Criteria for Assessing Efficacy of Stand-Alone Termite Bait Treatments at Structures

by

Barbara L. Thorne[1] and Brian T. Forschler[2]

ABSTRACT

Evaluation methods and criteria used to assess field efficacy of stand alone termite bait programs are described and compared. The four criteria examined are: 1) alate numbers; 2) activity on termiticidal baits; 3) monitors active prior to baiting; 4) post-treatment monitors (placed after termiticidal baiting). The justification, complexities and ambiguities, and interpretation of each criterion are discussed. Even apparent "success" of termite baiting, meaning sustained absence of termites in all four evaluation contexts, should be interpreted with caution and a commitment to continued monitoring for any signs of termite activity. Given current termite detection, inspection, and monitoring techniques, a zero tolerance framework, although conservative, is an appropriately cautious approach to termite control through baiting.

INTRODUCTION

Termite control is a process not an event. The process of termite control involves a rigorous, ongoing inspection program and use of one or more control tactics. Building construction practices, building materials, the termite species present, and soil and climatic conditions are all factors that influence the potential risk associated with termite infestation of structures. Historically, termite control in the United States has been practiced with the objective of excluding termites from a structure. Whether through employment of physical barriers, use of building materials that are unpalatable to termites, construction practices that inhibit termite entry, or use of chemical barriers, the conventional aim has been to prevent infestation by exclusion, with no regard for the impact that such control options have on termite populations. Termite baits are designed with a different approach. The intent of termite bait treatments is to impact populations of these social insects, i.e. to kill termites (Randall & Doody 1934, Beard 1974, Esenther & Beal 1974, Beal & Esenther 1980, French 1991, Su 1991, Traniello & Thorne 1994, Forschler 1998). The connection between killing termites and protecting structures can be tenuous because live

[1]Department of Entomology, University of Maryland, College Park, MD 20742-4454
[2]Department of Entomology, University of Georgia, Athens, GA 30602

termites in a yard will not necessarily infest a house, and termites feeding in a structure may not be directly impacted by reducing the population size of those foraging in the yard.

The premise behind termite baiting is that if populations of termites in the vicinity of a structure are reduced or eliminated, the threat of infestation by that population is also reduced or eliminated (Randall & Doody 1934, Beard 1974, Esenther & Beal 1974, Beal & Esenther 1980, French 1991, Su 1991, Traniello & Thorne 1994, Forschler 1998). A problem arises in scientifically testing this concept because of the cryptic habits and developmentally and socially dynamic life history of subterranean termites. If there are no termites around a structure, there would obviously be no risk of infestation, and in principle, if there are reduced numbers of termites, the threat of infestation is reduced. In practice, however, measuring the efficacy of a termite population management control tactic such as baiting is problematic. For example, subterranean termite population sizes cannot be accurately measured. In this paper we outline the goals of a termite bait control program, discuss the evaluation methods used to assess efficacy of applications according to those goals, and discuss termite baiting in light of models of subterranean termite foraging biology.

GOALS OF A TERMITE BAIT TREATMENT

The goal of termite control is to prevent or remove infestations in structures. The primary goal of a termite bait treatment is to eliminate termites in the structure. The secondary goal of a termite bait treatment is to suppress or eliminate the population(s) of termites in the vicinity of the structure such that the risk of infestation is low, and the structure is hopefully "protected". The long-term goal of termite baits is to detect termites that may resurge within or migrate into the area in and around the structure, alerting the need for subsequent application of pesticidal bait or other treatment options before an infestation is well established. A remedial bait treatment would commence with the first goal; a preventive bait application (or baiting in combination with a spot treatment of liquid termiticide) would begin with the second goal, and both types of treatment would include the long-term goal. An ongoing inspection program is the cornerstone of effective termite control, and must be rigorously maintained.

There are a variety of evaluation methods that can be used to assess efficacy of a termite bait treatment. None are direct, nor is any single one unambiguously compelling because subterranean termites are cryptic, mobile, seasonally active, and reproductively resilient insects that live in spatially diffuse colonies whose population sizes or colony boundaries cannot be accurately measured (Esenther 1980, Forschler 1996, Thorne *et al.* 1996, Evans *et al.* 1998, 1999; Thorne 1998, Haverty *et al.* 1999a, Jenkins *et al.* 1999, Roisin 2000). Therefore the goal of a specific termite control tactic such as a bait application must be clearly defined in order to assess efficacy and to determine the criteria used to claim a "successful" treatment. In this paper we list and review four criteria that can be used to infer efficacy of a termite bait treatment according to the objectives stated above. We also discuss termite baiting protocols and strategies in light of models of subterranean termite foraging biology.

Criteria for inferring the efficacy of a termite bait treatment:

1. Alate numbers:

Expected observation after an effective bait treatment: suppression or elimination of alate flights in and around the structure

Justification: Alates are a conspicuous indicator of termite presence. Residents may relay information on the relative numbers of alates flying within a home to a pest control professional. A sharp reduction or cessation of alates emerging during the flight season following bait treatment may indicate declining vigor or death of local termites.

Complexities and ambiguities: 1. This criterion applies only to structures that have had a history of alate flights, and it can only be assessed during the annual flight season. 2. The observed decline in alate numbers may be due to the bait treatment or it may simply reflect a natural fluctuation in termite reproductive output or flight location.

Interpretation: Elimination of alate flight is a good sign, but an ambiguous assessment of bait efficacy. Conversely, continued alate flights in and around the structure infer a lack of confidence in the bait treatment to that point in time.

2. Activity on termiticidal baits

Expected observation after an effective bait treatment: feeding followed by the sustained absence of termite activity at termiticidal baits. [If baits are developed that kill termites through contact vs ingestion, the expected observation would simply be evidence of termite activity followed by absence of activity.]

Justification: Conspicuous consumption of termiticidal baits demonstrates that foraging termites have discovered and ingested the toxin. Subsequent abandonment of the baits and lack of evidence of additional feeding could suggest absence of termites once active in the vicinity.

Complexities and ambiguities: Lack of activity at pesticidal baits must be interpreted with caution. It may be due to relocation of termite activity, seasonal variation, avoidance or repellancy of the toxic bait, or death only or mainly of individuals foraging at the baits. The colony may remain active elsewhere in the same local area.

Inference: A period of termite activity at one or more termiticidal baits followed by a prolonged cessation of activity at those baits suggests that the toxic baits were effective, ultimately resulting in the decline or elimination of termites in the local area. However, attentive monitoring and inspections should continue because one cannot have complete confidence in this interpretation due to potential repellancy of pesticidal baits and the variable activity of termites.

3. Monitors active prior to baiting

Expected observation after an effective bait treatment: sustained suppression or elimination of termites in monitoring stations or detection devices containing untreated cellulose or at "natural monitors" (such as mud tubes, stumps or a visible structural infestation) that were active in the treatment area preceeding termiticidal baiting.

Justification: Substrates active with termites prior to a bait application serve as a "window" into foraging sites of termites in and around the structure. These may be stations installed and discovered by termites prior to pesticidal baiting, and/or wood or other cellulose sources known to harbor termites before the bait application. If those established foraging sites become inactive after baiting, the absence of termites may be due to an effective bait treatment.

Inference: Elimination of termites in pre-existing feeding sites is reasonably convincing, but the change in activity might be due to movement, seasonal variation, or it may reflect only a temporary reduction of termite numbers. Cessation of activity at more than one pre-existing monitor or detection device is compelling evidence of bait impact, but still carries some degree of uncertainty. Continued termite activity at even one site in the vicinity of the structure provides evidence that a bait application has not yet been fully effective, at least if the ultimate goal is elimination of termites from the local area.

4. Post-treatment monitors (placed after termiticidal baiting)

Expected observation after an effective bait treatment: sustained absence of termites attacking termite detection devices or monitors placed directly in contact with soil in the treatment zone *after* pesticidal baits have apparently accomplished their objective. These termite detection devices should contain a highly palatable or "preferred" substrate to provide a reasonably accurate assessment of termite activity. Therefore, an apparently effective termite bait treatment would be indicated by measurable feeding or activity at termiticidal baits eventually followed by cessation of feeding and lack of termite activity at baits and in other known sites of previous termite activity, including at the highly palatable detection monitors.

Justification: If palatable and preferred termite food sources are placed directly in contact with soil in the general area inhabited by termites prior to the bait treatment, and if none of these hospitably presented monitors shows evidence of termite activity after a reasonable interval of time, it suggests that termites may be absent from the area or significantly reduced in population size. The "reasonable interval of time" depends on season and geographic location, and in our opinion such monitors should remain in place to continue to act as sentries to detect termites in the area.

Little is known regarding the number of foraging sites that are maintained concurrently by a single colony. It may be that single colonies can fragment their foraging attention among a very large number of sites, such that foraging at an installed, non-pesticidal monitor prior to a bait application does not compromise the probability of search, discovery, or recruitment to a subsequently installed termiticidal bait at a different location within the colony's foraging range. However, if subterranean termite colonies of a given size restrict their attention to a limited number of foraging sites, then placing both monitoring stations and termicidal baits in an area concurrently may distract attention from the baits, and thus reduce the colony's consumption of the pesticide and slow or dilute its effects. Monitors or detection devices installed *after* a bait treatment has had a chance to work may allow termites to first focus more of their activity at pesticidal baits, thus raising the probability of success of the treatment. Independent, post-baiting monitors could be installed even if pre-baiting monitoring stations or natural monitors were evaluated. Sustained absence of foraging at post-baiting monitors suggests, as in the case of eliminated termite activity at pre-existing monitors (criterion #3 above), that the bait treatment suppressed or eliminated local termites.

Inference: Sustained absence of any evidence of termite activity at highly palatable, directly accessible post-treatment monitors suggests a reduction or elimination of termites in the baited area, especially if a number of monitors are installed and all remain undiscovered even during seasons in which termites are known to search in that geographic region. The same ambiguities exist as with absence of activity at natural or installed monitors that were active prior to baiting, but the longer the duration of inactivity at untreated, preferred substrate monitors, the higher the confidence in efficacy of the baiting program.

DISCUSSION

Satisfaction of any of the four criteria described above for assessing efficacy of a termiticidal bait treatment is a positive sign. The most compelling suggestion of an effective bait program is sustained absence of termites in all four contexts. A marked reduction in termite numbers or amount of activity at baits, monitors, and detection devices may be evidence of bait impact, but only complete absence of termite activity in all contexts provides the degree of assurance required to assert protection of the structure using currently available assessment technologies. Obviously, even if all signs point to elimination of termites from the area, one must remain alert to signs of colony rebound or immigration into the area. Even if baits appear to eliminate foraging termites from a local area, we have no way to evaluate if they eliminate complete colonies. Subterranean termites are renown for their flexible reproductive options, even when only a very few survivors remain (Snyder 1920, Pickens 1934, Noirot 1985, Watanabe & Noda 1991, Pawson & Gold 1996, Thorne 1998, Roisin 2000). Hence a colony with a dramatically reduced population size could, in principle, recover and rebound to remain a threat to a structure.

The relatively low rate of "hits" at pine stakes or other monitoring substrates may not be, as it is generally interpreted, due to hit-and-miss search or to a lack of preference for the stakes or bait matrices. Rather, it may reflect a more intrinsic aspect of subterranean termite foraging that workers from a single colony exploit a limited number of foraging sites concurrently. There are infrastructure and energy investments in organizing and maintaining foraging loci, including trail construction and maintenance, search, defense, and communication. Because of these unknown components of subterranean termite colony foraging behaviors, the interpretation of a few or even no "hits" at monitors or detection devices remains ambiguous.

Some studies assessing termite bait efficacy have emphasized aspects in addition to presence or absence of alates and foragers in or near the baited area. Vital dyes may be used to associate monitors used by interacting termites (typically considered to belong to the same colony) (Li *et al.* 1976; Lai 1977; Jones 1987, 1990; Su & Scheffrahn 1988a; Grace *et al.* 1989; Su *et al.* 1993; Forschler 1994; Haagsma & Rust 1995; Forschler & Ryder 1996), or genetic markers or hydrocarbon profiles can be used to attempt to delineate colony associations (Reilly 1987, Haverty *et al.* 1999b, Jenkins *et al.* 1999, Thorne *et al.* 1999). Presence of different species of subterranean termites residing in the local area and perhaps moving in and out of monitoring stations can also be of interest (Su & Scheffrahn 1998b, Getty *et al.* 1999, Jenkins *et al.* 1999). This fine scale resolution of number and position of colonies and species is scientifically important to understand the foraging patterns and dynamics of these insects and how bait treatment protocols can best be designed to succeed under the broad range of circumstances that occur when different colonies and species live and move within a single neighborhood. Although these details are interesting and informative in comprehending and addressing the underlying challenges of termite baiting, they are not of consequence to a homeowner or a pest control professional in assessing protection of the structure. Colony and species associations and number need not be included in standard efficacy testing protocols, which can be accomplished with more simplicity and equal rigor by assessing presence or absence of any termites in the baited area, regardless of their origin.

From the point of view of a homeowner seeking to trust a stand-alone bait treatment, discovery of even a single live termite after termiticidal baiting is disconcerting and suggests the need to continue pesticidal baiting and/or to consider other treatment options. This "zero tolerance" action threshold is a conservative but appropriately cautious approach to termite control given the current state of available termite detection/monitoring technology (Forschler & Robinson 1999). Presence of a low number of termites at a natural monitor or inspection port in a yard may not signal substantial risk to a structure, but given the uncertainties involved and the value of homes, practitioners of stand-alone baiting must currently apply a zero tolerance action threshold. [In contrast to when baits are used as a stand alone treatment, the tolerance threshold may be viewed differently if a complete or localized chemical barrier has been applied around a structure with a bait program as a supplementary treatment. In that case, population reduction through baiting would likely reduce the risk of reinfestation, but complete elimination of termites from the area would not be such a high priority. The objectives and standards of a soil drench + bait treatment program are beyond the scope of this paper.]

Many homes have termites in the yard; only a relatively small fraction of those homes become infested if they were properly constructed and are appropriately maintained. Homes that have had an infestation, however, have one or more points of access and vulnerability to termites. Unless the breached areas were structurally sealed or corrected, the structure remains vulnerable to reinfestation. Monitoring should be particularly assiduous in and around such buildings.

The generalities of assessing efficacy of termite bait treatments as described above are more straightforward than details such as how long one must monitor and inspect before claiming success in eliminating all signs of termite activity in an area (prior to periodic, continued inspection for colony rebound or immigration), how many independent monitors (installed or natural) are necessary to convey a confident indication of local termite activity, how the monitors should be placed and spatially distributed, and how large an area should be monitored and found free of termites before a structure is considered "protected".

A completely unambiguous assessment of efficacy of a stand-alone termiticide bait treatment is impossible with today's detection and inspection techniques due to the cryptic habits and flexible life history of subterranean termites. Compelling inferences regarding impact, "success", or failure of a bait treatment can be drawn from the evaluation criteria of alate numbers and activity on termiticidal baits, monitors active prior to baiting, and post-treatment monitors. Apparent "success", meaning sustained absence of termites in all four evaluation contexts, should be interpreted with caution and a commitment to continued monitoring for any signs of termite activity. Stand-alone termiticide baiting is an environmentally attractive concept that, in principle, is cleverly designed to exploit the biology of subterranean termites. Baiting targets termites at their unique food sources and coerces them to assist in their own demise by distributing the pesticide to their colonymates through social behaviors. The promise of termite baiting has been convincingly established; we must now work to expand and refine our understanding of how best to design and implement baits, baiting protocols, and evaluation criteria to ensure success of the technique and/or to learn its limitations. Eventually, the goal of any termite population management/control strategy, such as baiting, will include assessment of population parameters and the risk posed by those termites in the vicinity of a structure. However, with the limited technology available today and the knowledge gaps in our understanding of termite biology, assessment of stand-alone baiting can best be accomplished by simply measuring presence or absence of termites using the four criteria described above and a zero tolerance framework.

REFERENCES

Beal, R.H. & G.R. Esenther. 1980. A new approach to subterranean termite control- the bait block method. Sociobiology 5:171-174.

Beard, R.L. 1974. Termite biology and bait-block method of control. Conn. Agric. Expt. Station Bull. No. 748:1-19.

Esenther, G.R. 1980. Estimating the size of subterranean termite colonies by a release-recapture technique. The International Research Group on Wood Preservation 11th Annual Meeting Proceedings (IRG Document IRG/

WP/1112), 4 pp.

Esenther, G.R. & R.H. Beal. 1974. Attractant-Mirex bait suppresses activity of *Reticulitermes* spp. J. Econ. Entomol. 67:85-88.

Evans, T.A., M. Lenz & P.V. Gleeson. 1998. Testing assumptions of mark-release protocols for estimating population size using Australian mound-building, subterranean termites. Ecol. Entomol. 23:139-159.

Evans, T.A., M. Lenz & P.V. Gleeson. 1999. Estimating population size and forager movement in a tropical subterranean termite (Isoptera: Rhinotermitidae). Environ. Ent. 28:823-830.

Forschler, B.T. 1994. Fluorescent spray paint as a topical marker on subterranean termites (Isoptera: Rhinotermitidae). Sociobiology 24:27-38.

Forschler, B.T. 1996. Baiting *Reticulitermes* (Isoptera: Rhinotermitidae field colonies with abamectin and zinc borate-treated cellulose in Georgia. Sociobiology 28:459-484.

Forschler, B.T. 1998. Subterranean termite biology in relation to prevention and removal of structural infestation. Part II, Research Report on Subterranean Termites, pp. 31-51. National Pest Control Association, Dunn Loring, Virginia.

Forschler, B.T. & W.H. Robinson. 1999. Ants and subterranean termites in the urban environment: The terminology of population control tactics. In: Proceedings of the 3rd International Conference on Urban Pests. Robinson, Rettich and Rambo eds. Graficke zavody Hronov, Czech Republic, 589-595 pp.

Forschler, B.T. & J.C. Ryder, Jr. 1996. Subterranean termite, *Reticulitermes* spp. (Isoptera: Rhinotermitidae), colony response to baiting with hexaflumaron using a prototype commercial termite baiting system. Journal of Entomological Science 31:143-151.

French, J.R.J. 1991. Baits and foraging behavior of Australian species of *Coptotermes*. Sociobiology 19:171-186.

Grace, J.K., A. Abdallay & K.R. Farr. 1989. Eastern subterranean termite (Isoptera: Rhinotermitidae) foraging territories and populations in Toronto. Can. Entomol. 121:551-556.

Getty, G.M., M.I. Haverty, V.R. Lewis & R.J. Sbragia. 1999. Interfacing basic biology of Reticulitermes spp. and the Sentricon termite colony elimination system in northern California, USA. In: Proceedings of the 3rd International Conference on Urban Pests. Robinson, Rettich and Rambo eds. Graficke zavody Hronov, Czech Republic, 601-604 pp.

Haagsma, K.A. & M.K. Rust. 1995. Colony size estimates, foraging trends, and physiological characteristics of the western subterranean termite (Isoptera: Rhinotermitidae). Environ. Entomol. 24:1520-1528.

Haverty, M.I. K.A. Copren, G.M. Getty & V.R. Lewis. 1999a. Size and dispersion of colonies of *Reticulitermes* spp. (Isoptera: Rhinotermitidae) in a wildland and residential location in Northern California. Environ. Entomol. (in press)

Haverty, M.I. K.A. Copren, G.M. Getty & V.R. Lewis. 1999b. Agonistic behavior and cuticular hydrocarbon phenotypes of colonies of *Reticulitermes*

(Isoptera: Rhinotermitidae) from northern California. Ann. Entomol. Soc. Am. 92:269-277.

Jenkins, T.M., C.J. Baste, S. Kresovich & B.T. Forschler. 1999. Mitochondrial gene sequence questions *Reticulitermes* sp. social structure (Isoptera: Rhinotermitidae). Sociobiology 34:161 – 172.

Jones, S.C. 1987. Foraging party and territory size of the desert subterranean termite, *Heterotermes aureus* (Snyder), in a Sonoran Desert grassland. Ph.D. dissertation, University of Arizona, Tucson, AZ.

Jones, S.C. 1990. Delineation of *Heterotermes aureus* (Isoptera: Rhinotermitidae) foraging territories in a Sonoran desert grassland. Environ. Entomol. 19:1047-1054.

Lai, P-Y. 1977. Biology and ecology of the Formosan Subterranean Termite, *Coptotermes formosanus*, and its susceptibility to the entomogenous fungi, *Beauveria bassiana* and *Metarrhizium anisopliae*. Ph.D. dissertation, University of Hawaii, Honolulu.

Li, T., K.S. He, D.X. Gao & Y. Chao. 1976. A preliminary study on the foraging behavior of the termite *Coptotermes formosanus* (Shiraki) by labeling with iodine-131. Acta Entomol. Sinica 19:32-38.

Noirot, C. 1985. Pathways of caste development in the lower termites. In: Caste differentiation in Social Insects. Watson, Okot-Kotber and Noirot eds. pp. 41-57, Pergamon Press, Oxford.

Pawson, B.M. & R.E. Gold. 1996. Caste differentiation and reproductive dynamics of three subterranean termites in the genus *Reticulitermes* (Isoptera: Rhinotermitidae) Sociobiology 28:241-251.

Pickens, A.L. 1934. The biology and economic significance of the western subterranean termite, *Reticulitermes hesperus*. In: Kofoid, C.A. (ed.) *Termites and Termite Control, 2nd Edition.* pp. 157-183, University of California Press, Berkeley.

Randall, M. & T.C. Doody. 1934. Poison dusts. In: Kofoid, C.A. (ed.) *Termites and Termite Control, 2nd Edition.* pp. 463-476, University of California Press, Berkeley.

Reilly, L.M. 1987. Measurements of inbreeding and average relatedness in a termite population. Am. Nat. 130:339-349.

Roisin, Y. 2000. Diversity and evolution of caste patterns. In Termites: Evolution, Sociality, Symbioses, Ecology. T. Abe, D.E. Bignell & M. Higashi, Eds. Kluwer Academic Publishers, Dordrecht, The Netherlands (in press).

Snyder, T.E. 1920. The colonizing reproductive adults of termites. Proc. Entomol. Soc. Wash. 22:109-150.

Su, N.-Y. 1991. Evaluation of bait-toxicants for suppression of subterranean termite populations. Sociobiology 19:211-220.

Su, N.-Y., P.M. Ban & R.H. Scheffrahn. 1993. Foraging populations and territories the eastern subterranean termites (Isoptera: Rhinotermitidae). J. Econ. Entomol. 22:1113-1117.

Su, N-Y. & R.H. Scheffrahn. 1988a. Foraging population and territory of the Formosan and eastern subterranean termite (Isoptera: Rhinotermitidae) in an urban environment. Sociobiology 14:353-359.

Su, N-Y. & R.H. Scheffrahn. 1988b. Intra- and interspecific competition of the Formosan and eastern subterranean termites: evidence from field observations (Isoptera: Rhinotermitidae). Sociobiology 14:157-164.

Thorne, B.L. 1998. Biology of subterranean termites of the genus *Reticulitermes*. Part I, Research Report on Subterranean Termites, pp. 1-30. National Pest Control Association, Dunn Loring, Virginia.

Thorne, B.L., E. Russek-Cohen, B.T. Forschler, N.L. Breisch & J.F.A. Traniello. 1996. Evaluation of mark-release-recapture methods for estimating forager population size of subterranean termites (Isoptera: Rhinotermitidae) colonies. Environ. Entomol. 25:938-951.

Thorne, B.L. & J.F.A. Traniello. 1994. Termite baits in theory and practice. Proceedings, National Conference on Urban Entomology, pp. 28-40.

Thorne, B.L., J.F.A. Traniello, E.S. Adams & M. Bulmer. 1999. Reproductive dynamics and colony structure of subterranean termites of the genus *Reticulitermes* (Isoptera: Rhinotermitidae): a review of the evidence from behavioral, ecological, and genetic studies. Ethology, Ecology, and Evolution 11:149-169.

Watanabe, H. & H. Noda. 1991. Small scale rearing of a subterranean termite, *Reticulitermes speratus* (Isoptera: Rhinotermitidae). Appl. Ent. Zool. 26:416-420.