BAMBOO FOR COMMUNITY NETWORKS

A plantation manual for green tower infrastructure

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Published by the Association for Progressive Communications (APC) and Rhizomatica February 2023

This manual is part of the project "Connecting the unconnected: Supporting community networks and other community-based connectivity initiatives", implemented by APC in partnership with Rhizomatica, which seeks to directly support the development of community networks, with funding from the Swedish International Development Cooperation Agency (Sida).

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LocNet Communities of Practice (CoP)

This manual is the result of one of the Communities of Practice (CoP) projects supported by the Local Networks (LocNet) initiative. LocNet is a collective effort led by Rhizomatica and the Association for Progressive Communications (APC) working with partners in Africa, Asia and Latin America and the Caribbean to support the development of bottom-up approaches to building communications infrastructure known as community networks (CNs). To achieve its objectives, LocNet adopts various strategies to contribute to a supportive ecosystem for CNs, such as related peer-to-peer exchange and institutional strengthening, training and mentoring, policy and advocacy, technological innovation and sustainability, addressing gender issues and promoting the participation of women and girls.

Over the past several years, LocNet has provided advice, financial resources and forums to support numerous CNs in developing countries and other partners working toward similar objectives. The goal of the CoPs is to increase cooperation among community network practitioners around the world through provision of online collaborative spaces created around different topics of interest to CN practitioners. The CoP approach includes activities aimed at enhancing support for key issues of interest to the CN community by bringing together the different threads of technology and innovation work from previous years. In this sense, a CoP is a group of people who share a common concern, set of problems, or interest in a topic, and who come together to meet both individual and group objectives. CoPs usually focus on sharing best practices and creating new knowledge to generate advances in a given field, and one of the crucial components in this exercise is ongoing interaction.

Why is bamboo of interest for community networks?

Tower structures are an essential but costly part of the network deployment of community networks. People, especially those living in rural areas, have to find ways to raise their antennas over treetops and other obstacles that obstruct radio signals. Providing practical information and experience of how to establish a tower for community networks has, until recently, focused on the elements to be hoisted on the tower: antennas, cables, maybe even solar panels and batteries. The tower structure itself remained biased on industrial designs using steel and concrete. However, those materials are expensive, hard to work with, and not always locally available. To address these constraints, locally available materials have been increasingly considered. Mythical stories were shared about giant, single bamboo stalks and even photo footage of more complex designs emerged in CN messenger chats and online forums. Community ownership of the network is an important aspect of CNs. Bamboo from bamboo groves of the community enables community ownership of the network infrastructure.

But it was only during the COVID-19 pandemic that Coolab, a practitioner from Brazil's community networks support group, proposed to prototype a bamboo tower as a specific contribution for a more inclusive and locally grown CN infrastructure. With funds from LocNet, the project included treating the harvested bamboo stalks to make them more resilient: the tower is still standing. After this first effort, LocNet began to include bamboo tower designs in their identification of foundational technologies; that is to say all the key elements that contribute to sustainable, autonomous and community-driven connectivity and communications approaches.

This led to an intense global exchange, and shared learning took off, beginning with an initial informal gathering of "bamboo lovers" during a LocNet webinar on the topic in 2020 and continuing with provision of support to a bamboo design grant application to Asia Pacific Network Information Centre (APNIC) from partners in India in 2021, and then finally a call for a community of practice (CoP) around bamboo deployment for CNs in early 2022. During the online exchanges of this emerging community, another learning became apparent: before thinking of building a tower, it is important to ensure a local source for the bamboo, planting some if necessary. In other words: there was a significant demand for a more systematic sharing of knowledge around bamboo species selection and cultivation.

This manual is a first contribution to the tremendous task of capturing the wide variety of bamboo, climatic conditions, differing cultivation approaches and local knowledge around the world. It is published under the licence of Creative Commons and is expected to be expanded, adapted, and improved by current and future bamboo tower practitioners. Please share your comments, thoughts and especially images or other visible results that have grown out of the postings in our CoP.

Telegram channel: *https://t.me/+qO4cZ3ZJPSsyYzhi*

Acknowledgments

The India-based NGO, BAIF Development Foundation, focuses on improving rural livelihoods, and has been a long-term LocNet partner supporting CNs in that country. We would like to thank the authors and experts of BAIF for accepting the challenge to take the lead with the production of this practical guide for bamboo plantation, which grew to publishable state within few months. The authors have taken pains to ensure their localised knowledge from the Indian context can be generalised to other regions, and have embraced the idea of inviting a team of international practitioners to share their experiences and perspectives on bamboo cultivation. Thanks therefore to Adhi Nugraha (Indonesia), David Garrido Bonilla (Mexico), Fabián Andrés Pulgarín Agudelo (Colombia), Hiure Queiroz (Brazil), and Y. Z. Ya'u (Nigeria). We tried as much as possible to include everyone's wisdom and ideas in this first edition of the manual but it is also apparent that this is just be the beginning of a necessary global dialogue on bamboo cultivation

1 These initiatives are best understood as a collective effort by local communities to connect in a meaningful and affordable way to build relevant digital networks. Their trajectory has been accompanied and supported since 2017 by the LocNet initiative.

2 The bamboo tower initiative won the concept only Prize in 2021 'IEEE Connecting the Unconnected Challenge'

3 *https://hiurequeiroz.github.io/projects/bamboo_tower/*

4 *https://www.apc.org/en/news/low-cost-community-based-communications-network-towers-one-many-reasons-love-bamboo/*

5 *https://isif.asia/2021-isif-asia-grant-recipients-announced/*

6 IEEE bamboo tower paper *https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9605064*

1.0 Introduction

1.1 Introduction

Bamboo has been part of early human civilisation because of the multi-utility aspects of its products in day-to-day life, especially in rural areas. It is a sustainable and renewable resource as it continuously spreads vegetative growth. It also can be used for the rehabilitation of degraded land, reforestation, carbon sequestration and poverty alleviation; therefore bamboo can certainly be part of the solution. It absorbs more carbon per unit area than tree species and can be a vital tool in the agroforestry and construction sector in shifting to "net zero" carbon emissions as the world pledged in the 2021 COP 26 UN Climate Change Conference in Glasgow.

It is not a surprise that seven out of 17 goals identified by the United Nations, popularly known as sustainable development goals (SDGs) for the progress of mankind, can be addressed by promoting bamboo plantation.

A well-established bamboo plantation stops soil erosion, restores degraded land, conserves water, gives life to springs, enables biodiversity and provides different types of materials, enabling to skill-based livelihoods for rural people, especially tribal communities, in an eco-friendly manner. For, bamboo is an integral part of the tribal culture and income generator in all stages of its growth – from baby baskets to shopping bags, housing material, furniture and even stretchers and gurneys. Its shoots are also a food for many communities.

In the last four to five decades, the use of iron, steel and other materials had taken precedence over the use of wood or bamboo. However, the use of metal and cement poles in construction is costly. Therefore, it is important to find an alternative to these materials that are eco-friendly and address sustainable development. Since timber has restrictions in length, bamboo is ideally the first preference due to its physical properties for use as electricity poles and setting up communication towers for antennas. Recent studies have advocated bamboo for towers and electricity poles as a cheaper alternative source.

A few companies in Southeast Asia have started experimenting with building bamboo towers. When it comes to utility purposes, select species of bamboo have advantageous properties such as length (15 to 25 metres), diameter (seven to eight cm), compactness and tensile strength to withstand wind force (44m/sec), and a long life span (10 to 15 years), all pointing to a cheap and readily available resource.

Bamboo plantations are spread across the world and have some specific limitations. These include biological ones such as a long gestation period (four or five years) for the first harvest. A few are technological challenges while policy constraints such as insurance (as yet unavailable for bamboo plantations) are a problem. In some areas, wild bamboo is abundant, but poor marketing leads to poor prices, which is a major factor in Southeast Asia and Latin America. While some areas have an abundance of bamboo for tower and construction purposes, lack of knowledge of processing and preservation also leads to low pricing. Hence, farmers hesitate to cultivate bamboo commercially.

The purpose of this manual is to bridge the gap by helping communities and entrepreneurs to understand market needs and help them overcome the biological and technical constraints by adopting the best and low-cost practices, easy-to-adopt management practices in planning and planting bamboo, and post-harvest processing near farms/villages for better income. It is based largely on information from India but with a global perspective as the techniques have been applied globally.

1.2 Need of bamboo

The compactness and strength of bamboo varies among the species, origin, and the type of processing method involved. Some bamboos are extremely “compact”, drawing comparisons to oak and maple. Therefore, besides its direct use to mankind, bamboo can be promoted to reduce carbon footprint as opposed to steel, which consumes a lot of energy and entails huge emissions. However, the local market usually has limitations as it mainly caters to rural needs like housing and simple artefacts. But in recent years, bamboo-related products are finding ways back into our lives through eco-friendly enterprises such as construction of cottages and towers, and artefacts such as tables, chairs, cots, baskets, perfume sticks, etc. Bamboo biomass is added to charcoal pellets and for the production of biogas and CNG (compressed natural gas). Therefore, promoting bamboo is a necessity to protect the earth from greenhouse gas effects.

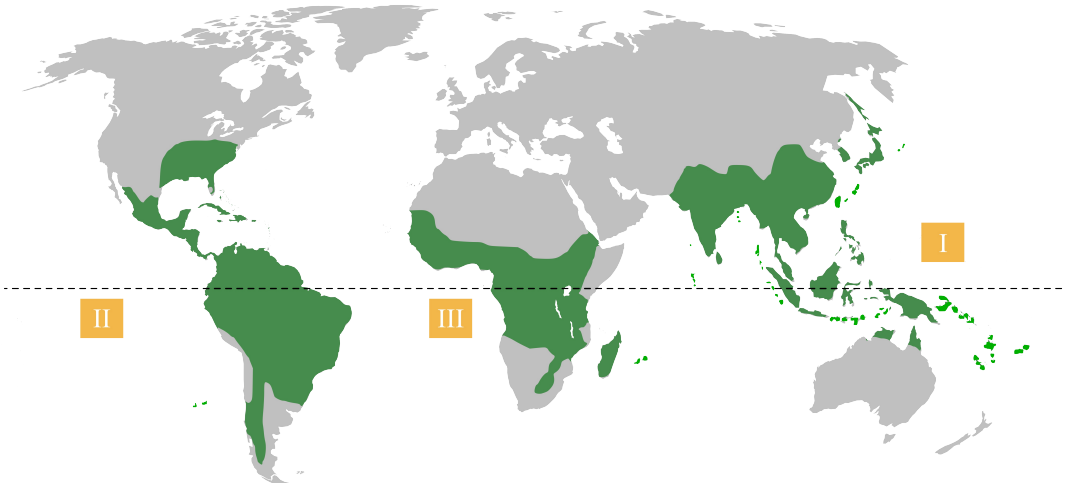
Today, there are thousands of bamboo products that can partially or completely replace wood, ranging from paper and pulp products to flooring, musical instruments, furniture, construction materials and so on. In addition, bamboo fibres are much stronger than wood fibres and less likely to be deformed due to changing atmospheric conditions.

Bamboo is a great alternative to traditional timber/plastic as it develops quickly into a hard, wood-like fibre. Bamboo stems reach maturity at three to five years, compared to 10 to 20 years for most softwood. Virtually every part of the plant can be used to make a variety of products. It is not stronger than steel but comparable to it in terms of much lower costs and so can be promoted to reduce environmental footprint. Improved preservation techniques to extend its utility has boosted the future of bamboo. Erecting bamboo towers will only incentivise bamboo cultivation, providing a remunerative livelihood to rural masses as an enterprise activity through community participation.

1.3 Bamboo- global scenario

There are more than 1,250 species and 91 genera of bamboo found worldwide but most of the species are agrozone-specific. The geographic distribution of bamboo worldwide falls into three major regions: namely, the Asian-Pacific, the Americas, and Africa (Illustration 1.1). About 80% of bamboo forest lands and species are distributed in Asia and the Pacific region. With its tropical and temperate climates, Asia has many advantages for bamboo growth, accounting for more than 900 species in about 50 genera. Asian countries (China, India, Myanmar, Indonesia, Thailand, and Vietnam) are very rich in bamboo resources. Constant cold temperatures have the potential to kill the plant. Colder climates limit its overall growth potential.

The major bamboo-producing countries in Asia are India and China, together accounting for about 70% of the output. The American region, which involves South America, Central America, and North America, has a high biodiversity of bamboo with about 400-500 species, including some 300 in 20 genera of woody bamboo. Africa has barely 40 species but large areas of natural bamboo forests.



[Illustration 1.1] - A sketch map of World Bamboo Distribution.
The Asian-Pacific Region (I); America's Region (II); The African Region (III)

1.4 Classification of bamboo

Bamboos have a unique anatomy and their super productive behaviours are interesting to study. Bamboo is part of the true grass family, comprising its largest and most productive member. The sizes of the species vary greatly. The smallest are a mere 11 inches while giant timber bamboo can reach heights of over 40 metres.

Below is a taxonomy under which bamboo is classified:

KINGDOM	:	Plantae	FAMILY	:	Poaceae
DIVISION	:	Magnoliophyta	SUBFAMILY	:	Bambusoideae
CLASS	:	Liliopsida	TRIBE	:	Bambuseae
SUBCLASS	:	Commelinidae	SUBTRIBE	:	Bambusinae
ORDER	:	Cyperales			

1.5 Life cycle of bamboo and it's parts

The length of the growth cycle varies widely, depending on the species, and can be anywhere from three to 120 years.

The main components of a bamboo plant include seeds, rhizomes, roots, culms, branches, leaves and flowers:

1.5.1 Seed

Most of the species flower after reaching maturity and produces a large number of seeds. The plants die after this biological action. Previously it used to fall in the same area. However, due to awareness, such seeds are collected as germplasm multiplication and also used for self-consumption by the local community for delicacy food or sold at a premium price.

1.5.2 Rhizomes

Rhizomes are horizontal stems–segmented and covered by a protective sheath–extending from the domain plant and travel underground to colonise new territory. Their appearance and behaviour differ among species. They are divided into two main categories: the pachymorph system and the leptomorph system.

The pachymorph rhizome system, found in clumping bamboo, expands horizontally only by short distances each year. New culms can only form at the very tip of the rhizome.

The leptomorph rhizome tends to branch away from the domain plant. These are generally long and thin in appearance and some species can send the rhizomes up to 20 feet away in a single growing season. At the nodes, they can produce buds that will form either new culms or rhizomes.

1.5.3 Roots

The primary function of roots is to anchor the culm to the ground. This also allows the culm to hold more weight, enabling it to grow more leaves over wider distances. The roots do store nutrients. In appearance, roots are typically symmetrical in size and shape. They form at the base of the culm from the rhizome nodes and generally go no deeper than one foot below the surface.

1.5.4 Culms

Culms can vary in size, shape, colour, and even smell. The appearance can range from thick or thin, tall or short, erect or bent, and can exhibit irregular patterns also. New culms generally emerge in springtime, but can vary among species. The newly emerging culm grows rapidly and reaches its final height by the end of the first growing season. The final size is determined by local growing conditions, as well as the age and size of the bamboo grove.

1.5.5 Branches

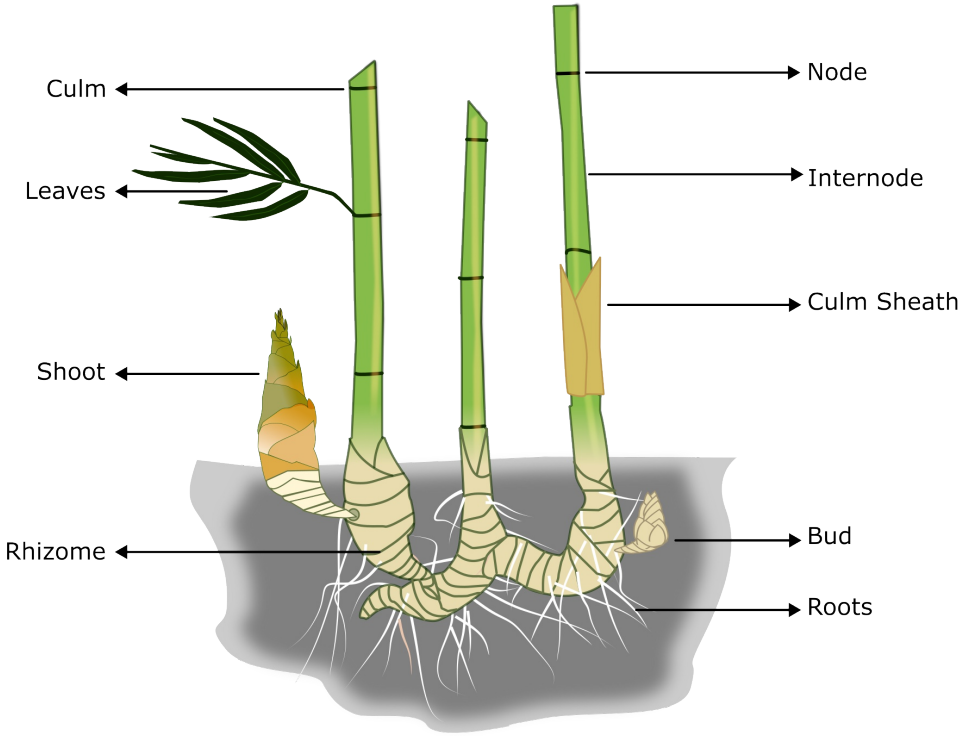
A majority of bamboo species grows multiple branches from a single bud located at the node. Some genera, such as Chusquea, can grow multiple buds from each node.

1.5.6 Leaves

Leaves are present in every main portion of the bamboo plant, which includes the rhizomes, culm and branches. The anatomy of the leaf itself includes a blade, sheath and ligule. The blade provides the photosynthetic function of the plant by converting sunlight into energy. The appearance of the blade varies among species. In some, the leaves are very large and less numerous, while others have a large amount of very small leaves.

1.5.7 Flowers

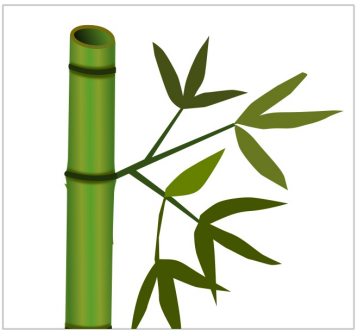
Most bamboo species seldom flower. Bamboo exhibits what is known as gregarious flowering, or mass flowering. The typical flowering interval can be decades long.



Clumping Bamboo

Seeds

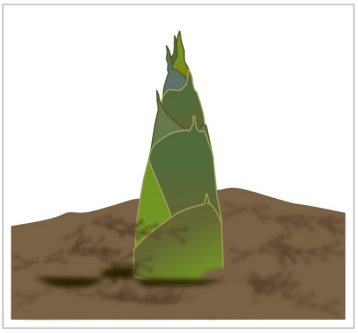
Culms



Branches

Leaves

Flowers



Shoot

[Illustrations 1.2] Bamboo parts: clumping bamboo, culms, branches, leaves & shoot
[Photos 1.1] Bamboo parts: seeds & flowers

2.0 Selection of bamboo

2.1 Physical factors

2.1.1 Suitable agro-climatic conditions

Most of the best bamboos suitable for towers and buildings are indigenous to tropical and subtropical climates.

2.1.2 Soil

Bamboos usually grow best in deep, well-drained, fertile soils, and they generally prefer neutral to slightly acidic soils although they can grow in a wide variety of the same, except of course rocky soils. Well-drained sandy loam and clay loam are best suited for bamboo farming. If soil is deficient, the extra time and expense of improving in terms of irrigation and fortification are usually well worth the effort and can also provide better results faster.

2.1.3 pH

A pH of 56.0 to 7.5 is good for the overall well being of bamboo growth grass, but it can tolerate pH up to 5.0 (acidic soils).

2.1.4 Temperature

Bamboo can tolerate temperatures ranging from 6° C to 48° C, but the ideal is 20° to 35° C.

2.2 Selection of species for towers

Despite the large germplasm of species with varied characters, bamboo species suitable for tower-making is limited to some 20 to 30. Besides towers, these can be useful for construction and other artefacts utilities, therefore having an assured market as an economical advantage.

2.3 Desired qualities in bamboo for towers

1. **Length:** Approx. 15 to 25 metres from the ground
2. **Straightness:** Should be preferably vertically straight (90° angle) and not bending in between
3. **Diameter:** Minimum 6 to 10 cm from the fifth internode from the ground
4. **Compactness:** The inner sheath should be compact and thick, and not hollow

5. **Tensile strength:** Should have the capacity to bear the pressure of wind flow (44 m/sec). Tensile strength is the maximum stress that can be sustained by a structure in tension
6. **Elasticity:** Ability of the material body to return to its original shape and size when force is applied and removed

Therefore these criteria should be taken into account while selecting the species for commercial farming. From our survey, the following species have the potential to comply with the specific demand and there could be more:

[Table 1.1] Comparison of strength properties of selected bamboo species Vs timber & steel

SPECIES	Geographical area country	COMPRESSIVE GPa	TENSILE GPa	BENDING GPa
INDIA				
Bambusa bambos	Moist zones	50	158	5.8
B. balcooa	E. India	54	75	4.2
B. nutans		98	208	7.7
B. tulda		66	226	6.6
Dendrocalamus strictus	All across	50	73	6.5
Psudooxytenanthera stocksii	S. India	37	60	9.6
Thyrsostachys oliveri	E. India	67	143	8
GLOBAL				
B. vulgaris	E. Asia, China	78	233	20
Guadua angustifolia	S. America	70	200	17
D. ginganteous	E. Asia	76	160	10
Gigantochloa scortechinii	E. Asia	65	160	15
Oxytenanthera abyssinica	Africa	46	120	14
Phyllostachys edulis	China	50	121	15
P. bambusoides	China, Japan	65	159	12
B. oldhamii	China, Japan	52	159	12
B. vulgaris (treated)	China & Africa	78	233	20
Phyllostachys bambusoides	Japanese Timber	52	159	12.5
Bambusa oldhamii - Giant Timber	Native to China, Taiwan and in United States and South America.	65	159	12
Timber (spruce)		43	89	11
Steel		250	410	21

Note: Bamboo possesses higher compressive and tensile strengths when compared with spruce wood, but lower compared to steel. Data in Kgf/cm2 was converted using a factor of 0.098 to compute N/ mm2 (newton/ sq. millimetre).
Gpa = Gigapascal i.e. Kilo Newton (force/ sq. metre).

3.0 Nursery cultivation

3.1 Cultivation practices

This chapter on cultivation practices applies to species grown in tropical and subtropical countries, specifically in India, Indonesia, Thailand, Brazil and Mexico, and applies to all suitable areas.

3.1.1 Management perspective

Following actions need to be taken before initiating bamboo cultivation

a. Identification/selection of best species and their availability

b. Confirming the reliability (on quality) and timely supply of seed source

c. Defining the quantity (No's) of a nursery to be prepared (15 to 20% additional) as per field plantation requirement

c. Identification of place and Nursery bed preparation at a secured place

d. Space and materials like the availability of polybags for further hardening of nursery plants

e. Identification of plantation site and preparation like mapping and pit digging

Most of the institutions like Government agency and private nursery owners do provide inputs but does not guarantee buyback arrangement. Therefore, its imperative that community-based farming should know about the selection criteria to grow plants which is market-based. Most of such farming in India and Asian countries has failed, as it was not market-based nor has the skill to develop into alternative products. Also, a lack of awareness to preserve it led to poor pricing after the harvest.

This manual is trying to bridge pre and post-plantation practices in practical and simple ways of understanding it.

Common suitable species in India are *Bambusa balcoa B. bambos, B. arundinacea, B. nutans, B. tulda, Dendrocalamus strictus, Psuedooxytenanthera stocksi, D. stocksii, Thyrsostachys oliveri*

The following species grown widely across the world are also kept in mind in these guidelines.

South East Asia	Latin America	China	Japan	Taiwan
Yellow bamboo	*Guadua*	*Moso Bamboo*	*Phyllostachys bambusoides*	*Bambusa oldhamii*
B. vulgaris	*Guadua angustifolia*	*Phyllostachys edulis var. pubescence*		*Giant Timber*
Giant bamboo				
Gigantochloa scorentchinii				

Bambus bambos

Thyrsostachys oliveri

B. nutans

B. tulda

Dendrocalamus stocksii

D. stictus

[Photos: 3.1] A few bamboo species ideal for tower building - India & Globe

Bambusa vulgaris - China, grown globally

Guadua angustifolia - South America

Phyllostachys edulis - East China, East Asia

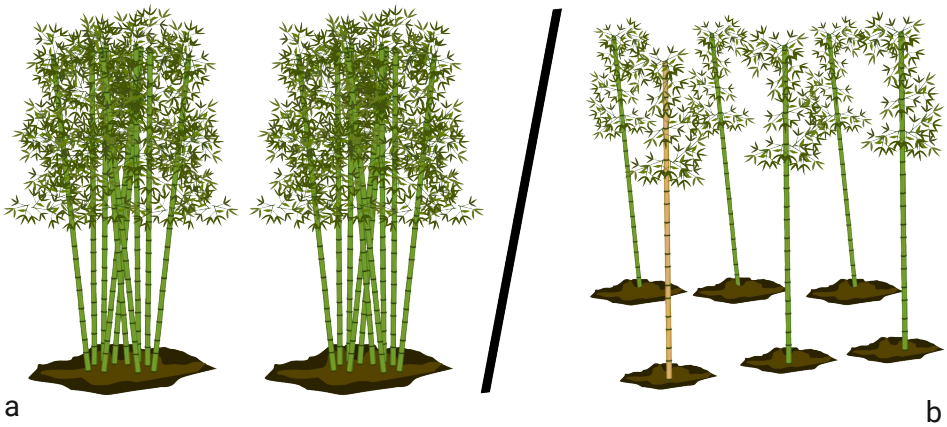
Bambusa oldhamii - Taiwan

Gigantochloa atter - South East Asia

Phyllostachys bambusoides - Japan

[Photos: 3.2] A few bamboo species ideal for tower building - India & Globe

Bamboos are basically classified into two types: sympodial (growing in culms) and monopodial (growing in single stems), based on culms growth or rhizomes.



[Illustrations 3.1] a. Sympodial b. Monopodial

Most of the species come under sympodial; however, these are difficult to harvest while monopodials are easier.

3.2 Planting source

Propagation of bamboo can be done by the following four methods, depending on the species' characteristics and availability of planting materials:

3.2.1. Seeds

Collection of seeds from matured and authenticated sources (January to March is the flowering season). After collection from the field, the seed should be shed-dried (less than 12% of moisture) to extend the storage period and kept in jute bags in a cool place/room. However due to the long maturation period (40 to 100-year. cycles), one cannot depend upon this type of sourcing of propagation materials and hence other methods are more effective in planning bamboo plantation. In bamboo, the seeds cannot be directly planted in the field and have to be used through nursery raising.

3.2.2 Rhizome plantation/offshoot planting

In most cases, the propagating materials are sourced from the circle or vicinity of mature parents or nursery beds. Digging should be done carefully to loosen the soil so that rhizomes with buds remain intact.

Criteria: For selecting rhizomes as planting materials: Rhizomes should be at least four years old. The plant should mostly be green in colour, culm sheath cover intact, and should have the ring on outer side.

Note: Rhizomes should be soaked in fungicides for 10 to 15 minutes before being planted in the nursery or directly in the field.

[Photos 3.3] Bamboo rhizome early stage and mature stage close-up view of the rhizome.

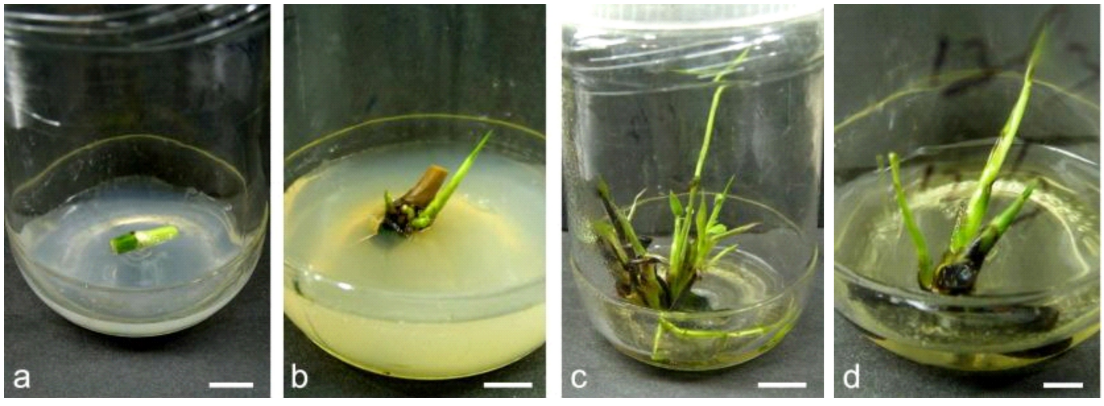
3.2.3. Vegetative plants materials

Part of stems/culms (two to three feet long and having two to three internodes) should be interred two to four inches below the ground horizontally, so that vegetative shoots grow from internodal areas and root formation takes place. In selective species, roots spread horizontally, and so the shoots sprout from these root zones. These can be selectively dug and cut from one foot on either side and used to plant the next generation.

[Photos 3.4] Bamboo cuttings and propagation of vegetative nursery.

3.2.4 Tissue culture

This is the most reliable source as one is assured of purity and free of disease, besides being assured of its supply in time. Saplings are available in huge quantities – in millions. Most commercials ventures prefer tissue culture-sourced materials but the cost and logistics of sourcing limit their access to just a few institutes/commercial organisations. Also, there are issues of early flowering in some tissue-cultured species. This is because the mother plant may be so old the sapling may flower early and die with low yield as it is the same age as the mother culture plants!



[Photos 3.5] Tissue culture-based sapling raised in Petri dish, later shifted to polybags for hardening.

Dendrocalamus stocksii. This species has the most desirable characteristics for the purpose of tower construction but rarely produces seeds that are too infertile, therefore we have to source from rhizomes, tissue culture and vegetative propagation. Therefore nurseries should be sourced from authentic institutes or government agencies.

After a three-month preparatory raising of the nursery (seeds, rhizomes, and tissue culture), the plants should be shifted to polybags for hardening and management (irrigation, counting and removing the deformed/infected plants).

[Photos 3.6] Bamboo saplings raised in polybags through methods mentioned above for two to three months till they are replanted.

3.3 Pre-nursery sowing preparation

Most of the species suitable for tower purposes can either be sourced as rhizome or tissue culture materials. One of the major lacunas is that most species produce seeds after the maturation period of 40 to 100 years. In case seeds are available, one should reaffirm the reliability of desired species' specifics and storage period.

The seeds should be shed-dried to an extent that moisture content is less than 10 to 12%, and stored in a cool place, preferably in jute bags till ready for use.

Seed germination is 90 to 100% during the first year and decreases in subsequent years of storage, reaching to almost 0% thereafter. Therefore, the fresher the seeds, the better the germination percentage.

3.3.1 Seed treatment method before sowing

Seeds should be soaked in water for 12 to 24 hours before sowing and then may be additionally treated with either fungicide (during rainy season) or insecticide specifically against termites (during summer season). Soaking the seeds for a minimum of 12 hours in normal warm water (less than 20° C.) is crucial to break their dormancy. They should then be tied in a gunny bag till used for sowing.

3.3.2 Nursery site

The site should be covered and protected from animals like monkeys, wild boars and goats as these animals love to eat the tender shoots or rhizomes. The nursery should be a partially shaded area, preferably near the plantation site. The ideal sunlight temperature should be less than 27° C. and more than 20° C for best germination and growth. Insecticides can be sprayed after germination at intervals of 20 to 30 days to ward off pest attack by aphids and other insects.

3.3.3 Protective irrigation

As per season and local condition requirements.

Summer period: Spray water daily, preferably in the morning and evening.

Rainy period: As needed; bed should remain moist.

Protection: Seeds and rhizome shoots are soft and sweaty and may be vulnerable to damage by birds, monkeys, rabbits and borers.

For protection from insect infestation: Apply chlorpyrifos or insecticides or fungicides available locally.

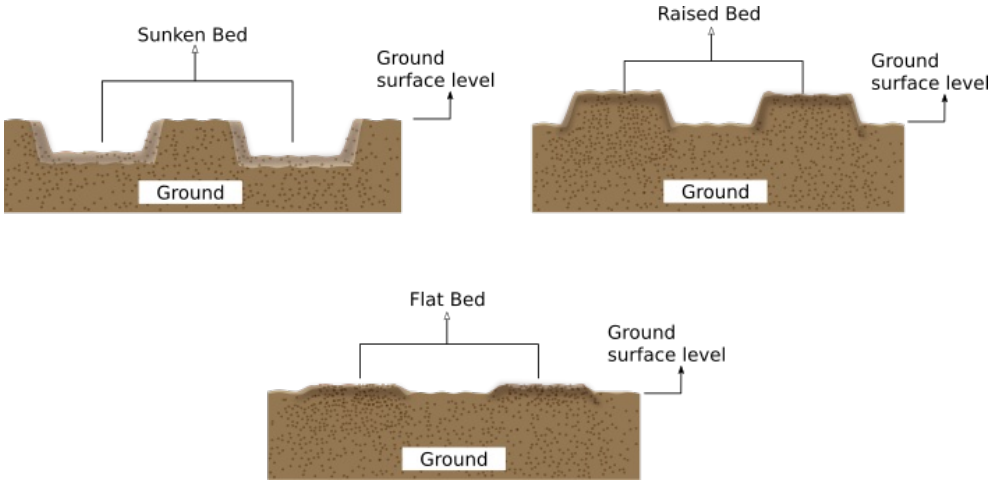
3.4 Nursery

Direct seed sowing and young rhizomes (three to six months old) are not successful for bamboo plantations as they succumb to mortality on the field. Therefore, to be assured of more than 90% survival, select at least year-old nursery plants to avoid gap-filling after planting.

3.4.1 Nursery bed

Nursery bed preparation is a must before seed treatment methods. The bed should be four feet wide maximally and 40 feet long, or could be extended in multiple beds as per requirement. This width is preferable as it is easy to weed and fortify the bed manually. The soil should be manured either with fertiliser NPK or single super phosphate or locally available organic manure.

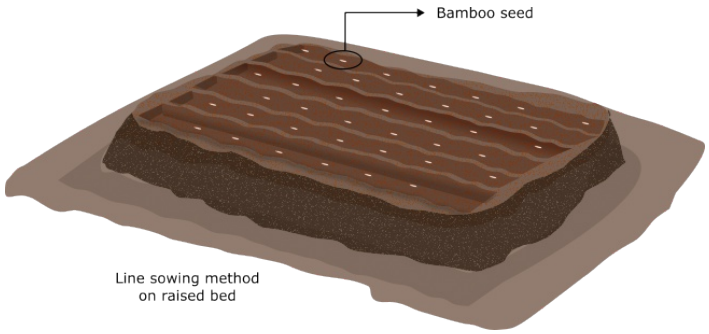
1) **A raised bed of six to 12":** This is to avoid waterlogging during the rainy season (July to September) as it will lead to root rot diseases and mortality.
2) **Sunken bed:** Prepared below the soil surface by six inches. In case sowing is done between October and March, it generates additional heat from the earth.
3) **Flatbed:** The bed is along the ground surface, and bunds raised on the border require less labour. This type of bed works when agro-climatic conditions are favourable, like no rain and normal temperature required protected irrigation.



[Illustrations 3.2] Different methods of preparing the beds.

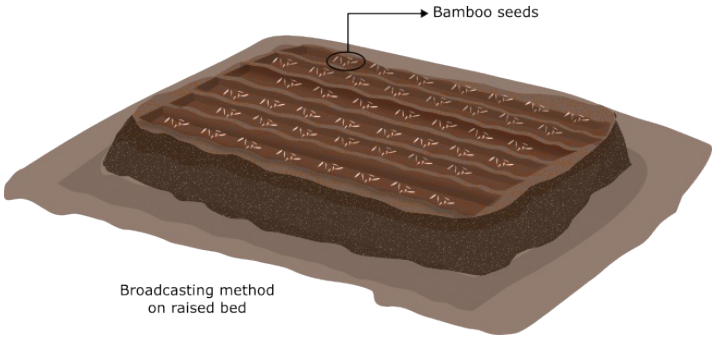
3.4.2 Methods of sowing

1. Line sowing method: A straight line is made on a bed, with tools like sharp rods or sticks or sickles, two or three inches below the manure bed, with a six-inch distance between the lines. After manually sowing the seed on this line, it is covered. Seeds should not be placed any deeper as it will delay germination. The line sowing helps in labour management as it is easy to uproot the nursery plants with tools without damaging the rhizomes, as also to undertake weeding during the initial three-month period.



[Illustration 3.3] Line sowing the raised bed method in the nursery bed.

2. Broadcasting method: The traditional method of sowing is where seeds are broadcast on the nursery beds and the sapling transplanted later. This is more labour intensive because along with the bamboo saplings, weeds also sprout, making it difficult for new farmhands to differentiate which is which. Secondly, while uprooting the nursery for transferring into polybags, most roots are intervened resulting in damaged roots/ rhizome bulbs, impacting the plant's survival in the field as later on they die.



[Illustration 3.4] Broadcasting the raised bed method in the nursery bed.

Therefore, the line sowing method should be preferred over broadcasting for better yield.

3.4.3 Management care

3.4.3.1 Weeding: While nursery beds are being raised, through seeds or rhizomes or vegetative methods, weeds occasionally sprout along with bamboo saplings. Therefore, community/ entrepreneurs should undertake weeding as soon as sprouting takes place as bamboo leaves are distinct from other grasses (weeds). This should be done at least on a monthly basis: two to three times during the nursery period. No weedicide should be used.

Insecticides: As per the requirement

Transferring :

1. Use of polybags: All the planting materials in nursery beds with a gestation period of three to four months should be shifted to polybags (sizes 25 cm x 20 cm or 12 cm x 25 cm) with porous, nutrient-rich soil so that excess water drains out. Big-sized bags help rhizomes to develop well and roots move down the ward.

a) Size of polybags

Observed the mortality in 1 yrs. matured nursery plants

Small-sized polybags (12 cm x 12 cm) have high mortality as rhizomes/roots penetrate the ground or tend to coil, leading to mortality while uprooting them for transfer.

Big-sized polybags face no such problems as the rhizome has sufficient space to grow and can be transferred to the site as per convenience.

3.4.3.2 Irrigation: Preferably in the morning or evening.

3.4.3.3 Pests/diseases: More than 19 types of insects attack the plants, and major pests among them are mites, aphids, bugs and crickets. Chlorpyrifos or any recommended insecticides and trichoderma as fungicides can help to protect the seedlings.

3.4.3.4 Protection: Preferably under the green shed net, as a full enclosure provides foolproof protection against animals and also insects.

3.5 Nursery preparation through community

A bamboo plantation can provide employment opportunities to deprived communities; however, they should be made aware of the benefit of nurseries, and their importance, through meetings and exposure. Involving them in planning and propagating long-term interest in bamboo cultivation will also help them understand the challenges and opportunities.

[Table 1.2] Importance on establishment of nursery through community

S.No	Need of Bamboo Nursery	Importance of Nursery Establishment at community level
1	Bamboos flowers once in life time	Saves time, money and efforts of each farmer to raise seedlings
2	Bamboos flower in long cycles ranging from 40 to 100 yrs. Usually, the cyclic flowering is gregarious and after the entire population dies	Quality planting material is available timely
3	Seeds produced are either washed away in hill slopes during rains or eaten by rodents (rats)	Established under supervision of technical professional
4	Availability of limited seed	Develop local entrepreneurs
5	Seed collection is limited, one time activity with low income potential	It provides employment opportunities for technical, skilled, unskilled families
6	Even in the forest area different block or district have different flowering years	Raising high yielding bamboo plantations in non-forest areas

[Table 1.3] Challenges and approach in nursery/plantation establishment with community

S.No	Challenges	Approach
1	Small and marginal farmer not aware improved techniques of nursery establishment	Regular group meeting with farmers to demonstration site or interaction with successful farming community in this activity.
2	Potential farmers selection	Selection of potential farmers and interaction
3	Availability of quality raw materials : Propagules, fertilisers Timely aftercare	Site visit by field officer
4	Variety identification at farmer level	Site verification by expert
5	Importance of Timely after care activities	Farmers training and demonstrating
6	Farmers needs Start-up capital for establishment of nursery	Handholding support for quality inputs
7	Farmer depends for marketing of saplings	Field facilitation

4.0 Plantation in field

4.1 Suitable planting sites

4.1.1 Land preparation

Well-drained, sandy soil on plain land is suitable for bamboo farming. A soil depth of one metre allows the fibrous roots to provide a strong hold for the main plant even on degraded land.

4.1.2 Climatic condition

Temperature of 6° C to 45° C and humidity range of 60% to 75% are ideal.

Notes:
i) Too acidic and alkaline soil conditions are not favourable for bamboo plantation.
ii) One should also avoid waterlogging and rain-dependent conditions during the first three years.
iii) In the case of rock or murum (gravel)/degraded land, a 1m x 1m pit should be dug for planting the nursery.
iv) Mixed vegetation in the surrounding land is preferred as bamboos are shade-demanding species.
v) Planting the saplings through vegetative means should be in a slanting way and not vertically.

4.1.3 Spacing

As per species requirement, paired and row systems should be advocated

[Table 2] Agro-climatic distribution of few main Bamboo species in India

Species	Common names	Natural occurrence	Soil pH	Rainfall range mm/year	Temperature ^{0}C
Bambusa bambos	Giant thorny bamboo, Female bamboo	eastern, western coasts (moist zones)	5 - 7	2,000 - 5,000	10 - 35
Dendrocalamus strictus	Male bamboo, Calcutta bamboo	dry zone county wide	7 - 8	1,000 - 2,000	5 - 45
Bambusa nutans		Orissa, east India (moist zone)	5 - 6	2,000 - 5,000	5 - 25
Pseudooxytenanthera stocksii		West & southern India (moist zone)	5 - 6		
Thyrsostachys oliveri		North Eastern India.	5 - 6		
Bambusa tulda		Eastern India	5 - 6		

4.2 Planting system

There are two types of plantation systems:

All the species identified for tower purposes require wider spacing as the main trunk grows to a height of 15 to 25 m, as their offshoot rhizomes also require space to grow and cover a minimum of 3 m diameter, while a few species like T. oliveri can be planted at 1 x 1 m distance for biomass/foliage purpose (not for towers).

4.2.1 Block or pit system

Conventionally, bamboos used to be planted at equal distances, irrespective of species. Later on, it was realised that each species require different spacing depending on their multiplication based on the economic cycle (five years to 50 years).

The traditional system (block system model) considered 4 x 4 m spacing (approximately 460 plants per hectare) as ideal. However, some species required specific spacing (Table 3).

This entails the digging of a pit measuring 1 m x 1m or less, depending on the soil condition. While placing the sapling in it, A third of the pit is filled with manure or compost, followed by a mixture of soil and manure or chemical fertiliser. The rest is covered with soil after planting. Depending on termite infestation, locally available chemicals can be used at the base of the root zone while planting.

[Table 3] Following species required spacing and No's of plants/hect. for plantation

S.No	Name of species	Minimum Spacing advocated	Mode of propagation	No of plants/ hect.
1	*Dendroclamus stocksii*	3 x 3 m	Rhizome/vegetative propagation	1110
2	*T. Oliveri*	3 x 3 m	Rhizome/vegetative propagation	1110
3	*B. balcooa*	5 x 5 m	Tissue culture	400
4	*Dendrocalamus giganteus*	10 x 10 m	Seed/vegetative/tissue culture	100
5	*Bambusa bambos*	5 x 5 m	Seeds/tissue culture/rhizome	400
6	*Dendrocalamus strictus* Best when planted along the periphery	3 x 3 m	Seeds/vegetative propagation	1110
7	*B. nutans*	3 x 3 m	Seeds/vegetative propagation	1110
8	*B. tulda D. strictus/P. stocksii*	5 x 5 m	Seeds/vegetative propagation	400

When the plants are about a metre high, they are transplanted to the field. Growing plants from seeds is the most economical and convenient method of propagating large numbers of plants. However, this is limited by availability and germination.

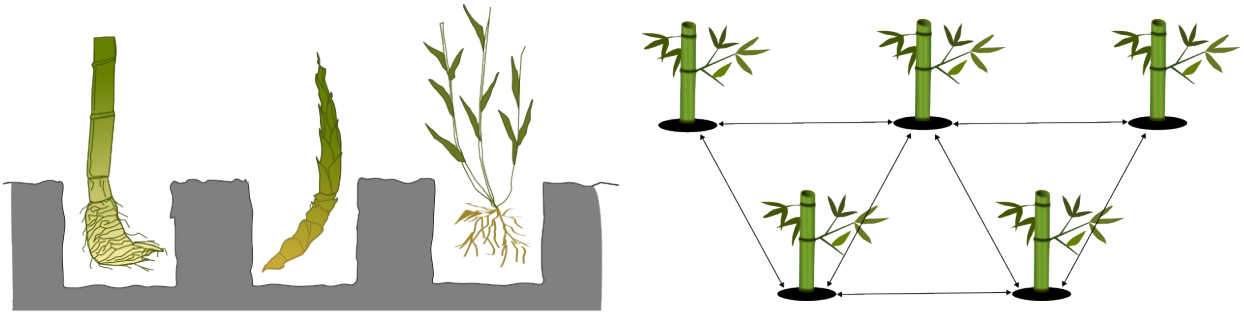
The clump is the traditional and most prevalent method of propagating bamboo vegetative.

Summer sees active growth of young shoots/buds on the rhizome. The commonly recommended practice is to process vegetative propagules just before the growth of these buds.

A clump is divided into two equal parts, retaining the root system, branches and leaves of each part as fully intact as possible. These propagules usually ensure the highest degree of success.

Notes: i) This system of plantation has negative aspects as pruning of side branches, and other care like weeding, are laborious. Extracting/harvesting bamboo poles requires space, particularly when it comes to intertwined growth. Manoeuvring of pruning tools and machinery like tractors is not possible due to space constraints.
ii) Also, generation of additional income through inter-cultivation is not possible here.

[Photos 4.1] In block or pit system of plantation, the bamboos are equidistant.



[Illustrations 4.1] Bamboo planting - pit design and Triangular System

4.2.2 Paired and row system

- This is the most preferred system being followed at the individual or community level as it addresses the shortcomings in the previous models, such as irrigation, labour constraints, additional income through intercrops, manoeuvring of machinery and more bamboos can be planted per hectare here as compared to the block system model.
- The most preferred spacing system is 6 x 2 m (833 plants/ha) or 4.5 x 3.5 m (900 plants), 4.26 x 2.43 m and 4.5 x 4.5 m. However, the spacing may be modulated based on the land and species-specific requirement. A few species require more spacing like 10 x 10 m.
- Though some experts advocate plantation in the north to south direction so that all the plants receive sunlight equally, there are however no scientific studies available in this regard.
- The best advantage of bamboo is that it can be planted in a wide range of locations like farm bunds, along riverbanks, ridges and nallas (ravines) having moist conditions.

[Photos 4.2] Paired and row system with fodder as an intercrop

4.2.2.1 Intercropping:

It is desirable to opt for intercropping initially to meet labour costs, but only for the first three years. Cash crops like chilli, tomato, lemon grass, creeper vegetables, turmeric, ginger, soybean, groundnut, potatoes and millets are viable during the first two years. During the third year, shade-loving vegetables can be cultivated.

Summer or monsoon/autumn is suitable for planting; cold season is not desirable

4.2.3 Pruning and leaf litter

Bamboo should be pruned annually to facilitate good growth. It is a hard task and only secateurs are viable as no machine or knives can be used.

The tools required for pruning the branches are:

a. Simple but good quality pruning secateurs (you will need four or five) are handy for pruning thin branches during the early stages.

b. Long range, anvil type pruning secateurs: These are useful for thick branches, inside branches and those at a height of more than five feet.

c. Pruning saws: For cutting green bamboo poles as chainsaws split the fibres at cutting points.

[Illustrations 4.2] Tools - a. Pruning secateur b. Anvil type pruning secateur c. Pruning saw

It is important to clear leaf litter to avoid forest fires. Bamboo develops more branches in dry zones and so it is a pressing issue. It also needs to be fenced in the initial years to prevent animal attacks.

4.3 Irrigation: Regular irrigation is a must during the first three years

During the initial period, the plantation has to be irrigated at least two to three times a week, depending on soil conditions and seasons. This can be done either through drip or flood system, depending whether the plantation is a block or paired row system. Bamboo grows well in moist soils found naturally along stream banks in forests.

In summer, the frequency of irrigation has to be increased to compensate for evaporation and the plants may likely get sunstroke. In winter it can be once or twice a week while rainy days take care of the watering themselves. The first four years are the formative period for bamboo and irrigation should be consistent. In the fourth and fifth years, the plants are on their own and require irrigation only in summer.

Fortnightly watering can help bamboo growth in autumn, while summer requires weekly watering for the first three years. About five litres of water every three days helps growth.

Drip irrigation is desirable but costly and so the flood (channel) irrigation method is common.

4.4 Manures/ fertilisers

The planting pit should be filled with farmyard manure/vermicompost (five kg per plant) along with urea (five gm per litre) plus five ml humic acid with insecticide (recommended locally 20 gm) spread over the root zone, depending upon the pit size..

First year: After the planting, for first four months, the saplings should be nurtured with a litre of water mixed with five ml humic acid and 5 gm NPK (19:19:19). Three months later, this should be followed by a single basal dose of single super phosphate plus urea mixed in equal proportion (50 gm/plant).

Second and third years: Spread five kg/plant manure along with 150 gm single super phosphate plus MOP 100 gm (March to June) before rains, while the second dose should be only fertiliser after rain. Micronutrients can be added as an additive.

Fourth and fifth years: Spread five to 10 kg of manure, depending upon the diameter of culms, and up to one kg of the above-mentioned chemical fertilisers.

Sixth year onwards: Not required.

4.5 Plant protection

4.5.1 Pests/diseases

Bamboo plants are usually less prone to diseases and hence are preferred over the other mass plantation enterprises. Even so, a few diseases have to be taken care of in the first three years.

There are very few insects that attack bamboo as compared to other crops. But crucial attention has to be paid to weevils as they attack new shoots and bore into them.

Other major threats are root rot or fungal diseases in new shoots, and termite attacks due to excess waterlogging or in dry conditions, leading to mortality of roots. Also to watch out for is witches' broom, a fungal disease.

Precaution: Applying neem cake at the base of each clump during pre-monsoon season may help control pest menace.

Avoid excessive irrigation or moisture in the soil/around the plants. You could use fungicides (either chemical or biological sources like trichoderma) as advocated. Spraying of insecticides around the plants prevents termite attack. Another non-invasive method is to place small eucalyptus branches around the infected plants. The smell attracts termites and they can then be removed manually.

4.5.2 Animals

Bamboo is vulnerable to grazing by goats and wild animals. Elephants and monkeys prefer the tender shoots while wild boars attack rhizomes. It is a good idea to erect a fence to keep out animals in the first few years.

Protection: An aromatic oil solution can be spread around the root zone, as the strong smell will keep away animals, particularly boar, from the plantation site. Therefore, one can opt for deep plantation in such areas.

4.5.3 Fire issues

During the dormancy period, bamboo and other plants shed leaves and become dry. Though these leaves are a good source of mulching/biomass, they are also an inherent source of fire, particularly in dry areas. Hence the leaves can be collected manually or trenches dug at regular intervals. This is so that water can be let into the trenches to extinguish or restrict the fire to avoid damage to growing rhizomes in case of a grown-up plantation.

[Table 4.1] Do and Don't for plantation activity

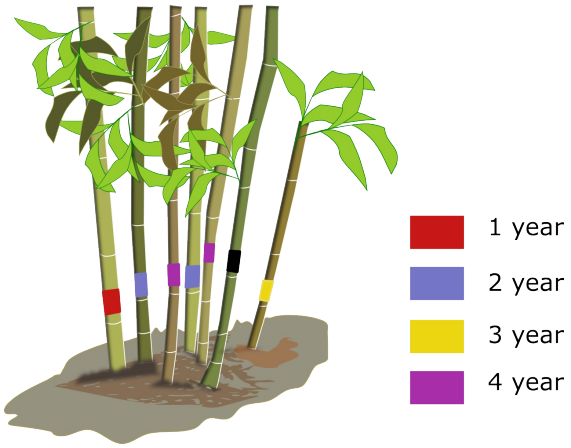
S. No.	Do's	DON'T
1	Well drained land	Water logging area
2	Irrigation for first 3 yrs facility must	Rain fed/shadow area
3	1 m. soil depth for tower specific species	Plantation in Rocky land having less 1m. soil depth result in drying of plants after 3 yrs.
4	Tropical or temperate specific species grow in respective zone.	Don't try or experimenting with opposite zone.
5	Prefer one year old nursery plants	Younger sapling has more mortality (up to 40%), therefore saplings have to be kept in stock for replacement up to 2 yrs.
6	Regular irrigation.Yearly pruning of branches is must do's, remove litter	Avoid planting rhizomes below 1 year age, due to high mortality.

5.0 Harvesting and post-harvest management

Under the irrigated conditions, most plantations reach the harvesting stage in the fourth or fifth year while in rain-fed conditions, it can be as long as six to 10 years. A minimum of four years' growth is needed for base thickening to harvest bamboo poles and the diameter should be measured at the fifth internode from the ground.

5.1 Management system

It is crucial to know the age of each bamboo best suited for tower construction. Colour coding helps in this exercise. As part of best practices, this should be done at the end of the shooting season and the colour applied one foot above from ground. The colour band should be at least four inches wide. One way could be painting a circular band on shoots year-wise: e.g. red (first year), blue (second year), yellow (third year), pink (fourth year) and so on. The bamboo is harvested at four years.



[Illustration 5.1] Colour coding of bamboo shoots as per age (red, blue, yellow, pink and white)

A simple way to cut bamboo is to harvest the inner poles as they may be older, and spare the outside poles in a clump. Monopodial or paired and row plantation systems are easier to harvest, but in sympodial or block plantation, it is a challenging activity unless the branches have been pruned of excess culm removed to avoid dense clumping.

Every cut bamboo culm is replaced by the next year, making bamboo harvesting sustainable, provided that all culms are not harvested at the same time!

5.2 Post-harvest management

Bamboo is soaked in water for a long time and dried to avoid microbial decay due to its high starch content. The following techniques are recommended:

5.2.1 Storage

As soon as they are harvested, bamboo poles should be kept vertically and NOT horizontally, so that sap inside drains out due to gravity. This also avoids warping due to uneven surfaces.

a b c

[Photos 5.1] Storing of bamboo in open and covered methods in a shed in stacks.
a. Criss-cross structure for aeration. b. Covering the poles to avoid exposure to sun and rain. c. Stored in stacks in a shed.

Primary treatment

5.2.2 Water treatment

For retaining quality and extending longevity, it is best to tie the bamboo in bundles and store in a river/pond /canal or artificial structure (any water bodies) for 15 days. This causes the water-soluble glucose /fructose to dissolve and/or avoid oxidation inside the bamboo.

5.2.3. Smoke treatment

One can also apply smoke treatment to avoid infestation from borer pests.

5.2.4. Bio-oils

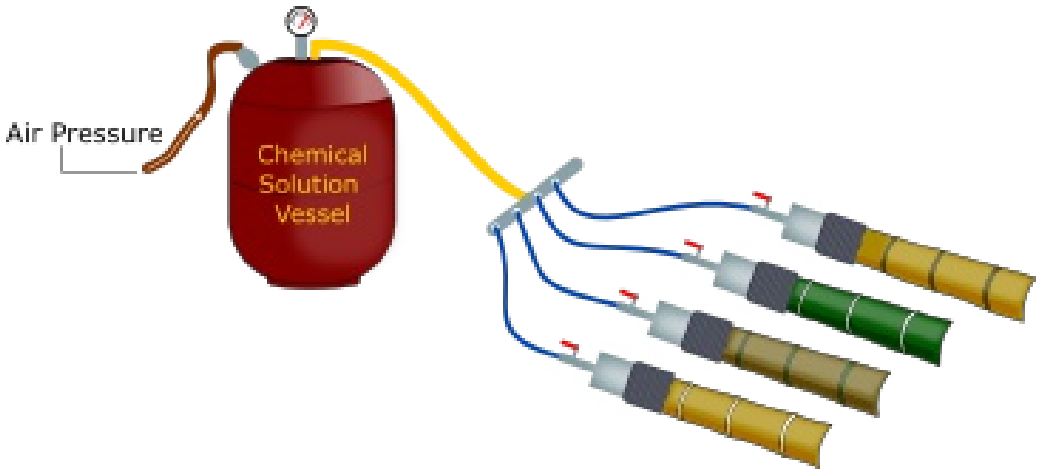
Bio-oils have great potential as a preservative against fungi and termites.

Effluent of paper industry waste could be successfully used as a wood preservative for a limited period.

Traditional bamboo preservation methods such as water leaching, smoke, and Bio-oil treatment are absolutely safe, economical, and environmentally friendly. However, scientific data regarding their effectiveness and the mechanisms involved are very limited.

5.2.5. Chemical treatment

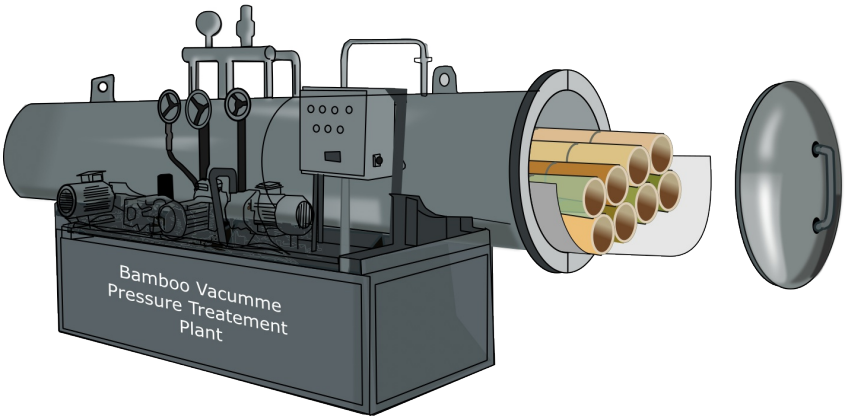
5.2.5.1 Chrome borate solution: This is a very common method of treatment. Inverted poles are kept slanting at 30° to 45° and the solution is poured inside the hole. After 24 hours or so, the solution emerges from the lower end. This treatment is repeated for three to four days and can be done manually or through simple innovation using spray pumps. However, the results may vary according to geography and the skill of the personnel



[Illustration 5.2] Modified Boucherie treatment process

5.2.6 Vacuum pressure impregnation

This is a common method to dry the bamboo, but only feasible in medium-sized enterprises.



[Illustration 5.3] Vacuum pressure impregnation

5.2.7 Post-use

A PVC coating or a coat of varnish is best to preserve dry bamboo against exposure to air, insects and microbes as these are its biggest threats during use.

Recent research has demonstrated that eco-friendly chemicals such as bio-oils, hydrogels and boron complexes are very efficient in improving the service life of bamboo culms.

Examples: In the recently set up bamboo towers in Bali, Indonesia and in Halekote, Karnataka, India two different varieties of treatment were done on the towers. While in Bali, a pre-treatment of sea water and sand gravel mix from the nearby sea shore was used, in Halekote, Karnataka, India, used engine oil procured from the local mechanic shop was injected into the bamboo poles by making holes at strategic locations below each node of the bamboo pole.

6.0 Economics and community entrepreneurship

6.1 Economics

- Due to advancements in processing, bamboo now has a shelf life of 10 to 15 years. If it is well maintained, its utility can extend up to 20 years. There are even treated bamboo buildings that are 50 years or older such as those at the Forest Research Institute of India (*http://fridu.edu.in/*) and in Northeast India (*https://www.caritasindia.org/a-bamboo-house-can-last-for-a-lifetime/, www.bmtpc.org*). Bamboo, with its availability, lower cost compared to timber, lightness and eco-friendly properties, is finding acceptability in cities too, though it is a part and parcel of rural communities.
- And now, the demonstration model of the tower points to one more application. This will help government agencies and private players to use these materials to improve communication networks in rural areas, thereby raising the quality of life for communities there.
- Studies indicate that it becomes economically sustainable when cultivated on a minimum of one hectare of land at the individual level and three hectares at the community level.
- Paired and row systems are preferable for the financially weak communities to support income from intercropping for the first three years.
- It is best to avoid planting bamboo on fertile land as it cannot compare to other cash crops. Low fertile or degraded land, forest areas, or riverine areas with high rainfall or irrigation facilities are better suited for the plantations.
- After the initial four years of maintenance, subsequent management cost is negligible as it grows on its own. Each rhizome has the potential to engender 12 to 35 new culms over five years. This has the potential to produce more than 12,000 bamboo poles per hectare a year. Usually, harvested plants are regenerated in three years.
- One hectare with 1,130 plants (paired and row system) will start yielding in the fourth or fifth year in a well-managed, irrigated plantation, and in the seventh to 10th year in a rain-fed plantation. Annually, a one-hectare plantation yields 5,000 to 8,000 bamboo poles per hectare a year, depending on the species.
- A pole 15 to 20 feet long fetches USD 1 each and a 40 to 50-foot one, twice that. Treated ones can fetch around USD 4 or 5. In contrast, costs USD 10 to 12 for 3' x 4" piece while a 20-foot metal/ iron pole could cost USD 12.
- Working out the economics, the sapling cost is USD 0.2 for D. strictus/B. tulda. A rhizome is USD 4 each and cuttings, USD 1 each. A year-old rhizome is best. From the sixth year onwards, labour and other costs are negligible, a mere 10% of the previous years'.
- A mix of bamboo species – *D. stocksii* 50%, *T. oliveri* 25%, *B. balcooa* 10%, *B. bambos* and *D. strictus* 5% each – is ideal for promoting tower-purpose bamboo plantation.

- Raising nurseries can also community-based entrepreneur activity as it provides income within a short gestation period (six month to a year). A community can produce a minimum one lakh saplings easily.
- The expenses and income will depend on the type of land, agroclimatic zone, management practices and prevailing local market rates. However, the aim is to promote high-value, market-based produce where the community has bargaining power and reaps the benefits.

[Table: 4.2] Economics of bamboo plantation /hectare

Activity wise Expense $/ ha in India - 2022

Activities/inputs	1st year	2nd year onwards	4th & 5th year onwards
Plant Sapling purchase ($ 0.25* 100) Seeding	61	0	0
FYM (farm Yard manure) -1 ton (100 plants* 10kg)	183	183	200
Fertilizers (200 plant * 1kg *$ 0.25/-)	122	200	200
Pesticides (Neem based/1-2 years)	30	30	30
Drip installation installing	1.524	0	0
Irrigation (electricity)	366	366	366
Labour	305	305	305
Machinery Cost (spade, shovel, tractor ploughing	152	0	0
Miscellaneous (harvesting etc.)	305	152	152
Total	3.049	3.049	3.049

Bamboo farming cost-benefit projection (India) - year wise - 2022- $/ ha

Year	Expense	Cumulative cost	Income	Cumulative income	Balance
1	30498	3049	0	0	-3049
2	1159	4208	0	0	-4208
3	1159	5367	0	0	-5367
4	1253	6620	0	0	-6620
5	1253	7873	3000	0	-4873
6	152	8025	3500	6500	-1525
7	152	8177	3500	10000	1823
8	152	8329	3500	13500	5171
9	152	8481	3500	17000	8579
10	152	8633	3500	20500	11867
Total	8633		20500		

Note: Cost not included - land, fencing, rent, loan interest, depreciation, supervision (exchange rate USD 1= Rs. 82 as in Nov. 2022). This value can differ based on local conditions and management practices and prevailing rate, depending on local conditions. The economics is based on the assumption that the community will give primary treatment post-harvest at their level. The net income is USD 12,000/ha in 10 years, i.e. USD 1,200/ha/year.

6.2 Bamboo as a community enterprise

All the activities right from nursery, plantation, harvesting, and treatment cum preservation, can become a community enterprise as the value of the product doubles and triples and even quadruples. Therefore, to make it a profitable enterprise, the community must undertake bamboo preservation and treatment also at the village itself. This will help attract direct buyers.

Earlier, most plantations were a part of social enterprises or government-supported programmes, where the saplings species had less commercial value. At present only 20% of species are useful for tower or construction purposes. This led people to use bamboo only for housing or making simple artefacts for daily use. In most cases, individuals sold non-treated bamboo to the trader who processed and sold it.

Hence, potential communities need to be sensitised and given, due exposure. Farmers could equipped with skills along with some working capital support. A common facility centre (CFC), understanding the market, training in processing, and making local products will set them on their entrepreneurial journey. Start-ups often get incentives such as easy capital, land, water, electricity and initial tax sops.

[Photo 6.1] A group of farmers raising a nursery as an enterprise activity In Maharashtra (India)

7.0
KEY TO SUCCESS

1. The selection of bamboo species should be based on desired quality required for the tower and preferably be growing in the local agroclimatic condition. Selective species of one agroclimatic condition may not be suitable when sourced from other agroclimatic conditions. Tropical species can simulate tropical conditions but not subtropical, and vice versa.
2. Cuttings and rhizomes are a more practical approach: cost-effective and efficient. Rhizomes have a higher success rate but cuttings are much easier and easily available to start a bamboo plantation.
3. Though tissue culture is costly, the genetic purity of the species is assured. It is disease-free and the most reliable way to plan bamboo plantation on a large economic scale.
4. In case the seed is used, it should be soaked overnight in water before sowing. During winter, warm water should be used to break dormancy, leading to more than 95% germination.
5. Line sowing method is preferable while preparing the nursery and seed should be sowed only two inches below the surface – no deeper – and covered with soil to avoid birds, squirrels, etc.
6. As mentioned before, nursery beds should be four feet wide and 40 to 100 feet long with a two-foot gap between beds.
7. The bed should be prepared in accordance with the season: Raised bed preceding rainy conditions, sunken bed preceding winter, and flatbed during summer or dry season. However, a raised bed is better as it is easy to uproot the saplings without injuring the rhizomes.
8. The three-month-old nursery (from seed /rhizomes) should be transferred to polybags for further hardening for the next five to seven months. Failure to do so will result in high mortality (up to 40%), adding to management costs.
9. For field plantation, year-old nursery plants are preferable as the survival rate is more than 95%. Always choose degraded land over fertile as bamboo is long-gestation (four to five years) crop.
10. Always plant 10% to 15% more in the nursery than the total requirement of the field as insurance in case of mortality during the first or second years.
11. Soil depth should be at least one metre and well drained. Paired and row system is easier to harvest and also provides additional source of income during first three years of maintenance. Branch pruning and fortification should be diligently done every year, allowing selected culm to grow while removing undesired clumping of culm in sympodial varieties. As part of management practice, the farmer must undertake colour coding of culm year-wise to identify the maturity of each and harvest accordingly. Leaf litter and compost from the plantation floor should be cleared regularly to reduce chance of fire.
12. The farmer should undergo basic training in plantation and in value addition (suitable low-cost preservation and treatment methods for storage) to derive maximum benefit after harvest.

Useful resources

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Bamboo organisations worldwide

Some of the agencies working on bamboo mentioned below are global or national; many are local. Their contacts may be useful for APC community networks partners to get local info, connects, and ideas. This is the summary of the internet survey.

Global

- **International Bamboo and Rattan Organization**
  Web: *https://www.inbar.int*

- **INBAR,**
  No. 8, Fu Tong Dong Da Jie, Wang Jing Area, Chaoyang District, Beijing 100102, China,
  Ph: +86 10 6470 6161, **Email:** info@inbar.int
  OR PO Box 100102-86, Beijing 10(2) 0102, China.

- **World Bamboo Network**
  Web: *https://worldbamboo*
  The Global Bamboo Resource Directory. **Web:** *https://worldbamboo.net/bambook/g/55*

- **Bamboo Batu Co.**
  Web: *https://bambubatu.com/*
  Ph: +1 805-316-1233, **Email:** mail@bambubatu.com

Regional

ASIA

- **Inbar South Asia Regional Office**
  41, Second Floor, Zamrudpur Community Centre, Kailash Colony Extn.,
  New Delhi - 110048, India,
  Ph: +91 11 4101 5489/90, Email: saro@inbar.int

AFRICA

- **Inbar Central Africa Regional Office**
  Road No. 1860, Behind Bastos Factory, Yaoundé 1st District, PO BOX 17056,
  Yaoundé, Cameroon,
  Ph: +237 222217304, Email: caro@inbar.int

- **Inbar East Africa Regional Office**
  9th Floor, Building 2, Yobek Commercial Center, Addis Ababa, Ethiopia
  Ph: +251 115 579949, Email: earo@inbar.int

- **Inbar West Africa Regional Office**
  Post Office Box CT1679, Cantonment Post Office, Greater Accra, Ghana
  Ph: +233 24 4872783, Email: waro@inbar.int

SOUTH AMERICA

- **Inbar Latin America, Caribbean Regional Office**
  Av. Eloy Alfaro N30-350 y Av. Amazonas, Edif. MAG, piso 10, Quito, Ecuador
  Ph: +593 2 255 8381, **Email:** laco@inbar.int
- **Hacienda Guadua Bamboo**
  Zabaletas, Dagua, Valle del Cauca, Colombia,
  Ph: +57 316 657-1547, **Email:** info@guaduabamboo.com,
  Web: *https://www.guaduabamboo.com/*

National

Nation-wise global directory:

BRAZIL

- **Brazilian Bamboo Producers Association,**
  Guilherme Korte, Brazilian Bamboo Producers Association
  Ph: +55 11 9971 19888, **Email:** aprobambu@gmail.com

COLOMBIA

- **The Best Bamboo,**
  Cra. 34 # 6A-12, Bogotá, Colombia,
  Ph: +57 (323) 2240-640, **Email:** bamboo@thebestbamboo.com
  Web: *https://thebestbamboo.com/*

INDIA

- **Bamboo Society of India,**
  Vana Vikas Building, 2nd Floor, 18th Cross, Malleswaram Bengaluru 560003,
  Ph: +91 80234 69153, **Email:** bamboosocietyofindia@gmail.com
  Web: *https://bamboosocietyofindia.in/*
- **Neelam Manjunath,**
  Manasarm Architects, 3JFC+M53, Sri Venkateshpura Layout,
  Sampigehalli, Bengaluru 560077,
  Ph: +9197318 14333

INDONESIA

- **IndoBamboo,**
  Factory, Jalan Kusuma Bahari, Br. Batur, Ds. Kusamba, Kec. Dawan, Klungkung, Bali, 80761
  Email: info@indobamboo.com, **Web:** *https://indnobamboo.com/*
- **Environmental Bamboo Foundation**
  Jl. Moh. Yamin IX No.15, Sumerta Kelod, Denpasar Selatan Knota Denpasar, Bali, 80239,
  Ph: +62 361 848 6134,
  Web: *https://www.bambuvillage.org/*
- **Bamboo You Training Co.,**
  Denpasar, Indonesia,
  Email: info@bamboou.com, **Web:** *https://www.bamboou.com*

MEXICO

- **Tosepan Bambu,**
  73560 Pahpatapan, 73560 Cuetzalan del Progreso, Pue., Mexico,
  Ph: +52 231 111 8250,
- **Ojtat taller de arquitectura alternativa,**
  Av 7 Pte 102, Centro, 72760 San Andrés Cholula, Pue., Mexicos, +52 712 106 5979
  Email: info@ojtat.org, **Cell:** (222) 1773576 for Spanish, **Cell:** (322) 2460336 for English
  Web: *https://www.ojtat.com/, https://www.facebook.com/Grupo.Ojtat/*

NIGERIA

- **Association for Bamboo Development in Nigeria – ABDN,**
  Web: *https://www.facebook.com/profile.php?id=100075907510841*
- **Rosulu,**
  H.O., Balongun E.O. And Hassan, T.I.*Department Of Agricultural Technology,
  Yaba College Of Technology, Herbert Macaulay Rd. Opposite WAEC office,
  Yaba Lagos, Nigeria
  Ph: +2348023319579, **Web:** *www.yabatech.edu.ng*