INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN (INBAR)

TRANSFER OF TECHNOLOGY MODEL (TOTEM)

BAMBOO PRESERVATION BY SAP DISPLACEMENT

by

Dr. K. Satyanarayana Rao

Institute of Wood Science and Technology (IWST), Bangalore 560 003, India

CONTENTS

TRANSFER OF TECHNOLOGY MODELS (TOTEMS)

Transfer of Technology Models (TOTEMs) are focussed educational tools providing relevant information and distance training on one specific area of bamboo/rattan management, processing or utilization. They are a means of technology transfer between similar regions throughout the world, with the emphasis on South-South transfer for livelihood development. They enable those involved in the management and use of bamboo and rattan resources to more efficiently and effectively develop and use skills relating to these resources.

TOTEMs are primarily intended as practical information resources and teaching aids for those at the local extension level in their communities, who can utilize them to assist local community development. Each TOTEM consists of a detailed written report of the technology, a PowerPoint presentation, a film, and, where relevant, a set of technical photographs. They also include information on target users, financial analyses of sample set-ups from the partner country preparing the report and information on where to source particular technologies (such as equipment). The TOTEM thus provides all the information required for establishing similar technologies within interested countries and regions.

- The **report** contains all the technical details of the particular processes involved, as well as other relevant information for establishing the technology such as costs of business establishment, running costs and cash flows.

- The **PowerPoint** presentation contains details of the relevant technologies and their applications, and is intended to provide an overview of the potential of the technology for development.

- The **film** provides a visual guide to the processes involved and helps to bring them alive in the minds of the learners.

The different parts of the TOTEM are targeted at slightly different audiences, via the local extension workers. The report and film are intended to be the main means of extension to the individuals and communities who will implement the technology and who will directly benefit from it. The PowerPoint presentation is primarily intended as a tool for the extension worker to sell the technology and its role in development to those who provide the infrastructural, policy and financial support for its implementation, such as government departments, donors and NGOs. There is considerable flexibility, however. Local extension workers will be able to incorporate the TOTEMs in their own work as they wish and adapt and develop the TOTEM to suit their particular requirements and conditions.

This TOTEM on the **bamboo preservation by sap displacement** has been produced by the Institute of Wood Science and Technology (IWST), Bangalore, India. It may be used alone or in conjunction with the TOTEM on traditional bamboo preservation techniques, which has been produced by the Forest Research Institute, Dehra Dun, India. The report section of this TOTEM describes the technology of preserving bamboos by sap displacement and establishing facilities to do so for rural development in regions where bamboo is available as a raw material. It is intended to be used in conjunction with the illustrative film included in this TOTEM package

The first part of the report introduces the technology, discusses its history, its development attributes, its benefits and it's applicability. The second part of the report provides detailed information on the technical aspects of sap displacement. **Appendix I** gives information on a practical demonstration of the technology in India. **Appendix II** illustrates the economic benefits of using treated bamboo compared to untreated bamboo. **Appendix III** is a bibliography of relevant publications and information used in the production of this report.

This TOTEM is one of the first to be produced by INBAR/ IWST and your feedback is most welcome - kindly contact INBAR or IWST with your comments or suggestions.

Note: This TOTEM has been edited at INBAR and differs from the form in which it was received from IWST.

<u>BAMBOO PRESERVATION BY SAP DISPLACEMENT</u>
<u>AT-A-GLANCE</u>

Why preserve bamboos?

Bamboos are a natural material and under natural conditions will gradually decay. If they are used as structural components they will need to be replaced after a period of time. The costs of this may prove prohibitive and the status of the bamboo will need constant monitoring to determine when it needs to be replaced. Preserving bamboos extends their life, reduces costs in the long run and improves safety of the structures they are used to form.

What are sap displacement preservation methods?

Sap displacement methods replace the sap in the vessels of a fresh bamboo culm with preservative. The culms are then left to stand for two weeks in order that the preservative can diffuse into the surrounding tissues and the preserving salts can be fixed in the cells. Sap displacement can be done by using natural capillary action or by one of a small range of simple pressurised techniques.

What is the role of a sap displacement preservation unit in rural development?

The unit itself offers employment opportunities to its employees and to many people in its forward and backward linkages. The unit can only treat freshly harvested bamboos and so a source of bamboos near to the unit is required. Local bamboo plantations can be established to supply the unit and create further income generating opportunities. Bamboos can be intercropped with food plants and the plantations can thereby increase the food security of the rural people that manage them.

How do I establish a sap displacement unit?

A sap displacement preservation unit can be established very cheaply. The only requirements are a supply of freshly harvested bamboos, labour and information from the secondary processors of their requirements. If a pressurised unit is to be established then a source of energy for the compressor will be needed. A pressurised unit capable of treating 50 bamboos per day can be established for USD $500, including a compressor, and non-pressurised units can be established for considerably less.

PART ONE

INTRODUCTION

DEVELOPMENT ATTRIBUTES, TARGET GROUPS and BENEFITS of a

BAMBOO SAP DISPLACEMENT PRESERVATION UNIT

1. Bamboo preservation by sap displacement

Bamboo is a natural material and will decay with time. Decay occurs because of the high cellulose and lignin content of the culm. The strength properties of the culm will therefore change over time and eventually it may become so decayed as to be structurally unsound and even highly dangerous in the role to which it has been put. If used in the frameworks of buildings it could even render them uninhabitable. Bamboo culms are also susceptible to attack by biological agents such as boring insects, termites and fungi that can cause massive, sudden and catastrophic deterioration in structural soundness. The attraction of bamboos to insects appears to be due to their starch content and it is claimed that water-soaked bamboos, depleted of starch, resist insects better.

The natural durability of bamboo is very low and depends on species, climate and age of the culm:

Natural durability of some bamboo species (graveyard test data)

Bamboo species.	Maximum life (months)	Minimum life (months)	Average life (months)	Information source
Dendrocalamus strictus	30	18	19.3	Unpublished data FRI, Dehra Dun
Dendrocalamus membranaceous	21	9	13.0	Unpublished data FRI, Dehra Dun
Bambusa balcooa	-	-	32.0	Purushotham et al, 1954
Bambusa nutans	18	6	9.8	Unpublished data FRI, Dehra Dun
Bambusa polymorpha	84	12	23.6	Unpublished data FRI, Dehra Dun
Melocanna bambusoides	24	9	19.9	Unpublished data FRI, Dehra Dun
Bambusa tulda	-	-	41.0	Purushotham *et al*, 1954

Source: Satish Kumar *et al*, 1994

Therefore it is essential to only use bamboo that has been preserved by proper preservative treatments. However, the preservative treatments applied to timber wood species are often not applicable to bamboo due to the different internal structure of the bamboo culm. Bamboo culms are divided into nodes and internodes and are composed of two types of tissue; parenchyma cells and vascular bundles. The latter consist of vessels, thick walled fibres and sieve tubes and it is through these that water movement takes place in the living plant. The vessels run straight along the length of the culm without branching or any obstructing connections to single vessel members in the inner and outer part of the culm. Bamboo culms have no radial elements as in timber wood. The nodes, however, interrupt the easy transport of fluid. Observations of the nodal structure have revealed that many vessels turn laterally and become shorter with many perforations for an intensive interconnection with other vessel members. It is at this point that the diaphragm (the inner part of the nodal area), provides for the distribution of liquid and sap in the vessels and sieve tubes of the phloem across the culm. Obstacles between these cells reduce an easy flow. Some vessels at the nodes do, however, run straight through into the following vessel. Additionally the outside and inside membranes are covered by hard cuticles that offer considerable resistance to the absorption of water particularly when dry, even after the application of pressure These anatomical features help to explain the refractory nature of bamboo to preservatives (Ding and Liese, 1995).

Thus conventional pressure treatment methods are not suitable and other methods have been explored.

Although the bamboo culm is resistant to lateral penetration of preservatives due to it's hard skin, living bamboo has a very high longitudinal permeability, because of the vessels and the associated sap flow activity. This property can be taken advantage of to achieve an axial liquid exchange, replacing the natural sap inside the culm with liquid preservative. This technique is commonly referred to as the **sap displacement technique** and is particularly suited for treating green bamboo. In this method, the sap is replaced slowly either by allowing the culm to naturally take up the preservative from the cut end due to it's own transpiration, or by using a pressurised flow of preservative solution applied to one end of the culm until it comes out of the other end.

2. History of the development of sap displacement methods

The technique was originally developed by Dr. Boucherie of France in 1838 to treat green timber and is commonly referred to as the "Boucherie Process". The treatment originally consisted of attaching a bag or other container of preservative solution (e.g. $CuSO_4$, $ZnCl_2$ etc) to a freshly felled tree with its bark, branches and leaves still attached and introducing the liquid to the sap stream. The subsequent evaporation of moisture from the leaves drew the preservative upward through the sapwood of the tree trunk. However, the results were erratic to start with and this early version of the Boucherie Process was limited to poles. Subsequently the process was standardised by raising the container of preservative higher than the end of the poles such that hydrostatic pressure would force the preservative through the pole. This is known as the "**Conventional Boucherie Process**".

The "**Modified Boucherie Process**" was developed in the 20th Century and adapted by a number of different workers in a range of countries. It differs from the conventional method by adopting a mechanical means of pressurising the flow of preservative into the pole, and the process is thus much faster and easier to control. The process was developed for bamboos by Grover in the 1950s. In 1943 Gewecke and Ludwig in

Germany developed a method for timber poles that not only involved pressurised entrance of the preservative but also included a vacuum at the discharge end. This method has not been tried successfully on bamboo.

A simple sap displacement technique that requires no equipment is presently being popularised to farmers, fishermen, NGOs and others in rural places in India by the IWST, Bangalore. This is similar to Boucherie's initial method, as it involves no pressurised flow of preservative. Details are given in section 2.3.1 of part two and in **Appendix 1**.

3. General development attributes and advantages

The main development attributes of the technology are as follows:

- Promotion of the sustainable use of wood-alternatives
- More effective use of natural bamboo resources
- Creation of employment opportunities for men and women at the preservation unit
- Increased community prosperity in rural areas
- Development of the local bamboo sector

The main advantages of the technology compared to other bamboo preservation techniques are:

- Rapid speed of application
- Limited amount of equipment required
- Low cost of equipment
- The preservation mixture can be recycled and re-used
- The preservative reaches all parts of the bamboo

4. Suitable agro-ecological regions

All temperate, sub-tropical and tropical parts of the world in which bamboos grow would be suitable. Bamboos are particularly effective for land rehabilitation and are excellent plants for erosion control. It would be particularly effective to establish the unit in areas where shifting agriculture has produced degraded land on which bamboo plantations could be established. Areas suffering serious soil erosion such as steep hillsides or where regular flooding along river plains is a problem would also be highly suitable.

5. Target groups

There are two main target groups. The first group are those who will work in the unit itself. Unskilled, semi-skilled and some technically trained personnel will be required by the unit and all jobs can be done by both men and women. The processes involved are not difficult to understand and appropriate vocational training will produce an empowered, skilled workforce. The second group are the bamboo cultivators and harvesters who will provide the raw materials. The establishment of the unit would be expected to increase the demand for bamboo and concurrently increase the number of cultivators and harvesters needed. Also, if the unit is established as a co-operative community project of which the local people have ownership then the community as a whole will benefit.

6. Benefits

The unit will create a wide range of employment opportunities for rural people and will improve the economies of their communities. The greater prosperity created would permit subsequent investment in new bamboo-based projects. Because the unit requires a supply of fresh bamboo only plantations close to the unit will be able to supply the raw materials. The increase in the management and size of bamboo stands needed required do this will benefit the local environment and the local people - bamboos can easily be intercropped with shallow-rooted food crops, thus improving the productivity of the land and the food security of the people. The cultivation of bamboo is beneficial for soil conservation and afforestation activities and plantations are encouraged as part of social forestry programmes.

7. Scope for small enterprise development

The unit represents a vital stage in the transformation of bamboo from raw material to finished product. The “market” for treated bamboo is huge - all enterprises requiring whole or sectioned bamboo culms for their own use will require them to be preserved. Low-cost housing units, suppliers of bamboo scaffolding, furniture makers, producers of bamboo gabions, and any other users who require the structural integrity of the bamboo culm to be maintained to extend its life will all require treated bamboos. There is thus a wide range of potential users.

The short rotational cycle of bamboo makes it far more attractive in terms of cash flow than timber trees and means it is attractive for those with limited capital. The technology is simple and requires low capital inputs and is ideal as a small enterprise - a unit capable of treating 500 or more bamboo culms per day could easily be established with minimal inputs. As a small-scale enterprise the unit may be eligible for development grants or other incentives from the government - check with your local government office or business advisory centre for details.

8. Requirement for success

The essential requirements for a successful sap preservation unit are:

- Start-up capital
- Secured workforce
- Access to a supply of fresh bamboo culms (for treatment within 24 hours of harvest)
- Proper linkages to users of the treated culms

Concluding remarks

Preserving bamboos is a vital stage in their use. The costs of not using preserved bamboos are far higher than the additional initial costs of preservation, and the structures produced are safer and more durable. Very simple sap displacement techniques can be applied on a small scale and with a little extra investment a moderate-sized treatment unit can be established The unit will provide income generating opportunities for its employees and help the sustainable development of poor rural communities in bamboo growing regions. The unit may be established alone, or as part of a wider community-based bamboo production and processing establishment.

As an intermediary stage between cultivation and processing the sap displacement unit requires strong forward linkages to its clients. Proper connections need to be in place to ensure this and it may be preferable to implement the technology with the assistance of state agencies or NGOs to ensure these linkages are in place.

PART TWO

BAMBOO PRESERVATION BY SAP DISPLACEMENT

1. Introduction

Bamboos are preserved by sap displacement methods as follows:

- Suitable culms are selected and harvested
- Culms are transported to the treatment unit within 24 hours of harvest
- The basal ends of the culms are attached to the preservative pipe
- All seals are checked
- Pressure is applied to force the preservative treatment into the culm
- The culms are removed and stored horizontally for two weeks

2. Production of preservative-treated bamboo

2.1 Raw materials

Bamboo culms 3-4 years old are the most widely used in the bamboo sector as they have optimum strength properties. It is of course necessary to ensure the species selected are those required by the end-users and good contact with them should be maintained to ensure this is so. The branches can be cut off and the culms then transported as rapidly as possible to the unit. The sap displacement methods listed here are only suitable for bamboos that have been freshly harvested. If there is likely to be a delay in treating the bamboos, they can be soaked in fresh water in a tank, trough, stream or pond for a period of one or two days without ill effect. Bamboos over a day old and not treated like this will not be suitable.

2.2 Preservatives

A wide range of preservatives are suitable for bamboos, such as copper-chrome-arsenate (CCA), copper-chrome-borate (CCB) and acid-copper-chrome (ACC). Arsenic is highly toxic to the environment and to those applying the chemical and in practice the most effective and safe preservative is copper-chrome-borate (CCB). Boron is a very effective preserving agent and is also cheap. Another effective boron-based preservative is the fertiliser disodium octaborate tetrahydrate, which is used in Costa Rica.

Copper-chrome-borate preservative is available from a range of suppliers. Preparation of CCB should follow closely the instructions given by the suppliers. The preservative should be correctly weighed and mixed carefully with the correct quantity of water. The preservative itself is heavier than water and unless mixed continuously will gradually sink to the bottom of the tank. Use a hydrometer and pH meter wherever possible.

2.3 Treatment

Bamboos may be treated either by a simple sap displacement technique or by the modified Boucherie process. The simple technique is suitable for on-farm small-scale processing and the Boucherie process may be done on-farm or in the treatment unit.

2.3.1 Simple sap displacement technique

The simple sap displacement technique is akin to Boucherie's initial method and involves no pressurised application of preservative. The only equipment required is a bucket or tank for the preservative. The basal ends of the bamboo culms are immersed 30 - 45cm deep in a solution of preservative (6 - 8% CCA or CCB) for 24 - 48 hours. The culms are then upturned and the apical end immersed in the solution for a similar length of time.

2.3.2 Modified Boucherie technique

This process is a very rapid and effective means of treating bamboo culms. Treatment usually lasts about 30 - 60 minutes. The new system used in Costa Rica can also be loaded very fast - twelve culms can be attached in only eight minutes.

Equipment

The equipment and facilities required are:

- Container able to take pressure of 1.5 kg/cm^2
- Rubber pipes
- Stopcocks
- Metallic clamps to seal the culm-pipe joints
- Electric or gas-powered pump (a bicycle pump would be suitable on a small scale)
- Pressure gauge
- Containers to collect the preservative as it flows out

Basically a large container of preservative is connected at its base via a series of pipes and tubes fitted with stopcocks to the basal ends of bamboo culms. In order to secure leak-proof contact between the rubber tubes and the bamboos, suitable metallic clamps or other devices should be used. The tank is also fitted with a screw cap to which is attached a motor car tyre tube valve so pressure can be applied. A pressure gauge (most suitably a pen gauge) is also attached. Note that the greater the capacity of the tank, the longer the pressure can be maintained.

Procedure

1. Cut a few centimetres off both ends of the culm
2. Attach the basal ends of the culms to the treatment pipes. Ensure they are tightly secured using metallic clamps or other devices.
3. Fill the tank with preservative solution to about two-thirds full.
4. Tighten the cap and check that all other joints are tightly sealed.
5. Bleed all air out of the system
6. Develop a pressure of 1.0 to 1.4 Kg/cm^2 in the tank
7. Open the valves to start the preservation process
8. Regularly check the concentration of the preservative flowing out of the end of the culms. When it reaches, or is close to, the initial concentration, preservation is complete and the procedure can be stopped.

After a few preliminary experiments, the concentration of the preservative solution and the time of treatment can be determined to find the optimum uptake rates.

The preservative solution can be reused but will need to be boosted to bring it up to the required concentration as it will have been diluted by the sap. The pH should also be adjusted to the correct value. Some preservative may come out of the culm nodes and galvanised roofing sheets may be installed underneath the culms to collect it and increase the rate of preservative recycling. The recycled solution should be filtered before re-use.

Two main precautions must be taken.

1) Ensure the water used in the preservative is clean.

The system will become blocked very rapidly if dirty water is used and the preservative will not penetrate into all the vessels. Everything should be cleaned with fresh water after each use, including the machine, buckets, the work area and the floor to keep everything dirt free. Remove and wash nozzles, rubber sleeves and hoses in fresh clean water. Cover the water pump and pressure regulation tank with a big plastic tarpaulin when not in use to keep sun, rain and dirt out. To stop corrosion, every month brush a light lubricant such as motor oil on all metal parts (inside and out). Use a lubricant on the screw threads of clamps and other metal fittings. Leaks around connector fittings on the water pump and pressure regulation tank can be stopped by applying epoxy glue around the leaking point.

It may be found that the flow rates decrease with time especially if the preservative solution is recycled. This is due to the picking up of particles by the solution and subsequent blocking. Two types of filters can be installed to overcome this. The first is made of cheesecloth and is placed so as to filter the mixture of the solution and sap exuding from the apical end of the culm. The second is a fine in-line filter with a paper filtering element, which is installed just before the point the solution enters the manifold to which the culms are connected.

2) Ensure no air gets into the system.

This will hinder the passage of preservative. In the new system used in Costa Rica the rubber cap embracing the culm end has been improved to simplify the system so that the culm can be fed into the cap more rapidly and a tight joint can be obtained between the cap and the culm without leakage. On the other hand, the problem of air that can penetrate the upper part of the cap during the preservation process and thus preventing the flow of the liquid in this part of the culm, was eliminated by adding a bleed valve, as was shown by Gonzalez and Gutierrez (1997).

2.4 Stacking

After treatment the culms must be stored for at least two weeks to allow the preservative to gradually diffuse from the sap-vessels into the surrounding tissues where the CCB salts will become fixed. Culms must be stacked horizontally on a rack, NOT vertically, otherwise the preservative will leak out. The culms must not be allowed to dry out too fast and so protection from sunlight is required. They must also be protected from rain to prevent the preservative from leeching out.

Drying in a very humid tropical climate takes a lot of time. It is therefore recommended to ensure the culms are spaced apart and are raised above wet soil (not less than 40 cm) for good ventilation.

2.5 Safety precautions in the preparation, handling and application of chemical treatments

In order to prevent or minimise the harmful effects of preservatives/ chemicals on the person using the chemical and the environment, knowledge of proper handling, preparation and application of chemicals is important. Hazards from preservative chemicals to human beings depend on their toxicity, form (liquid or solid), and methods of packing, storage, dilution and application. Basically there are three ways that preservatives can enter the human body, i.e. by inhaling, swallowing or from contact with the skin (FAO-1986).

1. Wear appropriate protective clothing (made of impervious material such as plastic), gloves, safety boots and helmets. Eye protection goggles are needed while mixing preservative solutions.
2. Do not drink, eat or smoke during or immediately after the application of the treatment.
3. Store preservatives correctly and follow the instructions of the manufacturer.
4. Spray in the direction of the wind, never into it.

5. Wash hands, feet or take shower after work. Change work clothes regularly.
6. Place containers out of reach of children. Empty containers can be disposed of by burying them under ground or by taking them to official chemical waste disposal sites.
7. Do not allow preservative sludge to accumulate.
8. Do not remove treated bamboo until dripping has stopped.
9. For material treated with water-soluble preservatives like CCA, CCB etc., store the bamboo under cover and use them only after drying.
10. Dispose of treating solutions properly. Allow water to evaporate and bury precipitates under ground or dispose of in dumping grounds for chemicals.
11. Do not release CCA preservatives into streams or the environment and do not burn CCA treated bamboos as firewood.
12. Train staff and display safety materials and equipment.

Pollution: Pollution can occur from wood preservatives, preservative process and the treated timber/bamboo. In most cases the pollution problem originates from the preservative chemicals themselves. The extent of pollution differs widely with the type of preservative and the treatment process employed. The disposal of waste from treatment requires much care. CCA preservative solutions are toxic and should never be released into streams or canals. CCA treated timber/bamboo should not be burned and especially it should never be used for cooking of in a barbecue.

3. Input requirements

Capital costs

The capital cost of establishing a simple processing facility are very low. Equipment capable of treating 50 culms per day would cost no more than USD $500 including a compressor and all the associated piping. Costs can be further reduced using a manual pump such as a bicycle pump. Costs of the non-pressurised conventional Boucherie process are even lower. And the cost of simple sap displacement is limited to the price of a container and the cost of the preservative solution.

APPENDICES

Appendix I

Demonstration of simple Boucherie techniques in Kusumali village in Khanapur Taluk, Belgaum District, Karnataka state

Sap displacement methods of preservative treatment are carried out on bamboos that have been very recently felled. This method can be carried out in remote areas where there are no power supply facilities and the use of pressurised equipment is not possible by using the conventional Boucherie process in which gravitational flow equipment is adopted. The recent simple demonstration programme of the Boucherie technique in Kusumali village, Karnatka, India is outlined below:

The lids of two empty 200 litre oil barrels were removed and the barrels welded together end to end. A 20 cms dia hole was cut in the drum on one side and provided with a lid. This opening was to enable recharge of the preservative mixed from a bucket of Galvanised Iron (GI) poured into the tank from top. One end of the drum was welded with two GI pipes of 15 cms length and diameters of 25 mm and 50 mm respectively, with a wheel valve fitted, so as to stop or control the flow of preservative from the drum into the flexible pipes tied below. 1 mm thick flexible plastic pipes in diameters of 25 mm, 50 mm, 75 mm and 100 mm were brought in rolls of 10 to 20 metres length, for leading the preservative from the valved outlet of the drum through a T arrangement to enable six bamboos to be treated at one time. The T arrangement was prepared in advance by joining 25 mm diameter Ts, collars and bends together. Strings of jute and thick cotton were used to fix the flexible tubes to the pipes on one end and the bamboos at the other end.

Six culms of three species of bamboo (*Bambusa bamboo, Dendrocalamus strictus* and *Pseudoxytenanthera stocksii*) were chosen for treatment. The preservative used, was Copper-Chrome-Borate (CCB). Measurements of the specimens prepared were recorded and weights taken after the specimens were ready for treatment. The culms of each of the three species were taken to the site of treatment and their basal ends were encased in the six outlets of flexible plastic pipes of the T and fastened tightly with jute string. The bottom ends were also encased in flexible plastic pipes as in the case of top ends and the green ends of pipes were lead to a GI bucket to collect the drained preservative. After the bamboos were tied, the preservative kept in the drum was allowed to flow into the single pipe by opening the wheel valve. The single pipe was connected through a 7.5 cm. flexible plastic pipe 3 metres in length, laid along a 30^0 slope and the bottom of this flexible pipe was tied to the top end of the T arrangement. The single entry of the preservative was distributed to outlets of rigid polythene T arrangements and the butt end of bamboos tied to each flexible outlet of the plastic pipe by jute string. The six bamboos were kept along the slope for gravity flow of the preservative, through the bottom flexible pipes into the bucket kept at the bottom. The time at which preservative form the storage drum was let into the pipes by opening the wheel valve was noted in each case. It was found that 5 cms dia flexible pipes could be used for encasing two species viz., *Dendrocalamus strictus* and *Pseudoxytenanthera stocksii* and 10 cms. dia flexible pipe had to be used for encasing *Bambusa bamboos*.

The wheel valve inlet near the drum was closed once a contuinuous flow of preservative was exuding from the apical end into the bucket. The bamboos were untied from the flexible pipe and weighed with a spring balance. It was found that the weight remained the same between the first and second weighings and thus full sap displacement had taken place. It should be possible to reduce the time for treatment by sap displacement if pressure is applied to push the preservative at the basal end. But the flexible pipes and fittings will have to be stronger to withstand such pressures.

The movement of the preservative by gravity is easy in green bamboos. It took about 20 hours for flow from one end to the other and 30 hours for sap displacement in the case of green bamboos of average length of 4mtrs. No difference in the weight of green bamboo before treatment and after treatment was noticed.

The results of sap displacement treatment by Boucherie process of the three species are given in Table 2 below.

Table 2: Result of sap displacement treatment by conventional Boucherie process

Sl. No.	Species	No.	Time when dripping at the bottom started	Time taken for sap displacement
1.	*Bambusa bamboos*	6	21 hrs	30 hrs
2.	*Dendrocalamus strictus*	6	19 hrs	24 hrs
3.	*Pseudoxytenanthera stocksii*	6	20 hrs	28 hrs

The above table demonstrates that conventional Boucherie process is quite suitable for treatments

Appendix II

Economic aspects of bamboo preservation by sap displacement:

Decay is inevitable in untreated, non-durable bamboo and may cause loss or early replacement of material, sometimes with heavy labour requirements. Failure of a piece of bamboo in a building through decay or insect attack may involve expenses far greater than the actual cost of the piece of bamboo itself. There are also indirect costs involved such as in the case of replacement of bridge bamboo where there will be traffic diversions and hence increased transportation costs, etc. Therefore the use of untreated bamboo gives rise to maintenance problems and high annual costs. A comparison of the annual charges presents the true cost of bamboo construction. This cost represents the amount necessary to provide simple interest on the investment, and an amount set aside annually at compound interest to provide for renewal. Comparing only the initial cost of treated and untreated material is misleading. It is also important to take into consideration, its useful life. It is a mistake to determine annual charges on the basis of excessive life, if relocation or revision is needed sooner, as is often the case with the temporary structures.

The annual cost of a structure is the amount of money that will have to be provided annually to replace the structure at the end of its useful life, and thus provide for perpetual service. This annual cost can be computed by the compound interest formula:

$$A = P \frac{r(1+r)^n}{(1+r)^n - 1}$$

Where A = annual charge
P = total investment cost
r = rate of interest expressed in decimals (0.15 for 15%)
n = number of years service

Bamboo is a low cost material and has therefore found extensive use in low cost products. Additional treatment costs have therefore to fit in the overall economics of these products keeping in view their marketing potential. Since costs of material and labour varies from country to country, exact analysis of treatment costs is rather difficult. In a house made completely of a bamboo, it is estimated that untreated bamboo posts last about 2 years, walls 5 years, ceilings 10 years and roofs 8 years. The average life of an untreated bamboo house thus may be considered not more than 7 years. Treated bamboo posts may last about 15 years and treated woven mats for walls about 20 years treatment may involve an additional cost of about 20% to 13% respectively. But this will help in increase the service life of bamboo and its products by 3 to 5 times. This means the cost of bamboo can be decreased to one third to one fifth of the original costs through treatment, and the benefits are obvious.

Appendix III

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