LABORATÓRIO NACIONAL
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TESTS OF NATURAL AND ACQUIRED DURABILITY OF SUGI TIMBER AGAINST DRY WOOD TERMITES

Characterization of azorean sugi timber

REPORT 227/**2015 – DE/NCE**
English translation

PROCONVERGENCIA AÇORES 2007-2013
CONSTRUIR O FUTURO

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AZORINA – Sociedade de Gestão Ambiental e Conservação da Natureza, S.A.

Lisbon • April 2015

R&D STRUCTURES

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Title

TESTS OF NATURAL AND ACQUIRED DURABILITY OF SUGI TIMBER AGAINST DRY WOOD TERMITES
Characterization of azorean sugi timber

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TESTS OF NATURAL AND ACQUIRED DURABILITY OF SUGI TIMBER AGAINST DRY WOOD TERMITES

Characterization of azorean sugi timber

Abstract

The current report presents the results for natural and acquired durability of *Cryptomeria japonica* (Thunb. ex L.f.) D. Don timber to dry wood termites *Cryptotermes brevis* (Walker) attack. The sampling of the pieces was done by AZORINA according to the sampling plan established in the Technical Report 1/2014-DE/NCE. The preparation of the test-specimens was conducted by LNEC and termite testing was done by ACDA (Associação de Ciência e Desenvolvimento dos Açores) at University of the Azores.

This document was produced within a project settled with AZORINA, Sociedade de Gestão Ambiental e Conservação da Natureza, SA.

Keywords: Azores / Sugi / *Cryptotermes brevis*

ENSAIOS DE DURABILIDADE NATURAL E ADQUIRIDA DE MADEIRA DE CRIPTOMÉRIA CONTRA TÉRMITAS DE MADEIRA SECA

Caracterização da madeira de criptoméria açoriana

Resumo

O presente relatório apresenta os resultados de ensaios de durabilidade natural e com tratamento de madeira de *Cryptomeria japonica* (Thunb. ex L.f.) D. Don ao ataque por térmitas de madeira seca, *Cryptotermes brevis* (Walker). A amostragem das peças foi realizada pela AZORINA de acordo com o protocolo estabelecido na Nota Técnica 1/2014 – DE/NCE, a preparação dos provetes foi realizada no LNEC e os ensaios com térmitas foram realizados pela ACDA (Associação de Ciência e Desenvolvimento dos Açores) na Universidade dos Açores.

Este documento foi elaborado no âmbito do projeto estabelecido com a AZORINA, Sociedade de Gestão Ambiental e Conservação da Natureza, SA.

Palavras-chave: Açores / Criptoméria / *Cryptotermes brevis.*

Index

Table index

1 | Introdution

1.1 Objectives

The contract with the Azorina, Sociedade de Gestão Ambiental e Conservação da Natureza, SA (Environmental Management Society and Nature Conservation, SA.), by direct award nº 36/Azorina/2012, covers the purchase of services for development of a standard for a visual strength grading standard of sugi for structural purposes, according to European standards, and evaluation of its durability after being subjected to different treatments to protect against subterranean (*Reticulitermes grassei*) and dry wood (*Cryptotermes brevis*) termites.

This report refers to the assessment of the durability of sugi wood, with and without treatment, to the attack by dry wood termites (*Cryptotermes brevis*). The study includes sugi wood from the islands of São Miguel and Terceira provided by Azorina. - Sociedade de Gestão Ambiental e Conservação da Natureza, S.A.. The sampling of the material was done by Azorina in accordance with the principles defined in the Technical Note 1/2014 - DE / NCE [1]. The preparation of the test-specimens was conducted by LNEC and termite testing was done by ACDA (Associação de Ciência e Desenvolvimento dos Açores) at University of the Azores.

1.2 Dry wood termites

The dry wood termites belong to the group of the social insects, but unlike the subterranean termites, more common in Continental Portugal, live inside the wood elements that they occupy without much contact with the external environment. This feature facilitates its dispersion, being easily transported by the movement of infested materials. Once introduced into suitable environments, colonies can survive and settle.

*Cryptotermes brev*is (Walker) is the termite species that has suffered more introductions and is the most important dry wood termite with pest status. *C. brevis* has a lifecycle with division of castes, characteristic of social insects (see Annex). In this species, the colonization of a structure in a building begins when a fertilized female lays the first eggs. From these eggs will develop the first nymphs that have the ability to give rise to any of the castes (pseudergates, soldiers and reproductives). When the colony reaches a suitable size and at certain times during the summer, new reproductives are formed and will fly and look for other places to establish new colonies.

More information on dry wood termites is presented in the annex to this report.

2 | Methods and Materials

2.1 Evaluation of the natural durability against dry wood termites

The natural durability of Azorean sugi was evaluated in the laboratory by a procedure adapted from a test method developed by the Instituto de Pesquisas (Research Institute) of São Paulo (IPT) [2].

Termites

For these test, termites from the *Cryptotermes brevis (*Isoptera: Kalotermitidae) species were used.

The tests were performed at the Universidade dos Açores, in Angra do Heroísmo and the termites were collected locally from infested construction wood (*Eucalyptus globulus* Labill).

Wood

All assays were performed with *Cryptomeria japonica* (L. F.) D. Don var. sinensis Sieb heartwood. In most trials "pink" sugi from two different locations was used: Terceira and São Miguel islands in the Azores. From each of the islands, heartwood test specimens were collected from three different trees of "pink" sugi, cut in two different locations. "Black" sugi wood from the island of São Miguel was also tested but with unknown exact origin. For each "pink" sugi sampled tree, 3 replicates were assayed and also 10 replicates of "black" sugi.

Termite virulence testing was also performed using for this purpose the untreated sapwood of a timber species of known susceptibility, maritime pine (*P. pinaster*) (3 replicates).

All test samples, which had approximate dimensions of 70 mm × 25 mm × 10 mm, were prepared at LNEC, in Lisbon, and sent to the University of the Azores to test with termites. Before starting the tests the average initial moisture content was calculated in a set of five test pieces following the procedures described in EN 13183-1 NP: 2013 [3].

Method

The details on method of application can be found at the ACDA's report attached.

2.2 Assessment of the acquired durability against dry wood termites

Termites

For these tests *Cryptotermes brevis* (Isoptera: Kalotermitidae) termite species were used, obtained as described above.

Wood

To evaluate the effectiveness of treatments, test specimens of “pink" sugi, randomly chosen from the ones obtained from the selected trees, were used.

Method

Heartwood test specimens were treated with two commercial wood preservatives named for the purpose of these tests Xy and Xz. These products have the active ingredients described in Table 2.1, in an organic solvent. Sugi heartwood test specimens treated only with the solvent (white spirit) were used as controls. For each of the variables (including solvent) 3 replicates were assayed from each sampled island.

The test samples were treated by brushing with three coats of wood preservative according to the manufacturer's instructions, and the absorption calculated by mass variation before and after treatment. The average absorption values are presented in Table 2.1.

Table 2. 1 – Average values for absorption of the wood preservatives used for treating sugi

Treatment product	Active ingredients	Mean and standard deviation of absorption (g/m2)		
		1ª coat	**2ª coat**	**3ª coat**
Xz	Propiconazol: 0.15%; Cipermetrina: 0.07%; Tebuconazol: 0.05%; IPBC: 0.05%	254,28 (65,21)	130,43 (39,34)	116,43 (26,56)
Xy	Propiconazol – 0.6%; Diclofluanida: 0.54%; Cipermetrina: 0.05%	223,28 (54,21)	120,86 (25,34)	141,43 (26,48)
White spirit	-	296,46 (87,99)	111,14 (37,82)	120,00 (62,56)

After a suitable period of drying (about 4 weeks) the specimens were packed and shipped to the University of the Azores for the termite test.

Resistance to attack by dry-wood termites on the treated test samples was evaluated also according to the test method developed by the Instituto de Pesquisas de São Paulo (São Paulo Research Institute) (IPT) [2]. Details on the method of application can be found on the ACDA's report attached.

3 | Results

The results of the evaluation of the natural and acquired durability to attack by dry wood termites are fully presented in the ACDA report attached.

4 | Discussion and Conclusion

Based on the results obtained it was verified that:

- There are significant differences in the survival of termites at the end of the test between sugi from São Miguel (particularly for the “black” variety) and sugi from Terceira. In the case of sugi from Terceira, the survival rate is not significantly different to the survival in the maritime pine control (figure 4 in Annex). The average survival rate for wood from São Miguel ("pink" and "black") is about 42% and for wood from Terceira and control about 57% and 63%, respectively.
- Termites died significantly faster in wood from São Miguel than in wood from Terceira;
- Probably as a result of the previous point, the damage to samples of "pink" sugi were significantly less important in the wood from São Miguel than that from Terceira but still relevant and equivalent to those obtained with the maritime pine control and the black sugi (figure 5 in Annex).
- The number of days that the termites were living was significantly higher in the control than in the wood from São Miguel, in particular for the "black" variety.

Therefore, under the conditions of this test there seems to be significant differences between the *Cryptomeria japonica* wood with origin in the island of São Miguel and with origin in the island of Terceira. These results give the wood from São Miguel, and in particular the "black" variety, some natural durability characteristics to dry wood termite that deserve further analysis.

With regard to acquired durability, both products tested, for the levels of absorption obtained, gave full protection to the sugi heartwood. All termites died by the end of the fifth day of the assay. These results should however be confirmed in the future after artificial aging tests (evaporation and leaching).

Lisboa, LNEC, April of 2015

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ANNEX
ACDA Final Report

ACDA – Associação de Ciência e Desenvolvimento dos Açores
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PROVISION OF SERVICES FOR **"Natural and acquired durability tests of sugi wood against dry wood termites (*Cryptotermes brevis*)"**

Scientific Coordinator: Orlando Guerreiro

Requester**: Laboratório Nacional de Engenharia Civil** (**LNEC)**

FINAL REPORT

Angra do Heroísmo, April of 2015

Natural and acquired durability tests of sugi wood against dry wood termites (*Cryptotermes brevis*)"

Orlando Guerreiro, Sophie Wallon & Paulo A. V. Borges cE3c – Centre for Ecology, Evolution and Environmental Changes / Azorean Biodiversity Group and Universidade dos Açores - Departamento de Ciências Agrárias, Rua Capitão João d'Ávila, São Pedro, 9700-042 Angra do Heroísmo, Terceira, Azores, Portugal

Executive Summary

In this study we tested the viability of dry-wood termite *Cryptotermes brevis* in different types of wood. We used a method developed by IPT (Instituto de Pesquisas de São Paulo (Research Institute of São Paulo), 1980 – Natural and acquired durability). In particular, we assessed: a) the natural durability of *Cryptomeria japonica wood* from two sources (São Miguel and Terceira); b) the effectiveness of preservative treatments (three products) against *C. brevis.*

Based on the results obtained we can say that there are clear differences between the wood of *Cryptomeria japonica* original from the island of São Miguel and the wood from Terceira Island, with the "Black" variety and the wood from São Miguel presenting a significantly lesser amount of survivors than the control. On the other hand the damage caused in the wood was significantly less important in the wood from São Miguel than in the wood from Terceira and the termites died significantly faster in wood from São Miguel than in the wood from Terceira; the number of days that the termites were alive was significantly higher in the control than in the wood from São Miguel and in the "Black" variety.

With respect to the test with the products Xz (Propiconazol - 00:15%; Cypermethrin - 00:07%; Tebuconazol - 00:05%; IPBC - 00:05%) and XY (Propiconazol - 0.6%; Dichlofluanid - 12:54%; Cypermethrin - 00:05%) they showed a great efficacy, with no live termites at the end of the fifth day of the experiment.

1. Introduction

There are three types of termites in the Azores: subterranean termites; wet wood; and dry wood. Some species cause large losses in human dwellings, attacking furniture and sculptures, but also structural parts, such as floors and ceilings.

The existing species of termite in the archipelago are:

- *Cryptotermes brevis* (Walker, 1953)
- *Kalotermes flavicollis* (Fabricius, 1793)
- *Reticulitermes flavipes* (Kollar, 1837)
- *Reticulitermes grassei* (Clément, 1978)

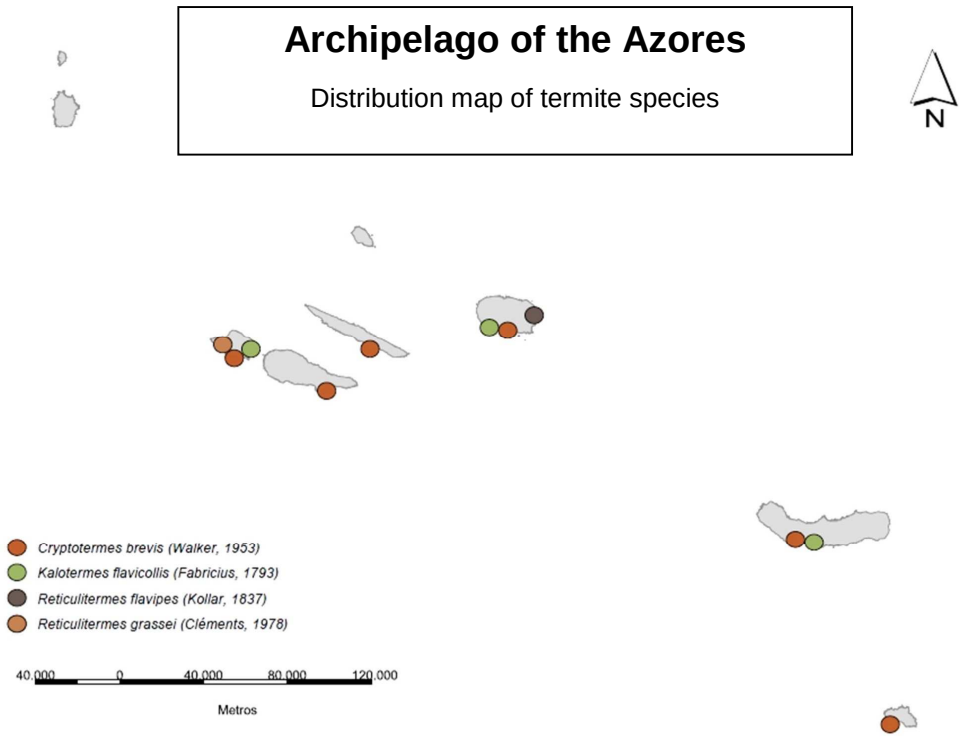

Figure 1: Map of the archipelago, indicating the occurrence of several species of termites**.**

Being social insects, they have a complex life cycle and several castes, as with *Cryptotermes brevis*, species of dry wood. In this species, usually a female and a male colonize a structure, laying eggs from which totipotent nymphs are born, this meaning, they have the capacity to become any one of the castes (workers or segregated, soldiers, reproductive). In an intermediate stage of development pseudo-workers and soldiers are formed. The pseudergates are characterized by performing all routine tasks, such as obtaining food, feeding individuals of other castes, including the king (father) and the queen (mother), elimination of sick or dead individuals, care for eggs. The pseudo-workers are kept as slaves because the mother (queen) prevents them from developing into reproductive by biting them in the areas of wings development. The segregated digest the cellulose with the aid of symbiont protozoa and regurgitate pre-digested cellulose for the other varieties to feed on. The caste of soldiers, in turn, has the function of guarding the nest and protecting the segregated during the search for food. All the workers and soldiers are blind, communicating through chemical compounds. At times during the summer, reproducers meant to look for other places to establish new colonies are formed. In some situations, such as the death of the queen, secondary reproducers may even be formed from workers.

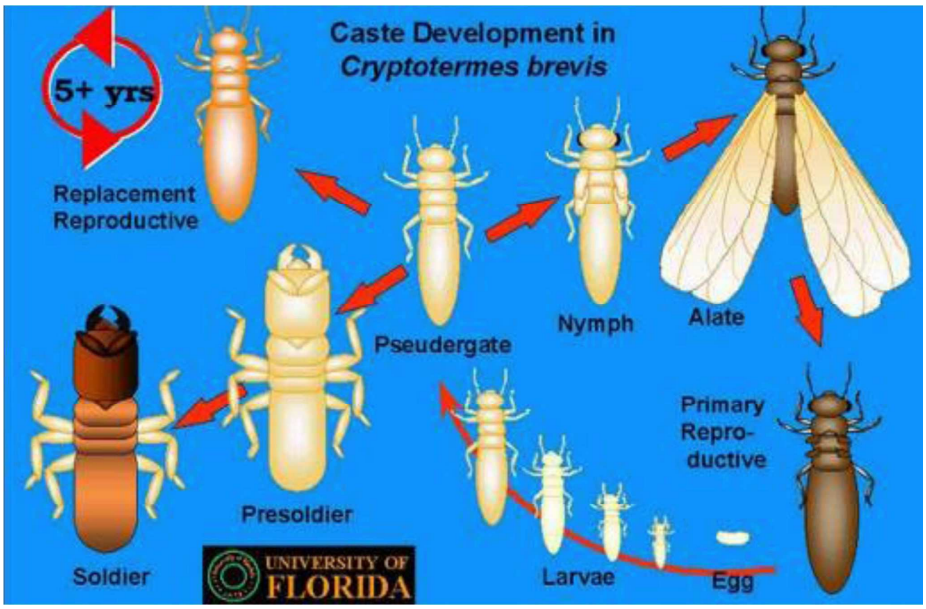

Figure 2: Life cycle of the Cryptotermes *brevis* (Walker, 1953) (dry wood termite from the West Indies).

A convenient way to detect the presence of a recent colonization by termites is by viewing loose wings on the floors or curtains and windows, since before colonizing a new location, the alates shed their wings. Released feacal pellets are also a way to detect the presence of this insect.

2. Objectives

- Evaluate the natural durability of *Cryptomeria japonica* wood from two origins (São Miguel e Terceira) against dry wood termite (*Cryptotermes brevis*)

- Assessing the effectiveness of preservative treatments (two products) against *C. brevis*

3. Materials and Methods

In order to test the virulence of *Cryptotermes brevis* in different types of wood, a method from IPT was used (Instituto de Pesquisas de São Paulo, 1980 (Research Institute of São Paulo) - Durabilidade natural e adquirida" (Natural and acquired durability).

A test specimen consisted of two heartwood samples (70 x 25 x 6 mm each) laterally fixed by an adhesive.

The wood tested was *Cryptomeria japonica*.

Test samples for natural durability (see Table 1 for more details)

SM – São Miguel, 3 trees (201, 217 e 240)

T – Terceira, 3 trees (22, 23, 80)

N – “Black” sugi wood board from São Miguel (unknown tree)

C – Casquinha (*Pinus sylvestris*) test specimens

Table 1. Details on the test specimens used for the analysis of natural durability

Code	Nº test specimens sent	For testing with termites	To know the initial moisture content **(**)**	Extra test specimens
SM 217	4	3	1	
SM 201	4	3	1	
SM 240	4	3		1
N	12	10	1	
T 80	4	3	1	
T 23	4	3	1	
T 22	4	3		1
C (pine)	7	3 to 6 **(*)**	1	

(*) subject to availability of termites

(**) immediately before the start of the test all samples were weighed. These 6 test samples were dried (24h) at 103ºC and weighed again to get a dry mass. Thereafter they were kept in the laboratory under the same conditions of the test samples under test.

Mass loss: At the end of 45 days of exposure all test pieces were again weighed (thus obtaining the "wet mass after test"), taken then to the oven at 103ºC (24h) to obtain the "dry mass after test".

On one side of the wood piece, a PVC pipe (height 4 cm, 4 cm in diameter) was fixed with wax on the timber. Then, inside the PVC tube (in direct contact with the wood) 30 termites of the ruling caste, **pseudergates** (Figure 3) were placed.

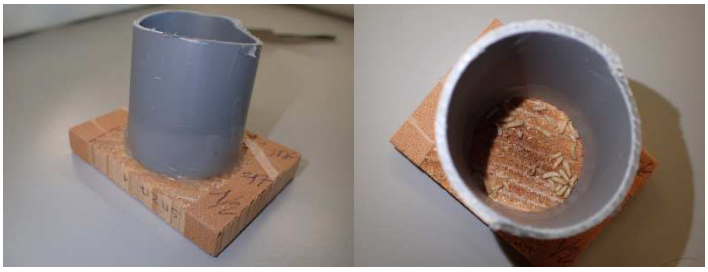

Figure 3: Experiment setting.

The pseudergates of *Cryptotermes brevis* came from the island of Terceira (Azores), having been extracted from eucalyptus beams.

Daily count of pseudergates was carried to identify dead and living individuals. A weekly droppings (feacal pellets) count was also held for 45 days.

In an additional experiment two combinations of commercial insecticides were used (see Table 2) applied in three coats according to the manufacturer's instructions present on the label:

Xz : Propiconazol - 0.15% ; Cipermethrin – 0.07% ; Tebuconazol – 0.05% ; IPBC – 0.05%

Xy : Propiconazol – 0.6% ; Diclofluanid – 0.54% ; Cipermethrin – 0.05%

Ag : White Spirit (used as a "control")

Table 2. Details about the test samples used to test two combinations of insecticides.

Code	Nº test pieces sent	For test with termites			Extra test pieces		
		Product Xz	Product Xy	Product Ag	Product Xz	Product Xy	Product Ag
SM217	3	1	1	1	0	0	0
SM240	3	1	1	1	0	0	0
SM201	3	1	1	1	0	0	0
T80	3	0	2	0	0	1	0
T23	4	1	1	1	1	0	0
T22	4	2	0	2	0	0	0

Data analysis

a) Analysis of natural durability

To compare the effect of different varieties of wood on the survival of termites, the average number of live termites after 45 days was analyzed according to the origin of the timber.

To analyze the extent of damage, a number was assigned to each day for each piece of wood (0 = With no damage; 1 = superficial damage; 3 = moderate damage; 4 = deep damage). At the end, the values of all the damage during 45 days were added for each piece of wood in order to perform a one-way ANOVA and post-hoc test.

To evaluate the effect of the wood on the mortality rate, the corresponding slopes were analyzed for mortality rate. To better understand the dynamics of mortality of termites, it was estimated and/or extrapolated the day when 50% of the population has died.

To evaluate the effect of the wood on the rate of faecal pellets, slopes corresponding to the droppings rates were analyzed.

All statistical analyzes were performed with R Core Team (2014) and Microsoft Excel.

b) Durability with insecticide treatment analysis

To evaluate the effect of treatment with insecticides on the different mortality rate, the corresponding slopes were analyzed for mortality rates. To better understand the dynamics of mortality of termites, it was estimated and/or extrapolated the day when 50% of the population have died.

To compare the effect of different treatments on the survival of pseudo-workers *Cryptotermes brevis*, mortality rate was investigated in the fifth, fifteenth and 30th days, and finally the last day (45 days). A nonparametric ANOVA (Kruskal-Wallis test) was used, carrying out the Wilcoxon test for comparison between pairs of samples.

To analyze the extent of damage, a number was assigned to each day for each piece of wood (0 = With no damage; 1 = superficial damage; 3 = moderate damage; 4 = deep damage). At the end, the values of all the damage during 45 days were added for each piece of wood in order to perform a nonparametric ANOVA (Kruskal-Wallis test).

All statistical analyzes were performed with R Core Team (2014) and Microsoft Excel.

4. Results

a) Natural durabillity analysis

A one way ANOVA was carried out to compare the effect of different varieties of wood on the survival of termites *Cryptotermes brevis* (Figure 4).

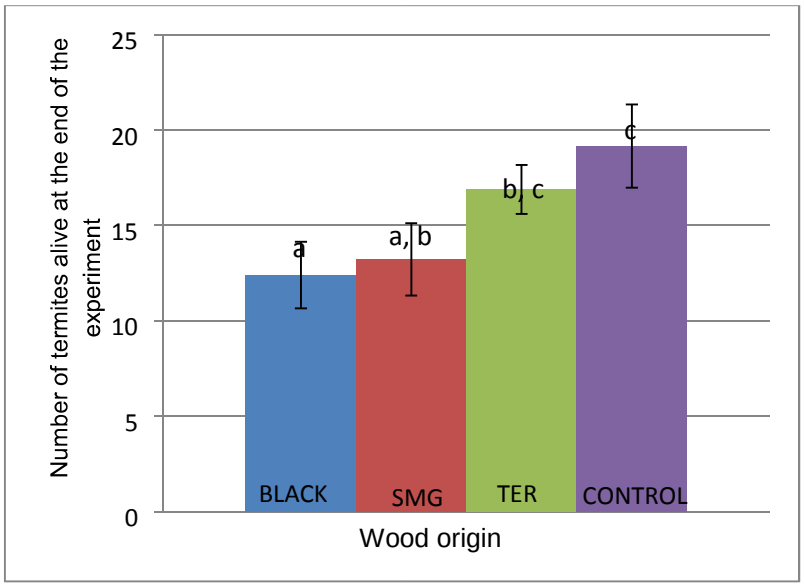

Figure 4. Average number of termites (*Cryptotermes brevis*) alive at the end of the experiment according to the chosen timber.One-way Anova [$F_{3,30}$=27.144, p=0.002]; Post hoc Tukey HSD ($p_{black-SMG}$=0.957; $p_{black-TER}$=0.045; $p_{black-Control}$=0.004; $p_{SMG-TER}$=0.145; $p_{SMG-Control}$= 0.016; $p_{TER-Control}$=0.617).

There was a significant effect of the wood for level p <0.05 for all varieties of wood [$F_{3,30}$=27.144, p=0.002]. Post-hoc comparisons indicated that the number of survivors of the variety "Black" was significantly lower than with the wood from Terceira Island (Tukey HSD; p=0.045) and the control (Tukey HSD; p=0.004). The Wood from São Miguel (SMG) also presents a number of survivors significantly lower than the control (Tukey HSD; p=0.016). However, no significant difference was observed for the number of survivors among the SMG wood and the Black variety (Tukey HSD, p=0957), between the wood from SMG and Terceira (Tukey HSD; p=0.145) and between the wood from Terceira and the Control (Tukey HSD, p=1).

The analysis of the extent of the damage showed significant differences between wood origin [$F_{3,30}$=3.406 , p=0.030] (Figure 5).

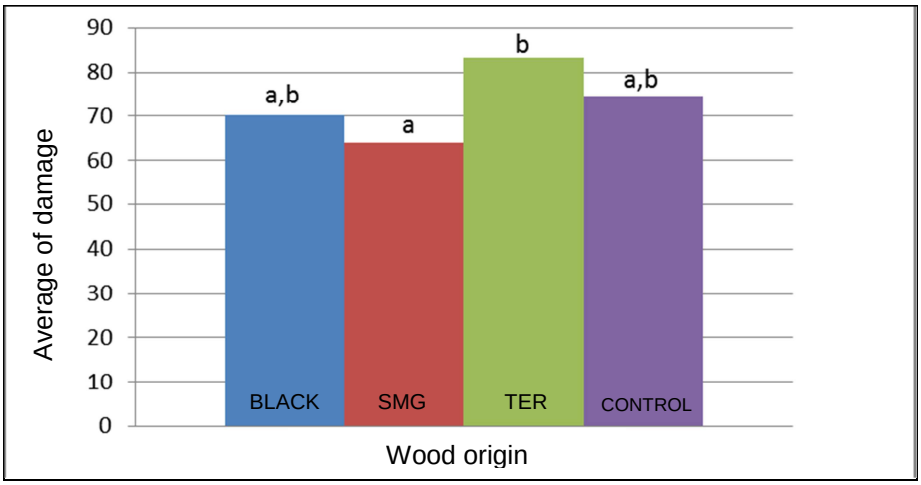

Figure 5. Average of damage inflicted in 45 days by *Cryptotermes brevis* according to the wood. Oneway Anova [$F_{3,30}$ = 3.406, p = 0.030]; Post hoc Tukey HSD ($p_{Black-SMG}$=0.720; $p_{Black-TER}$=0.591; $p_{Black-Control}$=0.927; $p_{SMG-TER}$=0.020; $p_{SMG-Control}$= 0.439; $p_{TER-Control}$=0.163).

The damages were significantly more important in the wood from Terceira than in the wood from SMG (Tukey HSD; p=0.020). No significant differences were observed between the damage to the wood from SMG, Control and “Black” variety (Tukey HSD; $p_{SMG-Control}$=0.439, $p_{SMG-Black}$=0.720, $p_{Black-Control}$=0.927); no significant differences were observed between the wood from Terceira, Control and “ Black” variety (Tukey HSD ; $p_{Terceira-Control}$=0.163 , $p_{Terceira-Black}$=0.591).

In order to examine how quickly the termites were dying, the slopes for death rate were compared (Figure 6). There is a significant difference between them [$F_{3,30}$ = 3.319 , p = 0.033]. Termites were dying significantly faster in wood from SMG than in wood from Terceira (Tukey HSD; p = 0.022). There was no significant difference between the slopes for death rates from SMG wood termites and the “Black” variety and Control (Tukey HSD; $p_{SMG-Black}$=0.777, $p_{SMG-Control}$=0.643,$p_{Black-Control}$=0.984). Likewise there were no significant differences between the slopes of the rates of death from Terceira wood termites, the “Black” variety and the Control (Tukey HSD; $p_{Terceira-Black}$=0.147 , $p_{Terceira-Control}$=0.413).

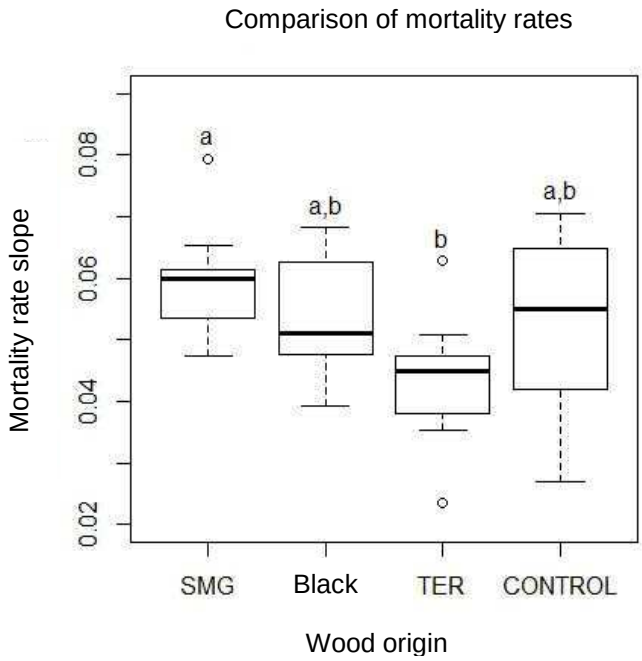

Figure 6: Mortality rate slope comparison for *Cryptotermes brevis*. One-way Anova [$F_{3,30}$ = 3.319, p = 0.033]; Post hoc Tukey HSD ($p_{Black-SMG}$=0.777; $p_{Black-TER}$=0.146; $p_{Black-Control}$=0.983; $p_{SMG-TER}$=0.022; $p_{SMG-Control}$= 0.643; $p_{TER-Control}$=0.413)

The day that 50% of the population has died was estimated and/or extrapolated (Figure 7)). The result of the analysis showed significant differences [$F_{3,30}$ = 4.813 , p = 0.00747]; B). The control is the one with the best survival (median 47.5 days). The number of live days is significantly higher than with the wood from SMG (Tukey HSD, p = 0.040, median = 40 days) and the "Black" variety (Tukey HSD, p = 0.009, median = 35 days). There is no significant difference in mortality between the wood from Terceira (median = 44 days) and the control (Tukey HSD; p = 0.547). In addition, there was no significant difference between wood termites from Terceira, SMG and wood of the "Black" variety (Tukey HSD; $p_{SMG-Negra}$=0.924, $p_{SMG-Terceira}$=0.368, $p_{Negra-Terceira}$=0.117).

There were no differences in the analysis of termite droppings that live in different woods [$F_{1,32}$= 1.48, p = 0.233] (Figure 8).

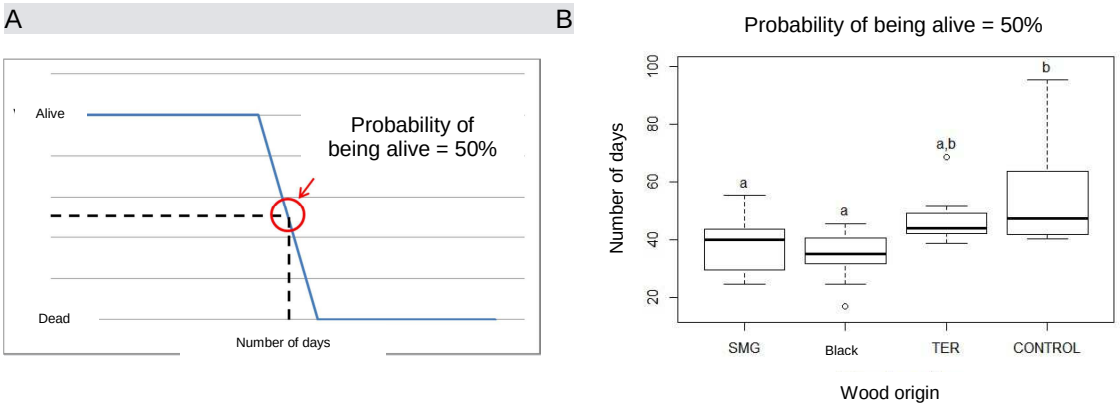

Figure 7: Estimation and/or extrapolation of the day when 50% of the population of Cryptotermes brevis have died, depending on the wood. [$F_{3,30}$ = 4.813, p = 0.00747]; Post hoc Tukey HSD ($p_{Black-SMG}$=0.924; $p_{Black-TER}$=0.117; $p_{Black-Control}$=0.009; $p_{SMG-TER}$=0.367; $p_{SMG-Control}$= 0.040; $p_{TER-Control}$=0.547).

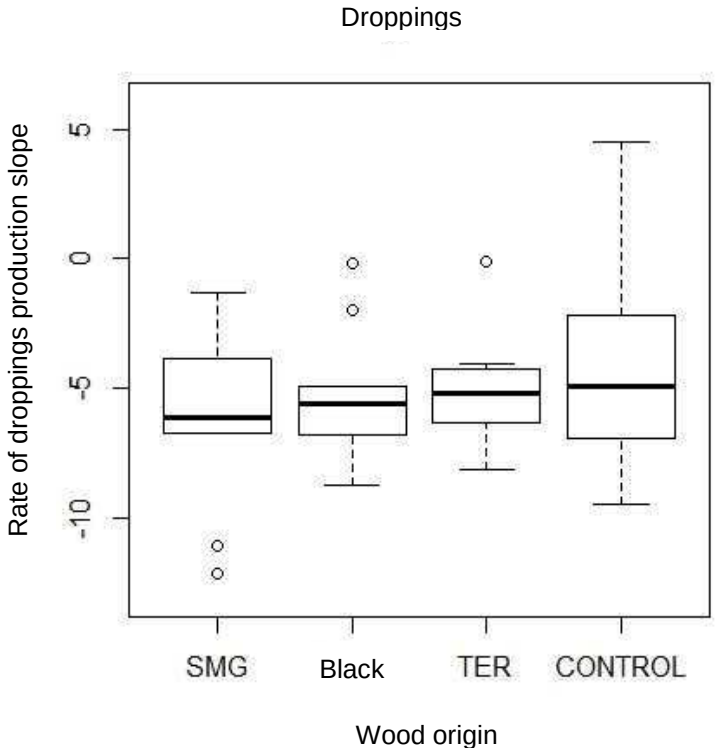

Figure 8: Comparison of slopes for rate of droppings production of Cryptotermes brevis depending on the wood. One-way ANOVA [$F_{1,32}$= 1.48 , p = 0.233].

b) Durability analysis for treatment with insecticides

The day 50% of the population have died was estimated and/or extrapolated, and the result of the analysis showed significant differences [$F_{2,15}$ = 37.75, p < 0.0001] (Fig. 9). The Ag control was the one with the best survival rate for *Cryptotermes brevis* (median = 54.3 days). The number of days was significantly higher for termites in the Ag control than in the wood treated with Xy product (Tukey HSD;

Ag-pxy = 0.0000077; median = 1.9 days) and with Xz product (Tukey HSD; p = 0.0000036; median = 2 days). No significant differences were observed in mortality for *Cryptotermes brevis* with Zy and Xz (Tukey HSD; pxy-Xz = 0.8858573) wood treatment.

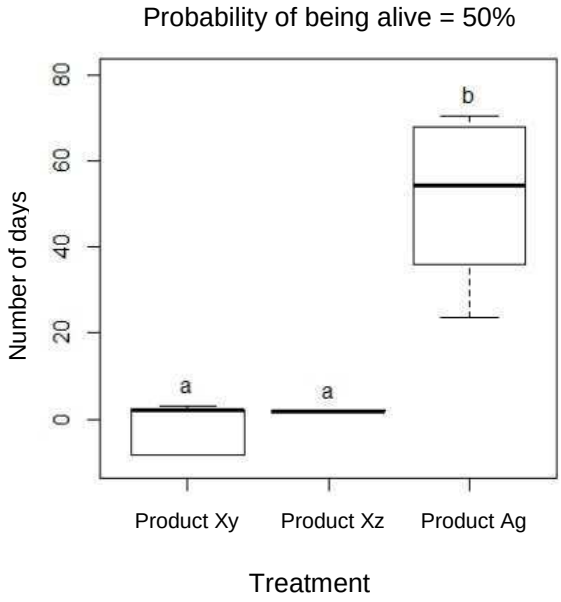

Figure 9: Estimation and/or extrapolation of the day 50% of the population of *Cryptotermes brevis* have died due to treatment. [$F_{2,15}$ = 37.75, p <0.0001] ; Post hoc Tukey HSD ($p_{Xy\text{-}Xz}$ = 0.8858573 ; $p_{Xz\text{-}Ag}$ = 0.0000036 ; $p_{Xy\text{-}Ag}$ = 0.0000077) ; Median : Xz =2 ; Xy = 1.9 ; Ag = 54.3.

A Kruskal-Wallis test was performed to compare the effect of different treatments on the survival of termites *Cryptotermes brevis* throughout the experiment (at 5, 15, 30 and 45 days) (Fig.10).

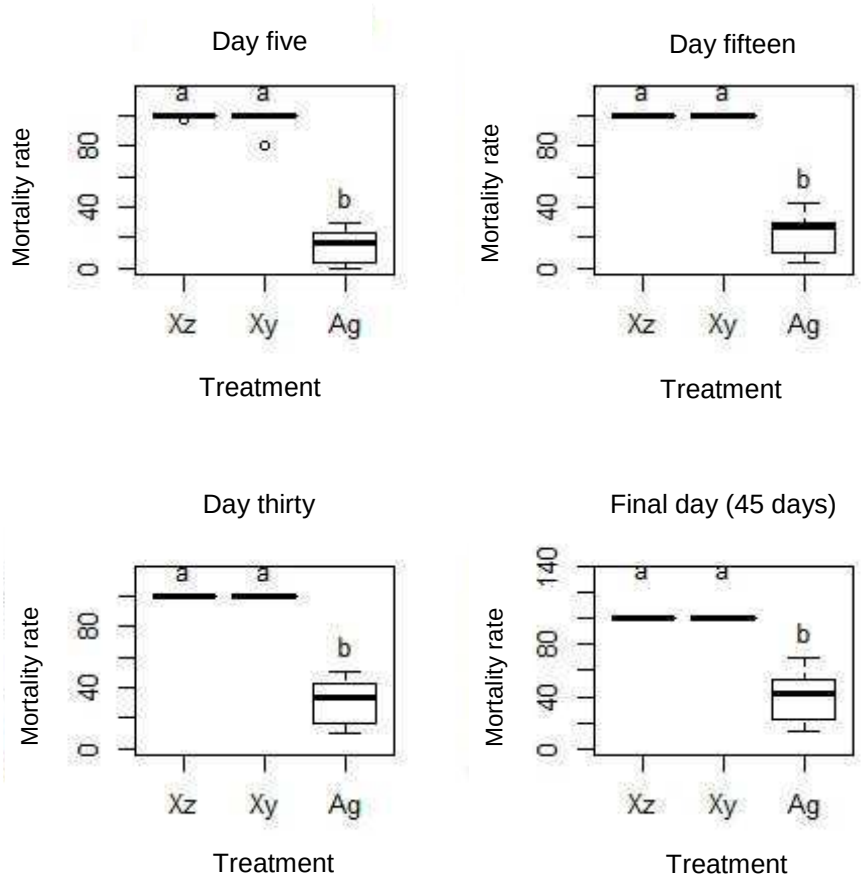

Figure 10: Mortality rate of *Cryptotermes brevis* at day five, at day fifteen, at day thirty and at the final day (45 days) depending on the treatment.

At day five: Kruskal-Wallis : [X^2 = 13.7221, df = 2, p-value =0.001048] ; Wilcoxon rank sum test:

P_{Xz-Xy}=1.000 ; P_{Xz-Ag}=0.011 ; P_{Xy-Ag}=0.011

At day fifteen: Kruskal-Wallis : [X^2 = 16.1525, df = 2, p-value =0.0003108]
Wilcoxon rank sum test: P_{Xz-Xy}=1.000 ; P_{Xz-Ag}=0.0054 ; P_{Xy-Ag}=0.0054

At day thirty: Kruskal-Wallis: [X^2 = 16.1288, df = 2, p-value =0.0003145]

Wilcoxon rank sum test: P_{Xz-Xy}=1.000 ; P_{Xz-Ag}=0.0056 ; P_{Xy-Ag}=0.0056

At the final day (45 days): Kruskal-Wallis : [X^2 == 16.1288, df = 2, p-value =0.0003145

Wilcoxon rank sum test: P_{Xz-Xy}=1.000 ; P_{Xz-Ag}=0.0056 ; P_{Xy-Ag}=0.0056

Over the course of the whole trial after the wood treatment (p <0.005) there was a significant effect (at 5, 15, 30 and 45 days) on the survival of the termites (Kruskal-Wallis At day five: [X2 = 13,7221, df = 2 , p = 0.001048]; Kruskal-Wallis at day fifteen: [X2 = 16,1525, df = 2, p = 0,0003108]; Kruskal-Wallis at day thirty: [X2 = 16,1288, df = 2, p-value = 0.0003145]; KruskalWallis at the end (45 days): [X2 = 16,1288, df = 2, p = 0,0003145]).

At the end of the fifth day, 100% of termites on the wood treated with Xy and Xz products were dead (median Xy at 5 days = 100%; median Xz at 5 days = 100%). Only the pseudo-worker on wood treated

with solvent (Ag control) survived until the end of the experiment, presenting a lower mortality rate than the other treatments (median Ag at 5 days = 7%; median at 15 days Ag = 26.5%; median Ag in 30 days = 33.5%; median at 45 days Ag = 42%).

The paired comparisons between treatments (Wilcoxon rank sum test) showed that throughout the whole experiment statistically significant difference were observed between control termites Ag and those with Xy and Xz product (at day five: P_{Xz-Ag}=0.011; P_{Xy-Ag}=0.011 / at day fifteen : P_{Xz-Ag}=0.0054 ; P_{Xy-Ag}=0.0054 / at day thirthy : P_{Xz-Ag}=0.0056 ; P_{Xy-Ag}=0.0056 / on final day (45 days): P_{Xz-Ag}=0.0056 ; P_{Xy-Ag}=0.0056). There were no significant differences for termites mortality rate with Xy and Xz products (at day five : P_{Xz-Xy}=1.000 / at day fifteen : P_{Xz-Xy}=1.000 / at day thirthy : P_{Xz-Xy}=1.000 / on final day (45 days): P_{Xz-Xy}=1.000).

Figure 11 depicts the analysis of the damage caused by termites. The study was conducted with a Kruskal-Wallis test and showed a significant effect of treatment on the damage (KruskalWallis: [X2 = 6,7335, df = 2, p = 0,0345]. However, because the power of the test is limited, no significant *p* value was observed for pair comparisons (Pair comparisons using the Wilcoxon test :. PXZ-xy = 1.000; PXZ-Ag = 0.15; pxy-Ag = 0.15). In comparison the median damage observed on treated wood with product Xy and Xz is 0. This shows that absolutely no damage was done on wood treated with these two products. In comparison, the median of damage observed in control Ag is 1. This corresponds to "superficial damage". In fact, during the trial on the 6 pieces of the control wood Ag, 3 of them began to be superficially damaged by *C. brevis*. Two pieces of wood were from Terceira Island (T223-4 began to be superficially damaged from day 29 and T221-2 began to be superficially damaged from day 43), and one from São Miguel (SM2011-2 began to be superficially damaged from day 42). For each piece of damaged wood, the damage came down to a small hole (1 mm diameter and 1 mm maximum depth).

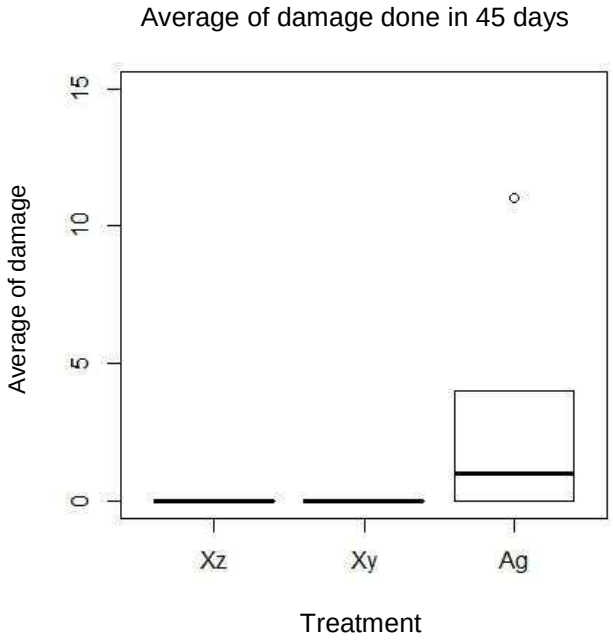

Figure 11: Average of damage done by termites *Cryptotermes brevis* in 45 days according to treatment. Kruskal-Wallis: [X^2 = 6.7335, df = 2, p-value =0.0345]; Wilcoxon rank sum test : P_{Xz-Xy}=1.000 ; P_{Xz-Ag}=0.15 ; P_{Xy-Ag}=0.15.

The analysis of faecal particles was not possible as all termites in wood treated with products Xy and Xz died extremely fast, and there is equally a lower production of faecal particles in the Ag control than expected.

5. Conclusions

Based on obtained results one can conclude that there are clear differences between the *Cryptomeria japonica* wood with origin in the island of São Miguel and origin in the island of Terceira.

In fact:

1) The number of surviving termites of the “Black” variety from São Miguel was significantly lower than in the wood from Terceira and the control. The Wood from São Miguel (SMG) also presented a number of survivors significantly lower than the control, with no significant difference observed in the number of survivors among the wood from SMG and the Black variety. These results give the wood from São Miguel, and in particular the “Black” variety some resistance capabilities to the dry wood termite.
2) The damages caused in the wood were significantly less important in the wood from São Miguel than that from Terceira;
3) Termites died significantly faster in the wood from São Miguel then that from Terceira;

4) The number of days that termites were alive in the control was significantly higher than that in the wood of São Miguel and in the “Black” variety.

With respect to the test with the Xz product (Propiconazol – 0.15%; Cypermethrin – 0.07%; Tebuconazol – 0.05%; IPBC – 0.05%) and Xy (Propiconazol - 0.6%; Dichlofluanid – 0.54%; Cypermethrin – 0.05%) they showed great efficacy, with no living termites at the end of the fifth day of the experiment.

6. References

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL : http://www.R-project.org/.

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