TRAINING PACKAGE ON BAMBOO PRODUCTION AND UTILIZATION

TECHNICAL MANUAL

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1. MODULE 1: GENERAL BACKGROUND

1.1 Introduction

Bamboo as a non-timber forest product supports the livelihood of millions of local people in Ethiopia. The goods and services gained from bamboo both at village and national level are essential in providing for basic human needs, such as; employment, fodder, food, shelter, and household materials.

Apart from providing the above-mentioned wide range of uses, bamboo plays a crucial role in environmental protection. It protects soil erosion, stabilizes riverbanks, improves environmental conditions, and most importantly, bamboo grows both in wide range and marginal lands of the country.

Bamboo is one the fastest growing and highest yielding renewable resources. Naturally, only two bamboo species grow in Ethiopia. These species are Yushania alpine (highland bamboo) and Oxytenanthera abyssinica (lowland bamboo).

This manual has been prepared to provide basic information about Ethiopia's lowland and highland bamboo species, and thereby aims to create awareness, knowledge and skill about these two important bamboo species among Woreda experts, Development Agents(DAs) and Farmers so that farmers (the end users) can plant and manage the cultivated and existing natural bamboo forests.

1.2 Description and characters of the two Species

The highland bamboo, *Yushania alpina*, is a monopodium, medium sized bamboo with straight culms ranging from 2 to 20 m height and a base diameter of 5-12 cm (Fig.1.1 to the left). The culms are hollow with an average wall thickness at the base of about 16 mm and of 5 mm at the top with 2 cm diameter.

The lowland bamboo *Oxytenanthera abyssinica* is a hardy species which can grow in poor soils and dry vegetation formations. The symposia bamboo grows in natural pure stands, covering large areas with the clumps considerably dispersed. The culms are grouped in large dense clumps, erect or leaning with a length between 6-10 m (Fig.1.1 to the right). The base diameter varies between 3-8 cm. They are solid during shooting and may develop a small central cavity with a thick culm wall later.

Y. alpina bamboo Masha

O. abyssinica Assosa

Fig 1.1 Highland and lowland bamboo forest

1.3 The bamboo growth habit of

The bamboo plant (Figure 1.2- 1.7) is made up of an underground axis and an above ground axis. The underground axis is comprised of rhizomes, roots, and buds. The above ground axis is comprised of stems, branches, and foliage. Buds on the rhizomes may develop into shoots that emerge from the ground. The new shoot elongates vertically into a main stem or *culm* until it attains its full height. The growth of a culm is completed in one growing season. In large bamboo species, new culms may grow to a height of more than 20 meters within 3 months, depending on the species.

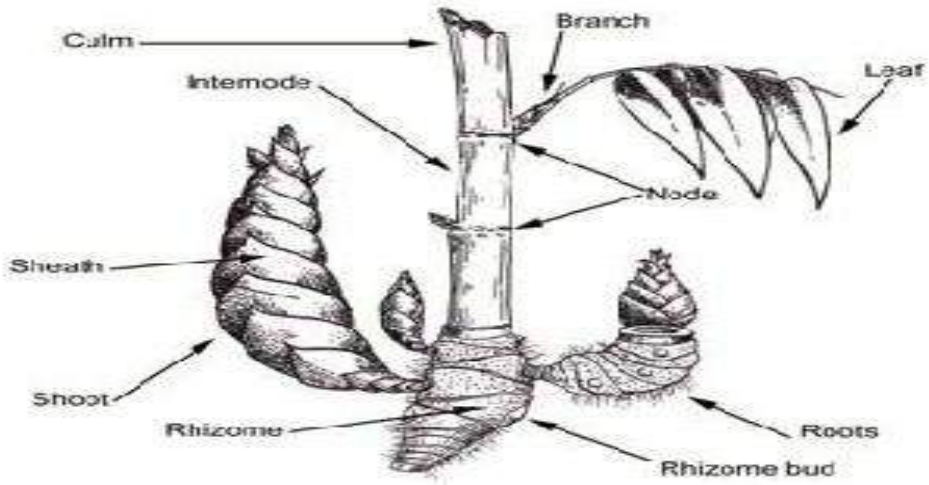


Fig 1.2 Parts of bamboo plant

1.3.1 The structure and Types of bamboo Morphology

- Rhizome:- is an underground stems
- Roots:- small hair-like under parts of the rhizome
- Culm:- above ground bamboo stem
- Clump:- A groove or compacted group of bamboo culms(stems)

1.3.2 Rhizomes

- Determined by the species type
- It has nodes and inter-nodes on some nodes
- It has many buds on some nodes
- New shoots/culms grow from these buds

1.3.2 Types of Rhizomes

- Monopodial (Leptomorphy) type
- Sympodial (pachymorphy) type
- Mixpodial (mesomorphy) type

1. Monopodial (Leptomorphy) type

- Rhizome has one bud at each node that develops monopodially every year.
- Rhizome is thin and extends for a long distance underground.
- Some buds grow into shoots/culms
- Some of the buds grow into new rhizomes in some (?) soils.

Two types of Leptomorphy

a) Rhizome forming systems

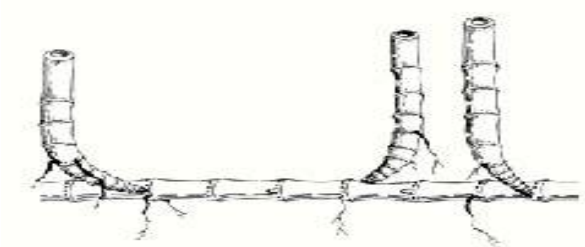


Fig 1.3 Rhizome forming systems

b) Tirllering Leptomorphy Rhizome

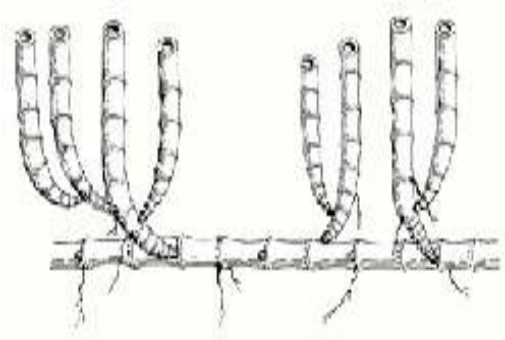


Fig 1.4 Tirllering Leptomorphy Rhizome

2. Sympodial (pachymorphy) type

- Apex of the rhizome has a node
- Buds do not protrude out of ground and grow into a culm like the monopodial type.
- Buds on culm base develop into shoots directly.
- The following year new shoots sprout from the new culm base.
- Cannot extend for long distances.
- Clump forming and grows close together.

Two types pachymorph Rhizomes System

a) Simple pachymorph rhizome

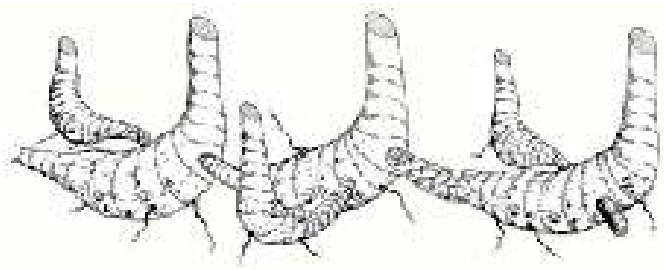


Fig 1.5 Simple pachymorph rhizome

b) Pachymorph Rhizome with elongated necks

Fig 1 .6 Pachymorph Rhizome with elongated necks

3. Mixpodial (Mesomorphs) type

- Intermediate type between monopodial & sympodial.
- Buds on culm base develop into rhizome.
- Rhizomes extend in soil horizontally.
- Buds on rhizome nodes develop into new culms to make scattered bamboo stands.
- Also buds on new culm base develop into shoots and form dense bamboo stands.

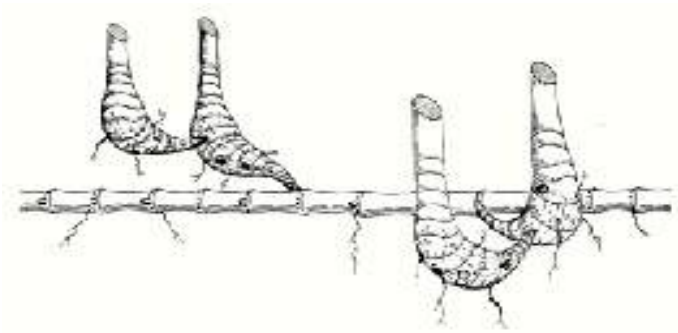


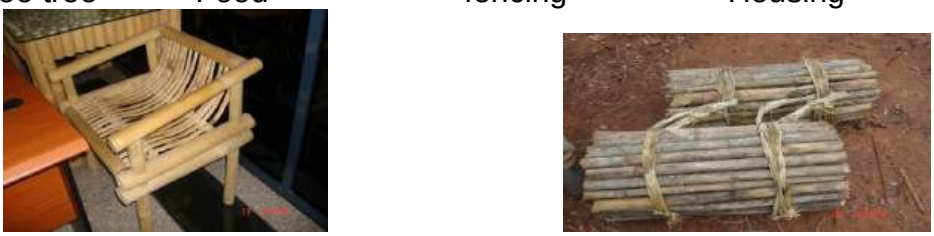
Fig 1.7 Mixpodial or Mesomorph type of rhizome

1.4 Benefits of bamboo

Bamboo is a multipurpose plant that can give multiple benefits to farmers:

- Raw material for construction of houses
- It is highly suitable for handicrafts;
  - mats,
  - baskets,
  - trays, hats,
  - lampshades,
  - caps,
  - Lanterns, etc.
- Widely used in modern wood and paper industries.
- Nutritional value:
  - Young bamboo shoots can be cooked and eaten as a vegetable. The cone-shaped sprouts that emerge from the ground to form tall poles are edible vegetables when harvested young.
  - 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 fibre content.
- Fodder: the foliage can be used as animal fodder.
- Bamboo provides considerable environmental benefits: it is used for ecological purposes such as soil stabilization and erosion prevention on hill slopes and verges.

Bamboo tree Food fencing Housing



Furniture Fuel

Fig 1.8 Examples of uses of Bamboo

1.5 Site requirement

The highland bamboo, *Yushania alpina,* grows between 2200 and 3500 m above sea level and at lower temperatures between 10-20°C in locations with annual rainfall between 1500 and 2500 mm and a short dry season.

The lowland bamboo *Oxytenanthera abyssinica* grows at an altitude between 700-1800 m. It is a hardy species that grows on poor soils in dry vegetation formations. As the most drought-resistant, bamboo tolerates as little rainfall 700 mm and temperatures that exceed 35°C.

Table 1.1 Site Requirements

Species	**Altitude(asl) in Meter**	**Annual rainfall(mm)**	**Temperature**	**Soil**
highland bamboo *(Yushania alpina)*	2200 - 3500	1500 - 2500	10-20°C	Volcanic And very fertile
lowland bamboo (*Oxytenanthera abyssinica)*	700-1800	tolerates rainfall down to 700 mm	above 35°C	Poor and shallow soil

2. MODULE 2: PLANTING MATERIALS

2.1 Bamboo seeds

It may take up to two years before seeds are released from the flowering clump. If bamboos start to flower, it is advisable to monitor the event and to collect seeds or in order to raise and propagate a new generation of planting material. Seeds are not always fertile; if they are, their viability does not exceed one year.

Fig.2.1 A flowering clump of O. abyssinica (left) and Seeds of O. abyssinica (right)

If seedlings are to be raised or directly sown, seeds are essential. Access to seed and information about seed is a limiting factor in the growing of the species.

Bamboo seeds have no dormancy period, so they can be planted as soon as they are mature and collected. There are two ways of obtaining seed:

1. From original sources such as: Assosa for lowland bamboo and Masha, SNNPR and Injibara, Amhara Region for highland bamboo. But, it is difficult to get highland seeds and mostly farmers use wildings from natural bamboo or previously cultivated plantations.
2. Seed centers and private suppliers from Southern Ethiopia, Hawassa, for lowland bamboo.

From 1kg of seed farmers can get 14000 seeds, and since the germination percentage of the species is 90-100%, the number of seeds that can be germinated per kg ranges from 12,600 to 14000 to cover about 20 - 22 hectare at spacing of 4 by 4 meters to 62 - 68 hectare at a spacing of 7 by 7 meters.

2.2 Propagation

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

Fig 2.2 Seedlings of O. abyssinica

2.2.1 Seed

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

2.2.2 Wildings

If wildlings or naturally growing bamboo seedlings in the forests are available, these can be collected and used as planting materials by raising them in a nursery or directly planting them at the site.

2.2.3 Vegetative propagation

Bamboos can be more easily 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.

2.2.3.1 Propagation by means of offsets

The most effective and common way of propagating bamboo 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 macro-proliferated at a 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 the 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 by noting that 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 offset after they have developed some branches and foliage which enable photosynthesis and growth.

Fig 2.3 How to dig out offset propaguels

Fig 2.4 How to transport of offset

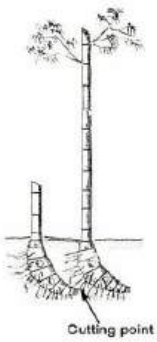


Fig 2.5 Point of separation of offset

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; first flood it with water, then mulch it.
- If planted directly in 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.

Important precautions!

- Offsets taken in the late rainy season after the new growth has started tend to fail. Therefore, acquire your planting materials as early as possible
- The younger the rhizome, the more the vigour in the buds
- Larger diameter materials do better in establishment and survival
- Avoid damaging the junction of the culm, the rhizome and the dormant buds
- The larger the aerial culm, the better the chances of survival
- Do not delay planting offsets after digging them out. Early planted offsets root easily.

2.3.4 Cuttings

Cuttings are the last option used for propagation. For detail see 3.2.4 cuttings in the nursery.

3. MODULE 3: ESTABLISHING A BAMBOO NURSERY AND NURSERY MANAGEMENT

3.1 Establishing Bamboo Nursery

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

3.1.1 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 very dry areas to prevent excessive daytime temperatures. Arid areas with desiccating conditions are not suitable for a bamboo nursery.

3.1.2 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, for 8 cm diameter polythene tubes at least 200 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.

Table 3.1 Effective areas for 10000 seedlings of different polythen tube diameter

Diameter(cm)	Area(cm2)/ seedling	Effective area for 10,000 seedlings(m2)
6	113	113
8	200	200
10	314	314
12	450	450
20	1250	1250
40	5000	5000

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.

3.2 Nursery management

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 a model farmer 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.

3.2.1 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.

Potting containers: A sufficient quantity of polythene tubes of various sizes should be available at the nursery to fulfil potting requirements. If possible, the polythene tubes should be large enough to allow root development of plants.

For seedlings, polythene tubes with 20 cm diameter x 40 cm height x 0.04 mm thickness are sufficient, if not available, a smaller diameter polythene tube can be used, or seedlings can be sown directly to the bed.

Larger polythene tubes 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.

Sowing: Seeds may be sown in a nursery bed or in polyethylene (polythene?) tubes filled with soil and then covered with a thin layer of soil.

Bamboo seeds 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.

Shading: The planted seeds should be maintained in a shaded area and protected from direct sunlight. This is the favourable 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.

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.

Watering: 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.

Mulching: 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.

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

3.2.2 Cultivation of wildlings in the nursery

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-seedling 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.

Transplant: Once the plants have grown to a height of 5cm, they should be individually pricked out and transplanted into polythene tubes.

Potting: Potting of propagules should be done carefully to ensure a high survival rate at the nursery. Polythene tubes or poly bags are commonly used as potting containers. Polythene tubes with a size of 40 cm diameter and x 50 cm height are suitable for small bamboo plants and generally provide sufficient space for the development of roots, rhizomes, and new shoots.

Soil for potting: 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 polythene tube with the soil mixture.
- Place the roots and rhizomes of the plant in the centre of the polythene tube and fill up the remaining portion of the polythene tube with soil ensuring that the base of the stems are on the level of the soil.
- Moderately compact the soil in the polythene tube.
- Water the newly-potted plants.
- Place them in a shaded area or in the lath house and ensure they are regularly watered.

Fertilizer application: Fertilizer application may be done in the seedbed in conjunction with watering long before transplanting. This is done by dissolving complete NPK fertilizer at the rate of 10g per litre 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 in the hole where the seedling will be transplanted.

3.2.3 Macro-proliferation

When seeds or wildlings are not available and a large quantity of planting materials is required, the method of offsetting 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 be 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 off 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.

Fig 3.1 Macro-Proliferation (division) of bamboo

3.2.4 Cuttings in the nursery

Even if it is less common and difficult for these two Ethiopian indigenous Bamboo species, propagation by cutting can be one propagation alternative by applying the following procedures:

- Double node or triple node cuttings can be propagated by being buried in the soil.
- All branches and leaves of the cuttings should be cut off down to the first or second branch node
- The cuttings should then be buried 6-10 cm horizontally on a raised nursery prepared with a light soil and sand mixture
- Buds at the nodes or branches should always be placed sideways or facing upwards but never downwards.

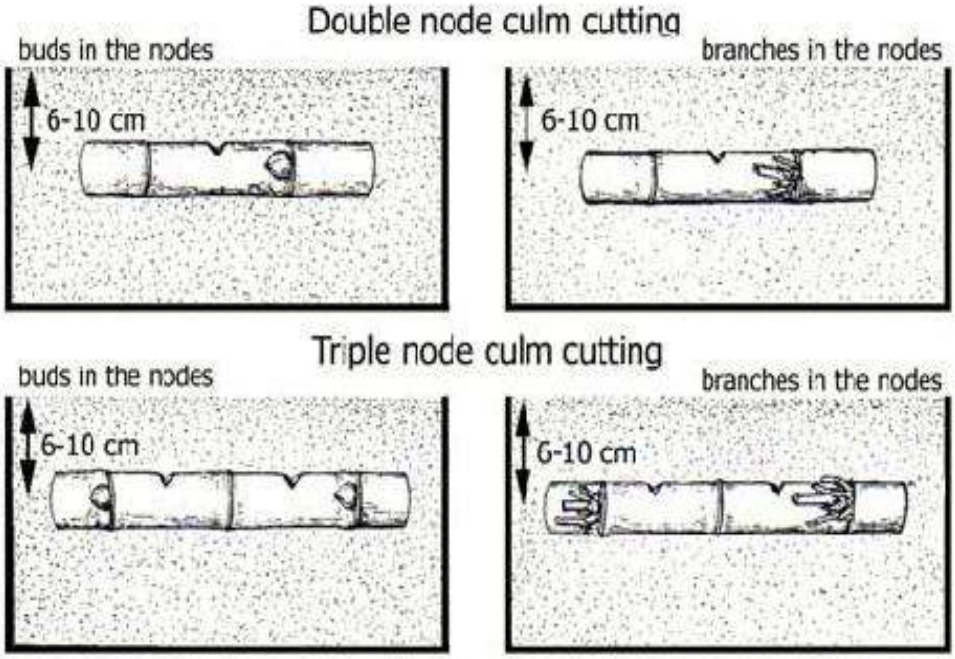


Fig 3.2 Propagation by cuttings

- **Watering:** Watering 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 nearby water source.

Plants should be watered manually using a watering can. If possible, use a pump and sprinkler system for effective watering on a regular basis.

Young bamboo plants need watering 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 watering is functioning properly so that plants in all areas of the nursery are watered.

- **Weeding:** Weeds compete with bamboo plants by absorbing nutrients, water, and sunlight. Weeds have rhizomes which re-sprout if not removed.

Measures to control weeds include:
- Weeding at the time of soil preparation 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 in 50% shade. But as soon as transplants have recovered and commenced growth, they should be exposed to a lighter environment 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 they should have healthy green foliage; these are prerequisites for shoot development.

At least one month before planting out, plants should be exposed to full sunlight and moved to an open field nursery where they will be maintained up to the time that they are taken out of the nursery and transported to field planting sites.

- Hardening works for all types of the above mentioned types of propagations
- To prevent the development of succulent tissues, fertilizer should not be applied during the hardening period, especially two months before field planting.

4. MODULE 4: PLANTATION

4.1 Types of plantation

The term ‘plantation’ can mean different things and it is useful to explain the various senses of the term in relation to different bamboo plantation systems. This can at the same time help to illustrate various applications for bamboo in relation to forestry and farming. It is useful to distinguish, for instance, between homestead, commercial plantations, agroforestry, and forestry programs.

4.1.1 Homestead farms

A homestead farm is a small property with a dwelling house where a family resides and adjoining land where cash crops and trees are planted. Planting bamboo clumps in a homestead can foster self-sufficiency of woody materials as well as fiber for producing domestic implements such as baskets and mats for farmers. The widespread cultivation and use of bamboo in homestead farms can be very economically and environmentally beneficial in as much as it creates a wood and energy substitute for trees.

4.1.2 Commercial Plantations

Bamboo can be planted as a commercial crop on farms of just a few hectares to large estates of thousands of hectares. Plantations have a well defined structure and a selection of crops that are cultivated mainly for generating economic gain. A bamboo plantation need not be a monoculture; on the contrary, it is advisable to have an assortment of bamboo species in the plantation.

4.1.3 Agro-forestry

The term ‘agro-forestry’ broadly refers to land use systems and agrarian practices that involve the cultivation of woody species in combination or rotation with agricultural crops and/or animals on the same land management unit. Agro-forestry systems are driven by economic and ecological goals. The aim is to generate a sustainable use of land for the benefit of livelihood and the environment.

The use of bamboo in agro-forestry systems involves intercropping of cash crops and the planting of hardwood trees. In this way cash crops can generate income in the short term, bamboo can generate income in the medium term, while the trees can generate high value in the long term.

The use of numerous species with different rotations has a beneficial impact on the soil. Knowledge, careful selection and good management of species are needed to maximize production and positive environmental effects while avoiding the shortcomings of monoculture plantations.

4.1.4 Conservation Programme

Bamboos can be integrated in forestry programs, primarily as fast growing woody species that can generate a green canopy in a short period of time. In forest environments, bamboo provides many environmental benefits, especially in relation to erosion control and protection of soil.

4.2 spacing

- Spacing varies according to the objectives of plantations and sites.
- A 4X4m with 625 plants per hectare to 5x5m with 400 plants per hectare layout may however be used for riverbank and gully stabilization, or when intercropping of cash crops is not intended. For riverbank and hillside rehabilitation dense and staggered planting is necessary (Fig 4.1).
- A 7x7m or 204 plants per hectare to 10X10m or 100 plants per hectare layout can be used to provide sufficient space for intercropping around the homestead and farmland and allows greater ease of movement for maintenance and harvesting activities, and for species with big diameter culms and clumps and thickets.

Field planting can be done either by direct planting of culm offsets or by using nursery-raised plants.

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

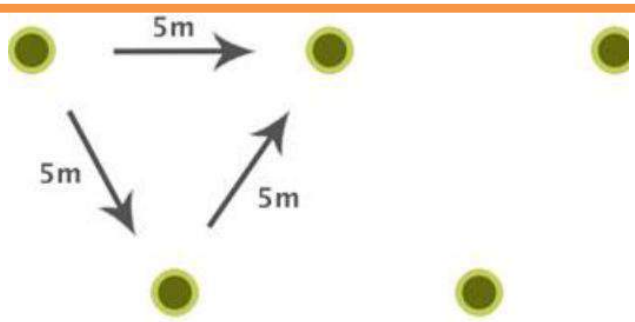


Fig 4.1 Staggered spacing

4.3 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.

The plants should be watered thoroughly prior to transport. When transporting plants to the field, they should be handled carefully and use proper materials to transport seedling.

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

4.4 Planting procedure

4.4.1The procedure of planting seedlings from nursery

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

- When selecting the plantation site, check the quality of the soil.
- 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.
- Carefully plan the layout of the 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 one to two months before planting.
- Planting holes with a diameter of 60cm and a depth of 60cm for offsets and rhizomes and 30cm diameter and 30 cm depth for seedlings (fig 4.2) should be dug and evenly spaced out according to the plant spacing,

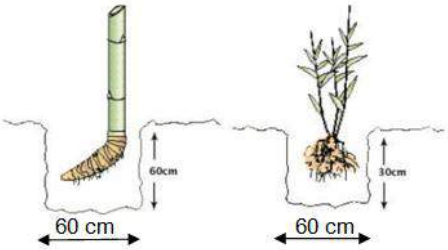


Fig 4.2 Planting holes for seedlings, offset, and culm derived seedlings

- 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

4.4.2 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 of offsets:

- 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 centre 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.

4.4.3 Direct planting procedures using culm cuttings

- Selection of planting stock should select from a good clumps.
- Select a one and a half to two-year old culm as a planting stock.
- Cut and remove the selected culm from the mother clump by using a sharp tool or saw to avoid splitting.
- Remove branches from the selected culm leaving two nodes of the branches intact with the nodes of the culm.
- Determine the usable portion of the culm (about one half to two to third), in general middle of the bamboo culms used for culm cuttings give the highest survival rate.
- Cut the usable portion to ease transport of the planting stock as soon as possible to prevent from drying.
- Another precaution taken to prevent desiccation is by wrapping the cuttings in moist gunny sacks.
- Cut into two-node culm sections leaving about 10-15 cm of culm portion at either end beyond the node, then propagules are ready to plant in the field.
- Cutting planted in the field.

5. MODULE 5: HARVESTING AND POST- HARVESTING TREATMENT

5.1 Harvesting and handling

Harvesting should be done selectively according to the age and maturity of the culms. 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 bamboo plantation 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.

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 bamboo.

- 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 (fig 5.2).
- Alternatively, the clump can be managed by creating a cross tunnel (fig 5.3), which divides the clump into 4 sections and allows full access for harvesting 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.

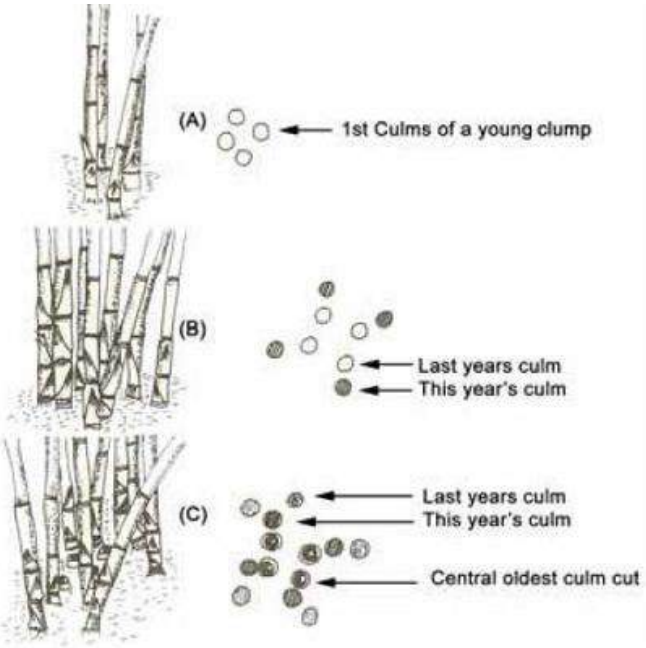


Fig 5.1 Growth and development of culms of a clump

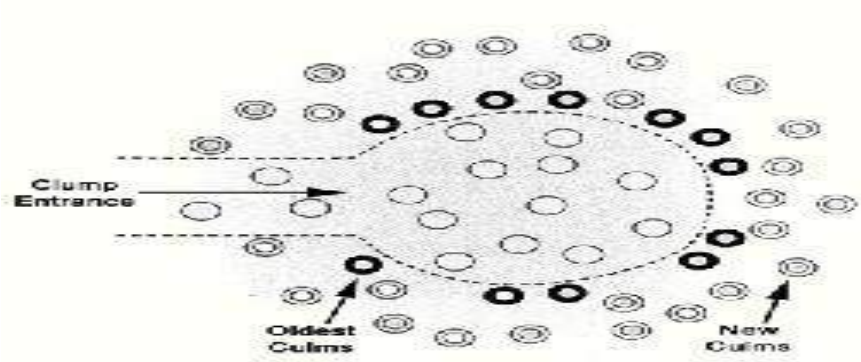


Fig 5.2 Horse shoe harvesting method

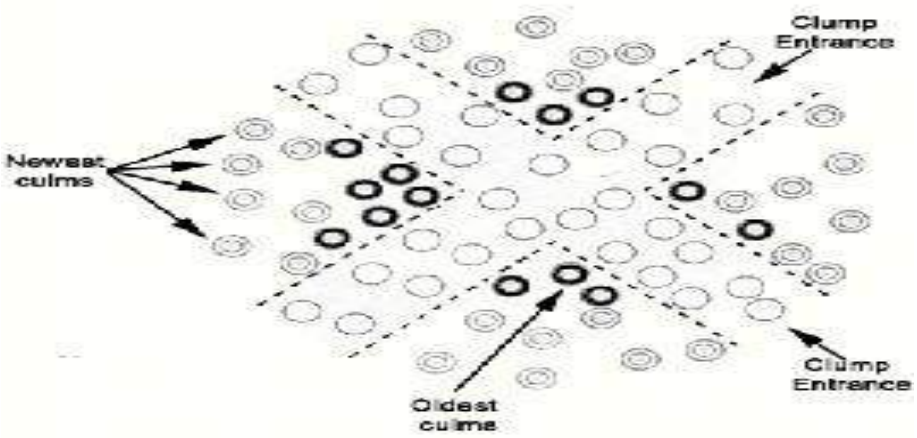


Fig 5.3 Cross tunnel harvesting method

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. The whole culms or culm segments are sold in local markets.

5.2 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.

5.2.1 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 (which this booklet focuses on) and chemical methods.

5.2.1.1 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.

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