Leaflet No. 4/87-88

Government of the Union of Myanmar
Ministry of Forestry
Forest Department

Treatability and Performance of In, Kanyin and Taung-thayet

U Austen Nyunt, B.Sc. (For.), D.I.C. (Lond.), Senior Researcher,
Forest Research Institute.

1988

Treatability and Performance of <u>In</u>, <u>Kanyin</u> and <u>Taung-thayet</u>

U Austen Nyunt, B.Sc. (For.), D.I.C. (Lond.),
Senior Researcher,
Forest Research Institute.

Abstract

In (*Dipterocarpus tuberculatus* Roxb.), Kanyin (*Dipterocarpus turbinatus*), Taung-thayet (*Swintonia floribunda*_Griff.) were tested for their treatability and durability after treatment with three different types of wood preservatives using Vacuum/Pressure treatment, and two types of preservatives using diffusion treatment method.

1. At the levels of preservative retention treated Copper Chrome Arsenic (CCA) was the most effective preservative for all the three timber species under study controlling decay by all fungi and Unsterile Soil Burial Test.
2. Boron Fluorine Chromium Arsenic (BFCA) and Boron preservatives were successful only in controlling decay caused by *Coriolus versicolor* and *Coniophora puteana* fungi in these timber species.
3. Diffusion treatment with Boron compounds gave very good preservative with penetration, indicating that constructional timbers for interior use could be treated with Boron compounds by diffusion as an alternative to pressure treatment method.

အင်၊ ကညင်၊ တောင်သရက်သစ်မျိုးများအား ဆေးပေးသွင်းပြီး၊ ပိုးအမျိုးမျိုးတို့၏ ဖျက်ဆီးမှု ခံနိုင်စွမ်းအင်ကို လေ့လာခြင်း၏

ဦးအော်စတင်ညွှန့်၊ B.Sc. (For.) Rgn. D.I.C. (Lond) သုတေသနမှူး
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်းချုပ်

အင်၊ ကညင်၊ တောင်သရက်သစ်မျိုးများကို Vaccum/Pressure Treatment ဖြင့်ဆေးရည်သုံးမျိုးကို အသုံးပြု၍ လည်းကောင်း၊ Diffusion Treatment ဖြင့်ဆေးရည်နှစ်မျိုးကို အသုံးပြု၍ လည်းကောင်း၊ ၄င်းသစ်မျိုးတို့၏ Treatability óSifh Durability များကိုစမ်းသပ်လေ့လာခဲ့ပါသည်။

၁။ စမ်းသပ်ပြုလုပ်ခဲ့သည့် preservation retention levels များအနက် CCA သည်၊ သစ်သုံးမျိုးစလုံးကို စမ်းသပ်သည့် ပိုးမျိုးသုံးမျိုးနှင့် Unsterile Soil Burial Test များမှ ပျက်စီးမှုကို ထိရောက်စွာ ကာကွယ်နိုင်ကြောင်း တွေ့ရှိရပါသည်။

၂။ BFCA နှင့် Boron ဆေးရည်တို့သည် သစ်မျိုးသုံးမျိုးစလုံးကို *C. versicolor* နှင့် *C. puteana* ပိုးနှစ်မျိုးတို့၏ ဖျက်ဆီးမှုမှသာ ကာကွယ်မှု ပေးနိုင်ပါသည်။

၃။ Boron -ဓါတ်ပေါင်းဆေးရည်များကို Diffusion Treatment ဖြင့် သစ်များအတွင်းသို့ အောင်မြင်ကောင်းမွန်စွာ သွတ်သွင်းနိုင်သဖြင့် အမိုးအကာအောက်ရှိ ဆောက်လုပ်ရေးဆိုင်ရာ သစ်များကို - Pressure Treatment method ဖြင့်ဆေးရည်သွတ်သွင်းမည့်အစာ; Diffusion Treatment method ကို အစားထိုး အသုံးပြုနိုင်ပါသည်။

Contents

1. Introduction

All wood is biodegradable. Many timber species have, however, sufficient natural durability to permit their use, particularly in protected situations without any special precautions. Many others, on the other hand, are readily attacked by insects and wood-destorying fungi especially when there is sufficient moisture and air. It is these timbers which benefit most from treatment with wood preservatives. Even the so called durables may also benefit since all sapwood is perishable and durable heartwood in the sea and on ground contact eventually fails from attack by animals and / or microorganisms.

Preservation involves additional-costs and must clearly be justified. The environmentalist may see preservation as a mean for reducing the demand for replacement wood, thus conserving the forests. The economists may wish to conserve the forests for rather different reasons, but the principle remains the same. Indeed wood importing countries will wish to preserve in order to conserve foreign currency by reducing wood imports, whilst wood exporting countries will adopt preservation in order to reduce the home demand for replacement wood, thus leaving the maximum possible volume available for export. If preservation is practiced, either by the selection of more durable species or by the adoption of a simple preservation process, structures may double their life.

The objectives of this study were:

a. To compare the treatment quality of In, Kanyin and Taung - thayet, all of which are plentiful enough to meet the internal demand as building materials using suitable preservatives to prolong their service life. In addition to this, this studies to find ways and means to place some of these supplies on the export market on a profitable basis;
b. To assess diffusion treatment with Boron and BFCA for building timbers in terms of their treatment quality and treated time;
c. To compare the biological effectiveness of preservatives in treatment In, Kanyin and Taung - thayet species, and
d. From results thus obtained, to suggest how these Burmese timbers could be treated for various end uses.

2. Literature Review

Wood preservatives are divided into three main types; namely tar - oils, water - borne and organic solvents, and there are many proprietary forms of these on the market. Not every method of application is employed with each type however, and general usage nowadays is broadly as follows Tar - oils preservatives are applied by pressure treatment, hot and could open tank method, and the simpler non - pressure processes such as immersion and brushing. Water - borne solutions are used in pressure treatment and diffusion processes. The organic solvent groups are mainly applied by double - vacuum or by a non - pressure method. In addition, each type of preservative to some extent has a specialised field of use. Water - borne and organic solvent types are widely used for building timbers including material that is to be painted in use. The tar - oils are not

normally used in building, but find wide application in large scale industrial use along with non - leachable water - borne preservatives.

In, Kanyin and Taung - thayet are generally used as constructional materials in Burma, and since a preservative treatment plant was commissioned recently using CCA preservative, it was considered most appropriate to study the treatability and performance of these timber species impregnated with CCA and also to extend the study to assess the use of diffusion treatments, using Boron compounds. These are all water - borne preservatives generally used in treating building materials either by vacuum / pressure treatments or by diffusion processes.

Reference should be made to an article by Aston D. "Copper / Chrome / Arsenic (CCA) Wood Preservatives and their application to timbers in the tropics " (Findlay, W.P.K. (1985); Preservation of Timbers in the Tropics, Chapter 7, pp. 141-155) for a detailed consideration of the most effective way to apply these preservatives to hardwoods under tropical conditions.

References should also be made to Carr, D.R. (1959), Cockcroft, R. and Levy, J.F. (1973), Tamblyn, N.E. (1985) on the use of Boron compounds in the preservation of wood.

The use of solution of multisalt preservatives containing boron, fluorine, chrome and arsenic has been found to give effective protection to building timbers in Papua New guines (Tamblyn, 1985).

3. Materials and Methods

3.1 Materials

Air-dried specimens of In and Green specimens of Kanyin and Taung - thayet from Burma were used.

The objectives of the present study were to determine the retentions for the three preservatives which will be able to prevent decay of In, Kanyin and Taung - thayet by two basidiomycete fungi representing white rot (*Coriolus versicolor*) and brown rot (*Coniophora puteana*) and by a soft rot fungus (*Chaetomium globosum*) cultured on laboratory media, and in an accelerated unsterile soil burial test. An additional objective was to assess the "treatment quality" of the preservative / treatment method combination in terms of the depth of penetration in larger dimension (50 x 50 mm) Cross - sectional material.

3.2 Procedure

Three preservatives were chosen for the vacuum / pressure treatment, and two preservatives were chosen for the diffusion treatment trials.

3.2.1 Decay Tests.

In, Kanyin and Taung - thayet mini - blocks (5 x 10 x 30 mm) were, weighed, immersed in water and put into the vacuum oven. They were subjected to a vacuum for 30 minutes at 750 Hg, and after that the vacuum was broken and the blocks were left to soak for one hour before they were taken out and weighed. From the wet weight the uptake of water was calculated, and for all three species the assumed uptake was to be 460 $1/m^3$. This value was used to calculate the preservative solution strength for the treatment trials.

3.2.1.1 Preservatives

1. CCA. Five concentrations of 0.76%, 1.50%, 3.24%, 4.54% and 7.57% W/V were prepared from a 10% W/V solution by means of serial dilution with distilled water.
2. BFCA. Five concentrations of 0.032%, 0.082%. 0.164%, 0.328%, and 0.459% weight / volume were prepared from a 1% weight / volume stock solution by serial dilution with distilled water.
3. Boron. Five concentrations of 0.036%, 0.045%, 0.09%, 0.178% and 0.266% were prepared from a 1% weight / volume solution stock by serial dilution with distilled water.

3.2.1.2 Treatment of Materials for Decay Testing.

Preservative treatment of air-dried, pre - weighed mini - blocks (5 x 10 x 30 mm) for the test was carried out with the mini-preservative treatment plant. The treating cycle consisted of a vacuum of at least 650 mm of mercury, lasting for one hour, followed by a 3 hours pressure at 1240 K N / m^2.

3.2.1.3 Fungi and Test Methods

The monoculture decay test was designed to determine the fungicidal efficacy of the three preservatives using one soft rot fungus (*Chactomium globosum*) and two basidiomycete fungi (*Coriolus versicolor*) and (*Coniophora puteana*) for each wood species after the method of Bravery (1975).

3.2.2 Treatability Trials.

For the treatability test of the three wood species, a 5% CCA solution was prepared in accordance with BS 4075, Type II.

All the samples were end grain sealed 3 times by using Epoxy resin in order to remove the effect of end grain penetration and simulate the treatment of large pieces of timber.

Vacuum / pressure Treatment

(a) Standard Cycle

The standard treating cycle consisted of a vacuum at least 650 mm of mercury, lasting for one hour, followed by a three hour pressure at 1240 K N / m^2

(b) Prolonged Pressure Treatment.

It consisted of a vacuum of at least 650 mm of mercury lasting for one hour, followed by a 24 hours pressure at 1240 KN/m^2.

(c) Steamed / Air - dried Treatment.

Green specimens of Kanyin and Taung - thayet (MC 46% for Kanyin; 28% for Taung-thayet) were steamed in the autoclave at 120°C - 15 psi for 2 hours and then conditioned to dry at room temperature (20°C-60% RH) for 8 weeks before pressure treatment where the moisture contents were 12% for In, 9% for Kanyin and Taung-thayet respectively.

(d) Incising

Air-dried specimens of In, Kanyin and Taung-thayet (MC 12% for In, 7% for Kanyin and Taung-Thayet) and partially dried specimens of Kanyin and Taung-Thayet (MC 46% for Kanyin and 28% for Taung - thayet) were incised and treated with standard schedule to compare the uptake and retention of the preservative.

3.2.2.4. Diffusion Treatment.

1. BFCA. A solution equivalent to a 30% weight/ weight BFCA " High Strength " in Tamblym (1975) was used.
2. Boron. A 25% " Polybor " was used.

Green wood blocks of In (Resaturated by vacuum/pressure with water), Kanyin and Taung-thayet, approximately (50 x 55x 114 mm) in dimensions were used for diffusion treatment, using 5 replicates for each wood species for each preservative.

4. Results and Discussion.

4.1 Decay Tests.

The average dry salt retention by vacuum / pressure treatment for In, Kanyin and Taung-thayet is shown in Table 1.

The toxic limit against the decay tests for each preservative wood species are summarised in Tables 2a, 2b and 2c. Mean weight losses for individual species treated with different solution strength of preservatives (including the untreated specimens) exposed to different decay tests are shown in Tables 3, 4 and 5. Mean weight losses against the preservative retentions are shown graphically in Figure 1 to 9 and 11 to 13.

The retention ranges chosen for each preservative type were to cover the expected toxic threshold in the laboratory tests and the results were relatively successful.

All the species were treated as expected and the tests under this study were considered as a true test of the treated wood and not the test of preservative distribution.

The untreated wood varies in their durability depending on decay types tested. The unsterile soil burial test was the most aggressive when the blocks were subjected to 16 weeks exposure time. The exposure time was decided after sacrificing the untreated blocks at various intervals of exposure time (Figure 10).

Of the species treated, Taung-thayet was the most susceptible to decay. This perhaps may possibly be due to their bigger sapwood content than In and Kanyin.

Of all the preservatives tested, CCA was the only preservative suitable for both ground contact and building materials. It gave effective protection against all decay hazards although the toxic threshold did vary in Taung-thayet which indicate more preservative retention was needed in the soft rot (C. globosum) hazard and unsterile soil burial test.

The toxic limit for CCA in the test ranged from 3.97 kg/m^3 to 37.62 kg/m^3, depending upon the fungus and wood species. Although the toxic limits were obtained, the preservative retention required to protect In, Kanyin and Taung-thayet in unsterile soil burial test, and Taung-thayet against C. globosum exceed those that are specified in BS 4072:1974.

BFCA and Boron treated blocks indicated good control of C. versicolor and C. puteana, representing the expected decay hazards out of ground contact in buildings.

The results from this study indicated that both BFCA and Boron preservatives failed in C. globosum test at the retention ranges tested.

4.2 Vacuum / Pressure Treatment.

The mean uptake and retention of preservatives for In, Kanyin and Taung - thayet sample blocks treated with 5% CCA by " Standard " vacuum / pressure method is shown in Table 6. Kanyin seems to be quite resistant to the treatment as the mean retention was 3.20 kg/m^3, which was rather lower than the minimum retention of 5.3 Kg/m^3 as specified in BS 4072:1974, for exterior timbers in ground contact liable to severe fungal decay and insect attack.

In an attempt to achieve better retention and penetration, various treatment methods were tested in comparison with the " Standard " treatment schedule on air-dried specimens. Partially dried specimens of Kanyin (46% MC) and Taung-thayet (28% MC) were steamed, air-dried, and then treated with " Standard " schedule and their uptake and retentions are compared in Table 7. The treatment showed that these timbers were still refractory with only a slight increase in retention for Kanyin and a decrease in retention for. Taung-thayet.

Air-dried specimens of In, Kayin and Taung-thayet were incised and treated with " Standard " schedule as well as with a long pressure schedule, while partially dried

specimens of Kanyin and Taung-thayet were incised and treated with " standard " schedule (Table 8 and 9). Comparison of difference in uptake of preservative for all the treatments are summarised in Table 10.

All the incised specimens with different treatment schedules show an increase in retention and better penetration of preservatives (Table 11), though Taung-thayet seems to be more resistant than In and Kanyin. Air-dried samples, incised and treated with long pressure schedule gave the best results in preservative retention.

The treatment results of partially dried and incised samples of Kanyin and Taung-thayet indicate that these species could be treated in partially dried condition. However, the problems of cracking and end-splitting of the treated timber due to drying after treatment should be taken into account as this may expose untreated wood directly to decay organisms.

4.3 Dip Diffusion Treatment.

Dip diffusion treatment with BFCA and Boron were considered as alternative mean of treatment to vacuum/pressure treatment in this study. The diffusion rate of Boron by both type of preservatives gave satisfactory results with complete penetration being achieved after 21 days diffusion time.

The uptake and retention of preservatives for both treatment is shown in Table 12. The mean depth of penetration of Boron together with corresponding diffusion time are shown in Table 13 and 14.

The results suggested that In , Kanyin and Taung-thayet timber, for use as interior timber, may be as well treated with Boron or BFCA preservative instead of pressure treated timber.

5. Conclusion

At the level of preservative retention tested, CCA was the most effective preservative for all the three timber species under study controlling decay by all fungi and in Unsterile Soil Burial Test.

BFCA and Boron preservatives were successful only in controlling decay caused by *C. versicolor* and *C. puteana* fungi in these timbers species.

Thought the three timber species under study were quite refractory in vacuum/pressure treatment, incising them prior to treatment led to increased uptake and better penetration of preservatives both in the air-dried and partially-dried conditions.

Diffusion treatment with Boron compounds gave very good preservative penetration, indication that constructional timbers for interior use could be treated with Boron compounds by diffusion as an alternative to pressure treatment methods.

Since the Numbers of Specimens for each test were limited in this study, no statistical analysis were made. Results of the present study were only general guides to the treatability and performance of the three timber species for future studies where statistical analysis should be included to assess the level of significant difference between treatments.

References

1. Bravery, A.F. (1975). Microbiological assay of chemicals for the protection of wood. Building Research Establishment Current Paper CP 92/75, October, 1975.
2. Barnacle, J.F. and Da Costa, E.W.B. (1975). " Field and Laboratory Testing In The Tropics." Tropical Wood Preservation Training Seminar, Session 7, Topic (d), Port Moresby, July, 1975.
3. Backer, G. (1976). Treatment of wood by Diffusion of Salts. Journal of the Institute of Wood Science Vol. 7, No. 4, Issue 40, November, 1976, PP.30-36.
4. B.S. 838 : 1961.
5. B.S. 5666 : Part 2 : 1980.
6. B.S. 5761 : Part 2 : 1980 (EN 84)
7. B.S. 6009 : 1982 (EN 113).
8. B.S. 913 : 1973.
9. B.S. 4072 : 1974.
10. B.W.P.A. Standard 105.
11. Carr, D.R. (1959). Boron as a Wood Preservative. Rec Ann. Conv. BWPA,1959. P 105-121.
12. Cockcroft, R. and Levy, J.F. (1973). Bibliography on the Use of Boron Compounds in the Preservation of wood. J. Inst. Wood Sci., No.33 (Vol.6 No.3), June 1973, p 28-30.
13. Cockcroft, R. (1974). Evaluating The Performance of Wood Preservatives Against Fungi.
14. Da Costa, E.W.B. and Greaves, H. (1975). " Laboratory Test Procedures. " Tropical Wood Preservation Seminar, Session 6, Tropic (c) I, Port Moresby, July, 1975.
15. Findlay, W.P.K. (1985). Preservation of Timber in the Tropics. Martinus Nijhoff/Dr.W. Junk Publishers, Dordrecht.
16. Levy, C.R. (1982). Methods of Treatment of Wood Preservatives. The Appropriate Preservation Process with Particular Reference to Mixed Tropical Forest Resources. IRG Document No : IRG/WP/3177.
17. Morgan, J.W.W. (1972). Incision as a means of Improving the pressure Treatment of Spruce. Document No : IRG/WP/3118, West Germany, 1972.

Table 1. Average Dry Salt Retention by " Standard " Vacuum/Pressure Treatment.

Preservative Solution Strength	Species					
	In		Kanyin		Taung-thayet	
	Uptake 1/m^3	Retention kg/m^3	Uptake 1/m^3	Retention kg/m^3	Uptake 1/m^3	Retention kg/m^3
0.76%	523	3.97	522	3.97	620	4.71
1.50%	512	7.68	482	7.23	668	10.02
CCA 3.24%	533	17.27	508	16.46	620	20.09
4.54%	516	23.43	498	22.61	611	27.74
7.57%	414	31.34	356	26.95	497	37.62
0.032%	440	0.14	413	0.13	551	0.18
0.082%	439	0.36	404	0.33	572	0.47
BFCA 0.164%	452	0.74	400	0.66	552	0.91
0.392%	552	1.82	527	1.73	624	2.05
0.495%	496	2.46	534	2.64	625	3.09
0.036%	517	0.19*	480	0.17*	653	0.24*
0.045%	678	0.31*	664	0.30*	768	0.35*
Boron 0.09%	523	0.47*	476	0.43*	658	0.59*
0.178%	688	1.22*	660	1.17*	693	1.23*
0.266%	650	1.73*	640	1.70*	625	2.02*

* Boric Acid equivalent.

Table 2 (a). Toxic Limits for CCA-treated In, Kanyin and Taung-thayet blocks exposed to Decay Tests.

Species	Toxic Limits (Retention kg/m^3)			
	Chaetomium globosum	Coriolus versicolor	Coniophora puteana	Unsterile Soil Burial
(1)	(2)	(3)	(4)	(5)
In	3.97	3.97	3.97	17.27
Kanyin	7.23	3.97	3.97	26.95
Taung-thayet	27.74	10.02	3.97	37.62

Table 2 (b). Toxic Limits for BFCA-treated In, Kanyin and Taung-thayet blocks exposed to Decay Tests.

(1)	(2)	(3)	(4)	(5)
In	2.46*	0.74	0.36	2.46*
Kanyin	2.64*	1.73	0.13	2.64*
Taung-thayet	3.09*	2.05	0.47	3.09*

Table 2 (c). Toxic Limits for Boron-treated In, Kanyin and Taung-thayet blocks exposed to Decay Tests.

(1)	(2)	(3)	(4)	(5)
In	1.73*	1.73	0.31	1.73*
Kanyin	1.70*	1.18	0.30	1.70*
Taung-thayet	2.02*	2.02	0.59	2.02*

* Toxic Limits were greater than maximum concentration tested.

Table 3. Mean weight losses for Untreated In blocks and blocks treated with 5 different Solution Strength of CCA, BFCA and Boron.

Preservative Solution Strength	Retention kg/m^3	Mean Weight Loss %							
		Soft Rot*		White Rot*		Brown Rot**		Soil Burial	
		Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
0.76%	3.97		3.99		5.12		3.03		22.99
1.50%	7.68		3.73		3.97		3.01		7.58
CCA 3.24%	17.27		4.24		3.84		3.52		4.87
4.54%	23.43		4.00		3.23		3.23		2.86
7.57%	31.34		4.68		4.68		4.00		2.28
0.032%	0.14		18.25		11.54		7.51		29.53
0.082%	0.36		16.23		7.02		1.59		34.19
BFCA 0.164%	0.74	13.95	16.29	6.96	5.66	6.35	2.92	22.38	27.10
0.329%	1.82		19.75		3.65		2.99		29.55
0.495%	2.46		15.87		3.10		2.64		27.87
0.036%	0.19		21.25		13.50		7.18		33.04
0.045%	0.31		23.04		12.73		2.23		33.42
Boron 0.09%	0.47		17.50		9.15		1.07		34.59
0.178%	1.22		18.13		6.59		4.38		38.56
0.266%	1.73		15.79		5.45		4.83		32.65

* Soft Rot (Cheatomium globosum) ; White Rot (Coriolus versicolor) ; Brown Rot (Coniophora puteana)

** 16 Weeks.

Table 4. Mean weight losses for Untreated Kanyin blocks and blocks treated with 5 different Solution Strength of CCA, BFCA and Boron.

Preservative Solution Strength	Retention Kg/m^3	Mean Weight Loss %							
		Soft Rot*		White Rot*		Brown Rot*		Soil Burial**	
		Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
CCA 0.76%	3.97		7.09		5.37		2.90		33.21
CCA 1.50%	7.23		4.77		3.69		2.30		19.08
CCA 3.24%	16.46		2.89		3.12		2.48		10.61
CCA 4.54%	22.61		2.92		2.84		2.21		8.56
CCA 7.57%	26.95		3.70		3.66		2.92		3.74
BFCA 0.032%	0.13		23.17		14.21		4.22		40.74
BFCA 0.082%	0.33		24.14		10.73		0.77		39.08
BFCA 0.164%	0.66	11.04	26.10	13.44	7.48	8.11	2.08	39.28	38.58
BFCA 0.329%	1.73		24.22		3.06		2.02		36.96
BFCA 0.495%	2.64		21.49		2.79		2.44		41.4
Boron 0.036%	0.17		26.65		16.17		7.16		43.56
Boron 0.045%	0.30		25.76		15.09		3.36		38.95
Boron 0.09%	0.43		25.63		11.67		1.13		45.80
Boron 0.178%	1.18		21.30		5.29		4.35		45.50
Boron 0.266%	1.70		25.19		4.58		4.11		37.61

* Soft Rot (Chaetomium globosum); White Rot (Coriolus versicolor); Brown Rot (Coniophora puteana)
** 16 Weeks.

Table 5. Mean weight losses for Untreated Taung-thayet blocks and blocks treated with 5 different Solution Strength of CCA, BFCA and Boron.

Preservative Solution Strength	Retention Kg/m^3	Mean Weight Loss %							
		Soft Rot*		White Rot*		Brown Rot*		Soil Burial**	
		Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
0.76%	4.17		24.06		6.87		1.31		33.65
1.50%	10.02		12.86		3.79		2.28		28.25
CCA 3.24%	20.09		6.08		4.19		3.00		16.37
4.54%	27.74		5.59		4.10		3.04		11.30
7.57%	37.62		6.18		5.03		4.17		4.92
0.032%	0.18		41.19		30.38		40.61		47.62
0.082%	0.47		42.44		32.70		5.61		48.04
BFCA 0.164%	0.91	17.79	42.01	48.20	7.34	36.62	3.01	45.29	47.82
0.329%	2.05		30.67		2.25		2.44		42.87
0.495%	3.09		32.64		2.58		1.94		42.37
0.036%	0.24		40.58		36.32		31.88		50.28
0.045%	0.35		32.87		52.34		20.63		52.94
Boron 0.09%	0.59		31.57		48.77		3.75		44.50
0.178%	1.23		36.42		7.69		4.30		55.02
0.26%	2.02		37.49		4.25		3.36		53.59

* Soft Rot (Cheatomium globosum); White Rot (Coriolus versicolor); Brown Rot (Coniophora puteana)
** 16 Weeks.

Table 6. Mean Uptake and Retention of Preservatives in In, Kanyin and Taung-thayet sample blocks treated with 5.0% CCA by " Standard " Vacuum/Pressure Schedule.

Species	Moisture Content %	Uptake $1/m^3$	Retention kg/m^3
In	8	184.43	9.22
Kanyin	8	63.96	3.20
Taung-thayet	7	99.98	5.00

Table 7. Comparism of the mean Uptake and Retention of preservatives between the Air-dried and Steamed/Air-dried specimens of Kanyin and Taung-thayet with 5% CCA by "Standard" Vacuum/Pressure Schedule.

Species	Air-dried		Steamed/Air-dried	
	Uptake $1/m^3$	Retention kg/m^3	Uptake $1/m^3$	Retention kg/m^3
Kanyin	63.96	3.20	69.39	3.47
Taung-thayet	99.98	5.00	93.20	4.66

Table 8. Comparison of the Average Uptake and Retention of Preservatives between the Unincised and Incised Specimens treated with different vacuum/pressure treatment schedules.

	Unincised (Standard)		Incised (Standard)		Incised (Long pressure)**	
	Uptake $1/m^3$	Reten-tion kg/m^3	Uptake $1/m^3$	Reten-tion kg/m^3	Uptake $1/m^3$	Reten-tion kg/m^3
In	184.43	9.22	226.37	11.32	287.41	14.37
Kanyin	63.96	3.20	127.01	6.35	181.70	9.08
Taung-thayet	99.98	5.00	100.61	5.03	207.57	10.38

Standard = 1 Hour vacuum and 3 Hours pressure period.
**Long Pressure = 1 Hour vacuum and 24 Hours pressure period.

Table 9. Comparison of the Average Uptake and Retention of preservative between the Incised/Air-dried and Incised/Part-dried specimens treated by the " Standard " treatment schedule.

Species	Incised/Air-dried			Incised/Part-dried		
	M.C %	Uptake $1/m^3$	Retention kg/m^3	M.C %	Uptake $1/m^3$	Retention kg/m^3
Kanyin	8	127.01	6.35	46	82.08	4.10
Taung-thayet	7	100.61	5.03	23	158.24	6.91

Table 10. Difference in Preservative Uptake of In , Kanyin and Taung-thayet sample blocks with different treatment schedules and pre-treatment in comparison with "Standard" schedule.

Species	Steamed/Air-dried (Standard)*	Incised/Air-dried (Standard)*	Incised/Air-dried (Long Pressure)**	Incised/Part-dried (Standard)*
In	-	+ 41.94	+ 102.98	-
Kanyin	+ 5.43	+ 63.05	+ 117.74	+ 0.90
Taung-thayet	- 6.78	+ 0.63	+ 107.59	+ 1.91

* " Standard " = 1 Hour vacuum and 3 hours pressure.
** Long Pressure = 1 Hour vacuum and 24 hours pressure.
(+) = Uptake greater than the " Standard " schedule.
(-) = Uptake less than the " Standard " schedule.

Table 11. Mean Depth of Penetration of Preservatives of In , Kanyin and Taung-thayet sample blocks treated with 5% CCA with different treatment schedule and pre-treatment.

Specimens and Treatment Schedule	Depth of Penetration (mm)		
	In	Kanyin	Taung-thayet
1. Air-dried " Standard "	3.5	0.9	2.8
2. Steamed/Air-dried " Standard "	-	1.8	2.4
3. Part-dried/Incised " Standard "	-	4.8	5.7
4. Air-dried/Incised " Standard "	4.7	4.1	3.0
5. Air-dried/Incised	5.2	4.3	3.8

Table 12. Mean Uptake and Retention of In, Kanyin and Taung-thayet for BFCA and Boron Dip-diffusion Treatment.

Preservatives Species	Moisture Content (%)	1st. Day Dipping		2nd. Day Dipping		3rd. Day Dipping		Mean Total	
		Uptake 1/m^3	Retention* kg/m^3	Uptake 1/m^3	Retention* kg/m^3	Uptake 1/m3	Retention * kg/m^3	Uptake 1m^3	Retention * kg/m^3
BFCA									
In	80	7.7	2.8	-	-	-	-	7.7	2.8
Kanyin	65	6.9	2.5	-	-	-	-	6.9	2.5
Taung-thayet	71	4.1	1.5	3.1	1.1	-	-	7.2	2.6
Boron									
In	80	1.9	0.5	4.4	1.1	5.3	1.3	11.6	2.9
Kanyin	65	5.0	1.3	5.0	1.3	5.3	1.3	15.3	3.8
Taung-thayet	71	5.0	1.3	2.3	0.6	3.5	0.9	10.8	2.7

*Retention are for Boric Acid Equivalent including BFCA preservative.

Table 13. Depth of penetration of Boron in BFCA Dip-diffusion Treatment.

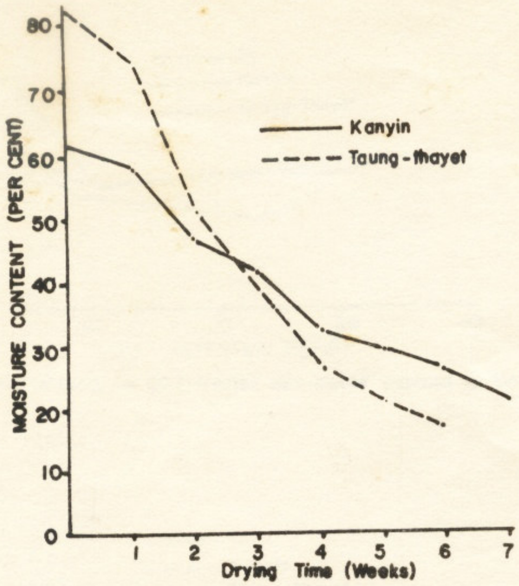
Diffusion time (Days)	Mean Depth of Penetration (mm)		
	In	Kanyin	Taung-thayet
7	8.6	7.8	10.2
14	12.3	11.5	15.3
21	14.5	13.5	20.1
42	25.0*	25.0*	25.0*

*Complete penetration

Table 14. Depth of penetration of Boron by the Conventional Dip-diffusion Treatment.

Diffusion time (Days)	Mean Depth of Penetration (mm)		
	In	Kanyin	Taung-thayet
3	3.2	4.1	4.0
7	7.3	7.7	9.0
14	10.4	11.2	12.5
21	25.0*	15.7	25.0*
42	-	25.0*	-

*Complete penetration.



Drying rate of Kanyin and Taung-thayet

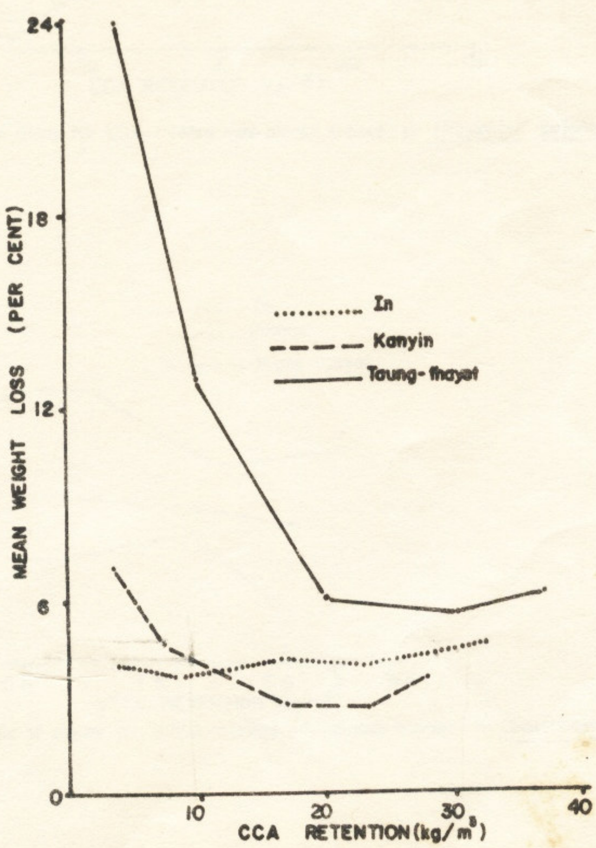


Fig. 1. Analysis of decay for CCA-treated mini-blocks exposed to *Chaetomium globosum*.

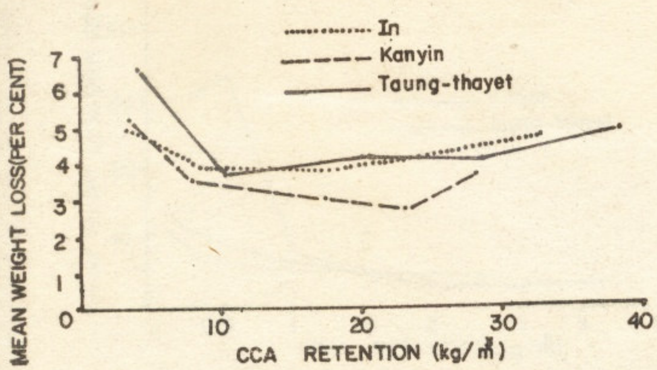


Fig.2. Analysis of decay for CCA-treated mini-blocks exposed to *Coriolus versicolor* (Fr.)Quel.

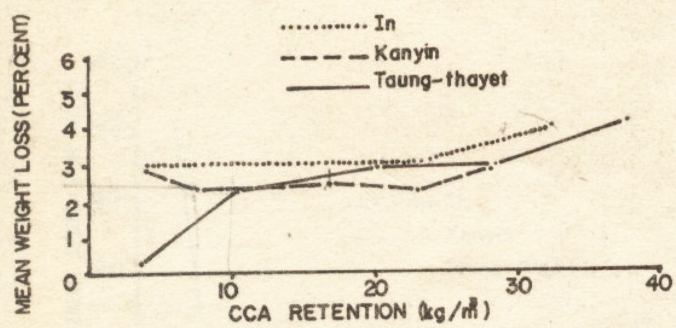


Fig.3. Analysis of decay for CCA-treated mini-blocks exposed to *Coniophora puteana*.

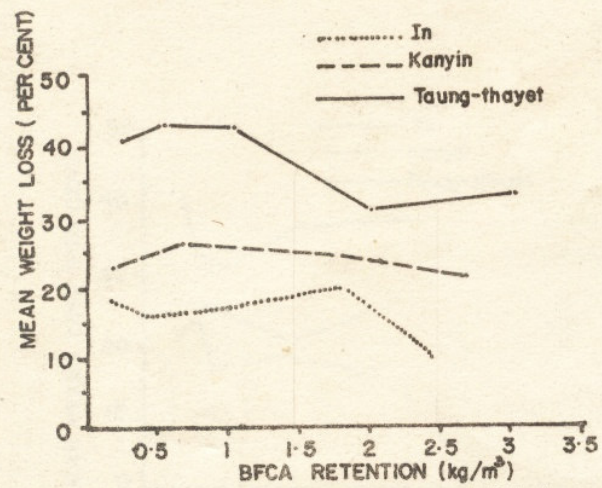


Fig.4. Analysis of decay for BFCA-treated mini-blocks exposed to *Chaetomium globosum* Karst.

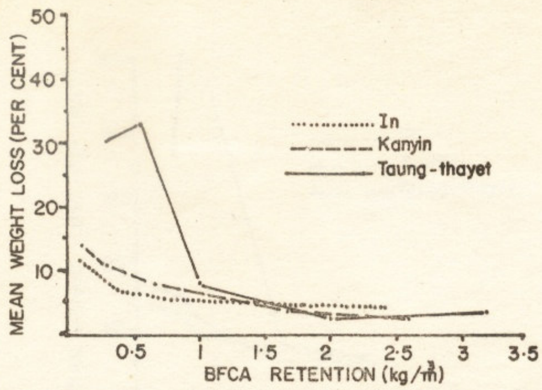


Fig. 5. Analysis of decay for BFCA-treated mini-blocks exposed to Coriolus versicolor (Fr.) Quel.

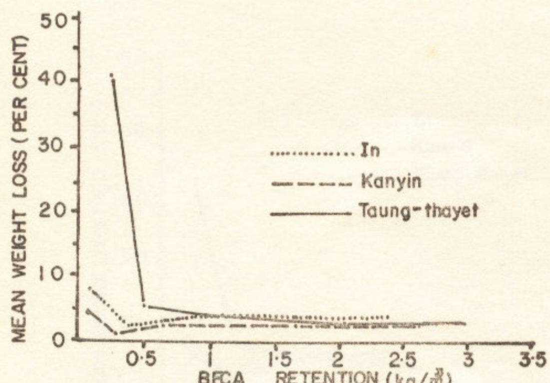


Fig. 6. Analysis of decay for BFCA-treated mini-blocks exposed to <u>Coniphora puteana</u>.

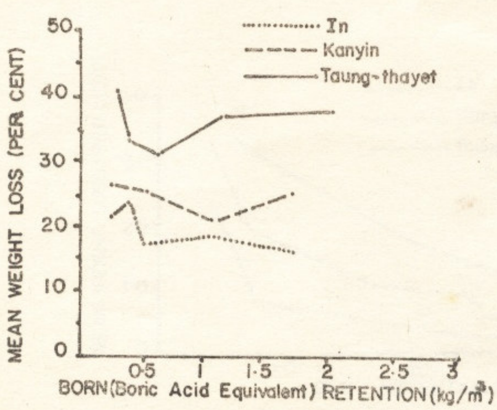


Fig. 7. Analysis of decay for Born-treated mini-blocks exposed to <u>Chaetomium globosum</u> Karst.

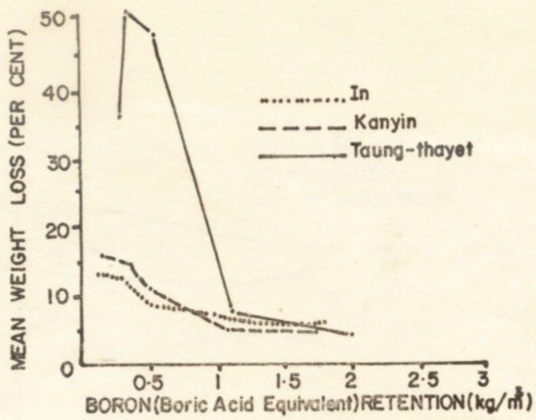


Fig. 8. Analysis of decay for Boron-treated mini-blocks exposed to Coriolus versicolor (Fr.) Quel.

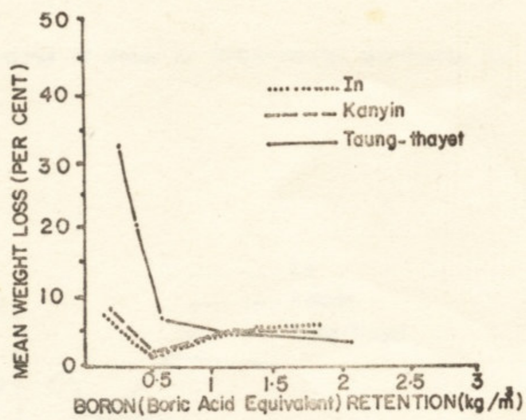


Fig. 9. Analysis of decay for Boron-treated mini-blocks exposed to Coniophora puteana.

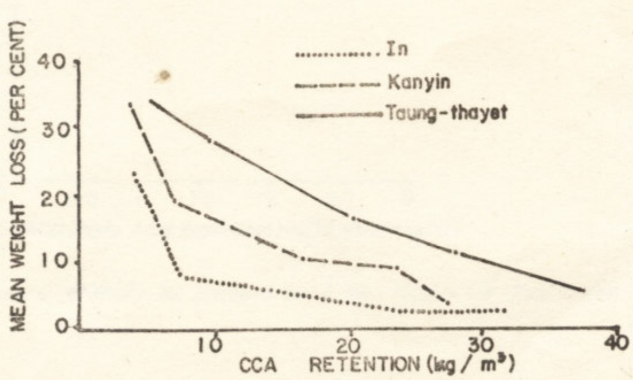


Fig. 10. Analysis of decay for CCA-treated mini-blocks for Soil Burial Test.

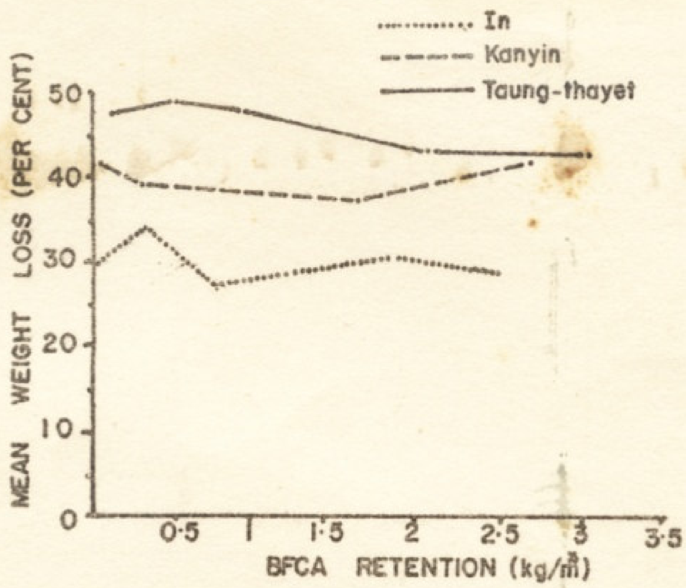


Fig. 1.1. Analysis of decay for BFCA-treated mini-blocks for Soil Burial Test.

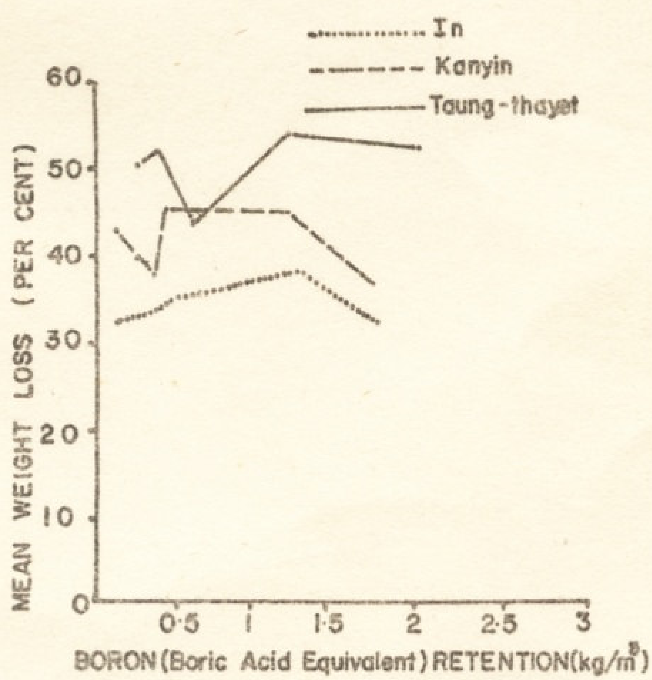


Fig. 1.2. Analysis of decay for Boron-treated mini-blocks for Soil Burial Test.