Kenya's Water Towers Protection and Climate Change Mitigation and Adaptation (WaTER) Programme

Training Manual on Bamboo Propagation and Management

Component 4: Science to Inform Design of Community-Level Actions and Policy Decisions

This programme is funded
By the European Union

Kenya Forestry Research Institute
(KEFRI)

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Rationale

Among the most important minor forest products, bamboo has continued to gain recognition. Bamboo is considered as a multipurpose plant and a valuable timber substitute. Bamboo raw materials are however scarce due to the current ban on bamboo extraction from public forests. Even if the ban were to be lifted, the cover of bamboo resource is presently low due to excisions of indigenous forests where bamboo was dominant. This calls for production of raw materials from farms not only to ensure expanded supply, but also to get the materials nearer to the market yards where handicraft industries are flourishing

Most of the bamboo resources in Kenya comprise one indigenous species, *Yushania alpina*. This species, which is commonly known as "alpine bamboo", occurs naturally on the main mountains and highland ranges of Kenya. The species is estimated to cover between 145,000 - 150,000 ha, located mainly at altitudes ranging from 2400 m to about 3400 m above sea level.

During the last twenty years, research on species selection and investigations on their growth was done by the Kenya Forestry Research Institute (KEFRI) in collaboration with several Asian research and development institutions. This research work introduced over twenty Asian bamboo species into the country. Half of these are successfully growing in the field under various ecological conditions. Appendix 1 lists some bamboo species successfully introduced in Kenya. The introduced species are more versatile and can be cultivated in areas where the local bamboo does not thrive. Background information about the origin and habitat of some of these species is provided in Appendix 2. These species can be cultivated in parts of Africa with similar growing conditions.

One of the limiting factors to the widespread planting of bamboo in Kenya is lack of information on availability of planting materials, methods of propagation, establishment, and crop management and harvesting methods. This manual consolidates and provides such invaluable information. In addition; the manual provides an introduction to simple methods suitable for treatment of harvested stems of bamboo and common uses of bamboo. Simple conversion methods necessary in preparation for use in the handicraft production are also provided.

The manual is therefore tailored to meet the needs of farmers, government and other tree planting extension NGOs, and the upcoming bamboo-based small-scale cottage entrepreneurs.

TRAINING MODULES

The training manual contains 7 Modules as indicated below:

1. The Growth Habit of Bamboo
2. Selection and Raising of Planting Materials
3. Nursery Techniques and Management
4. Propagation Methods
5. Field Planting and Establishment
6. Bamboo Clump Maintenance and Harvesting
7. Post-Harvest Treatments
8. Current and Potential Uses of Bamboo
9. Investment opportunities in bamboo

1.0. MODULE 1: THE GROWTH HABIT OF BAMBOO

- Learning objectives
- Introduction to bamboo
- Physical characteristics of bamboo
- Types of Bamboo
- Flowering and Seeding

1.1. Learning Objectives

By the end of this session the participant will be able to:

- Identify bamboo plant and name its various parts
- Identify different types of bamboo
- Explain the flowering and seeding patterns of different bamboo species

1.2. Introduction to bamboo

Bamboo is a member of the grass family and resembles trees in many properties. Worldwide there are over 1200 bamboo species. Most of the bamboo resources in Kenya comprise one indigenous species;

- *Yushania alpina*
- About 18 introduced species

Yushania alpina occurs naturally on the main mountains and highland ranges of Kenya. The species is estimated to cover between 145,000 - 150,000 ha, located mainly at altitudes ranging from 2400 m to about 3400 m above sea level. The exotics such as giant bamboo (*dendrocalamus giganteous*) and green bamboo (*bambusa vulgaris*) occur in low to mid altitude areas. Bamboo growing on farmlands is currently gaining interest but farmers lack technical information on propagation, growing and management

1.3. Physical characteristics of bamboo

The bamboo plant consists of:

- An underground axis, and an
- Above ground axis.

The underground axis consists of rhizomes, roots and buds. The above ground axis consists of stems, branches, and foliage (Fig. 1). 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 of between 8m -15m.

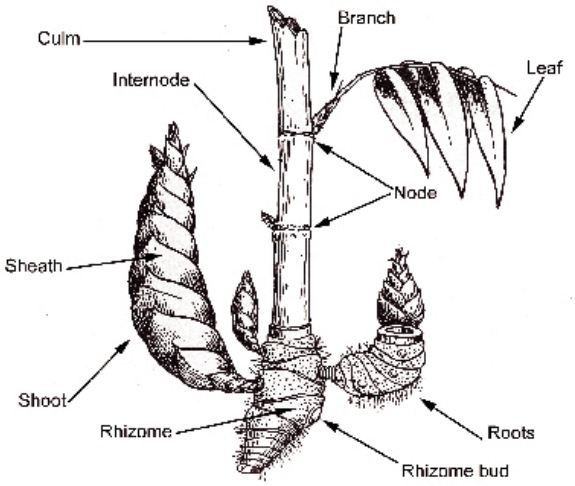

Figure 1: Under and above ground axis parts of the bamboo plant

The bamboo culm is cylindrical and is divided into sections by nodes. The section between two nodes is called an internode. Internodes are hollow in most bamboos, but solid in some species for example *Oxytenanthera abyssinica*. The new culm is protected by sheaths that are attached to each node. The culm gradually develops branches and leaves. As the culm matures, it lignifies and becomes harder and stronger. The life of a culm varies from species to species. Under ideal conditions a culm is fully mature after 3 or 4 years. As mature culms grow older, they deteriorate and eventually die and rot. The life of the bamboo plant is however sustained by the new shoots and culms through their extensive rhizome systems.

Silvicultural management of 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, thereby harvesting a crop that is valuable and useful. The removal of mature culms also maintains the vigour of the plant and allows for the continuous generation of new shoots.

1.4. Types of bamboo

Bamboos are classified according to the two main rooting (rhizome) systems namely;

1. Clump forming rhizomes otherwise called and a sympodial branching pattern as below

Figure 2: Sympodial formation

2. Running or creeping rhizomes- monopodial branching pattern as below

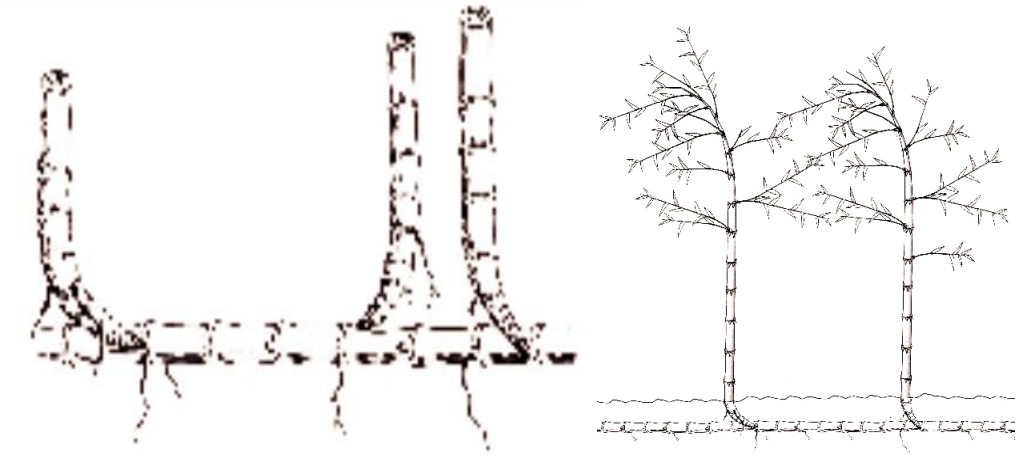

Figure 3: Monopodial formation

1.5. Flowering and Seeding

Bamboos generate seeds when they flower. For many tropical bamboos, flowering intervals range from 20 to 120 years. There are two types of flowering in bamboos:

1. Gregarious flowering
2. Sporadic flowering.

When gregarious flowering occurs, the clumps of an entire species flower, produce seed, and then die. Although large quantities of seed are produced during gregarious flowering, they are viable only for a short period, sometimes only for a few days or months. Sporadic flowering occurs in many species, including *Y.alpina*, *Dendrocalamus giganteus*, *Dendrocalamus strictus*, *Dendrocalamus hamiltonii*, *Bambusa tulda*, and *Guadua angustifolia*, among many others. In this type of flowering, seeds are produced but the clumps generally survive. What triggers the flowering of bamboo is not yet scientifically understood and the onset of flowering is therefore not predictable.

Because of the long flowering intervals of bamboo, seeds are seldom available and not always a viable method for large scale propagation. If seeds of a certain bamboo species become available, it is highly advisable to buy only from reputable vendors or specialized organizations that can guarantee the provenance and viability of the seeds.

2.0. MODULE 2: SELECTION AND RAISING OF PLANTING MATERIALS

- Introduction
- Propagation from seed
- Use of wildlings
- Use of Offsets
- Vegetative Propagation
- Use of tissue culture plantlets

2.1.Learning Objectives

By the end of this session the participant will be able to:

- Describe the different types of propagation methods
- Demonstrate practical application of the different types of propagation methods

2.2.Introduction

Growing bamboo starts with obtaining the materials for planting. Such materials may come in the form of seeds, wildings, offsets or cuttings that may be gathered from mother plants. Planting materials may also be raised through technology in laboratories by tissue culture. Such planting materials can be obtained and raised in the nursery as described below.

2.3. Propagation from seed

Once a bamboo stand or clump has flowered, seeds can be collected within the flowering period and seedlings raised as outlined below:

- Because of poor viability of seed, it is more desirable to collect and sow the seed without delay.
- Sow seeds in the nursery bed. Cover with a thin layer of soil and water daily. Watering should be done carefully using a fine rose can.
- When germinated seedlings attain a height of 3 cm, they are carefully transplanted into growing medium.
- After 3-6 months, good-sized transplants are obtained. Seedlings over one year old establish better. Where roots of seedlings have not developed well, such seedlings may be maintained in the nursery for over one year.

2.4. Use of Wildings

Wildings of bamboo are found underneath a bamboo stand and can be collected and nursed in the nursery for raising bamboo seedlings.

How to collect Wildlings:

- Scoop young clusters of bamboo wildings using a spade and take to the nursery.
- Prick individual wildling into potting container.
- Keep under shade small wildings of bamboo that have been pricked into containers.
- Water the seedlings regularly using a fine rose-can.
- Avoid disturbing intact small wildings which resemble a mass of grass in the field.

2.5. Using Offsets

Collect offsets at the onset of the rainy season and just before the emergence of new shoots by following the steps outlined below:

- Dig out about 30-60 cm below ground for a rhizome of one to two years old culm.. This can be recognized by the dark green colour and smooth velvety stems.
- Once a rhizome is exposed, cut back the aerial culm to 60 cm in length and 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 (Figure 4).
- Transport the extracted offsets to the planting site without any delay and plant immediately.

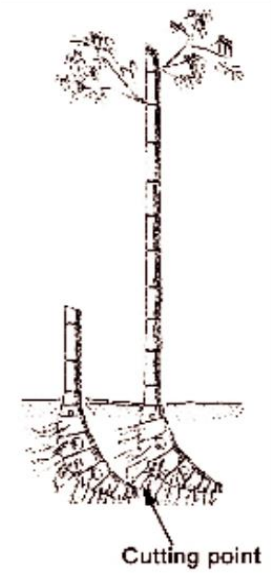

Figure 4: Point of separation of offset

2.6. Vegetative Propagation

Vegetative propagation of bamboo offers a better source of planting material. This can be done through use of offsets and culm cuttings. For exotic species which require warm climatic conditions, the use of a green house is recommended especially in cooler areas. However, where there is no greenhouse, a locally assembled polyethylene tunnelling structure can be improvised (Fig 5).

Figure 5: Simple tunnelling structure

Use of culm cuttings has several advantages. Multiplication of many clumping species is possible by this method. When out-planted, vegetative materials raised from cuttings develop into clumps much faster than offsets and even seedlings. Offsets (rhizome with attached section of stem) are commonly used but their extraction is laborious and time consuming. During extraction, damage may also occur to the roots, buds and rhizomes of mother clumps. The local species of bamboo, *Yushania alpina* and *Oxytenanthera abyssinica,* have however proved difficult to propagate in this manner.

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 are better in establishment and survival.
- The larger the aerial culm, the better the chances of survival.
- Avoid damaging the junction of the culm and rhizome and the dormant buds.
- Do not delay planting offsets after digging them out. Early planted offsets root easily.

2.6.1. Use of Culm Cuttings

Steps on selection of right type of culms for propagation

- Ensure culms have dormant buds at all nodes.
- Age of culms should preferably be from 2 to 3 years. Very young culms are likely to rot due to having soft tissues while too old culms have hardened tissues that might not shoot or root readily.
- Prepare double node or triple node cuttings from the cut culms and perforate a hole at the middle of two nodes using a sharp tool (Knife, Panga, Saw).

NOTE: It is essential that the cuttings have either buds on the culm nodes or buds on the culm branches. All branches and leaves of the cutting should be cut off down to the first or second branch node.

- Bury cuttings 6 – 10 cm horizontally on a raised nursery bed prepared with a light soil and sand mixture. For some species, there is a higher rate of success when a section of the branch with a bud is left emerging vertically from the ground.
- Always place buds at the nodes or branches on the sideways or facing upwards and never downwards. Under warm or hot propagation conditions, buds facing downwards will normally not grow.

2.6.2. Duration from laying to splitting

The duration from time of laying the culms to time of splitting largely depends on species ability of rooting. On average this time varies between 2-4 months. The indigenous species, *Y. alpina*, has difficulties in propagation. Research at KEFRI has pointed the major problem being as a result of poor rooting. Whereas shoots develop well, absence or development of few roots inhibit further growth after splitting resulting in death of split seedlings. Care should be taken in observing formation of roots and splitting should only be carried out when an adequate mass of roots has formed. Under ideal conditions, sustained warmth and adequate water, exotic species shoot and root readily.

Figure 6: Single and Double node culm cuttings

- For species like *Dendrocalamus hamiltonii* and *Bambusa vulgaris* 'Vitatta' use double node culm cuttings.
- Partially bury culm cuttings with one node in the soil in a slanting position as shown in Figure 7. Rooting from the buried node and sprouting from the node above the ground occur readily.

Figure 7: Slanted 2 node cutting propagation (foreground)

2.6.3. How to promote rooting and sprouting

For many bamboo species, the rate of rooting and shooting can be enhanced through use of hormones.

- Make an opening of about 2 cm in length and 1 cm in width in the centre of the internode as shown in Figure 8. Where the cutting has more than one internode the opening should be made at all internodes.

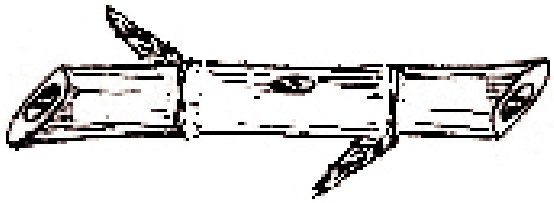

Figure 8: Opening at internode

- The most recommended treatment for root induction is the use of NAA. This is obtained as follows; dissolve 10 g of 1-Naphthalene acetic acid (NAA) in 250 ml of ethyl alcohol (95 %) in a container while stirring the solution gently. Pour the solution into a clean container and add water to make up 100 litres. Thoroughly stir to mix. The final concentration will be 100 mg/l of water.
- This quantity of solution is sufficient to treat 1000 cuttings. Small volumes can be

prepared by use of equivalent amount of NAA.

Pour about 100 ml of the solution into the culm cavity through the opening using a wash bottle or any other convenient apparatus to avoid spillage (Figure 9).

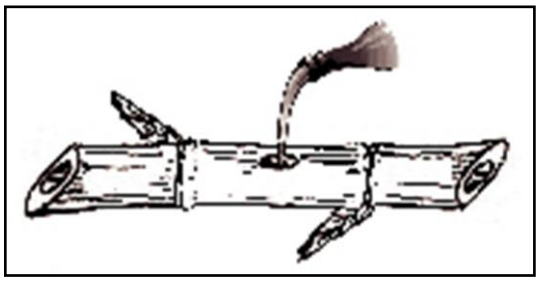

Figure 9: Pouring of NAA solution into culm cavity

- Close the hole by wrapping and tying it with a polythene strip (or any other material), ensuring that the wrapper is tight to prevent the solution from leaking (Figure 10).

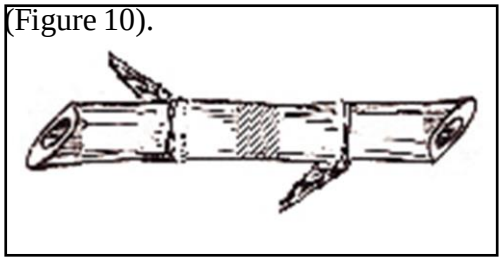

Figure 10: Tightly wrapped up culm opening

- Transfer the cuttings into a raised 1-m wide nursery bed filled with a mixture of soil and sand. Place the cuttings horizontally across the nursery bed, with the opening facing upwards.

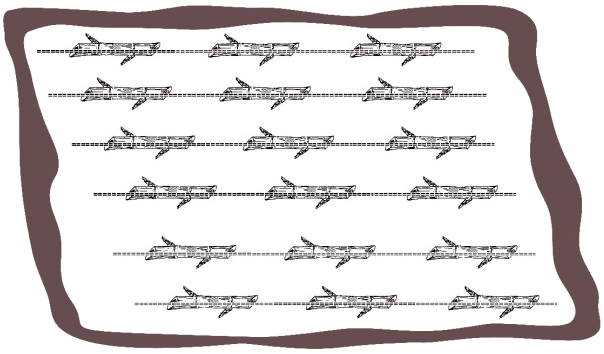

Figure 11: Culm cuttings nursery arrangement

- Treat the nursery bed with insecticide and a fungicide to prevent termite and fungal attack respectively one week before planting.

2.7. Using Tissue Cultured Plantlets

Tissue culture (TC) can be an alternative method of propagating bamboo on a large scale. It is a process that involves extraction of small tissues from selected mother plants and multiplied in the laboratory under aseptic conditions. When successfully done it can lead to rising of a large number of planting materials. However, its cost and level of technology required is prohibitive to local producers.

3.0. MODULE 3: NURSERY TECHNIQUES AND MANAGEMENT

- Trained personnel
- Site Selection
- Materials, tools and equipment
- Nursery establishment
- Record keeping
- Tending practices
- Nursery hygiene and seedling disease control
- Hardening

3.1. Learning Objectives

By the end of this session the participant will be able to:

- Describe requirements for establishment and management of nursery
- Demonstrate ability to keep records of plants and activities in the nursery
- Should be able to produce seedlings using methods described in module 2
- Should be able to tend seedlings up to time of transplanting to the field
- Learner should be able to identify and control incidences of pests and diseases

3.2. Trained personnel

The nursery needs to be run by either formally trained persons or persons sensitised on nursery management.

3.3. Nursery site selection

The selection of an appropriate nursery site is an important decision for efficient production of good quality bamboo plants. Factors to consider are:

- Availability of land

It is important that the site selected for the nursery has enough land to raise the number of seedlings required and room for expansion. The site should be accessible by an all-weather road. The nursery should be preferably located near a source of soil for use in the nursery to minimise transport costs. The topography of the nursery ground should be of a gentle slope to facilitate drainage. Contour terracing should be done if the slope is in excess of 2 per cent.

- Water supply

The nursery site should be located near a reliable source of water and have storage facilities.

- Preparation of media

The media for raising the plants should consist of a mixture of collected soil and farm yard manure in the ratio 2:1.

3.4. Nursery establishment

- Secure site by fencing
- Install internal facilities such as greenhouse (where necessary), watering systems, storage area, working shed, soil holding area, seedbed (where seed is used to raise material) and nursery beds (1-2m width).

3.5. Nursery beds

Ideal size of the bed is 1m to 1.2m wide. It should not be wider than 1.2m because of the difficulty of reaching the centre when weeding, watering or manuring. Seedbeds which are narrower than 1m are a waste of land. If possible, the beds should be oriented from east to west to provide better shade against the midday sun. Paths should be 50cm to 60cm wide to provide adequate working space. When the area for the beds has been levelled, protect the corners and the edges.

3.6. Materials, tools and equipment

- Tools and equipment; wheelbarrows, watering cans, pruning knives, hose pipes, secateurs, basins (holding fungicide)
- Materials; Potting bags (8cm by 12cm, 10cm by 15cm and 12cm by 18cm), polythene sheet for constructing tunnelling structure, media (soil, sand and compost)
- Record books
- Propagation materials (seeds, wildings and vegetative materials)

3.7. Record keeping

- Inventory of tools and equipment
- Identity of all plant materials in terms of history, collection sources, the size and dates is recorded.
- Production records showing processes, quantities involved
- Each material should be well labelled for identification purposes.

3.8. Tending

Standard nursery practices of weeding, watering, pruning, root pruning and hardening should be done appropriately.

3.9. Nursery hygiene and seedling disease control

- It is necessary to carry out regular monitoring and check the occurrence of pests and diseases and take appropriate control action.
- Bamboo has relatively few diseases at the nursery. Fungal attacks during splitting are common when fungicides are not applied. Termite control should also be done to prevent attacks on split culms that are prone to attacks and lead to eventual death of the culm.

3.10. Dealing with insect pests

- Monitor the presence and occurrence of the insect pests in the area.
- Practise proper sanitation in the area to control termites and sucking insects.
- Propagate seedlings using good potting materials preferably to control root feeding and sucking insects.

3.11. Hardening off

Before planting out, the frequency and intensity of watering should be reduced as well as reduction of shade to allow the plant to become more adaptable to field conditions. Gradually decrease the shade and watering levels and rates to harden the plants for between take one to two months. This process prepares the seedlings to withstand conditions in the field after planting.

MODULE 4: FIELD PLANTING AND ESTABLISHMENT

- Selecting the planting site
- Plantation Layout
- Site and ground preparation

3.12. Learning Objectives

By the end of this session the participant will be able to:

- Describe the physical conditions requirements and ecological factors to consider in the establishment and management of bamboo plantation
- Define and apply best plantation design and layout
- Apply best site preparation and planting practices

3.13. Selecting the Planting Site

It is important to apply site species matching when planning for planting. The indigenous bamboo species, *Y. alpina, grows best from an altitude of 2200 m.a.s.l.*

The planting area should be selected and demarcated early, preferably 2–3 months prior to the onset of rain in the year of planting. The identified site should preferably be prepared through complete cultivation. Where this is not possible strip clearing followed by holing at appropriate lines along a transect should be done. Establishing bamboo among crops promotes their growth through the tending and fertilisation of crops.

Bamboo prefers loamy and sandy loamy soils, but what is more critical is good drainage since the crop cannot withstand water logging. Species such as *Dendrocalamus strictus* and *Oxytenanthera abyssinica* are drought resistance and withstand environments having annual rainfall of less than 800 mm. For reasonably good growth most bamboos require annual rainfall of more than 1000 mm.

3.14. Plantation Layout

It is important to plan the field layout so that harvesting and hauling of culms is easened when the clumps have matured. A well planned field layout is essential to facilitate the management and enhance the yield of a bamboo plantation. Field layout should take into account the habit and size of the bamboos, such that small species are spaced more closely and large species are afforded wider spaces.

3.15. Spacing

A spacing of 5m x 5m may be sufficient for many bamboos but is inadequate for large species like *Dendrocalamus giganteus*, *Dendrocalamus brandisii*, or *Dendrocalamus asper*. For larger species, spacing should be widened and plants per hectare should be reduced; wider spacing will allow the clumps to reach their full potential, especially when the objective of the plantation is to harvest bamboo timber. Spacing of up to10 x 10m (100 clumps/ha) are suitable for large bamboos.

The following table shows spacing that may be considered for small, medium, to large bamboos.

Compare with table indicating bamboo species and size/common name

Plant Spacing (m) and Plants per Hectare			
In line	Between lines	Plants per ha	Species
4	5	500	
4	6	417	
5	6	333	
5	7	286	
6	7	238	
6	8	208	
7	8	179	
7	9	159	
8	9	139	
8	10	125	
9	10	111	
10	10	100	

3.16. Site and Ground Preparation

The preparation of the plantation site should only begin after a plantation layout has been clearly planned and defined. The planting site must be cleared of bush, grasses and other unwanted vegetation. Clean cultivation may also be carried out especially where intercropping of bamboo with other crops is to be done.

After ground clearing, planting spots are dug at spacing suitable for the species to be planted, in accordance with the plantation layout and design. The size of the planting holes will depend on the type of planting material as well as on rainfall and climatic conditions of the planting site. As a rule, larger and deeper planting holes are always better and allow for easier establishment of newly planted bamboos.

Usually holes of 60 cm diameter and 60 cm depth should be dug around each stake in areas of medium to high rainfall. Well rooted seedlings or TC bamboos may be planted in small holes of 30 cm diameter and 30 cm depth. Wider planting holes of up to 1 meter in diameter allow for improved micro-catchment and are preferred in areas where annual rainfall is less than 1000 mm. In all cases the holes must be refilled with soil up to 10 cm below the ground surface.

3.17. Field Planting

- Seedlings should be transported at the onset of the rainy season to ensure good survival.
- For offsets removed from the forest, with no nursing to be done at the nursery, planting must be done the same day with a maximum delay of one night.
- The rhizome portion of the offset should be placed 10-20 cm below the ground level and covered with soil.
- After placing the plant (either seedling or offset) in the hole, cover with soil and lightly press the soil around the plant. In areas that are prone to termite attack, the

plants can be protected using Marshal Suscon which is a slow releasing chemical lasting up to three years.

4.0.MODULE 5: PLANTATION MAINTENANCE AND HARVESTING

- Weeding and Mulching
- Replanting
- Plant Protection
- General Tending
- Harvesting
- Cutting cycles and methods of cutting
- Cutting Rules
- Cutting tools and extraction

4.1. Learning Objectives

By the end of this session the participant will be able to:

- Apply best bamboo plant husbandry
- Practice sustainable harvesting of culms (bamboo stems)
- Apply cutting rules

Proper maintenance and protection of the plantation is highly important. This involves replanting, plant protection, weeding, general tending and sustainable harvesting of culms.

4.2. Weeding and Mulching

In drier areas, with rainfall less than 800 mm it has been found that mulching around seedlings encourages growth through reduced evaporation of soil water.

Spot weeding rids the seedlings of competing weeds. This should be done at a radius of 60 cm around the seedlings after out-planting. Weeding should be regular or as necessary to avoid competition from weeds.

4.3. Replanting

Not all transplanted seedlings and offsets will survive the new environments. Plantations should therefore be visited regularly to check on the survival of plants and replace dead seedlings and offsets. Replanting should be done simultaneously with the first weeding schedule. This is done in the subsequent rainy seasons when there is enough moisture until the second year.

4.4. Plant Protection

Bamboos are palatable to many animals. Simple sticks can be used for protection; these are stuck in the ground around the seedlings and made to converge above the seedling, forming a conical shape of protection. Where browsing might come from large animals, some fencing may be necessary to allow establishment of the bamboo seedlings

4.5. General Tending

Depending on the intensity of weed growth, weeding and hoeing may have to be repeated in the second and third year. Soil should be heaped around the developing clump to allow and ease shoot production, which takes place mainly in the periphery of the clump.

4.6. Harvesting

As stated above, the main bamboo species under cultivation in Kenya are the clumping types. The clumping habit enables the plant to regenerate naturally after harvesting. Harvesting of bamboo is through selection of culms for cutting rather than clear felling.

The planted area should normally be ready for first harvesting in about six to eight years. Thereafter, cutting of mature stems can be done when need of the materials arises and there are mature culms.

The cutting cycles and methods of extraction of stems from a bamboo clump entail an important management system of the entire bamboo plantation. Success or failure of sustainability of crop production will therefore depend on how best stem extractions are carried out.

4.6.1. Cutting Cycles and Methods of Cutting

- After the first cutting in a plantation, subsequent selective extraction of bamboo stems should be done at intervals of 4 years.
- Unless properly managed, clumping bamboos tend to become congested, resulting in deterioration both in quality and in quantity.
- In a clump, new culms are normally produced outwards, towards the periphery of the clump and the older stems are left in the centre. Harvesting of bamboo therefore should be from the centre and not at the sides of the clumps. (Figure 16).
- This makes it necessary to maintain clumps in the shape of a horse-shoe (Figure 17), keeping the apex towards the side where the new culms are progressing. The open end of the horse-shoe facilitates entry inside the clump for cutting of mature stems.
- Alternatively, the clump can be managed by creating a cross tunnel (Figure 18), which divides the clump into 4 sections and allows full access for harvesting mature culms.
- The new culms which attain an average height of over 10 m within the first few months, under suitable conditions, are soft and tend to decline unless supported by mature erect stems of earlier years. A few older stems should therefore always be left in the clump after cutting.

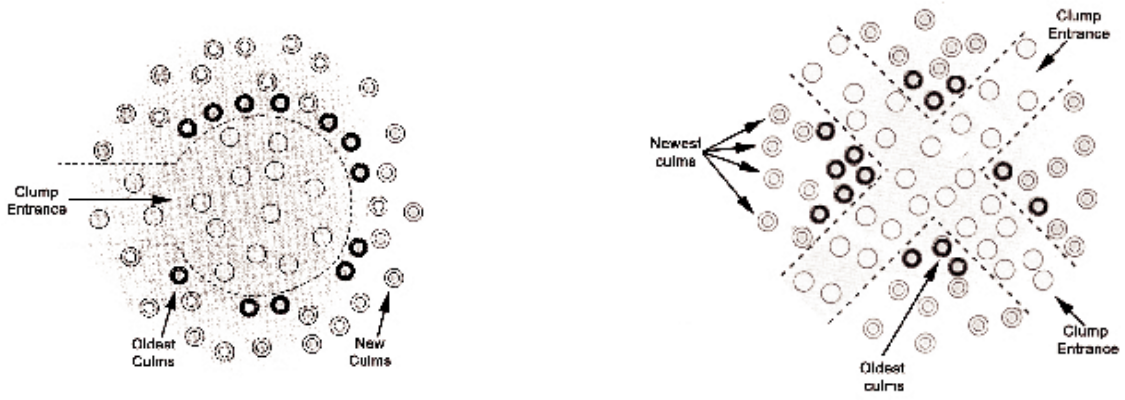

Figure 12: Horseshoe and Cross tunnel Clump harvesting method

4.6.2. Cutting Rules

The following bamboo cutting rules are to be followed for a well-established bamboo area, taking into consideration what has been stated above:

- Culms growing on the periphery of the clump should not be cut.
- Cutting should be restricted to the oldest culms in the centre of the clump.
- All dead and dry culms should be cut and removed.
- Heavily congested clumps may not be salvaged to productive state and should be clear-felled.
- Current year's and one-year old culms should never be cut unless in cases where they are curved and twining around other culms or are infested by disease or insects.
- The number of older culms retained should not be less than the number of current year's culms.
- Rhizomes should not be dug out.
- Culms should be cut between 15 and 45 cm from the ground, but not below the first prominent node above the ground.
- Cutting should be made with a sharp panga or saw so that the stump is not split.
- No cutting of culms should be done during the growing season, i.e. during the rains. Culm cutting should be done only during the dry seasons.
- In case of sporadic or gregarious flowering, all flowered clumps which have shed their seeds should be clear-felled.

5.0. MODULE 6: POST HARVEST TREATMENTS

- Non Chemical Methods
- Chemical Preservation Methods

5.1. Learning Objectives

By the end of this session the participant will be able to:

- Demonstrate different preservation methods
- Apply appropriate bamboo preservation treatments
- Distinguish methods that are environmentally friendly

5.2. BAMBOO PRESERVATION AND TREATMENT

Bamboo culms are rich in starch and sugars which makes them highly susceptible to fungal and insect attacks. This has been a major hindrance to its value and wider application. The lifespan of bamboo that has not been preserved is about 2 years. However, preserved bamboo can last up to 20 years.

Local communities and artisans have long used traditional methods for bamboo preservation. Although these methods provide some form of protection, long-term durability is not guaranteed and these methods should not be recommended for commercial products.

5.2.1. CHEMICAL METHODS

For local communities, without adequate resources, there exists simple and efficient ways of preserving bamboo. Two of these methods follow almost similar processes are; vertical soak and horizontal dip diffusion.

5.2.2. Preparation of Bamboo Culms for Treatment

5.2.2.1. Sizing culms

The length sizes to be cut depend on the end product proposed. For construction, for example, 2, 3 and 4 metres culms are cut. For construction purposes, 6 metre culms are cut. Therefore the end application will determine the length.

Figure 13: Bamboo sizing

5.2.2.2. Perforation of the culms

This is mainly done to facilitate the treating formulation to move throughput the culm. A long rod can be used to puncture the node areas or if available a drilling machine connected to a long metal rod can be used.

Figure 14: Culm perforation

It is important to note that the punching method is dependent on the treatment method. In the case of vertical soak diffusion, punch all nodes except the bottom node. In case of horizontal dip diffusion, all nodes should be perforated.

5.2.3. Vertical soak diffusion treatment

All nodes are perforated in this method. Culms are placed vertically in a drum and borax solution poured in.

Step 1

Ensure that the culms are properly cleaned before treatment. Scrubbing dirt from the Culm can be done using water and scourers.

Figure 15: Culm cleaning

Step 2

Prepare a 200 litres drum filled with water. The drum should be in an elevated position to allow setting up of fire. To avoid tipping, ensure the drum lies on a flat surface.

Step 3

Dissolve 5 kg borax oxide and 5 kg boric acid in 200ltr drum. The total of 10kg borax mixture mixed with 200lt of water will give a 5% concentration. With the fire on, stir the solution continuously until all the borax is dissolved.

Figure 16: Addition of borax and boric acid

Step 4

Place the culms to be treated in empty barrels maintaining a vertical position. Fill the culms with the borax solution. Leave the culms in the same position for 8-10 days.

Figure 17: Addition of borax solution to standing culms

Step 5

After the treatment period, puncture the bottom node and drain the remaining chemical in another container. This chemical can be used to treat other culms severally. The final borax solution that remains unused can be mixed with sawdust or other material and used as mulch or fertiliser.

5.2.4. Horizontal dip diffusion methods

Perforated bamboo culms are dipped in borax solution mixed in a trough. The trough can be made from cutting a drum into two. Steel barrels are preferable and in case of the slow cold method a concrete trough can be used.

Step 1

Clean culms as in the other method. Prepare the drum and elevate it as before to put up a fire. Heat the water while adding borax solution.

Step 2

The length of the trough should be designed to accommodate the required sizes of culms that will be used to make furniture products.

Three methods are applicable in this treatment type but they yield different productivity levels of equal efficiency.

Option 1: fast method (Hot)

Up to four full loads of bamboo can be treated in a day. 5% borax concentration is prepared and mixed with water in a heated trough. Adequate fire should be maintained to ensure the temperature of the solution ranges between 70^0 – 80^0C. Culms should be immersed in the heated solution and weight placed on top, preferably concrete, to ensure all culms are fully immersed. Boiling time is dependent on the size of culm walls, thin culms take between 1-2 hours while thick walled culms take 2-3 hours. Monitor the borax levels constantly and add as required.

Figure 18: Heating bamboo in borax solution

Option 2: Slow method: (Hot and Cooling down)

Two full loads can be done per day and the temperature should be maintained at 80^0C. Repeat the process of adding 5% borax while heating the solution. Allow the fire to die off gradually allowing the culms to be soaked in the warm solution for about 4 hours. The treatment of one load full might take about 6 hours.

Option 3: Cold Method

A metal or concrete trough is ideal in this method. The perforated culms should remain in the borax solution for 7 days. Using this method one load of bamboo can be treated every 7 days (one week).

Figure 20: Concrete tank for soaking bamboo culms

5.3. Non-Chemical Methods

Clump curing: Culms are cut at the bottom, but are left standing on the clump for some time with branches and leaves still on. Because the assimilation of the leaves still goes on, the starch content in the culm is reduced and as a result, the durability against infestation by borers is increased. This treatment does not influence attack by termites or fungi.

Smoking: culms are stored above fireplaces inside houses for some time so that the smoke blackens the culm. Due to heating, the starch within the stem cells may be destroyed. In Japan, the bamboo materials are kept in a heating chamber at 120 -150° C for 20 minutes. The treatment is effective against insect attacks.

Plastering: cow dung is mixed either with lime or with mortar and plastered onto the surface of bamboo. This is a common method used in the construction of bamboo houses.

Soaking in water: Freshly cut, green, culms are put into stagnant or running water or mud for several weeks. Subsequently the bamboo is dried in shade. During the soaking period, starch is reduced and the method therefore improves the resistance against borers which are usually attracted by the high amount of starch in bamboo culms.

6.0. MODULE 7: CURRENT AND POTENTIAL USES OF BAMBOO

6.1. Learning Objectives

By the end of this session the participant will be able to:
Describe various uses of bamboo

6.2. Various uses of bamboo

Bamboo can be put to many uses, most of which have not been locally developed. The following are only a few uses that could locally be developed for the benefit of the farmers. Appendix 4 provides a more extensive listing of some common uses of bamboo.

- Fencing is the most common use of bamboo in Africa and throughout the tropics, particularly for homesteads and farms as a protection against grazing.
- Farming has continued to make use of bamboo particularly as props or supports for horticultural crops like peas, flowers, and bananas. In addition, many farm tools are made from bamboo.
- Construction and Scaffolding are well known important uses of bamboo in Asia. Large and strong bamboos have a high potential use as scaffolding and construction material throughout tropical Africa. The use of bamboo in reinforced concrete in buildings of various designs, sizes and uses is on the rise. For general construction purposes, only mature bamboo culms that are at least 3 years old should be used.
- Handicraft is a traditional use of bamboo in Asian and African countries. Bamboo culms are split into strips and slivers and handcrafted into numerous products. Tea picking, fruit and laundry` baskets are common products. In some countries, mat making is very common and provides livelihood to many communities. Other handicraft items include toys, ornaments, containers, musical instruments and various household products.
- Production of edible bamboo Shoots of *Yushania alpina* are consumed by communities around Mount Elgon in Uganda and, to a lesser extent, in Kenya. In other countries in Africa there are niche markets for bamboo shoots.
- Bamboo Furniture production is on the rise in Africa. Bamboo furniture such as chairs, sofa sets, and beds are relatively low priced compared to timber products. They are particularly suitable
- Bamboo panels and particle boards are important applications in Asia with a strong potential in Africa. Asian countries have produced designs that are; marketed worldwide.

Figure 21: Bamboo particle boards

- Biomass from bamboo has comparable energetic value to wood. Bamboo can be used as an alternative to fuel wood, and it can be transformed into charcoal, briquettes, activated carbon, and biodiesel. The increased use of bamboo as biofuel can play an important role in reducing pressure on the slower growing trees.

7.0. MODULE 8: BAMBOO AS AN ENTERPRISE

7.1. Learning objectives

By the end of this session the participant will be able to:

- Appreciate bamboo as an income generating activity
- Recognise the costs associated with commercial bamboo production

Bamboo can be used as an income generating crop by farmers, individual or group nursery owners and even institutions. The current increased uptake of bamboo growing offers a good market for seedlings and culms.

Table 1.0: Potential revenue from sale of Bamboo seedlings

No. of seedlings	Unit price	Gross Revenue (Ksh)	Total Cost (Ksh)	Net Returns (Ksh)
2000	250	500,000	200,000	300,000

7.2. Bamboo seedlings production cost

- Green house installation cost…….…….250,000/=
- Fungicides…….……..…..3,000/=
- Production cost per bamboo seedling is estimated at …..100/=
- With adequate propagation materials and availability of initial capital, production of 2,000 seedlings can be done twice in a year. The area required to produce this amount of seedlings is around an $1/8^{th}$ of an acre.

Table 1.1: Potential revenue from sale of Bamboo culms per Hectare

Age	Gross Revenue (Ksh)	Total Cost (Ksh)	Net Returns (Ksh)
5	320,000	150,000	170,000
7	576,000	150,000	426,000

7.3. Bamboo culms Production cost

- Purchase of seedlings……100,000/=
- Holing, planting and maintenance…….50, 000/=

7.4. CONSTRAINTS TO BAMBOO DEVELOPMENT

7.4.1. The Image Problem of Bamboo

In Kenya, bamboo has a reputation of being a traditional and primitive material. People are generally unaware that high quality applications are possible with bamboo. Bamboo has not received adequate publicity to give it the image it rightly deserves, namely that of being a fast growing, multi-purpose and eco-friendly plant which has great potential of reducing pressure on forests.

7.4.2. The Harvesting Ban

The existing ban on bamboo extraction has prevented the sector from developing.
This includes the following aspects of resource management:

- Production of seedlings
- Knowledge about silvicultural treatments and harvesting techniques
- Post-harvest treatment practices
- Industrial processing
- Marketing of bamboo products

Developments in all these market segments have slowed down because bamboo has not been used and promoted in a planned and systematic fashion.

7.4.3. Weakness of the Institutional Environment and Networking

There is no proper interdepartmental cooperation to formulate and implement a comprehensive bamboo promotion strategy. The stakeholders have also failed to organize an effective system of networking. As a result, cooperation among stakeholders and lobbying in the political arena is very deficient.

7.4.4. Lack of Credit and Financing

Poor capital endowment and access to credits have prevented cottage industries from up-scaling their bamboo-related activities. Funding to upscale activities is not available from commercial banks, at least not at affordable rates. This lack of capital has prevented the sector from developing its full potential in the country, and it is likely to be a limiting factor even if the use of bamboo is legally sanctioned and politically promoted.

7.4.5. Global Competition

Bamboo industries in Asia are rapidly developing and imported products are already threatening Kenyan bamboo manufacturers. In order to survive and thrive in the global arena, the local sector will have to become increasingly competitive. The availability and quality of local raw material resources will have to increase substantially and stakeholders will have to upgrade their skills, production processes, designs and marketing techniques.

Glossary of terms

Clump - A cluster or group of stems of bamboo growing from a common underground rhizome system

Culm – Stem of the bamboo plant

Cutting cycle - Period between stem cutting or harvest from a clump and the next time cutting is done in the same clump or bamboo stand. Cutting cycles are series of cuttings or harvests taking place in a regularly repeated order.

Fine Rose can - A can usually with a handle and an arm fitted with arose- shaped cover at the end, with fine holes for watering seedlings.

Leptomorph Bamboo - Type of bamboo formation that spreads by underground rhizomes or stolons. Leptomorph bamboos are mostly found in the temperate climatic conditions.

Mulching - Protective covering of leaves spread over the roots of nursery or planted seedlings to retain moisture or smother weeds.

Offset - A dug out rhizome with a short portion of a culm (about 50 cm long) attached.

Pachymorph Bamboo - Type of bamboo formation that displays distinct clumping in their development and growth. Pachymorph bamboos grow mainly in the tropical climatic conditions.

Plantlets - Smalls plants that develop from mass of cells (callus) of plant parts being used in mass propagation of bamboo through tissue culture technique.

Proliferation – The method of separating a developed system of rhizome in young nursery material into many individuals.

Rhizome - Thick, horizontal stem of bamboo just below the ground, from which new shoots and roots grow.

Plant Tissue Culture – A biotechnological method that enables the nurturing of a plant organ, tissue, cells or even cells without walls in a controlled nutrient medium. The technique is useful in mass propagation of plants.

Wildings - Seedlings germinated in the wild under natural conditions after

APPENDIX 1: BAMBOO SPECIES INTRODUCED TO KENYA

Botanical Name	Form of Introduction	Origin
Arundinaria alpine	Offsets and wildings	Kenya
Bambusa vulgaris	Offsets	India
B. vulgaris var. striata	Cuttings	Asia
B. bamboos (B. arundinacea)	Seed	Thailand and India
B. nutans	Offsets	India
B. thornicornis	Offsets	Asia
B.tulda	Seed	Thailand and India
Cephalostachyum pergracile	Seed	Thailand
Dendrocalamus brandisii	Seed	Thailand
D.hamiltonii	Seed	India
D.membranaceus	Cuttings	India
D.strictus	Seed	Thailand
D.aspera	Seed	Thailand and India
Oxytenanthera abyssinica	Offsets	India
Phyllostachys pubescens	Seed	Zimbabwe
P. nigra var. henonis	Offsets	Zimbabwe
Shibataea ruscifolia	Seed	Japan
(syn. S. kumasasa)	Offsets	Asia
Thyrsostachys siamensis	Offsets	Asia
	Seed	Thailand