BAMBOO CULTIVATION MANUAL

GUIDELINES FOR CULTIVATING

ETHIOPIAN LOWLAND BAMBOO

EASTERN AFRICA BAMBOO PROJECT		
funded by	**executed by**	**supervised by**
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ETHIOPIA	**KENYA**	
Ministry of Agriculture and Rural Development Federal Micro and Small Enterprises Development Agency	Kenya Forestry Research Institute	

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INTRODUCTION

This manual provides basic information about Ethiopia's lowland bamboo species, and thereby aims to increase public awareness about this important natural resource.

Practical guidelines for cultivating and managing lowland bamboo species are offered herein to help growers establish new plantations and manage existing bamboo forests.

The lowland bamboo species is botanically known as *Oxytenanthera abyssinica*. It is a clump forming, solid stemmed bamboo that is widely distributed in the dry regions in the western part of Ethiopia.

Since ancient times, this woody plant has been a vital resource for communities living in the semi-arid regions of the country. It has traditionally been used as a raw material for building and it has also been used for making numerous household utensils, basketry, and handicrafts. It is also a plant with nutritional value: young bamboo shoots can be cooked and eaten as a vegetable, and the foliage can be used as animal fodder.

Bamboo is a fast growing woody plant, and as such, it is a renewable source of fuel which has a heating value comparable to that of timber from trees.

In Ethiopia, lowland bamboo naturally occurs and thrives in areas where living conditions are extremely harsh. The bamboo forests in the western side of Ethiopia are breeding grounds for malaria mosquitoes and tsetse flies. The grave risk posed to human populations, livestock, and domestic animals has compelled farming communities to settle at a distance from bamboo resources. Despite the risks involved, dependence on the bamboo raw material drives local people to go into the forests to extract culms for their domestic requirements.

Clump of *O. abyssinica*

A young edible shoot

The task of harvesting bamboo is very labor intensive. Bamboo stands are often found on very steep slopes which are difficult to reach. Bamboo culms are felled with machetes and manually hauled out of the forests and transported to villages on carts pulled by donkeys. Most areas do not have road access and modern transport is not available.

Much of the bamboo that is harvested is used and sold locally. However, due to inadequate border controls between Ethiopia and neighboring countries, vast amounts of raw materials are smuggled across the border and traded for other goods.

The area of lowland bamboo forest cover of Ethiopia has been diminishing at an alarming rate due to a combination of anthropogenic and natural factors.

Every year, bamboo forests are exposed to uncontrolled bush fire. Burnt forest areas are usually converted into farmland. In many cases bush fires are started intentionally to clear land for shifting cultivation.

The need to provide settlers with farming land has contributed to the destruction of bamboo stands. From 1984-1988, hundreds of thousands of hectares of natural stands around the town of Assosa have been recklessly and indiscriminately cleared by bulldozers for conversion into agricultural plots.

Such interventions have a very negative impact on the environment, and they fail to achieve their intended agricultural aim.

The reason for this is that *Oxytenanthera abyssinica* thrives in very poor and shallow soil which is unsuitable for most cereal crops. The species is very drought resistant, sustains itself with minimal rainfall, and has a very economical water uptake. It helps maintain soil fertility by returning nutrients and humidity to the soil in the form of leaf litter. However, when it is clear felled from the land, the soil dries out and erosion sets in.

To address agricultural needs, it is more appropriate to apply agroforestry strategies that promote the intercropping of cash crops with existing bamboo stands.

Such strategies imply the preservation, management, and sustainability of bamboo forests while creating possibilities for income generation through agroforestry. Instead of clearing entire areas of bamboo forests, corridors within the forest can be cleared for farming. Such corridors would also serve as firebreaks and transport routes. Under such a management scheme, bamboo forest cover can be retained while sustaining agroforestry activities.

GENERAL REMARKS ABOUT BAMBOO

Technically, bamboo is a grass belonging to the subfamily *Bambusoideae*. Over 1200 different species grow worldwide. Various species can reach heights of 30 m and more. About 18 million ha of bamboo are distributed in world forest ecosystems, in Asia, Africa, and America.

Unlike most timber, bamboo is a self-regenerating natural resource; new shoots that appear annually ensure future raw material after mature culms are harvested.

Bamboo provides considerable environmental benefits. In many countries, it is used for ecological purposes such as soil stabilization and erosion prevention on hill slopes and verges. It is a very important forestry plant which is harvested from existing natural forests, plantations, and mixed agroforestry systems. Bamboo silviculture is an option for conserving and protecting tropical forests while creating enduring supplies for the wood and cellulose industries.

Bamboo is a multipurpose plant with a myriad of applications ranging from construction materials, furniture, fences, handicrafts, pulp and paper, edible shoots, and animal fodder. In developing countries, it is a basic raw material with numerous traditional uses. It is highly suitable for handicrafts; it can be woven into numerous products including mats, baskets, trays, hats, lampshades, caps, lanterns, etc. Many bamboo products are functional while others serve decorative purposes.

Apart from its manifold uses in cottage industries, bamboo is also widely used in modern wood and paper industries. Governments, research institutions, and private enterprises around the world are taking increased interest in the environmental and economic possibilities of bamboo. In the last decade, there has been a boom of manufacturing industries utilizing bamboo worldwide.

Bamboo is also a source of food. The cone-shaped sprouts that emerge from the ground to form tall poles are edible vegetables when harvested

young. Bamboo shoots generally appear during the spring or early rainy season. When harvested young, they are a crunchy and nutritious vegetable. Young shoots contain up to 90% water, and are rich in vitamins, cellulose, and amino acids. They have a high nutritional value, are low in fat and high in fiber content. Young shoots vary in size and weight according to species; the edible content of a newly harvested shoot is usually 30% of its weight. Bamboo shoots are sold fresh but are also canned in brine. They are exported worldwide and constitute a multi-million dollar trade commodity.

For most products, bamboo processing does not require high capital investments but is labor intensive and contributes significantly to employment. Skilled labor as well as attractive designs and fine finishing are very important in making bamboo products for commercial purposes. The utilization of bamboo fences is widespread in tropical Africa. Applications of bamboo for structural construction, walls, ceilings, room partitions, windows, furniture, ladders, etc. that are common in Asia could also be developed in Ethiopia and neighboring countries.

There has been a growing awareness in recent years that bamboo is a vital component of development and an effective means to improve the livelihoods of rural poor people. Over 600 million people around the world generate income from bamboo. Hundreds of millions of people in the world live in bamboo houses. Women and children, many of whom live below subsistence levels in developing countries, harvest a great part of the bamboo that is used.

Bamboo is a natural vehicle for development because rural people generally have adequate access to it. It can be easily grown and harvested in the perimeter of forest areas or under agroforestry schemes. Bamboo agroforestry requires only a modest capital investment and generates steady income to farmers. In many parts of the tropical world, the rural poor are dependent on bamboo for their shelter and daily domestic uses.

ETHIOPIAN LOWLAND BAMBOO

The botanical name of Ethiopia's lowland bamboo is *Oxytenanthera abyssinica* (A.Rich) Munro. The local name of this species in Affan Oromo is *Shimalla*, while in Amharic, it is called *Shimel*.

O. abyssinica is a tufted, sympodial bamboo with a height ranging from 3 to 10 meters and a diameter ranging from 5 to 10 cm. The young shoots of the species are distinguished by their bluish green color and their creamy yellow blades. The culms of *O. abyssinica* are useful for woven and plaited products such as basketry, mats, and other handicrafts. The plant is also useful for bioenergy.

Like all bamboos, *O. abyssinica i*s made up of an underground axis and an above ground axis.

The underground axis consists of rhizomes, roots, and buds. The rhizomes collect and store the nutrients that sustain the life of the plant.

The rhizomes exhibit a sympodial branching pattern which gives the plant a clump forming habit.

Buds on the rhizomes develop into shoots that emerge from the ground to form a clump of culms. *O. abyssinica* is thus a typical clumping bamboo.

The above ground axis is comprised of culms, branches, and foliage. Each new shoot elongates vertically into stem or *culm* until it attains its full height. The growth of a culm is completed in one growing season.

The bamboo culm is cylindrical and is divided into sections by diaphragms or *nodes*. The section between two nodes is called an *internode*. Internodes are hollow in most bamboos, but solid in some species.

Harvesting culms in a clump of O. abyssinica

Cross section of culm showing hollow upper culm (left) and completely solid base (right)

The culms of *O. abyssinica* are usually semi-solid when young but solid in older culms. Generally, culms are solid in the lower internodes, and are hollow from the upper half up to the top of the culm. The full length of the culm is between 3-10 meters, but may extend up to 12 meters in exceptional cases. The diameter of the culm at the base ranges from 5-10 cm. The culms are green and densely silky with apprised hairs.

Like all bamboos, new culms of *O. abyssinica* are protected by sheaths that are attached to each node. The culm sheaths of the species typically have a dark brown color. New culms grow to their full height within 3 months and thereafter develop branches and leaves. As the culm matures, it lignifies and becomes harder and stronger. Unlike trees, bamboos do not undergo secondary growth. In other words, the culm does not get thicker each year. Rather, as the rhizome system develops

and matures, new and larger shoots emerge annually until the maximum culm size is reached.

Culms of *O. abyssinica* are fully mature 3 years after they emerge from the soil. As the mature culm ages, it deteriorates and eventually dies and rots. The life of the bamboo clump is however sustained by the rhizome system which annually generates new shoots which grow into culms.

Silvicultural management of this bamboo is heavily based on its growth habit, particularly the way the underground rhizome develops leading to the formation of culms.

Effective management involves systematic but selective cutting of mature culms. Selective harvesting of the crop ensures a sustainable supply of valuable and useful raw material. The removal of mature culms also maintains the vigor of the plant and allows for the continuous generation of new shoots.

The lowland bamboo, *Oxytenanthera abyssinica*

DISTRIBUTION

O. abyssinica is widely distributed in East and West Africa. It occurs in pockets of dry forest areas, savanna woodlands, and along rivers. Natural populations are found throughout Africa.

The distribution in eastern Africa ranges from Ethiopia in the north to Malawi, Zambia and Zimbabwe in the south.

In western Africa, the species occurs in parts of Ghana and Senegal.

The species has been introduced in several Asian countries, most notably in India.

In Ethiopia, the species grows on dry rocky hillsides where the mean annual temperature is above 30°C and where an annual rainfall of about 700-1000 mm is concentrated over a period of three to four months. The species occurs mainly in the western part of the country towards the savanna woodlands of Sudan at elevations between 1200-1800m. Stands of *O. abyssinica* thrive on poor soils and provide a buffer zone for desert areas.

DISTRIBUTION OF LOWLAND BAMBOO IN ETHIOPIA	
Region	**Local areas**
Southern Nations, Nationalities and Peoples Regional State	Gamo Gaelebena Hamer Baco Bench & Maji Majina Goldiya
Gambela	Gambela
Oromiya	Gimbi Guten Kelem Leka
Amhara	Hinde Chilga Wegera
Tigray	Shire
Benishangul Gumuz	Assosa Bambesi Begi Demi Guba Dibate Kamashi Pawae

FLOWERING AND SEEDS

Bamboos, like all grasses in the plant kingdom, are seed plants. Flowering and seeding are necessary for reproduction and new generations. Flowering of some bamboos is cyclic (e.g. every 30 or 100 years), but for most bamboos, flowering is unpredictable. The flowering of bamboos is sometimes followed by the death of the plant, but this is not the case for all species.

In the case of *O. abyssinica, d*ocumented information on flowering differs widely. It is widely held that the species flowers gregariously at intervals of about 30 years, but this is not supported by strong scientific evidence. It may well be the case that the species exhibits both cyclical gregarious flowering patterns as well as unpredictable sporadic flowering, which is followed by the death of the plant. This is not unusual since many bamboo species, for which the flowering cycle is well known, also flower sporadically. Although it is possible that flowering in *O. abyssinica* is influenced by environmental factors, scientific evidence is needed to support this view.

In general, there is still much to learn about the flowering of bamboo, and particularly about the flowering of *O. abyssinica*.

A flowering clump of *O. abyssinica*

It is however clear that the flowering of the species cannot be predicted with any degree of certainty.

Flowering is a rare occurrence. If bamboos start to flower, it is advisable to monitor the event and to collect seeds or wildings in order to raise and propagate a new generation of planting material.

PROPAGATION

Currently, there are no plantations of *O. abyssinica* in Ethiopia. All of the lowland bamboo species found in the country grow naturally in forests.

The uncontrolled exploitation of this resource, however, has resulted in reduced yields and deterioration in quality.

Considering the economic importance of *O. abyssinica*, the continuity of bamboo supplies for local and urban uses will depend on the establishment of plantations and on the effective management of existing forests.

SEXUAL PROPAGATION

Sexual propagation involves the production of new bamboo plants through seeds. Seeds of *O. abyssinica* are viable for a limited time, seldom for more than 10 months. Because of this poor viability, seeds need to be collected and sown in nursery beds without delay.

If wildlings or naturally growing lowland bamboo seedlings in the forests are available, these can be collected and used as planting materials.

Seedlings of *O. abyssinica*

Asexual Propagation

Bamboos can more easily be propagated using vegetative material such as rhizomes and offsets. Propagules are considered to be successfully established when they form new rhizomes and start to develop new shoots.

Propagation by means of Offsets

The most effective way of propagating *O. abyssinica* is by means of offsetting a culm from a clump. Although this method has a high success rate, it is not the most practical method for large scale propagation, nor is it the best way of obtaining planting material that will be directly

planted in the field. This is due to the labor intensiveness of the method and the time and logistical costs involved in obtaining and moving a large number of offsets to the field. The method of offset propagation is however very useful when one desires to raise a few clumps in a homestead or farm. It is also an excellent way of obtaining mother plants that can be further macroproliferated at nursery.

The method of offsetting involves separating culms from clumps and shortening them to the node above the first branches. Since the branches of O. *abyssinica* typically appear at upper nodes of the culm, the offsets will be very long and heavy, and not practical for transporting to another location. Some preparatory work is therefore advisable before proceeding with actual offsetting.

- 6 to 12 months before obtaining offsets, make a selection of 1 to 2 year old culms that will be used. Culms of this age can be identified by their green color and their culm sheaths have fallen off.

- The culms should be selected from a healthy and vigorous bamboo clump in the forest or homestead farm.

- Cut down or coppice the culms just above the 4th or 5th node from the ground.

- Remove all foliage and small branches and use them to mulch the clump. This returns nutrients to the soil and is a practical means of clump management.

- The coppiced culms will generate branches in the lower nodes. These shortened culms can be effectively offsetted after they have developed some branches and foliage which enable photosynthesis and growth.

Branching and new leaves on lower nodes
of coppiced culm of *O. abyssinica*

At the onset of the rainy season and just before the emergence of new shoots, offsets can be obtained from bamboo stands as outlined below:

- If the above mentioned preparatory activities are carried out, the selected coppiced culms which have developed some branches and foliage at the lower nodes can be used as offsets.
- Dig out about 60 cm below the ground to expose the rhizomes of the culm that has been selected for offsetting.
- Once the rhizomes are exposed, cut back the aerial culm just above the first branches with leaves, but not lower than the third node.
- Cut the rhizome off from the parent clump. Avoid injuring the junction of the culm and rhizome and the underground dormant buds at the base of the culm.
- Cut the roots and soil at least 10 cm away from the rhizome so that the offset includes rhizomes with roots and soil.
- Replant the offset immediately and flood it with water, and mulch it.
- If planted directly on the ground, make sure that the planting hole is sufficiently deep and large to facilitate the easy development of new shoots.
- If planted in a container, make sure that the container is sufficiently large and deep to allow the plant to grow as it would on the ground. Make sure that the container has holes so that there is good drainage.
- Water the plant frequently so that the soil is always moist.

SETTING UP A BAMBOO NURSERY

Establishing a bamboo nursery is a practical solution for maintaining a regular supply of planting material for plantations and forestry projects. The nursery does not require high investments. Basic equipment for manual operations can be used.

SELECTION OF A NURSERY SITE

Several factors should be considered in selecting a site for a bamboo propagation nursery.

Location and Accessibility: If possible, the nursery should be located near a highway or public road to facilitate operations, communication and transport. Ideally, the nursery site should be as close as possible to plantation areas. This will involve less transport time and costs in delivering plants to the field. Plants will undergo less stress during transport the quicker they can be delivered to the field.

Water Supply: This is a critical aspect of a bamboo propagation nursery. The nursery should be located in an area where there is an abundant and permanent supply of water. If the supply of water during the dry seasons is inadequate, a storage tank should be constructed. The amount of water needed depends upon the nursery size, watering frequency, rainfall and climatic conditions, the species to be raised, the quantity of propagation materials, and the method of watering to be employed.

Topography: Local topography is a crucial factor and ideally, the site should slope gently to about 5° so that rainwater can run off without causing erosion. In general, hilltops and valley bottoms are unsuitable; locations on middle to lower slopes are preferable.

Soil: Nursery production requires well-drained and fertile soil with a medium to light texture.

Sun and Shade: Plants in a nursery need a good balance of sunlight and shade. Sites that are heavily shaded throughout the day should be avoided. Partial shading is desirable in the very dry areas to prevent excessive day temperature. Arid areas with desiccating conditions are not suitable for a bamboo nursery.

NURSERY SIZE AND LAYOUT

The size of the nursery depends on its intended production capacity and on the size and age of plants to be grown. A nursery dedicated to the production of young liners or seedlings which are to be delivered to other nurseries will require less space than a nursery which grows and stocks older and larger plants.

On average, the amount of time bamboo seedlings have to remain in the nursery ranges from 8 to 12 months. In general, at least 5000 m^2 should be allotted for every 10,000 seedlings or young plants that will be raised annually. If seedlings will be grown at the nursery until they are 2 years old, then the area needed for production should be doubled. Adequate space is needed to maintain a stock of growing plants. A crowded nursery will only result in the production of poor stock quality.

The shape or layout of the nursery should be approximately square to minimize the length of the perimeter. This will not only reduce the cost of fencing the nursery, but will also enable faster movement of workers from one point of the nursery to another.

The area needed for paths, roads, irrigation, ditches, and buildings should also be taken into consideration, and represents additional space requirements to the entire nursery unit. Having more land than initially required provides an allowance for future expansion of the nursery production area.

TEMPORARY AND PERMANENT NURSERIES

The type of nursery that is established, including all infrastructure requirements, will depend on the duration of cultivation.

If plants or seedlings only need to be cultivated to provide planting material for one large plantation or for a group of small scale farmers in a given area, then a temporary nursery is usually sufficient.

A temporary village nursery near Assosa

A temporary nursery can be set up using very basic and low cost materials that can often be obtained in villages near the site. Concrete structures and sophisticated and expensive tools are not required; simple shade houses using palm or bamboo roofing are suitable in most cases.

However, if the nursery is intended to be used for a period of at least five to ten years, then permanent and durable structures should be built on site. The nursery should also be easily accessible by road at all times of the year. A permanent nursery is needed when mass propagation of planting stocks will be undertaken year after year.

Low-cost shading structure of a temporary bamboo nursery

NURSERY INFRASTRUCTURE AND EQUIPMENT

The infrastructure of a nursery generally includes an office and meeting room for workers, a warehouse or storeroom, a potting shed, a compost area, lath houses, shade tunnels, and an open-air container ground. The number and size of the structures will depend on the production capacity of the nursery.

Polyester ground cover cloth for the open air ground for plants in container or polybags is used in many professional nurseries since this prevents plants from rooting into the ground. This material is costly however, and is optional. Such an investment is however worthwhile when the nursery is intended for commercial purposes and investment costs will be recuperated through the sale of plants.

Irrigation in the nursery is essential. Irrigation may be done manually, but it is advisable to invest in a sprinkler system to ensure proper irrigation, especially in larger nurseries.

Tools such as spades, picks, pruning scissors, and wheelbarrows are essential equipment for manual operations in every nursery. Such equipment is affordable and does not demand a high investment.

Construction of the nursery can be divided into two phases. The first phase includes planning the site layout, clearing the land, leveling of the nursery grounds, excavating gutters and ditches, laying foundations, preparing pathways, installing piping and/or irrigation hoses, and primary installment of utilities. The second phase covers the construction of the buildings, lath houses, shade tunnels, and sheds.

PREPARATION OF THE OPEN NURSERY FIELD

Clearing and leveling of the land is the first step. The open field should be at a gentle slope of about 5° to ensure water run-off. The ground must be flat to prevent the water from accumulating in puddles. This is imperative because the bamboo plants will be cultivated in polybag tubes, which must never be submerged in water. The drainage system must be well planned. Gutters and trenches should be dug out to prevent water from flooding the container field.

As mentioned, using ground cover cloth is a proven way of reducing the risk of grasses and weeds from infesting the open field production area. The synthetic woven fabric is made of tough UV stabilized polypropylene yarns and is designed to inhibit weed growth and improve the

appearance of the nursery. It blocks sunlight and thereby prevents weeds from infesting the potted plants while allowing water and nutrients to freely pass through the soil. The use of ground cover fabric eliminates the need of applying large quantities of herbicides to the soil prior to bringing in the potted plants. While weed control through the application of herbicides implies a lower initial cost, it however involves work and maintenance all year long. The use of a ground cover cloth involves a moderate investment, but weed control will be more effective and requires less maintenance and labor. This option should therefore be considered depending on the purpose of the nursery and production scale that is forecasted.

GREENHOUSE STRUCTURES AND DESIGN

A greenhouse can be established without costly materials and equipment that are commonly used by nurseries in temperate regions. In tropical countries such as Ethiopia, there is only a slight variation in seasonal and nocturnal temperatures. This eliminates the need for expensive climate control systems. On the other hand, it is essential that the greenhouse structure is designed such that good cross ventilation can be provided by openings in the sides of the greenhouse.

The greenhouse structure can consist of a metal or wooden framework. The aim is to build sturdy structures that provide protection from wind, rain and excessive sunlight while providing very good natural ventilation.

A lath house or open-sided structure can be used to provide shade to young bamboo plants. The lath house protects container grown plants from high temperature and high light intensities. It is effective in reducing moisture stress and reduces irrigation requirements.

The roof of the lath house should be spaced with laths or slats, spaced with gaps as wide as the slats themselves, providing approximately 50% shade. Bamboo or palm thatching may be used as a low cost roofing material for the lath house. The walls are ideally made of cloth also providing at least 50% shade. The walls of the lath house should be

inclined, so they can resist wind. Doors can be made by cutting the cloth of the walls and can be kept closed using hooks.

A lath house has many uses. First and foremost, it is used as shaded area that safeguards young plants from direct sunlight. It is also serves as an area for maintaining, propagating, and transplanting young plants.

Alternatively, or in combination with a lath house, shade tunnels can be used at the nursery. Shade tunnels reduce light levels for the plants in cultivation protecting them from leaf bleaching or leaf scorch in strong sunlight. At modern nurseries, shade tunnels are usually constructed using steel hoops which are covered with polyethylene film or shade cloth.

A low cost shade tunnel can however be made using a combination of wood and bamboo strips, in combination with white polyethylene film. Flexible bamboo strips can be joined together and shaped into hoops. The bamboo hoops are then positioned on the ground to form a tunnel framework that is supported by round wood or bamboo poles. The framework is then covered with a polyethylene film to provide shade and protection to the plants. This low cost alternative will have the same effect as more expensive metal structures. It may not be very durable, but replacing or repairing any damages to the tunnel structure will involve very low costs.

Ventilation in the shade tunnel is achieved by creating openings on the sides and at both ends of the tunnel. Cross ventilation through these openings will enable the structure to withstand strong winds.

COVERED WORK SPACE

It is useful and advisable to provide a sufficiently large covered work space where propagation activities can be carried out. The design of the work space should be simple and functional. Benches made of wood can be used to facilitate manual operations such as dividing plants and

potting. Aisles space is necessary to allow easy movement between the benches, while at the same time maximizing the production space.

Water Supply and Irrigation System

Provisions should be made to allow for water harvesting during the rainy season in order to have sufficient water supplies during dry periods. A large tank can be used for this purpose; alternatively, a water reservoir can be excavated.

It is advisable to have a basic irrigation system including a deep well, pump system, and sprinkler system with controllers. This equipment involves a modest investment, which can go a long way in maintaining healthy and vigorous plants in the nursery.

The alternative to investing in an irrigation system is to have a very disciplined workforce that diligently waters the plants in the nursery every day. For a small nursery, manual watering of plants is possible, but for a nursery with a production capacity of thousands of plants, investments in a pump and sprinkler system are necessary to ensure proper irrigation and to minimize plant mortality.

Storage Room

A small building or shed is needed as a stock room for storing pesticides, fertilizers and tools. The stock room must be spacious enough to stock all materials. It should be well insulated to protect all materials from rain and excessive humidity.

Potting Soil

An area should be allocated for stocking components of the soil mixture. There must also be a leveled area to stock organic material for the composting process.

The amount of soil mixture needed will obviously depend on production activities. During periods of intensive potting, several cubic meters of soil mix may be required per day. The soil mixture can be prepared on site using traditional techniques. Making the potting soil involves using the right proportion of materials to create a good balance between water and oxygen allowing for good porosity and drainage. Soil fertility and plant growth can be stimulated using locally available organic inputs such as cattle and chicken manure, fish residues, groundnut shells, bran, and rock phosphate. In addition to providing nutrients, organic fertilizers also help to conserve water. The soil mixture should have good drainage and a pH value of 5.5, which is perfect for bamboo. Slow release fertilizers, such as Osmocote, can be used to enrich the soil mixture. This fertilizer will supplement the mineral nutrients of the plants in cultivation.

FENCES

A fence should be erected around the perimeter of the nursery to protect the nursery area from domestic and wild animals. The fence should be about 2 meters tall and may incorporate the use of barbed wire for added security.

NURSERY OPERATIONS

Operating a nursery efficiently requires a strong attention to detail and a high level of quality control. Young plants are like infants and need tender loving care so that they grow healthy and strong. The nursery manager or supervisor needs to strictly enforce standard operating procedures to ensure that all the plants in production receive adequate care and attention. Every stage in production, from potting, propagating, weeding, irrigating, fertilizing, etc., is crucial to the survival and vitality of the nursery stock. Staff working at the nursery must diligently perform their duties in the service of the young plants. Nursery workers should be selected carefully based on their ability and dedication to propagate and maintain healthy bamboo plants.

POTTING CONTAINERS

A sufficient quantity of containers or polybags of various sizes should be available at the nursery to fulfill potting requirements. The potting containers should be large enough to allow root development of plants of different sizes.

For seedlings, polythene tubes with 20 cm diameter x 40 cm height x 0.04 mm thickness are sufficient.

Larger polybags with a 40 cm diameter x 50 cm height will be needed to transplant the seedlings once they have grown and have started developing new shoots.

Failure to transplant growing plants to larger containers will impede root development and shoot generation, and inhibit their overall growth.

Preparation of Potting Soil

The best organic soils should always be used for cultivating nursery plants. As noted previously, a nursery should be situated near a supply of fertile soil.

A potting mix consisting of 50% forest soils, 25% sand soils and 25% other organic manures is ideal for potting bamboo.

Soil should be sieved to remove large lumps and stones. If necessary, fertilizer should be added in granular form when preparing the soil mixture.

If the soil mix contains many weed seeds, it is desirable to fill containers 3-4 weeks before sowing so that the seeds can germinate and be eliminated in advance.

Seed Propagation

In general, bamboo seeds should not be stored for a prolonged period of time. They have has a short-lived viability and their capacity to germinate rapidly begins to deteriorate after two to three months. Because of this poor viability, it is advisable to collect and sow the seeds without delay.

Seeds may be sown in a nursery bed or in polyethylene tubes filled with soil and then covered with a thin layer of soil.

Seeds of *O. abyssinica* should be sown either by dibbling with a stick or finger, to a depth equal to its shortest dimension or laid on the surface and covered to this depth.

Seeds of *Oxytenanthera abyssinica*

The planted seeds should be maintained in a shaded area and protected from direct sunlight. This is the favorable environment for high germination. In most cases, not all seeds will germinate, but numerous seedlings will develop provided that a generous amount of seeds have been planted.

The seeds should be watered daily and must be kept moist at all times. Watering should be done carefully using a fine rose can. Watering is best done in the morning or mid-afternoon, but never at mid-day to avoid the risk of scorching.

Very young bamboo seedlings (as well as small culm cuttings) are very susceptible to sun scorch. Shade capable of blocking up to 75% of direct sunlight should be provided to protect the plants.

Seedlings should be mulched during initial months. Mulching protects them from intense heat, strong winds, and the impact of raindrops. It also helps prevent the rapid evaporation of soil moisture. Dry grass, leaves, and straw are suitable materials for mulching. The kind and amount of mulch will depend on the time of sowing, and rate of growth of seedlings.

Seedlings that have grown to a height of about 5 cm should be gently pricked out of the seedbed and transplanted into polyethylene tubes. After 8-12 months from the date of transplanting, good-sized transplants can be obtained.

CULTIVATION OF WILDLINGS

Profuse natural regeneration of *O. abyssinica* usually occurs on the forest floor after bamboo flowering. Ripe seeds fall on the ground and germinate on site. Weeds and inter seedlings competition usually affects the establishment of most of these young plants.

Patches of wildlings in a two-leaf stage may sometimes be found on the forest floor after flowering has occurred. In case bamboo seeds are not available, these wildlings can be cultivated and used as propagules at the nursery. The wildlings should be carefully collected by scooping the soil on which they stand and quickly taken to the nursery and transplanted on shaded soil bed. Once the plants have grown to a height of 5cm, they should be individually pricked out and transplanted into polybags.

The lowland bamboo *O. abyssinica* wildlings

POTTING

Potting of propagules should be done carefully to ensure a high survival rate at the nursery.

Polythene tubes or polybags are commonly used potting containers. Polybags with a size of 40 cm x 50 cm are suitable for small bamboo plants and generally provide sufficient space for the development of roots, rhizomes, and new shoots.

If the polybags do not have holes at the base, it is necessary to perforate some holes to provide drainage and thereby prevent the roots from being waterlogged.

A light potting mixture with good drainage should be used at all times. Heavy soils should be avoided since they will constrain the growth and development of the young plants.

The potting procedure involves the following steps:

- Fill about 1/3 of the polybags with the soil mixture.
- Place the roots and rhizomes of the plant in the center of the polybag and fill up the remaining portion of the polybag with soil ensuring that the base of the stems are on the level of the soil.
- Compact the soil in the polybag moderately.
- Water the newly-potted plants.
- Place them in a shaded area or in the lath house and ensure they are regularly watered.

Potting mixture with good drainage

FERTILIZER APPLICATIONS

Fertilizer application may be done in the seedbed in conjunction with watering long before transplanting. This is done by dissolving complete NPK fertilizer (14-14-14) or (15-15-15) at the rate of 10g per liter of water.

Fertilizer may also be applied at the time of transplanting. After filling the pot with soil, a pinch (approximately 0.25g) of complete fertilizer is dropped at the hole where the seedling will be transplanted.

If available, slow release fertilizers such as Osmocote can be used for plants that are at least 1 year old.

MACRO-PROLIFERATION

When seeds or wildlings are not available and a large quantity of planting materials is required, the method of offsets should be integrated in a nursery macro-proliferation program. Offsets taken from the field should be immediately taken to a nursery and planted in large containers with drainage holes. Macro-proliferation involves the method known as clump division.

Division of plants on site provides a means for lowering overall costs and increasing margins. Care must however be taken that this process is planned and supervised in order to maintain a high level of quality.

At the nursery, the following procedure should be followed:

- Offsets placed in containers should be maintained and regular weeding is necessary.
- When the offset has developed at least 2 new culms, it can be divided into at least two plants.

- Division should de done prior to the development of new shoots in the spring.
- Prepare new containers filled with a light potting mixture.
- Remove the plant from its container and shake of the soil so that the rhizome structure can be examined.
- Divide the clump into 2 or more plants following the same method used in offset propagation.
- Replant the divided plants in new pots with a loose potting mixture, then water and mulch them regularly.
- One plant should normally yield at least 2 new plants every year.
- Always maintain a stock of plants that are regularly propagated and divided at the nursery.
- To ease delivery of plants to plantations, the plants can be shortened by cutting the stems above the first nodes with leaves and branches.

Macro-Proliferation (division) of lowland bamboo

IRRIGATION

Irrigation is a critical factor for the production of healthy plants. A deep well or water tank must be relied upon as a source of water if the nursery is not located along a lake or river. A pump and sprinkler system will allow for effective watering on a regular basis. Young bamboo plants need water daily; without water the soil humidity in the containers is reduced and the plants can become dehydrated. The plots of growing plants should be controlled on a daily basis. It is also necessary to ensure that the irrigation system is functioning properly so that plants in all areas of the nursery are watered. In the event that the irrigation or sprinkler system fails, plants should be watered manually. Failure to water plants will result in heavy losses.

WEEDING

Weeds compete with bamboo plants by absorbing nutrients, water, and sunlight. Weeds have rhizomes which sprout again if not removed. Measures to control weeds include a thorough preparation of the soil before sowing and the use of sowing media and manure which are free of weed seeds. The removal of weeds growing within the vicinity is also strongly advised in order to lower the occurrence of seed dispersal by wind or water.

The following are recommended practices in weeding:

- Weeding should be done thoroughly, systematically and regularly.
- When removing weeds from soil, no portion of the root system should be left behind.
- Weeding should be done only when the soil is moist.
- Weeds that have been removed should be properly disposed off in a rubbish heap.

- Wherever practical and convenient, mechanical weeding tools may be used.

HARDENING

After being transplanted or potted, the seedlings and cuttings are kept under 50% shades. But as soon as transplants have recovered and commenced growth, they should be exposed to more light and gradually hardened. Hardening is achieved by progressively exposing the plants to more adverse weather conditions similar to those in the planting field. By the time seedlings and cuttings are ready to be planted out in the field, their roots should be well developed and have healthy green foliage, which are prerequisites for shoot development. At least, one month before planting out, they should be bared to full sunlight and moved to the open field nursery where they are maintained up to the time they are taken out of the nursery and transported to field planting sites.

Fertilizer should not be applied during the hardening period, especially two months before field planting, to prevent the development of succulent tissues.

QUALITY CONTROL AT THE NURSERY

Quality control procedures should be applied from the moment of construction and installation of the nursery up to the time that plants are delivered to customers. The levels of quality control are described below.

GENERAL MAINTENANCE

Throughout the culture, it is necessary to regularly control plants and check on their root and shoot development.

If the plants stay in the nursery longer than anticipated, they must be pruned to a height of 40-50 cm, which can be done using hedge-trimmers.

It is also necessary to make inventories and to make sure that plants are properly labeled. This is crucial especially if the nursery cultivates different bamboo varieties.

The nursery should be kept clean and orderly. Equipment and tools should be regularly inspected, maintained and repaired when necessary. The structures, paths and plots should be periodically inspected to ensure that they remain in good condition.

QUALITY OF THE SOIL MIX

The pH of the soil mix must be controlled and brought to an optimum value. At pH of 5.5, the bamboos assimilate the nutritive elements better and show improved growth. If necessary, the pH of the potting soil mixture can be raised using chemical products such as Calcium carbonate and Calcium sulfate.

Quality Control During Repotting

During repotting, young plants must be protected from direct sunlight and dry winds. This is best achieved by performing the potting activities under a shaded area and immediately transferring the plants to the lath house or shade tunnel.

Careful attention must be paid to the plants during the first three weeks that follow the repotting operation. Initial irrigation must be abundant, and in the weeks following the repotting operation, irrigation must be frequently done.

Phytosanitary Treatments

Controlling the weeds is a regular maintenance task. If the potting soil components have not been disinfected, there will be too many weed seeds. Effective weed control and reduced manual labor for weeding can be achieved by using anti-germinative herbicides such as Cent 7, which has isoxaben as its active agent.

The first anti-germinative treatment should be carried out just after repotting at a rate of 6 liters/ha. Three months later, a second treatment must be done, just before the plants are brought to the fields. Nevertheless, a certain amount of manual weeding will be needed during the time the plants are in the nursery. In spite of reducing the time spent in weeding, herbicides cannot completely eliminate weeds and certain weeds manage to break through the Cent 7 film.

The paths between containers in the open field nursery can be treated with a solution of Roundup and Decimax. These herbicides have a systemic effect, penetrate the roots, and have a persistent action in the soil. Herbicidal treatments can be applied 4 to 5 times per year depending on weed infestation.

Bamboos only have a few natural enemies and they normally do not suffer from attacks or diseases when planted in the fields. Nevertheless,

a regular control can help to avoid invasions and infections, as well as to determinate the tolerance level to any problems. In the nursery, however, certain preventive and curative treatments will be necessary. Following the soil preparation in the nursery and before setting the plots, a treatment against ants and termites must be carried out. Spraying of the soil with Decis (deltamethrine) at 15 g/m^2 or with Diazinon (240 g/l) can be very effective.

The phytosanitary treatments in the nursery will be essentially of a curative nature, as in the case of the borer beetles that attack the young culms (*Estigmena chinensis*, *Conarthus jansoni*) or leaf rollers (*Pyrausta coclesalis*). These pests occur only occasionally.

Other treatments must have a preventive nature, to avoid the pests commonly found in the nurseries, such as aphids. The use of an insecticide such as the Pirimor will provide a good control over aphid populations. This insecticide has a persisting action and remains active for months; this helps to reduce the number of treatments, while protecting the culture.

Treatments with fungicides will be applied when common cryptogamic diseases arise (e.g. *septoriosis* and *fusariosis*). Serious diseases such as the *Rhizoctonia solani* can be avoided by utilizing good potting soil, but frequent controls must nevertheless be carried out.

RODENT CONTROL

Rodents may cause damage by eating the shoots and roots of the bamboo seedlings. Control of these animals can be achieved by laying traps or poisonous baits, or through other local methods.

PLANTING BAMBOO IN THE FIELD

Prior to planting bamboo in the field, a planting scheme which takes into consideration the size and growth habit of the species has to be determined. For *O. abyssinica* the recommended spacing is 7x7m or 204 plants per hectare. This distance provides sufficient space for intercropping and allows greater ease of movement for maintenance and harvesting activities. A 5x5m layout with 400 plants per hectare may however be used for riverbank and gully stabilization, or when intercropping of cash crops is not intended. Field planting can be done either by direct planting of culm offsets or by using nursery-raised plants.

As mentioned earlier, the use of culm offsets for a large plantation is not practical. The preferred types of planting materials are bamboos raised at a nursery.

SELECTION AND TRANSPORT OF PLANTING MATERIAL

Plants that are used for planting in the field should be hardened at the nursery before transporting them to the planting site. Plants which are very young and delicate have a lower chance of survival in the field. It is important to select plants that have well developed roots and rhizomes. Such plants will be able to absorb nutrients from the soil and will be able to adapt to the harsher conditions of the field more easily than plants which are still developing roots.

Plants at the nursery which have very long stems may be trimmed down to a height of 50 cm. It is however essential to ensure that the plants have sufficient foliage. Smaller plants with vigorous roots will require less energy for surviving in the field than taller plants.

When transporting plants to the field, they should be handled carefully. The plants should be watered thoroughly prior to transport. They should be loaded and unloaded from the transport vehicle in such a way that no damage is caused to them.

Upon arrival at the field site, the plants should be watered regularly up to the time that they are planted.

PLANTING PROCEDURE FOR NURSERY PLANTS

The following guidelines are suggested to aid the establishment of a productive plantation.

- When selecting the plantation site, check the quality of the soil. Bamboo can grow well on most soil, but deep porous fertile soil with high moisture content and a pH of 5.5 is preferable.

- Good soil drainage is very important. Verify that the land is not prone to flooding. Bamboo does not perform well on waterlogged soils. It is therefore preferable for the plantation to be situated on moderate slopes.

- Clear the land of all weeds and unwanted vegetation. Burning may be necessary during the dry season.

- Carefully plan the layout of plantation so that the planting holes are placed at the specified distances and intervals.

- Plan the activities so that the plantation layout is completed at least 2 weeks before planting.

- The planting holes should be positioned in a north-south orientation. This will provide an optimal distribution of sunlight to all the plants.

- Planting holes with a diameter of 1m and a depth of 60cm should be dug and evenly spaced out according to the plant spacing of 7m x 7m.

- Planting should coincide with the start of the rainy season. If available, organic fertilizer or manure should be placed into each hole and mixed with the topsoil. The plants should be planted

vertically in an erect position and the hole should be properly covered and mulched.

DIRECT PLANTING OF OFFSET CUTTINGS

Direct planting of offsets of *O. abyssinica* in the plantation may be done in small plots or homestead farms. Planting should be conducted at the beginning of the rainy season. The selection and preparation of offset cuttings for direct planting follows the same procedure as that of planting stock for nursery-raised cuttings except that cuttings are directly planted in the field pits without potting.

The procedure for direct planting is as follows:

- Haul the offset cuttings to the planting site.
- Loosen the soil in previously prepared planting pits/holes.
- Place the cuttings in the hole in a vertical position. The lowest node of the culm offset should be above the ground.
- Position the cutting at the center of the planting hole and fill up the pit with soil, ensuring that the culm stands firmly in place.
- Water the soil thoroughly and mulch around the planting hole.
- If necessary (and if financially possible), offsets should be protected against termite attack. The soil placed in the planting hole should be mixed with an anti-termite chemical. Marshal Susco controlled release-granules are suitable. The chemical has a persistent effect which lasts up to three years.

REPLANTING

Not all transplanted seedlings and cuttings will survive the new environment. The plantation should therefore be visited regularly to check on the survival of plants. Dead seedlings and cuttings should be replaced. Replanting should be done immediately at the start of the rainy season.

INTERCROPPING

During the first two years from the time of planting the bamboo, intercropping of cash crops and vegetables may be done between the rows of bamboo.

Intercropping serves several purposes. Vegetables provide a source of income to farmers. When cultivated between rows of newly planted bamboo, vegetable crops provide greater stability to the soil and help control erosion. Intercropping also creates an incentive for farmers to control weeds and pests in the plantation. In order to care for their vegetables, farmers will be involved with maintenance activities that are favorable to the growth of the bamboo plants.

When the bamboo canopy has developed, sunlight will be fully absorbed and the cultivation of vegetables will no longer be viable. During the third year after planting the bamboo, leguminous species may be planted to serve as ground cover in between the lines of bamboo.

Intercropping with Noog (*Guizotia abyssinica*, edible oil seed), at EABP nursery-Asossa

PLANTATION MAINTENANCE

Maintenance activities during the first 2 years after planting must focus on protecting the young plants from competing vegetation and pests. After the second year, maintenance activities are concentrated on clump management.

SOIL MAINTENANCE

During the first year, it is advisable to loosen the soil around the plant to improve soil aeration. Doing this about twice a year for each plant will enhance growth. Care should however be taken not to disturb the rhizome system of the plant.

WEEDING

The growth of bamboo plants can be hampered by weeds and competing vegetation. It is very important to control and arrest the growth of weeds around each bamboo clump. Failure to do so will invariably result in poor root and stem development in the young bamboos. An area within a radius of 60 cm around each plant should be cleared of all weeds and vegetation.

PEST CONTROL

The presence of pests and grazing animals should be thoroughly controlled. *O. abyssinica* is palatable to animals, especially in dry grazing. It may be necessary to carry out protection against goats and antelopes by partial or total fencing of the plantation. Every available means should be taken to prevent animals from grazing in the plantation. In small homesteads, fencing is a solution, but for a large plantation it is costly.

Careful supervision in this regard is therefore crucial. It is necessary to patrol the plantation, check for damage, seek the cause, and find suitable means to eliminate the problem.

MULCHING

Mulching is a proven way of improving the growth of bamboo. In drier areas, with rainfall less than 1000 mm, mulching around plants greatly encourages growth through reduced evaporation of soil water. Mulching is achieved by uniformly spreading a layer of leaf litter or other organic material on the surface of the soil around the bamboo clump. Mulching is an effective way of preventing weed growth. It helps conserve soil moisture and contributes organic nutrients to the plant.

Mulching is absolutely necessary for the production of good quality bamboo shoots. The mulch protects young shoots from direct sunlight and keeps them moist, thus allowing them to grow to an optimal size without hardening and losing their edible quality.

CLUMP MANAGEMENT

The proper maintenance of the clump not only improves productivity but also eases the job of the plantation worker. Clump management is partly a maintenance task and partly a result of harvesting. As a maintenance activity, it involves removing unwanted culms to prevent clump congestion. This is particularly necessary with densely tufted species such as *O. abyssinica*.

About 90% of new culms emerge in the outer borders of the clump. New shoots and culms cause the clump to widen in diameter. Culms at the periphery of the clump are generally new or young, while older culms stand towards the interior of the clump. Understanding this is important for maintaining a bamboo clump such that its productivity and vigor is maximized.

In maintaining a bamboo clump, it is necessary to extract the oldest culms in the interior of the clump. This is facilitated by creating an opening in the clump, and shaping the clump in the form of a horseshoe or “C shape”.

Unless properly managed, clumping bamboos tend to get congested resulting in deterioration both in quality and quantity. It is difficult to extract culms from congested clumps. Preventing clump congestion is important so that harvesting can be done with greater ease. Thinning the clump is essential to provide space for the emergence of new shoots. It is sometimes necessary to sacrifice a few young culms in order to allow for better shoot production in the clump.

Removal of old and rotting culms is also necessary to promote the healthy growth of shoots and new culms. Special attention should be placed on rotting in the stubs of culms that have been harvested. If rotting becomes apparent, it is advisable to dig around the stub and completely remove it. Likewise, rotting culms should be extracted. Symptoms of disease or fungal infections should be noted and a plant pathologist should be advised for possible remedies and control measures.

Protection from Termites

Termites are a serious pest in natural bamboo stands of *O. abyssinica*. Normally, termites attack old, decaying or sickly, injured, or partly burned bamboos. For this reason, it is important to ensure that clumps are managed properly and that all old and rotting culms are extracted. This is a cost-effective means of minimizing the risk of termite attacks.

Protection from Fire

Bush fires are a major hazard to lowland bamboo plantations and natural stands, especially during the dry season. Dry leaves, branches, twigs, and dead culms can easily catch and spread fire throughout a large area.

Proper mulching of dry leaf litter with humid organic material around the clump aids in preventing the spread of fires.

Firebreaks should be established to safeguard the plantation area. Corridors with a width of 10-15 m are usually sufficient to stop fire from spreading throughout the plantation.

HARVESTING AND HANDLING

Harvesting of *O. abyssinica* should be done selectively according to the age and maturity of the culms. Systematic and selective cutting of mature culms assures the continuous production of young shoots, which is an index of annual yield or increment. The implementation of plantation management strategies can help sustain the regenerative characteristics of bamboo and thereby provide an enduring supply of raw material for industries.

The bamboo plantation will be managed effectively if the exploitation is regulated on a sustainable yield basis. In other words, the clump should never be over harvested or clear cut. New culms as well as 1 to 2 year old culms should not be harvested. A few 3 year old culms should also be left standing so that the clump remains robust and so that harvesting can be performed annually. Following this method, culms are left standing on the clump until they mature, after which, they may be harvested.

A newly established plantation of *O. abyssinica* should normally be ready for first harvesting after 5 to 6 years from the time of planting. Thereafter, cutting of mature culms can be done annually or at predetermined intervals of years, according to the management plan and the end use of culms.

The cutting cycles and methods of extraction of culms from a clump should be implemented as an integral part of the management system of bamboo plantations and natural bamboo stands. Achieving sustainability in terms of culm production will therefore depend on how effectively culms are selected for harvesting, and on how the extraction from the clump is carried out.

Harvesting is a labor intensive operation and it is necessary to make good arrangements with plantation workers so that harvesting operations are not delayed.

The following rules apply for harvesting culms of *O. abyssinica* in particular.

- Harvesting of mature culms may begin 5 to 6 years after planting.
- Harvest culms only during the dry season. The starch content of bamboo is lower during periods of dryness. Lower starch content in the culms will make them less susceptible to attack by borers.
- Harvesting should be selective: only mature culms which are 3 to 4 years old should be harvested.
- In a clump, new culms are normally produced outwards, towards the periphery of the clump and the older culms stand towards the center. Harvesting of culms therefore should be from the center and not at the periphery of the clump. This makes it necessary to maintain clumps in the shape of a horseshoe, keeping the apex towards the side where the new culms are emerging. The open end of the horseshoe facilitates entry inside the clump for extracting mature culms.
- Plan the cutting operation to avoid harming young culms. New culms that attain an average height within the first few months are soft and may collapse unless supported by mature erect culms. A few older culms should be left in the clump after cutting, seeing to it however that congestion is under control.
- Use very sharp tools. It is highly advisable to disinfect harvesting tools using bleach. This lowers the risk of infecting the plants.
- Do not cut young culms unless congestion in the clump prevents the cutting of mature culms.
- Cut each culm between 15 cm to 30 cm from the ground or just above the first node from the ground level. This is necessary so that water does not accumulate in the protruding internode. The accumulation of water may result in rotting and invites insects to lay their eggs.

- Never clear-cut an entire clump unless it has been verified to be seriously infected by a disease.
- Never harvest culms during the rainy season!
- Mulch each clump after harvesting using branches and leaves of harvested culms. These should be neatly piled around the clump to provide organic material to enrich the soil around the clump.

If the plantation is situated near a river, the culms may be allowed to soak in water for a few weeks to aid in the removal of starch and protect them from beetle attack. Otherwise, they should be hauled to an area where they are sorted and air-dried. Good practices to enable drying will help minimize losses due to biodegradation of the culms. The large culms should be stacked horizontally on parapets where there is good air circulation. Smaller culms may be piled horizontally at a 60° angle to form a “tepee shape” allowing air to circulate around them to aid the drying process. After drying, the whole culms or culm segments are sold in local markets.

POST-HARVEST TREATMENT

Bamboo culms are vulnerable to decay and attack by fungi or insects, especially powder post beetles. Such attacks reduce the natural durability of bamboo and diminish their value and utility.

Post-harvest treatments can help to reduce the risk of decay and attack by pests and thereby increase the useful life and value of bamboo culms.

Depending on the end use of the culm, several methods of preservation may be applied to culms prior to their sale or industrial utilization.

DRYING AND SEASONING

Drying culms is common in the processing of bamboo culm for most uses. Culms are also subjected to seasoning prior to machining, processing, and finishing products that are durable, stable and of a high quality.

Bamboo culms can be air-dried with or without sunlight or they may be kiln-dried. Air-drying is more common that kiln drying since it is more economical. Bamboo culms may be split into halves to speed up drying operations.

Bamboo culms may be thoroughly air-dried in well-ventilated shade for several weeks. Drying requires horizontal stacking of culms on racks. In drying large quantities, the butts and tops of the culms are placed alternately then tied in bundles to prevent bending.

Straightening green culms without application of heat requires several weeks. This is done under the shade, either by suspending the freshly-cut curved culm by the tip and attaching a weight at the other end, or by laying the green culm on a flat surface and applying sufficient pressure over the culm during the period of drying and setting.

Mold Prevention

The risk of molding in bamboo culms can be reduced by drying culms such that the water content is reduced to less than 15 percent.

Stacking bamboo culms above the ground helps prevent molding and subsequent rotting. Storing bamboo in a cool and dry area also helps reduce decay from molding. Coating the bamboo culms with borax or wood preservative chemicals inhibits the formation of molds.

Preservation

Bamboo culms are susceptible to biological and physical deterioration especially when harvested young. Deterioration of the bamboo culm is mainly due to attack by powder-post beetles, termites, and decay caused by staining fungi. Methods to increase the durability or prolong the service life of bamboo culms are broadly classified into non-chemical and chemical methods.

Non-chemical Methods

Many of the methods mentioned below are practiced traditionally and are suitable for small scale industries or farmers with limited resources.

- **Curing:** After harvesting, the culms are left in the field for some time with branches and leaves intact. The transpiration of moisture through the leaves contributes to the reduction of starch in the culm.

- **Smoking:** The bamboo culms are cut into the desired length and stacked above a fire in an enclosed area. The smoke causes the culms to blacken and the heat destroys the starch in the parenchyma cells. Bamboo culms cured with smoke are known to last more than 15 years.

- **White washing**: whole or split bamboo culms are painted with slaked lime. This prevents the entry of moisture into the culm, keeping away stain fungi and halting decay.

- Construction methods: mounting bamboo poles over a concrete or stone foundation helps prolong their service life. Since the bamboo is not in contact with the ground, it is less susceptible to attack by fungi and termites.

- **Time of harvesting:** harvesting mature (3 years old or older) culms during the dry season when their starch content is lowest makes them less vulnerable to attack by termites and fungi. If properly dried after harvesting, their useful life is significantly extended.

- **Plastering:** plastering bamboo culms or strips using cow dung mixed either with lime or mortar is effective in extending the durability of low cost bamboo constructions.

CHEMICAL PRESERVATION METHODS

Using chemicals for preserving bamboo culms generally provides more effective protection than non-chemical methods. Chemical methods however imply greater costs and are only used when greater added value and a higher quality product are required.

- **Fumigation:** involves the use of chemicals such as Methyl bromide for insect control.

- **Steeping or sap displacement:** green bamboo culms are allowed to stand vertically in a container of preservative solution till adequate chemical is picked up. At times, the culm may be freshly cut with branches and leaves on.

- **The open–tank treatment:** culms are cut to a desired length and are soaked in a solution of a water-soluble preservative for several

days. The solution penetrates the culm by diffusion through the ends and partly through the sides.

- **Butt treatment:** the bottom part of green bamboo or dried bamboo culm is immersed in a container of preservative, for example an old oil drum. The culms are left for about one week.

- **Old engine oil:** many farmers have been reported to use old engine oil, particularly for green culms. The effectiveness of this method has not been widely reported and documented.

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APPENDIX 1: DATA TO BE RECORDED BASED ON PHENOLOGICAL OBSERVATIONS OF BAMBOO

Phonological Events	Observations per Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Flower bud formation												
Flowering												
Fruiting												
Matured fruits												
Fruit dropping												

APPENDIX 2: DATA TO BE GATHERED DURING THE VEGETATIVE PHASE OF LOWLAND BAMBOO

Vegetative Phase	Observations per Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Shoot Sprout												
Sheath Peel-off												
Clump Conditions After Reproductive Phase												
Rhizome Conditions After Reproductive Phase												
Interval Time Vegetative and Reproductive phase												

Symbols to be filled:

SSH = Shoot sprout SSP = Sheath Peel-off

D= Die L= Live