A MANUAL FOR VEGETATIVE PROPAGATION OF BAMBOOS

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UNDP/FAO Regional Forest Tree Improvement Project (FORTIP)
and
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1995

ISBN 81-86247-10-6

Designed by Scenario Publications, A-61/Sector 19, Noida, India. Tel.: 8532775

FOREWORD

The most endearing aspect of bamboo from the point of view of utility, perhaps, is that it comes almost ready-to-use. It could very well be that because of this singular feature, bamboo today is a much over-exploited plant. The acute shortage, at least in some parts of the bamboo world, of raw materials has forced greater attention to propagation practices and techniques.

Irregular supply of seeds for many common bamboo species has been the main reason for the high and continued dependence onvegetative propagation. Over the years, many new vegetative propagation techniques have been developed, tested and perfected. This manual is an attempt to summarize such techniques that are now in practice for the benefit of all those who are involved with bamboo cultivation.

This publication is a part of INBAR's continuing efforts to produce user-oriented manuals on a range of aspects that would help the sustainable use and management of bamboo resources. In this venture,INBAR has joined hands with FORTIP(UND P/FAO Regional Forest Tree Improvement Project) and BFRI (Bangladesh Forest Research Institute) to show the importance these institutions attach to bamboo research and development work. We strongly feel that the manual exemplifies the collaborative work which we believe is the key in bamboo R&D work.

The author Dr. Ratan Lal Banik is a well-known authority in bamboo silviculture with several years of research experience in bamboo. He is also the Co-Chairperson of the INBAR Working Group on Biodiversity, Genetic Resources and Conservation. We thank him for putting together this manual in a short time. It is hoped that bamboo growers and others associated with the cultivation of bamboo will find *A* Manual *for Vegetative Propagation* of Bamboos a practical and useful publication.

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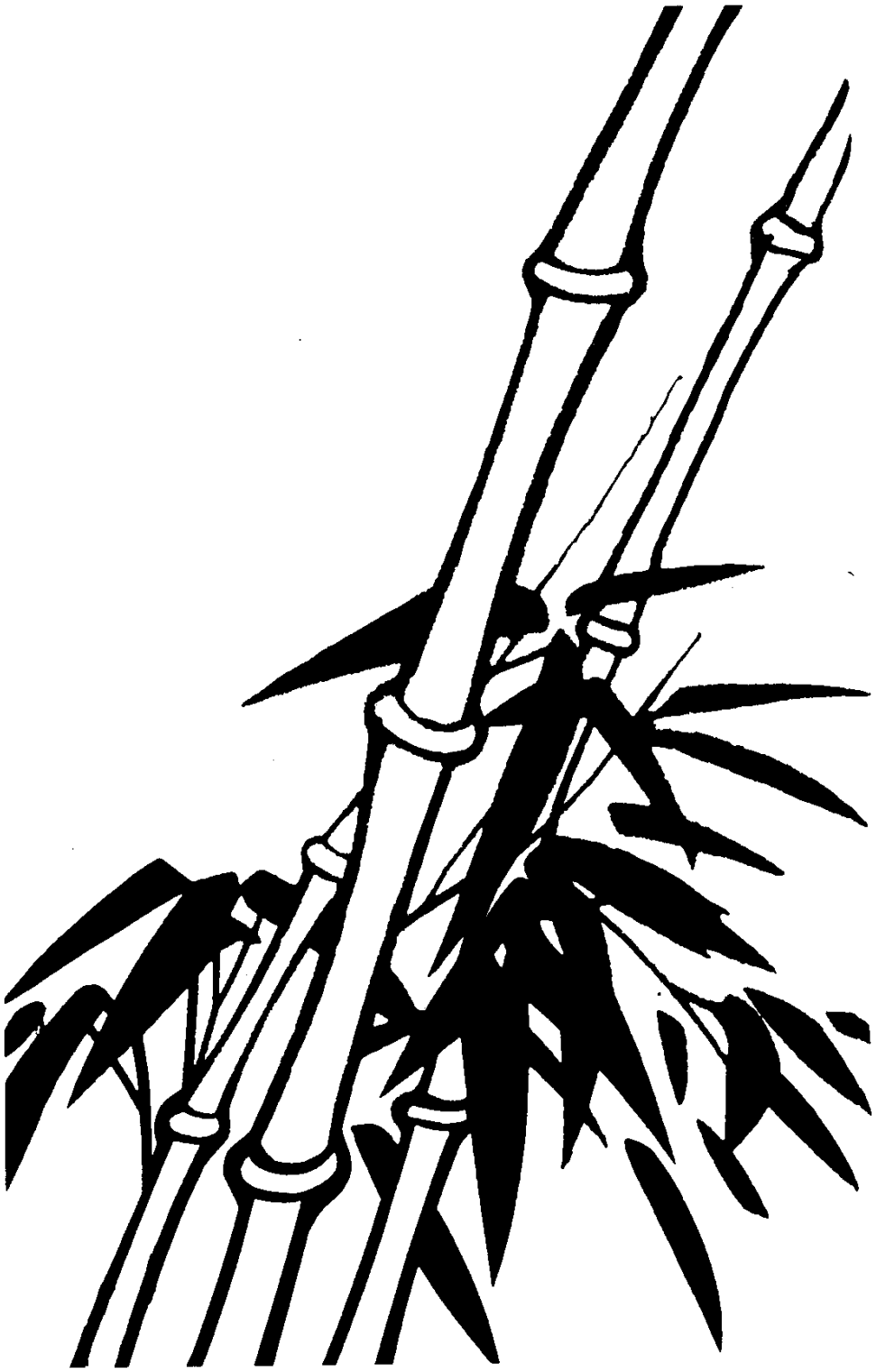
CONTENTS



BAMBOO AND ITS PROPAGATION

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1. What is bamboo?

Bamboo species are perennial woody grasses. They are important multi-purpose plants which grow rapidly and produce very high biomass. The more than 1,250 species vary widely in structure and form and occur under widely varying ecological conditions in the tropics and subtropics or in more temperate regions. Bamboo has a variety of uses ranging from its use in building, for pulp and paper manufacture, to cottage industries and household use. Bamboo is becoming more and more a farm crop in addition to being a major forest product. The principal users of bamboo are the rural poor.

2. Why is there a need to propagate bamboo?

In most Asian countries which produce bamboo there is a shortage of supply and in recent years the gap between supply and demand has been widening. Harvesting from natural areas or from secondary forest lands means that artificial planting schemes are necessary and plantations of bambooarebecoming more common. Over-exploitation occurs despite the vigorous growth and somewhat invasive nature of bamboo. In many areas even more planting stocks are needed to use bamboo as an ecological plant to help reclaim vast tracts of degraded lands, to check erosion and to conserve soil. Whilst the bulk of bamboo is still harvested from the wild or from rural environments, and there is over-exploitation, it is even more important to make available suitable planting stocks in order to complement efforts to conserve shrinking forest habitats.

3. What are the priority bamboos?

Some species are more useful than others. The 1,250 species include many with wide adaptations which have been selected by local people for multiple use over large areas. Others are limited in distribution to more restricted ecologies. Some are known to be very valuable but need wider recognition and cultivation and use outside their current areasSince the major beneficiaries are poor people it was necessary to prioritize the species so that research can be focused on those which will maximize the benefits for such people.

3.1 Highest priority species

The International Network for Bamboo and Rattan(INBAR)in cooperation with the International Plant Genetic Resources Institute, formerly the International Board for Plant Genetic Resources, canvassed national experts in 1993 for information, established criteria for choosing species and through an expert group agreed upon 19 species - or groups of species- as those meriting focused research and wider use. They are:

Bambusa bambos (L.) Voss.
B. *blumeuna* J.A. Schultes and J.H. Schultes
B. polymorphu Munro
B. textilis McClure
B. tulda Roxb.
B. vulgaris Schrad. ex Wendl.
Cephalostachyum *pergracide* Munro
Dendrocalamus asper (Schultes f.) Backer ex Heyne
D. giganteus Munro
D. latiflorus Munro
D. strictus (Roxb.) Nees
Gigantochloa apus J.A. Schultes and J.H. Schultes

G. Levis (Blanco) Merrill
G. pseudoarundinacea (Steud.) Widjaja
Guadua angustifolia Kunth.
Melocanna baccifera (Roxb.) Kurz
Ochlandra Thw.- a number of species considered reed bamboos
Phyllostachys pubescens Mazel ex. H. deLehl
Thyrsostachys siamensis (Kurz) Gamble

All these are Asiatic except for Guadua which is a New World species.

3.2 Other priority species

There are other species used locally and many are the subject of research by national programmes. INBAR recognizes this and has noted an additional 18 species. Further information is available from INBAR.

4. What are the growth forms of bamboo?

In the tropical and subtropical regions the bamboos tend to form clumps ("sympodial"). In the more temperate regions including large areas of China and Japan the bamboos are non-clump-forming ("monopodial"). All the species in 3.1 above are clump-forming except for *Phyllostachys* which has creeping underground stems from which cuhns are producedat intervals. Some clumps are dense, others more open.The parts of the bamboo plant are shown in *Figs. la, lb.*

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1. Including P. bambusoides Sieb. and P. edulis Makino.

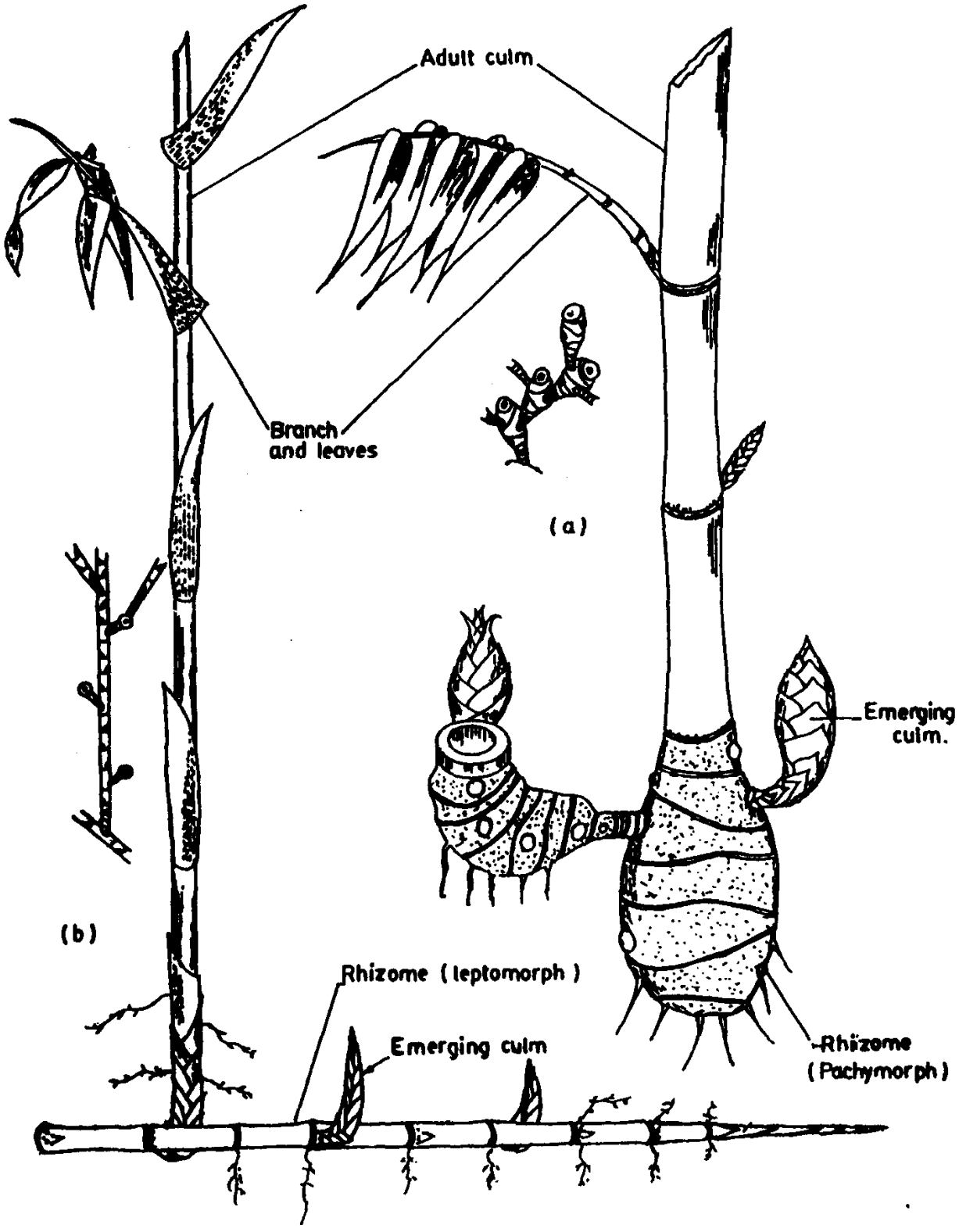

Figure 1: The rhizome system of bamboo

a) Clump forming (sympodial) bamboo
b) Non-clump forming (monopodial) bamboo

5. How are bamboos propagated?

Bamboos can be propagated through seed or by vegetative means.

5.1 Seed propagation

Some species do not produce seed (e.g.,*ambusa balcooa,Bambusa* vulgaris) and those which do so often flower at long intervals varying from30 to*70* years *(e.g. Bambusa bambos,Bpolymorpha,Dendrocalamus strictus,Melocann baccifea* and *Phyllostachy spp.)* Some species flower gregariously and then the parent plants all die, some flower sporadically with or without parent plant deaths, and some species combine both patterns*(e.g. B.tulda, B. longispicutata).In only* a few is there more frequent flowering and seed production (e.gchlandru spp.). These flowering patterns mean that seed is rarely, if ever, available when it is needed for propagation. Also bamboo seeds tend to be relatively short-lived and difficult to store without sophisticated controlled dryingand sealing in hermetic containers, techniques not available outside research institutions.

5.2 Vegetative propagation

Over the centuries, villagers have replanted bamboos by dividing up clumps and their underground stems or cutting up the underground stems (rhizomes) ofnon-clumping species. However many species produce extremely large plants and it is not always easy to dig out pieces for propagation. A number of other techniques have been developed for a variety of species in many areas of the world. Many of them have been refined by appropriate research over the past 20 years. This manual attempts to summarize the techniques and to make them easily understandable by the wide range of people involved with bamboo cultivation. This range of users includes forestry departments and extension services, through to homesteads and rural farmers, as well as non-governmental organizations involved with

community schemes, environmental rehabilitation and all aspects of bamboo production.

6. Are there advantages in using vegetative propagation?

There are two potential advantages in using vegetative propagationFirst, the methods reproduce the mother plant identically since they produce clones.Known high yielding plants can thus be propagated and a degree of selection introduced into the production system. This is not possible with seeds since they are genetically heterogeneous and do not necessarily reproduce the characteristics of the plants from which they are obtained. Second, refined techniques of vegetative propagation have been found to cut costs of bamboo plantations in comparison to the use of more conventional vegetative propagation methods.

7. Are there disadvantages in using vegetative propagation?

Yes! Most bamboos maintain a definite vegetative time period before flowering. Those which are cloned still maintain this time period, so there is a danger that flowering, and death, could occur in a short period after propagation. Only local knowledge, or recorded details, if available,will tell the age of the clumps used for propagation. Strategies, therefore, require an occasional sexual propagation. Also cultivation of diverse population sources in the plantation can provide a safeguard since it would buy time if flowering started in any one site. This strategy of developing polyclonal plantations (of anything from 10 to 30 different clones) will also ensure a wide genetic base, and help maintain the resource.

BASIC CONDITIONS NEEDED FOR VEGETATIVE PROPAGATION

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1. **What conditions are needed?**

These are: High air humidity
Appropriate rooting medium
Moderate to full light intensity
Protection from pests and diseases, waterlogging and strong winds.

Of these,maintenance of high air humidity and lack of water logging are the most critical.

2. **Why are humidity and water relations so important?**

Vegetative pieces of bamboos, such as cuttings lose water rapidly especially through cut ends. Such pieces have no roots to take up water to replace the water loss. Any waterlogging around the pieces will inhibit or delay the development of roots. Death due to desiccation before rooting is the major cause of lack of success in propagating. If the vegetative piece produces, new leaves through bud break these will transpire and exacerbate water loss.There are 2 ways to maintain high humidity:

(i) through the use of mist propagation systems; and
(ii) by using manual spraying.

3. **What is mist propagation?,**

Mist propagation is a mechanised way of spraying water onto material being propagated and it maintain sa film of water on the plant

pieces. As a result it,

(i) maintains high humidity thereby reducing loss by evaporation and transpiration, and

(ii) maintains a cooling effect which reduces respiration rate.

This combination of effects means that physiologically the plant material can synthesize food in light to a degree and slow down the rate of stored food utilization which will help the initiation and development of roots.

3.1. What are the details of mist propagation?

Water Supply: This should be reliable, with adequate flow and with sufficient pressure.

Water *Quality:* The water should not be hard and alkaline; also water containing iron should be avoided. Uncontaminated rain water is excellent.

Water Distribution: **Water needs to be distributed as evenly as possible over the propagation bed. This needs a pressure of at least 30 lb; low pressure will provide a coarse mist and a fine mist is required. Water supply is through a main feeder pipeline along the centre of the bed with 90 cm long uprights with baffle-type nozzles spaced lm apart *(Fig. 2)***

Timing: Water is best provided intermittently as mist for 30 s, with a gap of 15 s. Periodic cleaning of the nozzles may be needed to maintain this regime. The regime is mechanised by the use of electricity. Lack

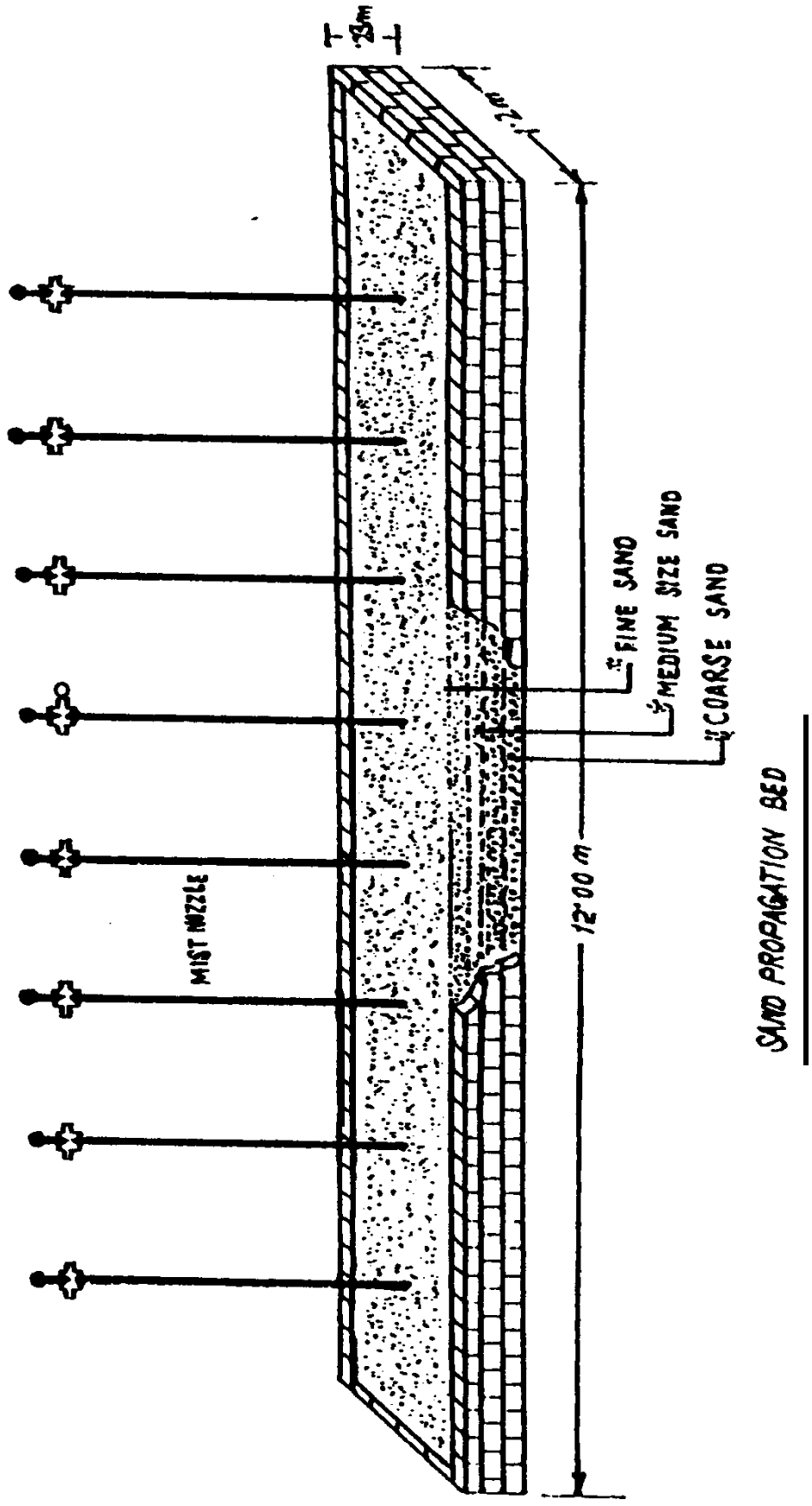


Figure 2: Water distribution through mist nozzles

of mechanisation can be overcome by the use of hosepipes or water spray buckets (Fig. 3).

Protection of the Propagating Bed Uniform mist can only be ensured by protection from winds and any major air movements.

3.2. What are the details of the rooting medium?

Properties of Rooting Medium Needed: The medium must support plant pieces so that they remain in particular positions. It should minimise water loss from buried parts and provide a moist but well-aerated bed for root initiation and development.

Bed Preparation: Usually a 3-layered structure is prepared *(Figs. 2,4).* The bottom layer should be gravel and large size sand; the middle, medium sized sand; and the top, fine sand. Each layer should be 7-10cm deep. Beds are normally ca. 1.2mx12m insize but length canvary. They are held in place by making a boundary of bricks. Sand used in preparing the bed should be clean. If the area is well-draining, the layered structure can be replaced by one type of sand: medium to fine. Beds should be on level ground to maintain uniform moisture throughout *(Fig. 4).*

Advantages of Sand: Sand is inexpensive, often readily available locally, can be washed and reused, provides good drainage, enables rooted plant parts to be dug up easily and maintains a more or less uniform temperature in the bed.

3.3 What stresses will affect success?

Stresses include:

- inadequate or too much water (see 2 above)
- temperatures: avoid extremes
- light availability (see 4 below).

Figure 3: Water spraying by hose-pipe

Figure 4: A 3-layered sand propagation bed

4. What shading should be provided?

It is not necessary for species which root easily e.g B ambusa *vulgaris.* Other species take longer periods to root and shade is beneficial e.g. *B. nutans, Dendrocalamus giganteus.*

Shading, when needed, should be such that 5060% of sunlight reaches the bed. Heavy shading promotes moulds and rotting of cuttings if the bed is enclosed with polythene. In open beds, shading to 15-30% of sunlight is possible. Shading should not be continuous e.g. it should be avoided during the rainy season or overcast days.

4.1 How is shading provided?

This is normally from lath fence rolls, laths being made of bamboo or wood and in sizes of 5 cm x l-3 m at 5 cm spaces held by wire or nylon ropes. The lath rolls are laid on frames *(Fig. 5).* Sometimes straw mats are used instead of lath rolls *(Fig. 6).*

5. Are there hazards in transplanting propagules?

When propagation is successful in the mist system, the propagules are normally transplanted into polythene bags. Propagules should not be allowed to dry out when dug up, soil in the polythene bags must allow good drainage and normally 3-5 days of shade is needed to help harden the plants. At transplanting some fertilizer is provided to promote healthy growth (no fertilizers are provided in the propagation beds).

6. What problems can occur?

These relate to two aspects of the work. First there may be constraints due to the biological nature of the materials; for instance poor health of propagules or inadequate rooting. Constant vigilance is necessary. Second there are clearly organizational problems if staff are untrained, if the facilities are inadequate or if staff are careless. Good supervision is, therefore, essential to success.

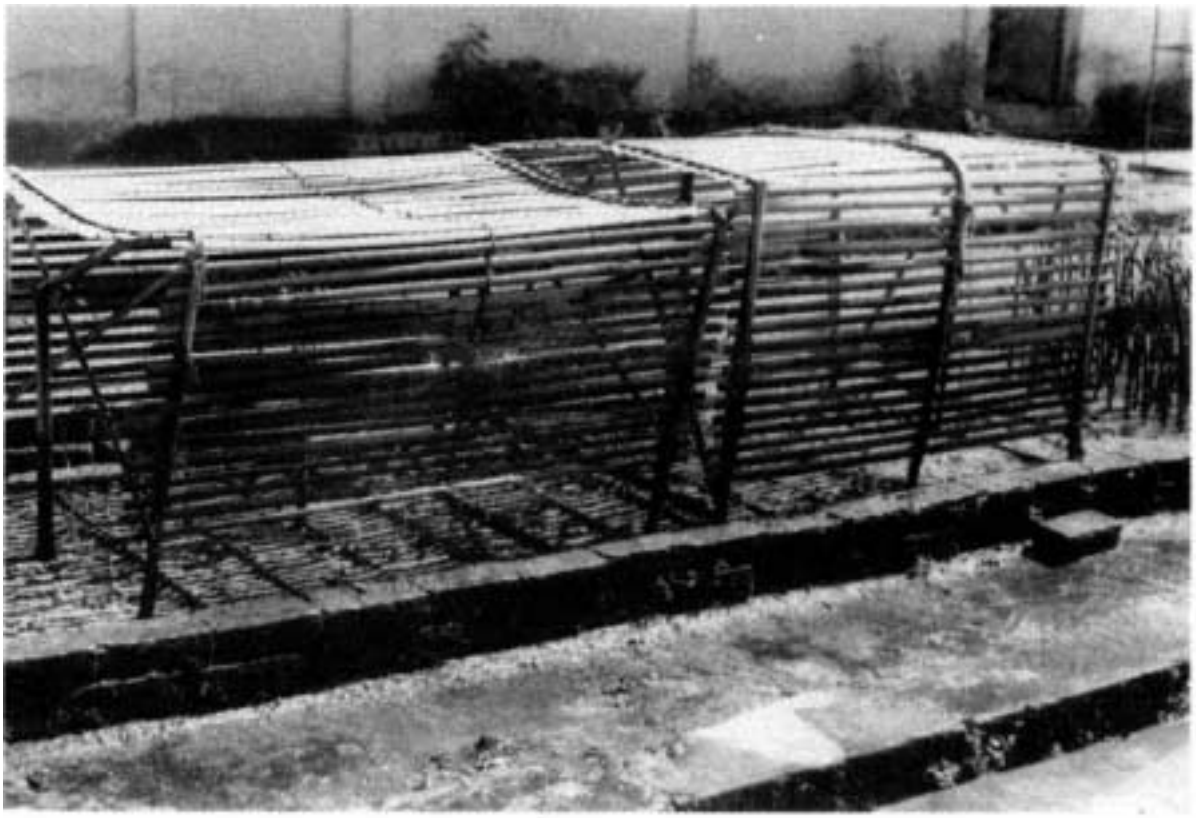


Figure 5: Shading on propagtion bed by ~r
lath bamboo rolls

Figure 6: Shading on propagation bed by bamboo

METHODS OF PROPAGATION

1. What are the vegetative parts used?

These are rhizomes, culm cuttings and branches.

1.1 *Rhizomes*

The rhizome is an underground stem. It consists of 2 parts, the rhizome proper and the rhizome neck which is the base of the rhizome proper. As a stem, the rhizome has nodes; those of the neck always lack buds and usually roots. The rhizome proper has roots or root primordia and buds at all or most of the nodes.

There are 2 distinct types of rhizomes, called pachymorph and leptomorph.

Pachymorph *Rhizomes:* These are short and thick usually curved and subfusiform, rarely subspherical in shape. They are usually thicker than the aerial part of the stem (culm). Internodes are broader than long and asymmetrical (being larger on the side which bears a bud), solid, and nodes are not raised or swollen. The buds at each node are in a row, usually 5 on each side of the rhizome. When dormant, the bud is dome shaped but asymmetrical. These rhizomes are generally distinguishable with a top (upper side) and bottom (lower side). More roots are produced from the lower size *(Figs. 1a, 7).* All tropical bamboos, i.e. the clump formers, have pachymorph rhizomes. The neck is short e.g. Bambusa, *Dendrocalamus, Thyrsostachys, Gigantochloa,* but sometimes long e.g. *Melocanna.*

Figure 7: A typical pachymorph rhizome in an offset propagule

Leptomorph Rhizomes: These are long and slender, cylindrical or sub-cylindrical in shape. They are usually narrower than the aerial culm. Internodes are longer than broad, relatively uniform in length and symmetrical, hollow (rarely solid) with the narrow central lumen partitioned by a diaphragm, and nodes may or may not be raised or swollen. The node generally bears a single bud and a single row of roots, as typified by Phyllostuchys, but others have buds absent on several nodes and roots may be absent or sparse.These rhizomes are not generally distinguishable with a top and bottom. Most buds produce culms, a few, however, produce other rhizomes. The rhizome neck is always short (Figs1 b, 8).

Priority bamboos with leptomorph rhizomes are the non-clump forming species of *Phyllostachys.* Other examples would include *Pleioblastus* and Pseudosasa of East Asia, and some species of *Semiarundinaria*

1.2 *Culm Cuttings*

The culm is the above ground stem which grows from the underground rhizomes. It is segmented with nodes and internodes. The length of internodes and their texture vary according to species. The nodes bear one or more buds, their shape and size also depending on species. The buds occur on alternate sides of the culm just above the leaf scar (Fig. 7).

1.3 Branches

Branching patterns vary among bamboo species. Each bud or culm node can potentially produce a branch; however, in many species the primary branch remains dominant and stout. Others are widely branched and the primary branch is indistinguishable from the other branches *e.g. Schizostachyum* and *Melocanna baccifera* branches near the top of the culm. Some *Ochlandra* species may also be much branched higher up the culms.

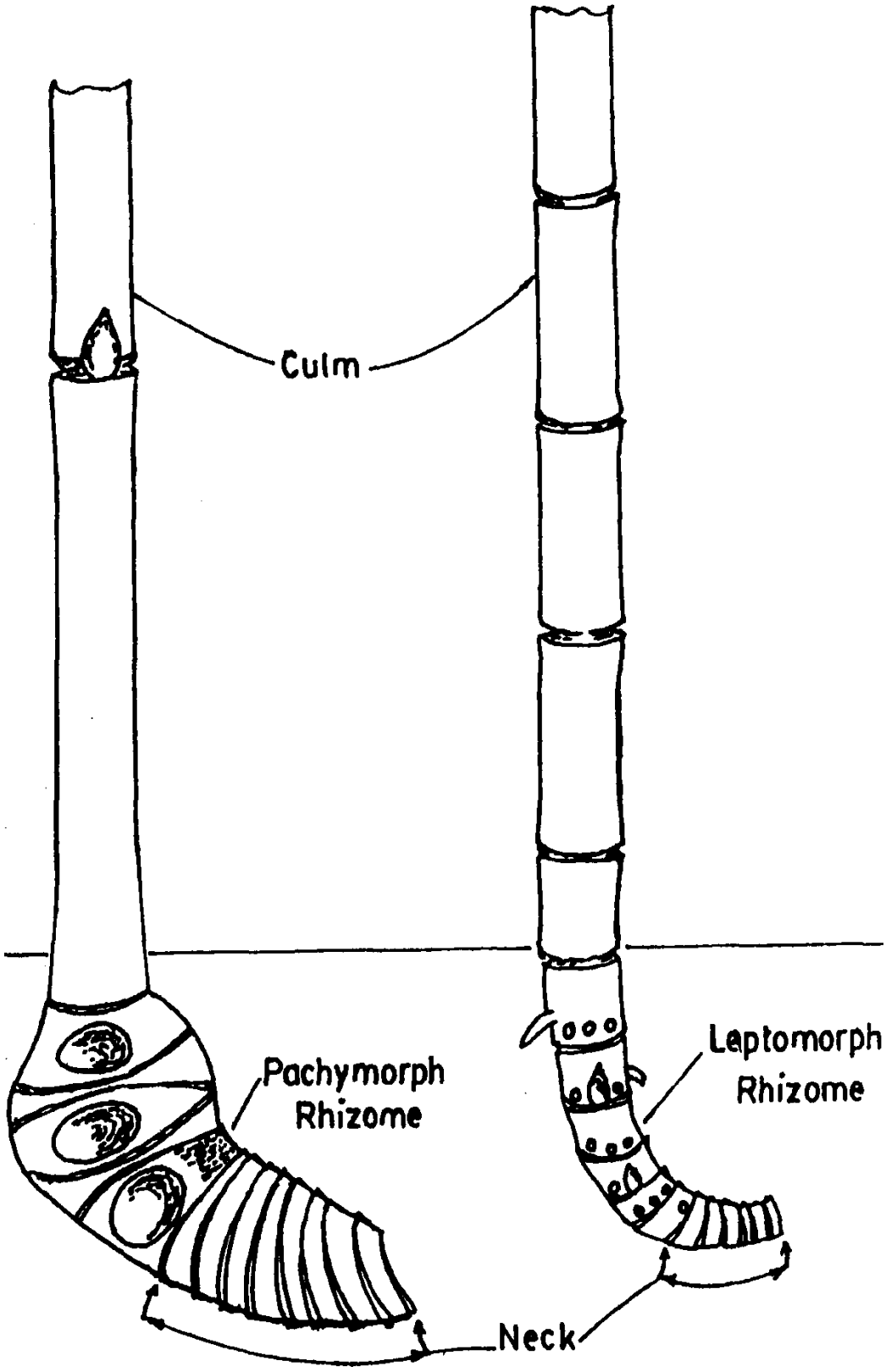


Figure 8: Lower parts of twoculms developed from a pachymorph artd leptomorph rhizome

Each branch is stem material. Primary stout branches have swollen bases and these look like the underground rhizome (usually referred to as a rhizomatous swelling) (Fig. 9).

2. What are the types of vegetative propagation?

There are a range of types that can be considered as conventional - since they have been traditionally used for generations, or improved - since they have been the subject of refinement All three plant parts described above (1.1 - 1.3) are involved. Special terms are used to describe the methods. These are:

PROPAGATION METHOD	PLANT PART USED (R=Rhizome, C=Culm or culm cuttings, B=Branches)
CONVENTIONAL	
a. Offset planting	**R+C**
b. Rhizome planting	**R,R+C**
IMPROVED	
c . Culm cuttings	**C**
c. 1 split culm cutting	**C**
c. 2 Branch cutting	**B**
d. Layering,marcotting	**C,B**
e. Macroproliferation of seediIings	**R**

3. To what species are the improved methods applicable?

For the priority species the techniques applicable are:*

Bambusa bambos	C			**d**	**e**
B. blumeana	c,b	**cl**		**d**	
B. polymorpha	c,b		**c2**	**d**	
B. tulda	C			**d**	**e**
B. vulgaris	**c,b**	**cl**	**c2**	**d**	

Cephalosfachyum pergracile	(4				
Dendrocalamus asper	c	c1	c2		
D. giga nteus	c,b		c2	d	e
D. latiflorus	c			d	
B. textilis	c,b		c2	d	
D. strictus	c,b		c2	d	e
Gigantochloa spp.	c				
Gtradua spp.	c			d	
Melocanna baccifera	(c)				
Ochlandra spp.	(c)				
Phyllostachys spp.	c		c2	d	
Thyrsosfachys siamensis 3	(c		(c2)		e

( ) = Method possible but not always successful.

* = Resultsmayvary. If successful propagation is not achieved using culm cuttings, rhizomes or offsets should be used.

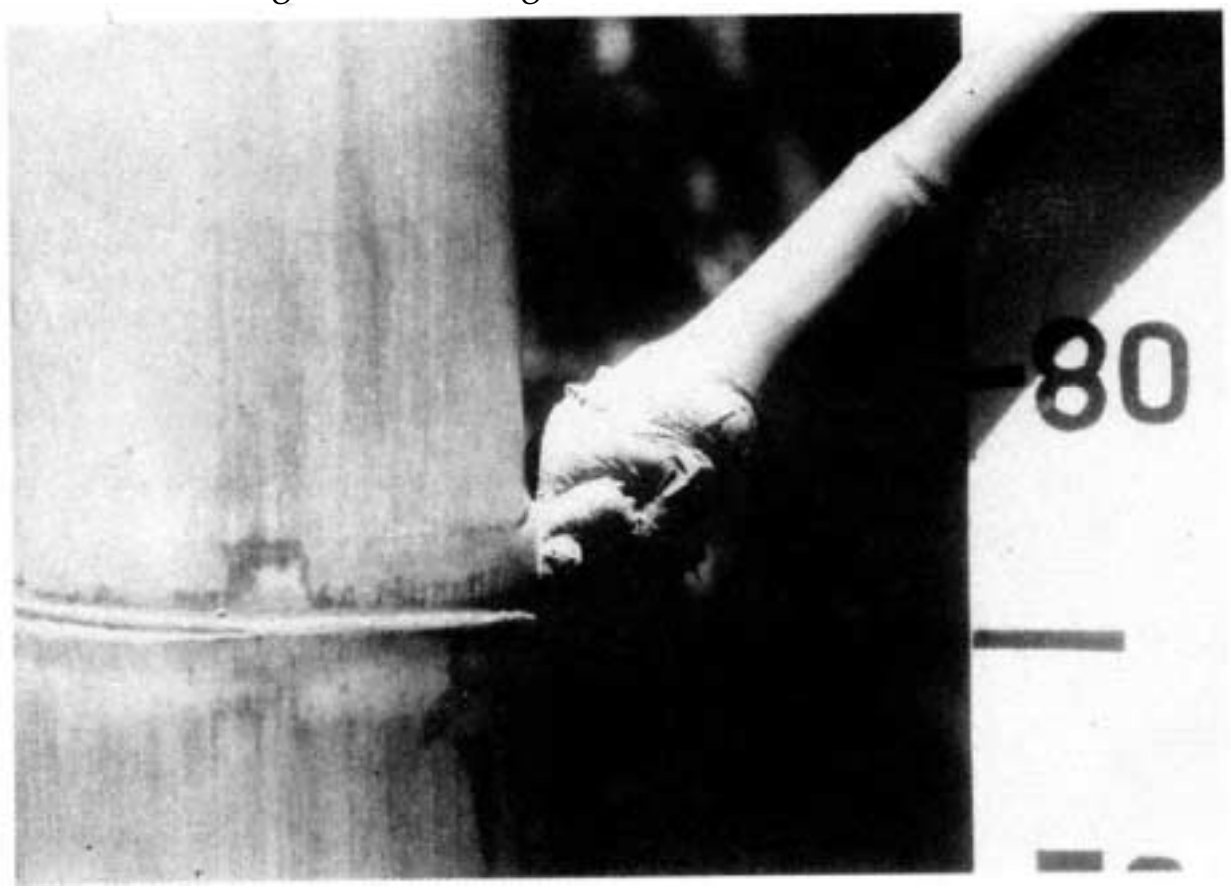


Figure 9: Rhizomatous swelling at branch base

THE OFFSET METHOD

1. What is an offset?

An offset is the lower part of a single culm (usually with 3-5 nodes i.e. about l-2.5 m) with the rhizome axis basal to it and its roots (Figs. 10a, 10b). Planting of these is the most conventional way of propagating bamboo. The culm is between 1 and 2 years old.

2. How is the offset obtained and prepared?

The culm is cut with a slanting cut and the rhizome to which it is attached is dug up and cut off to a suitable length to include well developed buds. To ensure field survival attention has to be paid to the following:

- The offset should be collected from a healthy parent clump
- The rhizome and attached roots should not be damaged
- The rhizome should be detached from the parent clump at the neck
- The buds on the rhizome should be lightly pressed to see they are not rotten. Healthy buds will be yellow-straw colour, rotten ones will be brown-black.

The underground parts of the offset should be wrapped in banana leaves/gunny bags or sacking containing water hyacinth/moist sawdust/moist straw for transportation.

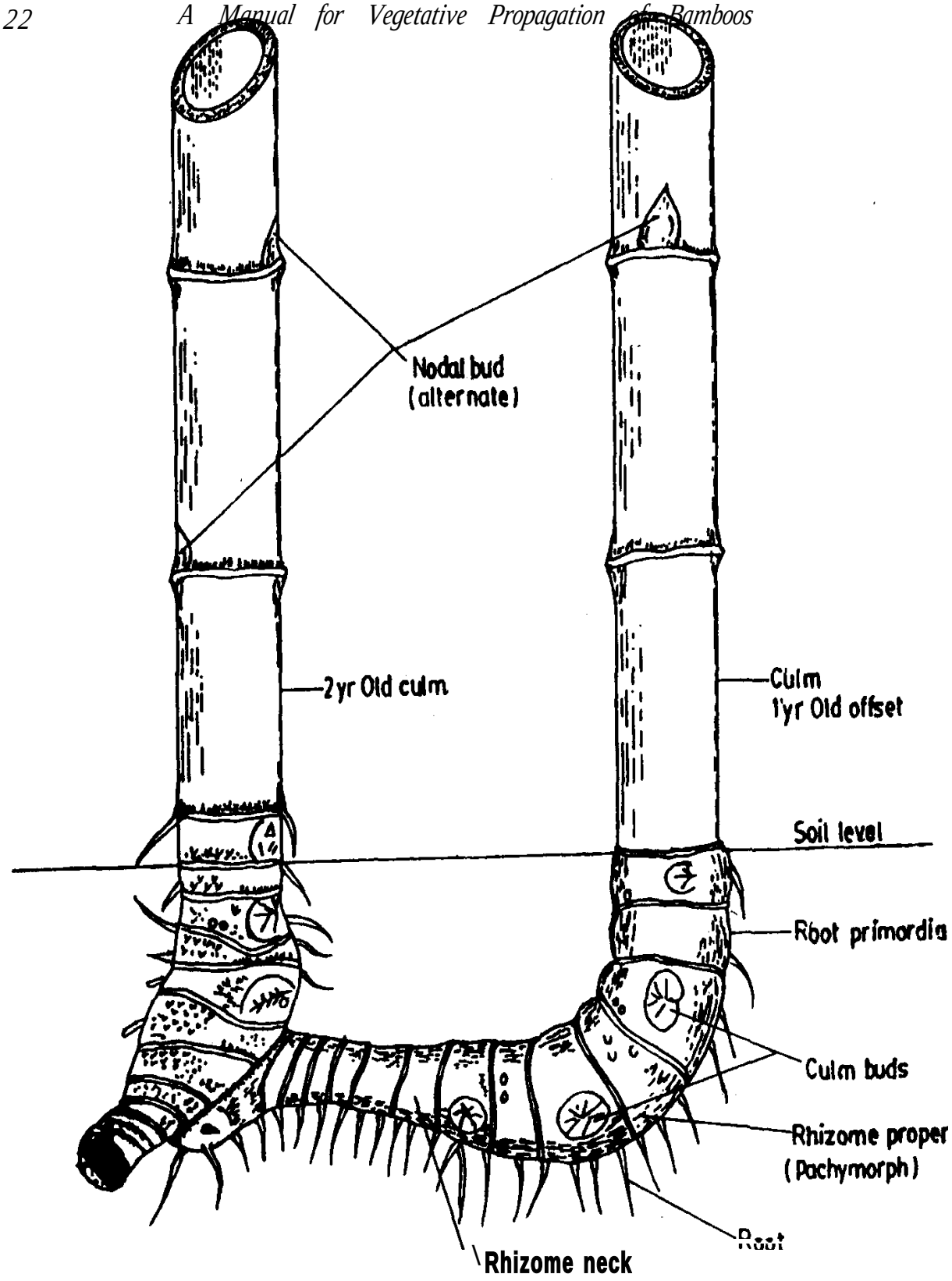


Figure 10a: A diagram of an offset

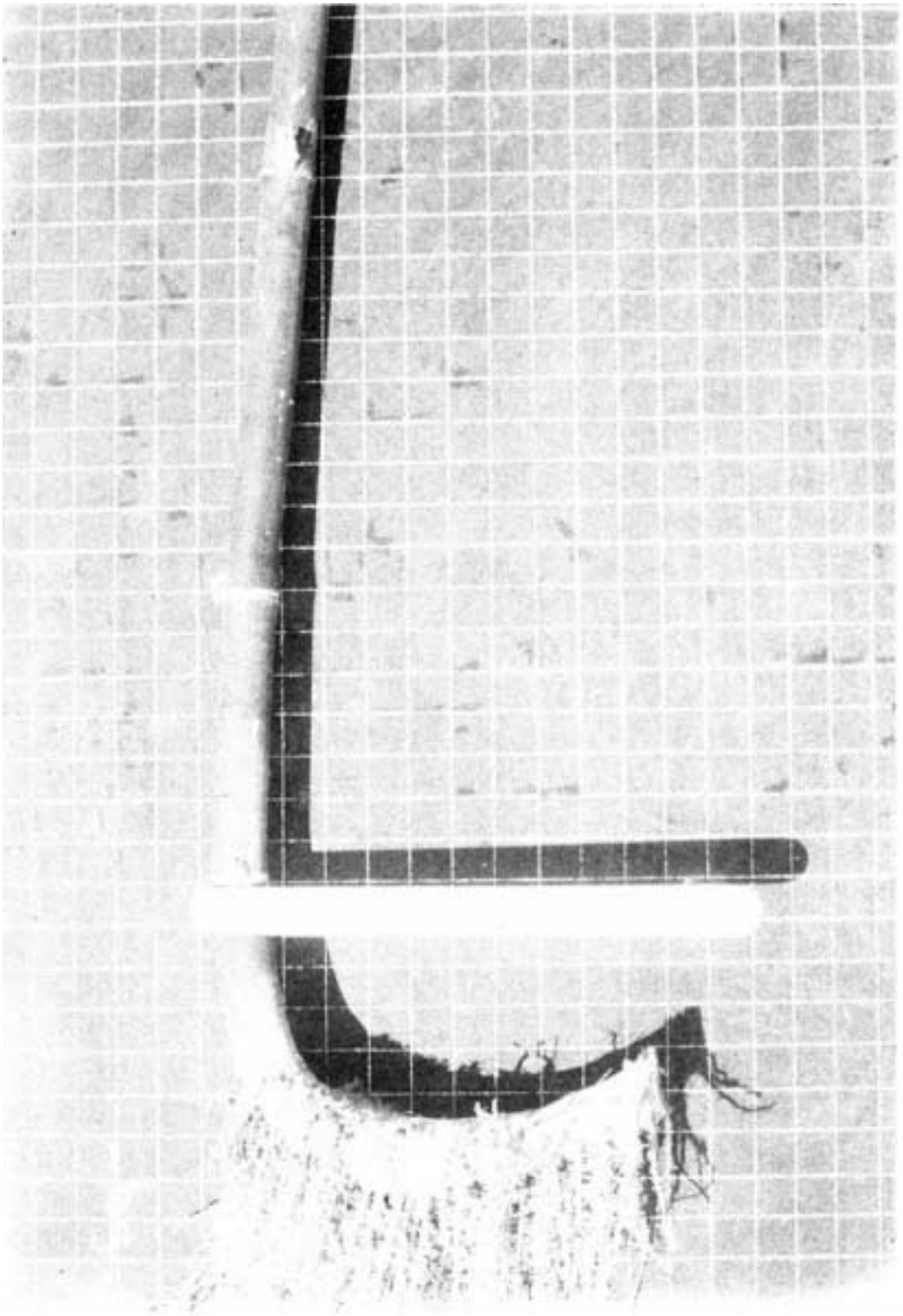


Figure iub: An offset of B. tulda

3. What treatments are needed at transplanting?

Offsets are normally obtained and transplanted just before the rainy season or after a pre-monsoon shower. Any prevailing drought has to be avoided by watering otherwise survival can be 05%; this is necessary when planting earlier. Collecting of offsets is frequently done 2-3 months before planting; in this case they should be kept in a temporary nursery near the site e.g. in a sandy bed of a stream. Timing of collecting is from just before the new growth season. If collected later, when culms are emerging, the buds will be elongated and liable to damage (Fig. 2 1). In 1ost tropical to subtropical regions mid-March to mid-May is the collecting period.

4. Are there other precautions needed at transplanting?

It is advisable to seal the slant cut of the culm with earth. Also some weeding might be necessary after transplanting.

5. Are there limitations to the offset method?

Yes! These include:

i. Offsets are bulky and heavy (each may weigh 6-30 kg).
ii. Labour can be costly for the excavation and transportation.
iii. Offset availability can be limited e.g. to 2-3 per clump. If more are excavated the regeneration of the parent clump can be lost.
iv. Survival, which is theoretically 100%, can be much lower.
v. The method is unsuitable to develop large plantations.

6. Does the method apply to some species more than others?

Yes! In general the method applies to thick walled clump forming species. Thin walled ones e.g. Melocanna baccifera, a priority species,

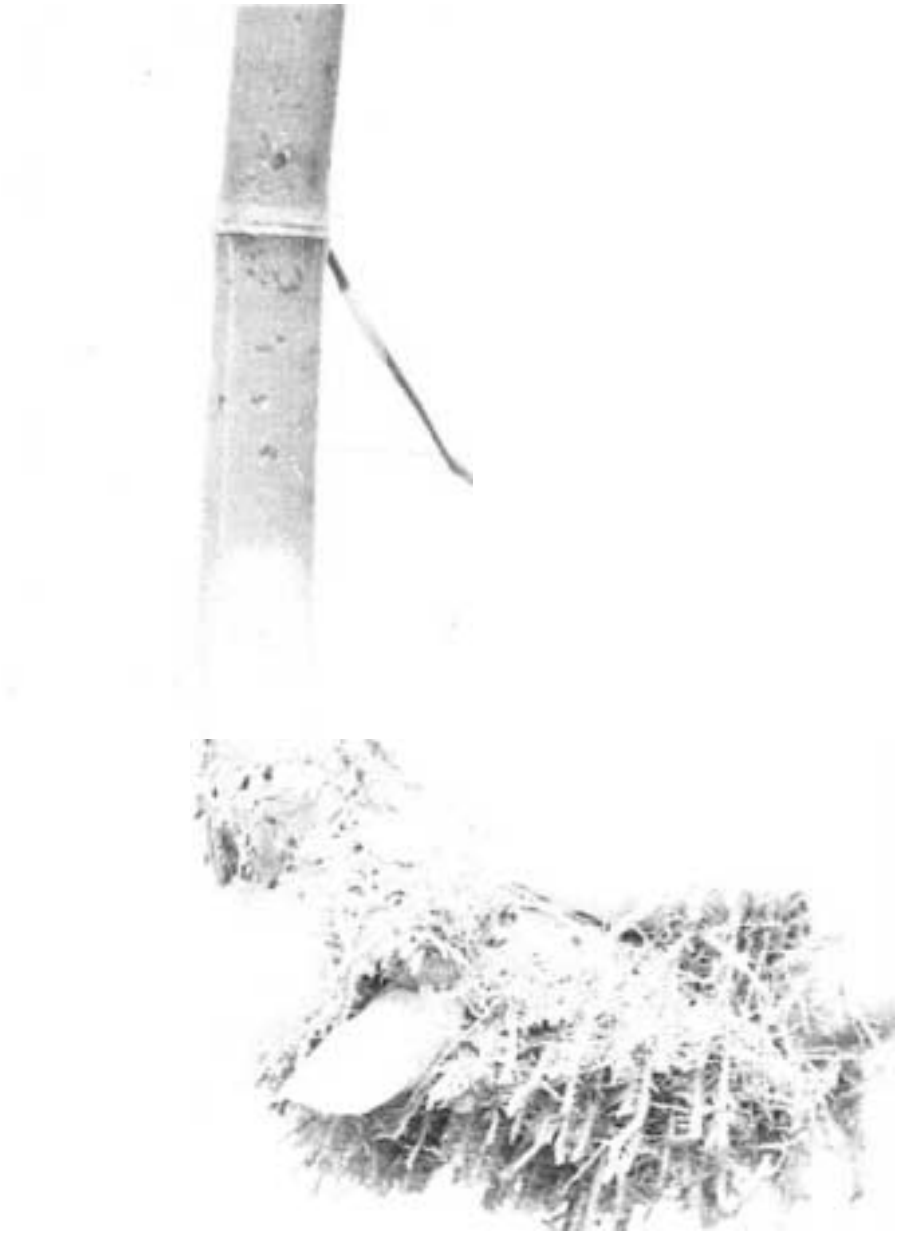


Figure 11: Damaging of bud on an offset

or Schizostachyum dullooa locally important in North-East India, show poor success in offset planting . However, success rate can be 30-50% in such species if part-clumps i.e. 2-3 jointed offsets are used.

THE RHIZOME METHOD

1. When is the method used?

Rhizomes are traditionally used to propagate non clump-forming species where rhizomes are long and slender: the leptomorph type. they are rarely used to propagate clump-forming species with pachymorph rhizome types.

2. How is the rhizome used?

Basically there are three ways; use of rhizome with roots, rhizome with culm and roots or rhizome with culm-stock and roots. The latter becomes similar to offsets but there are differences (see below).

Rhizome with roots (Fig. 12a)

- Rhizomes should be healthy and be "fresh" in colour;
- not more than 2-3 years old;
  (Rhizomes older than 3 years produce buds with reduced vigour and shoots that do not grow tall. The older the rhizomes, the less vigour of the buds.)
- not damaged; and
- should have roots.

Rhizomes without culms are cut 50-60 cm long with about 10-15 nodes and with roots. If the rhizomes are transplanted to distant places, they are to be wrapped with moist peat moss or sawdust or straw and covered with polythene tubes after the soil is washed away.

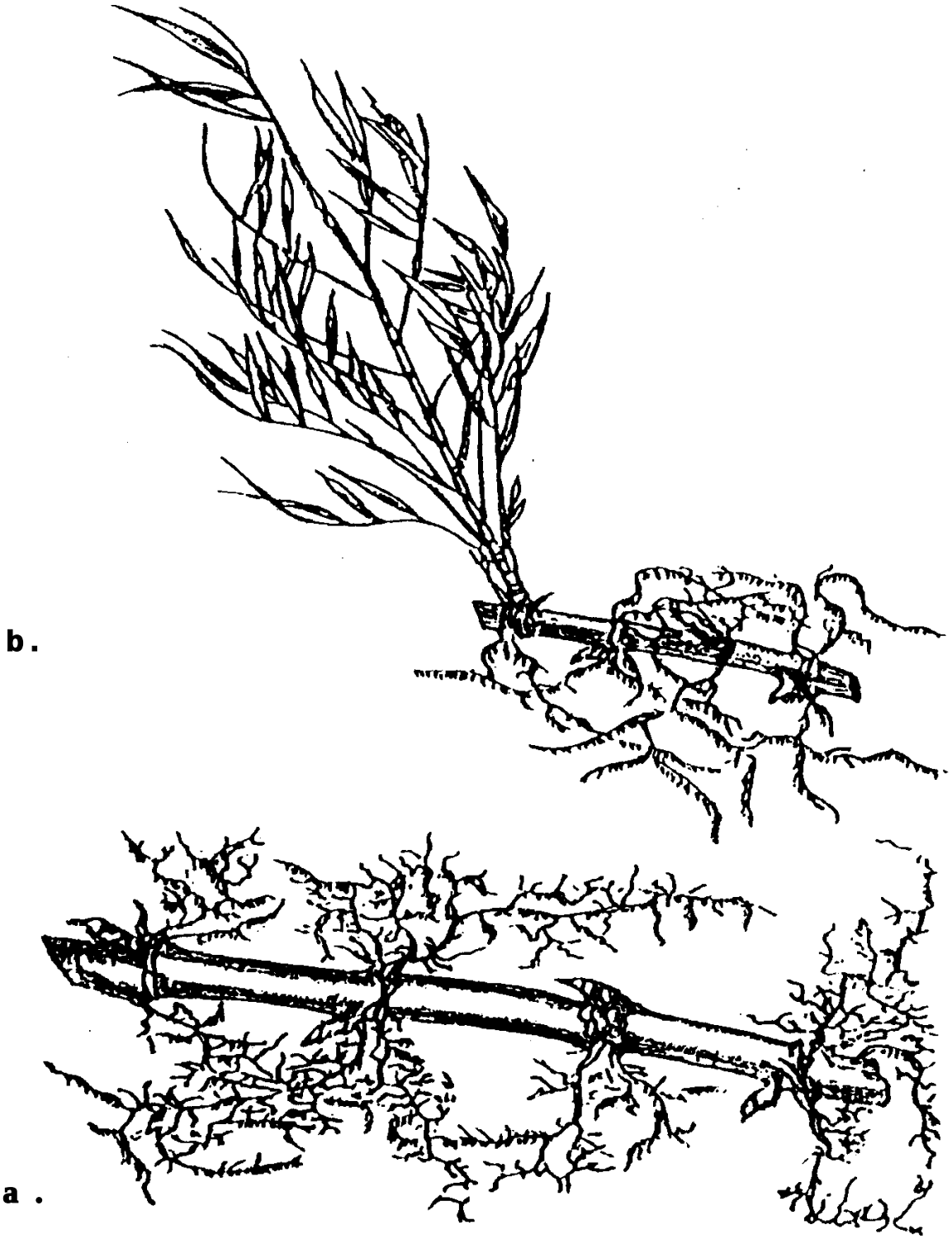


Figure 12: The rhizome method for non-clump forming bamboo

a) Rhizome with roots
b) Rhizome with culm and roots

Rhizome with culm and roots (Fig. 12b)

Generally young culms along with associated rhizomes and roots are used. If the culm is young, it is maintained intact, if it is large the upper part can be removed, or branches trimmed. It is essential that the rhizome attached bears buds; other rhizomes can be cut away.

Rhizome with culm-stock and roots (Fig. 12b)

This is essentially a rhizome with roots but only 30-60 cm of the basal portion of the connected culm.

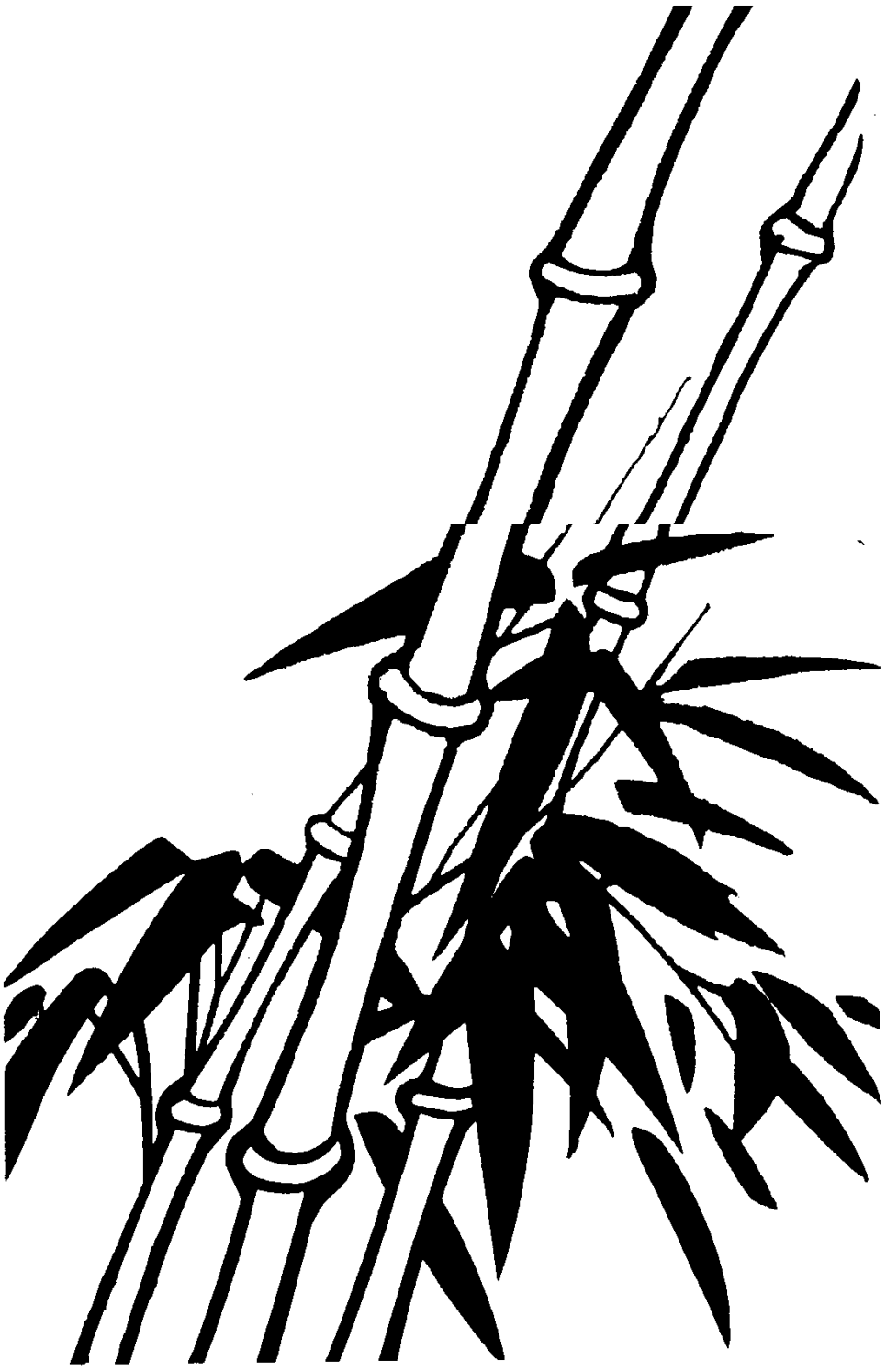
3. When are the rhizomes excavated?

February to March appears to be the best time for both collecting and transplanting. If the region has a cold climate the best planting time is April, if it is warm then it should be the cooler month.

4. Are any post-collecting treatments needed?

If rhizomes alone are used then they need a period in the nursery during which they are laid horizontally to root. The two other types are transplanted directly into the field. In a rooting bed the medium should be 3:1 soil: sand and rhizome planted 10-15 cm deep, and 25 cm apart. Watering is necessary and straw mulch is helpful. Shade is needed when young shoots emerge.

If many plants are to be produced from one piece of rhizome, they are to be separated and usually l-2sprouts may be kept per piece. The piece should be at least 15-20 cm long, with three or four nodes, each with an intact bud. The length of the rhizome affects the survival of the shoot. The longer the rhizome, the more nutrient it contains to support the new shoot. In general, bamboo species with large diameter culms require longer rhizomes, the length being about five times the basal girth of the culm. The usual rhizome length for *Phyllostachys* is 2 m.



CULM AND BRANCH CUTTING METHODS

CULM CUTTINGS

1. What are culm cuttings?

Culm cuttings are segments of the culm (stem) usually 1 or up to 2-3 nodes with buds or branches. They are suitable for clump-forming species but usually not for non-clump-forming species. Generally the culm selected for the cuttings should be not more than 2 years old and buds should be healthy.

2. How are the cuttings prepared?

- Segments are selected from the lower to mid zone of the culm. The upper part and the lateral branches of the upper culm are discarded. Mid-March to May is the best time for cuttings.
- The branches on the selected part of the culm are pruned to a length of 10-30 cm, care being taken not to injure existing buds *(Fig. 13).*
- A segment is cut with a sharp knife or saw. Avoid splitting at the cut *(Fig. 14)* especially in thin walled species. Keep 5-10 cm on either side of the node.
- Immediately after cutting, wax the cut ends or wrap segments with moist gunny bags or place in moist saw-dust/coconut husk/straw to minimise water loss from cut ends.
- Transport as quickly as possible to the propagation bed.

Note: If the internode is long (e.g. *Bambusa polymorpha, Schizostachyum lima* or S. dullooa) the segment may be l-2 noded. If the internode is

Figure 13: Branches on the culm are pruned

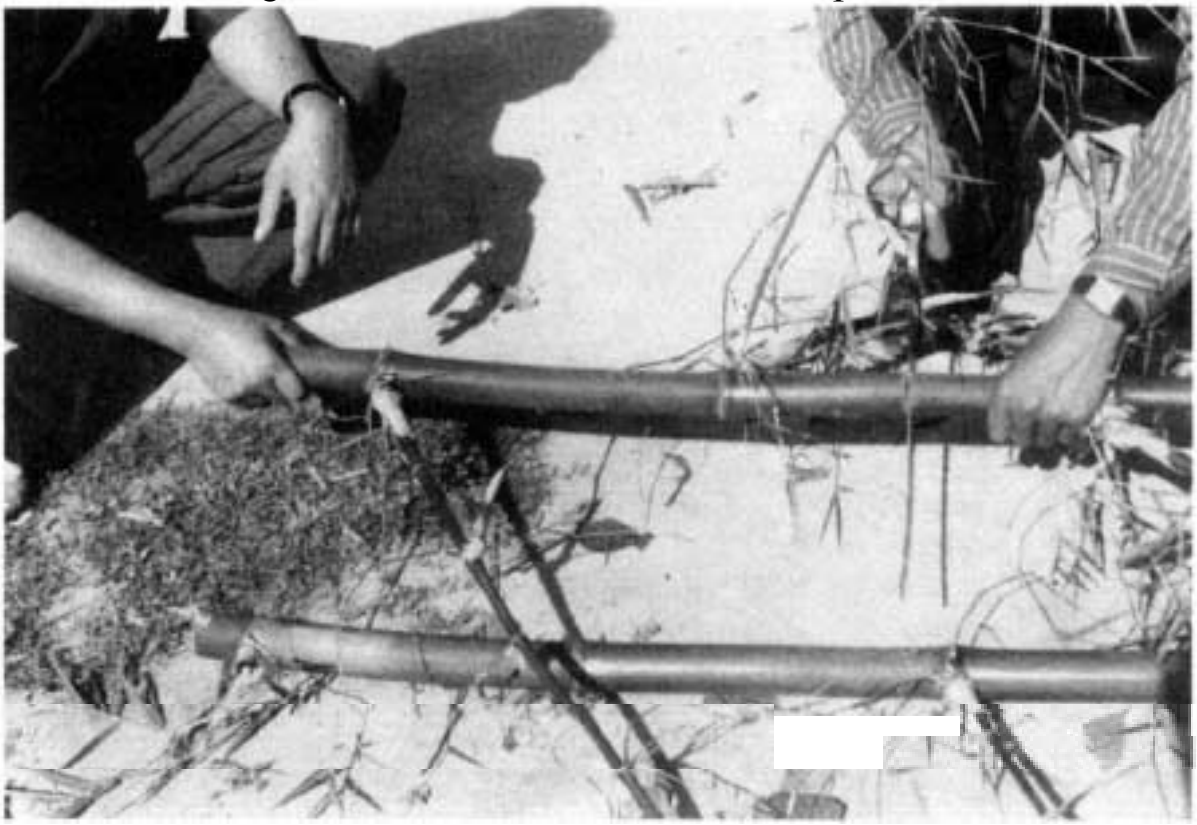


Figure. 14: Culms are cut into segments by saw

short, 3 noded segments may be prepared. The more nodes in the cutting, the greater the chance of regeneration. However, cuttings which are long create problems in handling and transportation.

3. How are the cuttings treated?

If cuttings are 2 or more noded, an opening ca. 2 cm long and 1 cm wide is made, or 2 holes each 7 mm diameter are drilled in the centre of the internode. A rooting hormone solution is poured into the segment cavity and the holes are closed by wrapping and tying a polythene strip. Hormone solutionis NAA 100 mg/l or 100 ppm. This is prepared by dissolving 10 g NAA (1-Naphthalene acetic acid), supplied by EMerck, BDH or Sigma, in 200 ml 90% ethyl alcohol and stirring. Add distilled water to make up to 100 1. Usually about SO-100 ml is needed for each treatment. Hence 100 1 will treat 1000-2000 cuttings.

4. How is the propagation bed prepared?

Beds are lm wide and range from 5-15 m depending on space available. They should be built on level ground and should be 20-30 cm deep. Sand is used as follows. At the base, medium to coarse sand should be laid for 10-15 cm. Over that a top layer of fine sand should be laid for 10-15 cm. If there is continous rainfall which can cause waterlogging it is advisable to prepare a 3-layered bed as shown in *Fig.* 4.

5. How are the cuttings placed in the bed?

Culm cuttings are placed horizontally in the bed, spaced 15-30 cm apart and so that branches if present are arranged away from those of another cutting *(Fig.* 25). The cuttings are placed in the top fine sand layer about 3-5 cm above the coarse sand and covered by 3-6 cm of the fine sand. The bed is misted or manually kept moist. Shading is needed, usually partial shade.

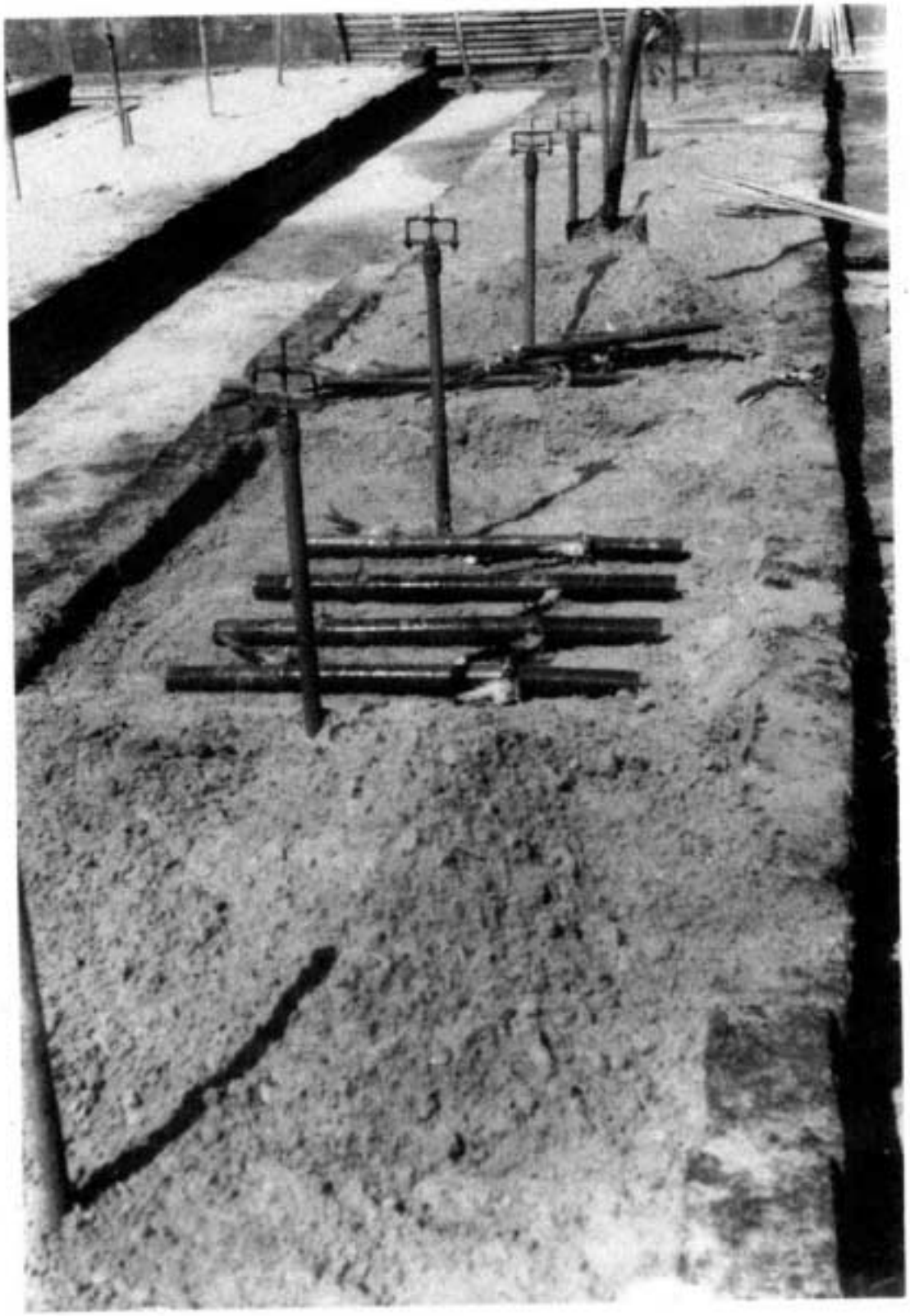


Figure 15: Horizontal placement of culm-cutting on sand propagation bed

6. Are there modified techniques?

Yes. These include:

SPLIT CULM TECHNIQUE: In this method the cuttings are cut longways into halves with newly developed small living branches attached to the nodes (Fig. 16). Thay require usually more shade, SO-70%. The split halves may be soaked in rooting hormone solutions for 24 h before placing in the propagation bed; however there is evidence that this is not overly advantageous. The method is especially suitable for *Bambusa blumeanu, B.* vulgaris - including *var. striata,* and *Gigantochloa asper.*

Whole Culm Technique: In this method 2-3 year old culms are selected, branches trimmed and the whole is placed into the bed. This is not a common method nor is it very successful giving a low number of regenerated plants. However, it is sometimes used for *Bambusa polymorpha,B. textilis,B. tulda, B. ventricosa, Cephalostachyum pergracile, Dendrocalamus strictus,Gigantochloa apus, Guadua angustifolia* and *Sinocalamus oldhami.*

7. How long does regeneration take?

Culm segment cuttings sprout within a week after planting and root between 45-90 days*(Fig.17).* (This is much longer with whole culmas).

8. Do the techniques apply to all species?

In general, thin-walled bamboo species only show a 20-50% success with culm cuttings. These species include *Melocanna baccifea, Ochlandratravancorica, O. scriptoria,Schizostachyum dullooa, S. lima, S. lumampao.*

Thick-walled, large sized species respond the best.

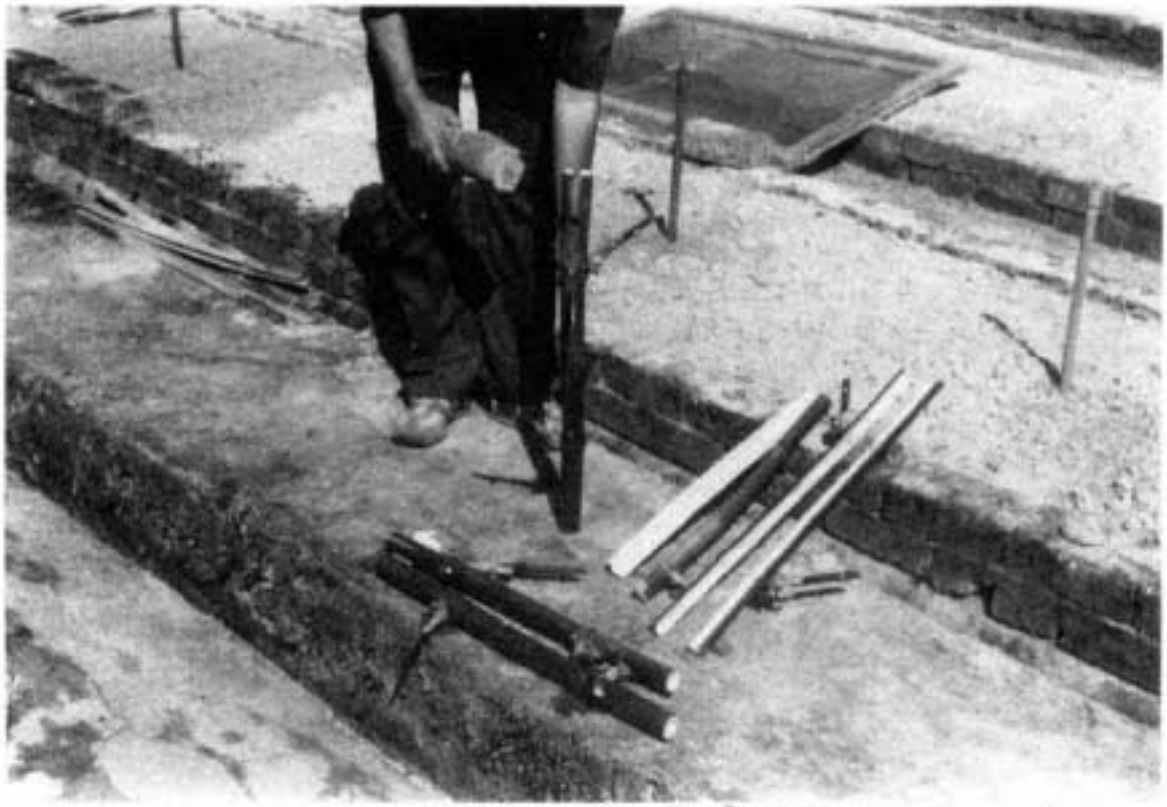


Figure 16: Preparation of split-culm

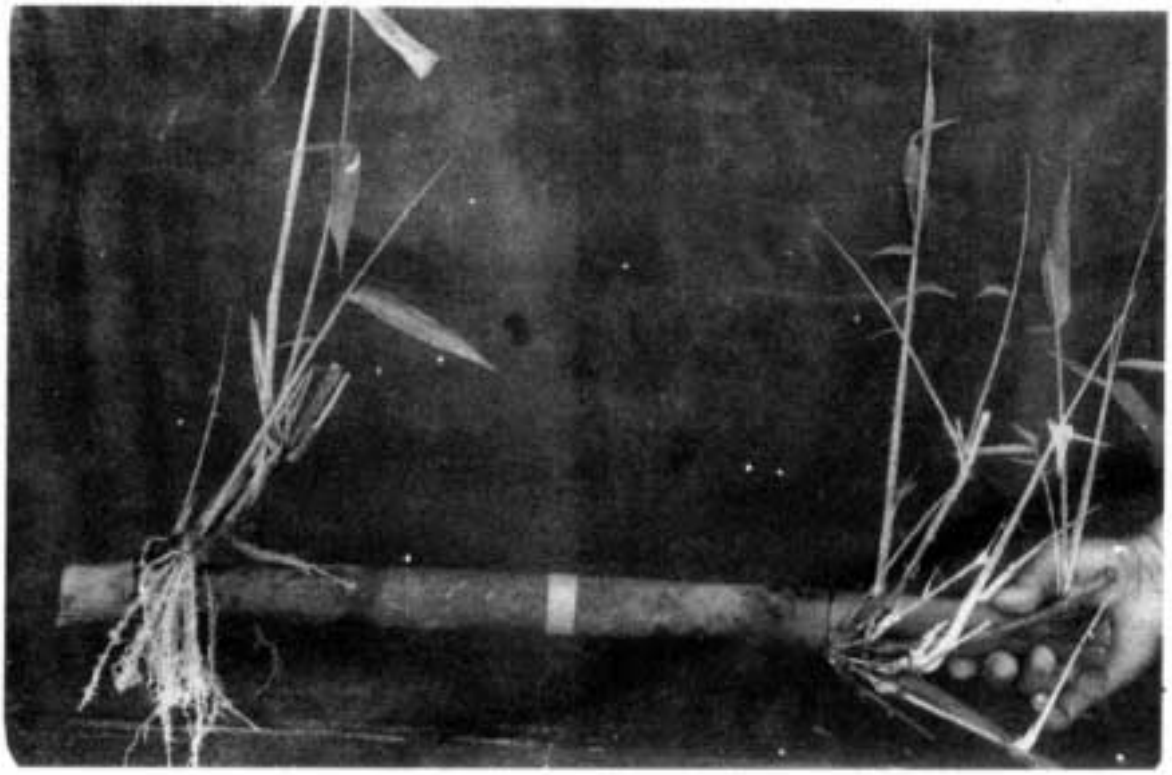


Figure 17: Sprouting and rooting in culm cuttmg

BRANCH CUTTINGS

9. Can branches be used instead of culms?

Yes. Propagation through branch cuttings is one of the most practical methods due to ease of handling. Like culms, branches are stem material. Thick-walled species with stout branches are ideal e.g. *Bambusa* spp. or *Dendrocalumus* spp., but survival sometimes is only about 50% as in D. hamiltonii. It is a common method used for *D. asper.* However, branches require 6-12 months for rooting, and 12-30 months for rhizome development essential for production of new culms. Species which bear small branches at the top of the culm e.g. *Thyrsostachys* oliveriand *T. siamensis* cannot be propagated in this way.

10. Can the regeneration time of branch cuttings be reduced?

In the field some branches may show natural aerial rooting with rhizome formation. This is seen especially on injured culms and in congested clumps. If cuttings are taken from there, they are known as *pre-rooted and pre-rhizomed branch cuttings (Figs. 18a, 18b).* Additionally methods are available to induce aerial roots and rhizomes at the branch bases. Use of such materials reduces the time of regeneration dramatically.

11. How is pre-rooting initiated?

This can be done by chopping off the top of the culm or removal of newly emerging culms from the clump. The latter, if done continously for 2 years, is more effective.

12. How are pre-rooted, pre-rhizomed branches propagated?

Cuttings are prepared as follows:

- Branches bearing aerial roots, buds and sometimes rhizomes, though not always, are selected. Roots should appear healthy. Branches should be selected on 1-2 year old culms.

Figure 18a: Pre-rooted and pre-rhizomed branch cutting
a) B. vulgaris

Figure 18b: he-rooted and pre-rhizomed branch cutting
b) D. *giganteus*

- Branches are cut from the culm using a saw *(Figs.* 18b, 19). Knives may cause splitting.

- Branches are kept in moist conditions (large moist gunny bags or polythene bags with sawdust) for transportation *(Fig. 24).*

- Cuttings are made by trimming leaves, small branches and the branch tip with secateurs. The branch is trimmed to 2-6 nodes with healthy buds and this usually is 50-80 cm long depending on the species. This final trimming occurs just before placing them in the propagation bed *(Fig. 20).*

- The cuttings are planted into the bed (see Propagating Conditions) 2-3 cm apart and the base at 7-10 cm depth. The sand is firmed around the base by pressing *(Fig. 21).* Cut ends exposed above the bed should be covered with wax or cow dung *(Fig. 22).*

- Proceed with misting and shading as explained earlier.

- Sprouting is usually seen after 7-10 days, but new root initiation is generally in the period 14-20 days and good root development is seen by 30-60 days (for cuttings taken April-August) or 55-70 days (for cuttings taken October-November). New culms will develop from the base of the cuttings within 30-60 days *(Fig.* 23). However cuttings should be removed from the bed before the new culms are produced and transplanted into polybags (15 x 23 cm) containing sandy 1oam:cow dung, 3:1 *(Figs. 24a, 24b, 25).*

- Transplanted cuttings are hardened under shade for 3-5 days *(Fig. 26).* Care has to be taken to see the polybags drain to avoid rotting.

Figure 19: Excision of pre-rooted and pre-rhizomed branches by saw from culm

Figure 20: Trimming of leaves and branches just before placing the cuttings in propagation bed

Figure 21: Sand is firmed around the base of cuttings by pressing on a propagation bed

Figure 22: Exposed cut end of branch cutting covered with wax or cow-dung

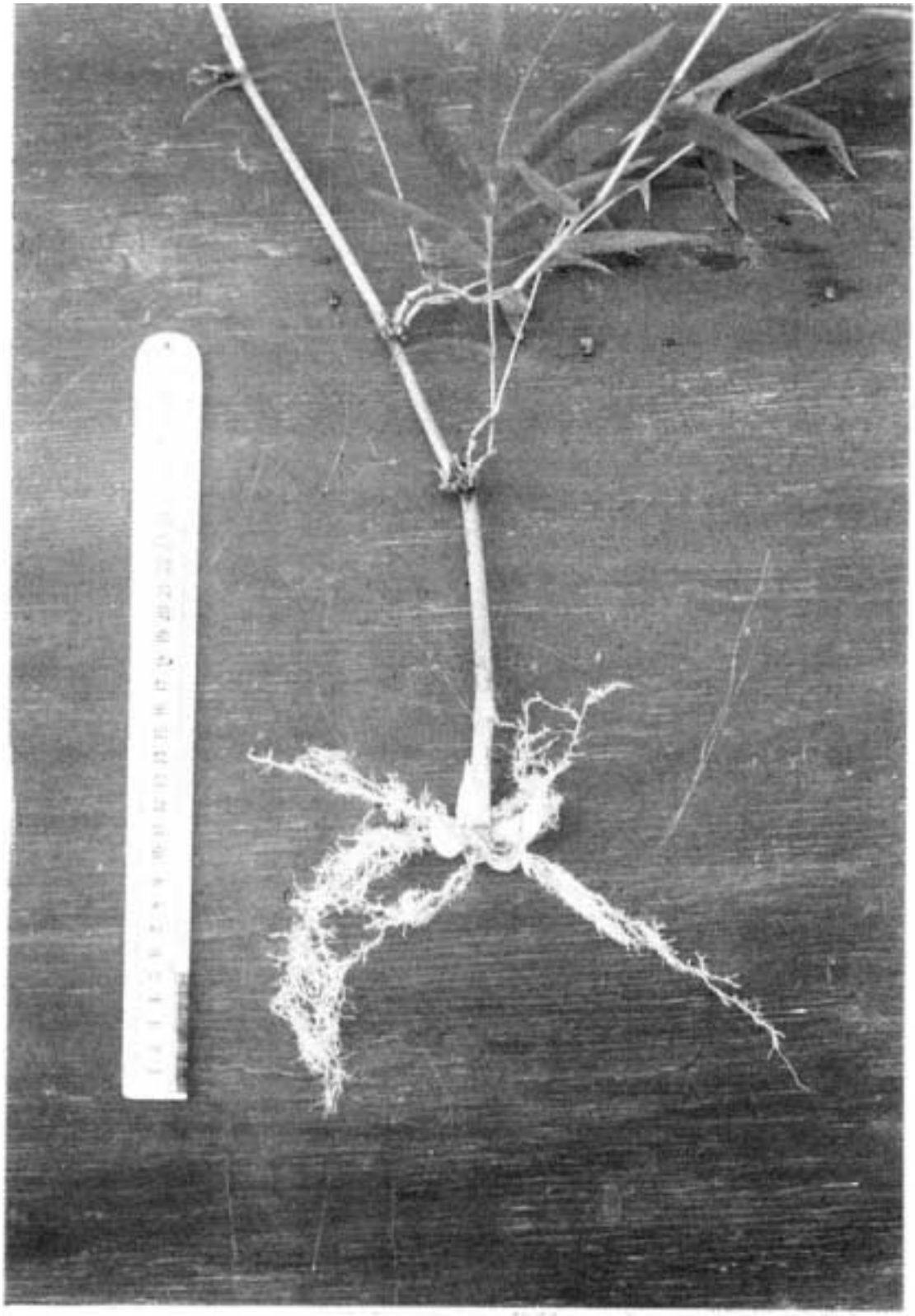


Figure 23: New culms developed from the base of cuttings

Figure 24: Removal of rooted cuttings from propagation bed

Figure 25: Transplantation of rooted cuttings into polybags

13. Are there advantages in using pre-rooted, pre-rhizomed branch cuttings?

Yes, for the following reasons:

- Branches are removed from the parent culm which is not destroyed.
- Branches are small and easy to handle.
- Usually branches are plentiful.
- Many cuttings (up to 1000) can be rooted at any one time in one 12 m x 1-5 m bed.

Figure 26: Hardening of transplanted cuttings under shade

LAYERING METHODS

1. What is layering?

Layering is a method of bringing a culm or branch in contact with soil so that propagation occurs. There are 4 types: ground, or simple layering; stump layering; air layering or marcotting; and seedling layering.

2. Can the same rooting medium be used for all layering types?

No. For ground layering and stump layering suitable media are 1:1 coconut husk:sand, or cow dung:sand or sawdust:sand, or peat moss:sawdust. For air layering coconut fibre or coir or peat moss is preferable. For seedling layering sand is most suitable.

GROUND LAYERING

3. In this method either a whole culm or a branch bearing part of the culm is bent down to the ground into a prepared shallow trench and pegged down and covered with the medium (Fig. 27). A young culm should be selected and the top cut off to stimulate the growth of buds at the nodes. Keep the branches and leaves in the upper few nodes of the culm but for lower branches keep only 4-5 nodes and trim minor branches. In a species such as *Melocanna baccifera* with no main branches, trim the many small branches. If the culm will not bend to the ground easily a partial cut can be made at the base.

4. What species are suitable?

These include *Bambusa gfaucescens, B. polymorpha, B. textilis, B. vulgaris, Guaduaangustfolia, Dendrocalamus giganteus, D. longispathus.*

Figure 27: Whole culm bent down to the ground and covered with rooting medium

5. What are the limitations?

If clumps are cultivated closely it is impossible to make the trenches for layering.

6. What type of trench is needed?

The size and depth depend on the size of the culm. Rooting medium is used to cover the culm 5-9 cm deep (Fig, 28); for medium type see 2 above. Regular watering is needed; waterlogging has to be avoided. A mulch of water hyacinth will help retain moisture.

STUMP LAYERING

7. In this method the culm is cut leaving 2-3 basal nodes. The stump is covered with rooting material (see 2 above). This method is uncommon and has successfully been reported only for Bambusa

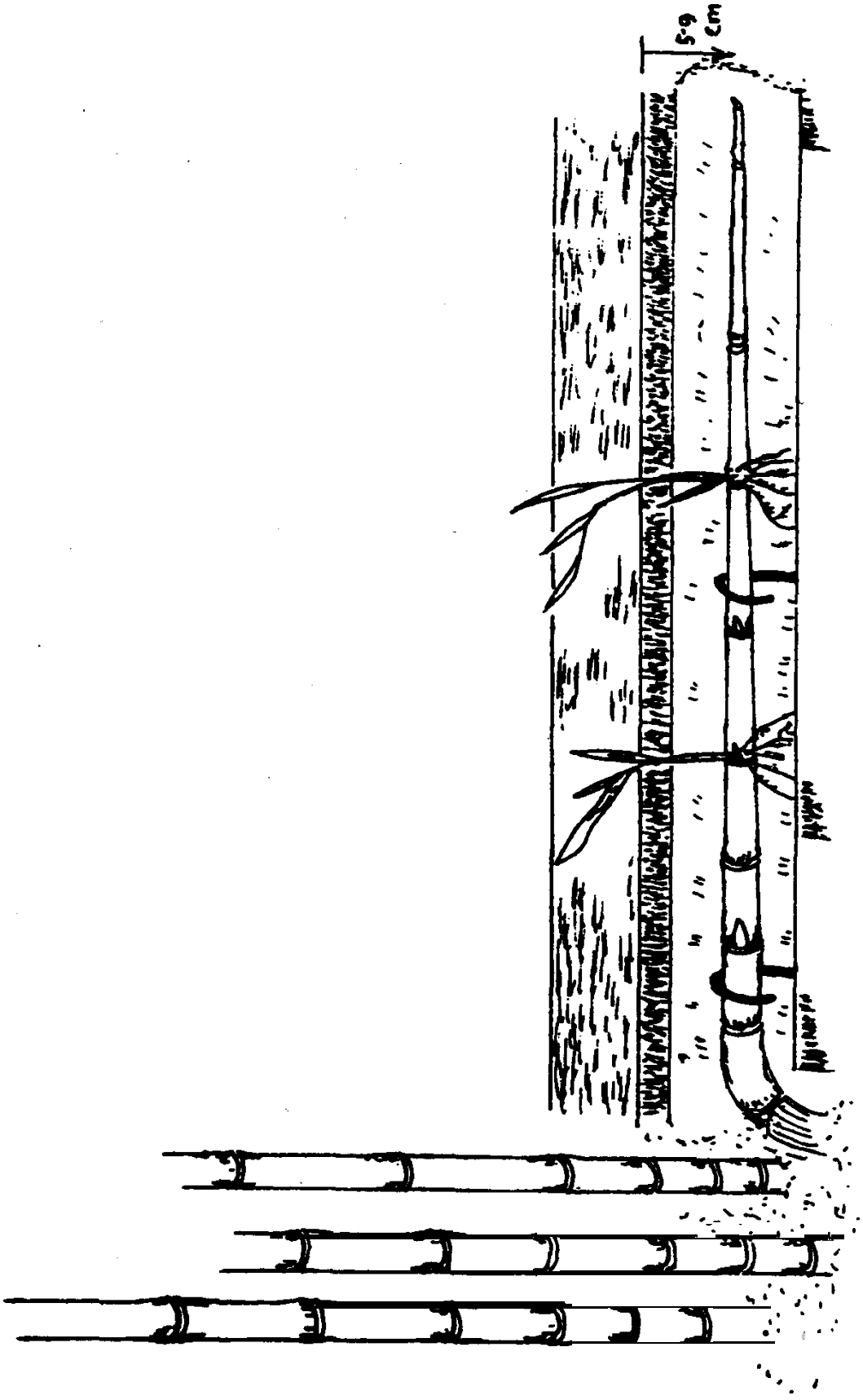


Figure 28: A trench for ground layerir

longispiculata. Stumps should only be covered by 1-2 cm of material; prior to covering 200 ppm IBA may be used to treat the stump-but this produces fewer sprouts. Sprouts usually emerge 150-180 days after cutting the culms.

MARCOTTING

8. This is a modified layering technique whereby the swollen base of a branch complement on the mid culm zone is covered with propagating medium and held in place by a suitable receptacle (Fig. 29). This method is comparatively suitable for thick walled species such as, *Bambusa blumeana, B.vulgaris, Dendrocalamus giganteus,* etc. having stout branches with swollen rhizomatous base.

9. What is the technique?

Marcotting involves bending a l-year old culm so that all the nodes are within easy reach of the workers. This is facilitated if an undercut is made at the base of the selected culm. The culm is then bent and supported with a strong prop. After that, branches at the nodes are pruned to about 2-3 cm in such a way that no dormant buds are injured. Pruning has to be done at the beginning of spring (March-May). An admixture of garden soil and leaf mould (rooting medium) placed around each node with branch base is longitudinally wrapped with coconut fibre or coir. This is then securely tied with wire or rope at both ends. The rooting medium should always be moist and, therefore, the rainy season is fhe best time for marcotting. Generally, within one month buds grow out into shoots and in the next 3-4 months root development takes place.

SEEDLING LAYERING

10. Seedlings aged 6-12 months are placed horizontally on the sand rooting medium, the culms are buried 1.5-2.0 cm but branches on the, nodes are allowed to project above. Most seedlings at this age have 3-4 culms each with 6-8 nodes. It is particularly successful for *Bambusa*

Figure 29: Marcotting or air-layering on the culm

polymorpha; it has low success with other species, particularly B. bambos, B. tulda and Dendrocalamus *strictus.* If performed in April-May, roots develop at the nodes in 60-90 days *(Figs. 30a,30b). New* plants are separated by cutting with secateurs and transplanting to polybags with soil and cow dung.

Figure 30a: Seedling layering

Figure 30b: Separation of rooted segments from layered seedling

MACROPROLIFERATION METHODS

1. What is macroproliferation?

Bamboo seedlings possess the capacity to proliferate. By cutting the rhizome system into pieces, each with roots and shoots, each seedling can be multiplied 3-7 times depending on species. The method is only suitable for species producing seeds. When seeds are ripe they are collected and seedlings raised in nurseries or polybags.

2. How are seedlings raised?

Normally polybags 15 x 23 cm, containing soil: cow dung, 3:1, are used. Clump forming species usually produce 48 culms over 150-270 days when they are ready for multiplication.

3. Proliferating seedlings

Soil is washed from the root and rhizome system (Fig. 31) and old roots may be trimmed (Fig. 32). The rhizome is cut into pieces *(Fig. 33),* each replanted, hardened under shade for 3-5 days and well watered. Thereafter the transplanted pieces are brought to the nursery bed under sun. A seedling can be multiplied in this way in any month of the year and survival rate is 90-100%. As the seedling pieces develop they, in turn, can be used as original seedlings and new proliferating pieces once again produced.

4. Are there advantages?

Yes. Once seedlings are available the process can be continued for a number of years. Proliferated seedlings are small in size, hence easy

Figure 31: Exposition of rhizome system for seedling multiplication

Figure 32: Trimming of old roots in macroproliferation method

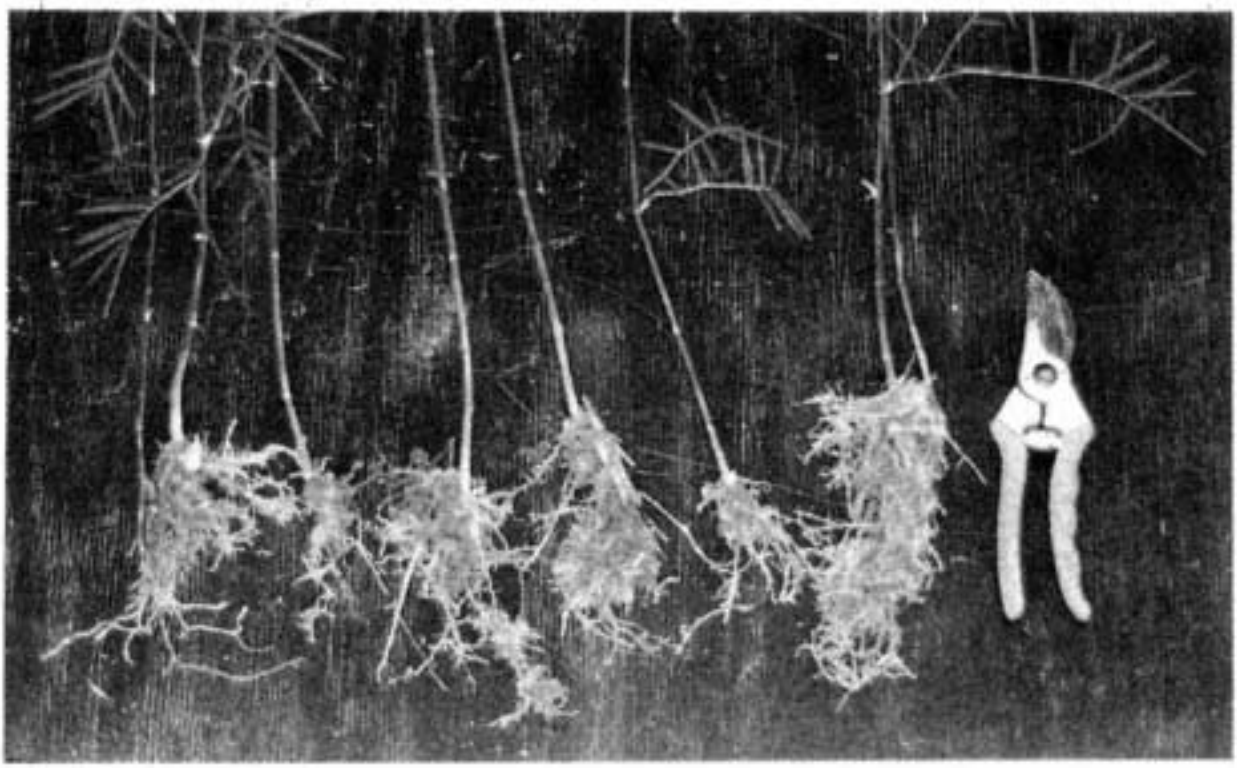


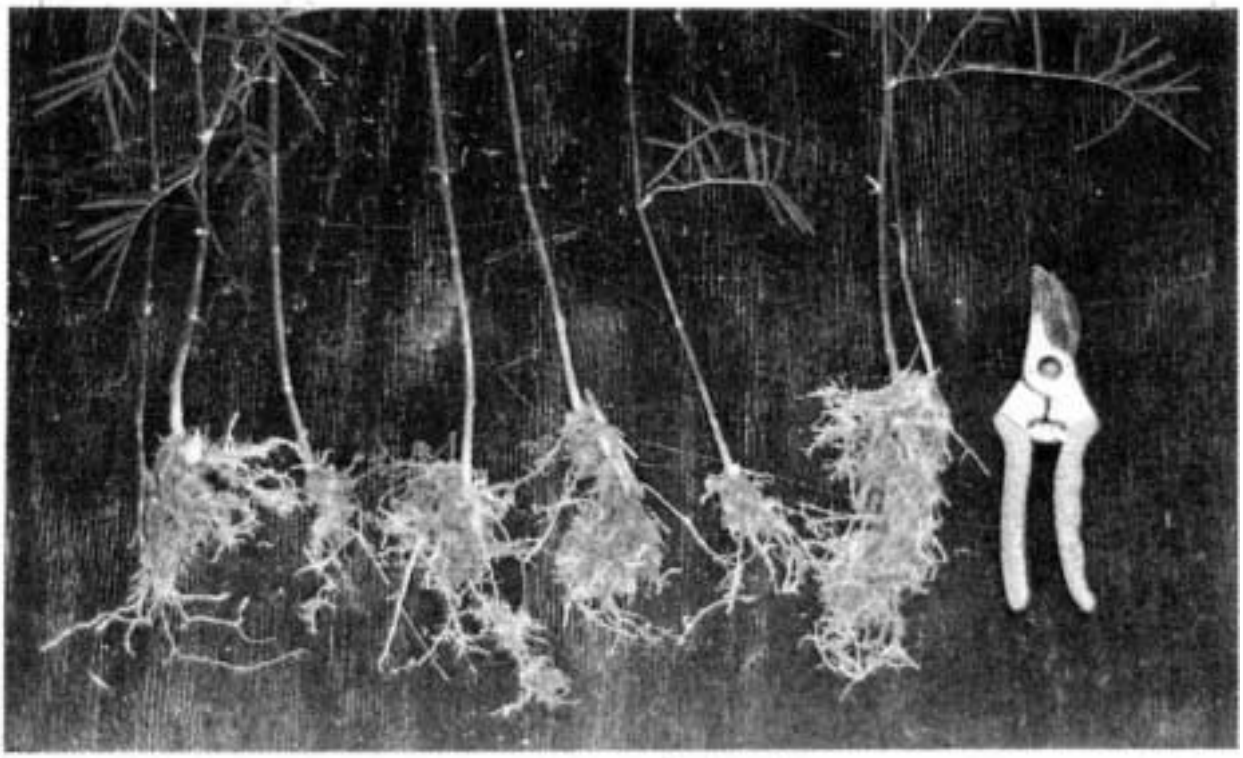
Figure 33: Separation of rhizome having new shoots and roots with young buds in macroproliferation method

to handle and transport. Finally, a small initial stock can produce large numbers of plants.

5. Are there disadvantages?

The only disadvantage would be if the propagation continued for many years and later multiplied plants might approach the physiological maturity/ flowering. However there are reasons not to excessively rely on limited seed stocks due to possible narrowing of the genetic base. Thus different provenances/ genotypes should be used and for each initial seed, the last multiplication should not exceed 10 years.

Figure 32: Trimming of old roots in macroproliferation method



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AFTERCARE OF CUTTINGS

USE OF POLYBAGS

The use of polythene bags for potting the bamboo cuttings is, nowadays, considered standard practise. They are easily available and reasonably cheap for handling the large number of bamboo propagules *(Fig. 34).*

Polybags of various sizes are used, depending on the nature of the cutting and the species. Some common sizes are:

a) for culm cutting: width 40 x height 50 cm, thickness 0.1 mm;

b) for branch cutting: width 15 x height 23 cm, thickness 0.1

c) for layeredseedling: initially 10 x 15 cm, 0.06 mm and finally 15 x 23 cm, 0.06 mm

The bags are usually black.However, transparent ones can also be used. When bamboo cuttings are raised during August to September it is not possible to transplant them in the field in the same rainy season, because they need at least 2-3 months to produce well-developed rhizome systems. Therefore, it is necessary to keep the cuttings in the nursery for up to 9-10 months before planting during the next rainy season.

CHOICE OF NURSERY SITE

The site should be near the propagation bed so that all operations can be streamlined. The nursery should be on level ground and have irrigation.

Figure 34: Use of polythene bags for potting the branch cutting

PLACING THE POLYBAGS IN THE NURSERY

The cuttings in polybags should first be placed for a week under partial (SO-60%) shade (Fig. 35). After that, they are to be exposed gradually to full sun.

The bags are placed side by side in rows and blocks The large sized polybags may be arranged in 4-bag wide blocks, while the medium- and small-sized ones are arranged in 10 to 12 and 15 to 17-bag wide blocks. However, 1.0 to 1.2 m width of the block is found to be ideal. Routine weeding, fertilizing and watering becomes difficult when the blocks are wider than 1.2 m The length of the block can be adjusted depending on the availability of land Generally 4.0 to 6.0 m long blocks are preferred to minimize over-crowding and over-shading.

There should be 0.7 to 0.8 m wide foot paths between the blocks to allow easy movement of the nursery workers and transportation of propagules.

SOME SPECIAL PROBLEMS IN THE NURSERY

In the nursery bed when the polybags are left for long periods (say 6-8 months), cuttings produce strong rhizome systems and roots which penetrate neighbouring polybags creating an intermingled rhizome and root mass of cuttings (Fig. 36). This creates a problem for the transportation of cuttings. In separating the polybags from each other, rhizomes and roots are damaged and as a result survival of cuttings in the field becomes low.

To overcome this, polybags should be shifted from one bed to another at 3 monthly intervals. This helps to minimize the problem.

If any cutting starts producing flowers it is to be marked Such flowering cuttings will die and therefore, should not be planted in the field.

Figure 35: Placing of polybags with cuttings in the nursery

Figure 36: Intermingling of the rhizome and root mass of cuttings

ROUTINE ACTIVITIES IN THE NURSERY

Regular watering, occasional weeding and adding of soil to the bags as and when needed are to be carried out as long as cuttings are kept in the nursery beds.

Generally bamboos have few problems of insects or pests in the nursery.

The most damaging pests are domestic and wild animals. Cows and goats eatbamboo leaves and damage the soft emerging shoots. Therefore, cuttings should be protected from such animals.

FIELD PERFORMANCE OF DIFFERENT PROPAGULES

Generally the survival percentage of branch cuttings culm cuttings and macroproliferated seedlings are higher than those of offsets and rhizomes.

The size (height and diameter) of the fully grown culms produced by offsets, rhizome andculm cuttings are comparatively big in the first year of plantation than those produced by branch cuttings But due to juvenility and vigorous nature of the rhizome system of branch cuttings and proliferated seedlings, within 3-4 years , c u1ms attain more or less similar sizes to those of offsets and rhizomes Once a well developed clump (say, within 5 years of planting) is formed it becomes impossible to distinguish whether it has originated from an offset or a branch cutting (Fig. 37).

Figure 37: A well developed clump from the planted branch cuttings

REFERENCES

Anon. (1990), "Propagation of Bamboos by Culm Cuttings", KFRI Irf. Bull., No. 8 (BIC Series 1), Kerala Forest Research Institute, Peechi, India (5 pages).

Banik, R.L. (1980), "Propagation of Bamboos by Clonal Methods and by Seeds", in Bamboo Research *in Asia*, G. Lessard and A. Chouinard (eds.), IDRC, pp. 139-150.

Banik, R.L. (1984), 'Macropropagation of Bamboos by Pre-rooted and Pre-rhizomed Branch Cuttings", *Bano Biggyan Patrika* (Bangladesh Forest Research Institute, Chittagong), 13: 67-73.

Banik, R.L. (1987), "Techniques of Bamboo Propagation with Special Reference to Pre-rooted and Pre-rhizomed Branch Cuttings and Tissue Culture, in *Recent Research on Bamboos*, A.N. Rao, G. Dhanarajan and C.B. Sastry (eds.), IDRC, pp. 160-169.

Banik, R.L. (1993), "Selection and Multiplication of Bamboos for Industrial Planting Programmes", in Proc. of Workshop *on Production of Genetically Improved Planting Materials for Afforestation Programmes* (Coimbatore, India. June 18-25, 1993), K. Vivekanandan et al (eds.), pp. 76-97.

Banik, R.L. (1994), "Review of Conventional Propagation Research in Bamboos and Future Strategy", pp. 115-142, in *Constraints to Production of Bamboo and Rattan*, IDRC/INBAR, Bangalore, India, 1994.

Burmalong, A.A. and Tamolang,F.N. (1980), "Bamboo Research in the Philippines", in *Bamboo Research in Asia*, G. Lessard; and A. Chouinard (eds.), IDRC. pp. 69-80.

Gonzales, L.L.; Marcos, J.; Ouimio, Jr. and Nicolas, S.U. (1991), "Propagation of Kawayan-Kiling through Split-Culm Cuttings", *Canopy International,* 17: 6-7.

Hasan, S.M. (1977), "Studies on the Vegetative Propagation of Bamboos", *Bano Biggyan Patrika,* (Bangladesh Forest Research Institute, Chittagong), 6: 64-71.

Longman, K.A. (1993); *Rooting Cuttings* of *Tropical Trees,* Volume 1, Commonwealth Science Council, London.

Maoyi, Fu and Jianghua, Xiao (1994), *Cultivation and Utilization of* Bamboos, The Research Institute of Subtropical Forestry, Chinese Academy of Forestry, Fuyang, Zheijang, China.

McClure, F.A. (1966), The *Bamboos: a Fresh Perspecfive,* Harvard University Press, Cambridge, Mass.

Rao, I.V.R., Rao, I.U. and Roohi, F.N. (1992), "Bamboo Propagation through Conventional and *in vitro* Technologies", in Rapid *Propagation of Fast-Growing Woody Species,* F.W.G. Baker (ed.), CABI, Wallingford, UK, pp. 41-56.

Surendran, T. and Seethalakshmi, K.K. (1985), "Investigations on the Possibility of Vegetative Propagation of Bamboos and Reeds by Rooting Stem Cuttings", KFRI *Res. Report,* 31: l-47.

Ueda, K. (1960), *Studies on the Physiology of Bamboo with Reference* to *Practical Application,* Resources Bureau, Prime Minister's Office, Tokyo:

Vivekanandan, K. (1987), "Bamboo Research in Sri Lanka", in *Recent Research* on Bamboos (Eds. A.N. Rao, G. Dhanarajan, and C.B. Sastry), *Proc. of the In ternational Bamboo Workshop,* Hangzhou, P.R. China, IDRC, pp. 61-66.