The Republic of the Union of Myanmar
Ministry of Environmental Conservation and Forestry
Forest Department

The Effectiveness of Wood Preservatives on the Natural Durability of
Eucalyptus camaldulensis

2013, August
ပြည်သူ့အမှတ်ကြီး ပြည်သူ့အုပ်ချုပ်ရေးကြီး အတွက် ရည်ရွယ်သောအချက်အလက်များ

စာရင်းအမျိုးအစား:
1. Polybor
2. Boric acid
3. Borax

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Investigation on the Effects of Wood Preservatives on the Natural Durability of *Eucalyptus camaldulensis*

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Wood Preservation Section

Abstracts

In this study, the decay resistance of *E. camaldulensis* was treated with three wood preservatives. The wood samples of *E. camaldulensis* were impregnated with 3%CCA (copper-chrome-arsenic) by using vacuum-pressure method and with 25% Polybor and 20% concentration of Boric acid and Borax mixture by using dip-diffusion method. The decay resistance of test specimens was evaluated by laboratory decay test (soil-block test). The control and treated specimens were exposed to white rot fungus (*Polyporus versicolor* and *Schizophyllum commune*) for 16 weeks. The oven dry weight loss percentage was used as a measure of severity of decay. Weight loss determination showed that treatment with 3%CCA provides a considerable decay resistance and weight loss reduced over 20 folds lower than the untreated one. The results also showed that treatment with Boron – based wood preservatives can also prevent the decay caused by *Polyporus versicolor* and *Schizophyllum commune* and weight losses reduced 4 to 5 folds lower than untreated wood samples. The untreated *E. camaldulensis* lie in moderately durable (Class III). After treatment, *E. camaldulensis* were promoted to Durable (Class II) by using Boron –based preservatives and to very durable (Class I) by using CCA.
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1. Introduction

Eucalyptus plantations were first introduced in Myanmar in 1922, on trial basis and for amenity planting. During the year 1922-29, about 600 acres of seven eucalyptus species had been planted as trial plantations. The species were *E. rostrata* (*E. camaldulensis*), *E. amygdalina*, *E. maculate*, *E. citriodora*, *E. resinifera*, *E. tereticornis* and *E. saligna*. Among these species, *E. camaldulensis* was the best. The Forest Department had also planted seven Eucalyptus species in trial plantations in 1967-69. The trial species were *E. camaldulensis*, *E. grandis*, *E. robusta*, *E. tereticornis*, *E. saligna*, *E. globules* and *E. citriodora*. Among the seven species, *E. camaldulensis* for its adaptability to survive severe climatic and edaphic conditions ease of establishment and wide-ranging usefulness was selected for large scale planting since 1970. About two lakh (two hundred thousands) acres of Eucalyptus had been planted in Myanmar by 2007.

Eucalyptus plantations in Myanmar are formed for the following objectives.

1. To supply fuelwood, charcoal, poles, posts and small timbers for rural community.
2. To supply timber for farm implements.
3. To supply raw material for paper industries.
4. To supply mine props and fishery posts.
5. To establish the plantation under harsh climatic conditions with poor soil as this is the only species that can withstand such severe condition and grows well.
6. To protect erosion in the cashment area.
7. To conduct research for other uses and for growth study.

Comparison of the mechanical properties of plantation grown *E. camaldulensis* with some Myanmar commercial timber species were made by (Ral Liam Sum & Win Kyi, 1975). The reports indicated that it is slightly stronger than In (*Dipterocarpus tuberculatus* Roxb.), Kanyin –byu (*D. alatus* Roxb.) and Kyun (*Tectona grandis* Linn. F.) and is slightly lower in strength than Thitya (*Shorea oblongifolia* Thw.) and Ingyin (*Pentacme siamensis*). But it is inferior to Padauk (*Pterocarpus microcarpus* Kurz) and Pyinkado (*Xyliya xylocarpa*).

Although, many research for *E. camaldulensis* have been done in Myanmar (Ral Liam Sum & Win Kyi, 1975; Mya Aung & Win Kyi, 1980; Soe Tint et al, 1985(a), (b); Saw Win, 1987), research for durability behavior of this species had not been done. Assessment on this characteristic of plantation grown *E. camaldulensis* is very important to promote the utilization of this species.

The objectives of this study are:

1. To study the natural durability of *E. camaldulensis* which can grow well and fast in Myanmar?
2. To upgrade the utilization potential of *E. camaldulensis* by using wood preservatives.
3. To support the rural people by using treated *E. camaldulensis* to build low-cost house.
2. Literature Reviews

*E. camaldulensis* Dehn. (Syn. *E. rostrata* Schlecht belongs to the family Myrtaceae and is a native of Australia where it is one of the most widespread species of genus *Eucalyptus* confining mainly to river banks and damp depressions. It is a medium-sized tree attaining a height of about 114 ft with a diameter of 6'7", but sometimes reaching a height up to 148 ft. In its native place of Australia, the timber is considered to be a fine utility timber used extensively for such purpose as railway sleepers and other outdoor constructions.

The wood has been used for heavy construction, railway sleepers, flooring, farming, fencing, plywood and veneer manufacture, wood turning, firewood and charcoal production (Boland, 1984). Due to its natural adaptation to both temperate and tropical climates with winter and summer rains, *E. camaldulensis* is the most widely planted species in arid and semi-arid regions around the world, primarily in timber plantations (Eldridge et al., 1993 in CAB International, 2000).

2.1. The natural durability of Eucalypt

Untreated Eucalypt sapwood is susceptible to decay and termite attack and often to lyctus borer damage. The natural durability of Eucalypt heartwood varies greatly between species, the high density timbers (over 800 kgm⁻³) are generally the most durable. Durability of heartwood is often much reduced near the pith, and the size of this less durable, inner heartwood area increases with the age of the tree.

The mature wood of *E. cloeziana* is the most durable in the ground. *E. agglomerate*, *E. camaldulensis* and *E. pilularis* have mature woods of second class durability. *E. diversicolor*, *E. globules*, *E. grandis*, *E. laevopinea*, *E. oblique* and *E. sieberi* are in third class and *E. deglupta*, *E. delegatensis*, *E. fastigata* have the least natural durability (E. Bolza, ). The estimated life of matured *E. pilularis* heartwood in contact with the ground is 15-25 years and above the ground 30-50 years (Hillis, 1977).

The world’s timber resources are being exploited at an ever increasing rate. Much replanting is being carried out with fast growing hardwood (particularly *Eucalyptus* spp) timbers, all of which have a significant proportion of the trunk as the non-durable sapwood, which requires treatment before it can be used in situations where it will be exposed to biological attack. Most fast-grown eucalypts have no high natural durability and may need preservative treatment if exposed to even a moderate decay or insect hazard.

The proper treatment of timber commodities will contribute to the more efficient use of one of Man’s few renewable resources. The service life of untreated timber may only be a few months in the most severe hazard conditions, whilst for pressure treated commodities the useful service life is extended many times with a consequent saving of raw material and maintenance costs.

2.2. The Preservative Treatment of *E. camaldulensis*

In South and North America, mostly poles of *Eucalyptus* spp are treated with CCA and used for railway sleepers and transmission poles. In east of Africa, plantation grown *Eucalyptus* species are extensively used for poles and posts and CCA treated.
Except in diffusion treatments, preservative penetration is confined initially to movement in longitudinal direction along the vessels. Penetration from radial and tangential faces is negligible unless assisted by sloping, checks, incisions or fungal damage (Tamblyn N.E).

Eucalypt heartwood is typically difficult or very difficult to penetrate with preservatives applied by conventional pressure treatment (i.e. up to 1500kPa). Improvement is obtained by means of higher pressures, with or without incising the wood, or boiling in preservative oil under vacuum before pressure treatment.

Although pressure processes are efficient methods of wood preservation, some woods are refractory and the pressure methods are not applicable. Many hardwoods in the tropic are resistant to pressure impregnation. Tamblyn et al. (1968) indicated that “70 % of timbers likely to be treated could not be penetrated satisfactorily in the heartwood” by pressure methods with either fixed or unfixed preservatives. Baines and Saur (1985) suggested that a diffusion process is suitable for such refractory woods.

Diffusion treatment of green heartwood to produce an envelope of treated wood is practicable and is useful for sawn building timbers that are reasonably protect from leaching. Diffusion treatment is a very simple process which involves low capital cost. It is suitable for treatment of timbers used in low hazard conditions not in ground contact, and has been approved for use by various Timber Preservation Authorities (Anon; 1980; Stevens & Cockerof, 1981).

The dip-diffusion process works on the principle that the higher concentration of ions in a solution (preservative) will migrate or diffuse to areas where the concentration of such ions is low (wood). However, not all preservative are suitable as only boron has this ability to diffuse into the wood.

This treatment was developed first in 1955, centered around the invention at the Division of Forest Product Melbourne of a BFCA diffusion preservative of high Boron content and very high solubility in cold water. Because of this high solubility, green timber of scantling size when dipped momentarily in cold solution could carry in the surface film sufficient preservative for effective treatment to a depth of ½ inch or more. This penetration was obtained by holding the green treated timber in closed sheds or in covered stacks for about 4 weeks to prevent drying while the required diffusion occurred.

Treated timbers give sufficient protection. In many countries where wood preservation is widely practiced this type of treatment account for a large percent of treated wood (Amemiya & Cockerof, 1982; Stevens & Cockerof, 1981; Vinder & Mc Quine, 1980).

Diffusion of preservative into the wood is affected by factors such as wood moisture content, temperature, solution concentration, diffusion period, sapwood and heartwood, wood density and grain direction (Tamblym, 1985). One disadvantage of diffusion process is leaching of treating chemical out of the wood after it has been treated. If the chemical is fixed by another chemical in the wood by applying it subsequently the deposit so formed become non-leachable.
3. Material and Method

3.1. Sample Preparation

The wood samples of *Eucalyptus camaldulensis* were collected from two different localities: Magwe Township and Tharzi Township. Only one tree per locality was tested. Sample sticks of size (30 mm x 30 mm x 500 mm) were cut from the lower portion of the trunk and outer portion of the heartwood. These sticks were free from knots, drying defects and without visible evidence of fungus infection.

The sample stick was planed and cut into small blocks of size 20 mm x 20 mm x 20 mm as accurately as possible. 50 clear blocks were selected for this study.

Both ends of each block were coated with lacquer thoroughly to restrict the penetration of preservatives from the ends. Among the 50 blocks of each species, Ten samples were used for control and marked as C_1, C_2, C_3, ..., C_10. Ten samples were used for the treatment of 20% Boric acid and Borax solution and marked as T_1-1, T_1-2, T_1-3, ..., T_1-10. 10 samples were used for 25% Polybor treatment and marked as T_2-1, T_2-2, ..., T_2-10. 10 samples were used for 3% CCA solution treatment and marked as T_3-1, T_3-2, ..., T_3-10. 10 samples which were denoted as moisture content samples (MC-samples), were used for estimating the initial M.C tested samples.

3.2. Chemicals Used

In this study, 20% concentration of mixture of Boric acid and Borax solution, 25% concentration of Polybor solution and 3% concentration of CCA solution were used as wood preservatives. CCA used in this study is Celcure A (P) Type, the product of Celcure...
The components of the treating solution were Copper Sulphate penta-hydrate 31.5\% \(\text{w/w}\), Sodium dichromate di-hydrate 39.0\% \(\text{w/w}\) and Arsenic pentoxide dihydrate 24.5\% \(\text{w/w}\). The 3\% concentration of CCA solution was prepared by dissolving 4.7194 g of CCA paste together with 1 liter (1l) of distilled water.

3.3. Methods

3.3.1. Dip-diffusion Method

The dip-diffusion method for 20\% concentration of Boric acid and Borax solution and 25\% concentration of Polybor solution was used in this study. Treatment Procedure was the follow:-

This treatment was suitable for freshly sawn timber. Therefore, the blocks to be treated by using dip- diffusion treatment were soaked in water for 24 hours to obtain the approximate green condition. The water - soaked blocks were weighed and noted as initial weight \(W_1\). The test specimens were dipped separately into the prepared 20\% of Boric acid and Borax mixture solutions and 25\% concentration of Polybor solution respectively for 30 minutes. After that, the treated blocks were taken out and wrapped in plastic bags for further diffusion of salt into the wood. Diffusion period was two weeks. After two weeks, the treated blocks were weighed and noted as \(W_2\) to determine the retention of preservative chemical. 10 samples of the treated blocks were oven- dried to calculate the retention.

3.3.2. Vacuum-pressure Method

For 3\% CCA solution, vaccum-pressure treatment method was used. The procedure taken for treatment was shown as follow:-

1) Before the treatment, each sample block was weighed and it was designated as \(W_1\).
2) The treatment plant was loaded with wood blocks and was sealed tightly.
3) Vacuum was drawn slowly until 20-25 in Hg in 15 minutes.
4) Vacuum at 25 in Hg was maintained for 1 hour.
5) While under vacuum, prepared CCA solution was introduced into the plant.
6) Pressure was applied into the plant until 150 psi was reached and maintained for 1 hour.
7) The pressure was gradually released and preservative solution was drained.
8) Treated blocks were allowed to sit for 15 minutes.
9) After that, the preservative solution was poured off and the blocks were taken out and left at room temperature for one week to allow the preservative to fix.
10) After that treated samples were weighed and noted as \(W_2\).
3.3.3. Laboratory Decay Test

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 Aplin, 1959; Da Costa et al. 1957). Among the laboratory decay tests, soil-block test (ASTM Standard) was used in this research.

**Test fungi**

The white rot fungus, *Polyporus versicolor* and *Schyzophyllum commune* were used in testing. 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 2% malt extract agar medium, kept in the room temperature and it was indentified at Forest Research Institute of Malaysia (FRIM).

**Culture Media**

For petridish cultures of the test fungi, Potatoes- Dextrose agar (PDA) media was used. 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. The media was distributed into the test tubes. The medium were sterilized in autoclave sterilizer at 105 °C and 15psi pressure for 20 minutes and allow to cool before inoculations. 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.

**Preparation of Soil Culture Bottles**

A soil substrate with a water holding capacity between 90 percent was used. The soil substrate, sifted and lightly compacted by tapping, and was half-filled a culture bottle. The soil surface was leveled and was placed directly on the soil one feeder strip for each test block. And then, the prepared culture bottles were steam sterilized at 15 psi for 60 minutes. After the sterilized soil culture bottles were thoroughly cooled.

The fungus inoculums sections were cut approx: 10 mm square from a petri-dish culture and immediately were placed them in contact with an edge of feeder strip on the soil. The bottles were closed with lids for three weeks. When the feeder strips were covered by mycelium, the test blocks were placed in the previously prepared culture bottles. The bottles were incubated for 12 weeks.

At the end of incubation period, the blocks were removed from culture bottles and carefully brushed off the mycelium. The blocks were oven-dried and oven-dried weights were recorded.

![Fig (3.5) Soil block test](image-url)
3.3.4. 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.

\[
MC(\%) = \frac{I.\text{wt} - O.D}{O.D\ \text{wt}} \times 100
\]

where,

- \(M.C\) = moisture content of the sample
- \(I.\text{wt}\) = initial weight of the sample
- \(O.D\ \text{wt}\) = 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.

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

where, \(C.O.D.\text{Wt}\) = calculated oven dry weight of the sample

To determine the weight loss percent of each of the test samples the following formula was used.

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

where,

- \(C.O.D\ \text{wt}\) = calculated oven dry weight
- \(F.O.D\ \text{wt}\) = final oven dry weight

The obtained average loss in dry weight percent of wood specimens were classified according to the Findlay (1985).
Durability Class | Average loss in dry weight (%) in pure culture test
---|---
Very Durable | Nil- or negligible
Durable | Up to 5%
Moderately Durable | 5-10%
Non-Durable | 10-30%
Pershable | Over 30%

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

3.4. **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 was done by using T’ Test and Least Significant Difference Test (LSD).

4. **Results and Discussion**

Results of the experiments were evaluated as mean weight loss percent of individual treatment.

Mean weight losses for each treatment with different solution strengths of two preservatives and untreated samples which were exposed to decay test are shown in Table (4.1). In order to clearly reveal the difference between the weight losses of untreated and treated blocks, mean weight losses against the preservative solutions are shown graphically in Figures (4.1).

**Table (4.1) Mean Weight Loss (%) of the Tested Specimens**

<table>
<thead>
<tr>
<th>Location</th>
<th>Treatment</th>
<th>Mean Weight Loss (%)</th>
<th>SD</th>
<th>T’ Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tharzi</td>
<td>Control</td>
<td>18.329</td>
<td>1.36</td>
<td>14.22**</td>
</tr>
<tr>
<td></td>
<td>T-1</td>
<td>3.449</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-2</td>
<td>3.524</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-3</td>
<td>0.295</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>Magwe</td>
<td>Control</td>
<td>19.533</td>
<td>2.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-1</td>
<td>4.927</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-2</td>
<td>4.489</td>
<td>1.78</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-3</td>
<td>0.373</td>
<td>0.87</td>
<td></td>
</tr>
</tbody>
</table>

* significant at $\alpha = 5$

** significant at $\alpha = 10$
Figure (4.1) Mean weight losses of Eucalyptus wood samples at different preservative solutions after 16 weeks exposure.

4.1. The Natural Durability of *Eucalyptus camaldulensis*

According to table (4.1), it was found that mean weight losses of untreated *E. camaldulensis* after 16 weeks exposure in fungus containing bottles were 18.33% for wood samples from Tharzi and 19.53% for that from Magwe respectively. According to Durability classification, it can be seen that *E. camaldulensis* lies in Moderately Durable (Class III). Hillis (1977) stated that *E. camaldulensis* has matured woods of second class durability. Different results can be obtained from different decay tests. Win Kyi-2 (1989) stated different results may be obtained with different fungi. Similarly, Kokutse et al (2006) also reported that degree of fungal attack on teak wood can be different depending on the fungal species.

The mean weight losses of untreated *E. camaldulensis* after 16 weeks exposure were found to be 18.33% for wood samples from Tharzi and 19.53% for that from Magwe respectively. Therefore, it could be concluded that the natural durability of *E. camaldulensis* effects on locality.

To know the effect of locality, mean comparison was made by using T’ test. According to T’ Test, calculated t-value 14.22 is greater than tabular t (3.25) for 9 degree of freedom at 1% level of significance. Therefore, the T’ test indicates highly significant difference between mean weight loss (%) of two localities at 99% confidence interval.

Wilson (1986) stated that, wood properties may also influence the environmental sites (eg. Soil type, rainfall, mean, maximum and minimum temperature, solar radiation, altitude and latitude) and anthropogenic factors (eg. tree spacing, thinning and pruning, irrigation, weed control and pest control) which exert and influence on cambial activity.
4.2. The Effect of Preservatives on the Durability of *Eucalyptus camaldulensis*

The weight losses of untreated and three concentrations of Preservative–treated blocks of test species against *P. versicolor* and *S. commune* are also given in Table (4.1).

This table showed that the weight losses of Polybor treated blocks were lower than the control for both of localities. According to the table, it was found that the weight losses of Polybor treated wood samples from Tharzi and Magwe decreased to 3.45% and 4.93% respectively. The weight losses were lower 4-5 folds than control and according to Durability classification, it can be promoted to Durable (Class II).

The weight losses of 20% concentration of Boric acid and Borax treated blocks were also lower than the control for both of localities. According to the table, it was found that the weight losses of Boric acid and Borax treated wood samples from Tharzi and Magwe decreased to 3.45% and 4.49% respectively. The weight losses were lower 4-5 folds than control and according to Durability classification, it can also be promoted to Durable (Class II).

The 3% concentration of CCA treated blocks has the lowest weight losses. According to the table, it was found that the weight losses of CCA treated wood samples from Tharzi and Magwe decreased to 0.295% and 0.373% respectively. The weight losses were lower over 20 folds than control and according to Durability classification; it can also be promoted to Very Durable (Class I).

Among three preservatives, CCA is the most effective to control the decay caused by *P. versicolor* and *S. commune* and followed by Polybor and Boric acid.

Firozjaii et al., were investigated the durability of *E. camaldulensis* against rainbow fungus (*Trametes versicolor*) and termites using Celcure and Creosote in Al-Bajie region. It was founded that untreated *E. camaldulensis* was subjected to 30% damage, while samples treated by Celcure and Creosote were unaffected.

Salamah (1995) stated that CCA is the most common commercial wood preservative which is widely used in treating wood used for foundation works, transmission poles, jetty poles and building construction. CCA formulation has been found to be most reliable general purpose preservative currently available. It generally gives rapid fixation, sufficient penetration and adequate retention and provides excellent protection against biodeterioration (Richardson, 1978).

Cleanness of treated wood, safety in handling because of the permanently fixed chemicals in treated wood, the most important quality and resistance of CCA treated wood to deterioration by decay fungi and insects dictate an increase in acceptance of treated lumber.

Warasan Wanasat (1988) was tested pressure treatment of *E. camaldulensis* poles with oil-borne preservative. He reported that with the increase of both treating pressure and time, penetration do not increase significantly. It was highly significant effect on sapwood penetration only.

Study of the decay pattern and suitability of Boron - treated *E. camaldulensis* reveals that *E. camaldulensis* is suitable for wood poles if the whole of the sapwood is treated with a fixed type of preservative. Although the boron compound in Boric acid solution and Polybor leaches out from outer surfaces of poles, Lahiry, A. K (---) observed that the service life of poles is increased with an increase in thickness of the treated shell.
There are minor differences in the toxicity of the various Boron containing preservatives. Studies have indicated that borax (Na₂B₄O₇) has a lower oral toxicity (5g/kg) than Boric acid (H₃BO₃) – 3g/kg) which in turn is slightly less toxic than the commercial preparation. Timbor (Na₂B₈O₁₃·4H₂O) at 2g/kg. It can be clearly these boron-based preservatives would not be considered toxic in a poisonous sense.

Boron-based compounds are very cheap compared to other preservatives and their method of use with green or semi-dry timber reduces handling charges to a minimum. It is usual to strip the timber for drying as soon as it is sawn and thereafter to handle it through the treatment tank in kiln sized packages. Costs are thus lower than is usually possible in a conventional pressure treatment.

The advantages of Dip-diffusion over pressure treatment are considerable. The capital cost of equipment is very small, the preservitives is very cheap, the handling of the timber is greatly reduced, the solid piles occupy less space than stripped stacks and the total treatment period is shorter as preliminary air drying is eliminated. Also diffusion treatments penetrate both heartwood and sapwood, a point of some importance in utilizing non-durable hardwoods which are refractory to normal pressure treatment.

5. Conclusion and Recommendation

5.1. Conclusions

The results of the experiment indicated that the durability of *E. camaldulensis* could be promoted through wood preservation. It can be successfully decreased the weight loss percent of test species when using the appropriate preservatives and treatment methods. According to the results of this study, it can be concluded that:

1) Among the test treatments, CCA with vacuum-pressure treatment was found to be the most effective to control the decay caused by *P. versicolor* and *S. commune*.
2) Boron – based preservatives namely Polybor and mixture of Boric acid and Borax treated wood samples also can be provided the resistance of decay caused by white rot.
3) *E. camaldulensis* can be promoted to Very Durable (Class I) by using vacuum-pressure treatment with 3% CCA
4) Treatment by Polybor and mixture of Boric acid and Borax, *E. camaldulensis* can be promoted to Durable (Class II).
5) According to the advantages of dip-diffusion treatment, *E. camaldulensis* should be treated with dip-diffusion treatment by using Boron – based preservatives.

5.2. Recommendations

Effective utilization of wood depends on strength, durability, beauty and availability of a species. Most of the properties of timber depend on the density of wood. Generally, high density timbers are more durable than lighter ones. Medium density timbers get wider range of most indoor utility purposes such as furniture, paneling, flooring doors and windows. Light density timbers get limited uses such as toys, packing box and match box etc.
The green density of *E. camaldulensis* is 0.713. It was similar to that of In/Ingyn (*Dipterocarpus spp.*) and superior than teak (*Tectona grandis*) and lower than Padauk (*Pterocarpus macrocarpus*). Mechanical properties of *E. camaldulensis* are greater than In/Kanyin, Teak and Pyinkado (*Xyliya xylocarpus*). It has lower shrinkage and it is dimensionally stable. One of the major deterrents to the fuller utilization of the *E. camaldulensis* has often been the lack of adequate knowledge on its durability and treatability (Win Chit, 2008).

There is a growing demand for tropical timber for various end-uses. Therefore, establishing information on durability-treatability-uses and other relevant facts becomes necessary in order to expand the timber trade for the mutual benefit of both timber producers and consumers.

The potential for wider application of preservatives and development of other process of treatment are tremendous. It is suggested that appropriate treatments be applied to timber and timber components that are not receiving treatment yet in order that their life span in service could be prolonged. Preservatives could also extend and widen the application of wood, thereby maximizing the usefulness of the timber resources.

The fuller utilization of preservative treated wood would lessen the pressure for the demand to cut down forests so that an efficient conservation programme for the proper management of this vital natural resource (timber) could be successfully implemented.
Table (1). Analysis of Variance for *E. camaldulensis* from Magwe.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degree Of Freedom</th>
<th>Sum Square</th>
<th>Mean Square</th>
<th>F -Value</th>
<th>CV%</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>3</td>
<td>2111.694</td>
<td>703.898</td>
<td>258.626**</td>
<td>22.51</td>
<td>2.9</td>
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<tr>
<td>Error</td>
<td>36</td>
<td>97.980</td>
<td>2.722</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>2209.674</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* significant at $\alpha = 5%$

** significant at $\alpha = 10%$

Table (2). Analysis of Variance for *E. camaldulensis* from Tharzi

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degree Of Freedom</th>
<th>Sum Square</th>
<th>Mean Square</th>
<th>F -Value</th>
<th>CV%</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>3</td>
<td>1965.469</td>
<td>655.156</td>
<td>645.563**</td>
<td>15.74</td>
<td>1.08</td>
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<tr>
<td>Error</td>
<td>36</td>
<td>35.635</td>
<td>1.015</td>
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<tr>
<td>Total</td>
<td>39</td>
<td>2002.004</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

* significant at $\alpha = 5%$

** significant at $\alpha = 10%$

Table (3) LSD Test of Significance for Difference between Treatment Means of *E. camaldulensis* from Magwe.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000000</td>
<td>14.880099**</td>
<td>14.804584**</td>
<td>18.033746**</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0.000000</td>
<td>-0.075515</td>
<td>3.153647**</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>0.000000</td>
<td>3.229162*</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>0.000000</td>
</tr>
</tbody>
</table>

* significant at $\alpha = 5%$

** significant at $\alpha = 10%$

Table (4) LSD Test of Significance for Difference between Treatment Means of *E. camaldulensis* from Tharzi

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000000</td>
<td>14.606493**</td>
<td>15.044846**</td>
<td>19.160437**</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0.000000</td>
<td>0.438353</td>
<td>4.553943**</td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td>0.000000</td>
<td>4.115590*</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>0.000000</td>
</tr>
</tbody>
</table>

* significant at $\alpha = 5%$

** significant at $\alpha = 10%$
Comparison the Properties of *E. camaldulensis* with commercial species of Myanmar.

<table>
<thead>
<tr>
<th>No</th>
<th>Property</th>
<th><em>E. camaldulensis</em></th>
<th>Teak</th>
<th>Pyinkado</th>
<th>In/Kanyin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density</td>
<td>52 lb/ft³</td>
<td>47 lb/ft³</td>
<td>52-59 lb/ft³</td>
<td>56 lb/ft³</td>
</tr>
<tr>
<td>2</td>
<td>Specific gravity</td>
<td>0.713</td>
<td>0.55-0.7</td>
<td>0.92</td>
<td>0.73</td>
</tr>
<tr>
<td>3</td>
<td>Tangential shrinkage (green to ovendry)</td>
<td>7.3 (%)</td>
<td>4.2(%)</td>
<td>6.7(%)</td>
<td>9.1(%)</td>
</tr>
<tr>
<td>4</td>
<td>Radial shrinkage</td>
<td>3.9%</td>
<td>2.3%</td>
<td>3.3%</td>
<td>4.4%</td>
</tr>
<tr>
<td>5</td>
<td>Dimensional stability</td>
<td>1.87</td>
<td>1.83</td>
<td>2.30</td>
<td>2.07</td>
</tr>
<tr>
<td>6</td>
<td>MOR</td>
<td>15798 (psi)</td>
<td>14965 (psi)</td>
<td>14280 (psi)</td>
<td>13925 (psi)</td>
</tr>
<tr>
<td>7</td>
<td>Durability</td>
<td>Moderately durable</td>
<td>Very durable</td>
<td>Very durable</td>
<td>Moderately durable</td>
</tr>
</tbody>
</table>

References

Anon (1975): Properties and Uses of Commercial Timbers of Peninsular Malaysia Forest Services Trade, Leaflet No. 40. Malaysia Timber Industry Board. (MITB)


Boland (1984): Internet


Win Chit (2008): ဝင်းချစ်၏စာစုများ