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THE FORMOSAN SUBTERRANEAN TERMITE: A REVIEW OF NEW MANAGEMENT METHODS IN HAWAII

Julian R. Yates III, J. Kenneth Grace and Minoru Tamashiro

Department of Entomology
University of Hawaii
Honolulu, Hawaii
U. S. A.

ABSTRACT

The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, is Hawaii's most economically important insect pest. Its biology, aggressiveness, and cryptic and unpredictable foraging behavior make this insect difficult to detect and control. Soil termiticides with less residual activity than organochlorine insecticides and consumer demand for non-chemical control methods has redirected research towards developing and evaluating alternatives for managing this pest. These alternatives include physical particle barriers, wire mesh barriers, in-ground and above-ground baiting systems, removable building components, and termite resistant construction materials.

INTRODUCTION

The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, has been estimated to cost approximately US$100 million annually in Hawaii (Tamashiro et al. 1990a). The problems caused by Hawaii's most economically important insect pest have escalated with the ban on use of residual cyclodiene insecticides in April 1988. Consumers in the U.S.A. and other parts of the world have concomitantly provided the impetus for a major change towards integrated approaches to urban pest management emphasizing less insecticide use.

Pest control research for many decades has concentrated on the management of agricultural pests, and many technologies have emerged to protect our food supplies and address environmental concerns. However, with the current shift towards urbanization, particularly in Hawaii where residential properties are being developed in areas formally used to cultivate pineapple and sugarcane, research on the control of structural pests, and environmental and health issues related to the use of pesticides are foremost. Of extreme concern is the protection of our fragile and limited drinking water supply since agricultural pesticide contamination of this important resource has already been documented, including a recent finding of chlordane, a long used soil treatment termiticide, at trace levels in a drinking water well (personal communication, Department of Health, State of Hawaii). Through a concerted research effort to minimize insecticide usage in the urban arena, non-toxic physical and chemical strategies have evolved and have been commercialized in Hawaii. Acceptance and successful implementation, however, will determine the fate of this technology in providing a safer environment and life-style for all.

NEW TECHNOLOGY

Basaltic Termite Barrier

Physical barriers are gaining in popularity world-wide as methods of preventing subterranean termite penetration and attack on structures. In Hawaii, crushed and screened basaltic gravel is marketed as the Basaltic Termite Barrier, or BTB (Ameron HC&D, Honolulu), and has gained wide public acceptance. A similar crushed granite product is marketed in Australia as Granitgard (Granitgard Pty. Ltd., Victoria). Crushed basalt (Tamashiro et al. 1987a, 1987b, 1990b, 1991), granite (Smith & Rust 1990, French & Ahmed 1993, French 1994, Ahmed & French 1996), quartz and coral sand (Su et al. 1991), silica sand (Ebeling & Pence 1957, Ebeling & Forbes 1988), and even glass shards (Pallaske & Igarashi 1991) screened to specific particle sizes have proven to be effective in preventing termite penetration, although the effective particle size ranges differ from one termite species to another (Su & Scheffrahn 1992).

The development of BTB as a permanent physical barrier for use in Hawaii was the result of extensive laboratory and field tests with the Formosan subterranean termite (Tamashiro et al. 1987a, 1987b, 1990b, 1991) at the University of Hawaii. It was observed that this termite had difficulty penetrating through certain types of media which was dependent on the physical size, smoothness, shape, weight and hardness of the substrate particles.

An investigation revealed that the smoothness, size and hardness of the substrate were controlling factors. Several types of substrates were examined and basaltic gravel was selected for further testing because of its hardness and potential commercial availability. Irregularly-shaped particles tested ranged in size from 0.2 mm (0.008 in) to 4.8 mm (0.19 in). Initial tests were conducted in the laboratory using a technique where 4 cm (1.57 in) of the test substrate was sandwiched between two pieces of 8% agar in a 13 mm diameter glass tube (Grace et al. 1993). Termites were introduced in the lower chamber and allowed to bore through the agar to the substrate.

The results from these laboratory tests showed that termites were unable to penetrate through basaltic particles ranging from 1.7 mm (0.07 in) to 2.4 mm (0.09 in) over a 60 month period. Additional field tests in an area of Formosan subterranean termite colonies, with layers of 10 cm (4 in) thick have also proven efficacious for more than 4 years (Tamashiro, et al. 1991). Control plots containing only sand or soil were penetrated by termites in this test.

In 1989 BTB was accepted into the City and County of Honolulu Uniform Building Code as a safe, and permanent alternative to chemical soil treatments in Hawaii. The barrier can be used as a fill before pouring a concrete slab foundation, around the perimeter of an existing concrete slab, and beneath and around retaining foundation walls during new construction. It can also be used to fill hollow voids in hollow tile construction. Although the primary use of BTB is for new construction, other post-construction uses are being developed.

Termi-Mesh System

Proper construction techniques, such as isolating wood from the soil, and the use of physical barriers to exclude subterranean termites are practical approaches to preventing termite attack on structures. All too frequently, construction details that are conducive to termite infiltration or to moisture accumulation and fungal decay are incorporated into new buildings under the guise of economy or aesthetics (Reinhardt & Yates 1995, Dost & Botsai 1990, Tamashiro et al. 1990b, Verkerk 1990). Certainly, adoption of vigilant construction methods and the use of inert physical barriers such as properly-sized gravel to prevent termite penetration into the structure promises more permanent termite control than is possible with insecticide applications to the soil alone.

Although sized particle barriers are useful tools for termite prevention, they can be difficult to install in some situations without proper training (Grace et al. 1996a). Unstable or not fully compacted soil, rough or irregular surfaces at the edges of the particle barrier, and protection from contamination or mixing with adjacent soil, sand, etc., are issues that must be addressed. Recently, an alternative termite barrier consisting of a marine grade 316 stainless steel mesh was developed and patented in Australia as TERMI-MESH (TERMI-MESH Australia Pty. Ltd.). This mesh has an aperture size of 0.66 mm by 0.45 mm, which is well below the 1.2 mm aperture size found by Ewart et al. (1991) to prevent passage of foraging Formosan subterranean termites, *Coptotermes formosanus* Shiraki. In laboratory and field trials, Lenz & Runko (1994) found that a variety of Australian termite species, including *Coptotermes acinaciformis* (Froggatt), were unable to penetrate this mesh, and it is currently used in building construction in Australia. Based upon the results obtained in Australia, this steel mesh has been used experimentally in Hawaii, both in conjunction with basaltic particle barriers and as a sole method of excluding subterranean termites.

A one-year field test (Grace et al. 1996a) was conducted in Hawaii to evaluate the ability of this steel mesh to prevent penetration by the Formosan subterranean termite, *C. formosanus*. Nine test units, containing susceptible wood, were placed above-ground under conditions of high termite pressure at three field sites on the island of Oahu, and a tenth test unit was buried at one of these sites. Test units were removed after one year, and examined for termite penetration. Termites did not directly penetrate the steel mesh, nor areas where pipes had been inserted through the mesh, in any of the ten test units. In one of the above-ground units, however, a crack in the bonding cement securing a heavy fold of the mesh to the corner of a concrete block allowed termites into the test unit. In practice, the mesh would not normally be sealed to a corner in this fashion. Thus, a second field test has since been initiated to more accurately simulate use of the bonding cement to secure the mesh in construction situations, and determine whether improvements are warranted. Our results indicate that TERMI-MESH is effective in excluding *C. formosanus*; although, as with other physical barriers, care must be taken in installation to prevent termites from circumventing the barrier.

Pre- and post-construction applications of the TERMI-MESH system are numerous. The product can be installed beneath concrete slabs, around plumbing and electrical conduits, to seal concrete cracks and cold joints, to prevent penetration through hollow tile retaining walls, and as a sock or boot to protect wooden fence posts, and telephone and electrical poles.

The TERMI-MESH system was accepted into Hawaii's Uniform Building Codes for all islands in 1995 as a stand alone pretreatment for new construction. Since then approximately 50 new home installations have been performed, and numerous post-construction retrofits have been made to homes which were infested by Formosan subterranean termites (personal communication, Mr. Wayne Parsons, Termi-Mesh Hawaii).

Sentricon Baiting System

Baits are an attractive method of control for cryptic social insect pests, since they require application of only a small amount of insecticide and, ideally, contact with a relatively small proportion of the foraging population, who then proceed to distribute the toxicant to other colony members.

In-Ground: The Sentricon Colony Elimination System is a baiting system for subterranean termite control manufactured and distributed by DowElanco (Indianapolis, IN) and introduced commercially in spring 1995. The Sentricon System uses a plastic cylinder, ca. 24 cm in length by 4.5 cm diameter, with side ports to permit termite entry (Su et al. 1995). The plastic cylinder is placed in an augured hole in the soil, has a tamper-resistant cap, and contains two small pieces of wood as removable monitoring devices. Monitoring stations are placed in the ground around the building (at maximum 15-20 foot intervals), and elsewhere on the property where subterranean termites might be expected to occur.

When termites are found in a monitoring station, the wood in the station is replaced with a plastic Baitube device (a plastic cylinder with small holes in the sides) containing either wood flour or a laminated textured cellulose impregnated with the chitin inhibitor hexaflumuron (Recruit). The studies described here utilized Baitubes containing approximately 35 g of wood flour matrix impregnated with 0.1% (wt/wt) hexaflumuron.

In fall 1993, field studies (Grace et al. 1995, 1996b) were conducted with a prototype Sentricon System around three representative structures in Hawaii, each of which had a history of subterranean termite infestation and recurring problems: a four-unit condominium building on the island of Kauai, a single-family home on the island of Oahu, and a large commercial building on Oahu. All of these buildings had concrete slab foundations, and had previously been treated around the exterior perimeter and through the slab at various locations inside with soil insecticides. Basaltic Termite Barrier (Ameron HC&D, Honolulu) gravel had also been installed in a trench around the condominium building. However, construction defects such as stucco extending into the ground, concrete and asphalt walkways abutting the buildings, and (in the case of the residential structure) rocky hillside soil conditions had contributed to continuing termite problems.

Using mark-release-recapture methods (Su & Scheffrahn 1988, Su 1994), termite foraging populations at these three sites were estimated at 0.33 million, 0.94 million, and 5.35 million. Following application of hexaflumuron baits, no termite activity has been detected at these locations for 24, 10, and 20 months, respectively. At these sites, the amount of bait consumed had a logarithmic relationship to the size of the estimated populations, although in each case there was a great deal of variation among the individual population estimates used to calculate the weighted-mean population estimate. Monitoring of termite activity at unbaited foraging sites is essential in order to document bait efficacy without the confounding factors of bait deterrence and/or localized termite mortality at the site of bait application. Suppression or removal of the termite population to a level where termite activity can no longer be detected in unbaited monitoring stations, in the structure to be protected, or elsewhere in the immediate vicinity of the structure is the only practical goal of bait applications.

Above-Ground: The in-ground Sentricon Baiting System is being marketed as a preventive method for subterranean termites, and a remedial control tool for existing infestations in structures. One limitation of the latter approach is the length of time it would take for termites to locate the baited station in order to mitigate an ongoing infestation in a building within a reasonable amount of time; time frames have ranged from one week to more than a year (personal communication, members of the Hawaii Pest Control Association).

Since December 1995, two field trials (Yates & Grace, in preparation) have been conducted in Hawaii to evaluate the practicality and efficacy of a Above-Ground (A.G.) Sentricon Baiting System developed by DowElanco. Each building had ongoing Formosan subterranean termite infestations: a 12-floor high-rise residential condominium building, and a large single-story United States Department of Agriculture (USDA) fruit fly rearing facility.

A thorough inspection of the high-rise complex determined that the aerial infestation (no connection to the ground) was limited to the roof and two units on the 12th floor. Using mark-release-recapture methods (Su & Scheffrahn 1988, Su 1994), the termite foraging population was estimated at 469 thousand. Following application of 0.1% and 0.5% hexaflumuron treated matrices contained in two above-ground plastic bait stations attached to the roofing membrane, the infestation was eliminated in 76 days. Termite activity in monitoring stations (Grace et al. 1996b) containing untreated wood wafers as a food source was also eliminated.

Infestations originating from the ground at the USDA facility included two adjacent larval holding rooms, the security office, a site at the exterior perimeter of the building and a detached storage container. Five bait stations containing 0.1% and 0.5% hexaflumuron treated matrices were attached to a wall in one larval holding room. Two monitoring bait stations were also included in this area and on a opposite wall in the adjacent larval holding room, and one bait station each in the security office and at the exterior perimeter site. Modified in-ground Sentricon stations (Grace et al. 1995) were installed around the detached storage container. Infestations in the two larval holding rooms were eliminated in 72 days, however, termites remained active in monitoring stations located in the security office, the exterior perimeter and around the storage container, indicating that multiple subterranean termite colonies were infesting these areas.

Interest in the development and testing of this type of application stemmed from the need to reduce or eliminate traditional pesticide spot treatments within residential structures, and the possibility that the system would be a compliment and/or substitute for in-ground bait stations. Moreover, applying the bait to existing infestations rather than waiting for termites to locate in-ground stations, offers an expedient and safer means of eliminating infestations within structures. The A.G. system is expected to be commercially available in early 1997 since research in Hawaii, the continental U.S.A and other countries has demonstrated that they offer a viable alternative to traditional remedial chemical spot treatments. There is also a possibility that the system can substitute for in-ground bait stations to mitigate an ongoing infestation.

Removable Base Boards

Termite inspections for double wall constructed buildings (containing finished interior walls) have long plagued the pest control industry, often resulting in litigation when termites that are present are not detected either during an ongoing preventive pest control inspection contract or when a home is inspected prior to its resale. This dilemma has increased with the advent of double wall constructed homes in Hawaii, particularly when construction materials that are less preferred by termites as a food source are utilized to finish interior walls. Very often subterranean termites will infiltrate these inaccessible wall voids and go unnoticed until severe damage to preferred structural members has occurred.

In 1993 P.I.M. Development, Inc. (Kaneohe, HI, personal communication) completed the design of a prototype removable baseboard product and began test manufacturing in late 1994. The original prototype consisted of a spring-steel clip and spacer block to attach a 3-1/4 inch, medium density fiberboard to the bottom edge of inner gypsum walls of double wall constructed homes. During construction of the building the gypsum wall is secured to wall studs at a three inch height above the finished floor. The clipped baseboard is then attached to the bottom edge of the gypsum wall. For existing homes, the gypsum wall has to be cut three inches above the finished floor to install the system as a retrofit.

The prototype proved not to be a simple system to install since its manufacturing and installation required the use of many carpentry tools and was labor intensive. Continued product development led to a all polymer Snap On Baseboard System (SBS) in June 1996. The baseboards are extruded from solid polyvinyl chloride and the clips are inject-molded out of acetyl plastic which snap-in into grooves that are molded into the back of the baseboard. A snap-in corner system was also developed to eliminate the need to miter baseboards to fit corners.

Homeowners and pest control operators now have a non-destructive means to inspect sill plates, wall studs and plumbing penetrations that are concealed within double wall voids. Interest in the SBS is gaining acceptance in Hawaii and the mainland U.S.A., and P.I.M. Development is expanding its distribution of the product to Australia, Japan and other parts of the orient where subterranean termites are a threat to wooden structures.

Resistant Building Materials

The use of steel framing in residential building construction has increased in the Hawaiian islands in the past several years. However, the higher cost of steel and the need for specialized installation procedures still limit its use. From an environmental standpoint, the energy costs associated with steel production, and the production of preservative-treated wood products, are also of concern. Naturally-durable wood species represent viable alternatives for many construction uses. For example, Western red cedar *(Thuja plicata)* (Su and Tamashiro 1986), Alaska-cedar *(Chamaecyparis nootkatensis)*, redwood *(Sequoia sempervirens)* and teak *(Tectona grandis)* (Grace and Yamamoto 1994) exhibit from moderate to high resistance to Formosan subterranean termite attack. Although wood from the neem tree, *Azadirachta indica*, is not sufficiently resistant to termites to be useful in construction, both the wood and bark are less preferred by termites than that of other tree species, suggesting that this tree might be useful for ornamental arboriculture in Hawaii (Delate and Grace 1995).

A recent survey of indigenous and introduced Hawaiian tree species (Grace et al. 1996c) found that *Cryptomeria japonica* (Sugi), *Cordia subcordata* (Kou), *Calophyllum inophyllum* (Kamani), *Thespesia populnea* (Milo), and *Eucalyptus microcorys* (Tallowwood) were very resistant to Formosan subterranean termite feeding. The current availability and wood characteristics of these species suggest that Sugi, Tallowwood, and Milo may have the greatest potential of the termite-resistant species in Hawaii for expanded cultivation, harvest, and development and marketing of wood products.

Conclusion

Urban entomology is an emerging science directed to address the needs of homeowners in rural and urban communities. Acceptance of new technology to control insect pests that affect this clientele resides in the education of not only the homeowner, but also residential developers, architects, the construction industry, and pest control operators (PCO). Developers are sales-oriented, architects are aesthetically aligned and often create conducive conditions for urban pests via structural designs, building contractors may unfortunately view structural pests as an economic benefit to their industry, and PCO practitioners sometimes believe non-chemical pest control methods are an economic threat to their livelihood. When consumers are advised about new technology, economics often results in traditional chemical applications which are falsely perceived as being more cost-effective. However, insecticide-reliant methods are temporary when used alone as preventive or remedial strategies. Homeowner acceptance and implementation of new technologies that are safe and environmentally compatible to prevent and/or control ongoing infestations by urban pests can only be accomplished through repeated educational efforts.

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Hong Kong Pest Control Association
c/o Mr. Jackson Chan
14-B Hang Shun Mansion
76 Jaffe Road
Wanchai HONG KONG

Tel: (852) 2861-0303
Fax: (852) 2861-1210