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Forest Department

Investigation on the Effectiveness of Preservation Methods on Natural Durability of Some Myanmar Important Bamboo Species

ချိုချိုဝင်း

သုတေသနလက်ထောက်(၂)

သစ်ကြာရှည်ခံဌာနစိတ်

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မြန်မာ့ဝါးမျိုးအချို့တို့၏ ကြာရှည်ခံနိုင်မှုအပေါ်တွင် ကြာရှည်ခံစေသောနည်းများ၏ အကျိုးသက်ရောက်မှုကို လေ့လာခြင်း

ချိုချိုဝင်း
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စာတမ်းအကျဉ်း

မြန်မာ့ဝါးမျိုးများဖြစ်သော ကျသောင်းဝါး၊ တင်းဝါး၊မျှင်ဝါးနှင့်သိုက်ဝါးတို့၏သဘာဝအလျှောက် ကြာရှည်ခံနိုင်မှုကို ဓါတ်ခွဲခန်းတွင်း စမ်းသပ်နည်းများဖြင့် စမ်းသပ်ခဲ့ပါသည်။ ဤသုတေသနလုပ်ငန်း၏ အဓိကရည်ရွယ်ချက်မှာ ဝါးမျိုးများ၏ မှိုဒဏ်ခံရသည့် ပြဿနာအား ဖြေရှင်းရန် ဖြစ်ပါသည်။ မှိုများ၏ ဖျက်ဆီးမှုနှင့် ဝါးတွင်ပါဝင်သော ကစီဓာတ်တို့၏ အချင်းချင်းဆက်သွယ်မှုကိုလည်း လေ့လာတင်ပြထားပါသည်။ ထို့ပြင် ဒေသခံတို့အတွက် ရိုးရှင်းလွယ်ကူပြီး အကျိုးသက်ရောက်မှုရှိနိုင်မည့် ဝါးကို မှိုဒဏ်မှ ကာကွယ်ပေးနိုင်သော နည်းလမ်းများကိုလည်းတင်ပြထားပါသည်။ ဤစာတမ်းတွင် ဝါး(၄)မျိုး အားရေတွင်စိမ်သောနည်း၊ ဝါးရုံမှ ဝါးပင်ကို ခုတ်ယူပြီးချင်း မသိမ်းယူဘဲ ဝါးရုံတွင် (၃)ရက်ထား၍ ခြောက်သွေ့စေပြီးမှ စုဆောင်းသောနည်းနှင့် ဓာတုဗေဒနည်းဖြစ်သော ၁၀%ပြင်းအားရှိ Boric acid နှင့် Borax ဖျော်ရည်တွင် စိမ်သောနည်းများဖြင့် စမ်းသပ်ခဲ့ပါသည်။ တွေ့ရှိချက်များအရ စမ်းသပ်သည့် ဝါး (၄)မျိုးအနက် သိုက်ဝါးသည် မှိုဒဏ်ခံနိုင်မှု အနိမ့်ဆုံးဖြစ်ပြီး တင်းဝါးသည် မှိုဒဏ်ခံနိုင်မှု အမြင့်ဆုံး ဖြစ်ကြောင်း တွေ့ရပါသည်။ ကစီဓာတ်ပါဝင်မှုတွင် ဝါး(၄)မျိုးလုံးတွင် အဖျားပိုင်း၌ အများဆုံးဖြစ်ပြီး အရင်းပိုင်း၌ အနည်းဆုံးဖြစ်ကြောင်းတွေ့ရပါသည်။ ကြာရှည်ခံစေသောနည်းများအနက် ရေတွင်စိမ်သော နည်းသည် ကစီဓာတ်ကို ထိရောက်စွာ လျှော့ချနိုင်သော်လည်း ၁၀% ပြင်းအားရှိ Boric acid နှင့် Borax ဖျော်ရည်တွင် စိမ်သောနည်းသည် မှိုဒဏ်ကို ထိရောက်စွာ ကာကွယ်ကြောင်း တွေ့ရပါသည်။

Investigation on the Effectiveness of Preservation Methods on Natural Durability of Some Myanmar Important Bamboo Species

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Abstracts

The natural durability of some important Myanmar bamboo species namely, *Kyathaung-wa* (*Bambusa polymorpha*Munra.), *Tin-wa* (*Cephalostachyum pergracile* Munro.), *Hmyin–wa* (*Dendrocalamus strictus* Nees.) *and Thaik-wa* (*Bambousa tulda* Roxb.) were tested. The aim of this research was to solve the problem of fungal attack on bamboo. The relationship between starch content and fungal attack was also studied. Another objective was to investigate the simple and effective methods for rural people to protect bamboo from fungal attack. In the case of non-chemical treatment, water immersion method and Curado method were used. In water immersion method, fresh bamboo culms were immersed in water for different periods of time. In Curado method, bamboo were collected 3 days after cutting, keeping the bamboo standing upright without trimming branches. In the case of chemical treatments, 10% solution of Boric acid and borax mixture were used to preserve tested bamboo species. Out of the tested four bamboo species, it can be found that ***Thaik-wa* has the lowest fungal resistance** followed by *Hmyin-wa* and *Kyathaung-wa* and ***Tin-wa* has the highest fungal resistance**. The starch contents determination showed that top portions have high starch contents and bottom portions have less starch content for all tested bamboo species. Although immersion in water can be reduced significantly the starch content of tested bamboo, chemical treatments is the best method to protect the fungal attack.

Contents

1. Introduction

Bamboo is one of the oldest and most versatile building materials with many applications in the field of construction, particularly in developing countries. It is strong and lightweight and can often be used without processing or finishing. So, it is well known as "the poor man's timber". In spite of these clear advantages, the use of bamboo has been largely restricted to temporary structures and lower grade buildings due to limited natural durability. Low-durability is a major reason for the poor acceptance of bamboo as building material, often considered as a short-term material suitable for temporary uses only.

Insects and fungi can attack on the raw material as well as the finished products. Losses are incurred due to discoloration caused by fungi or due to damage caused by powder – post beetles that produce bore holes on the culm. Termites attack bamboo culms that are in directly contact with the ground. Therefore, there is a need to treat bamboo and bamboo products prior to its use in order to enhance its service life.

There are 17 genera and 102 species of bamboos in Myanmar (Aung Zaw Moe, 2002). Among them, about 15 species are commercially important according to the criteria of priority selection as in INBAR Technical Report 1 (Appendix I & II). Although Myanmar is rich in bamboo resources, markets and bamboo – based technology was not well established and the value of the species was not realized. With the increase in population, the change in time and improve technology value – added bamboo products are becoming more and more important.

The objectives of this paper are:-

- to investigate the natural durability of some important Myanmar bamboo species,
- to improve the quality as well as service life of bamboo and bamboo products by using wood preservatives,
- to provide information on the available treatment methods and preservative chemicals for bamboo protection in rural area by simple methods.

2. Literature Review

2.1. Natural durability of bamboo

Bamboo is composed of 50 to 70% hemicellulose, 30% pentosans and 20 to 25% lignin (Tamolang et al, 1980; Chenef et al, 1985). It is known to be rich in silica content, up to 4%, but which is located in the epidermal layers with hardly. Because of the lack of any toxic constituents, bamboos form a ready food source for a variety of organisms. The presence of high contents of starch makes it more susceptible to attack by staining fungi and powder post beetles (Kumar et al. 1994).

The natural durability of untreated bamboo is generally low and the natural resistance of bamboo depends particularly on the species, the type of attacking organisms and environmental conditions such as soil contact, access of moisture, temperature and type of end-use. In ground contact, it is mainly destroyed by soft-rot fungi within less than 2 years and under cover untreated bamboo may last 4-7 years. Under favourable conditions, trusses and rafters may serve 10-15 years or longer. Bamboo structures exposed to sea water are destroyed by marine organisms and fungi in less than one year (Purushotham 1963, Tewari & Singh 1979, Tewari 1981, George 1985).

Systematic data on natural durability when there is ground contact and exposed conditions are very limited. Test conducted in the Philippines indicated that durability of bamboo against fungi and insects varies among the species. *Dendrocalamus merillianus* was found perishable while *Schizostachyum* species were found quite resistance. Laboratory exposure test showed that some species like *Bambus*a *blumena* and *Gigantochloa* showed moderate resistance (Guzman, 1978). According to durability classification, bamboos thus fall in class III (non-durable category) by Graveyard tests on some important Indian bamboo species. *Dendrocalamus longispathus* is slightly more resistant to termites than *D. strictus*. *Guadua angustifolia* has high resistance to both rot fungi and insects. *Bambus vulgaris* is best known for its preference by beetles due to high starch content.

The bamboo age is a factor of its resistance. In young stage, it contains a large quantity of starch in their parenchyma cells and bamboo develops quickly until reaching its maximum height. While the bamboo is getting older, the physiological activity decreases.

The durability of a bamboo culm is to some extent influenced by the harvesting season. Culms cut, during the dry season are, due to their starch content more susceptible to insect and fungal attack than those harvested during/ after the rainy season, where the new culms have reached their full size and before leaf development, since the starch content is its lowest(Liese, 1980). While, others manifest the opposite and bamboo should only be cut in dry periods or during the absence of rain. In rainy season, the existent humidity in the bamboo is higher and the parenchyma is softer therefore, infestation possibilities increase.

The preferred harvesting time varies from region to region, depending on the shooting season and where the insect population is low. In India this is mainly from November to January, in Malaysia, from May to September, in Vietnam from August to December, and in Japan from October to December. Culms of bamboo plants which have flowered are more resistant to beetles because of starch depletion.

The durability and resistance of the bamboo to the attack of insects is the period of cutting of the bamboo. Jorge A. Moran Ubidia (2002) reported that the crescent quarter (7 days after full-moon) is the period to precede the cutting of the selected bamboo. The clum contains less liquid and therefore, when being cut it contains lesser humidity and therefore a smaller risk of decay or infestation by fungus and micro organisms.

Similarly, he also reported that cutting should take place when the tide is low. In this period there is no water coming out. The tradition of cutting bamboo in hours of low tide is related to the influences of the moon on waters.

It is often believed that the durability of bamboo is improved when the culms are cut before sunrise. When cutting bamboo at night, down or during the 1st hours of the morning **(**the starch content which may be lower due to nocturnal respiration) leading possibly to a slightly reduced vulnerability to moulds and beetles compared to that during the rest of the day.

Liese and Kumar (2003) reported that bamboos with a relatively thick culm are less resistant than those with a thin one, which may be influenced by their lesser amount of nutritious parenchyma. Insect larvae prefer the inner part of the clum with its high amount of nutritious parenchyma in comparison to the outer part with more fibers which is often left untouched, showing only the exist holes of the beetles. This is probably related to the anatomical and chemical nature of the woody cells.

Split bamboo with its easier access to the parenchyma is more rapidly destroyed than round clum portions. Therefore, split bamboo is more rapidly destroyed than unsplit bamboo (Liese, 1959).

Investigations carried out in different parts of the world have conclusively established that bamboo when adequately treated with suitable preservatives, become resistant to the attack of fungi and insects and give satisfactory service life. Preservative treatment of bamboo culms depends on the species age, moisture content, treatment method and type of preservative (Liese 1959). Sultani (1985) studied the effect of treatment methods on *Dendrocalamus asper, Gigantocloa apus, G. atter and Bamoo vulgaries*. Liese (1959) studied various bamboo species viz. *Dendrocalenmus strictus, D. longispathus, D. Giganteus and Bambussa arundinacea* by modified Boucherie method. Tewari and Singh (1979) studied *Bambusa polymorpha* and *D. strictus* by steaming and quenching as well as double diffusion methods. Chowdhury (1992) reported that the effect of treating *Bamboosa balcooa, B. longispiculata and Melocenna baccifera* by diffusion and sap displacement methods. Ahmed Sultani (1985) reported that split bamboo can be treated by soaking process, where the soaking period was seven days.

It was reported that for outdoor and construction purposes, preservative treated bamboo lasted three to four times longer than untreated bamboo (Purushotham 1963, Tewari 1975, Liese 1980, George 1985).

It was reported that bamboo shingle roofing from Forest Research Institute last over 20 years. The bamboo shingles were treatment with earth-oil using boiling treatment Win Chit (2008).

2.2. Bamboo Preservation Status in Myanmar

In Myanmar, some bamboo species, Kyathaung-wa (*Bambusa polymorpha* Munra.), Tin-wa (*Cephalostachyum pergracile* Munro.), Hmyin–wa (*Dendrocalamus strictus* Nees.), Thaik-wa (*Bambousa tulda* Roxb.), Wa-net (*Dendrocalamus longispathus*) and Wabo-wa (*Dendrocalamus brandisii* Kurz.) are made for the handicraft and furniture parts.

Traditional preservation methods are applied for the durability of bamboo products. These methods are soaking method, dipping in Boric acid solution method and coal-tar method. Water soaking method is used before the handicraft weaving. Boric acid is used for bamboo parquet making. The bamboo splits of Kyalo-wa and Kyathaung-wa were boiled for 2½ hours in boric acid for bamboo parquet. Coal-tar is used for the shingle (Soe Tint, et al., 2004).

The durability of bamboo shingles after treating properly with locally available preservative like crude-oil was studied by Sein Win (1979).

3. Materials and Methods

3.1. Material

3.1.1. Selected Bamboo Species

In this study, the most well – known and abundant four bamboo species were selected. These species are the most economically important species for structural uses from the point of view of easy availability. These species are:

(1) Kyathaung-wa (*Bambusa polymorpha* Munro.)
(2) Tin-wa (*Cephalostachyum pergracite* Munro.)
(3) Hmyin-wa (*Dendrocalamus strictus* Nees.)

(4) Thaik-wa (*Bambusa tulda* Roxb.)
All these species are included in the International Network Bamboo and Rattan (INBAR)priority list.

Kyathaung-wa attains about 24 meter in height with culms 75 to 25 mm diameter. It is easily known by its ashy-white culms. It is very common in the Bago Yoma and one of the most useful bamboos in Myanmar. It is in great demand for building.

Tin-wa is 12-15 meter high and attains 35-90 mm diameter. It is particularly suited for split bamboo work.

Hmyin-wa is very common in upper and lower Myanmar. Under favourable conditions the culms are 15 meters long and 75-100 mm diameter, when growing in dry localities, they are much smaller and often solid, hence the name :male bamboo". The walls are always comparatively thick. The culms are useful for building, lance shafts, tent poles and tool-handles.

Thaik-wa is 15-18 meters high and attain 75-100 mm diameter. The culms are dark-green. It is strong and thick-walled bamboo, but the culms are not always straight. They are used for building, basket-work and mats.

The selected bamboo species were collected from Ngalaik Reserved Forest, near Moeswe, Pyinmana Township. Bamboo culms were selected from various clumps in standing condition. Ten clumps per each species were randomly selected, and at least four or six culms from each clump.

All the tested bamboo species were at least 3-years old and harvested in October. Bamboo culms were divided into 3 sections (bottom, middle and top) each of 2 meter long. The diameter and wall thickness of the tested bamboo culms were shown in Table (1) and (2).

3.1.2. Chemical used for treatment of tested bamboo species

Many chemicals may be toxic to bamboo destroyers but are not suitable as preservatives. The preservatives are either water-borne or oil - based types.

Boron containing compounds are the most widely used preservative for protecting bamboo, usually as a mixture of Boric Acid and Borax. Disodium-octaborate and Timbor (come as readymade mixture) have a very high solubility in water. Boron salts are effective against a variety of fungi, borers and termites. Boron salts in a high concentration also have fire retardant properties.

The mixture of Borax and Boric acid is more environmentally friendly than other wood preservatives currently used. The borax and boric acid solution can be used more than once for treating bamboo as long as the hydrometer reading of the solution is still at the initial level, of approximately 1.035.

3.2. Methods

3.2.1. Water soaking method

The fresh bamboo culm parts were split into 10 mm x 10 mm x 300 mm sticks. Ten sticks of each species were prepared for each treatment. Fresh bamboo sticks were immersed in water in the tank for 1, 2 and 3 weeks to reduce the starch from bamboo parts. Excessive dipping in water may also cause the bamboo brittle. The water was renewed every day.

After finishing the immersion in water, the soaked sticks were cut into (10 mm x 10 mm x 25mm) sized- blocks to test for decay resistance.

3.2.2. Starch reduced – cutting method (Curado)

This type of treatment is termed as "Curado" in some countries of America as a synonym of preservation. "Curado" means to preserve the bamboo before it leaves the forest, plantation or its spot. The procedure for this type of treatment is as follow:

- the selected bamboo culm is cut on the first knot and is left in the place of cutting on the tree stump or on a stone or on a brick of its base as vertical as possible,
- the cut bamboo is leaning on or supported by the neighboring bamboos without trimming branches and leaves.
- It stays on this position for a period of three to four days.
- When the crown has turn yellow-brown, the culms are trimmed

By this way, the starch contained in the bamboo culm can be progressively lost either through gravitation or transpiration via the branches and leaves. The decrease of infestation possibility through not cutting the branches and avoiding leaving the epidermis uncovered. The starch in the parenchyma cells become alcohol, natural insecticides through fermentation (J.A. Moran Ubidia, 2002).

In this study, some bamboo culms were cut and collected by this way. The test bamboo culms were also divided into 3 sections (bottom, middle and top) each of 2 meter long. After that, the test sticks were cut into (10mmm x 10 mm x 25 mm) sized- blocks to test for decay resistance.

3.2.3. Dip-diffusion method

Boric acid and Borax powder were mixed in the ratio of 1:1 and then dissolved with water to obtain 10% solution. The 10% solution of Boric acid and Borax mixture were used to preserve tested bamboo species, in this study.

Fresh bamboo culm parts were immersed in the prepared preservative solution for 1 hour. After that the treated bamboo blocks were taken out and wrapped in plastic bags for two weeks to diffuse the boron salt into the wood. After completion of diffusion period, the treated blocks were weighed and were calculated the retention of Boron.

After finishing the immersion and diffusion periods, the treated sticks were cut into (10 mm x 10 mm x 25mm) sized- blocks to test for decay resistance.

3.2.4. Laboratory decay test

Pycnoporus sanguings and *Schyzophyllum commune*, the white rot fungi were used in this study. Laboratory tests have indicated that bamboo is more prone to both soft rot and white rot attack than brown rot. That is why only the white rot fungi was selected in this test. The fungi specimen was cultured in 2% malt extract agar medium, kept in the room temperature and it was indentified at Forest Research Institute of Malaysia (FRIM).

Potatoes- Dextrose agar (PDA) media was used for the stock test tube culture of the test fungus. The procedure taken for the fungus culturing was as follows:-

a) 200g of peeled, diced potatoes, 20 g of dextrose and 15 g of agar were dissolved with 1000 ml of distilled water in a flask and heated till boil.
b) The media was distributed into the test tubes, approximately 20 ml in each tube.
c) The test tubes were plugged with cotton and sterilized in autoclave sterilizer for 20 minutes at 105 ˚C and 15psi pressure. It was necessary to sterilize the media before using in order to kill bacteria or fungal spores which will possibly present in the media or in the glasswares.
d) The test tubes were taken out from the autoclave sterilizer and cooled to room temperature.
e) The fungus inoculums were cut and placed on the media. After 3 to 5 days, the fungus grew well, with mycelium. These were ready for decay test.
f) After that, control (un-treated) samples and all the treated samples were exposed to fungal attack by placing them over the fungus mycelium in the test tubes. Tiny chips of glass- rod were placed between bamboo samples and the fungus in order to prevent the direct contact between them.
g) The test tube were placed at ordinary room temperature and incubated for 16 weeks.
h) After completion of the incubation period, the bamboo blocks were taken out and attached mycelium was carefully cleaned.
i) The test blocks were oven dried at 103 ± 2° C until the constant weights were obtained and then, the oven-dry weights were recorded to calculate the weight loss percentages of the test blocks.

3.3. Method of Analysis

3.3.1. Weight loss determination of the tested bamboo samples

To estimate the calculated oven dry weight of each test block, the average moisture content (MC) of the MC-samples was used. The MC of the sample was determined by using oven-dry method.

- The initial weight of each moisture content sample at was weighed and recorded as initial weight.
- After that, the samples were oven-dried at 103 ± 2° C to obtain the constant weight and the oven dried samples were weighed and recorded.
- The M.C of each samples were calculated.

The calculated oven dry weight of each test sample was calculated by using the following formula.

$$\text{C.O.D. Wt} = \frac{\text{I. Wt} \times 100}{(100 + \text{M.C \%})}$$

To determine the weight loss percent of each of the test samples the following formula was used. The obtained average loss in dry weight percent of bamboo specimens were measured as the decay because of test fungi.

$$\text{Wt. Loss (\%)} = \frac{(\text{C.O.D .Wt - F.O.D Wt})}{\text{C.O.D. Wt}} \times 100$$

where,

C.O.D Wt = calculated oven dry weight

F.O.D Wt = final oven dry weight

3.3.2. Statistical Analysis

The data recorded were mean weight loss percentage of individual species. The data obtained were statistically analyzed using ANOVA (Analysis of Variance), following a Complete Randomized Design (CRD).

4. Results and Discussion

4.1. Effect of preservation on the resistance to fungal attack

Mean weight losses for each of the tested bamboo species of control samples and treatment samples which were exposed to decay test are shown in Table (3). Where T- 1 is water soaking for 1 week, T-2 is water soaking for 2 weeks, T-3 is water soaking for 3 weeks and T-4 is bamboo which obtained 3 days after cutting, keeping them standing upright without trimming branches. It will be denoted as "Curado" and T-5 is 10% solution of Boric acid and Borax treatment.

Results showed that the mean weight losses of bottom parts were less than top and middle parts and higher durability than middle and top for all tested bamboo species. The mean weight losses of top parts have the largest and it has lowest durability. So, it may be said that variation in durability has been observed along the length of the culm and the lower portion of the culm is considered more durable.

According to table (2), it can be found that *Thaik-wa* has the largest wall thickness (9.03mm) among the test bamboo species and followed by *Hmyin-wa* (8.06mm), *Kyathaung-wa* (7.61mm) and *Tin-wa* (2.14 mm). Weight loss determination showed that the average weight loss of control sample caused by white rot fungi were 22.7% for *Thaik-wa*, 16.5% for *Hmyin-wa*, 16.7% for *Kyathaung-wa* and 14.4% for *Tin-wa* respectively.

Therefore, it could be concluded that bamboos with relatively thick culms are less resistance than those with thin one. Liese and Kumer (2003) stated that which may be influenced by their amount of nutritious parenchyma.

4.1.1. Treatment effects on *Kyathaung-wa*

Table (3) represents the treatment effects on *Kyathaung-wa*. In order to clearly reveal that treatment effects on *Kyathaung-wa* it was also shown in Figure (1).

Results showed that the mean weight loss of untreated *Kyathaung-wa* is 16.69%. By soaking in water for 1 week, the average weight losses decrease to 12.8% and 10.53% for 2 weeks soaking respectively. By soaking 3 weeks, the mean weight loss becomes 6.14%. It can be found that the weight loss was about **3 folds** less than untreated *Kyathaung-wa* samples. However, it remains slightly decay.

As for "Curado" bamboo (T-4), it can be found that the average weight loss was 5.21%. It was lower than water soaking samples. So, it may be assumed that "Curado" bamboo has higher durability than water soaking. It can also be found that the weight loss was **3.2 folds** less than untreated samples.

For T-5, the mean weight losses of samples treatment by dip-diffusion in 10% boric acid and borax solution were found to be 2.55% and it was **6.5 folds** less than untreated samples.

Among the treatments, it gives the best results and chemical treatment provides protection for fungal attack.

4.1.2. Treatment effects on *Tin-wa*

Table (4) represents the treatment effects on *Tin-wa*. In order to clearly reveal that treatment effects on *Tin-wa* it was also shown in Figure (2). According to Table (4), it can be found that, the mean weight losses of untreated *Tin-wa* samples were 14.42%. It was found that the mean weight losses of water soaking samples were 9.04% for 1 week soaking, 8.32% for 2 weeks soaking and 3.85% for 3 weeks soaking respectively. Water soaking for 1 and 2 week was not significantly different from untreated samples. Water soaking for 3 weeks can give satisfactory results and it reduced **3.7 folds** less than untreated samples.

The mean weight losses of (T-4) was 2.57% and it reduced **5.6 folds** lower than untreated samples and Curado method provides a considerable fungal resistance.

The mean weight loss of Tin - wa, treated with 10% boric acid and borax solution was found to be 1.12% and weight loss reduced **13 folds** lower than the untreated samples. Among the treatments, it gives the best results.

4.1.3. Treatment effects on *Hmyin-wa*

Table (5) showed mean weight losses of *Hmyin-wa* after 16 weeks exposure in white rot fungus. In order to clearly reveal that treatment effects on *Hmyin-wa* was also shown in Figure (3).

Major weight loss 16.5% was determined in untreated *Hmyin-wa* samples after 16 weeks incubation. The mean weight losses of water soaking samples were 9.3% for 1 week, 8.6% for 2 weeks and 7.96% for 3 weeks soaking respectively. Although the weight losses decreased about 2 folds lower than untreated samples, the treatment cannot provide the fungal resistance. For treatment - 4 and treatment -5, the mean weight losses were 4.1% and 3.6% and it reduced about **4 folds** lower than untreated samples.

Weight loss determination for *Hmyin-wa* showed that water soaking cannot give the sufficient protection for fungal attack; however it can give reduced weight loss than untreated one. For chemical treatment, it may need longer immersion time or stronger concentration.

4.1.4. Treatment effects on *Thaik-wa*

Table (6) represents the treatment effects on *Thaik-wa*. In order to clearly reveal that treatment effects on *Thaik-wa* was also shown in Figure (4).

Weight loss determination showed that, the mean weight loss of untreated *Thaik-wa* samples was 22.7%. The mean weight losses of water soaking for 1 week and 2 week samples were 6.1% and4.1% respectively. It was also found that water soaking for 1 week and 2 week was significantly different from untreated samples. The mean weight loss of water immersion for 3 weeks was found to be 1.77% and it can give satisfactory results and it reduced **13 folds** less than untreated samples.

For treatment - 4, the mean weight losses of the samples collected after 3 days harvesting was 3.2% and it reduced **7.1 folds** lower than untreated samples.

For chemical treatment samples, it can be found that the weight loss was 2.2% and the weight loss decreased **10 folds** less than untreated samples.

4.2. The Effect of Treatment on Starch Content of Tested bamboo Species

The starch content is of considerable importance for its vulnerability to insects and staining fungi. The starch granular is accumulated in the parenchyma cells, in culm fibers and subterranean rhizome. The amount of starch varies generally between 2-6%, but can reach up to 10%. It is influenced by age, height and site; whereby the lower part contains less starch than the middle and top portions (Walter et al, 2003).

In order to know the effect of starch content on weight loss (natural durability), the starch contents of tested bamboo species were determined at Wood Chemistry Section of FRI. The starch contents of tested bamboo species at different portions were illustrated in table (7). In this table, it was also shown the changes in starch contents by soaking treatments and dry harvesting method. In order to clear reveal, the changes of starch content by treatment were shown graphically in Figure (5,6,7 and *8*).

The starch contents determination showed that top portions have high starch contents and bottom portions have less starch content for all tested bamboo species.

The starch content of tested bamboo species reduced significantly with immersion periods. Higher starch contents (more than 1%) were found in case of the split of *Kyathaung-wa* and *Hmyin-wa* immersed for 1 week. Sulthoni (1985) stated that bamboo species with less than 1% starch content is considered as good quality bamboo for construction. Therefore, it may be assumed that the tested bamboo species can be used for construction purposes after immersion in water.

Among the tested treatment methods, except chemical treatment, T- 4 (bamboo collected 3 days after harvesting) is the best method to reduce starch content. This is an effective and low cost method. However, it may be suitable when the bamboos are harvested from own garden or plantations.

4.3. The Relationship between Starch Content and Weight Loss

In order to clearly reveal the correlation between the weight losses of tested bamboo samples after 16 weeks exposure in fungal attack and starch contents (%) of those tested bamboo samples, statistical analysis was made by using the simple linear regression method. The relationship between weight losses for the test bamboo species and starch contents were shown in Figure (9-*a,b,c* and *d*).

According to the figures (9-*a, b, c* and *d*), it was found that the weight losses of tested bamboo species after 16 weeks exposure in fungal attack were significantly correlated to the starch content of those species at 0.05 $\propto$ level by the following equations.

$Y= 6.053\,x + 3.252$ for Kyathaung-wa, $Y= 19.65\,x - 7.315$ for Tin –wa , $Y= 23.06\,x - 11.33$ for Hmyin -wa and $Y= 20.67\,x - 6.013$ for Thaik-wa respectively.

5. Conclusions and Recommendation

5.1. Conclusions

According to the results of this study, the following conclusions can be drawn**.**

1) Out of the tested four bamboo species, ***Thaik-wa*** **has** the highest weight loss (%) and **the lowest fungal resistance**. Then, followed by *Hmyin-wa* and *Kyathaung-wa* and ***Tin-wa*** **has** the lowest weight loss and **the highest fungal resistance**.
2) Bamboos with relatively thick culms are less resistance than those with thin one.
3) The starch contents determination showed that top portions have high starch contents and bottom portions have less starch content for all tested bamboo species.
4) The starch content of tested bamboo species reduced significantly by immersion in water and those values after water immersion were generally less than 1%. Therefore, water soaking treatment can safely use to reduce the starch contents.
5) Immersion in water can serve as base for the implementation of preservation process at large scale and industrial level. Immersion of bamboo sticks in water for three weeks is adequate to improve the resistance of fungi. However, long immersion causes high moisture content in bamboo culms that induce the fungal growth. Therefore, drying of bamboo after immersion should be carried out.
6) For traditional treatment, bamboo collected 3 days after cutting without trimming branches is the best method to reduce starch content. This is an effective and low cost method.
7) Chemical treatment by dip-diffusion is simple, cheap, does not require special equipments and gives the best protection against deterioration caused by fungi among the tested four species.

5.2. Recommendations

Bamboo is a renewable resource with a short rotation period of 5-7 years depending on species and locality. Deterioration by insects and fungi is the most serious drawback of bamboo. Often this deterioration requires that bamboo have to be replaced every two or three years in its various uses. With proper preservative treatment the service -life can be extended to 15 years or longer in the open and even in contact with the ground and 20-30 years under cover. The initial cost and effort of preservative treatment pay off for the much longer life of material.

One of the world's most interesting plant groups, bamboo is emerging as an exciting new economic opportunity for Asis's forest industry. Improved processing technologies, especially in terms of greater durability and better finish, have resulted in greater diversity and improved quality of bamboo products.

Application of preservative by soaking is the cheapest and simplest method of chemical treatment of bamboo for uses where higher absorption is required (George, 1985). But due to mishandling and during treatment there is a possibility of environmental pollution. Like boron the organic co-biocides used in the newly developed preservative formulation are considered to be relatively environmentally friendly, thus having received less scrutiny than the other compound. But it is stated that boron compound is diffusible, fire retardant and leachable, because borate are not fixed in the bamboo and therefore, boron treated materials are not recommended for use in ground contact, where frequent wetting occurs (Mulling and Mcknight 1981).

Since the partition, wall, ceiling are used under cover, during rainy reason there is less possibility of leaching. The leaching and mobility of boron in the environment may be of much less concern than that of chromium, copper and arsenic, because most organisms to tolerate relatively high aqueous concentration of boron compounds (EPA 1986). Generally the greater leaching is found from products on specimen that has large area of exposed surface. After treatment, the most important consideration in leach prevention is to ensure that adequate time is allowed for fixation before placing the materials in service.

Table (1) Average diameter of the tested bamboo at different portion

Species	Bottom (mm)	Middle (mm)	Top (mm)	Average (mm)
Kyathaung-wa	52.60	49.40	42.40	48.13
Tin-wa	17.05	15.80	11.00	14.62
Hmyin-wa	46.90	39.61	31.07	39.19
Thaik-wa	42.50	44.31	36.19	41.00

Table (2) Average wall thickness of tested bamboo species

Species	Bottom (mm)	Middle (mm)	Top (mm)	Average (mm)
Kyathaung-wa	9.20	7.40	6.24	7.61
Tin-wa	2.73	2.30	1.40	2.14
Hmyin-wa	12.40	10.43	6.36	9.73
Thaik-wa	13.44	9.50	6.14	9.69

Table (3) Mean weight losses of *Kyathaung-wa* after 16 weeks exposure in fungal attack

	Control (%)	T-1 (%)	T-2 (%)	T-3(%)	T-4(%)	T-5(%)
Top	18.24	15.74	10.73	9.34	7.41	4.44
Middle	16.69	8.55	10.52	2.71	3.86	1.66
Bottom	15.13	14.12	10.33	6.38	4.36	1.54
	16.687	12.803	10.53	6.143	5.210	2.547

Table (4) Mean weight losses of *Tin-wa* after 16 weeks exposure in fungal attack

	Control (%)	T-1 (%)	T-2(%)	T-3(%)	T-4(%)	T-5(%)
Top	17.774	10.252	11.050	5.934	5.030	0.790
Middle	10.725	12.818	8.450	3.997	1.424	0.630
Bottom	14.764	4.042	5.510	1.636	1.254	1.939
	14.424	9.037	8.323	3.850	2.570	1.120

Table (5) Mean weight loss of *Hmyin-wa* after 16 weeks exposure in fungal attack

	Control (%)	T-1 (%)	T-2 (%)	T-3(%)	T-4 (%)	T-5(%)
Top	19.937	10.31	10.01	11.87	3.93	4.48
Middle	17.629	10.124	7.81	5.17	2.76	1.69
Bottom	11.950	7.46	7.99	6.85	5.76	4.56
	16.505	9.298	8.603	7.93	4.15	3.58

Table (6) Mean weight loss(%) of *Thaik-wa* after 16 weeks exposure in fungal attack

	Control (%)	T-1 (%)	T-2(%)	T-3(%)	T-4(%)	T-5(%)
Top	25.698	10.73	8.32	1.82	5.98	3.68
Middle	27.832	4.27	2.17	1.81	1.86	1.65
Bottom	14.585	3.31	1.89	1.66	1.77	1.33
	22.705	6.103	4.127	1.77	3.20	2.22

Table (7) Starch content (%) of tested bamboo species at different portions

Species	Portion	Control	1 week soaking	2 week soaking	3 week soaking	Curado
Kyathaung-wa	Top	2.550	2.333	0.880	0.72	0.873
	Middle	1.780	1.841	0.388	0.34	0.776
	Bottom	1.300	1.355	0.389	0.17	0.390
		1.877	**1.843**	**0.552**	**0.41**	**0.679**
Tin-wa	Top	1.266	0.879	0.784	0.27	0.634
	Middle	1.119	0.871	0.686	0.97	0.652
	Bottom	0.871	0.871	0.394	0.40	0.526
		1.085	**0.874**	**0.621**	**0.55**	**0.604**
Thaik-wa	Top	1.376	0.393	0.393	0.45	0.241
	Middle	1.388	0.328	0.402	0.33	0.331
	Bottom	1.229	0.895	0.351	0.22	0.872
		1.331	**0.720**	**0.382**	**0.33**	**0.481**
Hmyin-wa	Top	1.273	1.102	0.864	1.03	0.650
	Middle	1.121	0.480	0.841	1.21	0.981
	Bottom	1.127	0.857	0.623	0.62	0.621
		1.174	**0.813**	**0.776**	**0.95**	**0.754**

Table (8) The relationship between Starch content and weight loss of tested bamboo species

Species	Number of samples	Correlation coefficient (r^2)	Regression equation
Kyathaung-wa	5	0.628	Y= 6.053 x + 3.252
Tin –wa	5	0.771	Y= 19.65 x -7.315
Hmyin -wa	5	0.749	Y= 23.06 x – 11.33
Thaik-wa	5	0.940	Y= 20.67 x -6.013

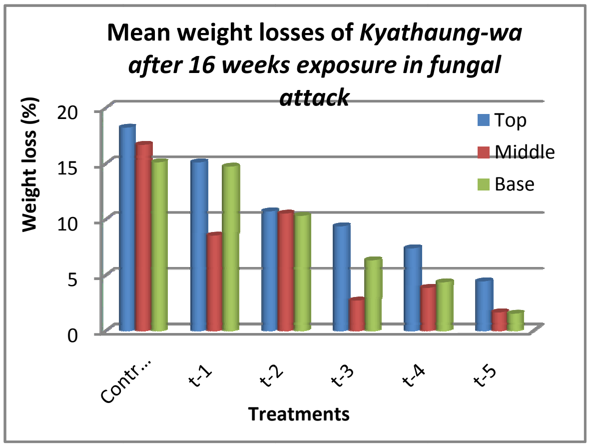

Fig.(4.1) Treatment effect of *Kyathaung-wa*

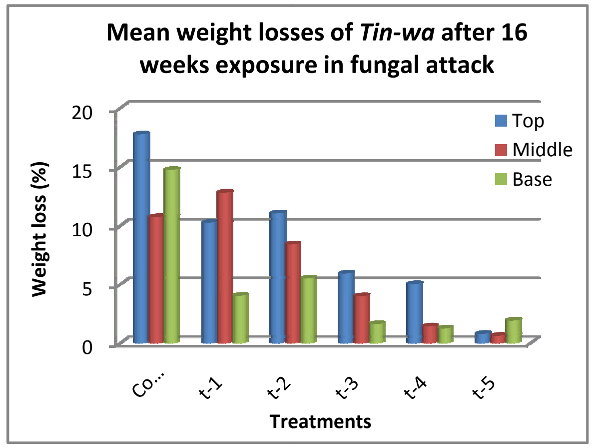

Fig. (4.2) Treatment effect of *Tin-wa*

Fig.1. Mean weight losses of *Kyathaung-wa*

Fig.2. Mean weight losses of *Tin-wa*

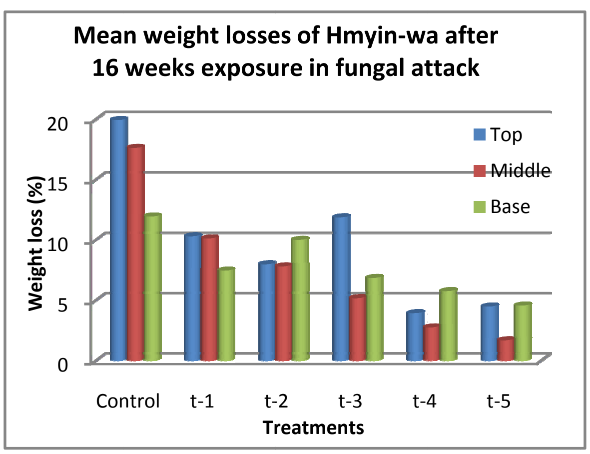

Fig.3. Mean weight losses of *Hmyin-wa*

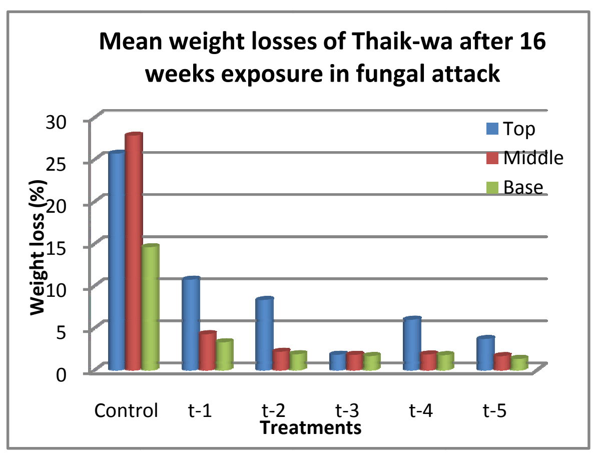

Fig.4. Mean weight losses of *Theik-wa*

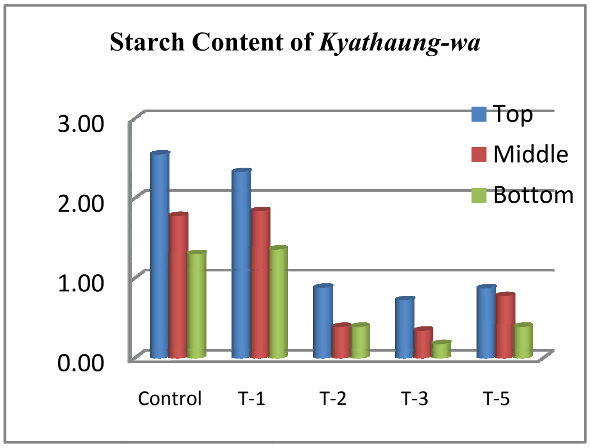

Fig.5. The starch content of *Kyatthaung-wa*

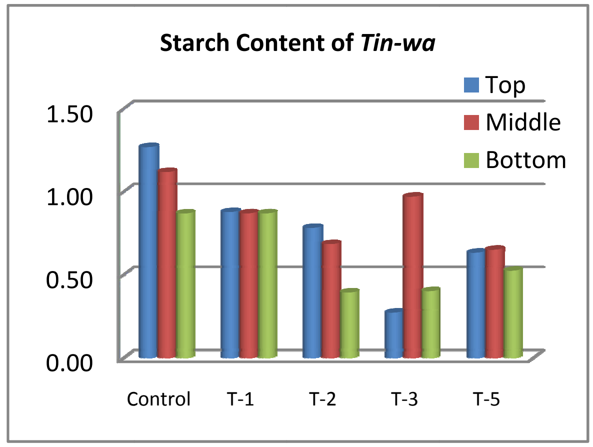

Fig.6. The starch content of *Tin-wa*

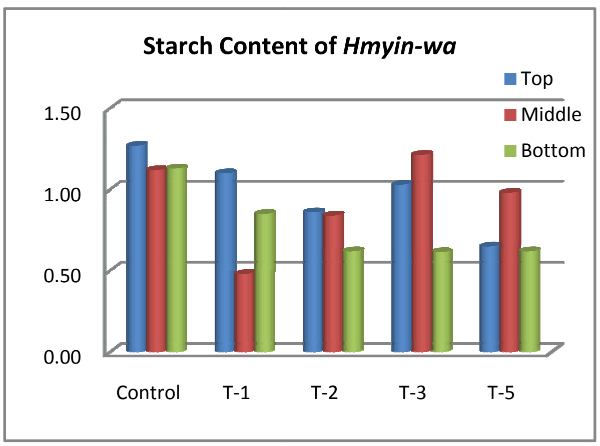

Fig .7. The starch content (%) of Hmyin wa

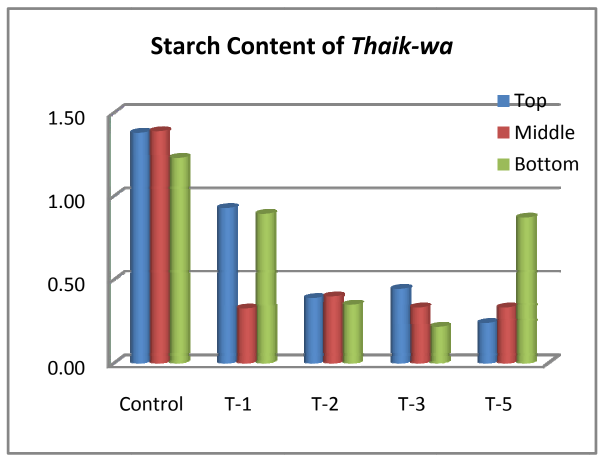

Fig .8. The starch content (%) of Thaik wa

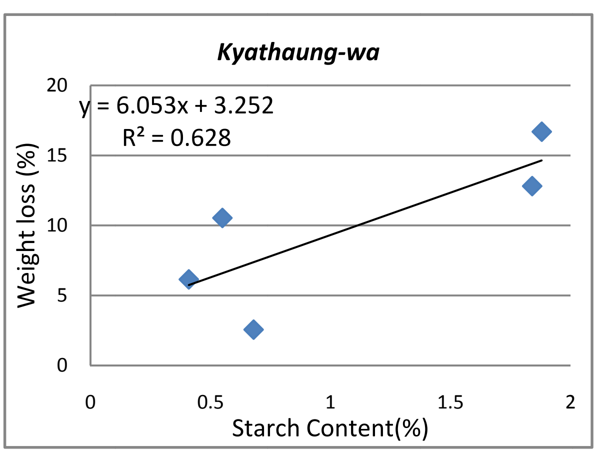

Fig. (9-a)

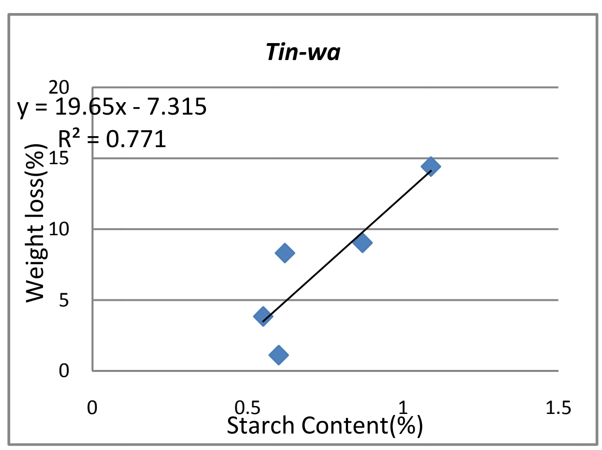

Fig. (9-b)

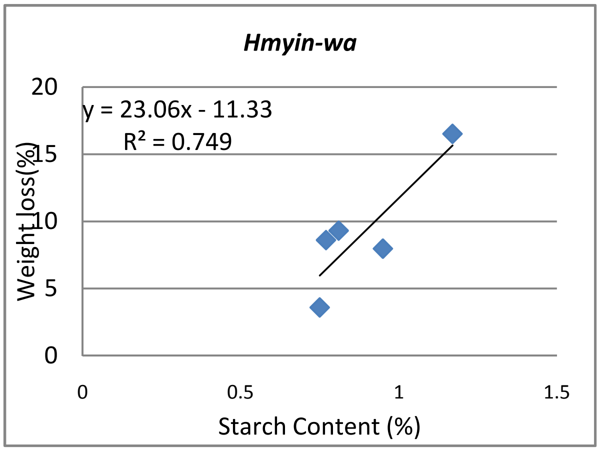

Fig. (9 -c)

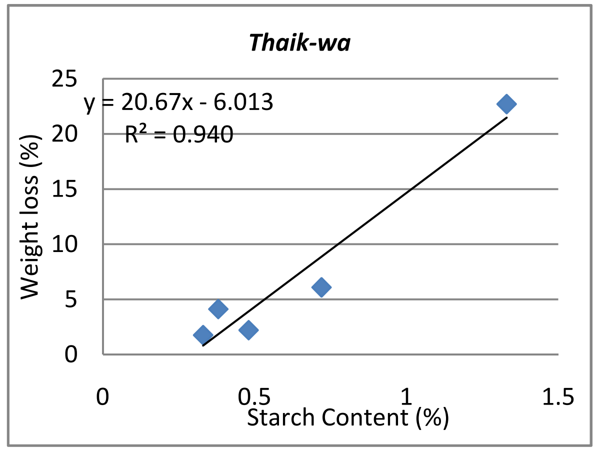

Fig. (9-d)

Fig. 9. The relationship between starch content (%) and weight loss (%)

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Appendix I

Some Commercial Bamboos of Myanmar according to the criteria of priority selection as in INBAR Technical Report 1.

No.	Name	Botanical Name	Major end use.
1	Hmyin-wa	*Dendrocalamus strictus* Nees.	Pulp & paper, building materials, agricultural implement, household utensil, shoot
2	Htiyo-wa	*Thyrsostachys siamensis* Gamble.	shoot, pulp & paper, handicraft, fence, wind break
3	Kayin-wa	*Melocanna bambusoides* Trin.	pulp & paper, construction, basket, roofing mats
4	Kyakhat-wa	*Bambusa arundianceae* (Retz) Wild.	construction, mats, baskets, shoots, medicinal
5	Kyathaung-wa	*Bambusa polymorpha* Munra.	building material, shoots, basket, pulp & paper
6	Tabindaing-wa	*Bambusa longispiculata* Brandis	shoots
7	Thaik-wa	*Bambusa tulda* Roxb.	building material, shoots, pulp & paper, handicraft, implement, (fodder, furniture)
8	Thanat-wa	*Thyrsostachys oliveri* Gamble	poles and fishing rod, shoots
9	Tin-wa	*Cephalostachyum pergracile* Munro.	handicrafts, mating, basket, temporatory construction
10	Wabo-wa	*Dendrocalamus brandisii* Kurz.	building construction, handicraft, shoot
11	Wabogyi	*Dendrocalamus giganteus* Munro.	building bamboo board, pulp, household implement, shoot
12	Wabo-myet-san-gye	*Dendrocalamus hamiltonii* Nees.	building construction, handicraft, shoots, fodder, weaving
13	Wagyi	*Dendrocalamus calostachys* Kurz.	house post, water pipe, utility
14	Wanet	*Dendrocalamus longispathus* Kurz.	building, basket, shoot
15	Wanwe	*Dinochloa m'clellandi*	basket, utility, shoot
16	Waya	*Oxytenanthera nigroceliata* Munro.	building, construction, handicraft, baskets, walking sticks.

Source : Soe Tint et al, 2004