Proc. Indian natn. Sci. Acad. **B63** No. 3 pp. 245-267 (1997)

Bamboos and Rattans: From Riches to Rags*

H Y MOHAN RAM and RAJESH TANDON
Department of Botany, University of Delhi, Delhi 110 007

Bamboos and rattans (canes) are two important groups of non-timber forest products of India. The enormous diversity and design exhibited by the spectrum of their products reflect their indispensability for tribal and rural communities. Once embarrassingly abundant and aptly termed poor man's timber, bamboo has increasingly turned into rich man's plunder. The incomparable assets such as grace, beauty, renewability, strength, resilience and straightness have been disastrous for their survival. Growing demands, habitat destruction, over-exploitation by paper mills at highly subsidized rates, lack of adequate seed storage facilities and poor nursery techniques have imposed a check on the sustained availability of bamboos. Bamboos also play an important protective role in the ecosystem. Rattans, the climbing prickly palms, unparalleled for furniture-making and handicrafts, are facing an even more serious threat in the recent times.

This paper presents a state of art report on various indigenous and introduced species of bamboos and rattans available in India, their distribution, important applications and identifies the research needs. The principal areas of thrust include inventorization of diversity and distribution, phenology, reproductive biology, growth rate, nursery techniques, cultivation and harvesting practices, micropropagation, *in situ* conservation of gene pools and storage in gene banks. Realizing the enormous social and economic value of bamboos and rattans, it is urged that a National Centre for research on bamboos and rattans be set up in India on top priority.

Key Words: **Bamboos, Rattans, Micropropagation, Flowering, Diversity, Utilization, Conservation**

Introduction

Bamboos and rattans (the latter also called canes) are two principal groups of non-timber forest products (NTFPs) which have become inseparable from humans because of their versatility and multitude of uses. Bamboos and rattans are distributed throughout the tropical and subtropical parts of the world forming an understorey. Whereas the old world bamboos are giant grasses (Gramineae or Poaceae), usually with hollow internodes, the rattans (Palmae or Arecaceae) are prickly climbing palms with solid stems.

Bamboos and canes are among the most ancient plant materials still in demand. They are valuable resources for all time and can be regarded as 'green gold'. They are important feed materials for wild herbivores and materials for construction and articles of commerce, especially in Asia and Africa, where the tribal communities have put them to countless practical uses and aesthetic

* Paper presented at the Seminar on 'Plant Wealth of India', held at Gangtok, Sikkim on 4 May, 1994.

artefacts. Their utility has been based on a unique combination of features such as abundance (in the past), strength, low weight, durability, lustrous finish and beauty. They have been used for various articles of daily requirement to such an extent that their association is difficult to demarcate 'who is made for whom'. The uses extend from simple home needs to early developments in aviation and as carbonized fibre in electric bulbs (Marden & Brandenburg 1980). Bamboos are preferred plant materials in afforestation programmes owing to easy establishment, fast growth, and soil-binding properties (Joshi et al. 1990).

Competing interests of the local requirements of forest dwellers, rural poor and artisans on the one hand and market forces for utility products and handicrafts on the other have mounted an unprecedented demand on bamboos and canes in recent times. Increasing needs are creating collection pressure on the natural stands, posing a serious threat to their survival. Shifting cultivation, habitat destruction and over-exploitation for industrial needs have caused a large scale elimination of abundance and diversity. There is an urgent need to upgrade our knowledge with respect to their occurrence in the wild and cultivation of economically important species.

For sustained availability of these renewable resources, methods of seed storage and propagation and nursery techniques have to be substantially improved. Micropropagation techniques have been initiated, but they need to be scaled-up by lowering the cost and by spreading the knowledge through demonstration plots and mass media. Production of profusely illustrated booklets written in Indian languages would benefit users.

Considering the enormous value of bamboos and rattans for the developing countries of Asia, the International Development Research Centre (IDRC), Canada has periodically organised workshop and conferences on various aspects of research and development (Lessard & Chouinard 1980, Rao et al. 1985,1988, Williams & Rao 1994).

Although every bamboo has an infinite number of local uses, the International Network of Bamboos and Rattans (INBAR) has identified and prioritized 19 species of bamboos and seven of rattans for international action on the basis of commercialization potential, environmental rehabilitation and usefulness in rural industries (Williams & Rao 1994). Among these, four species of bamboos viz., *Bambusa bambos* (syn. *B. arundinacea*), *Dendrocalamus strictus*, *Ochlandra* spp. and *Thyrsostachys siamensis* and three species of the *Calamus* viz., *C. andamanicus*, *C. caesius* and *C. nagbettae* occur in India.

Bamboos

Bamboos are fast-growing giant grasses that can reach enormous heights. They are characterized by a rhizomatous stem with a monopodial or sympodial branching system that puts out culm shoots. The latter bear prominent culm sheaths, the characteristics of which

constitute the basis of identification of species.

Each culm shoot elongates rapidly to give rise to a jointed stem (culm) that bears branches of several orders, sheaths, leaves and flowers. *Glaziophyton mirabile*, a rare species occurring in Brazil, is the only known leafless bamboo.

The numerous physical characteristics of bamboos are reflected in the variation of height, diameter and colour of the culm, thickness of the internodes and branching pattern. Species range from miniature ornamental types to stragglers and some even reaching a towering height of 40m. *Teinostachys helferi, Cephalostachyum capitatum* and species of *Dinochloa* and *Melocalamus* are stragglers.

Bamboo belongs to the tribe Bambuseae of the family Poaceae. There are about 75 genera and 1250 species in the world (Söderstrom & Ellis 1987, Williams & Rao 1994); of these 167 are herbaceous (Ohrenberger & Goerrings 1989). The first scientific description of the genus *Bambusa* was given in 1789 on the basis of *Bambusa arundinacea*. However, Munro's monograph of Bambusaceae (1868) and subsequent monumental work of Gamble (1896), have been regarded as foundations of taxonomic literature on bamboos in India.

Distribution

Bamboos have worldwide distribution, generally inhabiting the humid tropical, subtropical and temperate regions of the world. Most of the species are found in the tropics of the old world, a majority of them occurring in South East Asia. They are distributed in the New World 46° N in the Eastern USA to 47°S in Argentina. There is not a single native bamboo in the whole of Europe and Antarctica. Bamboos cover 18 mha of land, 75% of which is in Asia. India is endowed with over 136 species (Sharma 1980).

Bamboos in India occur naturally as understorey in many types of forests, especially in the North Eastern States (table 1). Their distribution is largely governed by rainfall (minimum of 100 cm) and temperature from 8-36° C. In India, 12.8% of the total forest area (including the plantations) is covered by bamboos. The North Eastern states represent around 58 species belonging to 16 genera. *Dendrocalamus strictus* is the most widely distributed species and predominantly found in the dry deciduous forests all over India. *D. sikkimensis* is abundant in Eastern India. *D. hamiltonii* also occurs in the lower hills in Eastern India. The latter has been recently introduced to Himachal Pradesh. *Bambusa bambos* is pantropical and flourishes in the moist mixed deciduous forests of Orissa, Assam, West Bengal and in all states of the Deccan.

The Forest Research Institute (FRI) at Dehra Dun, has maintained a very rich collection of over 35 native and exotic species of bamboos in the bambusetum (Varmah & Bahadur 1980). Besides, the Indian Botanic Gardens, Calcutta and the Tropical Botanic Garden and Research Institute (TBGRI), Palode, Kerala have

Table 1 *Distribution of Bamboos in India*

Species	Location
Arundinaria clarkei	Manipur and adjoining areas
A. hirsuta Munr.	Khasi, Naga hills 1525-3000m
A. maling Gambl.	N. Bengal, Sikkim, Arunachal Pradesh 3000-3660m
A. mannii Gambl.	Jaintia hills 900m
A. microphylla Munr.	Sikkim, Khasi hills 2400-3100m
A. rolloana Gambl.	Naga hills 1525-2300m
A. suberecta Munr.	Sikkim, Khasi and Jaintia hills 1200-1500m
Bambusa bambos Willd.	Throughout India in the plains, up to 1250m; commonly cultivated in the Deccan
B. atra Lindl. *B. lineata*	Andaman Island in marshy coast forests (Rutland Island)
B. auriculata Kurz.	Assam, cultivated at Calcutta and Dehra Dun
B. balcoa Roxb.	Eastern Uttar Pradesh, Bihar, Assam and Arunachal Pradesh up to 600m
**B. burmanica* Gamb.	Native of Burma, frequently cultivated
**B. copelandii* Gamb.	Native of Burma, cultivated at Calcutta & Dehra Dun
**B. glaucescence* (Willd.) Sieb. ex Munro *(B. multiplex, B. nana)*	From China and Japan, cultivated in tea hedges of Assam
B. gracilis Hort. ex A & C Rivi. *(Arundinaria graciclis)*	E. Himalaya
**B. guadua* Humb & Bonpl. *(Guadua angustifolia* Kunth.)	Native of tropical America, cultivated at Dehra Dun
B. khasiana Munr.	Khasi, Jaintia and Naga hills, Manipur up to 1250m
B. longispiculata Gambl. ex Brandi	Meghalaya, cultivated at Calcutta and Dehra Dun
B. mastersii Munr.	Assam (Dibrugarh)
B. nutans Wall. ex Munr.	Sub Himalayan tracts from Jamuna Eastward (Assam, Bengal, Sikkim and Arunachal Pradesh up to 600-1500m), commonly cultivated in N W India
**B. oliveriana* Gambl.	Native of Burma, cultivated at Calcutta & Dehra Dun
B. orientalis Nees.	Orissa and Bengal (Ganjam)
B. pallida Munr.	N. Bengal, Sikkim, Arunachal Pradesh, Khasi hills up to 1250m
B. polymorpha Munr.	Bengal and Assam
B. kurzii *(B. schizostachyodies* Kurz.)	S. Andamans
B. spinosa Roxb.	Circars and the hills of S. India, cultivated at Calcutta and Dehra Dun
B. teres Ham.	Bengal and Assam
B. tulda Roxb.	Wild in E. India and N. Circars 450-600m, widely cultivated in the plains and foothills of N. India
**B. ventricosa* McClure.	Native of China and Japan, cultivated as an ornamental plant

Species	Location
B. vulgaris Schrad.	Pantropical (origin unknown)
B. vulgaris var. *striata* Gambl.	Pantropical, cultivated as an ornamental plant
Cephalostachyum capittatum Munr.	Sikkim, Arunachal Pradesh, Meghalaya 600-2450m
C. capittatum var. *decomposita*	Sikkim
C. flavescence Kurz.	Andaman Islands, cultivated at Calcutta
C. fuchsianum Gambl.	Arunachal Pradesh, Naga hills 1800-2450m (also in Bhutan)
C. latifolium Munr.	Sikkim, Arunachal Pradesh, Naga hills, Manipur up to 2300m (also in Bhutan)
C. pallidum Munr.	Arunachal Pradesh, Jhasi hills, Manipur up to 1500m
C. pergracile Munr.	Bihar, Assam, Naga hills, Madhya Pradesh, Arunachal Pradesh, frequently cultivated
Chimonobambusa callosa Munro. *(Arundinaria collosa)*	Arunachal Pradesh, Khasi hills 1200-2280m
C. densifolia Nakai. *(A. densifolia)*	Annamalai hills 2600m (smallest Indian bamboo)
C. falcata Nakai *(A. falcata)*	W. Himalaya from Ravi to Nepal 1200-2300m
C. densifolia (falcata Nakai)	Arunachal Pradesh, Nagaland Khasi and Jaintia hills 900-1372m
C. hookeriana Nakai. *(A. hookeriana)*	Sikkim, Arunachal Pradesh and Khasi hills 1200-2450m
C. intermedia (A. intermedia)	Sikkim, Arunachal Pradesh 1200-3050m
C. jaunserensis (A. jaunserensis, A. anceps)	Himalaya from Jaunsar through Chamoli in Garhwal to the source of Pindar river in Kumaon 1800-3300m
C. khasina (A. khasiana)	Sikkim, Khasi hills 1525-1830m
C. polystachya (A. polystachya)	Sikkim, Khasi hills 900-1500m
**Dendrocalamus brandisii* Kurz.	Native of Burma, cultivated at Calcutta & Dehra Dun
**D. calostachyus* Kurz.	Native of Burma, cultivated at Calcutta & Dehra Dun
**D. colletianus* Gamb.	Native of Burma, cultivated at Calcutta
**D. giganteus* Munr.	Native of Malaya and Burma, frequently cultivated
D. hamiltonii Nees.	in W. Central and E. India in the lower hills from Shimla eastward extending to Upper Burma, up to 900m (perhaps only in cultivation in W. Nepal)
D. hookeri Munr.	E. Himalaya, Khasi, Jaintia hills and Himachal Pradesh
D. *hookeri* var. *parishii*	
D. longispathus Kurz.	Bengal and other parts of India
**D. membranaceous* Munr.	Native of Burma, cultivated at Calcutta & Dehra Dun
D. pattellaris Gambl.	N. Bengal, Sikkim, Naga hills, Arunchal Pradesh 1200-1850m
D. sikimensis Gambl.	Sikkim, Arunachal Pradesh, Garo and Naga hills 1200-1500m
D. strictus Nees.	Deciduous forests all over India except N. Bengal,

Species	Location
	Assam and moist regions of the west coast commonly cultivated throughout India in the plains and foothills
D. strictus var. *argentea* (*Bambusa stricta* var. *argentea*)	Rare, only seen in cultivation
D. strictus var. *prainiana* (*D. prainiana*)	Bengal
D. strictus var. *sericea* (*D. sericeus* Munr.)	Mt. Parasnath (Hazari Bagh), Bihar, also in Chhota Nagpur and Bengal
Dinochloa andamanica Kurz. (*D. tjankorrha* var. *andamanica* Buse.)	Andaman and Nicobar Islands, often climbing on tall trees
D. compactiflora (*Melocalamus compactiflorus*)	Bengal, Assam, Meghalaya up to 1850m
D. mclelandii Gambl.	Bengal, Assam, Burma, cultivated at Dehra Dun
**Gigantochloa atter* kurz. ex Munro	Native of Malaya, cultivated at Calcutta
**G. atter* (black mutant)	Native of Malaya, cultivated at Calcutta & Dehra Dun
G. machrostachya Kurz.	Garo hills
**G. verticillata* Munr.	Native of tropical America, cultivated at Calcutta
Indocalamus walkerianus (*Arundinaria walkeriana*)	Pulney hills in S. India 1500m
I. wightianus Nakai (*A. wightianus*)	Nilgiri, Palghat and Tinnevell in S. India 1800-2600m
I. wightianus var. *hispidus* (*A. wightianus* var. *hispidus*)	Nilgiri hills 200-2300m
Melocanna baccifera Kurz. (*M. bambusoides* Trin.)	Bengal, Assam, Meghalaya, Tripura, Mizoram and other parts of East India in the plains and lower hills, cultivated elsewhere
**M. humilis* Kurz.	Native of Burma, cultivated at Calcutta
Neohouzeoua dulloa Camus (*Teinostachyum dullua*)	N. Bengal, Sikkim, Khasi hills, cultivated at Calcutta & Dehra Dun
N. helferia Gambl. (*T. helferi*)	Garo, Khasi and Jaintia hills 900-1250m
Ochlandra beddomei Gambl.	Wynaad in Malabar
O. ebracteata & Ghatt.	Parithipalli Range, Kottur reserve, Trivandrum division, Kerala
O. scriptoria Fisch. (*O. rheedei* Bth. & HK.)	West coast, Malabar, Kerala at low elevation on river banks
O. setigera Gambl.	Nilgiri hills at Godalur 900m
O. sivagiriana Camus. (*O. rheedii* var. *sivagiriana*)	Pulney and Sivagiri hills 1200-2400m
O. talbotti	K. Kanara on the river banks
O. travencorica Kurz.	Plains and hills of S. India in Kerala and Tinnevelly up to 1500m
O. travencorica var. *hirsuta*	Kerala hills
O. wightii Fisch. (*O. brandisii* Gambl.)	Tinnevelly ghats at Courtallam (Kerala hills) at low elevations and up to 1100m

Species	Location
**Oxytenanthera albociliata* Munr.	Native of Burma, widely cultivated in Bengal and elsewhere
**O. abyssynica* Munr.	From Sudan, cultivated at Dehra Dun
O. bourdillonii Gambl.	Ghats of Kerala 900-1550m
O. monoadelpha Alston. (*O. thwaitsii* Munr).	Hills of Kurnool, Hills of Western Ghats from Nilgiri southward 1050-1850m
O. ritcheyi Munr.	Bihar, Orissa, Garo hills, Coorg, S. Kanara, Andaman and Nicobar islands
O. ritcheyii, Blatt. & McCann. (*O. monostigma* Bedd.)	W. Coast, W. Ghats from Konkan to Annamalai hills, rare
O. stocksii Munr.	Konkan coasts, Ghats of N. Kanara, usually cultivated
(*Phyllostachys assamica* Gambl.) ex Brandis (*P. bambusoides* sensu Gambl.)	Arunachal Pradesh 2400m
**P. aurea* A & C Riviers.	Native of Japan, cultivated at Dehra Dun & Mussoorie
**P. bambusoides* Sieb. & Zucc.	Native of China and Japan, Himachal Pradesh 2438m
P. mannii Gamble.	Naga hills, cultivated in Khasi hills 15000m
**P. puberula*	Native of Japan, cultivated at hill stations of India
**Pseudosasa japonica* Makino. (*Arundinaria japonica*)	Native of Japan, cultivated in Eastern Himalayas
Pseudostachyum polymorphum Munr.	Bengal, Sikkim, Garo and Naga hills, Manipur up to 900m
**Schizostachyum brachycladum* Kurz.	Native of Malaya, cultivated at Calcutta
S. rogersii Brandis	Andamans
Semiarundinaria pantlingii (*Arundinaria pantlingii*)	Arunachal Pradesh 3000-3350m (also in Bhutan)
Sinobambusa elegans Nakai. (*Arundinaria elegans*)	Naga hills 1525-2300m
Teinostachyum beddomei Fisch. (*T. wightii Bedd.*)	Slopes of Western Ghats from N. Kanara to Cape Comorin 900-1550m Nilgiri
T. griffithii Munr.	Assam, Meghalaya, Arunachal Pradesh
Thamnocalamus aristatus Camus (*Arundinaria aristata*)	Central Himalaya to Arunachal Pradesh 2700-3350m
T. falconeri Hk. f ex Munr. (*A. falconeri*)	Jaunsur to Arunachal Pradesh 2250-2750m
T. prainii Camus (*A. prainii*)	Naga and Jaintia hills 1000-2240m
T. spathiflorus Munr. (*A. spathiflora*)	W. Himalaya from Satluj through Nepal to Arunachal Pradesh 2250-3050m
**Thyrsostachys oliveria* Gamb.	Native of Burma, cultivated at Calcutta & Dehra Dun
**T. siamensis* Gamb.	Native of Burma and Thailand, cultivated at Calcutta and elsewhere as a hedge plant

*Species not native to India.

Source: Varmah and Bahadur 1980, Anonymous 1988.

also organised living collections of bamboos.

Flowering in Bamboos

Flowering in bamboos has been a matter of intense biological interest and speculation. There is wide diversity in the flowering and seeding cycle of bamboos (Anantchote 1987). This ranges from constant flowering *(Bambusa atra)* to constant sterility *(Bambusa vulgaris)* (Gaur 1987). Some bamboos have cycles of 3, 7, 11, 15, 30, 48, 60 years. *Phyllostachys bambusoides* takes 120 years to flower (Janzen 1976). The intermast periods estimated for *Bambusa bambos* and *Dendrocalamus strictus* in India vary from 30-45 years and 20-60 years respectively (John et al. 1995). The variation may be attributed to the existence of several cohorts or due to environmental factors. Some bamboos flower periodically and others do not, some die after flowering and others do not. Even though the culm is defoliated and temporarily weakened. The culms originating from the same batch of seeds flower simultaneously irrespective of the region where they are planted.

Bambusa vulgaris is one of the most vigorous of all the bamboos and has not been reported to have come to gregarious flowering since 1810. In contrast to this *Bambusa atra* and *B. bambusana* of Malaysia and Andamans have a tendency to flower consistently. In these bamboos flowering does not lead to death and the plants resume vegetative growth.

On the basis of flowering, bamboos have been categorised in three broad groups (Brandis 1899). Those that flower annually or nearly so *(Indocalamus wightianus, Bambusa atra, Ochlandra sivagiriana)*; those that flower sporadically or irregularly *(Chimonobambusa* sp., *Arundinaria falcata, B. ulda, Dendrocalamus giganteus, D. hamiltonii, D. longispathus)* and those that flower gregariously or exhibit synchronized production of seeds at long intervals *(Bambusa bambos, B. polymorpha, B. tulda, Ochlandra travencorica, D. strictus)*. A majority of bamboos belong to the third category in which the intermast period may range from 3 to 120 years (Janzen 1976).

Bamboos of the third category mentioned above generally die after gregarious flowering and production of an enormous quantity of seeds. With the availability of large amount of nutritious feeding material, there is a concomitant rise in the populations of squirrels, birds and notably rodents. After consuming the bonanza the populations of rats turn to the standing crops and cause severe devastation, resulting in famine. In India, Mizoram has been experiencing mast seeding of bamboos and resultant famines. The tribal lore and the forest records indicate a regular cycle of 48±2 years for *Bambusa tulda* and *Melocana buccifera* in Mizoram (Mohan Ram & Hari Gopal 1981). Flowering of *M. baccifera* causes a famine called 'mautam' and that of *B. tulda* brings about 'thingtam' famine. Whereas the gap between mautam and thingtam is 18 years, the interval between thingtam and mautam is 30 years (Hari Gopal 1982).

A serious handicap in the understanding of bamboo biology is the lack of systematic work on breeding systems operating in the individual species, compounded by long flowering cycles (see John et al. 1995).

Lack of ready availability of flowering material of bamboos is a serious problem for the taxonomists. Most of the new species are known by their vegetative parts like culm sheaths, juvenile shoots, microscopic and ultramicroscopic features of epidermal peels (Gaur 1987). Persistent investigations of a lifetime are required for a better understanding of the species that would involve recording of diversity in the morphology of the inflorescence and spikelets.

Bamboo Culture with Special Reference to India

India is reputed for its art and culture manifested through traditional skills of ethnic communities, using a wide range of available raw materials with ingenious processing methods.

The strength of bamboo culms, their straightness, lightness combined with hardness, range of sizes, easy establishment and short period in which they attain maturity, make them useful for a multitude of purposes.

Bamboos have played a cardinal role in influencing the pattern of civilized life in Southern and Eastern Asian Countries, where they are found in abundance. The seven North Eastern states of India share mountainous terrain and slops of the extended Himalayan region. These states are inhabited by over 60 major tribes belonging to different groups. Inaccessibility to these areas in the earlier days had influenced and preserved their lifestyle and creativity which are reflected in the tremendous diversity in material culture. Irrespective of their varied origin and language, bamboo utilization has been common to all.

Bamboos are everything to some people and somethings to every person (MacClure 1966). The use of bamboo starts at birth when a sharp edged bamboo knife is used to severe the umbilical cord of the baby and the baby is rocked to sleep in a bamboo cradle. A tribal child plays with bamboo toys. It was a common practice in Malaysia to use a bamboo knife for circumscission. As a tribal person grows up, he learns to build houses, use bows and arrows, feed the cattle, catch fish, weave baskets, light a fire, play on musical instruments—all made out of bamboo. The culm shoot serves as an item of food — cooked, pickled or fermented. Lastly a dead person is carried for last rites on a bamboo bier.

Bamboo is the most common material for house construction in the rural areas in South East Asia. Being wind resistant, bamboo in combination with canes and wood forms an ideal component of dwellings built on hill sides.

Bamboos are in use as water conduits and piping material in several developing countries. People of Arunachal Pradesh and Mizoram use bamboos for collecting and transporting rain water to storage tanks. In Tanzania over 100,000 people in the rural areas procure water through a

bamboo water system (Lipangile 1985). The cost of bamboo pipe is one fourth of the locally available plastic pipes.

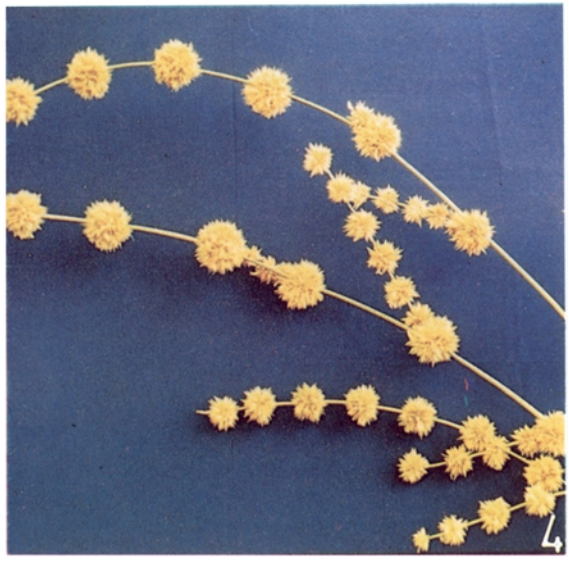
In the urban areas of India, bamboos provide an ideal material for scaffoldings during construction of buildings. The Bakhra Nagal Dam has been considered a marvel, for it was entirely built by human labour using natural materials from the earth, bambooo poles and wooden planks for support.

Suspension bridges are the only means to cross rivers in parts of the Western Ghats and North Eastern states. Construction of a bamboo suspension bridges by tribals is done ceremoniously (Ranjan et al. 1986). Bamboo is an ideal material in India for cottage industries such as sericulture. The tray used for feeding early stages of mulberry silkworms, named 'thatte' is made from bamboo. The large, partitioned tray called 'chandrike' used for rearing cocoons from the full grown larvae is also made from bamboo.

Bamboo is essential for the manufacture of incense sticks or 'agarbattis'. It is light, burns slowly, and does not spark or emit unpleasant smoke. Ropes, fences, mats, ladders, sticks are made from bamboos. Strips of bamboos and canes are the most common material for wickerwork. The design, shape and size of the baskets depend upon utility and local knowledge. Carrying baskets, represent excellence in aesthetics. The design and the style of the wickerwork products differ from tribe to tribe (Ranjan et al. 1986). Similarly the models of bamboo container, winnowing trays, fans, arrows and quivers can indicate the tribe to which they belong.

Paper is the most important bamboo product in use. Bamboo fibres, being more slender than wood fibers, contribute to the desired smoothness and flexibility. Paper made from bamboo has high tearing strength as compared to tensile and bursting strength. Liese (1986) reported that in India 30-35 factories produce paper from bamboo pulp. In addition to paper, bamboo has its application in rayon and cellophane industries. Young bamboo culm shoots are prized food material owing to their subtle flavour and crisp texture. Some of the bamboo delicacies include pickles, soups and vegetables made from young sprouts. Tender shoots of *Dendrocalamus strictus, D. hamiltonii, D. membranaceous* and *D. giganteus* are cooked as vegetables in India (Borthakur 1996). The world's best quality edible shoots are reported to be obtained from *Bambusa polymorpha* (Vivekanandan 1987). Rice beer fermented in the culms of bamboos has its own class.

Grains of *B. bambos* are cooked as bamboo rice, especially after mast seeding by the tribals in Tamil Nadu and Karnataka. Seed powder is often cooked and eaten (Raveendran 1996). The protein content and the quality of bamboo rice is comparable to that of wheat and rice respectively (Mitra & Nayar 1971).



Figures 1-4 **1,** A few culms of *Bambusa polymorpha*.Note the brightly coloured culm sheaths; **2,** Bamboo serves as raw material for a variety of products, especially basket; **3,** A clump of *Dendrocalamus strictus* in flower; **4,** A close up showing young fruits of *D. strictus* in clusters

Bamboo is a principal motif in oriental art, especially in China. Bamboos are favourite ornamentals in homes and gardens. Buddha belly bamboo *(B. ventricosa)*, the golden bamboo *(Bambusa vulgaris* var. *striata)* and the black bamboo *(Phyllostachys nigra)* are frequently grown in the gardens. Some of the finest painting brushes in China and Japan are made from bamboo.

Bamboos have also enjoyed a considerable reputation in medicine. Tabashir or banslochan, a siliceous secretion in the hollow stems, is used as a cooling tonic in cough, asthma, paralysis and as an aphrodisiac.

Ecological Role

Most bamboo species are excellent soil binders. They stabilize and enrich the soil by leaf litter. A few species of *Dendrocalamus* such as *D. hamiltonii, D. erectus* and *D. longispathus* are used for reclamation of wastelands (Anon. 1990). They are pioneers which colonize the jhumed areas in Meghalaya before secondary succession begins (Ramakrishnan 1992).

Bamboo plays a critical role in the nutrient management in shifting agriculture system of North Eastern India (Ramakrishnan 1994). Rao and Ramakrishnan (1989) have demonstrated that N, P and K contents of species like *Bambusa tulda, B. khasiana* and *Neohouzeana dulba* are higher than those in other species in the community.

Rattans

The term rattans (also canes) is collectively applied to the long, slender, pliable and jointed stems of certain spiny, trailing or climbing palms. They grow twining around trees in the tropical forests, often attaining enormous lengths. Lakshmana (1993) has mentioned a length of 160m for *C. manan* in Malaysia. Although conventionally classified under minor forest products, rattans are most valuable for forest dwellers as they furnish raw materials of daily use, for arts and crafts and importantly livelihood.

There are over 600 species of rattans belonging to 13 genera (family Arecaceae and subfamily Calamoideae) (Williams & Rao 1994). The maximum number are found in Sunda Shelf areas of Borneo

Figure 5 *Calamus rotang* : a common source of rattan

with the second centre of diversity in New Guinea. However, rattans of commercial value belong to the genus *Calamus*, which is believed to be a native of Africa. *Calamus* shares its distribution with India, Myanmar (Burma), and South China through Malaysia. Related genera viz, *Daemonorops* (115 spp.), *Ceratolobus* (6 spp.), *Plectocomia* (16 spp.), *Korthalsia* (26 spp.), *Colospatha*, *Myrialepis* and *Plectocomiopsis* (5 spp.) yield canes of lesser quality (Uhl & Dransfield 1987).

India is represented by 51 species of rattans belonging to four genera (Lakshmana 1993). Whereas most of them have been reported from the wild in Assam, Sikkim, Arunachal Pradesh, West Bengal, Karnataka, Kerala and Andaman and Nicobar group of islands, two species of *Calamus*, *C. arborescence* and *C. ciliaris* have been introduced and are being cultivated in the Indian Botanic Garden Calcutta. Besides, *Daemonorops* (4 spp.), *Plectocomia* (4), *Korthalsia* (2), *Myrialepis* (1) are also found in India (table 2). Out the total of 370 species of *Calamus* occurring in the world, 46 have been reported from India; 12 are endemic (Anon. 1992). A few new species of *Calamus* have recently been reported from South India (Lakshmana & Renuka 1990, Renuka 1990).

The species of *Calamus* exhibit a wide range of ecological adaptations. They possess versatility in terms of habit, habitat, properties and uses. Rattans are plants of the humid tropics, although some are adapted to seasonally dry habitats such as monsoon forests. Some species such as *Calamus erinaceus* are adapted to sub-mangrove conditions. They may occur in large stands of a single species or as components of a mixed tropical or sub-tropical forest.

Morphologically, canes may be climbers, twiners or scramblers. *C. inermis* is a spineless species found in South India. Canes differ in length and thickness of the internodes. The diameter ranges from 1cm *(Calamus travancoricus)* to 9-12 cm *(C. thwaitesii)* (Lakshmana 1993). Differences in properties are observed from the base of the plant to the top portion. Therefore, it is the intermediate portion which is more pliable and durable and finds extensive use in furniture work. It is the heterogeneity in the length and diameter of the internodes in combination with the differences in density, moisture content, fibre length and fibre wall thickness that have made cane an extremely useful material for various purposes. The final use depends upon the properties mentioned and the method of processing the raw material.

Utility

Export of raw rattan is monopolised by Indonesia. Commercially the finest quality canes that dominate international market are species of *Calamus*, namely *C. manan*, *C. caesius* and *C. trachycoleus*. The most commonly used rattans in India are *C. rotang* and *C. latifolius*. Canes such as *C. acanthospathus*, *C. guruba*, *C. latifolius*, *C. ratang*, *C. tenuis*, *C. rheedi*, *C. andamanicus* and *Plectocomia himalayana* find use in making furniture exclusive or in combination with bamboos. The latter

Table 2 *Distribution of Rattans in India*

Species	Location
Calamus acanthospathus Griff.	Sikkim and Assam
C. andamanicus Kurz.	Andaman and Nicobar Islands
**C. arborescens* Griff.	Native of Malaysia
C. brandsii Becc.	Evergreen forests Tamil Nadu and kerala 1000-1500m
C. caesius Blume	Native of Malaysia, cultivated at Dehra Dun, Assam and Kodanad
**C. ciliaris Blume*	Calcutta
C. collina	Sikkim, Assam, Manipur, Khasi hills up to 1200m
C. delessertianus Becc.	Nicobar Islands
C. dransfieldii Renu.	Evergreen forests of Bhagamandala (Kodagu), Southern Kannada district and Belur (Karnataka) Palghat (Kerala) and Dhoni hills (Tamil Nadu)
C. erectus Roxb.	Sikkim, Assam, Manipur up to 1200m
C. erectus Roxb. *var. schizospathus* Griff.	Meghalaya and Sikkim
C. polygamus Griff. (*C. flagellum* Griff.)	Sikkim-Himalaya, Assam, Khasi hills up to 1200m
C. floribundus Griff. var. *depauperatus*	Khasi and Mishimi hills in Assam
C. gambelei Becc.	Evergerrn forests of Karnataka, Tamil Nadu and Kerala, above 700m
C. gambelei Becc. var. *sphaerocarpa* Becc.	Pampa and Ranni forest of Kerala
C. gambelei Becc. var. *hookerianus* Becc.	Evergreen forests up to 1000m in Kerala and Tamil Nadu
C. gracilis Roxb.	Cachar district, Assam
C. guruba Buch.-Ham.	Bengal, Assam, Khasi hills, Orissa
C. huegelianus Mart.	Evergreen forests of Karnataka, Kerala and Tamil Nadu
C. inermis T. Anders.	Sikkim
C. karnatakensis Ren & Lax.	Endemic to Karnataka, Kerala and Tamil Nadu
C. khasianus Becc.	Khasi hills, Assam
C. kingianus Becc.	Assam
C. lakshmanae Ren.	Evergreen forests of Makut, Sampaje and Honnavar (Karnataka)
C. lacciferus Lax. & Ren.	Endemic to Karnataka
C. latifolius Roxb.	Sikkim and Assam
C. leptospadi Griff	Sikkim, Assam, Terai swamps, Khasi hills, Manipur hills
C. longisetus Griff.	Andaman and Nicobar Islands
C. metzian X Schlecht.	Deciduous forests of Karnataka, Kerala and Tamil Nadu (Nilambur)
C. nagbettae Fern. & Dey	Evergreen forests of Kodagu Southern Kannads (Karnataka)
C. namberiensis Becc.	Hill slopes of Assam

Species	Location
C. nicobaricus Becc. *var. palustris* Griff.	Nicobar Island
C. prasinus Lax. & Ren.	Evergreen forests of Mangalore and Sampaje (Karnataka)
C. pseudorivalis Becc.	Nicobar Islands
C. pseudotenuis Becc. ex Becc. & Hk. f.	Hassan and Coorg districts of Karnataka, Palghat and Trichur districts of Kerala
C. rheedii Griff.	Tinnevelly
C. rotang L.	Backwaters and coasts of Andhra Pradesh, Kerala and Tamil Nadu
C. stoloniferus Ren & Lax.	Western Ghats
C. tenuis Roxb.	Dehra Dun and Assam
C. thwaitesii Becc. & Hk. f. var. *canaranus*	Western Ghats (moist deciduous, semi-evergreen and evergreen forests of Goa, Karnataka, Kerala and Tamil Nadu)
C. travancoricus Bedd. ex Becc. & Hk. f.	Coorg (Karnataka), Kerala and Tamil Nadu
C. vattayila Renu.	Kerala and Karnataka
C. viminalis Willd.	Bengal, Orissa, Andhra Pradesh and Andaman
C viminalis Willd. var. *fasciculatus* (Griff.) Becc.	Andaman and Nicobar Islands, Western Ghats
C. uniferus Wendl. var. *betong* Becc.	Nicobar Islands
Daemonorops jenkinsianus (Griff.) Mart.	Sikkim-Himalaya, Khasi hills
D. kurziznus Becc.	Andamans
D. manii Becc.	Andamans
D. propinquis Becc.	
Plectocomia assamica Griff.	Lower Assam
P. khasyana Griff.	Khasi hills
P. himalayanana Griff.	Sikkim-Himalaya up to 2000m
P. bractealis Becc.	Sikkim and Meghalaya
Korthalsia echinometra Becc.	Andaman and Nicobar Islands
K. laciniosa (Griff.) Mart.	Andaman and Nicobar Islands
K. rogessii Becc.	Andaman and Nicobar Islands
Myrialepis paradoxa (Kurz.) Dransf.	

Sources: Badhwar 1983, Lakshmana 1993 and Anonymous 1992

include chairs, frames, seat mats, lamp shades, chicks and wall hangings. Canes are also employed in making baskets, umbrella handles, walking sticks, batons used by army officers or conductors directing orchestras. Owing to strength and resilience, rattans are used for making handles of hockey sticks and cricket bats. Fishing rods, polo sticks and javelin are also made from rattan species like *C. latifolius*, *C. viminalis* and *C. nagbettae*.

Apart from their application in the manufacture of chairs, tables and sofas, canes have gained importance as items of food and medicine. These canes are categorised as edible canes. Tender stems of *C. rotang, C. erectus, C. floribundus* and *C. latifolius* are used as vegetables (Borthakur 1996). Seeds of *C. erectus* and *C. extensus* are employed as substitutes for areca nut (Hajra & Chakraborty 1981). Fresh fruits of *C. latifolius, C. polygamus, C. longisetus* and the fleshy mucilaginous sweet pulp of *C. rotang* are edible. Fruits of these species are often pickled.

Calamus oil extracted from the roots contain palmitic acid, iso-eugenol, eraginol, calamine, calamol, etc. It is used in perfumery and for flavouring liquers (Anon. 1992).

The dried root of *C. rheedi* is powdered and applied for ulcers in Kerala. *C. rotang* is reported to have anti-cancer properties and is also useful in controlling biliousness and bleeding. The hard stem is often used as a vermifuge. In Cambodia (Kampuchea), a decoction from the roots of *C. rotang* is used in chronic fever, dysentery, biliousness and also as a tonic. Tender leaves of *C. travencoricus* are used in dyspepsia, biliousness and ear troubles. Juice obtained from *C. verus* enters into the preparation of an arrow poison and blow pipe darts.

Availability and Sustainable Utilization of Bamboo and Rattan Resources

Bamboo naturally occurs over an area of 11 mha in Indian forests. Cultivation is restricted to a few suitable parts of various states. *Dendrocalamus stricutus, D. hamiltonii, Oxytenanthera stocksii, Bambusa balcoa, B. bambos, B. nutans, B. tulda* and *B. polymorpha* are some of the most preferred species or cultivation in parts of Assam, Bihar, Orissa, Tamil Nadu, Karnataka, Kerala, Goa, and Maharashtra (Adkoli 1991).

Paper is one the most commonly used commodities in the world. Out of the 4.5 million tonnes of annual output of bamboo 1.8 million tonnes are utilized by pulping industries (Adkoli 1991). Since conservation methods and nursery techniques of bamboos differ markedly from those of agricultural crops, concerted efforts are needed to develop plantations of selected species (Williams & Rao 1994). However, plantations should not be raised exclusively for pulp production. Species suitable for several other purposes should also be grown to sustain the small-scale industries.

Mounting demands for the raw material have impelled an increase in the extraction from the appallingly limited natural resources. Since 1936, there has been a consistent fall in the contribution of bamboos in the pulp and board production (Adkoli 1991) primarily because of dearth of raw material and the inadequate source of supply.

Improper harvesting methods and poor silvicultural practices are important factors resulting in the shortages (Adkoli 1991). Seedlings are often grazed and the natural seed bank is robbed by the rodents after mast seeding, leaving a negligible

amount for propagation. It is estimated that there is a potential of 2.75 million tonnes of annual production of bamboos from the natural resources, provided proper nursery techniques are employed. Judicious thinning of culms is necessary for the growth and development of new culms (Sharma 1980).

As explained earlier, rattans for the manufacture of furniture and other articles in India come from the evergreen tropical and moist deciduous forests of Assam, Arunachal Pradesh, Mizoram, Sikkim, Manipur, Tripura, Kerala, Karnataka and Tamil Nadu. Extraction of rattans from the wild is often destructive as it devastates the supporting trees. A very small amount of canes is cultivated in West Bengal and Uttar Pradesh. Approximately 2000 small to medium-sized units are engaged in the supply of raw canes from these areas.

To support the traditional crafts and to meet the growing demands, some states in the Deccan have to depend on supplies from the North Eastern states, at high prices.

Natural regeneration of canes is very poor. Cane gatherers indiscriminately remove the immature plants along with the mature ones, accounting for irreversible losses. Current local supplies are insufficient to sustain the domestic market. This shortage has become acute at a time when the rattan industry is vastly expanding. Gross insufficiency in the supply of the raw material has affected the large manufacturing units which have closed down. The illegal drainage of raw material to the larger units has seriously threatened the small-scale industries located in the vicinity of the rattan resources.

Kerala, famous for its cane-craft is facing serious problem as the state's resources are drying up. Presently the state of Kerala has only 13 species of *Calamus.* The three formerly reported species have been lost, including the best known Malabar Cane, *C. rheedii.* Since management of the rattan resources in India is not organized, there has been an unprecedented procurement pressure on the wild stocks from the interior regions. Similar plight has been reported from countries like Indonesia and Philippines, where the rattan industries have become interdependent. These countries have banned the export of raw rattans in the form of poles and splits because of the growing raw material requirements of the industry and a decline in the local supply. Presently, the rattan growing areas are located in deep forests; their stands are situated in highly inaccessible places like steep slopes. Collection of rattans from such areas is tedious and dangerous. The raw material collected from these forests is not transported promptly. Raw canes left in the open are susceptible to fungal infestation and a large percentage of the harvest is destroyed before it reaches the user industries.

Indiscriminate exploitation and unmanageable supplies are bound to be major setbacks to cottage industries based on bamboos and rattans.

Conservation

An appropriate and integrated conservation approach is required to regenerate the natural stock of bamboos and rattans. Both *ex situ* and *in situ* conservation strategies are needed to replenish the resources on the one hand and to meet the demands on the other. Unlike bamboos which have faster rate of growth, commercial rattans require greater attention as the agro-techniques are not well-worked out.

The distribution pattern of rattans in India has become restricted to highly inaccessible areas. Concrete data on the natural distribution and affinities with the other components of the forests are lacking. This information is needed for protection of their habitat. Pollination biology, fruit set, seed storage and germination of rattans are yet to be investigated in detail.

Cultivation practices need improvisation at the nursery level. Species of *Calamus* are dioecious (Uhl & Dransfield 1987). A continuous supply of seeds demand availability of both the male and female plants in the vicinity of plantation sites. Growth rates and appropriate harvestable age of commerical rattans are imporant aspects which need to be considered to assure timely extraction. Canopy management and light play an important role in the establishment of nursery seedlings (Uhl & Dransfield 1987).

Propagation through Tissue Culture

Conventional methods of propagation of bamboos include use of propagules such as rhizomes, suckers, culm cuttings and seeds (Anon. 1988). Propagation by seed is the most convenient method because a single seed will result in a whole clump, that would yield several mature culms harvestable annually from the age of 4-7 years. However, as already explained above the availability of seeds is problematic as gregarious flowering in the commercially important bamboos occurs after long intervals of time followed by mass seeding and the death of entire populations. Importantly, bulk of the seed is consumed by predators. Only a few seeds that escape have to restart the new generation of bamboos. This is dependent on the timely arrival of rains. Certain bamboos that flower sporadically may not always yield sufficient quantity of seeds owing to sterility. Bamboo seeds are short-lived under natural conditions and loose viability after 6-8 months. Their viability can be substantially extended by storage at 4°C in seed banks. It is therefore important to monitor the time and extent of flowering so that collection and transport of valuable seed material can be organized promptly. Bulk cold storage of bamboo seeds is necessary for large-scale planting in areas inside and outside forests.

Tissue culture is advantageous over conventional methods of propagation. This ensures continuous supply of

planting material, helps in conserving wild germplasm and in scaling up rare mutants or elite materials. A large number of plantlets can be raised in a short span of time. Tissue culture and shoot bud culture in bamboos would reduce the difficulty often encountered with the bulky offsets for transportation (Varmah & Bahadur 1980).

Somatic embryogenesis and micropropagation from seeds, culm cuttings and rhizome are the most common *in vitro* methods employed.

The first successful report on somatic embryogenesis and plantlet regeneration from the seed cultures of *Bambusa bambos* and *Dendrocalamus strictus* was made by scientists of the University of Delhi (Mehta et al. 1982) through a project supported by the Department of Biotechnology, New Delhi. Once the plantlets were differentiated from the developing somatic embryos a major hurdle was their transplantation for hardening. Reproducible procedure for rhizome initiation and acclimation to potted conditions were developed. Over 10,000 tissue culture raised plantlets have been introduced in various parts of the country with a high percentage of success in their establishment and performance in the field (Rao et al. 1988). Subsequently successful reports on somatic embryogenesis and plantlet regeneration of *Bambusa vulgaris, Dendrocalamus giganteus* and *D. strictus* (Mascarenhas et al. 1988, Rout & Das 1994) and on *Bambusa tulda* (Saxena 1990) have appeared. Micropropagation using explants from mature plants of *B. longispatha* has been successfully achieved (Saxena & Bhojwani 1993).

Reports on precocious flowering of bamboos in aseptic cultures was a special achievement (Rao & Rao 1990, Nadgauda et al. 1990, Chambers et al. 1991). Nadgauda and co-workers (1990) reported the induction of flowering in cultures of *Bambusa bambos* and *Dendrocalamus brandisii* [on Murashige and Skoog's (MS) medium supplemented with sucrose (2%) BAP (0.5 ppm) and coconut milk (5%)] and also seed set *in vitro*. These authors had suggested that induction of flowering in bamboos would be useful for hybridization. If protocols for flowering can be standardized and repeatedly demonstrated, it would be possible to obtain flowers and seeds in off season (Mohan Ram 1994). There is expectation that if this work can be done using explants from selected mature plant, it could pave the way for improved breeding of bamboo stock, providing a perennial source of seeds. As most of the bamboo species are polyploid, it is yet to be examined whether test-tube flowering will fulfil the requirement on a scale that would be of commercial significance (Mohan Ram 1994). It is pertinent to recall that bamboo hybrids have been obtained *in vivo* for the first time by Guangjhu and Fuiqiu (1987) through conventional procedures.

The need to raise large plantations of rattan can not be accomplished with the limited quantity of seeds. Although micropropagation offers an ideal

alternative for preventing extraction from the wild and conservation of germplasm, the technique is yet to be fully exploited for rattans. Reports from India on micropropagation of rattans are scanty. Pioneering work on cane micropropagation has been done in the Philippines and Malaysia. Complete plantlet regeneration through consistently reproducible protocols has been reported for *C. manillensis* (Patena et al. 1984), *C. manan* (Yusof 1989) and *C. rotang* (Padmanabhan & Ilangovan 1989). Initial attempts have been made to develop micropropagation protocols in *C. manan* (Gunawan & Yani 1986, Gunawan 1989). There are problems in selecting suitable explants for the micropropagation of rattans. When the main shoot tip of the palm is used as an explant, it results in the total destruction of the mother plant. Juvenile shoots (internodes), and tender stems from selected canes must be tested for their performance. Therefore, research in this direction should be given high priority. *In vitro* studies on commercially important rattans should be taken up on priority basis.

Strategies for Augmenting Production

On the basis of the state of the art prepared by consulting various published accounts of experts, the following measures are suggested for increasing the productivity of bamboos and rattans in India.

* To meet the needs of the poor and the requirements of the cottage level industries, cultivation of economically important bamboos must be taken up through programmes involving local communities, using indigenous technologies as well as improved and simple methods in suitable areas.

* Extraction of bamboos and rattans from the wild must be stopped.

* A National centre for research on all aspects of bamboos and rattans should be set up.

* With the availability of seeds after mast seeding, large quantities must be deposited in cold storage and distributed to users for agroforestry and social forestry programmes and for individual users. Seeds of rare species and those that flower at long intervals must also be stored in gene banks.

* For sustained supply at the local level, measured distribution of the raw material to the traders and firms must be organised. Co-ordination is required between the suppliers and manufacturing units so that irregularities created due to unexpected shortages of the supply do not create obstacles in the smooth running of export-oriented firms.

* Farmers should be kept aware of the recent techniques and species dependent requirements under cultivation. Improvisation of the cultivation practices and the standardization of nursery techniques should be carried out in different states.

* Establishment of simple and inexpensive methods of preserving harvested raw material before transportation is needed to prevent losses during storage as these materials are susceptible to pests, microbes and fungi.

* Factories and processing units should be located in the proximity of areas where bamboos and rattans are cultivated. This will solve the problem of long distance transportation.

* Plant tissue culture could be profitably applied to increase the planting material of choice bamboos, especially during periods when seeds are not available. Unlike the situation met within bamboos, the technique has not yet been established for rattans.

* Cultivation of bamboos and rattans must be encouraged in agroforestry and social forestry. Educating about the high monetary returns from rattans should provide an incentive to the farmers to start cultivation of rattans at appropriate locations where water is abundant.

References

Adkoli N S 1991 Bamboo in the Indian pulp industry; in *Proc. Bamboo in Asia and the Pacific* pp 250-254 (Thailand : IDRC, FAO and UNDP)

Anantchote A 1987 Flowering and seed characteristics of bamboos in Thailand; in *Proc. Recent Research on Bamboos* pp 136-145 eds A N Rao, G Dhanarajan and C B Sastry (China : CAF and Canada : IDRC)

Anonymous 1988 *Bamboo: The Wealth of India* volume **2B** (New Delhi : CSIR)

—— 1990 *Plants for Reclamation of Wastelands;* pp 465 (New Delhi : PID)

—— 1992 *Calamus; The Wealth of India* volume **3** (New Delhi : CSIR)

Borthakur S K 1996 Wild edible plants in the market of Assam, India - An ethnobotanical investigation'; in *Ethnobiology in Human Welfare* pp 31-34 ed S K Jain (Delhi : Deep Publications)

Brandis D 1899 Biological notes on Indian Bamboos; *Indian Forester* **25** 1-25

Chambers S M, Heuch J H R and Pirrie A 1991 Micropropagation and *in vitro* flowering of the bamboo *Dendrocalanus hamiltonii* Munro; *Plant Cell Tissue and Organ Cult.* **27**(1) 45-48

Das P and Rout G R 1994 Analysis of current methods and approaches on the micropropagation of bamboo; *Proc. Nat. Acad. Sci. India* **LXIV** part III 235-246

Gamble J S 1896 Bambuseae of British India; *Ann. Roy. Bot. Gard. Cal.* **7** 1-33

Gaur R C 1987 Bamboo research in India; in *Proc. Recent Research on Bamboos* pp 26-32 eds A N Rao, G Dhanarajan and C B Sastry (China : CAF and Canada: IDRC)

Guangjhu Z and Friqui C 1987 Studies on bamboo hybridization; in *Proc. Recent Research on Bamboos* pp 179-184 eds A N Rao, G Dhanarajan and C B Sastry (China: CAF and Canada: IDRC)

—— Gunawan L W and Yani 1986 *In vitro* propagation of Rattan Manan (*Calamus manan* Miq.) for agroforestry plantation; in *IV International Congress of Plant Tissue and Cell culture,* (Minneapolis, USA) 282

—— 1989 Propagation of Rattan Manan (*Calamus manan* Miq.) by *in vitro* techniques; *Indian J. Trop. Agric.* **1** 40-43

Hari Gopal B 1982 *Reproductive biology of some Indian Bamboos,* Ph. D. Thesis (University of Delhi, India)

Hasan S M 1980 Lessons from the past studies on the propagation of bamboos; in *Proc. Bamboo Research in Asia* pp 131-318 eds G Lessard and A Chouinard (Singapore and Canada : IDRC)

Hajra P K and Chakraborty P 1981 Survey of wild plants sold in Lal Market, Gangtok; *Ind. J. For.* **4** 217-220

Janzen D H 1976 Why bamboos wait so long to flower; *Ann. Rev. Ecol. Syst.* **7** 347-391

John C K, Nadgauda R S and Mascarenhas A F 1995 Bamboos - some newer perspectives; *Curr. Sci.* **68** 885-896

Joshi A P, Sundriyal R C and Bahuri D C 1990 Nutrients dynamics of a lower shivalik bamboo forest in the Gharwal Himalayas, India; *Jour. For. Sci.* 238-250

Lakshmana A C 1993 *Rattans of South India* (India: Evergreen Publishers)

—— and Renuka C 1990 New species of *Calamus* (Arecaceae) from India; *J. Econ. Tax. Bot.* **14** 705-709

Lessard G and Chouinard A 1980 eds *(Proc. Bamboo Research in Asia)* (Singapore and Canada: IDRC)

Liese W 1986 *Bamboos - Biology, Silvias and Distribution;* Dt Ges Fur Techn, Zusammerasbeit (GTZ)

Lipangile T N 1985 The use of bamboo as waterpipe; in *Proc. Recent Research on Bamboos* pp 315-320 eds A N Rao, G Dhanrajan and C B Sastry (China: CAF and Canada: IDRE)

MacClure F A 1966 *The Bamboos—A Fresh Perspective* (Cambridge: Harvard University Press)

Marden L and Brandenburg J 1980 Bamboo the giant grass; *National Geographic* **158** 503-528

Mascarenhas A F, Nadgir A L, Thengane S R, Phadke C H, Kuspe S S, Shirgurkas M V, Parashrami V A and Nadagauda R S 1988 Potential application of tissue culture for propagation of *Dendrocalamus strictus;* in *Proc. Bamboo Current Research* pp 109-110 eds I V R Rao, R Gnanharan and C B Sastry (Kerala: FRI and Canada : IDRC).

Mehta U, Rao I V R, Mohan Ram H Y 1982 Somatic embryogenesis in Bamboo; in *Proceedings of V International Congress on Plant Tissue Culture,* Tokyo, Japan pp 109-110 ed. A Fujiwara

Mitra G N and Nayar Y 1971 Chemical composition of bamboo seeds *(Bambusa arundinacea); Indian Forester* **98** 479-481

Mohan Ram H Y 1994 Biological research; in *Forestry Research and Education* eds P D Dogra and R C Dhiman **60** 60-67

—— and Hari Gopal B 1981 Some observations on the flowering of bamboos in Mizoram; *Current Science* **50** 708-710

Munro W 1868 A monograph of the Bambusoideae including description of all the species; *Trans. Linn. soc. Lond.* **26** 1-57

Nadgauda R S, Parashrami V A and Mascarenhas A F 1990 Precocious flowering and seeding behaviour in tissue cultured bamboos; *Nature* **344** 335-336

Ohrenberger D and Goerrings J 1989 *The Bamboos of the World* (Dehra Dun : International Book Distributors)

Padmanabhan D and Ilangovan R 1989 Studies on embryo culture in *C. rotang; RIC Bull* **8** 1-9

Ratena L F, Mercado M F and Barda R C 1984 Rapid propagation of rattan *(C. manillensis)* by tissue culture; *Philipp. J. Crop. Sci.* **9** 217-218

Ramakrishnan P S 1992 *Shifting Agriculture (Jhum) and Sustainable Development of North-Eastern India* (UK:UNESCO-MAB, Parthenon Publication)

—— 1994 The jhum agrosystem in N E India - a case study of the biological management of soils; in *The Biological Management of Tropical Soil Fertility* pp 189-208 eds PL Woolmer and M J Swift (UK : John Willey & Sons)

Ranjan M P, Iyer N and Pandya G 1986 *Bamboos and Cane Crafts on Northeast India* (Ahmedabad: National Institute of Design)

Rao A N, Dhanarajan G and Sastry C B 1985 eds *Proc. Recent Research on Bamboos* (Canada : IDRC)

Rao I K and Ramakrishnan P S 1989 Role of bamboos in nutrient conservation during secondary succession following slash and burn agriculture (Jhum) in north-east India; *J. Applied Ecology* **26** 625-633

Rao I U, Rao I V R, Narang V, Jerath R and Pillai K G 1988 Mass propagation of bamboos and somatic embryos and their successful transfer to the forest; in *Proc. Bamboo Current Research* pp 167-172 eds I V R Rao, R Gnanharan and C B Sastry (Kerala : FRI and Canada : IDRC

Rao I V R, Gnanharan R and Sastry C B 1988 *Bamboo Current Research* (Kerala : FRI and Canada : IDRC).

—— and Rao I U 1990 Tissue culture approaches to the mass propagation and genetic improvement of Bamboo; in *Proc. Bamboo Current Research* pp 157-172 eds I V R Rao, R Gnanharan and C B Shastry (Kerala : FRI and Canada : IDRC).

Raveendran J C 1996 Some lesser known edible plants among the tribals of Kerala, India; in *Ethnobiology in Human Welfare* pp 52-53 ed S K Jain (Deep Publications)

Renuka C 1990 Two new species of the Calamus (Arecaceae) from India; *J. Econ. Tax. Bot.* **14** 701-704

Rout G R and Das P 1994 Somatic embryogenesis and *in vitro* flowering of 3 species of bamboo; *Plant Cell Rep.* **13** 683-686

Saxena S 1990 *In vitro* propagation of the bamboo (*Bambusa tulda* Roxb.) through shoot proliferation; *Plant Cell Rep.* **9** 431-434

—— and Bhojwani S S 1993 *In vitro* clonal multiplication of 4 year old plants of bamboo, *Dendrocalamus longispathus* Kurz; *In Vitro Cell. Dev. Biol.* **29** 135-142

Sharma Y M L 1980 Bamboos in the Asia Pacific Region; in *Proc. Bamboo Research in Asia* pp 99-120 eds G Lessard and A Chouinard (Singapore)

Söderstrom T R and Ellis R P 1987 The position of *Bamboo* Genus and allies in a system of grass classification; in *Grass Systematics and Evolution*, Söderstrom et al. (ed) Smithsonian Institution **72** 1-74

Uhl N W and Dransfield J 1987 *Genera Palmarum* (Allen Press, lawrence, Kansas) 257-261

Varmah J C and Bahadur K N 1980 Country report on Bamboo; in *Bamboo Research in Asia* pp 19-46 eds G Lessard and A Chouinard (Singapore and Canada : IDRC)

Vivekanandan K 1987 Bamboo research in Sri Lanka: in *Proc. Recent Research in Bamboos* pp 61-66 eds A N Rao, G Dnanrajan and C B Sastry (China: CAF and Canada: IDRC)

Williams J T and Rao I V R (eds) 1994 *Priority Species of Bamboos and Rattan;* INBAR. Tech. Rep. 1-86

Yusof A M 1989 Shoot formation in *Calamus manan* under *in vitro* culture; in *Seminar on Tissue Culture of Forest Species* pp 45-49 eds A N Rao and A M Yusoff (Malaysia : FRI and Canada : IDRC)