibited no or little growth (such as, bud activation branches, and leaves development), rhizome neck elongation was either normal or rapid. Thus it appears that in *M.baccifera* the growth periodicity of underground rhizome system and culm on the ground is interrelated and seems to be alternating with each other.

5.1.11 Estimation of flowering cycle

While reviewing the information on flowering cycle it was observed that reports were mainly on the flowering date in a region, and in some cases the extent of damage of the crop due to flowering. It is unfortunate that the recorded information, in most cases, did not include the specific locality of flowering. The period between two gregarious flowering over the same area for a species is called its physiological (flowering) cycle (Chaturvedi 1988). To estimate the inter-seeding period of a bamboo species, one has to calculate the time difference between the flowering dates recorded from same specific locality. But in the reports, localities were mentioned as Burma, Assam, Chittagong, Chittagong Hill Tracts etc. Since these reports do not provide the information of exact localities of flowering, it becomes difficult to estimate the probable flowering cycle of a bamboo species.

It is evident from literature (Troup 1921) that foresters, in most cases, were worried about the bamboo flowering mainly due to the death of the crop covering a large tract of land creating a shortage of raw material for housing, construction, fuelwood and pulping. Foresters were keen to know the flowering cycle of different bamboo species by which they could forecast the future flowering date and could take necessary measures.

Records of flowering in each species have been arranged in region-wise in tabular form (Table 13-21). Documented flowering records are analysed species-wise.

It is evident from the flowering records that among different bamboo species of Bangladesh forests, *Melocanna baccifera* exclusively shows gregarious flowering habit with a 10-15 years of flowering wave covering large tract of forest land (Table 19). Such behaviour is not distinctly prominent in most of the other species. The species like *B. polymorpha*, *B. tulda*, *D. longispathus* are of, in general, frequent flowering nature confined to a small locality in a few clumps, mostly merged with gregarious flowering. This is similar to the observation of Brandis (1899) in other parts of India. In other species reports on the flowering incidences were few and accordingly it is likely that these species, (*Melocalamus compactiflorus*, *Neohouzeaua dullooa*, *Oxytenanthera nigrociliata*, etc.) have either flowered rarely or after long intervals.

Specieswise flowering cycles are discussed in detail as follows:

***Bambusa balcooa* Roxb.**

The first available reports of flowering in *B. balcooa* was in 1849 in Purnea, India. In further east, the species again flowered in two localities of Assam in 1876 and

1889 (Table 13). During 1881 flowering reported from Goruckpore of Uttar Pradesh located in the west of Purnea. From these reports it appears that *B.balcooa* simultaneously flowered from 1876 to 1889 in Assam (Goalpara and Kamrup) including flowering in Goruckpore in 1881. So it is likely that the "flowering wave" (Janzen 1976) had continued for 13 years (1876-1889) in a belt extended from Assam in the east and Goruckpore in the west. Occurrence of flowering at any time in that period of "flowering wave" was not unlikely in Purnea district due to its central location between Assam and Goruckpore. Assuming that in Purnea the species flowered again either with the same recorded flowering period from 1876 in Goalpara to 1889 in Kamrup, the interflowering period would be 40 years (Table 13).

Flowering of *B.balcooa* occurred in Gofargaon and Saidpur during 1983 and 1985 respectively. These 2 places are geographically nearer to Assam and Purnea of India. Therefore it was likely that previous flowering in Gafargaon and Saidpur might have occurred either around 1849 or any time between 1876 to 1889. Thus, it seems that *B.balcooa* might have flowered in these two localities before 134-136 years or 94-96 years (Table 13). These periods, i.e., 94, 96, 134 and 136 years are more or less multiples of 40 or 45 years. Thus, it can be speculated that *B.balcooa* may flower at 40 ± 5 year intervals.

Regarding the flowering of the species Gamble (1896) has stated, "It has been but rarely collected in flower". In fact, only a few clump flowered at Hazirhat in Saidpur. In both the sites of Gofargaon and Saidpur seeds were not seen similar to the report of Gamble (1896).

Table 13 : Past flowering records and estimated flowering cycle in *Bambusa balcooa*

Country/ locality	Flowering date (Calender year)	Estimated flowering cycle (year)	Reference
<u>India</u>			
Purnea district	1849		Gamble(1896)
Assam (Goalpara)	1876		Gamble(1896)
Uttar pradesh (Goruckpore)	1881		Wood(1881)
Assam (Kamrup)	1889	40	Gamble(1896)
<u>Bangladesh</u>			
Mymensing (Baldi, Gafargaon)	1983-84 (Iso.clump)	134 (1849-1983) 94 (1889-1983)	Banik and Alam (1987)
Saidpur (Hazarhat)	1984-85 (Iso.clump)	136 (1849-1985) 96 (1849-1985)	Banik and Alam(1987)

N.B. Iso.clump: Isolated clump

Bambusa polymorpha Munro

It seems *B. polymorpha* flowers gregariously after long interval of time. Reported flowering were mostly sporadic or confined to isolated clumps (Table 14). Brandis (1899) has also classified this species as "flowering periodically and gregariously". Very little information on flowering in *B. polymorpha* could be collected from Bangladesh. This species is extensively occurring and natural to the Burma forests and a number of seeding records could be found from the literature. By analysing the seeding records of this species in Burma, it seems that the estimated flowering cycle for *B. polymorpha* could be 55 years or 50 ± 5 years. Records from Sylhet show that the species flowered after about 93 years of interval. If the cycle is more than 90 years the species would not flower in the Prome Division of Burma after 50 ± 55 year of interval. Therefore it is not unlikely to think that in Bangladesh the species might have flowered after 50 years or so from 1889 and this could be any time between 1934-45 and remained unreported.

However, it is evident that the species has long flowering interval --- 60 years (Prasad 1948, Troup 1921), or more than 68 years (Seifrizz 1923), or 50 ± 5 years as presently estimated.

Table 14: Past flowering records and estimated flowering cycle in *Bambusa polymorpha*

Country/locality	Flowering date (Calender year)	Estimated flowering cycle (year)	Reference
Burma			
Tharawaddi and	1853		Wathon(1903)
Prome districts (Pegu-Yoma)	1859(Greg.)		Brandis(1899)
Zamayi(Upper pegu)	1862(Iso.clump)		Brandis(1899)
Thaukyeghat	1871(Iso.clump)		Brandis(1899)
Prome Divn.	1914		
Pyinmana Divn.	1929-30(Iso.clump)	55 (1859-1914)	Bradley(1914)
(Yonbin & Palwe Reserve)	1929-30(Iso.clump)		Bodekar(1930)
Pyinmana Divn.	1934-35(Greg.)		Win(1951)
Bangladesh			
Sylhet	1889		Brandis(1906)
Sylhet(Kalenga)	1982-83	93 (1889-1982)	Author
BFRI bambusetum Chittagong	1984(Iso.clump partly)		Author
Cox's Bazar	1982(Iso.clump)		Author

N.B. Iso.clump : Isolated clump, Greg.: gregarious flowering

***Bambusa tulda* Roxb.**

The past reports indicate that *B.tulda* often flowers sporadically or in isolated clumps and sometimes also gregariously (Table 15). Prasad (1948) and Troup (1921) have reported such sporadic flowering nature of *B.tulda*. Troup (1921) mentioned that records on various flowering years by Brandis (1899) were not certain if these referred to gregarious flowering or to years when samples were collected. The species had flowered in different years without having any constant interval throughout Burma, Assam and lower Bengal (Table 15). Troup (1921) also reported similar flowering nature of the species as "frequently flower sporadically the flowering may be observed in single clumps, or in patches of a few clumps together, or in small groups of less than an acre".

The estimated flowering cycles of *B.tulda* seem to be 10, 12, 16-18, 19, 20, 24-29, 30, 40-42, 45, 48 years (Table 15) for different localities. As the species flowers frequently and the recorded cycles are 18-48 years, it might be an integral of 8-10 years.

It also appears that flowering of isolated clumps is not rare in this species. Similarly sporadic flowering and isolated flowering were also common in most of the years during 1978-1990 in Chittagong, Chittagong Hill Tract and Sylhet (Table 15). Thus it seems flowering is not a rare phenomenon in *B.tulda* as also reported by Brandis(1899).

The reports on the gregarious flowering on the species were limited. It seems that the species flowers gregariously after 15 and 20 years of interval in a specific area. In Sylhet the flowering years were 1889-1910-1930 showed a flowering cycle of 20 years. Again the species flowered gregariously in Adampur in 1978. So the interseeding period between 1930 to 1978 is 48 or (25x2) years. In lower Bengal the seeding years were 1866-68, 1872 and again in 1884 give 4

and 18 years interval. In Chittagong and Chittagong Hill Tract, it seems, in different localities the species have flowered gregariously after 10 (in 1876 and 1886) 30 (in 1930 and 1960), and 45 (in 1886 and 1931) years of interval. However, Prasad (1948) reported that in Bengal flowering cycle of *B.tulda* is estimated as 35 to 40 years. But how he made the estimation was not mentioned.

Thus it seems, there might have existence of a number of 'flowering genotypes' of *B.tulda* in the different forests of Bangladesh and other parts of the region. Banik (1987a) identified two seed sources of *B.tulda* --- one from Shishak of Chittagong Hill Tracts, and other from Lawachara and Adampur of sylhet. Thus, it seems that *B.tulda* can be grouped under both gregarious and sporadic flowering classes.

Table 15: Past flowering records and estimated flowering cycle in *Bambusa tulda*

Country/ locality	Flowering date (Calender year)	Estimated flowering cycle (year)	References
Burama	1863-68	12-17	Troup(1921)
Tharrawaddy	1880	12-17	Brandis(1899)
		(1863,68-1880)	
	1892	24-29	Gamble(1896)
		(1863-1892)	
	1903-1905	40-42	Troup(1921)
	1914	(1863-1903,05)	Troup(1921)
Prome	1908		Troup(1921)
	1914,1915		Troup(1921)
Gangaw	1911		Troup(1921)
Toungoo, Zigon, Rangoon,Pegu, Yames	1913,1914, 1915		Troup(1921) Prasad(1948)
Shan States: Palwe & Kaing ranges	1916		Troup(1921)
Pyinmana	1938-1939		Prasad(1948)
India			
<u>Assam</u>	1889		Brandis(1899)

Table 15 contd. ...

Bengal

Malda district	1866,1867,1868		Brandis(1899)
(lower Bengal)	1872		Brandis(1899)
	1884	16-18	Brandis(1899)
		{1866,1868-1884}	

Bangladesh

<u>Chittagong</u>	1876		Gamble(1896)
	1886 (Greg.)	10	Gamble (1896)
		(1876-1886)	
Patiya Range	1931(Greg.)	45 (15x3)	Coffey(1931)
		(1886-1931)	
	1936		Prasad(1948)
Hazarikhil	1978(Spor.)		Hasan & author
BFRI bambusetum	1980,83,84(Spor.)		Author
	1983,1984		
Hathazari	1984 (Spor.)		
Ichamati	1985(Iso.clump)		
Hathazari,BFRI	1987(Iso.clump)		
bambusetum			
Nazirhat	1988 (Iso.clump)		
BFRI bambusetum,			
Keochia	1989 (Iso.clump)		
Keochia	1990 (Iso.clump)		

Table 15 contd. ...

<u>Chittagong Hill</u>	1919-20		Prasad(1948)
<u>Tracts</u>			
Rangamati	1927,1929 (Spor.)		Trevor(1927,1929)
	1930(Greg.)		Nath(1930)
Kassalong Resv.	1960(Greg.)	30 (15x2)	Hasan(1973)
		(1930-1960)	
Shishak	1977(Greg.)		Banik(1987a)
Publakhali	1978		Author
Rangamati(Ghagra)	1979(Iso.clump)		Author
Kaptai	1981(Iso.clump)		Author
Matamuhuri	1984(Greg.)		Author
Bandarban	1988(Spor.)		Author
(Remakripransa)			
<u>Sylhet</u>	1889 (Greg.)		Gamble (1896)
	1910 (Greg.)	19	Prasad(1948)
		(1889-1910)	
	1929-1930	20	Baruah(1930),
	(Greg.)	(1889-1929)	Prasad(1948)
Adampur	1978(Greg.)	48 (25x2)	Author
		(1929-1978)	
Lawachara	1979,1980		Author
	(Greg.)		
Sreemangal	1989(Iso.clump)		Author
<u>Seraiganj</u>	1988		Author
<u>Akhaura</u> , B.barua	1988 (Iso.clump)		

N.B.: Spor.: sporadic flowering, Greg.: gregariously flowering
 Iso.clump: isolated clump flowered.

Bambusa vulgaris Schrad.

Very little is known about the flowering of *B. vulgaris*. The table 16 shows that the species is rarely found in the flowering and a few records on flowering are available in literatures. The species, so far known, is not gregarious flowering in nature (Banik 1979). Flowering in this species is rather confined to a few isolated clumps after long time (Banik 1979, McClure 1966). However, the time gap between the three records of flowering show that, the estimated cycle for the species could be about more than 80 years (Table 16).

Table 16: Past flowering records and estimated flowering cycles in *Bambusa vulgaris*

Country/locality	Flowering date (Calender year)	Estimated flowering cycle(year)	References
Not reported	1810		McClure (1966) reported from Wendland(1810)
Not reported	1898	88 (1810-1898)	McClure(1966) reported from Moebius (1898)
<u>Chittagong</u>			
Faridarpara (Bardarhat)	1979 (7 clumps flowered)	81 (1898-1979)	Banik (1979)

Dendrocalamus longispathus Kurz

A number of dates on the incidence of flowering were reported from different countries and forest areas of the region but little information could be compiled for a specific locality (Gamble 1896, Brandis 1906 and Troup 1921).

Three flowering dates have been recorded from Chittagong but the localities were not reported (Gamble 1896, Trigg 1930). So, it is difficult to estimate the flowering cycle of the species. First recorded date was in 1876 and only after 3 years second date (1876-1879) was reported (Gamble 1896). It is unlikely that they flowered repeatedly twice within 3 years of time. Therefore, it would be logical to believe that these two flowering reports were not from the same locality. In Chittagong, third flowering date was recorded in 1930 (Trigg 1930) and may or may not be from the same site. The time gap between the second and third report (1880-1930) is 50 years, but this calculated gap period could not be taken as estimated interseeding period for the species because it was not reported whether the species flowered in those years in the same area. Similar incomplete records have also been reported from Chittagong Hill Tracts, Cox's bazar and Sylhet.

Table 17 shows four seeding dates -- 1862, 1871, 1875 and 1891 - for this species from Pegu of Burma. By calculating the time difference between the successive records, irregular interseeding periods - 9, 4, 16 years are obtained from which no conclusion could be drawn on the duration of flowering cycle. However, the gap between the first (1862) and last (1891) report is about 29 years and has conformity with interseeding period between two gregarious flowering at Chittagong and Chittagong Hill Tracts. The calculated gap period for Chittagong is 92 and that of Chittagong Hill Tracts is 88 years. Both these periods 92 and

88 are more or less multiple of 29 years, i.e. $29 \pm 1 \times 3 = 88/92$. So it is likely that in Chittagong the species flowered in the year 1909-10 and 1939-40 after successive 30 years of gap from the first gregarious flowering year 1879-80, and remained unreported. Similarly in Chittagong Hill Tracts two unreported flowering dates might be any time during 1909-10, and 1939-40 after successive 29 or 30 years of gap from 1879-80 (Table 17). Thus it appears that the estimated flowering cycle in *D.longispathus* could be around 30 ± 1 years. But Hasan (1973) has estimated 20 years as flowering cycle for *D.longispathus* by considering two flowering dates (1871 and 1891) of Burma. There are four clumps of *D.longispathus* in BFRI bambusetum which are more than 20 years old (as planted through offsets during 1974, Clump 20/4-8) and have not yet flowered. So the flowering cycle is likely to be more than 20 years.

In describing the flowering nature of the species Prasad (1948) and Troup (1921) reported that "It is often found flowering sporadically. Gregarious flowering has also been reported"

However, during the period 1967 to 1979 the species flowered frequently in 1967, 1972, 1973, 1974, 1977 and 1979 in different parts of Chittagong and Chittagong Hill Tracts but not in the same place (Table 17). Brandis (1906) also reported that the species "flowers frequently". During this period the species flowered gregariously, sporadically and isolatedly in a few clumps indicating various nature of flowering as reported in *B.tulda* (Table 15)

Table 17: Past flowering records and estimated flowering cycle in *Dendrocalamus longispathus*

Country/locality	Flowering date (Calender year)	Estimated cycle(yrs.)	References
Burma: Pegu			
	1862		Brandis(1906)
	1871,1875		Gamble(1896)
	1891	29 (1862-1891)	Brandis(1906)
Tharrawaddy district	1887		Troup(1921)
Minhla, Kadinbilin	1912(Greg.)		Troup(1921)
Tungoo district	1913(Greg.)		Troup(1921)
Bangladesh			
<u>Chittagong</u>	1876(Spor.)		Gamble(1896)
	1879-80(Greg.)		Gamble(1896)
	1930		Trigg(1930)
Koila,Karerhat	1972(Greg.)	92(31x3) (1879-1972)	Hasan(1973)
BFRI,Bambusetum	1977-79 (Greg.)		Banik(1987b)
<u>Chittagong</u>	1879(Greg.)		Troup(1921)
<u>Hill Tracts</u>	1880(Greg.)		E.G.C.(1881)
Shishak(south)	1967(Greg.)	88(29x3) (1879-1967)	Hasan(1973)
Shishak(north)	1972		Hasan(1973)
Raingkheong	1974(Greg.)		Hasan(1973)
Dabua Rubber Est.	1977(Spor.)		Author
Cox's bazar	1928		Trevor(1928)
Sylhet			
Rajkandi Resv.	1973		Hasan(1973)
Dholai Tea Est.	1974		Hasan(1973)

N.B.: Greg. = gregariously, Spor. = sporadically

***Melocalamus compactiflorus* Benth.**

The reports on flowering of *Melocalamus compactiflorus* in Burma were not from the same locality (Table 18) and, therefore, it becomes difficult to estimate the interseeding period for the species. However, with the present records, it appears that in Burma, a number of incidences on flowering in *Melocalamus compactiflorus* have been reported. The time gap between the reports may be calculated and it varied from 7 to 16 years. If 16 years period is taken as multiple of 7 or 8, then the estimated flowering cycle could be 7 or 8 years in Burma (Table 18).

So far in Bangladesh the first flowering report was in 1928 from Cox's Bazar, and on the eastern side of the border in Arakan province of Burma the species was also reported to flower in 1878, and the time gap between 1878 and 1928 was about 50 years. The species again flowered in Cox's Bazar during 1975, thus giving a 47 years gap between 1928 and 1975. During 1977 seven seedlings of *M. compactiflorus* were collected from Cox's Bazar and planted in the bambusetum (line 41) of BFRI. These plants were 15 years old in the year 1990, and not yet produced any flower. This proves that Cox's Bazar source has the flowering cycle at least more than 15 years but not 8 years.

Therefore, it seems in Bangladesh the estimated interseeding period for *M. compactiflorus* is about 50 ± 3 years. Further the species might have two flowering genotypes -- one is with 7 ± 1 years cycle and other is with 50 ± 3 years flowering cycle.

Table 18: Past flowering records and estimated flowering cycle in *Melocalamus compactiflorus*

Country/locality	Flowering date (calender year)	Estimated cycle(yrs.)	References
Burma			
Martaban	1871		Gamble(1896)
Arakan, Yoma	1878	7 (1871-1878)	Gamble(1896)
Rubi mine Dist	1894	16(8x2) (1878-1894)	Gamble(1896)
Bhamo	1902	8 (1894-1902)	Blackwall(1902)
Byingyi	1917	15(7x2) (1902-1917)	Bahadur & Naithani(1983)
Thangyin Divn.	1926	9 (1917-1926)	"
Hlaing Yoma hill	1933	7 (1926-1933)	"
India			
Assam	1921		Bahadur & Naithani(1983)
Manipur	1974	53 (1921-1974)	Malick(1974)
Dehra Dun	1980	6 (1974-1980)	Bahadur & Naithani(1983)
Bangladesh			
Cox's bazar	1928	50 (1878 of Arakan -- 1928)	Trevor(1928)
Cox's Bazar (Panerchara)	1975	47+3=50 (1928-1975)	Author

***Melocanna baccifera* (Roxb.) Kurz**

In Burma, so far the flowering in *Melocanna baccifera* was first reported to occur during 1863-1866. After that the species had been reported (Table 19) to start flowering again in the area in 1902. Initially the flowering was sporadic for 4 years (1902-1905) which became gregarious during 1910-1913, and then finally it was again sporadic for the last two (1915-1916) years. So in total the "flowering wave" continued for 14 years (1902-1916) spreading over the whole forest area. According to Troup (1921) species exhibiting such 3-phase flowering nature (initial sporadic, then gregarious and finally again sporadic) with a long duration of flowering wave can be termed as gregarious flowering species. Such flowering wave could also be observed in Bangladesh. Both in Chittagong Hill Tract and Chittagong the last flowering was reported to occur in 1952 which was sporadic and continued for 8 years upto 1958 or 1959. There after a gregarious flowering took place and continued for two years during 1960 and 1961 (Table 19). The reports on final sporadic flowering from Bangladesh are not available in literature (Table 19). Therefore, complete duration of flowering wave exhibited by *M.baccifera* in Bangladesh region could not be estimated. However it can be seen that first phase of sporadic flowering existed for 7 years (1952-1959) and the second phase of gregarious flowering for 2 years (1960-1961). So the duration of flowering wave in *M.baccifera*, in Bangladesh though not completely reported, could be estimated as 9-10 years (1952-1961). It seems that *M.baccifera* belongs to the gregarious flowering bamboo group. Raitt (1929) reported that "with the gregariously flowering species, the flowering is not concentrated into one season, it may be

spread over 5-12 years. Thus *Bambusa arundinacea*, on the west coast of India, began to flower in 1909 and did not finish till 1921".

During 1957-1960 flowering in this species in Bangladesh occurred like a wave from south to north over an area of about 10,000 sq. miles in four years time (Hasan 1973). Flowering in the recent years (1986-1990) are still sporadic and did not show such directional movement from south to north in the country. During recent years first observations (1986-1987) on flowering were from Kamalchari (Khagrachari), Hyanko (Ramgarh), and Barabibirhat (Chittagong); then in 1988-1991 extended over Nazirhat, Hathazari, Fatehabad and Shishak. These areas are not in the southern part of Chittagong, rather flowering occurred in northern part and have been gradually extending towards the north eastern part (Shishak) of the region. Therefore, it seems that flowering in fact does not maintain any consistent direction.

All these previous documented flowering times (Table 19) of *M.baccifera* were from the incidental observations in any time during the flowering waves. That means one might have observed flowering at any time during the 10-14 year of wave of a flowering incidence and accordingly reported. During the next flowering incidence the reported observation might not be of the same time of the wave period as reported in previous incidence, because observations were mostly dependent on chances of visit. Besides this, incidence of flowering was not always in the same year for the 2 or more localities, rather it differed (Table 19). Probably that is why many different flowering cycles have been reported for *M.baccifera*.

The reported estimated cycles were 30-35 years (Gamble 1896, Gupta 1988, Kurz 1876); 45-50 years (Hossain 1962, Parry 1931, Troup 1921); and 60-65 years (McClure 1966,

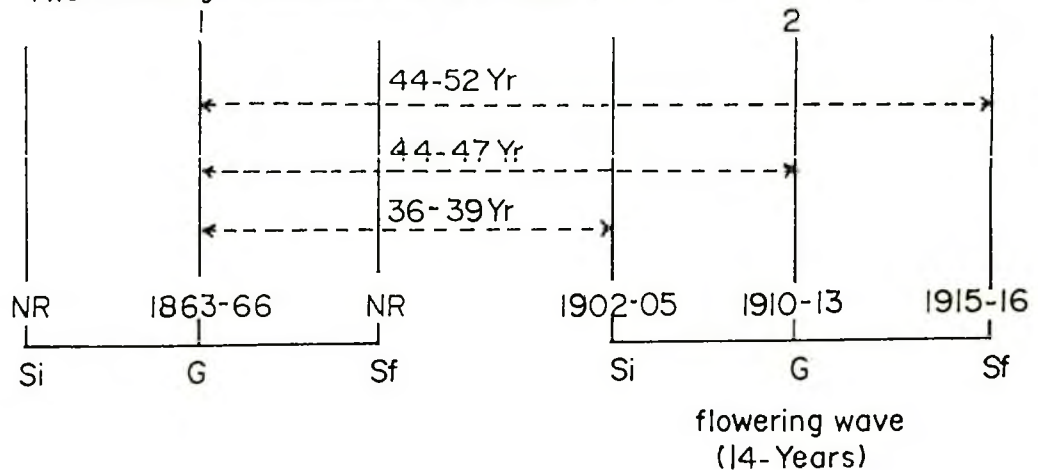
Raitt 1929). Chatterjee (1960) believed that in Mizohills the species exhibited two flowering cycles which were 7-10 years and 26-30 years.

The different flowering dates reported from similar localities have been grouped separately (Table 19) and 3-phases of flowering waves have also been illustrated (Fig. 10 for estimating the flowering cycle of *M.baccifera* from different localities of Indo-Burma region. Present analysis shows that gap period between the gregarious phase (G) of one flowering incidence to the initial sporadic (Si) phase of next flowering incidence were about 36-39 years in Burma (Fig. 10a); 27-29 years in Assam (Fig. 10b); 32-36 years in Haflong (Fig. 10c); 46-48 years in Sylhet (Fig. 10d); 35-39 years, 27-28 years in Chittagong (Fig. 10e, first to second, third to fourth incidence); and 61-64 years, 22-27 years, 28-30 years in Chittagong Hill Tracts (Fig. 10f). All these estimated gap periods were more or less within 30-35 years similar to the estimation of Gamble (1896), Gupta (1988) and Kurz (1876). One estimated cycle 61-64 years in Chittagong Hill Tracts (Fig. 10f; first to second incidences) shows different duration between phase G to Si. It is interesting to note that among the four flowering incidences in both Chittagong and Chittagong Hill Tracts the reported dates of first, third and fourth were more or less same excepting the second incidence where reporting dates were 1901-1912 for Chittagong and 1927-1935 for Chittagong Hill Tracts (Table 19, Fig. 10e and 10f). It might be that the flowering of *M.baccifera* in Chittagong Hill Tracts during 1900-1910 remained unreported. If this would be reported the estimated cycle from G-phase of first to Si-phase of second flowering incidence would be around 30-35 years. Similarly in Garohills the last gregarious flowering occurred during 1911-1912 and next incidence of initial

FIGURE 10. Estimation of flowering cycle in Melocanna baccifera from the hypothetical illustration (based on the idea of Troup 1921) of a number of incidences of flowering in the different localities of Indo-Burma region during last 150 years.
[Note: NR=flowering date not reported, NH=flowering not yet happen, Si=initial sporadic flowering, G=gregarious flowering, Sf=final sporadic flowering.]

(a) Burma (Arakan)

Two flowering incidences each one having 3-phase flowering wave



(b) India (Assam)

Two flowering incidences each one having 3-phase flowering wave

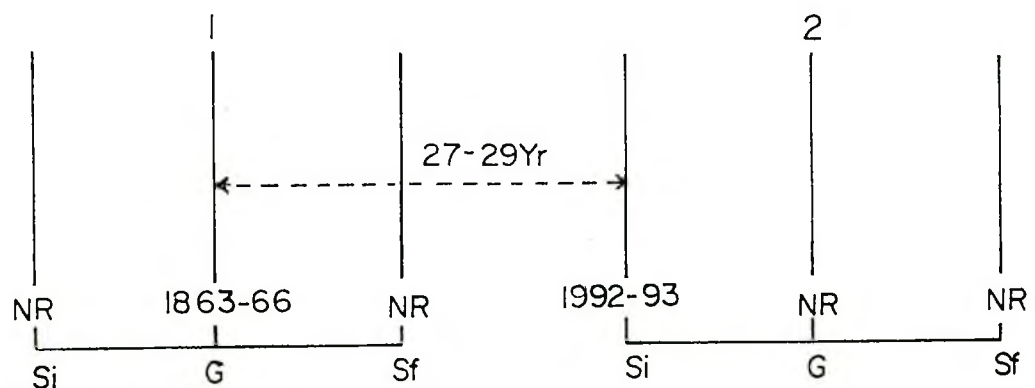
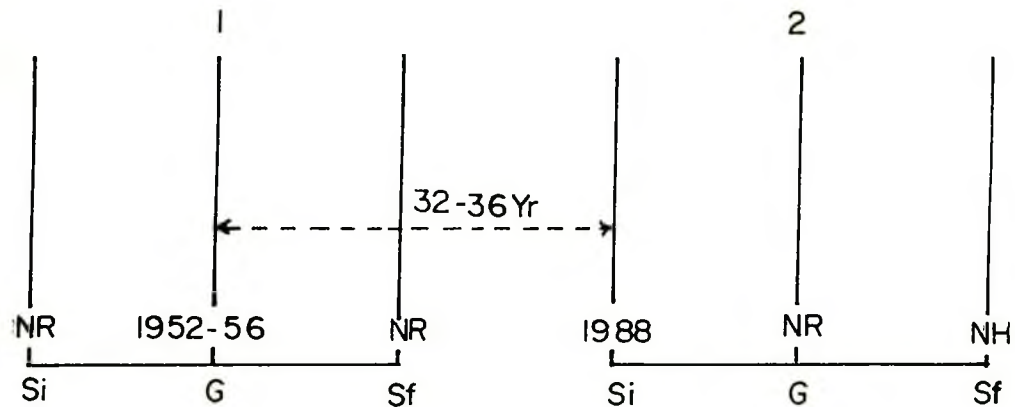


FIGURE 10. CONTINUED

(c) India (Cachar hills, Haflong)

Two flowering incidences each one likely to have 3-phase flowering wave



(d) Bangladesh (Sylhet)

Two flowering incidences each one likely to have 3-phase flowering wave.

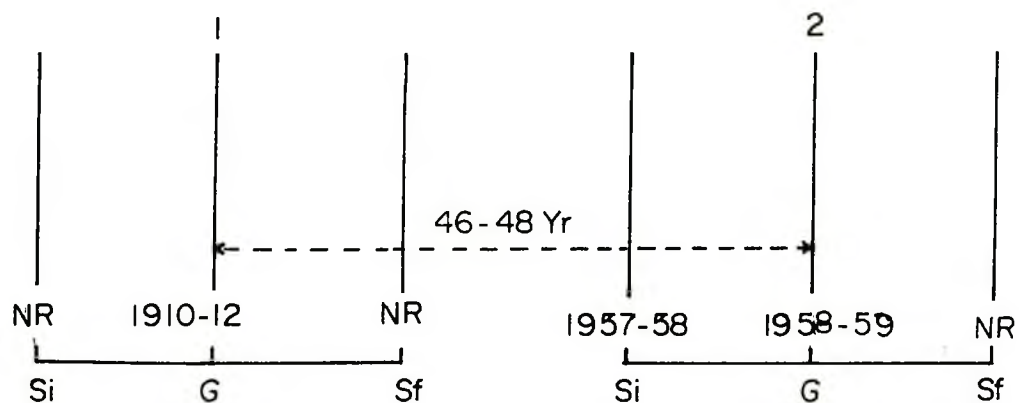
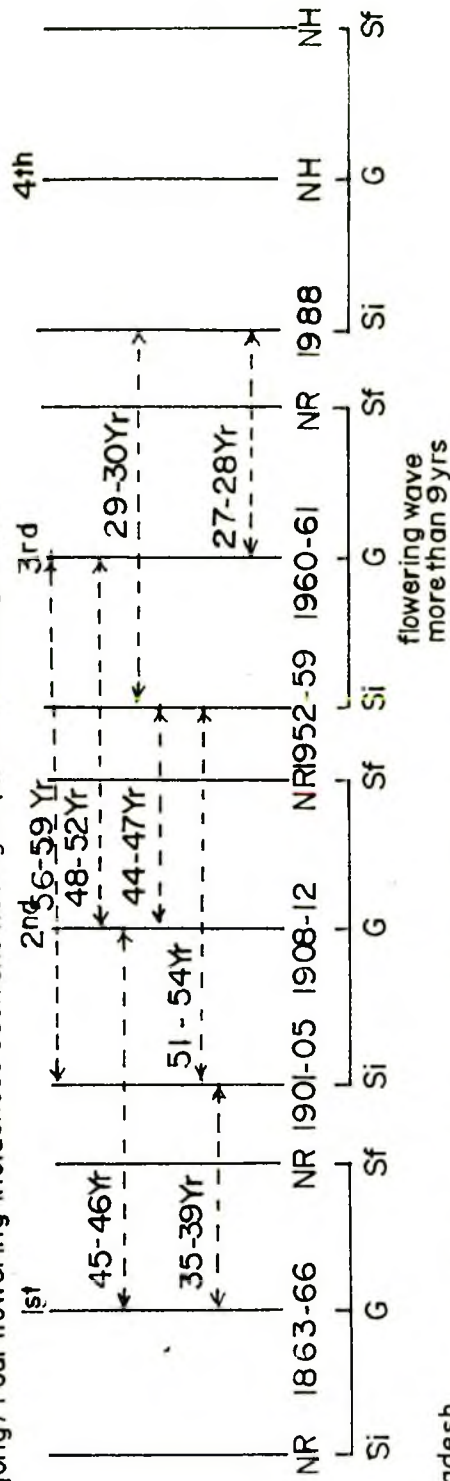


FIGURE 10. CONTINUED

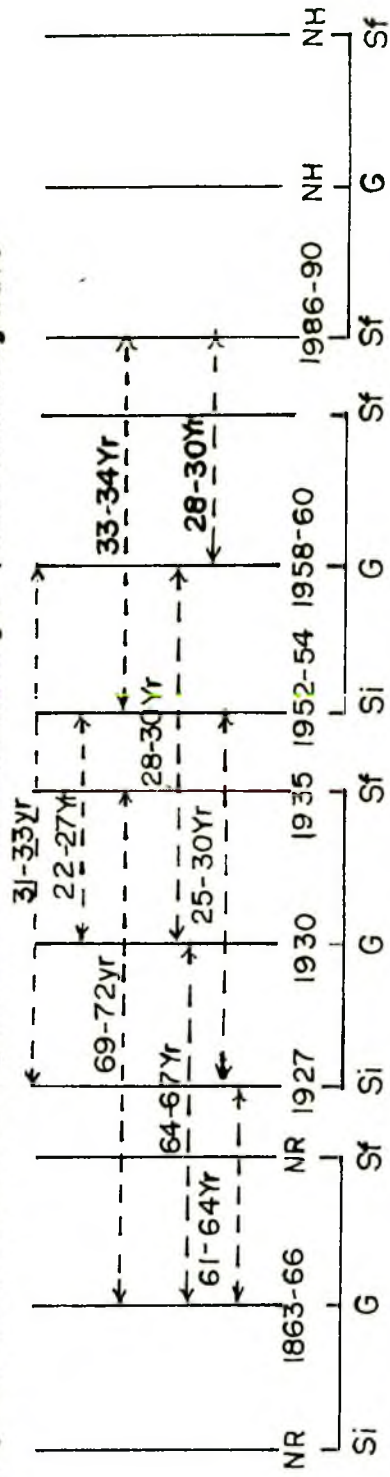
(e) Bangladesh

(Chittagong) Four flowering incidences each one having 3-phase flowering wave



(f) Bangladesh

(Chittagong Hill Tract) Four flowering incidences each one having 3-phase flowering wave



sporadic flowering in the region of northern Mymensingh bordering the Garohills was during 1974-1975 with a gap of 63-64 years (Table 19) which is again a multiple of 30 years.

When the estimations are based on G-phase of one incidence to G-phase of next incidence of flowering the period became generally longer -- around 44-47 years in Burma (Fig. 10a); 46-48 years in Sylhet (Fig. 10d); and 45-46 years, 48-52 years in Chittagong (Fig. 10e) similar to the estimated periods reported by Hossain (1962), Parry (1931) and Troup (1921). But for Chittagong Hill Tracts the reported periods were 28-30, and 61-64 years say multiple of 30 years which is again similar to the estimated cycles reported by others.

Much longer periods of flowering cycle 56-59 years may also be obtained by estimating the gap between Si-phase to G-phase of two flowering incidences of Chittagong (Fig. 10e). Further long period of cycle 64-67 and 69-72 years may also be obtained by estimating the gap between G-phase to G-phase and G-phase to Sf of two flowering incidence of Chittagong Hill Tracts (Fig. 10f). Such long duration flowering cycle of *M.baccifera* was also reported by McClure (1966) and Raitt (1929).

The variation of length in flowering cycle may be due to considering the gap between the different phases of two consecutive flowering waves. It seems to be logical to count the gap between the similar phases of two flowering incidences. Therefore, past reports 30-35, 45-48 and 60 years of flowering cycles for *M.baccifera* in Bangladesh are not contradictory and confusing, rather all might be acceptable provided the nature (sporadic or gregarious) of flowering is expressed. Keen observations, proper phase wise flowering reports and their documentation are important in this regard.

Table 19: Past flowering records and estimated flowering cycle in *Melocanna baccifera*

Country/locality	Flowering date (Calender year)	Estimated cycle (year)	Reference
<u>Burma</u> : Arakan			
	1863-1866(Greg.)		Munro(1868), Troup(1921).
	1902,1904-1905(Spor.)	36-39 (1863,66-1902)	Brandis (1906)
	1910-1913(Greg.)	44-47 (1863,66-1910,13)	Hossain(1962), Troup(1921)
	1915-1916(Spor.)		Raitt(1929), Troup(1921)
<u>India</u>			
Assam,Calcutta, Botanic garden.	1863-1866(Greg.)		Gamble(1896)
Assam, Tarai	1892-1893(Spor.)	27-29 (1863,66-1892,93)	Brandis(1899), Gamble (1896)
Garro and Khasia hills	1889(Greg.) 1900-1902(Spor.)	11-13 (1889-1900,02)	Troup(1921) Troup(1921)
Garro hills,Cachar, Lushai hills	1910-1912(Greg.)	22-23 (1889-1911,12)	Hossain(1962)
Mizo hills, Cachar hills	1933 (Spor.)	21-23 (1910,12-1933)	Chatterjee(1960)
Surma valley	1958-1961(Greg.)	48-49 (1910,12-1958,61)	Hadfield(1958), Nath(1959, 1960, 1962)

Table 19 contd. ...

Cachar hills, Haflong	1952-1956 (Greg.)		Gupta (1988)
Haflong	1988 (Spor.)	32-36 (1952, 56-1988)	Gupta (1988)
Bangladesh			
<u>Chittagong</u>	1863-1866 (Greg.)		Gamble (1896)
	1901-1905 (Spor.)	35-38 (1863, 66-1901, 05)	Brandis (1906), Troup (1921)
	1908-1912 (Greg.)	45-46 (1863, 66-1908, 12)	Troup (1921)
	1952 (Spor.)		Hossain (1962)
Southern	1958-1959 (Spor.)		Hossain (1962), Hasan (1973)
Northern	1960-1961 (Greg.)	48-52 (1908, 12-1960, 61)	Hasan (1973)
Hathazari, Nazirhat, Fatehabad	1988-1991 (Spor.)	28-30 (1960, 61-1988, 90)	Banik (1989)
<u>Chittagong</u>	1863-1866 (Greg.)		Brandis (1899)
<u>Hill Tracts</u>	1927 (Spor.)	61 (32x2) (1866-1927)	Hossain (1962)
Rangamati	1930 (Greg.)	64 (30x2) (1866-1930)	Nath (1930)
	1935 (Spor.)		Hossain (1962)
Kassalong	1952 (Spor.)		Hossain (1962)
	1957-1958 (Spor.)	27 (1930-1957)	Hossain (1962)

Table 19 contd. ...

Kassalong	1958-1959,60(Greg.)	30 (1930-1960)	Hasan(1973)
Kamal chari, Hyanko,	1986,87,88,89,90	29-32	Banik(1989)
Haludia, Chikanchara	(Spor.)	(1957-1986,90)	Author
Narayanhat, Shisak			
<u>Cox's bazar</u>	1959-1960(Spor.)		
	1960-1961 (Greg.)		Hossain(1962)
<u>Sylhet</u>	1910-1912 (Greg.)		Troup(1921)
	1957-1958 (Spor.)		Hossain(1962)
	1958-1959 (Greg.)	46-48 (1910,12-1957,58)	Hasan(1973)
<u>Mymensingh</u>			
North Range	1974 (Spor.)	63-64 (30x2)	Hasan(1973)
Rasulpur	1975 (Spor.)	(1911,12 of Garo-	
(New Kalibari)		hills - 1974,75)	

N.B: Spor.= sporadic flowering, Greg. = gregarious flowering

Neohouzeaua dullooa Camus

Very little published information on the flowering date of *N.dullooa* is available. In Chittagong Hill Tracts first recorded report on flowering might be around 1880, because Gamble (1896) described that the species might have "flowered 15 or 16 years previously". He also did not mention the specific locality from where the flowering specimen was collected. Further there were three more flowering dates recorded including the recent one (Table 20). The time gap between the first (1880) and second (1927) record is 44 years. The recent or so far fourth incidence of flowering has been reported from Shishak in 1990 which is only 16 years after the third report and shows no conformity with the previous estimated 44 or 47 years gap period. However, Janzen (1976) from the records of Gupta (1972) estimated the flowering cycle of this species as 14-17 years. But there are 3 clumps of *N.dullooa* more than 17 years old in the vegetative state in the BFRI bambusetum (line No.20) and yet have not produced any flower. This indicates that interseeding period cannot be 14-17 years. The stock in Shishak which have flowered in 1990 appears to be a different "flowering genotype" than those of Rangamati and Kassalong origin.

Thus the estimated flowering cycle for *N.dullooa* appears to be between 44 to 47 (say 45 ± 2) years.

Table 20: Past flowering records and estimated flowering cycle in *Neohouzeaua dullooa*

Country/ locality	Flowering date (Calender year)	Estimated cycle (years)	References
India			
Cachar, Mizo Hills	1951-53 1962 (Greg.) 1967-68	14-17	Gupta (1972) Nath (1962) Gupta (1972)
Bangladesh			
<u>Chittagong Hill Tracts</u>	1880		Gamble (1896)
Rangamati	1927	44 (1880-1927)	Trevor (1927)
Kassalong Reserve	1974	47 (1927-1974)	Hasan (1973)
Shishak	1990 (Spor.)		Author

N.B: Spor. = sporadic, Greg. = gregariously

Oxytenanthera nigrociliata Munro

The reports on the incidence of flowering in *Oxytenanthera nigrociliata* are very scanty. However, in connection with the flowering incidence of the species in Burma, Raitt (1929) reported, "So little has been known until recently about these forests (Tenasserim and Lenya) that no accurate data regarding its flowering cycle is available. Tribal information is to the effect that it last flowered 30 to 35 years ago, and the fact, that the oldest inhabitants do not know of the flowering before that, is some evidence that it is one of the long-cycled species, 60 to 65 years, in which case it may not flower for another 30 years. There are no signs of an early flowering at present".

Raitt (1929) in his report did not mention the last flowering time and he did not also mention how he came into conclusion that "it may not flower for another 30 years".

The flowering in Burma (Tenasserim) during 1849 and again in 1899 give an estimate of 50 years of interseeding cycle for this species (Table 21). The species flowered in Assam in 1889 and also during 1981-82 again in Cachar (southern part of Assam) which gives an interseeding cycle of about 93 years, that is, a multiple of 47 ± 3 or 50 years. It might be, that the species had also flowered in those areas after 50 years of first flowering (1889) and again around in 1940 which had not been reported. Mahapatra (1957) reported that the probable flowering cycle of this species is about 50 or 60 years.

So far from Bangladesh incidences of two flowering reports were available, one in 1978 and the other in 1990 (Table 21), giving an estimate of 12 years gap. It is to be noted that there are 15 clumps of *O. nigrociliata* existing in BFRI bambusetum (line nos.23). Out of these, 7 were raised through offsets planting during 1973-74 and their age was not

Table 21: Past flowering records and estimated flowering cycle
in *Oxytenanthera nigrociliata*

Country/ locality	Flowering date (Calender year)	Estimated cycle (years)	References
Burma			
Tenasserim	1849		Gamble (1896)
	1899(Spor.)	50 (1849-1899)	Raitt(1929)
Moulmein	1879		Gamble (1896)
India			
Andaman Isl.	1875		Gamble (1896)
Assam, Garo Hills	1889		Gamble (1896)
Cachar Hill	1981-82(Spor.)	92-93 (1989-1981, 82)	Gupta(1982)
Puri, Arang Block	1957(Greg.)		Mahapatra(1957)
Bangladesh			
Chittagong Hill Tracts Pakuakhali, Pablakhali Range Shishak	1978(Greg.) 1990(Spor.)		Banik(1987b) Author

N.B: Spor.= sporadic, Greg. = gregarious

known because the date in which those 7 clumps originated as seedlings were unknown. The remaining 8 clumps are of seedling origin which were raised in 1978 from seeds collected from Pablakhali forest. So if the interseeding period of the species would be 12 years, the 15 clump of BFRI bambusetum should have flowered within 1990. Because the offset originated clumps were planted 17 years before and the seed origin clumps are 12 years old (1978-1990). However, in Bangladesh the species had flowered twice since 1978 (1978 and 1990) in the Chittagong Hill Tracts, but not in the same locality. Therefore, it seems that Bangladesh might have more than one "flowering genotype" or varieties of *O.nigrociliata*

5.1.12 Flowering biology

Inflorescence character: It has been observed in different bamboo species (Table 22) that the inflorescence is an indeterminate compound panicle, usually large, with spicate branches on which spikelet-like branches developed (Plate 2a,b,c). McClure (1966) termed these spikelet-like branches as pseudospikelets. Each of these pseudospikelets consisted of a number of florets (Plate 2a,b,c; Plate 3a). The colour of the florets were green. The florets were not showy or bright. Anther filaments were long, free, and hanging in nature in case of *Bambusa arundinacea* var. *spinosa*, *B.longispiculata*, and *B.tulda* while these were comparatively shorter in *B.vulgaris*, *Dendrocalamus longispathus* and *M.baccifera* (Table 22, Plate 2a,b,c). The anther was generally yellow, but it was purple in the case of *B.vulgaris*. The florets of *M.baccifera* were diagnostically prominent and had elongated purple coloured stigma (Plate 3b).

The species studied (Table 23) produced distinct floral shoots (excepting *B.glaucescens*, *B.longispiculata*) in

Table 22: Morphological characters of pseudospikelets of 7 bamboo species .

Character	Species						
	B.ar.v.spn.	B.gla.	B.lon	B.tul	B.vul	D.lon.	M.bac.
1.Arrangement	alternate, somewhat loosely arranged	alternate, loosely arranged	alternate, loosely arranged	alternate, loosely arranged	alternate loosely arranged, flattened, bifurcate,	alternate, somewhat in clustered head	one sided alternate and compact
2.Measurement of spikelet	10-25mm long	20-50mm long 3 mm wide slightly flattened, forms cluster, rarely single	30-150 mm long, alternate, lanceolate to flattened 7-10 mm broad	12 mm long, 5-8 mm broad sessile cluster, rarely single	10-18 mm long, compressed cluster, rarely single	5-8mm broad when few flowers 13-16 mm broad when many flowers arranged in cluster	upto 60mm, cylindrical flowers 13-16 mm broad when many flowers arranged in cluster
3.Palea	2-4 veined between the keels, ciliated along the keels	5-6 veined between the keels, ciliated along the keels	linear lanceolate 3-5 veined between the keels, ciliated along the keels	boat shaped 5-7 veined between the keels, ciliated along keels	oblong obtuse, 2-3 veined between the keels, ciliated along keels	oval, truncate, faintly 2-keeled	convolute mucronate, 7 veined
4.Lodicules	3,fimbriate	3,fimbriate	3,fimbriate	3,fimbriate	3,fimbriate	None	2,fimbriate
5.Number of florets	6-8	5-6	6-16	3-7	6-11	6 rarely 16	3-8
a) fertile	5-7	3-4	6-15	3-6	5-10	5-15	1-2
b) sterile	1-terminal	2-4 terminal	1-terminal	1 terminal	1-terminal	1-terminal	1-7

Table 22 contd. ...

6. Stamen	6, drooping	6, pendulous	6, exerted,	6, drooping,	6, exerted	6 short	5-6, filament
number and	filament	and exerted	slender,	filament	free,	free	short, free
nature	slender,	free	free	8-12mm long,			7-9mm long
	free.		8-12 mm	slender, free			
	slender,		long,	hanging			
	free		hanging				
7. Anther	yellow	yellow	yellow,	yellow mot-	purple,	yellow,	yellow
colour	obtuse	blunt or	obtuse	tled with	slender,	apiculate	obtuse
and shape		apiculate		purple	obtuse	with black	2-4mm long
				streaks,		apex	
				obtuse			
8. Style and	short,	short, 3 long	short, hairy	short,	long, hairy,	short,	elongate 3-4
stigma	stigma 3,	feathery	stigma 3,	stigma 3,	stigma 3,	hairy	with short
nature	plumose	stigma	plumose	plumose	plumose		feathery purple
							stigma
9. Ovary	elliptic	obovate,	round to	obovate,	narrowly	broadly	ovoid,
	oblong	rough	obovate,	obtusely	-oblong	ovoid,	narrowed
	glabrous		hairy	3-sided,	pubescent	acute	upward
	except at			pubescent		and dry	
	the tip						

N.B. B.ar.v.spn. = *Bambusa arundinacea* var. *spinosa*, B.gla = *B.glaucescens*, B.lon = *B.longispiculata*

B.tul = *B.tulda*, B.vul = *B.vulgaris*, D.lon = *Dendrocalamus longispathus*, M.bac = *Melocanna baccifera*

the month of September to January. The complete development of pseudospikelets and their blooming on the floral shoots took about 3-7 weeks time and varied with the species (Table 23). Initiation, development, and blooming of flowers during the dry season of the year also supported the statements of Brandis (1899), Kadambi (1949) and Troup (1921) that drought influences flowering in bamboos. *Bambusa arundinacea* var. *spinosa* produced leafless floral shoots directly both on the nodes of culms and branches. In the case of *B. vulgaris* floral shoots mainly developed from the branch nodes and were not completely leafless. Very long (50-120 cm) leafless floral shoots were observed only on the broken and cut culms. These longer floral shoots had more pseudospikelets (11-19 in number) in each node. Thus it appeared that injury enhanced flowering intensity as also observed by Troup (1921). *Dendrocalamus longispatus* also produced long leafless floral shoots, which were unlike vegetative shoots and were slightly zigzag or wavy in nature. The branches were glaucous green and the floral buds were arranged alternately on each node and covered with a branch sheath. Pseudospikelets developed in cluster (somewhat round) at each node on the floral shoot. The inflorescences in *B. glaucescens* and *B. longispiculata* were short panicle and did not develop on any specialized branches (floral shoots) as observed in other species. The pseudospikelets were loosely arranged forming clusters and developed directly on the primary and secondary leafy branches. At the initial stage in *B. tulda* no floral shoots were observed and the inflorescences were also small and born directly on the leafy branches. The pseudospikelets were comparatively bigger in size and also loosely arranged. However, after about 1-2 months of first blooming vegetative branches rapidly shed leaves and buds on the branches developed elongated floral shoots.

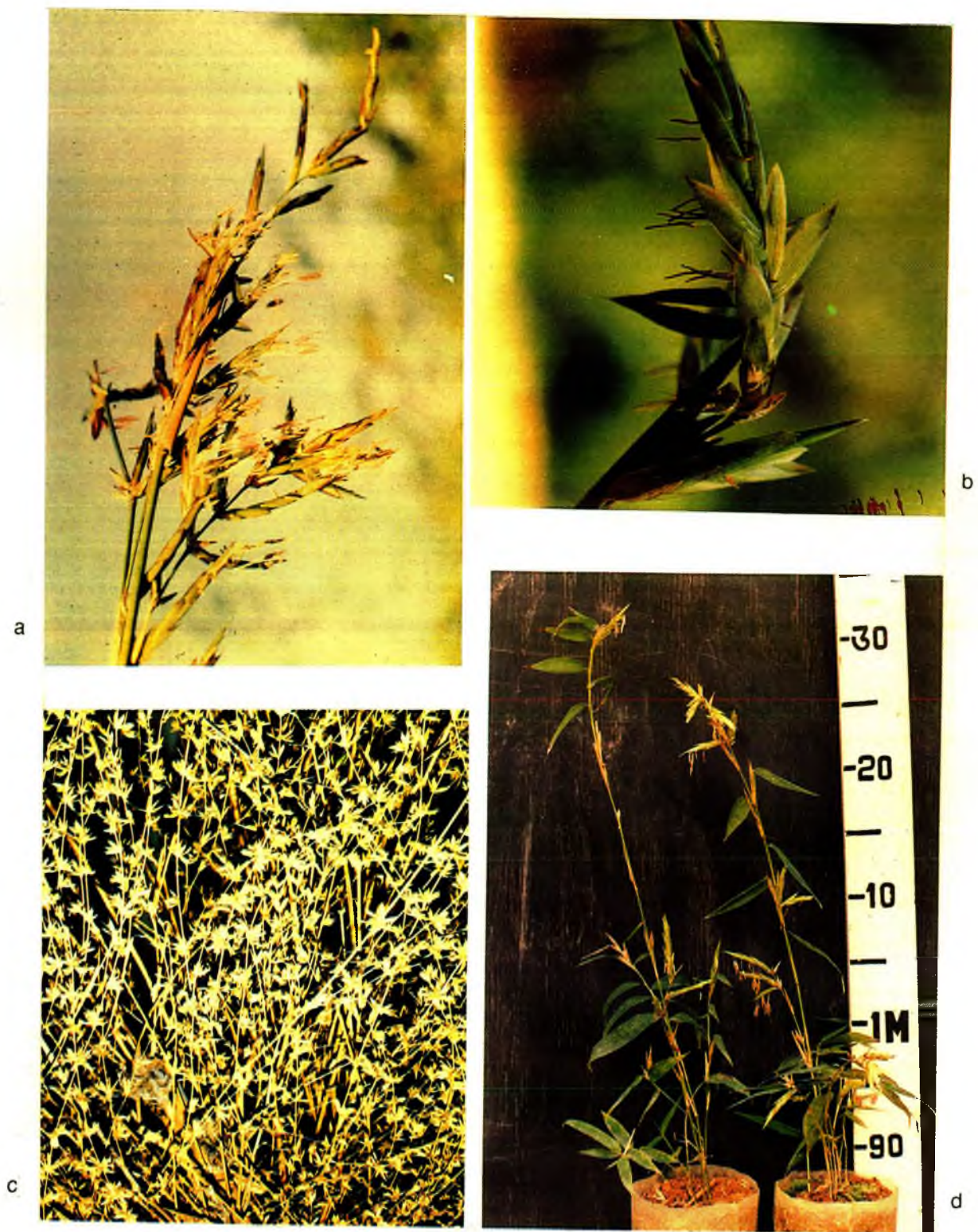


PLATE 2. : Pseudospikelets and florets :
 a) *B. longispiculata*,
 b) *B. tulda* (from adult clump),
 c) *B. vulgaris*, and
 d) *B. tulda* (from precocious seedling).

The initiation of inflorescence in *Melocanna baccifera* was distinctly different. The thin leafy branches produced leafless elongated floral shoots always at the apex (Plate 3a). The nodes along with buds on the floral shoots were covered with small sheaths. The floral buds were not alternate thus produced pseudospikelets on one side of the branches (Plate 3a). Soon after the flowering the leaves below the floral shoot rapidly turned yellow and withered, and after that the buds on the nodes of the branches also produced short panicles. In this species both flowering and fruiting were continuous (Plate 3c).

Clump behaviour to flowering intensity and duration:
All the culms of different age groups in each of the clumps of *B.arundinacea* var.*spinosa* and *M.baccifera* produced flowers simultaneously. In *B.arundinacea* var.*spinosa* flowering started in the first week of February and completed in early April (within 3 months). Then all the clumps died. The clumps of *M.baccifera* took almost one year to complete the flowering and then died. Thus the clumps observed in these two species were complete-flowering in nature.

In *B.glaucescens* all the 1-, 2-, and 3-year old culms in the clump flowered partially i.e., produced both leaves and flowers whereas 4-year old culms flowered completely. The species took 2 years to complete flowering. Therefore, the observed clump of *B.glaucescens* was part-flowering in nature.

The observed clumps of *B.longispiculata* and *B.nutans* produced only a few partially flowered (0.2-8.0%) branches. No flowering was observed in the younger culms which emerged in the current year of flowering. Flowering branches were mainly confined in lower mid-positions of the culms. Among 5 clumps of *B.longispiculata* 4 completed flowering within 2-3 years and then died, and remaining one have been flowering for the last



PLATE 3. : Floral shoot and flowers of *M. baccifera* :
 a) One sided spikelets at the branch apex,
 b) purple stigma,
 c) culm having flowers and fruits,
 d) culm production in precociously flowering seedling

Table 23: Floral shoot appearance, flowering and seeding period in 7 bamboo species.

Species	Floral shoot		Flowering	Shoot to	Seed
				flowering	ripen
	Initiation	length	date	(period)	(date)
	date	(cm)			
<i>B. arundinacea</i>	Dec. 2 wk	5-48	Feb. 1 wk	6 wks	Mar-Apr
var. <i>spinosa</i>	1979		1980		
<i>B. glaucescens</i>	No shoot	-	Apr. 1 wk	3 wks	May-Jul
	Mar. 1 wk		1977		
	1977				
<i>B. longispiculata</i>	Feb. 2 wk	-	Mar. 2 wk	3 wks	Apr-Jul
	1978		1978		
<i>B. tulda</i>	Dec. 3 wk	5-25	Feb. 1 wk	5 wks	Apr-Aug
	1979	1980			
<i>B. vulgaris</i>	Jan. 1 wk	10-45	Feb. 4 wk	6 wks	No seed
	1979	1979			
<i>D. longispathus</i>	Jan. 2 wk	50-90	Mar. 2 wk	6 wks	Apr-Jul
	1977,		1977,		
	78,79		78,79		
<i>M. baccifera</i>	Sep. 2 wk	12-45	Nov. 2 wk	7 wks	Apr-Sep
	1990	1990			

N.B: Observed in first year of flowering

12 years and not yet dead. Thus the clumps observed in this species showed both part-flowering and continuous-flowering nature.

Irrespective of age all the culms of flowering clumps of *B.tulda* produced both partially and fully flowered branches. Out of 10 clumps studied 9 completed flowering within one year and then died. The remaining one clump flowered mostly in the first year and a few twigs of the basal position of the culm flowered sporadically in the second year and then died. Thus in *B.tulda* out of 10 clumps 9 were complete-flowering in nature whereas one clump showed part-flowering behaviour.

Among the 7 flowering clumps of *D.longispathus* 4 clumps completed flowering within one year and died. These 4 clumps were complete-flowering in nature. The remaining 3 clumps were part-flowering in nature, where flowering period was 2 years (1978-79) for 2 clumps, and 3 years (1977-79) for one clump.

Out of 7 clumps studied in *B.vulgaris*, 5 flowered completely and died within 18 months. In the first year these clumps flowered profusely upto September with a pause from October to January and then completed flowering within next July through irregular flowering. The remaining 2 clumps were found to be part-flowering in nature. Out of these 2 part-flowering clumps one died after 3 years and remaining one stopped flowering and revived. It was learnt from an old villagers that all the five complete-flowering and part-flowering clumps had been planted from two completely different stocks through offsets. Thus it was likely that this species might have two genetical or physiological strains, one was part-flowering and other was complete-flowering.

Blooming nature and seed yield: Blooming in a bamboo clump (both part or complete-flowering) was not continuous rather it occurred in three distinct successive flushes (flush period) with two non-blooming periods (rest period) in between (Table 24). In case of part-flowering clumps, where flowering continued for 2-3 years, the flush and rest periods were distinctly identifiable generally in the first year of flowering. Similarly in Orissa, Nicholson (1945) also observed that flowering in *Bambusa arundinacea* was not continuous rather the species flowered successively 3-times in the year.

The growing pattern of pseudospikelets on the indeterminate inflorescence might explain such phase-wise flowering behaviour in bamboo. According to McClure (1966) in indeterminate inflorescence each pseudospikelet has its own independent "grand period of growth" and being repositories of meristem, the buds at the base of a pseudospikelet make possible the continued expansion as long as the favourable physiological condition of the adjacent meristematic tissue exists.

The total duration of all three flush periods in *B. glaucescens*, *B. vulgaris* and *D. longispatus* were $(50+20+9)=79$ days, $(75+68+44)=187$ days, and $(55+26+9)=90$ days respectively, whereas in case of *B. arundinacea* var. *spinosa* it was only $(12+15+13)=40$ days (Table 24). Longer time for first two flush periods in *B. glaucescens* and *D. longispatus* is likely to require higher physiological potentiality for flowering and as a result potentiality is exhausted in the final flush period. Probably due to this reason third flush period was short and yielded seeds (caryopses) were mostly empty. The clumps of *B. vulgaris* exhibited longest time in all 3 flush periods and did not produce any seeds. However, in this species partly flowered clump also did not produce any seeds. Gamble (1896) reported that caryopses were "not known" in this species. Unlike these species the duration of all the

three flush periods was more or less equal and short in *B.arundinacea* var.*spinosa*. Probably, therefore, in this species the physiological potentiality was not exhausted during the first two flush periods. It was rather being used equally in all the flushes resulting in the production of viable seeds throughout the whole flowering period. However, in all the species, excepting *B.vulgaris*, the amount of seed production was maximum in the first flush period and gradually decreased in the subsequent flushes (Table 24). Thus it appeared that for obtaining maximum amount of viable seeds from *B.glaucescens* and *D.longispathus* collection should be done in first two flushes that was from February to June. Presence of non-blooming phases (rest periods) in between three flush periods probably are required for resuming the physiological potentiality by repositoring the meristem at the base of pseudospikelet (McClure 1966).

Anthesis and pollination behaviour: Opening of flower and pollen discharge in all the species studied mostly occurred in the morning 6 am to 9 am as observed by Beddows (1931) in *Festuca pratensis*, a caespitose perennial grass. On touching or with gentle air movement the anthers of all the species, especially *B.tulda* and *D.longispathus*, discharged pollen grains in the form of pollen-cloud.

It was observed through a preliminary Acetocarmin test that about 70-92% pollen of *B.vulgaris* did not take any stain indicating the higher percent of sterility in the pollen. This might be one of the reason that *B.vulgaris* did not produce any seed. During anthesis honey bees and few ants were found to visit the bamboo flowers.

Seed production was much lower in case of self-pollination than cross-pollination (Table 25). Depending on the availability of fertile florets in a pseudospikelet, seed formation in *B.arundinacea* var.*spinosa* and *D.longispathus* was

Table 24: Successive nature of flowering with seed yield and germination in 4 bamboo species (FL = Flush and RT = Rest period).

Species	Flowering period		Seed per clump (g)	Average germination %
	Blooming (dates)	Non-blooming (dates)		
<i>B. arundinacea</i> var. <i>spinosa</i>	FL-1 (3/2-14/2) 12 days		30-80	49.5
	FL-2 (21/2-7/3) 15 days	RT-1 (15/2-20/2) 6 days	10-25	45.0
	FL-3 (22/3-3/4) 13 days	RT-2 (8/3-21/3) 14 days	4-6	62.4
<i>B. glaucescens</i>	FL-1 (5/4-24/5) 50 days		15	25.2
	FL-2 (30/5-18/6) 20 days	RT-1 (25/5-29/5) 5 days	6	55.2
	FL-3 (1/7-9/7) 9 days	RT-2 (19/6-30/6) 12 days	Empty seed	0
<i>B. vulgaris</i>	FL-1 (25/2-10/5) 75 days		Empty seed	0
	FL-2 (29/5-4/8) 68 days	RT-1 (11/5-28/5) 18 days	Empty seed	0
	FL-3 (17/8-29/9) 44 days	RT-2 (5/8-16/8) 12 days	Empty seed	0
<i>D. longispathus</i>	FL-1 (10/3-3/5) 55 days		40-90	51.0
	FL-2 (23/5-17/6) 26 days	RT-1 (4/5-22/5) 19 days	25-40	48.8
	FL-3 (28/6-6/7) 9 days	RT-2 (18/6-27/6) 10 days	Empty seed	0

Table 25: Seed yield through self and cross pollination in 3 bamboo species.

Species	No of pseudo-spike-let tested	Fertile floret per pseudo-spikelet	Selfing		Crossing	
			Seed yield (Nos.)		Seed yield (Nos.)	
			Expd	Obsd	Expd	Obsd
<i>B.arundinacea</i> var. <i>spinosa</i>	10	6 + 1	60	5	60	33
<i>B.glaucescens</i>	10	5 + 1	50	3	50	7
<i>D.longispathus</i>	10	10 + 4	100	6	100	39

N.B: Expd. = Expected, Obsd. = Observed.

Table 26: Average culm production per clump in 7 bamboo species during the current and preceding year of flowering.

Species	Clump flowered		Culm produced per clump (Nos)			
	Nature	Nos.	Current year	Preceding year of flowering		
				1	2	3
<i>B.arundinacea</i> var. <i>spinosa</i>	compl	3	0	2.0	2.3	2.0
<i>B.glaucescens</i>	part	1	0	8.0	6.0	4.0
<i>B.longispiculata</i>	part	5	4.2	4.0	3.2	2.6
<i>B.tulda</i>	part	1	2.0	3.0	3.0	2.0
<i>B.vulgaris</i>	part	2	8.5	16.5	21.5	-
	compl	5	1.6	6.8	6.0	-
<i>D.longispathus</i>	part	3	1.0	3.7	12.3	17.3
	compl	4	0.5	6.0	5.8	3.5
<i>M.baccifera</i>	compl	5	0	8.0	17.0	12.0

Observed in the first year of flowering

N.B.: Part = Part flowering, Compl. = Complete flowering nature

higher only when more than 1 clump flowered. In *B. glaucescens* only one clump flowered and, therefore, there was no chance of crossing and as a result seed yield was poor (Table 25). Thus it is evident that bamboos are cross-pollinating species similar to the nature of other perennial grasses (Evans 1964).

Flowering and culm emergence: It is evident from the Table 26 that all the bamboo species produced culms in the preceding year of flowering. There was tendency in decreasing the number of culm production in some species from third year to current year of flowering and in some species the condition was reverse (Table 26). Troup (1921) reported that checking of new culm production from a bamboo clump could be a reliable sign to predict flowering in the following years. Contrary to his statement the present observation showed that this is not true for all bamboo species. Complete-flowering clumps of *B. arundinacea* and *M. baccifera* did not produce any culms in the current year of flowering, whereas those of *B. tulda*, *B. vulgaris* and *D. longispachus* had produced culms but fewer in number. All the part-flowering clumps of different species, excepting *B. glaucescens*, produced culms in the current year of flowering.

Seeding season and adaptation: It was observed in Bangladesh that different bamboo species flowered in different years but all bloomed during November to April (Table 23). In Japan tropical types also flowered in November to February and produced seeds in April and May (Ueda 1960). Bangladesh is situated between latitude $20^{\circ}34'$ to $26^{\circ}38'$ N and longitude $88^{\circ}01'$ to $92^{\circ}41'$ E whereas Japan is located between 31° to 45° N and 130° to 145° E, yet bamboos in both the countries have been flowering and fruiting at the same time. So there seems to be some specific seasonal affinity for bamboo in flowering and seeding. Studies in both the countries indicated that

bamboo seeds are short lived and lose their viability within 1-2 months (Banik 1987a, Tanaka and Takimoto 1972, Ueda 1960). In Bangladesh bamboo seeds ripen during April to July (Table 23). Immediately after ripening, seeds fall on the ground during monsoon (May-August) and start germinating within a week. If the seed would mature much earlier to the rainy season, there would be no or less germination and most of the seeds would fail to develop into seedling due to their short lived nature. Thus ungerminated seeds remain exposed on the forest floor. These exposed seeds attract the predators like birds, bisons, wild bores and rodents, etc. (Janzen 1976, Kurz 1876, Ueda 1960). If the seeding distribution and seed fall move forward and prolong towards October to January, seeds would not germinate due to drought. So bamboo would fail to regenerate naturally. Therefore, the seeding season of tropical bamboos, like other tropical tree species (*Dipterocarpus sp.*) seems to be an adaptation to nature for protecting and maintaining the specific race.

5.1.13 Precocious flowering

A few cases of precocious flowering was observed in the seedlings of *Bambusa tulda* (Plate 2d) and *Melocanna baccifera* (Plate 3d) at BFRI nursery during 1978 and 1989 respectively, similar to the reports of Ahmed (1937), Brandis (1899) and Sen Gupta (1939) on *Dendrocalamus strictus*.

Among the five thousand seedling of *B.tulda* raised from seeds collected from Shishak during 1977, one seedling flowered and seeded at the age of 18 months in the nursery and then died. Another seedling from the same population flowered at 12 years of age during 1989 and is still alive. Other remaining seedlings were planted at Kaptai forest, Keochia field station, and BFRI bambusetum, Chittagong and upto May 1990 these were of 13 years old and none has yet flowered.

Precociously flowering 18 months old mother seedlings ultimately produced seeds. Seedlings raised as generation I from that mother exhibited 2 different precociously flowering behaviours. Some flowered partly at the age of 20 months and did not produce any seed and ultimately died. Other seedlings flowered completely, among them some at the age of 36 months and did not produce seed, the remaining ones at 12 months produced seeds (Flowchart 1). From the later group seeds were collected and seedlings were raised (Generation II). Then seeds were collected from the mother seedlings of Generation II and seedlings were raised as Generation III. Later on wild seedlings were also collected from the mother seedlings of Generation III and seedlings of Generation IV were raised. It is interesting to note that precocious flowering character have been exhibited by the progenies of all the five generations suggested that this character was transmitted from generation to generation. After publication (Banik 1980) of this report of precocious flowering in *B.tulda*, Watanabe and Hamada(1981) interpreted that such early flowering behaviour might be due to mutation in certain gene. So there must be some triggering factor(s) for such mutation. But however, there was neither extraordinary environmental variation during seed collection and germination nor seeds were treated with any mutagenic chemicals. Seeds collected from the gregariously flowering clumps naturally existed in the Shishak forest of Chittagong Hill Tracts. Bamboos and some perennial grasses are, in general, cross-pollinating in nature (Banik 1986, Evans 1964. As the clumps of *B.tulda* flowered gregariously covering a large tract of land in Shishak forest had enormous scope for cross-pollination resulting a heterogenous seedling population. Thus it seems that the precocious flowering character what observed in *B.tulda* is genetically controlled as the character transmitted from generation to generation. As all the seedlings of each generation did not always show the

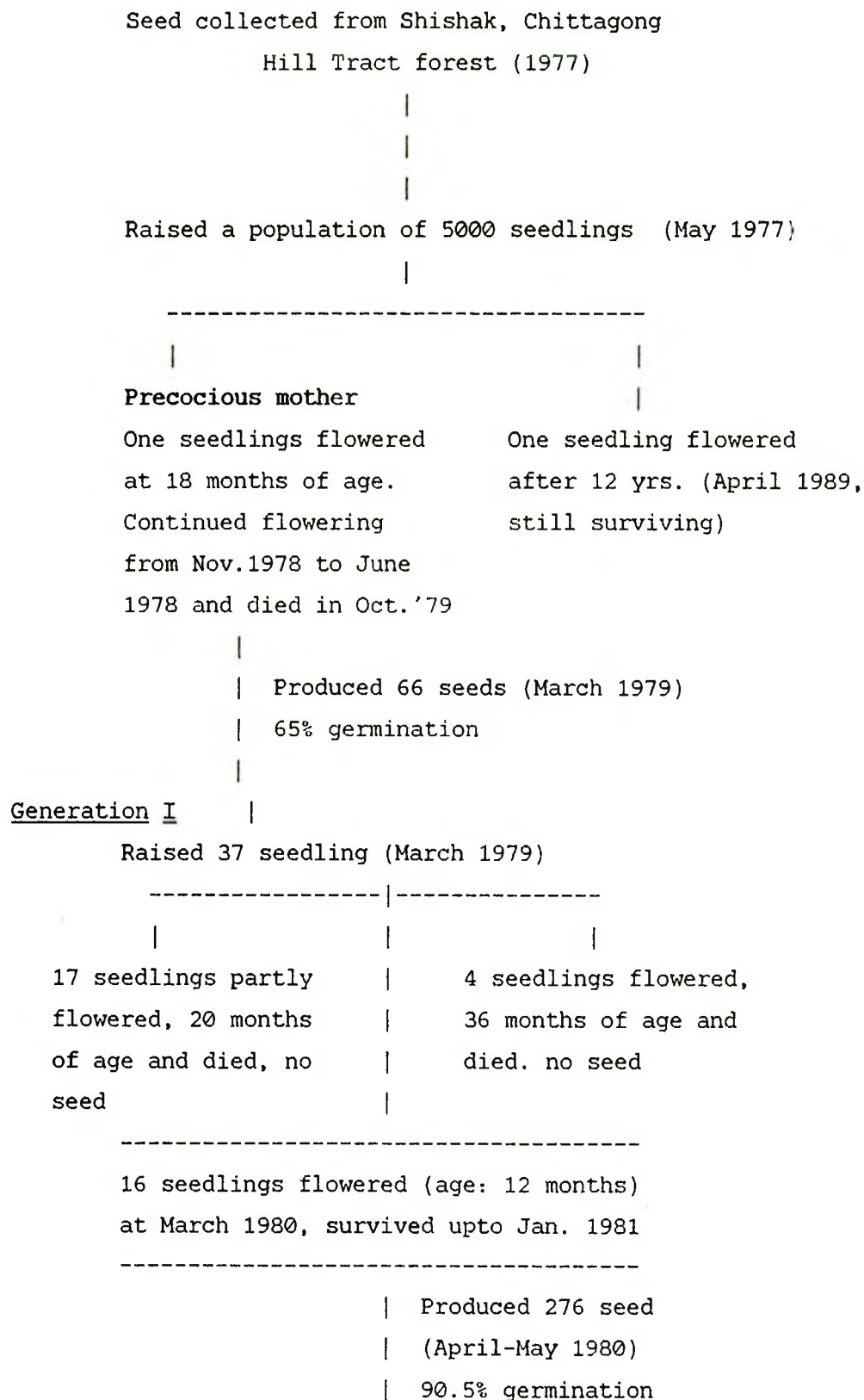
same type of flowering character indicated that the gene(s) responsible for early expression of flowering segregated and some expressed after 18 months, 12 months, 10 months, 20 months, 36 months and 12 years in different or same generation (Flowchart 1).

A number of 8156 seedlings of *M.baccifera* were raised during May 1989 from the seeds collected from Hyanko, Nazirhat and Ramgarh forest areas. In those areas a few mature clumps flowered and produced seeds and then died within December 1989. All the seedlings have been maintained in the nursery of BFRI, Chittagong and exposed to the normal climatic conditions. Among this population 4 seedlings started flowering precociously at the age of 10 months and one seedling at the 12 months of age (Table 27; Plate 3d). In total 5 seedlings flowered precociously. There was no environmental stress in the nursery during seed germination and seedling development. Thus it seems precocious flowering in *Melocanna* is more of segregation of gene(s) responsible for flowering than mutation same as explained in *B.tulda*. All these 5 seedlings produced seeds but all the seeds did not germinate. Mother seedling number 1, 3 and 4 yielded some viable seeds which were germinated and produced seedlings excepting in mother number 3 where seedling died within a week of germination. At present, upto December 1990, mother 1 and 4 have produced one and two viable seedlings respectively (Table 27). Investigations have been continued to observe the future flowering behaviour of the seedlings raised as Generation I. So far two flowering seedlings (mother number 2 and 4) died within December 1990. Mother number 1, 3 and 5 are still alive (Table 27). Among them mother number 1 and 5 have been producing flowers and new culms simultaneously (Plate 3d). It is generally known that flowering clumps of *Melocanna baccifera* do not produce new culms in the current year of flowering and die within one year. But the precociously

flowering seedling mother number 1 and 5 exhibited both sexual and vegetative growth simultaneously (Plate 3d and Table 27) and did not die. This could be the important and one of the most desirable genetic character for future clone selection in *M.baccifera*.

Recently Nadgauda, Parasharami and Mascarenhas (1990) reported that they could induce precocious flowering and seeding in tissue cultured plantlets of *Bambusa arundinacea* and *Dendrocalamus brandisii*. They have used excised 3-4 cm segments of coleoptile regions of the seedlings of these two bamboo species as explant and cultured on MS medium supplemented with 0.5 ppm BAP and 5% CM. After three consecutive subcultures on the medium plantlets produced panicles of normal spikelets. The interesting aspect of the study was that the explants used were of seedling origin and they have not tested any explants from adult origin. If the plantlets developed from adult explant could be induced to precocious flowering and simultaneously if the adult donor would not flower, then the treatment could be taken as an effective mechanism for induction of such artificial flowering in bamboos. However, the *in vitro* flowering, thus appeared to be an expression of early flowering gene(s) segregated into the seedling from where explants have been collected.

Flow chart 1: Subsequent 5 generations of precocious flowering
behaviour in the seedlings of *Bambusa tulda*



Flowchart 1 contd...

Generation II

250 raised Seedlings (April-May 1980)

22 flowered, 9-10 months age (March 1981),
survived upto Oct. 1982

Produced 70 seeds (June 1981)
62.8% germination

Generation III

Raised 44 seedlings (June 1981)

8 seedlings flowered, 10 months of age
(April 1982), died within Dec. 1982

Seeded

Generation IV

Seeds dropped from the mother to the ground,
germinated, 19 wild seedlings collected
(July 1982)

8 seedlings did not flower

11 seedlings flowered, 10 months (April 1983) age

Generation V

5 wild seedlings were collected (July 1983)

Flowered at 10 months of age (April 1984), died by Dec'84.

Table 27: Flowering age, seed and seedling production in precociously flowering seedlings of *M.baccifera*.

Mother seedling (germination date)	Flowering date	Flowering age (months)	Seed dropping date	Seed produced (Nos.)	Seed germinated date	Generation (Code No)	Remarks on mother seedling
1							
(05.5.1989)	03.3.90	10	05.6.90	1	failed	-	Active,
2							
(05.5.1989)	03.3.90	10	25.7.90	1	failed	-	Mostly dead
3							
(05.5.1989)	03.3.90	10	01.6.90	1	failed	-	
			23.9.90	1	failed	-	
			27.10.90	1	31.10.90	(M ₃)F ₁ /1	Alive
4							
(07.5.1989)	06.3.90	10	30.6.90	1	failed		
			23.9.90	1	9.10.90	(M ₄)F ₁ /1	
			01.11.90	1	8.11.90	(M ₄)F ₁ /2	Dead
5							
(07.5.1989)	10.5.90	12	No seed	-	failed	-	Alive, producing new culms

5.1.14 Selection and collection of "flowering genotype"

Records are there (as discussed under 5.1.11) that in addition to long interseeding period gregariously flowering species such as, *Bambusa tulda*, *Dendrocalamus longispathus*, and *Melocanna baccifera* also exhibited frequent sporadic flowering in a solitary or a few clumps and precocious flowering in seedling (Table 15, 17, 19, 27 and Flow Chart 2). In lower Bengal (Malda district) *B. tulda* flowered four to five occasions within 16-18 years of time (Table 15). It is likely that different clumps of this species flowered isolatedly in different times scattered within that reported period. Similarly the species also flowered sporadically 9 occasions in Chittagong within 13 years (1978-1990), in Chittagong Hill Tracts 6 occasions within 12 years (1977-1988), and 4 occasions in Sylhet within 12 years (1978-1989) (Table 15). Thus it appeared that the species has a number of "flowering genotypes" and have been flowering frequently in patches or in groups in between normal gregarious seeding cycle. Each of them might have different interseeding period and all of them are intermingly existing in the forests creating a diverse propulation with irregular sporadic flowering and fruiting. Dogra (1981) has stated that in Indian forests bamboo cohorts have been extensively fragmented and mixed up and sufficient genetical variation might be present. If seeds or seedlings of these mother clumps could be collected and centralized in an orchard it would likely that the progenies might flower also at different times like their mothers yielding seeds more than once within a very short interval of time. In describing the habit of such irregularly-flowering species Brandis (1899) stated that "sometimes all clumps on a limited tract of country come into flower at the sametime, at other times isolated clumps or group of clumps produce flowers and seeds and frequently some stems of the flowering clumps bear leaves". Similarly Menon (1918) also mentioned that *Bambusa arundinacea* had flowered gregariously in Tekkadi leased forests but in adjoining Cochin State Forest only a solitary

clump flowered with its sister population covering a large area. Thus flowering in *B.arundinacea* not necessarily be always gregarious but may be solitary to a clump.

A number of flowering cycle has also been reported for *Dendrocalamus strictus*. In south India reported interseeding period is 24-28 years (Kadambi 1949), in north, east and central India 40-44 years (Kadambi 1949, Gupta 1952), in western India 65 years (Mathauda 1952) and in Bangladesh it is 45 years (Banik 1981) for *D.strictus*.

Three "flowering genotypes" of *D.longispathus* were also observed in Bangladesh (Banik 1986). Out of 7 flowering clumps, 4 completed flowering in 1 year, 2 completed in 2 years, and 1 completed in 3 years. It is to be noted that all these 9 flowering clumps were planted in the BFRI bambusetum through offsets and collected from different forest localities of Chittagong and Chittagong Hill Tracts. In the forests these were originated from seeds in unknown year or years and presumably having different genetic makeup. Watanabe and Hamada (1981) reported that several clumps of *Arundinaria fastuosa* from separate sources planted at Pitt White flowered many times, but 4 stands did not come into flower at all and believed that inheritance of the flowering habit into its progeny depend on pedigree (Watanabe and Hamada 1981).

Similarly Hasan (1980) has reported the occurrence of sporadic flowering in a few clumps of *Melocanna baccifera* in Mymensingh, north eastern part of Bangladesh, during 1974-1975 and believed that such "out-of-phase" flowering was accidental mutation due to environmental factors. However, Watanabe and Hamada (1981) explained the observation of Hasan (1980) as "such an out-of-phase flowering may occur by the cause of not only environmental factors, but a certain pedigree to succeed different interseeding period".

It has also been reported (Troup 1921) that *M.baccifera* exhibited long flowering wave continued for 14 years (1902-1916) in Burma, 9 to 10 years (1952-1961) in Bangladesh (Table 19). It is not that a clump continue to flower for 10 or 14 years, rather, after flowering a clump die

within one year. Therefore, during the flowering wave of 14 years one can have seeds every year from 14 different mothers flowered in successive years. If progenies of all these mother could be collected and planted separately in an orchard they are likely to produce seeds in serial every year for 14 years in the next flowering incidence.

In describing the flowering habit of some temperate bamboos of Japan, Kasahara (1981) stated "the blooming cycle of bamboos is decided by the work of a gene locus and the bamboo brakes having the same gene bloom in the same years. Here, no environmental variation is seen". McClure (1966) reported that *Phyllostachys aurea* had more than one "flowering genotype".

Kawamura (1927) and, later on, Numata (1970) described the variation in the flowering intensity and seeding cycle in *Phyllostachys henonis* and *Ph.bambusoides* respectively. From their documentations, Janzen (1976) inferred that such variation is due to different clones within the same species of bamboo that are slightly "out of phase" in flowering with each other.

It appears that a bamboo species may not always show its gregarious flowering nature and or synchronized cycle of flowering with its remaining sister of same population. These isolated flowering or "out of phase" flowering clump or different flowering genotypes might have evolved due to genetic mutation (Hasan 1980, Watanabe and Hamada 1981) and may be designated as a 'variety'. A 'variety' may maintain the same length of interseeding period as all the sisters of the population do normally or may have short interseeding period. Let us designate the out of phase flowering in 1979 of *B.tulda* at Ghagra as a "*B.tulda* 1979/Ghagra" variety, and in 1981 at Kaptai as another 'variety' of "*B.tulda* 1981/Kaptai". Suppose these two seed source maintain normal (20 or 30 year) interseeding cycle, the 'variety' *B.tulda* 1979/Ghagra" is likely to flower either in the year 1999 or 2009. Similarly the other variety "*B.tulda* 1981/Kaptai" is likely to flower in the year 2001 or 2011. Thus in the next generation the

Table 28: Germplasm of flowering genotypes centralized in the Bambusetum of BFRI, Chittagong

Species	Normal clones in Bambusetum (localities)	Seeding year and origin	Total collected Nos
<i>Bambusa arundinacea</i>	Sylhet (Fl.1988)	1976(Bsetm) 1988(Keochia, Bsetm, Dhaka Bot.Gard.) 1990 (Keochia)	5
<i>B. arundinacea</i> var. <i>spinosa</i>	Dinajpur (Fl.1980).	1980(Bsetm)	1
<i>B. glaucescens</i>	Sylhet	1977(Bsetm)	2
<i>B. longispiculata</i>	Dinajpur	1978,1980(Bsetm)	3
<i>B. nutans</i>	Dinajpur	1979,1980(Bsetm)	3
<i>B. polymorpha</i>	Hill Tracts, Sylhet	1982(Kalenga, Sylhet)	3
<i>B. tulda</i>	Hill Tracts	1977(Shishak) 1978(Shishak) 1978(Adampur) 1979(Ghagra) 1979(Lawachara) 1980(Bsetm) 1981(Kaptai) 1984(Hathazari) 1984(Bsetm) 1987(Bstem) 1988(Akhaura) 1988(Serajgonj) 1989(Keochia) 1990(Keochia)	15
<i>B. vulgaris</i>	Sylhet, Chittagong, Khulna	1979(Partly flowered at Faridarpara,Ctg.)	4

Table 28 contd. ...

Dendrocalamus

<i>longispathus</i>	Kassalong,	1972(Koila,Ctg.)	
	Hathazari	1974(Dholai T.E. Sylhet)	
		1978(1 yr Bsetm)	
		1978-79(2yr Bsetm)	
		1977-79(3yr Bsetm)	7
<i>D.strictus</i>	Hazarihil (Fl.1983)	1983(Bsetm)	1
<i>Melocanna baccifera</i>	Hill tracts	1974(Mymensingh)	
	(Kassalong)	1986(Kamalchari)	
		1989(Narayanhat)	
		1990(Hyanko)	
		1991(Fatehabad)	6
<i>Oxytenanthera</i> <i>nigrociliata</i>	Chittagong	1978(Pablakhali)	2

Total "flowering genotype" number 52

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Note : Fl = All clumps flowered and year of flowering,
Bsetm = Bambusetum of BFRI.

availability of seeds are likely to be in the year 1999 or 2009, and 2001 or 2011 --- a gap of only 3 years.

Therefore it appears, centralization of different normal seeding clones and "flowering genotypes" or "out of phase" seeding varieties likely to shorten the long gap between the seed yield in each bamboo species. With this objectives available flowering genotypes under different bamboo species are being identified and have been collected and centralized in the Bambusetum of BFRI since 1974 (Table 28).

5.1.15 Natural regeneration after flowering and its maintenance

Influence of weed and shade on seedling density:
Clumps of both *Bambusa tulda* and *Dendrocalamus longispathus* flowered in February and March, 1978-79, 1983-84 and 1972-73, 1977-1979 respectively and started producing seeds during April to August of those years. Seeds started dropping soon after ripening from the mother clumps. During that time many seeds were found to be eaten up by birds like sparrow, weaver etc. from the clump and jungle fowl and rodents from the floor. Germination of seeds started within a week of falling on the ground. Huge number of seedlings below the dying mother clump were produced within May to August (Plate 4Ai). Many seeds and germinating seedlings were carried along with rain water, some times, far away from the mother. Density of seedlings (1-2 months old) was about 45/100 sq.cm in depressions and valley areas and it was lower in slopes (3/100 sq.cm).

It was also observed that some factors like shade and weeds had influenced the density and survivality of the regenerating seedlings (Table 29). Many seedlings died because of suppression and competition by weeds, such as, *Eupatorium odoratum* Linn, *Imperata cylindrica* Beauv., *Streblus asper* Lour., *Desmodium trifolium* Dc., and *Mikania scandens* Willd. In both the bamboo species number of seedlings present per unit area under the partial shade condition due to dead mother clump was higher than in area under complete shade or full of weeds (Table 29). Almost all seedlings died within 7-12 months under complete shade condition. In Burma, Kurz (1877) observed similar problems for natural regeneration of bamboo seedlings. He added that it was not certain whether the next generation would be a pure bamboo jungle or whether the bamboo population will be squeezed up. Dead mother clumps

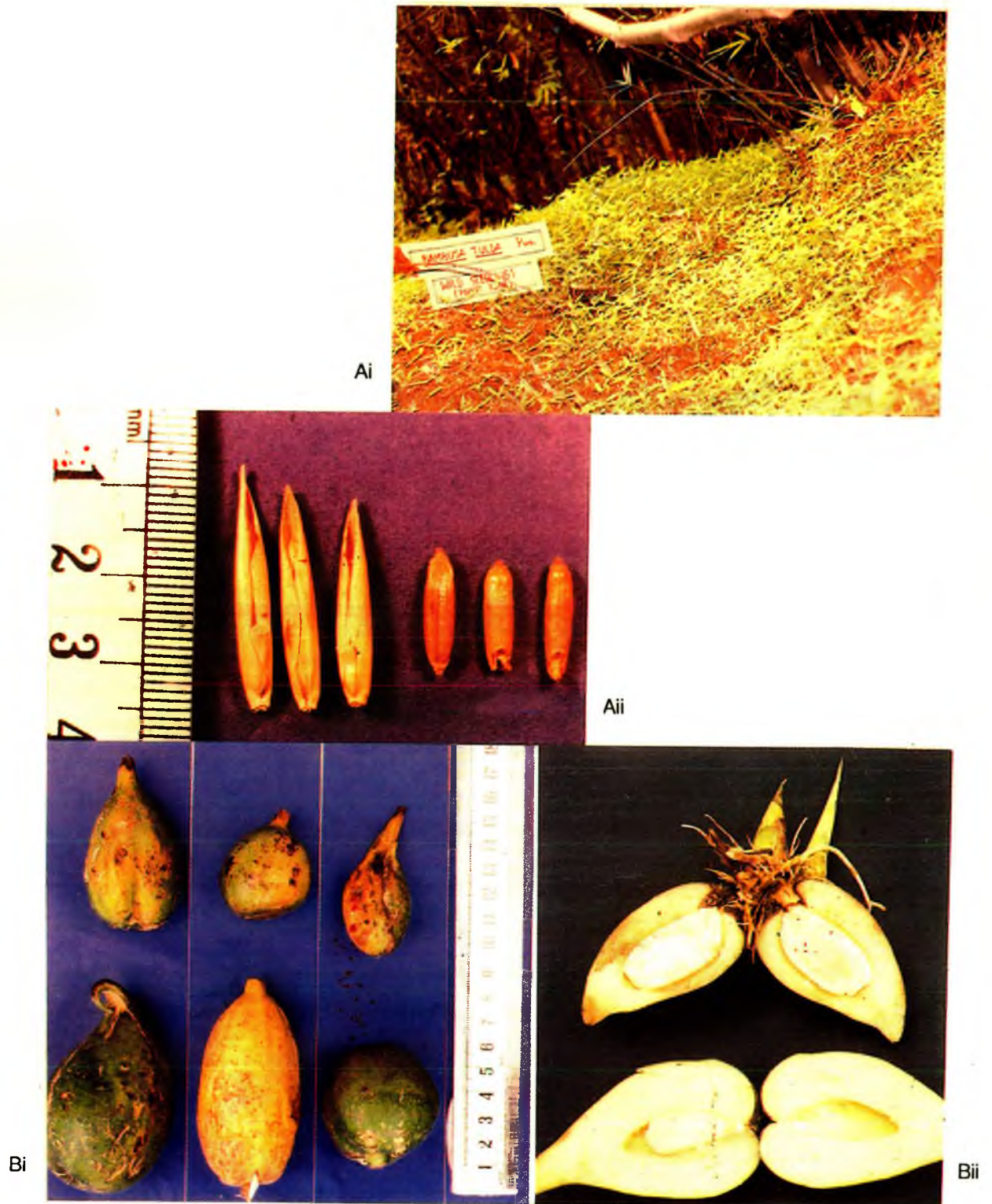


PLATE 4. : Natural regeneration and seed characters :

- A) *B. tulda*-i) wild seedlings in forest floor, ii) Glumed and deglumed caryopses:
 B) *M. baccifera* - i) seeds of different sizes and shapes, ii) L. S. of seed with embryo.

provided partial shade to the regenerating seedlings and this condition was found to be favourable for the regeneration process. It was further observed after 10 months that seedling density was better in artificially thinned than unthinned areas (Table 29). Competition between the seedlings were high in unthinned areas and as a result the rate of death was higher than that of thinned areas. Seedlings of thinned area showed better diameter growth than those of unthinned areas (Table 30).

Clear felling and burning in relation to seedling establishment: Burning or clear felling of dead mother bamboo clumps within 1-3 months of seedling production killed almost all the bamboo seedlings. The effect was not so hazardous when burning was done after 6-9 months of age. According to Troup (1921) and McClure (1966) bamboo seedlings, generally could produce underground rhizome after 4-6 months of age. Burning and felling operations after 6-9 months of age have destroyed only the aerial part of the bamboo seedlings, but within few months seedlings appeared again through the underground rhizome as observed by Naito *et al.* (1968) on *Sasa palmata* in Japan. Thus it appeared felling of dead mother clump may be delayed at least for 9-12 months and this will provide partial shade to the regeneration bamboo seedlings. In fact, Ahmed (1954) and Seth (1954) also discouraged to undertake felling operation of dead culms in the early stage of regeneration process and they were in opinion that it would benefit the regenerating bamboo crop considerably and lead to a well developed stand with healthy clumps.

Health of the bamboo seedling was found to be better in partial shade and less weed conditions than full weed and complete shade conditions (Table 30) which indicates that the bamboo seedlings require light at the early stage of

Table 29: Average density of natural bamboo seedlings
(number/100 sq.cm.) in different age under
various available site conditions.

Age (mon- ths.)	Full weed exposed		Less weed exposed		P.shade & less weed		C.shade & less weed		P. shade & seedling thinned		P.shade & seedling unthinned	
	Bt.	Dl.	Bt.	Dl.	Bt.	Dl.	Bt.	Dl.	Bt.	Dl.	Bt.	Dl.
1 Jun.	24.6	25.7	24.9	26.0	27.0	26.7	26.0	26.1	13.5	13.2	27.1	26.8
6 Nov.	6.2	4.9	9.2	8.6	14.2	11.4	2.2	3.1	7.5	8.1	8.4	10.3
12 May.	0.1	0.2	0.3	0.3	0.5	0.6	0	0	0.8	0.6	0.4	0.5

Note : P = partial C = complete

Bt = *Bambusa tulda* Dl = *Dendrocalamus longispathus*

development. In complete shade condition almost all seedlings perished after 12 months. In both less or full weed conditions seedlings were surviving but the general health were comparatively better under less weed areas (Table 30). It seems, the influence of light on seedling mortality and their health is comparatively more important than weed competition at least in early stage of regeneration process.

The study revealed that natural regeneration of bamboo under complete shade condition is not possible. Partial shade condition and occasional weeding promote successful natural regeneration of bamboo seedlings after each gregarious flowering in the forest. To provide partial shade to the regenerating seedlings felling of dead mother clump may be delayed at least for 9 months. Light thinning of bamboo seedlings from densely populated regenerating areas decreased the competition among the seedlings and also helped in getting 700-1000 bamboo seedlings/sq.m which can be used for further plantation programme.

Table 30: Average growth and development of regenerating bamboo seedlings upto 1 year of age in different available site conditions.

Site conditions	Age (month)	Species	Total culm/ clump (no)	Culm		Remarks
				Height (cm)	Dia. (cm)	
Full weeds (exposed)	3	B.tul	2.0	20.1	0.08	Wirey stem
	Aug.	D.lon	2.0	23.0	0.09	
	6	B.tul	1.3	18.1	0.24	Same
	Nov.	D.lon	1.4	20.3	0.28	
	12	B.tul	2.2	16.0	0.28	Same
	May	D.lon	1.9	14.9	0.30	
Less weeds (exposed)	3	B.tul	3.0	25.6	0.24	Normal stem
		D.lon	2.7	26.2	0.26	
	6	B.tul	2.6	32.6	0.26	Same
		D.lon	2.2	30.2	0.30	
	12	B.tul	6.2	34.2	0.36	Strong stem
		D.lon	6.3	32.4	0.38	
Less weed (complete shade)	3	B.tul	3.8	25.8	0.12	Very wirey stem
		D.lon	3.9	24.0	0.11	
	6	B.tul	0.0	20.7	0.10	Same
		D.lon	0.0	18.4	0.09	
	12	B.tul	0.0	0.0	0.0	All died
		D.lon	0.0	0.0	0.0	

Table 30 contd...

Thinned (Partial shade & less weed)	3	B.tul	4.2	25.3	0.31	Stronger
		D.lon	4.4	24.0	0.29	stem
	6	B.tul	5.8	33.0	0.41	Same
		D.lon	5.9	35.2	0.42	
	12	B.tul	6.2	60.3	0.58	Same
		D.lon	5.9	62.1	6.60	
Unthinned (Partial shade)	3	B.tul	4.0	31.3	0.25	Strong
		D.lon	4.2	35.7	0.27	stem
	6	B.tul	6.3	38.0	0.30	Same
		D.lon	5.6	39.0	0.34	
	12	B.tul	6.8	66.7	0.42	Same
		D.lon	6.2	68.2	0.49	

Note: B.tul = *Bambusa tulda*, D.lon = *Dendrocalamus longispathus*
Dia = Diameter

5.2 Propagation

5.2.1 Sexual propagation

5.2.1.1 Seed morphology and germination

Seed morphology: Excepting *M.baccifera* in all other bamboo species studied, seeds were found to be solid, grain-like and covered with persistent straw colour boat-shaped glumes. However, in all the species seeds (fruits) were indehiscent. In both the *Bambusa* and *Oxytenanthera* species the shape of seed was linear to oblong with either acute or truncate tips, while in *Dendrocalamus longispathus* it was more or less ovoid in nature and surmounted by a beak. The seeds were with a large mealy endosperm, the embryo being small. It was possible to record the length, mid-width, mid-breath of seeds of *Bambusa* and *Oxytenanthera* species, while in *D.longispathus* only mid-diameter was measured as seeds were ovoid and somewhat oblique in shape. Among the species having grain-like seeds, both glumed and deglumed (glume removed) seeds of *B.arundinacea* var.*spinosa*, and *D.longispathus* were found to be smaller in size and lighter in weight than those of *B.tulda*, *B.glaucescens* and *O.nigrociliata*. Therefore, a unit of 10 g contained more number of seeds in case of *B.arundinacea* var. *spinosa* and *D.longispathus* than those of *O.nigrociliata*, *B.glaucescens* and *B.tulda* (Table 31). The variation in size and weight in the seeds of a species was minimum among *B.arundinacea*, *B.glaucescens*, *B.tulda*, *D.longispathus* and *O.nigrociliata*. When the glumes were removed the seed was found to be covered with brown coloured thin pericarp fused with main seed body. One side of the deglumed seed of *Bambusa tulda* was smooth and on the other side it was furrowed longitudinally, and seed tip possessed a small persistent style base (Plate 4Aii). In case of

D. longispathus the deglumed seed was also covered by brown, comparatively hard thin pericarp fused with the seed.

In case of *Melocanna baccifera* the seed was green with smooth surface (Plate 4Bi). The seed was very large and obliquely ovoid, thick fleshy onion-shaped and the apex terminating in a curved beak. Like other bamboo species, seeds of *Melocanna* were also sessile and attached with the plant by swollen thick basal-end. There is no endosperm in the ripe seed, but had thick fleshy pericarp filled with starch. After dissecting longitudinally it was revealed that the seed was not solid but possessed a seed-cavity towards the stalk-end. Seeds of other species (*Bambusa sp.*, *Dendrocalamus sp.* and *Oxytenanthera sp.*) had thin either crustaceous or membranous pericarp (caryopsies), while in *Melocanna baccifera* the seed had a 7-13 mm thick white to creamy colour fleshy pericarp just below the green surface of the seed (fruit) (Plate 4Bii). More or less a round-shaped white coloured embryo with a broad fleshy cotyledonary body (scutellum) was present inside the seed cavity. The other species under investigation having grain-like seeds had a very minute embryo at the basal stalk-end. The embryo with large scutellum was separated from the pericarp by a thin layer of thin-walled more or less crushed cells (Brandis 1906). Kurz (1876) termed the seed (fruit) of *Melocanna* as "berry-like", Ueda (1960) termed as "bulbil", and Gamble (1896) as "caryopsis". The fruit (seed) of *Melocanna* is not an asexual part of the plant body therefore it cannot be termed as "bulbil", and also can not be termed as "berry" because it is not multicarpellary and many seeded. Though the fruit of *Melocanna* is 1-seeded and in monocarpellary origin, yet the pericarp is not differentiated into exocarp, mesocarp and endocarp, and therefore it also can not be classified into "drupe". Fruits of grasses are generally called caryopsis (Gould 1968) and defined as a one-seeded fruit which develops from the ovary of a monocarpellary pistil and pericarp remains

fused. The fruit is also not a true caryopsis because it possesses thick fleshy pericarp. Thus it appears, till now, there is no correct botanical term for the fruit of *M.baccifera*. Soderstorm (1981) defined a new genus *Olmea* from Mexico and described its fruit as large, fleshy and globose and categorized as 'bacciform caryopsis' following Tsvelev (1976). According to Tsvelev (1976) as seen in Soderstrom (1981) the fruits of *Melocanna baccifera* may fall under the category of 'bacciform caryopsis'. In Botanical Latin "Bacciformis" means shaped like a berry (Stearn 1980).

In an average the weight of the seed was about 55.3 ± 5.5 g having a mid-length and mid-diameter of 6.9 ± 0.3 cm and 4.1 ± 0.2 cm respectively. There was much variation in size and weight among the seeds of the species (Table 32; Plate 4Bi). In a sample, containing 1000 seeds collected from Hyanko (Ramgarh forest area) the length, diameter and weight varied from 3.6-10.9 cm, 2.2-6.1 cm, and 7.8-150.6 g respectively. Maximum variation (co-efficient of variation %) was observed in the weight (61.7%) in comparison to the length (26.2%) and diameter (23.5%) of the seeds. However, these variations were minimized when the seeds were grouped into 3 grades -- heavy, medium and light. (Table 32). It is likely that heavy seeds have maximum accumulation of storage material and generally these complex storage products are carbohydrates, fats, and proteins (Varner 1965).

Seeds of different species possess embryo at their swollen stalk-ends (Plate 4Aii, 4Bii) and therefore care is likely to be taken to bury this portion to the soil during sowing for protecting the germinating radicle from being dessicated.

Seed collection: In all the species mature seeds dropped on the ground below and became exposed to the predators, such as, birds, specially chicken and pegeons in

the homestead and rats, procupine and wild boar in the natural forests. Birds and squirrels also eat seeds while on the plant. Only careful collection can overcome the predation problem. Seeds could be collected both from the clumps and from the ground.

Seed germination: The nature of seed germination in all the bamboo species was found to be hypogeal (Plate 5Ai, 5Bi). Excepting *M.baccifera*, in most cases germination started within 1-2 days of sowing and the mean germination percentage was significantly better in petridishes than in other methods (Table 33). In the polythene bag the germination percentage was higher than in nursery bed (Table 33). In *B.tulda* the seeds from Adampur and Lawachara were found more fertile than those from Shishak source. Environmental factors during seed development might have a considerable effect on subsequent germination (Whittington 1973). Geographically and environmentally Sylhet and Chittagong sources were different (Table 33). The modern concept of seed vigour is attributed to the physiological properties determined by the genotype and modified by the environment, which ultimately govern the ability of a seed to produce a seedling (Perry 1972). The germination period was comparatively longer when seeds were sown in the soil than inside the petri dish. Seeds of all the species started germination within 1-5 days inside the petri dish whereas they took 5-10 days inside the soil. Similarly germination also ceased earlier inside the petri dish than in the soil (Table 33). Seeds inside the petri dish were under saturated moist conditions provided the opportunity for full imbibition which might have accelerated the germination and thereby shortening the seed life (Villiers 1973). The low oxygen content of the soil atmosphere has been suggested to act as a factor maintaining seeds in a state of dormancy, thereby increasing the longevity (Villiers 1973), and can

Table 31: Average size of glumed (GS) and deglumed (DGS) seeds and their number per 10 gm of weight in 5 different bamboo species

Species	Length		Mid width		Mid breath		Diameter		Number	
	(cm)		(cm)		(cm)		(cm)		per 10 gms	
	$\bar{X} \pm SE$		$\bar{X} \pm SE$		$\bar{X} \pm SE$		$\bar{X} \pm SE$		$\bar{X} \pm SE$	
	CV%		CV%		CV%		CV%		CV%	
	GS	DGS	DGS	GS	DGS	GS	DGS	GS	DGS	
B.aru	0.83	0.56	0.19	0.19	0.17	0.13	-	1320	1664	
	± 0.007	± 0.003	± 0.003	± 0.003	± 0.006	± 0.003	-	± 7.0	± 6.2	
	4.62	2.93	8.65	8.65	19.34	12.64	-	2.90	2.04	
B.gla	2.50	1.21	0.31	0.25	0.27	0.17	-	151	180	
	± 0.04	± 0.02	± 0.005	± 0.005	± 0.004	± 0.004	-	± 2.5	± 1.8	
	8.76	9.06	8.83	10.96	8.12	12.89	-	9.07	5.48	
B.tul	2.49	1.49	0.35	0.31	0.28	0.22	-	139	168	
	± 0.05	± 0.02	± 0.006	± 0.005	± 0.006	± 0.004	-	± 1.1	± 2.4	
	11.00	7.35	9.39	8.83	11.74	9.96	-	4.33	7.82	
D.lon	-	-	-	-	-	-	0.19	-	1351	
	-	-	-	-	-	-	± 0.004	-	± 2.2	
	-	-	-	-	-	-	11.35	-	0.89	
O.nig	1.91	-	0.29	-	0.21	-	-	265	-	
	± 0.04	-	± 0.007	-	± 0.004	-	-	± 1.1	-	
	11.47	-	13.22	-	10.44	-	-	2.27	-	

Note: B.aru = *Bambusa arundinacea* var. *spinosa*, B.gla = *B. glaucescens*,
B.tul = *B. tulda*, D.lon = *D. longispathus*, O.nig = *O. nigrociliata*

Table 32: Average size and weight of ungraded and graded seed of *M.baccifera* collected in May from Hyanko (Ramgarh forest)

Seed sample	Length (cm) C.L (CV%)	Diameter(cm) C.L (CV%)	Weight (g) C.L (CV%)
Ungraded	6.92±0.29 (26.2)	4.1±0.15 (23.5)	55.3±5.46 (61.7)
Graded	7.76±0.4 (13.64)	5.34±0.14 (7.13)	101.3±6.9 (18.20)
(Grade I, heavy, 51.0g and above)			
(Grade II, medium, 26.0 - 50.0g)	5.86±0.32 (14.4)	4.16±0.1 (7.0)	42.8±1.8 (11.4)
(Grade III, light, 1.0 - 25.0g)	4.77±0.31 (17.2)	2.9±0.20 (18.1)	16.4±2.23 (36.5)

NB: C.L. = Confidence limit ($\bar{X} \pm t_{\alpha} \cdot SE$)

Table 33: Germination period (start to cease) and germination percentage of glumed seeds of 6 bamboo species tested under three different methods.

Species	Petridish				Polyethylene bag				Nursery bed			
	Germination				Germination				Germination			
	Period (days)				Period (days)				Period (days)			
	(Avg.)				(Avg.)				(Avg.)			
	Start	Cease	Total	%	Start	Cease	Total	%	Start	Cease	Total	%
B.aru	5	14	10	52.3	10	33	24	23.6	-	-	-	-
B.gla	1	3	3	40.2	-	-	-	-	-	-	-	-
B.tul*	1	3	3	26.4	5	20	16	24.7	7	25	19	5.5
B.tul**	1	4	4	40.6	6	20	15	30.7	-	-	-	-
B.tul***	1	4	4	48.0	-	-	-	-	-	-	-	-
D.lon	2	9	8	50.0	7	25	19	33.4	-	-	-	-
O.nig	1	9	9	39.0	-	-	-	-	-	-	-	-
M.bac	-	-	-	-	5	27	23	33.0	7	32	26	29.0

B.aru = Bambusa arundinacea var. spinosa, B.gla = B.glaucescens, B.tul = B.tulda

D.lon = D.longispathus, M.bac = M.baccifera, O.nig = O.nigrociliata

* Seed from Shishak of Chittagong Hill Tracts Forest (Average total annual rainfall 250-280 cm, maximum temp. 31.3°C, minimum temp 21.8°C, more than 180 m above the sea level, longitude 92°21'E, latitude 22°38'N)

** and *** Seed from Adampur and Lawachara of Sylhet Forest respectively having more or less similar climatic conditions. (Avg. total annual rainfall 280-381 cm, maximum temp. 30.5 C, minimum temp. 18.9°C, 23 m above the sea level, longitude 91°44 E', latitude 24°12 N')
(Polyethylene bags and nursery beds in sunlight)

continue germination for comparatively longer period. Moreover, seeds in the soil were not always fully imbibed and subjected to maximum fluctuations of diurnal temperature than those were sown inside petri dish.

It has been observed that the seeds of *B.tulda*, *D.longispathus* and *M.baccifera* germinated in higher percentage ($58.2 \pm 4.4\%$, $61.2 \pm 3.7\%$ and $79.8 \pm 6.5\%$ respectively) under shade (diffused light) than in direct sun light ($30.7 \pm 2.53\%$, $33.4 \pm 3.02\%$, $33.0 \pm 3.7\%$ respectively). It can also be seen in the natural habitat that after completion of flowering a bamboo clump becomes leafless and ultimately dies. The mature seeds are dropped on the forest floor below the dead mother. The leafless mother clump then provides diffused sunlight to the germinating seeds and seedling for successful natural regeneration and their survival (Banik 1988b). Thus it appears that light has a role in bamboo seed germination. The seeds which are sensitive to light generally described as photoblastic (Smith 1973). Thus bamboo seed can be considered as negatively photoblastic. It is reasonable to believe that phytochrome system in the seed is the photoreceptor responsible for the perception of the light stimulus. According to Smith (1973) negatively photoblastic seeds perceive mainly the far-red region of light. However, effect of monochromatic light on the germination of bamboo seeds needs detail study.

In *M.baccifera*, mature seeds mostly germinated promptly just after collection even in the storage and usually produced 1-2 culm shoots at the thick swollen-end (Plate 5Bi). Seeds were also seen to produce 2-4 shoots occasionally and rarely 5-6 shoots at a time during germination. Shoots were thick and conical in shape. Simultaneous production of more than one shoot from a seed at the time of germination was unique feature in *Melocanna* whereas in other bamboo species seeds produced only one shoot (Plate 5Ai, 5Bi). During seed

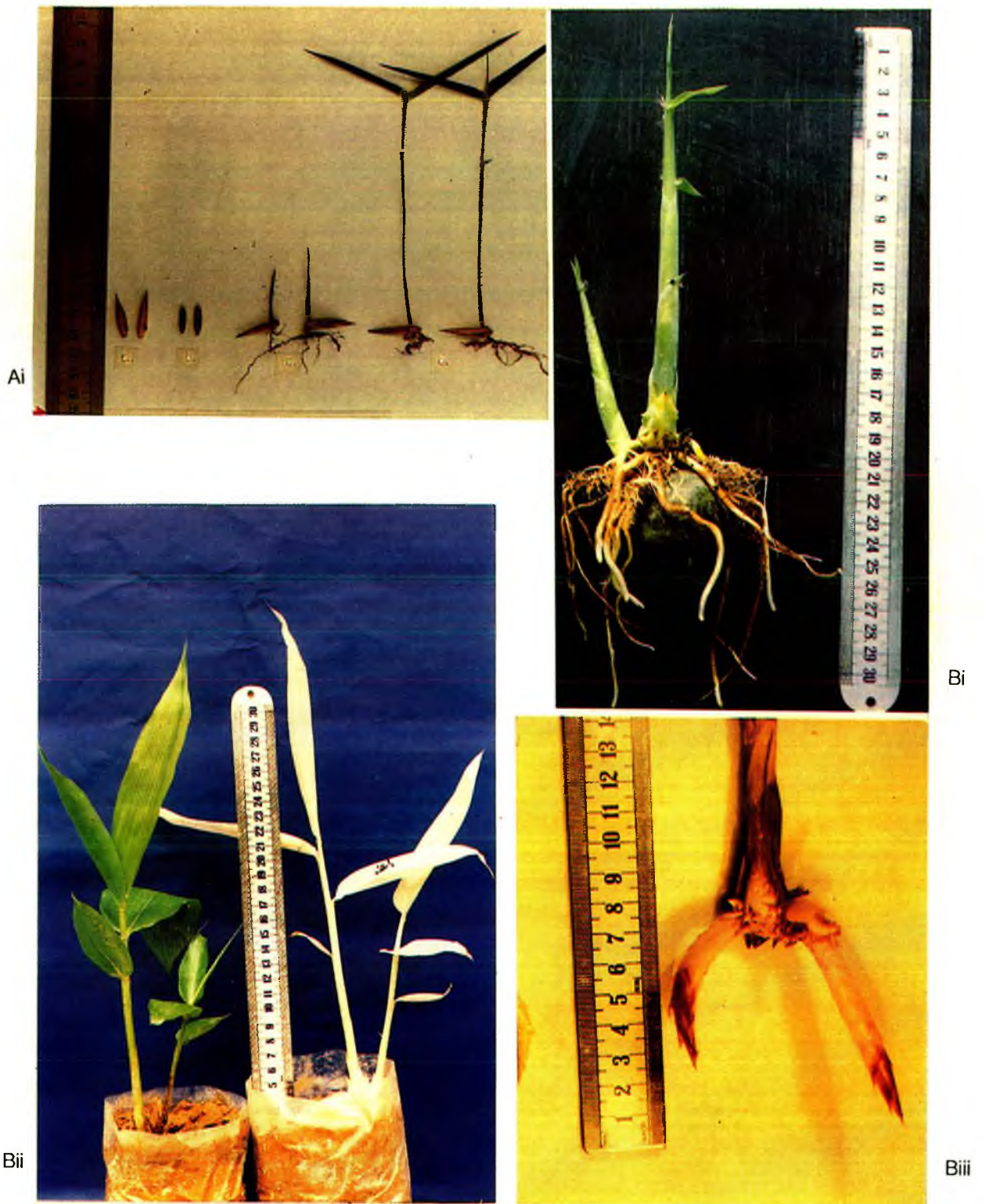


PLATE 5. : Seed germination :

A) *B. tulda* - i) hypogeal germination

B) *M. baccifera*-i) hypogeal germination, ii) green and albino seedling, iii) geotropic rhizome

germination of this species embryo derives food from starchy pericarp through the scutellum (Brandis 1906). Unlike grain like seeds of other bamboo species, the seeds of *M.baccifera* had starchy moist body and probably due to this reason they germinated promptly before sowing. The grain like seeds of other species were dry and not fleshy and therefore they did not germinate promptly just after collection, but quickly (within 1-3 days) germinated after imbibition (Table 33). Interestingly it was observed that at the later part of the seeding period (October to November) a few seed germinated even on the plant similar to the observation of Kurz (1876). So in addition to the normal hypogeal germination, the species may exhibit "vivipary" type of germination especially at the end of rainy season. In describing the germination behaviour of *Olmea*, a Mexican bamboo genus, Soderstrom (1981) reported that fleshy fruits of this species sometimes exhibited vivipary and germinated while still attached to the plant as in *M.baccifera*. High moisture and starch content in the seeds of *M.baccifera* favour germination still attached to the plant (vivipary) only during the later part of the seeding season (October-November) when drier climatic condition prevails. This might be an adaptation to overcome or avoid such unfavourable climatic condition. Thus, it seems that such fleshy bamboo fruits have an additional advantage over drier fruits (caryopsis) of other bamboo species to germinate in adverse conditions. Such vivipary character of a species is controlled both genetically and environmentally (Hartmann and Kester 1983). Different bamboo species including *Melocanna* species have been naturally growing in the same forest areas having similar environmental conditions. But excepting *Melocanna* no other bamboo species under study exhibited such 'vivipary' germination behaviour. Thus, presumably, the vivipary character of the species is more of genetically controlled than of environmental adaptation.

The survivability and health of the germinating seedlings of *M.baccifera*, were found to be influenced by the size and weight of the seeds (Table 34). The seedlings raised from light seeds (grade III) showed less survival (56.0%) and were comparatively weak in nature than those raised from the heavy (gr.I) and medium (gr.II) weight seeds. Maximum percentage of seedling from grade I had 2 shoots whereas in grade II and III maximum seedlings had 1-shoot. Similarly, Pollock and Ross (1972) also observed such effects of seed weight and size on the seedling performance of some other plant species.

Different types of abnormalities were observed only in the seedlings of *M.baccifera* produced from the medium (gr.II) and light (gr.III) weight seeds (Table 34). Big and heavy seeds (gr.I) did not produced any abnormal seedlings. Among the abnormal seedlings some were morphologically normal but did not produce chlorophyll (albino) throughout the body (Plate 5Bii). Others were mostly with morphological defects such as, rootless plumules, stunted radicles, radicles growing upward and leafless etc.

The mean seed size and weight of *M.baccifera* dropped significantly towards the later part (September) of the seeding season. The seeds produced in May-June were comparatively big (length 6.9 ± 0.3 cm, diameter 4.1 ± 0.2 cm) and heavy (weight 55.3 ± 5.46 g) and also germinated in higher percentage ($79.8 \pm 6.5\%$) than those produced in September. During September seeds were comparatively small (length 5.2 ± 0.5 cm, diameter 3.3 ± 0.4 cm), light in weight (17.8 ± 2.6 g) and had poor germination percentage ($46.6 \pm 11.4\%$). Thus, for obtaining better germination in *M.baccifera*, seeds may be collected in the early part (May-June) of the seeding season.

Table 34: Influence of seed size and weight on the germination, growth and abnormalities of seedlings of *M.baccifera* studied under shade

Observation	Weight grades of seeds		
	Grade I (heavy)	Grade II (medium)	Grade III (light)
1. Germination			
a) period(days)			
Start	3	4	6
Cease	19	21	16
Total	16	17	10
b) percentage	80.0	83.3	90.0
2. Survival %	70.0	76.7	56.0
3. Percentage of seedling bearing			
1 living shoot	38.1	56.5	76.9
2 living shoot	57.1	39.1	15.4
3 living shoot	0	0	7.7
4 or more living shoot	4.8	4.4	0
4. Albino seedling %	0	13.1	23.5
5. Avg.length (cm) of shoot after 40 days	108.7	76.1	37.2
6. Avg.diameter (cm) of shoot after 40 days	0.93	0.69	0.44

5.2.1.2 Investigation on the seed longevity and storage technique

In all the bamboo species freshly collected seeds possessed excellent viability which resulted in good germination percentage in comparison to stored seeds (Table 35, 36). The total germination period (start to cease) was longer for fresh seeds than those for stored seeds. Similarly the germination percentage decreased with longer storage time. The life-span of seed varied from species to species. It was 30-35 days for *B.tulda* and *M.baccifera*, 55 days for *D.longispathus*, and 65 days for *B.arundinacea* var. *spinosa* at normal environmental condition. Thus it appeared that seeds of different bamboo species are short-lived and should be sown just after collection. Delay in seed sowing resulted in poor germination. In general seed longevity of a species is controlled, most probably, by both environmental and genetic factors (Kozlowski 1971).

When the seeds of *B.tulda* were stored in a desiccator over silica gel the life-span increased upto 18 months (Table 37). To increase the longevity of grass seeds William (1938) observed that excess moisture should be removed. Silica gel in a desiccator provides a drier climate by absorbing the seed moisture and thus increased the seed longevity of *B.tulda* which is similar to the report of Varmah and Bahadur (1980) on *Dendrocalamus strictus*. In the past it was also possible to preserve the seed viability of a temperate bamboo species (*Phyllostachys* sp.) by storing the seed over calcium chloride (to remove moisture) at room temperature (White 1947a). Generally the two most important factors which govern seed longevity are seed moisture content and the seed storage temperature (Harrington 1972).

Table 35: Seed longevity for 2 *Bambusa* species at different time intervals after collection

Time between collection and sowing (days)	<i>Bambusa tulda</i> *				<i>B. tulda</i> ***				<i>B. arundinacea</i> var. <i>spinosa</i>			
	(Shishak)				(Lawachara)							
	Germination				Germination				Germination			
	Period (days) % (Avg.)				Period (days) % (Avg.)				Period (days) % (Avg.)			
	Start	Cease	Total		Start	Cease	Total		Start	Cease	Total	
3	-	-	-	-	-	-	-	-	5	14	10	49.5
10	1	3	3	26.4	2	5	4	48.0	5	12	8	29.3
20	1	3	3	8.0	2	4	3	30.0	5	10	6	35.0
25	2	2	1	5.0	2	3	2	23.0	-	-	-	-
30	1	1	1	2.0	2	3	2	7.0	4	10	7	34.0
35	0	0	0	0	3	3	1	2.0	3	8	6	31.0
40	0	0	0	0	0	0	0	0	2	8	7	35.7
45	0	0	0	0	0	0	0	0	2	7	6	27.0
50	0	0	0	0	0	0	0	0	4	7	4	13.0
55	0	0	0	0	0	0	0	0	3	7	5	8.0
60	0	0	0	0	0	0	0	0	3	7	5	5.0
65	0	0	0	0	0	0	0	0	6	6	1	2.0
70	0	0	0	0	0	0	0	0	0	0	0	0

* Shishak source *** Lawachara source, seeds were received after a week of harvest.

Table 36: Seed longevity for *Dendrocalamus longispathus*
and *Melocanna baccifera* at different time
intervals after collection

Time between collection and sowing (days)	<i>D. longispathus</i>					<i>M. baccifera</i>			
	Germination					Germination			
	period(days)					period(days)			
	(Avg.)					(Avg.)			
	Start	Cease	Total	%		Start	Cease	Total	%
3	2	9	8	51.1	4	21	18	78.4	
10	2	7	6	42.2	4	13	10	52.5	
20	1	5	5	28.8	5	11	7	29.2	
25	-	-	-	-	9	13	5	10.4	
30	3	7	5	17.7	10	13	4	4.5	
35	-	-	-	-	9	12	4	2.2	
40	2	8	5	15.3	0	0	0	0	
45	2	6	5	13.3	0	0	0	0	
50	2	4	3	8.8	0	0	0	0	
55	2	2	1	2.1	0	0	0	0	
60	0	0	0	0	0	0	0	0	
65	0	0	0	0	0	0	0	0	
70	0	0	0	0	0	0	0	0	

Table 37: Seed longevity of *Bambusa tulda** when stored over silica gel inside a desiccator.

Time between collection and sowing (month)	Germination period (days)			Avg. Germination (%)
	Start	Cease	Total	
3	9	14	6	11
6	8	12	5	7
9	9	12	4	8
12	10	11	2	5
15	11	11	1	3
18	11	11	1	2
21	0	0	0	0

* Lawachara source

Table 38: Seed longevity of *M.baccifera* when stored in jute bag with sand(s) and in aircondition(AC) room.

Time between collection and sowing (days)	Germination period (days)						Avg. Germination %	
	Start		Cease		Total		%	
	S	AC	S	AC	S	AC	S	AC
15	4	3	15	12	12	10	62.0	57.0
30	6	5	14	10	9	6	38.0	24.0
45	7	5	13	8	7	4	11.0	2.0
60	10	0	12	0	3	0	4.0	0
75	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0

The fleshy seeds of *M.baccifera* when stored in airconditioned room retained viability upto 45 days, while it was only 35 days at normal room condition (Table 36 and 38). The seed longevity was further prolonged upto 60 days when stored with dry sand in jute bags (Table 38). The germination was always better in fresh seeds and minimum at the end of the storage period. Sands are granular, inert and porous. Sandy medium with its porous nature likely to provide limited amount of oxygen to the seeds (because seeds were not fully exposed to the air). The dry sand is likely to absorb moisture from the seeds. Moreover, damages to the plumules and radicles of the germinating seeds were also minimum inside the sand. All these conditions are favourable for seed storage (Hartmann and Kester 1983, Villiers 1973). Thus it appears that the seeds of *M.baccifera* can be carried with dry sand in the jute bags during long distance transportation to minimise the damage and for retaining their viability.

5.2.1.3 Seedling growth and management at nursery

Culm emergence and development: In *Bambusa tulda* and *Melocanna baccifera* germinating seeds produced 1-5 cm long plumules within 3-7 days in the form of pointed cylindrical buds (Plate 5Ai, 5Bi). The plumules were very thin (1-2 mm) in *B.tulda* and thick (4-6 mm) in *M.baccifera*. The number of the emerging plumule was always one and very rarely two in case of *B.tulda*, whereas in *M.baccifera* it was usually one and sometimes were 2-4, and rarely seen to be upto eight. All the plumules in *M.baccifera* did not develop into stems, mostly died in the juvenile stage, usually 1-2 ultimately developed and formed into 1-2 stems. Within 1-4 weeks plumule elongated rapidly into a stem bearing single leaf arising alternately at

the nodes. The leaf base was sheath like and covered the soft stem. The primary shoot of *B.tulda* was thin, wiry and grass like, whereas it was comparatively thick (0.4-0.7 cm), and soft in case of *M.baccifera* (Plate 5Ai, 5Bi). Germinating seeds of *B.tulda* at the beginning produced long tap root, are unusual character for grass, but after 1-2 weeks secondary roots developed. Seeds of *M.baccifera* produced a number of fleshy roots at a time during germination (Plate 5Bi). Soon after 2-3 weeks of germination fibrous roots developed from the base of the young shoot. The germinating seeds remain attached to the seedlings of *B.tulda* for about a month only, whereas in *M.baccifera* they remained for longer time (80-100 days) to support the initial vigorous growth of the seedlings. After that period seeds start rotting and gradually mixed up with the soil.

The emergence of shoots was successive. The new shoots were bigger and taller than older ones. The diameter/length (cm) of seedling shoots of *B.tulda* emerged at 3, 6, and 10 months were $0.31 \pm 0.06 / 34.8 \pm 9.9$, $0.51 \pm 0.1 / 47.6 \pm 7.9$, and $1.1 \pm 0.4 / 73.2 \pm 31.2$ respectively. For *M.baccifera* these were $0.76 \pm 0.06 / 175.5 \pm 12.44$, $0.78 \pm 0.22 / 169.0 \pm 15.2$ and $1.05 \pm 0.14 / 70.3 \pm 22.24$ respectively. The average number of shoots present in a seedling of *B.tulda* increased as the age of the seedling increased. Unlike adult clumps, in the seedlings of this species culm(s) emerged and developed even in the dry seasons (December, March) at least upto 10 months of age. Thus it seems in one year old seedlings of *B.tulda*, culm buds on the underground rhizome remain active throughout the year irrespective of seasonal effect and, therefore, it is evident that even 3-10 months old *B.tulda* seedlings can establish themselves in the out door planting. However, in the seedlings of *M.baccifera* at least upto 6 months (September - February) of age no new shoots emerged excepting the primary shoot(s) which was produced directly from the germinating seeds. Older

thin shoots died and allowed the new bigger shoots to emerge vigorously. The primary shoots in both the species did not die before 6 months of age. Thus it appeared that in the seedling stage the life of a culm was too short compared to a full grown adult clump.

Rhizome development: After 30-40 days of germination in *B.tulda* secondary shoots started developing from the base of primary shoot forming a rhizome system that consisted of 5-6 segmented axes (rhizomes) and buds producing 4-5 aerial stems (culms). It has been seen that the culm number 1 and 2 were more or less on the same level of soil (Plate 6Ai). Gradually longer rhizome necks had been arising from the 2nd, 3rd, 4th and 5th culms moving subsequently downward deep to deeper to the ground forming swollen rhizomes. In *Melocanna baccifera* seedling, the rhizome neck was more elongated and development was strongly geotropic and preceeded that of the rhizome proper, which was terminal to it (Plate 5Biii). Both neck and rhizome proper was fully covered by many alternately arranged papery sheaths arising from the nodes. In both the species, at this stage, the rhizome proper, with a apical culm bud turned at a right angle and moved upward piercing the soil and produced a new culm on the ground as reported by Brandis (1899) and Troup (1921) in *B.arundinacea* and *D.strictus* respectively. At this stage the seedling gave an appearance of miniature clump. As the age of the seedling increased subsequent rhizome structures became bigger and swollen and also moved more deeper to the ground probably for better anchorage of above ground developing portion of the seedling (Plate 6Ai). Thus it appeared that the movement of rhizome neck in both the type of bamboo species (*Bambusa tulda* and *Melocanna baccifera*) was strongly geotropic and after that rhizome proper took a horizontal course for a very short distance deep inside the ground and then moved with negative



PLATE 6. : Seedling growth and management at nursery :

- A) *B. tulda* -i) successive culm emergence and rhizome development,
- B) *M. baccifera* -i) bigger leaves in seedling, ii) intermingleness of rhizomes, iii) chopped off shoot tip with stout and branchy stem;
- C) *D. strictus* -tall in partial shade, more stems in the sun,

geotropism for turning upward. Such change in the sequence of rhizome movement might be due to the change in the physiological state of the apical bud of rhizome essentially for developing the underground rhizome and above ground clump system in the bamboo plants.

Seedling growth and biomass: Both green and oven dry weight of different organs of the seedlings of *M.baccifera* were always higher from those of *B.tulda* at the initial stage of growth and development (Table 39). Similar trend was also observed even upto 10 months of age whereas weight of root decreased in case of *M.baccifera* since at the age of 6 months. A number of long rhizome necks developed from the seedling and filled up the room inside the polythene bag. Moreover each rhizome neck did not have roots. As a result the amount of rhizome production in each seedling of *M.baccifera* was higher than root production inside the polythene bag. On the other hand in case of *B.tulda* the rhizome necks were very short and most of the rhizome part produced roots. Therefore, the amount of roots produced by *B.tulda* seedling inside the polythene bag was higher. The biomass growth culm with leaves, rhizome and roots gradually increased as the seedlings became older. 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 seedlings became 10 months old (Table 39). But the oven dry weight of culms and leaves at 6 months of age was 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 at early juvenile stage. The data indicate that the biomass content of culms, rhizomes and roots of both the species reduced while it is increased in rhizomes from wet to dry season similar to the observation of Hasan (1975) in the seedling of *D.longispatus*. Stored photosynthate in the

Table 39: Average measurement of seedling biomass(g) of *B.tulda* and *M.baccifera* at different ages and seasons in the nursery stage.

Species	Age (month)	Green weight (g)			Oven dry weight (g)		
		Culm & leaves	Rhizome	Root	Culm & leaves	Rhizome	Root
B.tul	3	10.71	1.27	6.78	4.01	0.32	1.95
	(Sept.)	+2.11	+0.43	+1.76	+0.71	+0.09	+0.44
M.bac	3	60.14	11.11	12.63	16.75	2.81	5.09
	(Nov.)	+9.98	+5.32	+5.49	+3.36	+1.09	+1.80
B.tul	6	44.20	6.83	49.40	18.52	1.72	14.90
	(Dec.)	+6.50	+1.42	+30.10	+3.70	+0.21	+3.42
M.bac	6	43.59	35.40	13.28	19.87	12.38	7.90
	(Feb.)	+10.06	+10.39	+6.96	+5.22	+5.24	+5.14
B.tul	10	87.05	18.70	49.40	42.08	10.63	27.47
	(Mar.)	+10.50	+9.65	+25.01	+6.28	+5.31	+17.39
M.bac	10	86.76	38.05	14.00	43.59	16.42	5.05
	(May)	+31.40	+8.17	+6.80	+16.58	+10.01	+2.16
B.tul	14	382.11	47.63	371.25	155.82	18.32	117.65
	(Aug.)	+74.50	+6.39	+111.64	+24.71	+3.15	+32.69
B.tul	19	284.07	60.82	493.90	120.80	28.70	122.80
	(Jan.)	+48.50	+7.42	+72.54	+25.39	+3.33	+38.31
B.tul	24	438.16	104.12	510.50	175.53	60.03	153.65
	(Jun.)	+241.54	+59.75	+173.62	+60.10	+31.29	+38.69

Note: B.tul = *Bambusa tulda*, M.bac = *Melocanna baccifera*

Studies in *M.baccifera* were continued upto 10 months of age as after that period rhizomes pierced out from the polythene bags.

underground rhizome system during dry season was utilized in initiation and development of new shoots (culms) and leaves in the next moist and warm season as reported (Ueda 1960) for the adult clump of different bamboo species. Thus it appeared that the growth of different parts of seedlings, that is, culms, rhizomes, and roots were interrelated and also effected by seasonal changes.

Comparative leaf size of seedling and adult: The leaves produced by primary shoots of *B.tulda* were smaller in size than those of adult plant. The mid-length/mid-width(cm) of leaf blades produced at 3 months were smallest ($11.18 \pm 2.0 / 2.58 \pm 0.45$), but gradually increased when produced at 6 months ($17.91 \pm 2.29 / 3.24 \pm 0.31$), and then ultimately at 10 months attained the similar size ($19.5 \pm 1.86 / 3.61 \pm 0.32$) to that of adult plants ($21.11 \pm 1.52 / 3.05 \pm 0.52$). Similarly McClure (1966) observed smaller leaf blades in the seedlings of *Arundinaria tecta* than those of mature plants. But this was completely reverse in *M.baccifera*. Seedlings of this species at the beginning produced bigger leaves ($32.31 \pm 0.64 / 8.76 \pm 0.37$ cm) at 3 months than those of adult plants ($23.74 \pm 1.39 / 3.26 \pm 0.28$ cm) (Plate 6Bi). The leaves become smaller with age. After about 10 months the leaves produced by the seedlings have attained more or less similar size ($21.30 \pm 2.97 / 3.94 \pm 0.75$ cm) to that of adult clumps.

Effect of light on the seedling growth: Seedlings of both *B.tulda* and *D.strictus* at early stage showed higher rate of survival (more than 90%) under sunlight and partial shade conditions (Table 40). Survival was very poor (8-12%) under shade. Bamboos being the fastest growing plants require to need normal day long light for maintaining higher rate of food production. Higher rate of mortality under shade might be due to less amount of illumination insufficient for higher rate of

Table 40: Average survival and growth of seedling of
2 bamboo species under different light condition
at nursery stage upto 3 months of age.

Light condition	Species	Sur- vival %	Total culms Nos.	Culm diameter (cm.) small big		Culm length (cm.) small big	
Sunlight	B.tul	93.89	5.3	0.10	0.26	15.55	43.60
		<u>+2.20</u>	<u>+1.2</u>	<u>+0.01</u>	<u>+0.06</u>	<u>+2.37</u>	<u>+8.72</u>
	D.str	95.00	4.1	0.05	0.20	11.20	45.00
		<u>+2.19</u>	<u>+1.7</u>	<u>+0.01</u>	<u>+0.02</u>	<u>+2.29</u>	<u>+9.52</u>

Partial shade	B.tul	96.11	5.3	0.14	0.62	10.00	114.02
		<u>+2.31</u>	<u>+1.1</u>	<u>+0.03</u>	<u>+0.08</u>	<u>+3.71</u>	<u>+27.32</u>
	D.str	96.58	3.6	0.04	0.22	10.40	68.60
		<u>+1.14</u>	<u>+1.0</u>	<u>+0.01</u>	<u>+0.07</u>	<u>+5.22</u>	<u>+16.71</u>

Shade	B.tul	8.34	1.2	0.05	0.07	7.5	37.2
		<u>+2.35</u>	<u>+1.41</u>	<u>+0.005</u>	<u>+0.003</u>	<u>+2.24</u>	<u>+8.97</u>
	D.str	11.67	1.4	0.04	0.05	8.0	25.0
		<u>+4.56</u>	<u>+1.51</u>	<u>+0.005</u>	<u>+0.002</u>	<u>+2.17</u>	<u>+6.72</u>

Note: B.tul = *Bambusa tulda*, D.str = *Dendrocalamus strictus*

photosynthesis. Langer (1979) mentioned that if the leaves of grass plant were deprived of light through shading, one could expect their earlier senescence and ultimate death.

Overall growth performance of the seedlings was best in partial shade, good in sun light, and poor in shade conditions (Table 40). Seedlings of both the species were more elongated (2-2.5 times) under partial shade than in sun light while these were stunted and ultimately mostly died in the shade (Table 40, Plate 6C). Banik (1988b), Chaturvedi (1928) and Deogun (1937) have observed in the forest that a certain amount of overhead cover (partial shade due to leafless dead flowering mother) was necessary during the earliest stage of development of bamboo seedlings. According to Chaturvedi (1928) this condition improved the quality of bamboo seedlings.

Seedlings of both the species produced 4-5 culms showing a miniature clump formation under the partial shade and sunlight while under shade most of them produced only 1-culm (Table 40, Plate 6C). Langer (1979) observed that in perennial rye grass and cocksfoot the tiller numbers per plant declined continuously as natural light was reduced from 100% to 5%. Bamboo being a member of grass family also seems to require normal day length either in exposed or in partial shade condition for clump formation by culm production through the activation of rhizome and culm buds on the mother rhizomes.

Thus it appeared that maintenance of partial shade condition at the nursery stage is an important practice for obtaining more number of healthy bamboo seedlings of *B.tulda* and *D.strictus* (Plate 6C). Complete shading over the seedlings may be discouraged.

Seedling management for easy transportation: When bamboo seedlings were raised in nursery during June to August, it was not possible to transplant them in the field at the same rainy season, because they needed at least 3 months to produce well developed rhizome system. Therefore, it was necessary to keep the seedlings at nursery upto 10-12 months before planting into the field at next rainy season. In such a situation when the seedlings of *M.baccifera* were left undisturbed at nursery for a long time they produced long rhizome system and roots penetrated the neighbouring polythene bags of other seedlings creating an intermingled seedlings root mass (Plate 6Bii). This created a problem in seedling transportation. Therefore, the seedlings were shifted from one bed to another after 6 months of age at 3 months interval in *M.baccifera*. This practice helped in minimizing the rhizome and root anchorage of seedlings and as a result their transportation to the field was easy and less or no damage occurred in the root and rhizome system.

Unlike seedlings of other bamboo species under observation, the stems of 3 months old *M.baccifera* seedlings were comparatively taller (1.7-2.0 m), soft and tender. As a result they usually break and get damaged during handling and transportation. Damage not only affected the performance of seedling but also it created frustration and doubt in the mind of planters about the success of plantation. As a result they did not take proper care to the seedlings after plantation. Therefore seedling heights were kept limited by cutting the stem tips at different nodes. In average 3 different heights such as 46.15 cm, 116.42 cm, 162.93 cm were obtained when stems were cut after 3, 5, 7 nodes respectively. Within one month of treatment buds on the stem-nodes started activating from tip to base and produced branches and leaves (Plate 6Biii). Number of branches were more on the node which was just below the cut. Among the groups (3,5,7 node cut and not

cut), maximum percentage of seedlings produced branches when chopped above the 3 and 5 nodes. At 3-node cut 69% and at 5-node cut 71% seedlings produced branches. Within 5 months of treatment more number of seedling of these 2-groups also produced new culms than the 7-node cut and normal (shoot not cut) seedlings. Normal seedlings of this species usually produced branches after 9-10 months of age. Chopping of shoot tops seems to induce bud activation on the nodes below the cut and also on the underground rhizome through breaking the apical dominance. Hillman (1987) reported that when the apical portion of the stem of *Phaseolus vulgaris* were excised at the third internode vigorous lateral bud growth ensured. The excised seedlings of *M.baccifera* were comparatively woody than the normal seedlings as the later had more soft stem portions at the top (Plate 6Biii). It was observed that when seedling heights were kept limited within 45.0-120.0 cm (by 3- and 5-node cut) their stems did not break thus suffer little or no damage during handling and transportation from the nursery to the field. When 3- and 5-node cut seedlings were supplied and planted in both villages and forests they survived in higher (75-90%) percentage. Survival was poor (35-60%) in case of unexcised damaged seedlings.

Thus it appeared that the culm top chopping for maintaining the height of *M.baccifera* seedling at nursery stage might be a useful management technique for minimizing the seedling damage due to stem break in handling and transportation.

5.2.1.4 Collection and utilization of wild seedlings for reforestation

In both *Bambusa tulda* and *Dendrocalamus longispathus*, wild seedlings (with earth-ball attached to the roots) showed good survival percentage (90-98%) both in nursery. Root disturbance during the collection of wild seedlings also did not show any harmful affect on their survival in the nursery. Seedlings outplanted in the field from the nursery also survived well. The ultimate establishment (survival) of the wild seedlings in the field was around 70% in *B.tulda* and 68% in *Dendrocalamus* after three years of planting.

Thus it appeared that wild seedlings of bamboo can be collected and successfully utilized in both afforestation and reforestation work.

5.2.2. Macro-asexual propagation

5.2.2.1 Trials on offset planting and rhizome assembly

Offset planting: It was observed that both age of the offsets and their collection time have significantly influenced on the survival of offsets of 8-different bamboo species after field plantation (Table 41). The younger offsets showed higher percentage of survival than older ones in all the species under study (Table 41). Similar observation was also reported by Deogun (1937) on the offset planting of *Dendrocalamus strictus* in India. It is to be noted that a 1-2 year old rhizome has young underground rhizome with 3-5 viable buds on either side (Plate 7a,b). So in total 6-10 buds could be seen on the rhizome. The younger rhizome is partly covered with sheath and bears fibrous roots at the nodes, and generally yellowish and has vigorous buds. As the rhizome gets older it becomes brownish in colour and its nodes bear few living buds and fibrous roots. Banik(1987b) reported that culm buds on the rhizome of older culms (4-7 years of age) are mostly dead and therefore offsets collected from older culms fail to produce any new culms. According to Uchimura (1980) in *Phyllostachys bambusoides* rhizomes older than 3 years produced buds with reduced vigour and shoots that did not grow tall. The older the rhizomes, the less vigour the buds are. That was why 1-year old offsets of all the species under study showed better survival, while 2- and 3- year old offsets gave progressively poorer results. It is interesting to note that in *Melocanna baccifera* offsets irrespective of age, did not survive after planting (Table 41). It has been observed earlier that in *M.baccifera* underground rhizome neck started rapid elongation within March to May and during June emerged above the soil (Table 12). Therefore, excavation of offsets of *M.baccifera* during April and as well as in June could injure

Table 41: T-test showing the mean difference of survival percentage with standard deviation (S.D) of 3 different ages of offsets of 8 bamboo species collected and simultaneously planted in April and in June.

Species	1-year old offset		2-year old offset		3-year old offset	
	April	June	April	June	April	June
	a	b	a	b	a	b
B.bal	70.0 (7.1)	20.0 (7.1)	50.0 (7.1)	16.0 (5.5)	10.0 (7.1)	0
B.lon	74.0 (5.5)	32.0 (8.4)	60.0 (7.1)	20.0 (7.1)	24.0 (5.5)	2.0 (4.5)
B.tul	44.0 (5.5)	10.0 (0)	14.0 (5.4)	4.0 (5.5)	2.0 (4.5)	0 (0)
B.vul	76.0 (5.5)	38.0 (8.4)	62.0 (8.4)	28.0 (4.5)	18.0 (4.5)	4.0 (5.5)
D.lon	56.0 (5.5)	22.0 (8.4)	38.0 (16.4)	14.0 (4.0)	4.0 (5.5)	4.0 (5.5)
M.bac	all died		all died		all died	
N.dul	13.0 (5.8)	3.0 (5.8)	7.0 (5.8)	3.0 (5.8)	0	0
O.nig	23.0 (5.8)	27.0 (5.8)	7.0 (5.8)	10.0 (0)	0	3.0 (5.8)

N.B.: Values of T are calculated at 5% level of significance.

B.bal = *Bambusa balcooa*, B.lon = *B.longispiculata*

B.tul = *B.tulda*, B.vul = *B.vulgaris*

D.lon = *Dendrocalamus longispathus*,

M.bac = *Melocanna baccifera*,

N.dul = *Neohouzeaua dullooa*,

O.nig = *Oxytenanthera nigrociliata*

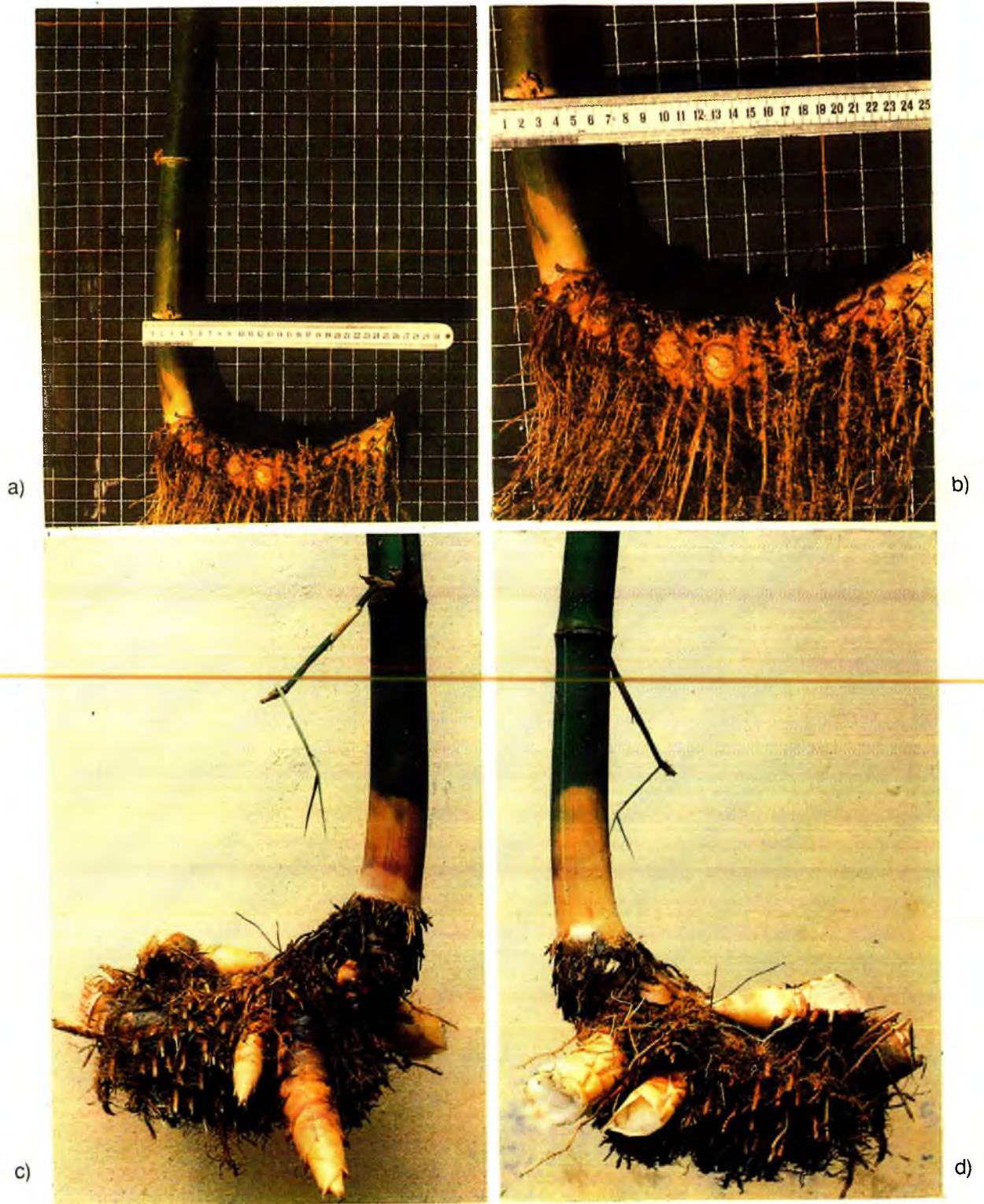


PLATE 7. : A typical bamboo offset of *B. tulda*

a) a 1-yr old offset, (b) healthy buds on the rhizome during April, (c) rhizome buds sprouted in June, and (d) buds damaged during excavation.

and disturb the growth process of the underground rhizome. Uchimura (1980) reported that rhizomes of *Ph.bambusoides* should not be dug during growth period as the nutrients that were stored in it were absorbed in the process of growth of the new rhizome and therefore the success of these propagules could not be ensured. This might be one of the important reason for the failure or poor success of offsets if collected and planted in the growing seasons.

It has been observed that offset age, collection time and simultaneous planting, and their interaction have significant effect on the survival of offsets (Table 41). In all the species under study offsets of same age showed significantly higher success when collected and planted in April than collected and planted in June (Table 41).

Most of the bamboo species of Bangladesh started culm emergence during May-June (Table 6). Culm buds on the underground rhizome became active and healthy (Plate 7b) in a few weeks earlier (March-April) to the emergence period due to an increase in both soil and air temperature and humidity after a 4-5 months dry and winter climate. After activation rhizome buds started to swollen and ultimately elongate into a new rhizome. Therefore, excavation of offsets during June may injure the elongating buds present on the underground rhizome portions (Plate 7c,d). As a result offset collected and planted in June either survived poorly or failed to establish and ultimately could not produce new culm even under higher amount of rainfall than April. On the contrary, excavation and collection of offsets during April have least possibility of injuring the culm buds on the rhizomes and as a result survival after immediate planting was higher ranging from 44.0-76.0% depending on the species (Table 41).

Rhizome assembly: Offsets planting technique in thin-walled bamboo species like *M.baccifera*, *N.dulloo*, and *O.nigrociliata* showed only limited success (Table 41). When these species were planted in part-clump, (different numbers of offset due to rhizome assembly) survival success was better (Table 42). In *M.baccifera* 3 and 4 offsets (rhizome assembly) propagules showed higher survival (46.7- 50.0%) than 1 and 2 offset (1 and 2 rhizome assembly) propagules. Similarly *N.dulloo* and *O.nigrociliata* also showed better survival success when 2-4 offsets propagules (2-4 rhizome assembly) were planted. In these 3 species survival of propagules was poor in 1-offset plantation (Table 42). As the survival percentage of 3-offsets and 4-offsets did not differ significantly in case of *M.baccifera*, 3 offset planting method may be adopted in this species. Digging out of such types of propagules is difficult and labour intensive, therefore, 3-offset propagules are likely to require less trouble and costs in collection than 4-offset assembly. Similarly in *N.dulloo* and *O.nigrociliata* there was no significant difference in survival of 2, 3 and 4-offsets (Table 42). Therefore, to minimise the trouble and costs in digging out such propagules, 2-offset method of planting was found optimum for these two species.

According to Uchimura (1980) the length of rhizome affected the survival of the shoot. He also reported that the longer the rhizome, the more nutrients it contained to support the shoots. A rhizome assembly has more than one rhizome and thereby has increased length and number of underground rhizome system. Therefore, it is evident that these types of propagules have advantage over single offset planting, especially, in thin walled bamboo species.

Table 42: Calculated F for the survival percentage of 4 types of offset assembly and their mean comparison (LSD 5%) in 3 bamboo species.

Species	F-value	Average survival of offset types (%)				
		T ₁	T ₂	T ₃	T ₄	LSD(5%)
M.bac	29.0 ^{**}	6.7	26.7	50.0	46.7	12.9
N.dul	16.23 ^{**}	6.7	26.7	30.0	40.0	12.0
O.nig	6.25 [*]	23.3	33.3	43.3	36.7	11.5

N.B: M.bac = *Melocanna baccifera*, N.dul = *Neohouzeaua dullooa*
O.nig = *Oxytenanthera nigrociliata*.

^{**} Significant at 1% level,

^{*} Significant at 5% level.

F-value calculated with 3 & 6 df

T₁ = one offset having one rhizome

T₂ = Two offsets: 2 rhizome assembly with 2 culms

T₃ = Three offsets: 3 rhizome assembly with 3 culms

T₄ = Four offsets: 4 rhizome assembly with 4 culms

5.2.2.2 Trials on induction of *in situ* rooting and rhizome at the branch base

Induction of *in situ* rooting and rhizome at the branch bases of different bamboo species was possible by chopping of tops of one year old culms as well as by removal of emerging culms from the clumps (Plate 8a,b). Excepting *M.baccifera* all the treated species produced aerial roots and rhizomes at the branch bases (Table 5.40). Roots and rhizomes generally developed at the branch bases within 3-6 nodes below the truncated culm tops in the next growth season of the treatment. That is rooting was only confined in branches of upper portion of the culms. With the culm removal method both rooting and rhizome formation were observed in almost all the culms of a clump after 1-2 years of treatment. Branches of the lower portion in the culms produced maximum roots and rhizomes than in the upper portion of the culms when newly emerging culms were removed from clumps. The former method yielded lesser numbers of rooted and rhizomed branches than the later method (Table 43).

It has been reported that a well developed, thick and stout branch possesses some rudimentary dormant roots and rhizome primordia at its swollen base (Hasan 1977). Chopping of culm tops may break the apical dominance and thereby released the growth and development of these lateral primordial buds present at the branch bases resulting in root and rhizome production. In *M.baccifera*, unlike other species under study, the branch complement is made up of numerous, small, slender and subequal axes. Such branches generally do not develop root primordia (McClure 1966). Due to this characteristics the branches of this species did not produce any roots. Removal of emerging culm limited the utilization of food reserve from the mother rhizome resulting in gradual increase of the level of



PLATE 8. : Prerooted and prerhizomed branch : roots and rhizomes induced at the branch bases of (a) *B. vulgaris* by removal of emerging culm, (b) *D. giganteus* by chopping of culm tops, (c) excision of cuttings by hacksaw, and (d) sticking of cuttings in the sand bed for rooting.

photosynthetic reserve in all the rhizomes and culms of the treated clumps. McClure (1966) reported that accumulation of food reserve and auxin at the nodal position might induce spontaneous aerial rooting at the branch of some bamboos in nature.

All the aerially rooted branches of *B.balcooa*, *B.nutans*, *B.polymorpha*, *B.vulgaris* and *Dendrocalamus giganteus* did not always produce rhizome, due to late activation of rhizome (Table 43). However, response to the treatments was not uniform in all the species and even among the clumps of the same species. Percentage of prerooted and prerhizomed branch formation was poor in *B.nutans*. In natural condition also, *in situ* rooting and rhizome formation at the branch base could be seen in a few but not in all the injured clumps of *B.vulgaris* growing in the same habitat. Such *in situ* rooting becomes prominent in the rainy season and also in moist places. Thus, *in situ* rooting and rhizome formation in bamboo depend on internal physiological state of the clumps which is mostly controlled by the genetic make up of the plant and may be influenced by the surrounding environment.

However, this type of aerially rooted and rhizomed branches may be termed as prerooted and prerhizomed branches (Banik 1980, 1987b). Thus, a clump treated in this manner yield many prerooted and prerhizomed branch cuttings that could be excised from the culm nodes by hacksaw (Plate 8c) and stuck them into sand rooting bed for profuse rooting (Plate 8d). Chaturvedi (1947) and McClure (1966) have stressed the importance of the presence of complete and rooted branches or branch complement for success in vegetative propagation.

Table 43: Initiation of aerial roots and rhizomes at the branch bases of different bamboo species after chopping of culm tops and removal of emerging culm from the clumps.

Treatment and species	Branches rooted %	Branches both rooted & rhizomed %
A. Chopping of Culm tops		
<i>Bambusa balcooa</i>	20.8	12.5
<i>B.nutans</i>	18.2	9.1
<i>B.polymorpha</i>	25.0	25.0
<i>B.vulgaris</i>	27.3	27.3
<i>D.giganteus</i>	24.0	20.0
<i>M.baccifera</i>	0	0
B. Emerging Culm removal		
<i>B.balcooa</i>	74.3	57.1
<i>B.nutans</i>	13.8	3.4
<i>B.polymorpha</i>	86.5	83.8
<i>B.vulgaris</i>	93.8	78.1
<i>M.baccifera</i>	0	0

5.2.2.3 Rooting trial on normal branch and prerooted branch cuttings

During 10-15 days of the experimentation almost all normal and prerooted branch cuttings were found to be dead and partly rotten inside the Small Perspex Tent without mist under the sun (STP-M/Sn). As this propagation bed was completely covered with clear perspex sheets, it was likely to maintain high air and medium temperature (Van Hof 1958). The average air and rooting medium temperature inside this frame were 36.8°C and 33.0°C respectively with maximum of $39.1-41.5^{\circ}\text{C}$ for air and $34.4-36.4^{\circ}\text{C}$ for the medium during 2 and 5 pm (Table 44). Moreover, this propagation frame could not provide any cooling effect on the cuttings due to the lack of mist supply (Hess and Snyder 1955, Welch 1970). This could be the main reason that the cuttings failed to survive and produce any roots. On the other hand, cuttings survived and produced roots and rhizomes inside the propagation frames placed under the sun and having the facilities of misting. Cuttings also survived without mist only inside the propagation frame when placed under shade. Thus, it appeared that the role of intermittent mist under the sun was important and critical for the survival and rooting of the cuttings as also observed by Burr (1957) with sugarcane.

It was observed that in all the propagation frames the daily temperature of both air and rooting medium were significantly warmer at 2 pm and 5 pm than 8 am. The temperature differences between 12 noon and 5 pm was not significant (Table 44). Temperature difference both in air and rooting medium were also significant among the propagation frames (Plate 1). The average daily temperature difference between Small Perspex Tent with mist under the sun (SPTM/Sn) and Big Perspex Tent without mist under shade (BPT-M/sh) was not significant (Table 44).

Table 44: Average temperature ($^{\circ}\text{C}$) of rooting medium (MD) and air (AR) recorded 4 times each day for 5 different propagation frames since the initiation of rooting trials during May-June 1984 (45 days).

Propagation frames		Time				Avg. temp. in the frame
		8:00 am	12:00 noon	2:00 pm	5:00 pm	
BPT-M/Sh	AR	28.5	30.5	33.0	31.0	30.8 b*
	MD	26.6	28.0	29.8	27.9	28.1 b
OIM/Sh	AR	21.3	24.0	25.9	24.6	24.0 d
	MD	20.2	22.0	24.2	22.2	22.2 d
OIM/Sn	AR	25.0	26.1	27.9	26.5	26.4 c
	MD	23.7	24.9	26.4	25.0	25.0 c
SPTM/Sn	AR	27.0	29.8	32.1	29.7	29.7 b
	MD	25.2	26.8	29.2	26.6	27.0 b
SPT-M/Sn	AR	31.5	35.0	41.5	39.1	36.8 a
	MD	29.0	32.1	36.4	34.4	33.0 a
Average of times	AR	26.7 d	29.1 b	32.1 a	30.2 b	
	MD	24.9 d	26.8 b	29.2 a	27.2 b	

Note: * significant at 5% level, The interaction between propagation frames and 4 times periods was also significant at 1% level

BPT-M/Sh : Big perspex tent without mist bed under shade

OIM/Sh : Open intermittent mist bed under shade.

OIM/Sn : Open intermittent mist bed under the sun.

SPTM/Sn : Small perspex tent with intermittent mist bed under the sun

SPT-M/Sn : Small perspex tent without mist under the sun.

It was observed that both normal and prerooted and prerhizomed branch cuttings of *B.balcooa*, *B.nutans*, *B.polymorpha*, *B.vulgaris* and *D.giganteus* rooted in different percentages under 4 different types of propagation frames (Table 45, 46, 47, 48, 49). In all the propagation frames prerooted and prerhizomed branch cuttings of all the species rooted and also rhizomed significantly in higher percentages than those of normal branch cuttings (Table 45-49). These cuttings of all the above 5 species also produced significantly higher amount of root biomass than those of normal cuttings (Table 45-49).

It is interesting to note that the normal branch cuttings of *B.balcooa*, *B.nutans* and *B.polymorpha* rooted but did not produce any rhizome inside the propagation frames (BPT-M/Sh, OIM/Sh) which were under shade (Table 45, 46, 47). Prerooted and prerhizomed branch cuttings of these 3 species were able to produce both roots and rhizome even under shade, 60-90% in BPT-M/Sh but only 3-7% in OIM/Sh propagation frame. The average temperature of both air and rooting medium of OIM/Sh bed were significantly lowest among all types of frames tested (Table 44). Such temperature condition was resulted from its open structure under shade and cooling effect of the mist spray and probably due to this reason cuttings either failed or gave poor results in OIM/Sh bed. Thus it appeared that light and temperature were important factors activating the rhizome development in such cuttings. Kender (1967) reported that rhizome development was increased in blueberry by long photoperiod and high temperature. Unlike the cuttings of other tree species bamboo cuttings must have both roots and rhizomes for their further survival and growth (Banik 1980). Hasan (1977) has also reported that bamboo cuttings rooted well but majority of them did not produce any new culm mainly due to the failure of rhizome development.

It was also observed that there were significant differences in interaction between the cuttings and propagation frames in each of the bamboo species under study. The prerooted and prerhizomed branch cuttings rooted and rhizomed in maximum percentage inside BPT-M/Sh, OIM/Sn and SPTM/Sn; but always poor in OIM/Sh bed. The amount of root biomass produced by the cuttings was also poor in OIM/Sh bed while it was found to be maximum in OIM/Sn and SPTM/Sn (Table 45-49). Thus, propagation beds under the sun have improved the amount of root biomass production in the cuttings of all the species (Plate 9a,b). Performance of cuttings of all the species in the four different propagation frames (BPT-M/Sh, OIM/Sh, OIM/Sn, SPT/Sn) was assessed by split plot analysis (Table 45-49). Though rooting and rhizome percentage were higher in BPT-M/Sh, OIM/Sn and SPTM/Sn frames the amount of root production was always found to be higher when the frames were under the sun (OIM/Sn and SPTM/Sn). Again the cuttings of all the species under study showed no significant differences in rooting and rhizome percentage, and in amount of root production (except *D.giganteus*) inside the OIM/Sn and SPTM/Sn frames. The OIM/Sn bed being open in nature requires no tent and therefore easy to construct. Therefore, use of OIM/Sn bed was best for producing viable propagules of *B.balcooa*, *B.nutans*, *B.polymorpha*, *B.vulgaris* and *D.giganteus* from the prerooted and prerhizomed branch cuttings. After profuse rooting within 35-45 days of trial, cuttings were collected from sandy rooting medium and immediately potted in the polythene bags (Plate 9a,b,c,d). Before transferring to the nursery bed, cuttings were hardened by keeping the polythene bags for 3-5 days under shade.

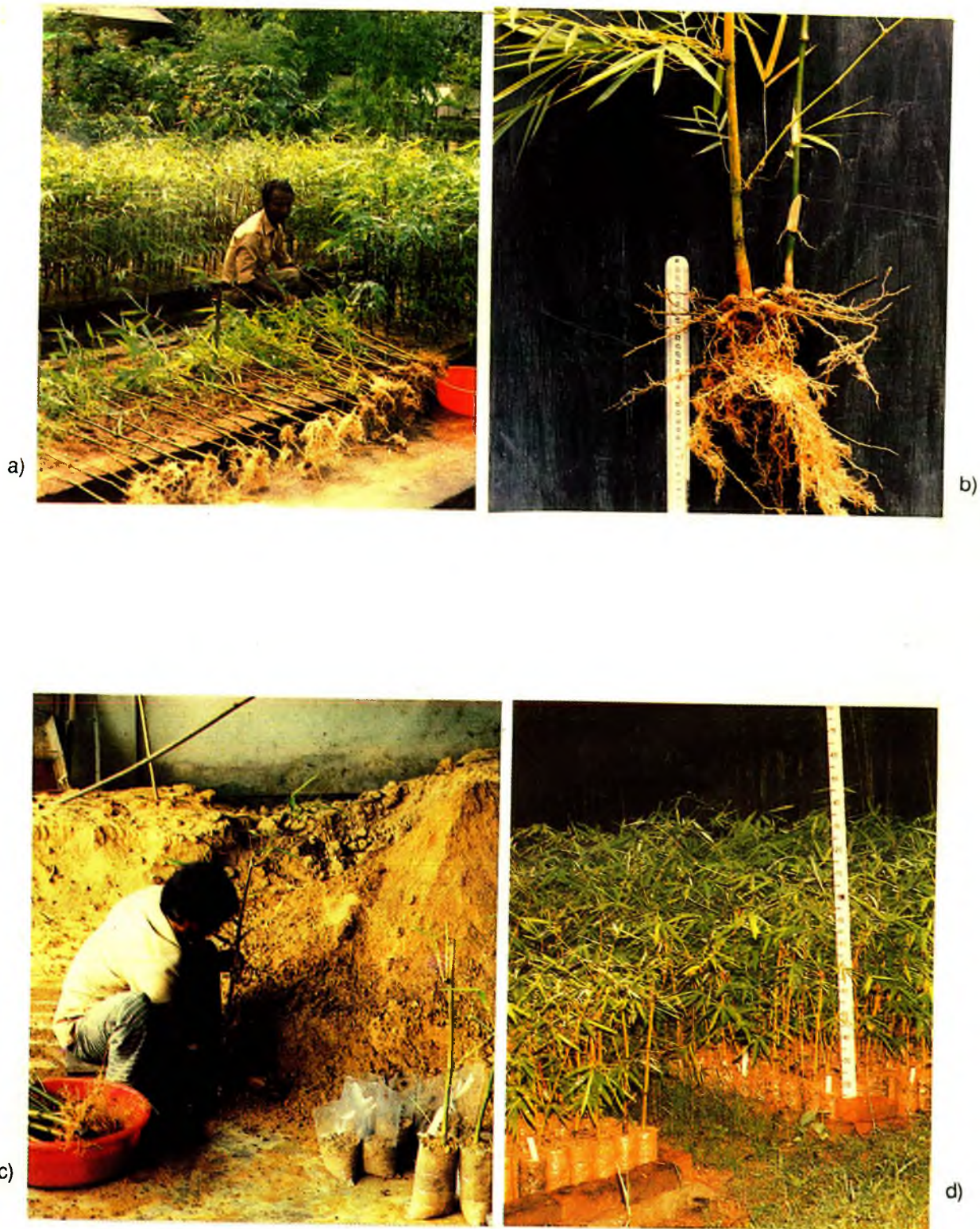


PLATE 9. : Prerooted and prerhizomed cutting propagation :

- a) collection of rooted cuttings from sand media, (b) cutting with well developed rhizomes and roots, (c) potting of cuttings in polybags and established cuttings in the nursery.

Table 45: Average rooting and rhizome formation ability of normal (NC) and prerooted and prerhizomed (PrPz) branch cuttings of *B. balcooa* under different types of propagation frames

Propagation frame		Rooted			Rhizomed			Root biomass		
		%			%			g		
		NC	PrPz	Avg.	NC	PrPz	Avg.	NC	PrPz	Avg.
BPT-M/Sh	A	6.7	60.0**	33.3	0	60.0**	30.0	1.57	3.0ns	2.28
OIM/Sh	B	3.3	10.0**	6.7	0	3.3*	1.7	0.70	2.3ns	1.50
OIM/Sn	C	10.0	67.0**	38.3	6.7	63.3**	35.0	1.90	4.0ns	2.95
SPTM/Sn	D	13.3	70.0**	41.7	6.7	67.0**	36.7	2.77	4.5**	3.63

Split plot analysis

A vs B	**	**	ns
A vs C	ns	ns	ns
A vs D	ns	ns	ns
B vs C	**	**	ns
B vs D	**	**	*
C vs D	ns	ns	ns

* = significant at 5% level, ** = significant at 1% level

ns = not significant

BPT-M/Sh : Big perspex tent without mist bed under shade.

OIM/Sh : Open intermittent mist bed under shade.

OIM/Sn : Open intermittent mist bed under the sun.

SPTM/Sn : Small perspex tent with intermittent mist under the sun.

Table 46: Average rooting and rhizome formation ability of normal (NC) and prerooted and prerhizomed (PrPz) branch cuttings of *B. nutans* under different types of propagation frames

Propagation frames		Rooted			Rhizomed			Root biomass		
		%			%			g		
		NC	PrPz	Avg.	NC	PrPz	Avg.	NC	PrPz	Avg.
BPT-M/Sh	A	6.7	80.0**	43.3	0.0	80.0**	40.0	0.69	2.4*	1.54
OIM/Sh	B	0.0	16.7**	10.0	0.0	6.7**	3.3	0.0	1.57**	0.78
OIM/Sn	C	13.3**	77.0**	45.0	6.7	77.0**	41.7	1.29	3.00**	2.14
SPTM/Sn	D	16.7	73.3**	45.0	10.0	70.0**	40.0	1.17	3.33**	2.24

Split plot analysis

A vs B	**	**	*
A vs C	ns	ns	ns
A vs D	ns	ns	*
B vs C	**	**	**
B vs D	**	**	**
C vs D	ns	ns	ns

* = significant at 5% level, ** = significant at 1% level

ns = not significant

BPT-M/Sh : Big perspex tent without mist bed under shade.

OIM/Sh : Open intermittent mist bed under shade.

OIM/Sn : Open intermittent mist bed under the sun.

SPTM/Sn : Small perspex tent with intermittent mist under the sun.

Table 47: Average rooting and rhizome formation ability of normal (NC) and prerooted and prerhizomed (PrPz) branch cuttings of *B. polymorpha* under different types of propagation frames

Propagation frames		Rooted%			Rhizomed%			Root biomass g		
		NC	PrPz	Avg.	NC	PrPz	Avg.	NC	PrPz	Avg.
BPT-M/Sh	A	6.7	93.3**	50.0	0.0	90.0**	45.0	1.4	2.93ns	2.17
OIM/Sh	B	3.3	10.0*	6.7	0.0	3.3*	1.7	0.0	0.73ns	0.37
OIM/Sn	C	10.0	90.0**	50.0	6.7	90.0**	48.3	2.5	4.8**	3.65
SPTM/Sn	D	16.7	93.3**	55.0	10.0	93.3**	51.7	3.5	5.03ns	4.25

Split plot analysis

A vs B	**	**	*
A vs C	ns	ns	ns
A vs D	ns	ns	*
B vs C	**	**	**
B vs D	**	**	**
C vs D	ns	ns	ns

* = significant at 5% level, ** = significant at 1% level

ns = not significant

BPT-M/Sh : Big perspex tent without mist bed under shade.

OIM/Sh : Open intermittent mist bed under shade.

OIM/Sn : Open intermittent mist bed under the sun.

SPTM/Sn : Small perspex tent with intermittent mist under the sun.

Table 48: Average rooting and rhizome formation ability of normal (NC) and prerooted and prerhizomed (PrPz) branch cuttings of *B. vulgaris* under different types of propagation frames

Propagation frames		Rooted			Rhizomed			Root biomass		
		%			%			g		
		NC	PrPz	Avg.	NC	PrPz	Avg.	NC	PrPz	Avg.
BPT-M/Sh	A	50.7	96.7**	73.3	36.7	93.3	65.0	1.90	3.83**	2.87
OIM/Sh	B	6.7	16.7**	11.7	0.0	6.7ns	5.0	0.40	2.67**	1.53
OIM/Sn	C	53.3	90.0**	71.7	6.7	90.0**	65.0	3.6	5.50*	4.55
SPTM/Sn	D	56.7	93.3**	75.0	10.0	90.0**	68.3	4.07	5.90*	4.98

Split plot analysis

A vs B	**	**	ns
A vs C	ns	ns	ns
A vs D	ns	ns	**
B vs C	**	**	**
B vs D	**	**	**
C vs D	ns	ns	ns

* = significant at 5% level, ** = significant at 1% level

ns = not significant

BPT-M/Sh : Big perspex tent without mist bed under shade.

OIM/Sh : Open intermittent mist bed under shade.

OIM/Sn : Open intermittent mist bed under the sun.

SPTM/Sn : Small perspex tent with intermittent mist under the sun.

Table 49: Average rooting and rhizome formation ability of normal (NC) and prerooted and prerhizomed (PrPz) branch cuttings of *D. giganteus* under different types of propagation frames

Propagation frames		Rooted%			Rhizomed			Root biomass		
		%			%			g		
		NC	PrPz	Avg.	NC	PrPz	Avg.	NC	PrPz	Avg.
BPT-M/Sh	A	6.7	93.3**	36.7	3.3	66.7**	35.0	0.4	2.0*	1.30
OIM/Sh	B	0	6.7**	3.3	0	3.3*	1.7	0	0.6ns	0.30
OIM/Sn	C	10.0	63.3**	36.7	3.3	63.3**	33.3	0.5	3.4**	1.95
SPTM/Sn	D	13.3	66.7**	40.0	6.6	63.3**	35.0	1.9	3.97ns	2.95

Split plot analysis

A vs B	**	**	*
A vs C	ns	ns	*
A vs D	ns	ns	**
B vs C	**	**	**
B vs D	**	**	**
C vs D	ns	ns	**

* = significant at 5% level, ** = significant at 1% level

ns = not significant

BPT-M/Sh : Big perspex tent without mist bed under shade.

OIM/Sh : Open intermittent mist bed under shade.

OIM/Sn : Open intermittent mist bed under the sun.

SPTM/Sn : Small perspex tent with intermittent mist under the sun.

5.2.2.4 Seedling multiplication by rhizome separation

It was possible to increase the number of bamboo seedlings by separating the rhizome with shoot and planting them separately in polythene bags (Table 50; Plate 10a,b). Study revealed that seedlings of *B.arundinacea*, *B.tulda* and *D.strictus* could be multiplied 2-3 times of the initial stock in every month of a year and their survival was also between 90-100%. It was also possible to multiply the seedlings in the consecutive 3 years from the last year stock. The process could also be repeated even after 5 years gap of multiplication (Table 50). The rate of proliferation was always higher (200-300%) in the first multiplication (first year) than next multiplications (second, third and sixth year). Banik (1987b) have termed this process of seedling multiplication as macro-proliferation, and later on Kumar et al. (1988) also used this term. It has been concluded from the study that macroproliferation of seedlings of above bamboo species can be repeated every year at least for a period of six years, and thus seedling number can be increased from the original stock to maintain a continuous supply of large number of seedlings for a couple of years. As an extra advantage the proliferated seedlings remain small in size due to continuous rhizome separation, thereby making it easy to handle and transport them. Multiplied seedlings are clones and become physiologically older as the time passes from the date of mother seedling germination. Under such condition, if the multiplication process is continued for a long time then and as a result the crop harvestable period will also be shorter, the last multiplied seedlings may start flowering due to their physiological maturity before attaining the merchantable culm size.



PLATE 10. : Seedling multiplication :
a) rhizome separation in *B. tulda*,
b) multiplied seedlings of *B. tulda*,
c) rooting in the nodes of ground layer (*B. polymorpha* seedling)

Table 50: Rate of success (mean number, percentage) in the multiplication of seedlings of 3 bamboo species in the three consecutive years and finally again at sixth year

Species	Original seedling		Multiplies seedlings			
	Nos.	1st yr -->	2nd yr -->	3rd yr	6th yr	
					Stock	Multiplied
B.aru	300	671.7 (223.9%)	1473.0 (219.3%)	-	-	-
B.tul	300	876.6 (292.6%)	1528.0 (174.3%)	2634.9 (172.4%)	100	162 (162%)
D.str	300	810.2 (270.1%)	1463.4 (180.6%)	2588.0 (176.8%)	100	171 (171%)

B.aru = *Bambusa arundinacea*, B.tul = *B.tulda*

D.str = *Dendrocalamus strictus*

N.B: Multiplication studies conducted for 2 years (1988-89, 1989-90) in *B.arundinacea*, Seedlings of other 2 species were multiplied for 3 year (1984-85, 1985-86, 1986-87) and again on the 6th year from the 1st year stock

5.2.2.5 Ground layering of seedlings

Among the species under study only the seedlings of *Bambusa polymorpha* produced roots at different nodes culm after 45 days of ground layering in the sand-rooting medium (Table 51; Plate 10c). Seedlings of *B.arundinacea* and *B.tulda* produced poor amount of roots after 60 days at the nodes of mid-culm zones (Table 51). *Melocanna baccifera* seedlings did not produce roots at any nodes on the culm even after 150 days of ground layering in the rooting medium.

Rooting percentage was maximum (93.3%) in *B.polymorpha* seedlings, but poor in *B.arundinacea* (13.3%), and *B.tulda* (16.7%). The number of rooted culm nodes (6.9) per rooted seedling and their survival in polythene bags were maximum (68.0%) in *B.polymorpha* than other two species (Table 51). It is interesting to note that the amount of rooting was maximum at the nodes of mid-culm zone and gradually decreased on the nodes towards the base and tip of the culms (Plate 10c). Thus, it appears that nodes on the mid-culm zones of the seedlings are physiologically more capable in rooting than those present on the base and tip of the culms. Most of the poorly rooted nodes did not survive after planting in polythene bags. Among all the species under study *B.polymorpha* seedling could be multiplied in large number by the above mentioned ground layering method.

Table 51: Rooting ability of culm nodes in the seedlings
of 4 bamboo species through ground layering

Species	Seedling	Rooting position			Rooted	Rooted
	rooted	on the culm			nodes per	nodes
	%				seedling	survived
		Base	Mid	Tip	Nos	%
B.arn	13.33	nil	poor	nil	3.5	14.3
B.pol	93.33	fair	max.	poor	6.9	68.0
B.tul	16.67	nil	poor	nil	4.6	17.3
M.bac	0	nil	nil	nil	0	0

N.B. B.arn. = *Bambusa arundinacea*, B.pol = *B. polymorpha*

B.tul = *B. tulda*, M.bac = *Melocanna baccifera*

5.2.3 *In vitro* propagation

5.2.3.1 Tissue culture in *Melocanna baccifera*(Roxb.)Kurz

Sterilization of explants: It has been observed that treatment with 70% ethyl alcohol alone for 1 minute was not effective to sterilize any of the explants. Almost all tissues tested were contaminated within 3-5 days and ultimately died.

Treatment with low concentration of calcium hypochlorite (4 and 7%) for 10-12 minutes or "clorox" (a commercial bleach, 5.25% sodium hypochlorite), 5 and 10% for 10-20 minutes were also not effective to stop the contamination of explants (Table 52). However, tissues were mostly contamination free when the percentage of Calcium hypochlorite was increased to 10% from 7% but the treated explants were discoloured and bleached (Table 52). Chemical sensitivity of tissue explants was considered an important factor by Yeoman and Macleod (1977), and it appears from these trials that *M.baccifera* was fully sensitive to calcium hypochlorite at the concentrations tested though these concentrations have been reported as effective treatments for sterilizing the stem segments of *Phragmites* sp. (Sangwan and Gorenflot 1975). With the 20% "clorox" either with 10 or 20 minutes treatments only 10% explants of BN; 20% of SB, RT and YCW; and 50% EM were sterilized (Table 52). When the explants were soaked with 0.1% benomyl solution prior to "clorox" treatments in lower concentration with shorter duration (10% with 15 minutes, 15% with 10 and 15 minutes) showed more or less similar result of sterilization as observed with the treatment of 20% "clorox" alone (Table 52). Due to the "clorox" treatment of above concentration, however, 100% sterilization was not achieved but explants retained their colour. The types of explants tested (Plate 4Bii, 11a) were either from the exposed parts of the plant body or covered by

sheathing organs. The explant (BN) of exposed origin sterilized in less number than those (SB,RT,YCW and EM) which were not exposed organs (Table 52).

Depending on the type, 60-100% explants were free of contamination when treated with 0.075% mercuric chloride for 7 or 15 minutes. But when the strength of the mercuric chloride increased (0.1%) and the explants were treated for 15 minutes, almost all were free from contamination (Table 52). But in most cases, after 1-2 weeks of inoculation, contamination appeared again on or around the explants. According to Torres (1989) internal contaminants generally appear after 10 days of culture. Therefore, the appearance of microbial contaminations after 2 weeks could be due to the presence of internal contaminants in the explants. However, with the prior treatment of 0.1% benomyl solution, mercuric chloride even in low concentration (0.075% for 10 minutes) showed 100% effectiveness in controlling the contamination of explants. Treatment of tissue by benomyl solution was also reported to be an effective method of controlling the internal contaminants of plant tissue (Torres 1989). Tissues became slightly whitish when treated with higher concentration (0.1%) of mercuric chloride for 15 minutes. On the contrary tissues were found to retain their original colour and became fully contamination free when treated with low concentration (0.075%) of mercuric chloride for short duration (10 minutes) after 10 minute soaking in 0.1% benomyl solution. Similar to the result of "clorox" treatment explants like SB, RT, YCW and EM were easily sterilized with low concentration of mercuric chloride solution treated for short duration than the explant (BN) of exposed origin. Explant BN had bud on its node and was covered by a number of small hairy leafy sheath and these organs were, probably, favourable sites for harbouring the

Table 52: Effect of disinfectants on the sterilization(%) of different types of explants of *M.baccifera*

Disinfectant	Treatments		Explants types				
	%	minutes	BN	SB	YCW	RT	EM
Calcium hypochlorite	4	8	0	0	0	0	0
	4	12	0	0	0	0	0
	7	8	0	0	0	0	0
	7	12	0	0	0	0	0
	10	8	100	100	100	100	100
'Clorox'	5	10	0	0	0	0	0
(5.25% sodium hypochlorite)	5	20	0	0	0	0	0
	10	10	0	0	0	0	0
	10	20	0	0	0	0	0
	20	10	10	20	20	20	50
	20	20	10	20	20	20	50
Benomyl 0.1% and Clorox	10	10	0	0	0	0	0
	10	15	10	20	20	20	20
	15	10	20	30	30	30	60
	15	15	20	30	30	30	90
Mercuric chloride	0.075	7	60	100	100	100	100
	0.075	15	70	100	100	100	100
	0.100	7	70	100	100	100	100
	0.100	15	90	100	100	100	100
Benomyl 0.1% and mercuric chloride	0.075	5	60	70	70	70	100
	0.075	10	100	100	100	100	100
	0.100	5	100	100	100	100	100
	0.100	10	100	100	100	100	100

Note: BN= Branch node, SB= Culm-sheath base, YCW= Young culm wall, RT = rhizome tip, EM= Embryo of seed

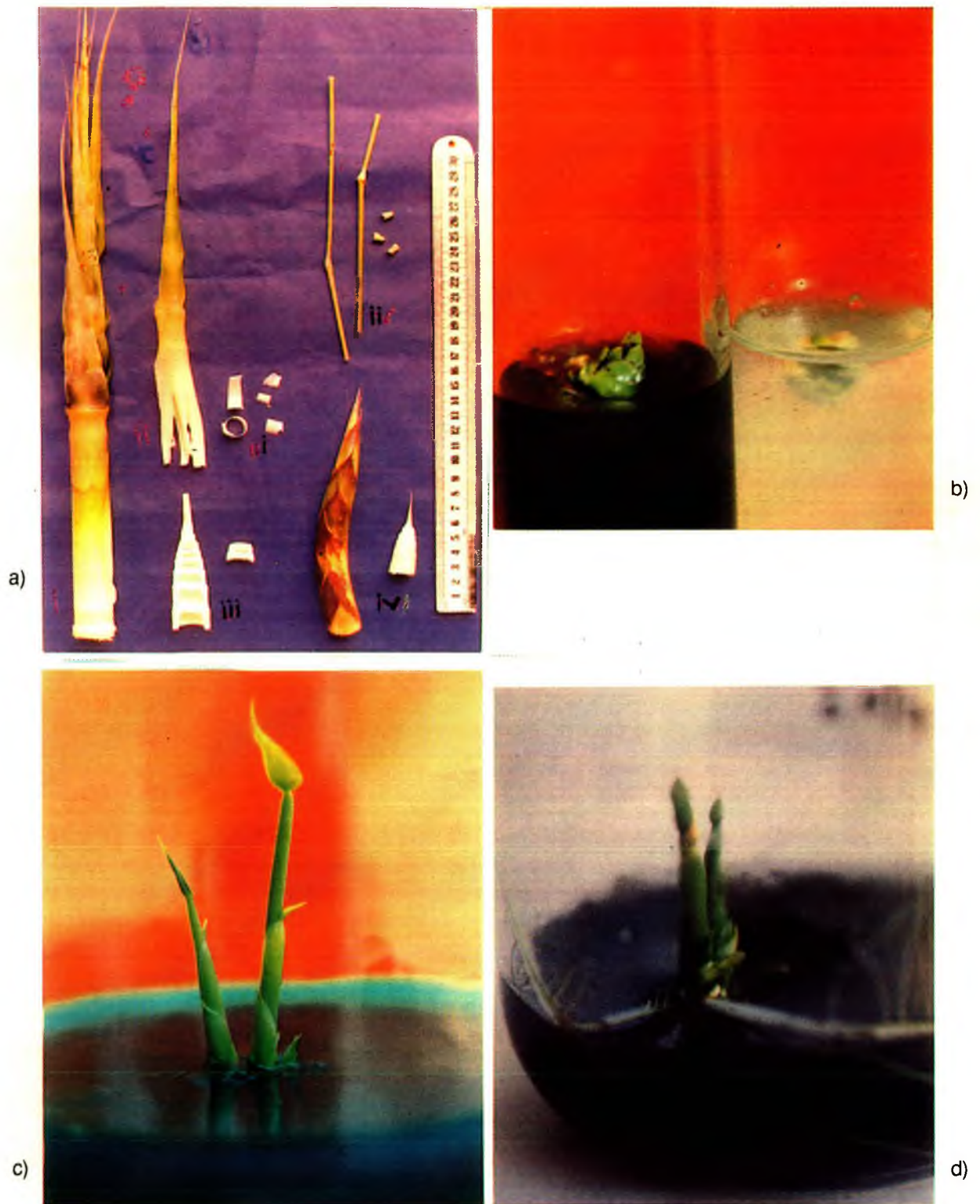


PLATE 11. : Micropropagation in *M. baccifera* :

- a) explant types : i) pieces of culm sheath base (SB), ii) branch with nodes (BN), iii) soft culm wall with intercalary meristem (YCW), iv) rhizome and rhizome tip (RT),
- b) sprouting of branch nodes, (c) proliferated branch node,
- d) rooting in proliferated plantlet.

fungus and bacterial spores. This might be a reason for requiring higher levels of disinfectant chemicals ("clorox" and mercuric chloride). On the other hand SB, RT, YCW and EM explants were either protected from outer environment by sheathing organs or fruit pericarp and therefore had less chances of being contaminated by microbial organisms and, probably, that is why these explants did not require higher concentration of chemicals for complete sterilization.

It appears from the above findings that "clorox" (5.25% sodium hypochlorite) and mercuric chloride are effective sterilizing chemicals for different types of explants of *Melocanna baccifera* for using in *in vitro* culture. Between these two chemicals mercuric chloride found to be the most effective sterilizing agent similar to the report of Nadgir *et al.* (1984) on *Bambusa arundinacea*, *B. vulgaris* and *Dendrocalamus strictus*. Therefore, all the following tissue culture trials tissues were treated with 0.1% benomyl solution for 10 minutes and then with 0.075% mercuric chloride for 10 minutes.

Nutrient media: All the explants of muli (*M. baccifera*) bamboo tested were found in living condition for 2-3 weeks on MS and B₅ nutrient media. Majority of explants remained alive for more than 4 weeks and showed growth only on modified MS medium (Table 53). All the five types of explants died within one week of culture on SH medium. Explants like SB and YCW did not survive even on any of these nutrient media (Table 53). The immature embryo (EM) showed growth both on MS and modified MS media but on B₅ medium it only remained alive not more than 2 weeks. The types and amount of mineral salts (both macro and micro nutrients) of MS and modified MS were similar excepting the later medium contained higher amount of sucrose and vitamins of B₅ medium. Thus it appeared that minerals of MS and vitamin formulation of B₅ medium

Table 53 : Effect of different nutrient media supplemented with various concentration of sucrose on the growth of explants of *M.baccifera*

Explants types	Nutrient media with different sucrose %					
	MS	Modified MS		B ₅		SH
	3	4	5	2	4	3
BN	+	++	+	+	+	-
SB	-	-	-	-	-	-
CB	+	++	+	-	-	-
YCW	-	-	-	-	-	-
RT	-	++	+	-	-	-
EM	++	++	+	+	+	-

Explant: BN = Branch node, SB= Culm-sheath base, YCW=Young culm wall, RT= Rhizome tip, EM =Embryo(immature).

+ = tissue alive for 2-3 weeks

++ = tissue remain alive for more than 4 weeks

- = tissue did not survive for more than 1 week

(combinedly used in modified MS, Table 2) were essential nutrient combination for the growth of explants of *M.baccifera*. In fact, Green (1978) mentioned that the MS or modified MS media have been used most frequently for culture initiation, maintenance and plant regeneration in grasses.

Different levels of sucrose were tested with B₅ and modified MS media for tissue culture of muli bamboo. Visual estimates of explants colour indicated that modified MS with 4% sucrose produced comparatively healthier tissue growth than the other sucrose treatments (Table 53). These results are similar to those reported by Banik (1987b) on *Bambusa glaucescens*, Mehta et al.(1982) on *B.arundinacea* and Yeh and Chang (1986b) on *B.beecheyana*. Moreover, Sangwan and Gorenflot (1975) also obtained better growth of explant tissues of *Phragmites* sp., a bambusoid grass, on MS medium with 4% sucrose. Generally, bamboos are known to be among the fastest growing plants in the plant kingdom (Liese 1985). Therefore, bamboo tissue culture might also need a comparatively strong carbon source. Thus, modified MS medium with 4% sucrose content was used during all subsequent experiments.

Growth regulator: Among the different types of explants vegetative in origin, bud in the branch node (BN) sprouted and produced new shoots only when cultured on modified MS medium supplemented with 2,4-D 4-12 mg/l (Flow chart 2). This type of explant also sprouted even in absence of 2,4-D but with 10% coconut milk (CM). The effectivity of CM on the sprouting of nodal explants of *D.strictus*, *B.arundinacea* and *B.vulgaris* was also reported by Nadgir et al. (1984).

**Flow Chart 2: Organ formation in branch node explants of
M.baccifera under different growth
regulator combinations and transfer cultures.**

Growth regulators		Observation
-----		-----
after 7-12 days of inoculation		
1)	2,4-D 0 mg/l + CM 10%	Sprouted 20% (2 explants)
2)	2,4-D 0 mg/l "	None sprouted
3)	2,4-D 4 mg/l + CM 10% "	Sprouted 40% (4 explants)
4)	2,4-D 4 mg/l "	Sprouted 30% (3 explants)
5)	2,4-D 8 mg/l + CM 10% "	Sprouted 30% (3 explants)
6)	2,4-D 8 mg/l "	Sprouted 40% (4 explants)
7)	2,4-D 10 mg/l + CM 10% "	Sprouted 80% (8 explants)
8)	2,4-D 10 mg/l "	Sprouted 70% (7 explants)
9)	2,4-D 12 mg/l + CM 10% "	Sprouted 50% (5 explants)
10)	2,4-D 12 mg/l	Sprouted 50% (5 explants)

Total 41 explants out of 100		

10 explants	10 explants	10 explants
	Transfer-I	Transfer-I
	2,4-D 5 mg/l	2,4-D 10 mg/l
	(loosing chlorophyll,	(loosing chlorophyll,
	all died 30-35 days)	all died 20-23 days)
		long shoot, died after
		40 days)

275

276

Branch nodal segments (BN) with buds sprouted 70-80% within 7-12 days of culture on 2,4-D 10 mg/l with or without 10% CM (Flow chart 2; Plate 11b). These sprouted explants produced plantlets after subsequent 6th transfer culture with 25-30 days of intervals. In the first three transfer cultures the modified MS medium were supplemented with constant amount (0.5 mg/l) of 2,4-D and gradual increase in the BAP from 1.0 mg/l to 3.0 mg/l. In the 4th transfer the medium was supplemented only with BAP 5.0 mg/l, CM 10% and Casein hydrolysate (CH) 100 mg/l, and the sprouted shoots then proliferated and produced leaves (Plate 11c). After 5th transfer on to the medium having BAP 5.0 mg/l, NAA 1.0 mg/l, CM 10%, and CH 50 mg/l the shoots with leaves further proliferated and root initiation took place. At the final transfer on the medium supplemented only with BAP 5.0 mg/l and NAA 1.0 mg/l the explants developed into a complete plantlet with fully developed root system (Plate 11d).

It is often the case that combinations of growth factors (such as coconut milk + naphthalene acetic acid or 2,4-D-dichlorophenoxyacetic acid) will cause mature tissue to proliferate actively and pave the way for later growth on a basal medium (Moore 1979). The time requirement for the complete development of a plantlet from the branch node (BN) was about 6-7 months from the date of first inoculation.

When the media did not contain activated charcoal, no culture survived even after 2 successive transfer. It was also observed that the growth rate of the tissues become slower after 25-30 days if they were left on the culture media even with activated charcoal without subsequent transfer (Flow chart 2). After transfer tissues showed their continuous growth and elongation without losing chlorophyll. Apparently, tissue culture survived and grew in higher levels of growth regulators (2,4-D 10 mg/l and BAP 5.0 mg/l) without problems after successive transfer. With the 6 successive transfers of cultures (explant BN) on the fresh media produced complete plantlets. At this stage it was necessary to use large glass

bottle (13 cm long and 8 cm in diameter) or large test tube (15 cm long and 2.5 cm in diameter) to provide sufficient room for shoot development. Therefore, it seems that frequent transfer of tissue into fresh media supplemented with activated charcoal and BAP comprise an important procedural step for *in vitro* culture of muli bamboo (*Melocanna baccifera*) through branch node (BN) explant.

The immature embryo (EM) of the species also started shoot and root development within 10-15 days of culture when the medium was supplemented with 2,4-D and BAP (Table 54; Plate 12a,b). All explants (80-100%) produced both shoots and roots when the concentration of BAP was low (0.1 mg/l). Percentage of plantlets decreased when the concentration of BAP was higher. However, BAP or 2,4-D either alone or in combination produced 40-100% complete plantlets (Plate 12c). But BAP in combination with NNA produced lesser (20-40%) number of plantlets. Thus it appears that BAP and 2,4-D is the better combination than BAP and NAA produce. It is interesting to note that 20-40% embryo produced only shoots when the medium was supplemented with either 2,4-D or NAA (Table 54). The application of BAP alone or in combination with NAA or 2,4-D was essential for root development (Nemeth 1979) has also demonstrated the root promoting effect of BAP on *Prunus* sp. The embryos did not produce any plantlets when cultured on medium having no growth regulator. Therefore, BAP seems to be an important growth regulator to initiate organogenesis in embryos of *M.baccifera*. However, other cytokinin like kinetin failed to produce any growth on the embryo explant. Rooting was excellent when medium was supplemented with activated charcoal as observed by Nadgir *et al* (1984) in culturing the nodal segment of 3 bamboo species. Some of the effects of activated charcoal may be due to darkening of the support matrix and thus approximating more closely soil conditions (Proskauer and Berman 1970). However few plantlets were successfully planted outside *in vitro* condition into sand after 85-90 days of culture.



PLATE 12. : *In vitro* culture of immature embryo in *M. baccifera* :
a) sprouting embryo, (b) shoot and root development, (c) shoot elongation and profuse rooting, and (d) plantlet planted in the sand.

Table 54: Effect of different growth regulator on organ formation in tissue culture of embryo of *M. baccifera*

Hormone (mg/l)			Organ formation (%)			
2,4-D	NAA	BAP	Shoot	Root	Shoot & Root	No growth
1.0	-	0.1	0	0	100	0
1.0	-	1.0	0	0	80	20
1.0	-	3.0	20	0	40	40
5.0	-	0.1	20	0	80	0
5.0	-	1.0	20	0	40	40
5.0	-	3.0	0	0	40	60
-	-	0.1	20	0	40	40
-	-	1.0	-	0	60	40
-	-	3.0	-	0	60	40
1.0	-	-	40	0	0	60
5.0	-	-	40	0	0	60
-	1.0	0.1	40	0	0	60
-	1.0	1.0	60	0	20	20
-	1.0	3.0	40	0	40	20
-	5.0	0.1	60	0	0	40
-	5.0	1.0	20	0	0	80
-	1.0	-	40	0	0	60
-	5.0	-	20	0	0	80
-	-	-	0	0	0	100

5.2.4 Field performance of different types of propagules

The offsets, part-clumps, prerooted and prerhizomed branch cuttings and seedlings (as the case may be) of 8 different bamboo species were planted in different years and, therefore, their growth data are not statistically comparable. However, the growth (culm numbers, diameter and height of culms), pattern of each of the propagules as per clump age has been given in Table 55. As the offsets and part-clumps (as the case may be) of a species was planted immediately after collection and the seedlings and branch cuttings were planted more or less after one year of age, the second years's growth data of offsets and part-clumps are comparable to those of first year of branch cuttings and seedlings. However, cuttings and seedlings were after cared and hardened in the nursery more or less for 9-12 months before planting into the field.

It has been observed that in all the species under study the survival percentages of prerooted and prerhizomed branch cuttings and seedlings were always higher (71-97%) compared to those of offsets and part clumps (rhizome assembly) in all the 3 site conditions. Depending on the species, offset did not survive for more than 11.1-69.2% (Table 55). In general final survival records were obtained after 3 years of planting. All the types of propagules survived in highest percentage in homestead condition probably due to better care and good soil conditon. In the homestead bamboos have been planted by farmers in the backyard where, generally, soil is well drained and has good amount of organic matter. This condition not only ensured higher survvival but also it provided better habitat condition for accelerated culm growth in all types of propagules (Table 55).

In all the species under study excepting *Dendrocalamus giganteus* and *D.longispatus*, both branch cuttings and seedlings from the beginning produced more number

of full grown (FG) culms than those produced by offset. In *D. giganteus* the number of FG culm production by branch cutting was more or less same to that of offset after 4-5 years of planting (Table 55), while in *D. longispathus* the seedlings produced equal or more number of FG culm after one year of planting than those produced by offsets. In all the species under study all types of propagules (offsets, prerooted and prerhizomed branch cuttings, seedlings and part clumps) produced thinner (0.76-2.54) culms at the beginning and in the subsequent years more wider and taller culms were gradually produced (Table 55). The diameter and height of the FG-culms produced by offsets were comparatively bigger at the beginning than those of culm produced by branch cuttings and seedlings. However, after 3-4 years of planting, branch cuttings and seedlings produced similar sizes of culms like those produced by offsets (Table 55). Once a well developed clump is formed it becomes impossible to distinguish whether it has originated from offset or from branch cutting or from seedling.

Thus it appeared both prerooted and prerhizomed branch cuttings and seedlings can be used as propagules (depending on the species) for bamboo propagation along with offset planting. Because of its familiarity, offset planting is more common in the villages of Bangladesh. Use of this propagule is practicable only in cultivating a few clumps, particularly with a small accessible area. However, the offsets are bulky, heavy (4-30 kg), and difficult to handle and carry (Banik 1980). Moreover, a clump can supply limited number of offset propagules, certainly not enough for large-scale plantations. Besides, offset are costly and difficult to collect by excavation.

Table 55: Comparative assessment of survivability of different propagules and their annual production (number, diameter and height) of full grown (F6) culm upto 5 years of clump age in 8 bamboo species planted at 3 site conditions.

Species	Propa- gules	Plant- ing	Clump age (year)										Dia cm	Ht m	F6 vival	F6 culm	F6 Dia cm	F6 Ht m	F6 vival	F6 culm	F6 Dia cm	F6 Ht m
			1	2	3	4	5															
8.bal.																						
Off	FOR	64.0	1.4	1.75	1.7	52.0	2.5	1.80	5.7	52.0	3.0	3.75	8.5	52.0	2.7	4.3	10.2	52.0	3.5	5.20	15.2	
	CNB	50.0	1.4	1.68	1.5	41.7	2.2	1.74	5.4	41.7	2.6	3.62	7.9	41.7	3.0	3.9	9.7	41.7	3.0	5.10	14.8	
	HST	76.9	2.0	1.80	2.2	69.2	3.0	3.8	7.2	69.2	3.0	3.8	7.2	69.2	4.1	4.3	10.2	-	-	-	-	
8c																						
Off	FOR	100	2.6	1.42	1.5	93.3	4.9	2.93	6.2	93.4	4.9	3.65	8.5	93.4	6.6	4.1	9.8	93.3	7.7	4.89	14.9	
	CNB	100	2.4	1.40	1.6	70.0	3.8	2.73	5.8	60.0	4.4	3.55	8.0	60.0	6.4	4.0	10.0	60.0	6.5	4.55	14.5	
	HST	100	3.0	1.50	2.0	96.7	5.2	3.0	8.1	96.7	5.1	4.0	9.8	96.7	7.0	4.5	11.2	-	-	-	-	
8.pol.																						
Off	FOR	500	1.75	0.89	1.6	37.5	3.1	2.11	6.95	37.5	3.3	2.70	8.9	37.5	7.7	3.57	8.6	37.5	2.9	5.02	13.3	
	CNB	100	3.7	1.3	1.4	90.6	5.57	2.63	5.9	90.6	6.0	3.45	8.9	90.6	7.0	4.57	13.0	90.6	7.2	5.96	16.3	
	HST	100	4.0	1.5	1.5	95.0	6.0	3.0	6.30	95.0	7.5	4.2	9.4	95.0	6.0	5.2	14.5	-	-	-	-	
Sdl																						
Off	FOR	85.5	1.5	0.6	1.2	76.3	3.2	1.8	3.3	71.3	7.2	2.8	6.2	71.3	6.4	3.5	9.0	71.3	5.9	3.91	11.0	
	CNB	80.0	1.3	0.5	1.0	63.3	3.0	1.6	3.0	60.0	5.5	2.5	5.5	60.0	6.0	3.2	8.2	60.0	5.7	3.20	10.5	
	HST	94.7	1.8	0.8	1.5	92.0	3.5	2.0	3.5	83.3	7.0	3.2	6.5	83.3	7.5	4.2	9.8	-	-	-	-	

Table 55 contd.

8.nut.	Off	FOR	60.0	1.8	0.76	1.8	50.0	3.0	1.9	7.0	40.0	5.5	3.0	11.4	40.0	6.7	4.4	12.3	40.0	5.1	5.3	15.65
	Bc	FOR	86.7	2.7	1.4	1.2	73.3	3.6	1.9	6.2	73.3	4.0	2.6	10.5	73.3	5.2	3.7	11.6	73.3	6.5	4.9	14.75
	Off	FOR	52.0	3.0	1.67	3.5	44.0	3.5	3.50	7.5	44.0	9.0	3.75	9.7	44.0	6.0	4.62	10.5	44.0	9.0	4.71	12.5
8.tul.	HST		46.7	4.0	2.0	4.2	46.7	6.0	4.0	8.2	46.7	10.5	5.1	10.2	46.7	7.0	5.5	11.0	-	-	-	-
	Sdl	FOR	83.3	4.5	2.18	6.2	73.4	4.0	3.41	7.75	70.3	6.0	4.55	3.1	70.3	7.0	4.86	9.8	70.3	9.6	4.72	10.3
	CNB		80.0	4.0	1.9	5.8	68.0	4.2	9.1	6.2	68.0	5.5	3.2	8.5	68.0	5.0	3.9	8.7	68.0	7.0	4.5	9.5
8.vul.	HST		90.4	5.2	2.20	6.5	87.2	5.5	3.6	7.2	84.0	7.0	4.7	9.2	84.0	9.0	5.5	10.5	-	-	-	-
	Off	FOR	56.0	2.0	1.8	4.2	44.0	4.5	3.0	6.5	44.0	3.9	4.1	11.5	44.0	5.5	5.4	14.2	44.0	9.5	7.0	18.5
	CNB		46.7	1.5	1.7	3.8	40.0	3.0	2.8	5.0	40.0	6.5	3.3	10.3	40.0	4.5	3.8	13.5	40.0	8.0	4.0	17.5
Bc	HST		64.7	3.0	2.1	6.7	63.0	5.0	3.5	7.3	63.0	10.0	5.5	12.5	63.0	7.0	4.7	17.5	-	-	-	-
	Off	FOR	96.0	3.3	1.77	5.1	84.0	4.8	2.7	9.5	84.0	6.9	3.6	10.3	84.0	6.0	5.2	15.5	84.0	9.5	6.77	18.0
	CNB		92.3	2.0	1.60	4.7	87.7	3.5	2.5	9.0	86.2	4.0	3.0	9.5	86.2	5.0	4.1	16.2	86.2	4.5	4.5	18.2
D.gig.	HST		96.5	3.5	1.9	6.5	93.7	5.0	3.0	10.2	93.7	8.0	4.0	11.0	93.2	6.5	5.5	18.2	-	-	-	-
	Off	FOR	22.2	6.0	2.54	10.2	22.2	4.0	7.78	4.14	11.1	5.0	11.56	12.2	11.1	14.0	12.3	16.8	11.1	18.0	11.56	24.4
	Bc	FOR	75.0	3.3	1.51	8.2	75.0	2.0	3.31	9.0	75.0	3.6	9.24	11.5	75.0	12.0	11.4	15.8	75.0	17.0	11.52	23.7

Table 55 contd. ...

Off	FOR	53.3	3.0	1.27	8.3	53.3	2.5	2.75	10.96	53.3	2.0	3.51	12.8	53.3	2.5	4.0	13.5	53.3	3.5	4.21	14.0
Sd1	FOR	82.4	2.3	1.66	9.0	70.2	3.0	2.34	11.06	68.2	5.0	3.43	12.3	68.2	5.0	3.95	12.61	68.2	4.20	4.13	13.2
Pc	FOR	50.0	2.2	0.92	2.7	46.7	5.7	1.25	3.4	46.7	13.5	1.42	6.6	46.7	17.0	1.92	8.6	46.7	24.0	2.4	9.5
Sd1	FOR	57.8	3.2	0.83	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	HST	70.0	4.0	0.95	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

N.B: B.bal= *Bambusa balcooa*, B.pol= *B. polymorpha*, B.nut= *B. nutans*, B.tul= *B. tulda*, B.vul= *B. vulgaris*,

O.gig= *Ondrocalamus giganteus* O.len. = *O. longispatus*, M.bac = *Melocanna baccifera*.

Dia = Diameter, Ht = Height, F6 = Full grown culm, Off = Offset, PrPz = Prerooted & Prerhizomed brnach cuttings,

FOR = forest, CNB = Canal bank, HST = Homestead

5.3 Germplasm conservation

So far 33 species of bamboos under 9 genera have been collected from different localities of Bangladesh and one from Thailand (line 49, 49A). These were centralized in the bambusetum of BFRI (Table 56). Among them seven species of *Bambusa* (line/clump number: 04/1-2, 17/1-10, 18A/1, 18B/1-7, 25/1-79, 26/13-14, 56/1-3), one species of *Dendrocalamus* (line 26/4, 8-12), one species of *Gigantochloa* and one species of *Thyrsostachys* could not be identified. Species were identified mostly by consulting Camus (1913) and Gamble (1896) and the nomenclature cited by Gamble has been followed.

Species centralized in the bambusetum has been given in Table 56. The species have been arranged alphabetically in the table along with local names, line/clump numbers, planting year, locality/source of collection, and propagules planted.

Each species has been planted in one or more than one lines. Each of these lines comprises the propagules collected from different localities and sources. Many species like *B.tulda*, *B.polymorpha*, *B.vulgaris* and *D.longispathus*, *O.nigrociliata* show phenotypic variations in vegetative characteristics like culm colour, length of the culm sheath, branching pattern, etc. Difference in flowering duration among the clumps of *D.longispathus* was also noticed. These observations indicate that there are many variable patterns even within a species. Such biodiversities are important from breeding point of view. Research in this field needs to be initiated.

Table 56: List of germplasm of different bamboo species centralized in the Bambusetum of Bangladesh Forest Research Institute, Chittagong.

Scientific name	Local name	Line/ clump Nos	Planting year	Locality/Source of collection	Propagules
Bambusa arundinacea (Retz.) Willd.	Kanta	24/1	1974	Bogra	Off
B.arundinacea(Retz.)Willd.	Kanta	24/2,4,7 12-17	1977	Dinajpur Fl: 1976	Sdl
B.arundinacea(Retz.)Willd.	Kanta	24/3,5,6 8-11	1974	Dinajpur	Off
B.arundinacea(Retz.)Willd.	Kanta	19/4-8	1979	Lawachara Sylhet	Off (FL:1989)
B.arundinacea (Retz.) Willd.	Kanta	16A/1-10	1989	Mirpur Bot.Gard Fl:1988	Sdl
B.arundinacea (Retz.) Willd.	Kanta	16B/1-10	1990	CL19/4-8 Fl:1989	Sdl
B.arundinacea (Retz.) Willd.	Kanta	16C/1-10	1991	Keochia CTG Fl:1990	Sdl
Bambusa arundinacea (Retz.) Willd. var.spinosa Roxb.	Bish kanta	39/1-5	1974,75	Mymensing	Off (FL:1980)
Bambusa arundinacea (Retz.) Willd. var.spinosa Roxb.	Bish kanta	39A/1-5	1980	39/1, FL:1980	
Bambusa arundinacea (Retz.) Willd. var.spinosa Roxb.	Bish kanta	39B/1-5	1980	39/2, FL:1980	Sdl
Bambusa arundinacea (Retz.) Willd. var.spinosa Roxb.	Bish kanta	39C/1-5	1980	39/3, FL:1980	Sdl
Bambusa balcooa Roxb.	Barak	34/1-8	1975	Dhaka	Off
Bambusa balcooa Roxb.	Baluka	35/1-4	1973,75	Dinajpur	Off
Bambusa glaucescens Sieb.ex Munro	Tetua	03/1-3	1973,74	Srimangal,Sylhet	Off(FL:1977)
B.glaucescens Sieb.ex Munro	Tetua	46/1-3	1979	CL08/3 FL:1977	Sdl

Table 56 contd. ...

<i>Bambusa longispiculata</i>	Talla	22/1-5	1973,75	Dinajpur	Off
Gamble ex Brandis					(FL:1978)
<i>B.longispiculata</i> Gamble ex Brandis	Talla	22/6-8	1979	CL 22/4, 5 FL:1978	Sdl
<i>B.longispiculata</i> Gamble ex Brandis	Talla	14F/1-4	1980	CL 22/2 FL:1978	Sdl
<i>B.longispiculata</i> Gamble ex Brandis	Talla	14G/1-4	1980	CL 22/3 FL:1979	
<i>Bambusa nutans</i> Wall.ex Munro	Makla,	0/1-5	1973,74	Dinajpur	Off
<i>B.nutans</i> Wall. ex Munro	Pichlee	01/1-3	1973	Sylhet	Off
<i>B.nutans</i> Wall. ex Munro	Baillo	37/1-16	1974,75	Tangail	Off(FL:1979)
<i>B.nutans</i> Wall. ex Munro	Baillo	14E/1-3	1980	CL 37/4 FL:1979	Sdl
<i>Bambusa oliveriana</i> Gamble	Aille	21/1-2	1974	Dinajpur	Off
<i>Bambusa polymorpha</i> Munro	Burma bans	05/1-3	1974	Tinkonia CHT	Off
<i>Bambusa polymorpha</i> Munro	Burma bans	06/1-3	1973,74	Mascumba CHT	Off
<i>B.polymorpha</i> Munro	Bethua	28/1-8	1972,74	Sylhet	Off(PFL:1980)
<i>B.polymorpha</i> Munro	Bethua	50/1-3	1982	CL 28/1	Bc
<i>B.polymorpha</i> Munro	Bethua	54/1-2	1989	Lawachara SYL	Off
<i>B.polymorpha</i> Munro	Farua	55/1-5	1989	Kalenga SYL	Sdl
				FL:1982-83	
<i>Bambusa tulda</i> Roxb.	Mitinga	27/1-5	1973,74	Hathazari	Off(FL:1984)
<i>B.tulda</i> , Roxb.	Mitinga	27/1-5	1986	CL 27/1-5 FL:1984	Sdl
<i>B.tulda</i> Roxb.	Mitinga	27/6-12	1973,74	Bandarban	Off
<i>B.tulda</i> Roxb.	Mitinga	13/1-10	1978	Shishak CHT	Sdl
				FL:1977,78	
<i>B.tulda</i> Roxb./ <i>B.teres</i> Ham.ex Munro	Mirtinga	14A/1-8	1979	Adampur SYL	Sdl
<i>B.tulda</i> Roxb./ <i>B.teres</i> Ham.ex Munro	Mirtinga	14B/1-8	1979	Lawachara SYL	Sdl
<i>B.tulda</i> Roxb.	Mirtinga	14C/1-4	1980	Rangamati,Ghagra	Sdl
<i>B.tulda</i> Roxb.	Mirtinga	14C/5-7	1981	Kaptai CHT FL:1981	Sdl
<i>B.tulda</i> Roxb.	Mirtinga	14D/1-4	1980	CL 27/4, FL:1980	Sdl
<i>B.tulda</i> Roxb.	Mirtinga	52A/1-7	1989	Hathazai FL:1980	Sdl
<i>B.tulda</i> Roxb.	Mirtinga	52B/1-5	1989	CL 27/1-3	Sdl
<i>B.tulda</i> Roxb.	Mirtinga	52C/1-5	1989	Shajadpur,	Sdl
				Serajganj. FL:1988	

Table 56 contd. ...

<i>B.tulda</i> Roxb.	Mirtinga	52D/1-5	1989	Akhaura, B.barua	Sdl
				FL:1987	
<i>B.tulda</i> Roxb.	Mirtinga	52E/1-3	1990	Keochia FL:1989	Sdl
<i>B.tulda</i> Roxb.	Mirtinga	52F/1-5	1991	Keochia FL:1990	Sdl
<i>Bambusa vulgaris</i> Schrad.ex Wendl.	Bahini	29/1-10	1973,75	Tangail	Off
<i>B.vulgaris</i> Schrad.ex Wendl.	Bariala,Jai	30,31/1-10	1973,74	Sylhet	Off
<i>B.vulgaris</i> Schrad.ex Wendl.	Bashri	32/1-10	1973,75	Khulna	Off
<i>B.vulgaris</i> Schrad.ex Wendl.	Jai	02/1-3	1973	Sylhet	Off
<i>B.vulgaris</i> Schrad.ex Wendl.	Baizya	02/4-5	1981	Faridarpa CTG	Bc
<i>B.vulgaris</i> Schrad.ex Wendl. var. striata(lodd.)Gamble	Sharna bans	53/3-4	1986	Seraiganj	Off
<i>Bambusa</i> sp	Mugal,	04/1-2	1979	Comilla	Off
	Kanakaich				
<i>Bambusa</i> sp.	Hedge bans	17/1-10	1989	Dhaka	Off
<i>Bambusa</i> sp.	Hye bans	18A/1	1980	Netrokona	Off
<i>Bambusa</i> sp	Hye bans	18B/1-7	1980	Netrokona	Sdl
				FL:1979	
<i>Bambusa</i> sp. (Mitinga type)	Bilati bans	25/1-7	1972	Hazarikhil	Off
<i>Bambusa</i> sp. (B.tulda like)	Mita	26/13,14	1973,74	Datmara, FL:1972	Sdl
<i>Bambusa</i> sp.	Kaldapri	56/1-3	1991	Jessore(Narail)	Off
				FL:1990	
<i>Cephalostachyum pergracile</i> Munro	Kharjaba	38/1-8	1975		Off
<i>Dendrocalamus calostachus</i> Kurz	Barua	19/1-3	1974,75	Mymensingh	Off
<i>D.strictus</i> Nees	Lathi	33/1,3-9	1973	Hazarikhil, CTG	Off(FL:1983-84)
<i>D.strictus</i> Nees	Lathi	33/1-6	1983	CL 33/1,3-9 FL:1983	Sdl
<i>Dendrocalamus giganteus</i> Munro	Bhudhum	18/1-2	1974,75	Ramu Cox's Bazar	Off
<i>D.giganteus</i> Munro	Bhudhum	18/3-6	1980,82,84	CL 18/2	Bc
<i>Dendrocalamus hamiltonii</i> Nees	Pecha	33/2	1979	Patharia R.F, SYL	Off
<i>D.hamiltonii</i> Nees	Pecha	48/1-4	1981	Srimangal, SYL	Off
<i>Dendrocalamus longispathus</i> Kurz	Ora	20/4-8	1974,75	Kassalong	Off

Table 56 contd. ...

<i>Dendrocalamus longispathus</i> Kurz	Ora	26/1-3,5-7	1972	Fatikchari CTG	Off(FL:1977-79)
<i>D.longispathus</i> Kurz	Ora	26/1-3	1980	CL 26/2 FL:1977	Sdl
<i>Dendrocalamus</i> sp. (Ora like)	Ora	26/4,8-12	1972,73	Koila CTG	Sdl
<i>D.longispathus</i> Kurz	Ora	36/1-10	1974,75	Dholai T.E. FL:1974	Sdl
<i>D.longispathus</i> Kurz	Ora	37/17	1974	Hathazari	Off
<i>D.longispathus</i> Kurz	Ora	15A/1-5	1979	CL 26/1, FL:1978	Sdl
<i>D.longispathus</i> Kurz	Ora	15B/1-6	1979	CL 26/3, FL:1978	Sdl
<i>D.longispathus</i> Kurz	Ora	15C/1-7	1979	CL 26/5, FL:1978-79	Sdl
<i>D.longispathus</i> Kurz	Ora	15D/1-5	1979	CL 26/6, FL:1977-79	Sdl
<i>D.longispathus</i> Kurz	Ora	15E/1-6	1979	CL 26/7, FL:1977-79	Sdl
<i>D.longispathus</i> Kurz	Ora	15F/1-3	1979	CL 26/17 FL:1978	Sdl
<i>Dendrocalamus membranaceus</i> Munro	Burma bans	58/1-3	1991	Chunati CTG	Off
<i>Gigantochloa</i> sp	Kala bans	47/1-4	1980	Mirpur	Off
<i>Melocalamus compactiflorus</i> Benth.	Lata	41/1-7	1977	Cox's Bazar FL:1975	Sdl
<i>Melocanna baccifera</i> (Roxb.) Kurz	Muli	07/1-3	1972	Lawachara SYL	Off
<i>M.baccifera</i> (Roxb.) Kurz	Muli	08/1	1974	Hazarikhil CTG	Off
<i>M.baccifera</i> (Roxb.) Kurz	Muli	08/2-3	1975	Mymensingh FL:1974	Sdl
<i>M.baccifera</i> (Roxb.) Kurz	Muli	09/1-3	1974	Mymensingh FL:1974	Sd
<i>M.baccifera</i> (Roxb.) Kurz	Muli	10/1	1974	Hathazari	Off
<i>M.baccifera</i> (Roxb.) Kurz	Bazzali	11/1-3	1974	Mymensingh FL:1975	Sd
<i>M.baccifera</i> (Roxb.) Kurz	Bazzali	12/1-4	1974	CTG	Pc
<i>M.baccifera</i> (Roxb.) Kurz	Muli	12/5	1975	CTG	Pc
<i>M.baccifera</i> (Roxb.) Kurz	Muli	40/1-3	1975	Mymensingh FL:1975	Sd
<i>M.baccifera</i> (Roxb.) Kurz	Muli	42/1-10	1975	Mymensingh FL:1974	Sdl
<i>M.baccifera</i> (Roxb.) Kurz	Muli	43/1-10	1975	Mymensingh FL:1975	Sd
<i>M.baccifera</i> (Roxb.) Kurz	Muli	44/1-10	1975	Mymensingh FL:1975	Sd
<i>M.baccifera</i> (Roxb.) Kurz	Muli	45/1-10	1975	Mymensingh FL:1975	Sd
<i>M.baccifera</i> (Roxb.) Kurz	Muli	51A/1-2	1989	Kamalchari CHT FL:1986	Sdl
<i>M.baccifera</i> (Roxb.) Kurz	Muli	51B/1-6	1989	Narayanhat CTG	Sdl
				Hyanko, CHT FL:1989	
<i>M.baccifera</i> (Roxb.) Kurz	Muli	51C/1-2	1990	Ramgarh	Off
<i>M.baccifera</i> (Roxb.) Kurz	Muli	51D/1-10	1991	Hyanko CHT	Sdl

Table 56 contd. ...

					FL:1990	
<i>M.baccifera</i> (Roxb.) Kurz	Muli	51E/1-5	1991	Fatehabad FL:1991	Sdl	
<i>Neohauzeava dullooa</i> (Gamble) A.camus	Dalu	20/1-3	1974	Kassalong	Pc	
	Dalu	57/1-2	1990	Barshijura SYL	Off	
<i>Oxytenanthera nigrociliata</i> Munro	Kali	23/1-7	1973	Harbang	Off	
<i>O.nigrociliata</i> Munro	Kali	23/8-15	1979	Pablakhali FL:1978	Sdl	
<i>Thyrsostachys siamensis</i> Gamble	Thai bans	49/1-3	1979	Thailand	Off(FL:1990)	
<i>T.siamensis</i> Gamble	Thai bans	49A/1-3	1990	CL 49/1-3	Sdl	
<i>Thyrsostachys</i> sp.	Rangoon bans	53/1-2	1990	Bhaluka,	Pc	
				Mymensingh		

N.B: Off = offset, Pc = Part clump, Sdl = Seedling, Bc = Branch cutting, FL = flowered and year of flowering
PFL = Partly flowered and year of flowering, CHT = Chittagong Hill Tract, CTG = Chittagong, SYL = Sylhet

6.0 SUMMARY AND CONCLUSION

Biological studies

In the present investigation altogether 17 species of bamboos (7 naturally grown and 10 cultivated) under 5 genera have been taken into consideration.

Muli bans (*Melocanna baccifera*) is the most common bamboo species naturally growing in the forest. Other species -- mitinga (*Bambusa tulda*), orah (*Dendrocalamus longispathus*), dalu (*Neohouzeaua dullooa*), and kali (*Oxytenanthera nigrociliata*) also occur sporadically either in association or in isolation forming small patches of pure vegetation. The lata bans (*Melocalamus compactiflorus*) and peecha bans (*Dendrocalamus hamiltonii*) are localized only in limited areas of Chittagong and Sylhet forest respectively. These two species, due to intensive biotic interference, have become threatened in Bangladesh forest. Bamboo do not grow naturally in the pure sal (*Shorea robusta*) forests and mangrove (Sundarbans) forests of Bangladesh.

Most commonly cultivated species in villages are barua or bhalku (*Bambusa balcooa*), bariala or baijja (*Bambusa vulgaris*), mahal or makla (*B. nutans*), mita or mitinga (*B. tulda*), and talla or taru (*B. longispiculata*) bans.

A bamboo clump start producing culm generally either from May or June and may continue upto 6 or 7 months ending either in October or November. Each species of bamboo has definite periodicity for culm emergence.

The total culm elongation periods for *B. balcooa* and *B. vulgaris* were observed to be 75-85 days, and 55-60 days in *Melocanna baccifera*. The culms showed maximum elongation per day in *B. balcooa* (77.0cm) and *B. vulgaris* (66.0cm), while it was comparatively low (40.0cm) in *M. baccifera*.

All emerging culms did not develop into full grown culms. The natural mortality of emerging culm was generally higher (28-69%) in thick-walled and tall species, whereas it was low (9-37%) in thin-walled and small size bamboo species. Mortality of emerging culms was higher (50-65%) in September and October when average rainfall was low. Eco-physiological conditions (clump congestion, soil moisture, food storage etc.) and genetic make up of each species and clump seem to influence the rate of mortality of emerging culms.

Internode length and ratio between wall thickness and diameter varied from species to species. The length of internode gradually increased from base to mid portion of the culm and decreased towards the tip. Among different bamboo species *Neohouzeaua dullooa* (105.0 cm), *Bambusa polymorpha* (75.0cm), and *D.longispathus* (65.0cm) have distinctly more elongated internodes in the mid-culm zones. Though *B.vulgaris* and *D.giganteus* have thick-walled culms but when ratio between wall thickness to culm diameter was considered they possessed the lower ratio values (0.206 and 0.187 respectively) than those of "thin-walled" species like *M.baccifera* (0.316), *N.dullooa* (0.237), and *Oxytenanthera nigrociliata* (0.239).

In the clumps of *B.balcooa*, *B.longispiculata*, *B.tulda*, and *B.vulgaris* production and growth (height and diameter) of full grown culm gradually increased upto 5th year of planting and after that it stabilizes or even declined. Therefore, in these species selected felling of older culms should be started after 5-7 years of planting. Similarly the clump girth expansion in these species was also rapid upto 5th and 6th year of plantation, then the rate of expansion reduced in the subsequent years. Considering the clump expansion pattern, 5m spacing between the planting stock has been suggested for these species. In *M.baccifera* both culm production and clump expansion continued upto the end of study period (10 years) with increased rate after 5th years of planting. Therefore,

spacing distance for planting could not be prescribed for this species. However height and diameter growth of the culm of *M.baccifera* were rapid upto the 4-5 years of clump age, and a culm of this species die within next 4-5 years due to aging effect. With these consideration felling in this species may not be delayed at beyond 7-8 years of planting. The life of culms in the clumps of *D.longispathus* and *O.nigrociliata* was 5-8, in *B.tulda* 5-9, in *B.polymorpha* and *M.baccifera* 5-10, in *B.longispiculata* 6-8, *D.giganteus* 10-12, and *B.balcooa* 11-13 years. Therefore the life period of individual culms was found to be an important criterion for fixing the upper limit for the felling cycle of a species.

Presence or absence of culm-sheath on the culm, culm colour and branching pattern were found to be important morphological characters for identifying the age of culm in the clump of different bamboo species.

Compared to other bamboo species of the country, both the culm emergence and rhizome neck development in *M.baccifera* took place simultaneously. The elongation of rhizome neck of *M.baccifera* was going on either slowly or actively throughout the year irrespective of seasonal variation.

Estimated range of flowering cycles of different bamboo species of the country were found to be within 20-80 years, where majority of the species have 30-50 years of cycles. Among all these species *B.balcooa* and *B.vulgaris* flowered rarely in isolated clumps and did not produce any seeds. *M.baccifera* showed distinctly gregarious flowering habit with a 10-15 years of flowering wave covering large tract of forest land. However, many different "flowering genotypes" of *B.tulda* and *D.longispathus* with short interseeding periods were found to exist in the natural stand and were collected and centralized in the BFRI Bambusetum for further studies.

The bamboo species which have flowered usually started producing floral shoots and inflorescences in the dry season

(September-February). Some clump may be complete-flowering and other may be part-flowering and take more than one year to complete the flowering. Blooming in bamboo clump was not continuous rather it occurred in three distinct successive flushes (flush period) with non-blooming periods (rest period) in between. The amount of seed production was maximum in the first flush period and gradually decreased in the subsequent flushes. Opening of flowers and pollen discharge mostly occurred in the morning 6 a.m. to 9 a.m. Bamboos showed cross-pollinating behaviour and selfing yielded less amount of seeds than crossing. A clump generally did not produce any new culm at the time of flowering.

A few seedlings of *B.tulda* flowered precociously between 12-18 months. Similarly 5 seedlings of *M.baccifera* flowered precociously at the age of 10-12 months. Among them 2 seedlings exhibited both sexual and vegetative growth simultaneously.

Partial shade conditions and occasional weeding promote successful natural regeneration of wild seedlings after each gregarious flowering in the forest. Delay in cutting operation of dead mothers at least for 9 months helped the regenerating seedlings to develop their healthy rhizome system.

Propagational studies

Seedlings could be raised successfully in polythene bags. Seeds of most of the species are short-lived, losing their viability within 1-2 months. The seed longevity of *B.tulda* could be increased upto 15 months when stored in controlled condition. Further, wild seedlings of bamboo can also be collected and successfully planted (68-70%) in both afforestation and reforestation works.

Stems of *M.baccifera* seedling were soft and had vigorous growth than those *B.tulda* and *D.strictus*. The growth

performance of different types of bamboo seedlings was best in partial shade than in direct sunlight.

In vegetative propagation 1-year old offset survived better than 2- and 3-year old offset. Success was higher (44-76%) when collected and planted in April than in June (3-38%). Thin walled species like *M.baccifera*, *N.dulloo* and *O.nigrociliata* showed poor success in offset planting. On the contrary, successful result was obtained by planting rhizome assembly (part-clump) with 2-3 offsets in these species.

Induction of *in situ* rooting and rhizome at the branch bases of different thick walled bamboo species was possible by chopping of tops of 1-year old culms as well as by continuous removal of emerging culms for 1-2 years from the clumps. These prerooted and prerhizomed branches produced maximum percentage of (60-90%) rooted and rhizomed propagules in open intermittent mist sand bed.

Seedlings were multiplied by separating the rhizome and planting them separately. The multiplication rate was 2-3 times of the initial stock and the survival percentage of multiplied seedlings were within 90-100%. The process would help in continuous annual supply of small-size transportable propagating materials for a number of years.

Only the seedlings of *B.polymorpha* produced maximum roots at the nodes of mid-culm zones and fair to poor on the nodes of lower and upper portion of culms after 45 days of ground layering in sand medium. The seedlings of *B.arundinacea* and *B.tulda* produced poor amount of roots only in the mid culm zones. *M.baccifera* did not produce any root.

In the field trials of different types of propagules, prerooted and prerhizomed branch cuttings and seedlings had a high survival percentage (71-97%) compared to those of offsets and part clumps (11-69%). At the beginning, offsets produced comparatively big size culms than those which were produced by cuttings and seedlings. However, after 3-4 years of planting,

branch cuttings and seedlings produced similar sizes of culms like those produced by offsets.

In micro-propagation studies on *Melocanna baccifera* contamination free cultures were developed by sterilizing the explants with the prior treatment of 0.1% benomyl solution, and then soaking in 0.075% mercuric chloride for 10 minutes.

The explants showed growth only on modified MS medium supplemented with 4% sucrose and vitamins of B₅ medium. Among the explant types branch nodal segments with buds sprouted (70-80%) within 7-12 days of culture supplemented 2,4-D 10 mg/l and with or without coconut milk. These explants produced plantlets after subsequent 6th transfer of culture with 25-30 days of interval. The culture survived and grew in higher concentration of growth regulators (2,4-D 10 mg/l and BAP 5.0 mg/l) after successive transfer. At the final transfer onto the medium supplemented with BAP 5.0 mg/l and NAA 1.0 mg/l the explants developed into complete plantlet with fully developed root system. The time required for the complete development of a plantlet from the branch buds was about 6-7 months from the date of first inoculation.

Immature embryo of *M.baccifera* also produced both shoot and root in 10-15 days of culture when the modified MS medium was supplemented with 2,4-D (1.0-5.0 mg/l) and BAP (0.1-3.0 mg/l). Interestingly 2,4-D or NAA produced only shoot but did not produce any root.

Germplasm conservation:

So far 33 species under 9 genera of bamboos, of which 29 identified, have been collected from different parts of Bangladesh and centralized at the Bambusetum of BFRI. Besides these 52 "flowering genotypes" of 12 bamboo species have also been recognised and are being maintained in the Bambusetum.

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*Original papers not seen.