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Abstract of the Proposal

Project Code: KFRI 414/03

Title

Development of bamboo sector in Kerala:
Resource enhancement

Objectives:

1. Establishment of Bamboo Multiplication Areas (BMA) in selected panchayaths

2. Popularisation of cultivation of bamboo in private and community lands.

Investigators: Seethalakshmi KK, Muralidharan EM, Sankar S, Pandalai RC and Raveendran VP

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Budget: Rs 20 lakhs

Funded by: Department of Industries, Government of Kerala

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Summary

Government of India has launched integrated projects which are implemented through two Missions viz., National Mission for Bamboo Applications (NMBA) under Ministry of Science and Technology and National Bamboo Mission (NBM) under Ministry of Agriculture and Cooperation for development of bamboo sector. The demand for bamboo is growing more than its production and no doubt resource enhancement is an immediate priority to support industries with sufficient raw material. Establishment of new plantations and improvement of productivity in existing areas are the two ways for bamboo resource enhancement. While establishing new plantations, focus is given for planting in forest and non-forest areas equally.

These projects were undertaken with the support from Department of Industries, Government of Kerala with the major objectives of enhancing the bamboo resources in the State and to increase the awareness about bamboo and its potential among different stakeholders of the bamboo sector.

As a first step, species suitable for growing in Kerala was identified, protocols for propagation using seed and vegetative methods were standardized, one commercial nursery and two satellite nurseries for large-scale production of planting stock was established and about one lakh plants were produced.

The planting programmes were implemented through collaboration with local bodies, farmers, institutions and NGOs. Twenty Panchayaths were provisionally identified, meetings were held in State Planning Board and respective panchayaths and participating farmers/institutions/NGOs were identified through these meetings. KFRI distributed the planting materials to panchayaths and panchayaths had undertaken the responsibilities for identification of potential planters and establishment of plantations. KFRI also conducted awareness programmes in all the panchayaths selected.

A technical seminar was organized on Integrated Development of Bamboo Sector in Kerala during Kerala Bamboo Fest. Invited resource persons from various organizations presented seventeen papers on relevant topics for the development of bamboo sector which was an eye opener about the immense scope for bamboo as an industrial raw material and methods for value addition.

During the second year (2004), Tsunami hit Kerala coast and different rehabilitation programmes were launched by the Government. Out of these

mitigation measures to reduce the impact of wind and waves received a lot of priority. Establishment of coastal vegetation (bio-shield) was one of the proven mitigation measures for this purpose. The possibilities of including bamboo in the bio-shield were investigated. About one kilometer length was planted with seven bamboo species and preliminary observations revealed that behind the salt tolerant species like *Casuarina*, bamboo can be planted.

Since bamboo flowering occurs at long interval and most often it is unpredicted no proper documentation is made on this aspect. About four species flowered during this period and observations on reproductive biology and post flowering behaviour could be made. Also some of the areas where flowering occurred previously were revisited and the status of regeneration could be assessed. Although not envisaged in the project, considering the value of this data it is included under appendix.

In short, the project intervention helped to establish demonstration plots in private lands and motivated farmers to take up bamboo cultivation. Technical seminars and interaction meetings increased the awareness about bamboo plantations, harvest and post-harvest techniques and value addition among public. The details of flowering, post-flowering behaviour and status of natural regeneration in the areas where flowering occurred could be documented for future reference.

GENERAL INTRODUCTION

Since the time immemorial, bamboo has been a part of human life due to its versatility which made it a good raw material for many applications. Over 80 per cent of the total area covered by bamboo is located in Asia, 10 per cent in Africa and 10 per cent in America. In Asia, India is one of the major bamboo producing countries (almost 11.4 million ha) which accounts for roughly half of the total area of bamboo reported from Asia. There are different reports on the number of genera and species of bamboos. As per the latest compilation 18 genera and 128 species has been reported from India (Seethalakshmi and Kumar, 1998). Later about six new species were added during the resource surveys conducted by KFRI. Kerala is one among the major diversity centers of bamboo in the country and 34 species of bamboos under seven genera have been recorded from this area. This comes to about 20 per cent of the total bamboo distributed in India and 95 per cent of the total species reported from peninsular India (Kumar and Ramesh, 1999). In addition to forest land, bamboo is found in homesteads also. As per the latest estimate (2004-05), the total standing crop of bamboo in homesteads is 13.61 million culms and its green weight was 0.331 million tonnes (Muraleedharan et al., 2007).

Bamboo is a viable replacement for wood and is one among the strongest and oldest building materials ever used. Application of scientific and engineering skills on bamboo has led to an extended diversity of products ranging from domestic household items to industrial applications and generates income and employment. It contributes substantially to the ecological, economic and social development. Ecologically, bamboo plays a critical role in soil and water conservation, the balance of oxygen and carbon dioxide in the atmosphere, lowers light intensity and protects against ultra violet rays. The inherent ability of different bamboo species to grow on marginal and wastelands makes it one of

the preferred crops for greening the wastelands and degraded sites resulting in conservation of soil moisture and resulting in carbon sequestration.

The employment potential of bamboo is very high and the major work force involved is rural poor, especially women. In India, recently a rediscovery of the potential of bamboo for developing it as one of the sunrise industries resulted in launching of an integrated bamboo development programme by the Prime Minister on World Environment day - June 5, 1999 with a view to focus on the development of bamboo sector. Subsequently the Planning Commission, Government of India prepared an Action Plan to give maximum emphasis for promotion and development of bamboo during the Tenth plan. Two bamboo Missions viz., National Mission for Bamboo Applications (NMBA) under Ministry of Science and Technology and National Bamboo Mission under Ministry of Agriculture and Cooperation were established in 2003 and 2006 respectively. One of the mandates of NBM is enhancement of bamboo resources through establishment of new plantations and improvement of productivity in existing areas. To establish new plantations, focus is given for forest and non-forest areas equally with a target of 1,72,000 hectares. The demand for bamboo is growing more than its production and no doubt cultivation of bamboo in large scale is an immediate priority to support the developing industries with sufficient raw material. Lack of seed and/or other types of propagules could be a limiting factor for the establishment of large - scale commercial plantations.

During last three decades, Kerala Forest Research Institute (KFRI) had been involved in Research and Development (R&D) activities and substantial information has been generated on species available in Kerala, species suitable for cultivation, nursery and plantation techniques, harvest and post-harvest technologies, ecological and economic aspects. Through an extension project viz., resource enhancement and processing of cane and bamboo species suitable for handicrafts, KFRI addressed promotion of organized cultivation in private lands

and transfer of necessary technologies. A couple of workshops were organized with different stakeholders like policy makers, sponsors, farmers and R&D institutions to achieve this goal. In the recommendations made during the interaction meeting organized at Thiruvananthapuram in June 2002, necessary steps for developing the bamboo sector in Kerala were made. KFRI was given the responsibility of taking necessary follow up actions. To enhance the resources by establishment of new plantations in the non-forest areas, a project was given to KFRI with the following objectives.

1. Establishment of Bamboo Multiplication Areas (BMA) in selected panchayaths
2. Popularisation of cultivation of bamboo in private and community lands.

During the project period three nurseries were established viz (1) in the campus of KFRI Field Research Centre (FRC), Velupadam (2) in collaboration with a farmer at Kanjirapuzha, Palakkad; and (3) in association with Kerala Bamboo and Reed Workers Society at Paruthipally, Thiruvananthapuram. Provisionally eighteen Panchayaths were selected and an awareness meeting was held at Kerala State Planning Board, Thiruvananthapuram. Detailed training programme was conducted in 10 selected Panchayaths. Protocol for seed and vegetative propagation of commercially important species was developed in the pilot nursery at FRC, Velupadam. Planting materials of about 15 commercial species were distributed to selected farmers. Technical seminar on bamboo development in the State was organized along with Kerala Bamboo Fest at Cochin and different resource persons threw light on bamboo cultivation, value addition and policy aspects. Since Tsunami occurred during the project period, i.e, in 2004 December, possibility of using bamboo in the bio-shield programmes was also attempted in the Munackal, Eriyad panchayath of Thrissur District. The details are provided in this report.

1. Development of protocol for propagation and production of planting stock in bulk

1. Development of protocol for propagation and production of planting stock in bulk

Abstract

During 2003-05, profuse flowering and seed formation was observed in three priority species (*Bambusa tulda*, *Melocanna baccifera* and *Ochlandra travancorica)*. Flowering of *Bambusa tulda* (Bengal bamboo) was observed in KFRI Bambuseta at two locations, Nilambur (Malappuram District) and Velupadam (Thrissur District) during 2003-04. The mother clumps were collected from Assam. Flowering of *M. baccifera* occurred in Tripura and *O. travancorica* in Kerala during the same period. In *B. tulda*, flowering, post flowering behaviour, seed characteristics, seedling production and influence of growth regulators on seed germination and macro-proliferation were studied. Synchronous flowering with profuse seed production and death of flowered clumps after seed set was observed. Seeds showed an initial germination of 64.5 per cent. The macro-proliferation was successful and the tillering capacity of seedlings was 3-5 times. Treatments with growth regulators such as GA and NAA enhanced the germination percentage and IBA and NAA enhanced the vigour of proliferated seedlings.

A comparative study of *M. baccifera* (species introduced from North East) and *O. travancorica* (endemic to Southern India) on seed and seedling attributes was attempted for six months. In *M. baccifera* there was large variation between seeds in size and shape than that of *O. travancorica* and on an average seeds of *M. baccifera* was seven times larger. Growth and biomass accumulation of *M. baccifera* was higher than that of *O. travancorica.* Both the species contained high moisture at seedling stage. There was no significant difference in the Relative Growth Rate (RGR) of two species, while Net Assimilation Rate (NAR) was different and *M. baccifera* had higher NAR. Although *M. baccifera* showed better

performance than *O. travancorica* at nursery stage, field evaluation of both the species is necessary before introducing *M. baccifera* to Kerala on a large-scale.

Protocols for vegetative propagation are essential for many commercial species since seeds are not reported so far. Experiments were conducted for the priority species in three genera, *Bambusa*, *Dendrocalamus* and *Thyrsostachys* to standardize vegetative propagation methods using culm and branch cuttings.

Effect of position of node and growth regulating substances on root induction of culm cuttings of four species belonging to the genus *Bambusa* (*B. nutans, B. polymorpha, B. striata, B. vulgaris*) were observed. Three-noded cuttings were prepared from the basal, middle and top portions of the culm and treated with 0, 100 and 200 mg/l of IBA and NAA. Rooting response varied and a maximum rooting of 86.43 per cent was observed in B. *vulgaris*, followed by 80 per cent in *B. striata,* 67 per cent in *B. nutans*, and 59.33 per cent in *B. polymorpha*. A higher rooting percentage was recorded for basal and middle cuttings in B. *nutans* and basal cuttings in *B. polymorpha.* Cuttings from all three portions were rooted in *B. vulgaris* and B. *striata.* Application of growth regulators enhanced the rooting response of cuttings. The application of NAA gave better rooting in *B. nutans* and *B. striata* while IBA was found better for *B. polymorpha* and *B. vulgaris*. Clustering of the different treatments identified the basal cuttings of *B. nutans* treated with NAA 200 ppm, middle cuttings of *B. striata* treated with IBA 100 ppm and the basal cuttings of *B. vulgaris* treated both 100 and 200 ppm of IBA and NAA as the superior in sprouting and rooting attributes. The selection of the cuttings based on position of node and application of proper concentration of growth regulating substances can be resorted for ensuring efficient rooting and cost-effective planting stock production.

Influence of the position of the node and different concentrations of IBA on the root induction in culm cuttings of five species of the genus *Dendrocalmus* (*D.*

asper, *D. giganteus*, *D. longispathus, D. membranaceus* and *D. stocksii)* was studied. Three-noded cuttings were prepared from the basal, middle and top portion of the culms and treated with 0, 100 and 200 ppm of IBA. The highest rooting percentage was obtained in basal cuttings treated with IBA 200 ppm in *D. asper*, those from top portion of the culm treated with IBA 100 ppm in *D. giganteus*, from basal cuttings treated with IBA 200 ppm in *D. longispathus,* those from the top cuttings treated with IBA 200 ppm in *D. membranaceus* and those from basal portion of the culm treated with IBA 100 ppm in *D. stocksii.* The interaction effects of species, position of the node and IBA treatment was significant at 5 per cent level.

Using culm cuttings of two species of the genus *Thyrsostachys (T. oliveri* and *T. siamensis*), effect of position, growth regulators and concentration were observed. Although profuse sprouting was observed in all the treatments of both the species, wilting of sprouts occurred within a month and rooting was not observed in any treatment.

Materials and Methods

Production of Seedlings and assessment of performance at nursery stage

1. ***Bambusa tulda, Melocanna baccifera*** **and** ***Ochlandra travancorica***

Seed collection and processing: Seeds of *M. baccifera* were collected and air lifted to Cochin from CIBART, Tripura during May 2004. Seeds of *O. travancorica* were collected from Neriamangalam, Kerala during the same period. One clump each of *B. tulda* located in the bambuseta at Nilambur, and Veluppadam, flowered during 2003-2004. The seeds from clumps were collected by clearing the ground and spreading tarpaulin under the clump. All the seed samples were brought to the nursery and mixed thoroughly to improve the homogeneity.

Seed characteristics and seedling production: Seed weight and the moisture content (on fresh weight basis) of hundred seeds were determined for all the three species and it was replicated ten times. From each seed lot, 25 seeds were collected at random to determine the individual seed characters like seed weight, width and total seed length. The seeds were germinated in the standard nursery beds at the KFRI-FRC, Veluppadam. The germinated seeds were transplanted to polythene bags (9" x 7" of gauge 250 mm). The seedlings were kept in the nursery for six months and they were irrigated daily except on rainy days. At the end of 60, 120 and 180 days after poly potting, 25 seedlings were randomly collected to record seedling characters.

Seedling attributes and dry matter accumulation: For *M. baccifera* and *O. travancrocia* the height of the seedlings was recorded from the tip of growing point to collar region. The number of tillers and leaves of the seedlings was counted. The leaves were detached from the plants and its area was recorded quickly using an area meter (Model LI 3100 LI-Cor, Nebraska, USA). The moisture content of the seedlings was determined by oven dry method and was

expressed as a percentage of dry weight. The leaves, shoots, roots and rhizomes were dried separately in hot air oven maintained at 75^{o} C±2^{o} C to a constant weight and the dry weight was determined using an electronic balance. From this the total dry weight was calculated.

Specific leaf area of the seedlings was calculated as by dividing total leaf area by leaf dry weight per plant and the average value was expressed in cm^{2} per g. Root- shoot ratio of the seedlings was calculated by dividing the average value of root weight by shoot weight of each plant (Hunt, 1990).

Relative Growth Rate and Net Assimilation Rate: The RGR for *M. baccifera* and *O. travancorica* was calculated from the formula given below (Hunt, 1990).

$$RGR = \frac{Log_e W_2 - }{Log_e W_1}$$

W_1= dry weight estimate at time t_1

W_2 = dry weight estimate at time t_2 and it was expressed in g g^{-1} $month^{-1}$

NAR is an index of the productive efficiency of plant calculated in relation to the total leaf area. NAR was calculated from the formula given below (Hunt 1990):

$$NAR = \frac{(W_2-W_1)\,(\log_e LA_2 - \log_e LA_1)}{(LA_2-LA_1)\,(t_2-t_1)}$$

where, W_2 = dry weight at time t_2

W_1= dry weight at time t_1

LA_2 = leaf area at time t_2

LA_1= leaf area at time t_1 and it was expressed in g cm^{-2} $month^{-1}$

Statistical analysis: Data collected for each variable were analyzed for comparing between species and between growth stages. Univariate repeated ANOVA was used for analyzing each variable. Least Significant Difference (LSD)

was used for pair wise comparison whenever necessary. Transformations were done wherever necessary.

Bambusa tulda: Observations were made on nature of flowering and post flowering behaviour of these clumps. Seed weight and seed characteristics were recorded as per the procedure given above.

To find out the influence of growth regulators on the germination, the seeds were treated with 0, 5, 10, 15 ppm of GA 3 (Gibberillic acid) and NAA (Naphthalene Acetic Acid) solutions overnight. Fifty seeds each in three replications for each treatment were sown in polyurethane sheets and the daily germination was recorded. The percentage and speed (Peak Value) of germination and Germination Value (GV) were calculated (Czabator ,1962).

Another set of 3000 seeds were kept for germination in the standard nursery beds under shade nets (50 %) and the seedlings emerged were poly-potted (9″x 7′″ guage 250) in medium soil, sand and cow dung in the ratio 3:1:1 in the nursery and irrigated daily. After six months the seedlings were subjected to macroproliferation (Banik, 1987). In this method, the individual tillers with some part of rhizomes and roots of bamboo seedlings are separated and the individual propagules are planted. The seedlings selected for macro-proliferation were uniform in growth having a height of 35-40 cm and 3-5 tillers. The seedlings from poly bags were uprooted with root system intact and the roots and rhizomes were gently washed to remove the soil without damage. The culms were separated by cutting rhizomes with secature so that each individual includes equal amount of roots, old and young rhizome and rhizome buds. The seedlings were separated and roots were dipped overnight in a solution containing the 0, 100 and 200 mg/l NAA and IBA (Indole Butyric Acid). The plants were transplanted in polythene bags containing the medium soil, sand and cow dung in the ratio 3:1:1. They were kept in the shade and watered regularly. Six

seedlings per treatment were uprooted at an interval of 30, 45, 60 and 90 days after planting to record the height and number of new tillers, number and length of the roots and root dry weight.

Vegetative propagation

Source of mother clumps: The mother clumps for taking culm cuttings were selected from the healthy clumps of 11 species grown in KFRI-FRC Bambusetum, Velupadam(Table1). This includes four species of *Bambusa,* five species of *Dendrocalamus* and two species of *Thyrsostachys*. All the mother clumps were more than 15 years old after planting in the bambusetum.

Table 1. List of bamboo genera and species used for vegetative propagation

Bambusa	***Dendrocalamus***	***Thyrsostachys***
1. B. nutans	*5. D. asper*	*10. T. oliveri*
2. B. polymorpha	*6. D. giganteus*	*11. T. siamensis*
3. B. striata	*7. D. longispathus,*	
4. B. vulgaris	*8. D. membranceus*	
	9. D. stocksii	

Experiments for root induction: The experiments were conducted at KFRI-FRC, Veluppadam, Thrissur, Kerala, during December 2006 to May 2007. The study area is located at 10^{o} 26′ 31″ North latitude and 76^{o} 21′ 36.9″East longitude. The area is gently undulating with an elevation of 40 msl. The soil was loamy sand and slightly acidic. The collected culms were measured and divided equally into bottom, middle and top portions and three-noded cuttings were prepared from each portion of the culm. Cuttings were treated with two concentrations (100, 200 mg/l) of NAA (Naphthole Acetic Acid, make SRL) and IBA (Indole Butyric Acid,

make Merk) along with a control, without growth regulating substance by cavity method of treatment (KFRI, 1990). A hole was made in the centre of the internode to provide an opening to the cavity and about 100 ml of the growth regulating substance was poured into the cavity. The hole was sealed with a polythene strip (KFRI, 1990). Fifteen nodes constituted one treatment and it was replicated thrice. The treated cuttings were laid on standard propagation beds and planted horizontally in trenches of sufficient depth to allow them to be covered at least 2.5 cm deep soil. The propagation beds were provided with 50 per cent shade using green shade nets. It was uniformly watered twice daily for the initial two months and then at an interval of two days except on rainy days. Water logging was completely avoided. The sprouted cuttings were uprooted after six months and observations were made on number and height of sprouts, rooting percentage, number and length of roots.

Statistical analysis: Bartlett's test of sphericity on the matrix of correlation coefficients among the variables (sprouting and rooting attributes) was significant at 1 per cent level (χ^2 = 327.384) indicating the suitability of Factor analysis to the present data. Hence, a Factor analysis was conducted using SPSS (Norusis, 1988). Since the *T. oliveri* and *T. siamensis* failed to root they were not included in the data set. Factor analysis allowed numerous inter-correlated variables to be condensed into fewer dimensions, called factors (Hair et al, 2005). Principal component analysis was the method of factor extraction and the factors were subjected to oblique rotation with Kaiser Normalisation (Kaiser, 1958) using direct OBLIMIN option. Factor scores were subjected to analysis of variance (ANOVA). To find the best species, position and treatment combination, a cluster analysis was carried out using average linkage method and squared Euclidian distance as distance measure (Hair *et al*., 2005) taking the treatment combinations as entities and sprouting and rooting parameters as characters to find the best treatment combination. The individual effect of position of the node in rooting

attributes of different bamboo species was assessed by calculating the average values irrespective of the growth regulator treatment and the means were compared against 'LSD' (least significant difference). Similarly, the influence of the growth regulating substances on rooting attributes of different bamboo species was also assessed.

Results

Seed and seedling production

Melocanna baccifera and *Ochlandra travancorica*

Seed attributes: The seeds of *M. baccifera* were large and green in colour (Fig 1. a). Individual seeds weighed 119.67(± 58.55) g and recorded a total length (including the beak) of 7.10 (± 3.40) cm, seed length of 5.69 (±2.91) cm and width of and 4.56 (±1.31) cm. Its average moisture content was 60.79 (± 9.91) per cent. Seeds of *O. travancorica* (Fig 1. b) were also green in colour but smaller in size compared to that of *M. baccifera*. A single seed weighed 12.61 (± 5.71) g and it recorded a total length of 8.27 (±1.32) cm, seed length of 4.24 (±0.80) cm and width of 1.15 (±0.21) cm. The moisture content of the seeds was 69.22 (±3.76) per cent (Table 2).

The apex of the seeds of both the species was terminating in a curved beak. The beak length of *O. travancorica* seeds was found to be larger and it was slender (more pointed) compared to *M. baccifera* (Fig 1. a & b). Weight of individual seeds in seed lot of *M. baccifera* and *O. travancorica* was found to be highly variable. The hundred seed weight of *M. baccifera* was in the tune of 11.38 (±6.10) kg and that of *O. travancorica* was 1.70(±0.57) kg. Significant variation (at one percent level) was observed in seed weight, seed length, seed width and hundred seed weight between the species (Table 2).

Fig. 1 a. Fruits of *M. baccifera* and b. *O. travancorica*

Table 2. Seed attributes of the *M.baccifera* and *O. travancorica*

Species	Seed wt. (g)**	Total length (cm)ns	Seed length (cm)	Seed width (cm)**	Moisture content (%)	100 seed weight (kg)**
M. baccifera	119.67b	7.10	5.69 b	4.56 b	60.79	11.38 b
O. travancorica	12.61a	8.27	4.24 a	1.15 a	69.22	1.70 a

** = significant at 1% level; ns = not significant

Seedling attributes: A comparison of the values for six months (180 days) after poly-potting indicated that seedlings of *M. baccifera* reached a height of 2.54 meters while that *O. travancorica* was only 0.81 meter showing a 3.1 fold difference (Fig 2. a & b). Capacity for tillering of both the species appeared similar reaching a mean of 2.2 in the former and 2.4 in the latter. *M. baccifera* produced more than 18 leaves while *O. travancorica* had only 11 leaves. Leaf area of both the species also differed considerably with *M. baccifera* having a leaf area of 407 cm^2 and O. *travancorica* with only 82 cm^2 (Table 3).

One per cent of the seedlings of *M. baccifera* were albinos. Two types, complete white and white with green stripes were observed among albino seedlings (Fig. 3 a and b). Some of the latter turned to green within a period of one month. Occurrence of albino seedlings was less than 0.5 per cent in *O. travancorica.* Analysis of variance indicated that there is significant variation between two species and between three stages of growth (60, 120 and 180 days) with regard to height, number of leaves and leaf area. Number of tillers of the species significantly varied at the third stage of growth only (Table 3).

Fig 2 a. seedlings of *O. travancorica* and b. *M. baccifera* seven months after poly-potting

Table 3. Seedling attributes of the *M. baccifera* and *O. travancorica*

Seedling attributes	Species	Days after polypotting			Mean
		60	120	180	
Height (m)	*M. baccifera*	1.23	2.02	2.54	1.93^{B}
	O. travancorica	0.43	0.70	0.81	0.67^{A}
	Mean	0.83^{c}	1.36^{b}	1.68^{a}	
Number of tillers	*M. baccifera*	1.13	1.67	2.20	1.67
	O. travancorica	1.33	1.93	2.40	1.89
	Mean	1.23^{c}	1.80^{b}	2.30^{a}	
Number of leaves	*M. baccifera*	7.07	11.60	18.20	12.29^{B}
	O. travancorica	4.27	7.27	11.60	7.71^{A}
	Mean	5.67^{c}	9.43^{b}	14.90^{a}	
Leaf area (cm^2)	*M. baccifera*	198.13	211.76	407.66	300.47^{B}
	O. travancorica	52.38	65.97	82.26	66.87^{A}
	Mean	125.26^{c}	138.86^{b}	244.00^{a}	

Seedling attributes with same superscript do not vary significantly.

Fig 3. a. Occurrence of albino seedlings of *M. baccifera* b. a close-up of one albino seedling with green stripes

Biomass accumulation and moisture content: Both species showed prominent difference in the accumulation of biomass in root, shoot, rhizome and leaves. In all the parameters *M. baccifera* showed higher values than *O. travancorica* (Table 4). After a period of six months total biomass was 83.20 g in *M. baccifera* while in *O. travancorica* it was only 8.10 g. Similarly, the values in shoot were 46.87 and 2.99, in leaf 22.7 and 2.83, in root 5.93 and 1.98 and in rhizome 8.13 and .03 in *M. baccifera* and *O. travancorica* respectively. The difference was significant statistically with regard to species, stages of growth and the interaction between species and stages of growth (Table 4).

Seedlings of both *M. baccifera* and *O. travancorica* contained high moisture. On an average, at the end of the observation period (six months) the moisture content of the leaves, shoot, root and rhizome of the former were 168.25, 253.61, 359.25 and 559.33 per cent respectively and 212.84, 288.27, 283.10 and 440.32 per cent respectively for the latter (Fig. 4). The difference was significant statistically between two species and different stages of growth. The interaction between species and stage of growth was also found significant.

Table 4. Biomass accumulation of *M. baccifera* and *O. travancorica* seedlings

Seedling characters	Species	Days after poly-potting		
		60	120	180
Total dry weight (g)**	*M. baccifera*	19.69	84.03	83.20
	O. travancorica	2.90	4.53	8.10
Shoot dry weight (g)**	*M. baccifera*	6.67	36.97	46.87
	O. travancorica	0.62	1.37	2.99
Leaf dry weight (g)**	*M. baccifera*	7.47	21.83	22.27
	O. travancorica	1.29	1.77	2.83
Root dry weight (g)**	*M. baccifera*	4.40	15.73	5.93
	O. travancorica	0.98	1.12	1.98
Rhizome dry weight (g)**	*M. baccifera*	1.15	9.50	8.13
	O. travancorica	0.02	0.25	0.31

** indicates that the interaction between species and growth stages was significant at 1 % level

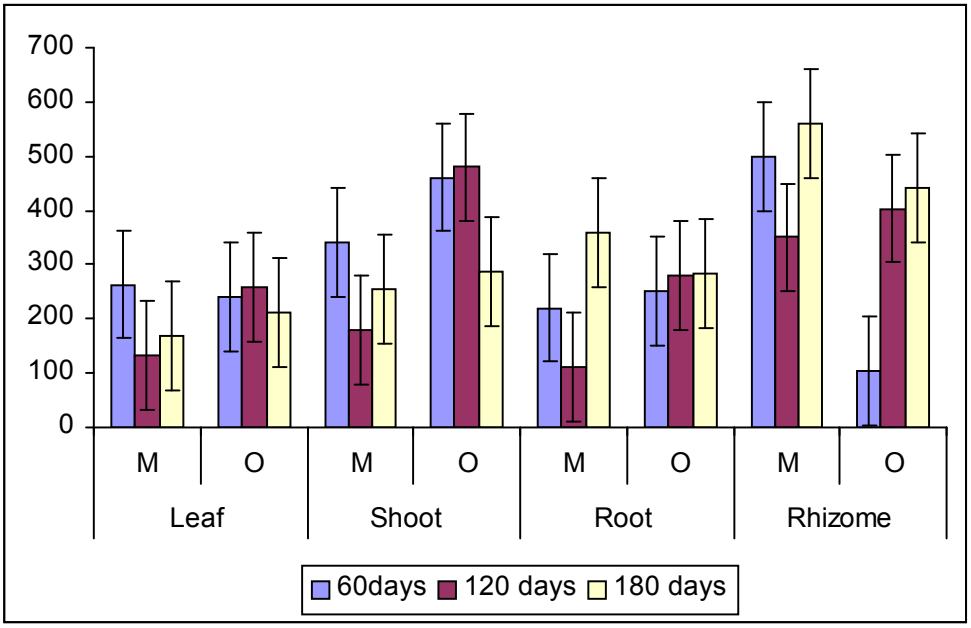


Fig. 4. Moisture content of *M.baccifera* and *O. travancorica seedlings*

Specific leaf area and root shoot ratio: The specific leaf area (the leaf area per unit leaf dry weight) was higher in seedlings of *O. travancorica* than that of the *M. baccifera* at all three stages of growth. The variation became less prominent at six months (27.88 and 41.74 at 60 days and 21.88 and 29.00 at 180 days). The interaction between species and duration was significant for specific leaf area (Table 5). But significant interaction effects were absent in root- shoot ratio and it varied significantly between the species. Similarly higher root- shoot ratio was observed for *O. travancorica* than *M. baccifera.* The values being 1.77 and 1.28 at 60 days, 1.72 and 1.20 at 120 days and 1.81 and 1.54 at 180 days for *O. travancorica* and *M. baccifera* respectively (Table 5).

Table 5. Specific leaf area (cm^2 g^{-1}) and root: shoot ratio of *M.baccifera* and *O. travancorica* seedlings

Seedling attributes	Species	Days after poly-potting			Mean
		60	120	180	
Specific leaf area **	*M. baccifera*	27.88	10.13	21.88	
	O. travancorica	41.74	39.97	29.00	
Mean					
Root: shoot ratio	*M. baccifera*	1.28	1.20	1.54	1.37 A
	O. travancorica	1.77	1.72	1.81	1.77B
Mean		1.59	1.45	1.68	

Seedling attributes with same superscript do not vary significantly.

Relative Growth Rate (RGR) and Net Assimilation Rate (NAR): The value of RGR (the dry mass increase per unit mass per unit time) of *M. baccifera* for the entire study period was 0.327 g g^{-1} $month^{-1}$ and that of *O. travancorica* was 0.252 g g^{-1} $month^{-1}$, which does not differ significantly. However, NAR (the accumulation of plant dry weight per unit leaf area per unit time) differed significantly at one per cent level.NAR of *M. baccifera* was 0.751 g cm^{-2} $month^{-1}$ and that of *O. travancorica* was 0.313 g cm^{-2} $month^{-1}$ (Table 6).

Table 6. Relative growth rate and Net Assimilation Rate of *M. baccifera* and *O. travancorica* seedlings

Seedling characters	Species	
	M. baccifera	*O. travancorica*
RGR	0.327	0.252
NAR	0.751[a]	0.313[b]

Bambusa tulda

Flowering and post flowering behaviour: *B. tulda* was planted during 1985 in Bambusetum at Nilambur through the offsets collected from Assam. From this

clump it was transplanted to the Bambusetum at Velupadam in 1992. In both locations, flowering started in 2003 and continued during 2004. Reports from Assam also indicated that flowering is also observed in the areas from where the offset collection was made. During the first year, flowering was observed only in two culms appearing as sporadic flowering (Fig. 5) and during the second year all the culms in the clumps flowered. Abundant seed production was observed in both the years. Flowered clumps dried completely within two years after seed set. Good natural regeneration was observed under the flowered clumps through germination of seeds.

Flowering history: Flowering cycle is reported to vary from 30-60 years. It flowers gregariously over considerable areas. The perusal of flowering history did not give any clue to conclude the flowering cycle of the species in the present area (Table 7).

Seed attributes: The seeds of *B. tulda* were like wheat grains and 100 seeds weighed 1.41 ± 0.04 g. The length and width of the seeds were 1.22 ± 0.18 cm and 0.25± 0.04 cm respectively. Seeds linear to oblong covered with glumes. Moisture content of the seeds ranged from 23 to 27 per cent.

Effect of plant growth regulators on germination of seeds: Generally, the treatment with growth regulators enhanced the germination of the seeds. A maximum of 72.66 per cent of germination was observed. The seeds treated with GA3 5 mg/l (T5) gave the maximum germination which was followed by GA3 10 ppm, T 6 (68.66%). The seeds kept as the control also showed a higher germination (65.34%). All other treatments did not enhance the germination rates above the control. The difference in germination percentage of the seeds due to different concentrations of growth regulators was significant at one per cent level ($p = 0.01$). Highest speed of germination was obtained for the seeds treated with GA3 10 mg/l (T 6) and lowest in the seeds treated with GA3 25 ppm (T 7). The

Fig 5. Initiation of flowering in the clump of *B. tulda* at FRC, Velupadam. Plastic sheet spread over the cleared ground for easy collection of seeds

highest germination value was obtained for the seeds treated with NAA 05 ppm (Table 8).

Table 7. Flowering history of *Bambusa tulda*

Year	**Locality**	**Reference**	**Remarks**
1886, 1910 and 1929-31	Chittagong, Sylhet Division, Patia Range, Assam	Baruah, 1930 Coffey, 1931 and Seethalaksmi and Kumar, 1998.	Gregarious flowering was followed by the seed production
1867-68, 1872, 1884, 1919, 1930 and 1936	Bengal	Seethalaksmi and Kumar 1998	Information compiled from literature
1963-65	Cachar, Assam	Gupta,1972	Description on occurrence of flowering
1977-79	Mizoram	Mohanram and Harigopal , 1981.	The previous flowering during 1880-84 and 1928-29 from forest records.
1986	Dehra Dun	Seethalaksmi and Kumar 1998	
1994	Tripura	Records of the Government of Mizoram	
2003	West Bengal and Arunachal Pradesh.	Bhattacharya et al. 2006 & Forest records of Arunachal Pradesh	Sporadic flowering
2008	North eastern states	Nautiyal et al. 2008.	

Table 8. Effect of GRS on germination of seeds

Treatment	Germination percentage	Speed of germination	Germination value
Control - T1	65.34	14.33	1.79
NAA 05 - T2	45.34	12.11	3.46
NAA 10 - T3	42.00	14.00	2.67
NAA 25 -T4	54.66	12.33	2.35
GA3 5 -T5	72.66	8.78	1.75
GA3 10-T6	68.66	17.11	0.95
GA3 25 -T7	28.00	6.22	0.78

Effect of plant growth regulators on macro-proliferation: Generally, the macro proliferated propagules treated with growth regulators performed higher compared to that of control. Maximum number of tillers per seedling was obtained in the propagules treated with IBA 50 ppm (1.67) followed by those treated with NAA 200 mg/l (1.33). The propagules treated with IBA 50 mg/l (9.67 cm) followed by IBA 100 mg/l (8.67 cm) recorded maximum height. Seedlings with the largest number of roots were obtained from propagules treated with IBA 100 mg/l (7.67) followed by NAA 50 mg/l (6.33). The least number of roots occurred on those kept as control and treated with NAA 100 mg/l (2.67). The highest root length was observed in propagules treated with IBA 200 mg/l (19.3 cm) followed by those treated with IBA 50 mg/l (16.67 cm). Highest root biomass was observed in seedlings treated with IBA 100 mg/l (0.29 g) followed by those treated with IBA 200 mg/l (0.25 g). In general the growth regulator IBA was more effective in root induction than NAA (Table 9). Statistical analysis of the data revealed no significant variation in seedling parameters due to individual effect of growth regulator treatments and different periods. The interaction effects of frequency of observation and treatments were significant in the case of number of roots ($p=0.05$) and root length ($p=0.01$) only.

Table 9. The variation in the sprouting and rooting attributes of macro-proliferated propagules in response to GRS.

Treatments		Control	NAA (ppm)			IBA (ppm)		
Characters/ Days after planting			50	100	200	50	100	200
New tillers	30	0	0	0.67	0	0.33	0	1.33
	45	0.67	1	0	0	0	1	0.33
	60	1.33	1.33	0.33	0.67	0.67	1	1
	90	0.60	0.67	1	1.33	1.67	0.67	0.67
Height of the new tillers (cm)	30	0	0.00	4.60	0.00	0.5	0	0.63
	45	1.73	1.87	0.00	0.00	0	2.47	0.17
	60	1.03	1.97	0.40	1.03	0.93	5.53	0.18
	90	1.06	2.73	4.70	5.73	9.67	8.67	1.73
Root number	30	2.67	3.00	3.33	5.00	19.33	6.00	6.33
	45	1.33	6.00	9.33	5.67	5.67	7.33	8.00
	60	2.33	4.00	5.67	5.00	5.33	5.33	23.33
	90	2.67	6.33	2.67	5.67	5.67	7.67	3.00
Root length (cm)	30	7.5	9.30	10.27	20.87	14.47	13.80	14.13
	45	8.8	15.03	18.50	19.47	11.57	13.03	19.60
	60	8.9	14.27	7.93	13.70	7.27	17.40	9.87
	90	7.5	8.63	8.77	17.70	16.67	14.73	19.13
Root dry weight (g)	30	0.05	0.05	0.09	0.04	0.22	0.06	0.14
	45	0.02	0.04	0.03	0.01	0.07	0.04	0.13
	60	0.02	0.03	0.09	0.05	0.04	0.08	0.10
	90	0.03	0.04	0.04	0.15	0.04	0.29	0.25

Development of protocol for macro-propagation

***Bambusa* species**

Factor analysis identified two factors of which first factor explained 51.99 percentage of the total variance and second factor accounted for only 16.45 per cent (Table 10). In the present analysis, more than 85 per cent of the variance in sprout height, rooting percentage and root length and more than 50 per cent variance in number of sprouts were explained by the first factor. Hence, ANOVA of the factor scores for factor one was carried out and the result is presented in Table 11. The interaction effects species x position of the node (p=0.01), species x growth regulating substance (p=0.01) and species x position of the node x growth regulating substance (p=0.05) were significant (Table 12).

Table10. Factor structure matrix and communalities after extraction of the rooting and sprouting attributes of different bamboo species

Variables	Loadings of Factor 1	Loadings of Factor 2	Communalities after extraction
Number of sprouts	0.511	-0.192	0.298
Sprout height	0.910	0.057	0.831
Rooting percentage	0.858	0.149	0.758
Root number	0.882	0.039	0.780
Root length	0.029	0.977	0.956
Percentage of variance explained	51.988	16.445	

Effect of position of the node on the rooting attributes of the bamboo species

In *B. nutans*, the average rooting was higher from the basal (41.87 %) and middle cutting (46.20 %) and it was significantly different from top cuttings (20.13 %). The highest number of roots (44.01) was obtained from the basal cutting which was significantly higher compared to other parts. Basal cuttings produced

significantly higher rooting in *B. polymorpha* (42.13 %) which was 3.27 and 7.90 times more compared to middle and top cuttings respectively (Table 12).

Table11. ANOVA of the factor structure matrix for the factor 1

Source	Degrees of freedom	Mean square	F value
Species	3	15.89	37.55**
Replication	2	1.25	0.128
Error1	6	0.42	
Position of the node	2	18.69	96.38**
GRS***	4	7.62	39.29**
Position of the node x GRS	8	0.41	2.13*
Species x position of node	6	2.06	10.60**
Species x GRS	12	0.74	3.79**
Species x position of the node x GRS	24	0.39	2.02*
Error 2	64	0.19	

** Significant at 1 per cent level * Significant at 5 per cent level *** Growth regulating substance

Table12. The rooting attributes of different bamboo species as influenced by the position of the node

Species	Position	Rooting (%)	Root No.	Root length (m)
B. nutans	Base	41.87^{a}	44.01^{a}	0.33^{a}
	Middle	46.20^{a}	28.29^{b}	0.48^{a}
	Top	20.13^{b}	10.27^{c}	0.21^{a}
B. polymorpha	Base	42.13^{a}	21.49^{a}	0.33^{a}
	Middle	12.87^{b}	12.57^{b}	0.15^{a}
	Top	5.33^{c}	4.33^{c}	0.08^{a}
B. striata	Base	44.47^{b}	41.87^{a}	0.51^{a}
	Middle	54.87^{a}	42.36^{a}	0.55^{a}
	Top	46.47^{b}	28.37^{b}	0.47^{a}
B. vulgaris	Base	69.91^{a}	38.95^{a}	0.59^{a}
	Middle	49.95^{b}	26.29^{b}	0.36^{a}
	Top	43.64^{b}	20.83^{c}	0.20^{a}

Note: Means within a species and in a column having same letter as superscript are homogeneous

Number of roots (21.49) per node also was the highest in basal cuttings and top cuttings recorded the lowest value (4.33). Meanwhile, all three portions almost equally rooted in *B. striata* of which, the average rooting was the highest for middle cuttings (54.87). Basal and middle cuttings produced largest number of roots (41.87 and 42.36 respectively) which was significantly different from top cuttings (28.37). Cuttings from all three portions rooted in *B. vulgaris* also and those from the base produce the highest rooting percentage (69.91) and the least rooting was obtained from the top portion (43.64 per cent). Significantly higher number of roots (38.95) was obtained in the basal cuttings and it was approximately two times more compared to top part. No significant differences were found in root length among different bamboo species.

Effect of growth regulating substances on the rooting attributes of species

Culm cuttings treated with growth regulating substances were superior in rooting attributes compared to control. The highest rooting (46.78 %) and number of roots (35.52) were obtained for the cuttings treated with NAA 200 ppm in *B. nutans*; the rooting percentage was almost 3.34 times more compared to control. Whereas, the highest rooting (29.00 %) was obtained for cuttings treated with IBA 100 and 200 ppm in *B. polymorpha* but the largest number of roots (22.22) was recorded in the cuttings treated with IBA 200 ppm. In *B. striata,* highest rooting (58.78 per cent) was obtained in cuttings treated with NAA 200 ppm, which was 3.2 times more compared to control. However, the highest number of roots (47.84) was obtained for the cuttings treated with IBA 200 ppm. In *B. vulgaris* the highest rooting (67.00 %) and number of roots (34.36) was obtained in cuttings treated with IBA 200 ppm. Root length did not vary due to growth regulator application among different bamboo species (Table 13).

Table 13. The rooting attributes of different bamboo species as influenced by growth regulating substances

Species	GRS *(ppm)	Rooting (%)	Root No.	Root length (m)
B. nutans	Contro1	13.89^{d}	19.00^{b}	0.16^{a}
	NAA100	44.00^{ab}	31.33^{a}	0.33^{a}
	NAA200	46.78^{a}	35.52^{a}	0.37^{a}
	IBA 100	38.89^{bc}	32.00^{a}	0.43^{a}
	IBA 200	36.78^{c}	19.77^{b}	0.41^{a}
B. polymorpha	Contro1	7.00^{b}	4.22^{b}	0.04^{a}
	NAA100	27.78^{a}	16.59^{a}	0.23^{a}
	NAA200	7.78^{b}	4.39^{b}	0.13^{a}
	IBA 100	29.00^{a}	16.56^{a}	0.22^{a}
	IBA 200	29.00^{a}	22.22^{a}	0.31^{a}
B.striata	Contro1	18.33^{b}	27.00^{d}	0.23^{a}
	NAA100	56.44^{a}	33.11^{cd}	0.75^{a}
	NAA200	58.78^{a}	41.99^{ab}	0.62^{a}
	IBA 100	54.89^{a}	37.72^{bc}	0.38^{a}
	IBA 200	54.56^{a}	47.84^{a}	0.58^{a}
B. vulgaris	Contro1	28.00^{c}	17.00^{b}	0.21^{a}
	NAA100	61.99^{a}	32.00^{a}	0.46^{a}
	NAA200	52.40^{b}	28.89^{a}	0.42^{a}
	IBA 100	67.00^{a}	34.36a	0.51^{a}
	IBA 200	63.11^{a}	31.22a	0.65^{a}

*Growth regulating substance

Effect of species, position of node and GRS on sprouting and rooting: As the interaction effect of species x position x growth regulating substances was significant at 5 per cent level, the different treatments were clustered (Fig. 6). Cluster analysis identified three clusters at 32 per cent variance level and the treatments 28 to 56 were falling in first group, 10-35 in second group and 48 to 3 in third group. The treatments falling with in the same cluster were considered as homogenous. When the average sprouting and rooting performance of different clusters was compared (Table 14), third cluster containing the treatment combinations 3, 39 and 47-50 was superior to first and second clusters in sprouting and rooting attributes.

Basal cuttings of *B. nutans* treated with 200 ppm NAA, treatment number 3 produced 55.33 per cent rooting with 69.33 roots of 0.32 m length. There were 2 sprouts per node with an average height of 2.87 m. Treatment combination 39 (*B. striata* cuttings from the middle portion of the culm treated with 100 ppm IBA) gave 80.00 per cent rooting and on an average produced 52.50 roots of length of 0.46 m. The sprouts were 2.67 in number and 1.83 m in height. The basal cuttings of *B. vulgaris* treated 100 and 200 ppm of IBA and NAA (treatments 47-50) gave rooting of 86.43, 77.77, 75.33 and 85.67 per cent respectively. The number and length of roots produced by the treatments 47-50 were 49.33, 42.00, 41.10 & 44.67 and 0.72, 0.57, 0.57 & 0.75 m, respectively. The number of sprouts per node produced in these treatment combinations was 2.43, 2.00, 2.33 and 2.33 respectively. While, the height of the sprouts of the treatments was 47- 50 was 2.24, 1.73, 2.35 and 2.28 m respectively.

Table14. Interaction effect of species, position of node and growth regulator treatment on sprouting and rooting attributes of *Bambusa* species

Treat no.	Species	Position	GRS	No of sprouts	sprout height (m)	Rooting %	Root number	Root length (m)
1	*B. nutans*	Base	Contro1	1.17	1.53	23.00	34.33	0.20
2			NAA100	2.00	2.40	52.33	43.33	0.28
3			NAA200	2.00	2.87	55.33	69.33	0.32
4			IBA 100	2.00	2.66	45.67	39.00	0.47
5			IBA 200	1.83	2.16	33.00	34.07	0.36
6		Middle	Contro1	1.33	1.30	18.67	22.67	0.27
7			NAA100	2.00	2.78	53.33	35.33	0.48
8			NAA200	2.00	2.27	59.33	26.23	0.52
9			IBA 100	2.00	2.99	46.67	44.00	0.56
10			IBA 200	2.00	1.43	53.00	13.23	0.56
11		Top	Contro1	0.00	0.00	0.00	0.00	0.00
12			NAA100	1.00	0.74	26.33	15.33	0.23
13			NAA200	1.33	1.45	25.67	11.00	0.27
14			IBA 100	1.67	1.07	24.33	13.00	0.26
15			IBA 200	2.00	1.28	24.33	12.00	0.31
16	*B. polymorpha*	Base	Contro1	4.33	0.49	21.00	12.67	0.11
17			NAA100	2.83	1.58	60.00	22.93	0.43
18			NAA200	1.25	0.49	20.00	11.50	0.29
19			IBA 100	2.83	1.68	67.00	27.67	0.49
20			IBA 200	2.00	1.55	42.67	32.67	0.34
21		Middle	Contro1	0.00	0.00	0.00	0.00	0.00

22			NAA100	2.20	0.47	16.67	22.83	0.16
23			NAA200	0.33	0.40	3.33	1.67	0.10
24			IBA 100	1.67	0.55	20.00	22.00	0.19
25			IBA 200	1.00	0.82	24.33	16.33	0.31
26			Contro1	0.00	0.00	0.00	0.00	0.00
27			NAA100	1.00	0.07	6.67	4.00	0.11
28			NAA200	0.00	0.00	0.00	0.00	0.00
29		Top	IBA 100	0.00	0.00	0.00	0.00	0.00
30			IBA 200	1.00	0.40	20.00	17.67	0.27
31			Contro1	0.73	1.10	22.00	30.00	0.28
32			NAA100	2.27	1.90	52.00	43.00	0.63
33			NAA200	1.63	2.12	57.33	40.33	0.58
34			IBA 100	2.07	1.68	53.33	41.33	0.44
35	*B .striata*	Base	IBA 200	2.33	2.06	37.67	54.70	0.61
36			Contro1	1.67	0.87	13.33	22.67	0.08
37			NAA100	1.53	1.55	50.67	27.33	0.94
38			NAA200	2.33	2.19	59.67	50.97	0.72
39			IBA 100	2.67	1.83	80.00	52.50	0.46
40		Middle	IBA 200	2.27	2.45	70.67	58.33	0.57
41			Contro1	1.33	0.83	19.67	28.33	0.32
42			NAA100	1.07	1.73	66.67	29.00	0.68
43			NAA200	1.33	1.75	59.33	34.67	0.56
44		Top	IBA 100	7.17	0.91	31.33	19.33	0.23
45			IBA 200	1.67	1.86	55.33	30.50	0.56
46			Contro1	1.67	0.71	24.33	17.67	0.23
47			NAA100	2.43	2.24	86.43	49.33	0.72
48			NAA200	2.00	1.73	77.77	42.00	0.57
49			IBA 100	2.33	2.35	75.33	41.10	0.75
50		Base	IBA 200	2.33	2.28	85.67	44.67	0.65
51			Contro1	1.33	0.91	24.33	12.00	0.19
52			NAA100	1.10	1.49	48.67	29.67	0.40
53	*B. vulgaris*		NAA200	1.10	1.46	55.43	25.67	0.28
54			IBA 100	1.67	1.72	68.33	36.80	0.47
55		Middle	IBA 200	1.50	1.40	53.00	27.33	0.47
56			Contro1	1.00	1.03	35.33	21.33	0.20
57			NAA100	1.37	1.24	50.87	17.00	0.27
58			NAA200	1.73	1.19	24.00	19.00	0.41
59		Top	IBA 100	1.00	1.62	57.33	25.17	0.29
60			IBA 200	1.62	1.22	50.67	21.67	0.84

Dendrocalamus species

Factor analysis identified a single factor which explained 59.37 percentage of the total variance (Table 15).

Table15. Factor structure matrix and communalities of the variables

Variables	Factor loading	Factor score coefficient	Communalities after extraction
Number of sprouts	0.790	0.266	0.625

Sprout height	0.170	0.057	0.029
Rooting percentage	0.910	0.307	0.829
Root number	0.829	0.279	0.687
Root length	0.894	0.301	0.800
Percentage of variance explained	59.37		

ANOVA of the factor scores was carried out and results are presented in Table 16. The interaction effects, species x position of the node (p=0.01), species x IBA (p=0.01) and species x position of the node x IBA (p=0.05) were significant.

Table16. Analysis of variance of the factor scores

Source	Degrees of freedom	Mean square	F value
Species	4	6.74	21.47**
Replication	2	0.54	1.73^{ns}
Error1	8	0.31	
Position	2	2.12	9.96**
IBA	2	21.84	102.84**
Position x IBA	4	0.63	2.98*
Species x position	8	0.74	3.48**
Treatment x species	8	2.48	11.69**
Species x position x IBA	16	0.50	2.35*
Error 2	40	0.21	

** - Significant at 1% level

Effect of position of the node on the rooting attributes

In *D. asper*, the average rooting was the highest from the basal cuttings (41.22 %) which was 1.3 and 2 times more compared to middle and top cuttings respectively. Basal cuttings also produced significantly higher number of roots (35.67) per node. But, maximum root length (41.50 cm) was obtained in the middle cuttings. The rooting percentage of cuttings from different parts of the

culm was at par in *D. giganteus.* But higher number (34.22) and length (41.50 cm) of roots was obtained in the middle cuttings. Rooting was also obtained in cuttings from all portions of the culm in *D. longispathus*. But basal cuttings produced significantly higher rooting (39.11 %) which was at par with top cuttings and significantly different from the middle cuttings which rooted the least (20.44 %). Number (32.42) and length of the roots (47.22 cm) was the highest in basal cuttings. There was no significant variation in rooting parameters of the *D. membranaceous* due to position of the node and middle portion even completely failed to root. Rooting was observed in all three parts of the culm in *D. stocksii*. However, the average rooting was the highest from the basal (54.22 %) cuttings which was 1.6 and 2.1 times more compared to middle and top cuttings respectively. Number and length of the roots were at par in cuttings from different culm positions (Table 17).

Table17. The rooting attributes of different bamboo species as influenced by the position of the node

Species	Position	Rooting (%)	Root number	Root length (cm)
D. asper	Base	41.22^{a}	35.67^{a}	38.17^{ab}
	Middle	31.63^{b}	25.39^{b}	41.50^{a}
	Top	20.67^{c}	18.00^{c}	30.78^{b}
D. giganteus	Base	24.11^{a}	30.13^{ab}	27.00^{b}
	Middle	27.78^{a}	34.22^{a}	41.22^{a}
	Top	27.22^{a}	25.49^{b}	34.56^{ab}
D. longispathus	Base	39.11^{a}	32.42^{a}	47.22^{a}
	Middle	20.44^{b}	18.44^{b}	23.30^{c}
	Top	32.33^{a}	22.88^{b}	34.16^{b}
D. membranceus	Base	6.56^{a}	5.44^{a}	11.89^{a}
	Middle	0.00^{a}	0.00^{a}	0.00^{a}
	Top	8.89^{a}	4.18^{a}	6.00^{a}
D.stocksii	Base	54.22^{a}	10.51^{a}	30.11^{a}
	Middle	34.72^{b}	7.29^{a}	22.69^{a}
	Top	25.7^{b}	6.433^{a}	21.86^{a}

Note: means within a species and in a column having same letter as superscript are homogeneous

Effect of IBA treatment on the rooting response

The highest rooting (55.44 %), number of roots (44.22) and root length (75.50 cm) was obtained for the cuttings treated with IBA 100 ppm in *D. asper*. In *D. giganteus*, the highest rooting (38.89 %) was obtained in cuttings treated with IBA 100 ppm but the largest number (42.98) and length of roots (52.11) was obtained in those treated with IBA 200 ppm. Cuttings treated with 100 ppm IBA produced the highest rooting (47.22 %) and number (37.21) and length of roots (56.34 cm) in *D. longispathus*. Meanwhile, cuttings treated with 200 ppm IBA produced the highest rooting and number and length of roots in *D. membranaceus* (12.56 %, 6.96 and 11.67 cm respectively) and *D. stocksii* (53.98 %, 11.37 and 38.11 cm respectively). The cuttings treated with IBA produced higher rooting response compared to control in all bamboo species (Table 18).

Table18. The rooting attributes of different bamboo species as influenced by different concentrations of IBA

Species	Treatment (ppm)	Rooting (%)	Root number	Root length (cm)
D. asper	Control	0.00^{c}	0.00^{c}	0.00^{c}
	IBA 100	55.44^{a}	44.22^{a}	75.50^{a}
	IBA 200	38.08^{b}	34.83^{b}	34.94^{b}
D. giganteus	Control	4.33^{b}	9.00^{b}	10.00^{c}
	IBA 100	38.89^{a}	37.87^{a}	40.67^{b}
	IBA 200	35.89^{a}	42.98^{a}	52.11^{a}
D. longispathus	Control	11.00^{c}	11.56^{c}	11.78^{c}
	IBA 100	47.22^{a}	37.21^{a}	56.34^{a}
	IBA 200	33.67^{b}	24.98^{b}	36.56^{b}
D. membranceus	Control	0.00^{b}	0.00^{b}	0.00^{b}
	IBA 100	2.89^{b}	2.67^{ab}	6.22^{ab}
	IBA 200	12.56^{a}	6.96^{a}	11.67^{a}
D.stocksii	Control	19.89^{c}	5.90^{a}	14.39^{b}
	IBA 100	40.78^{b}	6.97^{a}	18.16^{b}
	IBA 200	53.98^{a}	11.37^{a}	38.11^{a}

Note: means within a species and in a column having same letter as superscript are homogeneous

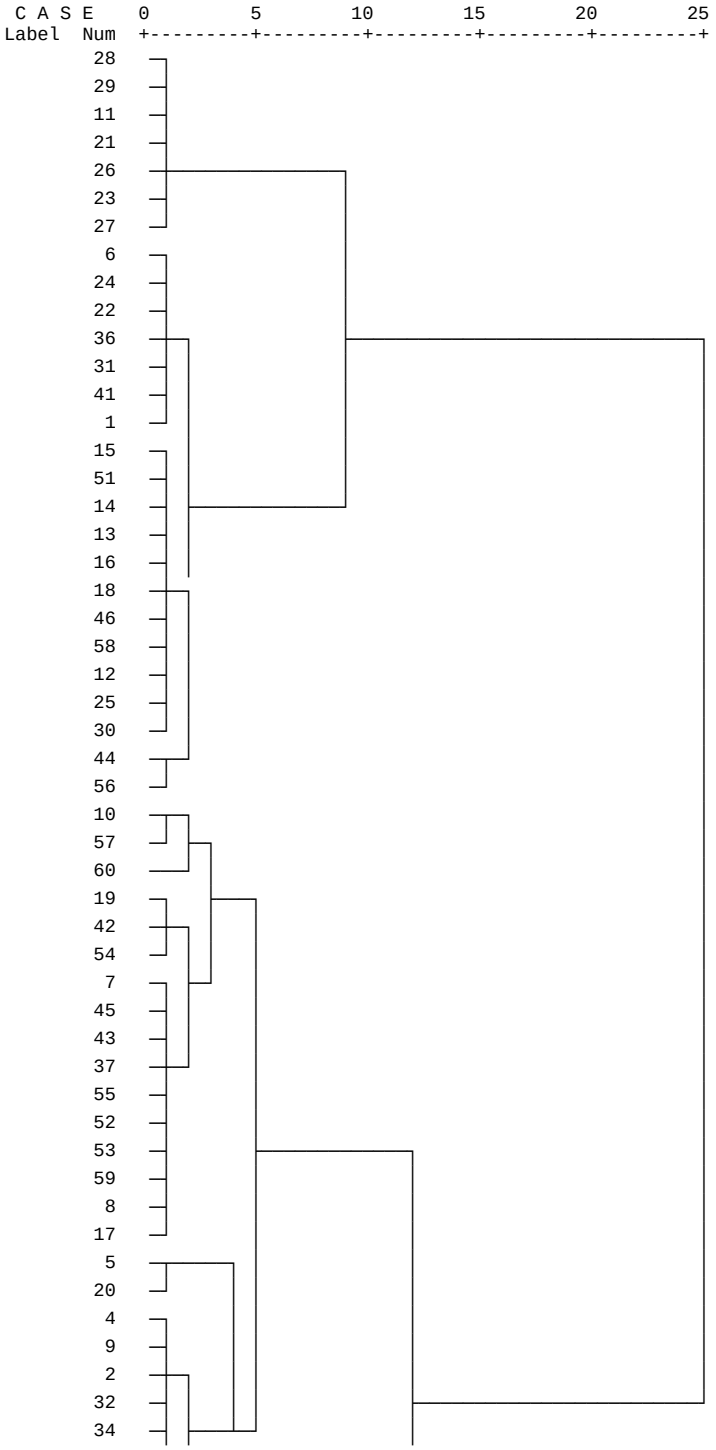
Effect of species, position of the node and IBA treatment on sprouting and rooting response: Since the interaction effect of species x position x IBA concentrations was significant (p=0.05), treatment combinations were clustered and the dendrogram is presented in the Fig.7. Cluster analysis identified eight homogenous clusters at 20 per cent variance level; the treatments 34-43 the first group, 9-36 the second group, 25 the third, 39, 45, 38 and 42 the fourth, 17-2 the fifth, 3 the sixth, 5 seventh and 6 the eight group (Fig. 7). The treatment combinations falling within a cluster are homogenous in nature.

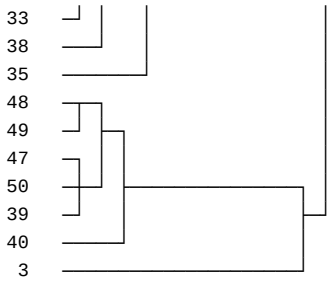
When the sprouting and rooting parameters of the treatment combinations were compared, the clusters 6, 7 and 8 were superior to other clusters and the least values were recorded by the cluster 1 (Table 19). Basal cuttings of *D. asper* treated with IBA 200 ppm, treatment number 3 produced the highest rooting percentage (70.67) with 53.67 roots of length 44.67 cm. There were 3.93 sprouts per node with a height of 2.34 m. The next highest rooting was observed in the middle cuttings treated with IBA 100 ppm (64.33 %) and which was followed by the middle cuttings treated with 200 ppm IBA (60.57 %); treatments 5 and 6 respectively. Middle cuttings treated with 100 ppm IBA produced 40 roots with an average length of 93.00 cm and 3 sprouts per node that are 1.93 m high. Those treated with IBA 200 ppm produced 36.17 roots of length 31.5 cm and 2.33 sprouts that are 0.67 m high(Table 19).

Table19. Interaction effect of species, position of node and IBA treatment on sprouting and rooting attributes.

Treat no.	Species	Position	GRS (ppm)	No of sprouts	Sprout height (m)	Rooting (%)	Root No.	Root length
1	*D. asper*	Base	Control	0.00	0.00	0.00	0.00	0.00
2			IBA 100	2.63	2.14	53.00	53.33	69.83
3			IBA 200	3.93	2.34	70.67	53.67	44.67
4		Middle	Control	0.00	0.00	0.00	0.00	0.00
5			IBA 100	3.00	1.93	64.33	40.00	93.00

Fig . 6. Dendrogram using Average Linkage for *Bambusa* sps.




33
38
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40
3

6			IBA 200	2.33	0.67	60.57	36.17	31.50
7			Control	0.00	0.00	0.00	0.00	0.00
8		Top	IBA 100	2.67	1.97	49.00	39.33	63.67
9			IBA 200	3.00	1.29	13.00	14.67	28.67
10			Control	0.00	0.00	0.00	0.00	0.00
11		Base	IBA 100	3.00	1.89	37.33	50.00	38.33
12			IBA 200	2.67	2.20	35.00	40.40	42.67
13			Control	1.33	1.27	13.00	27.00	30.00
14	*D. giganteus*	Middle	IBA 100	2.17	1.49	37.33	38.50	38.00
15			IBA 200	2.00	2.31	33.00	37.17	55.67
16			Control	0.00	0.00	0.00	0.00	0.00
17		Top	IBA 100	2.33	1.37	42.00	25.10	45.67
18			IBA 200	3.00	2.50	39.67	51.37	58.00
19			Control	3.33	0.97	22.00	28.67	27.67
20		Base	IBA 100	5.33	2.15	53.33	34.67	71.33
21			IBA 200	2.67	1.69	42.00	33.93	42.67
22			Control	0	0	0	0	0
23	*D. longispathus*	Middle	IBA 100	2.67	1.67	39.67	39.33	39.57
24			IBA 200	1.67	1.58	21.67	16.00	30.33
25			Control	0.67	40.00	11.00	6.00	7.67
26		Top	IBA 100	2.73	1.73	48.67	37.63	58.13
27			IBA 200	2.23	1.28	37.33	25.00	36.67
28			Control	0.00	0.00	0.00	0.00	0.00
29		Base	IBA 100	1.33	0.77	8.67	8.00	18.67
30			IBA 200	2.00	1.17	11.00	8.33	17.00
31			Control	0.00	0.00	0.00	0.00	0.00
32	*D. membranceus*	Middle	IBA 100	0.00	0.00	0.00	0.00	0.00
33			IBA 200	0.00	0.00	0.00	0.00	0.00
34			Control	0.00	0.00	0.00	0.00	0.00
35		Top	IBA 100	0.00	0.00	0.00	0.00	0.00
36			IBA 200	4.23	0.79	26.67	12.53	18.00
37			Control	3.67	0.51	40.00	8.03	22.00
38		Base	IBA 100	4.65	0.74	67.00	9.50	30.50
39			IBA 200	4.77	0.97	55.67	14.00	37.83
40			Control	4.33	0.30	17.67	6.33	9.17
41	*D. stocksii*	Middle	IBA 100	3.00	0.50	40.00	6.47	15.07
42			IBA 200	3.83	0.91	46.50	9.07	40.83
43			Control	0.33	0.06	2.00	3.33	12.00
44		Top	IBA 100	0.67	0.22	15.33	4.93	8.90
45			IBA 200	7.83	0.70	59.77	11.03	35.67

Thyrsostachys species

In both species only sprouting was observed in culm cuttings. All the sprouts dried after a period of three weeks. Hence data was not analyzed.

Planting stock production in bulk

Using the seeds available and rooted cuttings of different species obtained during the experiments, planting stock in bulk was produced for distribution to public. These plants were used for establishment of bamboo plantations in private/public sector. The details of planting stock are given below (Table 20).

Table20. Details of planting stock produced in KFRI nursery.

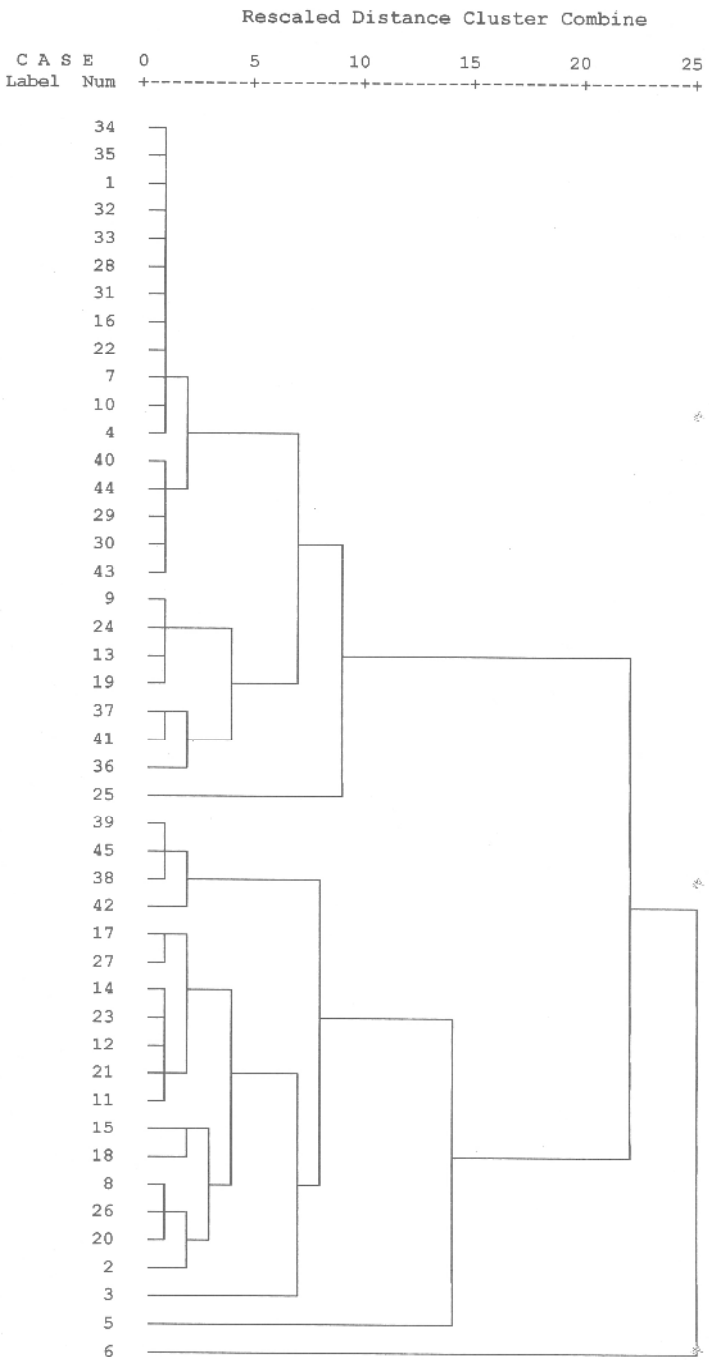
Species	No of plants
Ochlandra travancorica	60000
Melocanna baccifera	25000
Bambusa bambos	10000
Bambusa tulda	1000
Dendrocalamus strictus	1000
Rooted cuttings of different bamboo species	700
Total	97700

DISCUSSION

Both *M. baccifera* and *O. travancorica* come under the same sub tribe *Melocanneae* of the tribe *Bambusaeae* (Orhnberger and Goerrings, 1985). Both are species used commercially for slivering and raw material for same type of industries. The purpose of the study was to compare the performance of both the species in the nursery to establish commercial plantations for the raw material requirement.

In *M. baccifera* there was large variation between seeds in size and shape than that of *O. travancorica* and on an average it was seven times larger. Variation in seed weight and shape is reported during the previous collections also and to minimize the variation, grouping of the seeds as per the weight (heavy, medium and light) is recommended (Banik, 1991). At nursery stage, growth and biomass accumulation of *M. baccifera* was higher than that of *O. travancorica*. The difference between the two species is manifested in the first stage of observation itself (60 days). After 180 days, height of *M. baccifera* (2.54 m) seedlings was three times more than that of *O. travancorica*. Although *M. baccifera* produced multiple shoots at the time of seed germination, the number of tillers (shoots) produced at different six and twelve months of both the species was almost same. With regard to number of leaves and leaf area *M. baccifera* showed superior performance than *O. travancorica*. Leaf number was about 1.6 times higher at all stages of growth and leaf area was 486 per cent higher at the final stage of observation (after 180 days). The superior performance of *M. baccifera* seedlings can be attributed to larger size of seeds that might provide higher levels of reserved food materials for initial establishment and later higher leaf area and more number of leaves that increases the area available for photosynthesis leading to production of more carbohydrate.

Fig 7. Dendrogram generated for *Dendrocalamus* species with different clusters



Similar trend was observed in biomass accumulation also. The ratio of dry weight of *M. baccifera* and *O. travancorica* was 7:1, 21:1 and 10:1 at 60,120 and 180 days of observation respectively. All the plant parts such as leaf, culm, root and rhizome showed higher value for *M. baccifera* at all the three stages of observation. It is important to note that the rhizome development which is a critical factor for field establishment of the seedlings after transplantation is quicker and more in *M. baccifera*.

Generally, the *M. baccifera* and *O. travancorica* seedlings contained large amount of moisture. On an average, the moisture content of the leaves, stem, root and rhizome of *M. baccifera* seedlings were 168.25, 253.61, 359.25 and 559.33 per cent respectively for the entire nursery period. Similarly, the moisture content of the leaves, stem, root and rhizome of the *O. travancorica* seedlings were 212.84, 288.27, 283.10 and 440.32 per cent respectively.

Estimation of specific leaf area (leaf area per unit leaf dry weight), which is an important parameter in crop growth models, both for calculating leaf photosynthesis and for estimating leaf area development (Boote *et al*., 1996) was also taken into consideration for both the species. Its value often varies with developmental stages in many crops (Grashoff and d'Antuono, 1997). The same effect was found in these two species also. The specific leaf area of the *M. baccifera* seedlings was as high as 27.1 cm^2 per g at 60 days after planting; it declined to 10.14 g at the end of 180 days and again increased and was 21.78 cm^2 per at the end. In *O. travancorica* seedlings it was 41.74, 40 and 29.1 and 12 g cm^2 per g respectively at 60, 120 and 180 days after planting. Comparatively *O. travancorica* showed higher specific leaf area. There was no significant difference in the RGR of two species, while NAR was different and *M. baccifera* had higher NAR.

Observation during the first stage i.e., the growth performance in the nursery stage indicates that *M. baccifera* is better than *O. travancorica.* Multi-locational field trials are required to know the field establishment, growth and yield of these two species and also the suitable agro-climatic zones in which they can be cultivated and it is taken as second phase of this programme.

There are prior reports of albinism in both the species (Dakshindas, 1995; Kader *et al*., 2001) but incidence of an intermediate phase is noted for the first time. Albinism is governed by a pair of recessive genes and the trait is expressed only in homozygous recessive condition. This may be the result of inbreeding or by the mating of two albino carriers.

Observations on flowering, post flowering behaviour and seed production in bamboos report synchronous flowering of vegetatively propagated planting materials, either death or reversion to vegetative phase and total sterility to profuse seed production (Banik and Alam, 1987; Nadguada *et al*, 1997; Koshy and Pushpagathan, 1997; Beena et al., 2007; Jijeesh et al., 2009; Seethalakshmi et al., 2010). The current observations on flowering and seed production of *B. tulda* at Bambuseta at Nilambur and Velupadam along with the mother clumps at Assam confirm the synchronous flowering behaviour, death after flowering and profuse seed production. It is likely that the seeds have originated from one parent clump since the planting material of all flowered clumps is from the mother collection from Assam. However, the seeds were of good quality since the germination percentage was high (65.34 % in control).

The positive influence of growth regulators on germination and seedling performance have been reported for some of the bamboo species such as *Dendrocalamus strictus* and *Thyrsostachys siamensis* (Richa and Sharma, 1994; Chand and Sood, 2008). In general, the auxins play an important part in germination of seeds and subsequent rooting of the bamboo species (Saxena,

1990). Gibberellic acid also found stimulates the cells of germinating seeds to produce mRNA molecules that code for hydrolytic enzymes. It is a very potent hormone whose natural occurrence in plants controls their development. The effect of growth regulators on seed germination is found positive in *B. tulda*.

Like many other grasses, bamboo has the inherent proliferating capacity to reproduce itself probably due to its strong rhizome and root system. Macroproliferation is a simple and effective procedure for vegetative propagation to increase the number of planting stock from limited quantity of seedlings/vegetatively propagated propagules. In *B. tulda*, on an average, 3-4 propagules were obtained from one seedling and the survival rate at the end of 90 days after planting was 89 per cent. This technique is effectively used in propagating bamboo species like *Bambusa balcooa, B. bambos, B. nutans, B. vulgaris, Dendrocalamus hamiltonii, D. strictus* etc (Banik 1987, Kumar et al., 1994; Kumar and Pal, 1994; Koshy and Gopakumar, 2005; Dubey et al. 2008;). Observation on tillering capacity and success of macroproliferation confirms the earlier findings by Banik (1987). Treatment with growth regulators enhanced the rooting efficacy of tillers. In general, IBA was better than NAA. The best treatment was IBA 50 and 100 mg/l.

With regard to vegetative propagation every node of segmented axis of a bamboo plant bears a bud or branch, which in turn has bud on their axis (Banik, 1980) and the success rate of propagation depends on the capacity for transformation of as many buds as possible buds into planting material. It is established that there is wide variation in the rooting efficacy of different bamboo species. In the present investigations, the rooting varied from 0-59.33 per cent, 0-67.00 per cent, 13.33-80.00 per cent and 24.00-86.43 per cent in *B. nutans*, *B. polymorpha*, *B. striata* and *B. vulgaris,* respectively (Table 14). It is generally agreed that the thick walled bamboo species respond better than thin walled bamboo species (Surendran *et al*., 1983; Seethalakshmi *et al*., 1990, Banik, 2000) in

adventitious root induction. Present study with thick walled bamboos is inconsistent with this finding with the exception of *T. oliveri* and *T. siamensis*. Rooting was not observed in *T. oliveri* and *T. siamensis* culm cuttings which were considered to be difficult to root and they are normally propagated through offsets and rhizomes.

Time taken for rooting of the culm cuttings varied with species. Banik (2008) reported 70-75 days for rooting in *B. nutans*, 55-75 days in *B. polymorpha* and 30-40 days in *B. vulgaris*. In the present investigation, the culm cuttings initiated sprouts after one week and the rooting was observed after three weeks of planting. Sprouting of the culm cuttings started in the second week in *B. nutans B. polymorpha, B.striata* and *B. vulgaris* and continued up to 3rd week in all the species. Whereas, the *T. oliveri* and *T. siamensis* sprouted only in the 3rd week and sprouting continued up to 4th and 5th week respectively. The culms initiated rooting after the completion of sprouting and *B. striata* and *B. vulgaris* initiated rooting in 4th week, while *B. nutans* and *B. polymorpha* initiated to root in 5th week. Rooting was completely absent in *T. oliveri* and *T. siamensis.* Rooting of the cuttings in all bamboo species was completed in 9th week after planting and no more rooting was observed in the sprouted cuttings after this period.

It is observed that rooting ability of cuttings taken from different parts of the culm varied and which could even influence the survival of seedlings produced. Hoanh (1988) reported a higher rate of survival for the cuttings from the lowest portion of the culm. In our study, the average rooting response was higher from the basal and middle cuttings in *B. nutans* and while the basal cuttings gave maximum rooting in *B. polymorpha*. Whereas, cuttings obtained from all the portions of the culm rooted in B*. striata* and *B. vulgaris.* The positive response of growth regulating substances such as NAA, IBA and chemicals such as boric acid, coumarin etc on rooting has been reported earlier (Surendran and

Seethalakshmi, 1985; Surendran et al. 1986; Agnihothri and Ansari, 2000; Singh *et al.* 2004 and 2006). Exogenous application of auxins increased the rooting performance compared to control. The application of NAA gave better rooting response in *B. nutans* and *B. striata*, whereas, IBA gave better rooting response in *B. polymorpha* and *B. vulgaris*. In species context, the highest rooting percentage was obtained in middle cuttings treated with NAA 200 ppm in *B. nutans* (59.3 %), those from basal portion treated with IBA 100 ppm in *B. polymorpha* (67 %), from middle portion of the culm treated with IBA 100 ppm in *B. striata* (80 %) and those from basal portion of the culm treated with NAA 100 ppm in *B. vulgaris*. (86.43 %).

Of the different species of the genus *Dendrocalamus* studied, the rooting response was higher in *D. asper*, *D. longispathus* and *D. stocksii,* moderate in *D. giganteus* and poor in *D. membranaceus.* A maximum of 70.67 per cent rooting was obtained in *D. asper*, 42.00 per cent in *D. giganteus*, and 53.33 per cent in *D. longispathus*, 26.67 per cent in *D. membranaceus* and 67.00 per cent in *D. stocksii.* It has been demonstrated that the thick walled bamboo species respond better than thin walled bamboo species (Surendran *et al.*, 1983; Seethalakshmi *et al.*, 1990, Banik, 2000) in adventitious root induction. Our study is consistent with the finding that is the thick walled showed better rooting response.

It is generally observed that the time taken for rooting of the culm cuttings varies among different bamboo species. Banik (2008) has reported 60-70 days for rooting in *D. giganteus* and 55-70 days in *D. stocksii.* In our study, the cuttings initiated sprouting after the first week of planting in *D.giganteus* while in *D. asper, D. longispathus, D. membranceus and D stocksii* sprouted in second week. Sprouting continued up to four weeks in *D. giganteus,* three weeks in *D. longispathus* and *D. membranceus* and two weeks in *D. asper* and *D stocksii*. Rooting of the cuttings initiated after the completion of sprouting. Cuttings

rooted as early as third week in *D. longispathus.* Whereas, *D. asper* and *D. giganteus* initiated rooting in fourth week. Rooting initiated slowly in *D. membranceus* and *D.stocksii* (fifth and sixth week respectively). The rooting was completed after a period of eight to ten weeks in all the species.

It is generally observed that the rooting ability of the cuttings taken from different parts of the culm varies and also bears an influence on the survival of seedlings. In this genus, the cuttings from three portions of the culm rooted with the exception of *D. membranaceus* where the middle portion failed to root (Table 17). The average rooting from top portion of the culms was higher in D*. giganteus* and *D. membranaceus* and cuttings from top portion also could be included in propagation practice. Meanwhile, rooting was lower in top cuttings in *D. asper* and *D. stocksii* so it can be excluded during large scale planting stock production to reduce the nursery cost.

The positive response of growth regulating substances was evident in this genus also. Exogenous application of IBA increased the rooting performance compared to control which may be due to fact that low levels of auxins result in failure of adventitious rooting (Cooper, 1935, Smith and Wareing, 1972). With the exception of *D. stocksii*, higher rooting response was obtained in cuttings treated with IBA 100 ppm. Whereas, cuttings treated with IBA 200 ppm produced higher rooting performance in *D. stocksii* (Table 18). In species context, the highest rooting percentage was obtained in basal cuttings treated with IBA 200 ppm in *D. asper*, those from top portion of the culm treated with IBA 100 ppm in *D. gigantesus*, from basal cuttings treated with IBA 200 ppm in *D. longispathus,* those from the top cuttings treated with IBA 200 ppm in *D. membranaceus* and those from basal portion of the culm treated with IBA 100 ppm in *D. stocksii* (Table 19).

In summary, the rooting of culm cuttings in bamboos varied with species. The position of the node bears a positive correlation with rooting and the rooting can be enhanced by the exogenous application of growth regulating substances. All the nine species tried in this study *(Bambusa nutans, B. polymorpha, B. striata* and *B. vulgaris* are useful species recommended for commercial cultivation.

2. Selection of panchayaths and awareness programmes

Selection of panchayaths and awareness programmes

Selection of panchayaths

The data on panchayaths having traditional bamboo workers were collected from the records maintained at the office at Thiruvananthapuram. Eighteen panchayaths having maximum number of workers were provisionally selected from this list for implementation of the project (Table 21).

Table 21. Details of panchayaths involved in the programme

District	Panchayaths
Ernakulam	Kalady, Kusumagiri and Kathikudam (later two green belt by industries KCPL
Palakkad	Chalavara, Kanjirapuzha, Mundur, Thenkurissi
Thiruvananthapuram	Aryanad, Kuttichal, Anad, Panavoor
Wyanad	Meppadi, Panamaram, Pozhuthana, Muttil
Kollam	Sasthamkotta, Kottarakkara
Pathanamthitta	Pandalam

Awareness programmes

Kerala State Planning Board

A meeting of 18 panchayaths Presidents from six districts (Table 21) was held at the office of Kerala State Planning Board under the chairman-ship of Sri. C. P. John, Member, Planning Board and Vice-Chairman of Kerala Bamboo Mission on 25th August 2004. The agenda discussed and decisions made are given below.

Establishment of plantation and sustainable management

A presentation on potential of bamboo and support available from State Government, bamboo species suitable for plantation in Kerala (Table 22, Figs. 8-11), methods for propagation, sustainable management of new plantations and bamboo clumps already existing in homesteads were made by KFRI. The Institute has already produced plantable seedlings of some of the species

(*Ochlandra travancorica*, *Melocanna baccifera*, *Bambusa bambos*, *Bambusa tulda*, *Dendrocalamus strictus* in bulk and other species in small numbers) which is one-year old. Since the planting had to be initiated at the earliest with participation from panchayaths, the responsibilities to be undertaken by participating panchayaths and terms of reference for participating planters/institutions were discussed in this meeting. The panchayath Presidents requested that one meeting each may be conducted in the respective panchayaths by KFRI to provide the information directly to stakeholders and KFRI accepted it.

Table 22. Species suitable for planting in Kerala

Species	Approximate spacing (m)	Soil and climatic requirements	Flowering cycle (in years)
Group 1. Large size bamboos			
1. D. giganteus	10 x 10	Rich loam up to an altitude of 1200m	40
2. D. sikkimensis		Rich loam up to an altitude of 2100 m	50
Group 2. Medium size thick walled bamboos			
3. B. balcooa	8 x 8	Heavy textured soil with good drainage, up to an altitude 600 m	45 Only flowering reported and no seed set
4. B. bambos		Flat alluvial soil, up to an altitude of 1000 m	45
5. B. membranaceus (D. membranaceus)		Laterite and black lime stone, tolerates arid and barren condition, altitude up to 100m	Not known
6. B. nutans		Well drained sandy loam to clayey loam, up to an altitude of 1500m	35
7 B. tulda		Finer textured soil, alluvial flat land upto an altitude 1500 m	30-60
Group 3. Medium size medium thick wall bamboos			

8. B. polymorpha	6x6	Low hill slopes along the valleys with deep fertile, well-drained loam and riverine alluvial soil is suitable for the growth of the species	55
9. D. brandisii		Found in all types of soil and grows on calcareous rocks, up to an altitude of 1300 m	50
10. D. longispathus		Finer textured soil, alluvial flat land upto an altitude 1500 m	60
Group 4. Small size nearly solid bamboos			
11. D. strictus	4 x 4	Well drained, poor coarse grained and stony soils, upto an altitude of 100m	35
12. P. stocksii		Well drained deep loam soil, upto an altitude of 600m	50 flowers but no seed set
13. T. oliveri		Well drained deep loam upto an altitude of 600m	50
Group 5. Small size, thin walled bamboos			
14. M. baccifera	4 x 4	Grows on well watered sand clay loam, alluvial soil and well drained residual soils consisting of pure sand and even at the summits of the low sand stone hills.	45
15. O. travancorica		Dark brown, acidic sand loam with granular structure, high porosity and good water holding capacity, upto 2000 m altitude	30 7 years in literature, seedling planted by KFRI in 1982 not yet flowered

Role of panchayaths

The panchayaths will be supplied with 1000 seedlings free of cost (each seedling costs Rs. 25/-). They have to identify

- Area for planting the seedlings during this season.
- The agencies (SHGs/NGOs) suitable for maintaining the bamboo

- Nurseries and panchayath land or land on lease for bamboo nursery.

- Select trainers for transfer of technology on bamboo nursery and plantation techniques.

- KFRI to provide initial training to trainers.

- Identify farmers having bamboo and select participants for awareness programme on sustainable management of bamboo clumps

Terms of Reference

KFRI as a part of its various projects for popularisation of bamboo cultivation in private/institutional lands invites applications from parties who are willing to spare land for raising plantations for a period of five years. The owner of the land can undertake pure or mixed planting as per the availability of the land and requirement. Also large-scale planting programmes for watershed management and riverbank stabilization can be undertaken. The interested individuals/panchayath/ institutions may contact immediately.

KFRI will provide the following

1. planting stock of various commercially important bamboo species suitable for the area/preferred by the holder of the land

2. technical know-how on bamboo planting and maintenance

The land owners/Panchayath/institutions should execute a memorandum of understanding with KFRI, which agrees on:

1. availability of the plantation for taking observations for 5 years.

2. maintenance and protection of the area as per the directions from KFRI

3. samples of bamboo and soil for analysis as required by KFRI

The beneficiaries should also provide necessary documents about the ownership for verification by the concerned authorities.

The selection of beneficiaries will be based on the suitability and extent of area available. Larger area will be given preference.

The Institute will have the right to withdraw the scheme at any time based on the availability of planting stock and financial assistance from sponsoring agencies.

If the beneficiaries decide to remove the bamboo plants and use the area for any other purpose the actual expenditure incurred for planting, maintenance and 50 per cent extra as penalty has to be provided to the sponsors.

The bamboo raised under this scheme can be harvested by the participating farmers/institution/panchayath after five years till flowering and death of bamboo clumps (period ranges from 30-40 years based on the species planted).

Directions for sustainable harvesting and technical know-how for scientific management of bamboo plantations and value added processing of harvested bamboo will be provided by the expert team from KFRI to successful planters as and when required.

Interested parties may contact the undersigned within 15 days with the details and location of area available. Preference will be given for large area (more than 5 ha). Planting required to be done within two months.

Awareness meetings in panchayaths

Awareness meetings were conducted in different panchayaths (Table 23). During the awareness meetings presentations on potential of bamboo, propagation techniques, cluster development programmes were made by resource persons from KFRI (Fig. 12). Different types of bamboos and value added products of bamboo were displayed in the meeting.

Table 23: The details of meeting and response of participants

Name of District/Panchayath	Meeting date and outcome
Thrissur	
Kadangode	Meeting was organized in September 2003. Of the 22 farmers interested in bamboo planting 6 were ready to

	establish bamboo multiplication area.
Mundathikode	Meeting was organized in September 2003. Of the 34 farmers interested in bamboo planting four expressed their interest to establish bamboo multiplication area.
Pananchery	Meeting was organized in March 2004. Meeting with Panchayath officials over in March, activities in progress for meeting with potential farmers and setting up bamboo multiplication area in the Panchayath.
Thiruvananthapuram	
Aryanad	Meeting was organized in October 2003. A joint - venture reed bamboo nursery with the inhabitants of Paruthippally colony and KFRI was established in the colony of bamboo dependents.
Palakkad	
Thenkurussi	Meeting was organized in March 2004. A combined meeting with Panchayath members, Bamboo dependants, officers from District Industries Centre and KFRI officials were held on 15 March 2004. Development of a bamboo cluster and resource management is planned.
Mundur	Meeting with Panchayath officials over in October, 2004 activities in progress for setting up bamboo multiplication area in the Panchayath.
Kanhirapuzha	Meeting with Panchayath officials over in March 2004. A nursery of *Bambusa bamboos* established jointly with a farmer.
Wayanad	
Meppadi	Meeting was organized in November 2003. A nursery was established with URAVU
Muttil	Meeting was organized in November 2003. A nursery was established with URAVU
Pozhuthana	Meeting was organized in November 2003. A nursery was established with URAVU
Panamaram	Meeting was organized in November 2003. A nursery was established with URAVU

The planting stock of different bamboo species produced by KFRI was supplied to the participating panchayaths during 2004-05 (Table 24). Technical know-how was also provided. Thirteen Panchayaths, three institutions and two clusters participated in the programme.

Table 24. Details of participating panchayaths, institutions and clusters

District	**Panchayaths**
Ernakulam	Kalady[1], Kusumagiri[2] and Kathikudam[2] (later two green belt by industries KCPL
Palakkad	Chalavara[1], Kanjirapuzha[1], Mundur[1], Thenkurissi[1]
Thiruvananthapuram	Aryanad[1], Kuttichal[1], Anad[1], Panavoor[1]
Wayanad	Meppadi[3], Panamaram [3], Pozhuthana[3], Muttil[3]
Kollam	Sasthamkotta[4], Kottarakkara[4]
Pathanamthitta	Pandalam[5]

1 = panchayaths, 2 = institutions for green belt 3 = implemented in panchayaths through participation from URAVU, NGO 4 = Clusters of artisans. The details of planting stock provided are given in Table (Chapter 3).

Fig 8. 1 & 2. General habit of large size bamboos
1. D. giganteus, 2. *D. sikkimensis*. 3 &4 Medium size bamboos 3. *B. balcooa;* 4. *B. bambos*

Fig.9. General habit of medium size bamboos contd…
5. *B. membranaceus.* 6. *B. nutans 7. B. tulda 8. B. polymorpha*

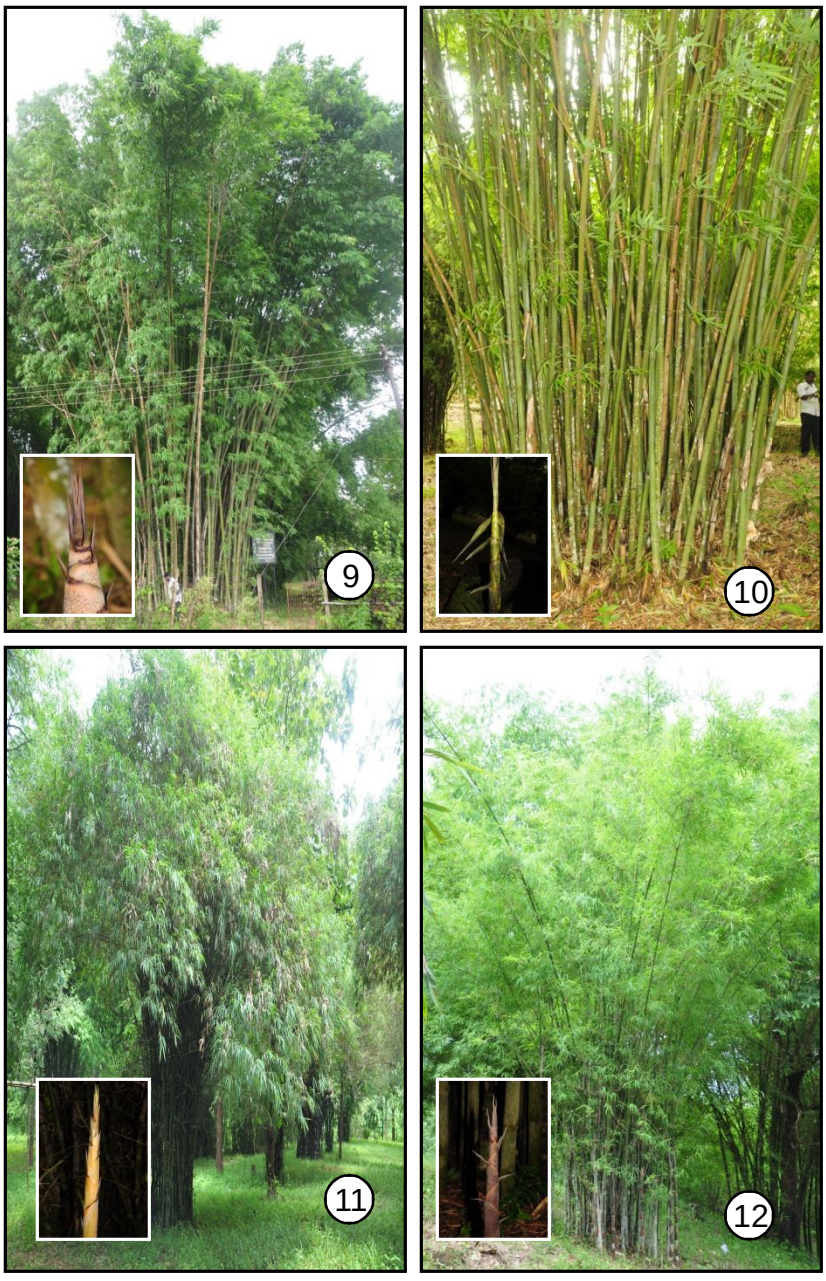


Fig. 10. General habit of medium size bamboos contd..
9. *D. brandisii* 10. *D. longispathus*. Small size nearly solid bamboos
11. *D. strictus*; 12. *P. stocksii*

Fig.11 General habit of small size nearly solid bamboos
13. *T. olveri 14.* General habit of small size thin walled bamboos
14. *M. baccifera* 15. *O. travancorica 16.* Natural regeneration of
B. bambos aftter gregarious flowering

Fig 12. Awareness campaign in Panchayath. 1. A view of the participants. 2. Dr. E. M. Muralidharan, KFRI delivers a talk on propagation. 3. Samples of different bamboo species exhibited on the table.

3. Distribution of planting stock and plantation establishment

Distribution of planting stock and plantation establishment

Distribution of planting stock

Panchayaths

Large quantity of planting stock was produced for two species for which seeds were available. Selection of panchayaths that will participate in this programme was made during the meeting conducted at Kerala State Planning Board in August 2003. Awareness classes were conducted in selected panchayaths during 2003-2004. Planting stock of two species (*Melocanna* 11500 and *Ochlandra* 34250 Nos) was distributed to 13 panchyaths from six districts as shown below(Table 25). The seedlings were made available at the office of the panchayath by KFRI. Selection of the beneficiaries was done by the officials of panchayath and seedlings were collected by the beneficiaries from respective panchayaths. A receipt was taken from the authorities while receiving the seedlings (Appendix 2) and MOU were executed with the individual beneficiaries (Appendix 3). For Wayanad district URAVU, an NGO which is involved in bamboo development has shared the responsibility of distribution of seedlings for which the seedlings were delivered at the office of URAVU at Trikaipetta, Wayanad by KFRI.

Table 25. List of Panchayaths and number of seedlings distributed.

Sl No	Name of the Panchayath	No. of Seedlings		Planting location
		Melocanna	*Ochlandra*	
1. Ernakulam District				
1	Kalady	1000	6000	In all wards of Panchayath
2	Kusumagiri And Kathikudam	100	300	KCPL
2. Palakkad District				
3	Kanjirapuzha	300	-	7th ward of the Panchayath
4	Mundoor	1000	1000	Mundoor Panchayath.

5	Thenkurissy	1000	2000	Thenkurissi Panchayath.
6	Chalavara	1000	4100	Chalavara Panchayath.
3. Wayanad District				
7	Meppady	1000	5000	Meppady Panchayath
8	Pozhuthana	1000	5000	Pozhuthana Panchayath
9	Panamaram	1000	5000	Panamaram Panchayath
10	Muttil	1000	5000	Muttil
4. Kollam District				
11	Sasthamkotta	2000	1000	In homesteads 04742451878
5. Pathanamthitta District				
12	Pandalam	100	150	Sugarcane seed farm
6. Kottayam District				
13	Changanasseri	120	200	For distribution in Eraviperoor, Thiruvall, Santhpuram, Mallappally 0474-2451878

Clusters of artisans

The clusters of artisans from Pathanamthitta and Thiruvanthapuram districts expressed their interest to plant *Ochlandra travancorica* in private as well as public land. Accordingly 6000 plants were provided by KFRI at the head quarters of the clusters. The details are provided below (Table 26).

Table 26. List of associations of artisans provided with reed seedlings

Sl No.	Particulars	Numbers
1	Kunnath Bhasi, Eeta Thozhilali Union, Pathanamthitta	1000
2	Manoharan MG Eeta Thozhilali Union, Pathanamthitta	1000
3	Sathi, Eeta Thozhilali Union, Pathanamthitta	1000
4	Vinobha Ashramam,	3000

Farmers

The farmers interested in planting bamboo in the homesteads were provided with planting stock of various species. The list of farmers who received more than 500 seedlings is given below. The list of farmers provided with seedlings of *M. baccifera* and *O. travancorica* through URAVU, Wayanad is given in Appendix - 4

Table 27. List of farmers provided with different bamboo seedlings

Sl No.	Address	Numbers
1	PJ Joseph, Palathingal House, P.O.Purapuzha, Thodupuzha	537
2	PJ Kunjachan, Karanthodu estate, Kurussupara, Kollar, Munnar	500
3	Distribution during open day celeberations	1237
4	KJ Baby Kolathukudy House, Manjipra, Krnakulam	1000

Establishment of demonstration plots

Demonstration plots were established in different locations in collaboration with various Institutions, individuals during the project period. Details are given below (Table 28).

Table 28. List of demonstration plots and species planted

No.	Location	Species planted
1	Film and Video Park, Kazhakuttam, Thiruvananthapuram	*B. vulgaris, M. baccifera, O. travancorica, D. giganteus*
2	Vinobha Nikethan, Aryanad, Thiruvananthapuram	*O. travancorica*
3	Ahalya Foundation Eye Hospital, P.B.No.120, Kanalpirivu, Palakkad, Kerala, India,	*Bambusa tulda, B. vulgaris, Dendrocalamus asper, D. giganteus, Ochlandra travancorica*
4	Kerala Varma College, Trichur, Kerala - Ela, Nature Club.	*Bambusa vulgaris, O. travancorica*
5	Mr. Ajay Kumar, Managing Director, G.A. Agro Pvt. Limited 10/312 Chorakode	*Dendrocalamus strictus*

7	Nitta Gelatin, Kathikudam, Cochin	*Bambusa balcooa, D. brandisii, B. vulgaris*
8	Rajagiri School of Management, Kakkanad	*O. travancorica, D. giganteus, B. vulgaris*
9	Eruthenpathy Panchayath	*O. travancorica*
10	Mr. Ramakrishnan, Vilayannur, Palakkad	*Bambusa bambos, D. strictus*
11	Vincent K Kodam kandath house, Karamuku, Kandassamkadavu.	*Dendrocalamus giganteus, D. brandisii, B. tulda*
12	Sakthan Palace, Trichur	*Bambusa balcooa, B. vulgaris, B. polymorpha, D. giganteus, D. longispathus,*

Observations on survival and status of clumps were recorded from some of plots after a period of 5-7 years (Figs.13 -17).

Fig 13. Demonstration plot at KINFRA a. a view of the pond with *D. giganteus* in the centre. b. *B. vulgaris* planted in a row

Fig. 14 a. *Ochlandra travncoria* b. basal part of the clump C. basal part of *B. vulgaris* clump

Fig 15. Demonstration plot at Mulayam a. A view of the plot b. One clump of *D. giganteus*

Fig. 16a. Planting of *O. travancorica* along the boundary of of Vinobha Ashram. b. Harvested reeds and bamboo artisan

Fig 17. Different types of baskets made by the bamboo Artisans at Ashram

4. Technical seminar and participation in exhibitions

Technical seminar and participation in exhibitions

Report of the technical seminar

A technical seminar was organized on Integrated Development of Bamboo Sector in Kerala in connection with Kerala Bamboo Fest (18th and 19th December 2004, in the Conference hall at Town Hall, Ernakulam). The seminar started with an inaugural address by Mr. PH Kurian, IAS, Secretary and Executive Director, Kerala Bureau of Industrial Promotion (K-Bip). He provided information on the National Level programmes being implemented for the development of bamboo sector along with the recent initiatives made by Government of Kerala, especially by K-Bip and the Kerala Bamboo Mission. Invited resource persons from various organizations presented seventeen papers on relevant topics for the development of bamboo sector. The details of the programme are given in Appendix - 5 and the name and addresses of the resource persons in Appendix – 6.

National and State level initiatives: Four papers were presented in this session one each from Kerala Bamboo Mission, Kerala Forest Research Institute, National Mission on Bamboo Applications and Inter National Network for Bamboo and Rattan on the initiatives taken on bamboo research, potential of bamboo and the development of bamboo sector. Shri C. P. John, Member, Planning Board and Vice-Chairman, Kerala Bamboo Mission in his presentation on Kerala State Bamboo Mission: Targets and Achievements highlighted the achievements of the Mission, which is just one-year old. The Kerala Bamboo Mission (KBM) mainly concentrated on development of Bamboo resources, capacity building of traditional artisans through training, development of new industries for value added products and organization of meetings and bamboo fest for popularisation of bamboo and bamboo products. Kerala Forest Research Institute (KFRI), Kerala State Bamboo Corporation Limited (KSBC Ltd), URAVU, National Institute of Design (NID),

Ahmedabad, Indian Institute of Technology (IIT), Bombay and National Mission on Bamboo Applications (NMBA) are some partner institutions for implementing the programmes. Dr. J. K. Sharma, Director, KFRI, in his paper on Modern trends in bamboo sector elaborated the potential of bamboo, the statistics about current bamboo industries and expected growth by 2015. He briefed about the formation of National Mission on Bamboo Technology and Trade Development, its targets and financial outlay. Also Dr. Sharma highlighted the contributions of KFRI. The Institute is currently providing good quality planting material and technical know-how on bamboo cultivation to user groups. He concluded by expressing the interest of the Institute to join hands with the bamboo development programmes in future in the State and National level.

The information provided by Shri S.K. Pandey**,** Mission Coordinator, NMBA, Delhi on National Mission on Bamboo Applications was an eye-opener to the participants regarding the activities already initiated in India for development of bamboo sector and the possibilities in future. He explained about the E^3 perspectives of bamboo i.e., energy and edible products, environmental protection and employment opportunities. NMBA has already transferred technologies such as mechanized processing using machineries and tools, edible shoot processing, composites and wood substitutes, energy and thermal applications, bamboo glass fibre composites, flooring, furniture and handicrafts etc. The presentation also covered value addition for the waste generated during bamboo processing, management of flowering, and products like activated carbon, charcoal, fibre and fabric from bamboo. NMBA is also focussing on resource enhancement and management by promoting cultivation in public as well as private sector. Shri T. P. Subramony, Resident Manger, International Network for Bamboo and Rattan, New Delhi summarized the details about INBAR and its contributions to bamboo and rattan research in the world. International Development Research Centre, Canada, the mother organization from which INBAR has

originated as an offshoot has been networking with most of the bamboo growing countries and strengthened the capabilities by providing financial support. INBAR extents its support to many states in India, especially in the north-eastern region through Cane and Bamboo Technology Centre. Several publications and the web site of INBAR provide the information to stakeholders.

Design and tool development: Two papers were presented on design and tool development from National Institute of design and Indian Institute of Technology. The achievements clearly show that we have the potential to develop innovative products and compete with domestic as well international markets**.** Prof. AG Rao, Industrial Design Centre, Indian Institute of Technology, Bombay in his presentation on Design, Tools and Small machineries for Bamboo Craft emphasized the requirement for repositioning to enter into the urban and semi-urban markets. Craft products need a design strategy, product innovation as well as technology and training support to enable a craft person to earn at least Rs. 100 daily. Three levels of design and technology intervention have been identified to meet the demands of 1.3 million craft persons in the country. Bamboo Studio of IDC developed tool kits and four small machines in different projects. In addition, colouring with natural dyes, special tools, product specific jigs & fixtures and communication materials were developed for three levels of the intervention. National Institute of Design, Ahmedabad has made significant contribution in the development of designs for furniture, house-hold items and toys using bamboo. The artisans in Tripura and other states of north-eastern states were trained for manufacture of these new items. Through display in buyers meetings, NID has procured sufficient export orders for many of these items and large-scale manufacture is under process. In the presentation on Design Development in Bamboo by Sri. C. S. Susanth, representing NID, the support that NID can provide for the development of bamboo sector in Kerala was highlighted.

Bamboo in construction: On use of bamboo in construction three papers were presented from BMTPC, IPIRTI and RV TIFAC. The products like glass fibre composites corrugated roofing sheets and panel materials can uplift bamboo from poor man's timber to a higher place in the construction sector. BMTPC offered to provide help to construct some model demonstration houses in Kerala and KBM and KFRI readily accepted it. The paper presented by Dr. C. N. Pandey, Director, Indian Ply Wood Industries Research and Training Institute, Bangalore on Application of Bamboo based products in housing highlighted the Research and Development undertaken at IPIRTI, Bangalore. The use of bamboo through industrial processing have shown a high potential for production of composite materials like bamboo Mat Board (BMB), Bamboo Mat Veneer Board (BMVC), Bamboo Mat Corrugated Sheets (BMCS) and Bamboo Laminates (BL) which are cost effective and have been approved as building material in National Building Code. These composites can be successfully utilized for structural and non-structural applications in construction of buildings. Dr. R. Gopalan, Director and CEO and his team at RV-TIFAC composites design centre (CDC) has undertaken a major R&D work to develop bamboo-composite materials and bamboo-composite sandwich structural products for common use and more critical applications such as aerospace and defence applications. By systematic blending and mixing of bamboo reinforcements with glass fibres and/or other natural fibers like coir, jute etc., and processing them using fabrication techniques such as filament winding, compression moulding, resin transfer moulding, etc, a variety of bamboo composite products like wall panel, roofing panel, door shutter, wall cladding, sandwich panels, etc., are successfully developed. His presentation on Technology development of bamboo-composite sandwich materials and products for socio-economic and industrial applications highlighted the perspectives of this new generation industrial product. The application of bamboo in construction was further demonstrated by Dr. Vishnukant Chatpalli, Chief Technology Marketing**,** Building Materials and

Technology Promotion Council, Bangalore. In this presentation he highlighted the use of bamboo for foundation, flooring, walls, for roof structures and roof covering. He showed some of the two and one-bed room houses constructed with bamboo for which construction cost is about Rs. 425/ sq.ft. BMTPC extended their support to construct some model houses in Kerala and Kerala Bamboo Mission and KFRI has readily accepted the proposal.

Pioneering bamboo industry in Kerala: Kerala is the first state to have a successful bamboo board factory. Kerala State Bamboo Corporation is one of the pioneering Industries in the bamboo sector, which was initiated about 30 years back. The presentation by Sri. N. C. Balakrishnan, Managing Director, Kerala State Bamboo Corporation highlighted the process of making bamboo ply and the activities of the bamboo board factory. He also touched upon the status and requirements of industry specific needs in Kerala through the presentation entitled Status of bamboo industries in Kerala and challenges.

Post harvest technology: The technology for prolonging the life span of harvested bamboo through simple and cost effective preservative treatments was presented from KFRI. Bamboo, as a biological material, is easily vulnerable to degradation by insect and fungal damage. The importance of post- harvest technology and details of some of the work done at KFRI that is of immediate application to mat weavers was highlighted by Dr. R. Gnanaharan, Research Coordinator, KFRI, Peechi in his paper on Post-harvest technology for bamboo. Some of the simple treatments like storing reed bamboo in running water proved very effective in minimizing the damage. Treatments for short term protection like use of boron compounds and TCMTB and for long term protection use of some of the treatment methods like modified butcherie method, vacuum pressure impregnation method and steeping was explained.

Bamboo for food: Bamboo shoot is rich in vitamins, cellulose, amino acids and trace elements and the nutritional value can be comparable to that of an onion. It is a good source of dietary fibre and low in cholesterol. Engineering Resources Group explained processing technology of bamboo shoot. The presentation by Sri Sanjunath**,** Engineering Resources Group**,** Bangalore on Nutritional aspects and processing of bamboo shoots highlighted the potential of using bamboo as food. India has several species of bamboo that are edible. Bamboo shoot is rich in vitamins, cellulose, amino acids and trace elements and the nutritional value can be comparable to that of an onion. It is a good source of dietary fibre and low in cholesterol. Bamboo shoot comprises of 90 per cent water. Bamboo shoot has been found to be effective in cancer prevention, increasing the appetite, decreasing blood pressure and cholesterol levels in the human body. Bamboo Shoot is a heart protective vegetable and its component phytosterols may be suitable as nutraceuticals. The technology for preservation and processing was also shared to the participants.

Policies and legal changes: The need for comprehensive legislation for promoting bamboo cultivation, provision for harvesting from the cultivated areas by the farmers, subsidy for development of plantation, bamboo cultivation in degraded areas, river banks and development of bamboo industries is urgently required. Sri. Trivedi Babu IFS, Chief Conservator (Planning and Research), Kerala Forest Department highlighted policy and rules regarding bamboo extraction and transportation in his presentation on policy and legal changes to promote cultivation and utilization of bamboo in Kerala. He explained the provisions in various policies and acts of Government, such as, National Forest Policy, Kerala Forest Act, The Kerala Preservation of Trees Act, The Kerala Private Forest Act, The Kerala Forest Rules, The Kerala Grants and Leases Act, The Kerala Forest Ordinance, Essential Commodities act, The Kerala Land Ceiling Act, The Kerala Forest Produce Act, The Plantation Labour Act and Kyoto Protocol on Climate Change. The need for comprehensive legislation for promoting bamboo

cultivation, provision for harvesting from the cultivated areas by the farmers, subsidy for development of plantation, bamboo cultivation in degraded areas, river banks and development of bamboo industries was emphasized in his paper.

Processing machineries and project cost*:* Different processing machines are available and viable projects have been planned in the bamboo sector. Details were explained in a presentation from Oriental Enterprise, Nagpur City. Through a presentation on bamboo processing and promotion of bamboo Industries in Kerala, Sri. Pratab Gosami, Oriental Enterprise, Nagpur City, Maharashtra explained the modern developments in bamboo sector and value added products made from bamboo. The project cost for various applications and requirements for promotion of industries was explained and some of the products were exhibited.

Resource enhancement: For all the industries bamboo raw material is required. The species suitable for plantation and cultivation techniques were provided from KFRI and commercial application of tissue culture was explained by Growmore Biotech. Dr. KK. Seethalakshmi, Scientist, KFRI ,while addressing the issue of bamboo resource development mentioned that lack of information on appropriate species for different uses, species site matching and plantation/agro forestry techniques for large-scale cultivation, synergy between micro and macro propagation techniques for production of planting stock in large-quantity are some of the constraints for development of industrial plantations. For development of bamboo resources about 16 species were identified at National level (*Bambusa balcooa, B. bambos, B. nutans, B. pallida, B. polymorpha, B. tulda Dendrocalamus asper, D. brandisii*, *D. giganteus, D. hamiltonii D. strictus, Melocanna baccifera*, *Ochlandra travancorica*, *Oxytenanthera stocksii, Phyllostachys bambusoides* and *Thyrsostachys oliveri).* The species collection at KFRI and expertise available on plantation establishment can help the State to develop bamboo resources. Meeting the requirement for

quality planting stock for species suitable for commercial exploitation is a challenge. Dr. Bharathi, CEO, Growmore Biotech, Hosur, Tamilnadu explained the potential of tissue culture in meeting the requirement of planting stock. He and his team were able to produce planting stock of some of the promising bamboo species like *Bambusa balcooa*, *Dendrocalamus asper* etc. by tissue culture.

Bamboo development plan in Wayanad - A case study: Bamboo development programme is taken up in a big way in one of the districts in Kerala and it is coordinated by an NGO, URAVU. Representing this organization the presentation made by Mr. C. Surendranath on role of local institutions in bamboo sector development: A case study from Wayanad District gave the objective, rationale, activities planned and partners in this venture. The programme, which is implemented with the help of KFD, KFRI, VSS, Tribal Cooperative Societies, NMBA, KBM and NABARD, is expected to set up a model for bamboo sector development in the State.

Recommendations

A panel consisting of Dr. R. Gopalan Director and CEO, RV-TIFAC, Dr. C. N. Pandey, Director, IPIRTI, Dr. N. K. Mohanan, Additional Director, Department of Industries and Commerce and Dr. Muktesh Kumar, Scientist, KFRI lead the discussions and the recommendations are given below.

1. Bamboo plantations need to be developed in a large scale in available land to meet the increasing raw material requirements. Research institutions like KFRI and private entrepreneurs like Growmore Biotech to provide species, planting stock and technical know how. There is a need for quality planting stock and all effort needs to be taken for this.

2. A species-specific cultivation manual that is of local application need to be brought out in Malayalam.

3. Bamboo need to be accepted in agro-forestry system and suitable models of bamboo mixed with other agricultural crops need to be developed. The economics of bamboo plantation along with other long rotation plantation crops in Kerala need to be studied.

4. Community participation is required for improving the degraded forest areas by establishing bamboo plantations, watershed protection along with pricing an access to bamboo produced to local communities.

5. There is a need for a comprehensive legislation and changes in policy to facilitate bamboo cultivation, harvesting, processing and transport of bamboo and bamboo products.

6. Development of bamboo industries such as bamboo shoot, bamboo composites etc is required in the State for which the possibility of joint-venture investment along with private entrepreneurs also need to be investigated.

7. Capacity building through training programmes in cultivation, product design and manufacture is required. The development of clusters of bamboo artisans to promote handicrafts and household items need to be given importance.

8. There is a need to recognize bamboo as an engineering material and use bamboo in house construction, tourism sector involving both private and public sector.

9. A social security network needs to be established for the benefit of labourers involved in the bamboo sector.

10. Basic research on bamboo to continue in the research institutions to develop technologies that is of application to improve bamboo economy.

11. An advisory committee consisting of representatives from all stakeholders need to be established to find out the requirements of the State, plan projects and monitor implementation.

The abstract of the presentations are given in Appendix 7.

5. Establishment of Bio-Shield with People's Participation

Establishment of bio-shield with people's participation

Coastal vegetations, such as, mangrove, coastal shelterbelt and community vegetations play a prominent role in protection of coastal areas from erosion and reducing the impact of natural disasters such as tsunami (Fig. 18). In addition, the coastal communities are directly or indirectly dependent upon coastal vegetation for their livelihoods. Establishment of a bio-shield (coastal vegetation) with suitable species is required along with long-term programmes with people's participation for effective management of coastal zones.

Bamboos are one of the plant groups that are well known for their efficiency to grow in a wide variety of soils and agro-climatic conditions. They are also found in association with many other plant groups. Traditional uses recorded for bamboos, also cover its application in fisheries. Recent documentation on the potential of bamboo by National Mission on Bamboo Development, Planning Commission, Govt. of India (2003) clearly indicated the role of bamboo for ecological protection, employment generation and enhancement of income.

General observations in coastal areas of the West coast and Andaman Nicobar Islands showed that about 16 species of bamboos namely *Bambusa balcooa, B. bambos*, *B. schizostachyoides, B. vulgaris, Dendrocalamus brandisii*, *Dendrocalamus giganteus, D. stocksii* , *D. strictus*, *Dinochloa andamanica* , *Gigantochloa andamanica, G. manggong*, *Melocanna baccifera, Ochlandra scriptoria*, *O. travancorica, Schizostachyum andamanicum* and *Thyrsostachys oliveri* are grown in coastal areas.

In coastal areas of Kerala, the common species found is *B. vulgaris* (yellow bamboo). *B. bambos* is seen occasionally. From northern Kerala to Maharashtra, *D. stocksii* (Konkan Bamboo) is growing well. Normally the growth is good on laterite soils. In Andamans, two species viz. *B. vulgaris* and *D. giganteus* are found in naturally and five species (*D. brandisii*, *B. bambos* , *M. baccifera*, *T. oliveri* and *D. strictus*) are found in cultivation. In addition, in the Havelock Island *Bambusa schizostachyoides, B. vulgaris* and *Dinochloa andamanica* are found growing

well between 100 to 500 m distances from coastal line. Besides these, *Gigantochloa andamanica, Schizostachyum andamanicum* and *Dendrocalamus giganteus* are commonly found in the Islands. In Nicobar Islands only *Dinochloa andamanica* is naturally distributed. Besides two species viz., *Bambusa vulgaris* and *Dendrocalamus giganteus* have been cultivated.

During this study, the possibility of including bamboo in the bio-shield and coastal afforestation programmes in Kerala and Lakshadweep was investigated.

Bamboo planting for establishment of bio-shield

A survey was conducted in the tsunami affected coastal areas of Thrissur District from Kadappuram to Eriyad Panchayath by officials of Kerala Forest Research Institute, Social Forestry Wing, Kerala Forest Department, Thrissur and Grama Panchayaths. An area of about 1 km was selected for experimental planting at Eriyad Panchayath (Fig. 18. 6).

The project had following objectives

1. To evaluate the survival and performance of different bamboo species in coastal areas
2. To identify species suitable for bio-shield establishment
3. To create awareness among local people on the role of bio-shield for protection of coastal areas

An inaugural function was organized for planting at Munackal on 24. 08. 2006. Sri. Binoy Viswam, Hon. Minister for Forests and Housing delivered the inaugural address and Sri. K. P. Rajendran, Hon. Minister for Revenue Presided over the function (Fig. 19). Voluntary participation from Schools, Colleges and Kerala Agricultural University, Self Help Groups, NGOs, Government officials, representatives from local bodies, fisheries, agriculture and forest departments

and several nature clubs in the locality in planting and interest shown by local people in the aftercare of the seedlings indicate the increased awareness of environmental protection among them.

Based on the information on bamboos in coastal areas, seven species were selected for experimental planting. A stretch of one kilometer was planted in two rows with seven bamboo species viz. *Bambusa tulda B. vulgaris, B. striata, Dendrocalamus asper, D. brandisii, D. longispathus* and *D. strictus*. Five plants from each species formed one replication and there were three replicates (5x3). Additionally 60 plants of *B. vulgaris* (yellow) and 55 plants of *B. vulgaris* green were planted. Survival percentage, number of shoots, height, number of internodes and the new shoots of the seedlings were recorded annually (Table 29). Of the seven species planted, maximum growth was observed for *Bambusa vulgaris* (yellow) and *Dendrocalamus asper* was not able to survive.

Suitable species of bamboos need to be planted as demonstration plots to popularize the idea of using bamboo for establishment of bio-shield for protection of coastal belt. Also the possibility of mixing bamboo with other species needs to be evaluated. Information on salinity tolerance of different bamboo species is required to plan assesses the planting distance from sea. A long-term plan is required to utilize the bamboo raw material generated from coastal areas for the benefit of coastal communities.

Table 29. Growth of different bamboo species planted under bio-shield establishment at Munackal

Species/ Year of observation	**Number of shoots**					
	2006	2007	2008	2009	2010	2011
B. tulda	3.8 ± 2.2	5.4 ± 5.6	1.3 ±1.7	1.5±2.0	1.5±2.5	3.4±5.2
B. vulgaris green	1.8 ± 1.1	4.5± 1.5	0.8 ±1.2	0.8±1.2	3.8±1.4	5.2±1.9
B. vulgaris yellow	1.9 ± 0.8	4 ± 1.2	1.2±2.1	1.6±2.5	7.4±2.8	**7.8±5.4**
D. asper	3.3 ± 1.3	6.4 ± 5.5	Dried			
D. brandisii	3.1 ± 2.0	4.0 ± 3.2	0.5±0.8	0.6±0.9	2.1±3.6	0.7±1.1
D. strictus	2.8 ± 2.0	2.5 ± 1.4	1.4±1.2	1.6±1.4	3.0±2.1	2.2±1.9
D. longispathus	2.0 ± 1.60	4.46 ± 2.55	1.2±1.0	1.5+1.4	2.4+2.5	3.6+3.1
Species	**Height of tallest shoot**					
B. tulda	59.4+14.1	64.9+63.4	67+111.3	44.3+63.0	50.7+77.32	66.66+89.47
B. vulgaris green	68.4+24.2	294.8+108.2	94+144.5	80+120.7	543+90.59	502.1+72.50
B. vulgaris yellow	93.9+28.4	201.0+38.6	74.33+129.0	74+138.8	384+109.34	**541.1+249.84**
D. asper	57.7+21.4	53.6+49.2	Dried			
D. brandisii	75.8+34.4	184.0+131.5	81.3+133.3	87.3+146.0	123.0+149.63	142.3+236.46
D. strictus	55.4+24.4	134.9+102.8	121.3+126.8	134+149.9	148.7+117.85	228.4+310.77
D. longispathus	60.7+42.0	212.9+168.8	181+230.1	141.3+146.2	202.3+228.68	508.1+441.97
Species	**Culm diameter**					
B. tulda	Not recorded	Not recorded	1.3+1.8	1.26+1.70	1.4+3.12	1.1+1.55
B. green	‘		2.3+3.4	2.46+3.70	7.7+1.78	8.5+2.95
B. vulgaris yellow			2+3.0	2.26+3.55	9.1+1.94	**11.5+4.47**
D. asper			dried			
D.brandisii			1.5+2.3	1.46+2.23	2.26+2.67	1.83+2.80
D.strictus			2.6+2.6	2.9+2.99	2.78+2.10	3+3.17
D.longispathus			4.8+5.0	5.36+5.18	4.36+4.28	7.13+5.73

Fig 18. Damages due to waves 1. Buildings, 2 & 3 Sea walls, 4. Coconut Plantation. 5. Visit of Experts to the affected areas 6. Selected area for experimental planting of bamboo at Munackal, Eriyad Panchayath

Fig 19. Planting of the bio-shield with people's participation, 2 & 3 KFRI Staff and public assembled for planting. 4. Inaugural function 5. Sri. K. P. Rajendran, Hon. Minister for Revenue and Sri. Binoy Viswam Hon. Minister for Forest and Housing lighting the lamp 6. People planting bamboo

Conclusions

Observations on different aspects regarding bamboo resources in Kerala and its enhancement could be made during this investigation. Seed production was observed for three priority species, namely. Seed characteristics, seedling growth, effect of growth regulating substances (GRS) on seed germination, proliferation and seedling growth were studied for *B. tulda*. Results clearly indicated that GRS has a positive effect. Flowering of two thin walled bamboo species used for weaving viz. *M. baccifera* and *O. travancorica* occurred during this phase and seed characteristics, seedling growth, RGR, NAR and biomass of both the species were compared. At nursery stage the former exhibited growth but field observations after establishing demonstration plot is required.

Experiments to standardize protocol for large-scale multiplication using culm cuttings were carried out for 11 species coming under three genera *Bambusa, Dendrocalamus* and *Thyrsostachys).* Rooting was influenced by GRS, concentration and position of node. Rooting could not be induced for both species coming under *Thyrsostachys* genera.

List of bamboo genera and species used for vegetative propagation

Bambusa	***Dendrocalamus***	***Thyrsostachys***
B. nutans	*D. asper*	*T. oliveri*
B. polymorpha	*D. giganteus*	*T. siamensis*
B. striata	*D. longispathus,*	
B. vulgaris	*D. membranceus*	
	D. stocksii	

Rooting response varied and a maximum rooting of 86.43 per cent was observed in B. *vulgaris*, followed by 80 per cent in *B. striata,* 67per cent in *B. nutans*, and 59.33 per cent *B. polymorpha*, A higher rooting percentage was recorded for basal and middle cuttings in B. *nutans* and basal cuttings in *B. polymorpha.* Cuttings from all three portions rooted in *B. vulgaris* and B. *striata.* Application of growth regulators enhanced the rooting response of cuttings. The application of NAA gave better rooting in *B. nutans* and *B. striata* while, IBA was found better for *B. polymorpha* and *B. vulgaris*. Clustering of the different treatments identified the basal cuttings of *B. nutans* treated with NAA 200 ppm, middle cuttings of *B. striata* treated with IBA 100 ppm and the basal cuttings of *B. vulgaris* treated both 100 and 200 ppm of IBA and NAA as the superior in sprouting and rooting attributes. The selection of the cuttings based on position of node and application of proper concentration of growth regulating substances can be resorted to ensure efficient rooting and cost-effective planting stock production.

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Appendices

Appendix - 1

List of Panchayaths with traditional bamboo workers in Palakkad and Thrissur Districts

Block	Panchayat	No. of workers
Thrithala (98)	Anakkara	NQ
	Chalissery	100
	Kappor	NQ
	Nagalasseri	8
	Pattithara	NA
	Thirumittakode	18
	Thirthala	26
Pattambi (99)	Koppam	NQ
	Kulukkallor	49
	Muthuthala	NQ
	Nellaya	NQ
	Ongannur	NQ
	Pattambi	NQ
	Paruthur	NQ
	Thiruvegappura	NQ
	Vallapuzha	28
	Vilayoor	21
Ottappalam (100)	Ambalappara	NQ
	Ananganadi	NQ
	Chalavara	100
	Lekkidi perur	NQ
	Vaniyamkulam	6
Sreekrishanapuram (101)	Cerpulasseri	NQ
	Kadampazhipuram	NQ
	Karimpuzha	NQ
	Pookottukave	NQ
	Sreekrishnapuram	NA
	Thrikkateri	NA
	Vellinezhi	NA
Mannarkkad (102)	Alanellur	NA
	Karakurussi	NA
	Karimba	NA
	Kottoppadam	73 families
	Kumarampathur	NQ
	Kanjirapuzha	100 families
	Mannarkkad	20

	Thachanattukara	78
	Thachampara	NQ
Attampadi (103)	Agali	NQ
	Puthur	NQ
	Sholayur	160
Palakkad (104)	Kodumbu	75
	Keralasseri	NQ
	Kongad	4 wards
	Mankara	25
	Mannur	15
	Mundur	1 ward
	Parali	NQ
	Pirayiri	NQ
Kuzhalmannam	Kottayi	Missing
	Kuthannur	
	Kuzhalmannan	
	Mathur	
	Peringottukurussi	
	Thenkurussi	
	Kannadi	
Chittor (106)	Eruthanepathi	NQ
	Kozhijampara	30
	Nallempalli	160
	Pattancheri	NQ
	Perumatti	NQ
	Paralam	NA
	Vadakarapathi	NQ
Kollengode (107)	Kollengode	186
	Koduvayoor	NQ
	Muthalamada	NQ
	Puthunagaram	NQ
	Vadavannur	20
Nemmara (108)	Ayilur	NQ
	Melarcode	NQ
	Nelliampathy	NQ
	Elavanchery	NA
	Nemmara	NA
	Pallassana	NA
Alathur (109)	Alathur	NQ
	Erimayur	100
	Kavasseri	100
	Kizhakkenchery	NQ

	Puthukode	21 families
	Tharur	30 families
	Vandazhi	NQ
	Vadakkanchery	NQ
	Kannambra	NQ
Malampuzha (110)	Malampuzha	NA
	Akathethara	253
	Puthuppariyaram	NQ
	Marutharoad	42
	Elapulli	30 families
	Polpully	NQ
	Puthusseri	NQ
	Peruvembu	10 families

NQ= Not quantified; NA=Not available

Appendix - 2

KERALA FOREST RESEARCH INSTITUTE

AN INSTITUTION OF THE KERALA STATE COUNCIL FOR SCIENCE, TECHNOLOGY AND ENVIRONMENT

PEECHI 680 653, **THRISSUR**, KERALA

Phone: 0487-2699037: 0487-2699062. Fax: 0487-2699249; Email: kfri@kfri.org

Memorandum of understanding for taking up bamboo plantations

I ……(name of the beneficiaries) agree to abide the following terms and conditions put forward by Kerala Forest Research Institute for taking up bamboo cultivation in my land under the Kerala Bamboo Mission Project (KFRI414/03. Bamboo Sector Development in Kerala: Resource enhancement.

1. The area planted with bamboo under the above project will be made available for taking observations for a period of 5 years and a display board giving the details of the area, species planted and the name of the project will be installed in the plot.

2. Planting, maintenance and protection of the planted area will be carried out as per the directions given by officials of the Kerala Forest Research Institute (KFRI), Peechi

3. Permission for collection of samples of bamboo and soil for analysis will be given to officials of the Kerala Forest Research Institute, Peechi as an when required.

4. Visitors sponsored by Kerala Bamboo Mission will be permitted to see the area

Kerala Forest Research Institute will provide

1. Planting stock of various commercially important bamboo species suitable for the area as per the directions of Kerala Bamboo Mission.

2. Technical know-how on bamboo planting and maintenance

The right for harvesting bamboo raised under this project is vested with the participating farmers/institution/Panchayath after 5 years till flowering and death of bamboo clumps (period ranges from 30-40 years based on the species planted). Directions for sustainable harvesting and technical know-how for scientific management of bamboo plantations and value added processing of harvested bamboo will be provided by the expert team from KFRI to successful planters as and when required.

Kerala Forest Research Institute or Kerala Bamboo Mission will not be responsible to settle any legal issues related to the ownership of land used for the plantation.

Place: Signature

Date: Full Address of Beneficiary

Appendix - 3

KERALA FOREST RESEARCH INSTITUTE
PEECHI

RECEIPT

Received …….. seedlings of *Melocanna baccifera* (Muli bamboo) and …… seedlings of *Ochlandra travancorica* (Reed bamboo), raised for planting under the project KFRI 414/03. Development of bamboo sector: Resource enhancement, from the bamboo nursery at FRC, Veluppdam. The seedlings will be used for planting in ……. (Planting location) of …….. …….. (Panchayath) …… (District) and the relevant details on survival and growth will be provided to Kerala Forest Research Institute on demand. Also permission will be given KFRI officials for taking any observations if required.

Place Signature
Date

Complete address of the receiver with contact details

Appendix -4

List of farmers supplied with bamboo seedlings through URAVU

SL. NO.	Name &address	Name of species *Ochlandra/ Melocanna*	Month of planting
1	Vijayakumar, Puthurvayal	3/0	June 03
2	Shyleh.C.P, Edakkal heritage, Ph: 221860	10/0	"
3	Thomas, Punnamattathil, Cherukade(po), Athiyodi, Ph:0496-2660935	3/0	"
4	Sheeja Arakkal, Ph:255648	5/0	"
5	Bijoy , St. Peters church, Chundale, Ph:202372	2/0	"
6	Ms.Swaminathan, Foundation, Puthurvayal	3/0	July 03
7	Sree chandranath, Ph:202344	30/0	"
8	Hassan, M. K.House, Munderi, Ph:204525	1/0	"
9	Jiscon Farm, Mysore, Mahadevapal	5/0	August 03
10	Sree Ratnakar, Kainatty , Vijayamill, ph: 202427	2/0	September 03
11	Krisnakumar , Bhavani sadan , Grameen bank, Erulam , Ph:283244	1/0	"
12	Reji, Varukkapalliyil, Vallikunnu(po), Ph:04936286363	1/0	June 04
13	Sreekumaran, Pozhuthana	7 /0	"
14	Shlesh , Edakkal	8/0	July 04
15	Thomas, Valiyapadikal, Cherukattur(po)	2/0	"
16	Muhammad, Turkibazar	2/0	September 04
17	Raju, Padinjarakuzhiyil, Karachal, Meenangadi	3/0	"
18	Unnikrishnan, Malakkad	2/0	October 04
19	Bunchamin padivayal	25/0	"
20	Anoop, Krishnagiri , Ph:247759	4/2	November 04
21	Babu mathew (Adv.), Ph:220045	6/0	April 05
22	Syriac , Pulpally, Ph:241060	1/1	"
23	Pradeep V Bagi , Meghadoot so.28, Laxmi Lane-11, Bharath Nagar, Belgaum-590003, Ph :(0831)2496344	1/1	"
24	Ajith Prasad, Banglore	1/1	"
25	Mannu, Kaniyambetta	10/10	July 05
26	Chandrnath, Mysore, Ph: 202844	10/0	"
27	Jose, Parayil , Thariyodu, Ph:250418	7/0	"
28	T.R.R.centre, Peringottukara	100/0	August 05
29	C.O.D Thamarassery	10/0	September 05
30	Surendran, Panamaram , Ph:220708	1/0	"
31	Amritha, Ambalakulangara	10/0	December 05
32	Malanadu, Karshaka Swasraya, Sangham	25/0	February 06
33	Biju Varghese, Wayanad Traders , Chulliyodu, Ph:220499	10/10	June 06

34	Kalindi Holyday House	2/0	"
35	KadamBari Jaiva, Karshaka Samithi, Nambikulam, 4962660935	15 /0	"
36	Roshini Charitable Trust	10/0	"
37	George Mathew, Thennitta Makkayl Payyambilli, Ph: 04935-215090	1/0	"
38	Jahamgeer, Kuttamangalam	1/0	July 06
39	Ali andoor	20/4	"
40	Chanrachoodamani, Ambika nivas, Chundale	2/0	"
41	Bamboo Ridge, Koorg	5/5	"
42	Sali T.S., Ph:248287	5 /0	"
43	Rastha kamblakadu	0/5	"
44	Balan koyilandy	0/3	"
45	Rajeev K.N, Peravoor, Ph:04902444779	1/0	"
46	St.Joseph, V.H.S.Kallodi	0/10	"
47	Poulose V.J., Vallikattuparambil , Konnnachal, Thalur, Ph:09442347650	10/0	"
48	Hopco Society, Panamarm , Ph:04935-222087	5/5	August 06
49	Thomas P.M., Seetha mount, Ph:234471	3/0	"
50	Edakkal Heritage	10/5	"
51	Estate Nadavayal J.J.	15/0	"
52	Talur nursery	50/0	"
53	Talur nursery	50/Il	"
54	Sreyas , Sulthan bathery	200/0	September 06
55	Raveendran, Edam	0/5	October 06
56	President, Vellachal Panchayat	10/0	December 06
57	Joseph, Chooranalil, Alakodu ,kannur	0/5	November 06
58	Adam yusuf , Dysp.Sp.Branch, 9447081925	1/0	"
	Kaniyambetta panchayath 11/8/05		
59	Shoukath Ali P., Palliyalil, Kaniyambetta	50/50	August 05
60	Joseph M.G., Mundanganath, Kayakkunnu.po	10/15	
61	K.s.chandranath, Kondarappassery.H, Varadoor.po, Ph:289632	500/300	
62	George K.P., Kandilikkal (H), Varadoor .po., Ph:289028	250/700	
63	Ananthan Nambiar, Naduvil veedu, Koodthummal, Ph:289578	50/125	
64	Sainudeen, Uruttiyil (H), Kaniyambetta	40/50	
65	Shibu K.M., Koonam makkil, Varadoor, Ph:289102	50/50	
66	Sarani arts & Sports, Club Kalluvayal, Karani .po	100/50	
67	Karunia Swarayasangm, Kalluvayal, Karani .po, Ph :289455	100/50	
68	Pranavam Sangam, Kalluvayal, Karani .po, Ph: 289346	100/50	
69	Anusree Swasraya, Sangam, Kalluvayal, Karani .po	100/50	
70	Prasanth M.K., Natural club,	25/25	

	G.H.S.S.Kaniyambetta, Ph: 286238		
71	Sajeev.P, Parakkal (H), Karani .po, Ph:289455	200/200	
72	Prameela P., Varadoor , Ph:289506	25/10	
73	Marudevi, Padkkara, Varadoor, Ph:289239	20/0	
74	Surendran P., Keerippatta, Varadoor	15/15	
75	Secretary, YMCA, Paralikunnu, Ph:285869	50/50	
76	Kuriakoe K.P., Kodangamparambil (H), Karani .po, Ph:289539	100/ 100	
77	Haridas V., Preethasadanam, Kaniyambetta, Ph:286252	25/25	
78	Varadoor Puzha, Samrakshanasamithi, No: 138/02, Varadoor , Ph:289631	250/500	
79	Venugopalan T.P., Chandranivas, Kallanchira	10/0	
80	Sankaran C., Karani , Varadoor .po.	15/0	
81	Vinu K. M., Kannothmelayil, Varadoor ,Ph:289820	50/50	
82	Narayanan nambiar M., Chunderi veedu, Varadoor (po), Ph:289631	200/200	
	Meppadi panchayat		
83	Haritha Shg, Thrikkaipetta, Meppadi	0/200	November 04
84	Thulasi Shg, Thrikkaipetta, Meppadi	0/200	"
85	Annakutty , Kuruppath, Kappikkadu, Meppadi	0/50	December 04
86	Archana Kudumbasree, Munduppara, Thrikkaipetta, Meppadi	0/20	March 04
87	Narayani, Moonjeli House, Thurayan Kunnu, Nathankuni.po	0/10	December 04
88	Choppa, Cheriyakallayichal Veedu, Kottanadu .po, Meppadi	0/100	"
89	Manuel K.M., Kannamballi., Nathankuni.po	0/35	"
90	Appukuttan A.P., Aancherippattathil .(H), Thrikkaipetta	0/50	"
91	Anthony K.K., Kadavan Veedu, Kottanadu .po, Meppadi	0/100	"
92	Bhaskaran.P.K ., Padassery (H), Nathankuni.po, Meppadi	0/20	"
93	Parukkutty Amma , Padikkakkudiyil, Nathankuni.po, Meppadi	0/50	"
	Total	**3062 / 3572**	

Appendix - 5

Technical seminar on
INTEGRATED DEVELOPMENT OF BAMBOO SECTOR IN KERALA

Date: 18 December 2004

9.30 –10.00	Inaugural Address
10.00–10.30	Kerala State Bamboo Mission: Targets and Achievements Sri. C. P. John, Member, Kerala State Planning Board and Vice Chairman, Kerala State Bamboo Mission.
10.30-11.00	Modern trends in bamboo sector Dr. J. K. Sharma, Director, Kerala Forest Research Institute, Peechi
11.00-11.30	National Mission on Bamboo Applications SK Pandey, Mission Coordinator, National Mission on Bamboo Applications, Delhi
11.30-11.45	Tea break
11.45-12.15	Policy and legal changes to promote cultivation and utilization of bamboo in Kerala Mr. N. V. Trivedi Babu IFS, Chief Conservator of Forests (Planning & Research) Kerala Forest Department
12.15- 12.45	Design, Tools and Small machineries for Bamboo Craft Prof. AG Rao, Industrial Design Centre, Indian Institute of Technology, Bombay
12.45-1.15	Discussion
1.15-2.15	Lunch break
2.15-2.45	Bamboo handicrafts and furniture Mr. C. S. Susanth, National Institute of Design, Ahmedabad, Gujarat
2.45-3.15	Technology development of bamboo-composite sandwich materials and products for socio-economic and industrial applications Dr. R. Gopalan, RV TIFAC, Bangalore
3.15-3.45	Post-harvest technology for bamboo Dr. Gnanaharan, Research Coordinator, KFRI, Peechi
3.45-4.00	Tea Break
4.00-4.30	Application of Bamboo based products in housing Dr. C. N. Pandey, Director, Indian Ply Wood Industries Research and Training Institute, Bangalore
4.30-5.00	Status of bamboo industries in Kerala and challenges Mr. N. C. Balakrishnan, Managing Director, Kerala State Bamboo Corporation.
5.00-5.30	Discussion

Date: 19 December 2004

9.30-10.00	Bamboo in construction Dr. Vishnukant Chatpalli, Chief Technology Marketing, Building Materials and Technology Promotion Council, Bangalore
10.00-10.30	Nutritional aspects and processing of bamboo shoots Dr. Sanjunath, Engineering Resources Group, Bangalore
10.30-11.00	Bamboo Processing and Promotion of Bamboo Industries in Kerala Mr. Pratab Gosami, Oriental Enterprise, Nagpur City, Maharashtra
11.00-11.15	Tea break
11.15-11.35	Bamboo resource development: species and technology for cultivation Dr. K.K. Seethalakshmi, KFRI, Peechi
11.35-11.55	Role of Local Institutions in Bamboo Sector Development: A case study from Wyanad District C. Surendranath, Uravu, Wyanad
11.55-1.00	Consolidation, discussion and preparation of an Action Plan

Appendix - 6

Technical Seminar on
Integrated Development of Bamboo Sector in Kerala

List of Resource persons

Mr. C. P. John, Member, Kerala State Planning Board and Vice Chairman, Kerala State Bamboo Mission. Phone 0471-2540973

Mr. S. K. Pandey, Mission Coordinator, National Mission on Bamboo Application, Technology Information, Forecasting and Assessment Council, Department of Science and Technology, Government of India. Viswakarma Bhavan, Shaheed Singh Marg.
New Delhi 110016. Phone: 011 26863877/01155659876; Fax: 011 26962267; E-mail: bamboo@tifac.org

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Dr. M. P. Ranjan, Faculty of Industrial Design and Chairman, Information Technology. National Institute of Design, Paldi, Ahmedabad 380 007
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Dr. R. Gopalan, Executive Director, Society for Development of Composites, TBI Block, Composite Technology Park, No-205, Bande Mutt, Kengeri Satellite Township, Banglore-560 060
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Dr. R. Gnanaharan, Research Coordinator, Kerala Forest Research Institute, Peechi 680 653. Thrissur, Kerala
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Dr. C. N. Pandey, Director, Indian Ply Wood Industries Research and Training Institute, P. B. No. 2273; Tumkur Road, Bangalore 560 022. Phone: 080 28394341; Fax 080 28396361
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Mr. N. C. Balakrishnan, Managing Director, Kerala State Bamboo Corporation Limited. Post Box No. 20. Angamaly South 683 573, India. Kerala. Phone: 0484 2452248. Fax: 0484 2453 006. 9447122248.

Dr. Vishnukant Chatpalli, Chief Technology Marketing, Building Materials and Technology Promotion Council, Karnataka Slum Clearance Board Premises, Opposite Krishna Flour Mill, No. 55, Risaladar Street, Seshadripuram, Bangalore - 560 020
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E.Mail:drveecee@vsnl.net bmtpcbangalore@vsnl.net.in

Mr. S. N. Sanjunath, Engineering Resources Group (ERG), 44, Palmgrove Road Austin Town, Bangalore - 560 047 Karnataka India
Phone: 080 25364338, 5576526, 5576539 Fax: 080 - 5561992 5510554 Mobile 92431 29941; e-mail: ergindia@vsnl.com

Mr. Pratab Gosami, Oriental Enterprises, 22 Ambazari Layout, Behind Dharmapeth Science College, Nagpur 440 033, Maharashtara. Phone: 0712-2239034 (09373108917-mobile) Fax: 0712 2224362; E-mail: **oriental2@rediffmail.com** .

Dr. K.K. Seethalakshmi, Scientist, Kerala Forest Research Institute, Peechi 680 653 Peechi 680 653, Thrissur, Kerala
Phone: 0487 2699037/2699063; Fax 0487 2699249; E-mail: seetha@kfri.org

Mr. C. Surendranath, Uravu, Indigenous Science & Technology Study Centre, Thrikkaipetta 673 577, Wyanad, Kerala. Phone: 9447538711 (mobile). E-Mail: suran@vsnl.com; uravu2001@yahoo.com

Appendix - 7

MODERN TRENDS IN BAMBOO SECTOR IN INDIA

JK Sharma

Director, Kerala Forest Research Institute, Peechi 680 653, Thrissur, Kerala.
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jksharma@kfri.org

Recently, re-discovery of the potential of bamboo for developing as one of the sunrise industries has resulted in launching of an integrated bamboo development programme by the Prime Minister on 05 June 1999 to focus on the development of an organized bamboo sector. Initiatives taken by Planning Commission, Government of India lead to launching of 'National Mission on Bamboo Technology and Trade Development' with the aim to implement an action programme involving bamboo as a key component for generation of employment through establishment and strengthening of existing bamboo industries and achieving environmental sustainability through bamboo resource enhancement in private and waste lands. Subsequently, in April 2003, the Planning Commission evolved a strategic perspective and developed an action plan to give maximum emphasis for promotion and development of bamboo during Tenth Plan. A financial outlay of Rs. 2608 crores has been provided for various activities to be undertaken immediately during the period. In addition to the paper pulp industries, it is envisaged to harness the potential to start other large-scale industries like bamboo shoot processing, bamboo based boards, flooring boards, furniture, new uses in building and road construction, etc.

Although re-discovery of the potential of bamboo and programmes for integrated development of bamboo sector is a recent initiative, Kerala Forest Research Institute, since its inception in 1975, has considered bamboo as one of the priority species for research. Significant achievements have been made in the areas of resource inventory through remote sensing and GIS, taxonomical identification and herbarium techniques, flowering and reproductive biology, seed and vegetative propagation methods, seed storage, tissue culture techniques, nursery and silvicultural methods, soil and nutrient management, genetic improvement through superior clones, molecular biology, pests and diseases problems and their management, anatomical, physical, chemical, mechanical properties and strength testing and grading rules, ISI standards, harvest and post-harvest technologies, socio-economical aspects and indigenous knowledge and information and networking. Of these, many technologies developed such as nursery and cultivation methods, preservative techniques, keys for field identification, disease and pest control were transferred to the user groups in recent past.

POLICY AND LEGAL CHANGES TO PROMOTE CULTIVATION AND UTILISATION OF BAMBOOS IN KERALA

N.V.Trivedi Babu IFS

Chief Conservator of Forests (Planning), Forest Head Quarters,
Vahzuthakkad, Thiruvananthapuram 695 014.
Phone: 0471 2339593. E-mail: **ccfplan@keralaforest.org**

To achieve the objective of extending the forest cover to a minimum of 33% of the geographical area, large-scale cultivation of tree species in private lands and homesteads is necessary. Bamboo is one of the ideal species in this regard due to its capacity to conserve soil and moisture, to restore the ecology of the degraded lands and to provide economic security to the rural poor because of its multiple uses and industrial applications. Bamboo grows abundantly all over India and it is the world's fastest and strongest growing woody plant. It produces a biomass of 40 tonnes/Ha/annum. It is the poor man's timber. It is estimated that annually 1.5 lakhs MT of bamboos and 1.25 lakhs MT of reed bamboos are available for extraction from the forests of Kerala. Bamboo is cultivated in the degraded forests of Kerala and to a small scale in the homesteads. The Bamboo Mission has targeted planting of 2 million ha of bamboos in the Tenth Plan, throughout the Country..

The National Forest Policy envisages that the bamboo based industries shall encourage the small and marginal farmers to grow bamboos by providing inputs like credit and technical advice and buy back arrangements. As per the Forest Act, transportation of bamboo harvested from private lands requires a transport permit whereas the articles made of bamboo do not require the same. There is no restriction on felling of bamboos cultivated on private lands as per the Kerala Preservation of Trees Act. As per Forest Conservation Act, 1980 Harvest of bamboos in a recorded forest area or any other forest area as understood in the dictionary sense, requires to be carried out in accordance with a Management Plan approved by Government of India. As the vested forests are being notified even now, any land cultivated by bamboos together with other forest species runs the risk of being declared as a vested forest. Bamboos standing in the assigned lands belong to the Government. To harvest bamboos in a leased land, the lessee has to pay seigniorage rate. Export of Bamboo to outside the State is not restricted under Essential Commodities Act. Bamboo cultivation employing more than 15 workers comes under the purview of the Plantation labour Act.

To encourage large-scale bamboo cultivation on private lands and homesteads, legislative changes to ease out regulations on felling and transport of forest tree species and provision of planting subsidy is suggested. Bamboos and other forest crops may also be exempted from the Land Ceiling Act. A cut off date may be prescribed for notifying the vested forest areas.

Either section 5 notification of the KPT Act be removed or issuing of section 5 notifications may be limited to a few very deserving cases. Bamboo may be supplied to the traditional workers and cottage industries at concessional rates. The Forest Department should supply the quality bamboo seedlings at concessional rates and provide technical help to the farmers in cultivating bamboo. The local bodies and NGOs may undertake planting of bamboo along the riverbanks and canal banks. Strategies shall be developed to market and export bamboo based products profitably. Import of pulp may be discouraged by imposing 5per cent duty.

DESIGN, TOOLS, AND SMALL MACHINES FOR BAMBOO CRAFT - REACHING THE CRAFT PERSONS EFFECTIVELY

AG Rao

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Bamboo craft needs repositioning to enter into the urban and semi-urban markets. Craft products need a design strategy, product innovation as well as technology and training support if we have to target a craft person earning Rs.100/- a day.

Three levels of design and technology intervention are identified to meet the demands of 1.3 million craft persons in the country. A tool kit and 4 small machines were developed by Bambu Studio of IDC under a UNDP programme. A mini tool kit has been developed under KVIC Mini Bamboo Clusters project. In addition, colouring with Natural dyes special tools, product specific jigs & fixtures and communication materials are developed for 3 levels of the intervention, which are elucidated in the paper.

TECHNOLOGY DEVELOPMENT OF BAMBOO-COMPOSITE SANDWICH MATERIALS AND PRODUCTS FOR SOCIO-ECONOMIC AND INDUSTRIAL APPLICATIONS

R. Gopalan

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Bamboo Composites are emerging as an attractive alternative to the well-established glass fibre polymer composites, which are proven satisfactorily as a cost effective substitute for wood and timber, for variety of applications. This has also enabled dramatic growth of the technology and applications of glass fibre composites over the last few decades. However there is some

concern among designers, engineers and environmentalists over the increasing use of glass fibre composites on account of their non-biodegradable nature. Research work has been under taken world over to develop bio-composites using plant and vegetable fibres such as bamboo, coir, jute, etc, to replace the glass fibre composites, and to overcome this serious environmental problem.

Bamboo, being a natural fibre with attractive engineering properties, it is an ideal choice for development of biodegradable and eco-friendly composites. The potentials of bamboo composites as an alternative to glass fibre could be realized if appropriate technologies to manufacture bamboo composite products on a commercial scale is developed and propagated.

RV-TIFAC Composites Design Centre (CDC) has undertaken a major R&D work, for the first time in India, to develop bamboo-composites materials and products for common's use, and bamboo-composite sandwich structural products for more critical applications using technology developed for advanced composites for Aerospace and Defince applications. By systematic blending and mixing of bamboo reinforcements with glass fibres and / or other natural fibers like coir, jute etc., and processing them using fabrication techniques such as filament winding, compression moulding, resin transfer moulding, etc, a variety of bamboo composite products such as wall panel, roofing panel, door shutter, wall cladding, sandwich panels, etc., are successfully developed.

These bamboo composites products were used to design and develop several full-scale structures like: prefabricated modular housing units, integrated toilet unit, sound proof cabin, etc. Extensive laboratory and field tests have been conducted on these structures to study their structural, thermal and environmental behavior, and the results are found to be satisfactory.

The CDC in collaboration with Composites Technology Park has successfully developed processing technique for large scale production of these bamboo composites roofing panel, wall panel, door shutters etc. The technology know-how for these bamboo composite products is now ready for commercialisation, through technology transfer, training and incubation.

APPLICATION OF BAMBOO BASED PRODUCTS IN HOUSING

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The Research and Development undertaken at IPIRTI, Bangalore in the recent past have established and amply demonstrated that bamboo could be a viable substitute to wood and several other traditional materials for housing and building construction sector. Its use through industrial processing have shown a high potential for production of composite materials like bamboo Mat Board (BMB), Bamboo Mat Veneer Board (BMVC), Bamboo Mat Corrugated Sheets (BMCS) and Bamboo Laminates (BL) which are cost effective and have been approved as building material in National Building Code. These composites can be successfully utilized for structural and non-structural applications in construction of buildings. This paper describes in brief the several advantages of using bamboo as eco-friendly material for building industry. Several applications of bamboo and bamboo composites for walls, door and window shutter, flooring, trusses, roofing and wall infill panel are enumerated. Advantages of IPIRTI-TRADA technology developed for housing using treated bamboo and bamboo composites are also highlighted. The technology evolved can be effectively adopted for construction of low-single storied houses with cost ranging from Rs. 300 to Rs. 450/- per sq.ft depending up on the design of the house nature of interior finish and also upon the location.

NUTRITIONAL ASPECTS AND PROCESSING OF BAMBOO SHOOTS

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Bamboo Shoot

Bamboo Shoot is an important component, which is consumed as a vegetable apart from the diverse uses the other parts of the plant. The emerging tip (Shoot) of the Bamboo plant that arises out of the ground during the monsoons, is consumed, in India, more as a vegetable by the natives and is made available to the others as a delicacy in up-market and specialty restaurants in metros and other cities.

Bamboo Shoot has been absorbed in the traditional cuisine in the North-East and Western Ghats in Karnataka. Bamboo Shoot is used in the fresh form during the season and as salted (pickled) and fermented products during the other seasons of the year. Bamboo Shoot is used in pickles and curries predominantly. Papads, snacks, and fried stuff are also made with Bamboo Shoot.

Some of the edible species of Bamboo in India are: *Dendrocalamus hamiltonii, D. brandisii, D. giganteus, D. strictus, Bambusa nutans, B. pallida, B. tulda, B.*

polymorpha, etc. *Dendrocalamus asper* has been recently imported from Thailand with a view to develop commercial cultivation.

Nutritional Qualities

Bamboo Shoot is rich in vitamins, cellulose, amino acids and trace elements and the nutritional value can be comparable to that of an onion. It is a good source of dietary fibre and low in Cholesterol. Bamboo Shoot comprises of 90% water. Bamboo Shoot has been found to be effective in cancer prevention, increasing the appetite, decreasing blood pressure and cholesterol levels in the human body. Bamboo Shoot is a heart protective vegetable and its component phytosterols may be suitable as nutraceuticals.

Processing and Preservation

Traditionally edible Bamboo Shoot, have been preserved by the natives of North East India as well as of Western Ghats in Karnataka, using conventional salting, drying and fermenting processes, primarily for their home consumption during the off-season. A very small quantity is also Sun Dried.

Bamboo Shoot was evaluated for preservation through the application of dry salting, wet salting, drying and canning methods. Of the four methods tried, salting (dry & wet) are scientific versions of the traditional preservation methods that could be well adopted for industrial scale processing even at the small or cottage levels.

The dry salted and brined (wet salted) products have shown very encouraging results in all the plastic flexible pouches that they were packed in. The colour, texture and flavour were retained in the packed products. The vacuum packed products were superior in quality over the other two packs. Our conclusion of the storage of the processed products is that the plastic flexible pouches can be used for packaging dried, brined or salted products for 6 to 9 months without loss in quality. A lot of effort is required to be put in by the different stakeholders for the promotion of processed bamboo shoot as a nutritive food substitute and making it available to the population at large.

BAMBOO PROCESSING AND PROMOTION OF BAMBOO INDUSTRIES IN KERALA

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Bamboo Processing can be broadly classified into two - Primary and Secondary Processing .Primary Processing means converting the raw bamboo culm into strips, slivers or sticks of the desired size. The size of the primary product depends on the size of the bamboo culm, that is the diameter, length wall thickness and internodal distance. The bamboo culm is tapered having the maximum diameter & wall thickness towards the lower end, which reduces gradually and is minimum at the higher end. Owing to this about 35% to 80% wastage of bamboo occurs during primary processing.

The Primary Processing

Cross cutting, splitting , width sizing and knot removing
Stick Making - Sizing Polishing – Round bamboo sticks
Two Side Planing– Four Side Planing – Bamboo strips STICKS
Curtain Making using a weaving Machine – BAMBOO CURTAIN

FOR BAMBOO PLY

SECONDARY PROCESSING

a. STICKS
- Agarbatti
- Toothpicks
- Skewers
- Window Roller Blinds

b. BAMBOO STRIPS
- Flooring Tiles
- Wall cladding

c. BAMBOO CURTAIN
- Shuttering Use Bamboo ply
- Flooring for Bus/Truck Railway
- Wapon
- Furniture /Partitions/ Cupboards / Table tops etc.

d. BAMBOO WASTE Particle board
Gasifier
Heat Energy
Electrical
Energy
Charcoal,
Barbeque
Activated
Carbon

PROCESSING OF EDIBLE BAMBOO SHOOTS Fresh
Canned
Dried

Bamboo Industry is labour intensive. The primary processing can be done at the village level. The Cost of Plant and Machinery for Primary Processing varies between Rs. 9.00 lakhs to 15 lakhs. The Primary Processing Units should act as an ancillary to the secondary processing units.

MANUFACTURING PROCESS OF BAMBOO PRODUCTS

A. Agarbatti
Round Bamboo Sticks – Coating (Saw Dust, Coal Powder and Jigit)- Applying perfume – packing.

B. Skewers & tooth picks
Round Bamboo Sticks – One End Shaving – Packing

C. Window roller blinds
Round Bamboo sticks – Treatment & Drying- Setting up of looms (creels)- weaving with Bamboo and Thread – Attachment of Accessories – Packing.

D. Flooring Tiles & Wall Cladding
Four Side Planed strips – Boiling (Treatment against insects, bores and fungi) – Drying – Strips selection- Gluing- Lamination using hot press- Sawing – Edge Cutting – Four Sides planning- Tongue & Groove Making- Sanding – Lacquering – Quality testing and Grading – Packing.

E. Bamboo ply
Bamboo curtain – drying – gluing- drying – arranging – hot press- trimming – packing

F. Bamboo shoot canning

Washing & removal of outer sheaths- sizing (slices /cubes / halves) – blanching – filling in cans – adding water – exhausting -simming -retorting – cooling – labeling – packing

PROJECT COST

a. Agarbatti – Rs. 7.50 Lakhs to Rs. 12.00 lakhs
b. Skewers and Tooth picks - Rs. 7.50 Lakhs to Rs. 12.00 lakhs.
c. Window Roller Blinds - Rs. 15 Lakhs to Rs. 25 lakhs
d. Flooring Tiles - Rs. 350 Lakhs to Rs. 500 lakhs
e. Bamboo Ply - Rs. 300 Lakhs to Rs. 500 lakhs
f. Bamboo Shoot Canning - Rs. 250 Lakhs to Rs. 350 lakhs

METHODOLOGY FOR PROMOTING BAMBOO INDUSTRY

1. Equity Assistance from State Government
2. Setting up of Demonstrative cum training units by the State Government.
3. Firm Commitments from KVIC/KVIB for Margin Money / Subsidy
4. Firm Commitments from CGTSI for providing guarantee to Bank for S.S.I's upto Rs. 25 lakhs having a maximum loan component of Rs. 17.5 lakhs
5. Soft Term Loans from TIFAC for Medium Scale Bamboo Units.
6. Special Status for Bamboo Industries under the State IndustrialPolicy.
7. Exemption in Sales Tax
8. Single Window Clearance System for Bamboo Industries.

MARKETING STRATEGY

1. Market Study – Domestic & Overseas (through Consultants).
2. Assessment of Market Demand and Pricing Policy
3. Sales Promotion through Advertising Campaign

BAMBOO RESOURCE DEVELOPMENT: SPECIES AND TECHNOLOGY FOR CULTIVATION

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Resource development to meet the raw-material requirement for all the forthcoming industries is important. Although bamboos are available in forest and non-forest areas, due to various constraints like lack of sustainable management, harvesting practices, gregarious flowering and death of flowered clumps, policies governing allotment of raw material to entrepreneurs in private sectors etc., lack of dependable source of raw material is the major constrain for upcoming industries. To meet raw material requirement a long term planning for management of existing resources and augmentation of resources with establishment of industry specific plantations along with policy changes promoting cultivation and supply of raw material to industries are required.

Lack of information on appropriate species for different uses, species site matching and plantation/agro forestry techniques for large-scale cultivation, synergy between micro and macro propagation techniques to produce planting stock in large-quantity are some of the constraints identified for development of industrial plantations. For development of bamboo resources about 16 species were identified at National level (*Bambusa balcooa, B. bambos, B. nutans, B. pallida, B. polymorpha, B. tulda Dendrocalamus asper, D. brandisii*, *D. giganteus, D. hamiltonii D. strictus, Melocanna baccifera*, *Ochlandra travancorica*, *Oxytenanthera stocksii Phyllostachys bambusoides* and *Thyrsostachys oliveri).* The details of the species, techniques for production of planting stock and method for plantation establishment and management are discussed in the paper.

ROLE OF LOCAL INSTITUTIONS IN BAMBOO SECTOR DEVELOPMENT: A CASE STUDY FROM WAYANAD DISTRICT

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Classified as non-timber forest produce but treated on par with forest timber for maximising revenue for the State and ambiguously described as "woody grass," bamboo is saddled with a dubious status in the country. Again, handled as a weed by both foresters and agriculture experts, bamboo has remained an "orphan crop" despite millions of people using bamboo as a dear livelihood resource in a multitude of ways. And despite its multiple ecological and economic functions, bamboo has not enjoyed any institutional support until recently, unlike the case of many other commodities. Even the formation of the Kerala State Bamboo Corporation has not made much dent in the institutional neglect of bamboo resources in the state as the activities of the corporation has remained confined to a single species of reed bamboo as well to a few select geographical pockets in southern and central Kerala. Even the implementation of decentralized planning with its theoretical thrust on development based on local resources and skills could so far pay only lip

service to the bamboo resources and the bamboo artisans in the villages in Kerala.

It is in this context that the present paper examines the institutional crisis in the bamboo sector in kerala as well as the role of non-governmental and quasi-governmental agencies in mitigating the problem. The experience of uravu, a non-governmental organisation working in the bamboo sector in wayanad district since 1996 is taken as a case in point. The relative operational mobility of non-governmental organisations vis-à-vis bureaucratic structures and partisan cooperative societies is seen as providing much-needed impetus to the development of the bamboo sector. The role of ngos in mobilising various players with partial stakes in the sector into full-fledged participants and in institutionalising a movement for promotion of indigenous knowledges into a comprehensive, decentralised and democratic development programme is examined here. A development programme for wayanad based on sustainable utilisation of bamboo resources wherein effective coordination between various developmental agencies is the key challenge is outlined in the paper.

Appendix - 8

Flowering, post-flowering behaviour and natural regeneration

Flowering and post-flowering behaviour

Flowering and seed production occurs in bamboos at long intervals and proper documentation is not available for many species. During the field investigations,flowering was observed in three bamboos (*Bambusa vulgaris*, *Dendrocalamus giganteus, Pseudoxytenanthera monadelpha*) that are commercially important**.** Observations were recorded on flowering, reproductive biology and post flowering behaviour. Also some of the flowered areas in the past were revisited during the field investigations and observations were made on status of regeneration. The details are presented in this chapter.

Dendrocalamus giganteus

Dendrocalamus giganteus Wall. ex Munro, generally known as the giant bamboo for its growth form, is the tallest of the sympodial bamboos (height, 20 to 30 m; diameter, 20 to 30 cm; wall thickness 2 to 2.5 cm ;an internode length 35 to 40 cm) with slender branches only on the top portions of the culm. In India, it is cultivated in Arunachal Pradesh, Assam, Manipur, Nagaland and West Bengal. Due to its multivarious uses like pulp, construction, boat masts, containers, edible young shoots and handicrafts, it is identified as one of the priority species for large scale cultivation. A scrutiny of earlier reports on *D. giganteus* indicates that flowering and seed production occurs very rarely (Gamble, 1896; Macmillan, 1907; Lahiri, 1974; Bahadur, 1979; Gupta, 1982, Ramanayake and Yankandawala, 1998; Islam et al., 2000). Most of the flowering reports are based on the year of first flowering after introducing the species to that locality from which a flowering cycle could not be derived. Limited clumps of *D. giganteus* are found in homesteads of Karnataka and Kerala, likely to be introduced from Northeast or

Myanmar about 50 years ago. Flowering initiated in few clumps in Kottayam and Kozhikkode districts of Kerala during 2004-07 and seed production was observed. Observations on the clump characteristics, floral morphology, seed set and post flowering behavior of the flowered clumps were recorded.

Field explorations were conducted all over Kerala in February 2007. Flowering was observed in a clump situated in a housing colony (N 09° 35′. 071″, E 076° 32′ 766″) near Kanjhikkuzhi, Kottayam district. Interaction with local people revealed that another clump, which flowered in 2006, was completely destroyed by removing all the flowered culms and setting fire at the base of the clump to prevent regeneration. However, about 25-30 seedlings were collected from the vicinity. The clumps of *D. giganteus* in other districts in Kerala were also examined for flowering. In one more clump in the campus of Government quarters (N 11°16′. 984″, E 075° 47′357′) near Civil station, Kozhikkode district flowering was observed. There was no flowering in the clumps of Wayanad district and rest of the clumps in Kottayam district.

The flowered clump in Kanjhikkuzhi, Kottayam consisted of 24 culms within an average clump width of 9.8 m. The average height, girth at fifth internode, number of nodes and internode length of the culms were 23.6 m, 57.5 cm, 45 and 40 cm respectively. Out of the total culms 16 were flowered, five died after flowering and three were yet to flower. The flowered clump in Kozhikkode recorded 36 culms in a width of 10.5 m of which nine had already flowered and died. Presently, 10 culms arein bloom. The local people have already extracted three culms. The individual culms had an average height of 23-26 m, girth of 55 cm and 60-65 nodes with an internodal length of 25-30 cm.

Inflorescence is a huge panicle with numerous spikelets arranged to form heads at nodes. Flowered branch (Fig. 1a) contained 35 ± 6 globular heads or spikes

(4.8± 0.3 cm width) arranged 3 to 8 cm apart at nodes; spikes consisted of 11± 2 spikelets which were fewer and loosely arranged at terminal portion of longer branchlets and in shorter ones. The spikelets (1.36 ± 0.05 cm long and 0.57± 0.04 cm wide); were many flowered pale green minutely pubescent and ovate acute. Each spikelet consisted 4 to 5 hermaphrodite florets and one or two empty glumes. Florets were closed, green in colour, dichogamous and protogynous. Presence of young anthers along with matured pistil in the FAA fixed flowers as well as maturation of pistil three to four days prior to anther emergence in the field studies revealed the occurrence of protogyny. The florets were 1 to 1.6 cm long and arranged in acropetal succession. Lemma (Fig 1c) was 1.3 ± 0.08 cm long,, 0.6 to 0.7 cm wide, broadly ovate, acute at apex, concave, glabrous, pale green and overlapped the palea. Palea subtending a bisexual floret was membranous, two keeled, sub acute at apex, puberulous with out, many-nerved, pale green, 0.99 ± 0.29 cm long and 0.3 to 0.4 mm wide (Fig 1d). Each floret contained six stamens, free and arranged in two whorls (Fig. 1e). Length of the stamen was 1.73 ± 0.23 cm. Anthers were linear, acute, bluntly sagitate at base and basi-fixed. They were yellow in colour with a length of 0.7 cm. Anthers dehisced linearly to liberate dusty yellow pollen grains. The pollens were monoporous. The pistil length ranged from 0.9 to 1.2 cm (Fig. 1f). The stigma, 1.18± 0.11 cm long and purple in colour and style was white. Ovary was globose, broad at the end, pubescent, white and one mm long.

The flowers opened at 6.00 am. The anthers dehisced from 9.30 am and shed pollens and stigma remained receptive which was indicated by the presence of fluid secretion over the stigma. Pollination appears to be anemophilous since no insects were seen visiting the flowers at the time of anthesis. None of the pollens germinated over the different combinations of the media. However, pollens showed a viability of 10 to 15 per cent in acetocarmine test.

Seed set was observed in the clump that flowered in Kanjikkuzhi, Kottayam. One gunny bag, which contained four kg of the floral mass after winnowing, gave 150 seeds (9 g) indicating the poor seed set. The floral mass, after separating the seeds sown in nursery beds did not germinate indicating absence of viable seeds. The individual seeds recorded the length and width of 0.65 ± 0.09 and 0.35 ± 0.05 cm and weight of 0.06 ± 0.01 g coming to about 16500 seeds/kg including glumes. Seed set was absent in the clumps flowered in Kozhikkode district.

During 2004, flowering was initiated in two out of the four clumps in a homestead at Kallupara (N 09° 23′. 345″, E 076° 38′ 510′′) and one clump on roadside at Mallappally (N 09° 29′. 814″, E 076° 34′ 380′′), both in Kottayam District. Although, profuse flowering was observed in all the three clumps at that time, seed formation could not be identified. During the visit to Kallupara in 2007, about eight young clumps were present in the vicinity of flowered clumps. The two clumps in the same homestead have not flowered yet. However, there were no young clumps in the vicinity of the flowered clump at Mallappally but the clump has reverted to its vegetative phase. Basal parts of the old flowered and dried culms are seen in towards the base of newer clumps (Fig 1 b).

The flowering reports of *D. giganteus* dates back to 1868 (Munro, 1868) and 1897 by Hooker (Clayton et al. 1994). Flowering records from India has been given by Gamble (1896), Lahiri (1974), Bahadur (1979) and Gupta (1982). Incidence of flowering is recently reported from Sri Lanka (Ramannayake and Yakandawala, 1998) and Bangladesh. (Islam et al., 2000).

Flowering of *D. giganteus* is reported for the first time from Kerala. The floral morphology agrees with the previous reports from other locations. The residents in the proximity of flowered clumps were not able to recollect the exact year of planting in the homesteads,however, they were sure that it is more than 50 years.

Since, most of the flowering reports are based on the year of first flowering after introducing the species to that locality the exact flowering cycle of this species could not be derived. Different flowering cycles, 25 years in South India, 40-45 years in North, East and Central India, and 45-50 years in Bangladesh and 65 years in West India have been reported (Banik, 1994). Janzen (1976) has reported a flowering cycle of 76 years based on the data given by Macmillan (1907). From the recollection of the residents, it appears to agree to 65 years in this location. Flowering of this species is occurring simultaneously in Arunachal Pradesh and in the campus of Delhi Zoo suggesting that same flowering cohort has been introduced to Kerala. Seed setting is generally poor; however from the flowered clump in Delhi seed formation is reported but there are no details about the quantity of seed produced (NMBA, 2007).

Post flowering behaviour of *D. giganteus* is an interesting phenomenon that deserves detailed investigation. Earlier reports indicate both death of flowered clumps and rejuvenation to vegetative phase (Ramanayake and Yankandawala, 1998). In present study, one of the three flowered clumps in 2004 has reverted to vegetative phase. A method of digging up of rhizome of flowered clumps after removing culms and treating with gibberellic acid solution has resulted in 64 per cent recovery from flowering of treated plants in *Phyllostachys vivax*, a monopodical bamboo in China (Hsuing, 1981). Similar observations were made in *P. bambusoides* by the 'prune and divide technology' where the culms are pruned and the rhizomes are divided to several bits, planted in soil with high nutrients (Jaquith, 2007). Reversion to vegetative phase after flowering was observed in another species of the same genus *Dendrocalamus stocksii* (Beena, et al., 2007).

Although the 'prune and divide technology' is useful only at small scale, recent development in micro-propagation techniques using nodal explants could be

used for selected clones with scaling up of the technology for commercial application (Ramanayake and Yakandawala, 1997). A clone with the capacity to rejuvenate after flowering offers good potential to circumvent the problem of gregarious flowering and death reported in many commercial bamboo species. If planting stock from such clones are used for commercial plantations, death after gregarious flowering can be avoided. Hence, the rejuvenating clump identified in the homestead of Kottayam provides a valuable source material for mass multiplication of a clone of *D. giganteus* with capacity to regenerate after flowering without death of the entire population.

Pseudoxytenanthera monadelpha

Pseudoxytenanthera monadelpha (Thw.) Soderstrom and Ellis *(Dendrocalamus monadelphus* Thw.*; Oxytenanthera thwaitesii* Munro*; Oxytenanthera monadelphus* (Thw.) is a thick-walled, straggling or subscandent bamboo endemic to Southern India and distributed between 900 to 1000 m in the ravines of Karnataka, Kerala and Tamil Nadu in India, Sri Lanka and Myanmar (Soderstrom & Ellis 1988, Tewari 1992). Gregarious flowering of *P. monadelpha* was observed in Rajamalai, Eravikulam National Park, Kerala during 2006-2007. Rajamalai is an eminent tourist place because of the rare and endangered Nilgiri Thar and a large number of tea estates. Hence, the flowered area is subjected to severe biotic interferences and the species is under threat of extinction. The absence of seed set after flowering aggravates the threat of extinction of this species from its current locality. The very first report on the flowering of *P. monadelpha* dates back to 1847 by White from Nilgiris, Southern India (Seethalakshmi & Kumar 1998). The original description of this species was based on the herbarium specimens collected from Sri Lanka during 1864 (Soderstrom & Ellis 1988). In later publications, other than the reports on incidence of flowering in different localities, no information was available on its floral biology or post flowering behaviour. The present investigations were conducted to study the floral

morphology, anthesis, pollination and pollen germination and the post flowering behaviour of *P. monadelpha.*

The flowered area was located at N 10°02'450" E 076°58'613" (GPS map 60c (Gramin) reading). Flowering was initiated in August 2006 and five clumps were in bloom during the first visit in February 2007. Three flowered clumps were randomly selected. The details on width of the clump (average of the two diameters at right angles) and the number of flowering and non-flowering culms in a clump, average height, girth (at fifth node), number of nodes and internodal length of the individual culms within the clump were recorded.

The plants were bisexual, with bisexual spikelets, with hermaphroditic florets. Since, almost all the clumps in the locality was flowered it can be considered as gregarious flowering. The details of the clump and culm attributes in the flowering locality during the first visit in February, 2007 are presented in the Table 1**.**

Table 1. Clump and Culm attributes of *P. mondadelpha*

Clump attributes	Mean	Culm attributes	mean
Width (m)	2.9 ± 0.39	Height (m)	3.63 ± 0.15
Flowering culms	66 ± 5.56	Girth at fifth node (cm)	2.13 ± 0.35
Non- flowering culms	10.66 ± 1.15	Number of nodes	12.33 ± 2.08
		Internodal length (cm)	37.66 ± 2.52

The inflorescence was a large leafy panicle with spicate branchlets bearing heads of more or less closely packed spikelets. The spikelets were clustered at the nodes of branchlets separated by 3 to 6 cm (Fig. 2 a and b) and the matured ones were seen towards base of the branchlets. The spikelets were one to three flowered (floret) and pale green in colour (Fig. 2 b). Several glumes were present but keels were absent. Florets were dichogamous, protogynous, closed. Presence of young anthers along with matured pistil in the FAA fixed flowers as well as maturation of pistil three to four days prior to anther emergence in the field studies revealed the occurrence of protogyny in the flowers. Lemma was 1.15±0.11 cm long and 0.1 to 0.2 mm broad (Fig. 2 c). Palea was ciliated and two keeled (Fig. 2 d). Stamens were exerted and six in number (Fig. 2 e). Anthers were white in colour with a purplish or maroon tinge, narrow, apiculate and hairy at the tip. The pollens were monoporate. The entire gynoecium was white and 0.96±0.23 cm long. It consisted of one to three stigmas hairy style and ovary. The latter is globose and broad at the end (Fig 2 f). The mean dimensions of spikes, spikelets, and florets of P. *monadelpha* are given in Table 2.

Table 2. Details of spike, spikelets, florets in P. monadelpha

Sl No.	Characters	Mean
1	The no. of spikes per branch	11±1.58
2	No. of florets with exposed stigma /head	4.85± 0.24
3	No. of florets with exposed anthers /head	57±15.8
4	Width of spike (cm)	3.58±1.99

5	Number of spikelets per head	3.5±1.93
6	Length and breadth of the spikelets (cm)	1.29±0.08, 0.31± 0.04
7	Number and length of florets(cm)	1-3, 1.0 -1.6
8	Length and breadth of lemma (cm)	1.170.26, 0.15±0.04
9	Length and breadth of Palea (cm)	1.15±0.11, 0.15±0.04
10	No. and Length of stamen (cm)	6, 1.32±0.16
11	Length of anthers (cm)	0.50±0.05
12	Length of the stigma + style (cm)	0.96±0.23
13	Length of ovary (cm)	0.10
14	Diameter of pollen grains (mm)	0.17±0.08

The flower opening started at 6.00 am and extended up to 11.00 am. The anthers emerged out from 6.00 am and they exerted out completely after 9.00 am and linearly dehisced to disperse the yellow pollens between 9.00 am and 11.00 am. Gentle breeze shook the anthers to liberate dusty pollen grains in the air. The stigma also emerged out in the early morning by around 9.00 am. The stigma receptivity was indicated by the viscous fluid secretion. Like other bamboos, *P. monadelpha* is anemophelous (wind pollinated, which was evident from the absence of insect visits to the male or female phase of the floret). The presence of large number of pollen grains on the adhesive tapes fixed near the flowers when observed under microscope also indicated the anemophily. Even otherwise, the presence of large anthers producing abundant uniform pollen grains which is the characteristic of wind pollinated species leads to occurrence the anemophily in this species. The freshly collected pollen grains of this species showed 92 to 95 per cent viability when stained with one per cent acetocarmine. However, when the pollens grains dusted in different germination media was observed under

microscope after one hour of incubation none of the pollens produced the pollen tube. Hence they could not be considered as germinating ones.

The recurrent visits to the flowering locality confirmed that the flowering of this species is followed by death of the clumps without producing viable seeds. Close examination of the fallen mass collected by shaking the clumps and sweeping floor did not show any viable seeds. There were no seedlings on the floor under flowered clumps or in the nursery where the collected floral material was sown which indicated that there was no seed set during the flowering in the present locality. All the flowering culms were green during the first visit in February 2007. They started to die and dry up during the visit in March, 2008 and all the culms in the locality were died and dried up during the last visit in March, 2009.

Previous reports on flowering of *P. monadelpha* have been made in 1846 and 1852 by White from Nilgiris, followed by Beddome in 1865 and 1871 from Anamalai; Clarke from Coonor (Nilgiris) in 1870; King from Ochterlong Velley in 1878; Gamble in 1865 and 1871 from Southern India (Gamble 1896, Blatter 1929). Recently, it flowered gregariously after a long gap of more than 120 years in Babubuden hills of Chickmangalur district of Karnataka (Naithani et al. 2001). It is ambiguous, whether the long gap of 120 years in flowering reports is due to absence of flowering or lack of reports in spite of flowering. Hence, flowering cycle of the species could not be ascertained from the flowering records available so far.

Flowering and fruiting of majority of the bamboo species occurs during August to December (Venkatesh 1984, Banik 1998, Koshy & Harikumar, 2001a) and flowering of *P. monadelpha* also followed this season. Dichogamy is observed in most of the bamboo species and protogyny is common. Although it encourages cross-pollination, while flowering occurs in small patches, it also restricts self-pollination since viable pollen grains are not available from the same floret or

neighbouring florets at the time of stigma maturity and thus may restrict seed formation. Opening of florets, time of stigma receptivity, type of pollination etc. agrees with the earlier reports from other bamboo species such as *Melocanna baccifera, Ochlandra travancorica, Bambusa vulgaris, B. bambos, D. strictus* etc (Venkatesh 1984, Banik 1979 & 1998, Nadguada et al. 1993, Koshy et al. 2001, Koshy & Harikumar, 2001b.). *P. ritcheyi* and *P. stocksii* (now *D. stocksii*) belonging to *Psuedoxytenanthera* genus also followed the similar pattern in anthesis (Beena et al. 2007). All these species produced large number of monoporate pollen. Bees visited the flowers of *D. stocksii* and *P. ritcheyi* but no insects were found to visit the flowers in *P. monadelpha*. *In vitro* pollen germination was absent in all the germination media tested in *P. monadelpha*. Meanwhile, 96 per cent and 11 per cent germination was obtained *P. ritcheyi* and *D. stocksii* respectively, using the same media (Beena et al. 2007). Even though, its caryopsis has been described based on the herbarium specimens collected from Sri Lanka during 1864 (Soderstrom & Ellis, 1988), the seed production was absent in the current locality. The later publications which cited information on flowering also did not cite seed formation (Blatter 1929, Naithani et al. 2001). The absence of seed set in this species might be ascribed to the in-ability of pollen grains to produce the pollen tubes.

The flowering of *P. monadelpha* poses serious ecological crisis in its habitat. Its root system was acting as good soil binder in the hill slopes. As the flowered clumps dried and finally degraded, the forest floor is exposed to various erosion agents like water, wind, among others which could be disastrous in mountainous areas like Rajamalai hills because the rate of erosion increases due to slope factor. As the regeneration was absent in the area, conservation activities are to be undertaken at the earliest to mitigate the problems associated with soil erosion.

Bambusa striata

B*ambusa striata* Lodd. ex Lindl. (*B.vulgaris var. striata (*Lodd. ex Lindl) Gamble; *B. vulgaris var. vittata* A and C. Riviere) commonly known as painted bamboo, golden bamboo, is a woody ornamental sympodial bamboo species usually found in cultivation. Native of China and Japan, common bamboo of Hawaii, introduced to many other tropical and subtropical countries, the species is grown in botanical gardens, homesteads and widely used for landscaping and erosion control. The mature bamboos are used for papermaking, scaffolding, construction, poles, curios and handicrafts and young shoots are edible. The species is also reported to have frost and salt tolerance (Seethalakshmi and Kumar, 1998).

B. striata flowers rarely and at long intervals. Flowering reports on this species are scanty. The recent flowering reported in 1996 from Cherthala, in Alappuzha district in Kerala is the report of flowering from India published after 100 years (Koshy and Pushpangadan, 1997). From Bangladesh sporadic flowering has been reported in 1851, 1863, 1879, 1890 and 1892 and then in 1977-1985. Careful observation of flowering during1980-81 (Alam and Islam, 1981) and 1983-84 did not reveal any seed production (Banik, 1987). Flowering cycle is believed to be 80 years (Banik, 2000).

During the field explorations in February, 2007 sporadic flowering of *B. striata* was observed in a homestead near MC road, 2 km after Thiruvalla in Kottayam district in Kerala (N 9^{o} 23′ 055″ E 76^{o} 35′ 369″). None of the clumps situated in the adjacent areas were flowered. Out of the 29 culms in the clump only eight were flowered of which three were already died. In the clump, two of the non-flowered culms formed in the previous year were completely green showing similarity to the cultural variety *B. vulgaris* of this species and the rest were yellow with green stripes (Fig 3 a). The clump characteristics of the flowered

clump was observed and the clump was 7.5 m in width, the culms were eight to 20 m in height, 30 to 60 cm in diameter and on an average recorded 16 nodes and internode length of 30 to 45 cm.

The flowered branches possessed 17.6 ± 1.26 spikes of width 2.77± 0.34 cm (Fig. 3 b). The Inflorescence was a large leafy panicle consisting of flat spikes clustered at the nodes separated at 2 to 4 cm. Each spike contained 21.1±1.28 spikelets of width 0.48±0.09 cm. Each spikelet consisted of 3 to 7 female phase and 2 to 5 male phase in different combinations. All florets often do not open. The spikelets were three to eight flowered, laterally compressed, dichogamous, protogynous, and pale green in colour. Florets had two lodicule, those are fleshy organs located at the base of the ovary that swell and force apart the palea and lemma to open the floret. The floret length ranged from 0.6 to 1.0 cm. Lemma was 0.91± 0.07 cm long and without keel (Fig 3 c). Palea, which encloses sex organs was ciliated, two keeled, 0.85±0.09 cm in length and 0.1 to 0.2 cm in width (Fig 3 d).

The androecium consisted of six exerted stamens and 1.05±0.05 cm long (Fig 3 e). Anthers were deep purple, with white filaments, apiculate, hairy at the tip and 0.46±0.05 cm long. The pollens were monoporous. Most of the flowers opened between 6.00 am and 6.30 am and the anthers and stigma emerged out. The pollen dehiscence started at 9.00 am. At the time of dehiscence, pollen grains were dusted in a cavity slide containing sucrose medium for *in-vitro* germination. Pollen germination was studied using media containing 10 per cent sucrose, 0.1 mg of boric acid and 0.3 mg calcium nitrate in different proportions (Table 3).

Pollens were highly sterile and failed to germinate under *in vitro* conditions. The viability of the pollens was tested. Only those pollens, which produce tube length more than its diameter was considered as viable. The pollen viability was also tested by acetocarmine staining considering stained grains as viable and the shriveled as non-viable. The viable pollen in the microscope field was counted

and expressed as percentage of the total. None of the pollens were found to be viable. Pollen grains failed to germinate both *in vitro* and *in vivo*. No insect pollinators could be observed during anthesis.

Table 3. Composition of pollen germination media

Composition	M1	M2	M3	M4	M5
Sucrose (g)	10	10	10	0	10
Boric acid (g)	0.01	0.01	0	0.01	0
Calcium nitrate (g)	0.03	0	0.03	0.03	0
Distilled water (ml)	100	100	100	100	100

Length of the entire gynoecium was 0.86 ± 0.11 cm and two to three stigmas was 0.3 to 0.4 cm long (Fig 3 f). The third one is not well developed. The gynoecium falls into three categories viz. the length of the entire gynoecium (a) less than the length of the palea (b) as long as palea and (c) slightly longer than the lemma. Ovary was umbonate and 0.1 to 0.2 cm in length.

The flowered clumps were shaken and the fallen mass was collected to assess the seed availability. The fallen mass was winnowed to separate fertile seeds. No seeds were obtained. A revisit to the same area after monsoon showers in April, to trace any wildlings was also in vain. The flowered clump is in a highly disturbed state. Since bamboo flowering is followed by the death of flowered clump, it is a common practice in villages to cut all the bamboo as soon as flowering is observed even before waiting for seed set.

The present observations on flowering of *B. striata* agree with the earlier reports on the species with regard to floral morphology, especially three types of gynoecium, pollen viability and seed set (Koshy and Pushpangathan, 1997). Although insect visits were recorded in some of the previous reports their role in pollination could not be ascertained (Koshy *et al.*, 2001). No seed formation is reported for this species in any of the flowering records (Banik, 1979; Alam and

Islam, 1981; John and Nadguada, 1997; Koshy and Pushpangathan, 1997; Koshy and Jee, 2001). Factors responsible for failure of seed set appear to be many. High rate of pollen sterility (as observed in present investigations), absence of natural pollination and inhibition of pollen tubes in stigmatic papillae act as cumulative factor for absence of seed set in this species (Koshy and Jee, 2001). The inherent unhealthy nature of stigma to receive pollen and the possible role of brisle-like hair as barriers preventing pollination has also been reported (Koshy and Pushpangadan, 1997).

Since seed formation has not been observed in this species, vegetative propagation is going on for a long time. All three names *Bambusa vulgaris* var. *striata*, *B. striata*, *B. vulgaris* var. *vittiata* has been used to describe this species. Three types are seen in nature – yellow culm with green stripes, complete green culms and green culm with yellow stripes. In the same clump both yellow with green stripes and full green culms are also observed. Since it is a vegetatively propagated species and synchronous flowering is known to occur, gregarious flowering and death of the entire population is likely. Hence, continuous observations on flowering and seed production and clear documentation of flowering are very essential to locate its different flowering cohorts. Since, it can tolerate adverse conditions like frost and salinity it can be developed as an ideal species for establishment of plantations in difficult sites.

Natural regeneration in flowered areas

During the present study many locations from where flowering was reported during the previous years were revisited to record observations on the status of natural regeneration. These include *Bambusa bambos* in Wayanad and *Ochlandra travancorica*, *O. soderstromiana* and *O. spirostylis* in Ranni Forest Divisions.

Bambusa bambos

B. bambos is one of the major species found in natural forests and grown in homesteads through out the country; it contributes to 13 per cent of the total bamboo culm production from the country (Rai and Chauhan, 1998). Gregarious flowering of *B. bambos* was observed in Wyanad wildlife sanctuary, Kerala during 1991- 92 after a gap of 30 to 35 years. The flowered areas were revisited after 10 years to assess the status of regeneration.

Observations on flowering and seed fall have been already reported from three localities, viz. Chethalayam (N 011^0 45′ 457′′, E 0760 09′ 645′′), Noolpuzha (N 11^0 35′498′′, E 76^0 21 571′′) and Tholpetti (N 011^0 54′ 231′′, E 0760 03′ 699′′) during 1992-93. The three locations were visited during March 2003; 10 years after seed germination to record the growth and establishment of bamboo plants which regenerated from these seeds. The density of *Bambusa bambos* clumps (clumps/ ha) was estimated by laying out ten quadrats of 100 m x 100 m in each locations. Five bamboo clumps were randomly selected from each location to record the clump attributes. The width of the clumps (m) and number of culms/clump were recorded. The height of the largest culm (m) in a clump, its girth at breast height cm (GBH in cm), length of the fifth internode (cm) and wall thickness (cm) were recorded.

The clump and culm characteristics were subjected to one-way analysis of variance to compare between the localities and the treatment means were compared with LSD (Least Significant Difference).

Significant variation due to location was observed in number of clumps per hectare (P=0.01). The highest number of clumps per hectare was observed in Noolpuzha (245.00±9.74), followed by Chethalayam (132.60±15.59) (Table 4). The lowest number of clumps per hectare (74.20 ±5.31) was observed in Tholpetti which was only 33.3 per cent of that in Noolpuzha. The width of the clumps ranged from 1.96 to 3.11 m and the clumps from Tholpetti recorded the highest width (3.11±1.69 m) and it was significantly different (P=0.01) from other two locations. The lowest width was recorded in clumps of Chethalayam (1.96±0.65 m) locality. The number of culms and height of the largest culm in the clumps varied significantly among different locations (P=0.05). The highest number of culms (21.05±11.23) was recorded in bamboo clumps of Tholpetti location and it was the least for those in Chethalayam (13.00±7.22). The largest culm height (12.53±4.84 m) was recorded in the clumps from Chethalayam while, which it was the lowest in Tholpetti, (8.95±4.48 m). Significant variation due to location was absent in GBH, Internodal length and wall thickness of the culms. The culms recorded the highest GBH (17.63±4.16 cm) in Chethalayam, highest internodal length (28.20±2.42 cm) in culms at Noolpuzha and the highest wall thickness in culms at Tholpetti (1.55±0.63 cm).

The density of natural regeneration and biotic factors in three localities seems to have some relationship. Major biotic factors affecting the regeneration were grazing by wild animals like elephants and cattle from adjacent settlements. Wild animals such as sambar (*Cervus unicolor*), elephants, langurs among other inflicting heavy damage to bamboo regeneration and new culms have been reported. Elephants feed on the bamboo culms which are their favourite food and langurs damage new culms (Prasad and Gadgil, 1981).

Table 4. Variation in clump and culm attributes of *Bambusa bambos* due to locations

Location / Parameters	Chethalaym	Noolpuzha	Tholpetti
Seedling density (#/m^2)	265.15 ±24.89^a	562.90±28.11^b	430.27 ±32.02^b
No of clumps / ha	132.60±15.59^b	245.00±9.74^a	74.20 ±5.31^c
Clump diameter (m)	1.96±0.65^b	2.17±0.60^b	3.11±1.69^a
Number of culms	13.00±7.22^b	17.55±10.28^{ab}	21.05±11.23^a
Maximum height (m)	12.53±4.84^a	11.05±2.09^{ab}	8.95±4.48^b
GBH (cm)	17.63±4.16	16.25±2.70	15.93±6.26
Internodal length (cm)	26.18±3.08	28.20±2.42	23.50±6.80
Wall thickness (cm)	1.34±0.20	1.32±0.26	1.55±0.63

Note: Values with same superscript within a row are homogenous

The lowest number of clumps/hectare was found in the Tholpetti, an area famous for ecotourism in Wayanad sanctuary, where the sighting of wild animal was very common especially the elephants. The lower clump density might be ascribed to the destruction of bamboo clumps by elephants. Human settlements are found near Chethalayam where unauthorized extraction of bamboos takes place by local peoples for various domestic purposes. Moreover, the seeds were collected illegally by local people. Moderate clump density observed here might be due to the anthropogenic as well as biotic disturbances. Whereas, the highest clump density recorded at Noolpuzha seems to be due to lesser biotic and anthropogenic interferences. Bamboo regeneration requires protection from grazing and premature extraction in the initial periods for successful establishment. Hence, protective measures to avoid such

incidents are to be undertaken at the time of flowering, seed production as well as in the initial stages of regeneration. Otherwise, after successive gregarious flowering, the bamboo resources deplete at a faster rate. Bamboo new shoots, leaves and seeds serve as a major and favourite food for animals and birds in forest areas. In the light of the present study, the major factors that influenced the natural regeneration of the *B. bambos* are seed predators, out break of *Udonga montana* and disturbances in the form of anthropogenic and biotic interferences.

Ochlandra soderstromiana, O. spirostylis and O. travancorica

Reed bamboo (*Ochlandra sps*) forests occur as primary and secondary formations and flourish in areas of high rainfall and impeded drainage. They form one of the most important long-fibre raw materials for the paper and pulp industry, mat and basket making, house construction, musical instruments like flutes etc. Degradation of forests due to fire, conversion of land to agricultural use and over-extraction is observed in many of the predominant reed bamboo areas. Sustainable management of reed bamboo areas is essential for conservation and enhancement of this vanishing asset (Basha, 1994). Ecologically, the positive effect of growing reed bamboos to prevent soil degradation is well established (Sujatha 1999; Sujatha et al., 2002, 2003). The reed growing soils contain high diversity and density of soil fauna (Kumar et al., 1999b).

Twelve species and one variety of reed bamboos are reported under the genus *Ochlandra* and many of them are rare and endangered (Kumar, 1995, Kumar et al., 1999a &2000). *Ochlandra travancorica* Benth**,** *O. soderstromiana* Muktesh and Stephen and *O. spirostylis* Muktesh, Seetha and Stephen are the three endemic reed bamboos of Western Ghats. *O. travancorica* is a large size reed bamboo about 6 m tall occurring widely as an undergrowth in the low level evergreen and semi-evergreen forests, especially in Thiruvananthapuram, Thenmala, Ranni and Konni Forest Divisions of Kerala, India (Kumar, 1995). *O. soderstromiana* is a

small straggling bamboo with culms erect up to 5 m with an internodal length of 40-50 cm, so far restricted in occurrence to Kallar valley estate, at an elevation of 1000m. *O. spirostylis* is gregarious shrubby bamboo, about 6 m tall, with an internodal length of 45 to 55 cm long, found on the river banks of Kallar at an elevation of 900 m near Chattuparakudy (Kumar et al., 1999a).

Flowering and seed set of *O. travancorica*, *O. soderstromiana* and *O. spirostylis* was observed in Ranni Forest Division of Southern Kerala during 1997-98. A comparison of the seed, clump and culm characteristics along with the status of regeneration, nine years after seed fall under natural conditions are given below.

The flowered areas were revisited in February 2007 (Nine years after the seed set and dispersal) to assess the regeneration status of the three species. 20m x 20m sample plot was randomly demarcated for *O. travancorica* and *O. soderstromiana* to record total number of clumps. The number of clumps in a length of 50 m was recorded for *O. spirostylis* as it was found as a single row on both sides of Kallar River. The clump and culm characteristics like the clump width, number of culms per clump, height of culms, number of internodes per culm, length and girth of fifth internode were determined for four clumps of each species at random. Only two clumps were present for *O. soderstromiana* to record these characters.

Univariate ANOVA was used for analysing the seedling characteristics of the three species. Least Significant Difference (LSD) was used for pair wise comparison whenever necessary (Jayaraman, 2001). The mean and standard deviations were calculated wherever necessary.

About 20-25 clumps were counted in an area of 20 x 20 m for *O. travancorica.* Only two clumps of *O. soderstromiana* were present which were located in the

buttress of trees at a higher spot, which was not accessible to cattle while grazing (Figs 4 a and b). *O. spirostylis* showed 17-20 clumps in a length of 50 m**.**

More number of culms per clump was recorded in *O. travancorica* (197) followed by *O. spirostylis* (110). The growth of same age clump of *O. soderstromiana* was very poor (7). *O. spirostylis* showed maximum height (9.54 m) followed by *O. travancorica* (7.61 m) and *O. soderstromiana* (6 m). The spread of clumps (clump width), internode length, and diameter of internode were also highest in *O. travancorica* followed by *O. spirostylis* and *O. soderstromiana*. But *O. spirostylis* had more number of internodes when compared to the other two species (Table 4). The analysis of variance revealed significant variation in number of culms, clump width, culm height and number of internodes of the three species at five percent level (Table 5).

Table 5. Clump and culm attributes of *O. travancorica, O. soderstromiana and O. spirostylis* after nine years of flowering and seed set

Species	*O. travancorica*	*O. soderstromiana*	*O. spirostylis*
No. of culms/clump	197±41.59[a]	7.00±5.66[c]	110±20.98 [b]
Clump width (m)	2.08±0.23 [a]	0.60±0.07 [c]	1.75±0.17 [b]
Ht.of the culm (m)	7.61±0.71 [a]	6.00±0.64 [b]	9.54±0.90 [c]
Diameter at fifth node (cm)	9.33±2.00	6.95±1.60	7.42±1.14
Length of fifth internode (cm)	67.06±13.56	52.63±16.32	61.63±6.51
No. of internodes	10.19±2.26 [b]	8.25±0.71[c]	13.06±1.69 [a]

Mean value with standard deviation. The parameters with same letter as superscript in the same row are homogeneous

As abundant seed set was observed in all the species a certain and profuse natural regeneration was expected. Profuse regeneration of *O. travancorica* was observed in natural forests of Nanattupara counting about 600 clumps/hectare almost equal to a plantation at spacing of 4 x 4m. The regeneration after

flowering was comparable with the initial stocking in this area. *O. spirostylis* also recorded good regeneration. As this species has become an integral part of the livelihood of local people for several purposes, they maintain it on the riverbanks in a single row as if it is planted with a uniform spacing. The height of present population is about 9.54 m, 50 per cent higher than the first report (Kumar et al., 1999a). The first report was based on the growth at the time of flowering and hence there may be slow vegetative growth in the previous years. However, the regeneration of *O. soderstromiana* was very poor. The number of houses in the locality has increased when the area was revisited and the road accessibility has been improved. There was heavy grazing of domestic animals like cows and goats in the vicinity. Moreover, prior to flowering, this species was the raw material resource of local people for housing and basketry and after flowering and death of the species they had to go to inaccessible areas. Grazing at initial stages and premature extraction before maturation could have resulted in poor regeneration of the species. Both *in situ* and *ex situ* conservation methods need to be resorted to protect this endangered new species.

Considering its natural habitat and culm characteristics, *O. spirostylis* appears to be a good species for planting on the riverbanks with potential commercial uses, such as, for construction and craft. From the local reports it is expected to flower around 2013 and seedling production could be possible. Although the difference between species was statistically significant in some of the growth parameters such as clump width, number of clumps, height of the culm and number of internodes the comparison is not meaningful until a species trial is conducted with proper replication. There is a potential to develop lesser-known reed bamboo species suitable for special habitats through in depth study on their growth and productivity in multi-locations including difficult sites.

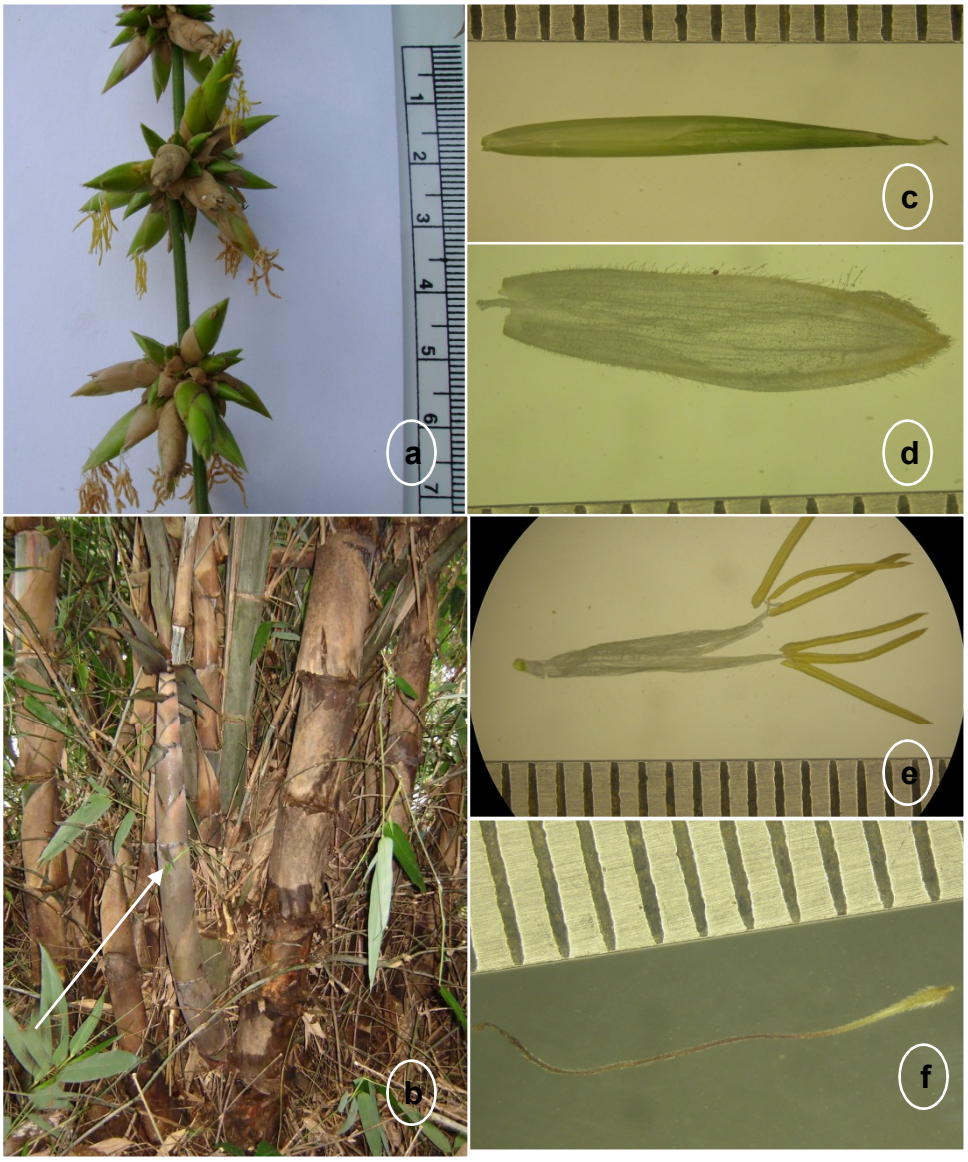

Fig.1 *D. giganteous* - a. inflorescence b. regeneration to vegetative phase after flowering c. lemma d. palea e. androecium, f. Ggynoecium

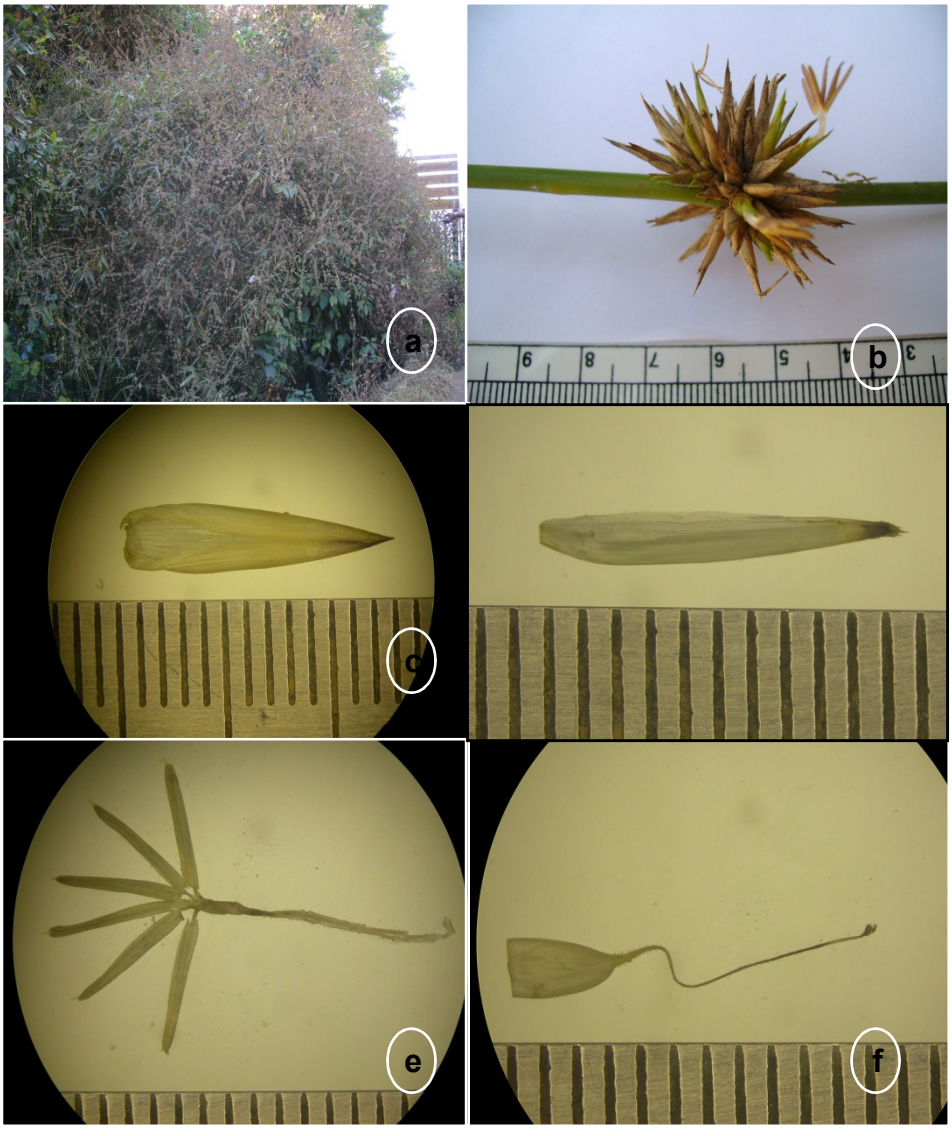

Fig. 2 *P. Monodelpha* -a. Gregarious flowering in Rajamala b. spikelet c. Single flower d. palea e. androecium, f. gynoecium

Fig. 3 *B. vulgaris* -a. A clump with green and yellow culms b. inflorescence c. lemma d. palea e. androecium, f. gynoecium

Fig. 4 Standing clump of a. *O. spirostylis* b. *O. soderstromiana*