Bamboo And Its Uses

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CONTENT

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1. Introduction

The origin of the word bamboo is still a mystery. There is no mention of the word bamboo in ancient writing until 400 B.C. Marsden recorded in his dictionary that it is a Malay word. But Gracia (1563) recorded Indians calling "*mambu*" to the canes of the bamboo plant in her medical book. Similarly, Fitch (1959) in his navigation book wrote that all the houses are made of canes, which are called bamboo. Now the word bamboo has been integrated into the everyday language of most countries and is generally accepted by botanist in every part of the world.

Bamboos are integral to the culture of South East Asia and it is the most important natural resource of the world since prehistoric days. They grow in tropical, subtropical and temperate region of the world. Latitudinal range of distribution varies from sea levels to high mountain areas at heights of 3000m – 4000m in the Himalayan and Andes mountains. The most northward distribution is in the North of China, Japan and Korea whereas the southern distribution is till Chile. The distribution areas are said to be 3.4 million ha in China, 0.81 million ha in Thailand, 1.48 million ha in Vietnam, 2.2 million ha in Myanmar and 9.57 million ha in India. According to Watanabe (1987) 80% of distribution of bamboo in the world is found in Asian countries. Out of total of 1573 species of woody bamboos, the potential distributions of 1021 species are found in the Asia Pacific region (INBAR 2000).

According to Nepali mythology, bamboos were created by Pandavas when they came to Bijayapur during their Guptabas (hiding period). Since that time bamboos are indispensable for Nepali people from birth to death. Now it plays an important role in the upliftment of the socio economic condition of people and national economy.

History of bamboo exploration in Nepal started from 1978 when Hara *et al.* reported 10 species of bamboo belonging to 5 genera from east to central part of Nepal. Das (1988) listed 30 species of 5 genera. Poudyal (1992) reported 33 species of 12 genera and Stapleton (1994) listed 32 species of 11 genera. Manandhar and Bhattarai (1997) listed 23 species of 5 genera in Kathmandu valley only. Recently Das (2001, personal communication) reported 50 species of bamboo found in Nepal.

Bamboo and Rattan represent an annual commercial value of over US $ 14 billion globally (Anonymous 1997). In China the value of bamboo products has jumped from US $ 50 million in 1980 to US $ 1.045 billion in 1997. The total contribution bamboo makes to Chinese economy is now estimated to be over US $ 2.1 billion (INBAR 2001). Similarly, bamboo furniture is an expanding business in Philippines between 1985-1994 exports rose from $ 625,000 to 1.2 million (INBAR 2001). Lahan bazaar situated in the eastern part of Nepal is the major trading center for bamboo products. The bi - weekly open market trades about 100 trays (Rs 20 – 25/each), 700 baskets (Rs 25- 30/unit) etc, (Karki *et al.* 1998). Similarly bamboo culms and crafts are also exported to India where the market price is 40% - 60% or more higher than in Nepal (Das 1988).

Simply Bamboos belong to the family *Gramineae* and form the tribe *Bambuseae* of sub family *Bambusoideae*. In Nepal, a national level inventory on bamboo has not been carried out to estimate natural and planted stock. A small survey of bamboo was carried out on the major production area by Karki *et al.* (1995). According to their study the estimated coverage of bamboos are 63000 ha, out of which 60% are estimated to be in natural forests.

2. Distribution

Bamboos are grown mostly on abandoned hill slopes and grooves near villages and on margins of farmlands. They are found naturally as well as in planted form. Distribution of bamboos are common in eastern half of the country from Dhaulagiri to Sikkim boarder as high as 4000m. Because of climatic variation, Nepal has both tropical bamboos found in South East Asia and temperate bamboos found in Tibet and Bhutan (Karki *et al.* 1998). Similarly, the higher rainfall areas like Pokhara, Ilam etc. have a wider variety of genera and species having larger number of clumps (Stapleton 1994). It has been reported that Bansbari, Ranibari and Kalikastan are the only areas in the city where bamboos are found in pure natural stand (Manandhar and Bhattarai 1997). In some parts of eastern Nepal like Inaruwa, Siraha, Saptari, Udaypur, farmers consider bamboo to be an important forest product and they grow it in the

farmland (Shrestha 1999, Karki *et al.* 1998).

But, according to Amatya (2000) the distribution of bamboos are found from Terai to high mountain areas. According to him some common species like *Bambusa balcooa*, *Bambusa nutans* subsp *cupulata*, *Bambusa nutans* subsp *nutans*, *Dendrocalamus hamiltonii* var *hamitonii*, *Dendrocalamus hookeri*, *Dendrocalamus strictus* are found from terai to mid hill areas whereas species such as *Yushania maling*, *Yushania microphylla*, *Himalayacalamus asper*, *Drepanostachyum falcatum*, *Borinda emeryi* etc are mostly found in high mountain areas. Brief description of ecological distribution of bamboo species found in Nepal is given in table 1.

Table. 1 Botanical names, distribution, size and major uses of bamboo species found in Nepal (Das 1988, Stapleton 1997, Shrestha 1997).

Botanical Names	Distribution	Size	Major uses
Ampelocalamus			
A. patellaris (nibha, ghopi bans, lyas bans)	Found between 1200-1800 m especially in high rainfall areas particularly Ilam and Taplejung of east Nepal and Kaski & Palpa of west Nepal.	Reaches up to 5cm in diameter and 12m in height. Leaves up to 40cm long.	Due to the flexible nature of culms and long internodes up to 50cm are useful for weaving purposes and flute and leaves are used as fodder.
Arundinaria			
A. racemosa	Found in high altitude coniferous forest of East Nepal above 2900m	Less than 2m tall and 1m in diameter. Leaves up to 10cm long	It is used for making arrow, brushes and drinking straws.
Bambusa			
B. alami (Mugi bans)	Found in Eastern Terai	Diameter 4cm and height reaches up to 10 m	It is used for weaving
B. balcooa (dhanu bans, ban bans)	Found from Terai to midhills	Diameter reaches up to 16cm and height up to 25m.	Large sized, big diameters, strong bamboo species used for scaffolding and weaving into panels for making hous walls. They are also used for pillars, beams of the houses in the villages.
B. multiplex	It grows up to 200 m altitudes	Reaches up to 4cm in diameter and 10m in height	Mostly used for ornamental purposes.
B. nepalensis (tama bans, phurse bans)	Cultivated species, coomon from East Nepal to Tansen in the West	Reaches up to 10cm in diameter and 20m in height.	Multipurpose species, used for weaving, general construction, and it also produces edible shoots.
B. nutans subsp. nutans (tharu bans, sate bans)	Cultivated species found in the hills of central and west Nepal. It is not found in the Terai.	Poles reaches up to 10cm in diameter and 23m long.	Strong and highly priced for all constructional purposes, weaving rough baskets, mats etc. The poles are used for carrying corpses to the funeral pyre.
B. nutans subsp. *cupulata* (mal bans)	Commonest cultivated bamboo, found in East of Okhaldhunga and Malangua from Terai up to 1500m.	Poles reach 10cm in diameter and 23m long.	Mostly used for constructional purposes, weaving of rough baskets and mats.
B. tulda (kada bans, koraincho bans, chab bans)	Rare in Himalayas, occasionally found in Terai, especially found in Chitwan area. It is also found in Kathmandu valley.	Culms reach a maximum diameter of 7 cm and a length of 15 m.	It is used for constructional purposes, weaving and leaves can be used for fodder.
B. vulgaris		Culms reach up to 7 cm in diameter and 15m in height.	It is mostly used for ornamental purposes.

Borinda			
B.emeryi (kalo nigalo)	Rare species of Eastern Nepal. Found in the Barun valley of Sankhuwasabha district and Milke danda between 2600m to 3200m.	Culms reach up to 4.5cm in diameter and 10m in height. Leaves reach up to 25cm long.	Culms used for weaving.
Cephalostachyum			
B.latifolium (ghopi bans, murali bans)	Mostly found between 1500m-2000m.	Culms reach up to 5 cm in diameter and 15 m in height. Leaves reach up to 30 cm.	Culms used to make flutes for weaving purposes. Leaves are excellent for animal fodder.
Dendrocalamus			
D. giganteus (dhungre bans, rachhasi bans)	It is a tropical species and grows well below 1000m.	Culms reach up to 30cm in diameter and 30m in height.	Culms are used as pillars of houses, for making containers, road barriers. Leaves are used as animal fodder.
D. hamiltonii var *hamiltonni* var. *undulatus* (choya, tama ban bans)	Commonly found in the hills mainly between 300m to 2000m.		Produces better quality weaving materials, new shoots used as vegetables, leaves as fodder and culms for house construction when other harder bamboo species are unavailable.
D.hookeri (kalo bans, balu bans)	Commonly found between 1200m-2000m, in eastern Nepal, rare in central Nepal.	Culms can reach a maximum diameter of 16cm and height upto 25m.	Used for weaving, house construction, larger size culms are used as containers, leaves are an important fooder source in winter.
D.strictus (kath bans, laathi bans)	Found in the terai region below 1000m in farmlands and also reported to occur in the natural forest of the mid and far western terai.	Culms reach up to 3cm in diameter and 6m in height.	Used for making sticks, house, often used in terai for driving animals. In India it is used as the raw material for paper mills.
Drephanostachyum			
D.falcatum (tite nigalo, diu nigalo)	Found between 1000m to 2000m in western Nepal.	Culms reach upto 2cm in diameter and 4m tall.	Used for basket making, leaves are used as fodder in winter. The species can be used for soil stabilization.
D.intermedium (tite nigalo)	Found from 1200-2400m both on cultivated land and in natural forests of eastern Nepal.		Used mainly for weaving baskets, mats etc and leaves are used as fodder in winter. It can also be used for soil stabilization.
D.khasianum (ban nigalo, tite nigalo)	Species found between 1000-2000m both on cultivated and in natural forest	Culms reach up to 1cm in diameter and 3m in height.	Used for weaving.
Himalayacalamus			
H. asper (ghunre nigalo, malinge nigalo)	Found in western and central Nepal, in temperate forest between 1800-2300m.		Used for weaving.
H. brevinodus (maline nigalo)	Valuable bamboo cultivated between 1800-2200m in east Nepal	Culms reach a diameter of 2.5cm and height of 9m.	Provides a superior weaving material.

H. cupreus (malinge nigalo)	Species found in cool temperate forests in Kaski district between 2300m and 2800m.		New shoots are edible.
H. falconeri (thudi nigalo, singhane)	Found in cool broad leaved forest of central and eastern Nepal between 2000m and 2500m. This species are found in Phulchowki in Kathmandu valley		Used for weaving, shoots are edible.
H. fimbriatus (tite nigalo)	Cultivated species of central and western Nepal, common around most villages between 100m and 1800m.		Used for weaving, animal fodder.
H. hookerianus (Padang)	Cultivated bamboo of east Nepal, found from 2000m to 2500m.	Diameter reaches up to 3cm and height up to 7m.	Used for basket making, leaves as animal fodder.
H. procatus (seto nigalo)	Found between 2000m to 2300m in central Nepal in cultivated land or in broad-leaved forest.	Diameter reaches up to 2.5cm and 6m tall.	Used for basket making, leaves as animal fodder.
Melocanna			
M.baccifera (lahure bans)	Commonly cultivated in the eastern Terai and occasional in other areas such as Palpa.	Diameter up to 5cm and height up to 12m.	Used for constructional purposes making mats etc.
Thamnocalamus			
T. spathiflorus sub sp *spathiflorus* (rato nigalo)	Commonly found in central and eastern Nepal between 2800m to 3500m.	Clumps forming bamboos reach up to 5m tall.	Provides food for wild animals like bears and shelter for birds and wild animal.
T. spathiflorus sub sp *nepalensis* (jarbuto)	Commonly found in central and western Nepal between 2800m to 3500m.	Clump forming bamboo species reach up to 5m tall.	Provides food for wild animals like bears and shelter for birds and wild animal.
Yushania			
Y. maling (malingo, maling, khosre malingo)	Mostly found in temperate region of eastern Nepal between 1600m to 3000m.	Culms reach up to 3m tall and 1.5cm in diameter.	Mostly used for fencing, basket making, tooth brushes etc.
Y. microphylla(maling, malingo)	Mostly found in cool temperate areas of central and eastern Nepal between 2300m to 3500m.	Culms reach up to 3m tall and 1.5cm in diameter.	Used as fodder for livestock and wild animals.

3. Taxonomy

In Nepal, bamboos are abundant between the hills and the terai with most of the species being found in mid hills. So from the point of utilization the important bamboo species can be broadly divided into four categories (Stapleton 1994).

(a) Large construction species

(b) Large multipurpose species

(c) Small low quality weaving species

(d) Small high quality weaving species

(a) Large construction species: The culm walls are thick and strong, but inflexible and brittle, so of less use for weaving. Poles are used for carrying weight but shoots are not used for food. It is generally known as "*bans*" and are mostly found in terai.

(b) Large multipurpose species: The culm walls are thin and flexible and good for weaving, but not strong or rigid enough for constructional purposes. The large leaves however make good fodder and the new shoots are used for human consumption. It is also called as "*bans*" and are mostly found in terai.

(c) Small low quality-weaving species: The small culms with no constructional value are superior to those of the larger genera for weaving. The shoots are not palatable. They are known as "*nigalo*" and are mostly found in mountains.

(d) Small high quality weaving species: They produce highest quality weaving material and also edible shoots. They are also found in mountains. In this category some are "*malinge nigalo*" type and others are "*malingo*" type.

According to Das (1988) bamboos are categorised into two types "*bans*" and "*nigalo*". *Bans* are big diameter bamboos whereas *nigalo* are of small diameter. The "*nigalo*" bamboos are not found in terai. In the high mountains, bamboos are categorised into three types, namely "*bans*", "*nigalo*" and "*malingo*". "*Malingo*" has smallest diameter of all.

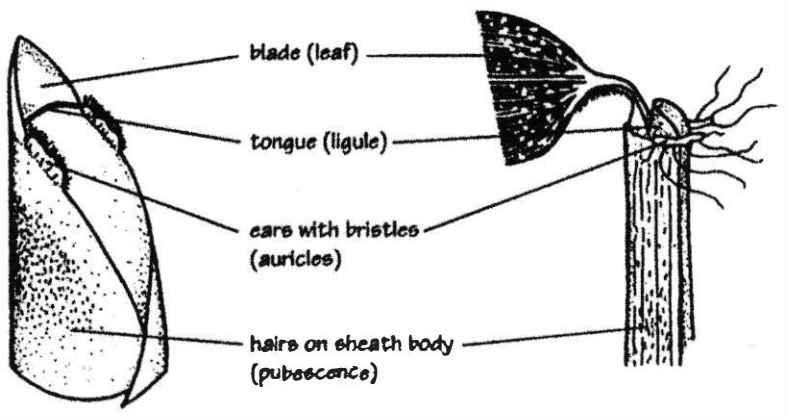
The taxonomy of bamboo is quite complicated and it has been neglected for a long time. Bamboos are giant grasses, but they differ from the smaller grasses in many ways. Bamboos belong to the family Gramineae and subfamily Bambusoideae. They have woody culms, well-developed branching specialized culm sheath, leaf bases narrowing to thin petioles and cyclical flowering. For a long time, taxonomists thought that the flowers were essential for identification of bamboo species, but now it is accepted that vegetative parts are also important.

The identification of bamboo species are mainly based on Stapleton (1985,1994) and the most important parts are:

(a) Culm and culm sheath
(b) Leaf and leaf sheath
(c) Branches
(d) Flowers
(e) Rhizomes

(a) Culm and culm sheath: The bamboo stems are called culms. A protective sheath covering the culms is called culm sheaths. At the top of culm sheath there is a central projecting tongue known as ligule. The ears like structure, which are present on each side of the culms, are known as auricles (Fig. 1a) The shape, size, edge varies from species to species. The shape, presence or absence of hairs, whether it is erect or reflexed and deciduous or persistent are the important characters to identify bamboo species (Stapleton 1994)

(b) Leaf and leaf sheath: The sheath below the leaf is called leaf sheath. At the top of the sheath, there is a central projecting tongue known as ligule, and side-projecting ear called auricles (Fig. 1a). The shape, size and length of the ligule and auricles, presence of stiff bristles on their edges are important characters for the identification of bamboo species (Stapleton 1994).



Fiugre 1(a) showing culm sheath and leaf sheath

(c) Branching: Branching is a very important characteristic of bamboos. The size and shape of the branches, whether the central branches are larger than the other, presence or absence of aerial roots are the important characters to identify species and genera (Stapleton 1994).

(d) Flowers: Flowers of bamboos are occasionally found. There are two kinds of bamboo inflorescence. One type of branching give dense clusters or rounded balls of flower which are well developed in genera like *Dendrocalamus*, *Bambusa*, *Cephalostachyum* sp. etc. The other types of flowers are large panicles similar to those of an ordinary grass. The panicles and flowers of *Thamnocalamus* sp. remain partially hidden by sheath. The colour of the flowers can allow quick identification of large bamboo species. *Dendrocalamus hamiltonii* var. *hamiltonii* has purple flowers with distinctive red anthers. *D. hookeri* has olive green to brown flowers. *Bambusa tulda* and *B.nutans* have green flowers, whiwhile *B. balcooa* and *B. nepalensis* have green flowers with purple tips (Stapleton 1994).

(e) Rhizomes: Rhizomes are difficult to examine as they grow under the ground. The rhizomes may be short and thick (Pachymorph) and clustered together. They produce bamboos in well-defined clumps. This type of rhizome is found in all the larger Nepalese bamboos (*Bambusa* and *Dendrocalamus* species). Species of *Arundinaria* have long thin (leptomorph) rhizomes, which run parallel to the ground and produce isolated shoots at intervals of upto 3m. Pachymorph bamboos may have a long neck between the main sections of the rhizome giving a very open clump (Stapleton 1994).

4. Botanical Discription of bamboo species found in Nepal

The botanical descriptions of bamboos are mainly based on Stapleton (1985,1994), Shrestha (1999).

1. *Arundinaria racemosa* Munro

It is usually less than 2m tall and 1cm in diameters, with leaves up to 10cm long. It is recognised by the presence of simple branching. Culms are smooth and have little or no wax. It has few, strong, less scabrous bristles on the leaf sheath auricles. It has different forms of rhizome where roots are present at each node {Fig. 1(b)}.

(a) (b)

Fig. 1(b) *Arundinaria racemosa*, a. Culm and culm sheath; b. Leaf sheath; (Stapleton 1994).

2. *Ampelocalamus patellaris* (Gamble) Stapleton

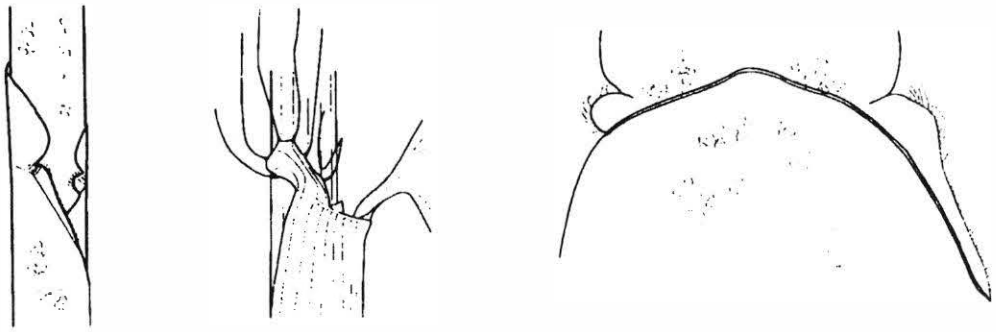
It is recognized by the presence of long fringed culm sheath. The leaf sheath has no auricles, but they have a few upright bristles and the edge of the ligule has long bristles and cilia (Fig. 2).

(a) (b)

Fig. 2. *Ampelocalamus patellaris*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

3. *Bambusa alamii* Stapleton

It has straight culms with long internodes and little swelling at the nodes. The species are easily distinguished by the presence of small glabrous asymmetrical culm sheath with prominent auricles. The auricles have long bristles. The culm sheath is intact, glabrous, and asymmetrical and auricle is extended to half. The leaves have no hair in the sheath (Fig. 3).



(a) (b) (c)

Fig. 3. *Bambusa alamii,* a. Culm; b. Leaf sheath; c. Culm sheath (Stapleton 1994).

4. *Bambusa balcooa* Roxburgh

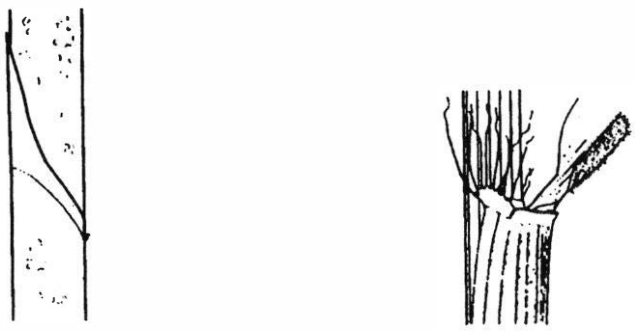
This is a large size bamboo, having diameter 15 cm and height of 25m. It has thick furry culm wax, densely hairy culm sheaths and large branches. It is different from *D. gigantea* in the presence of brown hairs on the leaf sheath and few hairs on culm sheath. Most important character to identify this bamboo is the absence of auricle, but presence of wavy edge blade, and wavy ligule margin (Fig. 4).

(a) (b)

Fig. 4. *Bambusa balcooa* a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

5. *Bambusa multiplex* (Lour.) Raeusch. Ex J. A. & J. H. Schult

It is the commonest variety found in Nepal and reaches up to 4cm in diameter and 10m in height. It has narrow culms and small culm sheath auricles. The undersides of the leaves are densely hairy. The leaf sheath has spreading bristles and small ligules (Fig.5).



(a) (b)

Fig. 5. *Bambusa multiplex*, a. Culm and culm sheath; b. Leaf sheath; (Stapleton 1994).

6. *Bambusa nepalensis* Stapleton

The culms reach a maximum diameter of 10cm and height of 20m. The culms are dull and have large leaf. The culm sheath is broad with short, dense and tightly flattened hairs against the culms (Fig. 6).

(a) (b)

Fig.6. *Bambusa nepalensis*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

7. *Bambusa nutans* Wallich ex Munro subsp. *nutans*

The pole reaches a maximum diameter of 10cm and 23m in height. Culm sheath auricles are larger. Presence of weakly cupped persistent culm sheaths blades and brown hairs, leaf sheath with few bristles and small auricles are the most distinguishing characters of this species (Fig. 7).

(a) (b)

Fig. 7. *Bambusa nutans* subsp. *nutans,* a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

8. *Bambusa nutans* Wallic ex Munro subsp *cupulata* Stapleton

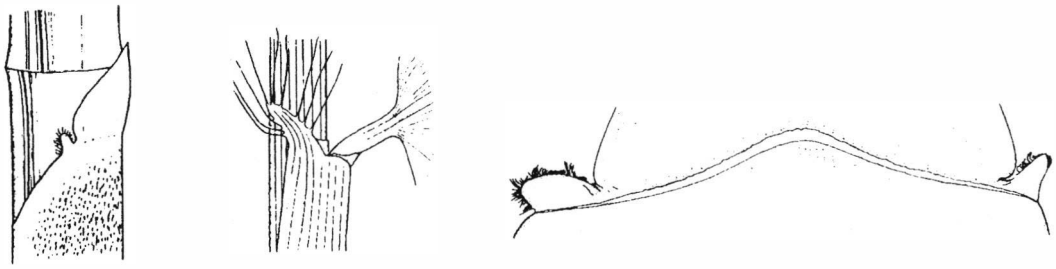
The pole reaches a maximum diameter of 10cm and height of 23m. It is recognized by large culm sheath with auricle, strongly cupped hairy deciduous sheath and few bristles with small auricle are present in leaf sheath (Fig. 8).

(a) (b)

Fig. 8. *Bambusa nutans* subsp. *cupulata*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

9. *Bambusa tulda* Roxburgh

The culms reach a maximum diameter of 7cm and length of 15m. It has a large leaf sheath auricle unlike *B. nutans*. Culm sheath is less cupped and persistent. One culm sheath auricle is taller than other. More bristles are present in leaf sheath auricle (Fig 9).



(a) (b) (c)

Fig.9. *Bambusa tulda*, a. Culm; b. Leaf sheath; c. Culm sheath (Stapleton 1994).

10. *Bambusa vulgaris* Schrader ex Wendland

The culms reach a maximum diameter of 7cm and length of 15m. It is recognized by the presence of striped culms, absence of bristles on the lower edges of the culm sheath blade. The leaf sheath auricles are larger.

11. *Borinda emeryi* Stapleton

Culms reach upto 10m tall, 4.5 cm in diameter and leaves upto 25cm. The species is distinguished by the presence of long internodes, fine grooved culms and persistent waxy covering in the culms. The culm sheaths have no hairs (Fig. 10).

(a) (b)

Fig. 10. *Borinda emeryi*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

12. *Borinda chigar*

The culm bases are curving. The culm sheaths are overlapped. Ligules are tapering and inside blades are not clearly distinguished. The leaves are narrow with long ligules leaf sheath, absence of auricle or bristles are the important characters to identify this species (Fig. 11).

(a) (b)

Fig.11. *Borinda chigar*, a. Culm and culm sheath; b. Leaf sheath(Stapleton 1994).

13. *Dendrocalamus giganteus* Munro

It is a bamboo of largest diameter of 30cm and as much as 30m tall, somewhat bigger than *B. balcooa*. The bamboo is easily distinguished due to the size, culm sheath, leaf sheath and absent of hairs on the leaf sheath. Fewer hairs on the culm sheath and presence of horizontal culm sheath blades (Fig. 12).

(a) (b)

Fig. 12. *Dendrocalamus giganteus*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

14. *Dendrocalamus hamiltonii* Munro var *hamiltonii*

The culms are thin walled and very flexible. It has a long leaf sheath ligule. The culm sheath auricles are naked and triangular. It has pale fur on the culms and long drooping culm tips but var. *hamiltonii* has straight culms, heavy branching and red anthers. Similarly, var. *undulatus* has shorter swollen culm internodes, more dimpled culm sheath blades and yellow anthers (Fig. 13).

(a) (b)

Fig. 13. *Dendrocalamus hamiltonii* var. *hamiltonii*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

15. *Dendrocalamus hookeri* Munro

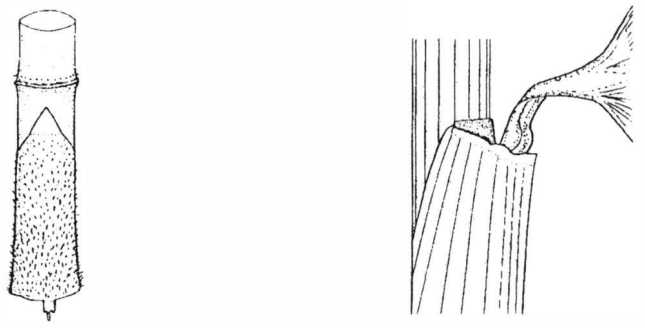
The culms reach a maximum diameter of 16cm and height upto 5m. Culm walls are thin and very flexible. It is recognised by the small auricles on the culm sheaths, presence of fewer bristles on leaf sheaths and abundance of aerial roots and strong branching (Fig. 14).

(a) (b)

Fig. 14. *Dendrocalamus hookeri*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

16. *Dendrocalamus strictus* (Roxb.) Nees

A small sized bamboo culm is less than 4cm and 6m tall. The wall is thick and solid. Leaf sheath have little or without hairs. Flowers are usually absent (Fig. 15).



(a) (b)

Fig. 15. *Dendrocalamus strictus*, A. Culm and culm sheath; B. Leaf sheath (Stapleton 1994).

17. *Drephanostachyum falcatum* (Munro) Keng f.

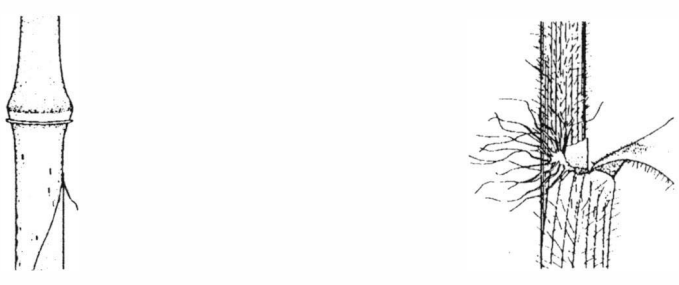
The culms reach upto 2cm in diameter and 4m tall. The culms are not very straight with swollen nodes and many branches. The most important character is, it has a long leaf sheath ligule like *Borinda chigar* (Fig. 16).

(a) (b)

Fig. 16. *Drephanostachyum falcatum*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

18.*Derphanostachyum intermedium* (Munro) Keng f.

The culms can be upto 2cm in diameter and 4m tall. It can be easily recognised by the well -developed and persistent leaf sheath auricles with widely spreading bristles. Hairs are present on the leaf sheath and the undersides of the leaves (Fig. 17).



(a) (b)

Fig. 17. *Derphanostachyum intermedium*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

19. *Himalayacalamus asper* Stapleton

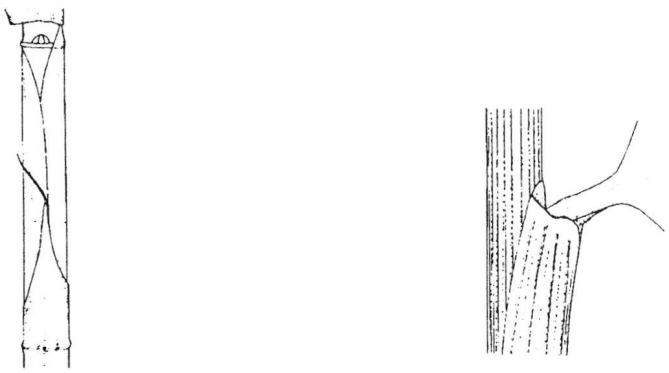
The culm sheaths are rough or lightly hairy. Leaves and the culm sheath blades are broad. In addition, the leaves and the culm sheath blades are very broad (Fig. 18).

(a) (b)

Fig. 18. *Himalayacalamus asper*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

20. *Himalayacalamus brevinodus* Stapleton

The culms reach a diameter of 2.5cm and height up to 9m. Culms are greener and internodes short and broad. There are white bands and purple color on nodes. Hairs or bristles on the culm sheaths are absent (Fig.19).

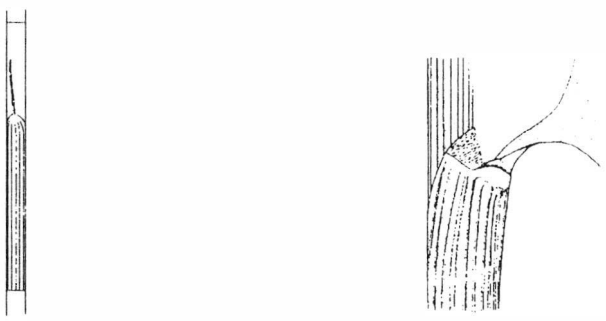


(a) (b)

Fig. 19. *Himalayacalamus brevinodus*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

21. *Himalayacalamus cupreus* Stapleton

The most important characters of this species are due to the presence of long culm internodes upto 40cm on length. The culm sheaths are long, tough and smooth with prominent copper coloured cilia along the edge (Fig. 20).



(a) (b)

Fig. 20. *Himalayacalamus cupreus*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

22. *Himalayacalamus falconeri* (Munro) Keng f.

It has smooth and short culm internodes. The culm sheaths are bullet shape with a short broad ligule with striped of yellow and purple lines. Absences of spines, hairs or auricles on the culm sheaths are the important character to separate from other *Himalayacalamus* species (Fig. 21).

(a) (b)

Fig. 21. *Himalayacalamus falconeri*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

23. *Himalayacalamus hookerianus* (Munro) Stapleton

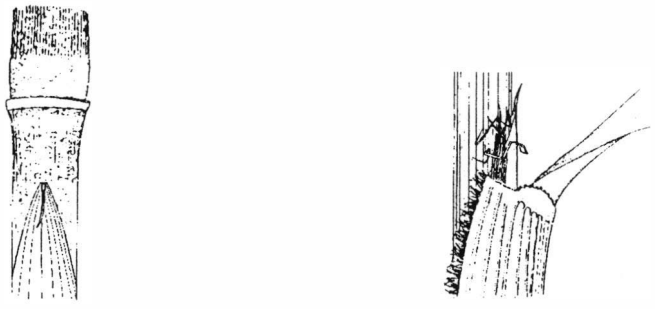
The species reach upto 3cm in diameter and 7m in height. The new culms are blue in color and culm sheath has narrow neck (Fig. 22).

(a) (b)

Fig. 22. *Himalayacalamus hookerianus*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

24. *Himalayacalamus porcatus*

The species reach up to 2.5cm in diameter and 6m tall. It is recognised from the other species of *Himalayacalamus* by the presence of finely ridged culm internodes. The leaf sheaths have more cilia on the edges, upright bristles and absence of auricles. The flowers are arranged in spiklets with fine spines (Fig. 23).



(a) (b)

Fig. 23. *Himalayacalamus porcatus*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

25. *Mellocanna baccifera* (Roxburgh) Kurz

The species is 12m in height and 5cm in diameter. The culm sheaths are covered by white hairs. The ridges are present on the outside of the sheath, where the blade is attached. The blade is sword shaped and longer than the sheath. The leaf sheath auricles are prominent with very erect white wavy bristles. The

fruits are larger in size and shape similar to that of pear (Fig. 24).

(a) (b)

Fig. 24. *Mellocanna baccifera* a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

26. *Thamonocalamus spathiflorus* (Trin.) Munro subsp *spathiflorus*

The leaves have prominent cross veins, and are often on long pendulous branchlets with many short internodes. The leaves are narrow, usually on groups of 5-9 on each branchlet. The culm sheaths are hairy or glabrous with broad cilia (Fig. 25).

(a) (b)

Fig. 25. *Thamonocalamus spathiflorus* subsp *spathiflorus*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

27. *Thamonocalamus spathiflorus* (Trin.) Munro subsp. *nepalensis*

The main distinguishing features of the species are hairless culm sheaths and lack of bristles on the leaf sheaths. The leaves are broad and are usually on groups of 2-5 on each branchlet (Fig. 26).

(a) (b)

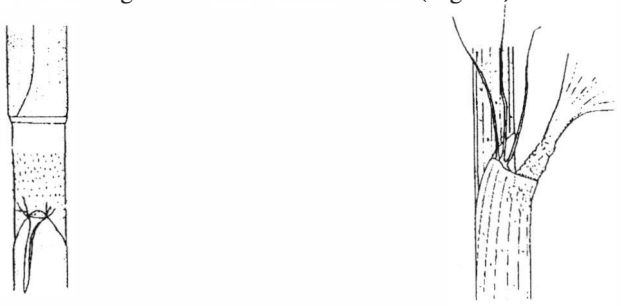
Fig. 26. *Thamonocalamus spathiflorus* subsp. *nepalensis*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

28. *Thamonocalamus spathiflorus* (Trin.) Munro var.*crassinodes* (Yi) Stapleton

It has swollen culm nodes and small leaves. The culm sheaths are hairy or glabrous with broad ciliate shoulders.

29. *Yushania maling* (Gamble) R. B. Majumdar

It is similar to *Thamonocalamus spathiflorus* and *Arundinaria recemosa* but can easily be distinguished by the presence of rough internodes in new culms (Fig. 27).



(a) (b)

Fig. 27. *Yushania maling*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

30. *Yushania microphylla* (Gamble) R. B. Majumdar

It is commonly 1m tall and 1.5cm in diameter. A group of short branches are present at each node. Leaves are less than 3cm in length. Below the culm nodes persistent flaky ring of wax are found, which turns from white to black with age (Fig. 28).

(a) (b)

Fig. 28. *Yushania microphylla*, a. Culm and culm sheath; b. Leaf sheath (Stapleton 1994).

5. Propagation

Bamboos can be propagated by vegetative methods, seed and from tissue culture.

5.1 Vegetative methods

Culm cuttings. In Nepal this is an effective method for propagating thick walled and large sized bamboos (8-12 cm in diameter) such as *B. vulgaris.* High success rates of propagation are achieved from single node culm cutting. Single node culm cutting propagation trials have been established for many species of *Bambusa*, *Dendrocalamus* and *Oxytenanthera* in different parts of Nepal. Sixty to eighty percentage survival was obtained in *B. balcooa*, *Bambusa sp.* (Tharu bans), *D. hamiltonii* and *D. hookerii.* The success rate was low in *B.nutans* (30%) (Das 1988).

During this process, a central culm (6-10 months) with strong branches should be chosen. The central branch is cut at a length of about 20cm, beyond the first long internode. In this culm cutting process, the buds at the base of the central branches should not be damaged. According to the species the culm is then cut into single and double node sections, each bearing a strong branch or a dormant bud. The cuttings are set in the soil so that the culm ends and the branch bases are just below the soil level. If the branch base has more buds on one side than the other, the side with more buds should be faced downwards. Downward facing buds are more likely to give rooted shoots (Fig. 29). The time required for

production of a reliable planting material varies from 6 months to 2 years depending upon the species and the age of the cut culm (Stapleton 1994, Amatya 2000).

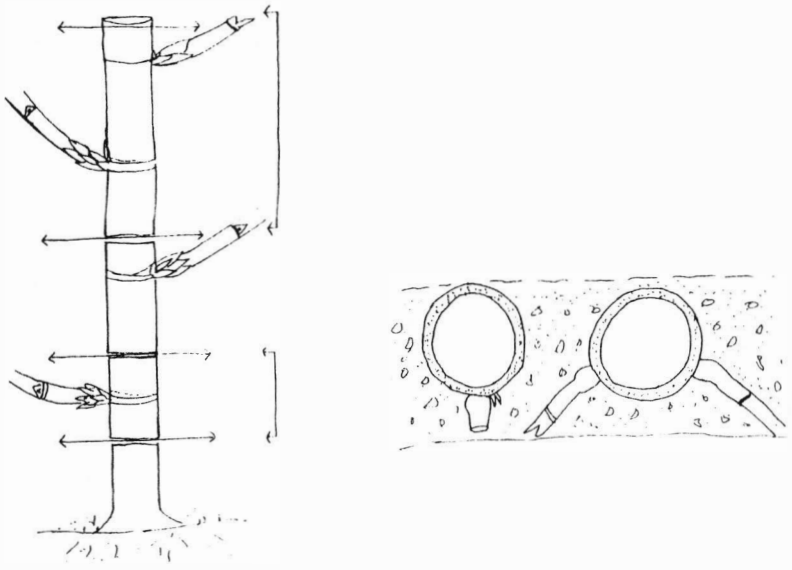


Fig. 29 showing propagation by culm cuttings.

By rhizomes. The one or two years old bamboo culms are dug out without causing any damage the buds. The so obtained culms are then to be planted. The length of the culms are cut leaving 1-2m from the ground level (Fig. 30). The propagation technique should be undertaken at the beginning of monsoon season (Stapleton 1994, Amatya 2000).

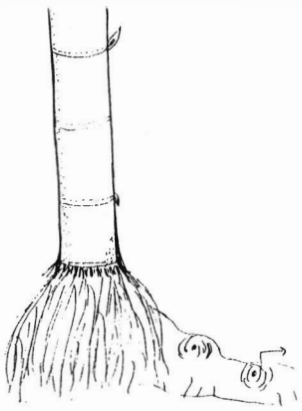


Fig. 30 showing propagation by rhizome

5.2 From seed

Any particular species of hard bamboo is unlikely to flower more than once in the course of many years. The bamboo seeds vary greatly in size and shape, depending upon the species. The seed should be sown flat, at a depth approximately equal to twice it's own thickness in pans of compost. These should be placed in a warm and humid corner of the greenhouse or on the shade. Germination takes place within three to four weeks after sowing (Stapleton 1994, Amatya 2000).

5.3 Tissue culture

Bamboos have a very wide spectrum of application in daily life (Varmah and Pant 1981). Bamboos are mainly propagated by seed, rhizome and culms. Seed propagation is unreliable due to the long and unpredictable flowering habit (from 25-60 years). Similarly propagation by culms and rhizomes gives about 10 culms a year (Anonymous 1948). Tissue culture methods offer a means of large scale of production in a short span of time. Development of the tissue culture technology, may be a slow and

time-consuming process. But once it is established, mass production on a factory or industrial scale becomes possible. Many workers have done mass propagation of bamboos from somatic embryos (Zamora *et al.* 1989, Nadgir *et al.* 1984, Rao *et al.* 1988). Similarly in Nepal, tissue culture was successfully carried out by taking seeds of *D. hamiltonii* and *D. strictus* (Niroula and Rajbhandari 1990).

6. Diseases and Pests

Although it is a valuable forest product, it is attacked by a number of pathogens. In Nepal, no detailed study on the pests and pathogens that attack bamboos have been carried out yet. But in some countries various pests and diseases that infect bamboos have been identified and reported.

6.1 Insect Pests

Standing bamboos are attacked by various insects belonging to the order *Coleoptera*, *Lepidoptera* and *Hemiptera*. These insects bore the standing clumps and suck the sap of stem leaf and seed. "*Ghoon*" (Coleoptera) and other borers attack dried bamboo culms. (Singh 1988). In Nepal the most serious pests of bamboos are the larvae of shoot boring moths of the family Noctuideae. The commonest species in the eastern hill is *Pareuplexia* sp (Stapleton 1985). Similarly die back of bamboo species have been reported in Eastern Nepal (Karki *et al.* 1998). Almost 700 insect species in China, 180 in India and 80 in Japan have been reported to be associated with attacks on bamboos (INBAR 2002).

6.2 Diseases

A large number of saprophytic and parasitic fungi have been reported on dead and stored bamboos. Some diseases that attacked the economically important living bamboos are leaf and branch blight by *Ascochyta phascolarum*, grey-blight of culms by *Geotrictum* sp; abnormal defoliation and withered culms by *Taphrina sp*; rotting of growing culms by *Fusarium* sp, sooty mould by *Capnodium* sp, foliage disease by *Rhizobium solani*, Culm sheath rot by *Glomerella* sp and *Pestaziella* sp, little leaf disease by mycoplasm like organism. Only few species of fungi, bacteria and viruses are involved in causing serious problems.

6.3 Diagnosis of the diseases

Leaf and branch blight: This disease is mostly found in species like *B.vulgaris*, *D. strictus* etc. where a large number of small longitudinal yellow lesions first appear on the leaves. These enlarge in size and turn brown. The leaf margins become necrotic extending towards the center, such leaves are gradually blighted and abscised (Balakrishnan 1988). This disease is mostly caused by *Ascochyta phascolarum*.

Grey blight of culms: This disease is observed in *Bambusa arundinacea* and *B. vulgaris*. Symptoms of this disease can be observed by the irregular patches of grey colour in the nodal region of a few basal nodes. These extend gradually both upward and downward in strips finally covering the entire internode portion (Balakrishnan 1988). This is mostly caused by *Geotrictum* sp.

Abnormal defoliation and withered culms: This disease is mostly observed in *Bambusa vulgaris* and caused by *Taphrina* sp. A large number of raised lesions appear in almost all leaves, which gradually become necrotic. The nearby lesions join together resulting in large blighted area where leaves dry up in certain branches and abscise (Balakrishnan 1988).

Rotting of growing culms: This disease is found to occur in all bamboo species. Rotting occurs in the young culms at all stages of growth. The affected culms gradually die and the inner tissues along with the outer sheaths become rotted (Balakrishnan 1988). This disease is mostly caused by *Fusarium* sp.

Sooty mould: This disease mostly occurs in *B. vulgaris* and caused by *Capnodium* sp. A black powdery fungal coating is seen on the upper side of the leaves of the affected branches and portions of culms. Such branches show withering (Balakrishnan 1988).

Culm sheath rot: Infection of young culm sheath caused by *Glomerella cingulata* and *Pestaoziella* sp. is recorded in *B. vulgaris* and *D. strictus*. The infection is often predisposed by injury done by insects (Mohanan 1988).

Little leaf disease: This disease occurs only in *D. strictus*. It is characterized by the production of a large number of abnormal shoots from the nodal regions giving rise to a bushy growth. The internodes and leaves are stunted (Mohanan 1988).

7. Uses of bamboo

7.1 Livelihood

Bamboos are the most important plants to mankind and approximately 2.5 billion people of the world derive their livelihood from them (Anonymous 1997). Bamboos are used for a variety of purposes all over Nepal. They have a wider range of application than other species of plant and are used by both rural and urban households. In Nepal, bamboos are commonly used for house construction, walling, thatching and roofing of huts, grain storage, scaffolding, walking sticks, handicrafts, tool handles, furniture, fencing material. Likewise they are also used for fishing rod, fishing traps, packing cases for tea and fruits, cages of poultry, pipes for water supply and irrigation, cart yokes, bullocks carts, ladders, windows etc. Many of the bamboo species produce edible shoots, which are used as vegetables in many parts of Nepal (Das 1998). Many households in terai consider bamboos as an important source of income as the demand for bamboos are constantly increasing.

Bamboos have both socio-cultural and economic value to the people of Nepal. So, the proper production, marketing and export of bamboo products can boost the socioeconomic condition of the people of Nepal.

7.2 Bamboo as food

Many of the bamboo species produce edible shoots, which are very popular among both the rural and urban people in Nepal. Despite the popularity of the shoots of bamboo, the market is not so large as compared to other Asian countries. It is because of the lack of awareness. In places like Makwanpur, Dhading, Lalitpur, Kathmandu etc, bamboo shoots are sold at the local market. But in China, Japan, Taiwan, Thailand young shoots of several species of bamboo are the important vegetable ingredients in the daily meal. In the western world, bamboo shoots are available only as imported canned products. During 1977, Taiwan exported nearly US $ 25 million worth canned bamboo shoots to the Western world (Sharma 1980). In 2001 it has exported nearly US $ 50 million worth bamboo shoots. In Japan and Taiwan about 8,000 tons of bamboo shoots are consumed every year.

Lian County in Zhejiang generates higher income by exporting bamboo shoots. The average annual household income from bamboo shoots amount to US $ 2500 whereas the highest income is over US $ 10,000 (Anonymous 1997). In Nepal income generation from bamboo shoots are derived from selling in local markets only.

Bamboo shoots are nutritious like other vegetables. Singh and Singh (1992); Young (1954) quoted that various bamboo species have total digestive carbohydrate 4.5%, protein 2.6%, fat 0.31%, ash 0.9%. As a source of phosphorous, the average analysis showed that bamboo shoots are as good as other succulent vegetables like asparagus, mung bean, sprout bean, spinach. Calcium and Iron content in bamboo shoots are low. The content of vitamins are relatively high (A: 50 i.u; B1: 0.1mg B2: 0.08mg and C : 10.0mg) . In their opinion the nutritive value of bamboo shoots can be roughly compared to that of an onion. Besides these nutritious compounds, edible bamboo shoot consists of low level of cynogenic substances whereas non-edible type contains considerably higher levels. Mostly edible bamboo shoots are *Bambusa tulda*, *Dendrocalamus giganteus*, *Melocanna baccifera* etc.

7.3 Biomass production

Bamboo generally yield high calorific values ranging from 4,244 to 5,500 cal/g dry tissue there by the bamboo have higher energy contents compared to common fuel wood (Sharma 1996). It was reported that, species like *Bambusa tulda*, *Dendrocalamus giganteus*, *Melocanna baccifera* provide better energy and are suitable for energy plantation and utilization. The biomass of bamboos increase 10% to 30% annually as compared to trees (2% to 5%) (Paudyal 2000). The high energy release, annual increment in biomass as compared to other trees, abundance, proximity, economic and sustainable raw material, the bamboo resources are utilized exclusively as an alternative source of energy in many parts of the world. The utilization of bamboo biomass would be helpful to reduce fuel wood harvesting from the forest. It was found that in many parts of Nepal dry, fallen leaves, culms are used as fuel wood and bundles of bamboo fuel wood are sold at a price of Rs 20-25/bundle (Karki *et al.* 1998).

The calorific value have attracted the interest of Zhejiang Fuster Group to develop superior technologies in the processing of bamboo and its waste material to produce charcoal (piece charcoal, body charcoal (10um – Icm mesh charcoal and powder charcoal). Now it has played an active role in saving natural resources and protecting the ecosystem.

7.4 House construction

Housing is a basic necessity of human beings. In South East Asia bamboos have a significant place in the construction of houses, scaffolding etc., bamboo's role in the construction field is substantial. Hundreds of million of people live in houses made from bamboo. In Bangladesh 73% of the population live in bamboo houses (INBAR 2001). Recent researches showed that as compared to other constructional timbers, bamboo possess better strength and are suitable for structural purposes. The strength data of bamboo species *Dendrocalamus strictus* and *Bambusa balcooa* are found similar to teak and sal (Limayee 1952, Mishrea 1988). Now, bamboos are widely used for low cost housing. It was reported that house developed by Hoger de Cristo in Ecuader costs only US $ 300 (INBAR 2001).

7.5 Pulp and Paper Industry

Deforestation has caused scarcity and increased the price of raw material for the paper industries. In this context some species of bamboo can be an alternative source of raw material. In the modern world, the utilization of bamboo as the raw material for the pulp and paper industries is increasing. Countries like India, China, Thailand, are using bamboo species as a raw material for the production of paper. Chemically bamboos contain four principal substances starch, pectin, lignin and cellulose. Cellulose is the basic material used in the manufacture of paper. Chemical analysis of *Melocanna baccifera* showed that it has the most important material for the production of paper. This species has a production potential of 100 t/day. The other reported important species are *Bambusa tulda* and *Dendrocalamus giganteus* (Sharma 2001). In India species *Dendrocalamus strictus* are used as raw materials for pulp and paper industry (Stapleton 1994). Modern paper industry in India has expanded to such an extent that 2.2 million tons of bamboos are used for this purpose (INBAR 2002).

7.6 Fodder

Leaves of larger bamboo species like *Dendrocalamus* sp. and *Bambusa* sp. have been used as fodder in eastern Nepal during winter season (Paudyal 1992). The chemical composition and taste of some *Bambusa* sp. and *Dendrocalamus* sp. are very nutritious for the lactating cows and buffaloes and help to produce milk. The leaves of *Bambusa tulda*, *Dendrocalamus* sp. and *Bambusa balcooa* were analysed for various nutrients. It was found that dry matter (DM) and crude protein contents were 87-94% and 12-15% respectively. So, bamboo leaves were found to be reasonably better than other tree leaves (Keir *et al.* 1997).

7.7 Soil erosion control

Nepal is one of the most erosion prone zone (National Research Council 1993). About 30-75 tons of soils are washed away annually from each hectare of deforested land. depleting 249 million cubic meter of

soil per year. (Wilson and Frances 1988). The valuable soil of riverbank could be protected through plantation of some important selected species of bamboo along the river and stream bank (Poudyal 2001). The rhizomes of bamboo grow about 12 feet a year so it builds a massive underground network and hold the soil well (Farrelly 1984). The plantation of selected species of bamboo along the riverside would be useful for soil stabilization and reduction of cost of construction. On Dharan Dhankuta hill roadsides, which are in the eastern region of Nepal, bamboos were planted in 1987 – 1988 on sites prone to erosion and landslides. Similarly species like *Dendrocalamus hamiltonii*, *Bambusa balcooa*, *Dendrocalamus hookeri*, *Bambusa nutans* subsp *cupulata*, *Ampelocalamus patellaris* and *Bambusa nutans* subsp *nutan* were identified as the most important species used in bioengineering (Howell 2001).

7.8 Purification of polluted air

Bamboo generates more oxygen than similar sized trees (Alexandar 1996). The culm of bamboo has more water in it, so there will be a greater volume of oxygen produced from the culms as well as from leaves during photosynthesis and a greater volume of Carbondioxide (CO2) will be consumed. Thus bamboo is the best plant to purify the polluted air. As it consumes more CO2 and produces more Oxygen (O2) during photosynthesis, it helps to lower the temperature of surrounding by 10^{0}C (Poudyal 2000)

7.9 Absorption abilities for dyes and phenol

Recent researches have found that preparation of activated carbon from bamboos appeared to be economically promising for the removal of dyes and phenol as compared to other commercial adsorbents (Chin *et al.* 1999, INBAR 2000).

7.10 Isolation of Phytosterols

Some species of succulent bamboo shoots after fermentation give phytosterols from 0.3 to 0.6% dry weight, which could be used as a raw material for the partial synthesis of pharmaceutically active steroids (Sarangtem 2001).

7.11 Physical properties of bamboo

The glass fiber reinforced plastic (GRF) composites are commonly being used in many industrial and commercial applications. These are however, very costly due to the high cost of production of glass fiber and polyester/epoxy resins (Jindal 1988). It is necessary for the production of natural fiber reinforced plastic composition as bamboos are available at a lower price. Verma *et al.* (1983) developed composites using coir fiber in polyester resin but the maximum tensil strength achieved was only 24Nmm^2. Satyanarayan *et al.* (1983) developed composites using natural fibers of jute, coir, cotton etc in polyester/epoxy resins and found tensile strength of 104 Nmm^2. Jindal (1984) studied the mechanical properties of *Dendrocalamus strictus* and found that the specific ultimate tensile strength of bamboo specimens are nearly six times than that of mild steel. Bamboo fiber reinforce plastic (BFRP) composites with different stacking sequences possess very high tensile strength ranging from 263.9 to 386.1 Nmm^2. Thus according to him BFRP composites can be used for a variety of structural applications where strength and lightness are important considerations (Jindal 1988).

7.12 Production of high value product

Bamboos possess excellent mechanical properties especially in regard to tensile strength. Very few species have been intensively evaluated for their physical and mechanical properties (Sekhar and Bhartari 1960). The wide distribution, low cost, easy workability and high strength characteristic have forced people to use bamboo as an alternative source to wood.

Modern processing technique can utilize the unique physiomechanical properties of bamboos to make high quality products. Bamboo board is one of the immediate interests as pressure on wood can be reduced to some extent. Due to the fast growing nature of bamboo as it can be harvested in four to five years cycle as against 30 – 40 years required for medium density hardwood species used for plywood. Recently

developed bamboo panels have been found to be suitable for concrete framework (Dong 1987). In China it is reported that more than 100 small-scale factories produce about 10,000 tons of bamboo plywood or bamboo particle - board (Suzhou 1987). Thailand is reported to be manufacturing bamboo mats and exporting them to European countries for use in paneling, wardrobes, ceiling etc (Sharma 1983). In Nepal, recently established bamboo factories like Unique bamboo, Everest bamboo etc. are producing bamboo particleboard, mats etc. The mostly used species in the production are *Dendrocalamus strictus*, *Bambusa arundinariceae* and *Bambusa vulgaris* etc. The production capacity based on culm production from a 500 ha plantation on a 15 year rotation is 1280 to 3200 culms daily; from one bamboo culm, it is possible to produce an average of 4 pieces of paraquet 1 x12x 90cm in size. (Othman *et al.* 1999)

7.13 Religious use

In addition to the above-mentioned uses, bamboos are used on many festive or religious occasions. They are used to make swings during the "*Dasain*" festival, prayer flags etc. At weddings four small poles may be placed as a guard around the center of activities. In many parts of Nepal brides are carried in a bamboo chair known as "*Doli*". Poles of certain species of bamboos are used to carry the dead bodies (Stapleton1994).

7.14 Medicinal and ornamental value

Bamboos can be used for ornamental and medicinal purposes. The small sized bamboo species like *Bambusa multiplex*, *Bambusa arundinaceae* have already found a position in garden and in crop fields. The species like *Bambusa arundinacea*, *Bambusa tulda*, *Bambusa balcooa*, *Dendrocalamus strictus* etc, are used as medicine. It was reported that *Bambusa arundinaceae* has medicinal value against haemorrhoides, opthalmopathy, gonorrhoea and skin disease. It is also used in ulcer, wound, inflammation, and flatulence and in cooling tonic, aphrodisiac and antihelminthic by different ethnic group in Sunsari district (Shrestha 1999). Similarly, stem and leaves of *Bambusa arundinaceae* are used in piles, anaemia, jaundice and fever (Shukla and Das 1981 in manual TCDC). Leaves of the same plant are used to prepare "*Banslochan*" as an aphrodisiac and stimulant, blood purifier, asthama etc. (Hussian *et al.* 1992 in manual TCDC). Roots are used as tonic, burns, ringworm, bleeding gums, joint pains, diluent etc. leaves of *Bambusa dendrocalamus* with water extract are used for lowering blood sugar (Nagarjan *et al.* 1982 in manual TCDC). *Bambusa tulda* are used as anti tetanus. Leaves of *Bambusa vulgaris* are used in burns and wounds (Chopra *et al.* 1986 in manual TCDC). Leaves of *Dendrocalamus strictus* are given to animals during parturition, antifertility, cough and fever. Siliceous matters found in joints of *Dendrocalamus strictus* are used for cooling, tonic and astringent medicine.

8. Economics

In Nepal, the rate of increase in the population is 2.24% per annum (CBS 2002) whereas the area covered with forest is annually decreasing by 3% particularly in the Terai (HMGN/FINNIDA 1999). The overall rate of decrease of the forest area for Nepal is 0.4% (HMGN/ADB/FINNIDA 1988). The current population in rural areas is expected to be about 88% for which fuel wood is the major energy sources (HMGN 2000). It has been estimated that almost 90% of energy in Nepal is supplied by biomass and among biomass energy fuel wood accounts for about 80% of the total energy use, which is derived from public, community and private forest and agriculture land (NEA 1999, WECS 1999). Increase in population, high demand of fuelwood and timber, degrading agricultural land has put pressure on the forest resources, which create deforestation and soil erosion. The other commercial important species of trees like *Eucalaptus* takes about 7-10 years to get mature. Similarly longer period are needed for Sissoo, Teak, Sal, Alnus and Pine etc (Das 2001, personal communication). Due to these factors, plantation of fast growing species and conservation of forest resources is a significant solution for solving the problems.

Physiological development of bamboos takes place within a year. Mature bamboo culms produce new shoots every year throughout the rainy season. These shoots develop rapidly, and within two or three months reach their full height and diameter; the current year's culms are however much softer and less

woody than older culms. Much greater productivity is obtained by thinning out the poles regularly. A single bamboo clump can produce upto 15 km of usable pole in its lifetime (Poudyal 2000).

The single bamboo culms can produce 10 mature culms in 3 years time. It clearly states that each bamboo clump does not have the same capacity of culms production. The number of clump, condition of cutting material at planting and number of sprout and finally the site condition mainly governs it. In a hectare 250-400 culms can be placed according to the species. For example *B. nutans* sub sp. *cupulata* and *B. nutans* sub sp. *nutans* can be planted 344 and 304 culms per hectare respectively (Thapa *et al.* 1998). On an average after 5 years one can generate Rs. 125000- 200000 per hectare by selling bamboo culms annually at a price of Rs. 50/ culm.

Nepal is rich in natural resources but 50% of the populations are under poverty line (UNDP 2000). The tenth five-year plan of His majesty's Government of Nepal (HMGN) has given emphasis to poverty alleviation program. The HMGN aims to reduce this level to 10% by 2010. In our context bamboos can be a suitable species for employment and income generation.

Most of the households are not getting good income from agricultural land and they are involved in off farm household incomes to meet their livelihood need. The establishment of bamboo-based industries can be an effective means to improve the income level of people. The results of this type of industries in many countries like China, India, Thailand etc. can be used as a guide for poverty alleviation program.

Bamboos are one of the most important minor forest products. They provide food, raw material, shelter and even medicine for population of the world (Austin *et al.* 1983) and they play an important role in the rural economy of the developing countries especially in Asia and Pacific region (Sharma 1980, 1985). Most of the people living in the rural areas of Nepal depend upon agriculture for their livelihood. Bamboos are generally grown as a living fence, shoots are used as food and culms are used for building material, making handicrafts, household materials tools of agriculture etc. during their off seasons in agriculture (Feb- April) bamboo culms and bamboo products are sold in the local and neighboring markets.

The demands of bamboo culms are also high in neighboring country. Similarly places like Siraha, Belhi, Kusha 500-1000 culms of bamboos are exported daily from each custom to India during Feb-April. The annual total export is around one million culms. It was also reported that bamboo culms are transported through Koshi river using bamboo rafts. During Feb-April 50000-60000 culms were transported per month to urban destination of Nepal and India. The market of these bamboo and bamboo products are high (40%-60%) in near Indian markets than local markets. Lahan bazaar in the eastern part of Nepal is famous for trading bamboos and bamboo's products (Karki *et al* 1998).

Due to the altitudinal and climatic variation, Nepal has both tropical bamboo species found in South-east Asia and temperate bamboos found in Tibet and Bhutan (Karki *et al* 1998). So Nepal is a unique place for the cultivation of bamboo species. The emphasis should be given to the economically important bamboo species as a source of income surplus, bamboos have good market and it also provides raw material for the bamboo-based industries. The plantation of bamboo are considered similar to bank savings in the terai and in the mid-hills where other opportunities are scanty.

9. Research and development

- The total area occupied by bamboo in the country has not been estimated so a detailed countrywide systematic inventory of bamboo resources is needed.
- Even though various taxonomical studies on bamboos were done but herbaria have not been collected for all the recorded species. So the detailed collection of herbaria is needed.
- Increased population pressure, over exploitation of natural resources, slash and burn has caused genetic erosion of several bamboo species. So, effort should be made to collect and built up germplasm banks for gene conservation of bamboo.
- The demand of bamboos are increasing and traditional methods of propagation are not popular because it is expensive and there is the limitation of using one year old culm which can be of other uses also. A mass propagation is needed through tissue culture method.
- Due to its fast growing nature it is used for windbreaks, soil stabilization, and bioengineering and further research is needed in this field.
- As the industries are increasing and there will be a shortage of raw material after few years so the identification and development of high quality bamboos are needed.
- Cultivation techniques of bamboo in marginal lands of hills and terai have to be developed through field trials in various ecological zones.
- The delicious taste of shoots, considerable yield and income play an important role in poverty alleviation. More research is needed in this field.
- The excellent properties of the culm are being utilized for the construction of low cost houses, so technologies should be developed according to our country's need.
- Bamboo handicraft items are coming into the market. This is facilitated by giving special training courses to the small-scale industries holder, which helps in income generation.
- Training should be given to traders, craftmakers and entrepreneurs about the growing marketing and benefits of bamboo.
- There is lack of market study on bamboos. So socioeconomic studies on bamboo is required, including marketing, demand and supply trends in all the regions of Nepal.
- There is a need of personnel exchange on various aspects of bamboo research of information and sharing knowledge, so that Nepalese researches can learn from other countries such as China, India, Taiwan, Thailand etc.
- Detail research on disease and pest management is also required.

Glossary

Technical Terms

Aerial root	:	a root growing above the ground
Aurical	:	an ear like projection at the top of the sheath
Blade	:	a leaf like projection at the top a culm sheath
Cilia	:	hairs along the edge
Clump	:	a collection of many culm growing close together
Culm	:	the stem or stalk of a bamboo
Ligule	:	a projecting tongue where sheath and blade meet
Node	:	ring around the culm joints
Petiole	:	narrow portion between leaf blade and leaf sheath
Pole	:	the stem or stalk of a large size bamboo
reflexed	:	bent backwards more than 90^0
rhizome	:	horizontal underground stem producing roots and new shoots
Species	:	a group of similar plants called by the species name
Variety	:	division of a species found in a small geographical area

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