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Evaluation the Decay and Termite Resistance of Untreated and Treated In (*Dipterocarpus spp:*)

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အင်သစ်ကို ကြာရှည်ခံ ဆေးအမျိုးမျိုးသုံး၍ ကြာရှည်ခံနိုင်မှုပြောင်းလဲပုံကို လေ့လာခြင်း

လွင်လွင်အောင်၊ သုတေသလက်ထောက် -၂
ချိုချိုဝင်း၊ လက်ထောက်သုတေသနအရာရှိ
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

အင်သစ်သည် မြန်မာနိုင်ငံအထက်ပိုင်း၊ စစ်ကိုင်းတိုင်းနှင့် ကချင်ပြည်နယ်တို့တွင် အများဆုံး ပေါက်ပြီး ကြီးထွားမှုကောင်းမွန်ခြင်းနှင့် အပင်ဖြောင့်တန်းခြင်းတို့ကြောင့် ထင်းရှားပါသည်။ အင်သစ် (*Dipterocarpus tuberculatus.* Roxb) သည် အင်အားဆိုင်ရာ ဂုဏ်သတ္တိအားလုံးတွင် ကျွန်းသစ်နှင့် နှိုင်းယှဉ်နိုင်သည်အထိ အင်အားကောင်းပါသည်။ သစ်သား၏အရောင်မှာ နီညိုရောင်ဖြစ်သည် (ဝင်းကြည်− ၂၊ ၁၉၈၈)။ သိပ်သည်းခြင်းမှာ air-dried အခြေအနေတွင် ၈၉၇ kgm^{-3} (ကျွန်း − ၆၇၃ kgm^{-3}) ရှိပြီး ရေချိန် သိပ်သည်းဆမှာ ဝ.၇၅ (ကျွန်း- ဝ.၅၉၈) ရှိပါသည် (ဝင်းချစ်၊ ၂၀၀၅)။ မြန်မာနိုင်ငံတွင် အလယ်အလတ် အဆင့်ရှိ ဆောက်လုပ်ရေး ပစ္စည်း (Medium grade structural timber) အဖြစ် အသုံးပြုလေ့ရှိပါသည်။ အင်သစ်ခွဲသားများကို အဆောက်အဦများဆောက်လုပ်ရန်နှင့် ကုန်တင်ကားများကိုယ်ထည်ပြုလုပ်ခြင်း၊ အထပ်သားအတွက် သစ်ပါးလွှာပြုလုပ်ခြင်းတွင် အများဆုံးအသုံးပြုကြပါသည်။ ၎င်းသစ်၏ အဓိကပြစ်ချက်မှာ ခြစားမှုဒဏ်နှင့် သစ်ဆွေးမှိုဒဏ်ခံနိုင်စွမ်း နည်းပါးခြင်းဖြစ်သည်။ ယခုစာတမ်းတွင် အင်သစ်များအား Boric Acid နှင့် Borax ဖျော်ရည်တွင် စိမ်ခြင်း၊ Acetic anhydride နှင့် Acetic acid ဖြင့် ဖိအားသုံးဆေးသွင်းခြင်း စသည့် ပြုပြင်မှုများပြုလုပ်ပြီး သစ်ဆွေးမှိုခံနိုင်စွမ်းစမ်းသပ်ချက်၊ ခြစားခံနိုင်မှုစမ်းသပ်ချက် စသည်တို့ ဆောင်ရွက်ခဲ့ပါသည်။ စမ်းသပ်ချက်များအရ သစ်ကြာရှည်ခံဆေးများဖြင့် ဆေးသွင်းပြုပြင်ခြင်းအားဖြင့် သစ်ဆွေးမှိုဒဏ်နှင့် ခြစားခံနိုင်မှု စွမ်းရည်တို့ ပိုမိုမြင့်တက်လာကြောင်းတွေ့ရှိရပါသည်။ သို့ဖြစ်ပါ၍ အင်သစ်အား အသုံးပြုမည် ဆိုပါက ပိုမိုကြာရှည်ခံနိုင်စေရန် ဆေးသွင်း၍ အသုံးပြုနိုင်ပါရန် လေ့လာတင်ပြထားပါသည်။

Evaluation the Decay and Termite Resistance of Untreated and Treated In (*Dipterocarpus spp:*)

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Abstract

In (*Dipterocarpus tuberculatus* Roxb.) was used as structural timbers. *Dipterocarpus* is a large and economically important genus. The timber is relatively strong in all mechanical aspects compared with teak. It is reddish-brown in color, resinous, and hard. The density is approximately 53 pcf at 12 % moisture content. Shrinkage from green to oven-dry is 4.4% radially and 9.1% tangentially. It is commonly used as a medium grade structural timber. It is moderately resistant to decay, but not resistant to termites. In this study, two methods such as dip-diffusion treatment using 10% concentration of Boric acid & Borax solution and vacuum pressure treatment using acetic anhydride by the catalyst of acetic acid were used. The average weight loss in dry weight percent of Acetylation treated In (*D. tuberculatus*) was found to be 2.56 and durability move to Durable Class (Class II). Similarly, the weight loss percent of Borate treated samples was found to be 3.89 and the durability classification is promoted to Durable Class. In the case of Polybor, the weight losses of treated samples were found to be 4.47 and it also lies in the Durable Class (Class II). Therefore preservation causes the upgrading of the durability of tested species.

Content

Evaluation the Decay and Termite Resistance of Untreated and Treated In (*Dipterocarpus spp:*)

1. Introduction

In (*Dipterocarpus tuberculatus* Roxb.) was used as structural timbers. *Dipterocarpus* is a large and economically important genus indigenous to Sourthern Asia. The various species within the genus are generally not segregated by the timber trade because of the difficulty of differentiating between them. Anatomical differences between the woods of various species are not obvious, although there is a considerable range in density reported in the literature.

The timber is relatively strong in all mechanical aspects compared with teak. It is reddish-brown in color, resinous, and hard. The density is approximately 53 pcf at 12 % moisture content. Shrinkage from green to oven-dry is 4.4% radially and 9.1% tangentially. It is commonly used as a medium grade structural timber.

It is moderately resistant to decay, but not resistant to termites. It is durable under cover, but not so in exposed condition. The disadvantage is its susceptibility to termite attack. Preservation is one of the resource management strategies. This report represents the initiative for termite resistant testing effect in Forest Research Institute, Myanmar.

Dipterocarpus tuberculatus is strong enough to use in structural applications. As it is extremely difficult to treat, enhancement of its durability will be difficult and thus its utilization is limited to indoor applications. When treated with oil and creosote, it lasts for 8 years under tropical conditions. The timber lends itself to preservative treatment but complete penetration as not always obtained. Modification with Acetic anhydride is the most promising process to upgrade their properties because it not only improves durability and physical properties, but also enhances some mechanical properties like side compression strength and surface hardness.

In the present research, we performed laboratory evaluations of selected In (*D. tuberculatus*) wood species (primarily heartwood, since sapwood rarely resists termite or decay) using standard laboratory method for termite resistant testing (AWPA 1997, Grace 1998).

The objectives of this study is

- To study the natural durability of *Dipterocarpus tuberculatus* (In) by evaluation of resistance to decay and termite tests.
- To compare the treatment quality of In which is plentiful enough to meet the internal demand as building materials using suitable preservatives to prolong its service life.
- From the results obtained, to suggest how this In species could be treated for various end uses.

2. Literature Review

In (*Dipterocarpus tuberculatus* Roxb.) belongs to the family *Dipterocarpaceae*. Generus *Dipterocarpaceae* consists of 19 genera and approximately 380 species of trees or rarely shrubs. The family is typically Indo-Malayan and in points of members attains its best development in the Malay Archipelago, extending eastward into New Guinea and northward to the Philippines (approx. 70 spp.) and into northern India to 32° Latitude.

Dipterocarpus tuberculatus is a deciduous tree, usually with a large but open crown, generally growing 15 - 25 metres tall, occasionally to 30 metres on good soils. The bole is short, cylindrical, straight but sometimes gnarled, generaly 40 - 60cm in diameter. The stem form is usually very good on good soils. This species grows in the range of E. Asia - Bangladesh, Myanmar, Thailand, Cambodia, Laos, Vietnam.

It grows gregariously in many parts of Burma. In (*Dipterocarpus tuberculatus* Roxb.) is the important role in timber production because it produce more timber the trees of all other families. This is in part due to the enormous size ans long clear boles of many of these trees. It is obtained able in large size and is available in large quantities. It is used as constructional materials in Myanmar.

The natural durability of timbers is determined from data obtained through field trials by long term exposure of timbers to biodegrading organisms in the field (Jackson, 1957). Many researchers had used this procedure for classifying natural durability of timbers (Anon 1975; Anon 1979; Chudnoff 1984; Matsuoka et.al 1984; Mohd. Dahlan & Tam 1985; L.T. Hong 1989). Such tests give good estimates of the natural durability because timbers are exposed to various types of biodeteriorating agents. This kind of study usually takes a long time to predict the life time of species tested in service.

Laboratory tests, however, are simple and obtain the results in a matter of months. Laboratory tests require small specimens of wood exposed to the conditions favourable for the rapid growth of wood-rotting fungi. Percentage weight losses of the specimens at the end of period tested is used as the parameter of decay development since wood-rotting fungi decompose structural material of wood into gases and water (Win Kyi -2, 1995).

In order to provide rapid evaluation of the relative durabilities of species, a series of laboratory tests of the relative decay and resistance of different species was carried out (Da Costa and Aplim, 1959; Da Costa et al. 1957). Among the laboratory decay tests, soil-block test (ASTM Standard) was used in this research.

In Myanmar, owing to the systematic management of the forest and wealth of the nation having durable species as Kyun, Pyinkado and Thit-ya, Ingyin, preservation of timber is still neglected in Industrial Wood Preservation Sector. However, earth oil has long been used traditionally elsewhere in the country as a wood protecting material. Use of Earth oil as wood preservative has been a lifelong practice in Myanmar. Earth oil protects wood from soaking by rain thereby prevent the growth of wood-rotting fungi.

Treatment of wood with creosote-disel oil using hot and cold bath process was found in limited area such as Myanma Railway-Sleepers Treatment Plant in Myohoung, (near

Mandalay) from 1955-1985. With the scarcity and steady increased price of imported wood preservative, Furnace Oil (FO) and Coker Gas Oil (CGO) were used in the place of creosote.

In 1984, Preservation of In (*Dipterocarpus tuberculatus*) by using vacuum-pressure impregnation technique with Tanalith- C was carried out at No. (75) Sawmill, O-Bo-Taung, Monywa Township, Sagaing Division.

Treatability of In (*D. tuberculatus*) with copper, chromium and arsenic water borne preservatives were carried out by Win Kyi -2 (1988) and results of the experiment were evaluated as calculated retention of the treating chemicals and as deposition and fixation of copper and chromium, analyzed using Atomic absorption Spectroscopy. He reported that the specimens of *D. tuberculatus* from the vacuum pressure process showed the very poor in penetration.

The treatability and performance of In (*D. tuberculatus)* was tested by Austen Nyunt (1988). The durability after treatment with three different types of wood preservatives using vacuum pressure treatment was studied and he also reported that the tested species was quite refractory in vacuum pressure treatment.

3.Materials and Methods

3.1. Sample Preparation

In this research, wood samples were collected from saw mill and 20 numbers of (3″x 2″ x 10′) stick were used. It was started on 2011-2012. These wood samples were identified at Wood Anatomy section of Forest Research Institute, Yezin.

For decay test, 12.7 mm x 12.7 mm x 25.4 mm blocks and for termite resistance evaluations, 20 mm x 20 mm x 20 mm blocks were cut from the heartwood of tested samples. Ten replications were prepared for each treatment and each test.

3.2. Preservation Treatment

In this study, two methods such as dip-diffusion treatment and vacuum pressure treatment were used.

3.2.1. Dip-diffusion treatment

The green wood blocks of In (re-saturated by vacuum/pressure with water) samples were dipped in 10% concentration of Boric acid & Borax solution for 30 minute. The treated samples were wrapped in plastic bags for diffusion. The initial weight and after treated weight of tested sample were weighed. After that the weight gained (retention) were calculated.

3.2.2. Vacuum-pressure treatment

The prepared samples were impregnated with acetic anhydride by the catalyst of acetic acid using vacuum-pressure method. The acetylation procedure 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). Acetic anhydride (BDH, Chemicals Ltd Poole

England) and acetic acid (as a catalyst) were mixed in the ratio of 3:1. The control specimens were water impregnated.

After acetylation, the samples were soaked in de-ionized water to remove un-reacted acetic anhydride and acetic acid by-product within a few days until the smell of these chemicals was no longer detected. The weights after acetylation were recorded. The percentages of weight gains (WPG) were calculated the following formula.

$WPG = (W_t - W_u) / W_u \times 100$ ……. eq: (3.1)

Where,

WPG = percentages of weight gains,
W_u = the dry weight before treatment and
W_t.=after treatment

3.3 Laboratory Decay Test

In order to provide rapid evaluation of the relative durability of species, laboratory tests of the relative decay resistance was carried out. Agar-block test (widely used in Europe and specified in British standard and German standard DIN52176) was used in this research. The monoculture decay test was designed to determine the fungicidal efficacy of three preservatives using white rot fungus *Coriolus versicolor.* This fungus was identified at Pathology lab of FRI. In hardwoods, white rot fungi were common. Only white rot fungi were tested in this study since these fungi are common to hardwood. The fungi specimen was cultured in Potatoes- Dextrose Agar (PDA) media.

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 test 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.

3.4 Evaluation of Termite Resistance

3. 4.1. Determination of Initial Mass

Initial mass of specimen were weighed after 48 hours at 60°C in oven. After weighing, these samples were kept at laboratory room temperature at least over 1 night.

3.4.2 Termite Attack

Traditionally, field test methods for determining the efficacy of wood preservatives against termites involved large scale outdoor field trials of poles or stakes. Trails of this type can take between five to ten years for stakes (Ruddick, 1989) and upwards to twenty years for poles to yield any meaningful results. As a result a need for a more rapid, interim evaluation of the regimes and chemicals tested became apparent (Desch and Dinwoodie, 1981; Johnson et al, 1982).

Internationally, various accelerated test methods, including laboratory and field exposure tests, have been developed over the years to determine the performance of treated wood samples in the presence of decay fungi (Smith and Byrne, 1985; Johnson et al, 1983; Hedley, 1978) or termites (Thornton et al, 1983; Preston et al, 1985; Johnson and Thornton, 1991; Lenz et al., 1992; Creffield, 1994) with varying degrees of success.

The chosen field site is in a forested area, well- drained, shaded, and moist and of high subterranean termite activity. In this study, the tested plot was selected in near nursery of FRI. The design of the field test procedure is as follows: a ditch of consistently 15-20 cm depth is dug to partly layer with residues from coconut fibers and susceptible wood veneers (to bait and aggregate termites). Wood blocks were then placed about this depth above the residue layer and additional amounts of residues added to conceal the blocks, and the ground covered with top soil. The blocks were kept together according to species to aid identification of the specimens at the end of test.

3.4.3. Determination of final mass

After 16 weeks, the specimens were removed from the tested sites and cleaned up. The ground was unearthed, the blocks carefully retrieved, weighed immediately to determine the final wet weight and then oven dried. Determinations of final block moisture content (% g/g), absolute mass loss (in mg) and percentage mass loss (% g/g). Then these final mass of specimens were weighed after 48 hour at 60°C in oven by the same way of determination of initial mass.

3.4.4. Grading the termite resistance

The test blocks were also rated according to an arbitrary 0-5 visual scale as: 0 = sound, l = surface, 2 = light attack, 3 = moderate attack with bore holes, 4 = heavy/severe attack and 5 = completely destroyed. The grading of termite resistance was estimated by mass loss of specimen and visual observation according to table (1). The grading by mass loss of specimen was corrected by visual observation according to table (2).

3.5 Method of Analysis

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 samples at air dry and green conditions were calculated by using the following equation.

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

where,

M.C	=	moisture content of the sample
I.wt	=	initial weight of the sample
O.D.wt	=	Oven Dry weight of the sample

Then, average initial MCs of MC-blocks were calculated based on the average initial air-dry M.C. The calculated oven dry weight of each test sample for vacuum-pressure treatment 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

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	=	calculated oven dry weight
F.O.D wt	=	final oven dry weight

The obtained average loss in dry weight percent of wood specimens were classified according to the Findlay (1985).

Table. 3.1. Durability Classification of Timber based on Weight Loss

Durability Class	Life of test stakes in the field		Ave. Wt.Loss (%)
	England	Tropics	
Very durable Class I	Over 25 yr.	Over 10 yr.	nil
Durable Class II	15-25 yr.	5-10 yr.	Up to 5%
Moderately durable (Class III)	10-15 yr.	Not given	5-10%
Non-durable (Class IV)	5 -10 yr.	2 - 5 yr.	10-30%
Perishable (Class V)	< 5 yr.	< 2 yr.	Over 30%

Source: W. P. K. Findlay (1985)

Visual rating for termite resistance was made using American Wood Preservers' Association (AWPA) Rating.

	Visual Rating	Rate
(1)	No attack (sound)	0
(2)	Slightly attack	1
(3)	Moderately attack	3
(4)	Severe attack	5

3.6. Statistical Analysis

The data recorded were mean weight loss percentage of individual species. The data obtained were statically analyzed using ANOVA (Analysis of Variance), following a complete Randomized Design (CRD). Mean comparison of treatments were done by using T' Test and Least Significant Difference Test (LSD).

4. Results and Discussion

4.1. Decay Resistance of In (*D. tuberculatus*)

The average weight loss in dry weight percent of untreated In (*D. tuberculatus*) were shown in table 4.1. According to the laboratory decay test, the average weight loss in dry weight percent of untreated In (*D. tuberculatus*) is 8.42%. Therefore, it lies in moderately durable class.

Table (4.1) The average weight loss in dry weight percent of untreated In (*D. tuberculatus*)

Sample no.	**Initial Wt**	**After 4 months**	**COD wt**	**Wt Loss (%)**	**Durability Class**
S1	5.295	3.173	3.53	10.11	Moderately durable
S2	4.886	3.03	3.26	6.98	
S3	5.066	3.156	3.38	6.55	
S4	4.933	3.052	3.29	7.20	
S5	5.048	3.146	3.37	6.52	
S6	4.785	2.956	3.19	7.34	
S7	5.152	3.143	3.43	8.49	
S8	5.003	3.063	3.34	8.17	
S9	5.034	3.138	3.36	6.50	
S10	5.15	3.002	3.43	12.56	
average				8.42	

The average weight loss in dry weight percent of preservative treated In (*D. tuberculatus*) were shown in table 4.2. According to this table, the average weight loss in dry weight percent of Acetylation treated In (*D. tuberculatus*) was found to be 2.56 and durability move to Durable Class (Class II). Similarly, the weight loss percent of Borate treated samples was found to be 3.89 and the durability classification is promoted to Durable Class. In the case of Polybor, the weight losses of treated samples were found to be 4.47 and it also lies in the Durable Class (Class II). Therefore preservation causes the upgrading of the durability of tested species.

Table (4.2) The effect of Preservatives on Decay Resistance of In (*D. tuberculatus*)

Control	**Stdev.**	**Acetylation**	**Stdev.**	**Boric/Borax**	**Stdev.**	**Polybor**	**Stdev.**
10.55	1.39	2.06	0.61	2.34	1.12	3.85	0.69
11.15	1.53	1.87	1.12	2.84	0.55	4.72	0.29
8.16	0.64	3.45	1.13	4.95	0.67	4.26	0.46
9.19	0.48	3.06	0.74	4.82	1.21	4.56	1.13
10.11	1.09	2.37	1.01	4.52	1.33	4.98	0.79
9.83		**2.56**		**3.89**		**4.47**	

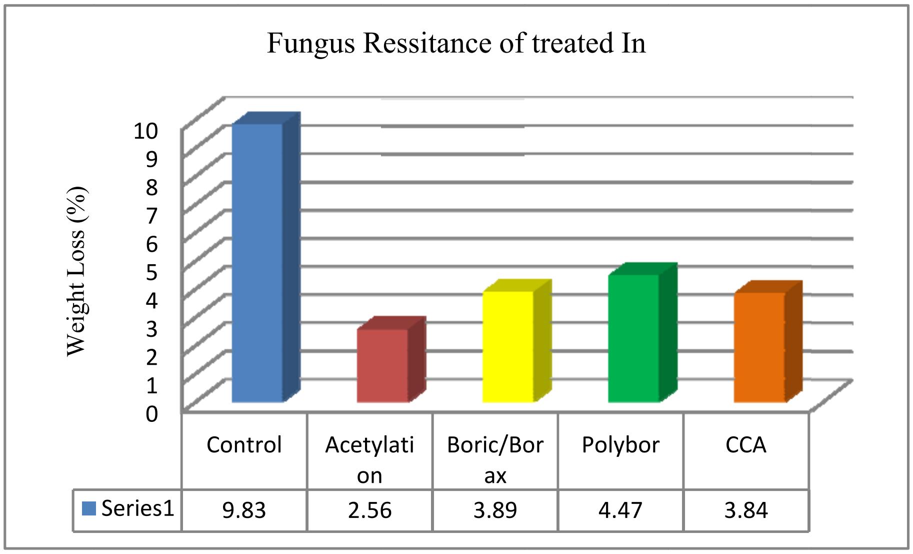


Figure 4.1. The effect of Preservatives on Decay Resistance of In (*D. tuberculatus*)

CCA = result obtained by Austin Nyunt (1988)

The effect of preservatives on decay resistance of In (*D. tuberculatus*) was shown in figure 4.1. It can be seen clearly that preservative treated samples were lower in weight losses.

Austen Nyunt, U (1988) reported that The air-dried mini-blocks (.5"x .5" x1") of In (*D. tuberculatus*) were treated with the 5 concentrations of CCA (0.76%, 1.5%, 3.24%, 4.54% and 7.57%) using pressure treatment. The treating cycle consists of a volume of at least 650mm Hg lasting for one hour, followed by 3 hours pressure at 1240 K N/m2. The results showed that the treated samples were promoted to very Durable Class.

Table 4.3. Mean weight loses for untreated and CCA treated In Blocks

Solution Strength of CCA	**Retention**	**Control**	**Wt Loss (%)**	**Durability Class**
0.76%	3.97	16.96	5.12	Durable
1.50%	7.68		3.97	
3.24%	17.27		3.84	
4.54%	23.43		3.23	
7.57%	31.34		4.68	

According to this experiment, treated by boron based wood preservatives can give the same results. It means In can be treated with boron based wood preservatives instead of CCA. Boron based wood preservatives are easy to treatment.

4.2. Termite Resistance of In (*D. tuberculatus*)

The resistance on subterranean termites of untreated and preservative treated wood samples was shown in Table 4.3. The visual rating of test samples and weight losses are presented in this table.

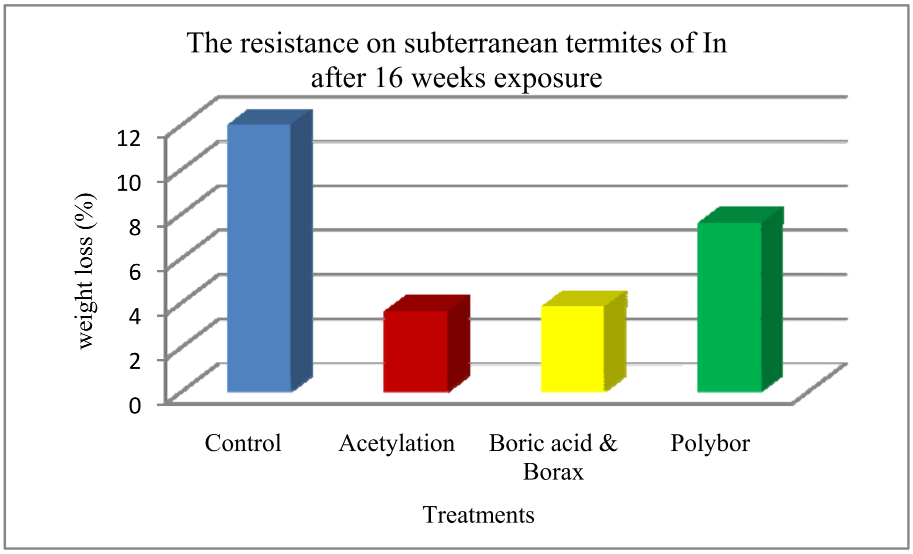
After 16 weeks of exposure, three of all the treated samples exceptionally sustained very slight attacks, while in general untreated controls were moderately to severely attacked. Borate-treatment was proved to be satisfactorily effective in protecting lumber in above ground situations from subterranean termites.

Visual rating of the test samples, mass losses are presented in table 4.3. According to this table, it can be seen that untreated In (*D. tuberculatus*) blocks lie in visual rating 4. Therefore, we can conclude that In species were very susceptible to termites. To compare, Teak and Pyinkado samples were also tested.

In the case of treated samples, the results also proved that preservative used were fairly toxic to termites force to feed upon it. But they do not deter them from doing substantial damage.

Table. 4.3 Results: IN – ground field evaluation

Wood Species	Visual Rating	Mass Loss (%)
Teak	0	2.10
Pyinkado	0	1.37
Untreated Blocks	3.99	11.99
Acetylation Treatment Blocks	2.52	3.606
Borate Treated Blocks	2.44	3.813
Polybor Treated Blocks	3.72	7.581



5. Conclusion and Recommendation

5.1. Conclusion

1. The average weight loss in dry weight percent of untreated In (*D. tuberculatus*) is 8.42% and it is moderately durable.
2. The weight losses for the "control" samples, generally indicate the naturally susceptible to decay of material being tested, so it must be treated with the suitable preservatives.
3. The durability of Acetylation treated In (*D. tuberculatus*) was found Durable Class (Class II).
4. Boric acid and Borax treatment of In(*D. tuberculatus*) was successful in controlling decay caused by *C. versicolor* and *S comune* fungi.
5. Although Diffusion Treatment can give satisfactory result, one disadvantages of diffusion process is leaching of treating chemical out of the wood after it has been treated.
6. So, to fix the chemical in the wood, it needs to apply another chemical and it is called double diffusion.
7. It was found that reactions taking place between the treating chemicals and the wood, resulted in poor penetration in dip-diffusion treatment.
8. The results suggested that In(*D. tuberculatus*) timber, for use as interior timber, may be as well treated with Boron based preservative instead of pressure treated timber.

5.2. Recommendation

The increased interest in boron treatment of wood over the past 20 years is mainly due to its environmental acceptability, potentially deep penetration in wood, and its efficacy against decay and termites. Based on Forintek's research in the past two decades, the boron penetration and retention requirements for decay and termite protection in various national and international standards for Canadian wood species can be achieved using a combination of pressure treatment schedules and a short diffusion period.

Since the biggest disadvantage of boron-treated wood is the chemical loss when in contact with liquid water, research has been carried out on boron fixation, but the most practical and successful method could be application of specific coatings on borate-treated wood. This has been in practice for exterior uses in New Zealand and the UK for decades. Results from a 10-year painted L-joint test by Forintek demonstrated the long-term decay resistance of borate-diffusion-treated hem-fir with a low retention of 0.2 % boric acid equivalent under exterior above-ground applications with surface protection provided by a three-coat paint. Forintek's recent accelerated testing has also shown that retardation of boron leaching can be achieved using certain water-based transparent coatings. The colourless nature of borates plus the transparent coatings allows improved durability while maintaining the natural appearance of wood. Long-term field tests for engineered wood products treated with borates and surface protected with a water-based transparent coating are now underway.

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