SILVA FENNICA 1983, vol. 17 n:o 1: 83–90

PRELIMINARY TESTING OF THE RESISTANCE OF FINNISH SOFTWOOD TIMBERS TO MACROTERMITINAE TERMITES

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Seloste

ALUSTAVIA KOKEITA SUOMALAISEN HAVUPUUN KESTÄVYYDESTÄ MACROTERMITINAE-TERMIITTEJÄ VASTAAN

Saapunut toimitukselle 7. 3. 1983

The resistance of Finnish softwood timbers to Macrotermitinae termites was tentatively tested under tropical conditions in Zambia using a field microtest method. *Picea abies* and *Larix sibirica* sapwood and heartwood, as well as *Pinus sylvestris* sapwood, and the sapwood of locally grown *Pinus kesiya,* exhibited no natural termite resistance. On the other hand, *Juniperus communis* heartwood appeared to be virtually immune and the heartwood of *P. sylvestris* had some resistance. There were also some differences in the resistance of the heartwood of the different *P. sylvestris* individuals tested, which was correlated with the width of the annual rings in the wood samples. The termite species involved were *Microtermes* sp. and *Odontotermes* sp. The possibilities of using different types of Finnish softwood timber in the regions in the tropics where there is a risk of termite damage is discussed.

INTRODUCTION

Termites are one of the principal destroyers of wood around the world. The activity of this insect order is mainly limited to the warm climates. However, the termite problem is also a matter for the termite-free colder areas, because timber and wood products are exported from there to the termite-risk regions. In addition, some wood-destroying termite species are expanding their distribution in the temperate zones as a result of suitable man-made conditions (e.g. Hickin 1971, Becker 1976, Mansikkamäki and Vihavainen 1977).

Therefore in addition to tropical timbers (e.g. Fuller 1924, Snyder 1924 b, Wolcott 1957, Williams 1973, Beal et al. 1974, Usher and Ocloo 1979), the natural resistance to termites of timbers from the cold and temperate zones has also been studied (e.g. Snyder 1924 a, Wolcott 1957, Mannesmann 1973, Kervina 1975, Carter et al. 1976). These tests have, however, so far been mostly limited to the termites which could cause damage in the economically developed temperate and subtropical zones, i.e. to the dry-wood (Kalotermitidae) and subterranean (Rhinotermitidae) species. On the other hand, the resistance of northern commercial timbers to termites dominating in the true tropics, i.e. Termitidae (mostly the subfamily Termitinae) species, is still poorly known. The information available about the resistance of timbers to Kalotermitidae and Rhinotermitidae termites may not be applicable to the Termitinae species, because their nutrition and symbiotic or associated microorganisms involved in breaking down wood cellulose are different. In general, the Macrotermitinae species are also attracted to dead, sound wood not attacked earlier by fungi (see Krishna and Weesner 1969, 1970).

The aim of this study was to assess tentatively the natural resistance of the main Finnish sawn timber species, i.e. Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.), to Macrotermitinae termites under tropical conditions. This information is needed, because the export of Finnish timber, wood-based panels and products of the woodworking industries to the tropical countries is expanding. It is relevant, in this context, to point out that Finnish softwood timber cannot in practice be made totally termite resistant by preservative treatments, because pine timber normally contains a varying proportion of heartwood (e.g. Uusvaara 1974) which cannot be properly impregnated by the vacuum and pressure methods. Spruce timber cannot be treated by conventional application methods at all.

The test material also included Siberian larch (*Larix sibirica* Ledeb.), an introduced tree species grown on a pilot scale in Finland, and indigenous common juniper (*Juniperus communis* L.). Although such timber is of minor commercial importance in Finland, information could be derived from the test results which would enable us to gain a better understanding of the nature of the resistance of wood to fungus-growing Macrotermitinae termites. In this respect, the resistance of the decay-resistant heartwood of these tree species, as well as that of Scots pine, would be especially interesting.

The author is grateful to S. Bacchus at the Commonwealth Institute of Entomology for identifying the reference termite specimens.

MATERIAL AND METHODS

The experiments were carried out at the Riverside Forest Research Laboratories (about S 12°50'; E 28°10'; alt. 1300 m) in Kitwe, Zambia. Zambia belongs to the savanna woodland region which is the favourite territory of Macrotermitinae termites.

The test wood samples originated from trees grown in South Finland and cut in October–November, 1977. Seven pine sample trees were taken from one stand and five from another stand, seven spruce sample trees from one stand and seven larch sample trees from a plantation (Raivola provenance). There were five juniper sample trees representing different populations. The sample trees were 80–100 years old, except for the junipers whose ages ranged from 100–200 years. Seven locally grown 17-year-old kesiya pines (*Pinus kesiya* Royle ex Gordon) were cut in May 1978 for control wood samples. Blocks (2 × 2 × 1 cm in size) were made from disks cut from the butt end of the sample trees. The blocks were aged and dried in oven at 105°C for 48 hours (see Williams 1973), weighed and kept in a dry place until testing. The spruce, pine, and larch wood samples were taken from both the heartwood and sapwood. The juniper samples were taken only from the heartwood and kesiya pine samples only from the sapwood. The average width of the annual rings in the wood samples were measured.

A field microtest method described by Williams (1973) was used in the testing. The method involves the use of small-size wood samples which provides a quick, preliminary estimate of whether the wood species are resistant to termites in conditions corresponding to those prevailing in woodwork protected from damp.

The wood samples were glued onto 20 × 20 cm plates of window glass. The 7 × 7 latin square distribution was used. The members were the sapwood and heartwood samples of pine, spruce and larch, and the sapwood samples of kesiya pine, representing seven different tree individuals of each tree species. Three such tests were prepared (Nos. 1–3). The fourth (No. 4) test contained the heartwood samples of five junipers and the sapwood and heartwood samples of five pines from another stand.

Each test was laid on a 20-cm-high concrete block with the wood samples facing downwards. The concrete blocks were placed on the ground in a miombo forest known to support a diverse and abundant termite fauna. *Eucalyptus* sapwood stakes, used as bait, were set out in order to lead the termites to the test. The whole testing system was shaded with a roof of zinc sheeting.

The tests were started during the rainy season in December 1978–March 1979, the activity of termites being high at such a time. Each of the four tests were started at different times, and at slightly different locations, in order to ensure that as many different termite species as possible could attack the samples. Attack by termites was observed through the glass plate, and the test was terminated when the samples of the most vulnerable wood species had been totally destroyed. This took five to twelve weeks, the period from the time when the test had been sealed by termites to the end of the experiment lasting for two to four weeks. The test was then opened and the termite damage assessed by drying and weighing the samples and comparing the values with the original dry weight. A termite sample was also taken for identifying the actual termite species.

RESULTS AND DISCUSSION

Each microtest had been attacked by one termite species only. The species occurring in tests 1 and 4 was *Microtermes* sp. and in tests 2 and 3 *Odontotermes* sp. (nr. *kibarensis* Fuller), both belonging to the Macrotermitinae subfamily.

No signs of deterioration in the quality of the wood caused by fungal attack were found in the test blocks (see Fougerousse 1969, Williams 1973). The loss in weight of the Scots pine blocks as a result of chewing by the termites is presented in Table 1.

On average, about one fourth of the Scots pine heartwood had been destroyed during the testing period. The most severely damaged block had lost 80 % of its weight, while some did not even show any traces of corrosion. On the other hand, the sapwood samples of Scots pine had been destroyed almost completely. Both the sapwood and heartwood blocks of spruce and larch, as well as the sapwood blocks of kesiya pine, had also been destroyed completely. It was not possible to detect any clear differences in the severity of damage between either the last-mentioned tree species or tree individuals. The juniper samples remained entirely untouched.

Table 1. Weight loss of *Pinus sylvestris* wood blocks as a result of chewing by Macrotermitinae termites, in per cent of original weight.

Microtest no.	n	Sapwood x ± S.E.	n	Heartwood x ± S.E.
1	7	98 ± 0.9	7	31 ± 8.7
2	7	96 ± 1.6	7	19 ± 7.5
3	7	88 ± 3.3	7	23 ± 12.4
4	5	98 ± 0.8	5	27 ± 5.6

The heartwood of Scots pine showed thus some resistance to attack by Macrotermitinae termites. If pine heartwood had been tested alone in the absence of the more susceptible wood species, the result might have proved even better on the average (cf. Carter and Smythe 1974). As some samples had, however, been badly damaged when exposed for as short a period as two to three months, the natural durability of pine heartwood cannot be considered to be more than slight or moderate. Furthermore, the wood samples were comparatively young, although an attempt was made to age the samples by drying in the oven. The durability of the wood may weaken with age as the effect of the protective substances decreases (Williams 1973).

There is not very much information available about the susceptibility of pine woods to Macrotermitinae species, especially about hearwood. The main reason for the lack of test results dealing with pine heartwood is that, in plantation conditions, the tropical pine does not usually have enough time to produce heartwood within the conventional rotation period. According to the tests and practical experience, the sapwood of pines has been found to lack all natural resistance (e.g. Fuller 1924, Fougerousse 1969). On the other hand, it is known that the heartwood of pines is resistant to lower termites, i.e. Kalotermitidae and Rhinotermitidae species, at least to the extent found in this investigation, and the heartwood of some southern pines has even been classified as nearly immune (e.g. Snyder 1924 a, 1924 b, Wolcott 1947, Williams 1965).

As far as is known, there are no published observations concerning the resistance of spruce, larch and juniper species to Macrotermitinae termites. The wood of tested spruce, including *P. abies*, and larch species has not been found to be resistant to lower termites (e.g. Snyder 1924 a, Kervina 1975). However, the heartwood of some North-American *Juniperus* species is almost immune to subterranean termites (e.g. Snyder 1924 a, 1924 b).

There is evidence that toxic or repellent chemical substances present in wood, are the main factor involved in the resistance of certain wood species to termites and in the differences in the susceptibility of different regions of wood. However, the physical properties of wood may play a subsidiary role (e.g. Wolcott 1957, Rudman 1963, Carter et al. 1975). Among the substances present in coniferous wood, certain secondary metabolites such as some terpenoids and phenolic and carbonyl compounds have been proved to be detrimental to the lower termites (e.g. Rudman 1965, Becker 1966, Becker et al. 1971, Saeki et al. 1971, Carter and Smythe 1974). Hardly anything is yet known about the role of these substances in the resistance of wood to Macrotermitinae species.

Some of the substances which posses antitermitic properties also play a vital role in the decay resistance of the heartwood of softwood timber. These compounds could also be detrimental to the *Termitomyces* fungi (Basidiomycetes) associated with Macrotermitinae termites. Hence the same wood substances may be responsible for the resistance to both decay and termites of pine and juniper heartwood. However, the susceptibility of the naturally decay-resistant larch heartwood to termites found here, shows that the resistance to decay fungi and Macrotermitinae termites is not caused by the same compounds in the case of all conifers.

The difference in the natural termite and decay resistance of larch may be related to the fact that no termites occur in the natural distribution area of the genus *Larix*. Thus there has been no evolutionary reason for developing resistance to termites. This same argument applies to the genus *Picea* as well, as far as termite resistance is concerned. On the other hand, the distribution areas of the *Pinus* and *Juniperus* species also extend to those areas infested by termites, including the Macrotermitidae family. Some other tree families and genera also exhibit the trend that woods from the temperate zone have no innate termite resistance, that it is rare in woods from the subtropics and that it occurs to a varying degree in many species of wood from the tropics (e.g. Snyder 1924 a, 1924 b, Wolcott 1957).

Clear differences were found in the resistance of heartwood between the pine individuals tested here ($F = 5.75^{**}$). The differences were correlated with the width of the annual rings (Fig. 1). Termites consumed more of the wide-ringed wood, and in such samples the early wood of each ring was primarily affected. As the experiment progressed, it was also found that the termites first destroyed the early wood of each ring in the sapwood. The reason for this may be that the late wood

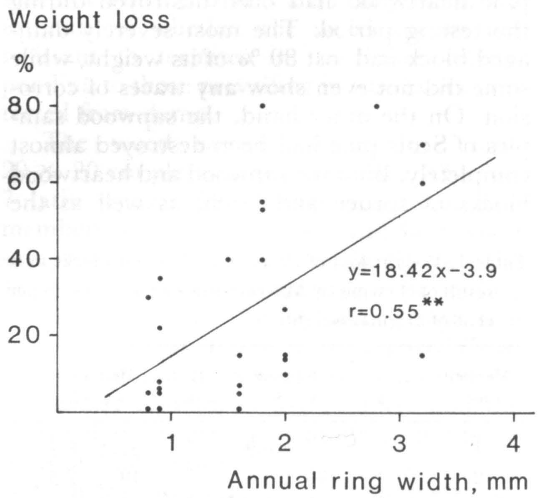

Fig. 1. Correlation between the weight loss percentage and the annual ring width of *Pinus sylvestris* heartwood blocks.

is mechanically harder since the tracheid walls are thicker than those in early wood. Similarly, the percentage of late wood is highest in slow-growing pines, thus leading to a higher wood density in such pines (Uusvaara 1974). The fact that the layers of late wood lie close to each other in a slow-growing tree mat have perhaps mechanically hampered chewing. On the other hand, it is not known whether the chemical composition of the early and late wood of pine is essentially different as regards the antitermitic substances.

Correspondingly, the wide-ringed fast-grown wood of *Callitris columellaris* conifer species has been found to be less resistant to some termites than the more closely-ringed wood (Rudman 1963).

The difference between the resistance of heartwood of pine individuals may also be due to the phenotypic and genotypic diversity in the chemical composition which is known to exist between individual trees and populations of *P. sylvestris* (e.g. Erdtman et al. 1966, Norin 1972, Hiltunen 1976) This would offer a basis for selection in favour of termite resistant pine wood.

CONCLUSIONS

The present experiments and conclusions only concern Macrotermitinae termites, which are the dominant wood consumers in the tropics, especially in the savanna region of Africa. The resistance of Finnish conifer timbers to lower termites may show some diversity.

Since Norway spruce wood was found to be totally unresistant to termites, it cannot be recommended for any purposes in termitic areas. Owing to its unimpregnability, spruce cannot even be made resistant by preservative treatment. This also applies to Siberian larch.

Scots pine sapwood proved to be attractive to termites and prone to fast destruction. Thus its use without impregnation with a preservative containing an insecticide component is not recommended in warm climates. As Finnish sawn pine timber usually contains varying amounts of heartwood, which cannot be properly impregnated, even "impregnated" pine timber is not completely resistant to termites. Thus attention should be paid to providing a mechanical termite shield for wood structures, even when using impregnated pine timber. On the other hand, pine timber from tropical plantations can be impregnated to completely resist termites as it has little or no heartwood.

Pine heartwood proved, however, to be slightly resistant to termites, and is not probably very attractive to termites. Thus in dry conditions and if there are no baits in the neighbourhood, the fast destruction of pine heartwood by termites is unlikely. In termite-risk sites where impregnated wood cannot, for some reason or other, be used, the use of slow-grown pine heartwood timber is recommended.

Owing to the fact that there was considerable variation in the resistance of pine heartwood to termites, it may be possible to choose timber according to its durability and to breed trees in favour of termite resistance. Similarly, analyzing the wood extractives of pine and juniper, and also larch, and testing their antitermitic properties may lead to the development of nontoxic natural repellents and antifeedants.

As far as pine heartwood is concerned, the experiment on the termite resistance of Finnish coniferous timbers produced such promising results and revealed such a large amount of new information that more detailed and prolonged experiments on its durability, including graveyard tests, should be carried out.

SUMMARY

The resistance of Finnish softwood timbers to Macrotermitinae termites was tentatively tested under tropical conditions in Zambia in 1978–1979. A field microtest method was used in the testing. The method involves the use of small-size wood samples which quickly provides a preliminary estimate of whether wood species are resistant to termites in the conditions corresponding to those prevailing in woodwork shielded from damp.

During the testing, the test wood samples were attacked by *Microtermes* and *Odontotermes* termites (Macrotermitinae). *Picea abies* and *Larix sibirica* sap and heartwood, as well as *Pinus sylvestris* sapwood, and sapwood of locally grown *Pinus kesiya,* showed no natural resistance and were quickly destroyed completely. On the other hand, *Juniperus communis* heartwood remained entirely untouched and Scots pine heartwood showed some resistance. There also appeared to be differences in the resistance of heartwood between the tested pine individuals. This was found to correlate with the width of the annual rings of the samples.

As spruce timber proved to be totally unresistant to termites, and as it cannot even be made resistant by means of impregnation, this timber species cannot be recommended for any purposes in termite-risk areas. Neither can Scots pine timber be used without treatment with a preservative containing an insecticide component. However, as Finnish sawn pine timber usually contains varying amounts of unimpregnable heartwood, not even treated pine timber is totally termite resistant. Thus attention should be paid to providing a mechanical termite shield for wood structures, even when using impregnated pine timber. Where treated wood cannot, for some reason or other, be used, the use of slowly-grown pine heartwood timber is recommended.

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SELOSTE

ALUSTAVIA KOKEITA SUOMALAISEN HAVUPUUN KESTÄVYYDESTÄ MACROTERMITINAE-TERMIITTEJÄ VASTAAN

Pohjoisten kaupallisten puulajien puun kestävyys lauhkeilla ja subtrooppisilla alueilla puuta tuhoavia termiittejä (Kalotermitidae, Rhinotermitidae) vastaan on melko hyvin tunnettu. Sitävastoin näiden puulajien kestävyydestä trooppisen vyöhykkeen Macrotermitinae-termiittejä vastaan ei ole tiedetty juuri mitään. Suomalaisen puutavaran termiitinkestävyyden tunteminen on kuitenkin tärkeää nimenomaan sen vuoksi, että kuusta ei voida tavanomaisin menetelmin kyllästää ja tehdä siten termiitinkestäväksi. Myös männyn sydänpuuosa jää samasta syystä termiittisuojaa vaille.

Tämän tutkimuksen tarkoituksena oli selvittää alustavasti mänty- ja kuusipuun kestävyyttä Macrotermitinae-lajeja vastaan trooppisissa olosuhteissa. Vertailuna testattiin myös siperialaisen lehtikuusen ja katajan, sekä yhden trooppisen mäntylajin (*Pinus kesiya*) puun kestävyyttä.

Kokeet suoritettiin Sambiassa 1978–79 kenttämikrotestimenetelmällä (kts. Williams 1973). Puunäytteet altistettiin maa- ja sadekosteudelta suojattuja puurakenteita vastaavasti. Puunäytteet oli otettu 12 Etelä-Suomessa kasvaneesta männystä, seitsemästä kuusesta ja siperialaisesta lehtikuusesta sekä viidestä katajasta. *Pinus kesiya* -näytteet otettiin seitsemästä paikallisesti kasvaneesta puusta. Koeajat vaihtelivat 5–12 viikkoon. Testeihin iskeytyneet termiittilajit olivat *Microtermes* sp. ja *Odontotermes* sp.

Kuusen ja lehtikuusen manto- ja sydänpuu osoittautuivat täysin kestämättömiksi samoin kuin männyn ja *P. kesiya* -männyn mantopuukin. Sitä vastoin männyn sydänpuu oli jonkin verran kestävää. Katajan sydänpuu säilyi täysin koskemattomana. Mänty-yksilöiden välillä oli sydänpuun kestävyydessä huomattavia eroja. Tiheälustoinen sydänpuu osoittautui kestävämmäksi kuin nopeasti kasvanut leveälustoinen puu.

Tulosten mukaan kuusi ei sovellu käytettäväksi trooppisilla termiittialueilla. Mäntypuutavaraakaan ei tulisi käyttää käsittelemättä sitä kyllästeellä, joka sisältää myös insektisidisen aineosan. Koska kuitenkin männyn sydänpuun termiitinkestävyys osoittautui keskimäärin melko huonoksi, ei kyllästyskään takaa suomalaisen mäntypuutavaran täydellistä kestävyyttä. Aina on siis kiinnitettävä huomiota myös puurakenteiden mekaaniseen termiittisuojaukseen. Jos kestopuuta ei voida käyttää, olisi käytettävä hitaasti kasvanutta männyn sydänpuuta.

Koska sydänpuun luontainen termiitinkestävyys vaihtelee mänty-yksilöiden välillä, saattaisi löytyä perusteita kestävyyden lisääntymiseen tähtäävälle valinnalle. Samoin voitaisiin löytää luston leveyden lisäksi myös muita tunnuksia kestävämpien puuyksilöiden ja puutavaran tunnistamiseksi ja valikoimiseksi. Kestäväksi osoittautuvan puun kemiallinen analysointi ja aineosien termitisidisen vaikutuksen testaus saattaa johtaa myrkyttömien karkote- tai syönninestoaineiden löytymiseen.

Nyt saatujen tulosten perusteella olisi männyn sydänpuun termiitinkestävyyskokeita tarpeellista jatkaa. Nimenomaan pitkäaikaiset kokeet käyttäen myös maahan kaivettuja puunäytteitä olisivat tärkeitä kestävyyden tarkemmaksi määrittämiseksi.