# Chapter 12
# Subterranean Termite Control Examinations on Current and Former Experimental Forests and Ranges

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**Abstract** For more than 70 years, the USDA Forest Service's Termite Team has engaged in research to extend the life of wood in service by studying chemical (and a few nonchemical) subterranean termite control products. These efficacy data are produced in distinct field trials on experimental forests across the USA, and are used by industry cooperators to register their products with the Environmental Protection Agency. Experimental forests and ranges allow long-term undisturbed efficacy examinations of termiticides in preventing subterranean termite attack on wood. This chapter provides historical information on the development of these efficacy studies over the years and the places where these data are collected.

**Keywords** Termite · Termiticide · Pesticide · Urban entomology · Subterranean pests

## 12.1 Introduction

Of all the types of pest management, few involve such an intimate relationship between affected persons and pests than urban pest management. Urban entomology involves pests affecting the three basic needs of people (health, food, and shelter) and includes medical, veterinary, structural, and stored products pests. As with many other pests, some urban pests may best be understood and controlled by examining their natural habitats as opposed to the urban environment. It surprises many people to find that the USDA Forest Service works in urban pest management by studying control technology for wood products insects.

The term "pest" has been used to describe a species that is found in an area where it is unwanted (Bennett et al. 1997). Termites fit this definition perfectly, as they are not considered pest species in forests. In fact, termites benefit forests by removing downed timber and recycling nutrients back into the soil. In the southern

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**Fig. 12.1** Subterranean termites and their damage to a pine bolt

USA, forests are being converted into urban areas quickly, due to the phenomenon of "urban sprawl" resulting in increased development in formerly forested areas (Cordell and Overdevest 2001). Subterranean termite colonies (Fig. 12.1) are fairly long lived (as long as 16 years for some species; Grace et al. 1995) and some may feed on downed timber 1 year and on a newly built home the following year. Proper preventive control measures can protect structures from this occurrence. One of the most common subterranean termite control methods over the past century has been the use of pesticides applied to soil to provide a barrier that prevents entry of termites into structural wood (Kofoid 1934; Mallis 1997).

Residences are one of the largest investments made by Americans, estimated at US$ 12.5 trillion nationwide for the year 2000 (Peterson et al. 2008). Obviously, protecting that investment is a key goal for homeowners, part of which is the prevention of termite damage (Fig. 12.2). The economic cost of termite control and repair of their damage is quite large, estimated at roughly US$ 5 billion annually (Su and Scheffrahn 2000; Peterson et al. 2008). From a resource preservation perspective, improving termite control is important. By protecting structures, wood in use lasts longer, decreasing the need for harvesting replacement wood.

The USA has not always regulated pesticides through efficacy and nontarget toxicity testing (Ware 1994; Peterson et al. 2008). Currently, all pesticides undergo some level of efficacy testing for registration (Pedigo 1989), but only two groups of pesticides require independent efficacy studies: termiticides, because of the investment loss resulting from heavy termite infestations, and public health pesticides, such as mosquito control products. For termiticides to be registered, the US Environmental Protection Agency (EPA) guidelines (Office of Prevention, Pesticides, and Toxic Substances, OPPTS 810.3600, and Pesticide Registration Notice 96–7) state that candidate product rates should achieve 100 % control at four US locations (detailed later) for a period of 5 years. After federal registration, state regulatory officials also review the product before it can be sold or applied legally in that state. Just over half of the states (26 plus Puerto Rico) belong to an organization

**Fig. 12.2** Subterranean termite damage to a 2.5 × 10 cm (1 × 4 in.) board

that makes these decisions as a group—the Association of Structural Pest Control Regulatory Officials (ASPCRO). It is important to consider that the EPA acceptance requirements are guidelines rather than hard-and-fast rules; thus, the EPA can register products that do not meet the efficacy standards perfectly if the product has other attractive properties, such as low nontarget (including mammalian) toxicity (Shelton and Wagner 2005). This chapter discusses the involvement of the USDA Forest Service in the protection of wood in use from subterranean termite damage.

## 12.2 The Termite Team, Past and Present

The termite team of the Insects, Diseases, and Invasive Plants Research Work Unit (SRS-4552) has been working in the Southeast for 75 years. The team was started by Thomas E. Snyder in 1934 in New Orleans to address problems with insect pests of forest products and forests. Snyder was one of the most respected termite authorities of his time.

In 1938, Snyder hired Harmon R. “Johnny” Johnston as a research entomologist (Mauldin 1989; Kard 2000). He was stationed at the Harrison Experimental Forest (HEF) in Saucier, MS. The HEF is part of the DeSoto National Forest in southern Mississippi. Johnston initiated work investigating means of protecting wooden structures and crates from termites. Over the years, Johnston was also recognized for his work on controlling wood-destroying beetles, such as ambrosia beetles (Kard 2000). In the 1940s, the US military funded research on soil-applied termiticides, allowing the work to expand into other areas (Kowal and St. George 1948; Mauldin 1989). Some areas of the world have more aggressive termite fauna than the USA, so any reliance on wooden containers or structures required protection from damage.

Johnston’s work involved the development of an appropriate field test for examining large numbers of replicates of candidate termiticides in the field. Due to

**Fig. 12.3** Ground board and modified ground board plots on the Santa Rita Experimental Range

**Fig. 12.4** Termiticide application to a ground board plot

the numbers involved with simultaneous testing of various formulations and chemistries, a simple evaluation method was needed to speed the process. The termite team's scientists eventually decided on a pair of simple protocols for measuring termite damage. One of these, the ground board test, was designed to simulate the use of a chemical applied to the soil as a barrier protecting wood on top of the soil (Figs. 12.3 and 12.4). The other test, the stake test, was also designed to work with soil applications of chemicals but measured the protection of stakes driven into treated soil. Both tests used a simple damage rating scale allowing rapid evaluation of test wood.

As a side note, soil applications of termiticides have changed in importance over the past century. In the early 1930s, soil pesticides for termite control were considered experimental and generally not recommended due to questions about efficacy and persistence of these applications (Peterson et al. 2008). The recommendations at the time were focused on treated wood products (brush or dip treatments; Peterson et al. 2008).

In 1960, the termite team moved into a new laboratory in Gulfport, MS, where it remained until 1996 when the team was moved to Starkville, MS. Work within the team is currently divided into more basic research (behavior, forest ecology), toxicology and environmental fate, and the termiticide testing program. The termiticide testing program is responsible for evaluating the performance of subterranean termite control materials in the laboratory and field, producing data that are used in registration packages submitted to EPA. In a sense, the termiticide testing program is the part of the unit that is most familiar to outsiders. The efficacy data are eventually made public following the successful registration of a termiticide in an annual report published in a trade journal for the pest management industry (most recently, Wagner et al. 2011).

Through the annual report and various appearances at meetings, the efficacy data are widely distributed as are topics surrounding the regulation of such materials. Thus, the termiticide testing program data are available for both the industry and the homeowners to whom the services are sold. This allows the consumers to educate themselves on the performance of the products before agreeing to purchase a pest control application, a very costly endeavor depending on treatment type and foundation of the structure. While some consumers access the testing program data through the published annual reports, many come to the termite unit staff directly via e-mail, phone calls, or occasionally in person.

## 12.3 The Termiticide Testing Program Locations

Originally, the Forest Service conducted termiticide research on the HEF. The HEF is a prime habitat for native southeastern subterranean termite species belonging to the genus *Reticulitermes* Holmgren. Over the years, the termite team has added (and dropped) termiticide research sites from use. For example, by 1942, termiticides were being tested in the Panama Canal Zone and at Beltsville, MD (Kowal and St George 1948). Military installations in several locations have also been used as testing sites, including Fort Dix, NJ, Fort Sill, OK, Puerca Point in Puerto Rico, and the Panama Canal Zone. Midway Island, HI, was also used as a location for the termiticide testing program. A further expansion occurred in 1965 with termiticides installed in seven locations, including Arizona, Florida, Hawaii, Maryland, Missouri, Oregon, and South Carolina (Carter and Stringer 1970a; Carter et al. 1970). This study was also used for an examination of termiticide persistence under differing rainfall and soil conditions (Carter and Stringer 1970a; Carter et al. 1970). Bait studies (using mirex) were performed near the city of Lake Charles, LA, in 1968 against the Formosan subterranean termite, *Coptotermes formosanus* Shiraki.

Many of these locations were on experimental forests, as long-term access to those areas could be secured. Private lands often changed hands, or were harvested from time to time, making a stable, consistent outdoor laboratory nearly impossible. Experimental forests filled this need nicely, and by working with the managers who maintained those forests (or ranges), the termiticide testing program could work in

**Table 12.1** Soil characteristics of the current termiticide testing program locations

| Soil type | Harrison | Chipola | Calhoun | Santa Rita |
|---|---|---|---|---|
| | Rumford sandy loam | Lakeland sand | Cataula loamy sand | Continental gravelly loamy sand |
| pH | 5.1 | 4.8 | 5.8 | 6.9 |
| Clay | 4.9% | 2.8% | 7.0% | 7.5% |
| Silt | 25.2% | 2.7% | 10.0% | 15.1% |
| Sand | 69.9% | 94.5% | 83.0% | 77.4% |
| Mean rainfall | 170 cm/yr | 163 cm/yr | 127 cm/yr | 35.5 cm/yr |

areas where there was little chance of man-made disturbance. However, that does not prevent nature from disturbing plots, as seen in 2005 on the HEF with Hurricane Katrina (Wagner et al. 2006, 2007).

While additional locations have been used from time to time, Beal (1986) states that from 1972 onward all candidate products considered for registration were studied on the HEF, Arizona, Florida, and South Carolina (detailed below). These decisions were based in part on variations observed in the initial penetration of organochlorine termiticides in plots of different soil types and moisture content (Table 12.1; Carter and Stringer 1970a, 1970b). Studies in Maryland were discontinued due to low termite attack on control plots (Kard et al. 1989), and the studies in Panama were terminated when control of the Canal Zone was returned to the government of Panama (Kard 2000).

**Harrison Experimental Forest** The value that this experimental forest has had on the multibillion dollar pest management industry is overwhelming. Virtually all soil-applied termiticides over the past 70 years have been tested there. This site tends to have the greatest termite activity (Mulrooney et al. 2007), and thus tends to be the most challenging site for candidate termiticides.

**Chipola Experimental Forest** The Chipola Experimental Forest (Calhoun County, FL) was established in 1952 on 1,116.93 hectares of land provided by corporate donors. This private property was leased to the Forest Service for research purposes, with the lease to be renegotiated after 50 years. The original research projects were aimed at establishing optimal procedures for growing pines in "sandhill" areas (Hopkins and Hebb 1954). Termiticide testing began there in 1965 (Carter et al. 1970). Over the years, the properties changed hands numerous times, moving from corporate to private (individual) holdings, and the Forest Service has periodically reduced its size. In 2004, the Southern Research Station purchased the property. The total area of the Chipola Experimental Forest is currently 380.4 hectares, and the scientists responsible for the testing program continue to annually install and evaluate termiticide products on this site.

**Calhoun Experimental Forest** The South Carolina site is located on the Calhoun Experimental Forest on the Sumter National Forest. The Calhoun occupies 4,451.54

hectares in the western end of South Carolina, near the town of Union. This area is known for soil erosion and water holding problems, and the Calhoun was originally set up in 1947 to research soil stabilization and forest productivity for similar Piedmont areas (Metz 1958). Although the testing program has been executed at two locations within the Calhoun, this forest has provided a stable location since 1965 (Carter et al. 1970). The Calhoun site has been one of the four major test locations used for termiticide efficacy testing (Beal 1986), with new termiticide products installed and evaluated annually.

**Santa Rita Experimental Range** This range is located south of Tucson, near the towns of Green Valley and Sahuarita in Pima County, AZ. The Santa Rita Experimental Range (SRER) was the first experimental range in the USA. Sayre's (2003) extensive history of research on the SRER provides much of the detail of the numerous property transfers affecting the SRER. A land transfer between the US Department of the Interior and the State of Arizona was finalized in 1991, with Arizona taking possession of the Santa Rita. It is currently managed by the University of Arizona (Sayre 2003).

Candidate termiticides have been installed and evaluated annually on the SRER since 1965 (Carter et al. 1970). It is an important part of the registration process as it provides access to two subterranean termite species not encountered on the southeastern sites, *Heterotermes aureus* (Snyder) and *Reticulitermes tibialis* (Banks; Table 12.2; Kofoid 1934; Mallis 1997). Efficacy data against *H. aureus* are a required part of the registration packages for candidate termiticides under current EPA guidelines (PR notice 96–7; OPPTS 810.3600). Thus, the efficacy data taken from this location provide information for western American homeowners and pest management companies on prevention and control of their local subterranean termites. It also provides information to chemical companies on the influence of high temperature and low moisture conditions on the persistence of their termiticides.

**Dorman Lake** An additional site has been established near Starkville, MS. It is used mainly for generic termiticides seeking Florida registration. This location is in a pine forest near Dorman Lake and is part of the John W. Starr Memorial Forest owned and managed by the Department of Forestry, Mississippi State University. This site is not used for new products; it is used primarily for additional data that are sometimes required by states, often after an active ingredient is no longer protected by patent.

## 12.4 Changes in Chemistry Lead to Changes in Testing

Advances in chemistry over the years have given rise to new products. As with previous termiticides, the new products have been tested by members of the termite team. Some products have required deviations from standard protocols. Additionally, new test methods were added to account for changes in American construction practices, most importantly the increased prevalence of concrete slab-on-grade con-

**Table 12.2** Termite species present at the current termiticide testing program locations

| Termites | Harrison | Chipola | Calhoun | Santa Rita |
|---|---|---|---|---|
| *Reticulitermes flavipes* (Kollar) | × | × | × | – |
| *Reticulitermes virginicus* (Banks) | × | × | × | – |
| *Reticulitermes hageni* (Banks) | × | × | – | – |
| *Reticulitermes tibialis* (Banks) | – | – | – | × |
| *Heterotermes aureus* (Snyder) | – | – | – | × |
| *Gnathamitermes perplexus* (Banks)[a] | – | – | – | × |

[a]*G. perplexus* is present, but not a pest species

struction occurring during the 1950s and 1960s (Peterson et al. 2008).The previous ground board test, that had been used, was appropriate for testing open (uncovered) weathering conditions, and was a worst-case scenario in testing termiticides. The modified ground board test (concrete slab test; Fig. 12.3) was used beginning in 1967 for a variety of organophosphate and carbamate products (Beal and Smith 1972). This test provided data on protected termiticide treatments (i.e., termiticide persistence beneath a slab foundation), and, to date, new studies are still being installed using both methods.

The termiticide testing program has also responded to requests for other types of termite control products developed over the years. Physical barriers (such as stone particles, metal meshes, plastic barriers, etc.) are nonchemical methods used for keeping termites out of structures, and have various benefits and drawbacks compared with conventional termiticide applications (Su 2002). When these products are impregnated with insecticides, the manufacturers must submit efficacy data similar to those for soil-applied termiticides for registration. The termite team also tests these products providing the necessary data for registration, as well as examining some of the non-impregnated products from a scientific perspective.

In the early 1970s, studies were performed on the HEF to investigate the feasibility of termite baiting (Esenther and Beal 1974). The objective of these studies was to examine the possibility of area-wide management of large numbers of colonies of subterranean termites (Esenther and Beal 1974). In the past decade, the use of termiticidal baits has become fairly common in the control of subterranean termites, although on a smaller scale (few or single colonies; Grace and Su 2000).

New chemistries such as the delayed action, non-repellent termiticides (DANR) have required modification of experimental layouts. Prior to the use of DANR products, test layouts were simple, completely randomized block designs with plots spaced on five-foot centers. Many products could be tested together in a design like this because plots of repellent compounds should not influence one another. However, the new DANR termiticides required changes to the layout because now there was a possibility for some products/concentrations to influence other nearby products. Several layouts were tried as scientists with the termite team looked for a reasonable accommodation for these products, balancing available space against the need for product separation (Peterson et al. 2006). Currently, a variety of layouts is being used to accommodate the DANR products (Peterson et al. 2006), using distances supported by colony foraging territory size and distribution data in the literature (Howard et al. 1982; Vargo 2003).

During the past decade, a slight change in the evaluation of products has also been implemented. Previously, when a block from a treated plot was damaged for the first time, it was recorded and removed from further consideration. Now, when a plot block is damaged it is recorded and provided with a new test block and evaluated again on future visits. Thus, additional data are collected on the fate of previously damaged plot blocks (are they damaged again and how badly), information that is needed for registration in Florida.

Changes in product evaluation have also been required in the past 10 years to give cooperators and regulators additional information regarding the performance of candidate products. Florida has implemented its own regulations on the efficacy of products that must also be satisfied by registrants before a product is registered in the state (Wagner et al. 2004). Most importantly, the Florida rule does not use 100 % control as a registration criterion (used by EPA). This leads to an increase in the number of years of efficacy data (compared to those used by EPA) for products when used as a standard (Wagner et al. 2004, 2006, 2009, 2011). EPA has initiated the process to change OPPTS 810.3600 (Shelton and Wagner 2005), and the methods of installation or evaluation of the testing program will be modified accordingly.

Clearly, the termiticide testing program benefits both the general public and those who determine public policy. The program's consistent studies on experimental forests produce unbiased efficacy testing of termite control products for the American consumer and also aids efforts by the EPA to register these products.

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