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Guidelines for Growing Bamboo

Bernard N. Kigomo

KEFRI Guidelines Series: No. 4 - April 2007

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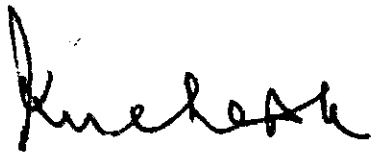
Foreword

Bamboo is a fast growing woody grass. Bamboo species grows naturally on the mountains and highland ranges of Eastern African countries, and in the medium lowlands of other countries of Africa. Bamboo plays a vital role in the protection of the soil and water resources in forested catchment areas. Bamboo has been and continues to be a material of choice for traditional crafts through out Africa. Bamboo is also important for construction, fencing, basketry and many other uses. These uses of bamboo makes a significant contribution to rural income and employment, although the rapidly diminishing supplies of forest bamboo through indiscriminate clearing of natural forests and the lack of priority in its development join forces to erode its status.

Because of such factors and the rapid growth in human population, the demand for bamboo has increased. This has also led to reduction in bamboo cover to make land available for human settlement and over-exploitation especially in the more accessible forest areas. The Governments in the Eastern Africa region have recognized the deteriorating situation and devised policies to encourage sustainable management of bamboo as a renewable resource. One of the options of increasing bamboo resource is through its domestication on farms. Farmers however need information to assist them to grow and manage bamboo because it is not a traditional agricultural crop in most of the African countries.

In 1995, the Kenya Forestry Research Institute published a booklet to provide guidelines on how best this important resource can be managed, especially under cultivation. This booklet has now been revised to enhance its use by extension officers and farmers. The guidelines are based on studies undertaken by the Kenya Forestry Research Institute from 1986 to date and inputs from experiences of other countries, especially in Asia.

This handbook starts by providing background information on the need for improved management of bamboo. It then presents detailed procedures on its propagation, field planting, tending, and maintenance of plantations. Knowledge on the utilization of bamboo is also important for its proper management. The handbook, therefore, provides guidelines on the proper harvesting, care and treatment of this valuable resource. In order to diversify its utilization, some current and potential uses are discussed. It is anticipated that this handbook will provide information for practical use by government extension staff, NGOs, bamboo growers and users.



Dr. Paul K. A. Konuche,
Director, KEFRI
April 2007

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Acknowledgement

This handbook is a revised and updated version of the booklet on 'Guidelines for Establishment and Managing Plantations of Bamboo in Kenya' which was published in 1995 by the Kenya Forestry Research Institute (KEFRI), with the support of the Goverment of Kenya and the International Development Research Centre (IDRC), Canada. Dr. Victor Brias has provided very valuable assistance in the revision of the booklet. The revised handbook has been published with the support of the Common Fund for Commodities (CFC), the United Nations Industrial Development Organization (UNIDO), and the International Network for Bamboo and Rattan (INBAR). Their cooperation and financial support are greatly acknowledged.

Introduction

During the last century, forests were mainly assessed in terms of the commercial value of timber. Rarely were other forest components considered to be of major economic importance. In the 1900s, when vast areas of tropical forests were denuded of timber for local use and exportation, bamboos and other non-wood products were usually discarded or destroyed during logging operations.

In the 21st century, however, there is a growing consensus that non-wood forest products are not only crucial to ecosystems but also invaluable to the livelihood of communities. Non-wood forest products are known to generate substantial foreign exchange and are increasingly being regarded as valuable commodities around the world. Our perception and evaluation of non-wood forest products is changing due to alarming rates of deforestation and decreased timber yields.

The government of Kenya has, for instance, formulated policies to address the state of low supply of wood products. A ban on logging was declared in most of the forests in the country and awareness campaigns on the importance of forests and forest conservation were undertaken by non-governmental organizations. In Kenya, policy makers have also focused on the importance of non-wood products and services and their economic potential as alternative sources of revenue. Similar initiatives have been made by other East African Governments.

Among the most important minor forest products, bamboo has continued to gain recognition. Once upon a time, bamboo was regarded as a weed; today it is considered as a multipurpose plant and as a valuable timber substitute. It is much sought after for use in horticultural flower farming, handicraft, residential fencing and other minor cottage industry products like toothpicks, basket making and match sticks. 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. Increased availability of materials would also provide for the fast expanding horticultural flower farming.

Most of the bamboo resources in Kenya comprise one indigenous species, *Yushania alpina*, which was formerly known as *Arundinaria alpina*. This species, which is commonly known as "alpine bamboo", occurs naturally on the main mountains and highland ranges of Kenya and eastern Africa. 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. In Ethiopia the species is estimated to cover 120,000 - 130,000 ha. With the exception of a few clumps of the species left on farms by farmers living around forest areas in the highlands, where the species grow naturally, little cultivation of this species has been done in both countries. Such farmers are keen to undertake planting themselves, but face problems with establishment and the lack of effective management interventions.

In addition to *Yushania alpina*, Ethiopia has a huge resource base of what is commonly called lowland bamboo or *Oxytenanthera abyssinica*. The species occurs at elevations of 300 – 700 meters and with rainfall of 300 – 800 mm/year (Treville and Kigomo, 1992). This species is estimated to cover between 750,000 – 900,000 ha in Ethiopia (LUSO- Consult, 1997). There have been no formal attempts of managing or domesticating this species (Kigomo, 1997). Sudan, Tanzania, and Uganda also have this species but at a much lower area cover. *Oxytenanthera abyssinica* is also distributed in isolated pockets between 12-13 degrees latitude, from Ethiopia to Senegal in the north, and Mozambique across to Angola in the south.

During the last twenty years, some research on species selection and investigations on their growth was done mainly by the Kenya Forestry Research Institute (KEFRI) in collaboration with several Asian research and development institutions. This research work has 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. Farmers, horticultural flower farming companies, and the Forest Department have expressed great interest in growing these bamboo species on their land, but no harmonized methods have been introduced to ensure that projected outputs are successfully achieved.

The situation of bamboo in Kenya is paradigmatic for much of tropical Africa. Governments, NGOs, and private enterprises in many African countries are developing initiatives to promote the cultivation of bamboo as an industrial crop. Whilst these guidelines on bamboo plantation management have been developed in response to a specific need in Kenya, it is thought that they will be useful in other parts of the continent.

The Growth Habit of Bamboo

The bamboo plant (Figure 1) is made up of an underground axis and 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.

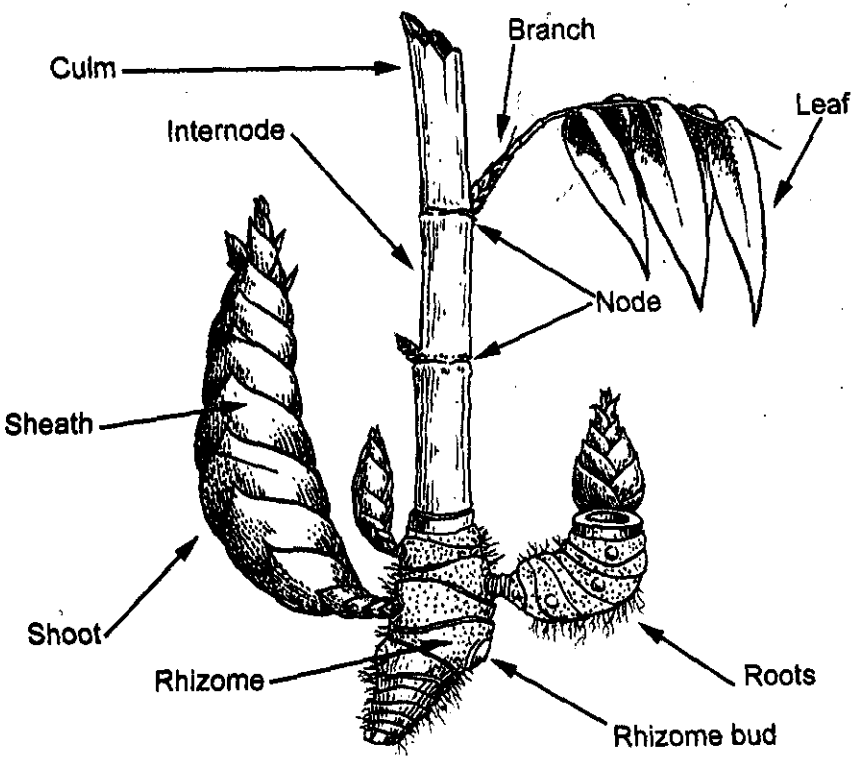


Figure 1: *Parts of the Bamboo plant*

The bamboo culm is cylindrical and is divided into sections by diaphragms or *nodes*. The section between two nodes is called an *internode*. Internodes are hollow in most bamboos, but solid in some species. 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 bamboo culm does not get thicker each year. Unlike trees, bamboos do not have any secondary growth. Rather, as the rhizome system develops and matures, new and larger shoots emerge annually until the maximum size of the species has been reached. The life of a culm varies from species to species. Usually 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.

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.

Two main systems of rhizome formation are predominant in bamboos, namely clump forming rhizomes and running or creeping rhizomes. Clump forming bamboos have rhizomes that exhibit a *sympodial* branching pattern. Running bamboos, on the other hand, have rhizomes with a *monopodial* branching pattern.

In sympodial branching, each branch or axis, becomes dominant. In the case of bamboos with sympodial rhizomes, each new rhizome turns upward and develops into a culm. On the other hand, bamboos with monopodial rhizomes have a single, dominant subterranean stem, or axis, that develops secondary stems that either extend laterally or turn upward to become culms. The lateral extension of the monopodial bamboos may exceed hundreds of meters.

Although the terms *sympodial* and *monopodial* describe the morphology and behaviour of rhizome systems, taxonomists use these terms to describe the branching pattern of all parts of the bamboo plant, not only the rhizomes. Taxonomists reserve the terms *pachymorph* and *leptomorph* to describe the morphology of two basic types of rhizomes (Judziewicz et al., 1999; Stapleton, 1997; Dransfield & Widjaja, 1995).

In all woody bamboos, the culms branch in a monopodial manner regardless of the branching pattern of the rhizomes. The rhizomes of tropical clumping bamboos branch out in a sympodial manner, but the culms branch in a monopodial manner. There are some bamboos where a combination of monopodial and sympodial branching occurs in the rhizomes, and this system of branching is referred to as amphipodial.

Pachymorph rhizomes always exhibit sympodial branching. Leptomorph rhizomes may exhibit simple monopodial branching, but the rhizome branching is amphipodial when tillering occurs. There is, however, another type of rhizome system known as amphimorph which combines leptomorph and pachymorph characteristics and which also exhibits amphipodial rhizome branching (Judziewicz et al., 1999).

Five types of rhizome systems (Figure 2) are distinguished by taxonomists, namely: (1) Simple pachymorph; (2) Long necked pachymorph; (3) Simple leptomorph; (4) Tillering leptomorph; and (5) Amphimorph.

Short-necked pachymorph rhizomes and long necked pachymorph both exhibit sympodial branching. Simple leptomorph rhizomes, on the other hand, always exhibit monopodial branching.

Tillering leptomorph rhizomes have not been observed in tropical woody bamboos. A species with this rhizome formation is *Shibataea kumasaka*, a herbaceous temperate bamboo that is used as an ornamental plant.

Amphimorph rhizomes are extremely rare in bamboos and have been observed in Latin America in only 3 species, namely *Aulonemia fulgor*, *Chusquea fendleri*, and *Chusquea scandens*.

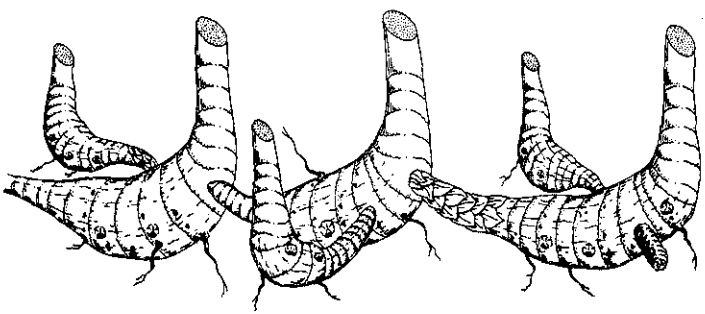


Figure 2a: Simple Pachymorph Rhizome

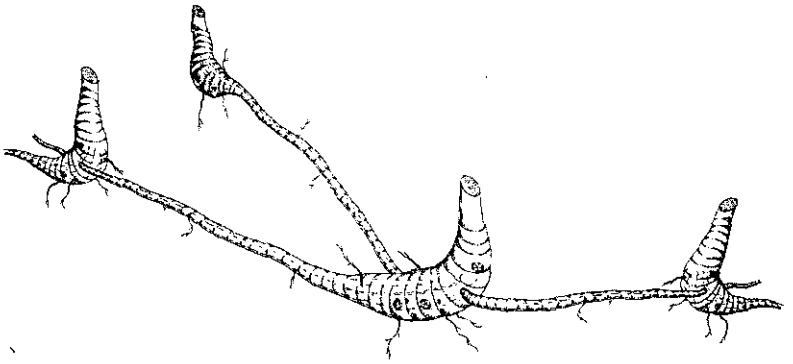


Figure 2b: Pachymorph Rhizome with elongated necks

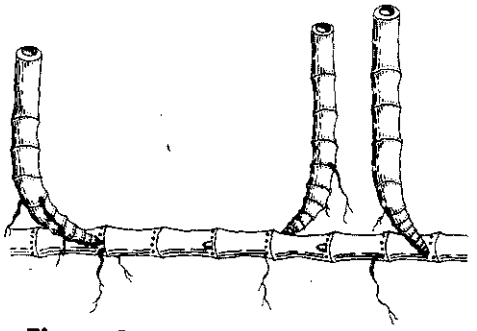


Figure 2c: Leptomorph Rhizome

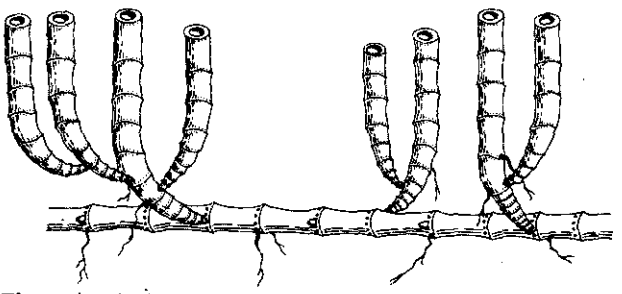


Figure 2d: Tillering Leptomorph Rhizome

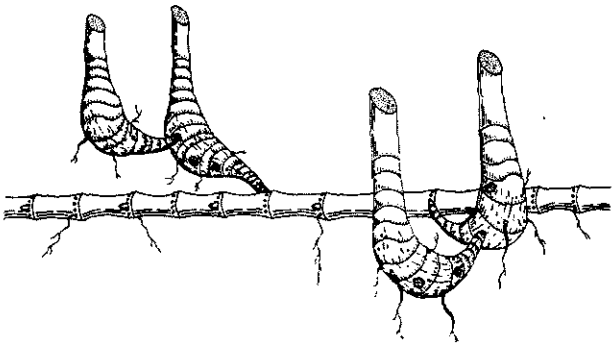


Figure 2e: Amphimorph Rhizome

Figure 2: *Five Types of Rhizome Systems*

The rhizome systems of the most common tropical woody bamboos are either pachymorph (Figure 3) or leptomorph (Figure 4). Most tropical clumping bamboos have short necked pachymorph rhizomes. Pachymorph bamboos can be broadly distinguished by tight and diffuse clumping varieties (Figure 5). *Dendrocalamus giganteus*, for instance, forms tight or densely tufted clumps. *Yushania alpina* is sometimes confused with running bamboo species, when in fact it is a loose clumping bamboo with elongated rhizome necks. Another example of an economically important pachymorph bamboo with very elongated rhizome necks is *Melocanna baccifera*, a species native to Northeast India and Burma.

Pachymorph, clumping bamboo (sympodial rhizome branching)

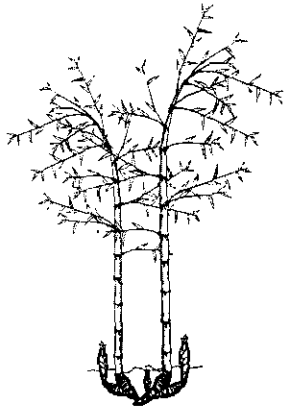


Figure 3: Pachymorph and Sympodial bamboo

Leptomorph, running bamboo (monopodial rhizome branching)

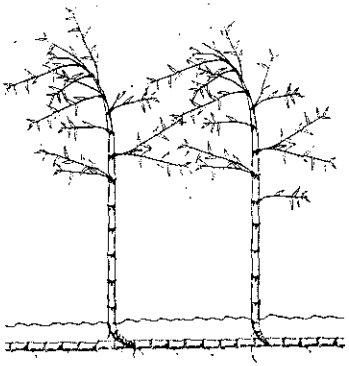


Figure 4: Leptomorph and monopodial bamboo

Tight clumping bamboo (left), Diffuse clumping bamboo (right)

Figure 5 : Tight and Diffuse Clumping Bamboos

While *pachymorph* bamboo remains isolated into identifiable clumps, *leptomorph* bamboo spreads over large areas. *Phyllostachys aurea*, which is cultivated in Kenya and throughout many parts of the tropics, is a running bamboo with leptomorph rhizomes. All bamboos of the genus Phyllostachys have leptomorph rhizomes. *Phyllostachys pubescens* is a very useful and economically important bamboo which thrives in sub-temperate regions of China and Japan but does not grow well in the tropics.

In natural conditions, the indigenous species *Yushania alpina* may also be confused with the spreading bamboo type since the clumps join and it becomes difficult to distinguish the parental sources. *Yushania alpina* is however a pachymorph species and under cultivation maintains very strong clumping characteristics. Most of the economically important tropical bamboos are clump forming. Since the indigenous species and exotic bamboo species introduced in Kenya and other parts of tropical Africa are mainly clump-forming types, the developed strategies for silvicultural operations will be based on this group.

As stated earlier, 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, crop management,

and harvesting methods. This handbook consolidates and provides such invaluable information.

In addition, the booklet 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 handbook 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. A glossary of some terms used in the text is provided in Appendix 5.

Clumps of *Yushania alpina*

Clump of *Dendrocalamus asper*

Types of Plantations

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 programmes.

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 fibre for producing domestic implements such as baskets and mats. The widespread cultivation and use of bamboo in homestead farms around Kenya can be very economically and environmentally beneficial inasmuch as it creates a wood and energy substitute for trees.

Commercial Plantations

Bamboo can be planted as a commercial crop in areas of 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.

Agroforestry

The term 'agroforestry' 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. Agroforestry 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

agroforestry 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 the production and positive environmental effects while avoiding the shortcomings of monoculture plantations.

Conservation Programmes

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.

Raising of Planting Materials

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 forests. Tissue-cultured plantlets provide other forms of planting materials. Such planting materials can be obtained and raised in the nursery as described below. Appendix 3 outlines some of the preferred methods for propagating various bamboo species.

Propagation by Seed

Bamboos generate seeds when they flower. For many tropical bamboos, flowering intervals range from 40 to 80 years. There are two types of flowering in bamboos, gregarious flowering and 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 *Yushania 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 very 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.

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 or in polyethylene containers. Cover with a thin layer of soil and water daily. Watering should be done carefully using a fine rose can.

- When germinated, seedlings should attain a height of 3 cm before they are carefully transplanted into soil filled boxes or polyethylene tubes.

- After 8-12 months, good-sized transplants can be obtained. It has however been observed with some species that seedlings over one year old establish better. Where rhizomes of seedlings have not developed well due to inadequate supply of water or soil nutrients, such seedlings may be maintained in the nursery for over one year.

Use of Wildings

Apart from raised seedlings, wildings of bamboo from indigenous forest stands can be collected and used for raising a bamboo plantation. There are a few places in the cold areas of Mt. Elgon, Mau and Aberdare ranges where wildings of *Yushania alpina* have been found.

Young clusters of bamboo wildings can be scooped using a spade and taken to the nursery for individual pricking into polyethylene tubes. Care should be taken to avoid disturbing intact small wildings which resemble a mass of grass in the field. Small wildings of bamboo that are pricked into tubes and kept under shade generally establish well. This method can raise many seedlings.

Once in the nursery and under shade, watering can be done regularly using a fine rose-can. Direct planting of large bamboo wildings has not been practised in Kenya. Most likely establishment would be poor due to disturbance of the rooting system during the uprooting from the forest.

Vegetative Propagation

When seeds or wildings are not available, bamboos can be propagated vegetatively. This offers a better source of planting material. Offsets (rhizome with attached section of stem) are commonly used but their extraction is laborious and time consuming, and it is difficult to collect large quantities of planting materials. During extraction, damage may also occur to the roots, buds and rhizomes of mother clumps. Offsets are bulky and also difficult to transport. Only small annual planting programmes may therefore be possible when using offset materials.

Use of culm cuttings is a viable alternative and has several advantages. Multiplication of several clumping species is possible by this method. When outplanted, vegetative materials raised from cuttings develop to clumps much faster than offsets and even seedlings. The local species of bamboo, *Yushania alpina* and *Oxytenanthera abyssinica*, have however proved difficult to propagate in this manner.

Bamboos with leptomorph rhizomes cannot be propagated by means of culm cuttings. Success rate is however very high by means of offsets.

Using Culm Cuttings

- Good cuttings are obtained from 2 to 3 years old culms of healthy clumps.

- Double node or triple node cuttings are then prepared from the cut culms. The cuttings should be made leaving a space of 5-7 cm away from the nodes. A sharp cutting knife or panga is necessary. For bamboos with thin walls the use of a saw is recommended to avoid splitting of the cut ends.

- The best culm cuttings are generally those that are obtained from the lower and thicker part of the culm, which has the vigour to generate roots and shoots.

  Successful rooting and shooting is generally harder to achieve with cuttings from the upper and thinner part of the culm.

- 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.

- The cuttings should then be buried 6 – 10 cm horizontally on a raised nursery bed prepared with a light soil and sand mixture (Figure 6). 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. Buds at the nodes or branches should always be placed on the sideways or facing upwards and never downwards. Under warm or hot propagation conditions, buds facing downwards will normally not grow.

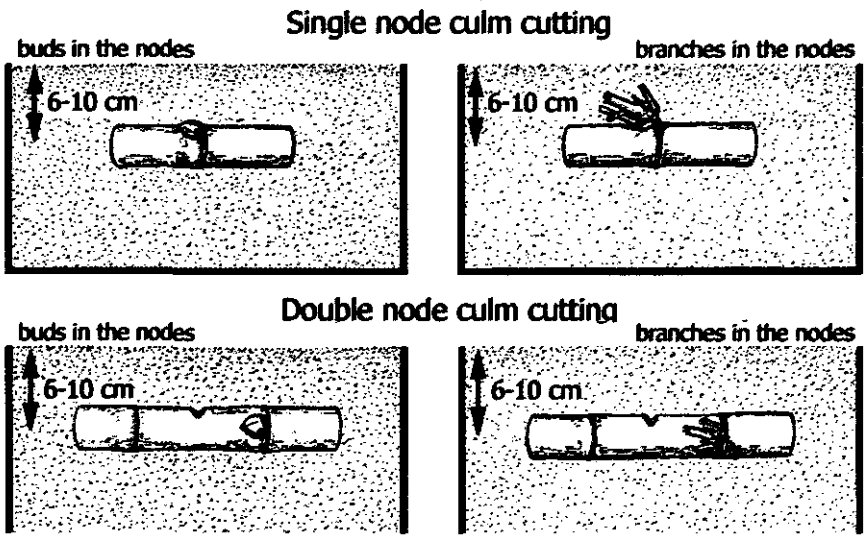


Figure 6: Double and triple node culm cuttings

- Remember that for many species, the propagation success rate by culm cuttings can be difficult or very low! For example, it is very difficult to propagate species such as *Dendrocalamus giganteus* and *Dendrocalamus brandisii* by means of culm cuttings. As for the local species, *Yushania alpin*a and *Oxytenanthera abyssinica*, the success rate is extremely low.

- Some species like *Dendrocalamus hamiltonii* and *Bambusa vulgaris* 'Vitatta' propagate very well by means of double node culm cuttings without any further preparation or treatment. The cuttings are partially buried with one node in the soil in a slanting position (Figure 7).

  Rooting from the buried node and sprouting from the node above the ground occur readily. Two node branch cuttings of *Dendrocalamus hamiltonii* also root and produce sprouts easily, but these should be stuck into the ground rather than buried.

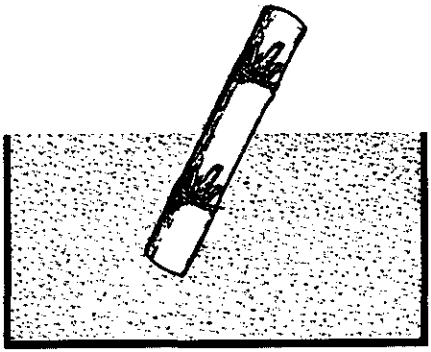


Figure 7: Slanted 2 node cutting propagation

- For many species, the rate of rooting and sprouting of cuttings can be enhanced by some form of treatment. For these, an opening of about 2 cm in length and 1 cm in width is made in the centre of the internode (Figure 8).

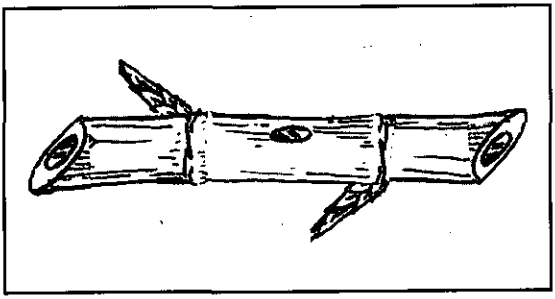


Figure 8: Making internode opening

- The most recommended treatment for root induction is the use of 1-Naphthalene acetic acid (NAA). This is prepared by dissolving 10 g of NAA in 250 ml of ethyl alcohol (95 %) in a container and stirring the solution gently. The solution is poured into a clean container and water added to make up 100 litres. Stir thoroughly to mix. The final concentration will be 100 mg/l of water or equivalent 100 parts per million (ppm). 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). Note that culm cuttings should be treated with NAA as soon as possible (preferably the same day). If this is not possible due to distance from the extraction site, the cuttings may be preserved by keeping them in moist sawdust, but for no longer than 3 days.

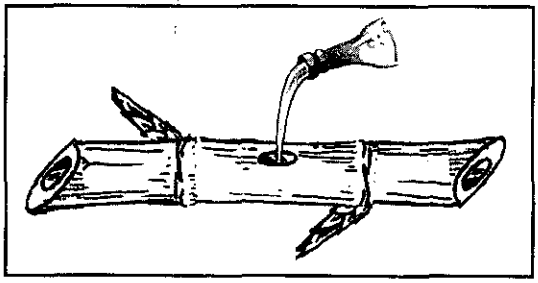


Figure 9: Careful adding of solution into cavity

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

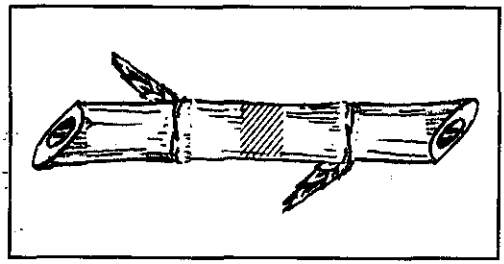


Figure 10: Tightly wrapped up culm opening

- The cuttings are then transferred into a raised 1-m wide nursery bed filled with a mixture of soil and sand. The cuttings should be placed horizontally across the nursery bed, with the opening facing upwards (Figure 11).

- One week prior to planting, the nursery bed is drenched with an effective insecticide (e.g. Aldrin or any other) and a fungicide to prevent termite and fungal attack respectively.

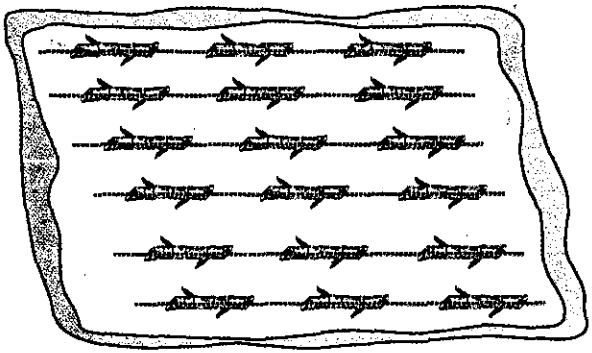


Figure 11: Culm Cuttings Nursery Arrangement

Using Multiple Node Culm Cuttings

- Using the same preparation methods described above, culm cuttings of more than three nodes may be used for propagation. This is especially successful with species that are easy to propagate. The preparation and arrangements in the propagation beds would be as illustrated in Figure 11, only that the culm cuttings are continuous. In preparing these long cuttings, great care has to be taken to avoid damaging the buds. These multiple node culm cuttings are then buried 6-10 cm below ground and incubated for a length of time to facilitate shoot and root development.

- Experiences at KEFRI, with culm cuttings of up to eight nodes, have shown that shoots and roots develop within 4 weeks for species that are easy to propagate such as *Bambusa vulgaris* 'vitatta' and *Bambusa hamiltonii*, and in 6 to 8 weeks for the more difficult species like *Dendrocalamus brandisii*.

- Once the shoots and roots have developed, separation is done between the nodes (See Figure 14) using a sharp tool and the nodal shoot/root system is transferred to polyethylene tubes. Some species, for example *Bambusa vulgaris*, develop very vigorous shoot and root systems. For such species several more seedlings may be obtained at this stage from the cut off nodal sections.

- In cold climatic conditions, roof cover with polythene sheets on top and sides improve the temperature and humidity levels,

giving better results for the multiple node cuttings. Furthermore, covering the top soil during the incubation period with polythene sheet reduces evaporation and the frequency of watering the buried culms.

Using Offsets

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:

- Dig out about 30-60 cm below ground for a rhizome of one to two years old culm (for the indigenous bamboo). This can be recognized by the dark green colour and smooth downy 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 12).
- Extracted offsets should be transported to the planting site without any delay (preferably the same day or the next) and planted immediately.

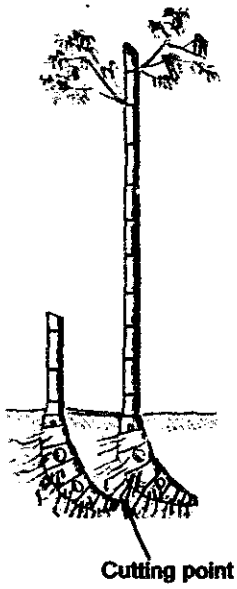


Figure 12: Point of separation of offset

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.

Using Tissue Cultured Plantlets

Tissue culture (TC) is an essential method of propagating certain plant species on a large scale. Commercial TC production is done in laboratories that need to produce and sell mass quantities of plants in order to be economically viable. TC has been successfully employed in mass-production of desirable species of sugarcane, banana, citrus, potato, pyrethrum and flowers in Kenya.

Research on TC of local bamboo at the Kenya Forestry Research Institute (KEFRI) is ongoing. Research is focused on *Yushania alpina* and *Oxytenanthera abyssinica*. Research and developments on bamboo TC in other countries have shown that this method is a very promising alternative source of bamboo planting stock. TC can greatly enhance the production of species that are difficult to propagate by other methods.

Presently, only a few commercial tissue culture labs around the world produce bamboos. A very important step prior to TC is the selection of elite mother plants with desired characteristics. When bamboos are micropropagated from the tissue of a mature plant, the result will be a clone of the mother plant. On the other hand, when seeds or the tissue of young plants are used as propagules, the properties of the resultant clones will not be predictable.

TC bamboo plantlets are small and generally more vigorous than bamboos propagated by more traditional methods. They can be grown to a size of up to 50 cm and planted into the field. Alternatively, they can be further

subdivided by means of rhizome division. Mass propagation of small tissue culture plants is easily achieved and much less labour intensive than propagating large cuttings. Each TC plant can be multiplied into 4 to 6 plants within a year. This allows for a rapid development of nursery stocks. When effective nursery management techniques are applied, an investment of, for example, 10,000 young TC plants supplied in the form of rooted plugs can be easily multiplied by division of small plants to produce 40,000 to 60,000 planting materials in one year.

Bamboo produced by TC may be widely used to develop large scale industrial plantations for timber, biomass, or pulp and paper. Cloning bamboo plants with superior traits opens opportunities for achieving a better quality crop, either in culms or in high quality edible shoots. It is important that farmers be on the lookout for the development of this technique locally.

Nursery Techniques and Management

Nursery Layout

Growing plants in a nursery becomes more efficient when the nursery is well organized in straight rows and blocks that are separated by paths. Each block or section should be clearly demarcated and small signboards on the ground should indicate the botanical name of the plants in each location.

Since different species of young bamboos are not easily identifiable or distinguishable from each other, it is advisable to label or tag each and every plant. This obviously implies extra costs but it reduces the risk of mixing up species in the nursery. It also facilitates the sales and distribution of plants and allows planters to distinguish the young plants when they are eventually taken to the field for planting.

Labelling

When labelling the plants, it is advisable to use a coding system that not only refers to the species, but also to the provenance of the mother plant.

Separation of Seedlings

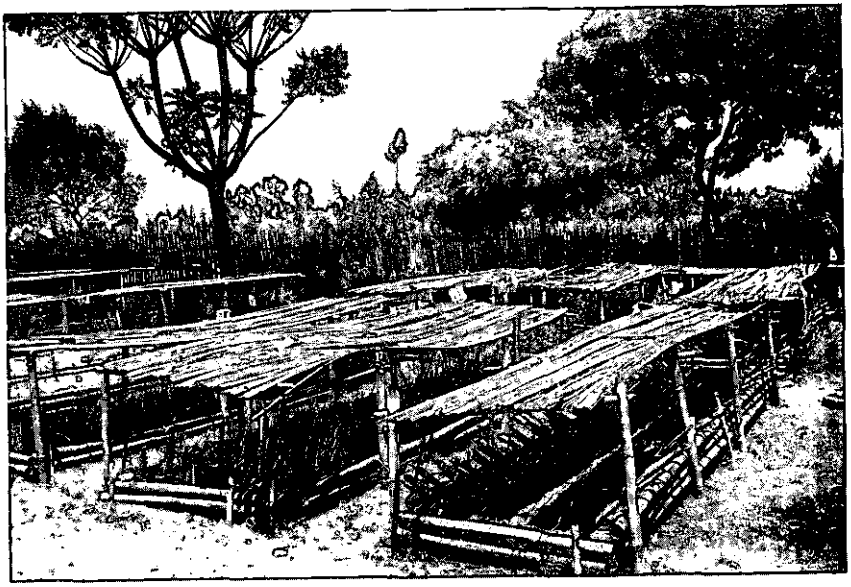
When propagating by seed, it is advisable to place the seedlings of a particular species in a separate nursery block or location. Seedlings should be separated from plants of the same species that were vegetatively propagated. The reason for this is that it is hard to tell if the seeds really are of the species. Seed suppliers make mistakes and sometimes packets of seeds are marked incorrectly. All precautions should therefore be taken to prevent mixing up plants and to allow for a clear identification of plants in the nursery at any time.

Weeding

Weeding in the nursery is essential for the health and vigour of the young plants. Competition from weeds should be minimized.

Shading

Whatever planting stock is used (seedlings, wildings, offsets, or cuttings) shade must initially be provided to protect them from direct sunlight. The shade, mostly of thatch or any other material could be removed during the onset of cool weather.



Watering

Water is needed by young seedlings and cuttings in beds or polythene tubes. During cold weather, watering may be done once per day. In the dry season, watering should be done twice a day. As a rule, plants in the nursery should be watered regularly.

Treatments

After one month, it is recommended that sprouts from cuttings are treated with some effective fungicide (e.g., Copper sulphate) to avoid fungal attack. If necessary, farmyard manure may be applied to increase the vigour of the sprouts.

Mass Production (Proliferation) of Seedlings

Growth of bamboo is supported by the development of a system of rhizomes. Establishment of planting materials depend very much on how well the rhizome system of a planting material is developed.

Development of the rhizome system starts early in seedlings and buried cuttings, and at some stage in the nursery and can be separated into several individual shoots. Proliferation is the method of separating developed system of rhizome in young nursery materials into many individuals.

Such individuals are transplanted into polyethylene tubes that give them 'new' vigour of growth. Where procurement of bamboo seed is difficult, available seedlings in the nursery are maintained through proliferation (mass production) while still carrying out annual planting programmes. Each seedling with sufficient stems can be cut down the middle and multiplied by 2 (Figure 13). Cuttings are also proliferated through initial

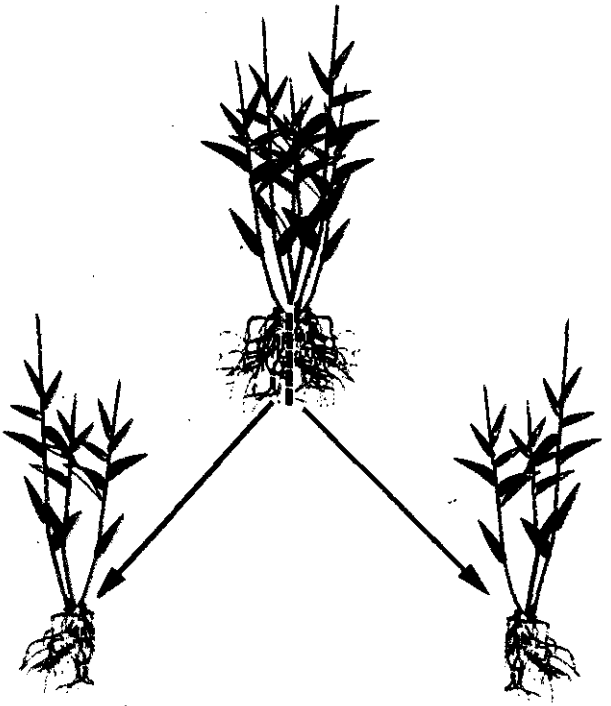


Figure 13: Seedling Division

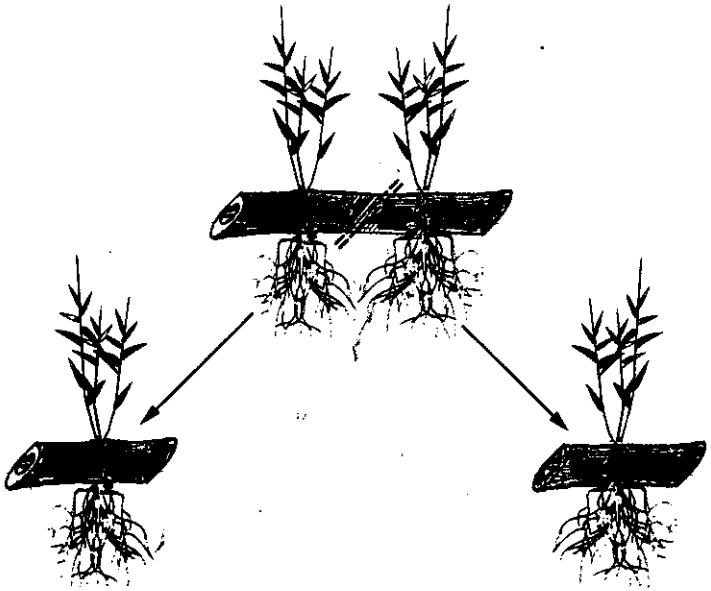


Figure 14: Separation of culm cuttings

separation of sprouted and rooted nodes (Figure 14) done by cutting at the middle. These are transplanted into separate containers and further proliferation can then be undertaken in the same way as seedlings.

Use fresh potting medium of forest soil or humus and new containers or polyethylene tubes each time in order to rejuvenate growth in separated shoots of seedlings. Multiplication of nursery seedlings should not be carried out at intervals of less than six months. This is to enable adequate development of a critical mass of rhizome system in the containers. Watering in the mornings and afternoons should be strictly followed to allow for fast recovery of the disturbed system of the young roots and rhizomes.

Hardening

Before planting, it is necessary to harden seedlings especially where some shading and frequent watering had been done. This is done by gradually decreasing the shade and watering levels and rates. Hardening can take one to two months. Through this process, the seedlings are expected to withstand conditions in the field after planting.

Field Planting and Establishment

Selecting the Planting Site

Site selection for various species of bamboo is important in order to enhance management, field operations and healthy growth. The selected area of planting should be one that is not prone to grazing and fire.

The planting area should be selected and demarcated early, preferably 2 – 3 months prior to the onset of rainfall in the year of planting.

Bamboo prefers loamy and sandy loamy soils, but what is more critical is good drainage since the crop cannot withstand water logging. Sloping land is thus preferable.

Species such as *Dendrocalamus strictus* and *Oxytenanthera abyssinica* are draught resistance and withstand areas having annual rainfall of less than 800 mm. For reasonably good growth most bamboos require annual rainfall of more than 1000 mm.

Plantation Layout

It is important to plan the field layout so that harvesting and hauling of culms is facilitated when the clumps have matured.

Planning the field layout in north-south rows is advisable to have an even distribution of sunlight in the plantation. Planting in lines and rows makes management of the plantation easier. The direction of rows and lines should however be planned with full consideration of the characteristics of the terrain. This is especially important when intercropping is to be done in slopes or hillsides. When furrows are ploughed for cash crops between the bamboos, they should be done across the slope, following the contour of the land, and never in an uphill-downhill direction. Furrowing across the slope will prevent the water runoff and thereby control erosion.

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. A spacing of 4.5m x 4.5m to 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, spacings should be widened and plants per hectare should be reduced, especially when the objective of the plantation is to harvest bamboo timber. Spacings of up to 10 x 10m (100 clumps/ha) are suitable for large bamboos; wider spacings will allow the clumps to reach their full potential.

When determining the spacing of plants, it is advisable to provide extra space between rows. The spacing of plants in-line may be reduced while the spacing between-lines can be increased. The aim is to have easy access and mobility between rows of clumps so that felled culms can easily be stacked and hauled to the farmgate. The following table shows spacings that may be considered for small, medium, to large bamboos.

Plant Spacing (m) and Plants per Hectare		
In line	**Between lines**	**Plants per ha**
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

If the main purpose of the plantation is to cultivate edible shoots, the spacing can be reduced significantly. Since most of the new shoots will be harvested, only a few shoots are left to grow into mature culms. A well maintained bamboo clump that is thinned down to about 15-20 culms of various ages will vigorously direct the plant's energy towards the production of new shoots. Thinning the clump also implies that it will require less space than it otherwise would.

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 a 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 metre in diameter allow for improved microcatchment and are preferred in areas where annual rainfall is less than 1000 mm. In all cases the holes must be refilled with

A stand of bamboo

soil up to 10 cm below the ground surface. Where necessary mix up to 2 kg phosphoric fertilizer or organic manure.in the top soil of each pit. Filling should be completed one month before the rainy season.

Field Planting

- Seedlings should be transported at the onset of the rainy season to ensure good survival.
- Planting of container or potted transplants from the nursery should be done immediately at the start of the rainy season.
- For offsets removed from the forest, planting must be done the same day with a maximum delay of one night.
- When planting, the potting material (plastic or tin containers, polyethylene bags, etc.) should be removed before placing the seedling in the planting hole.
- The rhizome portion of the offset should be placed 10-20 cm below the ground level and covered with soil.

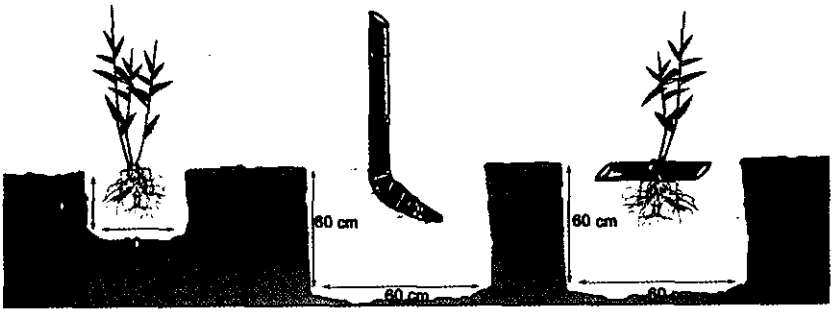


Figure 15: Planting holes for seedlings, offsets, and culm derived seedlings

- After placing the plant (either seedling or offset) in the hole, cover with soil and always lightly press the soil around the plant. Where necessary and if financially possible, offsets may be protected against termite attack. The soil returned into the hole is mixed with an anti-termite chemical. Marshal Suscon controlled release-granules are suitable. The chemical has an effect lasting up to three years. Twiga Chemicals Co. Ltd. markets the anti-termite. Due to its non-environmental pollution, it is preferable to the traditional anti-termite chemical formulations.

Plantation Maintenance and Harvesting

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

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 outplanting. Weeding should be regular or as necessary to avoid competition from weeds.

The soil should be loosened at least three times during the plantation establishment year to improve aeration.

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 rain seasons when there is enough moisture until the second year.

Plant Protection

Bamboos are palatable to many animals, especially in dry grazing areas where goats are left loose. It is necessary to carry out protection against goats and antelopes using simple sticks. These are stuck in the ground around the seedlings and made to converge above the seedling, forming a conical shape of protection.

Where browsing may come from large animals, some fencing may be necessary to allow establishment of the bamboo seedlings. Patrolling the area regularly can also protect the plantation from foraging animals.

Fire is a major hazard to a bamboo plantation especially during the dry season and in drier areas. To safeguard the area, firebreaks should be established. A 10 m wide fire-line is enough to stop fire from spreading into the plantation. In some species, the amount of bamboo litter on the ground is too thick. During the dry seasons, this needs to be reduced by collecting it and thus improving the degree of success in fire control.

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.

The very small and thin culms, broken and over-hanging culms, should be regularly removed to leave only clean culms standing within a clump.

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 at intervals of four or more years.

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.

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. This cycle of cutting is considered suitable for a number of clumping bamboo species.

- Unless properly managed, clumping bamboos tend to become congested, resulting in deterioration both in quality and in quantity. It is difficult to extract bamboo from congested clumps. If left untended, clumps of some species become extremely congested. For example, *Bambusa bambos* is notorious in congestion.

- 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).

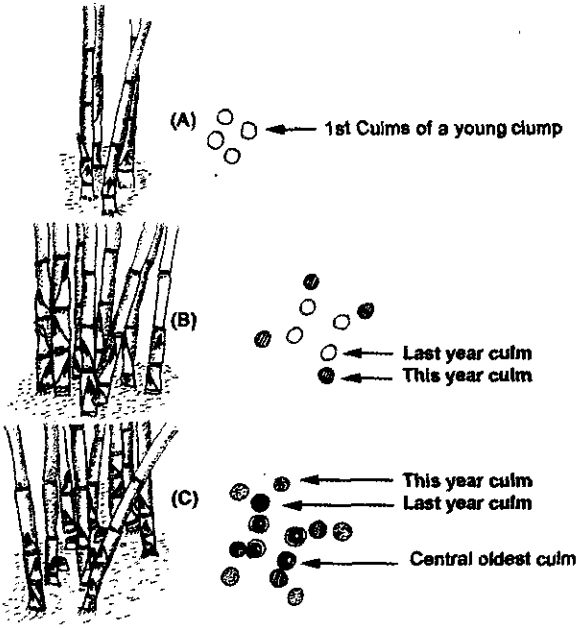


Figure 16: Growth and development of culms in a clump

- 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

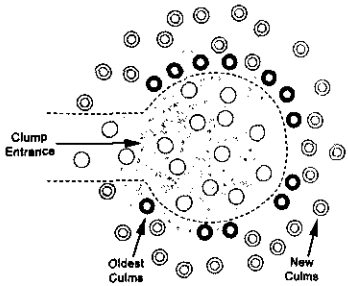


Figure 17: Horseshoe Clump harvesting method

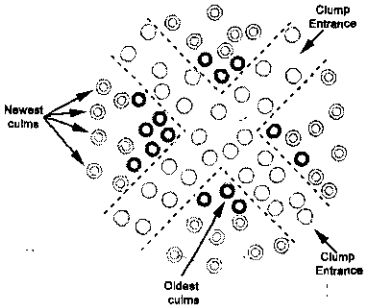


Figure 18: Cross tunnel harvesting method

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.

- Congestion should **never** be allowed to occur in a clump. Clump congestion decreases the productivity of the clump and the quality of the bamboo culms.

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.
- All broken, live stems, less than 2.5 m in length, should be removed except in clumps containing less than 10 culms. In the latter case, even shorter broken culms may be retained for support of new culms.
- 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.
- In order to avoid future congestion, all clumps should be worked, even though they may not produce usable or saleable material.
- 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 tool-bill-hook, a sharp* panga or saw so that the stump is not split.
- All cutting debris should be collected and removed away from the clump.
- Lopping of bamboos should be prohibited.
- 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 clearfelled.
- The areas under bamboo should be strictly fire-protected.

The above cutting rules are important management controls and may be used as a guideline. The rules may be suitably modified for formulating the cutting rules for other introduced species where experiences in their management may not have been locally gained.

Cutting Tools and Extraction

It is necessary that sharp implements, are used in order to avoid splitting

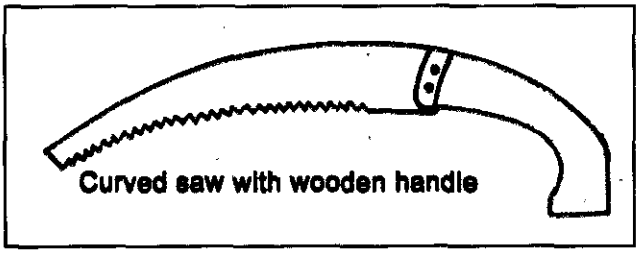


Figure 19: A curved saw for effective culm cutting

of stumps and the cut culms. A *panga* (long sharp knife) or preferably a curved saw may be used (Figure 19).

Hauling from Stump site

Extraction roads should be planned during plantation establishment. Fire breaks may also be used for extraction but must be planned in advance.

Hauling of culms should be carefully planned before any harvesting takes place. This is often ignored when planning for the extraction of bamboo. Failure to have a clear plan for the hauling of culms can result in excessive damage of other vegetation and may result in excessive soil compaction.

This is especially important when harvesting in areas where terrain is not level and where cutting is done in the bottom of a valley. In such cases, a tractor fitted with a winch and assisted by a pulley fixed to a tree can facilitate the hauling of the harvested culms (Figure 20). The stems are bundled together, so that these can be pulled easily to the roadside or collection area. Donkey or bull power can also be used instead of a tractor. On less rugged terrain, hauling of cut stems and loading onto the lorries can be done easily using human labour.

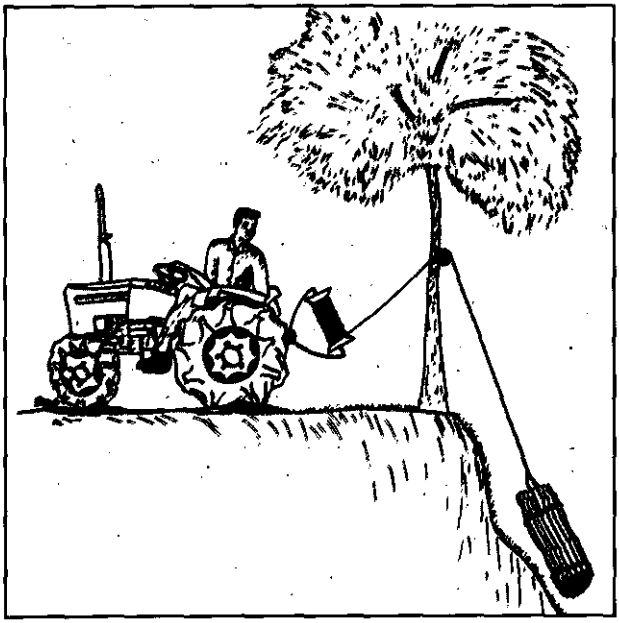
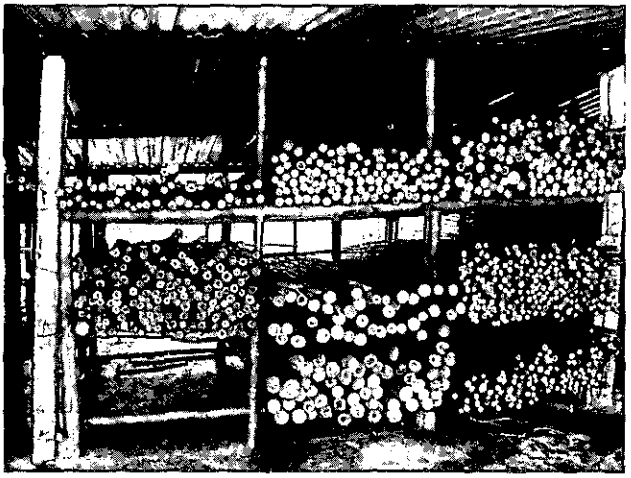


Figure 20 : Hauling cut culms from the valley bottom

Post-Harvest Treatments

Methods for Protecting Bamboo

Bamboo poles are susceptible to decay and attack by fungi or insects especially powder post beetles. Such attacks give bamboo low natural durability. One way to extend the life of bamboo under use is through preservation treatments. Processing and construction methods may also minimize attack by fungi and insect.



When bamboo culms have been preserved, and particularly when they will be used for construction or for value added products, it is strongly advisable to store them in an elevated and covered area to protect them so that their quality can be maintained

Techniques used to increase the durability of bamboo include non-chemical and chemical methods. The most useful and economical methods are listed below.

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.

White-washing: bamboo culms and bamboo mats for housing construction are often painted with slaked lime (white wash). This delays water absorption, leading to a higher resistance against fungi.

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.

Simple construction method: In constructions using bamboo, the upright culms that provide structural support should be elevated on stones, cement, or concrete blocks, and never directly on the bare ground or soil. This will reduce the risk of rotting and insect attack. Painting the culms with water repellent formulations helps to reduce mould.

Chemical Preservation Methods

Chemical preservation methods of bamboo generally provide more effective protection than non-chemical methods, but are not always economical. The following treatments are used.

Fumigation: application of methyl bromide or some other chemical to bamboo for insect control.

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

The open-tank treatment: culms prepared to size are soaked in a solution of a water soluble preservative for several days. The solution gets into the culm by diffusion through the ends and partly through the sides. Where a big drum is not available-due to cost limitation, a trough in the ground can be used as follows:

- Dig a pit measuring 4 to 5 m long, 60 cm wide and 1 m deep. Line the pit with plastic sheet, holding it firm with posts or stones at the surface of the ground.
- This pit will serve as the container of the chemical solution and as the dipping tank for the cut bamboo poles.
- The poles are left in the preservative for several days.
- It is always advisable for the workers to wear gloves, waterproof aprons, and protective masks as precautionary measures.

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

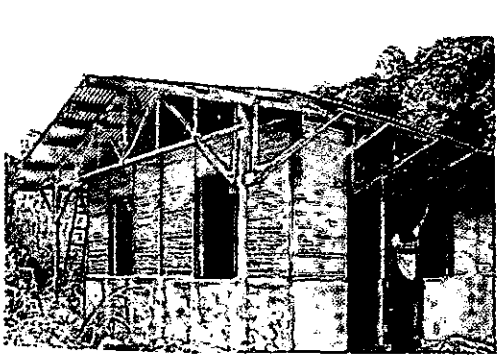
The open-tank and the butt methods are effective, economical and more popular. Using these methods, 10% Copper sulphate solution extends the service life in the ground extensively. For out-of-ground contact poles or strips, treatment with 10% boric acid will give extended service life.

Local farmers have been reported to use old engine oil particularly for green culms. The effectiveness of this method has not been widely reported and documented.

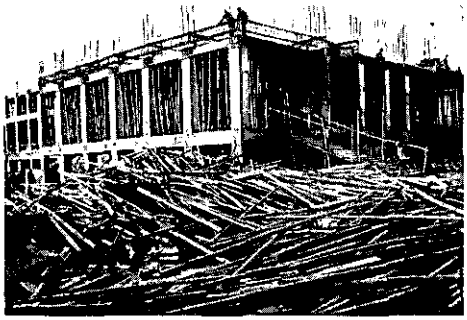
Current and Potential Uses of Bamboo

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.

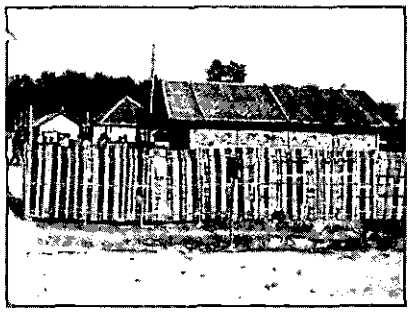
- **Fencing** is the most common use of bamboo in Africa and throughout the tropics, particularly for homesteads and farms as a protection against grazing.
- **Farming** has continued to make use of bamboo particularly as *props or supports for horticultural crops like peas, flowers, and* bananas. In 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.



In some South American countries, bamboo is used as a structural framework for Housing

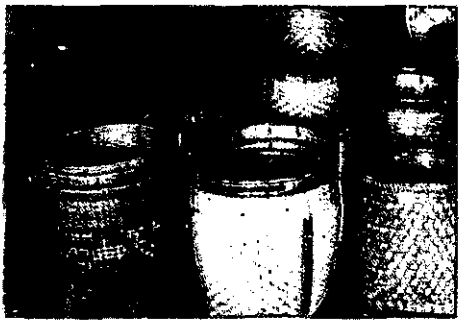


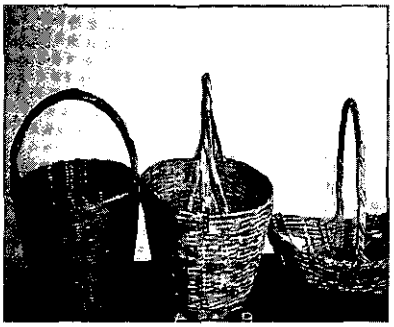
Bamboo used as scaffolding



Bamboo used as a fence

- **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.



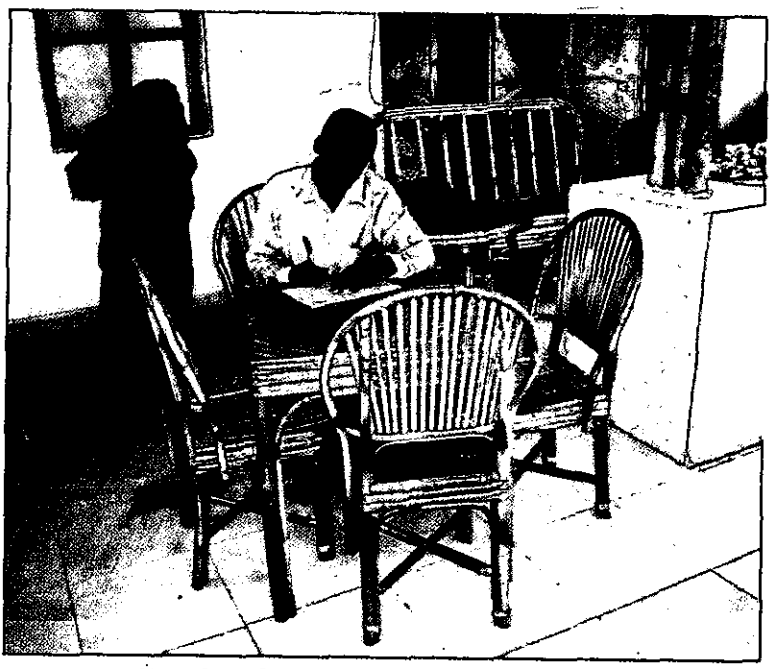


Bamboo handicrafts

- **Production of edible bamboo shoots** is more common in oriental countries especially China, Japan, Taiwan and Thailand. 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. Many hotels and Asian restaurants around Africa serve bamboo shoots as vegetable dishes. Some bamboo

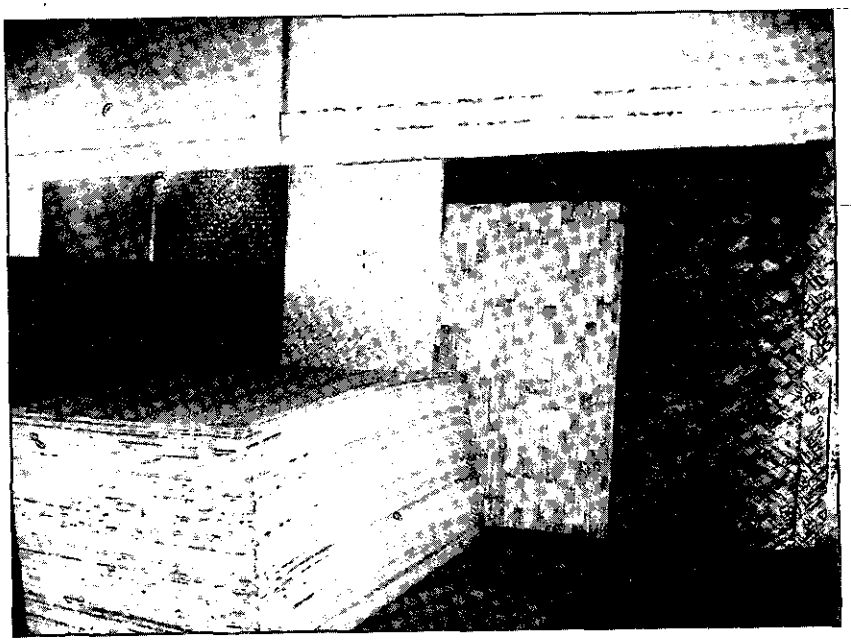
species recently introduced in East Africa produce good quality shoots. These include *Phyllostachys pubescens, Dendrocalamus asper, D. hamiltonii,* and *Thyrsostachys siamensis* among others.

- **Bamboo Furniture** production is widespread in Asia and 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 for tourism and household uses.



Handmade Bamboo Furniture

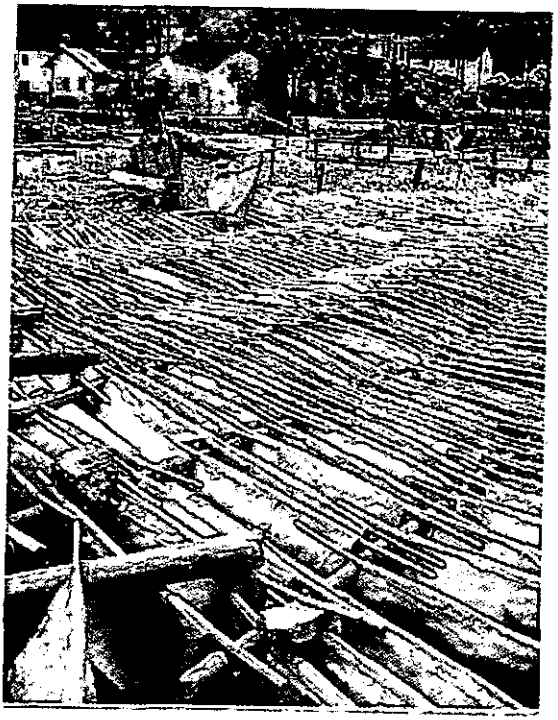
- **Bamboo panels and particle boards** are important applications in Asia with a strong potential in Africa. Asian countries have produced designs that are marketed worldwide. The technologies and machinery for manufacturing such products are readily available from China, Taiwan, and India. Production of bamboo panels and particleboard in Africa could reduce pressure on natural forests.



Bamboo panels and mat boards

- **Pulp and paper** production using bamboo is an age old occupation in China, where paper was originally handmade. Countries such as China, India, and Brazil produce significant amounts of pulp and paper from bamboo. Bamboo paper is sometimes blended with other species such as eucalypts.

- **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.



Bamboo used as pulp and paper can help generate income and employment

Other common uses of bamboo in Africa include water pipes and wine production in Tanzania using *Yushania alpina* and *Oxytenanthera abyssinica* respectively. Local people in East Africa use bamboo for medicine and as animal fodder. Split bamboo culms are used as gutters for water harvesting from corrugated roofing sheets.

In addition to all the above applications, natural bamboo stands and man made plantations protect soils and water catchment areas. Bamboo can be planted on sloping land to protect soil erosion, to shelter off sewage pools, and as ornamental plants at strategic positions in farms or homesteads.

Conclusion and Recommendations

Bamboo remains an important and promising resource for tropical Africa. It has immense potential added value for development compared to many other forest resources. Moreover, as a plantation crop, bamboo has great prospects for advancing social forestry.

It is necessary for the forest services and private sector in Africa to promote bamboo planting for rehabilitating degraded lands and as an alternative source of timber. The root system of bamboo effectively secures the soil mantle. Bamboo is a fast growing woody plant and has the potential to rapidly generate a canopy that protects exposed, barren, or degraded mountainsides.

Support for industrial development, especially at the cottage level, should be genuinely upgraded and deserves the attention of policy makers. The focus should be on livelihood improvement and diversifying market opportunities. Africans are well known for their ingenuity and creativity and clearly have the ability to design, develop, and produce novel bamboo applications for local markets and for export.

To be able to tap the existing potentials for development of the bamboo sector, it will be necessary:

- For public and private sectors to recognize that bamboo is an important and valuable commodity and not merely a minor non-wood forest product;
- for governments and NGOs concerned to pay adequate attention to the development and management of bamboo resources. Development plans for enhancing production and utilization should be formulated. The speed of replenishing the resource base should be increased by supporting farmers and rehabilitating public forests;
- to coordinate the sustainable production of bamboo in public forests by ensuring the implementation of effective harvesting regimes;
- to promote the cultivation of bamboo in homesteads as well as in small, medium, and large plantations.

- to ensure that research, production, marketing and utilization are coordinated in order that potential opportunities and benefits effectively reach the farmers, entrepreneurs, and traders;
- to focus more effort on aggressive dissemination of research results and technology transfer within Africa and other parts of the world;
- to formulate a policy statement on the development of non-timber forest products that would enhance development of bamboo particularly by local communities.

It is evident that bamboo has an important role to play in Africa in the creation of employment opportunities, providing food security, and enhancing construction industries. Bamboo can also contribute to environmental conservation by reducing pressure on dwindling natural forests. It is therefore critical that African governments embrace the development of bamboo as a natural resource and industrial commodity for their people and the environment. It is hoped the use of this handbook will go a long way in supporting these development needs.

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APPENDIX 1

Bamboo Species Introduced to Kenya		
Botanical Name	**Form of Introduction**	**Origin**
Bambusa bambos	Seed	Thailand and India
Bambusa nutans	Offsets	India
Bambusa tulda	Seed	Thailand and India
Bambusa vulgaris	Offsets	India
Bambusa vulgaris Vitatta	Cuttings	Asia
Cephalostachyum pergracile	Seed	Thailand
Dendrocalamus asper	Offsets	India
	Tissue Culture	Belgium
Dendrocalamus brandisii	Seed	Thailand
	Seed	India
Dendrocalamus hamiltonii	Cuttings	India
Dendrocalamus membranaceus	Seed	Thailand
Dendrocalamus strictus	Seed	Thailand and India
Oxytenanthera abyssinica	Seed	Zimbabwe and Sudan
Oxytenanthera abyssinica	Offsets	Zimbabwe
Phyllostachys nigra var. henonis	Offsets	Asia
Phyllostachys pubescens	Seed	Japan
Shibataea kumasaka	Offsets	Asia
Thyrsostachys siamensis	Seed	Thailand
Yushania alpina	Offsets and wildings	Kenya

APPENDIX 2

Origin and Habitat of some Exotic Species Successfully Introduced in Africa	
Species: Origin and Geographic Range	**Natural Habitat and Ecology**
Bambusa bambos: India, Southern China, Thailand and Indo-China. Found in cultivation Southeast Asia.	Humid tropical climate in mixed moist deciduous forests, less commonly in mixed dry deciduous forest and in semi-evergreen forest on hills. Occurs at altitudes up to 1000 m absl. Grows best along river valleys and in other moist conditions, but also grows in semi arid areas.
Bambusa tulda: Northern India (including Assam) and Bangladesh to Burma (Myanmar) and Thailand.	Mixed deciduous forest in plains, valleys, and along streams, up to 1500 m absl. In moist areas it often grows together with *Cephalostachyum pergracile;* in drier parts with *Dendrocalamus strictus*.
Bambusa vulgaris: Origin: Tropical Asia; Range: pantropical. Has been widely naturalized in many countries of Africa.	Occurs pantropically from low elevation up to 1200 m altitude. Grows best at low altitudes; culms become smaller in length and diameter at elevations over 1000 m absl. Thrives under a wide range of moisture and soil conditions. Grows well in permanently humid conditions along rivers and lakes, in areas with a severe dry season, as well as on degraded soils.
Cephalostachyum pergracile: India, Nepal, Myanmar, Thailand, South China	Mixed deciduous tropical forests, mainly in lowlands or hillsides up to an altitude of 1000 m. Thrives on well-drained loams. Growth is stunted in dry areas.
Dendrocalamus asper: Unknown origin. Occurs throughout Southeast Asia	Planted or naturalized in tropical Asia at low altitudes and up to 1500 m. Thrives at 400-500 m absl in areas with average annual rainfall of about 2400 mm. Grows in any type of soil, but prefers heavy soils with good drainage. Grows on sandy and acidic soils.

Dendrocalamus brandisii: Unknown origin. Native range extends from north-eastern India (Manipur), Myanmar, to northern Thailand, Indo-China, South China (Yunnan Province) and the Andaman Islands (India).	Thrives in wet, evergreen tropical forest, up to 1300 m absl. In Myanmar it is found on limestone, but it also grows well on well-drained loamy soil.
Dendrocalamus giganteus: Unknown origin; though possibly from Southern Myanmar and northwestern Thailand. Found in cultivation throughout southeast Asia.	Grows naturally in humid tropical highlands, up to 1200 m absl and grows well in tropical lowland areas with rich alluvial soils.
Dendrocalamus hamiltonii: Northeast India, Nepal, Myanmar, Thailand	Humid tropics, in lowlands and up to 1500 m absl
Dendrocalamus membranaceus: Northern Thailand, Eastern Myanmar, and Laos.	Tropical mixed deciduous or monsoon forest up to 1000 m absl, with annual rainfall of 950 mm and average minimum temperature of 21.7°C and average maximum temperature 33.3°C.
Dendrocalamus strictus: India, Nepal, Bangladesh, Myanmar, Thailand. Found in cultivation throughout southeast Asia.	Humid to dry mixed deciduous forest, tropics and subtropics, in lowlands and up to 1200 m absl. Grows best with a mean annual temperature range of 20-30°C. Mature clumps can withstand periods of extreme temperatures from -5°C to 45°C. Thrives with an annual rainfall of between 1000-3000 mm but is very draught resistant. It grows best on sandy loams, but grows well on all soils with good drainage.
Thyrsostachys siamensis: Thailand, Myanmar. Introduced throughout Southeast Asia.	Dry or semi-evergreen tropical forests as well as mixed deciduous forests, and hill forests around 300-400 m absl, with annual rainfall of 800-1000 mm. Grows on a wide range of soils, including poor soils but not on waterlogged soil. Tolerates partial shading.
Source: Dransfield and Widjaja, 1995.	

APPENDIX 3

Preferred Methods of Propagation of Selected Species				
Species	**Rhizome Offset**	**Culm Cutting**	**Branch Cutting**	**Seeds**
Bambusa bambos	Effective but highly labour intensive	Use 2-3 node cuttings planted horizontally with rooting media	N/A	Seeds are sometimes available in India after sporadic flowering
B. blumeana	Same as above	Use 2-3 node cuttings planted horizontally with rooting media	N/A	N/A
B. tulda	Same as above	Possible using 2-3 node culm cuttings with high mortality rate	Viable method but with high mortality rate	Seeds are sometimes available in India
B. vulgaris	Same as above	High success with one node planted in slanting position	N/A	N/A
B. vulgaris 'Vitatta'	Same as above	Same as above; also very successful with multiple node cutting buried horizontally on the ground.	N/A	N/A

Dendrocalamus asper	Same as above	2 node culm cutting, using upper internodes	Viable method	N/A
Dendrocalamus brandisii	Same as above	2 to many node culm cutting, using upper internodes	N/A	N/A
Dendrocalamus giganteus	Same as above	2 to many node culm cutting, using middle to upper internodes	N/A	N/A
Dendrocalamus hamiltonii	Same as above	High success with one node planted in slanting position	Viable method	Seeds are sometimes available in India
Dendrocalamus membranaceus	Same as above	Same as above	N/A	Seeds are sometimes available in India and Thailand
Dendrocalamus strictus	Same as above	Very difficult	N/A	Preferred method in India
Oxytenanthera abyssinica	Viable method, but very labour intensive	Extremely difficult	N/A	Seeds are sometimes available from natural sources especially in Ethiopia, and Sudan.

Phyllostachys aurea	Viable method	Not possible	N/A	-
Phyllostachys nigra 'Henonis'	Viable method	N/A	N/A	-
Phyllostachys pubescens	Viable method, but very labour intensive	N/A	N/A	Seeds sometimes available in China and Japan
Yushania alpina	Viable method	Difficult	N/A	Flowers sporadically but seed viability is poor.

APPENDIX 4

BAMBOO APPPLICATIONS		
Uses of Bamboo as a Plant		
Ornamental uses	**Ecological uses**	**Agro-forestry**
• Foliage Plant	• Soil Stabilization	• Natural Stands
• Landscaping	• Soil Remediation	• Mixed Stands
• Garden hedges and screens	• Cultivation of marginal lands	• Industrial Plantations
	• Roadsides and verges	• Windbreaks
	• Sound and Visual Screens	• Hedges
	• Erosion control along Riverbanks and Hillsides	
Uses of Bamboo as a Material		
Cottage Industries	**Wood Industries**	**Pulp & paper Industry**
• Traditional furniture	• Panels for walls and Ceilings	• Newsprint
• Woven crafts	• Particle board	• Bond paper
• Mats and basketry	• Medium Density Fiberboard	• Cardboard
• Household wares	• Oriented Strand Board	• cement sacks
• Housing materials	• Flat Matboards	
• Poles for building	• Corrugated Matboards (roofing)	**Textile Industry**
• Fish traps	• Bamboo Veneer	• t-shirts, socks, knitted fabrics
• Musical instruments	• Laminated lumber	• Towels
• Weapons	• Flooring parquet	• Composite suiting material
	• Building Poles	
Food and Beverage Industries	• Scaffolding material	**Bioenergy**
• Fresh bamboo shoots		• Charcoal
		• Biofuel

• Canned bamboo shoots	**Machine Processed products**	• Pyrolysis
• Vacuum packed bamboo shoots	• Blinds and curtains	• Gasification
• Pickled Bamboo Shoots	• Placemats	• Briquettes
• Bamboo Wine	• Chopsticks	
• Bamboo Beer	• Skewers, toothpicks, matches	**Chemical Industry**
• Bamboo Vinegar	• Door & window frames	• Chemicals
	• Furniture	• Biochemicals
		• Pharmaceuticals

APPENDIX 5

A Glossary of some Terms Used in the Text

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 bamboo plant has flowered and produced seed.

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