Wood-Consumption Rate and Survival of the Formosan Subterranean Termite (Isoptera: Rhinotermitidae) when Fed One of Six Woods Used Commercially in Hawaii[1,2]

NAN-YAO SU[3] and MINORU TAMASHIRO

ABSTRACT

Redwood and cedar were the most resistant or least preferred woods of the 6 wood species fed to the Formosan subterranean termite. Significantly more Ponderosa pine, spruce, hemlock and Douglas fir were consumed than redwood or cedar. There were no statistically significant differences in consumption between redwood and cedar and no significant differences in the amounts of the other 4 wood species consumed. Both redwood and cedar apparently were not completely suitable food for the termites. 100% of the termites fed redwood died within 3 weeks and approximately 50% of those fed cedar died in the same period.

Termites are major pests of wood and wood products in tropical environments. The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, is the most important insect pest in Hawaii. It causes significant damage to buildings, trees, plants, utility poles, etc. In addition, the cost of controlling this termite in Hawaii has been steadily increasing. This has been due in part to increases in the cost of construction and the concomitant increase in costs of repair. However, the main reasons for the increase have been due to: (1) the spread of this species within the state into areas where it previously did not occur, (2) the increase in the population density of *C. formosanus* in areas where it did occur, and (3) the increase in the number of structures at risk.

Beal (1967) first estimated the damage caused by this termite at 2–3 million dollars a year. Ten years later, this figure increased almost tenfold (Lai 1977). In 1981, Higa estimated that the cost of prevention, control and repair of damage caused by *C. formosanus* exceeded 20 million dollars a year. More recent data indicates that Higa's estimates were low and the actual costs may exceed 50 million dollars a year.

The relatively high costs incurred in Hawaii is in part due to the fact that (1) conditions in Hawaii are favorable for the termite, (2) almost all of the single family homes are of wood frame construction and (3) much of the wood used apparently is highly susceptible to attack by *C. formosanus*. In qualitative tests, redwood was found to be the most resistant of 14 woods to decay and insect attacks in ground and above-ground tests in humid residential areas on Oahu (Skolman 1974). The susceptibility of the woods commonly used in construction in Hawaii, however, has not been compared and quantified.

Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco, is the most frequently used wood in construction in Hawaii, in part because of its ready availability, physical strength, and ease with which it can be handled. According to Wilcox (1984), however, the popularity of Douglas fir in the Hawaiian market does not only reflect the consumers' demands but also is the result of the interaction of complex commercial and political forces in Hawaii. Unfortunately, Douglas fir heartwood is extremely

[1]Journal Series No. 2939 of the Hawaii Institute of Tropical Agriculture and Human Resources.
[2]Department of Entomology, University of Hawaii, 3050 Maile Way, 310, Honolulu, Hawaii 96822.
[3]Present address: Ft. Lauderdale Research and Education Center, University of Florida, 3205 College Ave., Ft. Lauderdale, FL 33314.

difficult to penetrate with wood preservatives so that treatment does not guarantee protection against attack by *C. formosanus.* Sapwood can be penetrated but does not have the structural strength of heartwood. In addition, spring wood of Douglas fir was found to be attractive to *C. formosanus* (Fujii 1975).

Studies have shown that each species of termite has its own preferences for different wood species (Ruyooka and Groves 1980). Smythe and Carter (1969) fed *Reticulitermes flavipes* (Kollar) 11 native wood species used commercially in the U.S. and found that the termites did poorly on redwood, *Sequoia sempervirens* (D. Don) Endl., baldcypress, *Taxodium distichum* (L.) Rich., and black walnut, *Jugulans nigra* L. (Bultman et al. 1979) indicated that some tropical African woods were resistant to the attack by *C. formosanus.* The resistance may be due to the physical (Behr et al. 1972) or chemical properties of the wood (Kofoid and Bowe 1984, Rudman and Gay 1967, Carter et al. 1975, Carter et al. 1983), or to the species of termites, or to the symbiotic protozoa (Carter et al. 1981). The results of these studies have lead to proposals to use the wood's natural resistance to protect structures from termite attack (Bultman et al. 1979).

This study was initiated to measure the resistance of 6 woods commonly used in construction in Hawaii to attack by *C. formosanus* to suggest possible alternatives to the current use patterns in Hawaii.

MATERIALS AND METHODS

Experimental

Boards of Douglas fir, redwood, Ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), Engelmann spruce (*Picea engelmannii* (Parry) Engelmann), Western hemlock (*Tsuga heterophylla* (Raf.) Sarg) and Western red cedar (*Thuja plicata* Donn), were obtained from a commercial lumber yard in Honolulu. Blocks 1.8 × 1.8 × 1.8 cm were cut from a single board of each species, oven dried at 90°C for 48 hours and weighed. Each block was placed in a screw-top jar (5.5 cm in diameter by 6.5 cm in height) and covered by 50 ml of coral sand moistened with 10 ml of deionized water. Two-hundred field collected termites (170 "workers," undifferentiated larvae of at least the 3rd instar and 30 soldiers) were introduced into each unit and stored at 29 ± 1°C. The average weight of the workers was determined by weighing 5 groups of 10 termites each and calculating the mean. Eighteen experimental units were prepared for each wood species. At weekly intervals 3 units of each wood species were selected at random and disassembled. The surviving termites were counted and wood blocks were cleaned, oven dried, and reweighed.

Data Analysis

Su and La Fage (1984a,b) found that there were two patterns of mortality in the termites in the feeding trials. In one type, most of the mortality occurred in the first three weeks. Very few termites died in the second three weeks. In the second type, mortality increased linearly and reached 100% before the experiment was terminated. In this study, levels at which mortality stabilized after three weeks were compared among treatments. Treatments in which all of the termites died in six weeks were excluded from the analysis.

The computation method for wood-consumption rate was similar to that described by Su and La Fage (1984a). A linear mortality model was used to correct for cumulative mortality. Thus, wood-consumption rate (WCR), mg wood/g termite/day, for each sampling date was calculated using the following equation:

$$WCR = 2(W1 - W2)/(a*t(170+Nt))$$

TABLE 1. Mortality and the wood-consumption rates of the Formosan subterranean termite when fed one of six commercially used woods in Hawaii. ($\bar{x} \pm SE$).*

Wood species	Ponderosa pine	Spruce	Hemlock	Douglas fir	Cedar	Redwood
Mortality (%)**	9.9 ± 0.9a	10.2 ± 1.0a	11.8 ± 1.0a	19.6 ± 2.2a	50.2 ± 4.2b	100.0
Wood-consumption rate (mg/g/day)	43.3 ± 1.3a	43.1 ± 1.8a	47.1 ± 2.7a	49.2 ± 2.6a	22.0 ± 1.6b	25.2 ± 1.3b

*Within a row, means followed by the same letter are not significantly different from each other at P=0.05 (Scheffe's test).
**Levels at which mortality stabilized after 3 weeks. All termites fed Redwood died within 3 weeks.

where W1 is the initial wood weight and W2 is the final weight, a is the mean wet weight of a worker, and Nt is the number of workers alive at time t (day).

The data for both mortality and wood-consumption rate were subjected to analysis of variance utilizing a randomized complete block design. Sampling date was treated as a blocking factor to separate variations due to sampling date from experimental error. Sheffe's test was used to separate the means at the = 0.05 level.

RESULTS AND DISCUSSION

The mean weight of the workers was 3.2 ± 0.8 mg. Of the six wood species tested, redwood and cedar appeared to be the most resistant or least preferred by *C. formosanus* as compared by mortality and wood consumption (Table 1). All of the termites feeding on redwood died within three weeks. With cedar, approximately 50% of the termites died after three weeks. The mortality in the cedar treatment was significantly higher than that of the other four wood species. Wood-consumption rates for redwood and cedar were similar and were ca. 50% lower than rates for the other four species.

Redwood is mostly used in exposed walls, fencing, etc.; cedar is used as wall paneling, in sheathing for open beam ceilings, shakes in roofs, etc. Both woods are known to be relatively resistant to decay and insect attack. The results indicate that redwood is highly resistant to *C. formosanus* and that cedar is moderately resistant. However, it should be noted that these results were obtained in the laboratory using small numbers of termites in situations where they had no other wood species to eat.

Our observations indicate that, in the field where *C. formosanus* does not depend solely on these unfavorable woods as food sources or where the resistance factors may be broken down by microorganisms, it is possible for this termite to attack both redwood and cedar, and survive. Both redwood and cedar have been severely damaged in the field.

There were no significant differences in mortality or wood consumption among the other four wood species (Table 1). The mean wood-consumption rate recorded for these four wood species was 45.7 mg/g/day, which was similar to the mean wood-consumption rate for *C. formosanus* when fed slash pine, *Pinus elliottii*, Engelm, var. *elliottii* (Su and La Fage 1984b).

Ponderosa pine and spruce are relatively soft woods and are currently used for decorative purposes; i.e., exposed ceilings, door panels, etc., in Hawaii. Hemlock is a stronger wood which can be used as structural lumber and is easier to treat than Douglas fir. However, it is not readily available and tends to warp after drying which makes it inferior to Douglas fir according to some people involved in construction.

Our results show that only redwood and cedar are resistant to *C. formosanus*, and this characteristic may be of sufficient value to offset its higher cost and lesser strength in some situations.

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