Ministry of Environmental
Conservation and Forestry

Forest Department

Forest Research Institute

Decay Resistance of Acetylated Three Lesser - Used Timber Species of Myanmar

By

Cho Cho Win, Research Assistant -2, FRI
Dr. San Oo, Associate Professor, UOF
Prof. Win Kyi, Retired Rector, UOF

February 2012

မွမ်းမံနည်းဖြင့် ဆေးသွင်းပြုပြင်ထားသော
မြန်မာနိုင်ငံမှလူသုံးနည်းသစ်(၃)မျိုး၏ဆွေးမြေ့မှုခံနိုင်အားကို စမ်းသပ်လေ့လာခြင်း

ချိုချိုဝင်း၊ သုတေသနလက်ထောက်(၂)၊ သစ်ကြာရှည်ခံဌာနစိတ်
ဒေါက်တာဆန်းဦး (တွဲဖက် ပါမောက္ခ၊ သစ်တောတက္ကသိုလ်)
ပါမောက္ခဦးဝင်းကြည် (အငြိမ်းစားပါမောက္ခချုပ်၊ သစ်တောတက္ကသိုလ်)

စာတမ်းအကျဉ်း

ယခုသုတေသနလုပ်ငန်းတွင် မြန်မာနိုင်ငံမှ လူသုံးနည်းသစ်(၃)မျိုးအား မွမ်းမံနည်းဖြင့် ပြုပြင်ပြီး ယင်းတို့၏ဆွေးမြေ့မှုခံနိုင်အားကို စမ်းသပ်လေ့လာခဲ့ပါသည်။ လူသုံးနည်းသစ်(၃)မျိုးဖြစ်သည့် နှော၊ လယ်ဇနှင့် ပျဉ်းမသစ်နမူနာတုံးငယ်များကို အက်ဆီးတစ်အင်ဟိုက်ဒရိုက် ဆေးသွင်း၍ ပြုပြင်မွမ်းမံ ခဲ့ပါသည်။ ဆေးသွင်းရာတွင် လေဟာနယ်နှင့်ဖိအားသုံးခြင်းနည်းနှင့် ဆေးစိမ်ခြင်းနည်းများကို အသုံးပြုခဲ့ပါသည်။ ဆေးသွင်းထားသောသစ်နမူနာတုံးငယ်များ၏ ဆွေးမြေ့မှုခံနိုင်အားကို သိရှိနိုင်ရန် အတွက် **ခါတ်ခွဲခန်းတွင်းဆွေးမြေ့မှုစမ်းသပ်နည်း** ဖြင့်လည်းကောင်း၊ **မြေမြှုပ်စမ်းသပ်နည်း** ဖြင့်လည်းကောင်း (၁၆)ပတ်ကြာစမ်းသပ်ခဲ့ပါသည်။ ဆေးဝင်ရည်ပမာဏ ၃၀%ထက်မြင့်သည့် သစ်နမူနာများသည် သစ်ဆွေးမှိုဒဏ်ကို သိသာစွာခံနိုင်စွမ်း ရှိကြောင်းတွေ့ရှိရပါသည်။ ဆေးသွင်းပြုပြင်ထားသော သစ်နမူနာများသည် ဆေးမသွင်းထားသော သစ်နမူနာများနှင့်နှိုင်းယှဉ်လျင် သစ်ဆွေးမှိုဒဏ်ခံနိုင်အား ၉.၅ဆ မြင့်တက်လာကြောင်း တွေ့ရပါသည်။ ဆေးဝင်ရည်ပမာဏ ၁၅% မှ ၂၅% ထိရှိသော သစ်နမူနာများသည် ကြာရှည်ခံနိုင်မှုအဆင့် (၃) မှ အဆင့်(၂) သို့လည်းကောင်း၊ ဆေးဝင်ရည် ပမာဏ ၃၀%ထက်ပို၍များသော သစ်နမူနာများသည် ကြာရှည်ခံနိုင်မှုအဆင့်(၃)မှ အဆင့်(၁) သို့လည်းကောင်း မြင့်တက်နိုင်ကြောင်းသိရှိခဲ့ရပါသည်။

Decay Resistance of Acetylated Three Lesser -Used Timber Species of Myanmar

Cho Cho Win, Research Assistant -2, FRI
Dr. San Oo, Associate Professor, UOF
Prof. Win Kyi, Retired Rector, UOF

Abstracts

In this study, the decay resistance of three LUS was treated through wood modification (acetylation). The three LUS namely Hnaw (*Adina cordifolia*), Leza (*Lagerstromia tomentosa*) and Pyinma (*Lagerstromia speciosa*) were impregnated with acetic anhydride and acetic acid as catalyst by using two treatment methods such as vacuum-pressure method and dipping method. The decay resistance of test specimens was evaluated by laboratory decay test (agar-block test) and soil bed test. The non- acetylated and acetylated specimens were exposed to white rot fungus (*Pycnoporus sanguings* and *Schizophyllum commune*) for 16 weeks. For the resistance to the attack of soft rot, the test specimens were exposed to soil bed for 16 weeks. The oven dry weight loss percentage was used as a measure of severity of decay. Weight loss determination showed that acetylation provides a considerable decay resistance at weight percentage gain higher than 30%. Weight loss reduced 9.5 folds lower than the unacetylated one. The results reveal that increasing weight percent gain considerably reduced weight loss in the acetylated tested species. All of the tested non-acetylated three species lie in the moderately durable (Class III). After acetylation, the species were promoted to the Durable (Class II) by 15-25% WPG and to the very durable (Class I) by gaining above 30% WPG.

Key Word: Wood modification, Acetylation, Decay Resistance, Acetic anhydride, Durability

Contents

Decay Resistance of Acetylated Three Lesser -used Timber Species of Myanmar

1. Introduction

Wood is a very aesthetic material and it is world - wide available in a wide range of properties. Because wood is a renewable resource, it will become the material of future. Due to the disadvantages of naturally-grown wood species, the possibility to use timber products is still limited. The main drawbacks are swelling and shrinking behaviors that lead to checking and warping, inhomogenity, lack of dimensional stability, surface destruction by UV-light, high combustibility and corrosiveness. The most common disadvantage is degradation by fungi (eg. white rot, brown rot and soft rot) and by a number of insects. Hence, attempts to increase the durability against fungi and insects represent one of the tasks in wood research.

Preservative treatment of wood has a long history throughout the world. The main concern was focused on the traditional wood preservatives that are presently used to improve the durability of wood. A number of scientific research reports have been revealed that typical preservatives that contain toxic chemical bases, eg. Arsenic, copper, chromium or oil base chemicals, eg. Creosote, are problematic for the environment.

Reports indicate that creosote is carcinogenic (Karlehazen, 1990), arsenic leach out of the treated wood and pollutes soils and waters (Bergholm, 1990; Garcia& Rowland, 2001; Solo-Gabriele et al, 1998; 2000; 2002). Chromium is also toxic and produces dermal inhalation diseases (Chen et al, 2001). It leaches out due to rainfall (Gabriele et al, 2001). The use of these preservatives is being subjected to decrease because of their environmental impacts or some of them (eg. CCA) are going to be banded in Europe (Germany and The Netherlands) and USA (Schert, 2002; EPA Report, 2002) and Canada (PMRA Report, 2002).

Wood modification is a new approach to preserve wood against biological and climatological damages with environmentally friendly chemicals. In wood modification, the basic chemistry of cell wall polymers is altered which can improve important properties of wood including durability, dimensional stability, and hardness and UV- stability. The modified wood itself should be non-toxic substances under services conditions and furthermore, there should be no release of toxic substances during services or at the end of its life following disposal or recycling of the modified wood.

Acetylation treatment of Myanmar timber species had never been studied previously. In this study, three lesser used timber species of Myanmar were acetylated and the comparison study for the durability of acetylated and non-acetylated samples was made. The objective of this research is **to investigate the effectiveness of acetylation** on the durability of three LUS from Myanmar.

2. Literature Review

Chemical modification of wood will be more important in the area of wood preservation because of its ability to enhance the biological resistance of the end products

in use without a hazard to health and the environment. A wide variety of chemicals have been studied including anhydrides, acid chlorides, carboxylic acid, isocyanates, acetals, esters, alkyl chlorides and expocides (Rowell, 1983). Among them modification with acetic anhydride (Acetylation) is a well known technique in many industrial and scientific areas.

Acetylation involves a chemical reaction between hydroxyl groups in wood polymers, mainly the hydroxyl groups in lignin, hemicelluloses and amorphous parts of cellulose. The reaction results in the formation of covalent bonded groups in wood and formation of acetic acid as by-products product which can be converted into acetic anhydride and be used again.

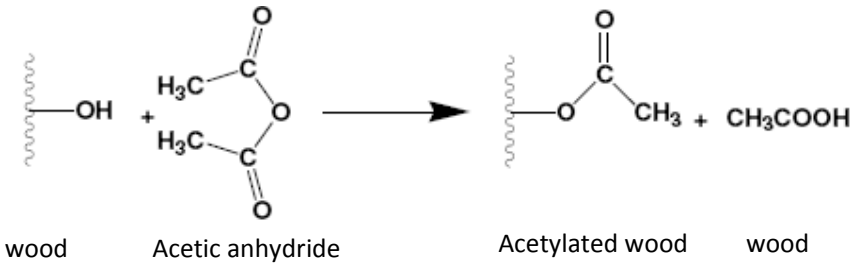

Figure 1: Reaction scheme of Acetylation with Acetic Anhydride

Like untreated timber, acetylated wood only consists of carbon, hydrogen and oxygen and, consequently, disposal of acetylated waste wood can be handled as untreated wood. Acetylation involves as in most chemical modifications, the reaction of hydroxyl groups which are the most abundant reactive chemical sites in wood. **Hydroxyl groups in cell wall polymers are not only the water adsorption sites but also the biological enzymatic reaction sites.** Wood rotting fungi and termites have a very specific enzyme system capable of degrading wood polymers into digestible units. Therefore, if the substance for these systems is chemically changed, this enzymatic reaction cannot take place (Takahashi, 1996).

Influence of the acetylation on wood properties depends on the method that is used. Uptake of acetic anhydride, reaction time, reaction temperature, initial moisture content, possible residual acetic acid in the wood and catalyst type and amount will influence chemical, physical and mechanical properties in the acetylated wood. (Behbood M., 2003). The effect of the treatment can therefore be expressed as a weight percent gain (WPG). A higher WPG represents a higher degree of acetylation.

Acetylated wood exhibits good resistance to brown rot, white rot and soft rot fungi (Beckers et al., 1994; Nilsson et al., 1988; Takahashi et al., 1989), but has been found to give no protection against the attack of mold and stain fungi, even at a weight gain of 20% (Beckers et al., 1994; Wakeling et al., 1992). Acetylation improves the resistance to subterranean termites (Imamura & Nishimoto, 1986). Acetylated wood also resisted marine borer attack, but the efficacy did not match that of samples treated with CCA or creosote (Johnson & Rowell, 1988).

For more than fifty years, there has been discussion as to why it is that acetylated wood is protected against attack by microorganisms. There have been many statements

made to the effect that 'the enzymes responsible for degrading the wood polymers are no longer able to recognize the material'. But it must be appreciated that enzymes commonly produced by fungi are not capable of penetrating the cell wall and so the blocking of enzyme activity is unlikely to be a significant mechanism.

By modifying wood with a variety of anhydrides it is possible to determine the relative importance of OH substitution against cell wall bulking as a protection mechanism. The first such study was of Corsican pine reacted with a variety of anhydrides and exposed to the brown rot fungus *Coniophora puteana* was reported by Papadopoulos and Hill (2002). Due to the acetylation, those hydroxyl groups were substituted by hydrophobic acetyl groups and wood becomes protected against absorbing surrounding humidity and decay by micro -organisms, e.g. fungi, etc. It is expected that fungi do not degrade wood due to this protection and due to lowering the moisture content in wood below the fungal limiting moisture contents. Following on from this work, a study was made to better understand the mechanism by which fungal attack was prevented (Hill et al. 2005). Hill et al. (2006) has investigated the decay of Corsican pine modified with acetic anhydride, showing conclusively that it is WPG rather than OH substitution that determines the degree of decay resistance.

Many reports showed and supported bio-resistant property of acetylated wood. However, it depends on the degree of acetylation. Reports have indicated that increasing degree of acetylation in wood, which is indicated by the WPG (weight percent gain), reduces or inhibits fungal activities. Fungal tests in different acetylated wood species have shown that fungi could not decay acetylated wood at higher weight gains. However, they colonize in those woods (Mohebby & Militz, 2002). Results for resistance of acetylated softwood were reported by the authors.

Goldstein et al. (1961) determined the resistance of acetylated **Southern yellow pine** to wood destroying fungi in a 3 month laboratory test and concluded that a 17% of WPG was sufficient to avoid attack. Acetyl;ation of **pine sapwood** to a WPG of 10.7% already prevented fungal attack. For poplar a WPG of 14.4% and for beech o WPG of 12.8% was required to achieve the same (Beckers et al., 1995). Peterson and Thomas (1978) tested white and Brown rot fungi and reported that the acetylation of wood has a high effect on decay at WPG of about 15% or more. Militz (1991) tested durability of acetylated wood against three types of brown rot fungi and reported no decay in treated wood.

A research by Okino et al. (1999) indicated that the decay by brown fungus became inhibited by acetylation at a WPG of more than 10% and mass loss due to decay became zero at a WPG of about 20%. The weight loss due to white rot fungus decreased slowly with the increase in WPG, reaching zero at a WPG of about 12%.

Ibach et al. (2000) tested bio-resistance of different acetylated wood against termites, brown rot and white rot fungi. Results showed acetylation was effective against brown rot fungus (*Tyromyces palustris*) and the white rot fungus (Coriolus *versicolo*r).

Takahashi et al. (1989) reported that enhancement of decay resistance by acetylation varies with used fungi and wood species. Takahashi (1996) revealed that brown rot fungi were more resistant to acetylation than white rot and soft rot fungi. For example, for a brown rot fungus (*Tyromyces palustris)*, the recorded weight loss was nil at WPG 20% and for a white rot fungus (*Coriolus versicolo*r) is also the same at WPG 12

– 15% at perishable hardwoods. It was also found that weight loss was reduced as WPG increased.

3. Material and Methods

3.1. Materials

3.1.1. Sample Preparation

The lesser-used timber species (LUS) tested in this study were collected from Phyukun and Kabaung Reserved Forests of Taungoo forest District, Bago Division. These wood samples have been authenticated under the ITTO Project at Wood Anatomy and Herbarium Sections of Forest Research Institute, Yezin. They were well storaged at Wood Preservation Section, FRI. Three LUS tested were:-

(1) Hnaw (*Adina cordifolia*),
(2) Leza (*Lagerstromia tomentosa*), and
(3) Pyinma (*Lagerstromia speciosa*). These species

Sample sticks of size (2″ x 2″ x 20″) were cut from the lower portion of the trunk and outer portion of the heartwood. The sticks were free from knots, drying defects and without visible evidence of fungus infection.

Then each stick was planed and cut into small blocks of size (12.5mm x 12.5mm x 25mm) for laboratory decay test and (10mm x 10mm x 100 mm) for soil bed test. Both ends of each block were coated with lacquer thoroughly to restrict the penetration of preservatives from the ends.

The preparation of test samples were based on BS (British Standard) 373-1957. The method of tests was conducted according to ASTM (American Society for Testing and Material) standard D-143-52 (Reapproved, 1965).

3.1.2. Chemical Used

Acetic anhydride (BDH, Chemicals Ltd Poole England) was used for acetylation of test species and acetic acid was used as a catalyst in this study.

3.2. Methods of Treatment

3.2.1. Acetylation

Acetylation was carried out using two different treatment methods namely, dipping method, Treatment-1 (T - I), and vacuum-pressure method, Treatment-2 (T - II).

For Treatment-1, acetic anhydride (BDH, Chemicals Ltd Poole England) and acetic acid (as a catalyst) were mixed in a glass – container in the ratio of 3:1. Then, test samples were dipped in the mixture of acetic anhydride and acetic acid for 6-8 hours.

For Treatment-2, acetic anhydride (BDH, Chemicals Ltd Poole England) and acetic acid (as a catalyst) were mixed in the ratio of 3:1 .The tested samples were placed in the treatment plant and then the mixture of acetic anhydride and acetic acid was poured into the treatment plant. Acetylation was carried out under the condition of temperature between 80-120°C and 15 psi pressure for 180 minutes (Beckers and Militz 1994, Beckers *et al.* 1994).

Fig 3.1. Acetylation by using dipping method

Fig 3.2. Acetylation by vacuum- pressure treatment

After acetylation, the samples were soaked in de-ionized water to remove un-reacted acetic anhydride and acetic acid by-product for several days until the smell of these chemicals was no longer detected. The extent of acetylation was determined by WPG in wood blocks because acetylation is a single – site reaction without polymerization and weight gain in acetyl can be converted into units of OH- groups blocked (Rowell, 1984). The weights after acetylation were recorded and the percentages of weight gains (WPG) of each sample blocks were calculated.

3.2.2. Laboratory Decay Test

Pycnoporus sanguings and *Schyzophyllum commune,* the white rot fungi were used in this study. The fungi specimen was cultured in 2% malt extract agar medium, kept in the room temperature and it was identified 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 for decay test 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.

The procedure taken for the fungus culturing for decay test was as follows:-

a) Acetylated and non- acetylated (control) 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 wood samples and the fungus in order to prevent the direct contact between them.
b) The test tubes were placed at ordinary room temperature and incubated for 16 weeks.

c) After completion of the incubation period, the blocks were taken out and attached mycelium was carefully cleaned.
d) 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.

3.2.3. Laboratory Soil Bed Test

The soft rot decay was assessed in non-sterile soil bed test. It can be determined the resistance of wood attacking soil microorganisms.

Fig 3.3. Soil beds with planted mini stakes in randomized WPG.

a) According to European Standard ENV 807(1993), soil beds were prepared in plastic containers (43 × 32 × 21 cm). The containers were filled with the soil mixture (river sand and nursery soil).
b) Water holding capacity (WHC) was determined and soil moisture was adjusted to 95%of its WHC.
c) Test sample were randomly planted into the soil vertically with 20mm of their length protruding above surface of soil and with a minimum between adjacent specimens and from sides of containers.
d) The prepared soil beds were kept under controlled conditions (temperature 26±1°C and relative humidity 65±5%).
e) Sampling interval was considered for 2months except for first sampling that was just for one month.
f) Any visual assessments were recorded and losses in mass were measured.

3.3. Method of Analysis

3.3.1. Determination of Weight Percent Gain

- The initial weight of each sample at air -dry condition was weighed and recorded as initial weight (Wu). The weights after acetylation were recorded as (W t).
- The WPG was calculated by using the following equation,

$$WPG\ (\%) = \frac{W_t - W_u}{W_u} \times 100$$

Where,

W_u is prior treatment and W_t is dry weight after treatment

3.3.2. Determination of Calculated Oven - Dry Weight of the Test Samples

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

- The initial weight of each moisture content sample at air -dry condition 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 sample at air dry condition was calculated by using the following equation.

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

Where, MC is moisture content of test samples, I. Wt. is initial weight of test samples and O.D. Wt is oven-dry weight of test samples.

3.3.3. Determination of Weight Loss Percent

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

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

where, C.O.D.Wt =calculated oven dry weight of the sample

In order to determine the weight loss percent of each of the test samples, the following formula was used.

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

Where, C.O.D Wt is calculated oven dry weight and F.O.D Wt is final oven dry weight of test samples.

3.3.4. Statistical Analysis

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

4. Results and Discussion

Results of the experiments were evaluated as average weight percent gain of individual species and as mean weight loss percent of individual species.

4.1. Weight Percent Gain of Tested Species (WPG %)

The WPG of tested species were shown in Table (4.1). According to this table, it can be seen that WPG of Hnaw and Leza were nearly the same (30.09% and 30.65%) for vacuum-pressure treatment and (24.5% and 25.9%) for dipping treatment. Pyinma has 17.91% for dipping and 24.86% for vacuum–pressure treatment.

The mean WPG of Hnaw ranges from16.98% to 30.5% by using dipping method. By using vacuum pressure method, the WPG of Hnaw ranges from 20.09% to 37.04%. As for Leza, 25.93% of WPG using dipping method and 30.65% of WPG using vacuum-pressure method were found. The mean WPG of Pyinma using dipping method ranges from 17.01% to 29.16%. For all species, vacuum-pressure treatment is higher in WPG.

Table (4.1) Average WPG of test samples at different Treatment Method

Species	Treatment	WPG (%)	SD
Hnaw	Control Treatment I Treatment II	0.0 24.505 30.087	- 4.843 5.238
Leza	Control Treatment I Treatment II	0.0 25.934 30.653	- 5.238 5.800
Pyinma	Control Treatment I Treatment II	0.0 17.91 24.856	- 1.873 4.248

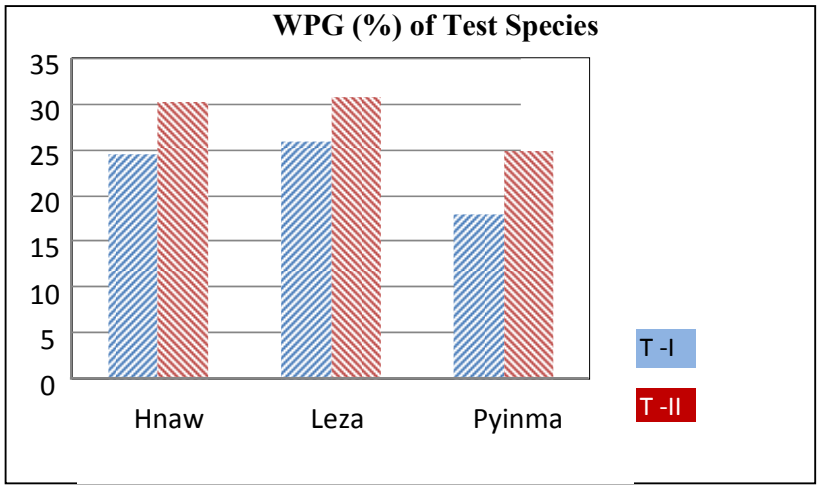

Figure (4.1) The weight percent gains of tested species

4.2. Effect of acetylation on the fungal resistance using laboratory decay test

Mean weight losses for each of the tested species of both non-acetylated and acetylated samples which were exposed to decay test are shown in Table (4.2). In order to clearly reveal the difference between the weight losses of un-acetylated and acetylated blocks, statistical analysis was carried out. To know the effects of treatment, the analysis of variance (ANOVA) was made by using an F-test. The F-test indicates highly significant difference between species and treatment by acetylation at 99% confidence interval. The ANOVA table was shown in the appendix (I).

Table (4.2) Average Weight Loss (%) of test samples based on WPG (%)

Hnaw		**Leza**		**Pyinma**	
WPG (%)	Wt. Loss (%)	WPG (%)	Wt. Loss (%)	WPG (%)	Wt. Loss (%)
0.00	9.93	0.00	8.89	0.00	9.08
18.10	3.70	14.65	3.70	18.07	4.93
24.15	2.90	23.37	2.38	23.92	3.59
29.22	2.21	27.69	1.32	26.52	2.27
34.28	0.89	35.75	0.93	28.62	0.95

The average weight loss of non – acetylated Hnaw samples was found to be 9.93%. According to the natural durability classification, it lies in moderately durable class. Figure (4.3) represents resistance of white rot attack in non-acetylated and acetylated Hnaw samples. The extensive white rot decay was found in acetylated wood samples at the lowest WPG (18.1%). At highest WPG of acetylation (34.28%), no decay was found. The acetylated Hnaw samples were 11 folds less than the loss in the non-acetylated samples.

Major weight loss (8.89%) was determined in non – acetylated Leza samples after 16 weeks of incubation. According to the natural durability classification, it also lies in moderately durable class. Figure (4.4) represents resistance of white rot attack in non-acetylated and acetylated Leza samples. An extensive white rot decay in acetylated wood samples at the lowest WPG (14.65%). The results showed that negligible weight loss (0.93%) was found at the highest weight gain (35.75%). The acetylated Leza samples were 9.5 folds less than the loss in the non-acetylated samples.

The average weight loss of non – acetylated Pyinma samples was found to be 9.08%. According to the natural durability classification, it also lies in moderately durable class. Figure (4.5) represents resistance of white rot attack in non-acetylated and acetylated Pyinma samples. The extensive white rot decay in acetylated wood samples at the lowest WPG (18.07%). At highest WPG of acetylation (28.62%), no decay was found. The acetylated Pyinma samples were 9.5 folds less than the loss in the non-acetylated samples.

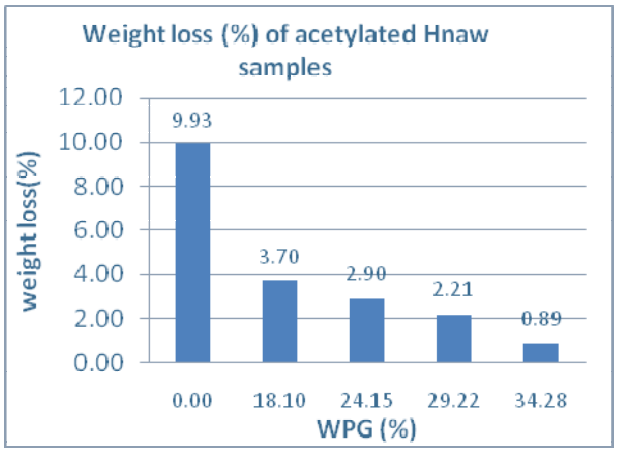

Fig (4.3) The weight loss (%) of Hnaw samples after 16 weeks exposure

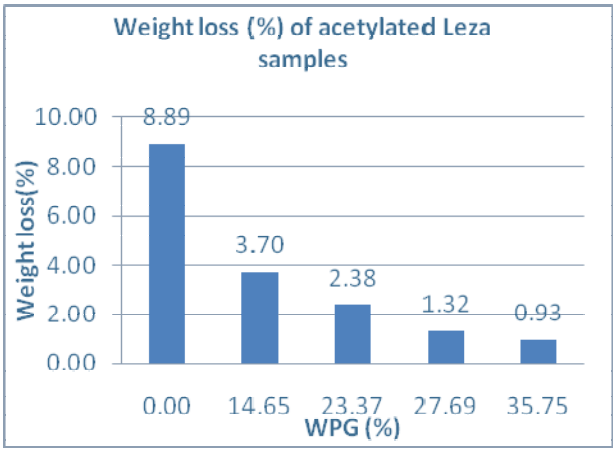

Fig (4.4) The weight loss (%) of Leza samples after 16 weeks exposure

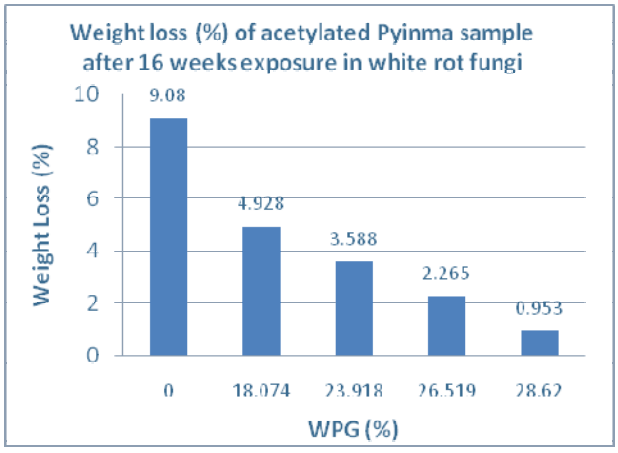

Fig (4.5) The weight loss (%) of Pyinma samples after 16 weeks exposure

According to Durability Classification, all the tested species lie in moderately durable class (class III). After acetylation, the species were promoted to durable class (Class II) by 15-25%WPG and to very durable class (Class I) by gaining above 30%WPG. Weight loss determination showed that acetylation provides a considerable bio-resistance at WPG higher than 30%, Weight loss reduced 9.5 folds lower than the non-acetylated one. The results reveal that increasing weight percent gain considerably reduced weight loss in the acetylated tested species.

Results were confirmed by other reports. Hill et al. (2006) has investigated the decay of Corsican pine modified with acetic anhydride, showing conclusively that it is WPG rather than OH substitution that determines the degree of decay resistance. According to the criteria for determination of natural durability as described in EN350 (1994), Corsican pine sapwood moves from class 5 (not durable) into class 1 (very durable) at 20% WPG.

In order to clearly reveal the correlation between the weight losses of acetylated samples and weight percent gain (WPG), statistical analysis was made by using the simple linear regression method. Figure (4.6), (4.7) and (4.8) illustrate the correlation between WPG (%) and weight loss (%) assessed by laboratory decay test of test species.

According to these figures, it was clearly indicated that weight loss (%) of test species were highly correlated to WPG at 0.01∝ - level by the following equations.

Table (4.3) The relationship between WPG and weight loss (%) for acetylated test species

Species	Number of samples	Correlation coefficient (r^2)	Regression equation
Hnaw	20	0.636	Y= -0.168x + 6.921
Leza	20	0.605	Y= -0.139x + 5.753
Pyinma	20	0.533	Y= -0.372x + 12.11

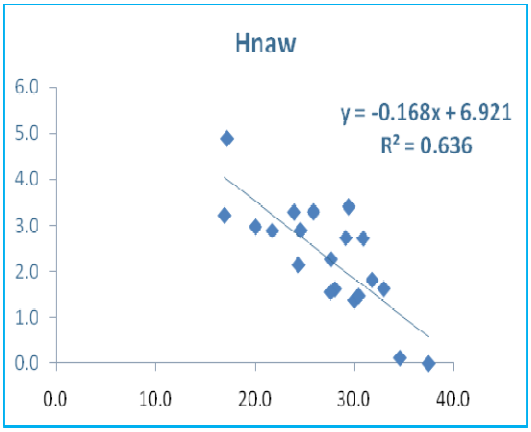

Fig: (4.6) The relationship between WPG and weight loss (%)for acetylated Hnaw samples

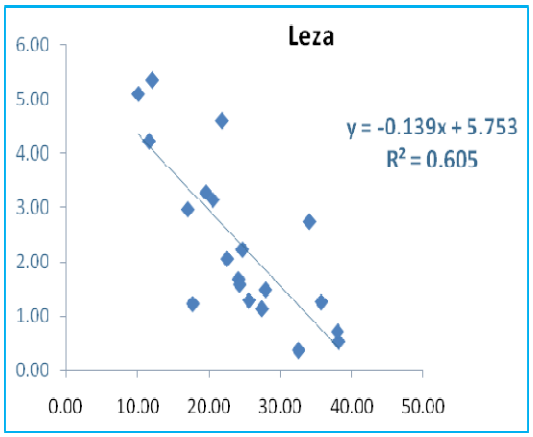

Fig: (4.7) The relationship between WPG and weight loss (%)for acetylated Hnaw samples

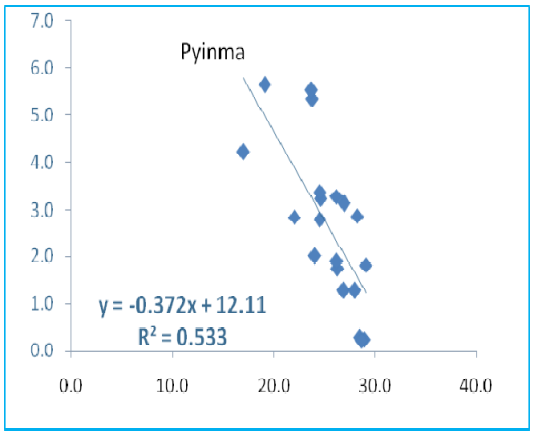

Fig: (4.8) The relationship between WPG and weight loss (%) for acetylated Pyinma samples

4.3. Effect of acetylation on the fungal resistance using soil bed test

Weight losses caused by soil microorganisms (soft – rot) were assessed in laboratory soil bed test for test species. The relative ability of the acetylation to prevent soft – rot decay in different weight percent gains is described in table 4.3. According to this table, Acetylation significantly inhibits microbial decay of wood in ground contact (mainly soft rot).

Table (4.4) Average Weight Loss (%) of test samples based on soil bed test.

Hnaw		Leza		Pyinma	
WPG (%)	Wt. Loss (%)	WPG (%)	Wt. Loss (%)	WPG (%)	Wt. Loss (%)
0.00	20.181	0.00	22.679	0.00	9.33
18.347	6.223	16.484	7.059	17.301	6.88
24.384	4.752	23.598	4.233	25.107	4.65
28.281	3.439	28.822	3.745	29.25	4.29
34.296	1.091	30.472	3.823	34.712	1.32

The results showed that raising the degree of the acetylation (WPG) reduces microbial decay in the acetylated wood. Results indicate that acetylation above 30% being considerably protect wood from the soft rot decay. However, the higher WPG are required for total protection in Leza. Figures (4.9, 4.10 and 4.11) give detailed weight loss data for wood modified with acetic anhydride. In these figures each point represents mean weight loss and WPG data for 10 stakes.

Figure (4.9) represents the resistance of soft rot attack in non-acetylated and acetylated Hnaw samples. An average weight loss of 20.18% was achieved in non –

acetylated control Hnaw stakes after 16 weeks exposure in soil bed test. It can also be found that a severe attack in non-acetylated wood samples. It can also be found that extensive soft rot decay in acetylated wood samples at the lowest WPG (18.347%). At highest WPG of acetylation (34.296%), slightly decay was found. It can easily be seen that from figure, only the stakes modifying with acetic anhydride was effective in controlling decay, with a threshold level of protection of approximately 34% WPG. This is higher than those levels to protected wood from decay by basidiomycete fungi in pure culture.

According to the natural durability classification, it lies in non-durable class. After acetylation treatment, it moves to durable class (Class II) with 20-30%WPG and to very durable class (Class I) over 30%WPG.

Major weight loss (22.679%) was determined in non – acetylated Leza stakes after 16 weeks of incubation in soil bed. Figure (4.10) represents resistance of soft rot attack in non-acetylated and acetylated Leza stakes. It can also be found that extensive white rot decay in acetylated wood samples at the lowest WPG (16.484%) and there remains decay (weight loss 3.823%) in even the highest weight gain (WPG 30.472%). This modifying chemical (acetic anhydride) proved less effective at protection Leza against soft rot than it did against white rot decay in pure culture tests, where thresholds of 35-40% WPG were estimated. No threshold level of protection appears achievable against soft rot fungi in these conditions.

The average weight loss of non – acetylated Pyinma samples was found to be 9.33%. It can also be found that a severe attack in non-acetylated wood samples. According to the natural durability classification, it also lies in moderately durable class. It can be assumed that Pyinma sample was more resistant to soft rot decay than Leza and Hnaw.

Figure (4.11) represents resistance of soft rot attack in non-acetylated and acetylated Pyinma samples. An extensive decay in acetylated wood samples was found at the lowest WPG (17.301%). At highest WPG of acetylation (34.71%), slightly decay was found.

The results by soil bed test showed that **it was necessary more weight gains to obtain the negligible weight loss against soft rot**. It can be carried out by using more concentrated acetic anhydride solution or by taking a long period of impregnation. This finding was agreed with Forster et al (1998). He reported that acetic anhydride failed to protect pine from soft rot decay, though WPGs were achieved maximum 15%. He estimated that any resultant uneven distribution across the cell wall may be reflected in a lesser ability of this chemical to protect against cell wall based soft rot decay than against decay by white rot or brown rot fungi.

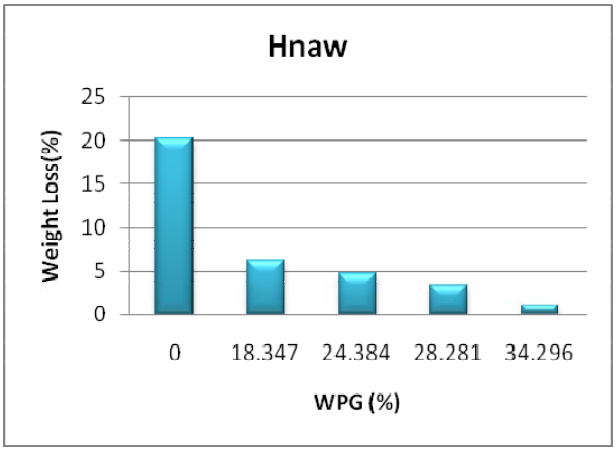

Fig (4.9) Weight loss (%) of un-acetylated and acetylated Hnaw samples after 16 weeks exposure in soil bed

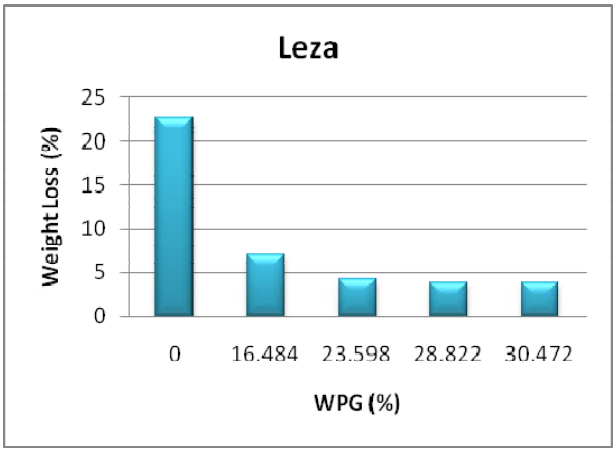

Fig 4.10 Weight loss (%) of un-acetylated and acetylated Leza samples after 16 weeks exposure in soil bed

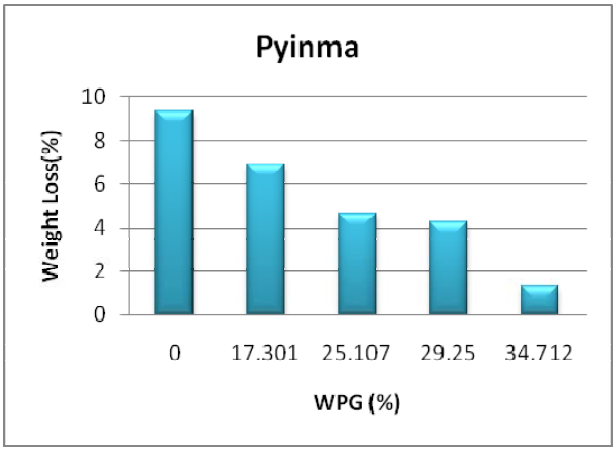

Fig 4.11 Weight loss (%) of un-acetylated and acetylated Pyinma samples after 16 weeks exposure in soil bed

In order to clearly reveal the correlation between the weight losses of acetylated samples and weight percent gain (WPG), statistical analysis was made by using the simple linear regression method. The relationship between WPG and weight loss for the test species were shown in Figure (4.12), (4.13) and (4.14). According to these figures, it was clearly indicated that weight loss (%) of test species were highly correlated to WPG at 0.01∝ - level by the following equations.

Table (4.5) The relationship between WPG and weight loss (%) for acetylated test species

Species	Number of samples	Correlation coefficient (r^2)	Regression equation
Hnaw	20	0.942	Y= - 0.305 x + 11.91
Leza	20	0.564	Y= - 0.272 x + 10.98
Pyinma	20	0.633	Y= - 0.230 x + 10.44

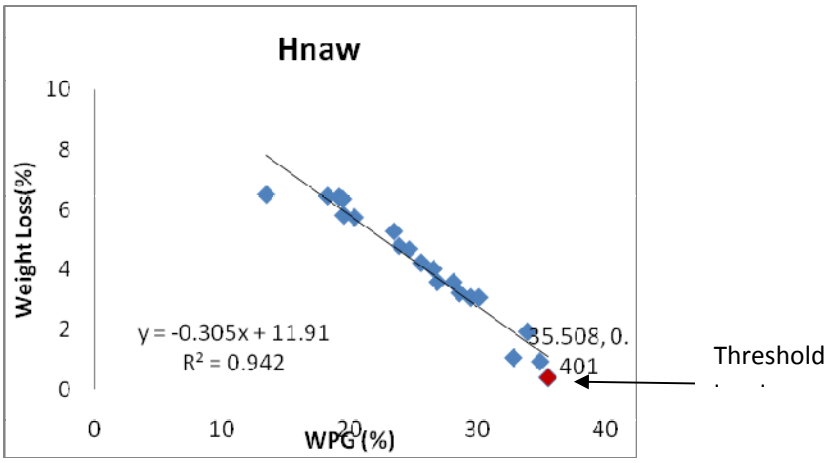

Fig: (4.12) The relationship between WPG and weight loss (%) for acetylated Hnaw samples

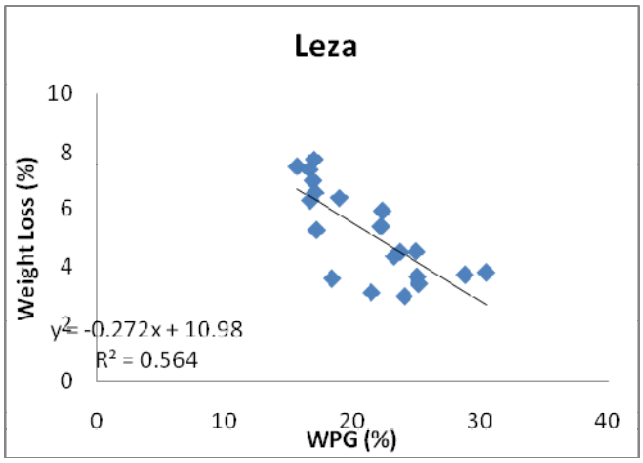

Fig: (4.13) The relationship between WPG and weight loss (%) for acetylated Leza samples

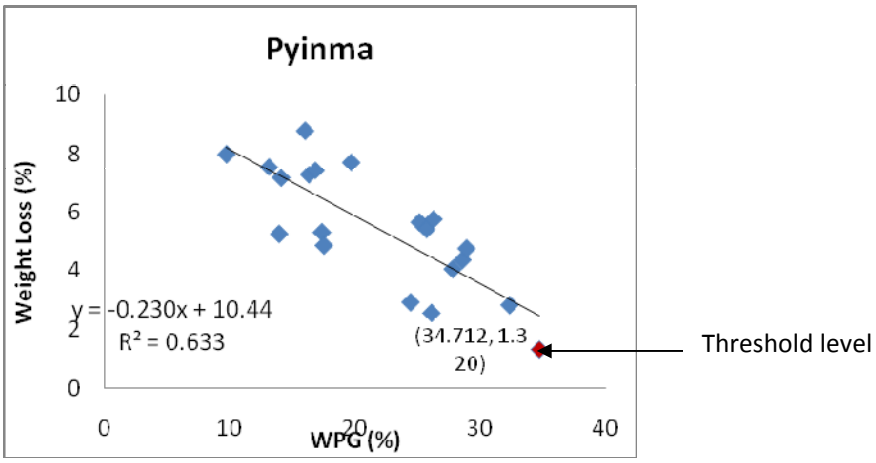

Fig: (4.14) The relationship between WPG and weight loss (%) for acetylated Pyinma samples

It can be seen that un-acetylated samples of test species were severely attacked by soft rot decay and acetylated samples of test species remain sound. However, some of samples which even at low level of acetylation the exterior of the stake remain sound. In these stakes the interior of the stakes was decayed while the outside remain sound. This is most likely to be due to higher WPGs being achieved at the stake surface. Although the modifying solution was vacuum impregnated into stakes, increased surfaced modification can occur from diffusion of addition of modifying chemical from the excess solution in which stakes were reacted.

This assessment has demonstrated that the modified Hnaw, Leza and Pyinma with Acetic anhydride improved its resistance to biological attack and confirms earlier findings (Goethals & Stevens, 1994; Rowell, 1991; Codd et al, 1992). This must be partly due to the lower moisture content associated with chemical modification since in most conventional fungal tests it is essential for the wood to research relatively high moisture content for fungal attack to commence. The soft rot soil bed tests (ENV 807) demonstrated most clearly that increasing the WPG associated with chemical modification increased resistance to wood destroying organisms and approximately 30% WPG was necessary to achieve virtually complete resistance.

5. Conclusion and Recommendation

According to the results it can be concluded that:

1) Acetylation treatment is significantly effective on the durability of three LUS of Myanmar.
2) According to the durability classification, the tested species improve from durability class III to class II at lower WPG level (20-30% WPG) and to class I with higher WPG level (over 30%).
3) The acetylation gives a good protection to the test species against white rot fungi (*Pycnoporus sanguings* and *Schyzophyllum commune,*above) 20% of WPG and weight loss determination also showed no fungal decay at higher WPG in the acetylated samples. Raising the degree of acetylation gives higher bio-resistance to tested wood.
4) A sufficient protection for soft rot can give at higher WPG level (34%) for all test species.
5) According to weight loss determination, acetylation provides a considerable bio-resistance at WPG higher than 30% and weight loss reduced 11 folds lower than unacetylated ones for Hnaw and 9.6 folds lower than unacetylated Leza and Pyinma.
6) The weight loss of test species was highly correlated with Weight Percent Gain.

Recommendation

One of the aims of modification of wood is the improvement of the dimensional stability of the wood. This is thought to be a result of lower MC of the wood because Hydrophylic hydroxyl groups are substituted by more hydrophobic side groups of the cell wall polymers. Some secondary modifications have permanently ultra-structural bulking effect, also resulting in increased dimensional stability. An antishrink efficiency of up to 80% is achieved by acetylation of wood (Beckers & Militz, 1994; Goldstein et al., 1961; Rowell & Plackett, 1988).

Chemical modification of wood has a positive, negative or indifferent effect on the mechanical properties of the wood. This lower MC can cause an increase in strength properties. Acetylation has been found to improve the mechanical strength of wood (Akitsu et al., 1993; Goldstein et al., 1961).

Positive effects on weathering are believed to be caused by improved dimensional stability (less cracks in the wood surface) and modification of lignin polymers which prevents surface degradation due to UV radiation. This result is color stabilizing and an improved weather ability effect. Acetylation reduces the rate of surface degradation due to UV radiation (Feist et al., 1991; Plackett et al., 1992; Dunningham et al., 1992).

Because of increased dimensional stability of the modified wood, the influence of changing RH on a acoustical properties is reduced. Reasonance frequency, an important factor in instrument tones, gets stabilized in the case of acetylated wood (Yano et al., 1986).

Because of the cost of acetylation wood, acetylated wood will find applications in value-added products. Since acetylated wood has greatly improved properties as compared to unmodified wood, codes and standards will need to develop. Consumer acceptance will require the education of architects, designers and purchasing agents as well as the general public. Acetylated wood could compete with chromate copper arsenate (CCA) in the market, but it would be limited by the amount of anhydride production.

For a unit size of 5/4 by 6 inches by 8 feet, the cost of acetylated lumber compared to that of standard treated wood and plastic lumber as follow: standard treated lumber is $ 0.50 to $0.65; Plastic lumber is $ 2.75 to $ 5.90 and very early estimates for acetylated lumber indicate $ 3.5 to $ 4.5. The range of prices depends on the seller. All of these cost projections depend on the price of acetic anhydride and the costs related to chemical recovery, equipment and processes (anon; 2010).

References

Akitsu H., Norimoto M., Morooka T., Rowell R. M. (1993): Effect of humidity on vibrational properties of chemically modified wood. *Wood and Fiber Science* 25(3): 250-260.

Anon (2010): Acetylation of wood: journey from analytical technique to commercial reality. Forest Product Journal.

Beckers E. P.J., Militz H., Stevens M. (1994): Resistance of acetylated wood to basidiomycetes, soft rot and blue stain. International Research Group on Wood Preservation, Doc. No. IRG/ WP/ 94-40021.

Beckers E.P.J., Militz H., (1994): Acetylation of solid wood - Initial trials on lab and semi industrial scale. Second Pacific Rim.

Bergholm J (1990): Studies on the mobility of Arsenic, Copper and Chromium in CCA contaminated soil; International Research Group on Wood Preservation, Doc. No. IRG/WP/3571.

Chen J., S. Malish & T. McMathon; (2001): Inorganic Arsenic- Report of the hazard identification assessment review committee; Research Report; Florida Centre for Soil and Hazardous Waste Management: p. 16

Cooper P.A (1990): Disposal of preserved wood- Canada; International Research Group on Wood Preservation, Doc. No. IRG/WP/3563.

Dunningham E. A., Plac-kett D. V., Singh A. P., (1992): Natural weathering of acetylated radiate pine: preliminary results. *Holz als Roh- und Werkstoff* 50: 429-432.

EPA (2002): Whitman announcer's transition from consumer use of treated wood containing arcenic; U.S Environmental Protection Agency.

Feist W.C., Rowell R. M., Ellis W. D., (1991): Moisture sorption and accelerated weathering of acetylated and methacrylated aspen. Wood and Fiber Science 23 (1): 128-136.

Garcia J. J. & J.G. Rowland (2001): What you need to know about pesticides used in pressure treated wood; FACT SHEET; Feb 2001:p. 4.

Goldatein I.S., E.B. Jeroski, A.E. Lund, J.F Nielson & J. W. Weaver (1961): Acetylation of wood in Lumber thicknesses; Forest product Journal; 11(8): 363-370

Johnson B. R., Rowell R. M., (1988): Resistance of chemically modified wood to marine borers. Material und Organismen, 23(2): 147-156.

Karlehazen S (1990): Creosote and cancer, The International Research Group on Wood Preservation; Doc. No.IRG/WP/3572.

Larsson P. B. (1998): Acetylation of solid wood: Ph. D. thesis; Chalmers University of Technology; Götteborg, Sweden.

Matsuda H. (1996): Chemical modification of solid wood. In: D. N. S. Hon(ed) *Chemical modification of Lignocellulosic material*, Marcel Dekker, Inc; New York, Basel, Hong Kong p. 159-183.

Militz H, &E. P. J. Beckers (1994, a): Acetylation of solid wood Second Pacific Rim Bio based composites Symposium; Vancouver Canada125-135.

Militz H, &E. P. J. Beckers (1994, b): Process for acetylation of solid wood; European Patent Application 85850268.5.

Nilson T., Rowell R. M., Simonson R., Tillman A.M. (1988): Fungal resistance of pine particle boards made from various types of acetylated chips. *Holzforschung* 42(2): 123-126.

Plackett D. V., Dunningham E. A., Singh A. P. (1992): Weathering of chemically modified wood- accelerated weathering of acetylated radiate pine. *Holz als Roh- und Werkstoff* 50: 135-140.

Rowell R.M., R. Simonson & A. M. Tillman (1985): A process for improving dimensional stability and biological resistance of lignocellulosis materials; European Patent Application 85850268.5.

Rowell R.M., R. Simonson & A. M. Tillman (1986, a): A simplified procedure for the acetylation of chips for dimensional stabilized particleboard products; Paperi ja Puu 68 (10): 740-744.

Rowell R. M., Plackett D. V.(1988): Dimensional stability of flakeboards made from acetylatedPinus radiate heartwood or sapwood flakes. New Zealand Journal of Forestry Science 18(1); 124-131.

Rowell R.M., R. Simonson & A. M. Tillman (1990): Acetyl balance for the acetylation of wood particles by a simplified procedure, Holzforschung; vol. 44(4)263-269.

Schert J. (2002): The phase out of CCA in the United States; Int.Research Group on Wood Preservation, Doc. No. IRG/WP/ 02-50194

Solo-Gabriele H.M., J. Penha, V. Catilu & T. Tolaymat (1998) : Generation, use, disposal and management options for CCA –treated wood ; Research Report No. 98-1; Florida Centre for Soil and Hazardous Waste Management: p. 84.

Solo-Gabriele H.M., M. Kormienko & B. Messick (1999): Disposal of CCA-treated wood: An evaluation of existing and alternative management options; Research Report No. 99-6; Florida Centre for Soil and Hazardous Waste Management: p. 137.

Solo-Gabriele H.M., T.G Townsend (2000): Alternative chemicals and improved disposal-end management practice for CCA- treated wood; Research Report No. 00-03; Florida Centre for Soil and Hazardous Waste Management: p. 203

Solo-Gabriele H.M., T.G Townsend, B. Messick & V. Calitu (2002): Characteristics of chromated copper arsenic treated wood ash; Journal of Hazardous Materials; B89: 213-232,

Stamm A. J.,& H. Tarkow(1947): Dimensional Stabilization of wood, Journal of Phys. And Colloid Chem.; 51: 493-505.

Takahashi M., Imamura Y., Tanahashi M. (1989) : Effect of acetylation on decay resistance of wood against brown rot, white rot and soft rot fungi. Int. Research Group on Wood Preservation Doc. No. IRG/WP/ 3540:1-16

Tarkow H., A.J. Stamm & E.C.O. Erickson (1950): Acetylated Wood; USDA Forest Service, Forest Prod. Lab. Report No. 1593.

Wakeling, R. N., D. V. Plackett & D. Cronshaw (1991): The susceptibility of acetylated Pinus radiate to mould and stain fungi. Int. Symposium on Chemical Modification of Wood. Kyoto, Japan. 142-147.

Yano H., Minato K. (1993): Controlling the timber of wooden musical instruments by chemical modification. Wood Science and Technology, 27: 287-293.

Table 1. ANOVA table for Hnaw with Decay Test

Source of Variation	df	SS	MS	F	Tabular F	cv(%)
Treatment	2	371.267	185.633	132.609*	3.35	23.77
Error	27	37.796	1.4000			
Total	29	409.062				

Table 2. ANOVA table for Leza with Decay Test

Source of Variation	df	SS	MS	F	Tabular F	cv(%)
Treatment	2	305.514	152.757	165.573*	3.35	21.18
Error	27	24.910	0.923			
Total	29	330.424				

Table 3. ANOVA table for Pyinma with Decay Test

Source of Variation	df	SS	MS	F	Tabular F	cv(%)
Treatment	2	277.341	138.670	36.781*	3.35	40.5
Error	27	101.795	3.770			
Total	29	379.135				

Table 4. ANOVA table for Hnaw with Soil Bed Test

Source of Variation	df	SS	MS	F	Tabular F	cv(%)
Treatment	2	1720.579	860.290	9.95	3.35	
Error	27	2333.605	86.430			
Total	29	4054.185				

Table 5. ANOVA table for Leza with Soil Bed Test

Source of Variation	df	SS	MS	F	Tabular F	cv(%)
Treatment	2	2043.241	1021.62	26.46901	3.35	
Error	27	1042.115	38.5969			
Total	29	3085.356				

Table 6. ANOVA table for Pyinma with Soil Bed Test

Source of Variation	df	SS	MS	F	Tabular F	cv(%)
Treatment	2	317.6167	158.808	4.100202	3.35	
Error	27	1045.76	38.7318			
Total	29	1363.376				