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ENTOMOLOGY
MAY 21-24**



**EMBASSY SUITES HOTEL
RALEIGH-DURHAM • NC**

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**DISTINGUISHED ACHIEVEMENT AWARD IN URBAN
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**ARNOLD MALLIS MEMORIAL AWARD LECTURE: THE GERMAN
COCKROACH: RE-EMERGENCE OF AN OLD FOE...THAT NEVER
DEPARTED**

Coby Schal

Department of Entomology, North Carolina State University, Raleigh, NC

STUDENT SCHOLARSHIP AWARD PRESENTATIONS

Blowing Rock, Tanglewood, Pinehurst

Moderator

Dan Suiter

University of Georgia

BACHELOR OF SCIENCE AWARD

**SOYBEAN OIL CONSUMPTION IN RED IMPORTED FIRE ANTS,
SOLENOPSIS INVICTA BUREN (HYMENOPTERA: FORMICIDAE)**

Rebecca L. Baillif, Dr. Linda Hooper-Bùi, and Dr. Beverly A. Wiltz
Department of Entomology, Louisiana State University, Baton Rouge, Louisiana

MASTER OF SCIENCE AWARD

**THE RESPONSE OF THE FORMOSAN SUBTERRANEAN TERMITE TO
DIFFERENT BORATE SALTS**

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Although boric acid and borate salts have been used since the 1800s as insecticides (Woods 1994), their mode of action is not well understood. Recent work (Lloyd 1990, Nunez 1995) indicates that effects at the cellular level are more important than mortality of intestinal fauna or the purported desiccant effects that are cited sporadically in the literature. Borate salts, in particular sodium and zinc salts, are popular and effective wood preservatives (Grace 1997), and are used extensively in Hawai'i to protect building materials from attack by both drywood (Kalotermitidae) and subterranean (Rhinotermitidae) termites (Grace 2002). The Formosan subterranean termite *Coptotermes formosanus* Shiraki is the most important pest in the state, and a threat to trees and crops in addition to causing over \$100 million in structural treatment and repair costs.

In the current study, *C. formosanus* workers were collected from field colonies maintained in Honolulu, Hawai'i, and exposed in the laboratory to composite boards containing different borate salt formulations. The treatments included zinc borate (0.88% and 0.18%), disodium octaborate tetrahydrate (DOT) (60/40 and 80/20 zinc borate/DOT formulations), anhydrous boric acid (B_2O_3) (60/40 and 80/20 zinc borate/ B_2O_3 formulations), and an untreated composite board control. Activity and mortality data were recorded over a 4-week period in order to determine whether different salt formulations elicited different responses from the termites. Results to date suggest that the concentration of boron in the wood sample, rather than the associated salt, has a greater impact on termite feeding, and that anhydrous boric acid affects termite activity more rapidly than the other formulations tested. We are continuing to assess the quantities of boron ingested and recovery rates of termites exposed to these and other borate salts.

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PH.D. AWARD THE MECHANISM AND FACTORS AFFECTING HORIZONTAL TRANSFER OF FIPRONIL AMONG WESTERN SUBTERRANEAN TERMITES

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In the last 10 years, research and development have focused on the slow-acting insecticides in which mortality and speed of kill are concentration dependent (Su et al.

1987). Two slow-acting insecticides, fipronil and imidacloprid, have become popular alternatives to the fast-acting and repellent pyrethroids barriers.

Even though fipronil has been widely used as a soil treatment against subterranean termites, little is known about how it kills termites. To determine the insecticidal activity of fipronil, topical and exposure tests on treated sand were conducted. To determine LD₅₀ and LD₉₅ values, topical bioassays were conducted as described in Rust and Saran (2006). At day 7, the LD₅₀ and LD₉₅ were 0.16 ng/termite and 0.75 ng/termite, respectively (Rust and Saran 2006). To determine the effect of the fipronil exposure on termite movement, termites were continuously exposed to 1 ppm (wt:wt) treated sand and at different time intervals (1, 4, and 8 h). Termites were removed and allowed to walk on 10 cm long trails treated with dodecatrienol at 10 fg/cm.

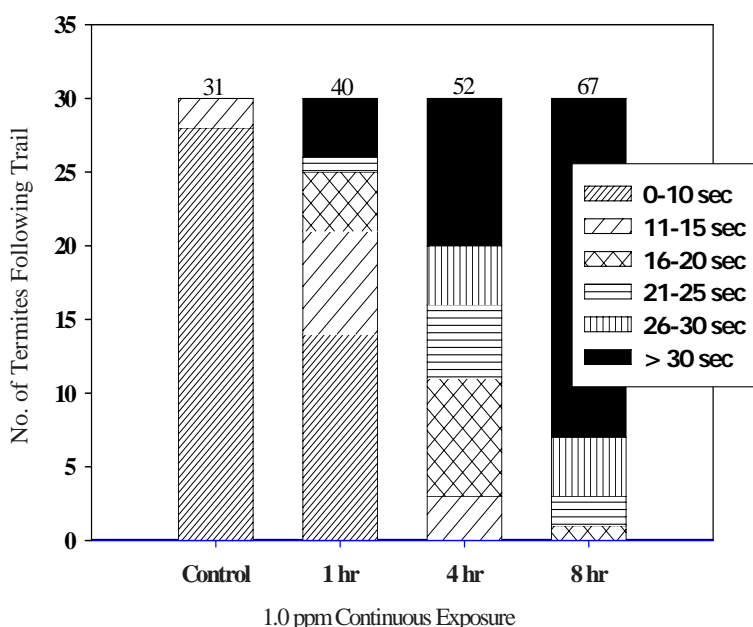


Figure 1. Time (sec) to traverse a 10-cm long trail after a 1, 4 and 8 h exposure to 1 ppm fipronil treated sand (wt: wt). The actual numbers of termites tested to provide 30 complete runs are shown on the top of the stacked bars.

The continuous exposure to fipronil treated sand seriously impaired termites' ability to move and respond to a dodecatrienol trail (Fig. 1). After 1 h exposure, ~50% of the termites were not able to finish the 10-cm trail within 10 sec. None of the termites were able to finish the 10 cm trail within 10 sec after 4 h continuous exposure to fipronil treated sand. After 8 h, 70% of the termites took >30 sec to finish the 10-cm trail. As the time of exposure increased, the number of termites required to finish 30 runs increased dramatically. It took additional 20 termites to finish 30 runs after 4 h of

continuous exposure. In field situations, impaired movements will adversely affect the transfer of fipronil from exposed to unexposed workers.

To study the horizontal transfer, fipronil SC was used to treat sand at 1 ppm (wt:wt). Termites were exposed to treated sand for 1 h and after that were mixed with blue dyed unexposed termites for 24 h (Rust and Saran 2006). The mixing ratio of exposed (donors) to unexposed (recipient) termites was 1:1. After 24 h, donors and recipients were held in separate petri dishes and mortality was recorded over 7 d.

Table 1. Percent mortality of donors and recipients over 7 d after mixing.

Termites	% Mortality over 7 d				
	Day 1	Day 2	Day 3	Day 4	Day 7
Donors	62	72	86	93	96
Recipients	14	22	24	32	68

Exposure to 1 ppm fipronil for 1 h resulted in > 95% mortality in donors over 7 d. By day 7, 68% of the recipients were killed. Fipronil showed delayed toxicity of both donors and recipients (Table 1).

A linear arena consisting of 3 petri dishes connected together by 3-m sections of tygon tubing was used to determine the effect of fipronil treated sand on movement and mortality Saran (2006). One hundred termites were released in a petri dish on the opposite end of the arena from the treated sand. Termite mortality at different locations in the arena was recorded over 7 d.

Few were found dead in the treatment petri dishes. Maximum mortality (~35 to 50%) was observed within the first 2-m from the treatment petri dish (Fig. 1). In the next 4 to 6 m section of tygon tubing, 5 to 18% of the dead termites were scattered. Total mortality in 6-m linear arena for different concentrations ranged between 52 to 77% at the end of the 7 d.

When exposed to a non-repellent and delayed toxicity termiticide such as fipronil, termites remained in contact with the treated soil. Consequently, the concentration of the fipronil did not affect the distance termites traveled before they died. This seriously reduces any potential for horizontal transfer to unexposed individuals, especially if the nest is > 6 m from the treated zone.

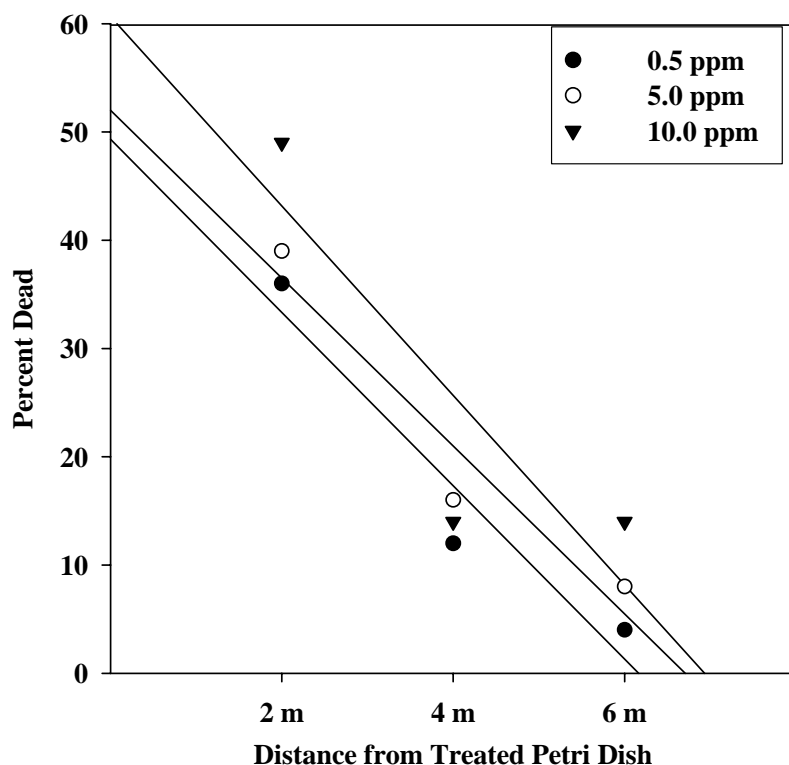


Figure 1. Relationship between distance from treated zone and percent mortality of termites. Each data point is an average of three replications.

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STUDENT PAPER COMPETITION

Blowing Rock, Tanglewood, Pinehurst

Moderator
Bill McClellan
DuPont

COMPARATIVE PROTEOMICS BETWEEN WORKER AND SOLDIER CASTES OF *RETICULITERMES FLAVIPES* (ISOPTERA: RHINOTERMITIDAE)

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To comprehend applied termite research, advancing our knowledge of fundamental termite biology is required. Methods for characterizing the *Reticulitermes flavipes* proteome have been established in our lab using the worker caste and provide the basis for our *R. flavipes* protein research. Our most recent study has utilized comparative proteomics to investigate differential protein expression between worker and soldier castes.

Termites were collected from Stillwater, OK and maintained in the laboratory for a minimum of 30 days. Termites were harvested from worker and soldier castes and converted to whole-body termite protein extracts. Each sample was processed using two-dimensional polyacrylamide gel electrophoresis (2D-PAGE) to separate the proteins. The gels were visualized using Coomassie brilliant blue staining. A worker caste protein map of the resulting protein spot pattern was generated by numbering each spot and assigning Cartesian coordinate measurements correlating to isoelectric point (pI) and molecular weight (MW). The soldier caste gel was compared to the worker caste protein map. After mapping, *R. flavipes* protein characterization was initiated using matrix assisted laser desorption/ionization – time of flight (MALDI-TOF) mass spectrometry to generate peptide mass fingerprints (PMFs). Protein identification was initiated by comparing the PMF against various databases for a putative identification.

Hundreds of proteins were differentially expressed between the protein profiles; many proteins were up regulated or down regulated. These protein changes demonstrated a substantial change in protein profiles between castes. This comparative study of the

proteome will facilitate future research among *R. flavipes* as well as among termite species.

TERMITE TRAIL PHEROMONE ATTRACTIVENESS AND SPECIFICITY

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Subterranean termites belonging to three different families and several different genera respond to (3Z,6Z,8E)-dodecatrien-1-ol (dodecatrienol henceforth) by following trails of this compound (Matsumura et al. 1968, 1969; Honda et al. 1975, Laduguie et al. 1994, Tokoro et al. 1994; Wobst et al. 1999). However, the threshold concentrations for various species vary over a broad range (<0.01 pg/cm to 10 pg/cm) (Pasteels and Bordereau 1998). The evolutionary origin of dodecatrienol is probably highly conserved across the termite families.

Our objectives were, first to determine the threshold responses for trail following to sternal gland extracts (SGE), dodecatrienol, and 2-phenoxyethanol. We also conducted studies to determine termite's ability to detect concentration gradients on trails and the role of antennae in detecting the trails.

Y-choice assays were conducted on a Y-maze cut out of cardboard. Each arm of the Y-maze was 120° apart, 5 cm in length, and 3 mm wide. One of the arms of the Y-maze was treated with SGE/dodecatrienol/2-phenoxyethanol and the other arm, which served as a control, was treated with hexane/acetone/water, respectively. Termites were released at one end of the Y-maze. The termites then made a choice when they walked up to the bifurcation. Data were analyzed using a binomial probability at $P < 0.05$. Thirty runs were conducted for each concentration tested (Saran et al. 2006).

Table 1. Responses of *R. hesperus* workers to trails of 2-phenoxyethanol, sternal gland extracts (SGE), and synthetic dodecatrienol, on a Y-maze.

Compound	Concentration ^a	Age (hr)
Control : Treatment	χ^2 ^b	
SGE	0.002 TE/cm	0.1
13: 17	0.53	
	0.02 TE/cm	0.1
3: 27	19.20*	
Phenoxyethanol	0.02 ng /cm	0.1
	0.53	17: 13
	0.2 ng /cm	0.1
4: 26	16.13*	
Dodecatrienol	0.01 fg /cm	0.1
14: 16	0.13	
	0.1 fg /cm	0.1
8: 22	6.54*	
	1.0 fg /cm	0.1
1: 29	26.10*	

^a TE = termite equivalent.

^b χ^2 values followed by asterisk (*) are significant at $P < 0.05$.

The minimum threshold concentrations for inducing trail following responses from termite workers was between 0.1-1.0 femtogram/cm of dodecatrienol. Termites were $\sim 10^6$ times more responsive to dodecatrienol compared to the phenoxyethanol (Table 1).

A bilevel Y-maze setup was used to study the role of antennae in detecting trail pheromone. When the antennae were within 1-2 mm of the trail, the termites followed the trail. Antennae played a key role in trail pheromone perception. High dodecatrienol concentrations (1 ng/cm) were repellent in Y-maze bioassays (Saran et al. 2006), but it was not repellent in bilevel Y-maze set up (Table 2). This suggests that termites have to touch the trail with either the antennae or the palpi to perceive the repellent concentrations.

Table 2. Detection of trail pheromone by *R. hesperus* workers on the double Y-maze arms.

Amount /cm χ^2 on Y-maze Arm	Distance between arms	Control : Treatment
1 fg	10 mm	
12: 18	1.2	
1 fg	5 mm	
11: 19	2.1	
1 fg	4 mm	
6: 24	10.8*	
1 ng	5 mm	
10: 20	3.3	
1 ng	4 mm	
7: 23	8.5*	

^a χ^2 values followed by asterisk (*) are significant at $P < 0.05$.

To observe the optimum responses of termites towards dodecatrienol, a 25 cm long line was treated with different concentrations of dodecatrienol (0.01/fg/cm to 10 pg/cm) (Saran et al. 2006). Gradient trail following assays were conducted by dividing the 25 cm long line in 5 sections of 5 cm each and then treating these sections with increasing concentrations of dodecatrienol (1, 2, 5, 8 and 10 fg/cm). Both number of termites finishing the 25 cm trail and their speed were recorded.

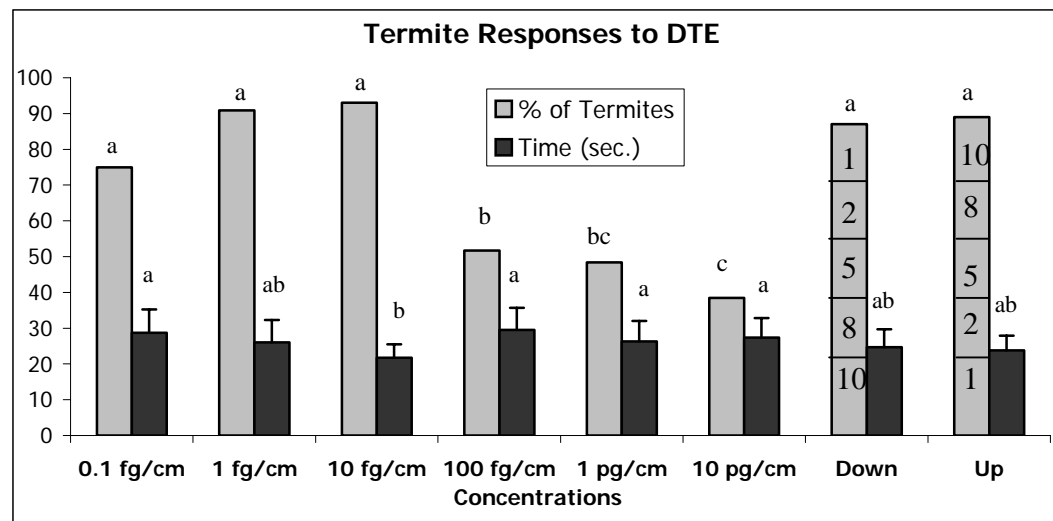


Figure 1. Temite responses towards different concentrations of dodecatrienol on a 25-cm long trail and on a 25-cm trail with gradient.

Workers showed optimal trail following behavior to dodecatrienol at a concentration of 10 fg/cm on 25 cm long trails. At concentrations > 10 fg/cm, termites did not follow the

trails very well. Workers did not detect pheromone gradients and responded equally to increasing and decreasing gradients of dodecatrienol (Figure 1).

Reticulitermes hesperus were very responsive to dodecatrienol and the concentrations did not play a role in providing polarity to the trails.

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PARASITISM OF SUBTERRANEAN TERMITES (ISOPTERA: RHINOTERMITIDAE: TERMITIDAE) BY ENTOMOPATHOGENIC NEMATODES (RHABDITIDA: STEINERNEMATIDAE: HETERORHABDITIDAE)

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In laboratory bioassays *Steinernema riobrave* Cabanillas, Poinar and Raulston (355 strain), *S. carpocapsae* (Weiser) (Mexican 33 strain), *S. feltiae* (Filipjev) (UK76 strain), and *Heterorhabditis bacteriophora* Poinar (HP88 strain) were all capable of infecting and killing three termite species, *Heterotermes aureus* (Snyder), *Gnathamitermes perplexus* (Banks), and *Reticulitermes flavipes* (Kollar) in lab sand assays. *S. riobrave* and *S. feltiae* caused low levels of *Reticulitermes virginicus* (Banks), mortality under the same conditions. At 22°C, significant mortality (≥80%) of worker *H. aureus* and *G. perplexus* was caused by *S. riobrave*, in sand assays, indicating the need for further study. Due to the short assay time (3 d maximum) reproduction of the nematodes in the target host species was not recorded. All nematode species were observed to develop to fourth-stage juveniles, pre-adult stages or adults in all termite species with the exception of *R. virginicus*. Only *S. riobrave* developed in *R. virginicus*. Nematode concentration and incubation time had significant effects on the mortality of worker *H. aureus*. *S. riobrave* consistently generated the highest infection levels and mortality of *H. aureus* in sand assays.

BUGS IN BUGS: STUDIES ON THE GUT BACTERIA IN TERMITES

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The phylogenetic diversity of the gut bacterial symbionts of the subterranean termite *Reticulitermes flavipes* was analyzed using partial-length 16S rRNA gene sequences and amplified rDNA restriction analysis (ARDRA). We amplified the genes by polymerase chain reaction (PCR) directly from a mixed population of termite gut bacteria and isolated them using cloning techniques. Analysis of 42 sequences identified a broad taxonomical range of ribotypes from the domain *Bacteria*. All sequences grouped into one of six bacterial phyla: *Proteobacteria*, *Spirochaetes*, *Bacteroidetes*, *Firmicutes*, *Actinobacteria*, and the recently proposed “*Endomicrobia*.” *Spirochaetes* formed the largest group, accounting for 29% (12 out of 42) of all clones, and clustered closely with clones previously defined as *Treponema*. *Firmicutes* included a large proportion of the clones (24%) and were taxonomically very diverse. A

relatively large proportion (17%) of clones corresponded to “*Endomicrobia*.” Analysis of the sequence data suggests a new group of *Bacteroidetes*, termed “Termite *Bacteroidetes* Group,” is only found termites. The Proteobacteria included examples from each of the major subdivisions of Proteobacteria except for β -proteobacteria. The ARDRA analysis of 512 clones likewise demonstrated high bacterial diversity in the termite gut. The 16S rRNA gene sequence data and the ARDRA data from *R. flavipes* indicate that the termite intestinal microflora is populated by many new and yet undescribed species of bacteria.

PEST ANT COMPLEXES OF PUERTO RICO

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The pest ant species complex was identified in Puerto Rican housing of different ages. Glass vials that had been baited with either sugar water or peanut oil were placed outside the house at common pest ant entry points. After one hour, the vials were collected and filled with 70% isopropyl alcohol. The ant species in each vial was identified and the number of each species captured was recorded. The bait that each species was captured with was also recorded for analysis on the feeding preferences of Puerto Rican pest ants.

NATURAL HISTORY, COMMUNITY STRUCTURE, AND MEDICAL STATUS OF AN INVASIVE, STINGING-ANT PEST, *PACHYCONDYLA CHINENSIS* (EMERY), IN THE UNITED STATES

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Pachycondyla chinensis (Formicidae: Ponerinae) is an invasive species thought to be endemic to Japan and parts of Southeast Asia. The first records of this ant in the United States were established in 1932; however it has been regarded as relatively uncommon, although locally abundant, since the original observations. An apparent increase in the occurrence of this species and associated stinging reports in the Piedmont region of South Carolina prompted an investigation of this exotic species ecology in South Carolina and a survey of sting victims.

To evaluate nest structure and habitat, thirteen nests were located by following baited foragers to nest entrances on the Clemson University campus and surrounding area in South Carolina. All nests were shallow, reaching maximum depths of approximately 2.5 to 10 cm beneath the surface in loose soil or were located above the surface in decomposing logs. Nests were characterized in three habitat types: urbanized areas around buildings and landscaping (6/13), forest edges (4/13), and interior forests (3/13).

No nests were found in open-grassy areas. Galleries were typically (13/13) associated with structural objects that were in contact with soil. These included logs (6/13), rocks (3/13), subterranean tree roots (1/13), and bricks, boards or other debris (3/13). The number of workers was highly variable with a range of 39 to 5,719 individuals (mean = $1,044 \pm 449$, $N=13$). Dealated female numbers were highly variable with a range of 0 to 37 (mean = 11.7 ± 3.7 , $N=13$). The number of workers was positively correlated with the number of queens in the nest ($P<0.022$, $r = 0.628$). The maximum percentage of dealated females we observed in our sample was 18% in a colony of 118 ants. In three of the excavated colonies no queens were found.

To investigate the ecological importance of *P. chinensis* in a formicid community context, three 180-m transects were established in the Clemson University Experimental Forest and sampled for epigeic ants with the complimentary techniques of Winkler litter sifting and pitfall trapping at 30 m intervals. This study yielded 750 individual ants comprising 15 genera, and 17 species from 21 sampling sites. The six most abundant species, *P. chinensis*, *Paratrechina fasionensis*, (Forel), *Aphaenogaster rudis* Enzmann, *Crematogaster ashmeadi* Mayr, *Myrmecina americana* Emery, and *Ponera pennsylvanica* Buckley account for approximately 85% of all individuals collected. *Pachycondyla chinensis* with 209 collected workers was the most abundant ant in the study. Relative importance values (RIV) had an exponential distribution, with three species that are in the upper end of the distribution: *P. fasionensis*, *P. chinensis*, and *A. rudis* complex. The value for *P. fasionensis* (RIV = 0.231) was the highest observed and was clearly significantly different, falling outside of the upper fence on a box and whisker plot, had a normal distribution percentile of 99.2%, and fell above the 99th percentile on an exponential distribution. The relative importance value for *P. chinensis* (RIV = 0.171) was the second highest observed and fell just inside the upper fence on the box and whisker plot, had a normal distribution of 94.8%, and fell at the 95th percentile on the exponential distribution. The third highest value of *A. rudis* complex (RIV = 0.165) fell inside the upper fence, had a normal distribution of 92.8% and fell within the 90th percentile on the exponential distribution. Interspecific species associations (Adapted C_7) were calculated for pairings between *P. chinensis* and the other five ants with the highest importance values: *A. rudis* complex, *C. ashmeadi*, *M. americana*, *P. fasionensis*, and *P. pennsylvanica*. *Pachycondyla chinensis* and *P. fasionensis*, the two most important ants in the community, had a significant negative association coefficient ($C_7 = -0.4$; $X^2 = 8.26$, $df = 1$, $P < 0.005$). No other species pairings revealed C_7 values significantly different from zero indicating that no other strong associations were present in the data matrix.

To evaluate the medical importance of *P. chinensis* stings, sting victims from Anderson, Greenville, Oconee, and Pickens Counties of South Carolina were asked to narrate their ant-sting experiences within the framework of a survey. Specifically, they were asked the following questions, 1) where on the body did the sting occur, 2) what activity were you engaged in when the sting occurred, 3) what were the medical symptoms of the sting (i.e., description of swelling size, pain, urticaria, and redness), 4) how long did the symptoms persist, and 5) was medication required to alleviate the symptoms? Stinging ants were collected into 80% ethanol and later identified as *P. chinensis*. Stinging

normally occurred when an ant became trapped between the victim's clothing and skin. The most common stinging site (11/25) on victims was the legs with the remainder (14/25) occurring on the arms, buttocks, hands, or torso. Stings were associated with outdoor activity in wooded areas and peridomestic situations. Medical manifestations of the stings were classified into three categories (i.e., minor, local, and large-local reactions). Eighty percent of sting victims experienced local reactions (i.e., swelling less than 5 cm in diameter around the sting site, recurring pain, redness of skin, mild to severe urticaria, and symptoms lasting 2 hours to 5 days), 12% had minor reactions (i.e., no swelling, localized redness, minor pain sensation at the time of sting, mild urticaria, and symptoms lasting less than 1 hour), and 8% had large-local reactions (i.e., swelling more than 5 cm in diameter around the sting site, recurring pain, redness of skin, severe urticaria, and symptoms lasting 3 to 14 days).

Stings were often (17/25) described as intense pain that diminished and returned frequently over several hours and manifested on victims in areas not confined to the original sting site, symptoms diagnostic of *P. chinensis* stings. Professional medical treatment was not sought in any of our cases; however, two cases required the self-administration of antihistamines (e.g., diphenhydramine HCL) for reprieve from itching/swelling (2/25) and analgesics (e.g., acetaminophen) for pain (1/25). *Pachycondyla chinensis* represents an emerging public-health threat throughout its range in the United States and further studies on the ecology and medical and veterinary importance of *P. chinensis* are warranted.

ARGENTINE ANT FORAGING ACTIVITY AND INTERSPECIFIC COMPETITION IN COMPLETE VS. WORKER-ONLY COLONIES.

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Short-term introductions of invasive species into uninvaded areas may elicit useful insights into interactions and behaviours between the invasive and native organisms. However, such manipulative field experiments with invasive species, such as the Argentine ant *Linepithema humile*, raise serious ethical concerns over the risk of accidental release. Argentine ant colonies are notoriously ephemeral and readily migrate once introduced into a field site, with potentially catastrophic results. In the laboratory, we compared the foraging behaviour of Argentine ant colonies containing queens and brood (complete colonies) against colonies containing only workers to a liquid sugar source. We also tested the interspecific competitiveness of complete and worker only Argentine ant colonies against the native odorous house ant, *Tapinoma sessile*, both in the laboratory and in the field. We found no significant difference in foraging behaviours or interspecific competitiveness between complete and worker-only colonies. Worker only colonies can be substituted for complete colonies in meaningful short-term field experiments with no risk to a novel environment if escape occurs.

Species 1: Hymenoptera Formicidae *Linepithema humile* (Argentine ant)
Species 2: Hymenoptera Formicidae *Tapinoma sessile* (Odorous house ant)

Keywords: Invasive species, *Linepithema humile*, foraging, interspecific competition

FIELD EFFICACY OF PYRETHROID AND NON-REPELLENT TREATMENT REGIMENS FOR THE CONTROL OF BED BUGS (*CIMEX LECTULARIUS*)

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Since the 1990s, bed bugs have been an increasing problem in the United States. Because bed bugs had been essentially eradicated in the United States during the 1950s, there are currently very few products available to treat the resurgence of bed bugs. Over the past year, our laboratory has been evaluating products that are labeled for bed bug control to determine which products work. The purpose of this study was to evaluate those products in a field situation.

Field trials were conducted at Buckingham Village with the assistance of Dr. Richard Kramer of Innovative Pest Management. Built in 1937, Buckingham Village is located in Arlington, VA, and is currently low income housing with primarily Spanish speaking residents. Few residents were present at the time of treatment, so there was little sanitation or IPM advice provided to them. Conditions in the apartments were generally crowded. While there was usually only one name on the apartment lease, other residents rented sleeping space from the lease holder at a daily or weekly rate. Since there was no lease binding residents to a single apartment, they could move from apartment to apartment at will. These transient residents also had a diversity of bedding arrangements, ranging from a box spring and mattress to simply a balled up jacket against the wall allowing them to sleep on the floor.

Conditions for this field test were challenging. The transient residents moved from apartment to apartment and transferred their belongings and bed bugs with them. This movement of residents amplified the spread of bed bugs throughout the apartment complex. Residents also used their own bed bug control methods. Duct tape was used along the baseboards and outlet plates in order to contain the bed bugs inside the walls and keep them out of the living quarters. Boric acid was applied along the baseboards and other locations where the tenants believed the bed bugs would encounter the product.

Our field test evaluated two different bed bug treatment regimens. These treatments were labeled “Traditional” and “Novel.” Products used in the traditional treatment were those that had bed bugs listed on the label and a history of use for bed bug control: Tempo SC Ultra (cyfluthrin, 0.1%; applied on baseboards, cracks, and crevices),

Suspend SC (deltamethrin, 0.06%; applied to the bed frames and box springs) and Gentrol Aerosol (hydroprene, 0.36%; applied to the baseboard, around the box spring, and to the bed frame).

The novel treatment consisted of products currently being used for bed bug control but that had not been evaluated for efficacy in the field. The products used were: Phantom (chlorfenapyr, 0.5%; applied to baseboards), Steri-Fab (cyclopropanecarboxylate, isopropyl alcohol, and dimethyl benzyl ammonium chloride; applied to the mattress seams and tufts and box spring until damp), N.I.C. 325 (lime-stone, and corn gluten meal; light dust applied to the bed frames, mattress, and box springs), and Gentrol Aerosol (hydroprene, 0.36%; applied to the baseboard, around the box spring, and to the bed frame)

Because of its quick knockdown effect, we first treated the mattresses in the novel apartments with Steri-Fab. Because Steri-Fab has no residual activity, N.I.C. 325 dust was applied as a follow-up mattress treatment after two weeks. Five apartment units were used to test each treatment combination and as controls.

Visual counts of live bed bugs for both traditional and novel treatments were made before treatments were applied. Subsequent counts were made on days 1, 3, 5, 7, 14, 28, and 42, with a final count on day 56. On each treatment date, visual counts were made in each room of the apartment except for the kitchen and bathroom. These counts were then organized by apartment number, room, and then by specific location (wall, bedding, or other furniture). Bed bug numbers in each treatment were plotted over time and compared to each other and to the untreated control units.

Visual counts were recorded by treatment (traditional, novel, and control) for each test date. The treatment efficacy was determined using repeated measures ANOVA (SAS Institute 2005) over the entire 8 week test period and values of $P \leq 0.05$ were used to indicate significance.

Pre-treatment counts in apartments receiving the novel treatment had a mean of 71.4 live bed bugs per apartment. Three days after treatment, this number dropped to 24.0. This decrease in bed bug numbers was due to the fast knockdown effect from the Steri-Fab application on the mattresses and bedding. Because there was some lag time for residual products (Phantom, N.I.C. 325, and Gentrol) to take effect, the surviving bed bugs continued to mate and reproduce, therefore the mean number of bed bugs increased to 31.8 by day 14. However, once the residual products began to work the number of live bed bugs per apartment decreased to 10.2 by day 56.

Apartments in the traditional treatment had a mean of 39.8 live bed bugs per apartment on prior to treatment. This number was reduced to 5.6 by day 3. This bed bug reduction was due to the fast acting qualities of pyrethroid products applied directly to bed bugs. Bed bug populations remained low in the traditional treatment through the 8 week test period with a final visual count of 2.2 live bed bugs per apartment.

Repeated measures analysis indicated that both of the treatment regimens significantly reduced bed bug populations. Both treatments were significantly different from the control units at the $P = 0.05$ level. However, they were not significantly different from each other. The traditional treatment did perform slightly better than the novel treatment at the $P = 0.10$ level.

Both treatments significantly reduced the number of bed bugs over the 8 week test period, with the most significant decrease in the population occurring within the first week of treatment. This reduction is due to the direct application of the insecticides onto the bed bugs. The traditional treatment performed slightly better than the novel treatment but was not significant at $\alpha = 0.05$.

TERMITES
Blowing Rock, Tanglewood, Pinehurst

Moderator
Brad Kard
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**COMPARISON OF THE RELATIVE ABUNDANCE OF SUBTERRANEAN
TERMITE SPECIES (ISOPTERA: RHINOTERMITIDAE:
RETICULITERMES) OCCURRING IN WOODLANDS AND URBAN
AREAS OF MISSOURI**

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Data regarding the occurrence and current geographic distribution of subterranean termite species within the state of Missouri is conflicting. Moreover, since the registered data is mainly from structural infestations, the occurrence of these species in wooded areas is not clearly documented, nor has relative frequency of different species compared between these habitats.

Taking in to account that more detailed knowledge of the subterranean termite species composition may be required, in the future, in order to use species specific targeted treatments, we began the Missouri Subterranean Termite Survey in the Household Insect Lab of the University of Missouri. The main objective of this project is to update the documented data regarding *Reticulitermes* (Isoptera: Rhinotermitidae) species by examining and comparing the subterranean termite species composition occurring in urban and wooded areas located in the north, center and south of the state. Samples of termite colonies were collected during 2004 and 2005 in 9 conservation areas, 9 cities located nearby and from home infestations occurring in different locations within the state of Missouri.

Since the differentiation of species in the genus *Reticulitermes* is particularly difficult because reliable morphological characters only occur in the adult stage that is seasonal, we are currently working in the species identification using not only morphometric characters but also the sequencing of mitochondrial DNA 16S, thus, more accurate

information regarding species composition and genetic structure of the species occurring in Missouri will be provided in the future.

Data from morphological identification of the samples supported with Discriminant Function Analysis of morphometric characters suggest contrasting predominant species occurring in urban and woody environments. While *Reticulitermes flavipes* is the predominant termite species in urban environments, *Reticulitermes hageni* is the predominant species in woodlands of Missouri.

***RETICULITERMES FLAVIPES* (ISOPTERA: RHINOTERMITIDAE) ON A NATIVE TALLGRASS PRAIRIE**

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Recent changes in termite management technologies have stimulated a need for better understanding of basic termite ecology. Studies estimating foraging populations and colony sizes of subterranean termites have been conducted in many areas of the United States. However, characterizations of *Reticulitermes* colonies occurring in the central Great Plains have not been conducted. Results of studies investigating three colonies of *R. flavipes* (Kollar) on the Nature Conservancy's Tallgrass Prairie Preserve (TGPP) in northeast Oklahoma are reported herein. In North America, only 10% of the original 142 million acres of tallgrass prairie remain. The TGPP's 38,700 acres sustain ~3,200 bison, and represent an important remnant of this vanishing native ecosystem.

Currently, there is a paucity of information available about the biology of *Reticulitermes* sp. inhabiting the Central Plains of the United States, although some characterizations of native termites in wildland sites have been conducted in other U.S. areas (Haagsma and Rust 1995; Haverty et al. 2000). We determined foraging population estimates and foraging territory sizes, as well as soldier caste ratios, of three colonies of *R. flavipes* on the TGPP. Monitoring devices consisted of cylinders of perforated PVC pipe (10.2-cm dia. × 20.3-cm deep) vertically installed as below-ground monitors, plus soil-surface ground-boards (Brown et al. 2004). A 'checkerboard' grid of 292 stations spaced at 3-m intervals was installed. Additionally, 257 surface ground-boards were placed within the grid. Five, larger below-ground PVC pipe stations (20.3-cm dia. × 25-cm deep) filled with tightly rolled corrugated cardboard were also installed to increase the number of termites collected for estimating populations. Thus, the grid consisted of 554 monitors covering an area of 2,313m² (Fig. 1).

Foraging population estimates were determined using the triple mark-release-recapture technique (TMRR; Grace et al. 1989; Su et al. 1993; Haverty et al. 2000). Both the

Lincoln Index and the Weighted Mean Model were used to estimate foraging populations so that these two methods could be compared (Bailey 1951; Begon 1979). Soldier caste ratio averages for each monitoring device and subsequently each colony were obtained based on data collected during the TMRR process. A chi-square test was used to compare soldier ratios from monitors centralized within the foraging territory of Colony 3 (blue colony) with ratios from those from the peripheral monitors. To ensure a more complete delineation of foraging territories, the mark-release-recapture procedure was continued beyond the third cycle until no new monitoring devices were found to contain dyed termites. Thus, a total of six cycles were completed for each of the three colonies. Maximum linear foraging distances were obtained by measuring the distance between the two most widely separated monitoring devices within each foraging territory (Table 1).

During the study, wood associated with 223 of the 554 monitors was fed upon by foraging termites. This large percentage (40.3%) indicated a high level of termite pressure within the site. Results of the mark-release-recapture procedure indicated that the termite pressure on our site could be attributed to the foraging activities of several small colonies. Foraging areas for individual colonies ranged from 9.0 to 92.3 m² (Table 1), and colonies contained \approx 10,000 to 184,000 foragers. When compared with previous studies estimating *Reticulitermes* sp. foraging populations, our estimates are substantially lower than the millions of foragers reported by Su et al. (1993) and Grace et al. (1989), but comparable to those reported by Forschler and Townsend (1996) and Haverty et al. (2000).

When comparing estimates using the Lincoln Index with those of the Weighted Mean Model, only one of three colony estimates agreed. Weighted Mean Model estimates for two colonies were 2.3 and 7.4 times greater than estimates derived using the Lincoln Index. Similar marked differences between estimates using these two methods were noted by Haverty et al. (2000). The advantage of using the Lincoln Index is that it requires less time and effort. Estimates based on either method do not account for termites that are not actively foraging, and therefore only provide estimates of foraging termite numbers.

Average soldier ratios of the three colony's foraging populations ranged from 2.69 to 4.46%. Soldier ratios from individual monitors rarely exceeded 5.0%. Soldier ratios calculated from the three central monitors within the area of the largest foraging territory (Colony 3, blue colony) were compared with soldier ratios from peripheral monitors. The weighted soldier ratio from the three central monitors was 7.48% compared with 2.52% for monitors on the periphery. A chi-square test indicated a significant difference ($P < 0.0001$).

In summary, colonies of *R. flavipes* characterized on the TGPP are relatively small in both foraging population numbers and territory areas compared with studies by Su et al. (1993) and Grace et al. (1989), but agreed with those reported by Forschler and Townsend (1996) and Haverty et al. (2000). It appears that within our study site numerous colonies are foraging in close proximity.

Table 1. Foraging territories and maximum linear foraging distances of three colonies of *Reticulitermes flavipes* on the Nature Conservancy's Tallgrass Prairie Preserve (Oklahoma)

Colony	Number of active monitors	Foraging territory m ²	Maximum linear distance, m
Col. 1 (Purple)	2	9.0	3.0
Col. 2 (Red)	6	24.8	9.5
Col. 3 (Blue)	21	92.3	19.5

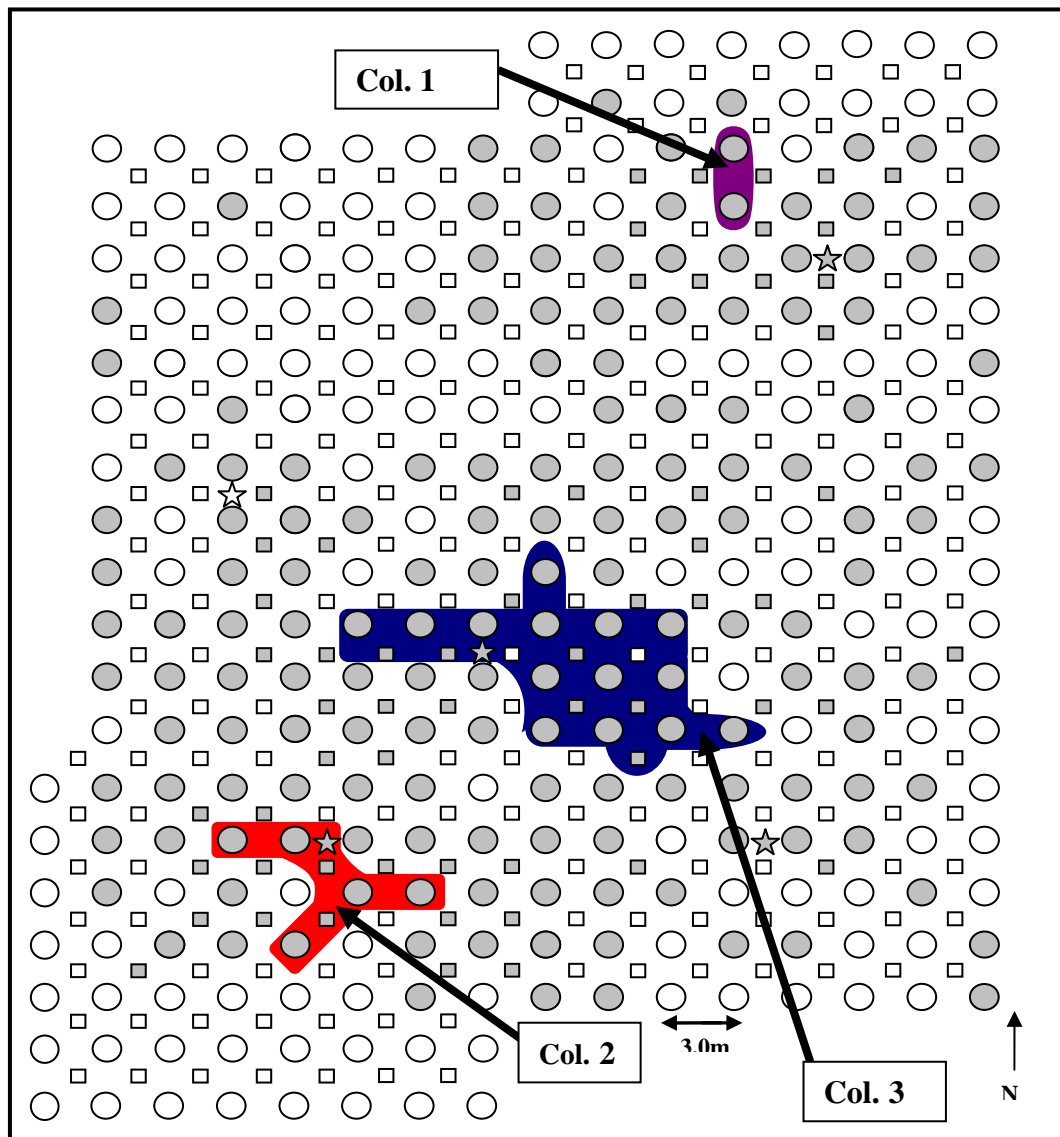


Figure 1. Foraging territories of three *Reticulitermes flavipes* colonies located on the Nature Conservancy's Tallgrass Prairie Preserve. Each circle denotes a 10.2-cm dia. x 20.3-cm deep in-ground monitor; squares denote surface ground boards; stars denote 20.3-cm dia. x 25-cm deep in-ground monitors. Solid and open figures represent monitoring devices with or without termite activity, respectively.

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DIRECT OBSERVATION OF TASK SPECIFICITY IN *RETICULITERMES FLAVIPES*

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We placed marked groups of *Reticulitermes flavipes* (Kollar) in an enclosed, darkened arena and videotaped them for several 24 h periods. Specific individuals were scored, over several days, for grooming, trophallaxis, cellulose consumption, and excavation behaviors for 3 h of each full day of video-tape. We found that most behaviors were performed universally but that excavation behavior was not. This suggests that there may be some degree of task specificity in the lower termites.

TERMITE CULTURE METHODS

S. Wise and B.T. Forschler
Department of Entomology, University of Georgia, Athens, GA

Ten years of termite culture experience has allowed development of methodologies that have demonstrated success (Grube and Forschler 2004). This talk will outline those techniques from dealate pairing through yearly movement into bigger and better containers.

NEUROPEPTIDE F IN *ZOOTERMOPSIS NEVADENSIS* (ISOPTERA: TERMOPSIDAE)

Andrew Nuss, Mark Brown, and Brian Forschler
Department of Entomology, University of Georgia, Athens, GA

Presence and distribution of NPF-like peptides were examined in *Zootermopsis nevadensis* using immunocytochemistry. Immunoreactive material was detected in the ganglia and innervation of the alimentary tract. Immunoreactive material was also present in endocrine cells of the midgut. Distribution of staining was mapped and compared between different termite castes, and compared to immunostaining patterns seen in *Reticulitermes flavipes*.

INSECTICIDE TRANSFER IN SOCIAL INSECTS

Chimney Rock

Moderators

Michael Rust

University of California Riverside

Mark Coffelt

BASF Corporation

INTRODUCTION: BRIEF LITERATURE REVIEW, OVERVIEW OF BIOLOGICAL RELEVANT TRANSFER WORK

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In the past six years there has been an increased interest in the use of non-repellent insecticides that exhibit delayed toxicity and have the ability to transfer between nestmates. Laboratory studies have shown that these insecticides are horizontally transferred from donors to recipients, especially among social and semi-social insects. However, the importance of horizontal transfer in field situations has not been definitively demonstrated. Quantifying transfer under field conditions with various termite species has proven to be extremely challenging, and there are several field studies in place trying to document this effect. Recent studies suggest that the transfer may not be as significant as first reported, limiting its distance and area wide effect (Su 2005, Saran 2006). However, as was discussed at this symposium, many of the studies are laboratory based, and evidence of transfer effects under field conditions is needed. There are numerous examples of pest management professionals utilizing nonrepellent chemistry in their termite and ant field programs and observing collateral effects away from the treated zones.

Mortality and insecticidal activity are dose dependent even with toxicants with delayed toxicity (Su et al. 1987, Haagsma 2003, Remmen and Su 2005, Rust and Saran 2006, Saran 2006). For example, 1-h exposures to sand treated with 100-500 ppm fipronil produced 100% kill of workers within 24 h (Saran 2006). In fact, within 15 h the survivorship probability of workers was nearly 0 (Fig. 1). Under laboratory conditions workers were immobilized so quickly that it is unlikely that they would actively transfer insecticide to recipients.

Not all exposures on treated substrates are lethal. Smith and Rust (1990) reported that sub-lethal exposures to pyrethroids resulted in inhibited tunneling and locomotion. Similarly, Thorne and Breisch (1999) reported that sub-lethal exposures to imidacloprid inhibited tunneling, movement, and feeding. While extremely interesting, these sub-lethal exposures do not result in the horizontal transfer of lethal doses to recipients.

Various techniques of exposing the donor termites have been utilized in the lab experiments. Insecticides can be topically applied to donors (Valles and Woodsen 2002, Ibrahim et al. 2003, Tomalski and Vargo 2004, Hu et al. 2005), or exposures on soils (Haagsma 2003, Shelton and Grace 2003, Tsunoda 2006, Rust and Saran 2006). Factors such as the time of exposure (1 or 4 hours or even longer), substrate utilized (sand, filter paper, field soil, etc.), donor:recipient ratios, concentrations (ranging from 0.5 to 100 ppm), and the species tested can have a tremendous impact on the extent of transfer. Studies by Haagsma (2003), Rust and Saran (2006), and Saran (2006) with radiolabelled insecticides indicate that amount of insecticide that donors pick up from treated soils is a limiting factor. For donors to pick up sufficient quantities of insecticide to transfer to recipients, they must be confined to high doses for extended periods. For example, the

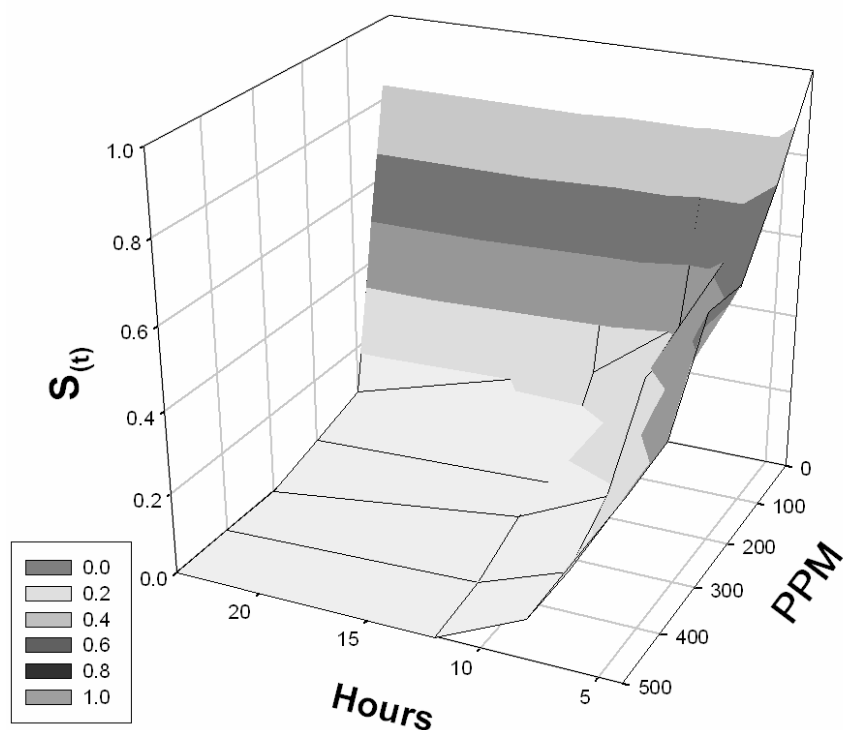


Fig. 1. Survival probability [$S(t)$] of workers exposed to fipronil SC treated sand for 1 h.

donor must be exposed for 1 h to 62-ppm deposit of chlorfenapyr on sand to provide an LD₉₅ (Rust and Saran 2006). For the donor to transfer an LD₉₅ to the recipient, the donor must be exposed to a deposit of 124-ppm deposit for 1 h (Fig. 1). Similarly, Shelton and Grace (2003) reported lethal horizontal transfers only when donors were exposed to 100 ppm of imidacloprid or fipronil for 1 h. The greatest amount of transfer occurred when the donor: recipient ratio was 1:1 (Ibrahim et al. 2003, Tsunoda 2006) and 1: 1 and 1:4 (Hu et al. 2005), suggesting that the donor has a finite amount of insecticide available for transfer.

The horizontal transfer of insecticides is dynamic process involving the exposure of donors, interactions between donors and recipients, and transfer of lethal quantities of insecticides. To allow significant interactions to occur the toxicants must have a delayed toxicity. This suggests that it may be possible to design formulations and toxicants that allow for maximum transfer. In addition, laboratory studies designed to demonstrate transfer effects should not be extrapolated to field conditions, unless data are generated to document this relationship. The next step in the evolution of transfer studies is take the information learned in artificial laboratory experiments and try to apply these to actual field conditions. We believe that replicated field studies are needed to document transfer effects amongst social insects.

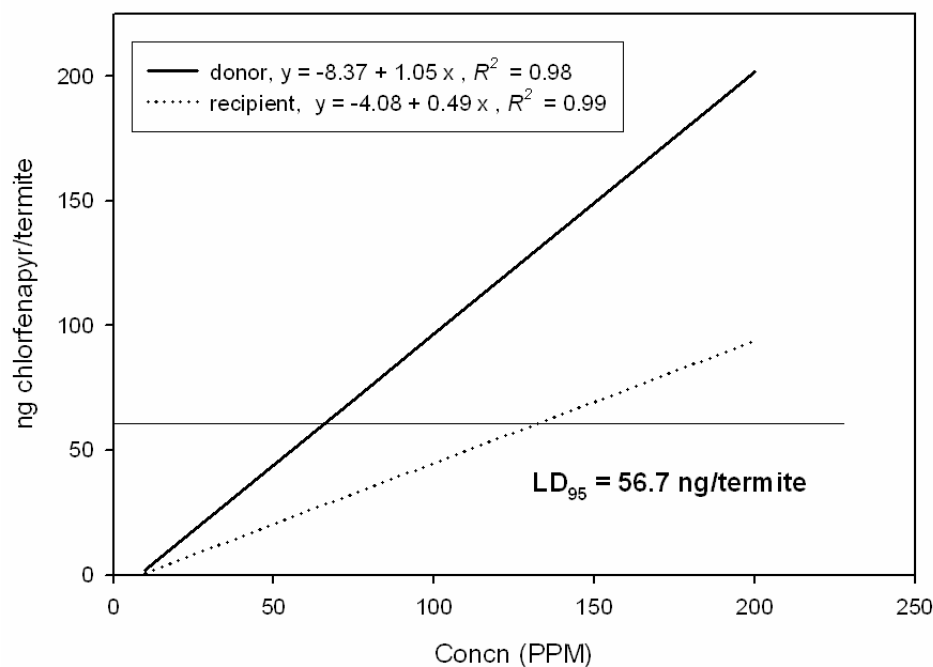


Fig. 2. The amount of chlorfenapyr picked up by the donor after a 1-h exposure to treated sand and the amount of transferred to recipients.

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LESS MAY BE MORE: HOW CONCENTRATION IMPACTS EFFICACY OF TRANSFER

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HORIZONTAL AND VERTICAL TRANSFER OF FIPRONIL WITHIN FUNCTIONAL COLONIES

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A model was developed to evaluate termite-fipronil interactions and termite-termite interactions at colony level under the closest simulated natural habitat conditions, using functional colonies and infrared videotaping technology. Localized soil application of fipronil (1 ppm) resulted in successful control of all the three tested colonies of eastern subterranean termite, *Reticulitermes flavipes* (Kollar), in less than 50 d. The efficacy of colony control was a tribute of multiple direct exposures, multiple transfer effects, or a combination of multiple direct and indirect exposures. Termites directly acquired lethal doses of fipronil via external cuticular uptake and oral ingestion. Unexposed termites also indirectly acquired lethal doses by interacting with contaminated colony members, both horizontally between the same generation and vertically between different generations. Fipronil was transferred within a colony by external cuticular uptake and oral ingestion and which were achieved via grooming, trophallaxis, contacting, cannibalism, necrophagy, or consumption of regurgitated gut content or fecal material. Rather than dying in the treated area or nearby adjacent tunnels, exposed termites aggregated and died at the nest site where they received intensive grooming from active colony members. The presence of termite corpus neither repelled nor deterred surrounding active colony members.

KEY WORDS *Reticulitermes flavipes* (Kollar), colony control, termite-fipronil interaction, soil-chemical barrier

Termites are one of the oldest and most primitive of insects (Krishna 1969). They play an important part in soil ecology by recycling fallen logs and decaying plant materials (Lee and Wood 1971). Unfortunately, they become the most destructive pests when their appetite for wood extends to homes, timber structures and cultivated plants.

Among the new technologies developed in recent years, soil treatment of nonrepellent insecticides—fipronil (Termidor®) in particular—has been a popular practice in subterranean termite control (Anonymous 2002). Fipronil is a phenyl pyrazole chemical that interferes with the function of termites' central nervous system. Field studies have

resulted in successful quick and relatively long-lasting termite control (Wagner et al. 2006, Hu and Hickman 2006). Soil treatment of fipronil also leads to significant suppression of surrounding termite populations as indicated by independent monitors installed around treated structures (Hu and Hickman 2006).

The nonrepellency and transferability of fipronil have been demonstrated in laboratory studies (Ibrahim et al. 2003, Shelton and Grace 2003, Osbrink and Lax 2002, Remmend and Su 2005, Hu 2005, Song and Hu, 2006). However, there are questions as to whether these laboratory results are a good representation of the effects that can be expected in the field, when only small groups of termites (10 to hundreds) workers and soldiers were tested in small arenas (Petri dish or small chambers connected with plastic tubes). Additionally, laboratory experiments were conducted under very limited conditions such as the presence of light, air movement, and human disturbance, which do not exist in termites' natural habitats. Furthermore, the transfer of fipronil has been demonstrated only between workers and soldiers (horizontal transfer) in isolated small groups, never at colony level.

In this study, a model was developed to examine the dynamics of behavioral interactions between termites and termiticide, contaminated termites and unexposed colony mates, lethal transfer of termiticide at colony level, and colony control effect. The following hypotheses were tested: 1) directly exposed termites would lose their mobility quickly and could not travel to meet unexposed colony mates; 2) exposed termites would aggregate in treated soil and die there; 3) dead termite bodies would block the treated area and/or adjacent tunnels to prevent unexposed colony mates from entering; 4) the presence of termite corpus would repel or deter unexposed colony mates from contact with them; 5) there would be no transfer of fipronil from exposed workers to young larvae and reproductives; and 6) soil application of fipronil would not result in colony control.

Materials and Methods

Recipient termite colonies: Eastern subterranean termites, *Reticulitermes flavipes*, were collected using the bucket-trapping technique described by Hu and Appel (2004) in the summer and fall of 2005 in Auburn, Alabama.

Experimental units were glass boxes ($30 \times 20 \times 10 \text{ cm}^3$) that contained moistened spruce (*Pinus pungens* Engelm) blocks and sterilized soil collected from termite habitat. The wood blocks and soil were $10 \times 20 \times 5 \text{ cm}^3$ in volume and were located at one side to cover 1/3 of a unit; five thousand workers and soldiers (in natural ratio at collection) were then introduced, and the unit was covered with a glass lid. Experimental units were kept in an incubator at $23 \pm 1^\circ\text{C}$ in darkness, except at the time of weekly inspections. Inspections were conducted by viewing from the outside of the boxes. The appearance of larvae of 1st and 2nd instar was used as the indication that a functional colony was established.

Experimental design. After 4 mo, a layer of moistened soil (1 cm thick) was placed into the unit to cover the 2/3 bare area. Termites were allowed to tunnel into the soil for at least 48 h to establish a network of tunnels. Then a section of soil ($8 \times 3 \times 1 \text{ cm}^3$) was

carefully removed from the middle of the opposite end of the nest site and replaced with the same volume of fipronil-treated soil (1 ppm w/w) that was stained with 2 ml Nile Blue A (0.1%). There were three colony replicates of the treatment and one control.

Videotaping technology. Termite activities within a colony were videotaped 24 h/d during the entire study period. An incubator was preset at $23 \pm 1^\circ\text{C}$ and interiorly lined with black flannel to reduce reflections and ambient light from two red Sylvania bulbs (25 watt) under a dimmer control. Inside the incubator, an experimental unit was positioned on the top glass shelf and a camera (Sony DCR TRV800 with super night shot) was located on a glass shelf below the unit. This arrangement allowed the camera to record termite activities from various angles and zoom levels. Video signal from the camera was split and captured at various time lapse rates by a VCR (Panasonic time lapse recorder) and a computer via an ATI video card. A tested colony was dissected to count the number of survivals 10 d after active termite was no longer visible.

Results

Pre-treatment. The mature workers made the tunnels. Although the tunnels along the edges were built faster, viewing from the bottom of the unit showed that multiple tunnels were built at the same time. Workers first grabbed soil particles and then transport the particles with their mouthparts back to where there was ample space.

After the tunnel network was established, foragers that moved in the network were predominately mature workers and soldiers. Larvae and nymphs of $> 3^{\text{rd}}$ instar also traveled in tunnels, but the majority of them remained inside the colony nest.

Occasionally, we saw 1^{st} or 2^{nd} instars wandered into tunnels, but often were grabbed and carried back to the nest by workers. Reproductives always concealed themselves in the heart of the colony nest and were never viewed from the outside of the glass box. Common termite-termite interactions were contacting, grooming, and trophallaxis.

Post-treatment. Workers tunneled into the stained fipronil-treated soil immediately after the soil was introduced into a unit. Particles of stained soil were observed lining up along tunnels adjacent to the treated area. These directly exposed termites remained active for at least 15 h before showing any poison symptoms. During the 15-h post-treatment, the entire colony was normally active with termites traveling between the treated area and nest frequently and carrying out social interactions such as contacting, grooming, and trophallaxis in the treated area, tunnels, and at the nest site.

Interestingly, both the poison symptoms of abnormal behaviors (15-h post-treatment) and death of termites (26-h post-treatment) were first evidenced in termites at the nest site, an indication that exposed termites did not lose mobility quickly and did not die quickly in the treated area or nearby tunnels. At the same time, other termites in and outside the nest were still normal and active. However, no new tunnel was built after 3-d post-treatment.

The process from exhibiting poison symptoms to death was slow, lasting from 10 to 24 h. Poisoned termites first showed impaired mobility (slow or staggering gait), followed by disorientation (erratic walking) and struggling to keep balance, and finally becoming

immobile (unable to walk) and losing equilibrium, lying on their backs twitching and shivering until death. Young larvae of <3rd instar exhibited poison symptoms after 26-h post-treatment, also at the nest site. The first death of young larvae occurred at 36-h post-treatment.

As the number of poisoned and dead workers increased at the nest site, the number of termites traveling in treated soil and tunnels decreased, and the number of young larvae wandering into tunnels increased. After 20-d post-treatment, the nest site was so crowded with termite corpus that some termites died in tunnels adjacent to the nest. By 40-d post-treatment, virtually no live termites could be viewed from outside the glass unit.

Video footages clearly show that the presence of dying or dead termites did not affect the normal activities of surrounding colony mates, whether they were unexposed or had not yet exhibited poison symptoms. Instead, dying termites seemed to attract active colony mates to provide them with intensive grooming and caring. Poisoned termites, especially those that were dying, were more likely to be cannibalized by active workers than those active workers, indicating that cannibalism was one of the mechanisms for the transfer of fipronil.

Colonies were dissected at 50-d post-treatment. The number of survivors was counted and sorted by castes (Table 1). Compared with the control, localized soil treatment resulted in not only significantly great mortality (98.8 - 99.5 %), but also nonfunctional reproductives that had lost their ability to produce eggs. Additionally, all the survivors were covered with parasite mites, had impaired mobility, and obviously were dying.

Discussion

Experimental design and conditions have critical impacts on the findings of experiments on social insects. This is particularly true for subterranean termites, the eusocial insects. The functional colony model we developed provides the advantages of observing termite activities under undisturbed conditions that closely simulate termite natural habitat. Therefore, the results should be a more accurate representation of what can be expected in the field.

Our results indicate that termites can directly acquire fipronil via external and internal routes. The external route is through cuticular uptake during tunneling and moving through treated soil or tunnels lined up with treated soil particles. The internal route is through oral ingestion when termites handling treated soil particles with their mouthparts during tunneling. Neither of the routes is a one-time event. Workers may grab and transport poison soil particles and travel in tunnels between the nest site to the treated area many times before becoming immobile.

Videotapes reveal the workers that directly acquired fipronil remained active for at least 15 h and did not die until at least 26 h later. Obviously, it took much longer time for those termites that did not directly expose themselves to treated soil but indirectly acquired fipronil from contaminated colony mates.

Above statements may help explain why active workers were observed walking in tunnels for 40-d post-treatment. Other possible explanations are that there were at least labor divisions of workers. Some workers were responsible for tunneling. They were the ones that first exhibited abnormal behaviors and died. Other workers were foragers that did not do the tunneling but traveled after the tunnels were built in search of food. It took a longer time for them to acquire fipronil doses high enough to result in a fatal effect. Still other workers were the care providers that stayed inside the colony nest and only acquired fipronil by interacting with contaminated ones. However, the colony would adjust the labor divisions accordingly to maintain a proper portion of each division. When the numbers of foragers significantly decreased, some of the care-providers might have converted their role to be foragers.

The most important phenomena this study observed are that, first, contaminated termites knew where to die. They always managed to return to the nest site and died there, rather than dying inside the treated zone or adjacent tunnels. Therefore, other termites could continuously enter the treated area freely. Second, dying termites received intensive grooming and care from colony members, rather than being kicked out and isolated. It is possible that active colony members were trying to remove the toxicant to minimize the fatal effect on the dying termites caused by fipronil. This kind of behavior has been reported in natural colonies where workers groom one another to remove microorganisms and other contaminants to minimize infections or other deleterious effects to benefit the colony. Unfortunately, when the contaminant was fipronil, these social interactions created a large chain reaction and became hazards that helped spread fipronil throughout the colony. Soil application of fipronil takes advantage of the hazards of termites being too social. Third, the presence of poisoned termite corpus did not interrupt surrounding active termites from executing normal activities.

Significant mortality of all colony members and the nonfunctional survivors could be the evidences of both horizontal and vertical transfers in this study. The lethal transfer of fipronil was caused by the interactions between contaminated termites (those directly and indirectly exposed to fipronil) and unexposed termites. Termite researchers have conventionally defined the material transfer between workers or from workers to soldiers as horizontal transfer because they are supposedly from the same generation. Logically, the transfer of contaminant between different generations should be defined as “vertical transfer,” a terminology that has been used in the study of human disease to define disease transfer between different generations. In this study, the transfer of fipronil from workers to neotenic reproductives could be either horizontal (because the majority of the workers were for the same generation with the workers that had developed into neotenic reproductives) or vertical (because some of the workers might be the offspring of the reproductives). For the same reasons, the transfer from workers to other workers and youngsters could also be either horizontal or vertical. These terminologies are used here but are subject to discussion.

The transfer of fipronil can also be achieved by cuticular uptake and oral ingestion. The mechanisms include cuticular contact with contaminated termites (contacting and

grooming), contact with contaminated substrate, trophallaxis, cannibalism, necrophagy, or consumption of regurgitated gut content or fecal material.

In summary, our results document lethal transfer of fipronil at the colony level and successful colony control by localized soil application of fipronil at 1 ppm within 50 d. Termites die from direct exposure, lethal transfer, or a combination of direct and indirect exposure. After all, the interactions of termite-fipronil and termite-termite are complex processes, not independent events.

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Table 1. Number of termite survivals at 50-d post-treatment

Colony	Reproductive	Egg	1 st and 2 nd instar	Worker and nymph of >3 rd instar	Soldier	Total
1	3	0	0	64	2	69
2	5	0	0	70	1	76
3	5	0	0	26	1	32
Control	15	209	987	4987	117	6335

INSECTICIDE TRANSFER AS A FACTOR IN THE CONTROL THE WESTERN YELLOWJACKET, *VESPULA PENNSYLVANICA* (SAUSSURE)

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Certain species of ground-nesting yellowjackets (Vespidae) belonging to the *vulgaris* subgroup are excellent predators, but may be annoying and dangerous. They represent serious regional public health problems seasonally during summer and fall. Besides inflicting serious psychological and economic injury, envenomization may cause painful or severe allergic reaction and may be incapacitating or fatal for hypersensitive individuals.

Other species are present, but the order of the most frequently encountered problematic species in California include *Vespula pensylvanica* > *V. vulgaris* > *V. germanica*. Transfer studies were made in sites where *V. pensylvanica* predominated. Intensive trapping of queens or foraging workers had no apparent effect on population numbers, but liquid heptyl butyrate (HB) dispensed from cotton dental wick was confirmed to be an excellent lure. HB is effective for *V. pensylvanica* but significantly less so for other species. More than >57,000 *V. pensylvanica* were captured in 2005 at a 1.2-hectare site ringed with traps baited with HB. Using HB as a standard lure, biotic (active) and abiotic (passive) transfer studies were made. Active transfer involved typical inter-stage trophallactic exchange of AI, presumably between developing larvae and recipient adult wasps. Factors affecting active transfer include the palatability of the bait matrix and concentration of AI. Fresh minced chicken tended to be the most preferred food matrix, but fish or specific pet foods were preferred in other areas. These measurable regional or geographic anomalies suggest learning or strain differences. Independent of matrix, foraging declined with %AI, <1 x 10⁻³% being foraged and >0.01% being nearly totally repellent. Some AI's were repellent or inhibited feeding at their presumably lower limit of activity.

Passive transfer involved no bait. Rather, foraging wasps lured with HB into traps from which they were allowed to readily escape became contaminated with AI before

escaping. Slow-acting AI's ultimately affected the 'trapped' foragers and in the meantime were presumably also disseminated via transfer to recipient larvae via contact. Rates for this "virtual baiting" were determined by LT trials which involved confining captured yellowjackets for as little as 15 min in wire mesh cages soaked with a discriminating dose [0.05% (vol/vol); 39.8 mg/m²] of AI. Effectiveness of both active and passive transfer was determined in the field with traps baited with HB.

INSECTICIDE TRANSFER IN ANTS

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**MOSQUITO MANAGEMENT IN STORMWATER CONTROL
PONDS**

Blowing Rock

Moderator

Nolan Newton

North Carolina Department of Environmental and Natural Resources

**MOSQUITOES OCCURRING IN STORMWATER CATCHMENT AND
RETENTION FACILITIES**

B. Harrison

North Carolina Department of Environmental and Natural Resources

**DISEASES ASSOCIATED WITH MOSQUITOES BREEDING IN
STORMWATER CATCHMENT AND RETENTION FACILITIES**

Nolan Newton

North Carolina Department of Environmental and Natural Resources

**MANAGEMENT OPTIONS FOR MOSQUITOES PRODUCED IN
STORMWATER CATCHMENT AND RETENTION FACILITIES**

C. Apperson

Department of Entomology, North Carolina State University, Raleigh, NC

TERMITES
Blowing Rock, Tanglewood, Pinehurst

Moderator
Michelle Smith
Dow AgroSciences

**FIELD STUDIES USING SIGHTS AND SOUNDS FOR LOCATING
TERMITES WITH MINIMAL DISTURBANCE**

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Abstract: Methods currently used to locate termites involve some sort of disturbance. A mud tube is broken, a monitoring device is opened and the inner contents removed, or a surface monitor is turned over in search of the insect. We conducted field studies on the campus of the University of Georgia, testing both the Pop-up and the Sentricon RTI Station detection devices.

**SUPPRESSION OF A SUBTERRANEAN TERMITE COMMUNITY.
(ISOPTERA, RHINOTERMITIDAE, *RETICULITERMES SPP*) USING THE
SENTRICON® TERMITE COLONY ELIMINATION SYSTEM: A CASE
STUDY IN CHATSWORTH, CALIFORNIA, USA**

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Abstract The RockPointe Condominium Complex in Chatsworth, California, USA, has had a long history of subterranean termite activity and termite-related homeowner complaints. A total of 7,327 Sentricon® stations were installed between October and December of 2001 along the perimeter of 134 buildings, and inspected monthly thereafter. Sentricon® stations with actively foraging termites present were immediately baited with hexaflumuron following label instructions. The active ingredient was changed to noviflumuron in April 2003. When feasible, auxiliary stations were installed adjacent to the active stations to increase the rate of station discovery and enhance bait consumption. Within two months of installation, 41% of the buildings had stations that revealed visual signs of subterranean termite activity. These stations were then baited. This percentage rose to 90% after 6 months and 95% after one year. A total of 423 auxiliary Sentricon® stations were installed between February 2001 and October 2003. Of the 7,327 Sentricon® stations initially installed, 12% had subterranean termite activity; 13% of the auxiliary stations became active. Comparing newly active stations between 2002 and 2003 resulted in 70% fewer Sentricon® stations with new activity, likely the result of baiting. Since March 2004, a few Sentricon® stations have become active. A reduction in resident's complaints of termites at the complex paralleled the reduction of termites in stations at the site. These results strongly suggest that the ongoing baiting program utilizing the Sentricon® Termite Colony Elimination System has had a significant impact on the subterranean termite population at this site.

Key Words termite baiting, hexaflumuron, noviflumuron, Recruit™ II, Recruit™ III

INTRODUCTION

Baits, using various active ingredients, are becoming increasingly available for the control of subterranean termites. In prior and current studies, our baiting research has involved field and laboratory studies in northern and southern California. We have been investigating the performance of the Sentricon® Termite Colony Elimination System since 1992, giving us long-term data on termite activity rates in stations (Lewis et al. 1998), foraging patterns (Haverty et al. 1999b); alate flight phenology (Haverty et al. 2003), and colony characteristics (Delphia et al. 2003; Getty and Haverty 1998; Getty et al. 2000a; Haverty et al. 1999a, 2000; Haverty and Nelson, 1997). This information has given us a unique regional perspective into the use and performance of baits for the control of subterranean termites.

The objective of this study was to gain insight into the performance of termite baiting, and specifically, the Sentricon® System, over a large, contiguous area with a history of termite activity and termite-related complaints by homeowners. Because the process of termites locating a bait station can vary from property to property based on factors such as termite foraging intensity, time of year, moisture, and food availability, a project site as large as the RockPointe townhouse complex was especially conducive to this type of study. Variations in all of these factors/conditions are prevalent at this site.

It is generally agreed that long-term, follow-up monitoring of a site is usually necessary to ensure that a baiting program was successful. Therefore, another important objective of our study was to observe the site over an extended period as it continued to be

serviced on a daily basis by a local pest management professional. We were further interested in determining how baiting multiple structures over an extended length of time affected homeowner complaints with respect to termite activity in and around residences.

METHODS AND MATERIALS

The RockPointe Townhouse Community is located in southern California in the city of Chatsworth, in Los Angeles County. The RockPointe Homeowners Association was incorporated in February 1969 with the construction in seven development phases the last of which was completed in 1979.

Fifty-four of the RockPointe property's 90 acres consist of common areas and greenbelts. There are a total of 139 buildings with 1.5 million square feet of property under roof. One hundred thirty two buildings are residential structures, containing 739 units which are home to over 2,600 people. The average linear perimeter of a building is 439 feet, with the total perimeter linear footage of the buildings estimated to be 59,714 feet or the equivalent of 18.2 km (11.3 mi).

Sentricon[®] station installation occurred from October through December 2001. Terminix International (21113 Superior Street, Chatsworth, CA 91311) installed Sentricon[®] stations around 134 of the 139 buildings. Three additional buildings had previously been treated by installation of Sentricon[®] stations in May 1999. These three buildings are included in this report.

Initially, 7,327 Sentricon[®] stations were installed, with a mean number of 54 stations installed per building. All Sentricon[®] Stations were inspected monthly throughout the study. This monthly monitoring was the responsibility of one Terminix technician. Halfway through the project the original technician left the company and was replaced by another who has serviced the property to date.

At each monthly inspection, all stations are manually opened and serviced following label instructions. When a Sentricon[®] station contained active termites, wood monitoring devices inside the station were removed, the live termites were placed into a moistened bait tube (containing either hexaflumuron or noviflumuron), and the bait tube was inserted into the station. From the initiation of the study through March 2003, 0.5% hexaflumuron (Recruit[™] II) was used as the active bait ingredient. From April 2003 to date, 0.5% noviflumuron (Recruit[™] III), has been the active bait ingredient. Noviflumuron, a new active ingredient developed by researchers at Dow AgroSciences LLC, has been under field investigation since 1998 and was registered by the U.S. Environmental Protection Agency in May 2003. It is similar in chemical composition to hexaflumuron and has been demonstrated to be 50% more effective than hexaflumuron in achieving colony elimination (Karr et al. 2004).

When feasible, auxillary stations were installed per label instructions around any Sentricon[®] station found with termites during an inspection. The protocol required that

two additional Sentricon® stations be placed around an active Sentricon® station with the intent of enhancing the rate of station discovery and bait consumption by termites.

After each inspection period, monthly service tickets for each structure and all Sentricon® stations were copied and forwarded to researchers at the University of California, Berkeley. All pest problems experienced by the RockPointe residents were reported to the Homeowner Association office, which generated a complaint record that was passed on to the Terminix office. Terminix would then send/dispatch a technician to the property in question to determine the nature and extent of the problem. The original complaint and the technician's feedback were supplied to the University of California, Berkeley and allowed us to follow the trends in homeowner complaints.

RESULTS AND DISCUSSION

Termite activity at the RockPointe Complex was substantial. Within two months of the initial Sentricon® station installation, 41% of the buildings had Sentricon® stations with termite activity that were subsequently baited with active ingredient; after 6 months, this number rose to 90% (Figure 1). Within one year of site installation, 95% of the buildings had some measure of termite activity within their respective Sentricon® stations (Figures 2 and 3). This activity rate rose to 97% by August 2003 when Sentricon® stations around three additional buildings became active with termites.

When analyzing overall activity rates of all Sentricon® stations installed, 878 of 7327 (12%) became active with termites, and were subsequently baited, within the first year of installation (Figure 3). This level of activity is typical of our California research sites over the last ten years. The mean/median number of days to termite activity was detected in a Sentricon® station was 153/105, respectively. Eighty three percent (727 of 878) of the active stations were successfully baited within the first year of installation. Successful baiting was defined as a newly active station that continued to contain actively foraging termites and at least 5% bait matrix consumption at the first 30-d, post-baiting inspection. If there was less than 5% consumption and no termites were present at the 30-d inspection, the station was considered abandoned.

In March 2002 it was discovered that the addition of a high-sugar-content sports drink to a bait station (prior to inserting the bait tube), and to the bait matrix itself, reduced the overall station abandonment rate by termites from 54% to 6% at this site. Similar results have also been recorded at our other research sites, in both northern and southern California (Neese et al. 2004). We do not have any direct evidence that the addition of a sports drink attracts termites to a station. However, their tendency to abandon a bait tube once they discover it was significantly reduced with the addition of sports drink.

Several Sentricon® stations continued to contain termites or showed evidence of continuous feeding on the matrix subsequent to being baited with active ingredient. In these cases, colony elimination for a station was defined as three consecutive monthly inspections after which no termites or new bait consumption was observed (i.e. the station was considered successfully baited). Some stations became active with termites after a station was declared successfully baited and the colony eliminated. This

occurred in 120 (14%) of the stations within the first year after installation. These stations were re-baited with active ingredient. It should be noted that neither colony size and dispersion (Haverty et al. 2000) nor affiliations (Haverty and Nelson 1997; Delphia et al. 2003; Getty et al. 2000a) were determined in this study. Getty et al. (2000b) showed that a Sentricon[®] station or other monitoring station can become re-invaded by a new colony as early as 12 days after a previous colony vacates or is eliminated from a station. Therefore, one must be cautious in implying that the same termite colony has returned to a station after multiple, successful baitings of that station.

The most accurate measure of a baiting system's effectiveness in providing control and long term protection of a site from termites is to follow the progression of activity in the number of monitoring stations over time (Su 1994, 2003) (Figure 3). In addition to the 7,327 Sentricon[®] stations originally installed, an additional 423 auxillary Sentricon[®] stations were added between February 2001 thru August 2004, 54 (13%) of which became active and were subsequently baited during the course of the study. The number of newly infested stations declined substantially in 2003, apparently due to a successful baiting program, with a 70% reduction in new activity between 2002 and 2003 and a negligible number of newly active Sentricon[®] stations by August 2003 (Figure 3). Paralleling this trend in the reduced numbers stations at the site with termite activity was a reduction in complaints of termite-related issues from residents at the complex.

Fifteen to 20 complaints about subterranean termite problems were received prior to the installation of the Sentricon[®] Termite Colony Elimination System at RockPointe. By June 2003 this number dropped to 5 to 7 calls per month, and as of August 2004 there have been fewer than one complaint per month. In addition, alate flights which typically have regularly occurred twice a year have significantly declined at this site (Haverty et al. 2003).

The effects of baiting on termite activity over the course of this study have been similar to the foraging patterns observed in both northern (Haverty et al. 1999b) and southern California (Haagsma and Rust 1995). Foraging activity typically increases rapidly during the late winter/spring months and declines in the late fall/early winter. This pattern was observed during 2002 and 2003; however, the total numbers of newly active stations were severely reduced in 2003, so this pattern was less evident. In 2004, the expected increase never occurred because few newly active stations were recorded. These results suggest that the continuous baiting program, utilizing the Sentricon[®] System, has had a significant impact on the termite community at this site.

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SEASONAL VARIATION IN TIME TO TERMITE COLONY ELIMINATION USING RECRUIT™ IV BAIT IN OHIO

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Recruit™ IV bait was evaluated against structural infestations of the eastern subterranean termite, *Reticulitermes flavipes*, in central Ohio. During May and June 2004, studies were initiated at five test structures, including four residences and one commercial building. We used dyed cellulose tubes and genetic analyses to determine that a total of 12 termite colonies were in very close proximity to these structures.

Recruit™ IV bait was installed in July - November 2004, April - July 2005, and March 2006 (results not reported herein). A quarterly monitoring schedule was simulated wherein intensive evaluations were conducted at 90-day intervals after bait was installed, with intervening monthly inspections to note only the presence or absence of termites at stations. At each 90-day evaluation period, we estimated the number of termites and amount of bait that had been consumed, and any new bait tubes were installed. Colony elimination was declared when no additional cellulose matrix was consumed and no live termites were present for three successive monthly inspections (excluding the winter months due to inclement weather).

It took an average of 4.2 months (n = 6) to achieve colony elimination when baiting with Recruit™ IV was initiated between April and July, and 5.8 months (n = 5) when colonies were baited in September through November. This study indicates that Recruit™ IV bait effectively controlled termites in Ohio, but seasonal differences in time to colony elimination were evident depending on when the bait was installed.

EFFICACY OF THE ADVANCE® TERMITE BAIT SYSTEM IN OHIO

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Field trials with the Advance® termite bait system (ATBS) were initiated in Columbus, Ohio (Franklin County) during April 2005. In-ground stations were placed at ~15 ft intervals encircling four structures (3 residential [*Middle, Stin, Can*], 1 commercial

[*City*]), each of which had an active subterranean termite infestation (*Reticulitermes flavipes*). Stations were inspected monthly except during winter. Once termite activity was noted in the blank cellulose monitoring cartridge housed within a station, a replacement cartridge containing Advance[®] bait (active ingredient, 0.25% diflubenzuron) was installed.

Termites quickly occupied ATBS monitoring stations, with at least one infested station noted 1 to 2 months after station installation at all four sites. The greatest initial termite activity in such stations was noted at *Middle*, with termites occupying four stations at the 1-month inspection. During the subsequent baiting phase, termites infested additional monitoring stations at all sites, which allowed the installation of additional bait cartridges.

Termites readily consumed the Advance[®] bait matrix, resulting in a relatively rapid decline then cessation of termite activity, typically within several months. Furthermore, soldier head capsules occasionally were noted in the wood monitoring base housed within baited stations, apparently due to the adverse effects of the chitin synthesis inhibitor. At *Middle*, termites consumed a total of 4 bait cartridges between late May and August 2005, with no further evidence of termites noted in or around the structure; hence, termite elimination was achieved within ~3 months. It took ~6 months for termite elimination at *Stin*, where termites fed on 2.1 bait cartridges between May and November 2005. At *Can*, termites consumed a total of 2.4 bait cartridges between June and November 2005, resulting in colony elimination in ~5 months. Despite the presence of swarmers during spring 2005 and other years prior to baiting with ATBS at *Middle*, *Stin*, and *Can*, no swarmers were observed during spring 2006. Also, after baiting with ATBS, no further evidence of termite activity indoors has been found during periodic inspections of the three structures. The situation at *City* requires additional study because termites have been found at 8 of 23 stations, and preliminary genetic analyses indicate that two termite colonies are associated with the site.

This study is on-going, and follow-up inspections will be conducted for 1 year after the cessation of termite activity at each site. These preliminary data indicate that the Advance[®] termite bait system shows efficacy against *R. flavipes*, which readily occupy stations and consume the bait matrix resulting in colony elimination.

THE INFLUENCE OF THE TRANSMISSION OF ACETAMIPRID ON THE MORTALITY OF SUBTERRANEAN TERMITE POPULATIONS

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FMC Corporation

In the laboratory, populations of the subterranean termites *Reticulitermes flavipes* and *Coptotermes formosanus* were exposed to fine chalk particles treated with acetamiprid.

The movement of the particles and the resulting termite mortality was measured through time.

THE IMPACT OF IMIDACLOPRID ON SUBTERRANEAN TERMITE (*RETICULITERMES* SPP.) COLONIES LOCATED INSIDE AND AROUND RESIDENTIAL STRUCTURES IN CENTRAL NORTH CAROLINA

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| This ongoing study in central North Carolina is using DNA genotyping and long term monitoring to observe the immediate and prolonged effects of imidacloprid on subterranean termite colonies (*Reticulitermes* spp.) located inside and around residential structures. A set of 11 termite-infested houses in Raleigh, NC with active and accessible termites were selected for study and placed into a multi-year monitoring program. Termite infestations inside and around each house were extensively monitored and genotyped at 10 microsatellite loci to determine colony identity for a period of several months before treatment to develop a map of colony location and activity across each property. A licensed PMP applied imidacloprid as a liquid treatment (Premise® 75 WSP) at 0.05% by trenching and rodding around the outside of the foundation, and in some cases making limited interior applications. Early results collected during the pretreatment phase showed numerous termite colonies (up to 15) across these residential properties and that attacks on a single house can originate from two different colonies simultaneously. The most expansive termite colonies were those located inside the structure and which frequently extended along the foundation, out into the yard and into the undisturbed natural areas. The application of imidacloprid resulted in a rapid decline of termites inside each building with complete elimination of all known interior infestations within 26 d on average (range = 6 - 85 d). Soil monitors close to the foundation showed a rapid decline in termite activity after treatment: 90% reduction by 14 d, 98% reduction by 30 d and >99% reduction by 180 d. It appeared that some termite colonies detected in the outer ring of monitors located 3 to 15 m from the foundation, and distinct from colonies inside the structure, were also impacted by the treatment. All houses remain termite free as of the most current inspections, ranging from 14-24 months post treatment. Long-term monitoring and genotyping over the next 1-2 yr will provide the best assessment of the effect of imidacloprid on the original termite colonies present at each site and the effect on new colonies that may try to recolonize the study area following application. The current status of results will be reported.

Key Words Microsatellite markers, Premise, efficacy, colony elimination

USE OF FIPRONIL IN EXTERIOR PERIMETER-LOCALIZED INTERIOR TREATMENTS FOR SUBTERRANEAN TERMITE CONTROL IN NEW MEXICO

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The excellent termite activity of fipronil (Termidor brand) was first discovered in 1997. Field research trials conducted under Experimental Use Permits produced the first data showing that fipronil had effects on termites distant from the treated area. Following this discovery, several homes were treated as exterior perimeter only treatments, or as exterior perimeter plus local interior treatments. Based on these studies, and field trials from urban entomology researchers, the activity of Termidor on termites remote from the treatment site was confirmed. However, data on the efficacy of Termidor on structures actively infested with *Reticulitermes tibialis* banks were limited. In 2005, six single family homes infested with *R. tibialis* were identified in New Mexico. Termidor treatments utilizing Exterior Perimeter (EP)/Localized Interior (LI) Directions for use listed on the Termidor SC and WG labels were performed. All homes had active infestations with at least one active interior site that required at least one localized interior treatment. Applications were performed by licensed pest management professionals under the supervision of an industry consultant. Pre- and post-treatment site inspections were conducted by North & Root Consulting. All structures were to be monitored at two-month intervals through two years post treatment. Data are currently being collected on different home construction types, sites and environmental conditions. Results at approximately one year post treatment show excellent efficacy of Termidor. All homes that received the EP and LI treatments have exhibited 100% termite contr support for use against other subterranean termites. ol to date. These data provide direct support for the continued use of Termidor EP/LI treatments by the pest management industry for use on *R. tibialis* and indirect

STRUCTURAL AND GENERAL PEST CONTROL CERTIFICATION IN OKLAHOMA

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Oklahoma State University

The need for a regional facility for structural and general pest control education was identified during the early 1980s. Since the first class was held for the Practical for structural applicators (March 19, 20 and 21 of 2002, 350 applicators have attended one of the structural practicals. The General Pest Control Practical has been attended by 180 applicators since the first class on July 6, 2004, and the Fumigation Practical has been attended by 90 applicators since the first class in 2003. States that are represented by one or more applicators in attendance at either practical are Oklahoma, Kansas, New Mexico, Arkansas and Texas. Oklahoma State University has also held

two workshops for the national sales forces for Whitmire Micro-Gen and BASF. During the classes OSU covered topics from basic termite biology to advanced liquid termiticides. Also presented in both workshops were the laws, rules, and minimum standards for termite control work for Oklahoma.

The need for a regional facility for urban pest control was identified during the early 1980s by Oklahoma State University faculty members in urban entomology and personnel of the Oklahoma Department Agriculture Food and Forestry (ODAFF) Pesticide Division. According to ODAFF records, during the 1980s structural complaints accounted for approximately 50% of all complaints registered with the Department of Agriculture, Food and Forestry. And, of that 50%, more than 40% involved problems with Wood Infestation Reports.

To help deal with these complaints, ODAFF formed a committee to address problems with liquid termiticide pretreatments. The recommendations of this committee were increased enforcement and several educational programs detailing both label requirements and state laws and regulations. As a result of increased termite pretreatment enforcement, there was an increase in complaints and violations of commercial and residential pretreats and a steady stream of post construction complaints. ODAFF's Board became very aware of the Structural Pest control operators representing the vast majority of complaint resolutions. ODAFF conducted a tank sampling "Blitz" in the Metropolitan areas of Oklahoma & Tulsa. ODAFF along with OPCA and OSU formed a committee to draft a Wood Infestation Report form to be used by every Structural Pest Control Operator.

Sandy Wells (ODAFF) garnered funds for construction of a facility to educate applicators doing termite jobs. OSU garnered funds from the pest control industry by approaching the manufacturers and convincing them to support this facility. ODAFF & OSU personnel traveled to Texas, Louisiana, Georgia, South Carolina and Indiana to see what their personal were doing at their respective facilities. ODAFF inspectors & OSU personnel attended a structural class at the Louisiana facility.

ODAFF & OSU cooperatively came up with a design for the OSU structural facility. The first part was the foundations, steps, fireplace, etc. The second part was obtaining a house for both classroom and inspection purposes. Primary funding for this facility was through the Department of Agriculture, Food and Forestry. Other funding sources were Pesticide Registrants, Pesticide Distributors, Oklahoma Pest Control Association, State and Federal Grants and Registration Fees

The number of students enrolling in Structural Pest Practical - 350, General Pest/Food Processing Practical - 180, Fumigation Practical - 90. Sixteen ODAFF Inspectors have attended all three practicals and 7 OSU Staff/Students have attended both the Structural and General Pest Practical. States that have had applicators enroll in the practical are Oklahoma, Kansas, New Mexico, Arkansas, Texas and two students from Saudi Arabia.

In 2005, structural complaints were approximately 43% of the total number of pesticide complaints. Of that 43%, Wood Infestation Reports accounted for 19%. Also in 2005, total structural complaints were down to 100 complaints compared to 360 in the mid 1980's. A drop of approximately 72% as illustrated in figure 1.

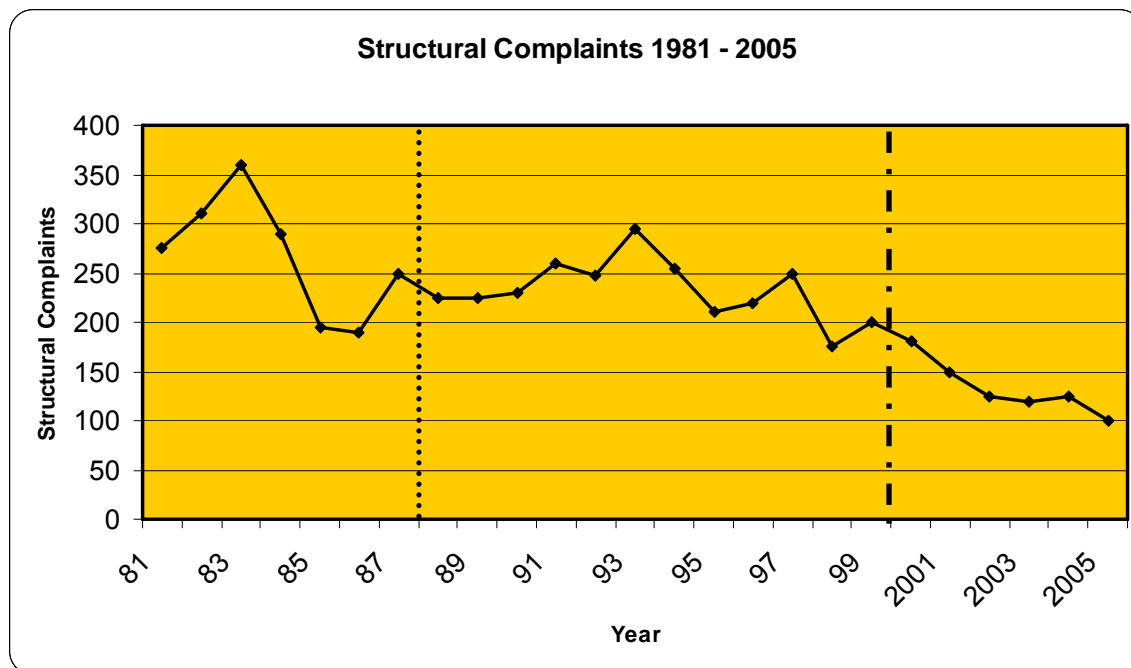


Fig. 1. Structural Complaints from 1981 through 2005

School is very much a "hands on" activity. Topics covered in class are calibration and structure identification, rodding and trenching techniques. The class is approximately ½ inside and ½ outside with focus on liquid application techniques as well as baits, barriers & identification. Much of the inside classroom time deals with Minimum Standards, Laws and Regulations.

Future plans for expansion of the Facility will include hands on classes in Ornamental and Turf, Right of Way, Agricultural Programs and Public Health categories.

Comments from the Oklahoma Department of Agriculture, Food and Forestry.

We saw a full year of activity at the Pinkston Educational Facility. It could possibly be stated that this is the single most important accomplishment that we have achieved in recent times. It is believed that this will do more to educate the pest control industry and develop consistency among Department staff members than all efforts combined previously. This is not meant to replace what we have accomplished with compliance meeting and administrative penalties. It is meant to extend the olive branch to concerned applicators and pest control organizations. Through education and allowing industry to view our own activities and concerns, we believe a strong bond can develop to create a partnership to address future issues and concerns.

The Pinkston Educational Facility continues to be a huge success. Classes have remained full and we have even conducted back-to-back sessions in March and April of this year. Industry remains high in the support of this training effort. We are currently seeing applicators compelled to attend the training as a result of informal resolution to administrative penalties. Success with this program involving structural pests has caused us to propose similar training facilities for fumigation, general pest and food processing. Oklahoma State University has agreed to establish training facilities for fumigation in FY-03 and general pest and food processing in FY-04.

URBAN AND PUBLIC HEALTH Chimney Rock

**Moderator
Dawn Calibeo-Hayes
BASF Corporation**

ASPECTS OF CREVICE PREFERENCE BY RECLUSE SPIDERS, *LOXOSCELES* SPP. (ARANEAE: SICARIIDAE)

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The medically important spiders of the genus *Loxosceles* include the infamous brown recluse spider, *L. reclusa* Gertsch and Mulaik in North America, and *L. laeta* (Nicolet) from South America. Both species are frequently implicated in necrotic (i.e., rotting flesh) skin lesions on their respective continents. Control of these spiders is difficult because they are found in high density in human structures and hide in crevices that are hard to reach with insecticide. Because of this, in North America, pest control operators typically do not guarantee eradication of *Loxosceles* spiders. Despite the spiders' infamy, very little research exists on their life history characteristics or pest control measures. At abstract submission, work has only been performed on the South American *L. laeta*, reared from Los Angeles specimens. Results to date show that *L. laeta* will choose most crevice sizes offered as long as they can fit inside, therefore, crevice size is not critical in designing pest control devices. Vertical crevice orientation is preferred over horizontal. *L. laeta* spiders also shift from one crevice to another of similar size over a several weeks indicating that they do not show extreme site fidelity, meaning that they might be easily attracted to a control station. Our studies should allow us to generate information, which will be useful in designing traps or insecticide stations as control devices for *Loxosceles* spiders.

REDUCING COCKROACH ALLERGENS IN INFESTED HOMES: CAN THE PMP MAKE A DIFFERENCE?

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Cockroaches, first linked to allergic disease in 1964 (Bernton and Brown 1964), produce several allergens exposure and sensitization to which are associated with the development of acute asthma morbidity. This is particularly important in urban homes where German cockroach infestations can be troublesome and quite severe. Approximately 26% of the U.S. population, aged 6 to 59, is allergic to German cockroaches (Arbes et al. 2005). An estimated 37% of inner-city, asthmatic children are allergic to cockroaches and these children have significantly more incidences of medical utilizations (e.g., asthma-related hospitalization, unscheduled physician office visit) and asthma-related morbidity (e.g., wheezing, school absenteeism) than other groups (Rosenstreich et al. 1997). Among cockroach allergic individuals, 30–47% are specifically allergic to *Blattella germanica* allergen 1 (Bla g 1) (Arruda et al. 1995).

A central tenet of asthma intervention is to minimize exposure through allergen reduction; this strategy has been shown to reduce asthma morbidity with other indoor allergens. Until recently, however, there has been little evidence that environmental intervention could attain long-term, clinically relevant reductions of cockroach allergens in infested homes. In 2003, we demonstrated, in a 6-month intervention, that combined integrated cockroach control using gel baits and extensive cockroach monitoring, resident education, and professional cleaning in Raleigh, North Carolina homes could reduce cockroach allergen Bla g 1 levels by 96% and below clinically relevant thresholds (Arbes et al. 2003). However, this experimental design could not separate which of the three intervention strategies was key to the observed effects. Therefore, in a 6-month continuation of the first study, the non-intervention control homes now received the intensive, targeted insecticide bait treatment, while the intervention homes continued to receive this treatment on an intermittent, “as-needed” basis guided by population monitoring; neither treatment group received professional cleaning or resident education. As expected, low Bla g1 levels persisted to month 12 in the original intervention homes with minimal, monitoring-guided intervention (Arbes et al. 2004). Both the cockroach populations and environmental Bla g 1 levels declined dramatically (93% and 95%, respectively), and at the conclusion of the study the Bla g 1 levels in homes receiving only insecticide bait were not different from those attained over 6 months in homes receiving the combined intervention in months 0–6. These results showed that monitoring-guided cockroach control alone could reduce environmental allergens below the proposed exposure thresholds.

The paradox of cockroach allergen mitigation studies is why numerous interventions involving professional and residential pest control have generally reduced allergens only marginally, yet our two studies, consisting of three independent interventions (Arbes et al. 2003, Arbes et al. 2004), resulted in highly effective reductions in both cockroaches and cockroach allergens. To address this, we evaluated the effectiveness of professional pest management in reducing cockroach allergens. German cockroach infested homes in Raleigh, NC were randomly assigned to an untreated control group or one of two treatment groups: homes treated with insecticide baits by NC State University research personnel following previously established protocols (Arbes et al. 2003, Arbes et al. 2004), and the others treated by a professional pest control company under an annual service contract. Cockroach populations were assessed using sticky traps deployed over three nights in the kitchen, living room, and a bedroom. Allergen levels were measured by ELISA in vacuumed dust samples collected from the kitchen, living room, bedroom floors, and the bedroom bed. Dust sampling and cockroach trapping were conducted at baseline prior to treatments and at the conclusion of the 12-month study.

Cockroach populations in homes treated by NCSU researchers were significantly reduced from baseline to months 6 and 12 compared to both untreated control and commercially treated homes; compared to controls, significant reductions were observed in commercially treated homes only by month 12 (Sever et al, unpublished results). Between the baseline assessment and month 6, Bla g 1 levels were significantly reduced in the living room and bedroom bed of both researcher- and commercially-treated homes when compared to controls; in the kitchens significant reductions in Bla g 1 were observed only in homes treated by researchers. Allergen reductions in the kitchen and living room were significantly greater in researcher-treated homes than in commercially-treated homes. By month 12, significant Bla g 1 reductions were achieved in all rooms of researcher-treated homes compared to untreated controls, whereas in commercially-treated homes allergen levels were significantly reduced only in the bed, bedroom floor, and living room compared to untreated controls; after 12 months the researcher intervention reduced allergens significantly more than the commercial intervention in the kitchens and living rooms (Sever et al, unpublished results).

This study again confirmed that cockroach management alone using insecticidal bait formulations can reduce environmental cockroach allergen levels in homes below clinically relevant thresholds. Furthermore, it demonstrated that current pest management practices employed by the professional pest control services in this study provided only modest cockroach population reductions compared to the intensive, extensive, and targeted treatments by research personnel. As a result, professional pest services managed only moderate allergen reductions compared to the large-scale reductions in homes treated by researchers. Thus, we suggest that the magnitude of the cockroach allergen reductions is likely dependent upon several factors, including technical expertise, the intensity and quality of the service, and the products used for cockroach management. Most of all, even when pest management professionals make appropriate choices of tactics to deploy in infested homes, they are severely

constrained by economic considerations, including time spent gaining access to apartments, time and cost of materials required for extensive whole-house monitoring and treatments, language barriers, and cooperation of residents. Nonetheless, recent evidence from the Inner City Asthma Study (ICAS) suggests that even modest reductions in German cockroach allergens on the bedroom floor (64%) and bed (51%) in the homes of cockroach allergic children can result in significant improvements in asthma morbidity and medical utilizations (Morgan et al. 2004).

The relationships among cockroach population reduction, cockroach allergen reduction and health outcomes of reduced exposure of cockroach allergic children are poorly understood. The results of the ICAS study, showing significant improvements in children's health with only modest allergen reductions (cockroaches were not monitored), suggest that the >95% cockroach and allergen reductions in our recent studies would result in even greater health improvements. Our ongoing studies aim to investigate the health benefits to cockroach-allergic children of an intensive cockroach-targeted home intervention.

Acknowledgements. Funding for these studies was provided by the NIEHS Division of Intramural Research and the National Center for Minority Health and Health Disparities. The Blanton J. Whitmore Endowment provided partial support for the North Carolina State University team. J.C.G. received a Scholarship and a Fellowship in Urban Entomology Structural Pest Management from the North Carolina Pest Control Association, a Graduate Scholarship from Pi Chi Omega, and Bayer Environmental Science's 2004 Young Scientist of the Year Award.

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EFFICACY OF IMIDACLOPRID WG 10 AGAINST THE LARGER HOUSE FLY *MUSCA DOMESTICA* L. AND OTHER INSECTS WITH SPECIAL REGARD TO URBAN PEST CONTROL

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The development of new compounds with oral action encourages the development of baits against insect pests. Imidacloprid, which belongs to the chloronicotinyl class of compounds, has shown great potential as active ingredient, when it is ingested and its use is seen as an important contribution in pest control particularly against flies and cockroaches (Londershausen 1996).

Sugar based granule formulations with imidacloprid have already been developed as excellent bait products against the larger housefly *Musca domestica* L. and other pests which feed on sugar (Maxforce^{®1} and QuickBayt^{®1} FlyBait) (Pospischil & Junkersdorf 2002). Imidacloprid WG 10, a sprayable bait, was developed as a sugar based spray to meet the requirements of the farmers for fly control in livestock facilities and of pest management professionals for fly control in urban areas.

Imidacloprid WG 10 consists of a water dispersible granule formulation based on sugar with 10.0 % (w/w) imidacloprid (CAS no.: 138261-41-3). The attractiveness of the bait is increased by the pheromone Z(9)-tricosene (0.1%) and LEJ 179 (0.25%), which acts as a flavoring agent. The product contains Bitrex^{®2} (0.01%) which may help to prevent accidental ingestion by people. Imidacloprid WG 10 can be used as a spray or as a paint-on application.

In contrast to residual contact insecticides imidacloprid WG 10 needs only be applied to surface areas, which are preferred by the flies particularly during their activity phase. The efficacy of Imidacloprid WG 10 is characterized by a fast knock down and high attractiveness for flies over a period of several weeks. Good results have also been found in fly populations with a high resistance level for organophosphates and pyrethroids.

The efficacy of imidacloprid WG 10 (application rate: 250g formulation in two liter water per 100m² ground size) was assessed in numerous trials under practical conditions in livestock and around dumpsters in urban areas. The product remained attractive for house flies (*Musca domestica*) over a period of several weeks and affected or killed flies were observed under field conditions up to six weeks after application in livestock and up to 14 days around dumpsters in urban environments (Pospischil et al. 2005). Efficacy of imidacloprid WG 10 during application was also found against other fly species and cockroaches, and further laboratory trials were carried out to assess the suitability of the product also against fly species with economic importance in pest control, like the vinegar fly *Drosophila melanogaster* Meigen, stable fly *Stomoxys calcitrans* (L.), garbage fly *Hydrotaea aenescens* (Wiedemann) and the sheep blowfly *Lucilia cuprina* (Wiedemann). The trials were carried out in test chambers with a size of 0.5 m³. 250g of the formulation were mixed with two liter of water and five gram of the spray suspension were sprayed onto a flake board (size: 50 x 50 cm) with a pressure sprayer.

These boards were dried and placed vertically at the back wall of the test chambers. One day later 100 flies were released into each chamber and the mortality was assessed after 10, 30 and 60 minutes and after four and 20 hours.

Imidacloprid WG 10 achieved 66% reduction of *D. melanogaster* after four hours and 88% after 20 hours, respectively. 58% mortality was found against *L. cuprina* after 20 hours. The onset of efficacy was slow against *S. calcitrans* with 11% reduction after four hours. However, the mortality was 59% after 20 hours even against this blood sucking species. 42% mortality was achieved against *H. aenescens* after 20 hours (tab. 1).

Tab. 1. Efficacy of imidacloprid WG 10 against flies (Diptera) (others than *Musca domestica*) in the laboratory

Species	% reduction			Untreated control		
	1 hour	4 hours	20 hours	1 hour	4 hours	20 hours
<i>Drosophila melanogaster</i>	20	66	88	0	0	7
<i>Lucilia cuprina</i>	10	25	58	0	0	8
<i>Hydrotaea aenescens</i>	13	20	42	0	1	11
<i>Stomoxys calcitrans</i>	5	11	59	0	0	22

The efficacy of imidacloprid WG 10 was confirmed by field trials against different fly species in pig stables in Germany.

In four stables which were heavily infested with the vinegar fly species *Drosophila repleta* a reduction from more than 1000 flies per m² (pre-count) to less than 10 flies per m² at one week after application was found (= 99% reduction). The fly population declined further during the following five weeks to less than one fly per m². The garbage fly *Hydrotaea aenescens* was reduced from 100 flies per m² to 20 flies per m² at one

week after treatment and to one to four flies per m² at two to six weeks, respectively. A residual activity of imidacloprid WG 10 was even found against the blood sucking stable fly *Stomoxys calcitrans*. The fly numbers of this species declined from 42 flies per sticky trap to 27 flies at day one (= 35.4% reduction) after treatment and remained between 16 to 12 flies from two days to 4 weeks after treatment (tab. 2).

Tab. 2. Efficacy of imidacloprid WG 10 against flies (Diptera) (others than *Musca domestica*) in pig stables

Species	% reduction							
	1	2	3 DAT	1	2	3	4	6 WAT
<i>Drosophila repleta</i>	n.d.	n.d.	n.d.	99.0	99.5	99.5	99.9	99.9
<i>Hydrotaea aenescens</i>	n.d.	n.d.	n.d.	80.0	96.0	97.0	99.0	97.0
<i>Stomoxys calcitrans</i>	35.4	62.2	73.6	n.d.	67.7	n.d.	74.0	n.d.

DAT: days after treatment; WAT: weeks after treatment; n.d.: not determined

During a field trial with imidacloprid WG 10 in Pretoria (Republic South Africa) against flies in pig stables many dead American cockroaches *Periplaneta americana* (L.) and some German cockroaches *Blattella germanica* (L.) were found one day after application. The efficacy of imidacloprid WG 10 (dose rate 250mg active ingredient per m²) was therefore tested on glazed tiles against these species and additionally against Oriental cockroaches *Blatta orientalis* L. (tab. 3). The insects were placed on the wet surfaces directly after application and on the dried surfaces one day after treatment. The Oriental cockroaches were tested on wet surfaces only.

Imidacloprid WG 10 achieved 100% mortality against American cockroaches on dried surfaces, but showed only low effect against German cockroaches on these surfaces. However, 100% mortality was found on wet surfaces within one hour (German and American cockroaches) and two hours (Oriental cockroaches), respectively.

Tab. 3. Efficacy of imidacloprid WG 10 against cockroaches (Blattodea) in the laboratory

Species	% reduction on wet surfaces			
	1 hour	2 hours	3 hours	6 hours
<i>Blattella germanica</i>	100	100	100	100
<i>Periplaneta americana</i>	100	100	100	100
<i>Blatta orientalis</i>	90	100	100	100
(Untreated control: 0 mortality after 24 hours)				
Species	% reduction on 1 day old dried surfaces			
	1 hour	2 hours	3 hours	6 hours
<i>Blattella germanica</i>	0	0	0	7
<i>Periplaneta americana</i>	20	80	100	100
(Untreated control: 0 mortality after 24 hours)				

Imidacloprid WG 10 sprayed at 250g in two liter water per 100m² ground floor area exhibited a fast initial knock down effect and a residual efficacy up to six weeks against *Musca domestica* in livestock, and outdoors in professional pest management up to 14 days, respectively. Efficacy was also demonstrated against other fly species (e.g. *Drosophila spec.*, *Stomoxys calcitrans*, *Hydrotaea aenescens*, and *Lucilia cuprina*) and cockroaches (*Blattella germanica*, *Periplaneta americana* and *Blatta orientalis*) in the laboratory, livestock, and urban environments.

The results from numerous field trials on farms and around dumpsters confirmed the potential of imidacloprid WG 10 as effective new pest control formulation. The bait product can be applied as spot treatment or paint-on and acts mainly through oral ingestion. Imidacloprid represents a different chemical class in fly control.

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¹ QuickBayt® = Trademark of Bayer CropScience AG, Monheim, Germany, and brand name of Bayer Environmental Science

² Bitrex® = Trademark of Macfarlan-Smith Limited

EFFICACY OF CHLORFENAPYR (PHANTOM) AS A SURFACE SPRAY IN CONTROLLING KEY PESTS FOUND IN FOOD HANDLING AND STORAGE FACILITIES

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Phantom, active ingredient Chlorfenapyr, is an insecticide labeled for use inside commercial food handling establishments. In addition to ants and cockroaches, there are other economically important pests found in these accounts. The research summarized here includes observed activity on three of these pests, including red flour beetles, confused flour beetles, and fruit flies. The beetles were tested at a constant rate of 0.11mg AI per sq. cm on concrete, vinyl, and wood. The adult beetles were exposed to the treated, dried surfaces for either two or four hours, transferred over to a clean test chamber, and mortality observed. Both species were successfully controlled by Phantom, but a four-hour exposure time increased speed of control. In addition, control was best on concrete, followed by vinyl tile, and finally concrete. Future research will include a dose titration, as well as effects of time and temperature on performance. Fruit fly larvae were controlled by a direct application of Phantom to a media-filled test chamber. The rate equivalent was one gallon of 0.5% solution per 1500 sq. ft. Phantom significantly outperforms an industry-standard synthetic pyrethroid in suppressing adult emergence, with nearly 100% control.

METAFLUMIZONE: A SEMICARBAZONE INSECTICIDE FOR STRUCTURAL PEST CONTROL FROM BASF

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Metaflumizone is a new active ingredient from BASF that exhibits excellent activity on key urban insect pests (Hymenoptera, Isoptera, Dictyoptera, Lepidoptera, Coleoptera, Diptera, etc). No cross-resistance with existing products has been observed. Metaflumizone has a favorable toxicology and environmental profile and it is compatible with IPM and IRM practices. Excellent control has been observed in *Solenopsis invicta* ant bait trials performed at urban single-family homes. Broadcast and individual mound bait treatments both gave effective control of the *S. invicta* infestations. Metaflumizone provided very quick control, with most of its effects to the colony occurring within the first day post treatment. Mound treatments appeared to be the most efficient, but were not significantly different than Broadcast treatments. Spastic paralysis was noted during the treatments using metaflumizone bait, where foragers were immobilized on the

surface of the mound. This provided evidence of the fast action of this bait. Long-term control of red imported fire ant populations post treatment was also evident.

ADVION®: NEW BAIT PRODUCTS FOR THE PROFESSIONAL PEST MANAGEMENT INDUSTRY BY DUPONT PROFESSIONAL PRODUCTS

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DuPont Professional Products, 1090 Elkton Road, Newark, DE 19711

Indoxacarb is a new active ingredient being introduced into the pest management market by DuPont Professional Products. With a novel mode of action and in a new class of chemistry, Oxadiazines, Indoxacarb-based products will offer Pest Management Professionals a new set of tools for managing key urban pests. Advion Cockroach Gel is a superior-performing gel bait for all pest species of cockroach including hard-to-control, bait averse populations of german cockroach. The Advion Cockroach Bait Arena[™] offers the same great performance of Indoxacarb in a containerized station for more sensitive accounts. The Advion Ant Bait Arena[™] is also a containerized bait and contains Indoxacarb in a formulation appealing to most pest species of ants with particularly good performance on hard-to-manage Pharaoh's ants. Background on the Oxadiazine class of chemistry and the mode of action of Indoxacarb will be presented as well as a summary of efficacy trials on all three new product offerings.

USE OF VIKANE® GAS FUMIGANT FOR CONTROLLING STRUCTURAL AND HOUSEHOLD PESTS INFESTING UNIQUE STRUCTURES WITH UNIQUE CONTENTS AT THE UNIVERSITY OF FLORIDA, GAINESVILLE

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Two buildings on the University of Florida campus, Leigh Hall and the McGuire Center for Lepidoptera and Biodiversity, were fumigated with Vikane® gas fumigant (Dow AgroSciences, Indianapolis, IN) in 2004 and 2005, respectively. Both buildings contain irreplaceable materials of scientific interest. Leigh Hall, used for education and research by the Chemistry Department, contains specialized analytical equipment and an extensive repository of experimental chemicals. The McGuire Center contains the Florida Museum Lepidoptera collection with 4.2 million specimens. It is the largest Lepidoptera collection in the U.S., second only to The Natural History Museum in London.

The buildings were fumigated for insects that could not be controlled using other methods. Leigh Hall had repeated applications, documented since 1994, of dust, gel and liquid residual insecticides to control extensive drywood termite infestations. These treatments did not provide satisfactory control because the drywood termites infested areas inaccessible for localized treatment. The McGuire Center Lepidoptera collection is maintained using highest standards for entomological specimen preservation. Nonetheless, psocids infested the collection and resulted in increasing complaints of dermal irritation by the museum staff.

Both buildings were difficult to seal due to their large size and complex structural features. Leigh Hall is 1.4 million ft³, 4-stories in height with many exterior architectural elements that could be damaged by tarpaulins, including a tiled roof. It was built in 1927 and is listed on the National Register of Historic Places. The McGuire Center contains a living butterfly rainforest vivarium, educational exhibits, and 39,000 ft² of research laboratories and collection space. The McGuire Center is connected to Powell Hall, Florida Museum of Natural History (FLMNH), with a combined size of 4 million ft³.

Both buildings required the development of unique fumigation plans and fabrication of customized sealing materials. A whole-structure fumigation was conducted at Leigh Hall. Forty-two tarps of 22 sizes were prepared by American Tarp and Accessories to cover this building. The largest tarp measured 110 ft x 130 ft. Using large tarps minimized worker time on the roof and reduced the potential for tile damage. Rappelling equipment and three 120-ft man lifts were used by trained fumigation personnel to install the large tarps in areas inaccessible to ladders. Analysis of all current and historical blueprints of Leigh Hall and intensive site inspections determined the locations of conduits and an above-walkway that connected Leigh Hall to adjacent buildings and required sealing.

A compartmentalized fumigation was conducted at the McGuire Center. The Lepidoptera collection, located on the basement and first and second floors of the McGuire Center, occupies only 2% of the volume within the FMNH. The entire basement, with a self-contained air-handling system, no windows, and concrete walls, floor and ceiling, was sealed and fumigated. The collections on the first and second floors are housed in custom-designed, high-density mechanical storage compactor cabinets. The cabinets were covered with 40-ft wide, 6-mil polyethylene sheeting. Custom-made, 2-inch diameter sand snakes were placed in the narrow spaces between the cabinets and the walls to seal the polyethylene to the floor.

Selected items in each building required special preparation or removal prior to fumigation. The University of Florida conducted chamber fumigations using Vikane gas fumigant to determine the polymer liner configuration in 30-gallon drums that resulted in no detectable sulfuryl fluoride inside the drums. The lined drums were then used to store selected chemicals and equipment in Leigh Hall during the fumigation. Using the drums was more efficient than removing these items or double bagging them in Nylofume™ nylon-polymer bags, as referenced in the Vikane label. In the McGuire Center, an insect rearing room located adjacent to the fumigated collections is used to

rear the endangered Little Miami Blue butterfly (*Cyclargus thomasi bethunebaker*). All butterflies were removed to an off-site location prior to the fumigation.

Public safety was a priority when executing these fumigations. Powell Hall, connected to the McGuire Center, and the Chemistry Research Building (CRB), connected to Leigh Hall, were evacuated and secured with entrances posted with warning signs as if they were fumigated. The Vikane label requires the use of locking devices or barricades to prevent unauthorized entry into structures during fumigation. A wide variety of locking devices, such as J-locks, split keys, chains and padlocks, were used to secure Leigh Hall and CRB. Bolts drilled into doors that could not be secured by other means. In addition, barricades, plastic fencing, and safety ribbon were used to demarcate a bystander exclusion zone around the perimeter of Leigh Hall during fumigation preparation, exposure, and aeration. All exterior entrances to Powell Hall and the McGuire Center were rekeyed immediately prior to fumigation so only the fumigator had access to the buildings. The fumigations were conducted over Thanksgiving when students, faculty, and staff were on holiday and Powell Hall was closed to the public.

The pounds of Vikane to introduce were calculated using the Fumiguide™ electronic calculator (Dow AgroSciences, Indianapolis, IN). All label directions were followed for introducing the warning agent, chloropicrin, and Vikane. Multiple fumigant introduction hoses were required inside each building; thirty in Leigh Hall and five in the McGuire Center (representing each compartmentalized fumigation space). After introduction, fumigant concentrations were measured using Model D Fumiscopes (Key Chemical and Equipment Co, Clearwater, FL). A vacuum pump was used to draw air samples through the ¼-inch ID monitoring hoses placed in sixteen locations in Leigh Hall and in the five compartmentalized fumigations in the McGuire Center. The monitoring readings were used to calculate accumulated fumigant dosage and determine if additional fumigant was needed to control the target pests. Fumigant was added to Leigh Hall and three of the five compartmentalized fumigations in the McGuire Center.

The final accumulated dosage in Leigh Hall was 199 oz-hr/1000 ft³ (CT calculator, L. Keeler, Dow AgroSciences, Indianapolis, IN) for the 33 hour exposure period. This dosage exceeded the 105 oz-hr/1000 ft³ required to control drywood termites based on the lowest temperature (68°F) measured. The final accumulated dosages in the five compartmentalized fumigations in the McGuire Center ranged from 589 to 1432 oz-hr/1000 ft³ for the 18 hour exposure. All dosages exceeded the 488 oz-hr/1000 ft³ required to control post-embryonic stages of psocids (unpublished data, Dr. C. Bell, Central Science Laboratories, York, England) at the lowest temperature (64°F) measured.

Extended 10-hr aerations were conducted at each building to ensure dissipation of Vikane from enclosed spaces, such as the 60,000 Cornell drawers storing Lepidoptera in the McGuire Center. Fumigant aeration was confirmed in all fumigated spaces and connected buildings using an Interscan gas analyzer (Interscan Corp, Chatsworth, CA). No damage was reported or observed to the contents of the buildings and the target insects were controlled. The University of Florida considers Vikane gas fumigant an

essential component of their pest management program to control insects damaging historic structures and unique scientific artifacts.

SUMMARY OF 2005 LABORATORY STUDIES ON THE USE OF PHANTOM® SC FOR THE CONTROL OF BED BUGS, STORED PRODUCT PESTS AND HOUSE FLIES

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Pest Management Professionals (PMPs) are seeking effective alternatives to organophosphates and repellent synthetic pyrethroids, as well as products for Insecticide Resistant Programs. PMPs are requesting efficacy of non-repellent chemistry for control of bed bugs, stored product pests and house flies. A 0.5% solution of Phantom™ SC (chlorfenapyr) was applied as a contact mist to 10 replicates of 10 each of the following pest species: bed bugs, confused flour beetles, saw-toothed grain beetles and house flies. Populations of 5 treated replicates were removed to recovery vessels and 5 treated replicates were left in treated containers. 10 containers of 10 insects were used as control populations. Knockdown and mortality counts were taken at 1hr, 4hr, 8 hr, and then daily until 100% mortality was found or mortality of controls reached 20%. Phantom™ SC provided 100% control of all insects tested. 100% mortality of House flies was reached in one hour. 100% mortality of both Confused flour and Saw-toothed grain beetles was reached in 24 hours. Phantom was effective as a contact treatment against Bed bugs , providing 100% mortality of transferred population in 6 days. 45 out of 50 Bed bugs in non-transferred containers were dead in 48 hours (similar to a PMP intensive treatment). 100% mortality of all bed bugs in 6 days may be a suitable material to control populations of bed bugs, stored product pests and house flies while providing Pest Management Professions with new non-repellent chemistry to incorporate into their Insect Resistant Program strategies.

INTRODUCTIONS OF EXOTIC AND INVASIVE TERMITES - WORLDWIDE PERSPECTIVE

Blowing Rock, Tanglewood, Pinehurst

Moderators

Brian Forschler

University of Georgia

Tracie Jenkins

University of Georgia

Susan Jones

Ohio State University

INVASIVE TERMITES: LESSONS FROM TWO SPECIES INTRODUCED TO GERMANY

Horst Hertel and Rudy Plarre

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In Hamburg termites were first discovered some 70 years ago. They belong to the species *Reticulitermes flavipes* and had presumably been shipped with timber from the US. From the harbour area the termites had spread downtown and finally concentrated in an area of about 2 ha. They became established in the neighbourhood of courthouses, where they caused some trouble with furniture and even court records. They survived cold winter periods by concentrating close to heating vents of the district facilities. If they have no access to food because of surface frost, food requirements may be met by cannibalism. With rising temperatures in spring an increased reproduction rate in the colony soon compensated for that loss.

As termites are non endemic to Germany, knowledge about those insects here is rather poor. Consequently, the possible threat was mainly overestimated and hence control measures overdone. Massive impregnation of the infested ground was accomplished in addition to trials that drenched house walls with hazardous biocides, and even a row of house was burned. Yet no success was achieved in these attempts at eradication.

In 2000 we started to control the Hamburg termites by baiting. Experience with this technique was gained in our institute in Berlin. There, in the 1960's, *Heterotermes indicola* had escaped from a laboratory culture. They survived for three decades in the

ground beneath the basement of several houses where they fed on old formwork and stored material. At the beginning of the control activities in 1993 the biocides available could not be used baiting, as the required doses caused repellent effects. This was overcome by microencapsulating the insecticide. Using this formulation technology we demonstrated that it was no longer detected by the termites, and by adjusting the wall thickness the release of the biocide could be controlled. Eradication of the termite infestation was achieved within three years using microencapsulated pesticidal bait.

The biocides available today are much better suited for baiting. In Hamburg we use Fipronil™, which shows very good biocidal effects even in extremely low concentrations. In laboratory assays we adjusted the concentration such that the lethal effect was delayed to about ten days. The food consumption on treated baits was as good as on untreated controls. The baits consist of stripes of corrugated cardboard, which is wound to a role of 15 cm in diameter. As the bait should outdo naturally available food, a piece of pine wood is placed in the center of the cardboard, which previously was decayed by a specific fungus, which in turn causes a high attractiveness to termites.

After two years of baiting the termite population in Hamburg decreased below 5 % of its original size, but a complete eradication has not been achieved. The infested area has been reduced to some small areas of known activity. Long term monitoring will be necessary to avoid resurgence from as of yet undetected spots.

***RETICULITERMES* AND *COPTOTERMES* – TWO SUCCESSFUL INVADERS WITH DIFFERENT STRATEGIES**

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The termite genera *Reticulitermes* and *Coptotermes* contain species which have successfully invaded many parts of the world outside their natural distribution range. Despite belonging to the same family, the Rhinotermitidae, there are major differences in their biology and this impacts on their strategies for successfully establishing in foreign lands.

Reticulitermes has a diffuse nest system. Reproductives can be located in various places in the territory and brood is cared for at feeding sites rather than in a definite nest structure. In contrast, *Coptotermes* builds a central nest, housing the reproductives in a royal cell, with eggs and larvae in an adjoining specially built nursery.

Secondary reproductives (neotenics) can arise in *Reticulitermes* from both the worker and the nymph/pseudergate line (Laine & Wright 2003) while in *Coptotermes* they originate only from nymphs (Roisin & Lenz 1999; Barsotti & Costa-Leonardo 2005).

Reported colony structures in *Reticulitermes* include colonies headed by a pair of primary reproductives, by multiple primary queens (parthenogenesis), by a primary pair and several sets of secondary (supplementary) reproductives or after the death of the primary pair by multiple secondary (replacement) reproductives. Budding of colonies with secondary reproductives and partial or complete colony mergers further add to the diversity of breeding options in this genus. *Coptotermes* colonies are headed by a pair of primary reproductives. If the founding pair dies secondary (replacement) reproductives will assume breeding. Cases of secondary reproductives acting as supplementary reproductives and being located in satellite nest within the territory of the primary pair have also been reported.

In *Reticulitermes* secondary reproductives can be produced at any time and groups with as few as 25 termites can re-establish as a full colony (T.E. Macom & R.E. Gold, unpubl.). The sum of the reproductive capacity of secondary reproductives in a colony can readily exceed that of the primary queen. With the help of secondary reproductives colonies of *Reticulitermes* could breed for indefinite periods of time. In field colonies of *Coptotermes* non-functional secondary reproductives develop with every nymphal cycle from one of the earlier nymphal stages. Isolated groups of workers are unable to re-establish as a colony unless nymphs or neotenics are present. Reproductives also require a much larger number of supporting workers in order to commence breeding.

In non-invasive species of *Coptotermes*, e.g. from Australia, orphaned colonies will readily resume breeding with replacement reproductives. However, the offspring includes workers of both sexes but only male nymphs [alates] (Lenz & Runko 1993; Roisin & Lenz 2002). This means that once the secondary reproductives have aged and perish that the colony dies out. Indications from one colony of the invasive *C. formosanus*, held in a Chinese laboratory, are that in this species the loss of the primary pair, and resumption of breeding with secondary reproductives is also accompanied by the production of male alates only. However, after a few years also a small number of female nymphs (alates) are found (Crossland et al. 1994; Roisin & Lenz 2002). This means that *C. formosanus* colonies will be able to replace sets of secondary reproductives with a new one as required, i.e. such colonies could live for long periods of time. Molecular studies of *C. formosanus* colonies in the US confirm that colonies with a history of generations of secondary reproductives frequently exist (Husseneder et al. 2005; Vargo et al. 2006). Initial results from orphaning studies with field colonies of *C. formosanus* in Kagoshima, Japan, indicate that the production of only male nymphs after orphaning does indeed occur (M. Lenz & T. Yoshimura, unpubl.). This may be a basic trait in *Coptotermes*, but in species such as *C. formosanus*, the restriction on the production of female nymphs is only temporary, thus ensuring significant longevity of established colonies. The differences between invasive and non-invasive species of *Coptotermes* may have a phylogenetic base.

The success of *Reticulitermes* as an invader appears to be due to its ability to readily develop secondary reproductives from both the worker and the nymph line, and to have a diversity of colony reproductive systems in adaptation to diverse environmental circumstances. Budding may be a key means of spreading in areas of introduction. Only

small groups of termites are required to serve as foci for new colonies. Such small termite groups easily go unnoticed in shipments of soil and wood products, hence entry into areas outside their natural distribution range can readily occur.

Invasive *Coptotermes* are physiologically a rather robust group. Ship-born alates have a high success in establishing at foreign shores. Within mixed-species termite faunas, the genus is the dominant one. Invasive species (e.g. *C. formosanus*, *C. gestroi*) originate from regions which for thousands of years have had a high human population and intensely man-modified landscape. By having a reserve of non-functional secondary reproductives invasive *Coptotermes* colonies can quickly replace lost primary reproductives. The handicap of only male nymphs once colonies are headed by secondary reproductives is not as pronounced in invasive species as in non-invasive ones. Thus, in e.g. *C. formosanus* multiple generations of secondary reproductives are possible (as demonstrated in several USA populations), ensuring the longevity of successfully established colonies.

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IS *COPTOTERMES FORMOSANUS* (ISOPTERA: RHINOTERMITIDAE) AN EXOTIC INVADER FOR JAPAN?

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Literature survey indicates that Formosan subterranean termite, *Coptotermes formosanus* Shiraki invaded >300 years ago (Mori 1987). A German doctor reported in the 18th century that severe termite infestations occurred in the southern parts of Japan during the 17th century. It has been thought that these infestations involved *C. formosanus*, although there was no scientific evidence to demonstrate that the species was endemic to Japan. However, *C. formosanus* has been distributed widely in not only urban areas but also forests, and it is likely that there has been a long history of *C. formosanus* in Japan.

Recent molecular biological studies demonstrated the relationship among colonies of *C. formosanus* in China, Japan and the United States (Wang & Grace 1995, 200a, 200b; Husseneder & Grace 2001a, 2001b; Husseneder et al. 2002; Husseneder et al. 2003). Most of researchers have believed that *C. formosanus* is native to P. R. China since a termitophilous beetle, *Sinophilus xiai* was first found from the nest of *C. formosanus*. Significance of its discovery to the zoogeographic distribution strongly suggested the origin of *C. formosanus* to be in mainland China (Kistner 1985). As reviewed elsewhere, every terrestrial living thing has generally established its own natural distribution under well-balanced conditions in association with other beneficial and detrimental communities. Consequently, the discovery of natural enemies (e. g termitophilous beetle, specific to a certain termite species) at the given locality means that the termite species is present in its natural distributional areas (Iwata 2000). Based on the discovery of *Madrasostes kazumai* from the nest of *C. formosanus* in Tokara-Nakashima Island, Kagoshima Pref. off Kyushu Island in the southern part of Japan, Iwata et al. (1992) discussed the zoogeography of the termite species in consideration of Kistner's discovery (1985). They finally assumed that Tokara-Nakashima Island is a part of zoogeographic origin of *C. formosanus*. Maruyama & Iwata later reported the discovery of two termitophilous species, *Sinophilus yukoe* sp. nov. and *Japanophilus hojoi* gen. nov. from Nansei-Shoto, most southerly part of Japan, and suggested that *C. formosanus* is native to Kyushu and possibly to mainland Japan.

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CHALLENGES TO TERMITE MANAGEMENT OF MULTI-FAUNA GENERA IN SOUTH EAST ASIA

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Termites are an important group of insect pests in tropical South East Asia. Due to the high diversity of termite species in this region, it is common to find several termite pest species co-existing and infesting buildings and structures. In Malaysia, 12 species of subterranean termites from 7 genera (*Coptotermes*, *Macrotermes*, *Microtermes*, *Globitermes*, *Odontotermes*, *Schedorhinotermes* and *Microcerotermes*) can be readily found in- and around buildings and structures, particularly in suburbia and rural settlements. Similar observations with species in the genera *Coptotermes*, *Microcerotermes*, *Macrotermes*, *Hypotermes* and *Odontotermes* are also recorded in urban and rural Thailand. Since the introduction of baiting in Malaysia, secondary pest species are more frequently encountered. Following elimination of the principal pest species (*Coptotermes* spp.) with bait, it is not uncommon to find species from other genera such as *Schedorhinotermes* and *Macrotermes* infesting the same building or structure after several months. Most of these species, particularly those belonging to genera such as *Macrotermes*, *Globitermes* and *Odontotermes* from the higher termite (Termitidae), however, do not respond well to paper-based bait matrices. Options for managing multiple genera termite pest faunas in the tropics are discussed.

RECENT DATA ON TERMITE INVASION AND INFESTATION IN WESTERN EUROPE.

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The European termite *Reticulitermes santonensis* is thought to be an imported species corresponding to the North American termite *R. flavipes*. Our team has been leading the debate about the relationship between these two species for almost 20 years. No definite conclusion can be drawn on the supposed invasion and synonymy without an exhaustive study like the one we are now conducting with our American colleagues. My presentation will provide some historical background about this putative importation and up-to-date scientific data about these species. I will also describe the termite infestation process in Western Europe, in France, and in the city of Paris.

THE IMPORTED FIRE ANTS' THREAT AND MANAGEMENT AROUND SENSITIVE ACCOUNTS

Chimney Rock

**Moderator
Bart Drees
Texas A&M University**

INTRODUCTORY REMARKS: THE TEXAS EXPERIENCE

Bastiaan "Bart" M. Drees,
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The title of this symposium, "The Imported Fire Ant Threat and Their Management Around Sensitive Accounts", is intended to highlight the treat, impact and management considerations associated with *Solenopsis invicta* Buren, *S. richteri* Forel and their hybrid (Hymenoptera: Formicidae) particularly in the southern United States. These species, although predominant in the landscape, readily migrate indoors and pose a medical threat to people (Drees 2002, Drees et al. 2000, <http://fireant.tamu.edu>). Although rare, serious medical complications and deaths have occurred from multiple stinging incidents in Texas and elsewhere (deShazo et al. 1999). Legal costs associated with incidents are high. Several cases in Texas can serve as examples and pose questions about the cause of ant migration indoors and into beds of patients in nursing homes and who should be held liable (Drees 1995). Management considerations were presented and discussed (Drees et al. 2002, Drees 2005, <http://tcebookstore.org>). However, no single product or approach is available that can guarantee complete elimination of the ants or probability of injury. New insecticides such as fipronil formulations add to the arsenal of tools to suppress imported fire ant colonies, but as a non-repellent slow-acting contact insecticide elimination of ant foraging remains a concern. Speakers participating in this symposium provided additional detailed information about incidents, at-risk sites such as nursing homes and schools, and what is being done to better prevent imported fire ant problems (Goddard et al. 2002).

Imported fire ants infest over 310 million acres in southeastern U.S. Polygyne fire ants have densities of 600 mounds per acre (or more). Attack (stinging incident) rates exceed 50% of population in the southeastern U.S. Anaphylaxis occurs in 0.6% to 6% of people stung. Ten incidents were reported in 4 years (1998-2002) by deShazo et al.

(1999). In Texas (Drees 1995) and elsewhere, bed ridden patients, youth and confined animals at most risk. Patients in bed next to windows were at highest risk. Flooding and droughts evidently caused colonies to suddenly move indoors, although this could not be determined because ant samples to reveal presence of brood (larvae and pupae) associated with incidents were not taken. This poses a question as to whether incidents were associated with sudden colony relocation or the ant's foraging activities and recruitment to food resources, bringing into question whether incidents resulted from negligence.

Imported fire ant colonies can occur almost anywhere in and around premises. Professional pest management service providers should share information about medical concerns and considerations. Working as a team consisting of clients and other firms or individuals providing services both indoors and outdoors, ant management should first be directed outdoors to prevent indoor incidents. Treatments and other control efforts should be coordinated between indoor and outdoor pest control service providers with an awareness of regulatory considerations (e.g., IPM in schools, etc.). When feasible, non-chemical methods such as sealing cracks (0.5 mm minimum) should be considered, and provide suggestions on site modifications such as drainage and grade changes around facilities should be provided to facility managers.

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INCURSIONS OF IMPORTED FIRE ANTS INTO STRUCTURES RESULTING IN MULTIPLE STINGING INCIDENTS AND MEDICAL PROBLEMS WITH SOME PREVENTIVE MANAGEMENT CONSIDERATIONS

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The title of the symposium that this presentation will be a part of is "The Fire Ant threat and their Management around Sensitive Accounts". The red imported fire ant (RIFA), *Solenopsis invicta* Buren, FA entered the United States around the early 1930's at Mobile, Alabama and spread from Mobile naturally by mating flights, on water during floods, and, artificially, through the shipment of infested cargo, especially nursery stock. Currently, the RIFA infest more than 320 million acres in the U.S. Residents in the infested states can be at risk as fire ants have expanded their habitat and densities and it is not uncommon for them to move indoors under certain environmental conditions. In several situations, this has led to multiple sting attacks occurring in primarily private homes and health care facilities. Residents in health care facilities are especially at risk from fire ant attacks because many of these patients are immobile or cognitively impaired. Some case studies will be presented in addition to some preventive management considerations.

LEGAL CONSIDERATIONS & ACTIONS FOR RED IMPORTED FIRE ANT (*Solenopsis invicta* Buren) INCIDENTS IN URBAN ENVIRONMENTS

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Red Imported Fire Ants continue to cause sever damage and discomfort to humans and their companion animals throughout the southern United States. The human populations that have proven to be the most at risk are the very young and very old, particularly when they are confined in hospitals, convalescent facilities and nursing homes. These specific facilities are referred to as being sensitive accounts and require an integrated approach to managing the RIFA populations below the detection threshold. A summary of five incidents involving RIFAs is summarized as follows:

Site 1:

- A. Assisted Living/Nursing Home in Texas
- B. 5 years old with good construction elements
- C. Heating/ Ventilation/Air Conditioning (HVAC) with outside grating system at ground level for each room
- D. Landscaping well maintained
- E. Property bounded by untreated city owned low land area
- F. Position of patient was next to exterior window and HVAC
- G. Rainfall in PM on weekend
- H. Patient stung multiple times and hospitalized, but survived
- I. Monthly pest control contract, but facilities manager refused RIFA additional service
- J. Role of staff to only notify PMP when problems noted
- K. Results of litigation: Directed verdict for PMP, Facilities ordered to pay family of patient

Reasoning: Inadequate preventative actions & improper response to situation

Site 2:

- A. Assisted Living/Nursing Home in Alabama
- B. 2 years old with good construction elements
- C. HVAC for individual rooms with grating at ground level
- D. Landscaping excellent but with mulch in planting beds
- E. Borders of property undeveloped, urban landscape
- F. Position of patient next to window and HVAC unit
- G. Rainfall event during night on weekend with patient hospitalized with 1000s of stings
- H. Monthly pest control service contract including RIFA control
- I. Facilities personnel role limited to call PMP if problems noted
- J. Results of litigation: Jury trial with award to patient from PMP and Facilities

Reasoning: Inadequate preventative action, not enough time in servicing account, and improper care and custody of patient

Site 3:

- A. Assisted Living/Nursing Home in Florida
- B. 10+ year old single story structure
- C. HVAC for individual rooms with grating at ground level
- D. Landscaping very good, but with mulch in planters
- E. Borders (within 5 ft of structure) low lands subject to flooding
- F. Position of patient next to window and HVAC, hospitalization and death from stings
- G. Rainfall event during evening on a weekend
- H. Monthly pest control contract including RIFA, but not landscape
- I. Facilities personnel role limited to notification of PMP if complaints
- J. Results of litigation: Settlement (sealed) payment from facilities & PMP

Reasoning: Inadequate pest control program and improper care and custody of patient

Site 4:

- A. Apartments for Elderly/Assisted Living/ Nursing Home Complex in Texas
 - B. 10+ years old, multiple stories depending on complex designation
 - C. HVAC for individual rooms with grating at ground level
 - D. Landscaping- excellent maintenance but under separate contract than pest control
 - E. Borders on developed, urban developments of single family homes
 - F. Position of patient in nursing home, first floor next to window and HVAC
 - G. Rainfall event during night with patient hospitalized with 1000s of stings, survived
 - H. Twice weekly pest control service contract including ant elimination
 - I. Facilities personnel limited to filling complaints with PMP using Pest Log Books
 - J. Results of litigation: Facilities settled with family (sealed) and then sued PMP who lost
- Reasoning: Contract called for ant control including RIFA (Jury determined)
Inadequate preventative treatments or emergency responses

Site 5:

- A. Hospital in rural Texas
- B. 20+ year old two story complex with add on structural elements through years
- C. Central HVAC with no outside grating
- D. Landscaping minimal but under separate management contract
- E. Borders on undeveloped urban lands and paved roads
- F. Patient position next to outside window on second floor of hospital wing
- G. Rainfall event during night on a weekend, patient died of 1000s of stings
- H. Monthly pest control services with RIFA in contract
- I. Facilities personnel limited to notifying PMP when problems are found
- J. Results of litigation: Settlement (sealed) involving hospital, PMP case pending

What Was Learned From These Cases:

- A. Red Imported Fire Ants will explore and eventually invade all structures unless an ongoing management program is implemented that stresses preventing ants from colonizing on the grounds of sensitive accounts.
- B. The emphasis of the management program must be on the exterior of the buildings to prevent invasions when it rains and floods adjacent areas causing the RIFA colonies to move to higher ground. The use of exterior baiting systems, protective chemical barriers, landscape design and structural modifications will help to impede invasion of these insects.
- C. The use of baits on the interior of sensitive accounts is not recommended unless it can be demonstrated that aerial nests have been formed. Interior treatments with insecticides can be helpful if the areas where the ants are entering or nesting can be identified. It is not enough to merely be satisfied that RIFA are not in the structures during routine service calls due to the movement of colonies during adverse weather conditions.
- D. When either offering or contracting for IPM services for RIFA, at least weekly inspections must be made by the PMP and daily "walk a rounds" done by the onsite personnel. In rainy weather these daily inspections are critical. Any evidence of RIFA

must be reported immediately with documentation provided as to the location of the problem. A pest log book should be required in all sensitive accounts involving RIFA. E. If PMPs are going to offer general pest control services they should consider “excluding RIFA” from the contract, and/or offering a separate contract specifically addressing these ants. If the client declines the additional RIFA contract, document that fact and keep records.

F. Never promise, imply or infer that you can “eliminate” RIFA or any other insect, from a property through time. This is biologically difficult, if not impossible.

G. PMP must have the support and cooperation of the onsite staff at the contract facilities. If this cannot be achieved then cancel the contract. RIFA management requires a joint effort from all parties to be effective and to protect the patients in the facilities. Every effort must be made to coordinate all phases of the management programs which would include other contractors that may be doing the landscape management. RIFA will exploit any weakness in the defense program.

H. If there is a RIFA incident, get specimens of the ants involved. They should be preserved in glass vials with 70% ethanol. These specimens are often times overlooked, and they are key to determining the effects of ant invasions on patients.

Suggested Reading:

Goddard, J., J. Jarratt, and R. deShazo. 2002. Recommendations for prevention and management of fire ant infestation of health care facilities. *Southern Medical Journal* 95 (6):627-633.

FIRE ANT MANAGEMENT AROUND TEXAS NURSING HOMES: WHAT’S BEING DONE?

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Fire ants pose an increasing threat to the elderly and infirm, as evidenced by the growing proportion of senior citizens in the U.S. and the documented number of attacks on elderly patients in nursing home facilities throughout the southern U.S. (deShazo et al. 2004). There were 35.9 million Americans aged 65 or older in 2003 (approximately 12.3% of the U.S. population). By 2030, it is estimated that 71.5 million Americans will be 65 years or older, representing 20% of the projected U.S. population and more than twice the year 2000 number (DHHS 2005). The growing number of elderly presages a growing demand for certified nursing care. Last year nearly 90,000 Texas residents received care at 1,134 Medicare and Medicaid certified nursing care facilities in Texas (AHCA 2005); this number will increase significantly over the next few years.

Eighty-percent of Texas residents report that they have been stung by fire ants (M. E. Merchant and B. M. Drees, unpublished data). For most adults fire ant stings are

merely an unpleasant event; but for small infants or the infirm, fire ant attacks can be more serious. In Texas 3.8% of nursing home residents are classified as dependent on nursing home staff for Activities of Daily Living (ADL), including getting out of bed (AHCA 2005).

At least 19 cases of fire ant attacks on patients in nursing home facilities have occurred since 1991 (Table 1). Case reports were drawn from both the scientific literature and newspaper accounts. Many or most fire ant stinging cases are undoubtedly overlooked because of the lack of a national reporting mechanism and the desire of most nursing homes and other litigants to keep such incidents quiet.

Deaths occurred in several of the cases researched, however it is difficult to say from most published accounts whether death was a direct result of fire ant attacks, or merely an extended consequence of the poor health of most victims who are often aphasic, unconscious or too weak or to request assistance when stung.

In addition to the victims themselves, such attacks are traumatic to caregivers who are horrified by the consequences of fire ant stings to beloved family members. Nursing homes and their pest control service providers are increasingly being brought to court by family members as well as the Centers for Medicare and Medicaid Services (CMS), the government agency that oversees nursing homes that receive federal funding.

Several important research challenges are posed by fire ant attacks occurring in nursing homes. First, the biological circumstances leading to mass attacks are poorly understood. Possible factors that might attract fire ants include moisture, sweat secretions, urine-stained bedding, bodily fluids associated with IV tubes or catheters, and food residues on the floor, in bedding or on the patient. I have observed fire ants in large numbers indoors on wet towels during hot, dry weather. Another theory proposed today is that fire ant colony migrations might randomly traverse patient beds and become arrested and provoked to sting when the patient moves or accidentally crushes one or more colony members. Additional research on indoor foraging behaviors of fire ants is needed.

Secondly, little is currently known about the level of awareness among nursing home staff and administrators about fire ant risks to patients and how such risks might be controlled. In addition, to my knowledge there have been no surveys of the pest control industry's standard practices in nursing homes. Such information would be useful to determine training needs for pest control professionals who service nursing home accounts.

Finally, there have been no published studies on the effectiveness of different outdoor management strategies in keeping fire ants out of nursing homes or other structures. Such research would provide essential information in establishment of pest control standards for health care facilities.

Entomologists at Texas Cooperative Extension are currently attempting to address some of these questions in a recently initiated study of fire ant problems in nursing homes. The project includes in-depth employee surveys of 30 selected nursing homes in Texas, questionnaires administered to the pest control providers for selected facilities, and an assessment of three different pest management strategies for preventing fire ant infestations of nursing homes. The project will also include a pilot training program for nursing home staff to increase awareness of what to do if fire ants are reported indoors.

Preliminary observations from initial contacts with Texas nursing homes revealed that 40% (n=15) of homes visited admitted to having had problems with fire ants in patient rooms at some time. Up to 73% of nursing home administrators interviewed during initial visits (n=15) reported that most of their fire ant control consisted of individual mound treatments, and 60% of nursing homes conducted at least some of their fire ant control using in-house (unlicensed) personnel. Only one of the 15 homes interviewed admitted to having had a patient stinging incident.

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Table 1. Documented cases of fire ant stinging cases in U.S. long-term care facilities. 2006.

Date	Location	Victim	Citation
1991	Abilene, TX	3 sting victims reported: 2 subsequent deaths (causes unreported), one recovery	Drees (1995)
1992	Houston, TX	Elderly female, delayed death	Drees (1995)
unrecorded	FL	74 y female, no reported consequences	deShazo and Banks (1994)
Unrecorded	TX	90 y female, death 6 days later	deShazo and Williams (1995)
8-17-1998	Houston, TX	Elderly male stung 2000+ times, recovered.	<u>Houston Chronicle</u> 4-8-2003
8-30-1998	Brookhaven, MS	67 y female, 500+ stings, died 5 days later	deShazo et al (1999)
2-15-1997	Starkville, MS	60 y male, confluent areas of stings on head, back, arms, chest, d 16 month later	deShazo et al (1999)
7-1-1998	Flower Mound, TX	89 y female, d 3 mo. later	<u>Dallas Observer</u> 10-5-2000
5-1-2000	North Port, FL	87 y female, 1600+ stings, d ? days later	<u>Miami Herald</u> 5-26-2000
5-29-2000	Hollywood, FL	85 y female, recovered	Author's case files
8-20-2000	Mobile, AL	30s female with mental incapacities, stung hundreds of times, recovered	Author's case files, <u>Mobile Register</u> 9/7/2000, 10/4/2000
7-19-2001	Palm Beach, FL	83 y male, 80 bites over body, recovered	<u>Palm Beach Post</u> 7/19/2001
8-5-2001	Galveston, TX	82 y old female, hundreds of stings, d 3 wks later	<u>Houston Chronicle</u> 3/18/2004
4-2002	Bradenton, FL	90 y old female; arm, neck, back, upper torso covered with stings. \$1.2 m award	<u>Orlando Sentinel</u> 6-5-2004
8-23-2002	Tyler, TX	91 y old female stung 600+ times. d 6 mo later, unrelated causes, \$300K award	<u>Houston Chronicle</u> , 9-8-2002
8-30-2003	Lake Mary, FL	Elderly female covered with stings upper body, d later of unrelated causes	Author's case files
7-7-2004	Calloway, FL	Elderly female with numerous fire ant stings, recovered	Author's case files

**PROPERTIES OF BARRIER TREATMENTS AROUND STRUCTURES:
FIPRONIL, A NON-REPELLENT SLOW-ACTING CONTACT
INSECTICIDE AND ITS USE**

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INTRODUCTIONS OF EXOTIC AND INVASIVE TERMITES NORTH AMERICAN PERSPECTIVE

Blowing Rock, Tanglewood, Pinehurst

Moderators

Susan Jones

Ohio State University

Tracie Jenkins

University of Georgia

Brian Forschler

AN EXOTIC INTRODUCTION OF *CRYPTOTERMES BREVIS* (WALKER) TO THE AZORES (PORTUGAL) AND THE INITIATION OF CONTROL MEASURES

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Wood damage and pellets of an unknown insect started to be noticed by some homeowners in Angra de Heroísmo, on Terceira Island of the Azores Archipelago of Portugal at least six to ten years ago. However, the insects causing the infestation were not brought to the attention of authorities until 2002, when it was identified as the West Indies powderpost drywood termite, *Cryptotermes brevis* (Walker). A survey project in 2004 determined that infestations of *C. brevis* are present on at least the two most populated of the nine major islands, Terceira and São Miguel. The number of city blocks currently estimated to be infested are only known from Angra do Heroísmo (Terceira), where at least 25% of private homes are heavily infested and plus 25% have medium infestations. Therefore, though only recently reported, this termite has probably been in the Azores for at least several decades. Given the reputation of *C. brevis* as a "tramp species" that is easily transported in dry wood such as furniture, it is not too surprising that this termite has arrived in the Azores. However, the Azores are considerably farther north than previously known cases of the establishment of this termite. Presumably this is made possible by the suitably mild conditions induced by oceanic currents and the particular local microclimatic conditions of the two main towns (Angra

do Heroísmo and Ponta Delgada), i.e. hot and humid. In view of the extent of the infestation, even with a massive fumigation effort, which would exceed disaster budget limitations, eradication at this point does not seem feasible. Since the Azores have had no previous termite problems, no termite control products are registered in Portugal and no local pest control companies have knowledge of termite control practices. Furthermore, the architecture is quite different from that in the US where tent fumigation is commonly practiced, with most houses within city blocks built wall to wall and with delicate tile roofs that would be dangerous for tenters to walk on. An initial project has been approved for 2006 to evaluate what control options should be implemented in the Azores, given architectural and cost constraints. Plans are underway to evaluate detection methods, wood surface treatments in attics, furniture treatment, spot treatments using drill and injection.

WHEN INVASIVES MEET: *COPTOTERMES FORMOSANUS* AND *COPTOTERMES VASTATOR* IN THE PACIFIC

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Coptotermes vastator Light (Isoptera: Rhinotermitidae) has an interesting history in the Pacific. Although it is the most serious termite pest in the Philippines and the Mariana Islands (including Guam) (Wang & Grace 1999, Yudin 2002), *C. vastator* was misidentified for many years in Guam as its notorious congener *Coptotermes formosanus* Shiraki (Su & Scheffrahn 1998). *Coptotermes vastator* was found infesting a single home, which was subsequently demolished during highway construction, on the island of Oahu, Hawaii, in 1963 (Bess 1966, 1970), but was not collected again in Hawaii until 1999 (Woodrow *et al.* 2001). All of the collections of *C. vastator* in Hawaii since 1999, have been within an approximately 10 km distance on the island of Oahu.

Although *C. formosanus* has been present in Hawaii for over 100 years, this species has not been confirmed to be present in Guam, where *C. vastator* is a serious pest. It is likely that *C. vastator* is more successful as an invader in the tropics, while *C. formosanus* enjoys a subtropical distribution. Shelton & Grace (2003) noted greater mortality of *C. vastator* than *C. formosanus* under dessicating conditions; and Grace *et al.* (2004) observed distinctly different tunneling patterns with these two species that suggested that *C. vastator* was more adapted to foraging in a tropical environment.

In comparative studies of these two termites species in Hawaii, Uchima & Grace (2003a,b) concluded that *C. vastator* had a lower feeding rate than *C. formosanus*, and generally smaller field colonies. When the two species were paired in the laboratory in agonistic assays, *C. vastator* generally suffered greater mortality (Uchima 2002).

However, neither species was consistently able to control a single food source when they were placed in direct foraging competition (Uchima 2002). Thus, in the subtropical regions of the world where *C. formosanus* has proven to be a successful invader, *C. vastator* appears to be at a disadvantage both from an environmental and a behavioral standpoint, but the advantage may shift towards *C. vastator* as one approaches the equator. One area where *C. vastator* has demonstrated an advantage over *C. formosanus* is in resistance to attack by the nematode *Heterorhabditis indica*, although the basis of this is not yet known (Mankowski *et al.* 2005). It is possible that the observed differences in cuticular hydrocarbons of these two *Coptotermes* species (Haverty *et al.* 2000) may influence both susceptibility to dessication and nematode attachment.

A final point of interest with *C. vastator* is its taxonomic status. *Coptotermes vastator* is morphologically virtually indistinguishable from *C. havilandi* Holmgren (N.-Y. Su, personal communication), which is now considered a junior synonym of *C. gestroi* Wasmann (Kirton 2005, Kirton and Brown 2003). Although *C. vastator* has often been considered to be indigenous to the Philippines (Light 1929, Bantayan 2005), recent genetic analyses suggest that it may also be synonymous with *C. gestroi* (C.-Y. Lee, personal communication). Thus, either *C. gestroi* or a “*C. gestroi* complex” of closely related species enjoys a broad distribution in the tropics similar in extent to that of *C. formosanus* in the subtropics.

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PHYLOGENETIC ANALYSES, MOLECULAR DNA MARKERS AND THE STUDY OF INVASIVE SUBTERRANEAN TERMITES

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DNA marker technologies have been used extensively in subterranean termite population genetics (Atkinson & Adams 1997; Jenkins et al 2001; Austin et al. 2004; Vargo 2003). They provide more accurate insight into termite dispersal than mark release recapture (MRR), the assumptions of which have been violated in both field and lab studies (Evans et al. 1999; Forschler and Jenkins 1999). DNA markers have been applied under the aegis of cladistic and phenetic assumptions, to illuminate

phylogenetic topologies, which provided insights into the adaptive and evolutionary potential of invasive termites (Jenkins et al. 2001; Jenkins et al. 2002). The purpose of this paper is to tell two stories of how DNA tools and population theory have been used to unravel the mystery of subterranean termite invasions.

Termite mitochondrial DNA (mtDNA) (Kambhampati et al. 1996; Jenkins et al. 2001; Austin et al. 2004; Scheffrahn et al. 2003; Szalanski et al. 2004), simple sequence repeats (SSRs) (Vargo 2000; Husseneder & Grace 2001), and amplified fragment length polymorphisms (AFLPs) (Forschler and Jenkins 2000) along with morphological characters have been used to study subterranean termite taxonomy and population structure. Tree topologies as phylogenetic hypotheses (Kambhampati and Eggleton 2000) have also become invaluable tools in the study of subterranean termite introductions and dispersal history (Jenkins et al. 2002) as the following story about a North American termite that invaded Europe shows.

Maritime commerce has been one of the main sources of termite passive transport around the world (Kirton and Brown 2003). Bagnères (1990) found, based on cuticular hydrocarbon data, that *R. santonensis* was very similar to *R. flavipes*. *Reticulitermes flavipes* is an indigenous subterranean termite in North America. Jenkins et al. (2001) serendipitously discovered using two mtDNA genes and the ITS2 nuclear DNA (nuDNA) intron region that *R. santonensis* and *R. flavipes* belonged to the same clade. Indeed, both species could not be differentiated using the ITS2 region. These findings were later confirmed by a similar study done by Uva et al. (2004). It was hypothesized, based on the DNA data and the known human history, that *R. flavipes* may have hitched a ride on the wooden ships that crossed the Atlantic from America to Europe in the late 1700s onward to successfully colonized the “old world” (Jenkins et al. 2001).

Coptotermes exist harmoniously with secondary neotemics that supplement colony reproduction. They are also flexible, opportunistic and a very successful pest upon human structures and agriculture (Costa-Leonardo et al. 1999). Invading populations are usually subjected to founder effect during the colonization. This is followed by a rapid expansion (reviewed in Sakal et al. 2001) as expected from the work of Mayr (1954), Carson (1990) and Templeton (1980) who hypothesized that genetic drift would facilitate rapid allele frequency changes and adaptation due to recombination. This phenomenon could explain the results of a *Coptotermes formosanus* site in Atlanta, GA.

A point source introduction of *C. formosanus* was documented at a site in Norcross, GA, USA in 1996 (Forschler, Harron and Jenkins 2001). Termites were later collected from 11 areas within this site. Individuals collected from each of the 11 sites were evaluated for mtDNA sequences and AFLP DNA fingerprints. Genetic analyses revealed that all individuals descended from a single female lineage, which had previously been traced to New Orleans, LA (Jenkins et al. 2002). But the AFLP fingerprints demonstrated more variation than expected from a point source introduction of a single female line. Because there was no male DNA marker, the male contribution to the gene pool may be likely but couldn't be confirmed. At least part of the genetic variation observed, however, would be expected of a founding population (Mayr 1954) under drift.

We will continue to learn more about termite invasive strategies through the combined use of DNA marker technologies and population genetic theories, particularly since bioinformatics continues to provide free software tools that are increasingly able to handle large DNA datasets. But we can't lose sight of the fact that DNA technologies must be coupled with good field biology techniques for a holistic picture of the invasive process to emerge. The DNA datasets will make no sense without a thorough understanding of the basic biology.

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STATUS OF TWO INVASIVE TERMITE SPECIES, *NASUTITERMES CORNIGER* AND *COPTOTERMES GESTROI*, IN SOUTHEAST FLORIDA

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Twenty termite species are known from Florida. Four are non-endemics that were first discovered on the southeastern coast of the state: the Formosan subterranean termite, *Coptotermes formosanus* Shiraki, the Asian subterranean termite, *Coptotermes gestroi* (Wasmann), the “tree termite”, *Nasutitermes corniger* (= *costalis*) (Motschulsky), and an, as of yet, unidentified species of *Heterotermes*. The Formosan subterranean termite is now found in most of the major urban centers in Florida while *Heterotermes* sp. has a limited distribution in the Miami area. We report herein, on the current status of *C. gestroi* and *N. corniger* in Florida

Nasutitermes corniger was found infesting several structures within an approximately 1 km by 1 km area in the City of Dania Beach, Broward County. This was the first worldwide record of establishment of a “higher termite” (Termitidae) outside its endemic range. Native to the Greater and Lesser Antilles, and Central and South America, *N. corniger* was probably brought into Florida 8 to 10 years before its discovery. The genus *Nasutitermes* is distinguished morphologically by the soldier caste with its elongate, conical “snout” or nasus from which a terpenoid defense secretion is expelled. It also builds characteristic arboreal nests which are a visible sign of their presence. Because of its nesting habit, it was dubbed the “tree termite” by the state regulators, University of Florida researchers, and pest management industry personnel who comprised the task force formed to eradicate it. Despite the presence of numerous nests, the infestation appeared to be contained within a restricted area. In April 2003, the task force treated all nests and sites of activity by directly spraying nests, foraging tubes, and other active sites with either Premise® 2 or Termidor™. Several subsequent surveys revealed nests and areas of activity but on a much reduced scale. All of these sites were treated with Termidor® SC. Three small, isolated sites of activity were found during a survey in June 2006 and immediately treated. Since its discovery in 2001, we have never received reports of *N. corniger* outside the original infestation area. Another survey is scheduled for late summer/early fall 2006. If no live termites are found, *N. corniger* will be considered eradicated.

Formerly known as *C. havilandi*, *C. gestroi*, was first discovered in Miami in 1996. This species has a more tropical distribution worldwide than *C. formosanus* which is found in more temperate locations. The Asian subterranean termite is endemic to Southeast Asia and is now found in Brazil, southern Mexico, and numerous West Indian islands. In 1999, *C. gestroi* appeared in Key West and has since been found infesting numerous structures and several boats there. In 2001, an infestation was found on a yacht docked in Ft. Lauderdale. Despite being a destructive, non-endemic species, no immediate control measures for this infestation were enforced by any state regulatory agency. The boat was fumigated several days later. In February 2005, an isolated infestation was

found at a private residence in Ft. Lauderdale. Up until this discovery, *C. gestroi* and *C. formosanus* had allopatric geographic distributions in southeastern Florida with the former being found approximately south of the Miami-Dade/Broward County border and the latter exclusively to the north. The two species also are temporally separated with *C. gestroi* dispersal flights in Florida occurring from February to April while those of *C. formosanus* begin in late April and continue through July. Several weeks after the discovery of the colony in Ft. Lauderdale, *C. gestroi* dispersal flights were reported at several locations in Riviera Beach, Palm Beach County approximately 70 km north. These colonies were significant because they marked the northernmost expansion of *C. gestroi*'s range worldwide and gave southeastern Florida the distinction of being the only known location in the world where *C. formosanus* and *C. gestroi* are sympatric. In the spring of 2005, several new *C. gestroi* locations were confirmed in Palm Beach Co. including two approximately 1.5 km north of the 2005 locations. None were reported in Ft. Lauderdale or the rest of Broward Co.

Conclusion

The establishment of four different non-endemic termite species in southeastern Florida and the likelihood of future introductions – given the heavy boat traffic, international commerce, travel, and immigration into the area – clearly highlight the need for state regulatory policy on established populations of non-agricultural, non-endemic pest insects in Florida. We expect *C. gestroi* to continue expanding its range throughout southeastern Florida. Florida's pest management industry and county extension personnel will play a crucial role in notifying us of infestations by non-endemic species.

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FORMOSAN SUBTERRANEAN TERMITE ATTACK ON THE FLOODWALLS AND SOIL LEVEES IN NEW ORLEANS LOUISIANA

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In 2005 alone, the Formosan subterranean termite contributed to over \$200,000,000,000 in damage and cost for repairs as a result of the compromised soil levees and floodwalls in New Orleans. No doubt, Hurricanes Katrina and then Rita that came ashore in August and September of 2005 were responsible for the floodwall and levee breaches, but Formosan termites are infesting the walls and levees and their excavations cause soil levee failures. Chinese researchers have also studied termites and levees. Documentation starting in 1954, indicate that over 50% of the 3500 levee breaks recorded in China were the result of termites. Our involvement in the termite connection began in August of 2000, almost 5 years to the day before the Katrina disaster, when we discovered Formosan subterranean termites infesting the bagasse seams that are used as spacers to separate the large expanses of concrete floodwalls lining the Mississippi River in New Orleans. The Corps of Engineers and New Orleans Mosquito and Termite Control Board were surprised by this finding but on further investigation noted that all of the seam walls inspected along the Mississippi protection system showed similar infestations. Moreover, they noted that the rubber seals in the seams were penetrated by the termites and water seepage was inevitable. Despite this knowledge no repairs were initiated.

Bagasse, a sugarcane waste product, is a commonly used expansion joint material in sidewalks. It was also used in China during the 1960s as an attractant bait additive to control Formosan subterranean termites (mixed with agar and mirex). After Katrina and Rita caused extensive flooding in New Orleans, we investigated the areas near the floodwall and levee breaks in New Orleans. We documented a strong correlation between the level of termite infestation and the proximity of infested food sources (seams, trees and structures) nearby with the number of breaks that occurred in the walls and levees. Bagasse seam infestations served as an indicator that termites were infesting the soil levees. Trees infested by Formosan termites were readily found near the breaks. Formosan termites consume the xylem of living trees and eventually hollow out the root system of their host. We noted that roots from several of these trees traveled well into the levee system causing what is feared by engineers in this line of work—piping (routes that water will follow and further excavate the soil levee). Development of an IPM program to control the termite infestations is needed. However, our greatest impasse so far is getting recognition of this problem from the people responsible for maintaining the protection system. In time, California will also be threatened by the Formosan connection in levee systems. A 200 BC Chinese proverb is used as a daily reminder of how a little mistake can cause a huge problem. Roughly translated it states “a single termite colony can destroy a thousand lengths of levee”.

EFFECT OF URBANIZATION ON THE DISTRIBUTION OF DRY WOOD TERMITES

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In the United States, termites belonging to the Family Kalotermitidae are of significant economic importance in California, Florida, Hawaii, Texas and a few Gulf Coast States. As of 1996, there are 419 species of drywood termites that have been described worldwide (Myles 2006). Within the U.S. there are some 18 species. Of these only 2 species, the western drywood termite, *Incisitermes minor* (Hagen), and West Indian powderpost termite, *Cryptotermes brevis* (Walker), are known to be serious invasive species and likely to expand their geographical ranges in urban settings. Many of the reports deal with infestations in furniture or wooden objects that have been transported to non-endemic areas such as *C. brevis* in furniture in Ontario, Canada (Myles 1995) or *I. minor* in Florida (Scheffrahn et al. 1988). Other reports indicate that invasive species have become established such as *I. minor* in Louisiana (Messenger et al. 2000). In Hawaii, another invasive species *Incisitermes immigrans* (Snyder) attacks primarily trees and *Cryptotermes cyanocephalus* Light attacks both trees and structures (Woodrow et al. 1999).

Most native species of dry wood termites have very restricted ranges and habitats where they occur. For example, *Incisitermes banksi* (Snyder) has only been reported from mesquite in the desert southwest and only on rare occasion (Snyder 1926). In Queensland, Australia, of the five species that attack structural lumber only one is native (Peters and Kennedy 1998). *Incisitermes fruticavus* Rust is found in living jojoba and sugar bush shrubs (Rust et al. 1979). *Cryptotermes cavifrons* Banks has an extensive range through out the Caribbean, but it has only been reported in dead trees, logs, and stumps (Brammer and Scheffrahn 2002). Its distribution and absence in structures may be influenced by its very high moisture requirements. Even though *Incisitermes schwarzi* (Banks) is common throughout parts of Florida, it was not reported a survey of structural pests (Scheffrahn et al. 1988). Biotic factors such as temperature and moisture requirements may dramatically limit the potential spread of many drywood termites.

Factors that may contribute to the success of *I. minor* and *C. brevis* as invasive species are their broad microclimate preferences, especially those ranges found in urban structures, and their propensity to attack structural lumbers. Drywood termites typical construct their nest within the piece of wood that they are attacking. Consequently, these termites are more likely to be exposed to seasonal and variable environmental conditions whereas conditions in subterranean termite colonies are largely moderated by the soil. In California, *I. minor* is rarely found above 2000 m avoiding freezing temperatures during winter months. In desert areas it is commonly found in partly dead roots of sycamore and cottonwood trees and subterranean portions of poles, posts,

roots and stumps (Light 1934). Woodrow et al. (2000) reported that the composition of the cuticular hydrocarbons in *C. brevis* changed with increasing exposure to desiccation. *C. brevis*, like *I. minor*, is not equipped to deal with high RH and actually prefers cool and dry conditions.

The propensity of *I. minor* and *C. brevis* to feed on structural lumber and woods used to make furniture, boats, and pellets has contributed to these species becoming important invasive species. In fact, in most areas of the world where *C. brevis* now exists it is limited to structures and structural lumber (Scheffrahn and Su 1999). Some feeding studies have been conducted with *C. brevis* and it will feed on a number of hardwoods. Several woods such as maple and poplar were highly preferred by *C. brevis* (McMahan 1966). In consumption tests, *C. brevis* consumed balsa > western red cedar = Douglas fir > southern pine (Minnick et al. 1973). Hoop pine, and cabinet woods such as maples, red cedar and silky oak were preferred (Peters and Kennedy 1998).

In contrast to *C. brevis*, *I. minor* has been reported in a number of trees including, sycamore, oak, alder, Monterey cypress, redwood, eucalyptus, willow, and almonds (Light 1934). Consumption studies showed that nymphs preferred Douglas fir > walnut ≥ ponderosa pine = red cedar = redwood (Rust and Reiersen 1977). The lack of termite feeding was probably related to secondary plant compounds in the woods. In choice studies, *I. minor* preferred Douglas-fir > sycamore > redwood (Rust et al. 1979).

The ability to withstand environmental conditions within human structures, especially the lower wood moisture content, and to feed on many species of woods used in human construction has contributed to widespread distribution of *I. minor* and *C. brevis*. Greater surveillance and inspections of lumber and wooden goods from areas infested should be conducted to prevent their spread.

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GERMAN COCKROACH IPM AND RESISTANCE TO GEL BAITS

Chimney Rock

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STAY AHEAD FOR GERMAN COCKROACH MANAGEMENT: BAIT AVERSION, INSECTICIDE RESISTANCE, AND IPM

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Abstract: Baits have been proven to be the most effective and successful method for German cockroach, *Blattella germanica*, management. The recent resurgence of cockroach bait aversion has resulted in some control inconsistency; therefore, the effective management of the German cockroach has once again become the focus of pest management professionals (PMPs). Industry and university researchers actively responded to investigate the root causes of the control problems. With the launch of Maxforce® FC Select Roach Killer Bait Gel (0.01% fipronil) in 2004, PMPs were provided with an effective bait formulation to regain control of their problem accounts. Several new cockroach gel baits have recently been commercialized. In this study we compared Maxforce FC Select and two new gel baits, Transport™ Roach Bait (0.35% acetamiprid, FMC Corporation) and Matrix™ Roach & Ant Bait (2.15% hydramethylnon, Zoëcon Professional Products), against field-collected strains of German cockroaches. Maxforce FC Select achieved 100% reduction while the two new gel baits had less than 50% mortality against bait averse CNC & DTX strains. Results indicate that a simple rotation with different (including new) commercial baits may not be effective against bait averse German cockroaches.

We also investigated concerns that insecticide resistance may be a key factor contributing to control failures with cockroach baits. A comprehensive review of published data showed that German cockroach resistance to several classes of insecticides as contact residual application was evident, however, resistance to insecticidal baits was documented only to sulfluramid based cockroach bait (Schal 1992). Researchers attempted but failed to demonstrate resistance to other commonly used insecticides, including hydramethylnon and fipronil, in baits. We conducted

studies to investigate if fipronil resistance is a contributing factor in German cockroach control failure using baits. Our studies showed that there were no statistical differences in mortality between lab susceptible and field-collected “problem” strains of German cockroaches when exposed to Maxforce FC Select gel bait containing 0.01% fipronil at labeled rate. More significantly, the Cr-AI strain, which has the highest level of resistance to fipronil ($RR_{50}=17$) documented by Holbrook et al. 2003, showed a normal mortality pattern (100% mortality in 7 days) when exposed with the Maxforce FC Select gel bait. Only 65% mortality was achieved by Maxforce FC gel bait in 7 days at the same fipronil level (0.01%). An independent study at Purdue University reached the same conclusion with the Cincy strain ($RR_{50}=8.7$ per gram body weight or $RR_{50}=9.2$ per male by topical) (Wang et al. 2004). They reported 100% mortality of the Cincy strain treated with Maxforce FC Select (0.01% fipronil) in 4 days, but less than 20% mortality treated with Maxforce FC (0.01% fipronil). We also tested a more fipronil-tolerant strain (KA, with $RR_{50}=26$), and reconfirmed the same mortality responses. In 7 days after treatment, Maxforce FC Select provided 100% kill, while Maxforce FC only had <30% mortality. Both lab and field trial results once again confirmed that bait aversion was solely responsible for the reported control failures with baits, not fipronil resistance.

Based on study results, we conclude that tolerance detected at low doses of fipronil in clinical studies do not translate to control failure in the field. Bait aversion is the key factor responsible for the reported control failures with baits, not fipronil resistance. It is very important to clearly distinguish bait aversion (or behavioral resistance) from insecticide resistance, and suggest a procedural approach in both research and operational practices on how to draw unbiased conclusions. Simple bait rotation with different commercial baits does not effectively manage control failures. The key to effective German cockroach management is to understand the root causes of treatment failure and use field-proven baits to manage bait averse German cockroaches. We recommend PMPs continue to follow sound IPM principles and use baits in conjunction with other control tools to effectively manage German cockroach infestations.

Key Words: *Blattella germanica*, bait aversion, behavioral resistance, insecticide resistance, integrated cockroach management

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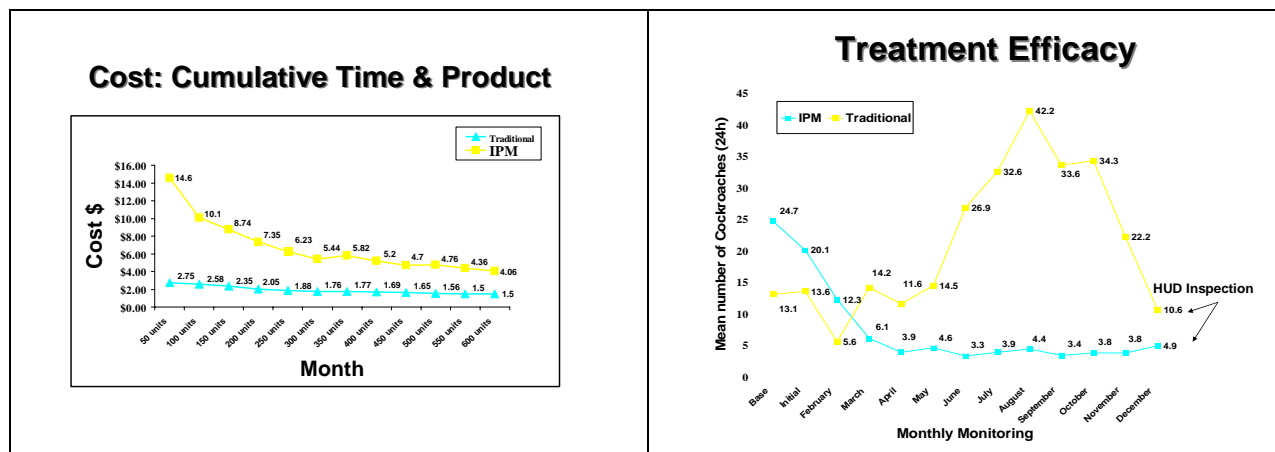
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ASSESSING THE VALUE THAT PUBLIC HOUSING RESIDENTS PUT ON IPM (REDUCED TOXICITY TREATMENT) FOR GERMAN COCKROACH CONTROL

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Public housing is considered a "sensitive" environment because many of the residents are children or elderly people. The children are prone to both allergies and asthma while the elderly residents are often afflicted with a myriad of health problems, including respiratory illnesses. Because sanitation is often poor in the public housing environment many apartment units are also infested with thousands of German cockroaches. German cockroaches, their frass, and cast skins are known to produce large numbers of allergens. Inhalation of these cockroach allergens has been identified as a major cause of asthma in inner city children. During the winter months, when residents close up their apartments and turn on the heat the cockroach frass dries out and the allergens become air-borne. Thus, the indoor air-quality inside these apartments can be greatly compromised.

Pesticide sprays have been the primary method of cockroach control in public housing because sprays are inexpensive. Yet, the environmental costs may be significant. Concerns about health risks associated with pesticides have stimulated the use of IPM for cockroach control in many facilities. However, it has been assumed that IPM is too expensive to use in public housing. The cost and efficacy of IPM for cockroach control in public housing was not known until Miller and Meek (2002) conducted a year long study evaluating IPM. Miller and Meek (2002) found that IPM was much more effective than monthly spray applications but that the cost of IPM was also much more expensive (average \$4.06/unit/month for IPM versus \$1.50/per unit /month for monthly spray applications).



Although the cost of IPM was significantly greater than that of sprays, the increased environmental quality and potential health benefits of IPM could off-set the additional cost. As of 2002, the cost associated with using IPM was a known quantity (\$4.06/unit/month for a year-long contract). What was not known is the monetary value that public housing residents would assign to a pest control program that reduced German cockroach numbers and the amount of pesticide applied in their living space. From our experience we knew that most residents were not familiar with the concept of IPM or its' potential benefits. Therefore, the purpose of this study was to conduct a survey of public housing residents to introduce them to the concept and benefits of IPM, then to ask them how much they would value (\$) such a program.

A total of 816 face-to-face surveys were conducted in Portsmouth, Charlottesville, and Roanoke public housing facilities. Residents' Associations from each of the housing facilities were hired to conduct the surveys. Graduate students, technicians, and Dr. Miller supervised the surveyors on a one-to-one basis. This supervision was necessary because in some cases individual surveyors had difficulty reading the survey, or tried to shorten the survey, or would lead respondents to give particular answers. However, the resident surveyors were beneficial in that we had very few respondents refuse to take the survey (< 5%).

The type of survey we conducted was called a valuation survey which was designed to assess peoples' willingness to pay for some theoretical service. The introductory narrative described the health problems associated with cockroach presence and the difficulty in controlling cockroach populations. The concept of IPM was then introduced and actual data was presented as evidence that IPM used less pesticide to produce superior cockroach control when compared with spray applications. After listening to the narrative, residents were asked a series of questions.

Below is a summary of responses given by respondents when asked how they felt about cockroach infestation and what level of infestation they would accept before taking corrective action.

Assessing Perceptions		Cockroach Action Thresholds		
Cockroaches in the home is a problem.	Strongly Agree 85%	How would you have to see cockroaches before you took action?		Do you have cockroaches today?
How important is it to limit the amount of pesticide applied indoors?	Very Important 73%	Several times a day	30% (241)	33% Yes (262)
Do you think there is a link between indoor pesticide use and health problems?	Yes 67%	Daily	26% (208)	67% No (532)
		Weekly	12% (93)	
		Monthly	14% (112)	
		Once a year	18% (144)	
		Would not take action	1% (9)	

When residents were asked how much they would be willing to pay every month in additional rent for IPM, the responses varied by location. In Roanoke public housing 39% of respondents indicated that they would be willing to pay between 1 and 10

dollars per month extra with the average amount being \$6.10. In Portsmouth, 62% of the residents indicated that they would be willing to pay an average of \$6.87 in additional rent. Seventy-two percent of Charlottesville residents indicated that they were willing to pay an average of \$8.00 a month for IPM. Overall, 56% of the total respondents indicated that they would be willing to pay some amount of additional rent between 0 and \$10 for IPM. Thirty-two percent of total respondents indicated that they would be willing to pay more than \$10/month (\$10 was the high end of the scale given to the residents as potential answers). When a resident indicated that they would be willing to pay more than \$10/month, they were asked to specify the maximum amount that they were willing to pay for IPM. Responses ranged from \$11-\$25. When these responses were averaged into the overall responses, the average amount that 56% of the respondents were willing to pay was \$11.32/month. This amount was considerably larger than the cost of IPM (\$4.06/unit/month).

Although 56% of respondents were willing to pay some amount for IPM, a total of 343 respondents (42%) indicated that they would pay \$0 for IPM. Of those that responded that they would not pay, 47% indicated that they would not pay because they could not afford to pay any additional rent. Eighty-eight percent of respondents indicated that they would not pay because they believed that the Virginia Department of Housing and Urban Development (HUD) should pay for IPM. Fifty-two percent of respondents who said that they would not pay for IPM (22% of total respondents) indicated that the reason for not paying was that it was not worth switching to IPM.

Residents were also asked about their recent pesticide product purchases to determine if they were already paying some amount for pest control. The results displayed below indicated that 59% of the residents were already paying an average of \$1.30/month to purchase their own pest control products.

What are Residents Paying Now?				
Product	59% of Respondents Purchased	Number Purchased	Cost	Total Spent
Bug Spray	87% (422)	2.3	3.50	8.05
Boxes Roach Bait	52% (254)	3.9	4.00	16.00
Roach Traps	38% (186)	4.2	1.00	4.20
Total Products	100% (486)	5.6 Products	2.80	15.70/yr 1.30/mo

Finally, residents were asked about the composition and health of their households. Thirty-eight percent of respondents indicated that their household contained children under the age of 13. Forty-one percent of the households contained residents over the age of 51. Twenty-five percent of households had at least one resident over the age of 65. By far one of the most compelling aspects of this study was the quantification of how many households contained a resident suffering from respiratory illness. **Fifty-three percent (429) of the respondents indicated that someone in their household**

had respiratory problems. Twenty-eight percent (224) responded that someone in the home went to the hospital for breathing difficulty within the last two years.

Summary:

From the study presented here we were able to conclude that over half of the public housing residents believed that IPM had value due to IPM's ability to improve cockroach control and reduce the amount of pesticide applied in their living space. These same residents were willing to pay more in additional rent than the actual cost of IPM. The sensitivity and bronchial health issues of these residents indicate that the costs of IPM could be offset by improved environmental quality and reduced air-borne contaminants (cockroach allergens and pesticide residues).

WHEEZES AND TEASES: COCKROACH ALLERGENS AND PHEROMONES IN IPM

C. Schal
North Carolina State University

GENETIC BASIS FOR RESISTANCE TO GEL BAITS IN GERMAN COCKROACHES (DICTYOPTERA: BLATTELLIDAE)

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A gel bait resistant *Blattella germanica* (L.) strain (Cincy) was collected in Cincinnati, OH, in 2003. This strain exhibited strong behavioral resistance to Avert[®] (0.05% abamectin), Maxforce[®] FC (0.01% fipronil), and Pre-Empt[™] (2.15% imidacloprid) gel baits. Reciprocal mass crosses and back crosses between the Cincy strain and a susceptible strain (Jwax) were made and tested for their inheritance of resistance to Avert, Maxforce FC, and Pre-Empt gel baits. Topical assays comparing the parental and reciprocal-heterozygous strains indicated the resistance to fipronil was incompletely recessive. LD₅₀ and LD₉₀ values of the Jwax♂ × Cincy♀ strain were not significantly different from the Jwax♀ × Cincy♂ strain, suggesting no sex linkage in physiological fipronil resistance. Feeding assays revealed that F₁ reciprocal crosses were significantly less responsive to blank Avert and Maxforce FC baits (without active ingredients) than the susceptible strain. The Jwax♀ × Cincy♂ strain did not display significantly greater consumption of blank Avert and Maxforce FC baits relative to the Jwax♂ × Cincy♀ strain. In feeding assays with agar containing D-fructose, D-galactose, D-glucose, D-lactose, D-maltose, and D-sucrose, the crosses showed an intermediate feeding response to glucose compared to the Cincy and Jwax strains, and a similar response to

other sugars compared to the Jwax strain. The Jwax♂ □□ Cincy♀ strain was significantly less responsive to glucose than the Jwax♀ □□ Cincy♂ strain. Mortality induced by Avert, Maxforce FC, and Pre-Empt gel baits against the F₆ Jwax♂ □□ Cincy♀ strain was $44.2 \pm 6.8\%$, $92.9 \pm 2.1\%$, and $78.7 \pm 5.2\%$, respectively, indicating the resistance to Avert and Pre-Empt gel baits inherited by Cincy females was extremely stable. The F₆ Jwax♂ □□ Cincy♀ strain was significantly more resistant to Avert, Maxforce FC, and Pre-Empt than the F₆ Jwax♀ □□ Cincy♂ strain. These findings suggest that behavioral resistance to gel baits has weak sex-linkage, with a greater degree of the resistance trait being inherited by female cockroaches. Alternatively, physiological resistance to fipronil has no sex-linkage, but is nonetheless important to the complete resistance phenotype.

CONTROL OF GEL BAIT AVERSE GERMAN COCKROACHES WITH AVERT® DRY FLOWABLE COCKROACH BAIT

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Whitmire Micro-Gen Research Laboratories, Inc.

German cockroaches have been a continual problem for humankind throughout the centuries. Many effective treatment techniques and products have been developed over the last century to control this public health pest.

The application of crack & crevice residuals had been the control method of choice for many years. This technique worked well with the introduction of the carbamate and organophosphate actives. The introduction of the synthetic pyrethroids extended the usefulness of this technique by allowing for the rotation of chemical classes to reduce resistance. By the late 1980s and early 1990s the resistance of German cockroaches to these chemical classes was becoming a recognized problem.

Fortunately, at this time a new method of control was introduced – baiting. This technique was started with the hydramethylnon bait station, followed by Blue Diamond Paste and Avert Dry Flowable Cockroach Bait. These bait products were supplemented by the cockroach gel baits and in the 1990s German cockroach control became routine. Excellent control was obtained even with less than perfect applications.

Unfortunately, in the 21st century the German cockroach has become gel bait averse. The continuing efficacy of Avert Dry Flowable Cockroach Bait on gel bait averse cockroaches has been extensively studied.

Initial tests during the development of Avert Dry Flowable Cockroach Bait, showed that it was a very promising product to control German cockroaches in adverse situations with poor construction and poor sanitation. In field trials in single family homes (see Chart 1), and multiple family homes (see Chart 2), excellent control was obtained.

CHART 1

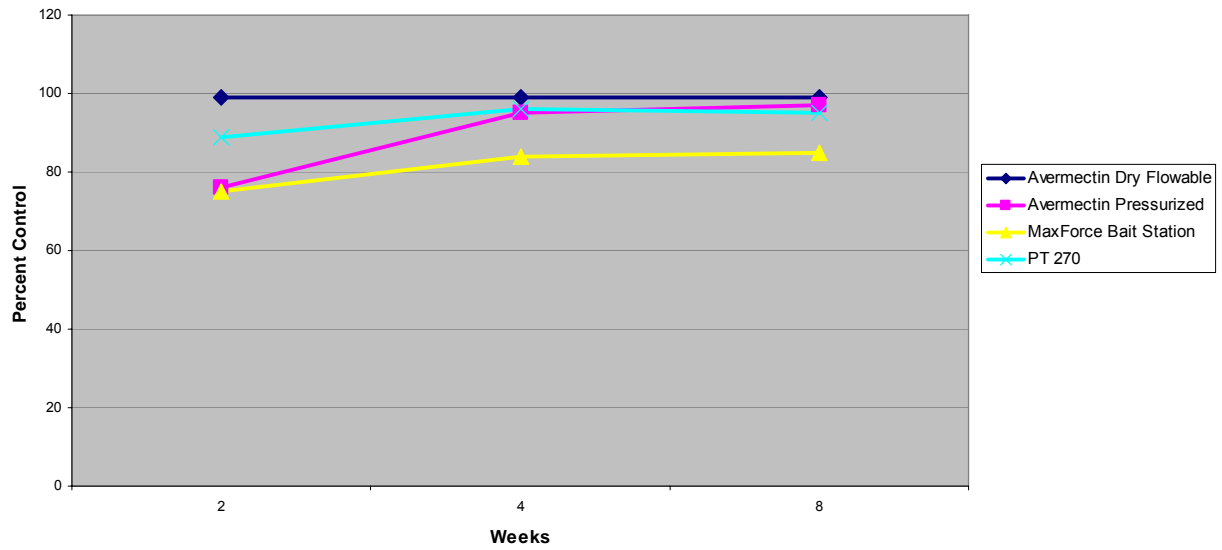
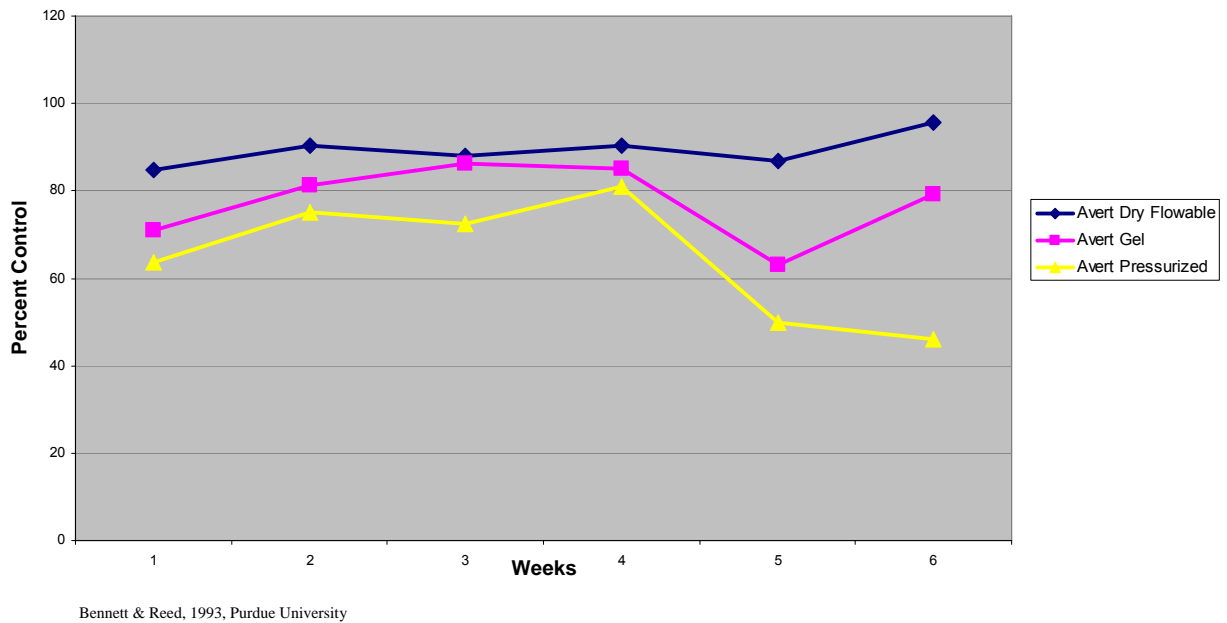
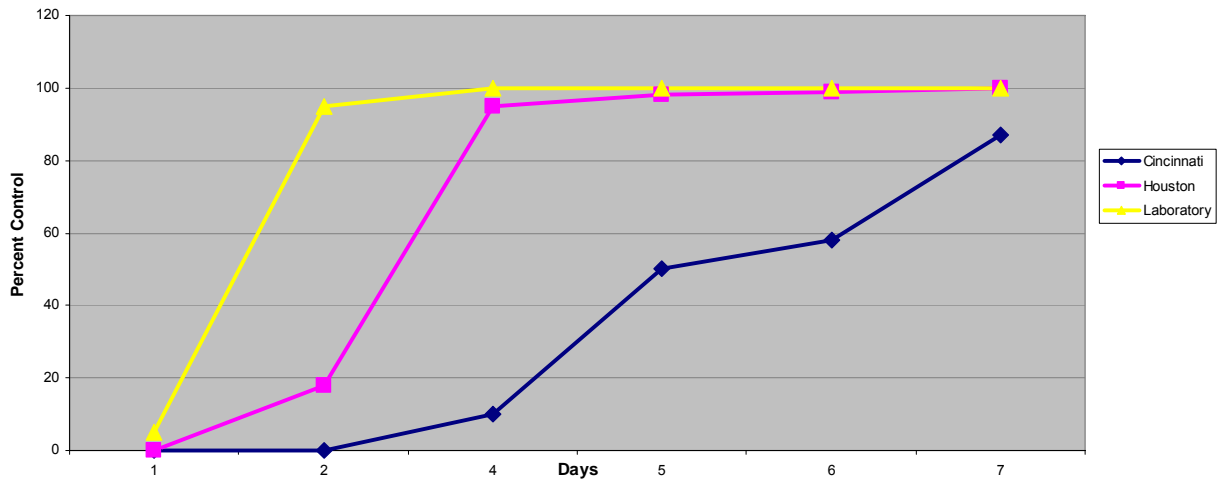


CHART 2



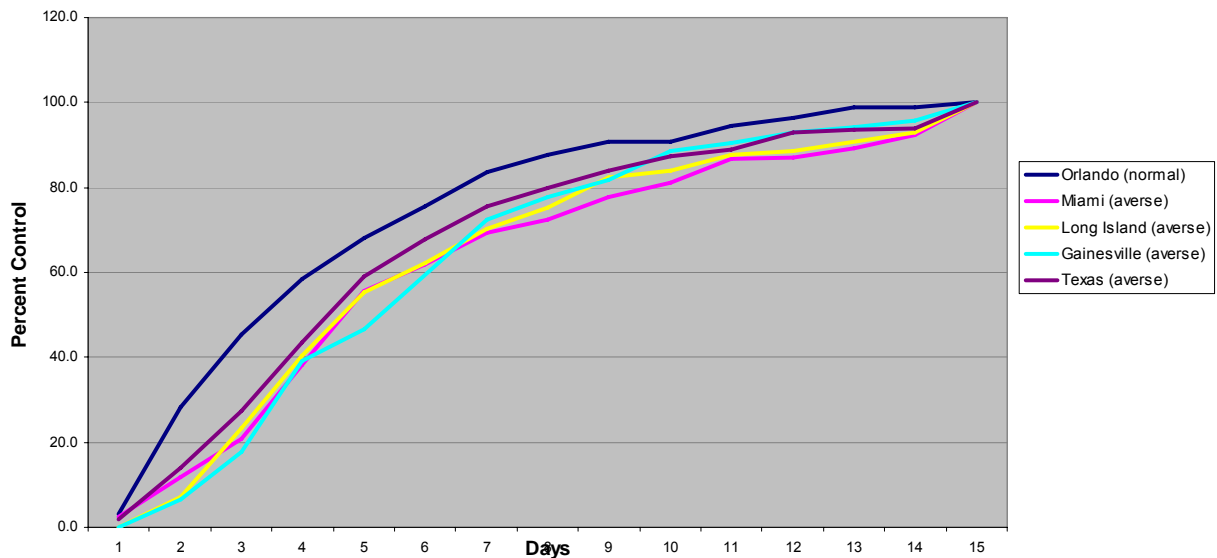
Testing in the laboratory on several gel bait averse strains of German cockroaches illustrates that Avert Dry Flowable Cockroach Bait works very well (see Charts 3 & 4), similar to laboratory raised German cockroaches.

CHART 3



Bennett, 2004, Purdue University

CHART 4



Liang, 2004, Apex Bait Technologies, Inc.

Extensive field trials in situations where gel baits would not control German cockroaches anymore, has proven that Avert Dry Flowable Cockroach Bait can control the German cockroaches in these facilities.

Avert Dry Flowable Cockroach Bait continues to control bait averse German cockroaches after being used for over 16 years.

TERMITES AND WOOD-BORING INSECTS

Blowing Rock, Tanglewood, Pinehurst

Moderator

Paul Baker

University of Arizona

SURVEY OF STRUCTURAL WOOD-INFESTING BEETLES IN FLORIDA

Brian Cabrera

University of Florida, Ft. Lauderdale Research & Education Center

After termites, wood-infesting beetles (WIBs) are the most important pests of wood in human-made structures in Florida. During my first two years at the Ft. Lauderdale Research and Education Center, I began receiving WIB specimens for identification and noticed an interesting trend. Several of the specimens were of the species, *Minthea rugicollis* (Walker) and *Lyctus africanus* Lesne. After searching the literature, I found almost no information on these species in Florida and very little for the U.S. As a result of this dearth of information, I conducted a survey of the WIBs of Florida. The objectives of the survey were to: 1.) Determine which species were common structural pests; 2.) Collect information on infestations; 3.) Collect information on the treatments being used and their effectiveness; 4.) Establish a reference collection; and 5.) Establish laboratory colonies of several WIB species.

Materials and Methods

Requests for volunteers to participate in the survey were sent to nearly 1600 pest control companies and county extension offices in Florida. Respondents who expressed interest in participating were sent a survey kit which contained plastic vials and padded envelopes for sending in specimens, survey instructions, and several survey forms. The forms asked for the following information for each WIB infestation: specimen collector's name, date, location of infestation, item infested, description of infestation, type of wood infested, origin of infested item, and treatment used. Samples brought into the office or mailed in by non-participants, or those that I collected personally were also included in the survey. The survey officially began on February 1, 2004 and ended on February 28, 2006. Specimens were identified using the keys of Gerberg (1957), Fisher (1950), and White (1971) or were sent to the Florida Department of Agriculture and Consumer Services, Division of Plant Industry for identification.

Results

A total of 94 insect samples consisting of 320+ specimens were received. Of these, 70 samples were of wood-infesting species (Tables 1 and 2.), of which 52 were exotics, and 24 were of non-wood-infesting species (Table 3). I received 11 samples of infested wood or bamboo items and 4 frass samples. I also visited 17 infestations. From several live beetle specimens or items with live infestations I established laboratory colonies of *Minthea rugicollis* (Walker), *Lyctus africanus* Lesne, *Trogoxylon aequale* (Wollaston), *Lyctoxylon japonum* (Reitter), and *Tricorynus herbarius* (Gorham).

Table 1. Beetle species in the family Bostrichidae collected for the survey.

Sub-Family	Genus	Species	Number of samples (56 total)
Bostrichinae (11)	<i>Heterobostrychus</i>	<i>H. aequalis</i>	4
		<i>H. hamatipennis</i>	2
		<i>H. brunneus</i>	1
	<i>Xylopsocus</i>	<i>X. capucinus</i>	4
Dinoderinae	<i>Dinoderus</i>	<i>minutus</i>	5
Lyctinae (38)	<i>Lyctus</i>	<i>L. brunneus</i>	4
		<i>L. africanus</i>	11
		<i>L. plannicollis</i>	2
	<i>Minthea</i>	<i>M. rugicollis</i>	17
	<i>Trogoxylon</i>	<i>T. punctatum</i>	1
		<i>T. aequale</i>	2
	<i>Lyctoxylon</i>	<i>L. japonum</i>	1
Unidentified			2

Table 2. Other wood-infesting beetle species collected for the survey.

Family	Sub-Family	Genus	Species	Number of samples (14 total)
Anobiidae	Mesocoelopodinae	<i>Tricorynus</i>	<i>T. herbarius</i>	5
	Xyletininae	<i>Euvrilletta</i>	<i>E. peltata</i>	1
Cerambycidae	Cerambycinae	<i>Hylotrupes</i>	<i>H. bajulus</i>	1
		<i>Elaphidion</i>	<i>E. mucronatum</i>	1
	Lepturinae	<i>Typocerus</i>	<i>T. zebra</i>	1
Micromelthidae		<i>Micromelthus</i>	<i>M. debilis</i>	2
Buprestidae		<i>Chalcophora</i>	<i>C. virginiensis</i>	1
Anthribidae		<i>Phoenicobiella</i>	<i>P. chamaeropsis</i>	2

Table 3. Non wood-infesting beetle species collected for the survey.

Family	Genus	Species	Number of samples (24)
Bostrichidae	<i>Rhizopertha</i>	<i>R. dominica</i>	2
Anobiidae	<i>Lasioderma</i>	<i>L. serricorne</i>	2
Heteroceridae	<i>Heterocerus</i>	unidentified	1
Scolytidae	<i>Xyleborus</i>	unidentified	2
Silvanidae	<i>Silvanus</i>	<i>S. castaneus</i>	1
		<i>S. planatus</i>	1
	<i>Cryptamorpha</i>	<i>C. desjardinsii</i>	2
Scarabeidae	Unidentified		1
Noctuidae (larvae)	<i>Litoprosopus</i>	<i>L. futilis</i>	1
Unidentified			11

Discussion

Information from the survey forms revealed the variety of wood items that were infested by WIBs including furniture, cabinets, plywood, doors, paneling, picture frames, artwork,

and carvings. Powderpost beetles (Lyctinae) and bamboo borers, *Dinoderus minutus* (F.) were common in bamboo and rattan items including furniture and basketry. Unusual infestations included the fungus weevil, *Phoenicobiella chaemeropis* Cockerell (Anthribidae) infesting the palm fronds of a tiki hut, *Heterobostrychus aequalis* (Waterhouse)(Bostrichinae) infesting a shipment of billiard cue sticks, and *Xylopsocus capucinus* (F.)(Bostrichinae) emerging from a large Christmas wreath and boring into expensive wood furniture. No structural, load-bearing wood was reported to be infested other than a buprestid, *Chalcophora virginianensis* (Drury) infesting a wooden porch post and a cerambycid, *Typocerus zebra* (Olivier) infesting the logs of a rustic cabin. Only one case of infestation by the old house borer, *Hylotrupes bajulus* Serville, was recorded. This was a severe infestation of attic joists and rafters in a large apartment building that I inspected.

Also of interest were infestations by the Mexican book beetle, *Tricorynus herbarius* (Gorham)(Anobiidae). This species will feed opportunistically on wood, though it prefers to feed on natural products such as seeds and leather, as well as book bindings (White 1963). Infestations I observed and from which I collected specimens were in books, stuffing in antique chairs, and baskets made from plant fibers and wicker. In some cases, the beetles had burrowed into wood furniture and book cases.

Among the other findings of the survey were that many treatments were not applied until positive identification of the infesting beetle was made. Also, there were several instances where non-wood infesting beetles were mistaken for WIBs. Both of these findings indicate the importance of having comprehensive information on WIBs published and available to the pest control industry as well as education and training on identification of exotic species.

Most of the infestations in the survey were apparently “built in”, the result of infested wood and items being brought into the structure. These infestations rarely spread to other items in the structure or to structural, load-bearing wood.

Information on the origins of infested wood items indicate that imports, especially from China (Table 4), southeast Asia, and South America, are likely contributing to a large percentage of infestations in Florida. Because imports of wood products have increased tremendously in the last 5 years (U.S. Department of Commerce 2006) a rise in WIB infestations, especially of exotic species, should be expected in Florida over the next few years. Increased imports will also increase the threat of accidental introduction into Florida of forest and ornamental pests in infested wood packing and decorative items (wreaths, pine cones, baskets, vines, etc.).

Table 4. Wood and wood articles (in thousands \$USD) imported from China.

Item	2000	2005	% change from 2000
Rough wood	114	989	769%
Packing	1,485	5,843	293
Veneer < 6 mm	4,680	18,685	299
Frames	104,123	215,299	107
Shaped wood	39,527	340,154	761%
Marquetry	313,791	371,628	18
Wood articles	184,624	383,353	110
Plywood, veneer, laminates	30,317	613,130	1,922%

* Source: U.S. Dept. of Commerce, TradeStats Express, <http://tse.export.gov>

Acknowledgments

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FIELD EVALUATION OF SPOT TREATMENTS OF FIPRONIL (0.06%) FOR CONTROL OF CARPENTER BEE, *XYLOCOPA VIRGINICUS* (LINNAEUS), ACTIVITY

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In the late-spring, homeowners often notice large, black Carpenter bees hovering around the outside of their homes. These bees have over-wintered in old brood galleries and are now out for approximately two weeks of mating and nest building. While the aggressive males can be a nuisance, the damage caused by nest building females can cause serious concern for homeowners. One female bee can construct new brood chambers that are 4-6 inches long or enlarge older ones, causing considerable wood damage. Additional damage can occur when woodpeckers drill into the galleries to eat the developing bee larvae. Homeowners are justifiably concerned and want effective control recommendations.

Unfortunately, the current control recommendations have remained unchanged for many years and are often impractical or ineffective. Recommendations include painting exposed wood to prevent infestation. Painted wood is not always a deterrent to Carpenter bees and they will often bore right through the paint. Also, in southwest Virginia many homes are log style or shingled with unfinished wood so painting is not an option. Other control recommendations include pyrethroid dust treatment of active galleries followed by plugging the holes after the adult bee is dead. However, by this time the wood damage has already occurred. Every year homeowners are looking for new treatment methods to control Carpenter bees. Therefore, in the spring seasons of 2003-2005, our laboratory conducted field tests to determine if spot treatments of Fipronil (0.06%; Termidor SC, BASF) could control Carpenter bees.

Materials and Methods

Our field evaluations were conducted during the month of May in 2003, 2004, and 2005 in the counties surrounding Blacksburg, Virginia and one county in far SW Virginia. The test sites included a variety of structures; painted homes; unpainted log cabins; barns; outbuildings; commercial buildings. To be included in the test, sites receiving the Fipronil treatment had to have at least 5 Carpenter bees flying prior to treatment. Control sites had to have at least 4 bees flying. Control sites were located either on the same structure, often on the opposite side of the building from the treatment, or in nearby areas where we could be confident that the treatment and control locations were exposed to the same environmental conditions.

A spot treatment was defined by the Termidor SC label as a 2'X2' area. This definition was expanded to accommodate areas that included eaves that might be 32' long but 6 inches wide. The treatment areas were chosen so that Carpenter bee activity could be easily counted from one viewpoint. Spray applications were made according to the label rate of 0.06% and applied to the point of run-off.

A baseline count of Carpenter bee activity was made at each site the day of treatment and then recorded every day for 5 days after treatment. Bee activity at a single site was counted for 1 minute, two times during a 15 minute period between the 10:30 am and 1:00 pm. Bee activity was averaged over both counts. Temperature, relative humidity and precipitation were also recorded. Dead Carpenter bees on the ground were collected and recorded daily from treated and control sites.

In 2005, sentinel honeybee hives were placed at Fipronil treated and control locations to determine if the Fipronil spot treatments had an effect on honeybees foraging in the area. One to three days prior to spot treatment, bee hives were placed 30-50 yards from a designated treatment area. Honeybee mortality was recorded for 5 days after treatment.

Carpenter bee activity data were analyzed using repeated measures ANOVA (SAS Institute 2005). The mean number of dead Carpenter bees found at treated and control sites were recorded and compared using the Student's *t*-test. Similarly, the mean number of dead honeybees at treated and control sites were compared using the Student's *t*-test. Values of $P < 0.05$ were used to indicate significance.

Results

Carpenter bee activity in both treatments declined over time (Figure 1). Carpenter bee activity in the Fipronil treated sites declined by 49% in the first 24 h. Carpenter bee activity continued to decline in the Fipronil sites over the next 4 days until the post-treatment activity was 14% of the initial.

During the first 4 days of the test, Carpenter bee activity in the control locations fluctuated but was not significantly different from the pre-test activity. The number of active Carpenter bees ranged from 117% to 79% of the original Carpenter bee counts prior to testing.

Carpenter bee activity in both Fipronil and control treatments declined during the 5 day test period. However, there was a significantly greater decline in the Fipronil (0.06%) treatment ($P = 0.001$). We can attribute the decline in Carpenter bee activity at the Fipronil treated sites directly to Carpenter bee death. An average of 6.7 ± 3.0 dead Carpenter bees were collected from each of the Fipronil (0.06%) treated sites over the five day test period (range 0 - 45). No dead Carpenter bees were ever found at the control sites including those on the same property.

Honeybee foraging activity was not affected by the Fipronil spot treatments. Mean mortality in honeybee hives placed at Fipronil treated sites was 52.7 ± 13.9 over 5 d. Mortality in honeybee hives placed at control sites was 54.5 ± 17.5 over 5 d. These difference in mortality were not significant ($P = 0.94$).

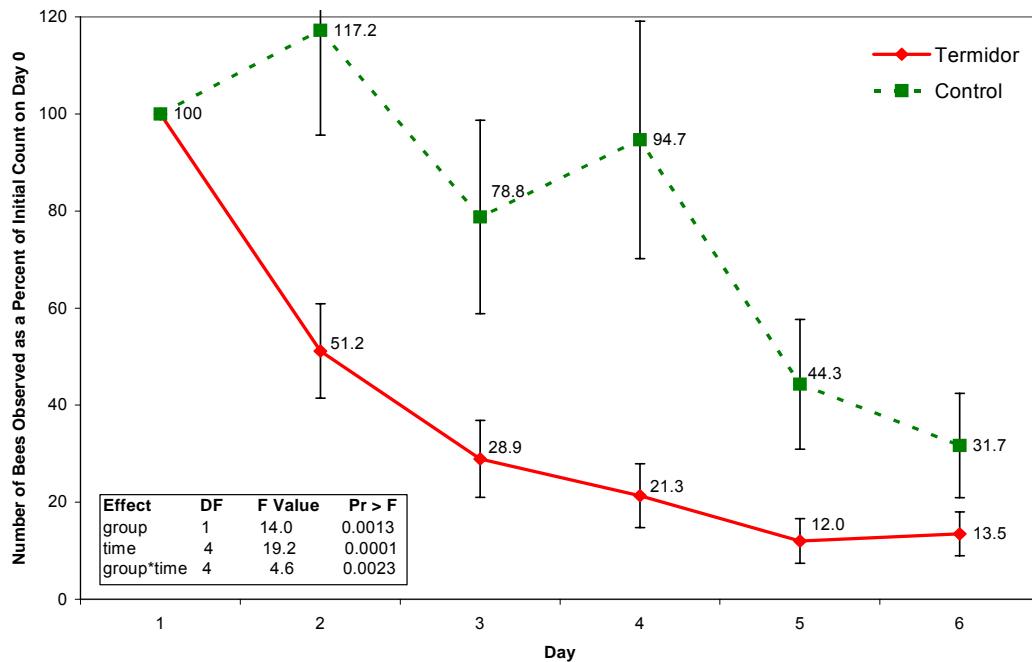


Figure 1. Carpenter bee activity presented as a percentage (\pm SE) of initial activity observed prior to spot treatment with Termidor (0.06% fipronil). Observations made over the 3 year of field test are pooled.

Summary

Spot treatment of structures with a 0.06% solution of Fipronil caused a significant decline in Carpenter bee activity as compared to control sites. The greatest impact on activity occurred within one day after treatment. The dead Carpenter bee counts confirmed that bees exposed to Fipronil treatments were actually dying and not just leaving the area. Dead bee traps on managed honeybee hives indicated that spot treatments of Fipronil had no impact on foraging honeybees.

USING ACETAMIPRID ALONE, AND IN COMBINATION WITH BIFENTHRIN, TO CONTROL THE SUBTERRANEAN TERMITE, *HETEROTERMES AUREUS* (ISOPTERA: RHINOTERMITIDAE) IN SOUTHERN ARIZONA

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Acetamiprid is one of the new classes of synthetic insecticides referred to as chloronicotinyls or neonicotinoids. These chemicals act as agonists at the acetylcholine-binding site of the nicotinic acetylcholine receptor of insects. They are potent neurotoxins with broad spectra and good systemic action. These insecticides display selective toxicity due to the specificity of insect and mammalian nicotinic receptors. Their low mammalian toxicity and high potency to insects make them excellent candidates for control of termite infestation. FMC Corporation is developing acetamiprid for use as an insecticide to control subterranean termites. We evaluated the efficacy of acetamiprid, alone, and in combination with bifenthrin, against the subterranean termite, *Heterotermes aureus*. We conducted both laboratory and field studies. In an initial 24 h continuous contact laboratory vial bioassay, we compared the concentrations (doses) of acetamiprid, chlorfenapyr, fipronil, imidacloprid, and thiamethoxam, required to kill 50% (LC₅₀) and 90% (LC₉₀) of *H. aureus* termites. In a second vial bioassay, we assessed the efficacy against *H. aureus* of acetamiprid and fipronil at 4, 6, 12, and 24 h intervals of continuous contact. In separate field studies, we evaluated the efficacy of acetamiprid alone, and then in a combination product [acetamiprid/bifenthrin (0.05/0.06%)], against infestation by *H. aureus* of residential structures.

Materials and Methods

Vial Bioassays. Laboratory tests were conducted on *H. aureus* termites recently collected from the Santa Rita Experimental Range, Tucson, Arizona. Test dilutions of acetamiprid, chlorfenapyr, fipronil, imidacloprid, and thiamethoxam were prepared at 0.1, 0.3, 1, 3, 10, 30, and 100 ppm. Stock solutions of technical material dissolved in 100% acetone were used to make all test dilutions. One ml of each dilution rate was added to a 20-ml glass scintillation vial. The open vial was placed on a hot dog roller in a hood. This allowed the inside of the vial to be uniformly coated with active ingredient, and at the same time allowed the acetone to flash off. The vials were then stored in a freezer until they were used in the bioassays. Ten to twelve workers were added to each vial and each vial was covered with its screw cap. Twenty replicates of each dilution rate for each insecticide and a water control were prepared in this manner. All vials were placed on a gentle slope so that termites could walk on the sides of the vials. Vials were stored at 25°C 90 % RH in the dark for 24 h. Tests were assessed 24 h after the termites were placed in the vials. Counting the total number of termites in a vial and comparing this number with the number of termites that could not move in coordinated manner determined mortality.

In a second vial bioassay, test dilutions of acetamirpid, and fipronil were prepared at 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3, and 10 ppm in the same manner as noted above. Ten to twelve workers were added to each vial and each vial was covered with its screw cap. Twenty replicates of each dilution rate for each insecticide, a water control, and an acetone control were prepared in this manner. All vials were placed on a gentle slope so that termites could walk on the sides of the vials. Vials were stored at 25°C 90 % RH in the dark for 24 h. Tests were assessed at 4, 6, 12, and 24 h after the termites were placed in the vials. Mortality was determined in the same manner as noted above.

Field Studies. In one field study, ten (10) infested single-family dwellings were selected in the Tucson metropolitan area for full treatment application with acetamirpid alone. Each of five structures received a treatment of Acetamirpid 70 WP at a rate of 0.025%, while another five structures were treated with Acetamirpid 70 WP at a rate of 0.050%. Selected home sites had not received any termite treatment within 12 months prior to the application. All homes were monitored by inspection for the termite activity at various times starting 14 d post-treatment, thereafter every 14 d for 2 m and then at least every 3 m until 24 m post-treatment. In a second field study, five (5) infested single-family homes in the Tucson metropolitan area underwent full treatment applications with the combination product. All homes were monitored for the presence of termites at various times starting 7 d post treatment, then every 14 d until the structure was clear of termites, and thereafter at least at 3 m intervals. Both visual inspections and inspections using a motion detector device, PestFinder™, were utilized to monitor these homes.

Results

Bioassays. The *H. aureus* mean percent mortality 24 h post-treatment for all doses of each insecticide tested was significantly greater than the control with the exception of chlorfenapyr at 0.1 ppm. Table 1 reports the 24 h post-treatment LC₅₀ and LC₉₀ doses for acetamirpid, chlorfenapyr, fipronil, imidacloprid, and thiamethoxam. Acetamirpid displayed high toxicity to *H. aureus* after 24 h of continuous contact. After 24 h contact, a dose as little as 0.1 ppm accounted for 90% termite mortality. Acetamirpid toxicity was comparable to the other tested neonicotinoids, and more potent than fipronil.

In a second bioassay, we tested smaller doses of acetamirpid and fipronil against *H. aureus* for 4, 6, 12, and 24 h of continuous contact. Figure 1 displays the dose response curves for acetamirpid after 4, 6, 12 and 24 h. Acetamirpid displayed high toxicity to *H. aureus* causing greater than 50% mean termite mortality for all dosages equal to or greater than 0.3 ppm after 6 h of contact.

Field Studies. Acetamirpid 70 WP formulation was mixed with water and full standard (4 gallons per 10 linear feet) liquid termiticide treatments were applied to ten *H. aureus* infested residential structures in Tucson, Arizona. One home was dropped from the study when it was sold during the study. Table 2 reports the linear feet of insecticide applied to each structure, the application rate, active mud tubes pre-treatment, and termite activity 1, 2, 8, 12, 24 m post-treatment for the remaining nine homes. Six of the

homes were clear of termites within 14 d post-treatment. One house cleared of termites within 28 d post-treatment. Two houses, one at the 0.025% rate and the other at the 0.050% rate, required 42 d to be clear of termite activity. The final house cleared of termites within 14 d, and then a new tube appeared at 28 d post-treatment, but all termite activity at this tube ceased within 14 d. Two houses, one at the 0.025% rate and the other at the 0.050% rate, had renewed termite activity prior to 24 m post-treatment. The Perry home had renewed activity at 12 m post-treatment in the garage. The Perry home received a selective re-treatment. In an area of the garage, the anchored cabinets were temporarily moved and a sub-slab injection was performed to a previously untreated area. This house has remained termite free 12 m post re-treatment. The Winter's home had renewed termite activity prior to 24 m post-treatment. It is pending re-treatment at this time. All other homes in the study remained clear of termites for at least 24 m post-treatment.

In a second study, five Tucson area residential structures received full standard (4 gallons per 10 linear feet) liquid termiticide treatments with an experimental combination product, 0.05% acetamiprid and 0.06% bifenthrin. Table 3 reports the linear feet of insecticide applied to each home, the application rate, the active mud tubes pre-treatment, and termite activity 1, 2, 8, and 12 m post-treatment for these five homes. Four of the five structures were termite free within 7 d. The Woon's home required 1 m to clear. The home showed evidence of termite activity by PestFinder™ within a hall wall at 7 d and 14 d post-treatment. The house was treated with foam applications of the combination product and cleared by 1 m post initial treatment. All homes in this study have remained free from termites 12 m post-treatment.

Discussion

Vial bioassay results support the potent toxicity of acetamiprid to *Heterotermes aureus* termites. The high levels of termite mortality caused by low dosages of this insecticide coupled with its low mammalian toxicity make it a good candidate to join the available liquid commercial termiticides. In our field tests, acetamiprid alone provided adequate protection to residential structures. One home underwent a selective re-treatment of a portion of its garage at 12 m. Termite activity appeared in an area of the garage that was not treated initially by sub-slab injection. This is more likely an error in the application of the termiticide. Another home awaits re-treatment. The combination product containing both acetamiprid and bifenthrin has afforded strong protection to the treated homes 12 m post-treatment. There has been no indication of any re-infestation at any of these study homes to date.

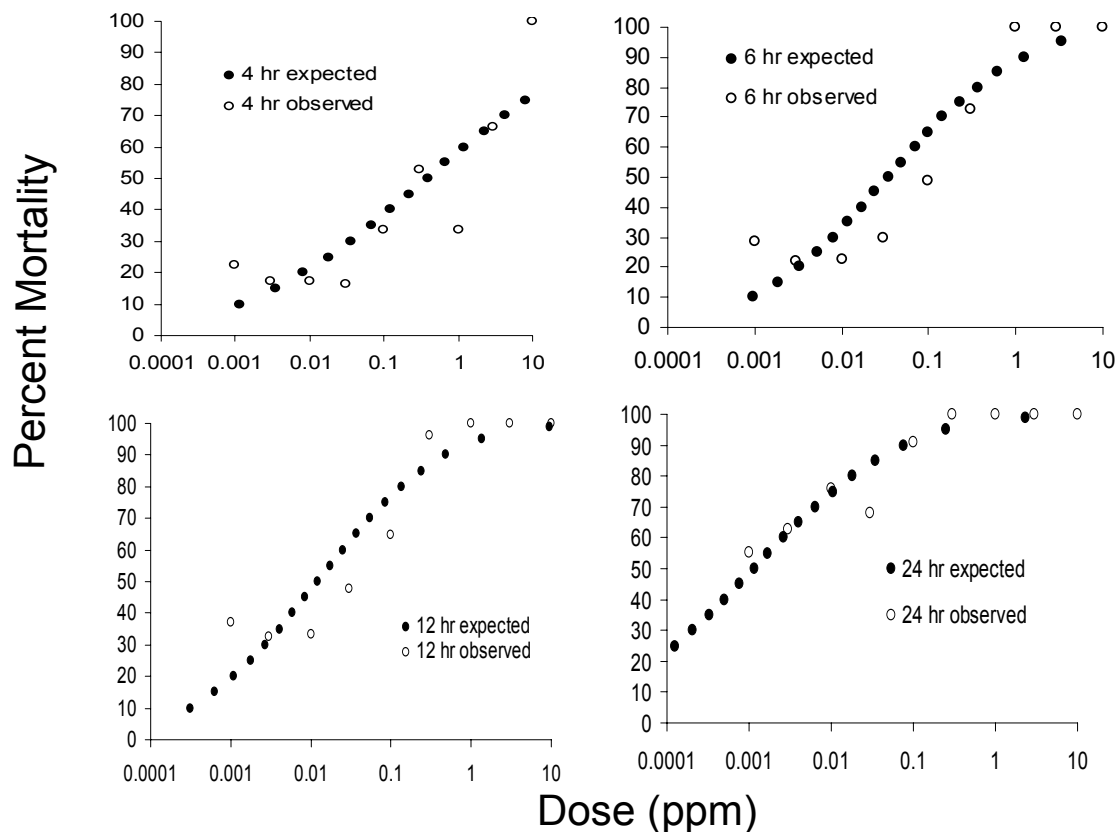


Fig. 1. The expected and observed relationship between doses of acetamiprid (ppm) and *Heterotermes aureus* termite mortality from continuous insecticide contact for 4, 6, 12 and 24 h.

Table 1. The LC_{50} and LC_{90} values (95% CI) of various insecticides to *H. aureus* workers exposed continuously for 24 h.

Insecticide	LC_{50} (ppm)	LC_{90} (ppm)
Acetamiprid	0.02 (0.004-0.038)	0.102 (0.067-0.132)
Chlorfenapyr	1.730 (0.974-3.069)	12.766 (6.6378-42.393)
Fipronil	0.075 (0.057-0.092)	0.311 (0.261-0.391)
Imidacloprid	0.054 (0.036-0.073)	0.408 (0.330-0.528)
Thiamethoxam	0.008 (0.0002-0.02)	0.055 (0.007-0.089)

Table 2. The structure name, linear feet of insecticide applied, the percent rate of active ingredient, the number of mud or ceiling tubes pre-treatment, and the termite activity post-treatment of homes treated with Acetamiprid 70 WP in Tucson, Arizona.

Structure	Linear Feet Applied	Rate	Mud or Ceiling Tubes	Termite Activity Post-Treatment					
				1 m	2 m	4 m	8 m	12 m	24 m
Ashram	420	0.025%	15	0	0	0	0	0	0
Butterbrodt	180	0.025%	28	0	0	0	0	0	0
Taylor	700	0.025%	4	1	0	0	0	0	0
Perry	355	0.025%	26	1	0	0	0	4	0
Walsh	179	0.025%	11	0	0	0	0	0	0
Winter	210	0.05%	28	0	0	0	0	0	7
Baumgarten	270	0.05%	7	0	0	0	0	0	0
Maglione	206	0.05%	14	0	0	0	0	0	
Angel Duplex	252	0.05%	27	0	0	0	0	0	0

Table 3. The structure name, linear feet of insecticide applied, the percent rate of active ingredient, the number of mud or ceiling tubes pre-treatment, and the termite activity post-treatment of homes treated with an acetamiprid/bifenthrin combination product in Tucson, Arizona.

Structure	Linear Feet Applied	Rate	Mud or Ceiling Tubes	Termite Activity Post-Treatment				
				1 m	2 m	4 m	8 m	12 m
Woon	416	0.05/0.06%	5	1	0	0	0	0
L'Armee	180	0.05/0.06%	4	0	0	0	0	0
Jones	388	0.05/0.06%	19	0	0	0	0	0
Riley	213	0.05/0.06%	3	0	0	0	0	0
Helton	417	0.05/0.06%	21	0	0	0	0	

* Helton home is at 11 m post-treatment.

PREVENTION WITH FIPRONIL OF COLONY FOUNDATION BY THE WEST INDIAN DRYWOOD TERMITE, *CRYPTOTERMES BREVIS* (ISOPTERA: KALOTERMITIDAE), IN ATTIC MODULES

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Fipronil SC (0.06% aqueous suspension), disodium octaborate tetrahydrate (10% aqueous solution), or water were sprayed on single sides of simulated attic modules with and without fiberglass insulation. Modules were exposed to dispersal flights of the West Indian drywood termite, *Cryptotermes brevis*, in April-June 2005. In November-December 2005, modules were disassembled and inspected for nuptial chamber composition and contents. No chambers were found in any of the fipronil-treated

modules, while significantly similar numbers of chambers with and without live termites were found in the DOT and control (water) treatments. The results support the efficacy of fipronil SC for prevention of drywood termite infestations in attics, wall voids, and other susceptible colonization sites within structures.

COPTOTERMES FORMOSANUS INFESTATIONS IN TIMBER RAILWAY BRIDGES: CHALLENGES FOR DETECTION AND TREATMENT.

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The Formosan subterranean termite (FST), *Coptotermes formosanus* Shiraki continues to expand its territory in the U.S. Twenty-five Texas counties are confirmed to have infestations of FST. Several of these have included infestations detected in timber railway bridges, particularly in the southeastern portion of the state. In order to fulfill inspection requirements, detection equipment was utilized to determine specific areas of infestation, in addition to typical visual cues. Due to the cryptic nature of this species of termite, visual cues were not effective indicators of infestation. Detection equipment included an infrared camera, an acoustic emission detector, a moisture meter, and the Termatrac®. Because of climactic conditions at the railway sites, the acoustic emission detector and the Termatrac® were the primary tools useful in the detection work. The location of the bridges over waterways or watercourses, as well as inherent limitations as a barrier treatment, or “passive” treatment, created situations that inhibited treatments with residual termiticides, utilized as liquid or foam. Termite baiting systems were utilized as in-ground and above-ground baiting strategy in an effort to be an “active” treatment strategy of population reduction. Results of efficacy of this strategy are presented.

ANTS
Chimney Rock

Moderator
Deanna Branscome
Syngenta

**DISPERSED CENTRAL-PLACE FORAGING IN THE ODOROUS HOUSE
ANT AS REVEALED BY A PROTEIN MARKER.**

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The odorous house ant, *Tapinoma sessile*, is a native ant species common throughout North America. In urban areas, this ant is classified a pest species and exhibits several attributes characteristic of invasive “tramp” ants (*sensu* Passera, 1994). These include: extreme polygyny, colony reproduction by budding, reduced internest aggression, generalist diet, and polydomy. We examined the organization of foraging and the pathways of food distribution in polydomous colonies of *T. sessile* in the laboratory and field using a novel marking technique (rabbit IgG protein) and enzyme linked immunosorbent assay (ELISA). Laboratory assays revealed patterns of food allocation from foragers to other castes and developmental stages. Foragers distributed the IgG-labelled sucrose to the majority of workers within 24 h, and workers retained significantly more sucrose than either queens or larvae. Approximately 50% of queens tested positive for the IgG marker and some queens received significantly more sucrose than others, indicating a possible reproductive dominance hierarchy. Larvae received little sucrose demonstrating their minor reliance on carbohydrates. The results of field experiments showed that odorous house ants are dispersed central-place foragers whereby ants from individual nests exhibit high foraging site fidelity, travel along well-established trails, and forage on a local scale. Dispersed central-place foraging most likely allows the odorous house ant to more efficiently secure both clumped and dispersed food sources and possibly increases its competitive ability. As a result, colonies become numerically large and ecologically dominant. The results of our study contribute to our understanding of the social behavior and colony organization in *T. sessile*. In addition, they provide a framework for designing more effective ant control programs based on liquid baits.

EVIDENCE OF AN EXOTIC *PARATRECHINA* SP. (HYMENOPTERA: FORMICIDAE) IN THE CONTINENTAL UNITED STATES: DESCRIPTION, DISTRIBUTION AND LABORATORY CONTROL

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An unidentified *Paratrechina* sp. nr. *pubens* Forel, believed to be an exotic ant species to the continental United States has been discovered. Morphometric observations of *P.* sp. nr. *pubens* demonstrated it to be smaller in overall size and possess fewer numbers of macrochetae in comparison to *P. pubens*. These findings may cause *P.* sp. nr. *pubens* to be considered an undescribed species in the continental U.S. This *Paratrechina* species has been found in businesses and homes of Pasadena and Deer Park, Texas, respectively. The distributions of this species within the two cities are 2.7 and 0.1 km², respectively. *P.* sp. nr. *pubens* was found in great numbers in both businesses and homes, causing numerous electrical shortages and immense annoyance to employees and residents. In areas where this species is well established, the red imported fire ant, *Solenopsis invicta* Buren, had been completely displaced. A laboratory bioassay was conducted to determine the susceptibility of this pest to a new insecticide, Dinotefuran®. Workers were found quite susceptible to most dosages. The LD₅₀ value for Dinotefuran®, calculated by log/probit regression, was 0.0003% (0.00008 – 0.0008) a.i. These results may justify the use of Dinotefuran® in the field for *P.* sp. nr. *pubens* control.

***MONOMORIUM FLORICOLA* (HYMENOPTERA: FORMICIDAE) CONTROL WITH MICROENCAPSULATED INSECTICIDES**

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Monomorium floricola is one of the main exotic ant species in Brazilian cities and is found in households, food facilities and hospitals. This species can be a mechanical vector of pathogenic microorganisms and thus there is a great interest in studying different insecticide formulations for its control. The aim of this work was to evaluate the microencapsulated formulation insecticides effectiveness on *Monomorium floricola* in laboratory conditions. The products tested were Demand 2.5 CS (Syngenta) and Dursban 20 ME (Dow AgroSciences) and three tests were carried out. In each test the mortality and repellence of the ants caused by those insecticides were verified. Tests

were divided into immediate application of the products, three-month as well as six-month residual applications. At the same time, the ants' behavior was evaluated when they got in contact with the products. Thirty colonies were used for each test, being 10 for each product and 10 for the control. The colonies were maintained in plastic trays placed between two tiles. In the treatments one of the tiles received the tested insecticide while the other one was not treated with insecticides. Food supply and water were placed on each of the tiles. In the control trays, one tile did not receive anything and the other one was treated with water. Repellency evaluations were made daily for 16 days, and the number of ants present on each tile was counted during observations. For the mortality analysis the number of dead ants was counted for 13 weeks. The ants' behavior observations were made for three hours. The ants that died when getting in contact with the insecticides as well as the treated tiles were submitted to the Scanning Electron Microscope (SEM) to analyze microcapsule presence. The microencapsulated insecticides did not show any repellency. Demand 2.5 CS provided a larger mortality of *Monomorium floricola* workers in all of the tests. Both insecticides killed the workers by contact and they were not transferred to the other members of the colony. The size of colonies increased during the tests. The SEM photos showed that the microcapsules burst previous to contact with the ants, and that during the dilution and application of the product; the active ingredients contained inside the capsules were exposed to the environment and operator. The products tested are not able to control *Monomorium floricola* colonies because they present high concentration of active ingredients, they are not protected by the microcapsules and they act by contact.

INTRODUCTION

The most common exotic ants in Brazilian cities are *Tapinoma melanocephalum*, *Paratrechina longicornis*, *Monomorium floricola*, *M. pharaonis* and *Pheidole megacephala* and the native ones are *Wasmannia auropunctata* and *Linepithema humile* among native tramp species the following native ant genera are also found *Crematogaster*, *Camponotus*, *Pheidole* and *Solenopsis* (FOWLER *et al.*, 1994; BUENO E CAMPOS-FARINHA, 1999).

Recent research in the Brazilian urban pest control sector showed that ants are among the most difficult pests to be controlled, especially in hospitals (CORRÊA, 2000).

Control methods using dry powders or sprays are not efficient because ant colonies are normally hidden and migrate when insecticides are applied nearby (GREEN *et al.*, 1954). In that way great amount of products is necessary contaminating human beings, animals, food and environment (JACOB, 2002) so, different formulations, like the microencapsulated ones, are studied in order to minimize such problems.

Therefore, this work had the aim at studying the efficacy of microencapsulated products disponible for ant control in Brazil. Ant repellence, insecticide residual and ant behavior were also analysed. For the first time it is studied microencapsulated insecticides behavior on urban ants.

MATERIAL AND METHODS

Monomorium floricola was chosen to the tests because it is a common species found in several regions of Brazil. The products tested were Demand 2.5 CS (Syngenta) and Dursban 20 ME (Dow AgroSciences) and three tests were carried out. In each test the mortality and repellence of the ants caused by those insecticides were verified. Tests were divided into immediate application of the products, three-month as well as six-month residual applications. The ants' behavior was evaluated when they got in contact with the products.

All tests were conducted using rearing units that consisted of Petri dishes (5 cm of diameter), filled with Plaster of Paris where two to three thousand ant workers, five queens and brood (eggs, larvae and pupae) were put inside.

The rearing units were maintained in plastic trays (30x26x8cm) placed between two tiles. In the treatments one of the tiles received the tested insecticide while the other one was not treated with insecticides. Food supply and water were placed on each of the tiles. In the control trays, one tile did not receive anything and the other one was treated with water.

Test I- Mortality and repellence – Immediate application

Thirty trays containing rearing units and tiles were used for the test, being 10 for each product and 10 for the control. Before observations, ants were starved for 48 hours. Only water was offered. After that period, *Tenebrio molitor* (Coleoptera: Tenebrionidae) larvae, a solution of honey and water and only water were offered to the ants and were disposed on the middle of each tile.

Repellency evaluations were made daily for 16 days, and the number of ants present on each tile was counted during observations. In the first day, food and water were offered at 9 a.m. and after two hours, observations were initiated. In the next days, observations started at 11 a.m. Food and water were changed three times a week, always at 9 a.m. For analysis and graphic confections, the mean number of ants from 10 repetitions were used and data were weekly accumulated.

For the mortality analysis the number of dead ants was counted for 13 weeks. Dead ants were taken off from trays three times a week, after food and water change. Tiles were not replaced during the test. For analysis and graphic confections, the mean number of ants from 10 repetitions were used and data were weekly accumulated.

Besides data described above, the development of the colonies (inside the rearing units) were weekly evaluated. Notes on the number of live workers on the tiles, number of brood, brood presence inside the rearing units, their development phases, amount of reproductive brood and winged adults and number of dead and live queens were done. Temperature was also noted. Quantitative data permitted to analyze colonies size.

The number of live workers on the tiles was established in the following way: N=0 – without ants; P = 1 a maximum of 10 workers; R = 2 from 11 to 50 workers and M = 3 more than 50 workers.

The amount of brood was determined in the following way: N = 0 without brood; R = 2 regular amount of brood and M = 3 great amount of brood. In order to infer the amount of brood, it was made a comparison between the initial quantity of brood disposed inside the rearing units.

Besides the presence of brood is related to its amount, it was separately evaluated once it is important to obtain information on the absence of eggs, larvae and pupae, independently, in order to better characterize the effects of the tested products. Thus, N = absence of brood; O = presence of eggs; L = presence of larvae and P = Presence of pupae. To analyze such variable the occurrences were considered in the following way: 0 = brood absence; 1 = presence of one development stage; 2 = presence of two development stages and 3 = presence of three development stages.

The presence or absence of reproductive brood or winged adults was evaluated in the following way: 1 = Yes; 0 = No, which furnished subsidies to interpret the other items. These observations were important to characterize colony temptatives of their preservation when conditions were not favorable.

Finally, the size of the colonies was evaluated through an assembly of observations for their maintenance. Thus it was assigned G = 3 when colonies had normal conditions; M = 2 when reduction of their initial size was noted and also compared to control colonies; P = 1 when great reduction compared to the control colonies was noted and M = 0 colony extinction.

Tests II and III – Mortality and repellence – Three and six months residual applications

The same methodology of Test I was used, but treated tiles were used three and six months after application. They were left in the laboratory without contact with insects or other organisms.

Test IV – Ant behavior

For the behavior analysis of ants that had contact with both insecticides, 12 trays were used, and the same methodology explained above was used. Four repetitions tested Dursban 20 ME, four tested Demand 2.5 CS and four served to control. Evaluations were made for three consecutive days (First day Demand 2.5 CS, second day Dursban 20 ME and third day control) and ants were left unfed for 48 hours before each test. Tiles were treated 24 hours before experiments.

Observations were done for 3 hours and notes were taken under a magnifying glass. Observed behaviors were trophalaxis between workers, toxic symptoms, self grooming, grooming, rejection of contaminated workers and death.

Test V – Scanning Electronic Microscopy (SEM)

Ant workers that died on the treated tiles and the ones that entered in contact with insecticides but did not die, were submitted to the scanning electronic microscope to analyze the presence of microcaps, and if possible, their number and how they were attached to the ant bodies.

RESULTS AND DISCUSSION

Test I – Mortality and Repellence – Immediate application

Tests with Demand 2.5 CS showed, in the first 5 weeks, ants equally foraging on the two tiles (treated and untreated). From the 6th week ants started foraging on the untreated tile ($\chi^2 = 8.16$; $p < 0.05$). Treatments with Dursban 20 ME showed ants foraging preferentially on untreated tiles since the first observations ($\chi^2 = 24.55$; $p < 0.05$).

Ants seemed to perceive the presence of insecticides and after six weeks, colony budding was observed, in both products. Ants moved brood and queens to under the untreated tiles and such behavior was observed in all colonies treated with both insecticides.

It was also observed that ant workers prevented walking on tiles that had dead ants, which died in the first contact with treated tiles, with both products. After dead ants were removed other ants tried to forage on treated tiles, but also died.

Thus, ant mortality differed, in both products from control [Demand 20 ME x Control: ($\chi^2 = 1140.5$; $p < 0.05$) and Dursban 2.5 CE x Control ($\chi^2 = 1081.4$; $p < 0.05$)], but did not differ between them ($\chi^2 = 1.1$; $p < 0.05$).

Colonies remained at the same size, in the treated colonies and control. The amount of brood did not decrease in any treatment and all development stages were observed (eggs, larvae and pupae). Products acted only in the workers and the microcapsules could not be transferred to any other member of the colonies.

Queens remained also equivalent in both treatments but lesser than control. It can be credited queen reduce in the treated colonies due to work mortality.

Test II- Mortality and repellence – Three month application

In the control trays, ants equally foraged in both tiles.

Results differed a little from Test I. Colonies treated with Demand 2.5 CS showed a higher number of ant workers on untreated tiles. From the second week the number of workers was almost the same in both tiles ($\chi^2 = 9.98$; $p < 0.05$).

In the treatments with Dursban 20 ME ants also foraged better on untreated tiles ($\chi^2 = 0.31$; $p > 0.05$), besides little difference has been observed on the number of ants foraging on both tiles.

Products did not lose their efficacy on mortality after three months from application once in this test, ants also died in contact with products. Budding occurred only with the colonies treated with Demand 2.5 CS, but such behavior was observed only in some repetitions.

Mortality in both treatments did not differ from control in the first four weeks of observation, where the number of dead ants was higher in the colonies treated with Demand 2.5 CS [Demand 20 ME x Control: ($\chi^2 = 851.8$; $p < 0.05$) and Dursban 2.5 CE x Control ($\chi^2 = 138.2$; $p < 0.05$)]. As in test I ant mortality was higher in the treatments with Demand 2.5 CS.

Colonies also remained at the same size, in the treated colonies and control, as in test I. The amount of brood did not decrease in any treatment and all development stages were observed (eggs, larvae and pupae). Products acted only in the workers and the microcapsules could not be transferred to any other member of the colonies.

Queens remained also equivalent in both treatments but lesser than control. It can be credited queen reduce in the treated colonies due to work mortality.

Test III- Mortality and repellence – Six month application

No significant difference was observed among ants foraging on treated and untreated tiles for both products [Demand 2.5 CS ($\chi^2 = 0.29$; $p > 0.05$) and Dursban 20 ME ($\chi^2 = 2.04$; $p > 0.05$)].

Ant mortality was higher in the colonies treated with Demand 2.5 CS (Demand 2.5 CS x Dursban 20 ME - $\chi^2 = 2436.8$; $p < 0.05$). Ants did not die immediately after contact with treated tiles, but it was noted that the number of dead ants was higher in this test. With residual application ants may have entered in contact with less microcapsules leading to a higher mortality.

Colonies also remained at the same size, in the treated colonies and control, as in test I. The amount of brood did not decrease in any treatment and all development stages were observed (eggs, larvae and pupae). Products acted only in the workers and the microcapsules could not be transferred to any other member of the colonies.

The number of queens was higher in this test in comparison to control.

Test IV – Ant Behavior

Behaviors were the same in all replicates and both products, during the three hour observations. It could be observed: shaking, antenation, slow walking, gaster raising and body bending. All behaviors were credited to toxic symptoms. Besides that, other behaviors were observed such as grooming, self grooming and trophalaxis.

Treatments with Demand 2.5 CS showed ants with toxic symptoms in the first 10 minute observation. Ants that entered in contact with all treated tiles died after 20 minutes and none of them could reach food supply.

Ants that entered in contact with Dursban 20 ME took much time to die, only after three hours of observation. But toxic symptoms appeared before the first hour. Some workers that entered in contact with the treated tiles and reached food supply got back to the colony and made trophalaxis.

Ant workers in the control colonies reached food supply in the first 5 minutes of observations and trophalaxis was observed, besides self-grooming. Such observations were important to compare behaviors in the treated colonies. Ants with toxic symptoms walked slowly, shaking, clean themselves several times. Other workers did not reject ants that entered in contact with products and came back to the colony.

Test V – Scanning Electronic Microscopy (SEM)

Samples of ants that entered in contact with treated tiles with both products did not show any microcap. Such results are credited to the absence of microcaps on the tiles that (estouraram) during application and ants died in direct contact with the insecticide. Those are important information, once microencapsulated formulations are sold in order to lesser environment contamination besides prolong insects' death.

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INTERCOLONY VARIATION IN BLACK CARPENTER ANT, *CAMPONOTUS PENNSYLVANICUS*, RESPONSE TO FIPRONIL (0.06%)

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Intercolony variation in black carpenter ant response to Fipronil (0.06%) was documented in laboratory trials. Black carpenter ants sampled from different colonies had significantly different LT50s when confined on substrates treated with fipronil. These differences indicated that carpenter ant colonies were differentially susceptible to

fipronil exposure. Differences in colony foraging activity (behavior) were also correlated with differences in colony susceptibility to fipronil. No clear dose response could be detected in toxicant transfer assays between different numbers of ants directly exposed to fipronil and unexposed ants. Our observations indicated that the intercolony variation in the assay replications, either due to differences in individual colony susceptibility or foraging behavior, confounded attempts to determine a dose/response ratio for all carpenter ants.

RED IMPORTED FIRE ANT CONTROL WITH A BAIT CONTAINING METAFLUMIZONE FROM BASF

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Metaflumizone, a new insecticide active ingredient from BASF, is effective in controlling red imported fire ants when applied in a bait formulation as indicated by the results of field trials comparing it to other commercially available baits. Field trials were conducted between 2002-2005 in several states infested with red imported fire ants and included both broadcast and mound treatments. Metaflumizone Granular fire ant bait (0.063%) applied as a broadcast treatment produced comparable reductions in mounds of red imported fire ants over a 30-70 day post application period compared to Amdro® Fire Ant Bait (0.73%) and Chipco® FireStar™ Insecticide bait (0.00015%). Metaflumizone fire ant bait was comparable to Dupont™ Advion™ Fire Ant Bait (0.045%) in eliminating field colonies of the red imported fire ant 14 days after treatment for both broadcast and individual mound treatments. In addition, the speed that Metaflumizone fire ant bait reduced fire ant worker foraging activity was comparable to Advion bait.

EVALUATION OF INTRASPECIFIC AGGRESSION AND NECROPHORESIS AS MECHANISMS OF DOSE TRANSFER FOR TERMIDOR® (FIPRONIL), PHANTOM® (CHLORFENAPYR) AND BIFENTHRIN

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Abstract: The Carpenter ant (subfamily Formicinae, genus Camponotus) is a cosmopolitan genera represented by over twenty species that constitute both structural and nuisance pest control problems. As social insects, carpenter ants exhibit certain behaviors that can be capitalized upon by insecticidal chemistries that have unique

physical properties in terms of lipophilicity, organic substrate binding, mode of action and repellency.

This paper evaluates the performance of two non-detectable chemistries, Termidor (fipronil) and Phantom (chlorfenapyr) as compared to the synthetic pyrethroid bifenthrin for dose transfer capabilities.

Termidor SC 0.06% , Phantom 0.50% and bifenthrin 0.06% prepared dilutions were sprayed directly over a porous substrate and allowed to dry. Live Carpenter ants were placed atop the dried surface and observed over time to determine intrinsic mortality. These primary victims served as donors for secondary transfer.

Upon death; the ants were transferred to non-contaminated arenas housing 50 ants with ample food and water. Ratio of transfer was 1 or 5 dead ants per 50 live ants and observed for mortality vs. time.

Discussion and results: Upon placement in the arenas, carpenter ants were observed to immediately aggress (initial *donor* carpenter ants were of different colonies; interspecific aggression) and move (necrophoresis) the carcass of the dead contaminated ants. Since the insecticidal residues were limited to the introduced dead ants; it is presumed that the transfer mechanisms involved in secondary transfer in this study were both through aggression and necrophoresis. Bifenthrin gave predictably high “knockdown” counts while full expression of mortality for both fipronil and chlorfenapyr came within 18 hours of exposure. Secondary transfer mortality was exceptional for fipronil only while chlorfenapyr and bifenthrin showed only slight differences from untreated controls.

MOLECULAR ADVANCES IN TERMITE RESEARCH
Blowing Rock, Tanglewood, Pinehurst

Moderator
Mike Scharf
University of Florida

***RETICULITERMES* OF NORTH AMERICA: MOLECULAR
IDENTIFICATION, BIOGEOGRAPHY, AND SYSTEMATICS**

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ABSTRACT Subterranean termites of the genus *Reticulitermes* are the most abundant, ecologically diverse, and structurally damaging species in North America. Consistent taxonomic identification of species within the genus is tenuous at best, and has led to several non-morphological methods, including molecular diagnostics and evaluation of gene sequence data. Evaluation of multiple gene markers has both corroborated and dismissed species descriptions based solely on morphological characters. Genetic evaluation of *Reticulitermes* from North America consistently follow biogeographic patterns and have revealed new species which should be further studied. Based on mitochondrial DNA (mtDNA) sequences, we present evidence of 4 new species, each monophyletically distinct and often occupying distinct bioclimatic zones. Significant differences in abundance of species between urban and undisturbed areas has revealed tremendous genetic variability of the species, and multiple exotic introductions of Nearctic *Reticulitermes* around the world are occurring. Given the small number of termite taxonomist which can accurately identify *Reticulitermes* species, molecular approaches offer alternative, efficient taxonomic tools that will invariably clarify the relationships of these important insects.

TERMITE POPULATION STRUCTURE REVEALED BY DNA MARKER TECHNOLOGY

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The way we analyze and interpret molecular data has changed significantly because of the synergy of two phenomena: the development of coalescent and phylogenetic theory and the invention of polymerase chain reaction (PCR) coupled with the discovery and introduction of sensitive DNA markers like mitochondrial DNA (mtDNA) and microsatellites or simple sequence repeats (SSRs) (Zhang and Hewitt 2003). Although 70% of metazoan studies to date involve mtDNA, the majority of ongoing metazoan research using nuclear DNA (nuDNA) employs SSRs (Zhang and Hewitt 2003). The last decade has witnessed substantial growth in the application of DNA marker methodologies to the study of subterranean termite population genetics (Broughton 1995; Kambhampati et al. 1996; Miura et al. 1998; Jenkins et al. 1999, 2001; Forschler and Jenkins 2000; Eggleton 2001; Husseneder and Grace 2001; Austin et al. 2002; Bulmer and Traniello 2002; Vargo 2000, 2003; Uva et al. 2004) because DNA can be utilized to illuminate problems which cannot be easily addressed by traditional field observations (Avisé 1994, p. 15). The processes of collecting and analyzing DNA marker data in order to evaluate termite population structure, however, presupposes an accurate assessment of population genetic diversity generally and genetic relatedness among individuals specifically. Technologies for data collection and software for data analyses, however, have limits. The DNA methodologies as well as the amount of data collected involve a compromise among available technologies, human resources and expertise, and financial constraints. The statistical software packages used to evaluate DNA datasets are each limited in scope by inherent assumptions that are part and parcel of the program and the limitations of the DNA marker employed. Thus, to understand the results generated by mtDNA and SSR markers that are so much a part of the Entomology literature, we must understand the limitations of each. It is the purpose of this paper, therefore, to briefly outline some of these limitations.

Mitochondrial DNA has a straight forward inheritance and is a powerful molecular marker for genealogical, evolutionary, and population genetic studies (Avisé 1994; 2000) as long as the marker's limitations are considered. It has been used as a DNA marker for more than 25 years (Ballard and Whitlock 2004). It is a haploid, neutral molecule with a high rate of nucleotide substitution and homologous gene sequences from myriad species (orthologous genes). It has become a potent tool in the study of termite population structure, gene flow and dispersal patterns, efficacy testing and phylogeny (Forschler and Jenkins 2000; Jenkins et al. 2001; Vargo 2003; Okhuma et al. 2005). A non-recombining molecule which lacks introns, mtDNA is generally maternally inherited. This means that the amassing of base substitutions sequentially along radiating female lineages generates new haplotypes. Multiple mitochondrial DNA gene trees, as opposed to a single mtDNA gene tree, therefore, have a greater chance of being congruent with a species' history because of this high mutation rate and an

effective population size (N_e) one-quarter that of any nuclear locus (Ballard and Whitlock 2004). But mitochondria also fix new alleles faster than nuDNA. If the population of an introduced or founding termite species were genetically depauperate, then genetic drift would further exacerbate this condition resulting in the loss of even more mitochondrial variation due to the haploid, maternal linearity of inheritance (Avice 1994). This phenomenon would in turn limit the use of mtDNA in invasive studies. But if there were multiple sources of invasion mtDNA haplotype analyses could be extremely informative (Kolbe et al. 2004). The among-population genetic variation of an exotic introduction from different source populations becomes within-population variation when introduced into a new geographic region or niche (Grapputo et al. 2005). These variable populations then become the source of secondary invasions, the natural history of which can be studied (Jenkins et al. 2002).

Mitochondrial phylogenies may mirror recent dispersal history because the deeper history has been erased due to mtDNA introgression (Ballard and Whitlock 2004). Furthermore, some studies suggest that repeated hybridization and interspecific gene flow have obscured allopatric speciation in favor of sympatric speciation (Shaw 2002). Mitochondrial pseudogenes have also been demonstrated in nuDNA genomes (Smith et al. 1992) and this has weakened the markers effectiveness in some population genetic studies since the resolving power of methods to reduce the interference of these pseudogenes has been limited.

Microsatellites, unlike mtDNA, are bidirectionally inherited. They are abundant and fairly evenly distributed in eukaryotes (Schlötter 2004), including termites (Vargo 2000; Husseneder and Grace 2001; Jenkins et al. 2002; Deheer & Vargo 2004). They have high mutation rates, and therefore are highly polymorphic (Schlötter 2004). SSRs have been used to detect population genetic structure, to test parentage, genetic mapping and relatedness as well as assess genetic diversity (Avice 1994). SSRs are co-dominant markers. This means that a heterozygote's parentage can be teased apart using SSRs, providing genetic information on the inheritance from both parents and insights into termite population structure (Vargo 2003).

Simple sequence repeats are DNA fragments. They are easy to score by length variation, which is a character based on variable numbers of tandem repeats, e.g. (ATG) n . Homology or similarity due to a common ancestor is assumed. Size homoplasy within and between species has been discovered when SSRs were sequenced (Ortí et al. 1997). This means that a specific SSR size class can include alleles that are identical by descent (homology) and alleles that have become the same length via convergent evolutionary events such as parallelisms or reversions (length homoplasy). If SSRs of identical size are not identical by descent, then the homoplasious allele distribution could result in an erroneous phylogeny (Fisher et al. 2000).

Differentiation estimators estimate the amount of genetic differentiation in the subdivisions of a population, e.g. F_{st} and R_{st} statistics. They are more likely to be used than the newer alternative methods (Pritchard et al. 2000) to study population structure (Ortí et al. 1997). This is true because differentiation estimators are inextricably linked to

the movement of individuals between groups that results in genetic exchange, which is referred to as individual gene flow or the effective migrants ($4N_e m_e$) of a population. SSRs are highly polymorphic with high mutation rates of mostly unknown mutation patterns. Thus, since mutation cannot be teased away from migration, F_{st} will underestimate differentiation if a population is highly structured (Ortí et al. 1997). The F_{st} statistic estimated from SSR data in a moderately structured population should be an effective and informative tool. But the statistic based on SSR data is questionable in a highly divergent or structured population (Ortí et al. 1997). If the microsatellite markers fit well a step-wise mutation model (SMM), then R_{st} is independent of mutation and can be used in place of the F_{st} estimator.

In conclusion, this paper had neither space nor intent to be an exhaustive review. It was an overview of the caveats to the use of mtDNA and SSR markers, the major DNA markers used in termite population genetics studies. These limitations do not mean that mtDNA isn't an effective tool for studying termite phylogeny, phylogeography and evolution, or that SSRs aren't good markers for studying population structure. They must, however, be considered when discussing mtDNA and SSR results.

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BREEDING SYSTEMS OF *RETICULITERMES* SPP.: A COMPARATIVE STUDY BASED ON MOLECULAR MARKERS

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Abstract. Within a population of subterranean termites (Rhinotermitidae), colonies can vary widely in their breeding structure. Colonies can be simple families each headed by a single pair of primary reproductives. Or they can be extended families containing from a few to dozens of inbreeding neotenics descended from the original primary pair. And on occasion colonies can consist of mixed families containing the offspring of multiple same sex reproductives originating from outside the colony. The cryptic nesting and foraging habits of subterranean termites have made it difficult to obtain precise information on the relative numbers of the different colony types through direct observation. For a number of years, my lab has been using microsatellite markers to infer colony breeding structure in subterranean termites based on the genotypes of workers. I report here a summary of results on three species of *Reticulitermes* from the eastern U.S.: *R. flavipes*, *R. virginicus* and *R. hageni*. Most of our work has concerned the eastern subterranean termite *R. flavipes*, in which we have characterized over 350 colonies from eight populations ranging from Delaware in the north to Charleston, SC in the south. Our analyses show that across all populations, simple families are by far the predominant type accounting for 72% of all colonies. About one-quarter of the colonies are extended families, and only 3% are mixed families. Our data also indicate that colonies of this species in the populations studied are relatively localized with foraging distance of less than 30 linear m and usually much less. Further analysis of the genotypes shows relatively low levels of inbreeding. Comparison of these inbreeding values to those expected for different possible breeding systems based on computer simulations indicate that the reproductives in simple family colonies of *R. flavipes* are unrelated, and that the extended family colonies generally contain few neotenics (3-6) who are most likely the direct offspring of the original primary founders. Mixed family colonies generally contain workers from two or more distinct families, consistent with their formation from fusion of different colonies with no interbreeding between reproductives from different families, as we previously reported. A more complex picture emerges when geographic location of populations is considered: namely northern populations are more inbred than southern populations. Population latitude was strongly and positively correlated with both the proportion of extended families ($r = 0.89$) and the degree of inbreeding in extended families ($r = 0.64$). Thus, there appears to be a strong environmental influence on the level of inbreeding in *R. flavipes* populations. Data on *R. virginicus* and *R. hageni* are more limited, but colony breeding structure in these

species is similar to what we find in *R. flavipes*, except that we have not found any mixed family colonies of either species. We have characterized 24 colonies of *R. virginicus* from two populations in North Carolina. 81% of these colonies were simple families and the remaining 19% were extended families. Of the 50 colonies of *R. hageni* we have investigated from three populations, 88% were simple families and 12% were extended families. As we found in *R. flavipes*, cohabiting reproductives heading simple family colonies in *R. virginicus* and *R. hageni* are largely unrelated. The extended family colonies of these two species also appear to be headed by relatively few neotenics inbred for only a generation or two. Colonies of *R. hageni* appear to be localized with linear foraging distances of only a few m. In contrast, colonies of *R. virginicus* are often expansive with linear foraging distances up to 125 m, a record for *Reticulitermes* spp. Thus our results on these three species so far indicate that they share strong similarities in colony breeding structure with relatively low levels of inbreeding: most colonies are simple families headed by a single pair of primary reproductives, whereas a much smaller proportion of colonies are extended families headed by relatively few neotenic reproductives. A very small proportion of *R. flavipes* colonies are mixed families which may arise through colony fusion. Finally, we found no strong evidence of genetic isolation by distance in any of these species, as expected if colonies were frequently formed through short-range mating flights or budding, suggesting that budding, thought to be a common mode of reproduction in subterranean termites, may occur only infrequently at best in these species. A recent update of the results will be presented.

PARATRANGENESIS IN TERMITES

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Paratransgenesis is the use of genetically engineered microbes that live in association with a host species for various purposes. For example, genetically altered insect symbionts have been enlisted for the control of certain plant diseases and arthropod-borne diseases. The application of paratransgenesis is especially promising in social insects, because social interactions promote the exchange of microbes naturally. Among the social insects, termites are known for their ecological and economical importance and their close relationship with microbial symbionts. Subterranean termites harbor a diversity of protists and bacteria in their guts that fulfill important functions for the survival of their hosts, such as cellulose digestion, nitrogen fixation and recycling, acetogenesis as well as vitamin production (Bignell 2000). These symbionts provide excellent tools and targets for research into termite biology and control of the pest species among the termites.

In previous studies the bacterium *Enterobacter cloacae* was isolated from the gut of the Formosan subterranean termite (*Coptotermes formosanus* Shiraki) and genetically engineered to express green fluorescent protein. This bacterium was able to deliver and express foreign genes in the termite gut and was rapidly transferred among workers and soldiers in laboratory colonies (Husseneder et al. 2005a, Husseneder and Grace 2005).

However, this shuttle system needs to be optimized in various ways, before field application for termite control can be considered. (1) We need to identify termite specific gut bacteria, which are exclusively adapted to the gut environment, in order to minimize environmental impact. (2) We need to identify bacteria that are among the most common inhabitants of the termite gut regardless of geographic region, colony origin or colony nutrition to guarantee efficient and wide spread application of paratransgenesis. (3) We need to culture termite gut bacteria to obtain candidates for genetic engineering to become “shuttle bacteria”. Also, culture is necessary to investigate the roles of symbionts in gut ecology and termite nutrition in order to identify the best “shuttle bacteria” and targets. (4) Detrimental gene products need to be tested to establish their efficiency against bacteria, protists and the termite itself. The last step in this process will be to genetically engineer the bacteria that were identified as the ideal “shuttle bacteria” to express the optimal detrimental gene in the termite gut.

We have made significant progress towards identifying the necessary components for using paratransgenesis in termite control. Using culture-independent 16S rRNA gene sequencing (Husseneder et al. 2005b) of the gut content of Formosan subterranean termite workers from four colonies we have identified 45 different bacterial ribotypes belonging to seven different phyla. Thirty-eight ribotypes were novel species exclusively found in the gut of the Formosan subterranean termite. Bacteroidetes was the dominant phylum with the Bacteroidales ribotype 1 having the most representatives.

Bacteroidales ribotype 1 was also the only ribotype found in all termite colonies, including colonies from Japan, where this bacterium was found to be associated with one of the protists (Shinzato et al 2005, Noda et al. 2005). The fact that Bacteroidales ribotype 1 was the dominant inhabitant in the gut of the Formosan subterranean termite regardless of geographic origin, colony origin and colony nutrition suggests that this bacterial species is an obligate symbiont. The only genus of the Bacteroidales that could be cultured was *Dysgonomonas*. We have shown that species of this genus contribute to termite nutrition by producing vitamin B₁₂ (an essential vitamin that cannot be produced by the termite itself), which makes *Dysgonomonas* spp. preferable candidates to serve as shuttle bacteria. Another candidate is *Pilibacter termitis*, a species found to be dominant in culture and shown to be present in most termite colonies across geographical regions by culture-independent methods (Higashiguchi et al. 2006). Experiments are under way to establish transformation protocols and assess expression of foreign genes by these bacteria species.

The three species of protists associated with the Formosan subterranean termite are promising targets for detrimental genes introduced via paratransgenesis, because of the vital role they play in cellulose digestion. We established that termites die six weeks after killing the protozoa in their guts. We are able to keep protists alive for at least 24hr in sparged Trager U media (ph 7.0, Trager 1934). This allows us to test candidate peptides and expressed genes for their effectiveness in killing protozoa before testing them *in vivo*.

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DARWINIAN THEORY AND THE ROLE OF THE SOLDIER IN COLONY CASTE REGULATION

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ABSTRACT. Molecular changes can result in phenotypic differences in a species that reflect a successful compensation to selection pressures. Traits become fixed within a species when they are well-matched to the environment and are passed on to future generations. The sterile caste in social insects posed a major threat for Darwin's theory of Natural Selection. Darwin argued that selection of the family could allow for this seeming contradiction. This possibility was later confirmed mathematically by W.D. Hamilton in his development of a relatedness model that included inclusive fitness as a component. Unlike the social Hymenoptera however, where all workers are more or less sterile, in the lower termites only one caste is truly sterile, the soldier caste. Thus, the soldier is the phenotype that must promote its genetic inclusive fitness for it to persist in the colony. Certainly, defense of the nest is one way the soldier can accrue some inclusive fitness points, but there appears to yet be another way. Juvenile hormone has been suggested to be a primer pheromone in termites and several publications from our laboratory have confirmed that JH titers of workers are somehow controlled by soldiers. Soldiers reduce the likelihood of a worker- to-soldier molt by reducing the JH titer in workers and promoting the development of nymphs (wing-budded individuals destined to become alates and ultimately reproductives). If JH is the regulator for this phenotypic expression the soldiers must be able to manipulate JH in

the colony environment. Work in the 1970s suggested that presoldiers (sometimes called white soldiers) and soldiers may be able to store JH in the corpora allata. As such, the soldier may act as some sort of JH sponge. A resulting low level of JH in the colony environment releases the constraints imposed on reproductive development mainly controlled by the queen's copious production of the hormone. How the soldier regulates the colony JH titers in workers is unknown, although it has been shown that contact between workers and soldiers is necessary. If JH is involved it most likely acts as a catalyst for induction of proteins controlling phenotypic expression and chemoreceptor sensitivity.

One way to gain insight into this phenomenon was to determine how JH titers are related to soldier production in different termite species. Remarkably, termite soldiers are maintained at a very specific level in a colony. I argued that species that have high soldier numbers may reflect a higher level of selection pressure. I hypothesized that Formosan subterranean termites (which have ca. 10% soldiers) may have a greater sensitivity to transformation in the face of JH compared with one of our native species in the US, *Reticulitermes flavipes* (which has fewer than 2% soldiers). Since ants are considered a major predator of termites, as species move from temperate to tropical climates ant pressure should increase and result in higher fixed ratios of termite soldiers. But how would control of JH fix such a colony level trait? Research published last year by my laboratory indicated that in fact worker-to-soldier molt in Formosan termites occurs when JH titers reach about 6pg/individual, whereas, more recent and presently preliminary results collected with the help of a colleague in Ohio (Professor Susan Jones) revealed that a much higher level of JH is required for worker-to-soldier molt in the temperate climate residing Eastern subterranean termites (17 pg/individual). These results have led to yet one more speculation that has piqued my interest over the last 10 years. Anyone working with Formosan subterranean termites knows that it is impossible to induce a worker-to-nymph molt in the laboratory. Eastern subterranean termites on the other hand will readily move in this direction. Meanwhile, in the field, nymphs of *C. formosanus* are collected frequently. I believe this phenomenon is JH related. Just as high JH titers can induce soldier production, low JH titers can produce nymphs. I propose that *C. formosanus* colony JH levels must be exceedingly low for nymphal production. We have collected some data to support this. The larval termite (1st and 2nd instar) is the critical point of transition to nymph in *C. formosanus* workers. Work with *Reticulitermes flavipes* indicate that the larval stage has the lowest JH titer of any termite stage or caste (including eggs!). So why can't we reach those low JH levels in the laboratory for *C. formosanus*? I believe that colony size may play a role here. Formosan colonies are typically 10X the size of a native termite colony. I suggest that large colony size is a necessary trait in *C. formosanus*.

DISCOVERY AND FUNCTIONAL CHARACTERIZATION OF TERMITE CASTE-REGULATORY GENES

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Polyphenism, also known as phenotypic plasticity, is the occurrence of multiple phenotypes within a species. Polyphenism is mostly induced by differential gene expression, which is typically driven by extrinsic environmental factors. Termite caste differentiation is perhaps the best example of insect polyphenism. Recent studies on termite gene expression from a number of laboratories worldwide have led to the identification of numerous genes potentially involved in mediating caste differentiation. Other research has focused on the hormonal basis of caste differentiation with much recent success; specifically juvenile hormone III (JH). While an understanding is emerging with respect to hormones and gene expression in termite caste differentiation, extremely little is known regarding how environment, genes and hormones interact to enable and/or suppress caste differentiation. Developing a complete understanding of termite caste differentiation will require an understanding of all these factors and their interactions.

In our laboratory, we have identified several dozen candidate caste-regulatory genes, and have begun to functionally characterize these genes using expression profiling and RNA interference (RNAi). Two genes to date, named *Hexamerin-1* and *-2*, have proven highly important to caste regulation. Both genes and the proteins they encode are inducible in workers during JH-induced presoldier differentiation. Both proteins constitute a major proportion of total worker protein, and one protein in particular (Hex-1) binds JH. Initially, we postulated that the hexamerins should mediate or enable caste differentiation; however RNAi revealed the complete opposite to actually be occurring. When the hexamerins were silenced by RNAi, presoldier differentiation increased between 3- and 5-fold. Thus, we conclude that the hexamerins serve a *status quo* regulatory function that attenuates presoldier differentiation. In the context of termite sociality, this mechanism is apparently important because it serves to maintain high worker caste proportions and high colony fitness.

The hexamerin system of caste-regulation is the first example of its kind from not only termites, but any social insect. It is extremely unlikely, however, that the hexamerins are solely responsible for termite caste regulation. Clearly, other important genes and regulatory factors must be out there awaiting discovery. As alluded to above, understanding the interactions of extrinsic factors, hormones and genes is essential to developing a complete understanding of termite caste differentiation. For example, it is known that JH induces presoldier differentiation, but what factors induce or regulate JH? Answers to such questions will require concurrent investigation of hormone titers and gene expression in response to: (1) extrinsic environmental factors such as temperature, moisture and food quality; as well as (2) extrinsic colonial factors such as

caste composition and caste-derived semiochemicals. Once the influence of these factors on gene and hormone expression are known, it will then be possible to use the powerful tool of RNAi to unequivocally define individual gene function and to delineate regulatory gene networks that underlie caste differentiation.

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BAIT TECHNOLOGY FOR PEST ANT MANAGEMENT

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INSECTICIDAL BAIT FOR PEST ANT MANAGEMENT: AN OVERVIEW

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Baits have been recommended for ant pest management for nearly a century (Rust 1986, Mallis 1969). Some of the first baits recommended for controlling the Argentine ant, *Linepithema humile* (Mayr), were prepared with lead arsenate (Newell 1909), sodium arsenite (Barber 1916), and thallium sulfate (Mallis 1969). However, Newell (1909) reported, "When supplemented by other measures, such as mechanical destruction of the colonies, the use of these mixtures will not be found satisfactory unless used steadily and persistently for a long period." Even with the earliest bait formulations, bait acceptance and slow-acting toxicants were a major concern.

Ants represent a diverse and broad group with 8,804 species being identified and possibly as many as 20,000 species worldwide (Hölldobler and Wilson 1990). In California, there are 9 subfamilies, 44 genera, and 285 described species (Ward 2006). Of these species probably about 30 to 40 species have been reported associated with human structures (Ebeling 1975, Hedges 1998, Smith 1965). These species have radically different nesting habits, foraging behavior, and nutritional requirements. Consequentially, there is no real universal bait base or ant bait. When Amdro fire ant bait was tested against 12 different species of ants found in California, none of the Dolichoderine ants such as Argentine ant, odorous house ant, velvety tree ant, or pyramid ants accepted the bait (Wagner 1983). Several species of harvester ants belonging the genera *Pogonomyrmex* and *Veromessor* accepted the bait and were killed.

Ant workers have specialized structures to ingest, transport and utilize liquids. The infrabuccal cavity screens out particles before liquids pass through to the pharynx (Hölldobler and Wilson 1990). The proventriculus is modified so that the crop can serve

as storage organ and permit fluids to be retained. Both of these modifications are important and contribute to the trophallaxis of liquids and semiochemicals between workers, larvae, and queens. Consequentially, only liquids are passed in trophallaxis. Solid foods are typically feed to the larvae. For example, solid protein was fed primarily to older larvae in Pharaoh ant, *Monomorium pharaonis* (L.) (Haack et al. 1995). Peanut oil and sucrose water were widely distributed among the workers. However, peanut oils were not as readily metabolized as the sucrose solutions. In the Argentine ant, sucrose water was primarily distributed among workers, queens and males. Proteins were readily distributed among larvae and queens (Hooper 1998). Liquid baits will be more readily passed through the colony.

The ideal ant bait must balance the speed of toxicity against the amount of feeding, trophallaxis and recruitment. Toxicants must have delayed activity. The ideal toxicant for baits to kill red imported fire ant, *Solenopsis invicta* Buren, must have the following properties (Stringer et al. 1964): delayed toxicity over at least 10- to 100 fold range, kill < 15% of workers at 24 h, kill no more than 89% at 14 d, be readily transferred, and be non-repellent. In developing baits for Argentine ants, there is a range of sucrose and toxicant solutions outlined by the box that are acceptable and active (Fig. 1, Rust et al. 2004).

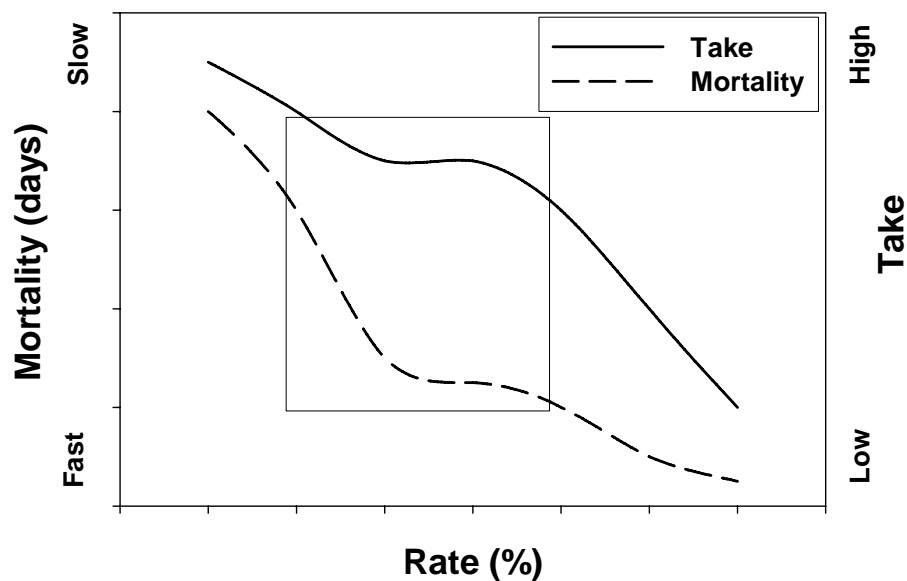


Fig. 1. The rectangle represents the concentrations of toxicant that provide the optimal kill and acceptance of bait.

In addition to determining the optimal concentrations and bait bases for the bait, there are additional challenges in developing suitable bait stations and formulations. For

example, the width of the ant worker's head dictates the size of solid particles that can be foraged by workers, except for harvester ants (Hooper-Bui et al. 2002). Small ants such as Pharaoh ant typically forage small particles, 420 to 590 μm . *L. humile* fed 8-fold longer on gel formulations than they did on sucrose solutions, but they only consumed about 5-fold less bait (Silverman and Roulston 2001). Evaporation and concentration of aqueous and gel baits are also a problem. These are real and significant challenges to developing baits to control ants in and around structures.

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DEVELOPMENT OF COMMERCIAL ANT BAITS

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ABSTRACT. Ants are difficult to control but, short of finding and directly treating the colony, baits remain the best control technique. However, good ant baits are not easy to develop for a variety of reasons. Baits that attract and kill multiple species of ants are clearly more desirable but they are more difficult to develop. The key North American ant species, or species groups, targeted for pest control include the following: Argentine ant, Acrobat ants, Bigheaded ants, Carpenter ants, Crazy ants, Fire ants, Ghost ants, Little Black ants, Odorous House ants, Pavement ants, Pharaoh ant and Whitefooted ant. These species represent very diverse feeding behaviors and food preferences. It is much easier to focus on a limited number of these species or on groups of species with similar feeding habits.

Taxonomy is an issue in ant bait development because it is often difficult to identify pest ants to species. Some groups are more complex or poorly studied than others. Examples include the *Solenopsis molesta* group (Thief ants), which are comprised of a complex of many species, all of them very small. The Little Black Ant group (*Monomorium minimum*) is also a complex of many species, all small and with few good taxonomic characters. The Rover ants (*Brachymyrmex* spp) are another difficult group. They are small and common in the Southeast United States. Pavement ants are not all *Tetramorium caespitum*. In St. Louis, for example, they are almost exclusively *Tetramorium tsushimae* Emery which probably invaded the area from Asia in the late 1980's.

Baits are simply mixtures of common food components such as carbohydrates, proteins and lipids mixed together in the optimum proportions. But, the proper ratios and the specific ingredients required makes development more difficult. Sources of information on food ingredients include books (ex. Food Chemistry, H. Belitz and W. Grosch and Gower's Handbook of Food Additives by M. Ash and I. Ash), technical journals (ex. Journal of Food Science and Journal of Agricultural and Food Chemistry) and trade publications (ex. Food Product Design).

Food ingredient samples for testing can be obtained from a variety of sources, including small specialty manufacturers up to huge companies such as ADM, Cargill, Nestle and Unilever. Free samples are usually available upon request. Use "Food Master", a food and beverage industry supplier database to help find companies that make, or supply, needed ingredients.

Test simple "non-processed" ingredients with known components for most understandable results. Processed (complex) ingredients are less consistent and can change without notification. Changes in processing or levels of minor ingredients can

affect ant food preferences. Primary bait matrix ingredients should be relatively inexpensive.

The characteristics of an “ideal” ant bait active ingredient are well-known. It should be non-repellent, have a delayed mode of action over a wide range (10X to 100X) of concentrations and it should be readily transferred from one ant to another. However, few active ingredients are ideal so, in these cases, how does one proceed? First, test the candidate active ingredient, on an acceptable matrix for repellency at many doses to learn if there is a non-repellent dose rate that provides effective control. Repellency testing differs according to formulation. All things being equal, repellency is potentially a bigger issue in liquid and gel baits due to evaporation concentrating the active.

In formulating and testing baits, always start with a simple formula that the ants will readily accept. Establish the physical details of the matrix from the beginning of testing. For example, add viscosity modifying ingredients to aqueous formulations and use a grit size in granular formulations optimized for the target ant species preferences.

Evaluation of new formulations should be done systematically by adding and testing one new ingredient at a time. The new formulation should then be directly compared to the previous formulation. In the field, these tests are conducted using a cafeteria-style design employing circular plastic disks containing four wells. Bait samples are offered to foragers and when the most preferred sample is completely removed, the test is completed and the amounts of bait remaining in the other wells are estimated and recorded. After suitable replication, the mean percentage of bait remaining is calculated for all samples and this value is used to rank ant preference for the baits.

Preservatives are added to baits to keep them fresh and attractive to ants. Preservatives include antimicrobials and antioxidants. Common antimicrobials include sorbates, benzoates, sulphites, propionates, nitrates and parabens. These help to prevent the growth of molds, yeasts and bacteria. They typically work best in acidic systems. Antioxidants help prevent the oxidation of food that occurs in the presence of heat, light and some metals. Oxidized foods become rancid and discolored with “off” odors-flavors that are unattractive to ants. Common antioxidants are BHA, BHT, vitamin C and tocopherol. At normal use rates these appear to have minimal effect on ant bait acceptance. Nevertheless, it is always best to retest formulations for ant acceptance after adding any preservative.

Baits must be shelf stable for a minimum of 12 months (EPA requirement) and preferably 24 months or more. Stability testing generally involves exposing the bait to a regimen of extremes of heat and cold followed by examination of the physical characteristics of the bait and ant acceptance testing. Bioassays similar to those described for prototype formulations are used.

Seasonal and short-term changes in ant feeding preferences must be recognized as variables in ant feeding preference studies. One example of this is *Tetramorium tsushimae* in the St. Louis, MO area. This species prefers protein-based foods

throughout most of the growing season but, within a sharply defined 2-3 week period from late summer to fall, it becomes equally attracted to carbohydrates, lipids and proteins. This switch probably corresponds to a reduction in brood rearing activity.

PRACTICAL CONSIDERATIONS OF BAITING ANTS

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Ants are social insects and baiting should be an effective control strategy. However, in a recent market survey Professional Pest Managers by Pest Control Technology, ants were ranked as the number one or two most common problems in the United States. Despite the recognized geographical, seasonal and species differences, there remain a number of reasons why baiting has not been successful in controlling ants. In this presentation, we consider the three aspects of baiting as they relate to control, bait formulations, sustaining recruitment and the transfer of a toxic dose by foragers to other colony members.

The type of bait formulation impacts the speed of obtaining a toxic dose. Liquid ant bait was consumed at a rate of nearly 2.5 times more than the best gel bait, indicating that a higher efficiency of “dosing” a forager should occur with liquid ant baits. However, the majority of commercially available ant baits are gels. Among gel baits, the handling efficiency may be dramatically different and affect how much toxicant is taken back to the colony over time. In a study comparing two different gel matrices, the number of ants found on the bait matrix was inversely related to the amount of bait consumed over time. Thus among these two gel matrices, although both were attractive, one bait was easily removed by foragers, increasing the chance of “dosing” an entire colony before the gel becomes unattractive in hours to days.

To “load” a colony with adequate toxicant to achieve control requires a “balancing act”, between sustained recruitment, transfer of toxic doses to other members and delayed toxicological responses. Often a reduction in foragers is observed, and success is “short-lived” as in several weeks to a month as foragers return. Are these baits too “fast acting”, killing workers before they reach colony members, or perhaps bait attractiveness is lost before a lethal dose can be obtained and then transferred, to effectively eliminate the colony? A study presented showed the potential interaction between bait matrix and level of toxicant in the bait on the amount of time foragers fed on the bait compared to sugar water. Foraging ants were exposed to contact and ingestion toxicity while feeding on one matrix compared with only ingestion toxicity from another. Ants receiving “double” exposure while removing bait were less likely to sustain recruitment over 72 hours compared to a single exposure via ingestion. To sustain recruitment on the bait matrix with double exposure (ingestion and contact), the rate of the toxicant had to be lowered significantly. Although lowering the rate enabled recruitment to be maintained, this rate may not be high enough to achieve colony

elimination. In another study discussed, the activity rating versus number of foragers that were alive was not correlated with boric acid bait, but was closely correlated with an experimental bait. This demonstrated that with many homeowners, the boric acid bait would appear to be successful for a week or so because activity has declined significantly. However, these “sick” ants are likely to return because they did not die from exposure.

A final consideration in baiting ants is demonstrating that a toxic dose is being transferred from foragers to queens. This is very difficult to assess in the field and so a laboratory method developed at Purdue University to evaluate food preferences of Pharaoh ants was adapted to assess the ability of foragers to obtain bait, carry, and transfer toxicant to brood and queens. Using slinkies or coiled tubing, bait sites were placed at 6 meters from the colony. This method was used to define effective rates for forager to queen transfer, resulting in queen mortality that followed closely forager mortality over time. Rates and baits selected with this method have demonstrated colony control under field conditions.

With a better understanding of ant behavior, insecticides, bait matrices and use of standardized methods to evaluate baits, “practically speaking” controlling ants with baits has a bright future.

TARGETED TREATMENTS WITH BROADCAST PRODUCTS

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BAITS USED ALONE OR IN COMBINATION WITH SPRAYS FOR ODOROUS HOUSE ANT MANAGEMENT

K. Vail
University of Tennessee

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1988	Dr. John V. Osmun, Purdue University Dr. Eugene Wood, University of Maryland
1990	Dr. Francis W. Lechleitner, Colorado State University
1992	Dr. Charles G. Wright, North Carolina State University
1994	Dr. Roger D. Akre, Washington State University Dr. Harry B. Moore, North Carolina State University Dr. Mary H. Ross, Virginia Polytechnic Institute & State University
1996	Dr. Donald G. Cochran, Virginia Polytechnic Institute & State University
1998	Dr. Gary W. Bennett, Purdue University
2000	Dr. Michael K. Rust, University of California, Riverside
2004	Dr. Roger E. Gold, Texas A&M University
2006	Coby Schal, North Carolina State University

NCUE Conference Chairs

- 1986 William H. Robinson, Virginia Polytechnic Institute & State University
February 24-27
College Park, MD
- 1988 Patricia A. Zungoli, Clemson University
February 21-24
College Park, MD
- 1990 Michael K. Rust, University of California, Riverside
February 25-28
College Park, MD
- 1992 Gary W. Bennett, Purdue University
February 23-26
College Park, MD
- 1994 Judy K. Bertholf, DowElanco
Roger E. Gold, Texas A&M University
February 20-22
Atlanta, GA
- 1996 Donald A. Reiersen, University of California, Riverside
February 18-20
Arlington, TX
- 1998 Brian T. Forschler, University of Georgia
Shripat T. Kamble, University of Nebraska
April 26-28
San Diego, CA
- 2000 Shripat T. Kamble, University of Nebraska
May 14-16
Fort Lauderdale, FL
- 2004 Daniel R. Suiter, University of Georgia
May 20-22
Phoenix, AZ
- 2006 Dini Miller, VA Tech
Bob Kopanic, S.C. Johnson
May 21-24
Raleigh-Durham, NC

BYLAWS

NATIONAL CONFERENCE ON URBAN ENTOMOLOGY

ARTICLE I- NAME

The name of this organization is the National Conference on Urban Entomology.

ARTICLE II-BACKGROUND

In the spring of 1985, individuals representing urban entomology and the pest control industry came together to organize a national conference to be held biennial. The mission of these conferences was to open channels of communication and information between scientists in industry, academia, and government, and to foster interest and research in the general area of urban and structural entomology.

The primary scope of the National Conference is to emphasize innovations and research on household and structural insect pests. It is the intent; however, to provide flexibility to include peripheral topics that pertain to the general discipline of urban entomology. It is anticipated that the scope of the conference could change through time, but the emphasis would be to provide an opportunity for urban entomologist to meet on a regular basis. It is not anticipated that any specific memberships would be required or expected, but that the cost associated with the conference would be met through registration fees and contributions. In the event that funds become available through donations or from the sale of conference proceedings, that these resources will be spent to meet expenses, to pay the expenses for invited speakers, and to provide scholarships to qualified students working in urban entomology. It is the intent of this organization to be non-profit, with financial resources provided to the Conference to be used entirely in support of quality programming and the support of scholarship.

ARTICLE III-OBJECTIVES

The objectives of this organization are:

1. To promote the interest of urban and structural entomology.
2. To provide a forum for the presentation of research and extension programs related to urban and structural entomology.
3. To prepare a written proceedings of all invited and accepted papers given or prepared at the biennial meeting.
4. To promote scholarship and the exchange of ideas among urban entomologists.
5. As funds are available, scholarships will be awarded to students pursuing scholastic degrees in urban entomology. Two levels of scholarships will be offered: the first level is for Bachelors and Masters degree students; the second level is for Ph.D. candidates. These scholarships will be awarded based solely on the merits of the candidates, and the progress that they have made towards completion of their research and scholastic degrees.

ARTICLE IV-JURISDICTION

The jurisdiction of this conference is limited to events held within the United States of America; however, we will be supportive of international urban entomology conferences as they are organized and held.

ARTICLE V-MEMBERSHIP

There are no membership requirements associated with this organization except for the payment of registration fees which go to offset the cost of holding the conference, printing of proceedings and the offering of scholarships. All persons with an interest in urban entomology are invited as members to attend the conferences and associated events.

ARTICLE VI-OFFICERS

Leadership for the Conference will be provided by a Steering Committee composed primarily of representatives from academia, but may include pest control professionals from industry and government. There will be seven officers including: Chair of the Steering Committee, Chair of the Program Committee, Secretary/Treasurer, Chair of the Sponsorship Committee, Chair of the Awards Committee, Chair of the Local Arrangements Committee, and an Industry Representative. The Chair of the Steering Committee will preside at all Steering Committee Meetings and will be the Executive Officer for the organization and will preside at meetings. In the absence of the Chair of the Steering Committee, the Chair of the Program Committee may preside. The voting members for executive decisions of the conference will be by majority vote of a quorum which is here defined as at least five officers.

The duties of the officers are as follows:

Chair of the Conference Committee: To provide overall leadership for the Conference, to establish ad hoc committees as needed, and to solicit nominations for new officers as needed.

Chair of the Program Committee: To coordinate the conference in terms of arranging for invited speakers and scientific presentations as well as overseeing the printing of announcements, programs and proceedings.

Secretary/Treasurer: To provide minutes of meetings, documentation of expenditures and the collection and disbursement of funds.

Chair For Sponsorship: To contact contributors and potential contributors to seek donations and support for the conference and associated events.

Chair For Awards: To oversee and administer the Mallis Award, scholarships and other honors or awards as approved by the executive committee.

Chair For Local Arrangements: To act on behalf of the executive committee in making arrangements with hotels, convention centers and other facilities in which conferences are held. To arrange for audio/visual equipment and to oversee the general physical arrangements for the conference.

Industry Representative: To be the liaison between the commercial manufacturers and distributors of pest control products and the Conference Steering Committee. This position will also be involved in fund raising and in seeking sponsorship for various aspects of the conference.

ARTICLE VI-TERMS OF OFFICE

Officers may serve for a maximum of four conference terms (8 years); however, if no new nominations are received, the officers may continue until such time as replacements are identified and installed. The Conference Chair may serve for one conference after which time they will become the Chair of the Awards Committee. The Chair for Local Arrangements should change with each conference unless the meetings are held in the same location. The Chair of both the Sponsorship Committee and the Industry Representative will serve for two conferences. The Secretary/Treasurer will serve for two conference cycles, unless reappointed by the steering committee.

ARTICLE VII-COMMITTEES

The standing committees are as follows:

1. Conference Steering Committee-Composed of the seven officers as described above, and chaired by the Chair of the Conference.
2. Nomination Committee: Chaired by Chair of Conference Committee
3. Program Committee: Chaired by Chair of Program Committee
4. Sponsorship Committee: Chaired by Chair of Sponsorship Committee
5. Awards Committee: Chaired by Chair of Awards Committee
6. Local Arrangements Committee: Chaired by Chair for Local Arrangements
7. Industry Representative Committee: Chaired by Industry Representative
8. Other ad hoc committees may be formed as needed, but will not be maintained longer than one year.

ARTICLE VIII-NOMINATION OF OFFICERS

Nominations for any of the chair positions may come from any individual, committee, or subcommittee, but must be forwarded to the Chair of the Nominations Committee (Chair of the Conference) before the final business meeting of each conference. It is further anticipated that individuals may be asked to have their names put into nomination by the Chair of the Nomination Committee. In the event that there are no nominations, the existing Chair may remain in office with a majority vote of the Steering Committee for the conference. It is clearly the intent of these provisions that as many new people be included as officers of this organization as is possible, and no one shall be excluded from consideration.

ARTICLE IX-MEETINGS

Conferences of the National Conference on Urban Entomology will be held every two years. Meetings of the officers of this organization will meet at least annually either in direct meetings or by conference calls in order to plan the upcoming conference and to conduct the business of the organization.

ARTICLE X-FINANCIAL RESPONSIBILITIES

All financial resources of the Conference will be held in a bank under an account named, "National Urban Entomology Conference". Expenditures may be made in support of the conference, for scholarships and other reasonable costs; however, funds may not be used to pay officers of the organization for their time or ordinary expenses. In the event that this organization is disbanded, all remaining funds are to be donated to the Endowment Fund of the Entomological Society of America.

ARTICLE XI-FISCAL YEAR

The fiscal year will run from January 1 through December 31 of each year.

ARTICLE XII-AMENDMENTS

The bylaws for this organization may be amended by a two-thirds affirmative vote of the attendees at the business meeting, provided that the proposed amendments are available for review at least 48 hours in advance of the voting.

ARTICLE XIII-INDEMNIFICATION

The National Conference on Urban Entomology shall indemnify any person who is or was a party, or is or was threatened to be made a party to any threatened, pending or completed action, suit or proceeding, whether civil, criminal, administrative or investigative by reason of the fact that such person is or was an officer of the Committee, or a member of any subcommittee or task force, against expenses, judgments, awards, fines, penalties, and amount paid in settlement actually and reasonably incurred by such persons in connection with such action, suit or proceeding: (I) except with respect to matters as to which it is adjudged in any such suit, action or proceeding that such person is liable to the organization by reason of the fact that such person has been found guilty of the commission of a crime or of gross negligence in the performance of their duties, it being understood that termination of any action, suit or proceeding by judgment, order, settlement, conviction or upon a plea of nolo contendere or its equivalent (whether or not after trial) shall not, of itself, create a presumption or be deemed an adjudication that such person is liable to the organization by reason of the commission of a crime or gross negligence in the performance of their duties; and (II) provided that such person shall have given the organization prompt notice of the threatening or commencement (as appropriate) of any such action, suit or proceeding. Upon notice from any such indemnified person that there is threatened or has been commenced any such action, suit or proceeding, the organization: (a) shall defend such indemnified person through counsel selected by and paid for by the organization and reasonably acceptable to such indemnified person which counsel shall assume control of the defense; and (b) shall reimburse such indemnity in advance of the final

disposition of any such action, suit or proceeding, provided that the indemnified person shall agree to repay the organization all amounts so reimbursed, if a court of competent jurisdiction finally determines that such indemnified persons liable to the organization by reason of the fact that such indemnified person has been found guilty of the commission of a crime or of gross negligence in the performance of their duties. The foregoing provision shall be in addition to any and all rights which the persons specified above may otherwise have at any time to indemnification from and/or reimbursement by the organization.

2006 NCUE Closing Business Meeting Minutes
Wednesday, May 24
Blowing Rock
Embassy Suites, Cary , NC

Called to order at 10:45am

Present: Committee members: Roger Gold, Dan Suiter, Dini Miller, Laura Nelson, Bob Kopanic, Shripat Kamble, Gary Bennett, Jules Silverman, Bob Cartwright, and at least 50+ other participants.

Discussion/review of 2006 conference:

Suggestions received from conference attendees:

Suggested sites for 2008:

New Orleans (USDA)

Okla. City (Kard)

Minneapolis (Kells)

Albuquerque (Jack Root and Bob Davis)

Portland/Vancouver (Tom Nishimura)

St. Louis, Mo (Whitmire folks)

Straw vote was taken and Okla. City was the winner. No decision will be made for 2010 at this time.

Paul Borth, Brian Cabrera, and Susan Jones would like to join the Planning Committee. Roger Gold was re-appointed Sec/Treasurer, it was seconded and approved by all.

A suggestion was made and approved to have some pre-selected sites WITH INFORMATION and approximate costs associated at the close of 2008's meeting for a site for 2010.

Expenses still to be paid:

Embassy balance

program printing & postage

Museum

Cost of printing and mailing for proceedings

Travel costs to be paid for the Mallis Lecturer (Coby Schal)

Registration personnel (Laura Nelson, and Mark Wright)

2008 committee members will be:

Conf. Co-Chairs: Richard Houseman and Bob Cartwright

Local Arrangements: Brad Kard, Jim Criswell

Program and Proceedings: Karen Vail, and Brian Cabrera, & Bill Kern

Sponsorship: Gary Bennett, Shripat Kamble

Treasurer: Roger Gold

Awards: Dini Miller, Bob Kopanic, Bill Kern (? See above)

Student Competition Committee: Ellen Thoms, John Paige, Clay Scherer, Paul Borth, and Mike Merchant.

Dan Suiter retires.

How to process symposia or accept/reject symposia? There needs to be criteria.

Call for papers and submit by a deadline. (That is what we had this year).

Ultimately, the Planning Committee decides.

Concurrent sessions are ok at 2, but not 3 at the same time.

Add posters? This adds tremendous expense.

Have those with/at the reception?

Replace the excursion with posters?

Have the student competition papers divided into groups (have Ph.D.'s against Ph.D.'s and Masters's against Master's), instead of all in one pot this year.

Some attendees are concerned about the cost of the conference. They don't want much "fluff", and keep it in low-cost locations.

Dini Miller pointed out that the student comp. paper deadline was missed by the due date. We sent out a reminder email, and got many more submissions after the original deadline.

The prof's need to keep their students aware of the upcoming deadlines for their students.

Committee members will remind Laura, who will need to send out reminder emails with deadlines to the listserve.

Austin Frishman discussed there is "inbreeding" within the Committee. There needs to be military contributions, and public housing, and sessions on bird flu, and public health issues need to be addressed.

From Jules Silverman: the presentation submission methods need to change from Cd's. Half the presenters missed the deadline. There needs to be an updated method for how they are submitted. Also, some people did not bring backups, and some brought their own equipment. This will not work!

From Roger Gold: This was the upper end of conference cost and hotel costs.

Future of NCUE: There was a unanimous decision to continue the conference. It is one of the few opportunities to merge industry and academia.

Start day was still requested to be on a Sunday.

This conference was expensive, the cost of the Sun. evening reception was about \$12k, and alcohol is expensive. People want to see more students involved, but it does involve expense to send them here and to house and feed them.

The student scholarship this time was

\$1500 for 1 Ph.D.; \$1500 for 1 MS.; and \$1500 for 1 undergrad. (with \$500 designated for travel).

The student competition paper this year (new) was 1st place=\$1000, and 2nd place=\$500.

They want to continue this next time.

Ellen Thoms suggested offering more travel fund. Scholarships to encourage attendance by students (like ESA does).

Continue the current length of the meeting for 2.5 days, like now.

Dini said we shouldn't go less than 2.5 days.

Maybe have posters for the evening rec. on opening night. This involved problems and expense with presentation stands, etc.

Continue to start Sund. Evening and go for 2.5 days later.

Industry sponsors are VERY important!

Dini: ICUP will be in 2008 and Int'l Congress. Will this prevent anyone from coming to this? Answer was no. Maybe go odd years for this, so as to not compete? NO.

Every 6 years this will overlap with ICUP. Period. 2000 was missed due to ICUP being held in the US.

11:30am meeting adjourned.

Letter Certifying Compliance with IRS Filing Requirements

Thompson, Derrig & Craig, P.C.

CERTIFIED PUBLIC ACCOUNTANTS

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Alice Monroe, CPA
Marian Rose Varisco, CPA

February 10, 2006

National Conference of Urban Entomology
Board of Directors' Members
C/o Texas A&M University
Center for Urban and Structural Entomology
College Station, TX 77843-2475

For the 2003, 2004, and 2005 years, no tax return (IRS Form 990) has been required based on the average gross receipts for each of these years. The IRS generally requires a return to be filed by a not-for-profit organization only when the average gross receipts over a three-year period are more than \$25,000. Therefore, the organization is currently in compliance with IRS filing requirements.

We have received the bank statements for 2004 and 2005. We checked the bank account activity and found no unusual or unreasonable transactions based on the knowledge we have of the organization's activities. We did not perform an audit, nor did we perform procedures that could detect fraud. However, based on the services performed, we found no transactions which we believe should be addressed in this letter.

We appreciate your business and look forward to working with you in the future. Please contact us if any additional information would be helpful.

We would also like to let you know that I plan to retire in 2006. Dillard Leverkuhn, a CPA within our firm, is taking most of my clients. He became a partner July 1, 2005 and has extensive experience.

Sincerely,



Andrea Derrig, CPA

List of Attendees
2006 National Conference on Urban Entomology
May 21-24
Raleigh-Durham, NC

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