Integrated Pest Management of Subterranean Termites (Isoptera)[1]

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Abstract IPM strategies and tactics to reduce insecticide use while protecting structures from attack and infestation by subterranean termites are reviewed. Standard termiticide and product testing methods are presented. Results of USDA Forest Service field tests generally demonstrate that currently registered termiticides provide five or more years of termite control. Stainless steel mesh has been a 100% effective termite barrier for more than 6 yrs in continuing field tests.

Key Words IPM, Isoptera, termites, termiticides, wood destroying insects, wood preservatives, Urban IPM Symposium

Subterranean termites cost United States property owners more than $2 billion annually in control efforts and structural damage repair expenditures. Additionally, millions of dollars are spent by the U.S. Department of Defense to protect military structures from termites and in damage repair costs each year. Furthermore, termite control measures protect wooden structures and products, thus conserving our nation's wood supply by prolonging the life of structural wood. Many thousands of hectares of timber are harvested yearly to replace structural wood destroyed by termites (Su and Schreffrahn 1990, Sharma 1993). Integrated pest management (IPM) within the structural pest control industry does not include an economic threshold because most building owners have zero tolerance for these pests. IPM of subterranean termites consists of a series of decisions by a building owner and pest management professional (PMP) that consider the integration of multiple long-term strategies and preventive and remedial actions to prevent or stop damage to buildings and wooden components or other wooden materials. Actions initiated may include, but are not limited to, complete and thorough inspections to determine the extent of infestation, and use of baiting systems, wood preservatives, physical barriers, noncellulose building components, sanitation, elimination of conducive conditions, building practices, steel frame construction, fumigation, biological agents, and aboveground and soil-applied termiticides.

The goals of this paper are to provide information concerning IPM of subterranean termites, describe some new technologies available to PMPs, review several current and emerging tools and practices useful for IPM of subterranean termites, and sum-

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marize field-test results of USDA Forest Service evaluations of some soil termiticides and stainless steel mesh (Termi-Mesh®, Termi-Mesh Hawaii, Inc, Honolulu, HI). These data are derived from non-copyrighted papers and presentations by the author and are courtesy of the USDA-FS Southern Research Station.

Taxonomy and Biology

Of the approximately 47 species of termites in the U.S., about 28 species from 8 genera are considered structural pests (Weesner 1965, Su and Scheffrahn 1990). *Reticulitermes* sp. and *Heterotermes aureus* (Snyder) are destructive native U.S. subterranean termites, but their taxonomy is in need of revision and clarification (Haverty et al. 1991, Haverty et al. 1996). Several investigators have produced useful taxonomic descriptions and keys (Banks and Snyder 1920, Miller 1949, Snyder 1954, Weesner 1965, Nutting 1990, Scheffrahn and Su 1994, Hostettler et al. 1995). However, differences in descriptions among these authors can lead to inconsistent and inaccurate identification. Additionally, cuticular waxes, and lipid and DNA analyses are emerging as useful identification and differentiation tools (Haverty and Nelson 1997, Jenkins et al. 2001).

Several species including the eastern subterranean termite, *Reticulitermes flavipes* (Kollar), the desert subterranean termite, *H. aureus,* and the Formosan subterranean termite, *Coptotermes formosanus* Shiraki, are important economic pests that collectively cause hundreds of millions to billions of dollars in damage and repair costs annually to wooden structures in the U.S. (Mauldin 1982, Sharma 1993, Beal et al. 1994). *Reticulitermes flavipes* and *H. aureus* are indigenous to the U.S., but *C. formosanus* is an exotic pest thought to originate in China (Kistner 1985). *Coptotermes formosanus* is widely established on Guam, some Hawaiian Islands, Japan, Midway Island, and Taiwan, and is found in several other locations including the southwestern, southern, and southeastern boundaries of the continental U.S. (Gay 1969, Bess 1970). Infestations have been found in Alabama, southern California, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia (Weesner 1970, Su and Scheffrahn 1986, Chambers et al. 1988, Atkinson et al. 1993, Gold et al. 2001, Woodson et al. 2001).

Knowledge of termite biology, ecology, foraging, and feeding behavior is needed for effective evaluation of new technology such as baits and baiting strategies, physical barriers, and new, unique mode-of-action materials intended for use in termite control. Chemical and genetic taxonomy of subterranean termites is useful, but intra- and inter-colony interactions and relationships have been only occasionally studied (Clement 1986, Grace et al. 1988, Shelton and Grace 1997, Polizzi and Forschler 1998). Taxonomic studies are needed to delineate cyclic colony variations in termite foraging, abandonment of and return to foraging areas or nutrient sources, size of foraging territories, and foraging population numbers.

Diversity among various termite species necessitates that new research approaches be designed to take advantage of interspecific biological peculiarities. The complexities of termite behavior and the diverse ways that new, non-detectable toxicants affect termites will require originality in formulating approaches to evaluate these potential termite management agents. Novel study designs and research methods are needed to address emerging questions (Lewis 1997).

A broadly accepted definition of what constitutes a termite colony needs to be clearly described due to varied hypotheses among researchers. Colony characteristics such as habitat preferences, social behavior, reproduction, foraging behavior, nutrient preferences, numbers of termites in a colony, caste ratios, and distinguishing peculiarities need to be investigated to better understand how termites operate (Gentry and Whitford 1982, Thorne and Forschler 1998).

Reproduction and differentiation is complex and variable, and neotenics are found in many species. Reproductive capability of colonies with a primary founding pair and with neotenics have been investigated in some studies (Snyder 1920, 1934, Pickens 1934, Noirot and Pasteels 1987).

Developmental biology has been investigated by McMahan (1969) and Noirot and Pasteels (1987, 1988). Division of labor has been described by Noirot (1985) and Roisin (1990). Caste ratios and morphology have been elucidated by several researchers (Howard and Haverty 1980, 1981, Grace 1996, Pawson and Gold 1996, Thorne et al. 1997). However, additional work to elucidate life cycles of different species, colony budding, and caste development is of interest.

Management Strategies and Tactics

From the 1920s through the 1980s, subterranean termites were almost always controlled by applying insecticide directly to soil to create a contact-toxic or repellent barrier under and around wooden structures. With the removal of widely-used chlordane from the U.S. termiticide market on 15 April 1988, research emphasis shifted to new insecticides and technologies directed toward IPM of subterranean termites (Kard et al. 1989). Subsequent research continues to assess effectiveness of new chemicals and formulations, unique new materials for baiting strategies, and non-chemical or low-chemical physical barriers that have potential for termite control.

Detection devices. On-site inspections using a flashlight, screwdriver, and knife to determine the presence of termites is a time-tested method, although these basic tools may not always find termites inside walls or other hidden areas of a structure. Additional tools are available to enhance our ability to detect the presence of termites. All are designed to improve the efficiency, ease, and reliability in detecting termite infestations.

Several types of borescopes are available including fiber optic and periscope devices (Hawkeye Precision Borescopes, Gradient Lens Corp., Rochester, NY). A small hole is drilled in a wall or other surface, and a slender cylindrical probe is inserted through the hole. The PMP can then rotate the probe to inspect hidden areas. A medical-grade laproscope can also be used to inspect inside walls or infested timbers or trees. However, laproscopes are relatively expensive (up to $20,000). Another mildly invasive detection instrument, the Sibert Digital Microprobe® (Sibert Technology, Ltd., Guildford, Surrey, England), is drilled into trees and timbers and resistance to drilling is measured to indicate potential infestations.

There are also several noninvasive detection technologies on the market. Instruments designed to detect termite sounds within wood are marketed to allow a PMP to listen for termite activity within infested structural components. These devices have been evaluated by researchers and found to be beneficial (Fujii et al. 1990, Scheffrahn et al. 1993, Lemaster et al. 1997). Two marketed acoustic devices are Termite Tracker System® (Dunigan Engineering Co., San Juan Capistrano, CA), and Scout-It-Out® (Acoustic Technology Group, Sacramento, CA). Other acoustic devices are also available (Lemaster et al. 1997).

A recently available device, Termatrac® (Protec USA, Inc., Coral Gables, FL), is an electronic instrument that detects movement of termites and other insects within solid objects. It uses microwave technology to detect activity in timbers, sheetrock, brick and masonry. Termatrac units are leased, and operating software is updated as needed. Technicians must receive training to become certified operators. Also, thermal imaging devices such as ThermaCAM® (FLIR Systems, Inc., Boston, MA) can also be used to detect infestations within walls or other voids.

Moisture meters are used to evaluate above average-moisture levels in walls and other structural components. Higher than average moisture in walls is a strong indication of termite activity. They can be purchased from several manufacturers and have been widely used with success. Additional technologies include electronic stethoscopes, methane gas detectors, and termite detection canines that are trained to recognize termite odors. The Termite Detection System™ (Termite Detection Systems, Inc., Oak Island, NC) locates termites by sampling and analyzing air inside wall cavities for elevated concentrations of carbon dioxide, an indicator of termite presence. Future noninvasive detection devices may utilize infrared and laser technology (Lewis 1997).

Boron. Boric acid is widely used for controlling household pests, and bioassays with borate-treated soil have demonstrated that borates mixed with soil are toxic to termites (Grace 1991a, Kard 1990, 2001b). The solubility of borates make them poor candidates for soil treatment termiticides. Also, high levels of boron in soil are phytotoxic, and boron compounds leach easily in many soil types (Moraghan and Mescagni 1991, Jones 1991). Yet, their broad-spectrum insecticidal activity has led to their above-ground use as a wood preservative to provide some protection against termites and beetles (Grace 1991a, Williams 1985, 1987, Williams and Amburgey 1987).

Several researchers have investigated the toxic effects of borates on termite gut protozoa (Rierson 1966, Yamin 1979, Yoshimura et al. 1992, Klotz et al. 1996). In one laboratory study employing choice bioassays, *R. flavipes* and *C. formosanus* were offered a tunneling soil consisting of boric acid mixed with sterilized soil at concentrations of 0.05, 0.25, 0.50, 1.00, 2.00, or 4.00% AI (w/w). Gut protozoa populations were significantly decreased after 12 wks, and termite mortality was as high as 94% (Kard 2001b).

Boron also has been investigated for use as a bait with moderate success (Grace et al. 1990, Jones 1991b). Cellulose treated with disodium octaborate tetrahydrate (DOT) or other boron salts and then fed upon by termites provides a direct method of introducing a boron-containing toxicant into a termite colony. The concentration of boron in a cellulose bait or treated wood has been effective at 0.15 to 1.4% (w/w) (Grace 1990, 1991b, Grace et al. 1992, Forschler 1996, Mauldin and Kard 1996).

Wood preservatives. Craftsmen from early civilizations rubbed essential oils extracted from various plants on wood surfaces to protect them from insect attack and decay (Snyder and Zetek 1941), though commercial use of wood preservative chemicals to inhibit insect and fungal damage dates to the early 1700s. Decay and insect-resistant heartwood from redwood and baldcypress trees was cut for building lumber and was commonly available in the 19th and 20th centuries in North America.

Numerous chemicals are widely used as wood preservative treatments. Pentachlorophenol, copper-chromium-arsenate, copper naphthenate, and to some extent creosote, are proven standards in reducing or preventing decay and insect damage to structural wood (ASTM 1999). Wood-plastic composites are also in use. Air spaces within wood are filled with a plastic substance that lends greater moisture resistance, strength, and hardness compared with non-treated wood (Hicklin 1971). Plasticized timbers are being used as fence posts, highway sign posts, noise barrier framing, and various other uses where the timbers are exposed to the elements and in contact with soil.

Borates are increasing in use as wood preservative treatments to inhibit termite and beetle feeding, and decay by some fungi. DOT is the active ingredient in wood treatment products such as TIM-BOR® and BoraCare® (Nisus Corp., Rockford, TN). If complete penetration of wood is achieved with boron-containing wood preservatives, then improved resistance to termites can be expected (Thornton 1964, McQuire 1974, Clamp 1983, Williams 1985, Williams and Amburgey 1987, Myles 1994). If penetration is shallow-surface only, then the interior of such partially treated wood remains unprotected from termites. Gay et al. (1958) noted that boron-treated wood was moderately protected from termite attack. Lumber sprayed with water and then surface-treated with borax dust, or lumber dipped in a borax solution, was moderately toxic to foraging termites (Williams 1934). Finally, borate treatment of South American wood imported into the U.S. provided protection against subterranean termites (Williams and Amburgey 1987).

Another commercial procedure called NovaGuard Two-Step™ preventive termite control, consists of two phases of spraying framed-in studs, sill plates, and other timbers with solutions of DOT. In this procedure, one liquid formulation, Shell-Guard®, is applied to entire sill plates and then to studs to a height of 0.6 m, followed by an Armor-Guard® treatment of dissolved DOT powder sprayed from the top down on all remaining framing. This results in a surface coating of borate that is toxic to many insects, including termites (NovaGuard Technologies, Inc., Knoxville, TN)

Baits. The past decade has seen great strides and successes in baiting research and technology development, and several insect growth regulators have been successfully commercialized (Jones 1984, Su et al. 1995). However, research is directed toward improving this technology, and new active ingredients are being tested (Lewis 1997). Considerable disagreement among researchers and commercial users exists concerning whether baits eliminate a termite colony or only reduce numbers in a population (Potter 1997a). This concern is being further pursued by some researchers, stating the need for additional studies of baits and their efficacy (French 1991a,b, Grace et al. 1995, Forschler and Ryder 1996, Potter 1997b).

Some companies are integrating several products into a IPM program for protecting a structure from subterranean termites. Bayer's Home Health™ (Bayer Crop Science, Vero Beach, FL) program recommends use of their in-ground bait containing diflubenzuron (Outpost® TBR, Bayer Corp. and Whitmire-Microgen Research Laboratories, St. Louis, MO), Premise® (imidacloprid) soil termiticide, Premise Gel® insecticide localized above-ground applications, and Premise foam applications in wall voids and other hard-to-treat locations. Bait manufacturers, including Dow AgroSciences (Sentricon® Colony Elimination System, Indianapolis, IN), FMC (First-Line® Termite Defense System℠, Princeton, NJ), and Ensystex (Exterra® Termite Interception and Baiting System, Fayetteville, NC), have seen their bait products employed within an IPM program, although Sentricon is marketed as a stand-alone colony elimination system. BASF's recently-marketed Subterfuge® Termite Bait (BASF Corp., Research Triangle Park, NC) contains hydramethylnon and exhibits delayed insecticidal action as do other baits (Moreland 2002a).

Bait manufacturers offer software that provides information and training for PMPs on proper use of their products. For example, FMC offers SMARTBAIT™ software for their FirstLine Termite Defense System. Dow AgroSciences has developed a hand-held Interrogator Device™ that allows a PMP to determine if a Sentricon bait station has been invaded by subterranean termites, without any need to remove the cap from the Sentricon station to look for termite activity (Rambo 2002). These bait systems have proven successful against termites in thousands of structural installations and are an important part of a termite management program (Moreland 2002a). Other innovations will undoubtedly enter the termite IPM market that will enable PMPs to manage termites more effectively.

Sized-sand particle barriers. Sand barriers were first investigated for termite exclusion in the 1950s (Ebeling and Pence 1957). Further studies of sized-sand particle barriers demonstrated their effectiveness with a limited number of termite species (Smith and Rust 1991, Tamashiro et al. 1991, Su and Scheffrahn 1992, Lewis et al. 1996). Sand barrier tests were installed in four U.S. mainland test sites during 1991, and on Midway Island from 1988 through 1991. After 5 to 8 yrs of testing on Midway Island and 7 yrs on the U.S. mainland, sand barriers varied in their effectiveness. On Midway Island, sand barriers placed under concrete slabs remained 100% effective for 5 yrs against *C. formosanus,* but declined to 70% effectiveness within 8 yrs. In studies on the U.S. mainland, effectiveness of 5.1- and 10.2-cm-thick barriers ranged from 0 to 70% and 30 to 90%, respectively. After 5 yrs, 15.2-cm-thick sand barriers were 80 to 100% effective in Arizona, Florida, and South Carolina, but only 50% effective in Mississippi. Control failures using native soils in lieu of sand particles reached 100% within 5 yrs (Kard 1996).

Termite-resistant structural components. Termite-resistant structural components are an important part of a IPM program to protect wooden structures. Metal and borate salts for wood treatments, new wood preservative treatment methods, naturally resistant woods, termite-resistant styrofoam insulation, rubberized insecticidal waterproof foundation coatings, and wiring coverings that are termite resistant are being developed and tested. Data from tests with insecticide-containing building components may be required as part of a U.S. Environmental Protection Agency (USEPA) registration package.

Metal termite shields are sheet-metal barriers that are used as a cap on the top of foundations and stem walls, piers, pipes, and other structural components to stop termites from clandestinely entering a structure. These shields force subterranean termites to build their mud foraging tubes where they can be seen. Shields work well for new construction but do not lend themselves to post-construction installations. If foundation walls are masonry blocks, bricks, tile, stone, or other material with potential entry points, they should be capped with a continuous barrier of high-grade mortar or concrete, and then capped with a continuous termite shield that extends across the entire width of the foundation outward 5 to 7 cm. Proper installation with no gaps for termites to by-pass the shield is essential if these barriers are to be effective.

Use of Termi-Mesh stainless steel screening is increasing in the U.S. with offices located on Oahu, HI, and in Austin, TX, and Altamont Springs, FL. More than 200 structures have been built in the Hawaiian Islands with stainless steel mesh preconstruction installations (Kard 1996, 2001c). Many houses in Orlando, FL, are marketed as Termi-Mesh houses and do not receive a preconstruction termiticide application. Technicians require training on proper installation techniques, and comprehensive, detailed training manuals are provided to trainees.

Steel frame housing and metal buildings are available from several manufacturers (Heritage Building Systems®, N. Little Rock, AR; Steelbuildings.com, Inc., N. Little Rock, AR). These structures provide strength and durability, while the framing, and in some cases walls, are metal and thus not damaged by termites. Other builders use concrete block construction for exterior and load-bearing walls.

Building materials companies offer building components that allow access to formerly inaccessible areas of a structure. These components are made of plastic or vinyl materials resistant to termites, and include access panels, crawlspace doors, synthetic removable baseboards, drill hole covers, and crawl space exterior and interior doors (Successful Builder, Inc., Waukesha, WI). A few builders place reticulation systems composed of a grid of plastic pipes or neoprene drip hoses placed around the inside and outside foundation perimeter as well as around service penetrations under a concrete slab. Termiticide can be introduced into these systems as needed for remedial applications without the need to drill through concrete floors or walls. However, these systems may require approval by state regulatory agencies.

Much interest has been generated concerning commercial vapor barriers that can double as an insecticidal barrier to subterranean termites. Currently, three insecticide-impregnated termite-resistant vapor barriers are undergoing field tests in the U.S. and abroad, but results are not yet available. Tests were initiated by the author from 1997 through 1999 when employed by the USDA Forest Service, and Forest Service researchers continue to monitor their progress. Trade names of these barriers are: Kordon TMB® (Bayer Environmental Science, East Hawthorne, Victoria, Australia), Termifilm® (Cecil Co., Chasse-sur-Rhone, France), and Impasse® Termite System (Syngenta AG Co., Inc., Greensboro, NC). These barriers have been placed in the standard concrete slab configuration, as well as wrapped around the bottom half of standard construction concrete blocks in the same manner as the stainless steel mesh tests. After 2 to 4 yrs in Forest Service field tests, these three barriers remain resistant to penetration by subterranean termites. Forest Service scientists should provide results after 5 yrs in testing. Of these three barriers, Impasse will first reach the U.S. market as it was registered by the USEPA in 2002 (Dorsch 2002).

Conducive conditions and sanitation. Termites require moisture, food, harborage, and appropriate temperatures for survival and proliferation. Preventing conditions that are conducive to termite success remains an important problem in termite IPM. The most significant of these conditions is the accumulation of waste wood and paper debris left behind in soil under and around wooden structures during the construction process. Wooden form boards and grade stakes that are not removed during construction also provide a ready source of nutrition for foraging termites. If these waste materials are not removed, the probability of termite infestation increases (Ebeling 1975, Bennett et al. 1988).

Additional conducive conditions that must be corrected include poor drainage around structures that allow build-up of moisture, water leaks within structures, wooden components, siding, or rigid foam insulation in contact with soil, and rain gutter downspouts that do not direct water away from the structure. Poor ventilation in crawl spaces or attics, planter bed mulches placed against the exterior walls, wooden steps or deck piers in direct contact with soil, garden timbers and planter bed wooden timbers with inadequate or no chemical preservative treatments, and fire wood stacked against or in close proximity to structures also create conditions favorable for termites (Edwards and Mill 1986, Bennett et al. 1988, Ware 1988, Mallis 1997, Kramer 1998).

Extreme temperature and asphyxiant gases. Above-ground infestations inside structures require special attention. Raising the internal temperature of a structure including wall voids, inside cabinets and drawers, and inside closets, to 54°C or higher will kill many arthropod pests including subterranean termites that are inside a structure. The house is sealed from heat leakage by tarps placed around the house and heating continues for several hours. Heat sensitive items such as candles, paintings, photograph albums, and similar items should be removed from the structure (Ebeling 1975, 1994, Forbes and Ebeling 1987, Rambo 1995, Goddard 2001).

Liquid nitrogen pumped into termite-infested wall voids or other infested areas will kill many termites if the application is correctly placed. Gaseous nitrogen or carbon dioxide in high concentrations will also kill termites. Termite-infested areas must be cooled to well below freezing to ensure high mortality (Rust and Kennedy 1992, Delate et al. 1995, Rust et al. 1996, Rust and Rierson 1997, Woodrow and Grace 1997).

Biological control. *Metarrhizium anisopliae* Metschnikoff (Sorokin), an entomopathogenic fungus commercially formulated as a powder (Bio-Blast®, EcoScience Corp., East Brunswick, NJ), is mixed with water for above-ground applications to galleries for direct contact with termites. Termites that contact a lethal dose of the fungus are killed after a few days (Bell 1974). Termites may spread fungal infective particles to other locations during their foraging activities, thus infecting other termites. Bio-Blast is safe to mammals and is especially useful in sensitive situations such as convalescent homes and hospitals where the use of standard insecticides may be prohibited, or where clients prefer alternatives to insecticides. Laboratory and field efficacy data are available for this fungus (Quarles 1993, 1995, 1997).

Soil-applied termiticides. Currently, termiticide treatment to soil is the most commonly used method for controlling subterranean termites in the U.S., and several termiticides are registered by the USEPA for use under and around buildings (Kofoid and Williams 1934, Johnston et al. 1971, Smith et al. 1972, Mauldin et al. 1987, Kard 2000). Several different trade names contain the same active ingredient, and about 15 different labels are actively marketed.

Chlorinated hydrocarbon, organophosphate (OP), and pyrethroid (PR) termiticides have been employed as treatments to soil, often providing 10 to 20 or more years of termite management (Brown et al. 1934, Beal 1986, Kard et al. 1989). One OP, chlorpyrifos, and several PRs are available, and two nonrepellent, delayed-action termiticides, Premise, and Termidor® (fipronil; BASF), are widely used. A third delayed-action termiticide, Phantom® (chlorfenapyr; BASF), entered the U.S. market in 2002.

In standard ground-board and concrete-slab tests in the U.S., termiticides provided varying years of subterranean termite management depending on rates applied to the soil and test site location (Kard 2001a). However, the dynamic nature of the pest control industry in the U.S. necessitates evaluation of potentially successful new insecticides and control methods to identify the most effective new compounds for management of subterranean termites.

There are two main categories of soil applied termiticides: (1) rapid-acting contact-toxic or repellent, and (2) nonrepellent, delayed-action toxicants. The active ingredients in registered termiticides have all undergone at least 5 yrs of field tests conducted by the USDA Forest Service as well as laboratory and field evaluations conducted by university researchers and manufacturer's research teams. Experimental use permit (EUP) structures across the U.S. have also received termiticide applications to validate efficacy, especially for the nonrepellent termiticides Premise, Termidor, and Phantom.

Termiticides degrade and lose effectiveness in soil and, after several years, retreatments usually become necessary as termites penetrate soil that has lost most of a termiticide. A primary factor in the success of termiticides is the necessity of creating a continuous, thoroughly treated barrier around and under a structure during construction. For post-construction applications, a continuous barrier around a structure, usually both outside and inside the foundation perimeter is important for success in using termiticides as subterranean termites are adept at finding breaches in applications to reach a structure. High-risk areas such as bath traps and utility service penetrations should also receive applications. Studies to determine the distribution and residues of termiticides in soil over time have been conducted (Lee and Wood 1971, Khoo and Sherman 1979) and additional studies continue to be evaluated (Kard and McDaniel 1993, McDaniel and Kard 1994). New termiticides and formulations, and new materials and application methods are currently in use or will become available within the next few years for termite control.

Nonrepellent termiticides applied to soil do not appear to disrupt termite foraging in the treated soil zone. This lack of immediate effect against termites allows extended foraging activities, resulting in a longer period of termite exposure to a toxicant as they tunnel through the treated soil. The delayed action of the toxicant provides extended time for termites that tunneled in the treated soil to transfer the toxicant to nest mates through trophallaxis including mutual grooming. These termiticides may be more forgiving of gaps in applications as the termites are not avoiding treated soil to find breaks in the treatment.

The question homeowners often ask is, "What termiticide or bait is the best and the one I should use?" The best termiticide or bait is the one that the PMP has had the most success with in the location and conditions where they will be used. The experience and knowledge of the PMP must be trusted as an important part of the IPM decision-making process.

Field Evaluation Methods

This paper has, heretofore, focused on several termite management technologies and tactics currently available or under development. Methods for evaluating termiticides and stainless steel mesh technology will now be described. These methods were developed or modified by me or my predecessors when employed by the USDA Forest Service. These or similar methods are routinely used by the Forest Service as well as both university and pest control industry researchers.

Rapid-acting contact toxic or repellent termiticides applied to the soil surface. Forest Service researchers have employed standard field testing methods for several decades that have been widely accepted and used by the research community (Beal 1986, Kard et al. 1989, Kard 2000). For most studies, a test site is established that contains 10 blocks of land, each 10.7 by 10.7 m, with each block subdivided into 49 plots, measuring 1.5 by 1.5 m each. Each termiticide treatment is replicated once in each block (one treatment per plot) in a randomized complete block design. Termiticides are evaluated using both ground-board and concrete-slab methods (Mauldin et al. 1987, Beal et al. 1994). Aqueous dilutions of termiticide are applied to the soil at several concentrations of active ingredient, usually ranging from 0.00% water-only controls to 1.00% (w/w), at label rate pre-construction volumes. Each block contains at least one concrete-slab and one ground-board treatment of each concentration, for a minimum of 10 replicates of each treatment in each test site. The ability of *Reticulitermes* sp., *H. aureus,* or other destructive subterranean termite species to penetrate termiticide-treated soil and damage pine blocks or boards is evaluated for at least 5 yrs. Decayed blocks and boards are replaced during annual evaluations.

Concrete-slab method. The concrete-slab method simulates a poured concrete foundation. To establish a test plot, leaves and debris are removed to expose soil in a square area 61 cm on a side. A square wooden frame (53-cm inside dimensions) consisting of four 56 × 2.5 × 2.5-cm-rectangular fir or spruce softwood strips is placed in the center of the cleared area, and a triangular trench 2.5 cm deep and 2.5 cm wide at the top is dug around the inside of and adjacent to the frame (hypotenuse sloped downward from inside toward outside).

A square galvanized steel frame with 0.5 cm thick walls, 43 cm on a side (inside dimension) by 10 cm high is then centered within the wooden frame (steel and wooden frames sides are parallel), and the termiticide is applied evenly to the soil surface within the metal frame. The metal frame is removed and a square plastic sheet vapor barrier 0.15 mm thick and 53 cm on a side is placed over the treated area. A 20 cm tall PVC pipe with a 10 cm inside diameter is placed upright on the vapor barrier in the center of the treated area, and concrete is poured over the vapor barrier until it reaches the top of the wooden frame. The concrete is finished with a trowel, resulting in a smooth-surfaced slab.

After the concrete hardens, the vapor barrier at the bottom of the PVC pipe is cut out to expose treated soil. Care is taken not to disturb the underlying treated soil when removing the circular piece of vapor barrier. A 5 × 8 × 10 cm pine (*Pinus* sp.) sapwood block is placed inside the pipe and directly on the treated soil. The tube is capped to reduce loss of moisture and to preclude rain and sunlight from affecting the termiticide.

Ground-board method. The ground-board method is similar to the concrete-slab method except that no concrete slab or vapor barrier is used. A 2.5 × 15.2 × 15.2-cm pine sapwood board is placed on the termiticide-treated soil and weighted down with a brick. The treated area remains exposed to weathering.

Non-repellent, delayed-action termiticides applied to soil. When evaluating non-repellent, delayed-toxic-action termiticides like Premise, Termidor, and Phantom, standard side-by-side treated plots are inappropriate due to possible overlapping effects of a higher concentration of termiticide on a lower concentration of the same termiticide with the potential for false-positive readings. Thus, new field methods were developed by the author to reduce the possibility of overlapping effects (Kard 1998) as described next.

Premise was applied in Forest Service field test sites in 1992, using standard concrete-slab and ground-board test configurations, except each concentration was installed in its own separated 4 × 5 grid of 20 plots, with each individual plot measuring 1.5 × 1.5 m. Ten Premise-treated plots were alternated with a water-only control plots, resulting in 10 Premise treatments and 10 water-only treatments within each grid. Each grid of 20 plots was separated by 15.0 m to reduce possible overlapping effects on termites of one termiticide concentration on another plot with a different concentration.

Unlike standard field research plots that are removed from a test when penetrated by termites, Premise plots that sustained termite penetration and attack to wood received fresh wood and remained in the test to evaluate changes in termite activity over time. Severity of damage to wood attacked by termites was rated yearly using the American Society for Testing and Materials numerical grading system: 10 =

sound, no attack by termites; 9 = trace of attack; 7 = moderate attack; 4 = heavy attack; 0 = failure from termites (ASTM 1999).

Initial fipronil field tests were installed in 1994 using a 80% AI water dispersible granule (WG) formulation in a standard 490-plot grid in four test sites (Arizona, Florida, Mississippi, and South Carolina). Other formulations were applied on later dates and results were reported by Wagner et al. (2002). Concrete-slab and ground-board test configurations were used (Kard 2000). WG treatment concentrations ranged from 0.00% water-only controls to 1.00% under concrete slabs and 0.25 to 1.00% under ground boards, with 10 replicates of each concentration. Additional WG concrete-slab and ground-board treatments were installed in a standard grid in 1996 at different concentrations than installed in 1994. Thus, 1994 and 1996 Termidor WG plots were not grouped and separated by concentration as was done in the Premise tests, and several different concentrations were located in the same plot grid.

Because termite foraging decreased over time throughout the standard 490-plot grid, Termidor WG was re-applied by individual concentration in separated plot grids at all four test sites during 1998. Each concentration grid consisted of 12 plots, ten treated at one specified Termidor percent concentration and two with water-only treatments randomly placed within the 12-plot grid. Separated water-only, 12-plot grids also were installed. The two water-only plots within a 12-plot grid were used to evaluate changes in termite foraging. The Forest Service is evaluating these Termidor tests as well as microemulsion, microencapsulated, and suspension concentrate formulations, and should publish 5-yr results as they become available.

Stainless steel mesh. In Australia, stainless steel mesh has been placed under many new homes and commercial buildings as a pre-construction barrier installation. Post-construction applications have also been developed. The application of stainless steel mesh under concrete floors and inside cavity walls is claimed to have a useful life of several decades (Hargreaves and Rolfe 1983, Lenz and Runko 1993).

In Forest Service field tests, concrete-block, concrete-slab, and mesh-sleeve test configurations were placed in Florida, Arizona, Mississippi, and South Carolina. These three test configurations, as designed by Kard (1996, 2000, 2001c), represent crawl-space and concrete-slab construction, and in-ground wooden post or pole base protection, respectively. Each configuration was replicated 20 times in each test site, resulting in 80 replicates each. Twenty control plots of each configuration without stainless steel mesh were also installed.

The concrete-block method consists of a square 38 × 38 cm × 20 cm tall concrete building block that is wrapped underneath one open side and halfway up around its four walls with stainless steel mesh. The block is placed horizontally on the soil, mesh side down, and capped with a square Plexiglas® (Atofina Chemicals, Philadelphia, PA) lid. Two pine sapwood blocks are placed inside the concrete block and on top of the mesh. Additionally, before placing the concrete block on the soil, a 18 cm tall × 10 cm diam PVC pipe is vertically inserted from the bottom through six precisely cut 10.0 cm-long, equi-angled, overlapping slits in the center of the mesh to a distance of 16 cm. The mesh fits tightly around the outside of the pipe, and the open pipe bottom is inserted 2 cm deep into the soil. The mesh is tightly sealed around the PVC pipe with a circular stainless-steel hose clamp. A pine sapwood block is placed inside the pipe and in contact with the soil, and the pipe is capped. Two additional pine sapwood blocks are placed inside the concrete building block and on top of the stainless steel mesh.

For the concrete-slab test, a 61 × 61 cm square piece of mesh is placed on the soil and covered with standard 0.15-mm-thick polyethylene vapor barrier. A PVC pipe, 18 cm tall × 10 cm diam, is held vertically on top of the vapor barrier and a 53 × 53 cm square concrete slab, approximately 5 cm thick, is poured over the vapor barrier and around the pipe. The vapor barrier has a pre-cut, 10 cm diam hole in its center that is located directly under the PVC pipe opening. After the concrete hardens, a pine sapwood block is placed inside the PVC pipe and on top of the exposed stainless steel mesh, and the pipe is capped.

In the mesh-sleeve method a 5 × 10 cm cross-section × 46 cm-long pine board has a sleeve of stainless steel mesh wrapped around one end and 38 cm up its length. The "sleeved" end is inserted vertically into termite-infested soil to a depth of 23 cm (Kard 2001c).

Analyses and Results

Plots were arranged in a randomized complete block design or completely random design. Results of termiticide and stainless steel mesh tests were evaluated by ANOVA using Categorical Analysis (PROC GLM) and separated by LSMEANS, $P \leq 0.05$ (Steel and Torrie 1980, SAS Institute 2000).

Rapid-acting contact toxic or repellent termiticides provided varying years of subterranean termite control depending on rates applied to the soil and test site location used for these evaluations. Mean (±SEM) years of 100% control of termites across four Forest Service test sites provided by currently marketed termiticides are provided in Table 1. For example, when averaging results from all four test sites, 1.0% fenvalerate applied to soil in 1978 provided 100% control of subterranean termites for 8.5 ± 1.5 yrs under concrete slabs and 5.3 ± 0.8 yrs under ground boards. Bifenthrin applied at 0.062% AI under concrete slabs provided 11.3 ± 1.7 yrs of 100% control, while water-only control applications lasted 1 yr or less before termites penetrated the soil to attack wooden blocks and boards.

After 6 yrs in concrete-slab and ground-board field plots, fipronil remained 100% effective against penetration by subterranean termites. Wagner et al. (2002) show 7 yrs of 100% efficacy, the duration of this continuing test through 2001. After 4 yrs, additional concentrations of fipronil applied in 1996 also remained 100% effective (Table 2). Notably, termite attack on wood in water-only control plots did not increase to 100% as would normally occur. Instead, attack on wood in control plots decreased during the first 5 yrs, but increased in Florida and South Carolina during the sixth test year (Table 3).

The yearly mean ASTM damage rating to wood in Premise-treated concrete-slab plots during the first 5 yrs of testing was 9.1 (trace of attack) or less severe (Tables 4, 5). However, there were some cases at the Mississippi site where termites that penetrated Premise-treated soil under concrete slabs caused more severe damage to wood than an ASTM rating of 9.0 (Kard 1998). In concrete-slab plots in Arizona, Florida, and South Carolina, Premise treatments at label rates to soil prevented termite damage to wood for 5 to 9 yrs (Wagner et al. 2002).

It is important to compare termite penetrations through treated plots with the severity of damage to wood. ASTM damage ratings provided in Tables 4 and 5 are means for wood in 10 concrete-slab plots, including both nonpenetrated plots (sound wood, no damage) and penetrated plots (wood contacted). Thus, the ASTM 10.0 ratings for plots that received no penetration, plus penetrated plots that sustained no, trace, moderate, or heavy ASTM damage ratings are included in these means.

Detailed 3-yr and 5-yr Premise field test data have been published by Kard (1998, 2000). Limited 9-yr data were published by Wagner et al. (2002). Premise has been

Table 1. Mean (±SEM) number of years that termiticide treatments to soil remained 100% effective in stopping penetration by indigenous subterranean termites in concrete-slab and ground-board tests in four field test sites, 1971 through 2000*

	Test method and mean number of yrs ± SEM**			
Termiticide and %AI	Concrete slab	Ground board	CS control	GB control
Chlorpyrifos 0.50 (Dursban) (1971)†	5.3 ± 1.0bc	3.5 ± 0.9ab		
1.00	9.5 ± 1.3cd	5.3 ± 1.4bc	1.0 ± 0.0a	1.0 ± 0.0a
Fenvalerate 0.50 (Tribute) (1978)	6.5 ± 2.0bc	NT‡		
1.00	8.5 ± 1.5bcd	5.3 ± 0.8bc	1.3 ± 0.3a	1.0 ± 0.0a
Permethrin 0.50 (Dragnet) (1978)	6.8 ± 2.1bc	NT		
1.00	11.3 ± 2.4d	4.5 ± 1.9ab	1.3 ± 0.3a	1.0 ± 0.0a
Permethrin 0.50 (Torpedo) (1980)	5.5 ± 2.1bc	2.5 ± 0.9ab		
1.00	11.8 ± 4.2d	4.0 ± 1.6ab	1.0 ± 0.0a	1.0 ± 0.0a
Cypermethrin 0.25 (Demon) (1982)	5.5 ± 1.8bc	NT		
0.50	7.0 ± 1.8bc	NT	1.0 ± 0.0a	1.0 ± 0.0a
1.00	8.5 ± 1.3bcd	5.0 ± 0.0b		
Bifenthrin§ 0.062 (Biflex) (1986)	11.3 ± 1.7d	NT		
0.125	8.8 ± 2.5cd	NT	1.0 ± 0.0a	1.0 ± 0.0a
0.50	12.0 ± 2.0d	11.0 ± 1.3d		

* Test sites are located in Arizona, Florida, Mississippi, and South Carolina.
** Means followed by the same letter within a column or row are not significantly different ($P \leq 0.05$, LSMeans). Each treated plot is replicated 10 times in each location.
† Year test initiated.
‡ NT = not tested at this percent AI.
§ After 14 yrs, all three bifenthrin AI concentrations have no failures in some sites, thus the mean years of effectiveness may increase following later readings.

reported successful in hundreds-of-thousands of applications to homes across the U.S. (Potter and Hillery 2000, Bayer Environ. Sci. 2001, Moreland 2002b).

When interpreting field evaluations with nonrepellent termiticides, penetration by termites through treated soil to reach wood is expected due to inherent delayed toxicity. Termites tunneling through a trench treated-zone around a structure would receive a longer exposure to a termiticide than they receive in the small 0.19 m^2 surface-treated plots in Forest Service field tests. This longer exposure could lead to improved control when evaluating EUP structures compared with small-plot field tests.

Stainless steel mesh. After 7 yrs of testing in Forest Service field tests, stainless steel mesh remained 100% successful as a barrier to native subterranean termites in all test configurations. Termites did not penetrate through the mesh, while non-protected wood in control plots was severely damaged or destroyed (Table 6). The mesh showed no apparent corrosion or physical damage (Kard 2001c). Forest Service field tests should continue for many years.

Professional Publications

Comprehensive texts are available to PMPs interested in general pest control, including subterranean termites (Ebeling 1975, Bennett et al. 1988, Ware 1988, Mallis

Table 2. Means (±SEM) number of years that fipronil 80 WG (Termidor® 80% AI water dispersible granule) treatments to soil remained 100% effective in stopping penetration by indigenous subterranean termites in four field test sites, 1994 through 2000*

		Mean number of yrs with no penetrations ± SEM**			
%AI	Test method	AZ	FL	MS	SC
0.0625	CS (1994)†	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a
0.125	CS	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a
0.25	CS	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a
0.50	CS	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a
1.00	CS	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a
0.25	GB	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a
0.50	GB	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a
1.00	GB	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a	6.0 ± 0.0a
0.00	CS control	4.8 ± 1.2b	2.0 ± 0.8d	4.8 ± 1.2b	3.5 ± 1.2c
0.00	GB control	4.0 ± 1.3bc	3.3 ± 0.7c	1.7 ± 1.2d	3.6 ± 1.1c
0.03125	CS (1996)†	4.0 ± 0.0x	4.0 ± 0.0x	4.0 ± 0.0x	4.0 ± 0.0x
0.0625	GB	4.0 ± 0.0x	4.0 ± 0.0x	4.0 ± 0.0x	4.0 ± 0.0x
0.125	GB	4.0 ± 0.0x	4.0 ± 0.0x	4.0 ± 0.0x	4.0 ± 0.0x
0.00	CS control	3.2 ± 0.8xy	1.6 ± 0.8z	3.2 ± 0.8xy	2.8 ± 0.7y
0.00	GB control	2.8 ± 0.8y	2.3 ± 0.7yz	1.3 ± 0.7z	2.9 ± 0.8y
Non-treated Control Plots‡		Cumulative percentage wooden blocks and boards damaged in non-treated plots during 6 yrs			
0.00	CS	20	80	20	40
0.00	GB	40	50	80	60

* Test sites are located in Arizona, Florida, Mississippi, and South Carolina.

** Means followed by the same letter within a column or row are not significantly different ($P \leq 0.05$, LSMeans); 1994 (a, b, c) and 1996 (x, y, z) data are not being compared in this table, and should be read separately.

† Year test initiated; additional treatments installed in 1996.
GB = ground board; CS = concrete slab.

‡ Damage percentages are total cumulative penetrated plots over 6 yrs.

Table 3. Changes in termite attack on wood in control plots treated with water only and randomly installed within field plot grids containing fipronil 80 WG (Termidor® 80% AI water dispersible granule) treatments to soil in four field sites, 1994 through 2000

%AI and test method	Non-cumulative yearly percent attack on wooden blocks and boards*																							
	AZ						FL						MS						SC					
	95	96	97	98	99	00	95	96	97	98	99	00	95	96	97	98	99	00	95	96	97	98	99	00
0.00 CS	20	10	10	10	20	10	30	30	10	10	0	30	20	10	0	0	0	0	30	0	0	0	0	10
0.00 GB	0	40	0	0	0	0	20	50	0	10	0	0	50	10	20	10	0	0	20	10	0	0	0	30

* Attack on wood in control plots declined over time during the first 5 yrs, but increased in Florida (CS) and South Carolina (GB & CS) during the 6th test year. GB = ground board; CS = concrete slab.

Table 4. Mean (±SEM) damage to wood in Premise-treated concrete-slab plots during the first 5 yrs of field testing*

%AI†	Method‡	Mean ASTM damage ratings over 5 yrs (Non-cumulative) ± SEM**		
		1993 through 1997		
		AZ	FL	SC
0.05	CS	10.0 ± 0.0a§	10.0 ± 0.0a	10.0 ± 0.0a
0.10	CS	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a
0.15	CS	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a
0.20	CS	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a
0.25	CS	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a
0.30	CS	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a
0.00 control	CS	8.6 ± 0.2b	5.3 ± 0.5c	9.1 ± 0.3b

* Test sites are located in Arizona, Florida, Mississippi, and South Carolina.

** Means followed by the same letter within a column or row are not significantly different ($P \leq 0.05$, LSMeans). Each plot was replicated 10 times in each location.

† AI = the active ingredient concentration in the termiticide dilution applied to the soil.

‡ CS = Concrete slab test method.

§ ASTM damage ratings: 10 = sound; 9 = trace of attack; 7 = moderate attack; 4 = heavy attack; 0 = failure by termite attack.

1997, Kramer 1998). Also, there are two exceptional monthly publications that provide a continuous flow of relevant and current commentary and useful information. These are Pest Control (Advanstar Communications, Inc., Cleveland, OH), and Pest Control Technology (GIE Media, Inc., Cleveland, OH). Both publications stay up-to-date and have knowledgeable contributors in each edition. They also include timely research articles on a range of pests including termites and ants, and contain numerous product advertisements of interest to PMPs.

These two publications include dates of events and meetings for the upcoming year with lead-ins and wrap-ups for many important conferences. The benefit of these two informative publications to PMPs is enormous, and they should be regularly read by members of every pest control company. Pest Control's RedBook 2002 issue provides comprehensive information including hundreds of contacts and addresses for pest management products (Pest Control 2002).

Future of Termite IPM

New termiticide delivery techniques, and sand particle barriers such as Granite-Guard™ non-toxic termite barrier (Granitgard PTY Ltd., Cohuna, Victoria, Australia) and Basaltic Termite Barrier™ (Ameron Hawaii, Inc., Honolulu, HI), are being utilized. Research emphasis concentrates on identifying environmentally acceptable, effective termite management methods and materials, to include new chemical termiticides and baits in addition to those presently registered for subterranean termite control, and to investigate new techniques, new formulations, and mechanical-physical barrier

Table 5. Mean (±SEM) damage to wood in Premise-treated concrete-slab plots during the first 5 yrs of field testing in Mississippi

		Mean ASTM damage ratings each yr (Non-cumulative) ± SEM*				
		MS				
%AI**	Method†	93	94	95	96	97
0.05	CS	10.0 ± 0.0a‡	10.0 ± 0.0a	9.3 ± 0.4a	9.3 ± 0.6a	9.1 ± 0.6a
0.10	CS	10.0 ± 0.0a	10.0 ± 0.0a	9.9 ± 0.1a	10.0 ± 0.0a	9.2 ± 0.6a
0.15	CS	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a	9.9 ± 0.1a	9.1 ± 0.5a
0.20	CS	10.0 ± 0.0a	10.0 ± 0.0a	9.4 ± 0.6a	10.0 ± 0.0a	9.7 ± 0.3a
0.25	CS	10.0 ± 0.0a	10.0 ± 0.0a	9.4 ± 0.4a	9.7 ± 0.3a	9.7 ± 0.3a
0.30	CS	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a	10.0 ± 0.0a
0.00 control	CS	6.2 ± 0.9b	4.5 ± 0.7c	6.0 ± 0.7b	3.2 ± 0.5d	3.2 ± 0.5d

* Means followed by the same letter within a column or row are not significantly different ($P \leq 0.05$, LSMeans). Each plot was replicated 10 times.

** AI = the active ingredient concentration in the termiticide dilution applied to the soil.

† CS = Concrete slab test method.

‡ ASTM damage ratings: 10 = sound; 9 = trace of attack; 7 = moderate attack; 4 = heavy attack; 0 = failure by termite attack.

Note. Damage ratings are means for wood in all 10 plots for each treatment, and include wood with no damage (ASTM = 10). Therefore, wood in penetrated plots sustained either no, trace, moderate, or heavy damage.

materials and methods. Determining the distribution and loss of termiticides and bait active ingredients in soil are also being studied.

Additional research focuses on basic ecological studies and termite foraging, laboratory and field evaluation of insecticides and insect growth regulators, national and international studies to determine the efficacy of new termiticide formulations and non-chemical physical barriers, and efforts to determine proper treatment methods and efficacy of borate formulations and other preservative chemicals to protect wood from termites (Grace 1991b, Thorne and Forschler 1998, Kard 1998, 2001c).

These new strategies and methods represent a significant evolution from and addition to traditional insecticide treatments to soil currently used to manage subterranean termites. Applying IPM concepts and new innovative termite management technologies could lead to a reduction in the amount of termiticides placed in the soil and improve the effectiveness of PMPs in reducing termite infestation of and damage to structures.

IPM of termites is a complex decision-making process that starts with assessment of the problem coupled with inspections to evaluate the extent and nature of an infestation. To manage an infestation, a combination of appropriate strategies and tactics is decided upon and implemented in a consistent and safe manner, and cyclic evaluations are conducted and continued as needed.

Acknowledgments

This paper represents a brief compendium of many years of study by the numerous researchers whose works are included in the References Cited. Information on termiticides and stainless steel mesh along with the data tables are derived from non-copyrighted papers and

Table 6. Mean (±SEM) number of years that Stainless Steel Mesh (Termi-Mesh®) barrier remained 100% effective against penetration by subterranean termites in four field test sites, 1993 through 2000*

Field test method (1993)**	AZ	FL	MS	SC
SS mesh plots	Mean number yrs with no penetrations ± SEM†			
Concrete Block	7.0 ± 0.0a	7.0 ± 0.0a	7.0 ± 0.0a	7.0 ± 0.0a
Concrete Slab	7.0 ± 0.0a	7.0 ± 0.0a	7.0 ± 0.0a	7.0 ± 0.0a
Mesh Sleeve	7.0 ± 0.0a	7.0 ± 0.0a	7.0 ± 0.0a	7.0 ± 0.0a
Non-mesh control plots	Mean number yrs with no penetrations through bare soil ± SEM†			
Concrete Block	2.6 ± 1.3b	0.2 ± 0.2d	0.1 ± 0.1d	0.2 ± 0.2d
Concrete Slab	1.0 ± 0.5c	0.1 ± 0.1d	0.1 ± 0.1d	0.2 ± 0.2d
Mesh Sleeve	1.2 ± 0.8c	0.1 ± 0.1d	0.0 ± 0.0d	0.1 ± 0.2d
Non-mesh control plots	Yrs before first penetration through bare soil by termites			
Concrete Block	≤1.0	≤1.0	≤1.0	≤1.0
Concrete Slab	≤1.0	≤1.0	≤1.0	≤1.0
Mesh Sleeve	≤1.0	≤1.0	≤1.0	≤1.0
Non-mesh control plots	Percentage wooden blocks damaged by termites in ≤3 yrs			
Concrete Block	55	100	100	100
Concrete Slab	95	100	100	100
Mesh Sleeve	95	100	100	100

* Test sites are located in Arizona, Florida, Mississippi, and South Carolina.

** Year test initiated.

† Means followed by the same letter within a column or row are not significanly different ($P \leq 0.05$, LSMeans). Each plot is replicated 20 times in each location.

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Internet Sites

Additional information about companies and products mentioned in this paper is available at the following internet addresses. There are hundreds of additional related company internet sites and links that are too numerous to list and their omission is not intentional. The list is not intended to favor any company, product, or web site over another.

BASF: www.pestcontrolfacts.com
Bayer Environmental Science: www.nobugs.com
BioBlast: www.ecoscience.com
Borescopes: www.gradientlens.com
Dow AgroSciences: www.sentricon.com; www.dowagrosciences.com
Exterra bait: www.ensystex.com
FMC Specialty Products: www.fmc-apgspec.com/pco.htm
Granitgard: www.granitgard.com; www.mawson.com.au/concrete.htm
Impasse: www.syngenta-us.com; www.impasse.com
Kordon TMB: www.kordontmb.com.au
NovaGuard Two-Step: www.novaguard.com
Pest Control: www.PestControlMag.com
Pest Control Technology: www.pctonline.com
Plastic building components: www.successfulbuilders.com
Steel buildings: www.steelbuildings.com; www.heritagebuildings.com
Scout-It-Out, email: greena4@asme.org; atgreen1@aol.com
Sibert Digital Microprobe: www.sibtec.com
Termifilm: www.groupe-fph.fr/distribution
Termite Tracker System: www.deci.com
Termitrac: www.protecusa.net
Termite detection dogs: www.termitedog.com
Termite Detection System: www.termitedetector.com
Thermal Imaging: www.flirthermography.com

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