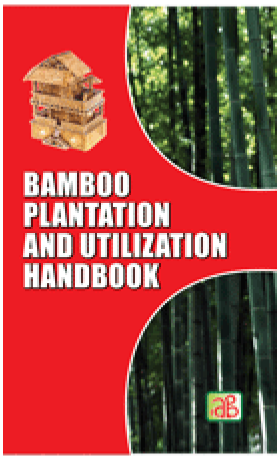
Bamboo Plantation and Utilization Handbook



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Bamboo is an important non wood forest product. In India, bamboo, which is traditionally considered the Poor man wood, and labelled as Green Gold is being considered a major export item by the centre for the global market. Bamboo is perfectly suited to agro forestry as a woody grass. Bamboo has been exploited from natural stands from time immemorial. Bamboo is increasingly being cultivated like other agricultural crops, that is, in professionally managed plantations. The growth of industries utilizing bamboo requires the sustainable cultivation and management of bamboo resources. India is blessed with very rich bamboo resources. Bamboo can play an important role in raising forest cover and a major role in stabilization of the environmental problems. The annual yield in tonnes/ha depends on the environment as well as the species. It is estimated that almost 25% of the biomass in the tropics and 20% in the subtropics, come from bamboo. The cultivation of bamboo as a wood substitute helps to offset depletion of the rain forest. Its rapid growth ensures an effective reconstruction of damaged eco systems. Bamboo is one of many sustainable non wood resources that can generate income for a large forest dependent rural population and it needs to take further steps to realize its full potential. In India, the North East has the largest stock and diversity of bamboos. Though India has the largest area under bamboo, the yield per hectare is very low compared to other countries. Bamboo plantation rising should be encouraged & promoted due to their high value, productivity, uniformity of crop, choice of species linked to peoples’ need and industrial need. Bamboo forest constitutes about 13% of the total forest area of the country. About 50% of bamboo produced in India grows in North Eastern region and West Bengal. India has the second largest bamboo reserves in the world after China.

This book basically deals with bamboos in India, the bamboo plant harvesting, cultivating, silviculture and management, collection of material and preparation of cuttings treatment for root induction in cuttings,
preparation of nursery and planting nursery management transplanting, pattern of biomass allocation in growing bambusa bamboos, biochemical characteristics of plantation bamboo leaf (bambusa bambos) with reference to organic productivity, economic analysis, bamboo plantation, problems and prospects, need for bamboo plantation, consumption pattern of bamboos in India, working and finishing qualities of bamboo, bamboos for structural use, pipe water supply system and drainage, bamboo furniture
weaving industry etc.

This book provides a complete detail on Bamboo plantation and its utilization. This book contains chapters like types of bamboo in India, taxonomy, cultivation, harvesting, growth management, bamboo utilization, Bamboo products and many more. This book will be very helpful to all its readers, environmentalists, agronomists, entrepreneurs, industrialists, or anyone with a special interest in bamboo cultivation.

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(Following is an extract of the content from the book)

Introduction

By far the single most important item of forest produce used by rural communities of the tropics, from the cradle to the coffin, is the bamboo. Bamboo is a member of the grass family (poaceae). Two important characters which make (majority of) bamboo distinct from other grasses are: (i) Woody perennial habit and (ii) peculiar flowering and seeding behaviour. Most woody bamboos flower and seed at the end of very long periods of vegetative growth. Over 75 genera and 1250 species are reported to occur in the world. India has perhaps the world's richest resources of bamboos, having about 130 species occurring over an area of 10.03 million ha. This is about 12.8 per cent of the total forest area of the country and represent 20 per cent of India's total production.

And yet, over exploitation associated with growing human populations, gregarious flowering, destruction of tropical forests and new demands on the resource for industrial uses, especially by the pulp and paper industry, have resulted in wide-scale-decimation of bamboo stocks; from vasts forests of bamboo in South and Southeast Asia at the beginning of this century, we are left with the current situation of acute scarcity. Many countries have been forced to severely restrict and in some cases even ban outright the harvesting and exporting of bamboos.

The report on the National commission on Agriculture brought out some figures about the current demand and output of the projected bamboo requirements for 1980 (4.274 million Cu M) and 2000 (7.005 million Cu M) and recommended the measures required to bridge the increasing gap between demand and supply. It was recognised that the availability of bamboo can only be sustained by raising elaborate bamboo resources and also using of existing natural bamboos judiciously and efficiently. Systematic cultivation of bamboos and their scientific management can therefore, ensure sustainable production.

However, we know very little about several aspects of this fascinating plant and these are receiving a high priority in the research activities of bamboo specialists. Thus its biology, embryology, cytology, physiology of flowering, ecology, silviculture and utilisation are all under detailed investigation. Even the authentic identification of the different species of bamboos which is basic to all other studies has to be undertaken with a sense of purpose.

Research has increased rapidly in recent years. The growth pattern and productivity of different bamboo species has been studied by several workers. Activities were strengthened by the creation of a IUFRO project group on Bamboo in 1976. This was followed by an IDRC - IUFRO workshop in Singapore, 1980 a subsequent conference at the IUFRO congress in Kyoto 1981 and an International workshop in Hangzhosuw 1985. Organised by the Chinese Academy of Forestry and IDRC in cooperation with IUFRO. A third international Bamboo workshop was held in Cochin India in 1988, organised by KFRI and IDRC, the fourth was in Chiengmai. Thailand in 1991 and the fifth was in Ubudi, Bali, Indonesia in 1995. These efforts are already bearing fruit.

The demand for bamboo is increasing much more than their availability. In the near future, a major shortfall in the availability of bamboo raw material for the paper industry is expected. Due to severe deforestation and the present limitation of bamboo propagation and improvement, it is unlikely that the increasing demand will be fulfilled. This emphasizes the need for enhancing bamboo production. This can be achieved by (i) increasing the area under bamboo cultivation, (ii) selective multiplication of better clones and (iii) use of improved varieties. Bamboo needs to be given more importance in agro-forestry. Social forestry and wasteland development. Rural economics in Southeast Asian countries are dependent on biomass production and popularization of bamboo cultivation and bamboo based industries would greatly help in rural development.

The present bamboo plantation technique is based on experience rather than on scientific basis. Species which have attained a crop status in agriculture have decades of directed endeavor behind them. Bamboos have not attained the same status due to lack of sustained investigations. A few problems of fundamental and applied nature, which need to be tackled immediately regarding bamboo farming. This book focuses the importance of raising bamboo plantation, establishment and management, yield and economics, felling cycle, fertilizer application and also discusses the problems and prospects of plantation bamboo.

Felling shall be made as far as possible on the side of the clump opposite to that from which the largest number of new culms spring-up.

But on many occasions the felling-rules prescribed were followed more in breach than in practice by the contractors in the past. Hence, Bamboo should be extracted only departmentally under the supervision of technically qualified foresters.

Distribution of Bamboos in the World

Bamboos are versatile group of plants of multiple utility and usually form rich belt of vegetation in moist deciduous, semi-evergreen, tropical, subtropical and temperate forests. About 14 million hectares of the earth surface is covered by bamboo forests with 80 per cent in Asia. They are fairly well represented in all the continents except Europe. All other tropical and subtropical regions of the world are endowed with a rich vegetation of bamboos. The tropical belt is characteristic of a large number of species.

The distribution of bamboos extends from 51 degree N Latitude in Japan to 47 degree S Latitude in South Argentina. The altitudinal range is just above the sea level upto 4000 m. The herbaceous bamboos have never been reported from an altitude exceeding 1500m. South America and East Asia are considered to be the centres of diversity of bamboos. Compared to these two regions: Africa is endowed with a lesser number of bamboo species. But Madagascar is rich in endemic genera and species. Australia has 4 indigenous species while North America has only one. Bamboos are found in greatest abundance and variety on the southern and South eastern borders of Asia. There are many regions in the world which are to be explored for new bamboo species. Further taxonomic revision may alter the existing number of bamboo taxa. The total number of bamboo species is represented by 75 genera and 1250 species. Ohmberger in their compilatory account on Bamboos of the World have however, mentioned higher number of taxa i.e., approximately 110 genera and 1010-1140 species without any exception to the congeneric elements.

Bamboos in Asia

Asia is rich in bamboos with approximately 65 genera of which 14 are endemic to the region. The number of species is around 900 spread over the range of 51 degree N to 47 degree S Latitude and 140 W to 70 E Longitude. Out of the total 900 species, about 100 species are of woody nature. The Asia-Pacific region has representatives of all the three types of bamboos viz., monopodial, sympodial and intermediate. The distribution of bamboos in different Asian countries are as follows:

Bangladesh

Bangladesh has 20 species of bamboos under 8 genera. It occurs as an understorey in the native hill forests of the eastern region. The most important species is Melocanna baccifera which constitutes around 75 per cent of the total bamboo crop in the region. Different species of Bambusa are commonly grown in the villages. The area under bamboo plantation is over 212,468 hectares with an annual yield of 0.8 metric tonnes/hectare.

China

There are 26 genera and more than 300 species of bamboos in China among which 22 genera and more than 200 species have high economic value. The common bamboos belong to the genera Bambusa,Dendrocalamus, Dinochloa, Lingnania, Phyllostachys, Schizostachyum, Semiarundinaria, Sinocalamus, Thamnocalamus and few other genera. China tops in bamboo culms producing countries with around 5000,000 tonnes year, followed by India and Japan.

India

India is one of the leading countries of the world, second only to China in bamboo production with 323,0000 tonnes per year. India shelters a large number of bamboo species and is considered as one of the largest reserves of bamboos in the world. There are 125 indigenous and exotic species of bamboos falling under 23 genera in an area of 10.03 million hectares. This constitutes around 12.8 per cent of the total area of forest cover in the country. They form an important constituent of the deciduous and evergreen forests and are spread from tropical to temperate regions, extending from alluvial plains to high mountains, ascending to altitudes of 3000 m above mean sea level. Bamboos are found as an understorey in the forests of almost all the states except in Kashmir Valley. They form rich belts of vegetation in well-drained parts of tropical and sub-tropical habitats and rise upto 3700m of altitude in the Himalaya.

Since bioclimatically, India is divided into five major regions viz., the alpine, sub-tropical, tropical moist and dry tropical regions. The distribution of bamboos also differs from one region to another with certain bamboo taxa characteristic of a particular zone.

Other principal genera of India like Arundinaria, lndocalamus, Oxytenanthera, Schizostachyum and Melocanna are concentrated in the Western Ghats and in the North-eastern region. The generaSchizostachyum, Phyllostachys and Gigantochloa are widely distributed in the North Eastern India.

Indonesia

There are about 65 species of both indigenous and cultivated bamboos in Indonesia. The important species are Melocanna baccifera, Gigantochloa atter and G. apus. Species of Dendrocalamus andDinochloa are also common.

Japan

Japan has 13 genera with over 237 taxa of different form, sections, subspecies and varieties. Bamboo groves cover about 123,000 hectares in Japan. The main bamboo species are Phyllostachys reticulataand P. edulis which occupy around 84 per cent of the total area under bamboo cultivation.

Korea

10 genera and 13 species have been reported from Korea.

Loas

The commonly found bamboo genera are Arundinaria, Bambusa, Schizostachyum, Chimonobambusa, Dendrocalamus, Dinochloa, Oxytenanthera and Thyrsostachys. They occur in association with rain forests as understorey.

Malaysia

This country has 7 genera and 44 species of bamboos out of which 25 are indigenous. The most common genera are Bambusa, Dendrocalamus, Dinochloa, Gigantochloa and Schizostachyum.

Myanmar

About 90 species of bamboos are reported from Myanmar which occur as an understorey of evergreen, semi-evergreen and deciduous forests. Sometimes it occurs in pure stands also.

Papua New Guinea

26 species of both indigenous and exotic bamboos are recorded from this region.

Phillippines

54 species of bamboos have been recorded in the Philippines including the introduced ones. The common genera are Bambusa, Dendrocalamus, Dinochloa, Gigantochloa, Schizostachyum,Thyrsostachys, Phyllostachys and Yushania.

Singapore

There are large natural reserves of bamboos in Singapore. Totally 6 genera and 23 species have been recorded. The common genera are Bambusa, Dendrocalamus, Gigantochloa, Phyllostachys, Schizostachys and Thyrsostachys.

Sri Lanka

Seven genera and 14 species are reported from Sri Lanka of which 5 species are endemic to the region. The important species are Bambusa orientalis and B. vulgaris var. vitata.

Thailand

Thailand has 41 species of bamboos in a total area of 1.02 million hectares. The important genera are Bambusa, Schizostachyum, Dendrocalamus, Gigantochloa and Thyrsostachys.

Bamboos in India

India is endowed with rich diversity of bamboos distributed in different bio-climatic zones of the country. North-eastern region has over 50 per cent of total species of bamboo occurring in India. The principal genera are : Arundinaria, Bambusa, Dendrocalamus, Melocanna, Neomicrocalamus, Ochlandra, Pseudoxytenanthera, Schizostachyum, Thamnocalamus, etc. Following is the systematic account on the species growing in India with emphasis on flowering, where available, distribution and specific uses of the species.

Arundinaria Michaux s.s.

Usually tufted, erect Culm hollow, glabrous or hairy; internode striate, glabrous or scabrous; node prominent with 1-3 branches. Culm-sheath deciduous or persistent, striate, straw-coloured, chartaceous or coriaceous, glabrous or scabrous, with or without oral setae. Leaves linear-lanceolate to oblong-lanceolate, tip acute to acuminate, with conspicuous transverse veinlets; petiole short or long; leaf-sheath striate, glabrous or scabrous or covered with bulbous based hairs cal1us with or without bristled auricles. Inflorescence generally racemes or racemose-panicle with few to many spikelets; spikelets 2-8-flowered. Stamens 3; anther basifixed. Style undivided with 3 long plumose stigmas.

Caespitose. Culm ca 4-5 m in height, 2 cm in diameter, green at first, turning yellow with age, branchlets numerous, fasciculate. Culm sheath 12-15 cm long, narrowed towards the apex; imperfect blade absent in lower culm-sheath. Leaves 9-10 x 0.8-1.0 cm, bright green, apex acuminate, base attenuate into a short petiole. Inflorescence a divaricate panicle; spikelets pedicelled and provided with 1 to many membranous longitudinally striate bracts, 2(-3)-flowered; empty glumes 2, lanceolate, outer is smaller than the inner; lemma ovate, violet, many-nerved; lodicule 3, small, rounded, tip ciliate; stamens 3, pendulous, filament long. Ovary surmounted by 2 plumose stigmas. Caryopsis ovoid-oblong, acuminate at the apex.

VERNACULAR/LOCAL NAME: Khasi hills - Ustoh, uskong, daitsisal.

Tufted, shrubby, with single stems from the rhizome. Culm ca 2.0 m high, greyish green; internode ca 15 cm long, striate, strigosely hirsute, scabrous in young culms; node not much swollen, with 1-2 thick branches and a ring below the node formed by the scars of the fallen sheath. Culm-sheath 10-15 x 2.5 cm, papery, striate, covered with long brown hairs on the dorsal surface, rounded at the tip; inner glume ca 9 mm long, 5-nerved; lemma ca 12 x 4 mm, ovate, setaceous, acuminate, striate, 9-nerved, ciliate at the tip; palea ca 8 mm long, with 2 ciliate keels, 1-nerved on either side of keel, apex bifid; lodicules 3, ca 2 mm long, ciliate on the margin, 2 are ovate-acute and 5-nerved, third one is ovate-obtuse and 1-nerved. Stamens 3, free; anther basifixed, tip bifid, blunt; filament very short, delicate, twisted. Ovary ca 1,5 mm long, oblong, ovoid, hairy at the base; style undivided, long, curved with 3 plumose stigmas. Caryopsis ca 3 mm long, oblong, dorsally furrowed with persistent base of style.

DISTRIBUTION: North-East India - Sikkim, W. Bengal, Arunachal Pradesh. Wide spread and gregarious; common in low level hills.

USES: In Darjeelling and Sikkim maling is used for a variety of purposes. The maling bamboo mats are extensively used as roofing material, temporary partition walls, doors and nursery sheds. The culms are also used for fences and garden supports. Young leaves are in great demand as cattle and Pony fodder. Emerging young shoots are good for edible purposes.

DISTRIBUTION: North East India: Sikkim and Khasi hills in Meghalaya. Distributed mostly in cool temperate to sub-alpine zone; gregarious and forming large patches in wet places.

USES: Used as Pony fodder.

LOCAL NAME: Sikkim - Sanu maling, pummoon, pat-hioo; Lepcha and Bhutia - Miknu. mikner.

Shrubby, erect, gregarious, with long rhizomes. Culm ca 4.0 m high, ca 5.0 cm in diameter, glaucous when young; internode ca 11 cm long, scabrous, yellow; with prominent, node; branches 1-3, fascicled at the node. Culm-sheath ca 6 cm long, ca 2.5 cm broad at base, striate, chartaceous, pubescent and narrowed towards the tip; imperfect blade ca 1.5 cm long, narrow, striate, ciliate on the margin, acute at the tip; auricles bristly; ligule ca 2 mm long, fimbriate. Leaves ca 10 x 1.0 cm, linear-lanceolate, apex sharply acuminate, base attenuate into a 3 mm long petiole, ciliate on the edges, glabrous on the surface; main vein prominent, secondary veins 3 pairs, intermediate 6, transverse veinlets many; leaf-sheath striate, straw-coloured, scabrouson the surface, edges glabrous and ending into a callus with auricles having brown bristles on both side of callus; ligule short, blunt. Inflorescence an axillary panicle on leafy branches; rachis glabrous, with 3 spikelets; spikelet ca 3.5 cm long, with 4-8 florets on glabrous pedicels, upper most floret empty; rhachilla ca 5 mm long, clavate, pubescent with tuft of hairs below the flowers; empty glumes 2, very small, ovate, acuminate, papery, hairy at the tip; outer glume ca 4 x 1.0 mm, 3-nerved; inner glume ca 5 x 2.5 mm, 5-nerved; lemma ca 10 x 4 mm, ovate, tip long-acuminate and ciliate, margin minutely ciliate, brownish-red, 9-nerved; palea shorter than lemma, ca 8 mm long, tessellate, 2-keeled, ciliate on the keels, tip bimucronate and ciliate; lodicule 3, ovate-lanceolate, acute, ciliate, 5-nerved, ca 2 mm long, one is shorter. Stamens 3; anther ca 4.5 mm long, bilobed, basifixed, tip-bifid, acute, yellow; filament ca 1 mm long; ovary ca 1 mm long, ovoid-oblong, glabrous, orange in colour; style undivided, short with 3 long plumose stigmas. Caryopsis ca 5 mm long, elliptic, acute, glabrous, furrowed on one side with persistent base of style and stigmas.

DISTRIBUTION: North-East India - Arunachal Pradesh, Sikkim, West Bengal. It grows gregariously and forms a very dense Undergrowth in mountain tops and valleys.

USES: The culms are used for mat-making, roofing of native houses, fencing, garden supports, and leaves as fodder.

Shrubby and culms arising at distance; rhizome creeping, covered with imbricating scales. culm ca 3.0 m high, 1 cm diameter, greenish yellow, flattened on one side; internode ca 20 cm long, walls thin; node somewhat swollen, with 1-3 branchlets. Culm-sheath ca 10 x 4 cm, thin, striate, covered with brown stiff hairs on the dorsal surface, ciliate on the edges, narrowed into a broad truncate mouth; auricles rounded with long bristles; ligule long, Fimbriate, narrow; imperfect blade ca 5 cm long, subulate, recurved.

The Chinese Bamboo

A thickly growing, evergreen caespitose bamboo. Culm usually 2-4 m high, 1.5-2.5 cm in diameter, glabrous, smooth, green when young, afterwards yellowish, hard, much branched from the base; nodes prominently thickened; internodes usually 20-40 cm long. Culm-sheath 10-15 x 5-8 cm, green at first, then yellowish, stiff, glabrous, striate, slightly narrowed upwards and rounded at the top; ligule up to 1.5 mm high, entire; auricles small, bristly; blade 5-8 cm long, triangular, linear, acuminate. Leaves usually 5-10 cm long, 8-13 mm broad, linear-lanceolate, base broadly cuneate with a very short stalk, pale glaucous and finely velvety-hairy beneath. Inflorescence a rather short, diffuse, leafy panicle with few spikelets solitary or clustered. Spikelets 1.2-3.7 cm long, 0.5 mm broad, very glabrous; straw-coloured, bearing 5 or more flowers, separated by glabrous, flattened, 0.25-0.5 mm long rachillae, the terminal flower only imperfect; empty glumes none, or very rarely one; flowering glume, 2-keeled, minutely ciliate only at the tip, many-nerved; lodicules 3, unequal, 0.25-0.5 mm long, entire, linear, somewhat concave or thickened below, usually 2-nerved. Stamens exserted, pendulous; anthers blunt or slightly apiculate, yellow. Ovary obovate, rough, pubescent above; style very short, almost immediately dividing into 3 long feathry stigmas. Caryopsis elliptic, furrowed, roughly hairy above, with a short beak.

The Environment

The bamboos grow well at a temperature range of 8° to 36°C, a minimum annual rainfall of 1000 mm and a high atmospheric humidity. The distribution of bamboos in India appears to be influenced by the rainfall within a range of 1200-4000 mm per year. They thrive best in monsoon forests where they attain their maximum development. They extend from flat alluvial plains to high mountains. The bamboos become undershrubs at high altitudes and in temperate regions, some species appear like grasses. They are found in moist valleys, sheltered depressions, along streams and lower hill slopes, rarely occurring in higher slopes and hilltops. They are usually found mixed with or under tree species, except in case where they form secondary brakes, or more or less pure stands. Though all species form brakes, those of Arundinaria, Ochlandra, Melocanna and Bambusa bambos are more extensive. Bamboo brakes are more common where shifting cultivation is practiced.

The Bamboo Plant

The correct identification of species is often a Herculean task, as most bamboos look alike and flower at long intervals. There is widespread confusion in their scientific names and their common names vary from place to place. The bamboo plant is woody like a tree. It has a leafy aerial part, the culm having nodes and internodes. The branches and leaves are present at the nodes, in the upper region of the culm. The underground part consists of rhizome and roots. The rhizome is similar to culm in structure and has closely spaced nodes that root profusely.

The bamboo varies in size with stems 40 m high and 30 cm thick to mere shrubs at high altitudes. They are monopodial, i.e. erect as in Melocanna and Phyllostachys, sympodial or clump forming, as inBambusa and Dendrocalamus and climbing as in Dinochloa. Between the single-stemmed and the densely clumped forms, there are intermediate types with somewhat open clumps as in Bambusa nutansand B. vulgaris. The erect and clump forming species are characteristic of tropical regions and single-stemmed species are generally found in sub-tropical or temperate regions. Bamboos are classified into two general types depending upon the growth behaviour of their rhizomes: (i) 'Running' or leptomorphic in which the rhizome spreads laterally to a considerable distance instead of being massed together and sends out single culms at intervals. They grow in areas higher than 1000 m and are mostly confined to temperate regions of the world. (ii) Clump-forming caepitose or pachymorphic in which the shoots develop into a thin stem with foliage at the nodes.

Culm

A single bamboo stem is called a culm and a cluster of culms originating from the rhizomes is collectively called a clump. The average life of a culm is 7 to 10 years but some may live up to 15 years. The culms are generally round and smooth. Sometimes they condense into bulges as in Bambusa ventricosa. The culms may be hollow or solid. The hollow bamboos have transverse septa at the nodes. The diameter of the culms varies from a few millimeters to more than 30 cm. The number of fibre bundles and the distribution of scattered bundles contribute to the hardness of the culm. The deposition of silica in the outer cortical layers adds to the hardness. The culms are jointed at intervals and most have prominent rings bearing sheaths, which are characteristic of each species. A white powdery mass covers the tender skin of young culm that disappears as the culm matures. The culms of most of the species are green when fresh but those of Bambusa vulgaris have a gorgeous golden colour with green stripes or are variegated.

Rhizome

The rhizome in bamboos is woody in nature, slightly arched, upturned at the tip like a walking-stick-handle, thick and broad at the end bearing culms and narrow at the proximate end called ‘neck’ where it is attached to older rhizomes. The rhizomes are of two types: (i) short, knotty, thick and solid, forming an entangled mass, giving rise to congested clumps, e.g. Sinarundinaria anceps (ii) runner-like spread over a wide area forming open clumps, as in Melocanna baccifera.

The rhizome of a fully-grown clump gives rise to two types of buds: a scaly and pointed bud producing a new rhizome, and a flat bud producing culms. The scaly and pointed buds are formed during summer and develop during the monsoon and perish after the rains when humidity becomes low. The flat culm producing bud develops during the winter and emerges in the rainy season.

Flower

The inflorescence is an indeterminate compound panicle, usually large, with spicate branches on which spikelet-like banches develop. The flower is composed of lemma, palea, stamen, pistil and lodicule. When in bloom, floral glumes open, stamens strech out and the stigma separates in three directions. The flowers remain open for about 2-3 hours and then close.

Flowering

The flowering in bamboos is an enigma. There are several misconceptions regarding their flowering behaviour. Most bamboos flower and seed gregariously once during their lifetime and perish soon there after. The reasons for this mass mortality after flowering are still not understood. All populations from the same seed source irrespective of their locality start flowering at the same time, indicating the presence of a biological clock mechanism. The germplasm of every seed seems to have been provided with a flowering calendar set to a fixed time. Most bamboos flower at long intervals. Thyrsostachys oliveri clumps flowered simultaneously at Kolkata. Melocanna baccifera was observed flowering simultaneously in Assam and Dehra Dun, and Bambusa bambos also flowered almost throughout India in 1970-71.

Cultivation

The bamboos require warm temperatures to grow success fully. A temperature range of 8° to 46° C is suitable for their cultivation; some cold hardy species can grow even at –18°C. They are light demanding and should be planted away from shade. Nearly 60 species are cultivated in India from sea-level to an altitude of 4000 m. Dendrocalamus strictus is the most common bamboo cultivated throughout North West India up to 2000 m, Bambusa balcooa in Bihar and eastern Uttar Pradesh and Arundinaria and its species throughout the Himalayas. In Western India, the commonly planted species are Bambusa bambos, B. nutans, B. vulgaris, Dendrocalamus hamiltonii and D. strictus and in Central and South India Dendrocalamus strictus (on dry slopes), Bambusa bambos (in moist valleys), B. tulda, Schizostachyum pergracile and Gigantochloa rostrata. In the Western Ghats, where semievergreen forests occur species of Gigantochloa and Ochlandra are grown. In the higher reaches of Nilgiris and Palni Hills, four species of Sinarundinaria occur.

Soil

Bamboos can grow on denuded wastelands and watersheds along the riverbeds. They grow luxuriantly on loamy soils, sandy loams and in fertile clay loams. They are drought-resistant and frost-hardy, but the extent to which they flourish depends upon the physical nature of the soil including the depth, texture, moisture-content and fertility. Most of the soils where bamboos grow, have a good reserve of sesquioxides and potassium but are not so rich in calcium, magnesium and phosphorus.

Preparation for Plantations

The site for plantations is cleared of bushes and wire-fenced before the onset of monsoon. Bamboos are planted both in pits (60 cm x 30 cm x 30 cm) and contour trenches (21 cm x 50 cm x 50 cm) by staggering the space at 3 m x 3 m depending upon the degree of slope. In areas of low rainfall, bamboos are planted in sunken pits for moisture conservation.

Fertilizers

Generally the application of fertilizers is not resorted to for plantations but small doses of nitrogenous fertilizers (200 gm ammonium sulphate or calcium-ammonium nitrate) are applied in a furrow during the first year of planting. Superphosphate (200 gm per plant) applied at the time of planting, promotes better development of roots. Another fertilizer dose in the second year in July is also recommended. An application of biofertilizer Azotobacter alone or in combination with inorganic manure yields significant height growth of bamboo seedlings. Application of 200 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha per year increased the number of culms produced.

Regeneration

Bamboos regenerate from seeds. After gregarious flowering the bamboos wither and the seeds are shed on the ground. At the commencement of rainy season the seeds germinate forming a carpet of green seedlings on the floor of the forest. The growth of seedling is affected due to shade and weeds, but several seedlings manage to persist for several years and develop into clumps after 6-12 years. If the bamboos are not harvested in time after flowering they wither and dry up. In hot season they may become inflammable and cause accidental fires.

Fire and grazing are hazardous to natural regeneration of forests. Seedlings have remarkable power of recovery after injury from fire or repeated grazing. Fire is less disastrous than grazing. Heavy grazing by herds of deer, elephants, bisons, pigs and cattle is responsible for considerable damage to the crops. Even in heavily grazed areas, a few seedlings survive inside the dead clumps and eventually grow up. The underground rhizome often survives for 2-3 years in spite of grazing to bareness, and produces new clumps if fenced at this stage.

Propagation

Bamboos can be propagated through: seeds transplanting seedlings raised in nurseries, planting separated rhizomes, through culm cuttings, offsets, layering, marcotting, micropropagation and macroproliferation. In India propagation of bamboos has been taken up on a large scale in Madhya Pradesh, Maharashtra, Orissa and Uttar Pradesh.

Collection and storage of seed—Small quantities of bamboo seeds can be collected from sporadically flowered clumps. Seeds should be collected when these are fully ripe and start falling, which occurs between the months of February and June. The seeds are either collected from the ground or on a cloth spread around the clump and then shaking the culms. Sometimes the fruits are cut and heaped on the ground and beaten with a stick till the seeds fall out. These seeds are cleaned of husks, by rubbing with hand and then winnowing, and dried before storage. Large quantities of seeds are collected from the forest floor after gregarious flowering. The weather conditions during seed collection influence the viability of seeds. The storage of seeds without loss of viability is of utmost importance, as seeds are not always available. Seeds stored in gunny bags lose viability in about a year or less, depending on the species and climatic conditions.

Harvesting

For harvesting, forests are either leased out or permits and licenses are issued to individuals. The period may range from a few days to years. Tribals and people living in the forests are permitted to fulfill their bamboo needs from forests. In some states, bamboos are harvested by the forest departments and distributed. This practice prevents indiscriminate exploitation of bamboos. Generally, three-year-old culms are harvested but it is rather difficult to assess the age of a culm in a clump. To determine the exact age, the new culms are marked either by marking with Indian ink or painting after rubbing the thin waxy film with a piece of coarse cloth over a small area of culm surface, or the year is stamped on to the surface tissue by using a small steel die and a hammer.

After gregarious flowering, all the mature bamboo clumps, in case of species that die after flowering, are felled to avoid the hazards of fire. Harvested bamboo is highly susceptible to insect and fungal damage, hence requires suitable preservative treatment. After air-drying they are stored in sheds in gunny-bags or in suitable containers, 30 cm above the ground, to protect them from rains. In the absence of proper care a significant amount of bamboo is lost during transport and storage.

The economic life of bamboo farming is assumed to be 25 years. Few new clumps sprout after 21 years hence the entire crop is harvested after 25 years.

Yield

The yield of bamboo varies considerably, depending upon the density of the plantation and biotic interference. The bamboo area can be roughly classified into four categories: (1) Dense or pure - where more than 125 mature and well developed clumps occur per hectare (2) Predominant-areas having 50-125 clumps per hectare (3) Sparse-areas having 25-50 clumps per hectare (4) Poor and scattered-areas having less than 25 clumps per hectare.

In plantations, raised through seedlings at a spacing of 5 x 5 m, the clump formation generally takes place in the third or fourth year. Full-grown culms are produced by sixth year. On an average 3-5 culms are produced per clump per year, so about 275 to 300 clumps are produced per hectare. A systematic and commercial exploitation of a plantation can begin from eighth year. On a three-year cycle, a plantation may yield about 3-4 tonnes of bamboo per hectare at the first cut, 5-6 tonnes at the second cut and 8 tonnes from the third cut. Assuming on the basis of a life cycle of 32 years, when the clump dies due to gregarious flowering, in all about eight cuttings can be made.

Ecological Requirements

Bamboos have a wide distribution in the country and there is hardly any state where lack them. Their distribution is governed largely by the condition of rainfall, temperature, altitude and soil. In India, bamboo forms rich belts of vegetation in well drained parts of the monsoon region at the foot of the Himalayas and rises upto 7000 metre of altitude. Their distribution is quite dense in the Western Ghats, Bengal, Sikkim, Assam, Arunachal Pradesh and Andamans.

Climatically bamboo prefers regions of high rainfall ranging from about 1270 mm to about 6350 mm or even more, though they also occur in dry deciduous forests with as low a rainfall as 750 mm. Rainfall plays a very important and dominating role in the distribution and growth of different species. A maximum temperature of 46.70ºC and a minimum temperature of 3.30ºC are recorded from bamboo bearing localities.

The distribution of various bamboos in areas adjoining the sea coast appears to be governed to a great extent by the relative humidity. It has been observed that the interior dry regions unaffected by the sea breeze are usually occupied by Dendrocalamus strictus while those situated near the coast, characterised by relatively high humidity are dominated by Bambusa bambos.

Bamboo is a light demander. Under heavy shade thin and whippy culms are produced. However, a certain amount of overhead shade is also necessary during the early stages of development of bamboo seedlings before they form clumps. There is a direct relationship between the incidence of light and density of clumps, largest number of bamboos is obtained when overwood is clearfelled. Removal of overhead cover is beneficial.

Bamboo being a very hardy plant comes up with on a wide variety of soils, derived from different parent rocks, within its climatic habitat. However, each species of bamboo has its own optimum site and soil conditions and rarely occur in mixture in close association. Generally bamboos make luxuriant growth on hilly slopes and on well drained, sandy loam to loamy soils, with adequate supply of nutrients and moisture. Bambusa bambos and Oclandra which make good growth on clay soils and under moist situations such as the river and nala banks. The low level depressions, steep slopes are not conducive for the growth of bamboos.

Dendrocalamus strictus, one of the most widely distributed species of bamboo in our country, is well adapted to a wide range of climatic conditions. It thrives well under climatic conditions typifying xerophytic characteristics of evergreen forests. Bambusa bambos another widely occurring species next to Dendrocalamus strictus prefers heavy rainfall areas.

Bambusa bambos is somewhat exacting in its site and soil requirements. It prefers moist situations, seldom grows in dry areas and is most common along the streams, in depressions along lower slopes and other localities where moisture is available in large quantities. In dry tracts, it prefers to grow on alluvial other deep, fine textured soils, which have high moisture retaining capacity. The growth of this bamboo is much inferior on dry lateritic soils than on moist deep alluvial soils.

Soil moisture regime has an important role in the distribution of various bamboo species so much so that the influence of geology becomes a secondary conditions to any of the soil characteristics that affect the soil moisture regime. Within an area having the same parent rock, the upper and middle slopes characterised by coarse texture and dry conditions are occupied by D. strictus, whereas the bottom lands characterized by fine texture and moist conditions are occupied by B. bambos. The natural regeneration and clump size of the bamboo are greatly affected by the moisture conditions of the soils.

Dendrocalamus strictus is a versatile species making good growth on a variety of soils derived from such widely varying parent material as granite, basals and rchirts. One of the essential conditions for its successful growth is the sandy nature of soil and good drainage. It prefers a dry soil and is a characteristic constituent of open dry types of deciduous forests. The various climatic, edaphic and biotic factors which accentuate dry conditions appears to be conducive to the dominance of this species. In moist localities the culms of D. strictus are usually hollow while in dry tracts they are solid. This species gives way to B. bambos in moist localities.

Growth Characteristics

Development of Bud

The bamboo forms a unique group of giant arborescent grass. Bamboo grows in two distinctly different forms due to the types of its subterranean rhizome., i.e. either single stemmed monopodial (leptomorph) (or) densely clumped Sympodial (pachymorph). A complete bamboo plant consists of three morphologic structures - the leafy aerial part (the culm) and the two underground parts (the rhizome and roots). For successful growth, all these structures must develop. Failure in development of any of these phases leads to complete failure. The stems are called culms and their joints nodes. A scaly rhizome underground stem is produced from the base of the seedling-plant which after growing vertically downwards for a short distance, curves up again and appears as a small culm (bud).

The buds in rhizome are initially flat in shape, usually less than 2.5 cm in diameter and are covered profusely with scales. These scales are at first not very apparent, but develop rapidly as the buds develop. These scales are the underdeveloped sheaths of the future culm. On carefully dissecting away the scales one by one, it can be seen that a bud contains a complete bamboo in embryo. Each bud has as many as 35 more telescopic internodes with an equal large complement of scales in appearance, like the growth rings on the stump of a tree, in the form of a terraced mound.

During the development of a rhizome bud into a culm, the first thing formed is a short new rhizome. Before the culm appears above the ground, the new growth develops into a complete rhizome for the support of the culm. At this stage, it is equipped with several fully grown buds, which in turn lie dormant until the following years). The function of the rhizome is to give support to the growing aerial shoots (culms) and to act as a feeding channel.

The sheaths are of vital importance to culms during growth. Each internode is carefully wrapped up in a single sheath, but the basal internode always has more than one sheath. In a bud, the sheaths are arranged alternately clockwise and anticlockwise. The sheath is a nurse to the tender internodes against injury and desiccation. Its outer surface is armed with a cluster of stiff hairs, which are detached on the slightest touch and cause irritation to any naked part of the human body.

Clump and Culms

Most bamboo species of commercial importance form clumps. The new seedling produces rhizomes which develop new rhizomes that inturn produces culms. New rhizomes are produced from the previous year rhizomes. The number of new rhizomes may vary from one to many. Some seedlings fail to produce clumps. This may be due to selfing or depression. In India new culms generally appear during the rainy season. An unusual rain during winter months may induce the emergence of new culms. Though the culms do not grow in diameter after sprouting, they continue change in density and strength properties.

Two kinds of buds are observed on the rhizomes, the scally pointed buds and the flat buds. The former develop into rhizomes and the latter into culms. The scaly buds are formed during the summer months while the culm buds develop during the winter months. The culm buds emerge out of the soil with the early rains and grow rapidly. The culms are very tender during the growing period. They are sometimes art and made into vegetable (or) pickles. The age of an individual culm is not related to clump age. Culms are tender during first year. They grow tough during the second year and are mature during the third year. At the age of three years they acquire full density and strength.

Rhizomes

Rhizomes generally grow at an upward inclined angle. The angle of incline depends on the species and the condition of soil. During this period of growth any exposure to sunlight stops the rhizome development. Consequently, the bamboo culms that are covered with earth humus produce more culms while in areas where soil erosion takes place, the production of new culms gets reduced. The rhizome development is not peripheral as generally believed. Rhizomes may develop in any direction and the culms may appear anywhere in the clump provided overhead light is available for the emergence of the culm. It is only in congested clumps that the new culms appear to grow at the periphery. The new culms can even be seen in the middle of the clump.

Flowering

Bamboos differ significantly from other vegetation because of the mechanism of flowering. Most of the woody bamboos flower and seed after an exclusive vegetative grown for a species specific supra annual interval, ranging between 3 and 120 years. There are three types of flowering. (i) Those which flower gregariously and periodically (ii) those which flower irregularly (or) sporadic (iii) those which flower annually. In gregarious flowering all members of a cohort (Plants from seeds of common origin) enter the reproductive phase approximately at the same time and after flowering and seeding the parents die enmasse. This death of the bamboo parents used to be given more importance, probably because of their long intermast periods and arborescent habits.

Due to this peculiar flowering behaviour in bamboos, flowers and seeds are available only at very long intervals. This has resulted in a poor understanding of their inter-relationships, besides making the perennial raising of plantations using seeds and hybridizations difficult. Selection is the only method available at present for bamboo improvement. It is possible now to induce flowering is bamboos by tissue culture methods. Induction of flowering in Vitro can be used for perennial seed production and hybridizations.

Establishment and Management

Direct Sowing of Seeds

Seed Characters

Possibilities of raising bamboo plantations from seeds are not always practical because of the unusually long seeding cycles. Except in the case of Melocanna baccifera, seeds of most of the commercially important species of bamboo resemble grains of paddy wheat and are light in weight. Seeds for direct and nursery sowing should be obtained direct from the forest. The seed may be collected either on the ground previously cleared on a cloth spread around the culm, by shaking the culms. The best time for collecting the bamboo seeds is between the months of February and July consequent to the flowering. The number of seeds per kilogram varied from 75,000 to 1,05,000. The bamboo seeds remain viable for short periods, with the initial viability is good, the seeds rapidly lose germination vigour. The longevity of seeds varies from species to species but they are generally viable upto 1-2 months, although the period can be increased under controlled storage conditions. Seeds of Bambusa tulda stored in a desiccator over silica gel maintained their viability even after 18 months. By storage of seeds under suitable temperature and moisture, the longevity of Dendrocalamus strictus seeds could be extended upto 34 months.

Direct Sowing

For direct sowing, the soil should be dug upto a depth of about 10 -15 cm, deeper in case of poor soils, either in lines 3 m apart, in patches 3 m x 3 m 4.5 x 4.5 m apart and cleared of all weeds. Seeds, after having been soaked for 48 hours before sowing are dibbled in beds at the plantation site and slightly mulched. The resultant plant kept clean weeded for the first 2, 3 seasons. 1.25 kilogram of seed per hectare will suffice for widely spaced patch sowing and about 11.5 kg for line sowing. Though direct sowings are an easy method, they are generally neither practicable nor desirable owing to shortage of seed, the necessity of continues weedings till plants are well established, and the liability of destruction by seed eating birds and rodents.

By Rhizome With Roots

Rhizome without culms are cut 50 - 60 cm long with about 10 - 15 nodes and their roots. The 2 - 3 year old rhizomes with roots are most satisfactory, but over 5 year old rhizomes are entirely unsuitable. This method is recommended for transplanting to distant places. In this case, they are wrapped with sphagnum moss and covered with vinyl sheets after the soil is washed away. Usually, they are first laid in the nursery bed 20 cm deep and covered with soil (Figure - 3). They are transplanted next spring, as new culms begin to grow. This method is applicable to monopodial type.

By Offset Planting

This is the good method of vegetative propagation of clump - forming bamboo species in which success has been achieved. One year old culms which are ready to sprout within the year are cut off with short rhizomes. The culm should be about 30 to 50 cm in length. The success of this method depends in part on the vitality of the rhizome stock used and the time of the year when it is planted. If the rhizomes are taken from young healthy stock and planted immediately at the break of rain success can be expected. But if the rhizomes are taken from old stock and planted much before the rains, complete failure may result.

By Culm Cutting

This method, however, has a limited use because of the limited availability of the planting material. Rooted culm cutting can be successful with most bamboo species. The age of the culm and the period when these cuttings are put out for rooting are important considerations. The two year old culm and spring season have been found to give best results.

Collection of Material and Preparation of Cuttings

Extract 2 to 3 years old culms from healthy culms by cutting just above the first node during March - April. The leaves and side branches should be trimmed. Care should be taken not to injure the auxiliary buds while removing leaves and branches. The culms should be transferred to the nursery site as quick as possible. Maximum care should be taken to prevent drying. This can be done either by wrapping in moist gunny bags embedding in boxes containing moist sawdust. Two - noded cuttings (a cutting with two nodes leaving about 5 - 7 cm on either side of the nodes) should be prepared using a sharp knife saw. For bamboos with thin walls use of a saw is advised to avoid splitting of the cut ends. Make an opening (about 2 cm in length and 1 cm in width), drill two holes (about 7 mm diameter) in the centre of the internode.

Treatment for Root Induction in Cuttings

10 gram of NAA (1-Napththlene acetic acid) BDH, Loba Chem E. Merck), should be dissolved in 250 ml of ethyl alcohol (90%) in a container by stirring the solution gently and add water to make up 100 litres. The solution is mixed thoroughly by stirring. The final concentration of NAA will be 100 mg/1 of water equivalent to 100 ppm. This solution is sufficient to treat 1000 cuttings. About 100 ml of the solution should be poured to the culm cavity. To avoid spillage, use a wash bottle to pour the solution through the drilled holes. The holes should be closed by wrapping and trying with a polythene strip (60 cm x 6 cm). Ensure that the polythene wrapping should be tight so that the solution does not leak out. The cuttings should be kept horizontally with the opening facing upwards. For bamboos with narrow culm cavity like Dendrocalamus strictus the treatment is given by dipping the basal portion of the culm cutting in solution of NAA for 24 hours.

Preparation of Nursery and Planting

Raised nursery beds of 10m x 1 m is prepared and filled with a mixture of soil and sand (3:1). One weak prior to planting, drench the nursery bed separately with the insecticide, Aldrin and the fungicide, Bavistin to prevent termite and fungal attack. For each bed, use to 40 litres of 0.015% (9.1). Aldrin prepared by adding 0.5 ml of Aldrex 30 EC per litre of water and 30 litre of 0.05% (9.1). Bavistin prepared by adding 1 g of bavistin 50 WP per litre of water. The treated cuttings were placed horizontally (the opening facing upwards) across the nursery bed. About 50 - 60 cuttings may be conveniently planted on a raised nursery bed of 10m x 1 m.

Nursery Management

Nursery beds must be provided with a thatch to protect the cuttings from direct sunlight, which may be removed on the onset of monsoon. The beds should be watered regularly in the morning and evening with 30 to 40 litres of water pre bed at each watering. Care should be taken to avoid water logging. The sprouts after one month were treated with 0.01% of Bavistin to avoid fungal attack. If necessary, farmyard manure may be applied increase the vigour of the sprouts.

Transplanting

Rooted cuttings can be uprooted and transplanted to the field during June - July. If cuttings are sprouted and rooted at both the nodes, cut should be done carefully at the middle of the cutting to get two plants.

Precautions

The collection of culms from clumps which are likely to flower in the near future is to be avoided, because new clumps developed from such cuttings will also flower and perish along with the mother clump. The year in which the clumps are likely to flower can be found out by checking the previous flowering record the area and the flowering cycle of the species.

Growth and Development

Growth of Seedlings

The seedling bamboo resembles a blade of grass. Seedlings should be watered daily and death does not appears to be due to onset of the dry season. Bamboos (the monocotyledons) have very different root system. The seedlings develops a underground rhizome system, which carries a dense mat of thin usually undivided adventitious roots, which show no secondary thickening and are replaced by new ones as they die off in the course of time. From the rhizome, in due course, culms of successively larger size are sent up.

Development of Rhizome

A scaly rhizome underground stem will be produced from the base of the seedling plant and after growing vertically downwards a short distance curves up again and appears as a small culm. Further rhizome sections will be develop in succession from the first and follow the same penetrating deeper into the soil till the optimum depth of about 0.5 m is reached and sending up successively larger culm. Full sized culms will be produced after 2 - 5 years depending on species and conditions. The rhizomes often branch two more club shaped lengths each sending in a culm or culm bud developing from buds on a single older length. It appears to be unusual for culms to be produced from rhizome sections more than 2, 3 seasons old growth accordingly it normally tends to be peripheral, but rhizomes sometimes grow towards the centre specially if conditions are unfavorable. In the species in which the rhizomes extends some distance before sending up new culm, the culm themselves may well spaced out and individual plants often cannot be distinguished from their neighbourhood e.g.

in Melocanna baccifera, but in many of the more important species notably Dendrocalamus strictus the rhizome section are short and culms remain close together in a clump.

Culm Growth and Development

There are three phases of growth and development of culm viz., culm elongation (first phase) which on nearing completion triggers thorn emergence (second phase) and finally leaf appearence (third phase). The first phase commences with “Komali” which means tender culm (30 to 40 cm high) completely covered by sheaths with no isternodes seen outside and looking funny like a foolscap. This stage lasts for about ten days and growth will be extremely slow. After the initial period of slow growth the elongation will takes place in spurts of increasing rates and reaches the peak lasting a few days and then falls rapidly marked by leaf appearence, culm elongation is over in 70 to 90 days depending on the length of culm. The emergence of thorns (in Bambusa bambos) commences from the 25th to 50th day of “Komali” appearence and will be completed in about 135 days. Leaves appear on the 60 - 90th day and the culm becomes fully leafy in about 150 to 180 days.

Annual Recruitment of Culms

The productivity of bamboos will be assessed by the number of new culms produced annually. At a given site, the production of new culms mostly depended on, the degree of congestion, clump age and rainfall of the previous year. In India, new culms generally appear during the rainy season. An unusual rain during the winter months may induce the emergence of new culms.

Bamboo seedlings (Bambusa bambos) were planted in 1987 at Kallipatty, Tamil Nadu, India. Almost all seedlings (250 seedlings ha-1) produced culms in 1988, the next year of plantation. Since then the culms were treated as 1 - year and recording of different growth measurement have been continued for nine years. The Bambusa bambos species produced only 5 culms per clump in the first year. The number of culms gradually increased in the subsequent years and became maximum (17 culms) in the 6th year of clump age. Number of culm production then slowly decreased from the 7th year and were only 6 in the 9th year of clump age. Similar results were also observed by Banik in four other Bambusa species, namely Bambusa vulgaris, Bambusa balcooa, Bambusa longispiculata and Bambusa tulda andMelocanna baccifera at the Forest Research Institute, Bangladesh. Cumulative total culms produced in the clumps of all these Bambusa species upto to 6th year of age made crowded condition due to short (7 -12 cm) neck pachymorph rhizome system. This crowded and congested condition created a scarcity or room for the new emerging culms and also increased competition among them for survival. Probably due to this reason culm production subsequently decreased from the 6th year in the Bambusa species.

In Melocanna baccifera the average production of culms was 2.5 in the first and from third year the number increased rapidly to 12.5 . Culm production also rapidly increased in the subsequent years reaching 35.7 after the 10th year of clump age unlike, other clump forming bamboos M. baccifera has underground pachymorph rhizomatous system with strongly elongated (1.0 - 1.5 m) neck. Owing to this rhizome nature the species produces culms at varying intervals in all directions forming a diffuse and open type of clump condition which can accommodates the space required for the increased number of culm production in the subsequent years after plantation. Probably due to this reason the rate and pattern of clump girth expansion in M. baccifera are different from those of other Bambusa species. Othman reported that the annual recruitment of culms was decreased from the third year clumps of Gigantochloa scortechnii at Forest Research Institute, Malaysia.

Culm Height and Diameter

Culms of all bamboo species complete their growth within 2 to 3 months after the emergence of sprouts from the ground, but their diameter and height do not increase after the growth is over. It has been observed that in all bamboo species that the culms emerged in the first year after plantation were short in length and narrow in diameter at breast height. Culm produced in subsequent years were distinctly taller and wider in diameter then those produced in the past years and such trend is continued upto 6 years in Bambusa bambos. 5 - 6 years in B. longispiculata and B. tulda and 7 years in the case of B. vulgarisand B. balcooa. After these periods clumps of these Bambusa species did not produce any taller and wider culms in the subsequent years. Clumps of Melocanna baccifera produced taller as well as wider (with increased diameter) culms in the subsequent years of planting and the trend was distinctly rapid upto four years of age.

Introduction in Social Forestry

Bamboo is one of the most important multipurpose species and therefore, it is being introduced in a large scale under various programmes of social forestry. It is a domestic orborescent grass and villagers like to plant it in home gardens, around wells, compounds and in the agricultural fields. Almost every part of the bamboo finds some use. The culm has high market value and is used as building material, paper pulp resource, scaffoldings, fishing rods, weaving material, agricultural implements, parquet manufacture and as water conduits. Leaves of several species of bamboo are utilized as fodder during scarcity. The thorny branches are used as fencing material.

The bamboo is highly versatile. It is capable of growing in a variety of soils derived from different parent rocks, within its climatic habits. However, each species of bamboo has its own optimum site and soil conditions and rarely occur in mixture (or) in close association. The bamboo has been planted on a large scale along road and canals. It is also planted in degraded forest areas particularly near habitations. This can also be planted on agricultural fields and homestead plantations.

Strip Plantation

The strip plantations along road, canal and agricultural fields combine, three recognised social forestry aspects viz. protection, community and subsistence forestry. They offer physical protection to the land resource, in that they not only conserve topography, soil, water, air and fertility, but also provide shade and amelioration of surrounding environment. Their existence provides protective barrier to adjoining cultivated fields. They resist and prevent the effects of high velocity winds and thereby avoid losses due to the detrimental effects of intense heat, light, wind velocity and abrasive and chemical effects of air pollutants. They meet the immediate requirement of the agricultural population of small timber, fuel and fodder and cater to grazing.

Roadside strips, through state government owned land resource, can be fully deployed for commercial purposes Managerial limitation render the strip resource ineffective for sustained commercial production. The management problem further deepens due to variable site conditions. Soil characteristics in particular, vary greatly within a short length affecting the uniform growth of the bamboo species under the circumstances create problem. Road side strips are common property resources and can be effectively utilised for the production on a sustainable basis only when bamboo vegetation is grown with the active participation of local population. People's participation can be achieved provided the right species is selected and people have sharing benefits. Production and influential benefits would naturally reach the community.

Bamboo is the fastest growing species attaining harvestable maturity in a brief spell of three years. The rural poor are the principal users of bamboo, using many time more material than the pulp and paper industries. The easy availability of bamboos, can help provide part time seasonal employment in its processing for villages women. Bamboo are used for manufacture of large number of value added goods handicrafts, by the rural people. The growth in strip plantation is encouraging and support the productive aspects achieved through strip planting under social forestry programme.

Community Forestry Programme

Bamboos for community forestry programme was suggested by Shanmughavel. Community forestry programmes are based on growing bamboo on public Community land contrary to private farms. The degree of local participation in planting and looking after the tree varies. What all community programmes have in common, is that they are intended to provide benefits which are shared by the community as a whole.

The most common type of community forestry programmes is that in which the forest department takes on the responsibility for carrying out the planting. Inputs such as fertilizers and seedlings are provided without any outlay by the community. The engagement of the local community in the implementation of schemes of this type is largely passive and is normally restricted to the provision of hired labour for planting and an agreement to co-operate in protecting the plantation.

Other programmes rely on a much higher level of community participation and control. They are generally designed to use land, which is under direct community ownership they can take place on state lands, which have been specially designated for community control. The main responsibility for planting and looking after the trees is taken by community itself and the role of the promoting agency is primarily a catalytic one.

Degree of Local Participation

As discussed earlier, the aim of community forestry programmes are to regenerate the degraded forests and barren lands by planting bamboo.

Local Institutions

Community bamboo growing programmes are crucially dependent upon the active collaboration of village councils, community groups other local institutions. Programme planning must therefore be based upon a clear affairs, their potential for realising thwarting the aims of the programme. The village community groups should be trained giving proper instructions about the growing of bamboo in the barren land by the specialists in the field. While selecting the village community groups, preference will be given only to the educated unemployed youths.

Land Allocation

Maximum 25 ha. area of degraded/barren forest land is to be allocated at a time to each participating village group. In future, more land can be allocated if the work of the participating village committee is found encouraging.

Procedure of Working

After collaborative micro planning a need based management plan will be drawn up. The forest department will assist the village committee to establish joint protection and management systems.

Requirements/Rule of Working

Order requires participating village committees to protect the allocated land against non-forestry use, encroachment, grazing, illicit felling and wildlife. Land in no case is to be allocated to individuals and ownership of the land shall remain with the Government.

Need for Bamboo Plantation

Bamboo is considered to be a unique raw material from the point of its quick growth, easy availability, straightness, smoothers etc. It is used for various purpose such as construction of rural houses, ladders, mats, baskets, pipes and handicrafts etc. But the largest demand is for the manufacture of paper. During the last few decades, it has become a major source of raw material for the Indian Pulp and Paper Industry. The Industry is presently facing problems of non-availability of suitable fibrous raw materials in adequate quantity to meet its requirements. The supply of bamboo, so far the main raw material for the Industry, has been dwindling in the recent years. Still bamboo accounts for 80 percent of the fibrous raw material requirement of the Industry. The report on the National Commission of Agriculture brought out some figures about the current demand and output of the projected bamboo requirements for 1980 (4.274 million (CuM) and 2000 (7.005 million (CuM) and recommended the measures required to bridge the increasing gap between demand and supply. One such recommendation is, the sustained availability of bamboo can be ensured, only by raising elaborate bamboo plantations, and also to use the existing bamboo resources judiciously and efficiently.

Present State of Pulp and Paper Industries

Pulp, paper and fibre industries are dependent on raw materials like bamboo, softwoods and hardwoods. Agricultural residues like bagasse, paddy straw, mesta, kenaf and grasses account for 30 percent of the raw material consumption of pulp, paper and Board industries. The per capita consumption of paper in India is only 2 kg/Yr-1 as against 200 kg/yr-1 in some advanced countries. The planning commission has estimated to annual requirement of paper products by the year 2000 to be 4,250 million mt yr-1 as against the present installed capacity of 2.754 million mt.

According to statistics collected by the development council for pulp and paper, the installed capacity in India as on 01.01.1992 was 0.3 million mt of newsprint pulp, 0.196 million mt of rayon grade pulp and 0.040 million mt of paper grade pulp.

Raw Material

Thirty per cent of the raw material used by the paper mills consists of agricultural residues. By technological advances and modernization, it is estimated that the production of paper in the country can increase the use of non-forest raw material to 40 per cent. However, the dependence on forest raw material for major portion of paper manufacture cannot be ruled out. The rayon grade pulp industry in mainly dependent on debarked Eucalyptus, Casuarina, bamboo and a small percentage of mixed hardwoods for their manufacture.

The bulk of the bamboo supply to the paper mills was through natural bamboo available in the moist deciduous forests of India. With the exception of Kerala, where reed bamboo available from evergreen forests which is being used by some pulp mills. Most of the bamboo supply comes from two main species viz. Dendrocalamus strictus and Bambusa bambos. In Northeastern states, bamboo is available in secondary succession after jhum cultivation. Bamboo is also grown in homesteads and farms and sold to mills.

Raw Material Status

Systematic efforts at projecting the wood requirement of the country for industrial and non-industrial uses was first taken up by the National Commission on Agriculture in 1972-1974. The report on the National Commission on Agriculture broughtout some figures about the current demand and output of wood, projected requirements for 1980 and 2000 and recommended the measures required to bridge the increasing gap between demand and suppliers (Table - 4). The Development Council for Pulp and Paper in the Ministry of Industry appointed a raw material committee for pulp and paper. This committee reported on shortages in the year 2000 (Table - 5). The shortages projected by this committee for the year 2000 were 0.300 million t. of bamboo, and 3.55 million t of wood. In addition, the committee projected the shortfall in the raw material for newsprint production to be 0.161 million mt. of bamboo and 0.925 million t of wood. The bamboo shortfall can be compensated only by raising elaborate bamboo plantations.

Guidelines for Raising Bamboo Plantation

Seeds from bamboo are limited and also possessing short period of viability. So the seedlings obtained from tissue culture techniques preferably employed for raising plantation widely.

Preparation of Nursery and Planting

A nursing area of 10 m x 5 m should be prepared in a field and filled with a mixture of soil and sand in the ratio 3:1. Seedlings when they were about 7 cm in height the seedlings should be removed from polythene bags, and transplanted with about 25 to 30 per square meter in a raised nursery bed, irrigated 2 to 3 times a day taking care to avoid excess saturation. The nursery beds should be provided with a coconut thatch to protect the seedlings from direct sunlight.

Transplantation

The seedlings in the nurseries will be carefully uprooted and transplanted to the field after about 10 months. The seedlings should be planted at 6 m x 6 m spacing with 250 seedlings per hectare. The transplanted seedlings should be irrigated for two hours on a regular basis in both the morning and the evening. Weeds should be removed from the plantation areas as and when required. After one year, the plantation will be irrigated as 15 days intervals.

Bamboo Plantation—Problems and Prospects

The present cultivation technique is based on experience rather than on scientific basis. Species which have attained a crop status in agriculture have long decades of directed endeavour behind them. Bamboos have not attained the same status due to lack of sustained investigations. A few problems of fundamental and applied nature and biomass cultivation prospects are listed below.

Cultivation Techniques

Generally bamboos are cultivated by planting offsets (rhizomes, as seeds are not readily available except in seed years, which again are few and far and far between. Seedlings obtained from tissue culture techniques can also be used. Planting pits are prepared about two months ahead of the planting time and the pit as well as the dug-up soil allowed to weather. Seeds seedling were planted in the field at a spacing of 6 m x 6 m. In one hectare 250 seedlings can be planted. If it is, off-set planting, the collection of off-sets should be done very carefully. They should be properly dug up so that the buds are not damaged in anyway. These are than to be transported as quick as possible to the planting site, ensuring protection against exposure and kept puddled under shade before planting. The time of planting is a most decisive factor in the ultimate success of the plantation. Planting work must be undertaken immediately after the first showers of the monsoon. In plantations, profuse watering is done, but over watering is avoided. All causalities must be replaced in due course.

Projection of Culms

All the germinated seedlings produces rhizomes, which develop, new rhizomes that produce lateral culms, which are the chief causatives for the total biomass yield. The number of culms developed from the rhizome totally constituted to a clump. During the first year 3 to 4 culms generally increased year after year. The culms produced during first year is shorter in length and smaller in diameter, but culms from subsequent years will be longer in length and bigger in diameter.

Problems of Cultivation

There are many irremediable problem, if large scale plantation is planned. The problems relate to seed collection, vegetative propagation, soil moisture conservation, plant protection, weeds, grazing and fire and clump congestion.

Seed Collection

Seeds of bamboo resemble grains of paddy wheat and are light weight. Seeds for direct and nursery sowings should be obtained direct from the forest. Possibilities of raising bamboo plantations from seeds is unreliable due to the long and unpredictable flowering habit of the bamboo. Besides, the seeds have no dormancy period and are viable only for short period. It is suggested that, a practical and cheap method of prolonging the viability of seeds has to be developed. Some basic studies on seed biology needs to be undertaken.

Plant Protection

The formation of bamboo plantations is not without risks. Young plants, most of which develop the rhizomes in the seedling stage, suffer from depredations by rats, hares, porcupines, squirrels, pigs, deer and cattle including goats. But the chief damage is caused by man, monkeys and elephants.

Effective fencing is most essential in the early stages. In the nursery wire-netting should be used to protect the seedling beds from hares which can do a very great harm to them. Insect attack on the new growing culms, on cut bamboos, is a normal factor in bamboo management. In the life of a growing culm, the stage of greatest susceptibility of fungal attack is the "Komali" stage. The green Komali turns brown and comes off easily when pulled, leaving the area of transformation soft and brown, smelling strongly like molasses. The pathogenic fungi kill a large percentage of komalis and this is commonly experienced in heavy soils of impeded drainage. The measures like drenching the clumps with blue copper in advance.

Weeds

Weeds are the another important problem during the initial stages of plantation. For this weeding was done as and when required. If there is weed competition, the bamboo regeneration suffers more less heavily and shade also thins it out.

Grazing and Fire

Grazing and fire are most detrimental to seedling regeneration. Therefore the plantation area needs protection from grating and fire when protection against grazing fire is not provided the regeneration in form of seedling are grazed/browsed and killed.

Utilization

Consumption Pattern of Bamboos in India

The bamboos which are giant, woody, tree-like grasses, have a long history as an exceptionally versatile and widely-used resource. Especially in Asia, where it is known variously as the "poor man's timber", the cradle to coffin plant and "green-old" bamboo has and still provides, the materials needed for existence. The strength of bamboo culms, their straightness and lightness, combined with hardness, range in sizes, hollowness, long fibre and easy working qualities, make them suitable for variety of purpose. From the tender shoots used for pickles and curries, lowly sticks used per tooth picks and meat barbeques, through the ribs for ubiquitous fans the slats for sun screens, to the sturdy lathies and the so called bamboo houses, the versatility of bamboo is legendry. The thousand and one uses of bamboo have long been known and established. Some of the traditional uses are:

Agriculture implements, anchors, arrows, back scratchers, basket, beds, blinds, boats, bottles, bows, bridges, brooms, brushes, building, caps cart-yokes, caulking material, chairs, chicks, chopsticks, coffine, combs containers, cooking utensils, cordages dust-fans, fans fences, fish-traps, fishing nets, fishing-rods, flagpoles, floats for timber, flutes, flower-pot, food, food baskets, fuel, furniture, hats, handicrafts, haystack stabilizer, hedges, hookah-pipes, joss-stick, kites, ladders, ladles, lamps, lance staves, lanterns, lining of hats, and sandals, loading, nessels, masts, match-sticks, mats, milk-vessels, musical instruments, nails, net-floats, ornaments, paper, pens, polomatlets, rafts, rayon pulp, roofing, ropes, sails, scaffoldings, scoops, seed-drills, shoes, shuttes, tales, thatchings, tobacco pipes, toys tool-handles, traps, tubs, umbrella-handles, walking-sticks, walls, water vessels and wrappers.

In addition, bamboo is popular ornamental. As a living plant it is used for hedges, and in landscape gardening. It is valuable as a wind-break and is particularly useful for preventing soil erosion on account of its interwoven root system. In view of the extraordinary range of uses to which bamboos are put they have assumed world importance.

Other Recent Uses

Research is continuously going on to develop new uses of bamboo. Some of the recent uses developed in the country and elsewhere are briefly described as under:

Bamboo Parquet (Block Flooring)

The term parquet is applied to the flooring in which strips, 3.81 cm x 6.71 cm are cut and laid out in geometric pattern.

Laminated Bamboo

The bambob culms are cracked, spreadout and flattened into sheets with suitable binding and filling material. Then the sheets are combined, lapped, arranged, glued, treated and pressed to the desired form. They are then cut and trimmed to the desired size and shape and finally given finishing touches according to ones fancy.

Bamboo Strip for Air Craft

The use ot bamboo-woven mat glued to wood laminated to other bamboo mat for use in light air craft has been studied. The material has been found to be relatively stronger and its fatigue strength under bending stress in much higher than that of wood. The bond strength of bamboo to bamboo is comparable to the bond between bamboo and wood.

Bamboo - Reinforced Concrete

Bamboo reinforcement was first used in China in 1919 in concrete piles in railways. Since then, the possibility of bamboo reinforcement is being thoroughly investigated.

Bamboo and Its Uses

The utilitarian value of bamboo has been well established.It has age-old connections with the material requirements of human beings. Its rapid growth, easy propagation and short production cycle make it an ideal substitute for timber. It can be an attractive commodity for commercial exploitation, as its cultivation requires little effort and investment. Out of 128 species reported from India only ten are exploited commer cially. Besides food, bamboo is commonly exploited for traditional art, craft, and agricultural uses, and in the industry for furniture as a raw material for paper and rayon industries, for construction in low cost housing in typhoon andearthquake-prone areas and a number of traditional cottage industries.

Bamboo Shoots

The tender shoots of bamboos are edible. They usually emerge after the rainy season and are harvested when they are 20-30 cm high. In India, the shoots of Bambusa bambos, B. multiplex, B. tulda, B. vulgaris, Dendrocalamus giganteus, D. hamiltonii, D. longispathus, D. strictus and Sinobambusa elegans are pickled and also used as vegetable. In the Northeast, and in some other parts of the country, bamboo shoots are a part of traditional cuisine - fresh, dried, shredded or pickled. Pilgrims to Haridwar often partake bamboo shoots pickle. Bamboo shoots are very popular in China, Japan and Indonesia, The edible portion of shoots is about 27%. The tender shoots are very delicate and luscious, a chemical analysis yielded moisture, 87.1%; protein 3.9%; carbohydrates 7.5%; and minerals 1.4%. The shoots are rich in phosphorus but low in calcium and iron. The shoots have been found to be tough and more fibrous when collected late during the rainy season. The shoots of Bambusa polymorpha are sweet where as those of some species of Bambusa, Dendrocalamus and Melocanna are slightly bitter or acrid. The shoots contain cyanogenic glucosides, which on endogenic hydrolysis yield hydrocyanic acid. The contents of hydrocyanic acid vary from 0.05 to 0.03%, the tips of immature shoots sometimes contain up to 0.8%. The bitterness or acridness is leachable and can be removed either by changing the water several times during cooking, or by soaking in different changes of common salt water (2%) for several hours. The shoots also contain homogentisic acid and its glucoside. An acidic xylan, an arabinogalactan and µ-glucan have been isolated as the water-soluble polysaccharides from immature bamboo shoots.

Seeds

During famine the seeds of Bambusa bambos, Dendrocalamus strictus and Schizostachyum pergracile are consumed. The seeds resemble paddy though bigger in size. When mixed with honey, they are a delicacy. They are pickled, candied and used for making beer. The starch content of bamboo seeds is comparable to that of rice and other cereals. The protein content is comparable to that of wheat, predominantly glutelin. The essential amino acids reported in bamboo seed protein are: arginine 8.9; cystine 2.1; histidine 2.0; isoleucine 5.0, leucine 7.7; lysine 4.6; methionine 1.7; phenylalanine 4.4; threonine 3.6; tryptophan 0.8; tyrosine 3.2; and valine 5.9 g/16gN, respectively.

Leaves

The leaves of Arundinaria racemosa, Bambusa bambos, Dendrocalamus sikkimensis, D. strictus, Ochlandra travancorica, Schizostachyum capitatum, S. pergracile, and S. densifolia, are much valued as fodder, particularly during scarcity of other usual fodder materials. Young bamboo leaves and twigs are a favourite fodder of elephants, and relished by cattle and horses. Arundinaria racemosa is used as fodder for ponies in the eastern Himalayas. In the Terai region of Nepal, bamboo is one of the main sources of fodder for cattle and buffaloes during winter. The giant pandas of western China feed exclusively on the tender stems and foliage of Bambusa and Dendrocalamus spp. The gorillas of the eastern Congo and Zaire depend largely on tender stems of bamboos, particularly of Arundinaria spp. An analysis of the leaves of Dendrocalamus strictus (dry matter basis) gave; crude protein 15.09; crude fibre, 23.15; ether extr, 1.43; and ash 18.33%; phosphorus, 170.0; and calcium 155.0 mg/100g.

Fruits

Cattle, elephants, bison, rhinoceros, deer, pig, etc consume fruits of Melocanna baccifera in Northeast India.

Rhizomes

The rhizomes contain nutritive elements N, P, K and Ca, and are suitable for preparing compost or manure. Woody rhizome is used as an artefact.

Banslochan, Tabashir or Tabasheer

The hollow internodes of Bambusa bambos, B. bambos var gigantea, B. vulgaris, Dendrocalamus strictus, and Melocanna baccifera, accumulate a substance, generally called tabashir, tabasheer, banslochan or vanslochana. A rattling noise on shaking the culms indicates its presence. It is amorphous silica in microscopically fine state and occurs as chalky, translucent or transparent, tasteless, 2.5 cm thick fragments of masses (sp gr 2.16-2.19; nD 1.11-1.15) usually the colour of pumice. There are two varieties: pale blue, which is more common, and white. It is mainly composed of silicic acid (SiO_2, up to 96.9%) with traces of iron, calcium, alum, alkalis and c. 1% organic matter.

Working and Finishing Qualities of Bamboo

Bamboos are extensively used as timber, particularly in the humid tropics where houses are made from them. Bamboo can be cut and split easily with hand, saw or axe. Strips of any length and size can be made with penknife. Immature bamboos are soft, pliable and can be molded to desired shape. It takes polish and paint well. Bamboos are stiff and strong but lightweight. Their physical form with nodes and cross-partition walls makes it a strong structural component for houses at low cost. Since the outer surface of culm is smooth, clean and hard, it can be used as such without any waste of bark. This characteristic of bamboo promotes its use in various utility items and handicrafts.

Bamboos for Structural Use

Because of its natural properties like renewability, easy workability and flexibility bamboo is accepted as a versatile construction material. About one third of the entire bamboos in India are utilized for constructional purposes. Bamboos have been put to a wide range of applications in numerous fields. Bamboos with a greater wall thickness having close nodes and which grow on ridges and warmer areas are often considered good for structural use particularly for use as columns, beams, roofs, rafters, purlins and trusses. Bamboo species extensively employed in construction are: Bambusa bambos, B. balcooa, B. khasiana, B. nutans, B. polymorpha, B. tulda, B. vulgaris, Dendrocalamus giganteus, D. hamiltonii, D. longispathus, D. membranaceus, D. strictus, Melocanna baccifera, Pseudoxytenanthera stocksii, Schizostachyum beddomei, S. capitatum, S. dullooa, S. pergracile, and Thyrsostachys oliveri.

Bamboo Products

Bamboo is the most versatile forest produce and its potential can be harnessed in the service of the mankind both humble as well as the great, for their comfort and shelter, etc. It is one of the most important renewable natural resources of humble grass which has the capability to produce maximum biomass per unit area and time compared with other forest plants. The importance of bamboo to rural communities can hardly be overstressed. It plays an important role in their daily life in numerous ways, from house construction, agricultural tools and implements, to providing food material and weaponry etc. Besides being a convenient source of cellulose for paper manufacture and rayon, it supports a number of traditional cottage industries such as basket making, furniture, handicraft etc. Recent advances have however put it in the hands of scientists for hard boards, reinforcement in concrete, roof truss construction, and the packaging material, etc. Even in today’s world of plastics and steel, bamboo not only continues to make its age old contribution but is also rapidly gaining importance both in the foresters’ attitude and researchers’ quest. Bamboo plays a significant role in the national economy and in the development of rural areas to ameliorate an acute housing problem, furniture, and other diverse needs.

Bamboo may be used in different shapes as per requirement of the situation as under.

Full : The most common shape of bamboo is the full culm. Although no equipment is required to produce this shape it has to be made suitable for building components. The culm is generally tapered at the tip end and therefore the best way to use it is by cutting the culms into shorter lengths for close fittings.

Half : Half shapes are produced by longitudinally splitting the culms. Two cuts, 180 degree apart are made by knife or axe. Wedges are placed in the cuts for splitting it into two. The half-shaped bamboo are generally used in roofing. Likewise quarter shapes are produced as per half shapes except that in this case four cuts are made.

Splits : Splits are made from quarters by cutting radially or longitudinally.

Boards : For flooring, walls etc., bamboo boards are used. A board consists of culms that has been cut and unfolded till it is flat. The culm thus is finally spread open, the diaphragms at the nodes removed and pressed flat.

Mats : They are made by plaiting splits of bamboo. These could be produced in a variety of shapes and patterns as a woven stuff.

Strength Properties and Other Parameters

Physical properties : The woody portion is present in the form of a hollow tube. The culms are without any bark and have a hard smooth outer surface due to the presence of silica. It improves its natural durability as well as the strength. Its density varies from 0.4 to 0.8 g/cc. Limaye determined the moisture contents and specific gravities of green and dry bamboo Dendrocalamus strictus of various ages and compared with teak and sal as follows.

Most of the bamboos are hollow, however a few solid bamboos also occur in nature. The moisture content in different parts of a culm is almost the same in immature bamboo but in mature ones, the initial moisture content decreases with height of a particular culm. Unlike wood, bamboo starts shrinking both in wall thickness and diameter as soon as moisture loss starts. Experiments show that in drying from green conditions to about 20 percent moisture content, the shrinkage ranges between 4 percent to 16 percent in wall thickness and between 3 percent to 12 per cent in diameter.

Mechanical properties : The mechanical strength of bamboo depends upon the species, climatic conditions under which it grows and on its age and moisture content. The strength increases during 3 to 4 years age and with decrease in moisture content. Of all the bamboo species tested Dendrocalamus strictus is found strongest. When its various strength properties, relative to teak as 100 are compared with the corresponding properties of heaviest timber i.e. Acacia chundra it is found quite comparable both in dry and green conditions. Similarly the weakest species of bamboo i.e. Dendrocalamus membranaceus when compared with the lightest timber i.e. Ochroma sp. it is found better.

Various strength properties in green and dry conditions of bamboos from different states of India show that dry bamboos are more stronger than green ones and are comparable with teak.

Characteristic Uses

Due to its fast growth, easy propagation, soil binding property and short period in which they attain maturity, bamboo is an ideal species for use in afforestation, soil conservation and social forestry programmes. Bamboos find a large number of fascinating uses in the rural sector. They are used for walling, huts, thatching and roofing. Besides landscaping/hedging, they can also be used for medicinal purposes and for food material. Some of the traditional uses are in agricultural implements, anchors, arrows, protection shields, baskets, bed, bunds, boats, masts, bows, bridges, brooms, brushes, strings, cart-yokes, chairs, combs, utensils, dust-pans, spears, fences, fish-traps, fishing-rods, flutes, fuel, furniture, hats, handicrafts, hookah-pipes, kites, ladder, ladles, lamp-stands, pan trays, musical instruments, dowel-pins, rafts, sports-goods, toys, chicks for doors and windows, tool-handles, umbrella handles, walking-sticks etc. The general consumption pattern of bamboo in India is as follows.

Seasoning of Bamboo

Seasoning is an essential pre-requisite for maintaining shape and strength of bamboo products and controlling cracks. Unseasoned bamboo is highly susceptible to fungal discolouration and decay associated with splitting at the nodes, collapse and deformation. Seasoning of the bamboo in the round form presents considerable problem due to drying defects compounded with the (i) relatively impermeable outer skin, (ii) concentration of fibro-vascular bundles in the peripheral portions of the wall, (iii) concentration of drying stress at the nodal partitions, (iv) variation in the wall thickness, (v) excessive shrinkage, (vi) variability of green moisture content, (vii) degree of maturity of bamboo and (viii) liability to decay. Bamboos are best dried without serious damage, by air seasoning under cover for a period of 2-3 months. Kiln seasoning under control conditions is carried out in about 2-3 weeks. The outer (surface) membranes and to some extent inner membranes are quite refractory to seasoning and cause splitting. However, if green bamboos are split into halves and then used, further cracks are avoided. According to Sharma et al., Bambusa nutans in round form can be seasoned by giving a precoating of linseed oil to reduce surface cracking. Similarly modified solar heated air drying technique helps bamboos drying faster with minimum surface cracking. Sharma while studying the effects of prefreezing on reduction in collapse and cracking of round bamboos during drying found that green bamboos responded to prefreezing treatment in a manner akin to already established collapse susceptible species.

Chemical Analysis of Bamboo Tissues

Like any other woody material bamboo is not a homogeneous substance. It is composed of tissues which are divided into two broad classes : (i) Prosenchymatous tissues (ii) parenchymatous tissues. Long thickwalled fibres arranged in clusters of fibrovascular bundles are the components of the prosenchymatous tissue which gives strength and toughness to bamboo, whereas the parenchymatous tissue is composed of tiny, nearly isodiametric cells whose function is conduction and storage of carbohydrate food material elaborated by plants.

The proportions of these two tissues in the internodes of bamboo vary from bottom to top of the culm and have been recently determined for the first time. In a D. strictus culm of 52 internodes, in which 93 per cent of the total tissue material was in the bottom 32 internodes, the overall average proportion by weight of the parenchyma tissue in these bottom 32 internodes (nodes excepted) was reported to be c.32 per cent varying from 44.5 per cent in the bottom internode to 29 per cent in the thirtieth internode up. Corresponding proportions of parenchyma cells determined by volume on the same culm of bamboo were 68.2 per cent in the third internode to 50.5 per cent in the twenty-sixth internode; the internodes being numbered from bottom upwards. Thus bamboo is considerably heterogeneous and contains large amounts, both on volume and weight basis, of tiny parenchyma cell material. So far, nothing is known to have been published regarding chemical composition of these tissues, nor about their role when bamboo is subjected to various chemical and mechanical treatment.

It is obvious that best utillization of either wood or bamboo would depend on the appraisal of anatomical, morphological, physical and chemical properties of its constituent tissues. In case of pulping, no matter what procedure is used, the final properties possessed by the pulp will mainly depend on the properties inherent in the cellular tissues of the parent raw material. Investigations on varied properties of constituent tissues of untreated wood have been few because of the difficulty of separating these tissues in pure form from raw wood. In the case of coniferous woods the percentage of other tissues besides tracheids is small. In the case of hardwoods, although the percentage of parenchymatous tissue is appreciable, the separation of the tissues from raw wood is extremely difficult as they are interwoven in both longitudinal and transverse directions. However, in some instances where a single tissue occupied a fairly distinct area in the structure of wood, it was carefully removed and analysed chemically. In such a manner Harlow and wise1 isolated the medullary ray cells of untreated flame-she-oak and white oak by merely scrapping out these cells from thin tangential sections of wood. They were the first to publish the chemical analysis of the ray cells of a hardwood.

In pulp industry a standardized procedure is followed by which a finely divided sample of wood is taken for analysis. The procedure recommended by the Technical Association of Pulp and Paper Industry (T.A.P.P.I.) of U.S.A. consists in comminuting a sample of wood so that all of it passes through 40 mesh sieve, than the fraction of this which passes through 60 mesh but is retained on 80 mesh is taken for chemical analysis. From the viewpoint of pulp and paper technologists this is regarded as representing the chemical constituents of wood, but essentially it may not be so, because some botanical tissues like ray or parenchyma cells might pass out through the 80 mesh screen more or less completely, and hence the sample of wood taken for chemical analysis may not be completely representative of the wood under study. In the case of bamboo it was observed that a considerable portion of the parenchyma tissue passed out of the 80 mesh screen, and hence, the routine chemical analysis of bamboo would not be representative in the true sense.

Experimental

Separation of fibres and parenchyma cells—Details about the principal and technique of separation of parenchyma cells from fibrovascular bundles are given below.

Freshly felled culms of 3-5 years age of D. strictus were taken for investigation. Tissue samples were separately taken for bottom and top internodes of the culm. For bottom internodes the central portion of the first four internodes from bottom of culm were taken. For upper internodes the central portion of internodes 29, 30, 31 and 32 were used from the same culm which contained in total 52 internodes and wherein the internodes above the thirty-sixty were thin, of solid core and contained little woody material.

For nodal tissues, the nodes of the entire culm excluding the septa in centre of nodes were taken out, crushed in a hammer mill to pass 40 mesh, but the portion from this passing 150 mesh was rejected as it would cause trouble in filtrations during chemical analysis.

To know the comparative values of chemical constituents of the tissues of another species of bamboo, the bottom internodes of a culm of Bambusa nutans Wall, were separated into its two constituent tissues and analysed for significant values like lignin, cellulose, ash, solubility, etc.

Preparation of pure samples of analysis—Annulus rings c 2 cm. long were cut from central parts of bottom internodes. These were then divided into 4 to 6 segments and aspirated and slightly softened by boiling for about an hour in distilled water. From these segments of internodes radial sections or shavings c. 40 micron thick were cut by a knife on a microtome. Alternately, annulus rings could be peeled carefully on a lathe with fine edge of a chisel and tangential shavings so produced could be used in place of radial sections. When these longitudinal shavings were subjected to mild, careful and repeated mechanical disintegrations in a small coffee mill or disc attrition mill, the fibres and parenchyma cells separated out at their middle lamella giving entities consisting solely of fibres or parenchyma cells. The shavings were disintegrated repeatedly till it was observed under microscope that the cleavage between the tissues was complete. The tissue mixture was then sieved through 30 mesh and the portion passing 30 mesh was passed through 150 mesh. The portion passing 150 mesh was rejected as it would create distillates in filtrations during chemical analysis. The portion between 30 and 150 mesh was died in an oven and was then spread over water in a shallow dish; when the fibrous portion sank down and the parenchyma cells being lighter floated on the surface of water; these were then taken out. Both the portions were filtered, dried and separately refloated on the surface of water to remove impurity of one tissue in the bulk of the other. Three to five such flotations gave pure samples of the tissues.

Effect of Beating on the Cell Mechanics of the Individual Bamboo Fibre

Beating is essentially a process which in principle does not differ from other mechanical action put upon the fibre. Considering this, better understanding of the material in question is of course of the greatest importance. Added to the fibre length and other fibre dimensions, the basic morphological features of the individual entity of the fibre are also important in explaining the beating phenomenon of the fibres. The assumptions (rather proven ones) proposed to explain the cell wall mechanics of the wood fibres has been taken into confidence, as can be applied to bamboo fibres with the required modifications.

Elementary Fibril

To explain the mechanisms of beating, apart from the fibre itself, the individual entity that constitute the fibre is also an important aspect to be considered. Though Hanna could support his concept on the existence of sub-elementary fibrils in certain regions of the cell wall of the fibre, the ultimate individual entity of the fibre should be the elementary fibril because it is the final micro structure that should possibly be obtained morphologically through mechanical means. Fengels definition of fibre as a fibrillar bundle formed by the aggregation of microfibrils, which in itself is the cluster of elementary fibrils, hold good for all the fibres whether it is a wood fibre or a bamboo fibre. These fibrillar bundles lie as layers along the fibre axis in different angles, to form the different “Cell Walls” of the fibres. So the orientation of the elementary fibril along the fibre axis, and those influencing factors which bring forth changes on it are the essential features to be considered upon to explain the beating theory.

Cell Wall Mechanics of Wood Fibres

Elementary fibrils are assumed upon the be perfectly crystalline with the crystal axis in line with the fibril axis and that these crystallites are embedded on an amorphous matrix of hemicelluloses. Since the definition of fibre makes the elementary fibril as the individual entity and that the microfibril is nothing but a randomnly oriented and distributed microfibril network, it is appropriate to say that the elementary fibril lie in different angles in the microfibril and a three dimensional structure of fibre ensues. The distribution pattern of the force along the fibre axis is therefore different. This prompts to say that the fibre with its different cell wall construction and fibrillar orientation in them is like a beam having a differential structural features along its axis. The theory of solid mechanics, that govern the force distribution pattern in the beams and rods should apply unreservedly in predicting the behaviour of fibres under stress. The behaviour of microfibrils should then fall within the limits of Hook’s law of elasticity and the force distribution along the different cell wall regions can be calculated using appropriate tensorial equations meant for solid mechanics of the anisotropic elasticity.

Force Distribution Across the Cell Wall

Mark pointed out that the fibril bundles wound around the axis in a variety of angles and the real difficulty lie in estimating their specific orientation. Also he has assumed that the crystalline orientation on the axis is same as that of the microfibrils. He has shown from the calculated elasticity constants that in a fibre where the crystalline frame work is embedded in the amorphous matrix as parallel strings the frame work will take the maximum load.

The primary wall with its fibrillar orientation normal to the fibre axis is isotropic from a mechanical point of view. The high rigidity (modulus of elasticity is 0.272×1012 dynes/m2) and lower thickness (below 0.5 µm) makes this particular section rigid in character. Added to this, any applied force to the fibre axis will be an uniform distributive load, like placing the load at the centre of the beam. The rigidity of the primary wall will make it to take the load less frequently: The lower co-efficient of contraction will make this part of the fibrillar network to resist any mechanical action on it. The region is rigid, brittle and will not swell and if a strong mechanical action is but upon, it will come out of the fibre as a thin sheath. Any fibrillation of this primary wall produces fines which are very difficult to activate. Though it appears that this portion of the fibre wall is difficult to remove, in practice this is the region which is stripped off at the very early stage of beating.

Internal Fibrillation

During beating, the fibre is not only subjected to mechanical action but also to the stresses of water. So the constraints at P and S1 layer initiates the breakage of interfibrillar bonds between the celluloses and the hemicelluloses (internal fibrillation). None of the cell walls of the fibre is a solid block but layered regions. The building material between them may be water (through hydrogen bonds) or hemicelluloses. When fibres are immersed in water, they imbibe and swell when beaten. The swelling is a "limited swelling" because of the constraining crystaline cellulose and the partly crystallined hemicelluloses. A weak force is enough to break the bonds in the already swollen gel which is under stress.

External Fibrillation

The swollen fibre has subjected to all the mechanics as described already. When beating proceeds or when the fibre is exposed to extra strong mechanical action, the fibrillar layer of the middle secondary wall splits in the longitudinal direction to form fibrils external fibrilation.

The swelling pressure of the interfibrillar substance is an important aspect to consider upon in discussing the mechanism of the fibrillation. The lateral expansion and the consequent longitudinal split up indicates that the fibre explodes only after a through internal fibrillation. So for fibrillation, a certain advanced swelling is necessary. Moreover, the maximum the swelling and more softer the material the maximum fibrillation is achieved. This sort of advanced swelling can take place only in the regions of steeper helical winding and higher hemicelluloses concentration. The concentration of hemicelluloses decrease from primary wall (P) to the inner secondary wall S3. This may prompt to say that the maximum swelling would take place at the S1 layer. But it is not so, because, it is primarily dependent on the accessibility of water which in turn is affected by the fibrillar orientation (poor swelling of S1 because of interwoven fibrillar structure).

Bamboo Fibres

Having explained the cell wall mechanics of the wood fibres to an applied load, the necessary logic to counter upon is, can these theories proposed for the wood fibres be extended to explain the morphological changes of the bamboo fibres during beating?

Purkayastha has taken the polyamellate structure of the thick walled bamboo fibre proposed by Parameswaran for studying the changes in the morphological characters of bamboo upon beating. Krishnagopalan, has shown that bamboo has both thin and thick walled fibres in its vascular bundles Referring the micrographs the polylamellate fibre wall structure of both thin and thick walled fibre is evident.

Studies on the Fines of Bamboo Pulp

A very fine material is generally produced during the course of beating or mechanical treatment of pulp fibres. This material, which consists of ray cells as well as fibre fragments is known to play an important role in controlling some of the sheet properties. Early studies by Steenberg, Sandgren and Wahren1 have clearly established the existence and importance of fines fraction in papermaking. Since then several investigators have dealt with the influence of finer fraction on the sheet properties.

The morphology and physico-chemical properties of the fines are quite different from those of the fibre fraction. A basic knowledge of the chemical composition of fines is therefore, essential as it controls the physico-chemical behaviour of fines4. Fines from groundwood pulp are fairly uniform in chemical composition and they form a desirable part of the furnish but, they are very undesirable in chemical wood pulps if present in higher percentage use, they reduce the colour and strength of the pulp and tend to produce pitch trouble on the paper machine.

The present investigation deals with the chemical composition of whole pulp, pulp without fines and fines alone as well as the influence of fines on some these properties.

Experimental

Fractionation of Pulp

A commercial bleached Kraft pulp from bamboo produced by Central Pulp Mills India, was used. The pulp was defiberized and fractionated in a Bauer-McNett fractionator using three different screens with mesh numbers 28, 48 and 100.

The same pulp was beaten in a laboratory valley beater to different freeness levels. The fraction beaten to 210 ml. C.S.F. was fractionated in the Bauer-McNett fractionator using the same screens as in case of unbeaten pulp.

The percentage of various fractions so obtained was determined. The results are recorded in Table 1.

Isolation of Fines

The fines were isolated by fractionating the pulp (beaten to about 250 ml. C.S.F.) in the Bauer-McNett fractionator and collecting the fraction passing through the 100 mesh screen (–100). The fibre fraction retained on 100 mesh (+100) was also collected in bulk.

Chemical Composition of Fines & Coarse Fractions

Whole pulp, fractionated pulp and fines were analysed for ash, K. lignin, Pentosans and alpha cellulose by TAPPI standard methods. The results are recorded in Table-2.

Evaluation of Whole Pulp and Fractionated Pulp in Valley Beater

The whole pulp and the fractionated pulp were beaten to different freeness levels in Valley beater till the final freeness was about 250 ml.

Stocks beaten to different freeness levels were made into handsheets on the British sheetmaking machine. The strength properties were determined after conditioning the sheets at 65±2% R.H. and 27± 1ºC temperature. The results are recorded in Table 3.

Evaluation of Recombined Pulps

The coarse fibre fraction (X_c) and the fines fraction (X_f) were recombined into proportions 95 : 5, 90 : 10, 85 : 15, 80 : 20 respectively. The sheets were prepared by recirculation process and the drainage time was noted. The strength properties of the artificial furnishes were also determined. The results are recorded in Table-4.

Discussion of Results

Fractionation of Pulp

The results from the Bauer-McNett fractionation of unbeaten and beaten pulps (Table-1) indicate that there is a change in the percentage of fibres retained on screens of various mesh sizes (28, 48, 100). There is a considerable accumulation of fines (passed 100 mesh) especially after beating of the pulp.

Chemical Composition of Fines and Coarse Fibre Fractions

A perusal of the data on the chemical composition of fines, whole pulp and fractionated pulp (Pulp without fines) in Table-2 indicates that the fines fraction has a much higher ash and lignin content than the coarse fibre fractions. The data on the carbohydrate compositions suggests that there is no major difference in the carbohydrate distribution between the fines and the fibres. These data are similar to the data on spruce sulphite pulps obtained by Kallmes and Lindstrom et. al.

Diseases and Decay of Bamboo

Bamboo is in great demand for paper industry and for constructional and other purposes. Its productivity is reduced considerably in the event of a serious disease inflicting the crop. In India a number of diseases occur in bamboo nurseries, plantations and natural forests. Besides, seed borne fungi also cause considerable damage to seeds particularly in storage and thus reduce seed viability and germinability. A brief description of important diseases and fungi associated with decay of bamboo is given and the seed borne fungi are listed.

Microflora of Stored Bamboo Seeds

Seeds carry a variety of microorganisms such as fungi and bacteria of which the former are the principal ones. They attack seeds while still on the trees and also during harvesting, storage and subsequent handling prior to sowing. Seeds are prone to attack by a number of fungi in storage if proper storage conditions are not maintained. Studies on seed microflora of Bambusa bambos, B. tulda andDendrocalamus strictus have revealed the occurrence of 28 fungi and 2 bacteria of which 10 fungi* are potential seed borne pathogens capable of causing infection in nursery seedlings. The number of seed borne fungi are more in D. strictus than in B. bambos and B. tulda.

Namdeo reported that treatment of seeds with fungicides, like Ceresan @ 4g/kg checked fungal flora and increased seed germination when seeds were treated with gibberellic acid and potassium nitrate, Heydecker also found increase in seed germination on treatment with fungicides, GA3 and potassium nitrate. Somen reported Aspergillus, Cephalosporium, Chaetomium, Fusarium, Penicillium andTrichoderma species on seeds of Bambusa bambos. They also reported enhancement in seed viability and germinability in Bambusa bambos when seeds were stored over calcium chloride. They attributed decline in germinability of seeds to see mycoflora. Pongpanich reported 20 fungi other than recorded in India to be associated with seeds of B. bambos, B. nutans and D. strictus indicating a wide variation in mycoflora of bamboo seeds.

Nursery Diseases

The success of plantations largely depends on disease free planting stock. A large number of nursery diseases have been recorded on bamboo in India of which damping-off root rot are important ones. They cause heavy mortality of seedlings under warm and excessive humid conditions. Studies carried out during the last two decades showed that disease severity varied from nursery to nursery depending on the climatic conditions, seedling density and cultural practices. The important nursery diseases are described and illustrated.

Damping-off

Viability and germinability of seeds are of prime importance for raising adequate nursery stock. Both these qualities of seeds are greatly affected by seed borne fungi which may deteriorate the seeds right from the time of collection to the time of sowing. Fungi like Fusarium spp. which cause damping-off, are often associated with bamboo seeds. Seedling mortality due to damping-off was recorded in Bambusa bambos, Dendrocalamus strictus and B. tulda and the fungi associated were identified as Fusarium spp. and Rhizoctonia solani. Seedling and stem rot caused by R. solani and Sclerotium sp. was recorded in B. bambos and D. strictus. Besides, Fusarium moniliforme was associated with seedling rot in Ochlandra scriptoria whereas F. oxysporum and F. semitectum were associated with wilt in the same species. Dual infection by Rhizoctonia sp. and Fusarium sp. took a heavy toll of vegetatively propagated seedling of B. vulgaris.

Foliage Diseases

Rhizoctonia leaf blight The caused by R. solani disease has been recently reported by Mehrotra in the Silvicultural nursery at Kalsi under. The infected seedlings showed blighting of leaves with profuse mycelial growth of the fungus all over the stems and infected leaves forming a sort of fungal cobweb and entangling the detached blighted leaves. The fungus advanced both vertically and laterally resulting in complete defoliation and group infection of seedlings. The disease was highly destructive as it caused premature defoliation and death of young shoots. Clustering of hyphae at the base of the sheath was a characteristic feature of the disease. The infected leaves is early stages of the disease often showed brown stromatoid aggregates on the under surface. The fungus developed characteristics dark brown sclerotia on the infected plant parts and also on leaf litter. The disease has also been recorded from central India.

Witches’ Broom

The disease occurs commonly in nurseries and plantations. The infected plants show excessive branches at the nodes which arise as clusters, producing typical witches’ broom. The cause of this malformation is, however, unknown. Bakshi reported 43.7 per cent incidence of witches’ broom in a forest nursery at Ranchi, Bihar.

Diseases of Bamboo in Plantations and Natural Forests

The plantations and natural forests are damaged by a number of diseases. A total of 45 pathogens are recorded by various workers of which 12 are potentially important causing significant damage.

Bamboo Blight

This is one of the most destructive diseases of bamboo recorded in the Indian sub-continent in recent years. The first record of the disease was made by Boa who observed large scale mortality in Bambusa balcooa, B. tulda and B. vulgaris in village groves in Bangladesh. The pathogen was identified as Sarocladium oryzae. Bridge et al. have given a detailed taxonomic account of Sarocladium based on biochemical and morphometric analysis. The fungus, well known to cause sheath blight in rice finds the bamboo as a highly susceptible collateral host. In bamboo, the blight disease appears in August and assumes a serious proportion by mid November. Thereafter little or no increase in the number of blighted culms in seen. Boa worked out an integrated control measure of the disease which included removal of blighted culms, burning of debris in clumps in April before onset of rains and application of Dithane M-45 and copper oxychloride as soil drench. In India, large scale mortality in B. nutans caused by S. oryzae was recorded from Orissa State. Jamaluddin et al. reported that the pathogen occurred widely in coastal districts of Orissa and caused large scale mortality to planted bamboo affecting the economy of bamboo growers