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OF THE
2010 NATIONAL
CONFERENCE ON
URBAN
ENTOMOLOGY**

**MAY 16 - 19 , 2010
PORTLAND, OR**

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2010 NATIONAL
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ENTOMOLOGY**

Edited by
Susan C. Jones

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DISTINGUISHED ACHIEVEMENT AWARD IN URBAN ENTOMOLOGY

ARNOLD MALLIS MEMORIAL AWARD LECTURE:

IF YOU COME TO A FORK IN THE ROAD, TAKE IT

Donald A. Reiersen

Department of Entomology, University of California, Riverside, CA

Organizing Committee, Mallis Award Selection Committee, attendees, friends, and guests:

It is indeed an honor and privilege to join the extraordinary scientists who have presented the Mallis Lecture in the past. Known by many primarily for his seminal *Handbook of Pest Control*, first published in 1945 and revised eight times since, Arnold Mallis (Fig. 1) is a perfect example of getting somewhere after taking those convolutions, those forks in the road along the way. As a teenager Arnold moved from New York, his birthplace, to California where a high school art teacher taught him how to draw cartoons. He actually began his career in the pest control industry as a trade magazine cartoonist and illustrator. After receiving his degree from the University of California, he took a job as a pest control technician in Hollywood and soon after became head of Pest Control Services at UCLA until 1942 when he left to work on malaria control for a year in Louisiana. *Handbook of Pest Control*, volume I, was published just 2 years later. Arnold

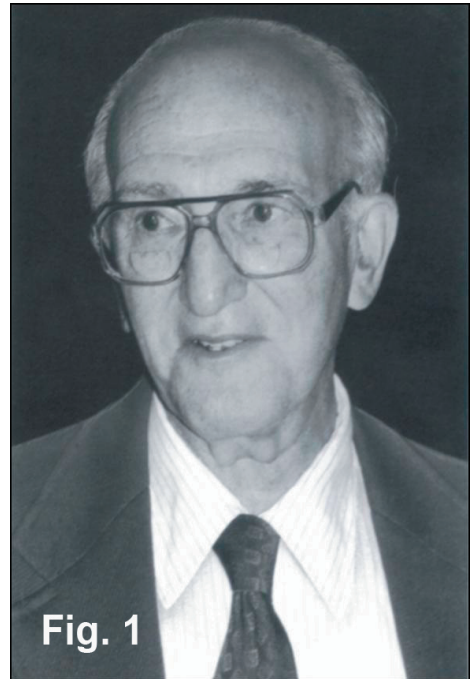


Fig. 1

joined Gulf Oil in Pittsburg where he was senior research entomologist developing insecticides for household and livestock pests and he eventually left Gulf Oil and joined the entomology department at Pennsylvania State University as associate professor. He retired in 1975 and passed away in 1984. I have special affection for Arnold, not only as a legend and a special person, but because of our mutual connection to UCLA and the ironic fact that he retired the same year as former Mallis Award winner Walter

Ebeling, considered one of the ‘founding fathers of urban entomology’ and someone for whom I worked for years.

One of my favorite people is Yogi Bera. As they say, “nobody says it like Yogi.” Like his “Ninety percent of baseball is half mental,” or “You can observe a lot by just watching,” baseball legend and America’s unofficial Philosopher Laureate, Yogi, said more in a few words than most of us can in an entire publication. As with most of Yogi’s quotes, it takes a while to sink in, a while to figure just what he said, and even longer to comprehend beyond its superficial simplicity. His “Fork in the Road” advice, probably excepted from Robert Frost’s “The Road Not Taken” has always struck me as particularly relevant for where we as urban entomologists have been, where we are, and where we go from here.

One of my favorite TV shows is Guy Fieri’s ‘Triple D,’ “Diners, Drive-ins, and Dives.” A cook himself, Fieri is constantly amazed at the foods and tastes he discovers as he tules the country in his restored ‘67 Camero convertible. From meatloaf burgers in New England, New York snappy dogs with sauerkraut in Atlanta, deep fried cinnamon rolls in Kansas City, to grilled squid tacos on the Embarcadero in San Francisco, Fieri discovers those tasty pearls of small family-run diners, tiny store-front restaurants, and well-worn places tucked off the beaten path. One of his favorites for breakfast is a place he discovered just two blocks from the house where he has vacationed with his family for more than ten years in Rhode Island. His secret, “slow down, take your time, and look around.”

Fieri’s discoveries are just one example of how making the turn off the highway, taking the fork in the road, leads to a universal principle – the Principle of Unintended Consequence – one thing leads to another. In his case, maybe a special diner with mouth-watering food on the one hand or a greasy spoon he wishes he had missed on the other. But unless he turned off the well-traveled interstate, unless he took the fork, how would he ever discover these special places?

I would like to share with you a bit about some of our accomplishments at the University of California in terms of where we are in urban entomology, our perspective, and where we, as a science, might be going. Hopefully some of what we have done over the years has served as a basis for what is to come in the future.

As a starting point for me, I had the undeniably good fortune to have my research career begin with Walter Ebeling for 12 years and continue with Mike Rust for over 30 years. Uncannily inquisitive, capable and perceptive, Walter’s oft-repeated saying was that “research is inherently inefficient.” What he meant was that in the process of productive original research, there are bends and twists and detours–no shortcuts, no straight-line paths. Like Arnold Mallis, who would know better than Walter Ebeling? What twists! Growing up in a tiny town on the edge of the desert in southern California, this outdoor-loving backpacker and mountain climber would become a world-renown citrus entomologist working on refined spray oils for mite control, taking a turn at a

fork in the road becoming *the* world expert on subtropical fruit pests, and finally taking the momentous fork helping define the infantile science of urban entomology as we researched cuticle morphology and wax loss and the associated behaviors of termites, cockroaches, and house flies.

The general topics I will address are areas of our research in which we have been deeply involved for years. There is a bit of timeline, but don't expect a straight-line chronology. By the end I hope you have an appreciation of some of the concepts we have uncovered that, in one way or another, have affected urban entomology to this day. The areas I want to address are:

1. Permeability of insect cuticle
2. Repellency and learning
3. Insecticide activity and resistance
4. Baits, baiting, and alternative treatment strategies

As one of our former graduate students Art Appel said many times in our brainstorming sessions (usually over a beer at the local pub), "fat is where it's at." Not only subcutaneous fat, fat bodies, and lipids circulating in the hemolymph, but also the permeability of insect cuticle and the significance of cuticular wax. Permeability and its related water regulation not only affect the mechanisms of insecticide penetration, but also affect behaviors and even the population distribution of some pests. For instance, I showed that the discontinuous distribution of certain species of yellowjackets in the United States is due primarily to their differential cuticular permeabilities and their ability to regulate water loss in certain environments. Dr. Appel and others have shown this for cockroaches and for other insects as well. Walter Ebeling, Bob Wagner and I demonstrated the functional significance of the permeability of insect cuticle and lipid adsorptivity as related to both behavior and control. The thin epicuticular wax-containing protective layer of many insects could be fatally disrupted not merely by the trauma of removing cuticular waxes with abrasives such as carborundum, but also with benign clays and amorphous silica gel dusts such as Olancha clay and Dri-Die®. Under dry conditions Dri-Die® literally adsorbed the wax filaments from the cuticular wax canals of insects more rapidly than the insect could replace it. The insect died of dehydration. On the other hand, under humid conditions Dri-Die®-treated cockroaches survived because although Dri-Die® adsorbed the wax, the insect retained its moisture and did not dehydrate. Developed into prototype treatment strategies for termites and cockroaches, these dusts were one of the first low-impact IPM (insect pest management) strategies for urban insect control. This concept has been utilized widely around the world, including protecting stored grain during transit in cargo ships and in go downs and commercial silos in India and Africa.

As with most any find, there were downsides. Bulky, messy, and impractical in many situations, the primary downside was that if given a choice, most insects tended to avoid finely divided sorptive dusts. Appreciating only later that cockroaches were significant household pests, we obtained a starter colony of Orlando Normal German cockroaches from Donald Cochran and Don Mullens at Virginia Tech as an easily-

reared insect we could use to study this phenomenon. We have maintained and used colonies of that strain to this day. This fortuitous fork began our long relationship with the German cockroach. After some not-so-successful designs, we soon developed the choice box (Fig. 2) as a means in the laboratory to examine and quantify this avoidance. By challenging cockroaches in our simple, two-compartment 'choice box,' the untreated side light and the treated side dark, we found that the most insecticidally active dusts such as silica gels and pyrethrins may be nearly totally ineffectual. If given a choice, cockroaches and other insects, tend to avoid fast-acting toxic deposits. If confined in it, the amorphous silica gel Dri-Die® killed cockroaches within hours and fresh deposits of pyrethrins affected them within seconds, but these treatments were so repellent that it was virtually impossible to kill cockroaches in a choice box within 4 weeks. On the other hand, slow was better. Results from the choice box mimicked field results and could be used as a predictive model for efficacy. Thus, we developed a way to measure the effectiveness of spray treatments. Field results with cockroaches showed that treatments providing KT-100s in choice boxes over a few days were more effective than were treatments providing KT-100s within minutes or hours in Petri dishes.

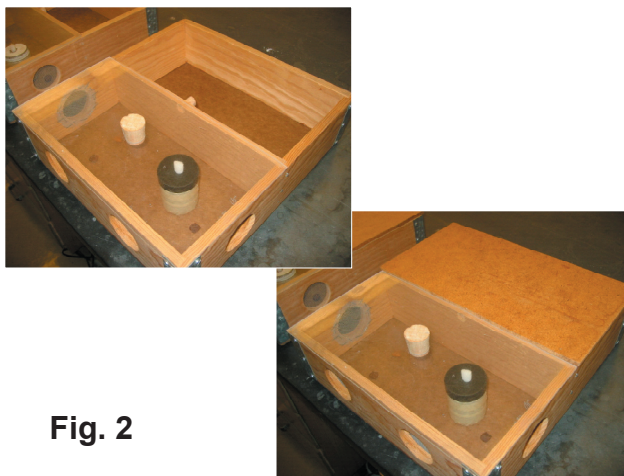


Fig. 2

The concept of slow or delayed toxicity actually being more effective and *lower* rates being more effective than high rates was novel and counterintuitive. This concept of 'inverse rate' has become extremely important in terms of baiting to control cockroaches, ants, and others. That repellency adversely affects control is readily apparent from Fig. 3-- acrobat ants avoid honey containing only $1 \times 10^{-4}\%$ cypermethrin (Fig. 3A), and foraging Argentine ants avoid protein bait containing imidacloprid (Fig. 3B). The idea of repellency affecting control persists to this day and remains a standard of testing in one form or another in the registration process of most insecticides for urban insect control.

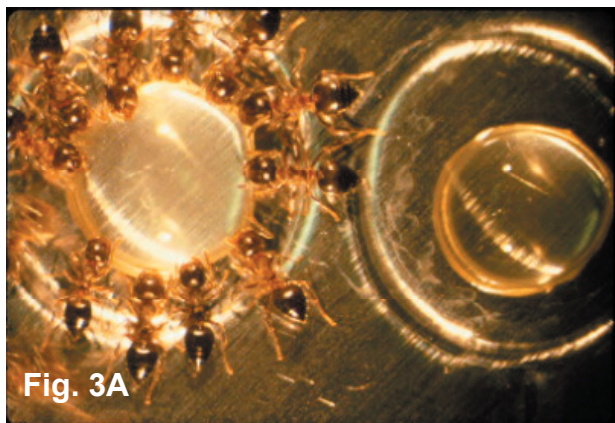


Fig. 3A

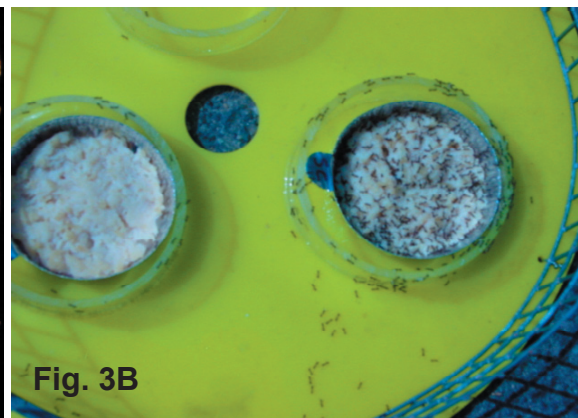


Fig. 3B

Beyond avoidance, however, was the idea of insect learning and modified behaviors—the importance of operative conditioning, associative learning, and retention. We found that insects such as cockroaches are more intelligent than we give them credit—they learn quickly and retain operant behaviors for long periods of time. Similar to punishment-reward conditioning used to study behaviors in psychology’s Skinner Box, we found that surviving cockroaches avoiding insecticide deposits in the choice box became conditioned to avoid toxic deposits. For example, ‘apparent’ or ‘virtual’ repellency persisted for days after we removed a repellent pyrethrin-treated insert in the box. The cockroaches became conditioned to remaining in the less-preferred light side of the box even though the so-called repellent treatment was removed. The reinforcing stimulus was survival and our shaping stimulus was insecticide rather than a stimulus such as electric shock. Factors such as crowding, starvation, and distractions, factors that affect human learning, also affect learning among cockroaches.

As with nearly every important pest, questions related to their biology and control can quickly develop into critical areas of major interest and importance. Rather than a fork in the road, our adventure with boric acid was more like taking a look in the rear-view mirror. Somewhat akin to “the image in this mirror may be larger than it appears.” A fortuitous phone call from a local pest control operator, and a nearly simultaneous fortuitous visit from none other than Arnold Mallis himself, initiated what has become an epic journey. Both asked, “Will borax effectively control cockroaches?” Borax had been used to control insects not only in the early 1900s but for hundreds of years before, but its use declined as fast-acting broad-spectrum synthetic insecticides such as DDT, chlordane, and others were becoming available. The timing was right, we were interested, and we included borax and eventually boric acid in our choice box studies. Borax was not effective but boric acid powder, on the other hand, was essentially non-repellent and was effective in the choice box bioassay. Besides efficacy, the question for years was boric acid’s mode of action in insects. It is a cellular toxin that most researchers assumed entered the haemolymph by way of lesions it caused in the gut wall after being ingested, presumably by preening. We showed, however, that dusted cockroaches with sealed mouthparts died about as quickly as ones without sealed mouthparts, indicating that boric acid readily penetrates cockroach cuticle. That an inorganic water-soluble compound could penetrate insect integument was highly controversial. Because it was inorganic and affected cells or organs rather than single nerve sites, boric acid was not likely to induce resistance, which was beginning to be of major concern at that time. Properly applied, we found that boric acid powder was the most effective cockroach control agent we evaluated. Boric acid powder continues to be an effective reliable IPM control strategy.

Upon Walter’s retirement in 1975, the landscape of urban entomology changed with the arrival of Mike Rust from Kansas University. As a behavioral ecologist, Mike extended, broadened, and deepened the legacy begun by Dr. Ebeling. As it turns out, not only was Mike a fantastic person and an inquisitive and capable scientist, but different from Walter, in that he has had the good fortune to mentor so many similarly

talented and capable graduate students. I owe much of what we have accomplished not only to Mike, but to those students as well.

Cockroaches continued in the 1970s and '80s to be the number one urban insect pest. Cockroach problems were rampant, especially in restaurants and multi-unit housing. We showed that without doubt there were high levels of physiological resistance in field populations. We found a synergistic relationship between physiological resistance and repellency resulting in widespread control failures. A good example of this was Ficam® W, a carbamate insecticide. An initially fantastic material for controlling cockroaches, it was only a short time before its widespread use resulted in high levels of resistance and control failures. Although not as frequently, failures were also being reported for Dursban®, an organophosphate. We found that topical dose resistance levels of only 6- to 10-fold could result in control failures when coupled with a moderate degree of avoidance or repellency. Ficam® induced higher levels of resistance and was more repellent than Dursban®, a combination that doomed Ficam® as a cockroach control material. In Fig. 4, the red lines are plots of the resistance levels for our German cockroach lab strain versus a field strain for a more recent pyrethroid insecticide. Not atypical for pyrethroids at that time, this illustrates the state of resistance among cockroaches in the field in the 1980s. We found that most pyrethroids also are very repellent. Coupled with the repellency-resistance phenomenon, under conditions of use, surface porosity as well as competitive binding of these highly lipophilic sprays with surface oils reduced efficacy even more.

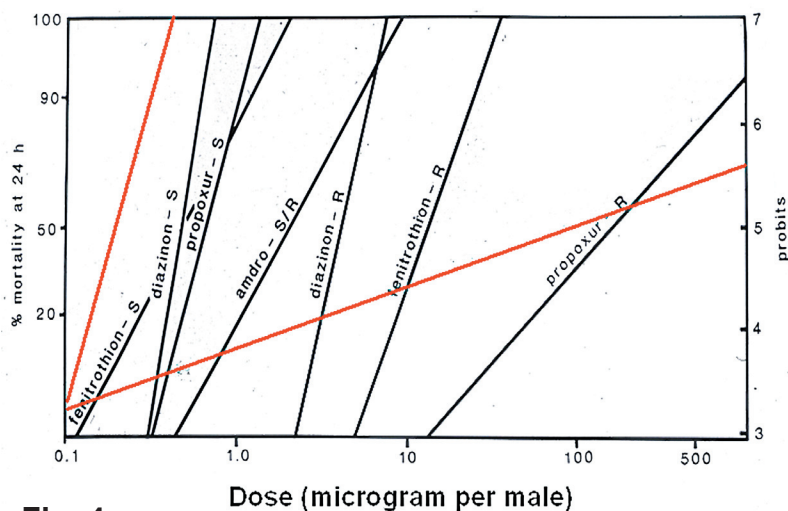


Fig. 4

During this time when we were determining the extent and relevance of resistance and how best to manage it, as well as intensely screening coded slow-acting, hopefully non-repellent compounds as actives, we began researching cockroach baits as an alternative to residual sprays. The first so-called bait stations contained chlorpyrifos waxed food bait in small round metal cans with openings in their side and Baygon®-treated grain bait in small matchstick-sized cardboard boxes. Neither was effective at other than killing a few cockroaches, but it was a beginning—an attempt to use less pesticide in a more focused strategy.

Having followed our research with slow-acting insecticides, we were contacted by a new-venture group from American Cyanamid Company interested in exploring the possibility of using one of their slow-acting, reportedly non-repellent insecticides as a cockroach bait. A top-secret project, the chemical they proposed using was hydramethylnon. They quickly developed a solid food matrix for what was to become MaxForce® bait containing hydramelthynon. Advised by their legal department to avoid potential liability, they were committed to dispensing bait only from a station. Assuming similar pest behaviors including avoidance, we use many of the same concepts for baiting cockroaches and other kinds of insects that researchers have used for years in baiting rodents. Those issues are insecticidal activity, attractancy, and palatability. In quart-jar arenas, hydramethylnon bait kills cockroaches if they eat as little as 1/2 mg of it, and some of the gel baits are even more active, especially in the absence of competitive food. But by using bait inside shallow trap jars positioned in a box we call the 'Bait Box' (Fig. 5), we discovered that bait was not attractive, even over short distances. We found this to be true for gel baits as well. This apparent dilemma was overcome by bait placement—placing the bait where cockroaches would likely intercept it. Depending on setup, we had excellent results with hydramethylnon bait in choice boxes, with large mixed-group populations of cockroaches in huge arenas that mimicked the field, and in hundreds of cockroach-infested apartments. Later we had even better results with gels. The introduction of effective cockroach bait was a major fork in the road in many ways. Years of development later, gel baits containing other AIs have been added to the cockroach control tool box, but more importantly the *concept* of “baiting” now has validity, not only for cockroaches, but for several urban insect pests including ants, yellowjackets, and perhaps termites.

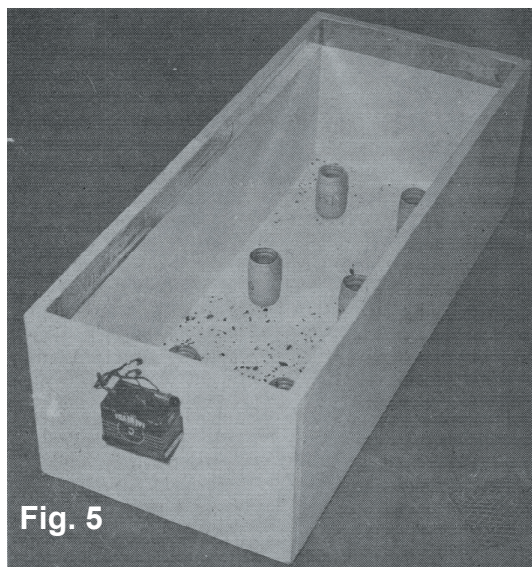


Fig. 5

The widespread use of baits has reportedly reduced the frequency and intensity of cockroach problems—they are no longer the ‘number 1’ urban pest. Rather, ants, spiders and termites, and we now hear a lot about bed bugs, have taken their place. The demise of chlordane years ago, the cancellation of diazinon and chlorpyrifos registrations, and changes in the marketplace have presented forks in the road for us all. We here are involved in big business, important business. In his latest analysis, Gary Curl reported that the structural pest control industry, the end-user and service provider for much of what we research, generated \$6.3 billion in 2009. In addition, Bayer’s imidacloprid flea products alone gross up to \$1.5 billion in sales in the animal health area—second only to their famous aspirin as their highest grossing drug. These figures illustrate how important our efforts are for protecting human health and well-being. We must work together integrating innovative research and state-of-the-art

service to control urban pests affecting people and their living environments around the world.

In that regard, we continue both basic and applied research, for instance, concerning termites. We examine abiotic *and* biotic factors as they interrelate to affect control. On an applied level, Fig 6A shows Mike digging trenches to be treated with termiticide, covered and backfilled, and sampled months later for analysis and bioassay (Fig 6B) to provide clinical data concerning effective application rates and longevity. As in several laboratories, we do repellency trials that hopefully predict efficacy. We have devoted a significant portion of our effort to understanding and quantifying horizontal transmission of insecticide and its relevance to control. And although individual per-weight sensitivities to toxicant may be similar, results in our field trials often differed significantly from those in other parts of the country. We found that biotic factors such as differences in foraging behavior, population size, and repellency of our western subterranean termite species contribute to the observed difference. Until recently it was not generally accepted that biotic differences could be responsible for the differences we were seeing.



Fig. 6A

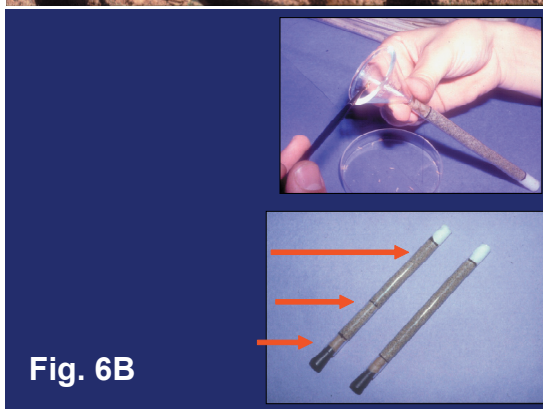


Fig. 6B

We are all aware there is increasing regulatory pressure to control urban insects by using the least amount of least toxic chemicals possible, commonly referred to as 'low-impact' or 'reduced-risk' strategies. Fig. 7 is a schematic of what we proposed just 5 years ago as an effective ant spray treatment strategy. Depending on chemical, this kind of treatment provided excellent long-term ant control. But because the contemporary backdrop is different and dynamic, this strategy is no longer acceptable.

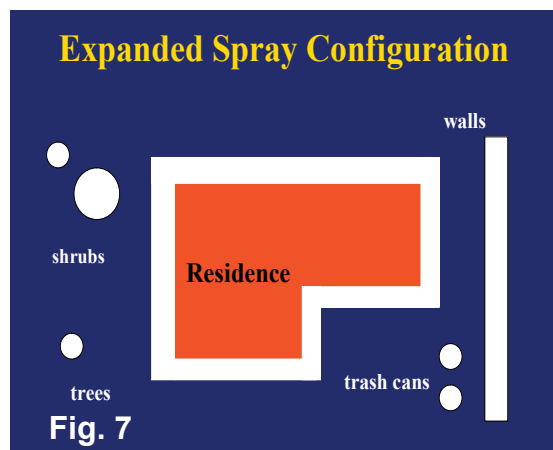


Fig. 7

Over the last 2 years, research mandated in California by Regional Water Boards has detected low but biologically active levels of insecticides in urban water runoff throughout the state. The source of the detected pyrethroids could be from farmer or homeowners, but since the fipronil was almost certainly coming from PMP (pest management professional) applications

for ant control, primarily to control Argentine ants, it was assumed that much of the pyrethroid was also coming from PMPs. We have been conducting research and working with PMPs to develop effective IPM strategies to reduce pesticide runoff. Using “customer satisfaction” as the measure, six large PMP companies used their own individualized IPM strategies to reduce the amount of pyrethroid they applied for ant control by up 95% with no increase in time spent per account and no increase in the number of complaints or callbacks. Opting for every-other-month or once-a-quarter service significantly reduced the amount applied. Baiting or using minimum-risk, low-impact sprays like essential oils was a component of each of their strategies. This work showed that effective ant control could be attained with much less pyrethroid. We have recently found the same holds true for spiders, with 1/10 to 1/20 maximum label rate of many sprays being effective against cellar, black widow, and brown recluse spiders. Regulators were impressed and vowed to work with the industry to modify labels and use patterns rather than simply withdrawing registration.

Besides sprays, we showed that baiting can also be effective for controlling ants and yellowjackets. For example, a queen ant can receive toxic food from a forager. Based on lab trials, we developed a model to predict the window of effective concentrations of sweet bait to effect control of Argentine ants for various toxicants. As before, we found that rates too high were repellent or killed ants before they had an opportunity to return to their colony, hopefully repeatedly until they died. Slow or delayed effects ultimately provide better overall results. We have demonstrated this not only around structures, but also in agricultural settings such as grapes and citrus.

In trials to develop an effective bait to control yellowjackets, as we showed with cockroaches and ants, palatability, a low level of repellency, delayed toxicity, and transfer of insecticide among cohorts are essential for a good bait and bait active. The good transfer of toxic doses of some insecticides such as fipronil and indoxacarb has led us to the concept of “virtual baiting,” whereby in this case foraging yellowjackets lured into a container treated with a low concentration of fipronil are allowed to leave, return to their colony, where they contaminate their nestmates (Fig. 8). This schematic shows the same strategy and concept for Argentine ants (Fig. 9). Using no adulterated food whatsoever, virtual baiting may have an important IPM role to play in the control of some species of ants and other insects as well.

And finally, I challenge you to take the road less traveled when it comes to pest management. We showed in our laboratory, for instance, that moderate levels of heat are lethal not only



Fig. 8

“Virtual Bait Stations”

- Ants attracted to food (C)
- Ants contact surface (D), die slowly
- Foragers recruit

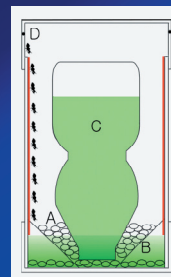


Fig. 9

to German cockroaches, but also to drywood termites, ants and other pests. Heat fumigation in the industry has been an extension of our work. Similarly, the Getty Museum and the Egyptian Museum in Cairo use IPM practices we helped develop, in this case commercial applications of anoxia by nitrogen replacement, to help protect an assortment of valuable artifacts in sealed display cases or in storage. Relatively short exposure times are needed to kill cockroaches in an oxygen-deprived environment; the adults and nymphs of three species (German, American, and brownbanded cockroach) were killed within a day. As a practical matter, we displaced the oxygen, or essentially suffocated clothes moths that infested the upholstery of Edward Kienholtz' famous "Back Seat Dodge '38" in the Los Angeles Museum of Contemporary Art. This process was a total success and shows how valuable this IPM option is.

So, these are some of the low-impact, reduced-risk IPM strategies we have been investigating. I am sure there are many others that we will hear about during the next days. I am looking forward to it.

I want to make sure you know how much I appreciate those with whom I have had an opportunity to work, share, discuss, and debate. Besides ever-grateful thanks to Dr. Ebeling and Dr. Rust, I have listed here many of those special people to whom I am especially indebted (Fig. 10). I value their science and their accomplishments, but more-so their friendships.

Undoubtedly there will be new and exciting target-specific chemicals, parasites, bacteria and viruses, microbiological and genetic manipulations, genome sequencing, and other yet-to-be-discovered strategies and concepts to help manage urban insect pests. I look forward to the future—seeing these techniques and strategies implemented. Hopefully we will hear about some possibilities over the next two days. Take the road less traveled, and as Yogi says, "When you come to a fork in the road, take it." Thank you.

Sincere thanks and appreciation to

**Dr. Walter Ebeling and Michael Rust
Robert Wagner and R. J. Pence**

Students and friends

**Jules Silverman
Arthur Appel
Weste Osbrink
Brian Cabrera
Raj Saran
Ronald Knight**

**Rudi Scheffrahn
James Smith
Marco Metzger
Linda Hooper-Bui
Dong-Hwang Choe
Stephanie Vega**

Fig. 10 Andrew Soeprono

STUDENT SCHOLARSHIP AWARD PRESENTATIONS

BACHELOR OF SCIENCE AWARD:

RAFT BEHAVIOR OF RED IMPORTED FIRE ANTS

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Department of Entomology, Louisiana State University, Baton Rouge, LA

The environmental adaptations developed in the South American floodplains make *Solenopsis invicta* (Buren) (Hymenoptera: Formicidae), the red imported fire ant, highly competitive in areas with high water tables and/or seasonal flooding (Tschinkel 2006). During floods, ant colonies create floating rafts of workers in order to survive inundation and exposure. The ants maintain this floating conglomeration until contact occurs with solid substrate; they then find soil to excavate in the new location. The floating clusters are also believed to be a means of founding new colonies in previously uninhabited areas using rivers and streams as a source of transport (Morrill 1974). It has been known since *S. invicta* invaded North America in Mobile, Alabama, that these ants exhibit rafting behavior; however, there is a gap in knowledge specifically related to the behavioral mechanisms and the maximum duration of rafting behavior in flood situations. This behavior particularly impacts the southeastern United States due to the common occurrence of heavy rains, catastrophic floods, and storm surges.

Methods

To study rafting behaviors, whole colonies of *S. invicta*, including both dealated and alated sexuals with brood, were collected from fields near Louisiana State University. Colonies were removed from the soil 24 h after collection through pre-established flooding techniques (Banks et al. 1981). The surviving portions of each colony were reared in plastic arenas with the sides coated in Teflon to prevent escape, and the ants were provided large Petri dishes with moistened plaster of Paris for harborage. Colonies were fed 20% sugar water and crickets. All colonies were allowed to habituate to the lab environment for a minimum one-week period.

Prior to the start of experiments, the harborages were secured to the bottom of the arena with hot glue to prevent floating. An initial 1000 ml of water was added to the arenas. Water was then continuously added, via a drip line, at the rate of 1500 ml

per h for 5 h or until complete submersion of all solid substrates within the arena. This simulates a rainfall of approximately 1 cm per h. Ants were considered rafting when a multilayered structure of ants was formed and the majority of individuals within this structure were free-floating in the arena with no attachment to solid substrate. Observations were conducted to describe aggregation, unusual pre-rafting behavior (such as workers dragging sexuals out of the raft), and the mode of interconnection between individual ants within the structure.

The rafts were first observed for the means of interconnection. Once the raft structure was formed it was removed from the water, quickly placed in a folded paper towel and zipping plastic bag, and placed in an ultra-cold (-80°C) freezer for observation. Due to the degree of entanglement of the raft structure, the majority of ants were unable to disassemble before dying due to the cold. Later, untangled portions were viewed using a stereomicroscope for analysis of interconnection.

Rafts were also tested for a static or dynamic structure. During rafting, ants were observed for cycling (a periodic movement in and out of the water) by painting the gasters of numerous workers, including ≥ 20 workers prior to beginning flooding, 20 workers free-moving on top of the rafting structure, and 20 workers well-entangled within the rafting structure. Movement and dispersal of marked ants within the formation were recorded at the beginning of the experiment. Any visibly marked ants were counted every hour for 2 h at the surface and sides of the raft formation. After 2 h, the raft was flipped and marked ants on the bottom were also counted. Again, any visibly marked ants were counted every hour for 2 h.

The average maximum time colonies were capable of maintaining the rafting formation was also determined. The time recorded for maximum longevity of rafting behavior was taken from the point that the conglomeration of interconnected ants became free-floating on the water's surface until only a single layer of ants was floating on the water's surface. Colonies were allowed to float undisturbed for these trials.

The presence of brood and reproductives within the raft was observed in all trials including frozen rafts, movement tests, and longevity tests. In frozen rafts the location of reproductives was recorded as well as the location of brood prior to removing the raft from the water. The presence and location of reproductives and brood were also recorded every day during longevity tests until no more could be found within the raft structure.

Results

The main mode of interconnection between individual workers was tarsi-to-tarsi linkage with occasional connection made via tarsi-to-body and tarsi-to-mandible. Individual ants linked to another within the rafting formation, and they folded their appendages under their bodies forming themselves into a tight ball.

The raft formation was also shown to be a dynamic structure with individual workers cycling out of the water to the top of the raft and from the edges to the center of the raft. One hour after marking individuals within and on top of the raft, the number of visible marked individuals significantly decreased in all trials. Individuals marked as free moving on top of the raft and entangled within the raft were found on the bottom of the formations of several trials indicating movement of individuals from the top to the bottom of the raft (underwater).

Red imported fire ants were found to be able to maintain rafting for a maximum of 12 d and an average of 7 d (± 3 d). The presence of brood greatly affected the longevity of the rafts. When brood was not present in the colony, the rafts were never maintained for longer than 12 h. When brood was present, the rafts were maintained between 3–12 d.

Both alated and dealated female reproductives, when present in a colony, were usually found in the middle of the raft outside the water. This was observed both in disintegrating rafts and in dissected frozen rafts. Male reproductives were observed being removed from the rafting structure by workers prior to the structure separating from the all solid substrate. In raft longevity tests, males represented a large portion of the initial dead and were the first caste to be completely removed from rafts. Brood, when present in the raft, was always found at the bottom of the formation comprising the foundation of the raft.

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MASTER OF SCIENCE AWARD:

THE IMPACT OF HARBORAGE ON OCCASIONAL INVADERS IN THE SUBURBAN LANDSCAPE

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Occasional invaders are sporadically encountered insects and other arthropods that may enter structures at different life stages or due to environmental cues, such as excessive moisture, extreme temperatures or unsuitable humidity levels (Appel 2003). Occasional invaders may be found in a structure at some point in their life, but do not complete their life cycle there (Bennett et al. 1997). Because they are infrequently encountered, their overall biology, life cycle and general ecology are not completely understood (Mallis 1990, Bennett et al. 1997, Appel 2003).

Ebeling (1978) suggested that urbanization affects the habitat of certain insects and is a direct result of human behavior that creates new habitats or modifies existing habitats. Fleet et al. (1978) suggested that reduction in indoor populations of smokybrown cockroaches, *Periplaneta fuliginosa* (Serville), required the management of outdoor populations. In particular, they recommend that all harborage sites within 30 m of any building should be eliminated.

According to Appel and Smith (1996), smokybrown cockroaches can be controlled through various nonchemical control methods. In their study, similar to studies by Fleet et al. (1978) and Smith et al. (1995), habitat was modified or eliminated after identifying the host's harborage site(s), resulting in a decrease in cockroach populations. Robinson (1999) highlighted the importance of utilizing effective nonchemical control methods in the urban environment, suggesting that ineffective nonchemical control methods can result in increased chemical use, and possible misuse, by the consumer. He also noted the importance of nonchemical techniques in slowing the development of insecticide resistance in urban pest populations.

Since the original concept of integrated pest management (IPM) was outlined by Stern et al. (1959), implementation has not been fully accepted in the urban and suburban environment (National Research Council 1996, Ehler and Bottrell 2000). According to Appel (1997), the control of domestic and peridomestic pests depends almost entirely on the use of chemical control tactics. While chemical control may be necessary, it should not be the sole means of insect or arthropod control.

In this experiment, we evaluated the impact of existing, natural harborage and simulated, artificial harborage on crawling arthropod trap catch at two different trapping sites. Sampling was achieved with destructive pitfall trapping at both sites. Pitfall traps design was similar to that of Northup and Crawford (1991). Traps consisted of a 118

ml Kendall® Precision™ screw-cap specimen cup placed inside of a 473 ml, plastic Solo® cup. A Solo® Cozy™ cup was installed as a funnel and was placed on top of the specimen cup and inside the 473 ml plastic cup.

Earwigs, crickets, isopods, spiders, *Harpalus* spp. beetles, and all other ground beetles (Coleoptera: Carabidae) were used as indicator species to monitor occasional invader activity related to harborage. These insects and other arthropods showed activity before the initial trapping and, therefore, could be used as indicators of occasional invaders in the landscape.

Trap catch in plots containing more artificial harborages was significantly higher than in plots containing less artificial harborages or no artificial harborages (control plots). When analyzed by species, adult crickets, nymphal crickets, and carabid beetles (other than *Harpalus* spp.) showed significant differences in trap catch, while earwigs, *Harpalus* spp. beetles, and spiders showed no significant differences.

Trap catch comparison in presence or absence of natural harborages showed no significant difference. When analyzed by indicator species, only isopods showed a significant difference, with more being trapped when harborage was present. Trap catch among plots where harborage was present and absent was not significantly different for adult crickets, nymphal crickets, earwigs, *Harpalus* spp. beetles, other carabid beetles, and spiders.

Seasonal pitfall trap catch from both trapping sites was totaled and graphed. In terms of the total number of each indicator species trapped in comparison to the total number of arthropods trapped, terrestrial isopods (37%) and spiders (28%) represented 65% of the total number of arthropods trapped. Earwigs (14%), *Harpalus* spp. (9%), nymphal crickets (6%), other carabids (4%), and adult crickets (2%) comprised the remaining 35% of total trap catch.

For certain arthropods, trap catch was associated with known factors of their ecology and biology. For example, *Harpalus* spp. beetles are multivoltine insects with population activity from spring until fall (Kirk 1973). In our data, *Harpalus* spp. trap catch peaked throughout the spring, summer and fall. Other indicator species, such as crickets, exhibited a relatively stable trap catch throughout the year-long study.

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DOCTOR OF PHILOSOPHY AWARD:

INVESTIGATIONS OF THE GUT CHITINASE GENE-ENZYME SYSTEM IN THE EASTERN SUBTERRANEAN TERMITE

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Recent advances in the areas of genomics, molecular biology, and bioinformatics are providing detailed information on many gene-enzyme systems from non-model organisms. Inhibition of a specific gene-enzyme system that has deleterious results within a pest insect is one possible future “green” pest control solution in the urban environment. This study investigated the gut chitinase gene-enzyme system of the eastern subterranean termite, *Reticulitermes flavipes*. Alignments of previously sequenced insect chitinase gene sequences displayed areas of conserved sequences (chitin binding domains, enzyme active sites). These conserved sequences were then used to conduct BLAST searches on unidentified genes within a cDNA library from the eastern subterranean termite digestome (courtesy of Dr. Mike Scharf). Numerous chitinase cDNA sequences were identified within the library. Alignment of these cDNA sequences allowed eastern subterranean termite-specific PCR primers to be created for the gut chitinase. A 1000 bp genomic DNA chitinase PCR product has been sequenced and aligns with other type 4 insect gut chitinases. Quantitative and RT-PCR will be conducted to allow quantification of gut chitinase gene expression. Chitinase inhibitor bioassays, using the molecules psammaplin A and pentoxifylline, then will be conducted to provide quantitative information on their effect on gut chitinase at both the mRNA and protein level, as well as qualitative information (mortality, feeding) on the termites themselves.

STUDENT PAPER COMPETITION

IMIDACLOPRID WITH MINIMUM INVASIVE TREATMENT TO CONTROL SUBTERRANEAN TERMITES (*COPTOTERMES GESTROI*) (ISOPTERA: RHINOTERMITIDAE) IN MALAYSIA

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Asian subterranean termites, *Coptotermes gestroi* (Wasmann) (Isoptera: Rhinotermitidae), cause US \$1.47 million (RM. 50 million) in structural damage annually in Malaysia. Currently, these termites are controlled with liquid termiticides using conventional treatments that require trenching, rodding and injecting termiticides around exterior perimeters plus additional rodding around inside walls. Such treatments are expensive, labor intensive and require a large volume of termiticides. Therefore, this research was undertaken to evaluate a minimally intrusive technique to reduce the quantity of termiticides, time, labor cost, and stress to property owners. The homes, used in this research, were located in the northwest region of Penang State in Malaysia. Six homes with active infestations of *C. gestroi* were selected for this study. Pre- and post-treatment termite populations were monitored using in-ground and above-ground monitoring stations. An in-ground monitoring station consisted of a plastic container (20 cm in diameter by 19 cm in height) with a 2 cm hole in the center of the bottom panel. Nine pine stakes (2.5 cm wide by 15 cm long, oven-dried for 48 h at 80° C, cooled at room temperature and weighed) were placed in each monitoring station and covered with a lid. Each in-ground station was buried to a depth of 16 cm. A total of 10-20 in-ground monitoring stations were used per home based on size. The above-ground monitoring station consisted of a black plastic container (6 cm length by 11 cm wide by 6 cm height) with two rolls of toilet tissue paper weighing between 40-80 g. Each above-ground station was placed over an active termite mud tube. Approximately 10-20 above-ground stations were used per house based on intensity of termite activity.

We used a target application technique requiring treatment of only locations where active termites were located around homes (minimum exterior and interior areas). Using this technique, we treated five homes with water-diluted Premise® 200 SC

(imidacloprid) [0.5% active ingredient (AI)] at five liters per rodding-hole, spaced 45 cm apart. Total termiticide volume per home ranged from 280 to 430 liters. The sixth home was treated with 1,360 liters of water-diluted Premise® (0.5% AI) using a conventional method of trenching and rodding around the exterior foundation walls and rodding around inner walls.

Post-treatment termite populations were monitored at 2-wk intervals until termite feeding activity completely ceased and there were no visual signs of termite infestations. Our data revealed that 40% of homes had no visual signs of termites 2 wk after termiticide treatment; 20% of homes had no signs of termites after 4 wk, and 100% had no signs of termites after 6 wk. Surprisingly, the sixth home with a full treatment was not free of active termites (based on a visual inspection) until 6 wk after termiticide treatment. Based on these data, there was a savings of 70-80% in termiticide quantity using the targeted treatment. Further, there was approximately 78% savings in economic costs and 50-75% less time spent using the targeted rather than the conventional treatment.

LABORATORY TRIAL OF FATE OF IMIDACLOPRID IN SOIL, AND FIELD EVALUATION OF IMIDACLOPRID GRANULES AGAINST *RETICULITERMES FLAVIPES* (KOLLAR) IN TEXAS

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Laboratory trials were initiated to investigate the dissipation and translocation of imidacloprid (0.1% AI) in urban environments. Four different plant species commonly found in urban environments were planted in 19-liter buckets and replicated three times. Treated sandy loam soil was added to buckets prior to planting plants. Soil was treated at the manufacturer's highest recommended rate. Leachate and soil samples were taken at 1, 3, 6, 9, and 12 mo post-treatment. All samples were properly prepared and analyzed by high performance liquid chromatography. This trial was carried out in a secure greenhouse on the Texas A&M University campus in College Station, TX.

Industry needs for safer transportation of termiticides to work sites, ease of application, and worker exposure safety have prompted the development of granular termiticides that specifically ameliorate these concerns. A second study was initiated in Texas that focused on gaining efficacy data on Premise® Granules (0.5% imidacloprid) when applied as a spot treatment to structures and when broadcast over an open field for control of subterranean termites (*Reticulitermes flavipes*). All structures used in the study were built on monolithic slabs and received a spot treatment with Premise® Granules at points of infestation 0.61 m either side of mud tubes. Applications of

Premise® Granules were made according to manufacturer's recommendations. Structures were inspected at 1 wk, 2 wk, and then monthly for 1 yr post-treatment. Suppression of *R. flavipes* was sustained for 8 wk in all five treated structures following application of granules.

In the open field study with active *R. flavipes*, grids measuring 8.53 m x 7.32 m were marked off, in-ground commercial termite monitors were installed, and grids were treated with Premise® Granules. Untreated pine boards were then placed in grids to determine if granules would suppress foraging and feeding on surface boards. Treatments suppressed surface feeding of *R. flavipes* for at least 9 mo post-treatment, although subterranean termites were active throughout the study at in-ground termite monitors within treated grids.

Results from these 1-yr studies demonstrated suppression of *R. flavipes* when Premise® Granules were applied as a spot treatment to structures and when broadcast over an open field.

COMPARATIVE STUDY OF TUNNELING AND FEEDING PREFERENCES OF *COPTOTERMES FORMOSANUS* SHIRAKI AND *COPTOTERMES GESTROI* WASMANN (ISOPTERA: RHINOTERMITIDAE) IN FORAGING ARENAS

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The subterranean termite genus *Coptotermes* (Rhinotermitidae) contains a number of highly destructive species. Two of these species occur in Hawaii: *Coptotermes formosanus* Shiraki (Formosan subterranean termite) and *Coptotermes gestroi* (Wasmann) (= *C. vastator*, *C. havilandi*) (Asian subterranean termite). *C. formosanus* is the major pest species in Hawaii and is widely distributed. Annual costs of management and damage repairs have been estimated to exceed \$100 million. *C. gestroi* is a major pest in Southeast Asia, Guam, and the Philippines, but currently occurs in Hawaii only on the southwest side of the island of Oahu (Woodrow et al. 2001, Grace 2006). Comparative evaluations of the tunneling and foraging behavior of these two species in Hawaii will contribute to our understanding of their distribution and ecology and may help to improve pest management programs, particularly those based on placement of toxic baits. The present study was initiated to quantify differences in tunneling patterns that were noted qualitatively in earlier work (Grace et al. 2004). We also compared feeding rates and wood preferences, and we tested whether the presence or absence of wood influenced termite tunneling patterns.

To study tunneling behavior and spatial dispersion of tunnels, six two-dimensional acrylic laboratory foraging arenas were constructed, as described by Campora and Grace (2001, 2007). Three arenas were set up with each species. Silica sand (40-100 mesh; 150-425 μm sieve) was used as the tunneling medium. Yellow pine, *Pinus palustris*, and Douglas-fir, *Pseudotsuga menziessii*, were used as feeding substrates. *C. formosanus* was collected from a field site located on the Manoa campus of the University of Hawaii (Miller Hall). *C. gestroi* was collected from a Kalaeloa (formerly Barber's Point Naval Housing) field site on the island of Oahu (Uchima and Grace 2003a). Termites were collected and counted using techniques modified from those of Tamashiro et al. (1973) and Su and La Fage (1984). For each arena, 1500 termites (1350 workers + 150 soldiers) were added through a portal in the center, and termites were allowed to tunnel for a period of 22 d. Air temperature and humidity were recorded daily and digital photographs of tunnel galleries were taken every 12 h using a Nikon D40 digital camera with 18-55mm f/3.5-5.6 AFS-DX Nikkor lens. Tunnels were analyzed using Adobe Acrobat 8 Professional software. Visual observations were also recorded daily. Different parameters in tunnel formations were compared between the two species (following the method of Puche and Su 2001) using one-way ANOVA and Tukey HSD procedures (Minitab 15, Minitab, Inc. 2007). Mean termite biomass and wood consumption rates were also calculated for each species and each wood type using the procedure described by Su and La Fage (1984).

Our results indicate differences in tunneling and foraging behavior between these two termite species. In tunneling, *C. gestroi* constructed a large number of narrow, highly branched tunnels whereas *C. formosanus* excavated fewer, wider and less branched tunnels (Table 1).

Table 1. Summary of *C. formosanus* and *C. gestroi* tunneling comparison

Species	Total number tunnels	Total tunnel length (cm)	Total width (cm)	Area (cm ²)	Density (no. workers/cm ²)	Speed (cm / day)	Angles (1° & 2°)
<i>C. gestroi</i>	65	1043.56	0.08	87.66	15.40	47.43	52.13
<i>C. gestroi</i>	61	715.85	0.07	50.83	26.56	32.53	53.21
<i>C. gestroi</i> *	96	1294.45	0.06	81.55	16.55	58.84	54.22
<i>C. formosanus</i>	59	816.87	0.20	166.64	8.10	37.13	38.81
<i>C. formosanus</i> *	39	611.37	0.35	212.76	6.35	27.78	38.55
<i>C. formosanus</i>	31	496.00	0.50	247.01	5.47	22.55	41.10
P value ^a		0.012	0.031	0.006	0.024	0.012	

* = controls without wood.

^aTermite species comparison by ANOVA, $P < 0.05$.

Neither species exhibited significant differences in the number of tunnels in arenas with and without wood. Neither did we observe any differences in tunneling patterns in arenas with and without wood.

The two species exhibited different feeding rates and different wood preferences. *C. gestroi* had lower feeding rates in comparison to *C. formosanus* and fed more on yellow pine, whereas *C. formosanus* fed more on Douglas-fir. In no-choice (force feeding) experiments with Douglas-fir, Uchima and Grace (2003b) also observed a lower feeding rate with *C. gestroi*. However, this lower feeding rate, and agonism between workers of the two species, did not translate into dominance of resources by *C. formosanus* when wood was made available to both species simultaneously (Uchima and Grace 2009).

Table 2. Summary of *C. formosanus* and *C. gestroi* feeding comparison

Species	Mean termite wet biomass (g)	Feeding substrate	Wood consumption rate (mg/g per day)*	Number surviving workers	Number surviving soldiers
<i>C. gestroi</i>	1.12	Douglas-fir	0.3865	663	20
<i>C. gestroi</i>	1.24	Yellow pine	0.4675	913	29
<i>C. gestroi</i>	1.24			924	36
<i>C. formosanus</i>	1.94	Douglas-fir	3.2367	485	35
<i>C. formosanus</i>	1.72			658	66
<i>C. formosanus</i>	2.99	Yellow pine	0.8173	1040	133

*P = 0.021 (Termite species comparison of wood consumption by ANOVA)

We conclude that the two species have quantifiably different food searching/tunneling patterns. *C. formosanus* excavates fewer, wider, and less branched tunnels while *C. gestroi* makes many, narrower, highly branched tunnels. Wood consumption rates also differ, with *C. formosanus* feeding at a relatively higher rate than *C. gestroi*. Furthermore, the two species appear to show differences in their wood preferences. *C. formosanus* consumed more Douglas-fir and *C. gestroi* consumed more yellow pine. As previously found with *C. formosanus*, the presence or absence of wood in the foraging arenas did not influence the basic tunneling pattern exhibited by either termite species.

Acknowledgements

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THE RELATIONSHIP BETWEEN SUBTERRANEAN TERMITE (ISOPTERA: *RETICULITERMES*) INFESTATION FREQUENCY AND HISTORICAL LANDSCAPE

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Abstract

Spatial distributions of populations depend on contemporary landscape mosaics and are also influenced by historical landscape conditions. Although urbanization processes such as subdivision development dramatically alter a landscape, it is unknown how historical vegetation and former edaphic conditions might also influence subterranean termite populations that have life histories heavily tied to soil. The purpose of this study is to determine important historical landscape features that explain termite infestation frequencies. Homes constructed on former agriculture and forested landscapes were surveyed for evidence of treatment for subterranean termites to determine if termite infestation frequency is correlated with historical landscape type.

Introduction

There are four species of termite (Isoptera: *Reticulitermes*) found in Missouri (Pinzon & Houseman 2009). Although urbanization processes such as the development of a subdivision drastically alter the landscape, including the distributions of plants, moisture regimes, and habitat fragmentation (Turner et al. 2001), it is unknown how historical vegetation and former edaphic conditions may also influence current subterranean termite populations that have life histories heavily tied to the soil. The objectives of this study were to 1) examine how termite treatment patterns within subdivisions is related to historical landscape conditions; and 2) examine how treatment patterns differ with subdivision age. Specifically, we compared termite treatment patterns between 10- and 20-yr-old subdivisions built on previously agriculture or forested landscapes.

Materials and Methods

Subdivisions in Columbia, MO were selected for this study when homes met one of the following four criteria: 1) 10-yr-old homes built on agriculture landscape; 2) 10-yr-old homes built on forested landscape; 3) 20-yr-old homes built on agriculture landscape; or 4) 20-yr-old homes built on forested landscape. Homes that fell into this age classification plus or minus 2 yr were examined. Subdivision delineation and home age were determined using the Boone County, MO Assessor's online parcel viewer (<http://www.showmeboone.com>). Historical landscape type was determined by using historical aerial photography and land use/land cover spatial data. Individual homes in 12 subdivisions were examined for evidence of termite treatment including termiticide soil treatment, bait stations, or verbal confirmation of treatment by the home owner.

A linear regression was used to plot the percent of treated homes against home age, and a GLIMMIX procedure (SAS Institute Inc. v.9.1) was used to test for differences between subdivisions built on agriculture and forested landscapes.

Results

In all, 1,440 homes were examined for evidence of termite treatment, of which 139 were found to be treated. Treatment frequency increased with home age for homes built on agriculture and forest landscapes (Fig. 1). Subdivisions containing 10-yr-old homes built on forested landscapes had a significantly higher treatment frequency than subdivisions containing 10-yr-old homes built on agriculture landscapes (Fig. 2). Twenty-yr-old homes built on forested and agriculture landscapes had significantly higher treatment frequencies than both of the 10-yr-old subdivision types, but did not significantly differ from one another.

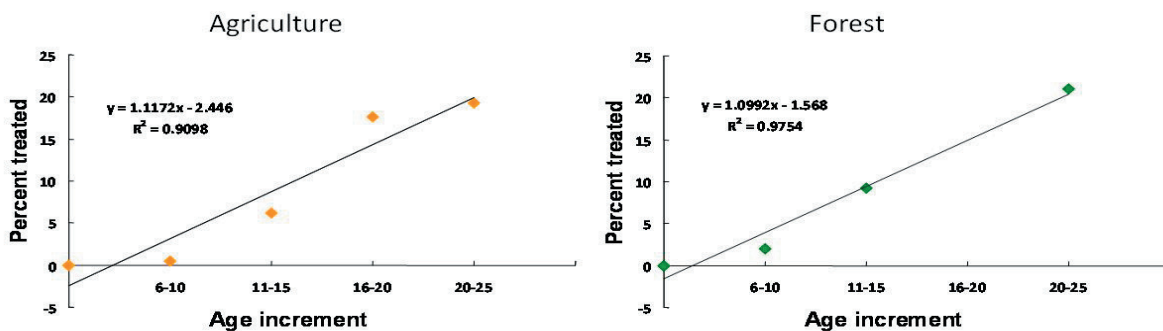


Fig. 1. Linear relationship between home age and frequency of termite treatment for subdivisions built on agriculture landscapes and forested landscapes.

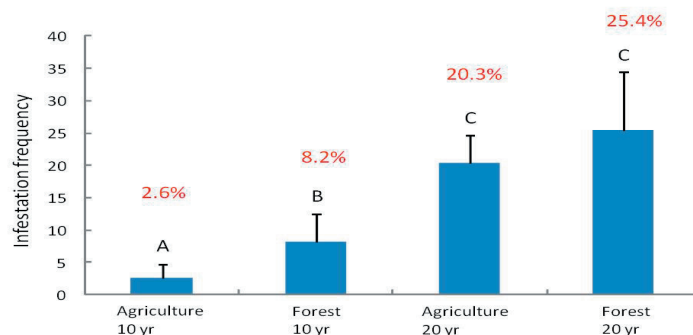


Fig. 2. Frequency of treatment for subterranean termites for 10- and 20-yr-old subdivisions built on agriculture or forested landscapes. Percent treatment for each subdivision type is given. Significant differences between subdivisions are provided above the standard deviation bars.

Discussion

Treatment frequency was significantly different between historical landscape types at age ten. Previously forested landscapes had higher treatment frequencies than agricultural landscapes. Treatment frequency in both historical landscape types was approximately 20% at age 20. Therefore, treatment frequencies in subdivisions built on agriculture appears to eventually “catch up” to forested landscapes. Future work on this project will include examination of additional subdivisions in peripheral geographic regions and analysis of spatial distribution of treated homes relative to contemporary features such as current forest stands.

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ORIGIN OF THE INFESTATION BY THE WEST INDIAN DRYWOOD TERMITE *CRYPTOTERMES BREVIS* (WALKER) IN THE AZORES ISLANDS

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The West Indian drywood termite *Cryptotermes brevis* (Walker) is a serious urban pest that causes great damage to wood structures and furniture. It was first identified as a pest in the Azorean Island of Terceira in the year 2000. It has since been found infesting buildings and furniture in the Islands of São Miguel, Santa Maria, Faial, and São Jorge. In order to study the origin of this infestation in the Azores, samples of termites were collected from four different islands in the Azores in 2009. DNA from these samples was extracted and both mitochondrial DNA (Cytb and 16S rRNA genes) and nuclear DNA (microsatellite analysis) were used to assess differences between the Azorean populations and the endemic populations of Chile and Peru. The Azorean populations were also compared to populations from non-endemic locations, such as south Florida, Bahamas, and Dominica.

SPECIES DISTRIBUTIONS AND PHYLOGENETIC RELATIONSHIPS OF *RETICULITERMES* SPP. FOUND IN GEORGIA, USA

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This study examined the species distributions and the phylogenetic relationships of the *Reticulitermes* species found in three locations in Georgia: Athens, Sapelo Island, and Thomasville. Morphological and molecular data were used to identify the different species. Distributional patterns were examined within and among sites. DNA was extracted from workers or soldiers, and the mitochondrial gene cytochrome oxidase II, was sequenced, yielding 685 base pairs. Phylogenetic reconstruction of the data was achieved via Neighbour-Joining (MEGA), Maximum Parsimony (MEGA), Maximum Likelihood (PHYML) and Bayesian Inference (MrBayes). The resulting phylogenetic hypotheses were compared to determine if any undescribed, cryptic species were represented among the samples.

VARIABILITY OF SALIVARY RESERVOIRS AMONG *RETICULITERMES FLAVIPES* CASTES

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Termites are highly susceptible to desiccation, and moisture is a critical factor in their survival. Consequently, water relations govern many facets of termite biology. Termites possess a pair of salivary reservoirs that function in water storage. The stored water presumably is used to raise the humidity in unfavorable microclimates. The main objective of this research study was to evaluate the variability of salivary reservoirs among the various castes/developmental stages of the eastern subterranean termite, *Reticulitermes flavipes*. Termites were collected from different locations, including food sources, shelter tubes and the nursery. Termites were dissected and the volume of the salivary reservoirs was determined. Salivary reservoirs were always largest from termites collected in food sources and the nursery. Salivary reservoirs were usually depleted in termites collected from shelter tubes. Soldiers always had the largest salivary reservoirs, followed by workers. Small workers always had the smallest salivary reservoirs, except when they were in the nursery. Alates and nymphs consistently had empty salivary reservoirs. These data demonstrate that differences in salivary reservoir size and associated tasks within the colony may be due to task specialization.

EASTERN SUBTERRANEAN TERMITE CHITINASE ACTIVITY IN RESPONSE TO PENTOXIFYLLINE-TREATED DIET

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Eastern subterranean termite (*Reticulitermes flavipes*) gut chitinase activity can be assayed both colorimetrically and through Native substrate polyacrylamide gel electrophoresis (PAGE). The objectives of this experiment were to examine the protein level response of *R. flavipes* chitinase in response to a novel (insecticidally) chitinase inhibitor. A diet (filter paper) was treated with two concentrations (25 and 50 μ M) of pentoxifylline (a known Family 18 chitinase inhibitor in fungi) both with and without soybean trypsin inhibitor (certain chitinases are produced as zymogens and require trypsin mediated activation) and fed to the termites for a period of fifteen days or until there was 100% mortality in test population. Control treatment termites were fed filter paper treated with acetone. Groups of termite workers were removed from the feeding units at seven time points (1, 3, 5, 7, 11, and 15 d after treatment) and chitinase activity was assayed by both methods. Response variables measured include protein activity and termite mortality in response to pentoxifylline treatments (+/- trypsin inhibitor). Pentoxifylline (at the two concentrations assayed) was shown to not deter feeding as no significant differences were seen in feeding between treated and control groups. There was also no significant difference in mortality between the two treatment and control groups. Lastly, there were no significant differences amongst chitinase protein levels in the three groups. This research is a preliminary portion of an on-going project in which a much larger range of inhibitor concentrations is now being assayed with longer feeding durations to examine response in the termite.

ASSESSMENT OF VIOLATIONS IN GEORGIA PUBLIC SCHOOLS

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The Georgia Department of Agriculture, Structural Pest Control Division (GDA SPCD) began reviewing, in 2006, pesticide use records of pest management professionals servicing Georgia public schools. GDA SPCD inspectors were divided among 19 districts and required to inspect daycares and schools for company records not in compliance with state, local and federal laws. Companies not in compliance were cited and subject to loss of licensure or fines. This assessment reviewed the GDA SPCD records from April 2007- April 2009. The citations and violations associated with Georgia schools were collected from all 19 districts and tabulated into thirteen violation categories. A total of 1,926 pesticide use records were reviewed with the number of violations reaching 13,300. The information will be used to direct future training/educational efforts.

BIOGEOGRAPHY OF *TRIATOMA SANGUISUGA* ON TWO BARRIER ISLANDS OFF THE COAST OF GEORGIA, USA

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Triatoma sanguisuga is a haematophagous insect known to carry the protozoan causative agent of Chagas' disease, *Trypanosoma cruzi*. Thirty-three *Triatoma* nymph and adult specimens were collected on Cumberland and Sapelo Islands, GA between June and July 2009. The cytochrome oxidase II mitochondrial gene (699 base pairs) was extracted and sequenced from all specimens then aligned with MUSCLE, and a total of 52 variable sites were detected. In all, 12 haplotypes were identified, with nine coming from Cumberland Island and three from Sapelo Island. In order to determine phylogenetic relationships, neighbor-joining and maximum parsimony trees were created using *Triatoma dimidiata* and *Triatoma infestans* as outgroups. The trees created with both phylogenetic methods had similar topologies, with no distinct clades containing haplotypes from a single island. Nested clade analysis resulted in two separate haplotype networks. One network contained haplotypes that were collected on both Cumberland and Sapelo Islands, with the ancestral haplotype arising from Sapelo Island. The other completely independent network contained only three haplotypes, all from Cumberland Island. This pilot study is the first to use the cytochrome oxidase II mitochondrial gene to look at *Triatoma* populations in the southeast U.S., and these results suggest that there may be a previously unknown cryptic *Triatoma* species on the Georgia Coast.

LIFE TABLES AND MATHEMATICAL MODELS: A CONTRIBUTION TO THE LIFE HISTORY OF *CIMEX LECTULARIUS* L.

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Very little is known about the ecology and growth potential of bed bug (*Cimex lectularius* L.) populations in the U.S. Therefore, it is necessary to measure life history changes in bed bug populations. The use of life tables quantifies changes in the development, survivorship and fecundity of populations under specific conditions. We constructed life tables to compare life history parameters of pesticide resistant and susceptible populations. We discovered that resistant bed bug colonies develop faster and have higher survivorship than susceptible colonies. Using the information from the life tables we developed a population projection model which allowed us to determine the state of a bed bug population under ideal conditions. The results showed that for both

susceptible and resistant strains, eggs and first instars make up a large proportion of the total population. However, the life stages that make the greatest contribution to future generations are the third to fifth instars. Interestingly, these late stage nymphs make a larger contribution to future generations of the resistant strain than they do in the susceptible strain. In the future, these life tables will be used to make a population projection model. This model will be used to estimate the potential growth of bed bug population in the field.

GENETIC VARIATION OF THIEF ANTS, *SOLENOPSIS MOLESTA* (SAY) (HYMENOPTERA: FORMICIDAE)

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The thief ant, *Solenopsis molesta* (Say) (Hymenoptera: Formicidae), a common nuisance ant species found throughout the U.S., is genetically related to other stinging ants. This research was undertaken to illustrate genetic variation utilizing mitochondrial DNA sequences of cytochrome oxidase I in thief ant populations from various geographic locations. Thief ants were collected from nine states and identified to species using morphologic characteristics from available keys. DNA extractions were completed with Qiagen's Gentra PUREGENE® DNA Isolation Kit using their solid tissue protocol. PCR reactions were run on the extracted DNA using primers Lep-F1 (forward) and Lep-R1 (reverse). The resulting DNA products were concentrated and purified by Microcon Centrifugal Filter Unit YM-100. Purified samples were sent to the University of Arkansas Medical Sciences (UAMS) DNA Sequencing Core Facility for sequencing. Sequences obtained from UAMS were edited and align using Codon Code Aligner. The contigs were then uploaded to www.Phylogeny.fr and phylogenetic trees were produced. The trees obtained displayed nucleotide variation in genetic makeup of the thief ants collected and this genetic variation corresponded to the morphologic identification. Using several phylogenetic tree rendering softwares (Neighbor joining, Maximum likelihood and Bayesian) found at www.Phylogeny.fr, the thief ants collected from the different states were separated into three groups. Ants collected from New York, Indiana, and one location in Nebraska formed one group identified as *S. molesta validiuscula*; another group with ants from Louisiana was identified as *S. carolinensis*; and the third group comprised of ants from South Dakota, Washington, New Jersey, Tennessee, Kansas, and two other locations in Nebraska was identified as *S. molesta molesta*. Sequences were submitted to GenBank and were issued accession numbers HM179641 to HM179653.

THE REPELLENCY OF FIVE ESSENTIAL OILS AGAINST THE ARGENTINE ANT (HYMENOPTERA: FORMICIDAE)

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The Argentine ant, *Linepithema humile* (Mayr) (Hymenoptera: Formicidae), is an invasive, cosmopolitan species that was introduced into the U.S. around 1891 via the port of New Orleans, LA (Foster 1908, Newell and Barber 1913, Suarez et al. 2001). In the U.S., the Argentine ant is a major pest in urban, agricultural and natural environments due to its unicolonial structure which allows the formation of supercolonies with multiple shared nests (Newell and Barber 1913, Suarez et al. 1999, Tsutsui et al. 2000, Vega and Rust 2001, Tsutsui and Suarez 2003). Because these ants were introduced and have lost genetic diversity, they lack intraspecific aggression, allowing populations to increase rapidly (Newell and Barber 1913, Holway et al. 1998, Holway 1999, Human and Gordon 1999, Tsutsui et al. 2001, Suarez et al. 2002), which provides a competitive advantage to *L. humile* when competing against native ants, other introduced ant species (Kabashima et al. 2007), and other insect and arthropod species (Holway et al. 1998, Holway 1999, Tsutsui and Suarez 2003). Other factors in the success of *L. humile* include sociotony, polydomy, polygyny, lack of natural enemies, and human dispersal, mostly through commerce and various other business operations (Holway et al. 1998, Holway and Suarez 1999, Holway and Case 2000, Vega and Rust 2001, Tsutsui and Suarez 2003).

Control of Argentine ants has typically relied on chemicals, more specifically, slow-acting baits and perimeter sprays (Vega and Rust 2001). Klotz et al. (2007) found that slow-acting fipronil sprays reduced ant activity by 90% in an 8-wk period; however, using a perimeter spray of fipronil and a perimeter-broadcast of bifenthrin granules achieved the greatest reduction of ant activity around structures. Rust et al. (2003) proposed that the broader the range of concentrations in insecticidal baits, the more effective the control because of delayed toxicity. However, they also noted that finding suitable bait bases and active ingredients that provide delayed toxicity are the most difficult obstacles to overcome when formulating effective Argentine ant baits. Klotz et al. (1995) suggested that the lack of information on Argentine ant biology has contributed to the failure of most traditional chemistries to successfully control Argentine ants.

According to Curtis et al. (1990), a large number of plants that yield essential oils are known to be feeding deterrents to insects and other arthropods. Some of these plant-extracted oils have been the starting point for some commercially-produced repellents. The long-term repellent characteristics of essential oils have been challenged by some (Buescher et al. 1982, Rutledge et al. 1983, Nerio et al. 2010), who reported efficacy when freshly applied, but reduced effectiveness as the oils began to age. Thus, the objective of this study was to evaluate the repellent effects of freshly-applied and aged essential oils on Argentine ants, using a choice-based assay similar to that of Ebeling et al. (1966).

Seventeen treatment combinations (five oils at three concentrations each plus two controls) were evaluated for their repellency to Argentine ants. Spearmint, wintergreen, peppermint, cinnamon, and clove oils were acquired from Polarome International (Jersey City, NJ). With the exception of spearmint (60% purity), all oils were technical grade. Each oil was serially diluted in n-hexane to produce 5 ml of 10%, 1% and 0.1% (v/v) solutions. Two additional treatments (n-hexane alone [negative control] and 1% Cinnamite™ (cinnamaldehyde) suspension in water [positive control] [Mycotech Corporation, Butte, MT]) were prepared and used as controls. Each of the 17 treatment combinations were replicated 20 times with four replicates initiated each week over a 12-wk period.

In this bioassay, repellency was indicated by the number of Argentine worker ants entering the treated harborages, with lower numbers indicating avoidance of the harborage by the worker ants and, thus, relative repellency of the active ingredient. The largest number of ants recovered (approx. 82%) was from the hexane-treated harborages, which served as a negative control in these assays. There also was no difference in the number of ants recovered from the hexane treatment after 2 h of aging vs. 168 h of aging, thus, confirming complete hexane evaporation from the Castone surface within the initial 2-h period. Cinnamite™, the positive control in these assays, was highly repellent to Argentine ants when the workers were placed with the harborages treated only 2 h earlier. However, significantly greater numbers of ants entered the treated harborages 168 h after treatment (approx. 41%) in comparison to only 4% entering the harborages only 2 h after treatment. Cinnamite™ clearly lost repellency within 7 d of application.

Repellency and residual activity of the five essential oils were concentration dependent. At 0.1%, the numbers of ants entering the harborages treated with the oils 2 h earlier were significantly less than numbers of ants entering the hexane-treated harborages, but these numbers were also greater than the numbers of ants recovered from the Cinnamite™-treated harborages. The percentages of ants recovered from the harborages were 82.4% for hexane (negative control), 58% for peppermint, 38.8% for cinnamon, 35.2% for clove, 34.8% for wintergreen, 25.2% for spearmint, and 4% for Cinnamite™ (positive control). At the higher concentrations, the percentages of total ants recovered from the harborages treated with the essential oils ranged from 8.8% to 14.4% at the 1% concentration and from 9.2% to 20% at the 10% concentration, while the percentage recovered from the hexane-treated harborages was 82.4%.

At 0.1%, all essential oils tested exhibited significant declines in repellency within 7 d of application to the harborages. At 7 d after application, only the spearmint oil treatment had significantly fewer ants entering the treated harborage than entered the hexane-treated control. At 1%, only wintergreen oil showed a significant decline in repellency within 7 d of application. However, the numbers of ants entering the harborages treated 7 d earlier with the five oils, including wintergreen, was significantly less than the numbers of ants entering the hexane-treated harborages. There were no reductions in repellency over the 7-d period of any of the five essential oils when applied at a 10% concentration to the harborages.

These results, although only laboratory-based at this time, indicate the potential of using plant-derived essential oils to repel Argentine ants from harborages. Essential oils have been used since ancient times in many aspects, including pest control. They have excellent repellent, toxic and/or fumigant effects toward insects that are of medical (Buescher et al. 1982, Rutledge et al. 1983, Isman 2000, Omolo et al. 2004, Yang and Ma 2005, Amer and Mehlhorn 2006, Jaenson et al. 2006), agricultural (Curtis et al. 1990, Zhang et al. 2004, Wang et al. 2006, Koschier et al. 2007), stored product (Hori 2003), and structural or urban importance (Appel et al. 2001, Meissner and Silverman 2001, Peterson et al. 2002, Meissner and Silverman 2003, Cheng et al. 2007, Wiltz et al. 2007). Because of the recent ecologically friendly movement away from pesticides to naturally-derived alternatives, essential oils are becoming increasingly popular among consumers who want lower impact substitutes to traditional chemistries, with the same reliability of control provided by chemical insecticides or repellents (Isman 2000).

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EFFECT OF BROADCAST FIRE ANT CONTROL PRODUCTS ON NON-TARGET ANT SPECIES IN VIRGINIA

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In 2009, several cities and counties in Virginia were placed under the Federal Red Imported Fire Ant Quarantine. As a result of the quarantine's implementation, the Virginia Department of Agriculture and Consumer Services (VDACS) is no longer responsible for treating red imported fire ant, *Solenopsis invicta* Buren, mounds in the quarantined cities and counties. Based on increases in *S. invicta* incidents reported to VDACS and the recent implementation of the quarantine by APHIS, it is apparent that there is need to better understand and control *S. invicta* populations in Virginia. Therefore, fire ant product evaluations are essential. Advion® fire ant bait (indoxacarb 0.045%; DuPont, Wilmington, DE) and Top Choice® granular (fipronil 0.143%; Bayer Environmental Sciences, Cary, NC) are two broadcast treatment products with proven fire ant control efficacy. It is reasonable to suggest that these broadcast products could be used in quarantined counties. However, these products have never been used in Virginia and may have negative impacts on ants native to the quarantined areas. Hence, the effects of these two broadcast control products on the foraging activity of non-target ants was evaluated in field plots located in Virginia Beach, VA. Treatment applications were conducted in August 2007 and foraging activity was documented until December 2007. Sampling was resumed in April 2008. Repeated-measures analysis of variance indicated that foraging activity significantly decreased ($P \leq 0.05$) in Advion® and Top Choice® plots compared to control plots. However, decreases in foraging activity were not significantly different ($P \geq 0.05$) between Advion® and Top Choice® treatments. A separate repeated-measures analysis of variance was conducted with foraging activity data collected from April 2008 to August 2008. Foraging activity increased in treatment plots and control plots over the April-August sampling period. Repeated-measures analysis of variance results show that increases in foraging activity were significantly higher ($P \leq 0.05$) in control plots than in plots treated with Advion® or Top Choice®. However, the increases in foraging activity were not significantly different ($P \geq 0.05$) between Advion® and Top Choice® treatments. These results suggest that native ant populations may not be completely decimated if Top Choice® or Advion® were used as part of a fire ant control program in Virginia.

Student Paper Competition Winners



Winners of the 2010 NCUE Student Paper Competition (left to right): Andrea Polanco (Virginia Tech) 2nd place, Su Yee Lim (University of Georgia) 1st place, Nirmala K. Hapukotuwa (University of Hawaii) 3rd place (not shown).

SUBMITTED PAPERS

GENERAL PESTS

CONTROL AND WEB MANAGEMENT OF A LONG-LEGGED CELLAR SPIDER, *HOLOCNEMUS PLUCHEI*, IN SOUTHERN CALIFORNIA

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Web-spinning spiders can be a nuisance around the home because their unsightly cobwebs result in homeowners requesting control measures. Insecticidal sprays may affect spider populations but leave cobwebs behind. Mechanical removal may affect both spiders and webs, but there may be no residual effect to prevent re-infestation. We performed a study on the marbled cellar spider, *Holcnemus pluche*, a non-native immigrant from the Mediterranean region, which has become incredibly common in and around homes in southern California and much of the southwestern U.S. We used four treatments: vacuuming, web brush, 0.5% Tengard® SFR emulsion (permethrin), EcoPCO® EC-X (3% pyrethrins). A treated site consisted of a 5-m length of an outbuilding with eaves (approximately 15 m²); there were eight sites per treatment as well as four untreated sites. A census of spiders was conducted just prior to a single control application and at 2 wk, and 1, 2, 3, and 4 mo post-treatment. In untreated plots, spider numbers rose slowly over the summer then decreased in autumn. Tengard® eliminated all spiders by the week 2 census and its residual activity greatly curtailed re-infestation. The other three treatments reduced spider populations to about half of the untreated sites. A one-time treatment of Tengard® eliminated spider populations for the entire summer; mechanical removal of the remaining webs is recommended. A single treatment with a vacuum, brush, or pyrethrin spray did not eliminate the spiders, although multiple treatments possibly would have provided better efficacy, albeit being more time intensive.

THE ACTIVITY OF INSECTICIDES AGAINST URBAN SPIDERS: METHODS AND IMPLICATIONS

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In general, people do not tolerate spiders. Although some are considered public health pests, spiders such as cellar spiders can become a serious nuisance by their propensity to breed to large numbers and by their webs being unsightly and clogging vents and machinery. A few species of spiders can become direct or secondary medical pests from the infection that sometimes develops when people are bitten. This is particularly the case with recluse or violin spiders, *Loxosceles* spp. Although spiders are effective insect predators, they are discouraged from being in homes and other urban situations where their presence may be problematic. Cellar spiders are common under exposed eaves; black widow spiders, *Latrodectus* spp., are found in a variety of secluded places around homes; and other web-building species can be found indoors and outdoors. Problems with spiders and their control have been reported across the U.S. One large pest management company in southern California reported that up to 90% of their service calls were for spider control during the summer.

Several species of cellar spiders (Pholcidae) are established throughout the U.S., and the biology of most of them is similar. The common urban pholcid in southern California is the marbled cellar spider, *Holocnemus pluchei*. We studied the activity of insecticide sprays to control this spider and used *H. pluchei* as an indicator species, theorizing that similar size public health spiders such as *Latrodectus* (Theridiidae) and *Loxosceles* (Sicariidae) are likely to have similar responses to an insecticide. Many pest management professionals (PMPs) use integrated pest management (IPM) strategies such as web removal to help control spiders, but insecticide sprays remain a common treatment strategy. Most labels for insecticides used for urban pest management include spiders, but there are few data available to confirm activity and effective rates.

Replicated series of individual field-collected spiders maintained in the laboratory were directly sprayed with aqueous dilutions of insecticide. This treatment mimics current common commercial spider control methodology. Acute knockdown and mortality were determined every few hours for 48 hr and chronic or delayed effect was determined daily for up to 7 d thereafter. The lowest rate that provided 100% moribundity was considered the minimum effective rate (MER).

Although a few insecticides, such as imidacloprid and thiamethoxam, were not active against spiders, most were. The MER of many registered insecticides against *H. pluchei* was far below their maximum label rate (as percent active ingredient) (LR_{max}). Most sprays were effective at 1/10 (LR_{max}) and some were active at less than 1/20 LR_{max} . For example, the MER for pyrethrins was 1/16 LR_{max} (0.012%), 1/20 LR_{max} (0.025%) for permethrin, and 1/20 LR_{max} (0.005%) for beta-cyfluthrin (Temprid®). Preliminary trials indicated similar sensitivity against *Latrodectus hesperus* and *Loxosceles reclusa*.

These results demonstrate that significantly lower than LR_{max} sprays of many insecticides are active against *H. pluchei* and suggest that low rates may be effective against this spider and other species under field conditions. Thorough treatment with dilute sprays of these spider-active insecticides at MER is a low-impact strategy that may provide good control of spiders while simultaneously minimizing risk and runoff. Multiple spray treatments spaced every few months may be even more effective. Although they may be equally sensitive, overall control of *Loxosceles* with an active spray is problematic unless the spider and inaccessible refugia where they reside are treated.

PERSISTENCE OF OUTDOOR SPIDER CONTROL USING A SINGLE APPLICATION OF TEMPRID™ OR TRANSPORT® GHP INSECTICIDE

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A single application of Temprid™ (0.075%) solution and Transport® GHP Insecticide (0.11%) solution was applied to run-off on ten 1-m² sites for each treatment. Water was applied as a control to nine 1-m² sites. The spider populations on these 29 sites were monitored for three months. The results were analyzed for all spiders combined and when possible by family for Pholcidae, Theridiidae, and Araneidae. Both Temprid™ and Transport® GHP showed spider population reduction that was significantly different than the control sites for all three months of the project. The results of the two treatments were also not significantly different from each other during the three months of the study except for one sample period.

A REVIEW OF NUISANCE INVADER HOUSEHOLD PESTS OF THE UNITED STATES

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A survey of nuisance invader arthropods found within homes in the U.S. was conducted during 2009. Data collected to identify the most common species of arthropods that act as nuisance invaders of homes in the U.S. recognize shifts that have occurred in the relative importance of some species, and gives attention to landscape practices that may affect incidence of certain nuisance invaders entering homes and other buildings. Species that invade homes include representatives from most all classes of terrestrial arthropods: Diplopoda, Chilopoda, Malacostraca, Arachnida, and Hexapoda (i.e.,

Collembola, Protura, Insecta). At least 72 arthropod families within 27 orders include species that are reported to invade homes. Topping the list of those most frequently listed were the multicolored Asian lady beetle, boxelder bugs, various millipedes, and ants; each ranked in the top five nuisance invaders of over 40% of the responding states. Various hemipterans were primarily indicated as having increased within the past 5 yr including the western conifer seed bug, brown marmorated stink bug, the “tuxedo bug” (*Raglius alboacuminatus*), and birch catkin bug (*Kleidocerys resedae*). Several landscaping practices and features were offered as contributing to incidence of certain nuisance invaders. Most commonly mentioned were local availability of host plants, outdoor lighting, mulches, and dense plantings around building foundations.

ARILON™: A NEW RESIDUAL SPRAY INSECTICIDE WITH UNIQUE FORMULATION AND WIDE SPECTRUM OF ACTIVITY AGAINST KEY URBAN PESTS

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Abstract

Arilon™ (20 WDG, indoxacarb), a new residual spray formulation, demonstrated excellent efficacy against cockroaches and ants at labeled rates of 0.05 and 0.1%. Adult male German cockroaches (GCR) and argentine ant (AA) workers exposed for as little as 1-10 min to treated surfaces (ceramic tiles and wood panels) exhibited 100% mortalities within 3 d. In simulated rain studies, GCR, American cockroaches, and AA, exhibited 100% mortality within 5 d when confined to Arilon™ (0.05 and 0.1%) treated ceramic tiles and wood panels. Exposed GCR and AA were able to transfer lethal doses to unexposed individuals. Amounts of active ingredient picked up by GCR on Arilon™-treated tiles and wood panels after 5 min exposure were very similar (~400 ng/insect).

Introduction

DuPont Professional Products launched a new residual spray insecticide under the brand name Arilon™, designed and formulated especially for pests and surfaces in urban environments. Arilon™ (20 WDG) contains indoxcarb (20% wt:wt) as the active ingredient, which is converted to Meta-Active™ form by insect enzymes once it enters the insect body, thus providing a novel mode of action and offering great potential to control resistant strains of insect pests (Wing et al. 2000). Indoxcarb has proven very effective against urban pests with the Advion® line of bait products. Arilon™ is the first ever household residual spray liquid insecticide being offered in pre-measured biodegradable Terrene™ packaging. There are ~0.33 dry ounces (~9.4 g) of Arilon™

(20 WDG) in each Terrene™ pack, which when dissolved in 1 gallon water provides a 0.05% solution. Since this formulation is designed both for indoor and outdoor uses, it is readily picked-up by insects on a wide range of surfaces. The objectives of this research were to study the efficacy of Arilon™ by observing effects of limited exposure on cockroaches and ants, determining efficacy in a simulated rain situation, quantifying transfer to unexposed individuals, and quantifying the amount of active ingredient picked up by cockroaches.

Methods and Materials

Limited Exposure Study. Arilon™ was applied to the ceramic tiles (6 x 6 inches), wood panels (8 x 8 inches), and concrete pavers (12 x 6 x 2 inches) at the labeled rate of 1 gallon/1000 ft² of 0.05 and 0.1% product diluted in water. Surfaces were kept at room temperature to dry. Adult male German cockroaches (GCA) and Argentine ants (AA) were exposed to the surfaces for different time periods (1, 5, 10, 30, and 60 min). After exposure, insects were transferred to clean petri dishes with food and water. Knock-down and mortality was recorded for next 2-3 d.

Simulated Rain Study. Surfaces were treated as described above and were placed under a structural overhang, located under a greenhouse rain simulator. At each rain event (each month), 0.25 in of rain was applied. Surfaces were allowed to dry before exposure assays were established. GCR, American cockroaches (ACR), and AA were exposed at 0, 4, and 12 wk after the surfaces were treated and weathered under simulated rains.

Transfer Study. GCR were exposed for 0.5, 1, 2, and 4 h to ceramic tiles treated with 0.05% Arilon™ at the labeled rate of 1 gallon/1000 ft². After exposure, five exposed roaches (donors) were transferred to a group of five unexposed roaches (recipients) marked with a pink “marking agent” on their dorsal side. To look at the effects of mixing them in different ratios, donors were exposed for 1 h and then mixed with recipients at different ratios including 5:5 (1:1), 5:10 (1:2), and 5:20 (1:4).

Horizontal Transfer among Nestmates and Harborage Contamination. AA workers (N = 20) were exposed to ceramic tiles treated at 0.05 and 0.1% at the labeled rate of 1 gallon/1000 ft². Ants were exposed for two time intervals (10 and 60 min) and then they were transferred to new petri dishes (150 x 2 mm) and provided with 20% sugar water. In one treatment, unexposed ants (recipients = 20) were added to the arena and dead and moribund donor ants were left in the petri dish, whereas in the other treatment dead and moribund donor ants were taken out of the arena after 24 h and then recipient ants (N = 20) were added to this new petri dish. Mortality was recorded for the next 1-7 d. Ants were provided with 20% sugar solution as food. Controls were set by exposing ants to untreated surfaces using the same procedures.

Quantification of Active Ingredient (AI) Picked Up by GCR. Adult male GCR were exposed to two surfaces (tile and wood) treated at 0.1% Arilon™ at the labeled rate

of 1 gallon/1000 ft². Two exposure times were tested (5 and 60 min). Exposed insects were pooled (N = 5) in a 2 ml vial then 1.5 ml acetone was added. Using a bead mill, the GCR bodies were pulverized and then centrifuged. A small amount of supernatant (1.0 µL) was injected in a HPLC mass spectrometer (Sorval 6000 HPLC and Sorval Quattro Micro) system to quantify the AI. Appropriate controls and control matrices were used for the background noise levels.

Results and Discussion

Limited Exposure Study. Time of exposure did not have much effect on mortality as both 1- and 60-min exposures provided similar mortality. Since there were no obvious trends in mortality with respect to time of exposure, we combined the data to reflect mean percentage mortality after 1-60 min of exposure. Arilon™ caused 100% mortality within 48 h for GCR exposed to ceramic tile, wood, and concrete treated at both rates (0.05 and 0.1%) (Table 1). The speed of kill for AA was dependent on the nature of surfaces as 100% mortality was achieved by day 2 on ceramic tiles whereas it took 3 d to achieve similar mortality on concrete (Table 1).

Table 1. Mean percentage mortality of German cockroaches and Argentine ants during days 1, 2, and 3 following limited exposure (1-60 min) to 0.05% and 0.1% Arilon™-treated surfaces

Pest	Surface	Concentration	% Mortality (after exposure for 1-60 min)		
			1 DAE	2 DAE	3 DAE
German cockroach	Tile	0.05-0.1%	80-90	100	
	Wood	0.05-0.1%	80-90	100	
	Concrete	0.05-0.1%	80-90	100	
Argentine ant	Tile	0.05-0.1%	60-80	90-100	100
	Concrete	0.05-0.1%	20-40	70-80	80-100

DAE= days after exposure

Simulated Rain Study. For all of the insects (GCR, ACR, AA), both concentrations (0.05 and 0.1%) of Arilon™ caused 100% mortality within 1-2 days of exposure on different surfaces (ceramic tile and wood) (Table 2). Even when these treated surfaces were weathered for 12 wk under greenhouse conditions (75-80°C and >50% RH) and simulated rains (0.25 inches per month), 100% mortality of GCR, ACR, and AA was observed by day 5 (Table 2). These data indicate that Arilon™ is an excellent residual spray providing ~3 mo of control on different types of surfaces under field conditions.

Table 2. Mean percentage mortality of German cockroaches (GCR), American cockroaches (ACR), and Argentine ants (AA) after continuous exposure to 0.05% and 0.1% Arilon™-treated surfaces that were weathered by simulated rains and a greenhouse environment for 0 and 12 weeks

Week	Pest	Surface	Concentration	% Mortality (cont. exposure)		
				1-2 d	3 d	5 d
0	GCR, ACR	Tile, Wood	0.05-0.1%	90-100		
	AA	Tile, Wood	0.05-0.1%	80-100		
12	GCR, ACR	Tile, Wood	0.05-0.1%		20-80	100
	AA	Tile, Wood	0.05-0.1%		20-80	100

Transfer Study. GCR recipient mortality was approaching 100% by day 3 for all exposure periods (0.5, 1, 2, and 4 h) (Fig. 1). Twenty-four hours after combining the donors and recipients, ~50% mortality was observed in recipients (Fig. 1) indicating that it takes some time for the insecticide to transfer to unexposed individuals through grooming and body contact with the exposed individuals. Similarly, even when mixed with recipients at different ratios (1:1, 1:2, 1:3, and 1:4), an individual donor exposed to a treated surface for 1 h was able to kill four recipients within 3 d (Fig. 2). These data indicate that donors picked up at least 3-4 times the lethal dose required to kill an individual cockroach.

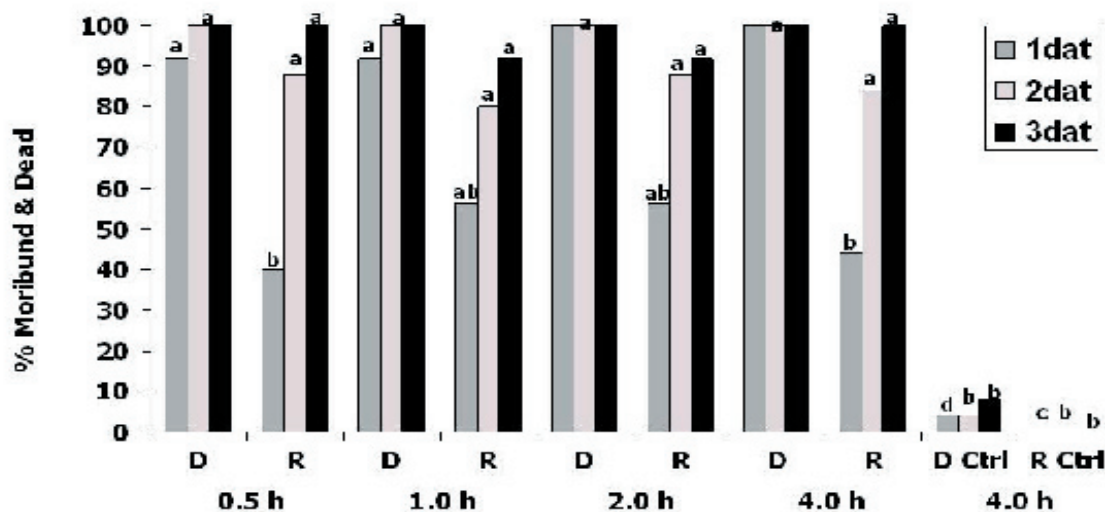


Fig. 1. Percentage of moribund and dead German cockroaches in bioassays in which donors were exposed to 0.05% Arilon™-treated ceramic tile for different time periods and mixed with recipients at 5:5. D = Donors, R = Recipients, D Ctrl = Donor Control, R Ctrl = Recipient Control.

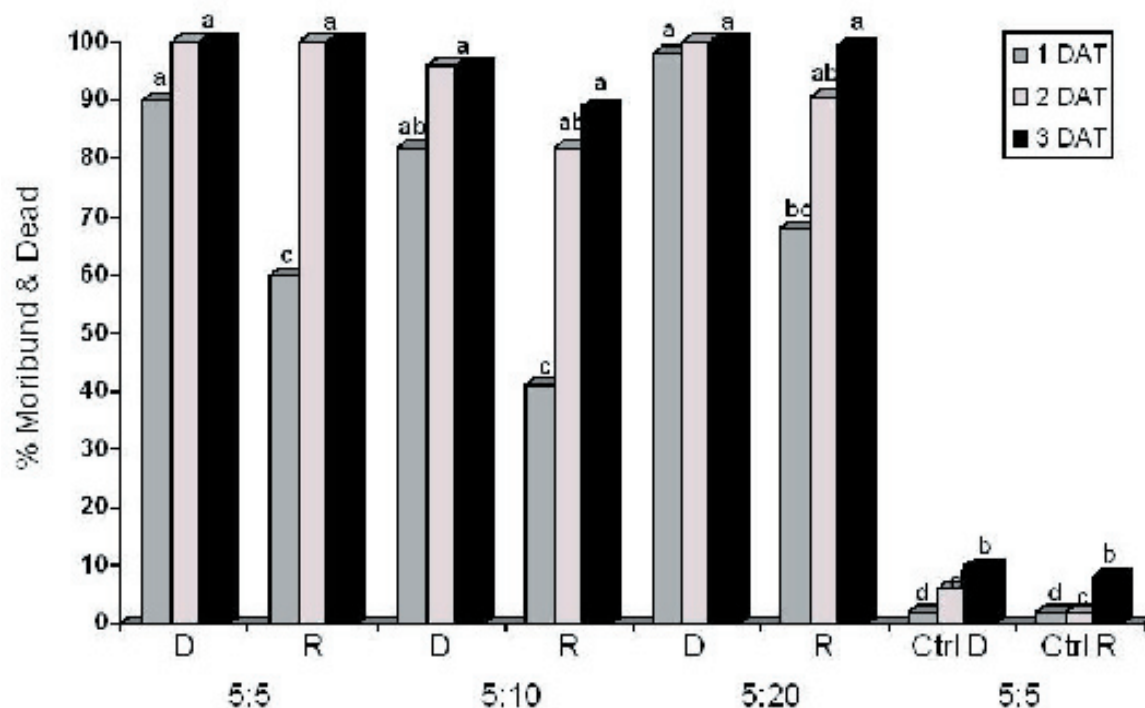


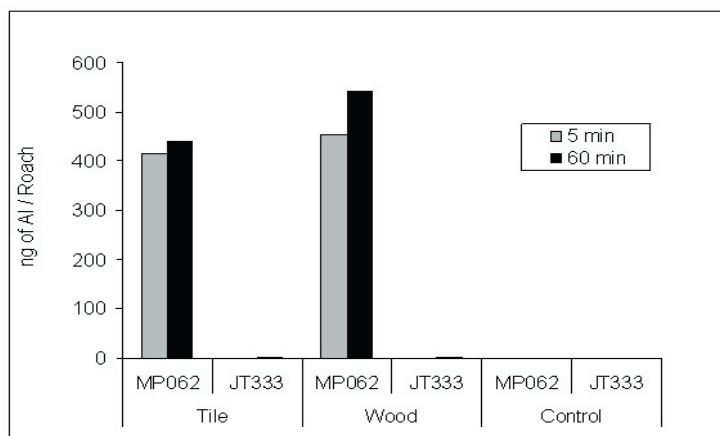
Fig. 2. Percentage of moribund and dead German cockroaches in bioassays in which donors were exposed for 1 h to 0.05% Arilon™-treated ceramic tile and then mixed with recipients at different ratios. D = Donors, R = Recipients, Ctrl D = Donor Control, Ctrl R = Recipient Control.

Horizontal Transfer to Nestmates and Harborage. Regardless of the concentration and time, 100% of recipients were killed at day 7 when donor dead and moribund AA were left in the arena (Table 3). When dead and moribund donor ants were removed from the arena after 24 h, 100% mortality of recipients was observed for all the concentrations and exposure times, except at 0.05% where 91% of recipients died by day 7 after donors had been exposed for only 10 min (Table 3).

Table 3. Percentage mortality of recipient Argentine ants after mixing with donors that had been exposed to Arilon™-treated ceramic tiles for 10 min and 1 h

Type of Arena	Concentration (%)	Time of Exposure	% Mortality		
			Day 1	Day 3	Day 7
Dead and moribund donor ants left in arena	0.05	10 min	60	86	98
		1 hour	86	99	100
	0.1	10 min	82	99	99
		1 hour	78	95	99
	Control	1 hour	5	6	12
Dead and moribund donor ants removed from arena after 24 h	0.05	10 min	24	69	91
		1 hour	52	92	100
	0.1	10 min	28	86	98
		1 hour	88	100	100
	Control	1 hour	0	5	10

Quantification of Active Ingredient (AI) Picked Up by GCR. HPLC mass spectrometer results suggest that GCR were able to pick up nearly equal amounts of AI from both the treated tiles and wood panels after 5 min exposure (~400 ng indoxacarb/insect) (Fig. 3). Increasing the exposure time by a factor of 12 to 60 min on both the surfaces did not increase the amount of AI picked up correspondingly. The maximum amount of AI picked up by GCR was ~525 ng/insect when exposed for 60 min to treated wood (Fig. 3).

**Fig. 3.** Amount of indoxacarb picked up by German cockroaches on ceramic tile and wood surfaces when exposed for different time periods. MP062 = indoxacarb (parent molecule), JT333 = activated metabolite.

Conclusions

Arilon™ is a very effective formulation and offers great potential as a residual spray liquid insecticide against key urban pests such as GCR, ACR, and AA. Mortality from limited exposure to different surfaces demonstrated that this insecticide is readily picked up from different surfaces. Arilon™ has great potential for horizontal transfer in crawling insects such as cockroaches and ants because when they walk over the Arilon™-treated surfaces they pick up sufficient AI within a very short period of time (~10 minutes). Because the AI in Arilon™ is indoxacarb, which causes delayed mortality, these exposed insects can walk back to their harborage and nests, thereby transferring lethal and sub-lethal doses to other insects directly through mutual grooming and contact as well as indirectly by contaminating the hiding and nesting areas.

References Cited

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FORMULATION OF A HIGHLY PALATABLE GRANULAR HOUSE FLY BAIT

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Granular bait is the dominant type of bait used by pest management professionals and is an effective tool for controlling house flies. An extensive study was conducted in order to formulate a highly palatable granular fly bait. Several factors were examined to contribute to an optimal granular fly bait, including the size of the granules, oral and topical toxicity of active ingredients, and fly attractant effects. The resulting granular bait is highly palatable with much higher consumption than current leading commercial granular housefly bait products.

PILOTING INTEGRATED PEST MANAGEMENT (IPM) AT PUBLIC HOUSING AUTHORITIES NATIONWIDE

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The U.S. Department of Housing and Urban Development (HUD), Office of Healthy Homes and Lead Hazard Control has an interagency agreement with the U.S. Department of Agriculture's National Institute of Food and Agriculture to provide training and technical assistance regarding integrated pest management (IPM) to 12 conventional (not Section 8 or voucher-based) public housing authorities (PHAs) nationwide. The Northeastern IPM Center was awarded this grant in 2007. Progress to-date is reported, and successes, challenges, and failures are highlighted. The audience should come away from this presentation knowing what resources are available for them to begin working with low-income housing in their area and some tips for working with PHAs.

As background, the program being offered by the Northeastern IPM Center consists of three parts:

1. Train-the-trainer training (T4) for regional IPM experts to orient them to the training materials and PHAs. Through this training, we hope to build the capacity of IPM experts who are ready to support IPM efforts in affordable housing. Twelve trainers were T4-trained in 2009 and are running the IPM in Multifamily Housing Training at PHAs.
2. A day-long training for PHA staff, led by a T4-trained trainer. By the end of the day, trainees (including maintenance, housekeeping, property managers, local university representatives where available, and contracted pest control representatives) should know about IPM and how it can be used to manage cockroaches, rodents, and bed bugs. One of the overarching messages in this training is that IPM is a team approach to managing pests: everyone needs to communicate and do their part towards making the PHA inhospitable to pests. This training day starts the one-year IPM pilot at the PHA, during which IPM is implemented at the development where the training was held. As of 1 March 2010, five housing authorities were in their implementation period. EPA, HUD, CDC, USDA, NPMA, and NCHH all support the training materials that are used to run this day. All training materials are available online at the project's website: www.stoppests.org.
3. A resident's briefing DVD and IPM kit. This short training is intended for residents during their orientation to the PHA or annual housekeeping inspection. Each resident receives an IPM kit once they have watched the DVD and been shown lease language that pertains to pest control. The DVD introduces them to the way pests are managed in their building. This includes the basics of pest biology and behavior, who is on the IPM team, and how residents can use their

knowledge and the tools given to manage pests. The DVD, IPM kit contents, and instructions for running a briefing are available online at the project's website: www.stoppests.org

IPM can be described as an approach to pest control that uses the most economical means with the least possible hazard to people, property, and the environment.

- ☐ IPM is a healthy approach to pest control because it uses non-chemical measures to prevent infestations from growing.
- ☐ IPM eliminates the source of the problem while utilizing reduced risk pesticides if appropriate.
- ☐ IPM involves routine monitoring and inspection (in place of applying pesticides regularly) so that pest problems are dealt with quickly and efficiently.

The process used in this project to begin IPM at a housing authority is:

1. "Sell" the Executive Director or Director of Public Housing for the housing authority on IPM. Suitable housing authorities come to our attention from news stories about pest control or from the HUD Healthy Homes regional representatives. Often initial contact is made by HUD, a local health department, a task force, or an asthma prevention group.

Selling points include:

- IPM is a system-wide approach to pest control that synergizes the efforts of maintenance, social workers, and pest control.
- An IPM program has potential for great public relations: partnerships, happy residents, higher inspection scores, "healthy," "sustainable," and "green."
- There is a business case: reduced transfer requests, reduced pest work orders, increased satisfaction with housing, fewer asthma attacks, and its cheaper in the long run.
- IPM is a healthy and sustainable approach to reducing asthma triggers.
- Supported by HUD as evidenced by "HUD's Voluntary Guidance on IPM" (available at www.stoppests.org) and webcast on IPM, which can be viewed at: www.hud.gov/webcasts/archive/multifamily.cfm.
- It's not rocket science...it's cockroaches: remove their food, water, shelter, and access points.
- It makes homes good for people and bad for pests.
- NO ONE has to live with pests!

2. Have management pick a suitable development to receive training and pilot IPM for one year. A suitable development has both a need and the staff capacity and willingness to support a new way of doing pest control. Specifically, the property manager must be enthusiastic about the program.

3. Describe the program to the chosen development's Property Manager, Maintenance Head, and Head of Pest Control (if in-house). The program is described during a phone call in which IPM also is described, we review the

program, and we run through the "Planning the Training Day" document word-for-word.

4. Have the property manager "officially" commit to the project by replying to an e-mail stating "I ____ (property manager's name) ____ agree to do the following to support the IPM pilot at ____ (development name) ____: (text from the "Planning the Training Day" document goes here.)

5. Complete an internal review board (IRB) exempt survey and checklist to determine current practices and collect pertinent documents. Documents include the pest control contract or RFP (if any exist), resident lease, housekeeping standards, documents associated with pest control (48 hr notice, unit inspection report, service summary), and any other policies or procedures having to do with pest control.

6. Bring outside support groups up-to-speed and set a training date. Health departments, social service agencies, and the local cooperative extension office may be interested in supporting the PHA's efforts.

7. Hold an IPM in Multifamily Housing Training.

8. Write a "Suggestions for IPM Implementation" report for the property manager. Much of this is based on the Survey and Checklist, but some issues will come to light during the training day. The following is always included:

- Set up your IPM Team: property manager, maintenance staff, resident support services, pest control contractor, residents, and local support groups.
- Encourage communication through documentation procedures.
- Educate EVERYONE to think like a pest—know the enemy.
- Focus efforts on accessing, inspecting, and getting resources to pest reservoirs such as trash handling areas, homes of hoarders, homes of the handicapped.

Issues that are often encountered are:

1. Resident cooperation
 2. Unit preparation for pest control
 3. Trash handling
 4. Over-the-counter pesticide use
 5. Local municipality's trash pick up
 6. Trash chutes and compactor rooms
 7. Pesticide application by unlicensed staff
 8. Communication with pest control contractor
 9. Schedule monthly calls to check in and support the IPM effort as-needed.
- Implementation will be catered to the development. Usually getting residents to

comply with housekeeping standards and new policies will be the most difficult part. When possible, make changes to existing policies and procedures to minimize burden on staff.

10. Collect data as funding and time allows.

DEVELOPING A PROFESSIONAL ASSOCIATION FOR TEXAS SCHOOL INTEGRATED PEST MANAGEMENT COORDINATORS AND HOSTING A STATEWIDE CONFERENCE

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Relevance. Quality pest control is a critical component of school maintenance programs and contributes significantly to indoor environmental quality and safety measures. In recent years, however, many conventional pest control practices have been questioned because of increased concern over the effects of pesticides on children's health. Integrated pest management (IPM) is a strategy that has been shown to reduce the amount of pesticides needed to control pests as well as improve the overall quality of pest control. Since 1995, the state of Texas has required all public schools to follow IPM principles. In addition to having an IPM program, Texas requires that all IPM coordinators receive training via a standardized 6-hr course, and in 2007 Texas required that coordinators receive six additional hours of training every 3 yr. Because of evolving technologies and the complexity of IPM, however, a 6-hr course is generally considered inadequate to equip IPM coordinators to do their jobs well. Even with the new mandate of continuing education, training for IPM coordinators is limited to general pest control topics.

There are 1,030 school districts within the state of Texas, each with at least one IPM coordinator. Currently, IPM coordinators have little or no means of communicating with one another, nor do they share information efficiently. As a result, they have little political power and receive little professional recognition or status within their districts or the agencies serving school districts. The current system of training (private providers, TASB, and AgriLife Extension) is not run by, directed, or evaluated by IPM coordinators; hence, they have little say in the quality, frequency, or manner of training. In addition, when the 80th Legislature adjusted the school IPM law, school districts were not consulted as to the impact of these new mandates. It became apparent during the rule-making process that Texas school IPM coordinators were very passionate about their role in the school IPM rule-making process and the impacts these rules had on how they conducted business within the district.

The purpose of this project was to help create a state association that would raise the profile of school IPM coordinators, provide a new venue for communication, and give IPM coordinators more say in the regulatory process. A periodic statewide conference,

not a regional mandated training, would provide new learning opportunities and allow IPM coordinators to discuss issues of mutual interest. The conference would allow them to plan their own training meetings and arrange for topics that they wanted to learn more about.

A professional association would raise the professional status and visibility of school IPM coordinators. An association would provide a new venue for recognition by their supervisors and district administrators. Finally, a professional association would make this group less dependent on outside groups for leadership. An organized association of IPM coordinators could better influence political decision-making and more effectively inform regulatory policy.

Response. In spring 2008, Texas AgriLife Extension submitted a grant proposal and was awarded a grant from the U.S. Environmental Protection Agency (EPA) Pesticide Environmental Stewardship Program (PESP) to host a statewide conference and facilitate the adoption of a professional association for Texas school IPM coordinators. The grant budget allowed for seed money to host the statewide conference and to help facilitate the necessary means to develop a recognized professional association. In addition to the grant, the school IPM program at AgriLife Extension also worked with other state agencies to facilitate the process and to help obtain recognition of this group.

In the fall of 2008, an initial call went out to school IPM coordinators via the School Pest News, the quarterly newsletter that is sent out to over half of Texas school IPM coordinators, requesting their participation in setting up the statewide conference and putting together a professional association. The response was very favorable as almost 20 individuals signed up immediately. In addition to the school IPM coordinators, the Texas Association of School Boards Onsite Environmental (TASB) group and the Texas Association of School Business Officials (TASBO) agreed to work with Extension to develop a process for developing the professional association and getting the word out to all school districts about this new venture. By the end of 2008, a 22-member steering committee was formed.

An initial face-to-face meeting was held at Frisco Independent School District (ISD) in February 2009. At this meeting, four people were selected to develop a set of by-laws for the Texas School IPM Coordinator Association and be the original set of officers. They were Victor Melton, Carrollton-Farmers Branch ISD; Tom Ohm, Frisco ISD; Paul Duerre, Killeen ISD; Dixie Mathews, Arlington ISD; and C.G. Cezeaux, Spring ISD. The group worked with TASBO to become an affiliate chapter under their direct supervision. This would allow the group to obtain 501.3c status and have a form and structure that has been proven for many years. According to TASBO, this is the first statewide affiliate chapter under their direction and it is also the first type of professional association for school IPM coordinators nationwide. TASBO is one of the largest state chapters under the Association of School Business Officials International and this group is watching to see how the success of this chapter goes, as they would like to replicate this in other states where there also is a need.

At the initial planning meeting, 18 individuals came together to discuss the format of what the statewide meeting should be. It was determined that a late fall meeting date (18-19 November 2009) would be ideal for school IPM coordinators; that San Marcos, which is centrally located within Texas was best suited for the meeting; and that a 1.5-day program would be more than adequate to kick off the association and offer educational programming. An additional planning meeting was held in June 2009 at the summer annual TASBO conference held in Grapevine, TX; a slate of topics and speakers were suggested and assignments were given out.

The slate of speakers at the November 2009 statewide conference varied from two national speakers, Gene Harrington, National Pest Management Association; and Dr. Bobby Corrigan, research scientist with New York City Department of Health, Veterinary Pest Control Services; to Charles Adams, IPM Coordinator, Sherman ISD; and a state-licensed trapper. In all, there were 11 speakers from Extension, Texas Department of Agriculture, industry experts, and public health.

To measure the success of the statewide conference, a retrospective post- evaluation and intention-to-adopt survey was developed for the conference. Participants were asked nine questions regarding their knowledge prior to and after the conference; additionally, seven questions were asked about participants' plans to adopt some of the new technology and information presented. There were 237 attendees, with 115 school districts represented, which is about 11% of the total number of schools in Texas. Of the 237 attendees, 110 people responded to the post-evaluation survey, with 89% of the attendees mostly or completely satisfied with the entire program.

To measure the results of specific speakers and topics the participants were asked about their perception of knowledge change based on the program. The results are in Table 1, which only reflects a small portion of the program. Table 2 indicates participants' level of adoption of new methodology taught at the seminar.

Table 1. Ranked mean value¹ of participants' perception of their level of knowledge as a result of the statewide conference for school IPM coordinators

Perceptual Knowledge	BEFORE Mean	AFTER Mean	Change
Q # 1 - I understand how Texas school IPM rules compare to other states	2.79	3.09	30%
Q # 5 - I can list three types of zoonotic diseases associated with urban wildlife	3.80	4.34	54%
Q #6 - I can identify three of the most common school infractions of Structural Pest Control Services rules	4.32	4.43	11%

¹Likert scale was defined as: 1 = not at all, 2 = slightly, 3 = somewhat, 4 = mostly, and 5 = completely.

Table 2. Plans to adopt (percentage of respondents who definitely will adopt the following practices and percentage of respondents who have adopted a given technology or practice)

Practice or technology that could be adopted	Definitely will	Already adopted
My district will use information from this conference to improve its pest reporting process	58%	23%
My district will use information from this conference in our in-house education program	64%	14%
My district will use information from this conference to change the way we do termite control	28%	12%
Our district will rely less on rodenticides because of what I learned at this conference	43%	20%
My district will begin using sticky traps in all kitchens to monitor pests	24%	66%
My district will rely less on pesticide sprays for pests as a result of this conference	31%	42%
I will become a member of TIPMAPS	39%	12%

Finally, at the end of the 1.5-day conference, the first meeting was held for the Texas Integrated Pest Management Affiliate for Public Schools (TIPMAPS). All five members of the executive board and 48+ potential members were in attendance. By-laws were summarized and explained by Victor Melton, member-at-large. It was explained to potential members that they had to read and agree to the by-laws before requesting membership. Any changes to the by-laws must be voted on and approved by the majority of the membership. Membership dues were set at \$25 for an individual or for a school district, with associate memberships available for vendors and other non-school personnel. The group also discussed having regional chapters so that coordinators could meet with and discuss timely topics with their neighbors.

This group also indicated that they liked having the 2010 statewide meeting in San Marcos. They requested that TASBO and Extension work with the hotel to have the meeting at the same location and the same week in November.

As 2010 began, three areas around the state hosted their first TIPMAPS meeting, Houston, San Angelo, and Fort Worth with one of the three regions determining that they would meet quarterly.

Lastly, TIPMAPS membership brochures were developed by Tom Ohm, President, and sent out to 1,335 IPM coordinators, non-commercial applicators, vendors, and other interested individuals. By May 2010, the group had 120 members and was in the process of developing their website: www.tipmaps.org.

IPEST MANAGER—A WEB-BASED PEST REPORTING SYSTEM FOR IMPROVING EFFICACY OF A SCHOOL INTEGRATED PEST MANAGEMENT PROGRAM: A CASE STUDY OF THE SALT LAKE CITY SCHOOL DISTRICT

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In 2005, Utah's Salt Lake City (SLC) School District received an Environmental Protection Agency (EPA) grant to initiate a pilot integrated pest management (IPM) program in three district schools. Since then, the district has received awards of excellence in IPM, including the 2006 EPA Award of Recognition, 2008 IPM Star Certification, and the 2009 International IPM Excellence Award. In 2009, the SLC School District continued to exhibit their dedication to IPM with the creation of a web-based pest reporting system called iPest Manager (iPest).

Launched in 2010, iPest allows district employees to quickly identify and report pests using pull-down menus, photographs, and written descriptions. Pest observational data, including location descriptions, date, observer, control status, control tactics, and IPM implementation costs are recorded to accurately track pests. Data can be summarized by iPest's reporting function, which allows administrators to view the number and specific location of pests reported at each school, pest species, mitigation tactics, and their associated costs in tabulated or graphical output. If pesticides are necessary, iPest has specific data fields that record products used and pertinent application information. iPest is an innovative IPM tool that streamlines pest detection, identification, and managerial decision-making, and would be a useful addition to any schools' IPM toolbox.

Visit iPest Manager online at:

<https://aal.slcschools.org/pls/apex/f?p=118:1:7536057333779007>

DEVELOPMENT OF AN IMPROVED INTEGRATED PEST MANAGEMENT PROGRAM TO PROTECT RETAIL AND DISTRIBUTION FACILITIES

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Pest management programs in most retail distribution and sales outlets are considered conventionalized programs. Practices to monitor pest activity largely exist as a series of traps placed in a perimeter defense to detect mice and insects moving into the facility. Response to outbreaks of pests inside buildings relies on facility personnel to report a problem. The result is reactionary pest management practices after infestations have occurred. With this type of program, pesticide applications play a very significant role in controlling pest outbreaks and then applications may continue periodically as a measure of prophylaxis.

From initial facility assessments, an integrated pest management (IPM) program was designed for retail distribution and sales outlets. This new pest management program re-distributed effort from servicing traps to increased labor used for inspections, reporting, and preventative measures. To measure the success of this system, as well as determine possible avenues for improvement, a survey was conducted. This survey compared distribution warehouses on the old pest management system versus warehouses that had been converted to the new IPM system for at least 1 yr. The results and significance of this survey are discussed; additional findings and experiences also are described for the retail company's expanded use of this new IPM program in all of their facilities.

CONDUCTING EFFICACY STUDIES AGAINST URBAN PEST SPECIES FOR ENVIRONMENTAL PROTECTION AGENCY PESTICIDE PRODUCT REGISTRATIONS

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The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Good Laboratory Practice standards (GLPs) were originally published in November 1983 (40 CFR Part 160) by the U.S. Environmental Protection Agency (EPA). This was in response to investigations conducted by EPA and the Food and Drug Administration (FDA) during the mid-1970s which revealed that some studies submitted to these two agencies had not been conducted in accordance with acceptable laboratory research practices.

Some of these studies were so poorly conducted that the EPA could not rely on the data to make decisions regarding product registrations. Some of the problems encountered included poor adherence to protocols; under-qualified personnel or supervisors; little or no sponsor monitoring; results selectively reported, under-reported, or fraudulently reported; poor animal care procedures; and inadequate record-keeping techniques. EPA's revisions to the FIFRA GLP standards also extended their scope to include product performance data (efficacy testing) as currently required to be submitted by 40 CFR 158.640. A harmonized Compliance Program was established by EPA and FDA to regularly conduct laboratory inspections and study audits of all testing facilities used for data submissions to the agencies.

Laboratory and field efficacy studies are conducted on many urban pests by universities, industry, government, and contract research organizations to determine product efficacy necessary for everything from proof-of-concept to final product registration. Many of these studies are conducted using good scientific methods, but may or may not be conducted under GLP guidelines as established by EPA. This presentation illustrates and highlights some of the challenges of conducting laboratory and field efficacy studies which may be used for EPA product registrations.

DISCOVERY AND DISTRIBUTION OF THE BEAN PLATASPID IN NORTHEAST GEORGIA

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In mid-October 2009 County Extension Agents with the Georgia Cooperative Extension Service (University of Georgia's College of Agricultural and Environmental Sciences) and individuals from several independent pest management firms filed multiple reports with the University of Georgia's Homeowner Insect and Weed Diagnostics Laboratory regarding large numbers of insects that had "swarmed" onto the sides of homes and other structures (Suiter et al. 2010). Homeowners complained of thousands of insects on the sides of their homes. When numerous, the insect apparently moves from nearby kudzu patches onto the warm, sunlit south and east face of nearby structures.

Identification and Distribution. Further investigation by Joe Eger revealed that this insect was not native to the U.S. He, along with colleagues from the U.S. National Museum of Natural History, the Florida State Collection of Arthropods, and North Dakota State University, identified the insect as *Megacopta cribraria* (F.) (Heteroptera: Plataspidae), commonly known as the bean plataspid although it has no ESA approved

common name. Eger et al. (2010) provides the most recent review (including 82 references) of *M. cribraria*. The bean plataspid was not previously known from the western hemisphere. It is native to Asia, where its preferred food source is kudzu [*Pueraria montana* var. *lobata* (Willd.) Ohwi], a leguminous vine introduced into the U.S. more than 100 yr ago as a ground cover to prevent soil erosion. In June 2010, the bean plataspid was found on another legume, soybeans (*Glycine max* Merrill) in 13 Georgia counties and several counties in South Carolina. As of July 2010, the bean plataspid's distribution was restricted to approximately 25 counties in northeast Georgia and several counties in nearby South Carolina.

Control on Structures. We believe the control of bean plataspids on structures may prove frustrating for both homeowners and pest management professionals. Some stink bugs (*M. cribraria* is a stink bug relative) overwinter as adults. We suspect their movement onto structures (Fig. 1A,B) in the summer, and especially fall, of the year is an attempt to locate overwintering sites as temperatures begin to cool. The situation appears to be similar to the long-standing multicolored Asian lady beetle [*Harmonia axyridis* (Pallas)] situation, where adults move into structures in the fall when temperatures begin to drop. Although perimeter based pest control sprays might be used to treat the perimeter of the structure and provide some relief from invading plataspids, the overwhelming numbers of bugs combined with nearby foci



Fig. 1. (A) The bean plataspid, *Megacopta cribraria*, was first reported from Georgia in October 2009. (B) Thousands of bean plataspids congregate on structures, particularly on warm south and east faces.

(i.e., kudzu) and the inability (legally) for pest management professionals to engage in off-property source reduction (with insecticides to kill bugs or herbicides to kill kudzu) is likely to make lasting control difficult unless the kudzu can be physically removed or killed by the property owner where the kudzu resides. DRS has fielded several complaints from homeowners, who have large numbers of bugs on and around their home, where the source of the bugs (kudzu) is located on neighboring properties owned by private individuals or city and county municipalities. Ultimately, relief from invasion by the bean plataspid will be source reduction---i.e., elimination of kudzu within several hundred meters of the structure.

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THE FIRST NEW WORLD RECORD OF *MEGACOPTA CRIBRARIA* (F.) (HETEROPTERA: PLATASPIDAE) FROM GEORGIA: A SERIOUS HOME INVADER AND POTENTIAL LEGUME PEST

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Megacopta cribraria (F.) was collected in north Georgia in late October 2009 (Eger et al. 2010, Jenkins et al. 2010). The bugs were invading homes in large numbers. This is the first known occurrence of this species and the family Plataspidae in the New World. *M. cribraria* was previously known from Asia and Australia.

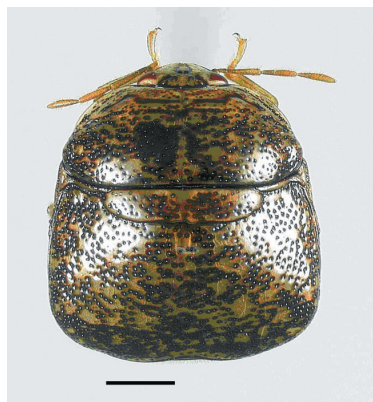


Fig. 1. *Megacopta cribraria*, habitus. Dimensional line equals 1 mm.

M. cribraria (Fig. 1) and the family Plataspidae can be distinguished from other Pentatomoidea found in America north of Mexico by the following characters: scutellum enlarged, wider than long, truncate posteriorly; tarsi 2-segmented; small size (3.5 - 6.0 mm); pseudosuture on anterior margin of scutellum defining distinctive macule; and short second antennal segment. *M. cribraria* differs from other Plataspidae by the relatively uniform dorsal coloration, the superior surface of the tibiae sulcate for entire length, and venter of abdomen black mesially, pale laterally.

There are a number of reported host plants, primarily in the family Fabaceae. *M. cribraria* is considered a pest of numerous legumes in Asia. Kudzu, *Pueraria montana* var. *lobata* (Willd.) Ohwi, appears to be the preferred host, but large numbers of bugs have been reported attacking other legumes. *M. cribraria* may have the potential to provide biological control of kudzu, and will probably continue to be a household pest in the vicinity of kudzu or bean fields. It will likely become a pest of legume crops as well.

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TEACHING SYMPOSIUM

**MOLECULAR TECHNIQUES
AND URBAN ENTOMOLOGY–
THE WHY AND THE HOW**

Organizers:

**Michael Scharf (University of Florida)
Grzegorz Buczkowski (Purdue University)**

**NUCLEOTIDE-BY-NUCLEOTIDE: HOW MOLECULAR
SYSTEMATICS PROVIDES INSIGHTS INTO THE COMPLEXITY OF
URBAN PEST BIOLOGY**

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High through-put sequencing machines coupled with increasingly sophisticated and easy-to-use bioinformatic software programs have had an enormous impact on the growth of molecular systematics generally and on insect molecular systematics specifically. DNA technology has been used to identify, confirm or corroborate the taxonomy of an exotic urban insect pest as well as to investigate its evolutionary history and adaptive potential. Once the insect species is confirmed, questions of geographical origin, ports of entry, dispersal patterns, and the natural history of an urban insect pest can be explored. The overall purpose of this paper, therefore, is to plainly tell the story of how applying DNA molecular techniques to confirm the taxonomy of a recent Asian stink bug introduction into Georgia, USA also provided insights into its natural history and rapid dispersal across the state.

The Asian bean plataspid, *Megacopta cribraria* (L.), was identified for the first time in North America in October 2009 on kudzu vine in Georgia. By November 2009, the bug had become a serious urban nuisance pest in eight Georgia counties as thousands of the adults moved out of kudzu fields to overwinter on, in, or around urban homes. Identification as *M. cribraria* was initially made based on morphological characters (Eger et al. 2010). But because the only difference between species in Asia identified

as *M. cribraria* and *M. punctatissima* were size and color (Eger et al. 2010), and these physical features were variable for the *Megacopta* species in Georgia, identification of the species was confirmed from mitochondrial DNA (mtDNA) sequences and a GenBank search (Jenkins et al. 2010).

Once the taxonomy was confirmed, the polymerase chain reaction (PCR) was used to amplify a 2300 bp gene fragment composed of cytochrome oxidase subunit I (COI), leucine (L), and cytochrome oxidase subunit II (COII) genes, respectively, from 30 individuals across five Georgia counties. All samples had the same sequence for this gene fragment. Since this maternal haplotype was first characterized morphologically from Georgia, its genotype was designated as GA1. Then the entire mitochondrial genome (15,465 bp) was sequenced from 5 of the 30 individuals, representing four Georgia counties. There was no difference in sequence. This suggests that the bean plataspid dispersing across Georgia are descended from a single female lineage identified as GA1.

As of November 2010, *M. cribraria* has been found on kudzu vine and soybean across 80 Georgia counties. The bug also has been reported in South Carolina, North Carolina, Tennessee, and Alabama. To date, GA1 is the only haplotype that has been found. Phylogeny analysis of mtDNA sequence from individual bugs sampled across Asia is underway in order to identify the country of origin. This knowledge will provide insights into the natural history and adaptive ability of *M. cribraria*. It also will facilitate closing ports of entry into the U.S. as well as the application of effective management strategies.

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WHAT CAN MOLECULAR MARKERS TELL US ABOUT URBAN PEST POPULATIONS THAT WE DIDN'T ALREADY KNOW?

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With the relatively recent advent of molecular markers, opportunities now exist for the investigation of genetic structure and population dynamics within and among urban pest populations. As time has progressed, molecular markers with greater levels of polymorphism have been developed and utilized, opening avenues of research previously unfeasible with behavioral studies alone. Over the past two decades, such markers have contributed significantly to furthering our understanding of urban pest populations. Microsatellite markers in particular have emerged as a powerful tool for investigating not only population genetic structure, but also within population/colony breeding structure, temporal stability and population persistence, size and utilization of foraging area, population/colony size, and dispersal dynamics, to name but a few research areas. Although the greatest application has been observed in studies of termites and ants, research focusing on other urban pests such as cockroaches and bed bugs are now in progress. With selected case studies, we demonstrate the potential modern molecular markers offer for advancing our understanding of urban insect pest populations.

SYMBIOSIS IN URBAN PEST TERMITES AND ITS DISRUPTION FOR CONTROL

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Subterranean termites, such as the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (FST), are costly pests on a global scale due to their voracious appetite for lignocellulosic material (wooden structures, trees, etc.). Foraging termite workers ingest and initiate the breakdown of the wooden material, but the digestion is largely dependent on the multifaceted network of symbionts in the hindgut of subterranean termites. The symbionts span the three domains of life, i.e., Eukaryota (protozoa), Archaea (e.g., methanogens) and Eubacteria (true bacteria). The gut symbionts not only aid in the digestion of lignocelluloses, but, among other functions, also provide energy to the termite via acetogenesis, synthesize vitamins, and fix and recycle nitrogen to supplement the nutrient-deficient diet of termites (Breznak 2000, Husseneder 2010). Since subterranean termites cannot survive without their symbionts, symbionts can be used as tools and targets to achieve termite control.

We use symbionts to develop paratransgenesis as a technique for termite control. Paratransgenesis is based on a “Trojan Horse” approach. According to Homer’s Iliad, the Trojan Horse was used to secretly smuggle soldiers into the city of Troy to circumvent its impenetrable walls and destroy the city from within. In an analog approach, we are using genetically engineered symbionts as “Trojan Horses” to introduce, express and spread toxins (“soldiers”) undetected by the termites’ defense systems to destroy a termite colony (“Troy”). Proof of concept for the feasibility of paratransgenesis in termites has been achieved previously using bacteria (Enterobacteriaceae) expressing green fluorescent protein as a monitoring system. We showed successful introduction, spread and long-term stability of genetically engineered bacteria in lab colonies of FST (Husseneder and Grace 2005).

To develop paratransgenesis for termite control, we first identified targets and toxins that can be expressed in the termite gut to kill the targets with a high degree of specificity. While other workgroups chose to target the termites directly by engineering bacteria to express insecticidal toxins (Zhao et al. 2008), we considered the indirect approach as being more environmentally safe. We target the three species of cellulose-digesting protozoa in the gut of FST (*Pseudotrichonympha grassii*, *Holomastigotoides hartmanni*, and *Spirotrichonympha leidy*), because it has been well documented that these protozoa are specific to the termite gut and necessary for termite survival (Eutick et al. 1978, Husseneder and Collier 2009, Husseneder 2010). We chose lytic peptides as toxins that are a natural part of the innate immune system of eukaryotes. Lytic peptides disrupt membranes of microorganisms but are largely inactive against higher eukaryotes (Boman 2003). We tested three lytic peptides: cecropin B (a natural lytic peptide from the giant silk moth), melittin (a component of the bee venom) and hecate (a synthetic lytic peptide, Mutwiri et al. 2000) *in vitro* and *in vivo* for their efficacy in killing termite gut protozoa. A concentration of 50 μ M of any one of the lytic peptides killed all three protozoa species in anaerobic culture within 5-10 min (Husseneder and Collier 2009). Three days after injecting up to 0.5 μ l of 500 μ M lytic peptide solution into the hindgut of termites (through enema) all protozoa were destroyed. Melittin killed termites within a few days (acute toxicity), while hecate and cecropin killed termites within 3-6 weeks, which is consistent with the time it takes for a termite to die of starvation (Husseneder and Collier 2009). We chose one of the slow-acting toxins (hecate), because the success of paratransgenesis requires the spread of the toxin expressing “Trojan Horse” throughout an entire colony.

We then genetically engineered yeast as a prototype to express hecate in culture and in the termite gut, and demonstrated the efficacy of the yeast against protozoa *in vitro* and *in vivo*. We chose the commercially available yeast *Kluyveromyces lactis* as our prototype “Trojan Horse”, because it can be easily genetically engineered to express and secrete proteins. The gene encoding hecate was synthesized and inserted into the yeast chromosome. Transformed yeast strains were screened in bioassays to determine their ability to kill protozoa *in vitro*. Yeasts were grown for 72 h and the supernatants (containing secreted hecate) were tested against a culture of free-living aerobic protozoa (*Tetrahymena pyriformis*) (Husseneder and Collier 2009). Strains

whose supernatant caused significant mortality in *Tetrahymena* were subsequently tested *in vivo* by feeding them to termites. Four weeks after termites were fed for 24 h with hecate-expressing yeast strains, their guts were completely devoid of protozoa and after 6 wk the termites died (while control termites fed on moist filter paper stayed healthy) (Husseneder and Collier 2009). This experiment proved that a yeast expressing protozoacidal lytic peptide is effective against termites in the laboratory. Before field application can be considered, we needed to increase environmental safety by increasing target specificity of the lytic peptide. Although lytic peptides are already fairly safe for higher eukaryotes (Boman 2003), we took additional steps by designing a ligand that binds the lytic peptide specifically to the protozoa membrane. This was accomplished via phage display. We purchased phage libraries (New England Biolabs Inc., Ipswich, MA) where each phage was genetically engineered to express and display a specific set of heptapeptides on its surface. The library contains on the order of 10^9 independent clones, i.e., surface peptides represent almost all possible combinations of seven amino acids. As shown in Fig. 1, protozoa were extracted from the termite gut and incubated with the phage library. After removal of unbound phages, the phages displaying peptides that bound to the protozoa membrane were eluted, amplified with *E. coli*, and subjected to three additional rounds of binding/amplification cycles to increase positive selection. Selected phages were purified and the oligonucleotides coding for the specific heptapeptide sequences inserted in the phage genome were sequenced to identify the actual ligands (protocols at <http://www.neb.com/nebecomm/ManualFiles/manualE8110.pdf>). With this method we initially identified 19 unique heptapeptide sequences that putatively bound to protozoa membranes. A search of public protein databases (UniProt at <http://www.uniprot.org/uniprot/Q57WM6>) identified similarities of one of the peptide sequences (ALNLT LH) generated by phage display to putative glycoproteins on the membrane of the protozoan *Trypanosoma brucei*.

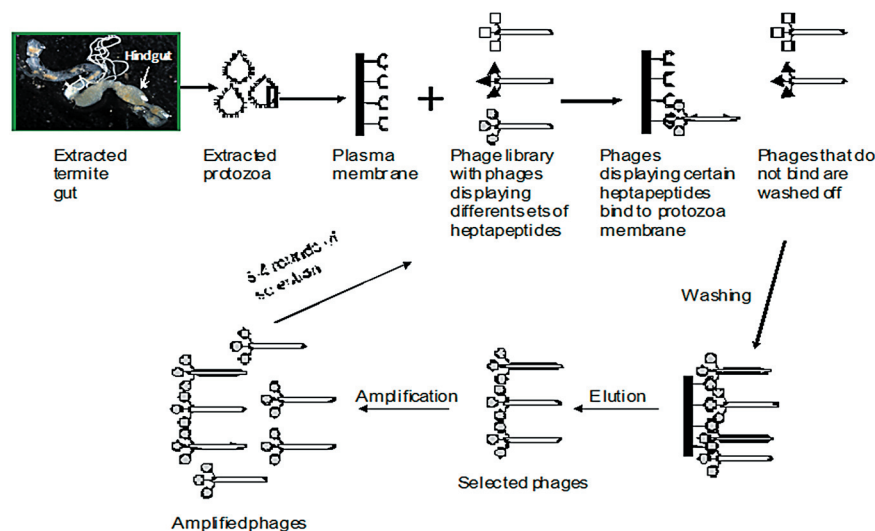


Fig. 1. Identification of ligands binding to the membrane of termite protozoa using phage display (modified from www.neb.com/nebecomm/ManualFiles/manualE8110.pdf).

The ligand was subsequently coupled with a fluorescent probe (EDANS, EMD Chemicals Inc., Gibbstown, NJ) and tested for specific binding to the three species of protozoa from the termite gut *in vitro* (protozoa culture) and *in vivo* (termite enema). Fluorescence microscopy showed that the ligand marked with the fluorescent probe bound to the surface of all three species of protozoa from the gut of FST under both conditions). The ligand also was found to bind to other free-living protozoa species, such as *Tetrahymena pyriformis*, *Euglena* sp., *Paramecium* sp., and *Amoeba* sp., but not to bacteria (Husseneder et al. 2010).

Next, we attached the ligand to the lytic peptide hecate and tested the efficacy of the ligand-hecate against gram-negative bacteria (*E. coli*) and gram-positive bacteria (*Pilibacter termitis*, which is exclusively found in the gut of FST, Higashiguchi et al. 2006). The plate counts of both, gram positive and gram negative bacteria cultures treated with up to 50 μ M of ligand-hecate were not significantly different from plate counts of cultures treated with water. However, plate counts dropped significantly when the same concentrations of hecate (without the ligand) were applied (Husseneder et al. 2010). Thus, the specificity of the ligand, which does not bind to bacteria (see above) reduces toxicity of hecate against bacteria and thus protects non-target organisms to some degree. This result was encouraging, since bacteria could potentially serve as “Trojan Horses” to express lytic peptides in the termite gut and spread among colony members (Husseneder et al. 2005, Husseneder and Grace 2005). However, we still needed to show that ligand-hecate killed protozoa with at least as much efficiency as hecate without the ligand (Husseneder and Collier 2009).

Even concentrations as low as 1 μ M of ligand-hecate killed all three species of protozoa extracted from the termite hindgut in less than 10 min *in vitro*. When 0.3 μ l of 500 μ M ligand-hecate was injected into the hindgut, the protozoa were killed within 24 h and the treated termites died within 2 wk after loss of their symbiotic protozoa, while controls injected with water stayed healthy. Previously, Husseneder and Collier (2009) injected the same concentration of hecate (without ligand) into termite hindgut. Without the ligand, the time from injection of hecate until death of protozoa (72 h) and termites (up to 6 wk) was at least three times longer. This suggests that the ligand increases protozoacidal efficiency of hecate, most likely by binding the lytic peptide to the protozoa.

We are currently engineering “Trojan Horses” (yeast and termite-specific gut bacteria) to express the ligand-coupled lytic peptide in the termite gut (Fig. 2). Yeast already has been a successful prototype for lytic peptide expression in termites (Husseneder and Collier 2009) and could be easily formulated for bait application since it can be freeze-dried. Successful engineering of termite specific gut bacteria would add another step towards environmental safety, since bacteria only known to exist in the termite gut are unlikely to survive for an extended period in the environment. Moreover, we have already shown that genetically engineered bacteria survive long enough in the termite gut to be spread among colony members (Husseneder and Grace 2005). To date, we have cultured over 50 bacteria strains from the gut of FST (Higashiguchi et al. 2006,

Husseneder et al. 2007, 2009, Sethi et al. unpubl.). Sequencing of the 16S rRNA gene revealed that most of them are yet unidentified and not known from the environment. Thus, the hundreds of species of bacteria in the gut of FST (Husseneder 2010) provide ample “raw material” to construct a feasible “Trojan Horse”.

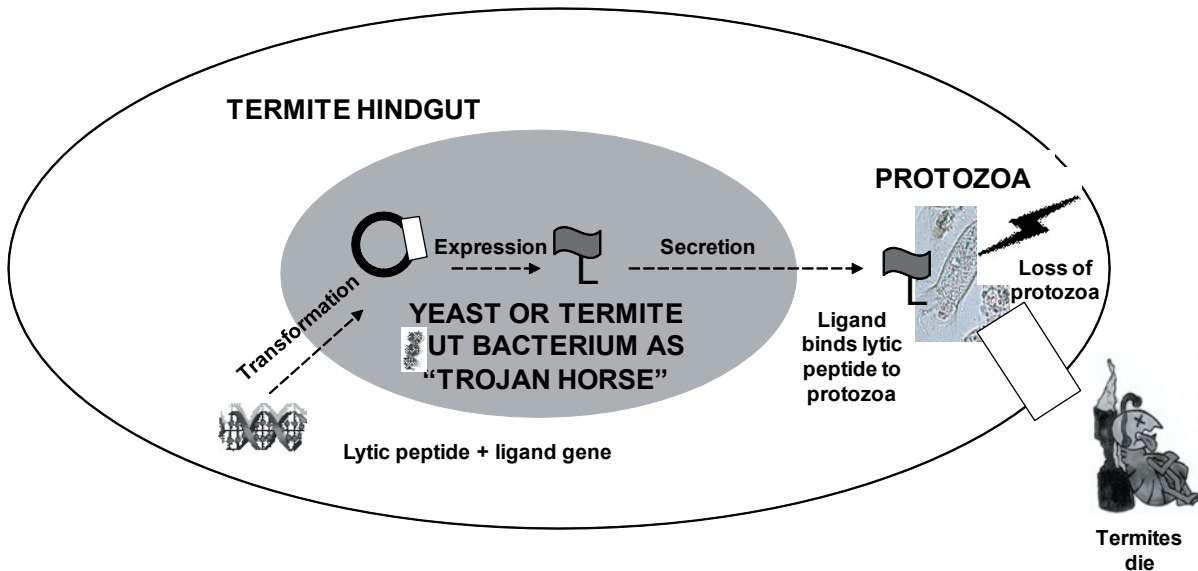


Fig. 2. Paratransgenesis for termite control.

Paratransgenesis using ligand-lytic peptides would provide a targeted approach to control insects in urban and agricultural environments with reduced reliance on chemical pesticides. Bait systems could be developed that introduce customized microorganisms producing ligand-lytic peptides to target pest species, such as other subterranean termites and cockroaches that rely on protozoa for survival. Grooming, trophallaxis, and coprophagy will likely spread the microbes among colony members (Husseneder et al. 2005, Husseneder and Grace 2005) and eliminate the colony.

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HIGH THROUGHPUT SEQUENCING: ADVANCES AND APPLICATIONS

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Sequencing technologies have undergone revolutionary changes in the past few years. It is now possible to obtain hundreds of millions of bases of DNA sequence within a few days without the need for cloning or library construction. The source can be total genomic DNA or cDNA from specific tissues. With improving accuracy and read length, we are now on the cusp of obtaining the full genome sequence of any organism within a few weeks and for a few thousand dollars. I will review the new and emerging sequencing technologies and their potential applications, which include de novo sequencing of genomes, transcriptome sequencing from tissues or whole organisms, and sequencing for detection of single nucleotide polymorphisms.

TRANSLATIONAL GENOMICS: GENES TO FUNCTION TO PEST CONTROL

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Whereas the field of genomics is concerned with the simultaneous sequencing of large quantities of genes contained in whole genomes or in association with biological processes or environments, translational genomics is concerned with assigning function to sequenced genes. Translational genomics embodies the Central Dogma of biology, which states that DNA codes for RNA, which codes for protein; or more generally, that sequence information contained in DNA, RNA and protein (within organisms) is highly interconnected. Thus, function at the protein and organismal levels can be directly inferred from DNA sequence information. By understanding pest biology in such detail, it is now possible to rapidly design and test pest control tools and strategies based purely on knowledge of DNA sequence. This review presentation focused on methods and approaches to translational genomics using the eastern subterranean termite, *Reticulitermes flavipes*, as a representative urban pest. Methods and approaches that were overviewed included sequencing of expressed gut genes (Scharf and Tartar 2008, Tartar et al. 2009), specific identification of digestive genes, and the use of protein biochemistry and RNA interference to (1) define gene function and (2) develop novel pest control tools (Scharf and Boucias 2010; Scharf et al. 2010; Tarver et al. 2010; Wheeler et al. 2007, 2010; Zhou et al. 2006, 2007, 2008a,b, 2010). Through the use of translational genomics tools now available to biologists, it is possible to use the vast amounts of information provided by large-scale sequencing projects and rapidly move forward by linking genes to biology.

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SUBMITTED PAPERS

TERMITES

DISPERSAL OF THE EXOTIC ARBOREAL TERMITE *NASUTITERMES CORNIGER*: POPULATION DYNAMICS STUDY USING MICROSATELLITE MARKERS

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Nasutitermes corniger is an exotic arboreal termite and an economically important structural pest. This termite was discovered at Dania Beach, FL, in May 2001 and was estimated to have been established for 5-8 years. Due to the proximity of the area to seaports it is assumed to have arrived shipboard from an unknown location in the Caribbean Basin.

In order to better understand the dynamics of exotic termite introductions, a study using polymorphic microsatellite markers is being conducted. Termite specimens have been collected from Dania Beach and preserved since 2001. Comparison of various subpopulations from this area would help estimate the population structure and probably the parentage of the colony. Preliminary results on percent polymorphism, number of alleles per locus, observed and expected heterozygosity will be presented.

SPATIAL ASSOCIATION OF MARINE DOCKAGE WITH LAND- BORNE INFESTATIONS OF INVASIVE TERMITES IN URBAN SOUTH FLORIDA

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Marine vessels have been implicated in the anthropogenic dispersal of invasive termites for the past 500 years. It has long been suspected that two invasive termites, the Formosan subterranean termite (FST), and the Asian subterranean termite (AST), were introduced to and dispersed throughout south Florida by sailboats and yachts. We compared the distances between 190 terrestrial point records for FST,

177 records for AST, and random locations with the nearest marine dockage using spatial analysis. Results show that the median distance to nearest docks associated with AST is significantly smaller than for the random points. Results also reveal that the median distance to nearest docks associated with FST is significantly smaller than for the random points. These results support the hypothesis that AST and FST are significantly closer to potential infested boat locations, i.e., marine docks, than random points in these urban areas. The results of our study suggest yet another source of aggregation in the context of exotic species, namely hubs for pleasure boating.

**PERSISTENT FORMOSAN SUBTERRANEAN TERMITE,
COPTOTERMES FORMOSANUS SHIRAKI (ISOPTERA:
RHINOTERMITIDAE) INFESTATIONS IN NEW ORLEANS'
FRENCH QUARTER**

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The Formosan subterranean termite, *Coptotermes formosanus* Shiraki (FST), was first introduced to the continental U.S. after WWII. New Orleans' French Quarter (FQ) in particular has been severely impacted, experiencing reoccurring cycles of damages and repairs since FST was introduced to the region 70 years ago.

Operation Full Stop is a federally-funded program established in 1998 by the U.S. Congress. As part of Operation Full Stop, a project was begun in the FQ to apply area-wide management to suppress the FST population, thereby potentially limiting future damages. To measure the impact of the area-wide program, alate traps (sticky cards), suspended under street lamps at or near every intersection were used to determine the level of alate activity during the swarm season. An inspection program of structures was initiated in 2003 to determine the percentages of properties with active infestations and to reveal their location for additional treatment.

Since 2006 there has been a 44% to 76% reduction in the number of alates captured, depending on the neighborhood and how recently it was entered into the program. The inspection program has revealed lingering infestations in some structurally complex facilities. These infestations are problematic for successful area-wide suppression of FST in the FQ. Thus, finding and treating these persistent structural infestations and those in open spaces such as the adjacent levee are necessary for further reduction of FST.

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INTERACTIONS OF THE FORMOSAN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE) WITH A BROWN ROT AND A WHITE ROT FUNGUS

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Lignocellulose is the major component of plant cell walls. The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, uses cellulases secreted from salivary glands and symbiotic flagellates to digest cellulose. Lignin is a physical barrier to cellulases. Wood rot fungi may facilitate the digestion of cellulose by Formosan subterranean termites by modifying or degrading hemicellulose and lignin. Brown rot fungi circumvent the lignin barrier and metabolize cellulose and hemicellulose without removing the lignin. Therefore, lignin remains the major component of plant cell walls degraded by brown rot fungi. However, brown rot fungi modify the lignin by demethylation and oxidation. In contrast, white rot fungi simultaneously degrade the three major components of the plant cell wall: lignin, cellulose, and hemicellulose.

In previous research, *C. formosanus* has shown a significant preference for sawdust inoculated with both the brown rot fungus, *Gloeophyllum trabeum* (Persoon: Fries) Murrill, and the white rot fungus, *Phanerochaete chrysosporium* Burdsall, over control sawdust, but termites strongly preferred sawdust inoculated with *P. chrysosporium* over sawdust inoculated with *G. trabeum*. The interaction of *C. formosanus* with these two fungal species was examined further in order to determine how decay rates influence termite behavior and to identify the optimal condition of sawdust decayed by each species for eliciting termite aggregation behavior.

ALTRISSET™: NEW TERMITICIDE WITH NOVEL MODE OF ACTION AND ENVIRONMENTALLY-FAVORABLE PROFILE

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Abstract

Altriset™ (18.4% SC, chlorantraniliprole) exhibited delayed mortality in termites both in topical and limited exposure bioassays. When exposed for 30 min on sand treated at 50 ppm, worker mortalities reached 100% by day 11. Similarly, 30-min exposure to 10 and 50 ppm caused ~80% mortality only after 4 d and 3 d, respectively. Termites behaved normally (walking, grooming, etc.) for several hours after acquiring lethal doses. A tunneling study showed that it is a non-repellent compound and as little as 1 ppm on sand will stop the termites from penetrating the treated length of the sand column (8 cm). All the concentrations in tunneling assays caused 100% mortality in termites.

Introduction

Cyclodienes (chlordane, dieldrin) were used as termiticides in the 1960s and 1970s. Due to environmental concerns these termiticides were replaced by organophosphates such as chlorpyrifos in the 1980s and early 1990s. At the same time, pyrethroids were popular alternatives and are still popular in pre-construction treatments. Since the mid-1990s to the present time, baits and non-repellent termiticides proved to be much more popular alternatives because of enhanced control and relatively better environmental profiles. However, in the last 10 yr, new termiticides have not been registered in professional pest management markets, although a number of advances in insecticide discoveries have been made.

DuPont has recently discovered a new insecticide (chlorantraniliprole) which belongs to a new chemical class, anthralinic diamides (Lahm et al. 2007). It has a novel mode of action as an activator of insect ryanodine receptors. In termites, it causes delayed mortality; even after acquiring lethal doses, termites show normal movement and behavior for 6-7 h, affected termites do not feed, there is increased aggregation and grooming among workers, and death finally occurs within 7-28 d.

Chlorantraniliprole has a water solubility of ~1 ppm and an octanol water coefficient (K_{ow}) of 721 (at temp. 20°C, pH 7). It has a soil organic carbon partitioning coefficient (K_{oc}) ranging from 153 to 526 (L/g) depending on soil characteristics (<http://www.epa.gov/oppr001/factsheets/chloran.pdf>.) Therefore, it tightly binds to soil and is less likely to move in soil columns. It also has an excellent environmental profile with both acute oral and dermal toxicity of >5,000 mg/kg, making it one of the most low hazard liquid insecticides. It is the first liquid termiticide classified as “Reduced Risk” by the Environmental Protection Agency.

DuPont™ has recently registered chlorantraniliprole as a termiticide under the brand name Altriset™. This study was conducted to elucidate the intrinsic toxicity, post-exposure effects on termite workers, non-repellency and tunneling by termite workers in chlorantraniliprole-treated sand.

Materials and Methods

Termites: *Reticulitermes flavipes* were collected from the field in cardboard roll traps. Termites were carefully taken out for bioassays and were used within <14 d.

Topical Bioassays: A stock solution of chlorantraniliprole (0.1%, wt:wt) was prepared in acetone and was serially diluted (11 dilutions, 1000 – 0.781 ppm). A small amount (0.25 µL) was applied to the dorsal thorax of individual termites using a micro-syringe (Hamilton Co., Reno, NV). Controls were treated with acetone only. Termites were then transferred to a fresh petri dish (50 x 9 mm) containing a moist brown paper towel disk as a food source. Four replications per concentration and 10 termites per replication were used. Mortality of termites was recorded every day for the next 9 d.

Limited Exposure Studies: Termites were exposed for a limited time (1, 5, 10, and 30 min) to sand treated with Altriset™ (18.4% SC) at different concentrations (1, 5, 10, 25, and 50 ppm, wt:wt). Termites were exposed in groups of 150 each and then divided in 5 groups of 20 each by transferring them into petri dishes (50 x 9 mm) containing moist brown paper towel disks. Mortality was recorded for the next 21 days.

Post-Exposure Behavior: Termites were exposed (limited exposure) as described above, and at different time intervals after exposure (2–3:30 h), termites were allowed to walk over a 15 cm long line drawn on a white print paper sheet with a ball point pen (Papermate®). For each concentration (1, 5, and 10 ppm), termites from the various replications exposed for different time periods (1, 5, 10, and 30 min) were pooled together. The amount of time it took to cover a 15 cm distance was recorded.

Tunneling Assays: Termite tunneling was tested in small tubes (20 cm long x 1 cm diameter) having an untreated section of sand (4 cm) followed by a treated section (8 cm). The tubes were prepared and termites (N=20) were introduced as described in Saran and Rust 2007. Distance travelled was recorded every 24 h and mortality was recorded at the end of 7 d.

Results and Discussion

Topical Bioassays: Chlorantraniliprole was effective on termites at even very low doses of 0.29 ng/termite (LD₅₀) and 1.57 ng/termite (LD₉₅) at day 9 (Fig. 1). Dose response curves indicated a delayed mortality in termites such that even at higher doses (13–14 ng/termite), termites start dying only after 48–72 h. In most cases, 100% mortality was achieved only after 5–7 d and at low doses of <3 ng/termite mortalities were observed up to 7–14 d.

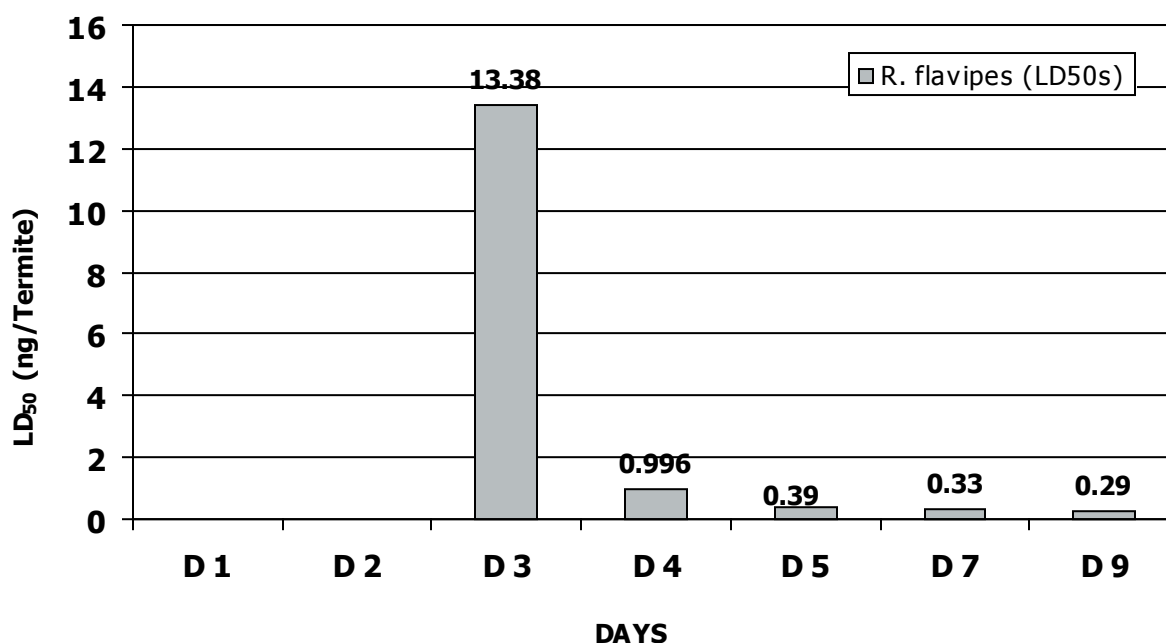


Fig. 1. Termite LD₅₀ values for different time periods after topical applications.

Limited Exposures: Delayed mortality was also exhibited in these assays. Regardless of the concentration x time (dose) to which termites were exposed, >50% mortality was achieved only after 2–3 d. Chlorantraniliprole caused only 15–20% mortality at 24 h even after 30-min exposure to 50 ppm of Altriset™-treated sand (Fig. 2). Thus, both topical and limited-exposure assays indicated that termites were not affected immediately even after acquiring lethal and sub-lethal doses.

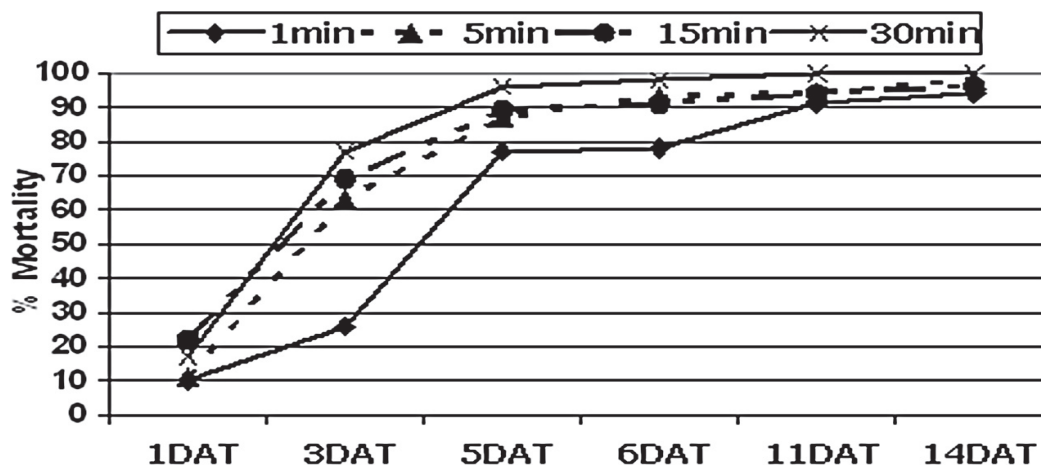


Fig. 2. Percent mortality in termites after limited exposure for different time periods to sand treated at 50 ppm Altriset™ (wt:wt).

Post-Exposure Behavior Assays: For each concentration (1, 5, 10 ppm), even at 2–3 h after exposure, termites were able to walk 15 cm within 11–13 sec, similar to control termites. However, termites' walking behavior after exposure to Altriset™ was slightly affected, as there was greater variation in walking speeds of termites exposed to treated sand (Fig. 3). Both exposure assays as well as post-exposure behavior observations support that exposed termites may very well interact with unexposed workers because the intoxication symptoms are sufficiently delayed. This may potentially lead to better and more effective horizontal transfer of sub-lethal and lethal doses among termite workers.

Tunneling Bioassays: For all the tested concentrations (1, 10, 25, 50, 75, and 100 ppm), termite tunneled in treated sand (Fig. 4). This indicates that Altriset™ is a non-repellent termiticide. Termites did tunnel for longer distance in 1 ppm treated sand (<7 cm) but termites were not able to tunnel through the entire 8 cm length of treated sand and 100% mortality was observed at day 7. At concentrations ≥ 10 ppm dependent termites tunneled <2.0 cm, regardless of the concentrations. In controls, termites tunneled through 8 cm untreated sand without any significant mortality (~10% mortality) at day 7. Thus, Altriset™ was effective and termites could not tunnel completely through a treated sand column at all the concentrations tested.

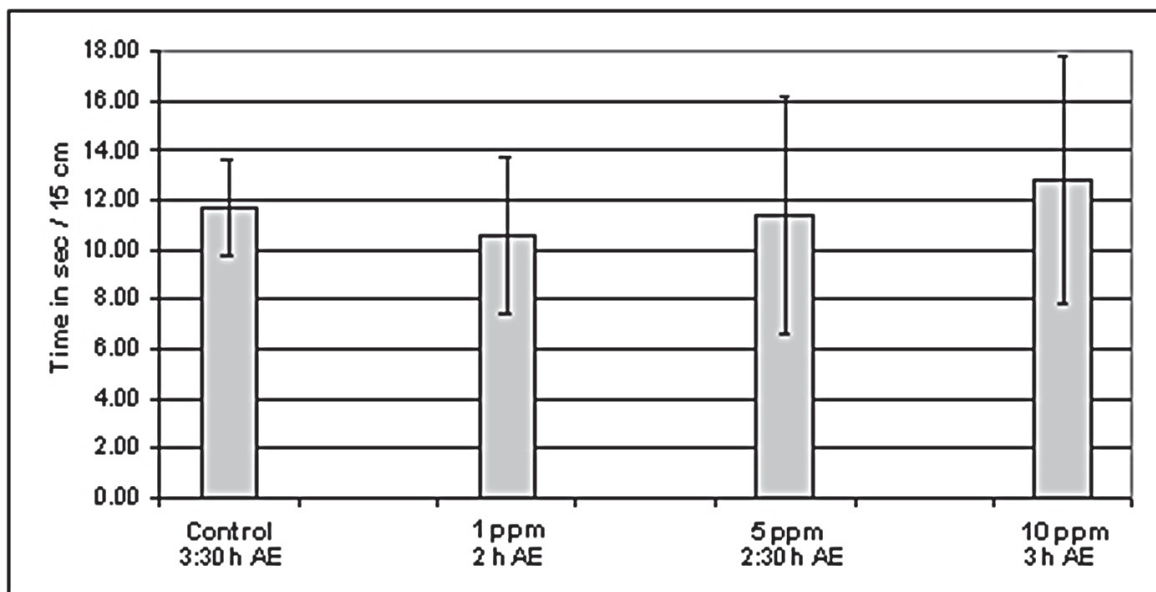


Fig. 3. Post-exposure behavior of termites: time to travel a distance of 15 cm after exposed (AE) to different concentrations of Altriset™.

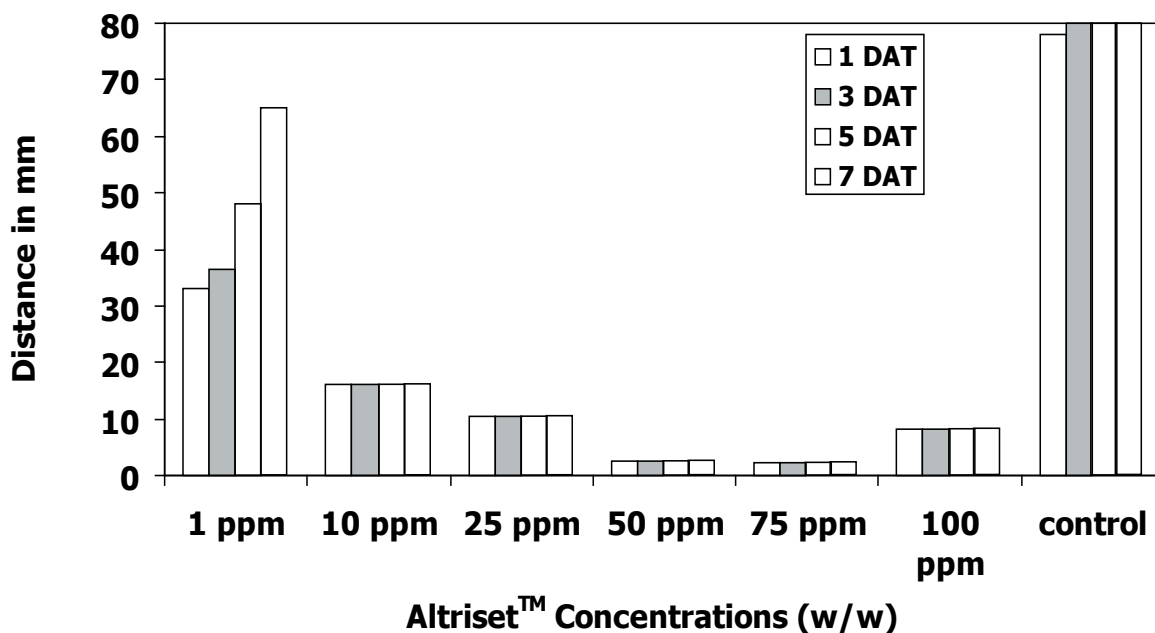


Fig. 4. Distance tunneled by termites in Altriset™-treated sand (1–100 ppm) at 1–7 days after treatment (DAT).

Conclusions

Chlorantraniliprole is a new insecticide in a new class of chemistry with novel mode of action. It clearly exhibits delayed mortality in termites, and the formulated termiticide, Altriset™ (18.4% SC), is also non-repellent causing 100% mortality in termites that tunneled in treated sand. Its delayed action and non-repellency may lead to better horizontal transfer in field situations compared to other faster acting non-repellent termiticides.

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**EVALUATION OF SMALL IMPASSE® TERMITE BARRIER PLOTS
AROUND UTILITY PENETRATIONS AND VERTICAL WALLS
AGAINST TWO SUBTERRANEAN TERMITES, *HETEROTERMES
AUREUS* AND *GNATHAMITERMES PERPLEXUS*, IN SOUTHERN
ARIZONA**

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Novel laminate polymer membranes (IMPASSE®) containing lambda cyhalothrin within an interior layer surrounded by polymer layers were established at the Santa Rita Experimental Range, south of Tucson, AZ. Fourteen concrete slabs were constructed to overlie the IMPASSE® Termite Barrier (ITB) for a period of 6 yr. Seven slabs consisted of ITB fabric seamed around utility penetrations with a single utility penetration (SUP), while another seven slabs with double utility penetrations (DUP) consisted of ITB seamed on vertical surfaces and with a “T”-fold. Evaluation portals were established within each slab to assess foraging termite activity underneath and into the slabs. Thirty termite-monitoring stations were placed adjacent to the 14 slabs to monitor termite foraging activity in the area. Monitoring stations showed evidence of occupancy by termites upon 37% of the inspections. *Gnathamitermes perplexus* (Termitidae) was identified as the most abundant termite, occurring in 68% of the inspections where termite activity was detected. Evidence of foraging by *Heterotermes aureus* (Rhinotermitidae) into a monitoring station was detected in 9% of occupied stations upon inspection. During the 23 sampling dates, the number of monitoring stations with evidence of termite occupancy ranged from a maximum of 14 to a low of 4. SUP treatment slabs scored positive for termite foraging activity in adjacent monitoring stations on an average of 41 ± 3.4 months during the inspection period (59 months). The mean number of months that there was evidence of termite occupancy in the monitoring stations adjacent to the DUP slabs was 37.2 ± 6.3 . Although the termite foraging activity around slabs differed, there was no significant difference in the mean number of months that termites occupied stations adjacent to SUP and DUP slabs. There were no hits (entry by termites into a portal anytime during the study) to any of the ITB observation portals (N=28). Six hits to the control portals (N=14) were observed. Subterranean termite foraging activity was significantly more likely to occur into control portals than observation portals covered with the ITB. The ITB sealed around utility penetrations, and the ITB sealed around vertical surfaces provided a high degree of protection against subterranean termites attack while located in areas of persistent subterranean termite foraging activity.

DECAY IN TERMITE MONITORING STATIONS

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In-ground monitoring stations and termite baits are widely used in the southern U.S. for detecting and eradicating subterranean termite activity near buildings. The usual practice is to inspect the stations for termite activity every few months. If termites are detected, a treated bait is added to the untreated monitor. Because of the labor cost associated with inspections, there is a trend to extend the time between visits and also to place the toxicant within the station from the beginning (rather than monitoring and then adding the toxicant).

Less frequent disturbance of the monitors and baits may increase the likelihood of termites attacking the systems. However, in addition to termite attack, the baits are subject to water uptake and fungal decay. There have been reports from pest control operators that rapid decay in high hazard areas is interfering with the usefulness of the monitor and bait approach and some professional pest management companies have now stopped using them due to the higher costs associated with unanticipated frequent monitor changes and additional inspections.

Su (2007) has recognized the disadvantage of regularly monitoring stations and has shown that a bait that is protected from water by being wrapped in plastic can be long-lasting and yet remain accessible to termites. Peters et al. (1994) observed that different wood species, in direct ground contact and within plastic stations, were attacked at different rates. The different wood species and shapes, and configurations of the station and monitoring/bait material, may also mean that the rate of wetting, and the fungal susceptibility, of the material could vary among the systems. Finally, additives to, or treatments of, the material could affect the decay risk.

This study was initiated to investigate the fungal susceptibility of a variety of commercially-available monitoring stations and to test alternative systems that attempt to increase the fungal durability of the monitoring material and/or bait.

Materials and Methods

Preliminary Testing of Commercial Bait Stations. Several commercially-available termite monitoring systems were installed in a forested area near a lake in Knoxville, TN. This was done as part of a collaborative work program between the University of Tennessee (UT) and Laboratorio Nacional de Engenharia Civil (LNEC), Lisbon, Portugal, and not for the intention of this project. However, the unused systems still out in the field were then collected after approximately 18 mo of exposure and assessed as part of this study. Systems assessed were: Halo[®] Electronic Termite Detection

(available commercially from Dow AgroSciences), Advance® (formally available commercially from Whitmire-Microgen, now BASF) and Termitrol® (formally available commercially from Whitmire-Microgen, now BASF).

A number of commercially-available termite monitoring stations were put in test in Knoxville (average annual precipitation 122 cm) and in Lisbon, Portugal (average annual precipitation 71 cm) to monitor moisture content dynamics as well as fungal and termite activity. Five replicates of each station were applied around buildings in Knoxville and in Lisbon. A station modified to include a rubberwood (*Hevea brasiliensis*) bait with and without borate treatment was also included in this test. The systems included:

1. Prescription Treatment® Advance™, Whitmire Micro-Gen Research Laboratories, Inc. (now BASF): a plastic cage that contains both a set of aspen (*Populus* spp.) wood pieces and cellulose material in a plastic holder;
2. Prescription Treatment® 701, Whitmire Micro-Gen Research Laboratories, Inc. (now BASF): a plastic cage containing a solid piece of pine (*Pinus* spp.) wood within a 'toilet paper' cardboard tube (tested in Knoxville only);
3. Spectracide Terminate®, Spectrum Brands: corrugated cardboard and string attached to a spring-loaded activity indicator within a plastic cage;
4. Hex-Pro™, Dow AgroSciences LLC: two pieces of aspen (*Populus* spp.) wood on a plastic hanger within a plastic cage (tested in Knoxville only);
5. A piece of untreated Southern pine (*Pinus* spp.) wood was placed in direct soil contact as a control; and
6. Untreated rubberwood blocks held within an empty Advance™ cage.

Results and Discussion

Decay in Field-Exposed Stations. After 18 mo of exposure, all of the monitoring stations showed significant fungal decay but very little (one possible case) evidence of termite attack (Fig. 1). This is despite the appearance of much termite activity in the fallen woody debris at the site.

Moisture Content of Monitoring Materials in Commercial Termite Stations. The moisture content of the monitoring materials increased rapidly in all the systems tested, albeit at different rates (Fig. 2). Many of the stations contained materials with moisture contents above fiber saturation after 1-wk exposure in Knoxville, and fungal activity was observed in some stations after 2 wk, even at the very low ambient temperatures during that time (2°C average, 3 mm precipitation). Moisture content was measured based on the weight of the whole piece, which in some cases was quite large. Thus it is likely in some cases that the moisture content was not uniform across the entire cross section.



Fig. 1. Fungal decay but no termite activity in commercial termite monitoring stations exposed in Knoxville, TN. From left to right: Halo®; Advance® with cellulose monitor at top and wood below; and Termitrol®.

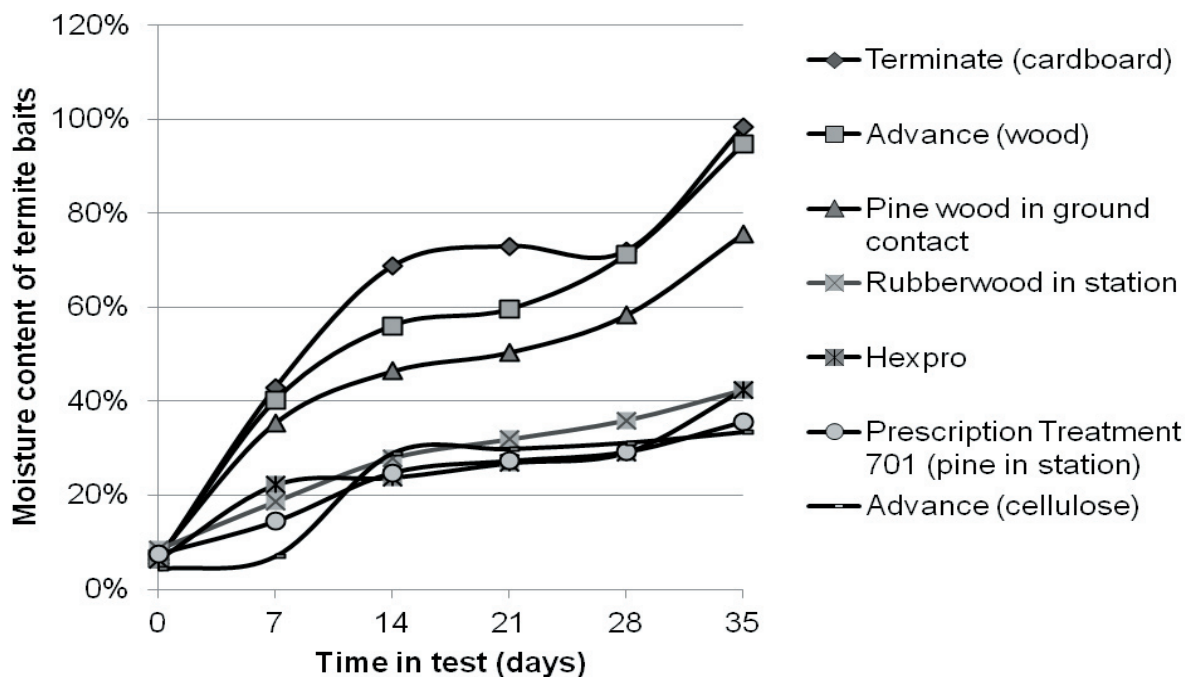


Fig. 2. Moisture content over time of monitors in termite stations in Knoxville, TN.

Conclusions

While rapid wetting occurred in all the stations tested, there were distinct differences. The monitors in the Terminate® and Advance® systems increased in moisture content at least as quickly as pine wood in direct ground contact. The cage surrounding the monitor in other systems appeared to reduce the rate of wetting (i.e., the Prescription® 701 and HexPro® systems). Because decay can occur in all the monitoring materials

tested, differences in the rate of wetting for the different systems may affect their longevity in application.

An interesting question for future study is the possible interaction of fungal activity and termite attack in these commercial systems. A monitoring system that allows some fungal activity may be preferred because decay can be attractive to termites (Cornelius et al. 2002, Cornelius et al. 2004, Su 2005). However, fungal activity can also be repellent to termites (Grace et al. 1992, Su and Scheffrahn 1998), so the species and extent of fungal activity that occurs within commercial termite stations could have important practical implications.

Acknowledgements

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REFINING UNDERSTANDING OF THE TRAIL-FOLLOWING STRATEGIES OF TERMITES

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Reticulitermes workers have a trail-laying and trail-following behavior when foraging. Individual workers employ dotted pheromone trails laid with the secretion of their abdominal sternal gland for orientation while walking. After discovery of contact with a food source, they lay a recruitment trail on their way back to the nest to direct nest-mates to the food. Therefore, the ability to detect and follow the odor trail is of importance to termites. Antennae play a key role in trail pheromone perception. Although termite trail communication has been studied for decades, detailed knowledge is only fragmentary. Evidence has indicated that the cost-benefit relations affect many aspects of behaviors of animals. To maximize their fitness, termites may lay and detect trail of pheromone plume marked at an optimal/maximum gap. This study characterized behavior reactions and strategies of *Reticulitermes flavipes* (Kollar) workers to navigate along different patterns of artificial trails drawn by a ballpoint pen ink containing 2-phenoxyethanol. In general, workers walked faster following continuous trails than trails intercepted by gaps. Walking speeds were higher in termites following dotted trails than dashed trails. Of the trails intercepted by gaps, termites significantly slowed their walking speed on trails intercepted by gaps longer than the sum of body and antenna. Workers were able to run along one side of the trail but at a significantly slow speed when one antenna was amputated. The ability to follow a trail ceased with antennal amputation or cross-over. Workers displayed a similar navigation strategy to moths in chemical orientation. With antennae moving constantly side-to-side and up-and-down, workers made prominent klinotaxis (casting patterns) in trail following by probing the trail at intervals and repeated correct orientation towards the center of the trail where the highest chemical concentration occurs. The bigger the gaps, the wider the casting range. These results corroborate the observation made by Reinhard and Kaib (2001) that workers lay dotted foraging trails by dabbing their abdomen at intervals.

PREDICTING THE LIKELIHOOD OF TREATMENT FOR SUBTERRANEAN TERMITES (*RETICULITERMES* SPP.) IN MISSOURI NEIGHBORHOODS

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The state of Missouri is located at intermediate latitudes in North America and the climate varies along a northwest to southeast gradient, with a cooler, drier climate in the northwest and a warmer, more humid climate in the southeast. Structural infestations of *Reticulitermes* spp. are common throughout the state, but pre-treatment of structures is not required by law so relatively few are normally performed. Little is known about the earliest ages when homes begin to be treated in Missouri or about the rates of treatment within neighborhoods as they age.

Various environmental variables and features within urban landscapes and neighborhoods may be associated with rates of treatment for subterranean termites. These variables include things such as home age, foundation type, appraised value, and adjacent land uses. The association between these landscape variables and treatment frequency within neighborhoods of Missouri is not understood. It is possible that a predictive model of expected subterranean termite treatment frequency based on urban landscape features would be beneficial to homeowners, realtors, and pest management companies when making decisions regarding subterranean termite treatments in Missouri neighborhoods.

The objectives of this study were to determine:

1. At what age do homes within neighborhoods begin to be treated for infestations of subterranean termites (*Reticulitermes* spp.)?
2. What proportion of homes within neighborhoods are treated as they age?
3. Does the proportion of homes treated at different ages differ according to construction type?
4. Which urban landscape features are spatially associated with variation in subterranean termite treatment frequency?
5. Can we create a spatial model that predicts the likelihood of treatment within a neighborhood based on urban landscape features?

Materials and Methods

A grid of 1 km x 1 km squares was overlaid on a map of the city of Columbia, MO. Neighborhoods within each grid square having homes of varying ages and construction types were selected for sampling. In the field, individual homes were randomly selected within each neighborhood by rolling dice to determine the number of homes to count before sampling and by alternating sides of the street after each sample. The direction to turn at intersections was determined by previous rolls of the dice. A total of 30-40 homes were sampled from each neighborhood.

Randomly selected homes were examined carefully for evidence of treatment for subterranean termites. Drill marks in porches, patios, driveways, and other adjoining slabs, as well as the presence of termite bait stations and information from homeowners were used as indicators of treatment. Treated homes were given a score of 1 and untreated homes a score of 0. In addition, urban landscape variables such as construction type (slab, basement, split level), and adjacent land use (forest, field, other backyard) were recorded along with the GPS coordinates of the home. The Boone County assessor's website was used to obtain the ages and appraised values for each home sampled in the field. A total of 409 homes were randomly sampled in May and June of 2008.

To examine the proportion of all homes treated at different ages, homes were categorized into five age classes (1-10, 11-20, 21-30, 31-40, and 41-60) and the proportions treated in each age class were plotted. The proportions of slab and basement homes treated in each age category were also plotted and compared using a Z-test ($\alpha=0.05$). The association of urban landscape variables with treatment proportions was examined by regressing the proportion of homes treated in each neighborhood against mean home age, mean appraised value, proportion slab, proportion basement, proportion adjacent to forests/fields/yards for the same neighborhoods.

Spatial models to predict treatment based on home age were developed for individual neighborhoods. These models require continuous data rather than categorical data (i.e., treated/untreated). Treated/untreated values (1/0) for each home were converted to treatment likelihood values using a moving window that included the home of interest and its three nearest sampled homes. Treatment likelihood represents the proportion of treated homes within each moving window. Treatment likelihood values ranged from zero (none of the four homes treated) to one (all four homes treated). Intermediate values included .25 (one of four treated), .50 (two of four treated), and .75 (three of four treated).

Cross-variate regression defined the relationship between treatment likelihood and home age. Semivariograms were computed to identify the range of spatial dependence between these variables. Kriging used the range of spatial dependence to compute intermediate values for treatment likelihood across the entire neighborhood and created a kriged surface contour map of treatment likelihood which was overlaid onto images of the neighborhood. The spatial model was tested by exhaustively sampling all homes in a neighborhood for evidence of treatment. The total number of treated homes and their locations in the neighborhood were recorded. The proportion of treated homes within each kriged surface contour zone of the spatial model were calculated and regressed ($\alpha = 0.05$) against the predicted treatment likelihood for each contour zone to evaluate the relationship between model prediction and actual values. Results of spatial modeling are reported only for the Valleyview neighborhood.

Results

The proportion of homes treated in each neighborhood ranged from 0.20 to 0.84. The proportion of treated homes in each age class for all neighborhoods increased with age and ranged from 0.0 to 0.74 (Fig. 1). Approximately 0.20 of homes were treated by age 20, 0.45 by age 30, 0.72 by age 40, and 0.75 by age 60. Regression analysis revealed that the proportion of homes treated in each neighborhood was significantly correlated with mean home age in the neighborhood ($p < 0.001$) and the proportion of homes adjacent to forest ($p = 0.033$) (Fig. 2).

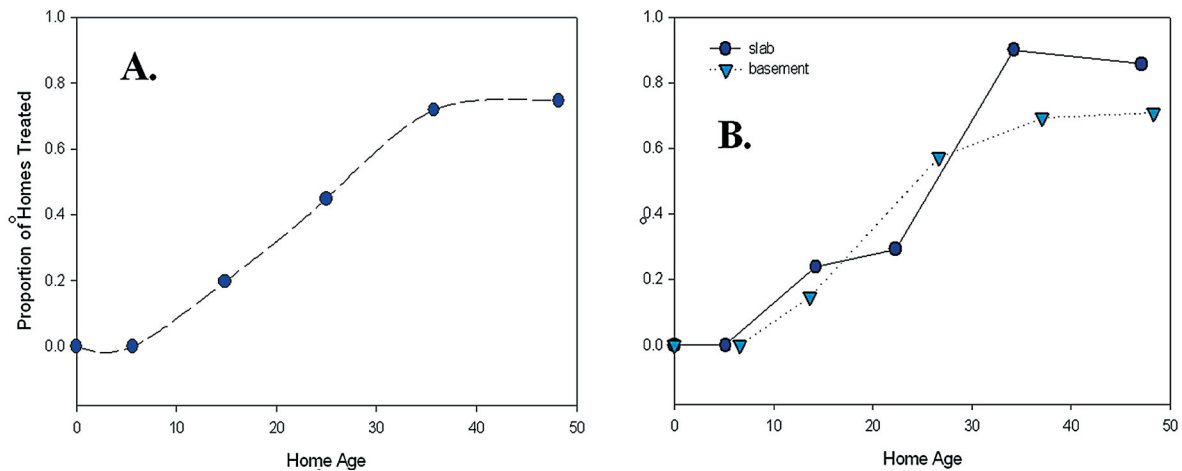


Fig. 1. Plots showing the proportion of homes ($n = 409$) treated for *Reticulitermes* spp. according to age class for neighborhoods in Columbia, MO. Each dot represents the mean age of homes and the proportion of homes treated within the age class. A.) All homes combined; B.) slab versus basement homes.

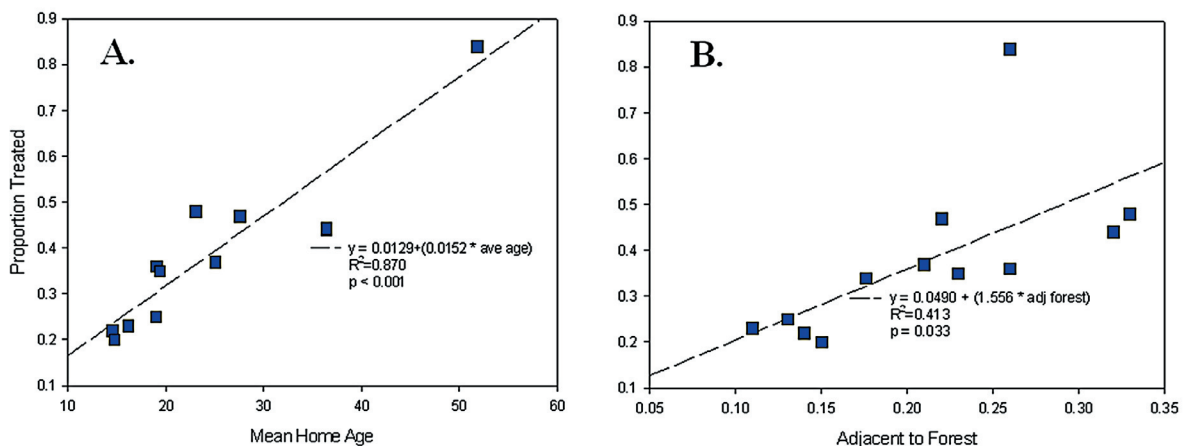


Fig. 2. Regression plots showing the relationship of A.) mean age of homes; and B.) percent of homes adjacent to forest patches to the proportion of homes treated for *Reticulitermes* spp. in neighborhoods in Columbia, MO.

Semivariograms revealed that the range of spatial dependence between treatment likelihood and home age in the Valleyview neighborhood was 1,018 m. The model predicted treatment likelihood values between 0.07 and 0.96 for the Valleyview neighborhood (Fig. 3). Actual treatment values ranged between 0.10 and 0.73. Predicted likelihood and actual treatment values within each kriged surface contour zone were significantly correlated with one another ($p < 0.001$) (Fig. 4).

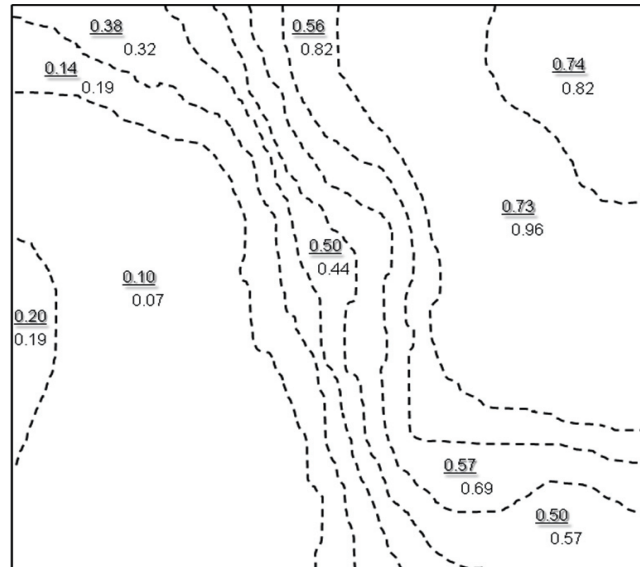


Fig. 3. Kriged surface contour map of predicted treatment likelihood values across the Valleyview neighborhood after randomly sampling 30-40 homes. Underlined values show the proportion of homes actually treated within each contour area following exhaustive sampling.

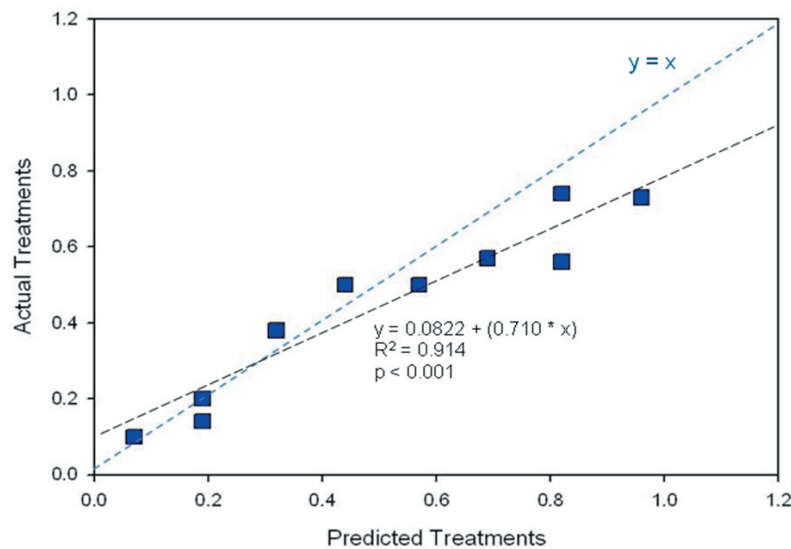


Fig. 4. Regression plot showing the relationship between predicted and actual proportion treated within each kriged surface contour area of the Valleyview neighborhood.

Conclusions

There is a low frequency of treatment in homes less than 10 years of age in Columbia, MO. Although about 20% of homes are treated before the homes reach 20 years of age, the largest increase in the number of treated homes occurs between 30 and 40 years of age, when an increase of 27% occurred over the previous age class. Basement homes apparently had a higher rate of treatment than slabs, but this difference was not significantly different.

Home age and adjacency to forested patches within the urban landscape are the best predictors of treatment frequency for neighborhoods in Columbia, MO. As the time since construction increases, *Reticulitermes* spp. colonies and populations become established throughout neighborhoods and locate a larger proportion of homes. Forest patches represent remnant patches of undisturbed land within urban landscapes. These remnant patches apparently play a role in *Reticulitermes* spp. invasion into neighborhoods. The importance of forested patches within urban landscapes is being examined further to understand *Reticulitermes* spp. invasion dynamics.

Kriging was an effective method for predicting treatment likelihood across entire neighborhoods based on random sampling of a few homes. However, this method slightly overestimated treatment likelihood for areas of the neighborhood where treatment was highest and slightly underestimated treatment likelihood in areas where actual treatment was low.

INNOVATION HISTORY OF THE SENTRICON® TERMITE COLONY ELIMINATION SYSTEM

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Termites cause an estimated \$2.5 billion in property damage and repair costs annually (Mannes 2005). In 1995, Dow AgroSciences launched the Sentricon® *Termite Colony Elimination System*, the world's first termite baiting system as an alternative to liquid termiticide soil treatments. Initially sold in the U.S., the product was subsequently marketed globally for termite control. Termites were historically controlled through the use of high volumes of persistent liquid insecticides applied to soil under and around structures. The introduction of Sentricon® revolutionized termite control by providing a more environmentally-friendly termite control alternative based on the integrated pest management principles of monitoring and baiting. The Sentricon® *Termite Colony Elimination System* is already the leading termite baiting system, with more than 2 million structures treated. The active ingredient in the Sentricon® system is a chitin-

synthesis inhibitor with low mammalian toxicity. The method of application significantly reduced the amount of active ingredient in the environment (>1000 fold) and minimized labor and property disruption compared to the traditional liquid treatments for termite control.

How the Sentricon® Termite Colony Elimination System Works. The Sentricon® termite baiting system functions in the following manner: termite stations are installed in the soil around a termite-infested structure as specified in the labeling at approximately 10-20 ft intervals. Upon initial insertion into the ground, the termite station typically contains an untreated wooden monitoring device. These monitoring devices are inspected every 60-90 d for termite presence. After the indication of termite feeding is observed on untreated wooden monitoring devices, the cap of the hard plastic termite station is removed and the wooden monitoring devices are replaced with a bait cartridge containing a cellulose-based bait matrix formed into briquettes containing 0.5% hexaflumuron or 0.5% noviflumuron.

Each bait cartridge is encased in plastic shrink-wrap packaging that protects the bait matrix during preparation for use of the bait. At the time of installation of the bait cartridge, up to 80 ml of water or sports drink may be added to the bait cartridge and allowed to soak into the cellulose-based bait matrix briquettes. Once all the liquid has been absorbed, the cap is replaced onto the bait cartridge, the plastic shrink-wrap is removed, and the bait cartridge is placed into the in-ground termite station with the top cap of the termite station locked into place. The bait cartridge is inspected every 60-90 days and is replaced as needed until the termite colony has been eliminated. Once the termite colony is eliminated, the system is converted back to wooden monitoring devices and the cycle is repeated thus providing monitoring and control of termites for as long as the system is in place and serviced. Termite stations can be either installed in the soil (in-ground) or attached to the structure (above-ground). The above-ground system delivers bait immediately upon installation and does not have a wood monitor phase.

Rationale for Continuous Innovation in the Sentricon® System. The Sentricon® system business model has always relied on continuous innovation. Since the inaugural launch, Dow AgroSciences has made numerous enhancements to the system, some jointly with cooperators and some solely proprietary. Continuous innovation is critical for maintaining market leadership and intellectual property protection, and for staying competitive in the face of generic liquid termiticides. A multi-generation plan was developed to define product attributes and drive innovation toward an ideal state. Research on the Sentricon® system was conducted to optimize system performance, resolve issues, minimize component costs, reduce labor expense, and best meet customer expectations. Significant innovation has enhanced above-ground and in-ground termite stations, wooden monitoring devices, bait active ingredients, and bait matrix. The innovation history of the Sentricon® system and the evolution of various system components will be reviewed.

Evolution of the Sentricon® In-Ground Station. Initial proof of concept work in the early 1990s with an in-ground station involved a plastic test tube perforated with holes and filled with wood flour bait. The tubes were placed in the soil in termite-infested areas to determine if termites would find the wood source and determine whether termite monitoring was possible using this approach. This crude prototype validated that termites could be intercepted and monitored via in-ground stations. Later, a perforated square metal tube was used as a more rigid device for insertion into a hole augered into the soil. This design also had a square insulated soil cover to produce a thermal shadow on the soil surface. At the time, scientific literature implied termites were attracted to cellulose associated with thermal shadows. Shortly thereafter, the in-ground portion of the termite station moved to a molded plastic cylinder having open slots along the sides for termite entry. The soil cover was also made of plastic but now took the shape of a circle. The plastic station incorporated a unique locking top cap that was opened by a special key to ensure child resistant properties. Later, an experimental wooden dowel type station was explored which was to be hammered into the ground. There was also some work on an experimental horizontal station. These alternatives were abandoned. From 1994-2004 the plastic in-ground station was optimized with various fins and tags along the side to minimize heaving out of the soil during freeze-thaw conditions. The ready-to-install termite station was launched in 1994. This station had the soil cover molded onto the in-ground soil cylinder thereby saving assembly time for users.

In 1996, Dow AgroSciences in Japan launched a special termite station to minimize disturbance upon inspection and avoid station abandonment. This station used two cylindrical blocks of wood as monitors. When inspected for termites only the top block was removed, avoiding disruption of the termites in the lower block of wood. A bait canister was then substituted into the top half of the station. Europe launched bucket traps as the mechanism to intercept termites in the ground in 1997. A large wooden block was placed into each bucket trap for detection of termites. When termites were found on the wood, bait was then placed onto the wood.

Evolution of the Sentricon® Above-Ground Station. Development of the above-ground termite station was pursued for use in situations where installation of the in-ground system was difficult and as a means to immediately deliver toxic bait to the termite colony. Early proof-of-concept work was done with a crude prototype involving a small plastic electrical box containing a wood block or two cartridges of wadded paper. This system validated that interception of termites above ground was feasible when the box was attached over mud tubes or termite damage. In 1996, a larger square plastic box was developed. This box contained a pad of paper impregnated with 0.5% hexaflumuron. In 1997, the above-ground station was redesigned as a plastic rectangular box with snap out tabs for placement over mud tubes. This station contained laminated textured cellulose (LTC) paper rolls and carried either 0.5% hexaflumuron or 0.5% noviflumuron. In 2005, the same station also accommodated the preferred textured cellulose (PTC) briquetted bait matrix contained in a plastic bag. Both LTC and PTC were able to be wetted with water or sport drinks.

Evolution of Sentricon® Monitoring Devices (Visual and Electronic). In 1994-1995, wood monitors in the Sentricon® system were made from Southern yellow pine and were visually inspected to detect termites. In 1997, Dow AgroSciences launched monitoring devices made from a unique species of wood found to be more palatable to termites than pine. This new wooden monitoring device was called MD-499. This was also a visually inspected system. During this time, the monitor removal device known as an extractor evolved from a simple twist tie to a nylon strap to a high tensile strength design. One extractor design was placed between two pieces of wood monitor for the visually inspected device and another design wrapped around the monitors for an electronically inspected system. In 1996, Dow AgroSciences and Dr. Nan-Yao Su at the University of Florida began to experiment with electronic detection of termites to minimize effort and expense associated with visual inspection. The initial prototype involved a thin foam strip containing a conductive ink trace that was tested via a circuit tester. This foam strip was sandwiched between two wooden monitoring devices and placed into an in-ground termite station. Once termites found the monitoring device they fed on the foam strip, breaking the conductive ink circuit. Once the circuit was identified as broken, the station was visually inspected to validate presence of termites and to start the baiting procedure. In 1999, the circuit-tester approach was replaced with a passive radio device connected to the foam sensor which allowed the circuit to be tested without having to make physical contact. Equipment known as an Interrogator, similar in appearance to a hand held metal detector, was used to generate energy to test the circuit. The radio unit attached to the sensor strip was called a transensor. In 2000, the foam sensor was replaced with a paper sensor to improve palatability to termites. This electronic means to detect termites was called Electronic Sensing Protection (ESP) and was commercially launched in 2001. Since then, the paper sensor was extensively redesigned to optimize in-field durability and sensitivity for detection of termites. The new paper sensor was launched in 2008. Transensor modifications included enhancements to moisture resistance to improve in-field durability and functionality. It also evolved from a two piece plastic unit sealed with an o-ring to a one piece plastic housing. The Interrogator was also modified to be more durable. The Interrogator's data collection unit received programming and design changes to increase user friendliness.

In order to capture site specific details to manage the business, Dow AgroSciences put computers in customer's offices in 1995 enabling them to graph sites, and track history of activity account by account. Several improvements were made over the years - going from a stand alone system, to a web based system, to eventually integration into standard software packages offered by industry service providers. Dow AgroSciences leveraged the electronic sensor approach into a new termite detection system known as Halo® Electronic Termite Detection. This detector was based on the same principles of a paper sensor strip with a conductive ink trace sandwiched between two pieces of wood in an in-ground station. The system did not have a transensor, however; the conductive ink trace on the paper sensor was attached directly to rubber contacts extending out from the top cap of the station. These rubber contacts were tested via a handheld indicator which functioned as a circuit tester. Since this detector did not

use a transensor or Interrogator, it was a less expensive electronic approach. It was offered to the pest control industry in 2007.

Evolution of Sentricon® Termite Bait Matrixes and Active Ingredients (AIs).

Recruit®, the termite bait matrix with toxic AI, is the core of the Sentricon® system. The toxic bait is the means by which the active ingredient is taken into the colony where it is shared among colony members. Termites that have fed on Recruit® bait die during the molting process. As the worker population is reduced the termite colony is no longer able to sustain itself and is eliminated. In nature, termites consume cellulose in wood so termite bait matrixes are cellulose based. In 1995, Dow AgroSciences used wood flour bait impregnated with 0.1% hexaflumuron to validate that toxic baiting could affect termite colonies and provide structural protection. Use of this prototype bait resulted in detrimental colony effects. In 1996, the system moved from wood flour to a paper roll called laminated textured cellulose (LTC). This bait matrix contained 0.5% hexaflumuron as the active ingredient. This paper roll was highly palatable to termites and was wettable with water or sport drinks. The paper roll originally contained 20 grams of cellulose which was later increased to 35 grams of cellulose by winding the paper tighter on the roll. In 2003, another active ingredient called noviflumuron was launched in addition to hexaflumuron. Noviflumuron was an improved active ingredient developed specifically for the Sentricon® system. It provided quicker colony elimination with less bait consumed. In 2005, a new bait matrix made from briquetted purified cellulose known as preferred textured cellulose, or PTC, was launched. This new bait matrix was first developed with 0.5% noviflumuron which was followed later with 0.5% hexaflumuron. This new matrix was even more palatable to termites than the LTC matrix and extended in-ground durability from 30 days out to 60-90 days. This enhanced durability enabled label changes extending the service interval from 30 days to 90 days which saved significant expense for customers.

Even though enhancements to the bait matrixes successfully extended the service interval to 90 days, a commercial need still existed to extend the service interval even further. This need was driven by the declining price of soil applied liquid termiticides and the subsequent reduced cost of competitive termite control options. In order to offer a termite baiting system to compete against these low cost options, a termite baiting system with a 12 month service interval was needed. A new long-term durable bait that could be serviced yearly was identified as a product goal for Dow AgroSciences R&D. Development efforts resulted in Recruit® HD and Always Active Technology. Employing the latest technology of extrusion and manufactured wood science, cellulose based toxic bait was combined with a polymer to produce a termite-palatable, durable toxic bait that could be serviced on a yearly interval. The new bait incorporated the toxicant and protected it from environmental degradation. The development of this new highly palatable, long term durable bait for termites presented another revolutionary concept for the termite control industry. Federal registration was received from US EPA in Sept., 2009. Concurrent monitoring and baiting from the time of system installation yields a baiting system that is always active (i.e. delivers toxicant to control termites as soon as they find the bait). Recruit® HD is an innovation in the Sentricon® System

that is expected to improve the adoption of a reduced-exposure technology in an economics-driven environment.

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RECRUIT® HD, A NEW TERMITE BAIT: LABORATORY PERFORMANCE CHARACTERIZATION

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Laboratory studies were conducted to characterize the performance of the Recruit® HD bait matrix containing 0.5% noviflumuron versus key U.S. termite species including *Reticulitermes flavipes* (Kollar), *Reticulitermes virginicus* (Banks), *Reticulitermes hesperus* Banks, *Heterotermes aureus* (Snyder), and *Coptotermes formosanus* Shiraki. In no-choice tests designed to determine bait consumption and resultant termite mortality, Recruit® HD was shown to be both highly palatable and toxic as all species tested readily consumed the Recruit® HD matrix and overall mortality was similar to Recruit® IV. In addition, Recruit® HD was transferred in *R. flavipes* from bait exposed termites to non-exposed termites via trophallaxis with mortality levels similar to Recruit IV. Durability and subsequent palatability are important components of the development of a termite bait matrix designed for long term use. Blank Recruit® HD bait that was field-aged in Florida for greater than five years was found to be highly durable yet still palatable to *R. flavipes*. In no-choice and choice tests, *R. flavipes* consumed the aged Recruit® HD greater than fresh Recruit® HD and both aged and fresh Recruit® HD was consumed greater than southern yellow pine. Recruit® HD bait pieces exposed to white rot and brown rot fungi lost a percentage of their weight over time; however both blank and noviflumuron-containing Recruit® HD exposed to the wood rot fungi were equal to or more palatable to *R. flavipes* in comparison to non-fungal exposed. Moreover, mortality of *R. flavipes* that consumed the fungal exposed Recruit® HD containing noviflumuron was comparable to the non-fungal exposed Recruit® HD with noviflumuron.

DOES PREVIOUS FEEDING BY *RETICULITERMES* SPP. (ISOPTERA: RHINOTERMITIDAE) ON BLANK RECRUIT® HD BAIT PRECLUDE SUBSEQUENT FEEDING BY OTHER COLONIES OF THE SAME OR DIFFERENT SPECIES?

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There is some evidence of agonistic behavior based on cuticular hydrocarbons when worker termites from different colonies interact (Haverty et al. 1999, Getty et al. 2000). Little is known regarding the behavioral effects of previous termite feeding in the absence of direct contact between workers. This study attempts to explore the inter-colony and inter-species effects in the absence of direct contact between workers. Two colonies of *Reticulitermes flavipes* and one colony of *Reticulitermes virginicus* were collected from Mississippi. The distance between the *R. flavipes* colonies was approximately 140 miles so it is unlikely they are related. Blank Recruit® HD termite bait was provided to all colonies for an initial 2 weeks to establish exposure. After 2 weeks, exposed bait was placed into choice or no-choice tests. Treatments included *R. flavipes* colony A exposed blank bait placed into *R. flavipes* colony B, *R. flavipes* colony B exposed blank bait placed into *R. flavipes* colony A, *R. flavipes* colony A exposed blank bait placed back into colony A, and *R. flavipes* colony B exposed blank bait placed back into colony B. The same single species and reciprocal treatments were completed for *R. flavipes* versus *R. virginicus* colonies. Results from the *R. flavipes* no-choice experiments showed a significant difference in consumption between colony A and colony B, but no difference when the bait had been previously fed upon by another colony. *R. virginicus* had significantly less consumption than *R. flavipes* in no-choice tests, but there was no significant decrease in consumption when blank bait was previously exposed to another species. Results from the *R. flavipes* and *R. virginicus* choice tests are forthcoming and will be reported.

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PRELIMINARY FIELD EVALUATION OF RECRUIT® HD, A NEW DURABLE TERMITE BAIT

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“AlwaysActive™” baiting technology is a new concept developed by Dow AgroSciences. This concept employs highly durable bait that is always present around structures. AlwaysActive technology will allow structures to have perimeter termite protection year round through use of a new durable noviflumuron termite bait, Recruit® HD. The “Always Active” concept will maximize efficiency with longer service intervals while still maintaining green attributes of the current Sentricon® Termite Colony Elimination System. In order for a baiting system that is always active to be effective, the bait must be: readily consumed by economically important subterranean termite species, toxic to these species, durable, effective after aging, and provide structural protection via colony elimination. Recruit® HD was evaluated for performance in preliminary field studies involving hit rate, palatability, durability, and colony elimination. In field studies, termites colonized and consumed significantly more Recruit® HD when compared to wooden monitoring devices. Recruit® HD that had been aged in the field for a period of 5 years was consumed in the laboratory by termites at a rate greater than or equal to fresh Recruit® HD bait or wooden monitoring devices. Initial studies using Recruit® HD eliminated 12 out of 13 termite colonies within 112 to 343 days, with bait consumption ranging from 0.8g to 240g. Based on these results, Dow AgroSciences initiated field trials to validate structural protection with Recruit® HD in the Sentricon® Termite Colony Elimination System using AlwaysActive™ technology.

**FIELD VALIDATION OF SUBTERRANEAN TERMITE
(ISOPTERA: RHINOTERMITIDAE) CONTROL WITH RECRUIT® HD,
A NEW TERMITE BAIT**

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One hundred trials (trial sites) were completed in 2007-2009 under a protocol approved by the Termiticide Scientific Review Panel. The protocol was designed to evaluate the performance of Recruit® HD durable bait for control of subterranean termites in the United States, as a requirement for registration. Monitoring stations were installed at test structures according to label directions for Recruit IV termite bait. A similar number of additional stations were installed between the monitoring stations. Recruit® HD bait, containing 0.5% noviflumuron and weighing about 150 grams, was installed into each of these additional stations. Although stations were monitored quarterly in this study for data collection purposes, Recruit® HD baits were only replenished after one year of baiting and if the bait was depleted by more than one third. Recruit® HD baits hit by termites are expected to be monitored and replenished as necessary at intervals up to about 1 year enabling an annual service and monitoring concept for commercial use.

Termites were eliminated at all of these structures. Elimination of structural infestation or termite activity within 1 yr or less was achieved in 94.0% of these structures. Structures in which the 1 yr time period for termite elimination was exceeded were usually a result of structural inspections not being conducted in time. These results surpass the 85% successful elimination rate set forth by the protocol, thereby exceeding the efficacy standard established for registration consideration. The percentage of installed baits that were consumed by termites prior to elimination was 33.3% or less in all cases, leaving 66.7% or more of the total bait installed still available after elimination.

SUBMITTED PAPERS

ANTS

A SURVEY OF THE ANTS OF WASHINGTON AND SURROUNDING AREAS IN IDAHO AND OREGON FOCUSING ON DISTURBED SITES

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Ants were collected in disturbed habitats at 58 sites in 54 counties of Washington, Idaho, and Oregon in order to determine the diversity of species and incidence of structural pests. Three collection methods were used: Winkler extraction, baiting along transects, and point sampling. Several characteristics of each site were also noted: latitude, longitude, elevation, surrounding vegetation, percent ground cover, ground cover height, soil type, air temperature, humidity, and time of day. A total of 41 ant species were collected of which three (*Lasius pallitarsis*, *Tetramorium caespitum*, and *Formica* spp. [*fusca* group]) were found at a majority of the sites. Two of these species, the moisture ant, *L. pallitarsis*, and pavement ant, *T. caespitum*, are common structural pests while *Formica* spp. only occasionally infest structures. An average of 5.79 species was found per site. A multivariate analysis was conducted comparing the site characteristics with the species found at each location, but there were no significant correlations. These findings are compared with a previous survey of ants in Washington that was conducted by Smith (1941) (Table 1).

Table 1. A comparison of the number of ant species found in the current survey with those of Smith (1941)

Subfamily	Different than Smith	Same as Smith
Dolichoderinae	2	1
Ponerinae	1	0
Formicinae	6	11
Myrmicinae	15	4

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Smith, F. 1941. A list of the ants of Washington state. Pan Pacific Entomologist 17: 23-28.

WHO'S NESTING IN MY HOUSE?

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Ant species in a survey (2007-2008) of disturbed sites in the counties of Washington state and the surrounding counties in Oregon and Idaho were compared to species at 201 infestation sites for the years 2007-2009. Identification at infestation sites was made only to genus for *Formica* and *Lasius*. The seven species of *Camponotus* were combined and the two species of *Liometopum* were combined for comparison. Fig. 1 shows the differences of all ant groups in this comparison, with higher numbers at the infestation sites of only the wood destroying genera: *Camponotus* and *Liometopum*. Homeowners and extension personnel may be more concerned with these species and that therefore contributed to the higher numbers reported.

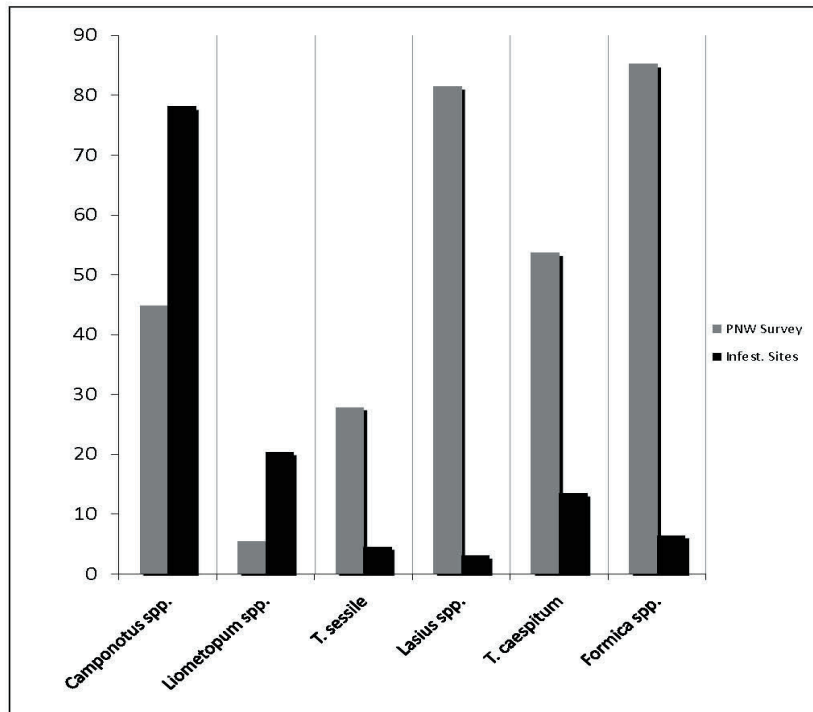


Fig. 1. Comparison of ant numbers from the Pacific Northwest survey and infestation sites.

The species survey included sampling from 56 counties while the infestation sites were recorded in only 16 counties. Comparison was restricted to the same 16 counties in the species survey to counties with reports of infestations (Fig. 2). Again, higher numbers of infestations occurred with the wood destroying ants compared to other ants.

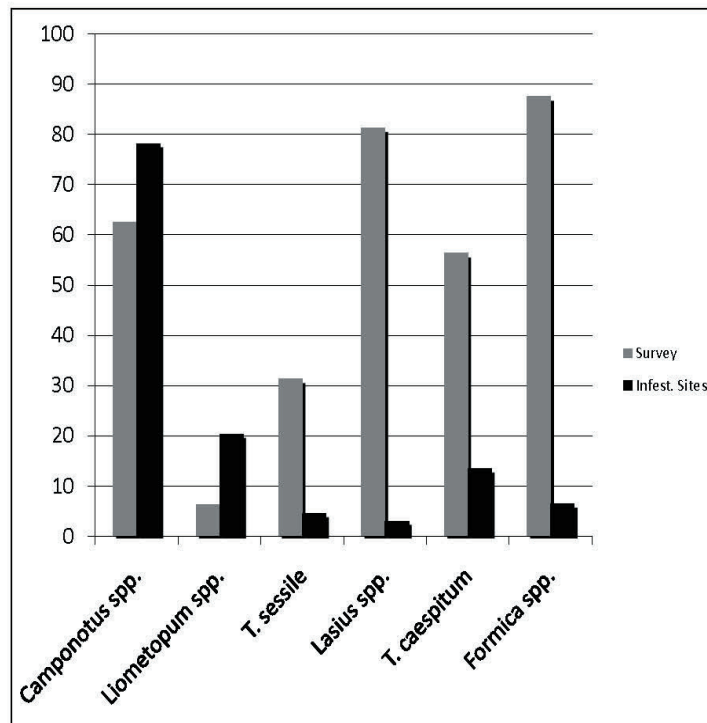


Fig. 2. Comparison of ant numbers from 16 counties: survey and infestation sites.

The higher numbers of *Camponotus* and *Liometopum* species occurring in structures compared to the species survey can be attributed to the following factors recorded at infestation sites: presence of trees near structures, decks, wooden fences, railroad ties in landscaping, vegetation near the structure, construction problems, and firewood/stumps. These factors contribute to infestations because both *Camponotus* and *Liometopum* are associated with trees or wood and both groups of ants follow structural guidelines. The most common ants found in the species survey and least common ants found at infestation sites were *Formica fusca*, *Tetramorium caespitum*, and *Lasius* spp. These ants are ground nesting and do not follow guidelines.

CRAZY ANTS' SUPERCOLONIES IN URBAN LOUISIANA

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The dawn of Raspberry crazy ants (*Nylanderia* sp. nr. *pubens*) has brought new attention to ant taxonomy and how we cope with invasive and potentially new species. Discovered in 2002 by pest management professional Tom Raspberry, these ants have cut a path across Texas and have now yield reported sightings in Louisiana. It has been recently reported in Mississippi (MacGown and Layton 2009) We discovered supercolonies of crazy ants in Port Allen, LA in September 2010. James Trager recently confirmed that those ants are *Nylanderia* sp. nr. *fulva*. Although these two populations of crazy ants are being referred to by different names, the problem of ants that form supercolonies is the same. Until the taxonomy is revised, the population in Port Allen, LA will be referred to as crazy ants that form supercolonies.

Background Information on *N. sp. nr. pubens*. This reddish-brown ant is seen in disorganized foraging trails that enter houses and trees. Legs and antennae are usually longer than the body, which is characterized with coarse hairs. These ants have a one-segmented petiole and 12-segmented antennae. They do not possess a sting but can spray formic acid. They are best identified by examining the color and number of macrochaetae.

These ants are known to be omnivorous and will feed on items such as dead insects and honeydew. Their colonies contain numerous queens, are unicolonial, and are not known to extensively excavate soil. Little is known about their natural history; however early evidence suggests that they can be compared to the Argentine ant (*Linepithema humile*), yellow crazy ant (*Anoplolepis gracillipes*), and the European garden ant (*Lasius neglectus*), which LaPolla (2010) used as an outgroup for taxonomic studies (see Table 1).

Meyers and Gold (2008a) first studied this ant and alerted researchers to the high populations that are seen throughout the invaded areas of Texas. They present anecdotal evidence that Raspberry crazy ants homogenize other ant fauna. Meyers and Gold's (2008a) morphometric analysis demonstrates differences in morphology. They put specific focus on the number of macrochaetae, which provides evidence that the ants may be different from described species of crazy ants. They offer additional evidence that this ant is a new species by noting differences in behavior (e.g., biting) from other ants such as the Caribbean crazy ant, *Nylanderia pubens*. Meyers and Gold (2008b) also tested two toxicants as baits in the laboratory. Although federal authorities are aware of the growing concern about crazy ants that form supercolonies, at this present time, no federal expansion prevention has been made (Meyers 2008; Meyers and Gold 2008a; C. Brown, pers. comm.).

Table 1. Comparisons between crazy ants that form supercolonies and European garden ant (EGA), Argentine ant (AA), yellow crazy ant (YCA), and fire ant

	Crazy ants	EGA	AA	YCA	Fire Ant
Low Temp Activity	Yes	Yes	No	No	No
Colony Structure	Unicolonial	Unicolonial	Unicolonial	Unicolonial	Monodom./ Polydom.
Mode of Distribution	Fission	Fission	Fission	Fission	Mating flight and fission
Impact on Local Fauna	Large	Large	Large	Large	Large/min.
No. Queens	Hundreds	Hundreds	Hundreds	Hundreds	Many 10s
Mating	Internidal?	Internidal	Internidal	Internidal/ flights rare	Flights
Nest Structure	Shallow/little excavation	Shallow/little excavation	Shallow/little excavation	Shallow/little excavation	Extensive

Management Plan for Crazy Ants that Form Supercolonies. Area-wide or community-wide management of fire ants and Argentine ants has been successful in Louisiana for >9 yr. The information presented here is based on modified techniques that were developed for Argentine ant management due to the ants' similar biology. These techniques have not been fully tested on crazy ants that form supercolonies. They are based on preliminary results and strong results we have from Argentine ants. Argentine ants have very similar biology and the following recommendations are the result of 5 yr of our research. The following protocol must be done with most people in the area at the same time in order to be successful. It must be stressed that the process must be repeated after 6 wk and possibly after 12 wk. This recommendation is based on the knowledge we have about the natural history of Argentine ants and other polygynous ants; they have queens that are rarely fed and are kept in reserve that will not be fed bait until the later treatments. We suggest that early April is the best time for this protocol to be implemented, but this can be done at any time. However, it will be more successful if the crazy ant populations are disrupted before they grow too large and unmanageable. If new infestations are observed and treated early enough, the crazy ants that form supercolonies may be eliminated and the ant and arthropod biodiversity can be preserved.

1) Monitoring and identification: Correct identification of the crazy ant is important. Send the ants to an expert who will identify them and send the ants to the North American experts on *Nylanderia* for verification. Once the ants have been identified as crazy ants that form supercolonies, the following integrated pest management (IPM) protocol should be followed.

2) Sanitation: Clean up the area. Remove harborage that provide nest sites such as fallen logs, children's toys, overturned boats, pots with soil, free-standing basketball nets, woodpiles, lawn tools and other items that crazy ants can nest in and under. These items also provide extra heat for rapid development of colonies, which can quickly overwhelm the area. Trim plants and trees so that they do not touch the structures. Ants can gain entry into structures from tree branches that are simply close to the roof. Crazy ants are very attracted to spaces that are moist and wood that is rotting. Rotting wood provides moisture and heat needed for colony reproduction. To prevent infestation, consider replacing rotting siding, window sills, and door frames on homes and outbuildings. Look for ground-to-wood contact around structures and find a way to eliminate this problem. The next time it rains, walk around the property and look for water that may pool or contact the wood on the structures. Eliminating water-soaked wood will help prevent ant infestation of homes and siding.

3) Disrupt the foraging into trees and structures: Using a contact insecticide in a handheld pump or backpack sprayer, apply a liquid barrier around trees approximately 2 ft up and 1 ft out at the base of the tree on which the ants are trailing and around houses or other structures that are infested. Make sure to treat all surfaces of the bark of the trees and try to treat all the trees on your property at the same time. If possible, drench with contact insecticides any nests of crazy ants seen. This will partially disrupt the nesting and foraging and allow the rest of the treatment to be successful.

4) Destroy visible nests: Using the same technique described above, use a contact insecticide to destroy any visible nests. Many of the nests are not detectable by humans, so the next step is to employ the natural behavior of the ants to do the work to suppress their own nests with baits.

5) Let them eat bait (use small particles!): This process capitalizes on the ants amazing foraging behavior to gather a palatable bait that contains a small amount of insecticide. Broadcast a granular bait in the early spring. Colleagues in Texas report that the Raspberry crazy ants are attracted to Whitmire Advance® Carpenter Ant Bait but have had limited success when only one broadcast application was conducted. It is important that you use fresh bait and apply it when the ground is dry and no rain is expected for 24 h. Broadcast bait over the entire infested area. Liquid baits can be tested for palatability and offered in bait stations. Hooper-Bùi's experience with other species of crazy ants indicates that liquid baits can be effective. Ants will usually visit liquid bait stations when they need sugars or carbohydrates and may come to them intermittently. Be sure to place the bait stations out of direct sunlight; ants will not enter a bait station that is hot.

6) Repeat after 6 weeks and again after 12 weeks. Repeating this process (items 1–5) is important as this polygynous ant species potentially has reserve queens.

Survey. In 2009, our laboratory began an extensive statewide survey to determine both potential presence of Raspberry crazy ants and which ant species were still

viable in post-hurricane areas. We sent packages containing vials, checklists, and instructions on how to collect ants for research to 65 county agents and pest management professionals. Unfortunately, this process has been very slow in that weather conditions have impeded results for the survey. Members of this laboratory still conduct opportunistic collection whenever possible. In 2010, we sent packages to pest management professionals across the state in hopes of furthering our survey. Few of these boxes have been returned.

At this present time, several unconfirmed sightings of crazy ants that form supercolonies have been reported. These areas include St. Landry Parish, Jackson Parish, Calcasieu Parish, Port Allen, Shriver, New Orleans, Johnson's Bayou, Morgan City, Slidell, the Lakeshore area, and the state of Mississippi (Joe MacGown). Extensive searching has been conducted in the city of Port Allen. Hooper-Bùi and Chen have discovered more than 14 species of ants in areas adjacent to the city's initial infestation. One population has caused particular concern in Port Allen. This large infestation includes a home, a farm, a pipeline construction area, and the parish (county) public works yard. Observations have yielded discovery of Louisiana crazy ants patterning foraging activity after EGA. The ants are active at lower temperatures (52°F) than is typical for other ants in the south. Extended freezes (>36 h) severely impacted the population but did not eliminate them.

Another major area of concern is the presence of ants in the Port Allen Department of Public Works Yard. The ant has infested sand and other materials that are routinely transported around the parish (county). It has also infested a pasture used for hay production (infested hay is shipped outside the parish), and area homes and businesses (tourist information building and truck stops). We have reported the findings to USDA-APHIS and the Louisiana Department of Agriculture and Fisheries.

Provided that funding can be secured, we can document the effects of these invasive, unicolonial ants on the natural ant fauna in natural, urban and agricultural areas. If we mobilize quickly, we have the opportunity to conduct research to quantify the ecological effect of this invasive ant species. This species will radically impact urban and agricultural systems.

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IDENTIFICATION OF TWO EXOTIC ANT SPECIES, *ODONTOMACHUS HAEMATODUS* AND *NYLANDERIA PUBENS*, IN LOUISIANA

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The ants *Odontomachus haematodus* and *Nylanderia* sp. nr. *pubens* are reported from Louisiana. *O. haematodus* is a Neotropical species with a broad distribution in South America east of the Andes. The earliest collections in the U.S. were made in 2001 from a single population found at Audubon Zoo, New Orleans, LA and from coastal marshes in LA. Excavation of the population on zoo grounds was thought to have effectively managed the potential for populations to spread into densely populated neighboring communities. However, six additional colonies were identified from this location in 2009. This species has now been collected as far east as the Florida panhandle. Also in 2009, a single sample of *N. sp. nr. pubens* was submitted to the New Orleans Mosquito and Termite Control Board lab for identification. The collection was made by a pest control operator working in the Port Allen, LA area. *N. pubens* was described from St. Vincent, Lesser Antilles and has been found on multiple West Indian islands as well as multiple locations throughout peninsular Florida. *N. pubens* is considered a pest species throughout its distribution and has proven difficult to control. A similar ant was recently introduced into the Houston, TX area. Morphological and genetic variations between this introduced ant and *N. pubens* prompted the designation of *N. sp. nr. pubens* for the Texas populations. Results of morphological and genetic analyses of the Port Allen, LA sample, described herein, indicate a likely introduction of *N. sp. nr. pubens* from Texas. Descriptions of colonies of both *O. haematodus* and *N. sp. nr. pubens* from Louisiana are discussed herein.

MECHANICAL TRANSMISSION OF *ESCHERICHIA COLI* BY RASBERRY CRAZY ANTS (*NYLANDERIA* SP. NR. *PUBENS*) IN TEXAS

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Many ant species in the U.S. and elsewhere are known to serve as vectors of bacteriological pathogens. As a result, such species can be of urban/medical importance. Recent studies in our laboratory have demonstrated that Raspberry crazy ants (*Nylanderia* sp. nr *pubens*) are capable of transmitting *Escherichia coli*. In a bio-safety level 2 laboratory, all cohorts of *N. sp. nr pubens* that were exposed to laboratory cultured *E. coli* (top 10 strain) transmitted this bacterium to novel (unexposed), sterile culture plates (LB kanamycin). The results indicated that these ants are capable of serving as vectors of *E. coli* and exhibit the potential for transferring this and other pathogens in sensitive environments. This is of particular concern as the ever-expanding range of this newly invasive species is concurrently associated with a growing record of infestations in medically-sensitive situations (hospitals, convalescent homes, etc.). The results of this work have provided the impetus to examine aspects of this phenomenon through a series of more elaborate experiments.

DEVELOPMENT OF A NEW BROAD-SPECTRUM GRANULAR BAIT FORMULATION FOR THE CONTROL OF ANTS AND OTHER INDOOR AND PERIMETER PESTS

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Baits are widely used in the pest control industry for their effectiveness and ease of application. Baits have become even more popular due to their reduced risk effect on the environment. Baits make up a significant proportion of the PMPs control strategies today and will continue to grow as more and better bait formulations are developed. Granular baits are the most popular bait for perimeter pest control; however, most granular baits were developed with a specific insect target, usually an ant, often very specific and narrow in pest spectrum. The latest innovation by Bayer Environmental Science is a broad-spectrum insect bait for indoor and outdoor use. Extensive lab and field studies conducted by PMPs and university researchers alike have demonstrated that the new bait formulation is highly attractive to 12 of the most common ant species and more than 10 species of indoor and perimeter pests, with more pest species being tested. Test results have shown better recruitment, brood and queen elimination for many ant species, and effective control for major indoor and perimeter pests.

MAXFORCE® QUANTUM: A BETTER “MOUSETRAP” FOR ANT MANAGEMENT

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Ants have historically been the most difficult groups of pests for pest management professionals (PMPs) to successfully control not only in the U.S. but also abroad. Contact insecticides applied to surfaces, particularly porous surfaces around the perimeters of structures, have typically provided good short-term knockdown of foraging workers but little to no control of the colonies. Insecticide-containing granular baits have been used with some success, but many ant species do not prefer solid baits or the bait matrix itself is unattractive to enough pest species to be unsatisfactory. Many palatable liquid and gel baits have been able to address ant feeding preferences, but the physical and chemical characteristics of these baits provide only short-term efficacy after placement due to dehydration and /or hardening of the bait. Due to these many less than optimal attributes of ant management options, we undertook a development program to design a “better mousetrap” for ant management. Maxforce® Quantum is a hygroscopic ant bait syrup proven to be palatable to and efficacious against a wide variety of insect pests. University trials conducted in major urban entomology laboratories across the U.S. were undertaken to profile the efficacy against laboratory colonies of major ant pests. These trials demonstrated successful mortality of workers, brood, and queens in many of the toughest-to-control pests, including but not limited to those in the genera *Tapinoma*, *Technomyrmex*, *Paratrechina*, and *Linepithema*. The formulation is easy to apply and is very resistant to dehydration so it therefore remains attractive to ants long after placement in the field. The product can be used indoors or outdoors and can be applied either in a bait station or directly on a suitable surface. Maxforce® Quantum has been labeled and used in Europe and around the world for some time now, but was only recently registered in the U.S.

NATIVE “INVASIVE” ANTS: A NOVEL EVOLUTIONARY TREND IN THE AGE OF GLOBAL CHANGE?

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Disturbance resulting from urbanization is a leading cause of biotic homogenization worldwide. Native species are replaced with widespread non-native species and ants are among the world’s most notorious invaders. To date, all documented cases of ant invasions involve exotic introduced species that are spread around the world by human-mediated dispersal. I investigated the effect of urbanization on the evolution

of invasive characteristics in a native ant species, the odorous house ant, *Tapinoma sessile* (Say). Colony social structure, life history traits, and the spatial pattern of nest distribution were compared by sampling *T. sessile* across a gradient of three distinct habitats: natural, semi-natural, and urban. Results demonstrate a remarkable transition in colony social and spatial structure and life history traits between natural and urban environments. In natural habitats, *T. sessile* colonies are comprised of small, monogyne (single queen), and monodomous (single nest) colonies. In invaded urban areas, *T. sessile* exhibits extreme polygyny and polydomy, forms large supercolonies, and becomes a dominant pest. Results also suggest that urban *T. sessile* colonies may have a negative impact on native ant abundance and diversity. In the natural environment *T. sessile* coexisted with a wide array of other ant species, while very few ant species were present in the urban environment invaded by *T. sessile*. Habitat degradation and urbanization can lead to extreme changes in social and spatial colony structure and life history traits in a native ant species and can promote the evolution of invasive characteristics such as polygyny, polydomy, and supercolonial colony structure.

EVALUATION OF ARILON™ FOR CONTROL OF FIELD POPULATIONS OF ARGENTINE ANTS

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Several insecticide spray treatments were evaluated for their ability to control Argentine ants under field conditions during the summer of 2009 in Griffin, GA. Four treatments and a control were applied to the outside perimeter wall and grassy areas (no inside treatments) of 46 apartment buildings (each structure was about the size of a single family home) as follows:

- *Termidor*® SC: 0.06% fipronil applied at 1.5 gallons/1,000 square feet in a continuous band around the perimeter of 12 structures; *Termidor* was applied one foot up the side of the building and one foot out on the grass and vegetation. Treatment performed 23 June 2009.
- *Talstar*®: 0.03% bifenthrin applied at 1 gallon/1,000 square feet in a 6-8 foot continuous band (up the wall and on the grass and vegetation) around the perimeter of nine structures. Treatment performed 23 June 2009.
- *Arilon*™ (low rate): 0.05% indoxacarb applied at 1 gallon/1,000 square feet in a 6-8 foot continuous band (up the wall and on the grass and vegetation) around the perimeter of seven structures. Treatment performed 25 June 2009.
- *Arilon*™ (high rate): 0.05% indoxacarb applied at 4 gallons/1,000 square feet in a 6-8 foot continuous band (up the wall and on the grass and vegetation) around the

perimeter of eight structures. Treatment performed 25 June 2009.

- *Control* buildings (n = 10) were left untreated.

Products were applied with newly purchased, unused sprayers in a fan application. Vega & Rust (2003) highlighted the difficulties associated with treatment of individual properties for Argentine ants because off-property populations so quickly re-invade treated areas. Our study design addressed this problem--structures treated with the same product were next to one another (nearest neighbors) but separated from the other treatments.

Measuring Ant Activity. Ant trailing was determined pre-treatment (16-17 June 2009) and then again at 1, 2, 3, 4, 6, and 8 wk post-treatment by visually inspecting each wall of each building for the presence or absence of an ant trail. For each treatment, the percentage of walls with ant trails was calculated according to the number of walls on which an ant trail was present divided by the total number of walls on all buildings in the treatment. For instance, given that each of the 10 buildings in the control treatment had 12 walls, or 120 walls total, and 75 of the walls had an ant trail prior to treatment, this resulted in $75 \div 120 = 62.5\%$.

On each sampling date, walls were visually inspected and scored a "0" if no ant trail was present; "1" if a low intensity trail was present; "2" if a medium intensity trail was present; or "3" if a high intensity trail was present. For each treatment, infestation intensity was calculated by dividing the sum of its scores (i.e., the sum of all scores for all the walls on all the buildings in that treatment) by the maximum potential score for all the buildings in that treatment (i.e., the number of walls in a treatment multiplied by a maximum trail score of 3 [high intensity]). For instance, for the 10 buildings in the control treatment, if each of the 120 walls scored a trail intensity of 3 (a high intensity trail), then the maximum score achievable in the control treatment would be 360, or 120×3 .

For each treatment for each week post-treatment, percent reduction in ant activity was expressed as follows: $\{\text{Sum of Scores for all Buildings in Treatment Before Treatment} - \text{Sum of Scores for all Buildings in Treatment After Treatment}\} \div \{\text{Sum of Scores for all Buildings in Treatment Before Treatment}\}$.

Results

Ant Activity Prior to Treatment. Prior to treatment, ants were active at each group of buildings. As shown in Fig. 1, prior to treatment, 71.4% of the walls among the Talstar®-treated buildings had an ant trail on them, followed by 64.6% of the walls among the Arilon™-High treatment buildings, 62.5% among the control treatment buildings, 53.6% among the Arilon™-Low treatment buildings, and 47.1% among the Termidor® treatment buildings. Even the least-infested group of buildings (Termidor®; 47.1%) had an ant trail on nearly every other wall among the buildings in the treatment.

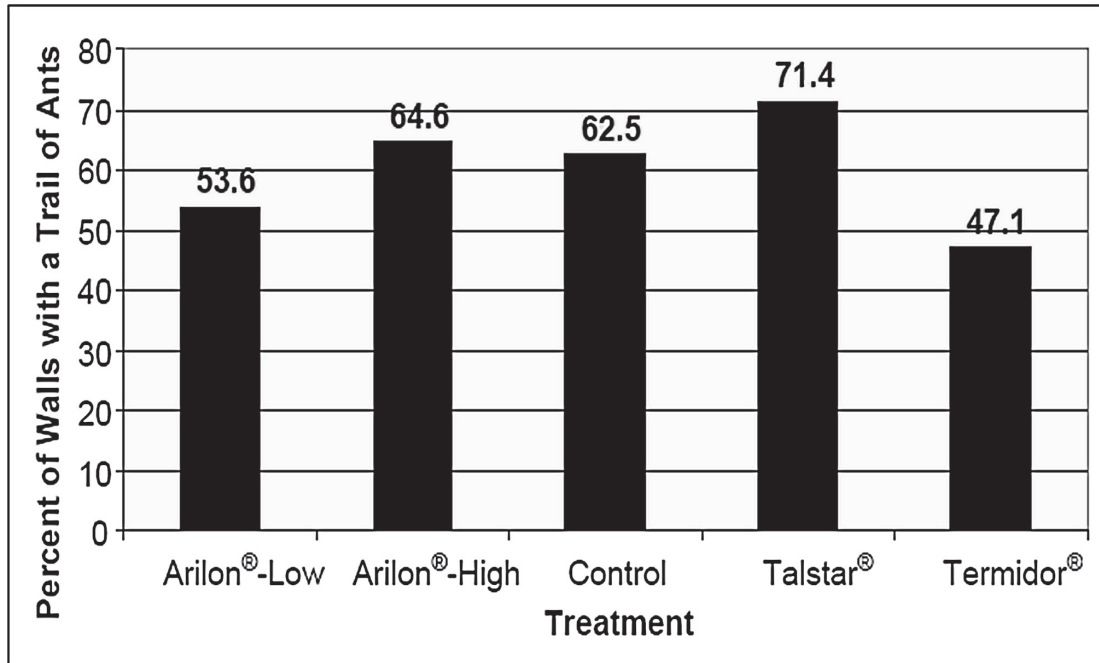


Fig. 1. Percentage of walls in the various treatments on which an ant trail was present prior to treatment.

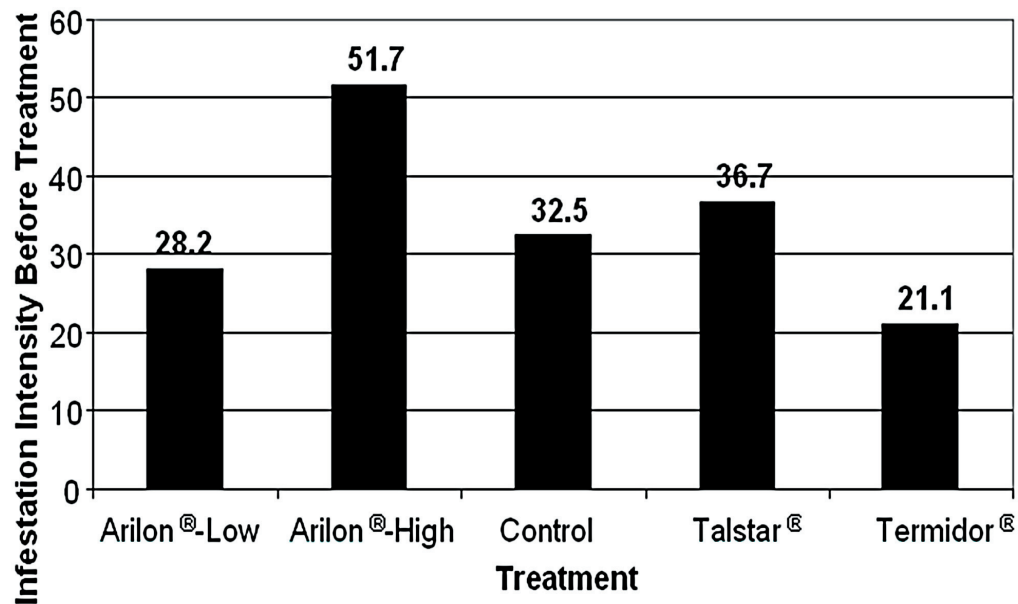


Fig. 2. Intensity of infestation in the various treatments prior to treatment. The larger the value, the more infested the group of buildings.

As shown in Fig. 2, the intensity of infestations prior to treatment was approximately 21.1% to 51.7% of *full infestation*. In the control treatment, infestation intensity was 32.5% ($117 \div 360$) of maximum. The Arilon™-High buildings were most-infested (51.7%), followed by Talstar® (36.7%), control (32.5%), Arilon™-Low (28.2%), and Termidor® (21.1%).

Control. Activity of Argentine ants in the control treatment grew from pre-treatment through wk 8, the end of the test. With the exception of the first week post-treatment, activity of ants in the control treatment was greater than the activity pre-treatment, clearly suggesting that ant populations in the control treatment grew throughout the study (Fig. 3). Growth of ant activity in the control treatment is important because it validates the conclusions drawn from the study.

Arilon™-High. The high volume application rate of Arilon™ outperformed all other treatments in this study (Fig. 3), and it did so under conditions of ant activity that were more intense than in any of the other treatments as determined by two metrics (Figs. 1 and 2). One-week after treatment with the high volume of Arilon™ spray, there was a 99% reduction in ant activity, which was the highest reduction among all treatments at this time period. Moreover, during the 8 wk that we followed ant activity after treatment, it was the only treatment that did not permit activity to recover to the activity level documented before treatment. In Fig. 3 this is the point at which activity crosses “0” on the Y-axis---the point at which activity had completely recovered. Points below “0” indicate greater activity in comparison to activity pre-treatment (Fig. 3).

Termidor®. The Termidor® treatment performed better than the Talstar® and low volume rate of Arilon™, but not as well as the high volume rate of Arilon™ (Fig. 3). One-week after treatment with Termidor®, there was a 95% reduction in ant activity, which was the second highest reduction among all treatments at this time period. After more than 7 wk, the activity of ants was equal to what it was prior to treatment (that point at which the line crossed “0” on the Y-axis, Fig. 3). After 8 wk, activity was 14% greater than it was prior to treatment.

Talstar®. The Talstar® treatment did not perform as well as the high volume rate of Arilon™ or Termidor®, but was comparable in efficacy to the low volume application rate of Arilon™ (Fig. 3). One-week after treatment with Talstar® there was an 85% reduction in ant activity. After almost 6 wk, the activity of ants was equal to what it was prior to treatment. After 8 wk, activity was 41% greater than it was prior to treatment.

Arilon™-Low. The low volume application rate of Arilon™ did not perform as well as the high volume rate of Arilon™ or Termidor®, but was comparable to the efficacy of Talstar® (Fig. 3). One-week after treatment with the low volume of Arilon™ spray, there was a 76% reduction in ant activity, which comprised the lowest reduction among all treatments at this time period. After just more than 5 wk, the activity of ants was equal to what it was prior to treatment, and after 6 and 8 wk, activity was 31% and 17% greater than it was prior to treatment, respectively.

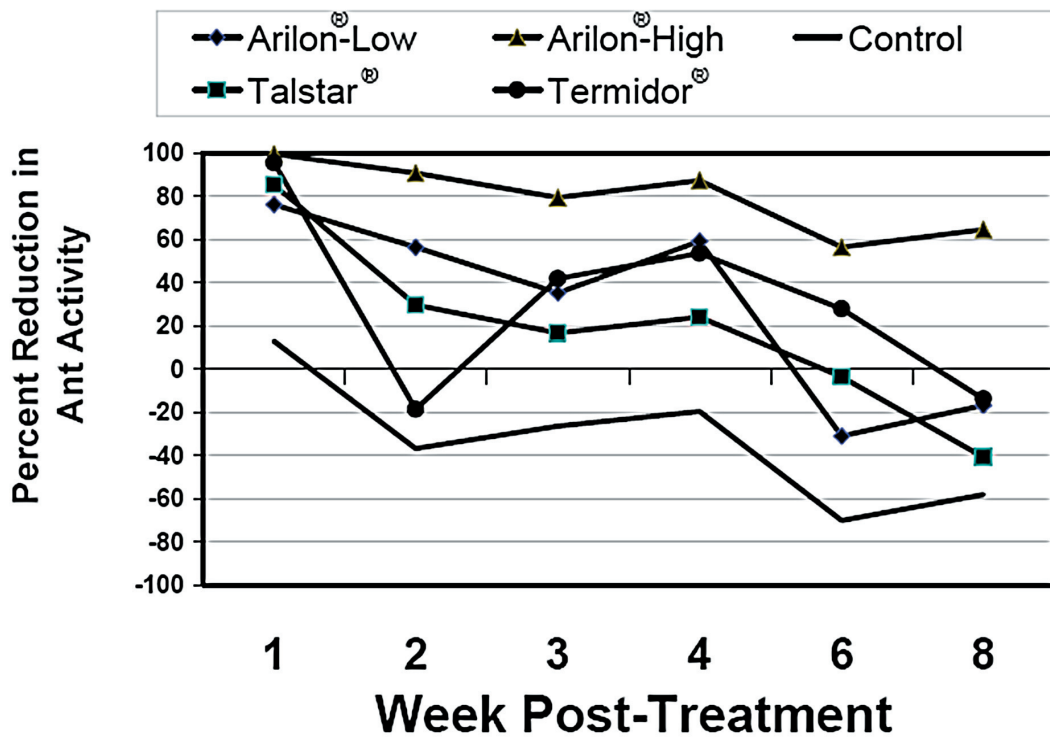


Fig. 3. Percent reduction in Argentine ant activity following treatment with various insecticides to the outside perimeter of apartment buildings in Griffin, GA.

SUBMITTED PAPERS

PUBLIC HEALTH

TIME TO AGGREGATION IN FED AND STARVED BED BUGS, *CIMEX LECTULARIUS* (L.)

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Bed bugs typically forage at night, actively searching for a blood meal. Prior to the daylight hours, bed bugs begin to form resting aggregations in harborages with other conspecifics. Our preliminary observations have indicated that recently fed bed bugs and starved bed bugs form these resting aggregations at different rates. Our research quantifies and compares the time to aggregation between bed bugs that foraged and fed during the previous scotophase and bed bugs that foraged but did not feed during the previous scotophase.

KNOCKDOWN, RESIDUAL, AND LARVICIDE EFFICACY OF TEMPRID® SC INSECTICIDE AGAINST SUSCEPTIBLE AND RESISTANT STRAINS OF THE BED BUG, *CIMEX LECTULARIUS* (L.)

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Since the bed bug, *Cimex lectularius* (L.), returned to prominence in the early days of this century, its resistance to pyrethroids has been a concern to academics and practitioners alike. With a paucity of insecticides registered for bed bug control, very few tools other than pyrethroid insecticides were available to counter the resurgent pest. Whether resistance to pyrethroids was a factor contributing to, or just a consequence of, the increased frequency of bed bugs makes for an interesting, academic debate

-- but this discussion does nothing to provide “front line” practitioners with effective solutions to worsening bed bug problems.

Recognizing that new solutions were required, we evaluated a new combination product for bed bug control. Temprid® SC Insecticide is a mixture of a chloronicotinyl (imidacloprid) and a pyrethroid (β -cyfluthrin), and it has proven to have exceptional efficacy against bed bug strains with proven metabolic and target site resistance to pyrethroid insecticides. Laboratory trials were completed to profile the knockdown efficacy of Temprid® following direct spray applications and the residual efficacy of Temprid® applied to both wood and fabric substrates aged for as long as 11 weeks. Additional laboratory trials evaluated the ovicidal actions of Temprid®, whether bed bug eggs were sprayed directly or deposited on treated substrates. Finally, field trials were concluded to confirm Temprid® performance under conditions of actual use.

On 14 January 2010, the U.S. Environmental Protection Agency approved an amendment to the Temprid® label for bed bug control, and state registrations are being implemented as rapidly as possible. As a true “stand-alone” product, Temprid® will not require tank-mix partners or the use of supplemental treatments; the label claims control of bed bugs that are resistant to pyrethroids and is approved for direct application to mattresses and upholstered furniture in addition to other harborage sites within infested structures. Given the global nature of the problem of bed bug resistance, international registration actions for Temprid® are now pending in Australia, Canada, Latin America, and other countries around the world.

While the registration of Temprid® SC is an important next step to achieving effective control solutions for pyrethroid-resistant bed bugs, we fully recognize that Temprid® - alone - cannot solve the problem in the long run. Therefore we are continuing to invest in research on the biochemical and molecular basis of resistance in bed bugs and a search for new classes of public health insecticides (in collaboration with the International Vector Control Consortium) that offer potential resistance breaking benefits.

EVALUATION OF A BED BUG CONTROL PROGRAM USED IN RESIDENTIAL PROPERTIES

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Field trials were initiated in 2009 with Viking® Termite and Pest Control, Inc. of Bridgewater, NJ to evaluate the performance of a bed bug control program including one aerosol (CB-80 Extra™ or CB-40 Extra™), one dust (Tempo® or Cynoff®), and one residual spray (Transport™ GHP). Six residential properties were included in the trial, with three site visits 7-14 days apart that included an inspection and rating of the infestation followed by an insecticide treatment. All of the insecticide use was measured as well as the time required to perform the treatments. Efficacy of the treatments was measured by visual counts of bugs and ratings of the premises.

GENE DISCOVERY IN BED BUGS (*CIMEX LECTULARIUS*)

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Bed bugs (*Cimex lectularius*) are poised to become one of the major pests in households throughout the U.S. Despite their high impact status, very little is known about this blood-feeding insect at the molecular level. A functional genomics approach will not only allow us to decipher knowledge at the gene level but also will provide a better understanding of the physiology-driven molecular processes in bed bugs. We have applied the newer-generation Roche-454 sequencing strategy and obtained 21,434 bed bug transcriptome sequences with the total length of 8,123,324 bp. Based on sequence similarity with an E value cutoff of 1e-5, 7,582 bed bug transcriptome sequences matched to protein sequences in GenBank nr database, with the majority to sequences from insects, including various species of aphids, *Drosophila*, mosquitoes, beetles, Lepidoptera, and others. The remaining 13,852 sequences are potentially bed bug-specific sequences. Interestingly, we have identified 48 *Wolbachia* sequences suggesting the presence of *Wolbachia* endosymbionts, which is consistent with the observations of female-skewed natural populations. *Wolbachia* endosymbionts may serve as potential targets for bed bug control. Finally, the EST database revealed 639 single nucleotide polymorphisms (SNPs) in 204 bed bug transcriptome sequences and 290 microsatellite loci in 269 bed bug transcriptome sequences. These genetic resources can be used for bed bug population genetic studies that may identify bed bug distribution patterns and facilitate control efforts. Overall, the current study provides a solid foundation for both basic and applied studies on bed bugs.

BED BUG (*CIMEX LECTULARIUS*) LIFE STAGES AND ADULT SEX RATIOS IN A MULTI-STORY APARTMENT COMPLEX

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Bed bugs (*Cimex lectularius*) live in close association with humans and are becoming increasingly common in houses, apartments and hotels. An understanding of the behavioral and ecological tendencies of bed bugs in urban infestations is important given that such behaviors may differ from those observed under laboratory conditions or small scale experiments. To better understand the process of active dispersal by bed bugs, research was conducted to investigate bed bug life stages and adult sex ratios in a heavily infested multi-story apartment building. Bed bugs were collected from inside apartments and also from the common hall surrounding each apartment door. Those collected in the hall were assumed to be actively dispersing between rooms. Data revealed that adults and nymphs were represented in hall samples. Bed bug adults taken from inside apartments and the hall were compared to a 50:50 sex ratio to determine if either population statistically deviated from unity. Unequal sex ratios in hall samples suggested the greater likelihood of females engaging in active dispersal, however, female-biased sex ratios also were evident inside apartments. *Wolbachia* spp. endosymbionts may play a role in female-skewed natural populations. These findings may prove useful in the design of control techniques for intercepting dispersing bed bugs.

SYMPOSIUM

GREEN PEST MANAGEMENT

Organizer:
Daniel R. Suiter (University of Georgia, Griffin)

THE PEST MANAGEMENT COMMUNITY NEEDS TO DEFINE GREEN PEST MANAGEMENT

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The word “green” recently has become a marketing catchphrase for a variety of causes. The term “green pest management” (GPM) likewise has an identity crisis within the pest management community. The consumer, practitioner, regulator, manufacturer, and research members of this community, more often than not, either have no idea or have conflicting concepts of GPM. This presentation outlines a number of approaches to GPM and highlights two organizations that have attempted to address the issue for their respective constituents. The National Pest Management Association and the Georgia Department of Agriculture have both framed GPM as an integrated pest management (IPM) philosophy. Does placing a vague concept within a shapeless definition make any sense? The need for the pest management community to come to a consensus on a definition for GPM is highlighted and offered for further discussion.

EFFECTS OF ESSENTIAL OILS AND BLENDS ON URBAN PESTS

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Naturally occurring insecticides have been used in pest control for centuries. Many of these compounds are secondary plant substances produced by aromatic plants and include alkaloids, quinones, essential oils (including terpenoids), glycosides, and flavinoids (Isman 2006). Aromatic plants have a distinctive and usually pleasant odor and contain high concentrations of aromatic volatile organic substances collectively

known as essential oils. These oils have low vapor pressure and therefore evaporate very easily at room temperature. Aromatic oils are secreted in oil glands distributed in flowers, fruits and seeds, leaves, bark, roots, and wood and occur in some 60 plant families, but are most commonly found in Labiatae, Rutaceae, Geraniaceae, Umbelliferae, Compositae, Lauraceae, Gramineae, and Leguminosae.

Monoterpenoids such as d-limonene in citrus and *l*-menthol and menthone in mint add distinctive aromatic characteristics to plants. These compounds are often used in cosmetics, foods, and pharmacological additives where they provide flavors and fragrances. Monoterpenoids induce a variety of responses by insects. For example, several monoterpenoids, cedar oils (Appel and Mack 1989) and mint oils (Appel et al. 2001) are repellent to American cockroaches, *Periplaneta americana* (L.), and German cockroaches, *Blattella germanica* (L.), affect insect growth and development, or are acutely toxic to insects. Monoterpenoids are considered neurotoxic because of their speed of action and their effects on neurotransmission. A wide variety of essential oils have been evaluated as fumigants for control of stored products insects and for management of foulbrood, Varroa mite, and tracheal mite infestations in honey bee colonies. These studies have generally shown that many essential oils have fumigant toxicity, but must be tightly enclosed with their target pest for optimal control. There have also been a number of studies on the essential oils as possible replacements for the soil and stored commodity fumigant methyl bromide. Although generally effective, the amounts of essential oils necessary for satisfactory control of soil-borne pests were not economically feasible.

Toxicity of 12 essential oil components (carvacrol, 1,8-cineole, *trans*-cinnamaldehyde, citronellic acid, eugenol, geraniol, S-(-)-limonene, (-)-linalool, (-)-menthone, (+)- α -pinene, (-)- β -pinene, and thymol) to adult male and female, gravid female, and large, medium, and small nymphs of the German cockroach was determined by topical application (Phillips et al. 2010). Thymol was the most toxic essential oil component to adult males, gravid females, and medium nymphs whereas *trans*-cinnamaldehyde was the most toxic essential oil component to adult females, large nymphs, and small nymphs. Toxicity was positively correlated with essential oil component density and boiling point; however, there was no significant correlation between toxicity and lipophilicity. The effect of essential oil components on oothecae hatch was also investigated. S-(-)-limonene had the least effect, with a mean of 35.2 nymphs hatching per ootheca. Menthone had the greatest effect with a mean of 20.9 nymphs hatching per ootheca. The numbers of nymphs hatching from each ootheca generally declined as dose increased. However; no essential oil component completely prevented ootheca hatch suggesting that multiple treatments or more effective blends of components might be required in the field to prevent re-infestation.

Fumigation toxicity studies showed that 1,8-cineole was the most toxic essential oil component to adult males and females, gravid females, and large nymphs of the German cockroach; (-)-menthone and carvacrol were the most toxic essential oil components to medium and small nymphs (Phillips and Appel 2010). (-)-Menthone

had the greatest effect on ootheca hatch (only 73% hatch). Percentage of hatched oothecae decreased linearly with increasing concentration for (-)-menthone, S-(-)-limonene, (+)- α -pinene, and (-)- β -pinene. No essential oil component completely prevented ootheca hatch suggesting that multiple treatments would be required in the field to prevent re-infestation. The most toxic essential oil components to red imported fire ants, *Solenopsis invicta* (Buren), were cyclic aliphatic hydrocarbons [1,8-cineole, (-)-menthone, (+)- α -pinene, (-)- β -pinene, and S-(-)-limonene]. Ring size and the presence of a carbonyl functional group may have also contributed to the toxicity of the compounds. Our goal now is to determine the most effective essential oil component, or mixture of components, in actual fire ant mound injection studies. We will also be examining how the toxicity of these components is affected by mound soil type and moisture.

The repellency of essential oil components to adult male German cockroaches was determined using Ebeling choice boxes and a harborage-choice method (Phillips and Appel, in preparation). Repellency ranged from a high of 45% for citronellic acid to 6% for S-(-)-limonene in the Ebeling choice box. Repellency was negatively correlated with fumigant toxicity. Repellency ranged from 76% for carvacrol to 43% for 1,8-cineole using a harborage-choice method. In this assay repellency was negatively correlated with vapor pressure. Analysis of variance showed that there was a significant effect of day on repellency for both the Ebeling choice boxes and the harborage-choice method indicating that these essential oil components dissipate over time and therefore lose their repellency. The Ebeling choice box is the superior method of the two for determining repellency of essential oils to the German cockroach because it is a more realistic approximation of normal cockroach habitat. Phillips and Appel (in preparation) also examined the immediate repellency or “flushing activity” of essential oil components to adult male German cockroaches. In this assay, cockroaches were confined in small cardboard boxes, allowed to acclimate for 24 h, and then treated with a 50 to 250 μ l mist of either 1% essential oil component or pyrethrum diluted in 70% ethanol. The pyrethrum resulted in the greatest percentage of flushing in 10 min (66.7%); essential oil components had relatively little flushing effect. There was <12% flushing activity by the essential oil components.

In conclusion, essential oils and their individual components show promise as topically active and fumigant insecticides. Many of the compounds are also repellent and several have flushing action. Essential oils will play an increasing role in “green” or “minimum risk” pest management; however, further research concerning formulation of these compounds will be critical if essential oils are to have a role in residual pest management.

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REPELLENCY AND TOPICAL TOXICITY OF VARIOUS PLANT OILS TO VARIOUS PEST ANTS

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In light of pest management, what does “green” mean? During the past several years, the urban and structural pest control community has capitalized on a society-wide movement to minimize one’s impact on the environment. To many, “green” is simply repackaged integrated pest management (IPM). To meet this demand, many companies now offer specialized “green services” to their customers. One common denominator among pest management professionals has been the adoption and use of products containing non-traditional active ingredients, namely plant essential oils. Indeed, the use of pest control products containing plant essential oils has been front and center in the new “green” revolution.

The Georgia Structural Pest Control Commission defines *green pest management* as “a service that employs an IPM approach while utilizing fewer of the earth’s resources as part of a larger effort to reduce human impacts on the environment.” Green-based pest management programs have partially quenched the public’s growing demand for low-impact alternatives to traditional pest management practices, and have, in turn led to renewed interest in research on plant-derived chemicals (botanicals).

In general, and in comparison to more conventional insecticides, plant essential oils exhibit low to moderate contact and topical toxicity and moderate to high fumigant toxicity, but are very effective repellents. For example, Meissner and Silverman (2001, 2003) showed that aromatic cedar mulch was more repellent to Argentine ants, *Linepithema humile* (Mayr), than cypress mulch or pine straw. They suggested that the use of aromatic cedar mulch around homes and in landscapes might inhibit Argentine ant nesting. In their studies, the aromatic red cedar was also toxic when ants were confined to treated surfaces.

Appel et al. (2004) tested peanut shell granules containing 2% mint oil against red imported fire ants, *Solenopsis invicta* Buren. After placing 10 ants inside a glass petri dish, half of the bottom treated with peanut shell granules and the other half left untreated, the granules were highly repellent as ants avoided the treated side. In both continuous and limited forced exposure tests the mint granules were toxic. Mint oil granules were toxic even at low rates in the continuous exposure test. The limited exposure test also showed that as little as 15-min exposure resulted in double the mortality of the untreated control after 24 h. In our laboratory, Wiltz et al. (2007) tested basil, citronella, eucalyptus, lemon, peppermint, and tea tree essential oils against *S. invicta* and *L. humile* for their deterrent and toxic effects. The deterrence tests were designed to determine whether ants would cross oil-impregnated cardboard barriers in order to acquire a food source. In the experiment, ants were given a choice to cross treated or untreated bridges. To evaluate toxicity, ants were force-exposed for 24 h to oil-impregnated filter paper. All of the tested essential oils, except eucalyptus, were successful at deterring both types of ants. Citronella oil killed all Argentine ants, while both peppermint oil and tea tree oil were slightly less toxic. Citronella oil killed 50.6% of treated fire ants.

In another study, C.M.S., D.R.S., and W. A. Gardner (in preparation) screened for repellency of cinnamon, clove, peppermint, spearmint and wintergreen oils against the Argentine ant. Oils were applied at three concentrations (0.1, 1, and 10%) and for two periods (fresh deposits and 7-day-old deposits) to moistened dental stone-based dishes, which served as ant nests. Ants either entered or did not enter treated nest sites based on the presence or absence, and concentration, of oil. When freshly deposited, all concentrations of all oils were repellent. However, after the oils had aged for 7 d, excluding spearmint oil (0.1%), only the 1% and 10% oil concentrations were repellent. Because essential oils are highly volatile, further research is needed to extend the residual life of essential oils as repellents (e.g., such as time-released microencapsulation to slow the volatilization process). In other studies in our laboratory (M.D.G. and D.R.S., in preparation), topical applications of nine essential oils (2 μ l droplet of 10% oil in hexane) to the abdomen of field-collected black carpenter ants, *Camponotus pennsylvanicus*, resulted in little mortality after 7 d in comparison to a more traditional pyrethroid insecticide (0.03% bifenthrin [Talstar®, FMC Corp.]). For example, ant mortality in all the essential oil treatments and control groups was significantly lower than the bifenthrin treatment, which killed 96% of the ants after 7 d. No essential oil caused more than 33% mortality after 7 d, and seven of the oils killed 20% or less of the treated ants after 7 d. For six of the nine oils, 7-d mortality was not significantly different from the control.

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GREEN URBAN PEST MANAGEMENT: WHERE DID IT COME FROM AND IS THERE ANYTHING TO IT?

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Shades of green. For years there has been controversy among researchers and pest management professionals (PMPs) concerning the reality and utility of green urban pest management. Yes, there is something to it. It may be subjective and difficult to identify, but an obvious green pest management trend has been emerging and evolving, among consumers as well as among researchers and PMPs. Several definitions of 'green pest management' have been proposed, but there has yet to be universal agreement as to what constitutes truly green management programs or if they are effective. The green management discussion generally centers around using cultural control strategies as the primary management tool and minimizing pesticide applications to the least amount as possible of so-called 'soft,' low-risk, minimum-hazard pesticides.

The primary impetus for this discussion has arisen from real and perceived concerns by consumers of the deleterious health effects of pesticides. For instance, the Environmental Protection Agency (EPA) reported that nearly one million children under six years old are poisoned each year and that synthetic pesticides have been linked to birth defects, learning disabilities, and asthma. These concerns are reinforced by celebrities such as Danny Seo, Bob "This Old House" Vila, Robyn O'Brien, and others who promote green pest management techniques and products, as do popular internet sites such as <http://healthychild.org/> and a host of internet bloggers. Recognizing the burgeoning popularity and commercial opportunities of "a green choice" in residential and commercial pest management, many PMP companies provide a separate essentially all-green service in which essentially no synthetic pesticide is applied. Responding and lending credence to the situation are state and national PMP associations that have established official green certification programs to ensure that PMPs electing to use green pest management strategies are knowledgeable and

trained. Although not much different than the traditional urban IPM cultural control recommendations made for years, trade magazines routinely feature experts such as Anderson (2010) providing tips and techniques for crafting and maintaining a green pest management program.

According to Ottman (2007), the rules of green marketing involve 1) credibility and perception and 2) efficacy. Both are required. This is true for light bulbs, solar power, hybrid vehicles, and pesticides. Not only must any potential green product in the marketplace be perceived as being truly green, but it also must in the end be efficacious. Consumers will soon quit purchasing light bulbs that are not bright enough and do not save money; they will not install solar power cells that do not provide adequate power; and they will shun buying a hybrid car that performs poorly or does not get good mileage. Even though perceived as green, the product must perform well.

From the client's perspective, the term "green pest management" means preventing or controlling insect pests in an "environmentally friendly" manner using a bare minimum of synthetic pesticide. Their primary concern is reduced toxicity and use of least- or non-toxic alternatives. They want assurances that a minimum of synthetic pesticide will be applied in or around their home. Given a choice, they prefer that no pesticide be applied rather than small amounts as needed. Concerns about the negative human health effects of pesticides and perceptions that low-risk green alternatives are available impact the marketplace in terms of where green urban pest management has come from and why it has become so popular. Of distant secondary importance to these clients are other important related green factors such as the pesticide's effect on the environment, its reusability and energy efficiency, eco-responsible recyclable packaging, or that the product was manufactured with minimal environmental impact.

For PMPs, the driving forces sustaining the green pest management movement include a widespread and growing "green conscious" core group of consumers; economic competition; a growing sense among some PMPs of responsibility and business opportunity; possible potential government regulation of some important synthetic pesticides; and the availability of proven effective green pest management products and strategies. A large and increasing number of "core group" consumers are concerned with pesticides, and we as researchers hear from these concerned individuals on a daily basis. Mostly female, younger, and affluent with children, they often are the decision-makers when it comes to allowing pesticides and management practices to be used in and around their home. In addition, many managers of commercial establishments such as restaurants, markets, and hotels opt for green services in an attempt to avoid potential costly lawsuits from customers claiming to have been harmed by exposure to a synthetic pesticide. This so-called core group is increasing as more green service options become available. Some PMPs have responded to marketplace concerns by providing green pest management services and others have implemented green services defensively in response to their competition providing such service. Also contributing to this increasing segment of green urban pest management is a committed core group of PMPs. Usually younger and less experienced in traditional

pest management that relies on synthetic pesticide chemistry, a growing number of PMPs embrace green techniques, promote them to their customers, and avoid using many of the registered synthetic pesticides available to them.

Beyond the marketplace (*viz-a-viz* the concerns of consumers and the economics to PMPs), green pest management is growing as the threat of regulation of traditional pest management tools looms. For reasons beyond the scope of this presentation, suffice it to say that this threat is real. Regulatory agencies at many levels are in the process of identifying and restricting use of selected pesticides presently widely used in urban pest management. Although others are being assessed, two important pesticides being evaluated are bifenthrin (Talstar®) and fipronil (Termidor®). In California, >50 tons of AI of these chemicals are applied annually, mainly for managing ants around structures. Presumably applied in accordance with the label, bifenthrin, the non-pyrethroid fipronil, and several synthetic pesticides commonly used by PMPs have been detected at biologically relevant levels in streams and watershed throughout the state. It is unclear if California is representative, but the agencies presently assume that similar runoff occurs wherever large amounts of these chemicals are used. Aware of possible regulation and restriction of these pesticides, many PMPs are being proactive in searching for and utilizing green alternatives.

According to the USDA's National Institute of Food and Agriculture, integrated pest management (IPM) is "the implementation of diverse methods of pest controls, paired with monitoring to reduce unnecessary pesticide applications; pesticides are used in combination with other management approaches to minimize the effects of pests while supporting a profitable system that has negligible negative effects." Similarly, the California Department of Pesticide Regulation, the issuing agency for pesticides in California, defines IPM as "a long term, preventive approach to managing pest that combines biological, cultural, physical, and/or chemical options; pest management practices that are effective and economically viable used in a manner that benefits consumers, urban neighborhoods. Pesticides are used judiciously and only as a last resort." Although a simple definition of 'green' is "any activity that is environmentally responsible" (Anderson 2010), green urban pest management is even more restrictive in that no synthetic chemicals whatsoever are used in the management process. In summary, green urban pest management has become green urban IPM. It has grown to its present status in response to consumer concerns about pesticides, because an increasing number of PMPs provide green pest control, and because of the eminent threat of regulation and restriction of the use of synthetic pesticides.

Efficacy (i.e., pest reduction) is key in traditional or green pest management. Safety and efficacy have highest priority. Many green IPM techniques are safe, but they are not necessarily as effective as conventional insecticides. There has been a proliferation of green products marketed as effective as synthetic pesticides. That is usually not the case and has hindered acceptance of green urban IPM by many PMPs. In fact, many of these so-called green products are not effective at all. We call these bad ideas. Bad ideas have a habit of periodically surfacing in pest management. Bad ideas 1)

have little or no basis in fact, 2) are inappropriate application of a proven concept, or 3) are a gross simplification with exorbitant expectations. An example of a bad idea is electromagnetism for repelling cockroaches and other insects from an area. A harmless green IPM idea, electromagnetic devices have repeatedly been shown to be ineffective. Similarly, although a safe green product, *Metarhizium anisopliae* (BioBlast®) is not effective in controlling German cockroaches under conditions of use. On the other hand, caulking, sealing, improving sanitation, proper use of lighting, good warehousing practices, and others are obviously good green urban IPM cultural techniques used and recommended by most PMPs. Until recently these techniques were considered non-toxic add-on supplementals, usually things to be done by the customer in partnership with the service they were receiving. That has changed.

PMPs now have a several green options to offer customers. They now not only offer cleaning and caulking service, a variety of green operational and oversight services, but also have an arsenal of effective green products to supplement or take the place of synthetic pesticides. Early reports showed that high rates of a variety of safe plant oils were effective against insect pests. Grossman (2008) reported on the work of others with oils against ants and cockroaches, and Coats (pers. comm. [2009]) and others have reported on the action and efficacy of specific plant essential oils against agricultural insect pests as well as cockroaches and other household pests. Some oils are repellent and rate-dependent (active only at high concentrations) but are nevertheless effective, producing irreversible knockdown within minutes or hours. Exempt from federal registration, select essential oils and blends provide possible alternative safe spray strategies. Wintergreen and rosemary oil are particularly promising, geraniol and lemongrass have been commercialized as aerosols, and other exempt sprays are also available.

Enan (2001) showed that effective essential oils interfere with the insect's hormone systems, and Coats (pers. comm.) found they also retard nerve impulse transmission and may be involved with other systems as well. Phillips and Appel (2010) reported that low rates of some essential oils were active as fumigants against German cockroaches while others were more active when applied directly. Although some oils killed small flies quickly, Isman (pers. comm.) was unable to induce resistance among up to 15 successive generations of *Drosophila* treated with essential oil. That there are multiple modes of entry and sites of action may explain Isman's results. Resistance has not been reported for inorganic chemicals such as boric acid or diatomaceous earth that have multiple sites of action, and multiple modes of action may also be advantageous for essential oils. Mode of action studies support claims that specific essential oils affect insects. Research has demonstrated the activity and utility of essential oil formulations and others. Essential oils and other exempt green products have been commercialized by EcoSMART Technologies, FMC Corp., Whitmire Mico-Gen Research Laboratories, and others. Because pyrethrins, synergists, and ingredients contained in some green products are not exempt, low-risk green products containing these ingredients must be registered with the EPA. Besides sprays and dusts, there are several other effective green urban IPM products available as well.

To determine whether there was anything to it, we facilitated a cooperative 2-y green urban IPM study to control Argentine ants around homes. The objective of the study was to determine whether PMPs could achieve good ant control with less pesticide, specifically at least 50% less pyrethroid pesticide per year (a goal mandated by the California Department of Pesticide Regulation). Six large, well-known, multiple-branch PMP firms cooperated in the study. Prior to the summer season, each firm developed an individualized IPM strategy to reduce pesticide use that they believed might work for them. Each strategy was different. The companies assigned two typical existing routes to the study--one route kept on their traditional spray service schedule (Traditional), and a similar route where less conventional pesticide was applied (IPM). Each route consisted of 150 to 220 homes (i.e., >950 Traditional, >950 IPM). The PMPs elected to rely on green spray products (e.g., essential oils and others) to replace the pyrethroids they were currently using. The PMPs kept spreadsheet records for every application as to date, which products and amounts were applied, and time spent at the account. Call backs, complaints, and customer change were also recorded.

One company reduced by 50% the amount of pyrethroid applied by treating, for example, every other month rather than monthly, but most actually ended up applying more product, albeit softer, greener and less potentially harmful than the pyrethroids they had been using. Another company completely eliminated pyrethroids on its IPM route and mandated using only green products. The PMPs used almost no other IPM tactics. A simple standardized telephone survey of the homeowners on each route was conducted by each company at the end of the ant season. Basically, the program was evaluated in terms of customer satisfaction. The strategy was considered a success if the customers were satisfied. Comparisons were made between the results obtained for the Traditional Routes and the IPM Routes. The most important findings for this presentation are that 1) IPM Route customers were as satisfied with the service provided as were the Traditional Route customers [>97% satisfaction], 2) it took no longer to service IPM accounts than traditional accounts, 3) over the season there was no statistical difference in the number of callbacks, and 4) virtually no customers were lost on either account. The cooperating PMPs in the study participated this year in statewide seminars as advocates of using green technology and less synthetic pesticide for ant control.

Rather than specific sprays or products, we have researched the practicality of other effective "alternative" green technologies including heat, cold, and anoxia modified atmospheres (Reierson et al. 1996), synthetic natural chemistry, physical barriers and traps (Reierson and Wagner 1999). These and other alternative methodologies are effective and, if properly implemented, do provide control of insect pests, but difficulties persist as how to develop these technologies into successful functional business programs. That is a challenge for the future.

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SHADES OF GREEN: OPPORTUNITIES FOR THE PEST MANAGEMENT INDUSTRY

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How Green Is Green Enough? Whether pest management companies should be green or not has already been decided by the industry's target clientele. It's too late to debate the validity of green; for better or for worse, we have to get on board. But there are many different shades of green from which to choose:

1. Going green can be as simple as practicing integrated pest management (IPM) and educating our clients through better communication that our pest management practices are environmentally responsible.
2. To some, green means using only naturally-occurring pest control materials or "least-risk" alternatives.
3. Individual pest management companies might seek formal green certification under Green Shield, NPMA's Green Pro, or a similar program.
4. Pest management companies' clients might ask them to submit proof that their pest control programs comply with their own green requirements, such as those of the LEED (Leadership in Energy and Environmental Design) program.

5. Clients (e.g., retail store chains) may have decided for themselves what green means, and may have established green service criteria with which their pest management contractors must comply.
6. Food plants that manufacture and package organic products require another shade of green: compliance with the rules for organic pest management.

Depending on the individual companies and the markets they serve, any or several of the shades of green might be the right ones. The purpose of this presentation is to sort out the different shades of green, and show how the pest management industry meets our society's green expectations.

IPM and Our Industry's Image Problem: In terms of damage done to the environment, the structural pest management industry can hardly be seen as the problem. Most progressive pest management firms practice IPM, relying primarily on inspection and monitoring, along with non-chemical prevention and control strategies wherever practical. Pesticides, when used, are applied in small amounts to targeted locations; and the pesticides themselves are often relatively mild.

But there is a gap between what our industry actually does and the way the industry is perceived by the public. To many people, the word "pesticide" carries many negative connotations, and this colors their expectations of what pest management entails. When a pest management professional says "pesticide," she might be referring to a 30-gram tube of ant or cockroach bait whose toxicity is almost too low to measure; when members of the general public hears the word "pesticide," they may conjure images of rusty 55-gallon drums oozing lime-green toxic waste into a landfill.

Thus, the pest management industry has before it the task of communicating to the public the many ways in which we are already green. Homeowners, school officials, daycare operators, retail store management, healthcare facility administrators, food processors, and government building managers are among the groups of people whom we must better educate about what we really do.

IPM Practices and Improving Our Communication: Pest management companies and individual pest management professionals must take action in order to "be seen as green" and gradually break down prejudices about pest management. There are many communications tools available to PMPs that can help accomplish this task, including:

- Company-to-client newsletters providing information on ecologically responsible IPM practices
- News media (for example, appearances on TV or radio "fix-it" programs and appearances in news features on pest-related issues; articles written for community newspapers)
- Community activism (Adopt-A-Highway, community cleanups, Earth Day activities, etc.)
- School visits by pest management experts as a supplement to schools' study of insects in science classes

Individual pest management technicians can be trained to communicate green messages to their clients: “If you fix this downspout diverter, there will be less moisture accumulating around the foundation of your house, which will solve some pest problems without using any pesticide;” or “I’m going to repair this broken door-bottom sweep to prevent mice from getting inside.”

There are many green things the structural pest management industry does on a daily basis; communicating what we are doing and why will go a long way towards educating the public to see that the industry is on board with “green.”

- Recommending changes in lighting to make facilities less attractive to pest insects
- Using copper mesh, expanding foam and other exclusion materials to prevent pest entry and eliminate pest harborage
- Recommending improvements in sanitation and maintenance to reduce the attractiveness of interior and exterior environments to pests
- Making or recommending changes in temperature, humidity or air flow in order to make interior environments inhospitable to pests
- Using passive monitors, mechanical traps, and pheromone monitors to provide early warning against pest invasion
- Making targeted applications of reduced-toxicity pesticides
- Making barrier treatments outdoors in order to reduce the need for pesticides indoors

PMPs engage in many, many more such activities every day; they just need to get better at reporting their own green practices and “talking the talk.”

Should We Go Natural? In some markets, particularly those with upscale homes and high-earning homeowners, there is a demand for pest management services using only “natural” pest control products. Ignoring for the moment the questionable validity of such demands (is it really “safer” to spray a yard with horticultural oil-based products than with bifenthrin?), the fact is that some consumers have accepted the notion that natural is better. The pest management industry can, in such cases, respond with programs utilizing only natural products. There are a great many such products available, including products with a variety of oils, plus boric acid, diatomaceous earth, and other active ingredients that are perceived by the public as having lower toxicity or risk. When pest management companies offer their customers pest management programs using natural products, the programs are well accepted and the results are good. Major pesticide manufacturers including BASF, FMC, Bell Laboratories, Rockwell Laboratories, Woodstream, and EcoSmart have all responded to the demand for natural pesticides, so pest management firms that want to offer services using only natural products have many materials from which to choose.

Client-Driven Green Programs: Among retail chains that have decided for themselves what constitutes green practice, Walmart is probably the most prominent. Recognizing the immense share of commerce at their command, the management of Walmart decided that they could make a difference by not only changing their own practices

to be more environmentally friendly, but also by requiring that their service vendors adopt green practices as well. Pest management firms hoping to do business with retail chains that have green standards must conform to certain requirements that pertain to materials and equipment used, and to pesticide use policies.

Green Certification: All of the aforementioned points might lead one to believe that exactly what constitutes “green” can be rather fuzzy, so it is no surprise that various agencies and programs have arisen whose purpose is to standardize green practices. Among those programs available to pest management companies are Green Shield and Green Pro, the former operated by the IPM Institute of North America, and the latter a program sanctioned by the National Pest Management Association. Whichever agency a pest management firm seeks to be accredited by, they will have to demonstrate compliance with that program’s requirements for:

- Knowledge about pests and IPM practices
- Monitoring and inspection as central activities
- Documentation
- Pesticide use policies (e.g., no routine use of pesticides; or decision-making hierarchy detailing when to use no pesticides, when it is permitted to use least-toxic pesticides, and when it is permitted to resort to use of conventional pesticides)
- Definition of least-toxic materials
- Whether a separate program or division is required for a company’s green service; and whether a separate training program and separate vehicles are required

Many pest management companies will expend a great amount of their resources to obtain green certification so that they can gain the right to display a green certification logo on their vehicles, uniforms, and advertising materials.

LEED Programs: One variety of green certification that is gaining ground at an especially rapid rate is LEED, which stands for Leadership in Energy and Environmental Design. LEED, a system for rating buildings’ environmental practices, is a program of the U.S. Green Building Council and the Canada Green Building Council. Property management companies seeking LEED certification for their buildings must show that their facilities’ energy usage, heating and cooling efficiency, waste management, recycling practices, landscaping, and chemical usage are all in line with accepted standards of environmental sustainability. Pest management companies that want to serve LEED-certified facilities must demonstrate that they practice IPM, and that they will rely on least-risk materials when it is necessary to use a pest control product. In the event it becomes necessary to use a material that is not defined as least-risk, they must provide written notification to all building occupants 72 h prior to the application (or within 24 h of the application in the case of a legitimate emergency application).

Many pest management companies are rising to the challenge of providing service to LEED-certified buildings and complexes.

Organic Programs: Pest management in organic food growing, processing and packaging facilities is the last, but not the least, of the shades of green from which pest

management companies can choose. The rules for organic pest management are set down in the text of the National Organic Program (NOP) (in Canada, the Canada Organic Regime), and they provide their own set of challenges. Pest management companies desiring to provide service to this market segment must create and carry out programs that conform to the following hierarchy of actions:

1. First and foremost, pest management efforts must rely on non-chemical strategies such as sanitation, exclusion, physical and mechanical control, plus inspection and monitoring (including monitoring using pheromone attractants).
2. If non-chemical measures are demonstrated inadequate to prevent or control pests, it is permitted to apply a pest control material named in the National List. (The National List is the portion of the National Organic Program text that names pest control materials that can come in contact with organic food.) National List materials that would be recognizable as pest control materials include boric acid, horticultural oils, non-synergized pyrethrins, Vitamin D3 (cholecalciferol rodenticide), and possibly diatomaceous earth.
3. If non-chemical measures and the use of a pest control material named on the National List are both demonstrated inadequate to prevent or control pests, it is permitted to apply a pest control material that is not named in the National List, provided the application is approved in writing in advance (as part of the written pest management program), and provided the application is made in such a way that contact between the pest control material and the organic food is prevented.

For pest management firms, the key to serving the organic food industry is to have effective written programs that are created according to the NOP rules, and then to have perfect, exhaustive documentation on file that enables them to show – step by step – their compliance with the rules.

This is, of course, a gross oversimplification of the rules for pest management in organic facilities; but it will serve for this abstract. Persons wishing to know more may contact the author.

Summary: Pest management companies that truly and responsibly practice IPM are already green; they only need to adjust their image through better advertising and communication. Those companies that have found, through market research, that there is a demand for pest management services using “all-natural” products can do so due to the availability of a variety of natural products.

Our clients, it seems, will continue to dictate what they think is green, and if we want their business, we’ll adapt our own practices.

Formal green programs, such as Green Shield, Green Pro, and LEED, have clearly spelled-out rules for green practice.

Finally, organic rules have been standardized both in the U.S. and in Canada, and complying with organic standards is only a matter of following the rules and documenting compliance.

REDUCED RISK PRODUCTS FOR URBAN PEST CONTROL: PAST, PRESENT, AND FUTURE

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Chinese and Egyptians used nicotine and pyrethrum to control stored product insect pests as early as 1000 BC. Pyrethrum was introduced into Europe around 1300 AD, and in 1858, pyrethrum powder arrived in the U.S. From that time on, pyrethrum has dominated the history of botanical insecticide use in the U.S. Most early pyrethrum use was in agriculture. Structural pest control use of pyrethrum and other botanicals in the U.S. is relatively recent – starting in the 1950s. Pyrethrum remains the most commonly used botanical in pest control – in 2006 there were 1300+ Environmental Protection Agency (EPA) product registrations using pyrethrum.

A very large number of plant species (>3000) contain compounds with documented insecticidal activity, and many published studies have demonstrated pesticidal and/or repellent properties of plant essential oils. Relatively few products have been commercialized in any country, but the U.S. has more botanical products than the rest of the world primarily because of regulatory initiatives. Many “reduced risk” botanical active ingredients (AIs) were registered in the 1940s (with the beginning of FIFRA [Federal Insecticide, Fungicide, and Rodenticide Act] in 1947) and have been re-registered. In 1996, several “reduced risk” actives, along with previously unregistered actives, moved to the EPA 25(b) “exempt” list comprised of selected minimum risk pesticides exempt from FIFRA requirements. To qualify for exemption as a minimum risk pesticide, each AI in the pesticide product must be listed in 40 CFR 152.25(g)(1). Exempt pesticides must contain only AIs on the 25(b) list combined with other (inert) ingredients on the EPA 4A list.

A large number of products containing botanical ingredients are currently available for consumer and professional use (Table 1). In a recent survey, we found more than 300 products for insect and mite control, 147 products used to repel animals, and 83 products for weed control. More than 50% of the ingredients used in insect control products were soaps of fatty acids, garlic extract/oil, neem oil/azadirachtin, clove oil, cedar oil, and rosemary oil.

Table 1. Major reduced risk active ingredients (AIs) used in insect and mite control products (total products = 301). Total number of ingredient uses = 472 (many products contain more than one AI)

Active ingredient	# times used	% times used
salts of fatty acids	55	11.7
garlic and garlic oil	43	9.1
neem oil	38	8.1
clove and clove oil	34	7.2
cedar oil	29	6.1
azadirachtin	27	5.7
rosemary & rosemary oil	23	4.9
peppermint & peppermint oil	21	4.4
citric acid	18	3.8
sodium lauryl sulfate	15	3.2
sesame and sesame oil	15	3.2
cottonseed oil	14	3.0
mineral oil	14	3.0
	Sum = 346	Sum = 73.3%

The modes of action of insecticidal botanical ingredients are usually not well understood. They can be neurotoxic, octopamine receptor antagonists, and acetylcholinesterase inhibitors. They can also disrupt cell membranes and act as metabolic inhibitors (i.e., dillapiol, piperine).

Many products contain combinations of AIs, but the reason for this is usually not obvious. Some possibilities include increased efficacy and/or synergy. The cost of ingredients may be a factor. Marketing claims may be involved. Companies may use several AIs to “disguise” the real actives and hence maintain trade secrets.

Future directions in the use of botanicals for pest control may involve the following:

1. Attractants and repellents including pheromones and food-odor attractant. Attractants and repellents do not have a toxic mode of action and can be registered as “biochemicals” with reduced regulatory requirements.
2. Mixtures. Products will contain mixtures of AIs. This may result in increased efficacy, synergy claims, and patent protection.
3. Stored product protection products using botanical ingredients. Fumigant activity of botanicals will repel or kill insect pests.
4. Residual formulations. Botanical formulations with greater residual activity would be highly desirable. Short residual time of current botanical products is a benefit but re-treats are often necessary.

A STATE REGULATORY PERSPECTIVE ON “MINIMUM RISK” PESTICIDES

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In 1996, the Environmental Protection Agency (EPA) exempted certain minimum risk products from the requirements of FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act). This 1996 exemption of minimum risk pesticides is often referred to as the 25(b) exemption, since section 25(b) of FIFIRA provides EPA the authority to exempt pesticides.

Exempt minimum risk products are required to comply with restrictions on composition and labeling. Active ingredients are limited to 31 specific ingredients and all inert ingredients must be on EPA's list of minimum risk inert ingredients. Although many of the allowable active ingredients are plant-based oils, not all plant oils are allowed.

Minimum-risk exempt pesticides must also comply with certain labeling requirements, including a prohibition on false and misleading claims. Unlike EPA-registered pesticides, they are allowed to make safety claims and claims to be “natural”. This may provide these products with a competitive advantage over reduced-risk EPA-registered pesticides.

Although the minimum risk requirements include limits on public-health related claims, the Colorado Department of Agriculture (CDA) believes these limitations are insufficient. Of greatest concern is that these products can claim to control, repel, or provide protection from pests that are significant disease vectors, as long as they do not make claims regarding specific diseases. Many exempt products are mosquito repellents, which is allowable as long as they do not mention West Nile Virus (WNV) or any specific disease.

For EPA-registered pesticides, EPA can and does require efficacy data for products claiming activity against a wide range of pests of public health concern, including a wide variety of insects, snakes, rodents, dog repellents, and even bear repellents. However, there is no federal oversight of the label claims of exempt products, which could mislead customers into expecting protection from mosquitoes, ticks, or other disease vectors.

Colorado requires state registration of pesticides exempted from EPA's registration requirements under the minimum risk exemption, as do most states. CDA is responsible for pesticide regulation in Colorado, including state pesticide registration. Until March of 2006, we looked closely at efficacy claims for minimum risk pesticides, and often required efficacy data to be submitted for review prior to making a registration decision. In many cases, applicants failed to respond to our notification of the need for efficacy data or initiated testing only after learning that we required it.

Colorado was hit hard with WNV in 2003, with 2947 confirmed human cases of WNV disease and 63 fatalities. We were concerned that prior to 2003, some 25(b) mosquito repellents may have been registered with weak efficacy data. In 2004, we required mosquito repellent registrants for all personal human mosquito repellents for use on skin (except for those containing DEET) to submit efficacy data. We conducted 11 efficacy reviews of 25(b) exempt mosquito repellents during this process. Five products were eventually accepted for registration renewal, but all required changes to the efficacy claims on the label. For 12 products, the registrant voluntarily cancelled their registration instead of submitting data.

Despite the significant resources we were devoting to efficacy reviews for 25(b) exempt products, we were still not protecting Colorado consumers from the availability of these products in the marketplace. For example, we had some contact with 44 different mosquito repellents from 2002-2006, with over half of them found unregistered at Colorado stores. Only seven were registered after we initiated our data call-in and a more rigorous review process.

By 2006 and 2007, more conventional registrants were introducing 25(b) exempt products, and the efforts we were expanding in efficacy reviews and subsequent communications with applicants became overwhelming. In March of 2007, we changed policy, and no longer required efficacy data for 25(b) products. By the end of 2007, the number of registered 25(b) products in Colorado more than doubled, from 96 to 202.

Fig. 1 shows the number of registered 25(b) exempt products registered for distribution in Colorado by CDA from 2002 through 2009. The number of registered products increased gradually from 56 in 2002 to 105 in 2006. The jump to 202 in 2007 could at least partially be due to our change in policy on efficacy reviews. However, the numbers have continued to increase rapidly, with >300 products registered in 2009.

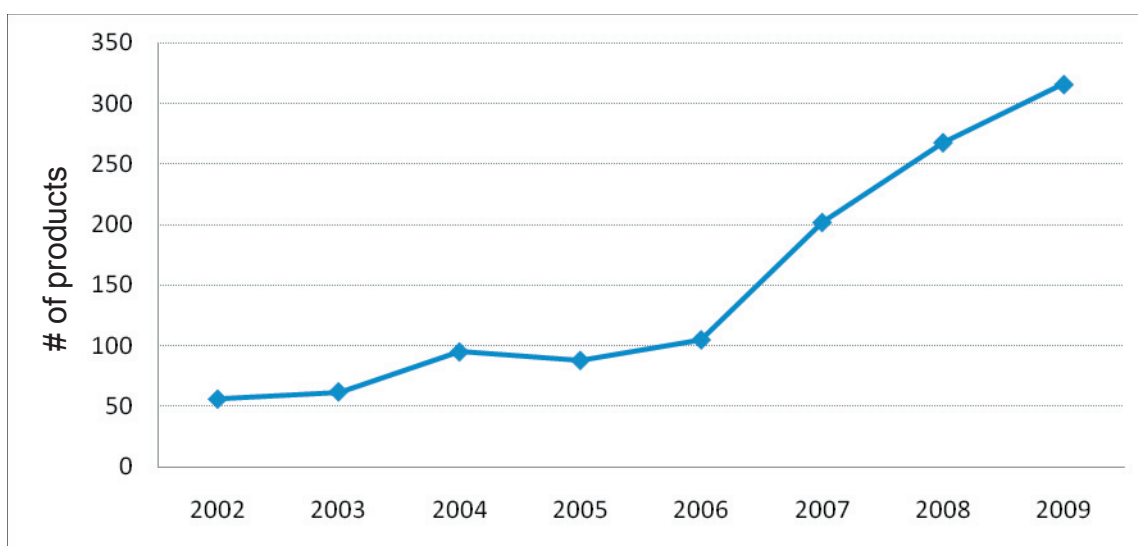


Fig. 1. Number of 25(b) exempt pesticides registered by Colorado Department of Agriculture for distribution in Colorado, from 2002 – 2009.

In Table 1, the various types of registered 25(b) products are broken out for a selection of years. The most common categories are insecticides, insect repellents (including lawn and garden insect repellents), and mammal repellents (primarily mole repellents and rabbit/deer repellents).

Table 1. Types of 25(b) exempt pesticides registered by Colorado Department of Agriculture for distribution in Colorado, in 2003, 2006, 2007, and 2009. A single product can have more than one type.

Year	2003		2006		2007		2009	
Total # of products	62		105		202		316	
<u>Pesticide Types</u>								
Insecticide	21	33.3%	25	22.7%	64	30.6%	101	29.8%
Insect Repellent	21	33.3%	30	27.3%	49	23.4%	76	22.4%
Mammal Poison/Repellent	6	9.5%	29	26.4%	63	30.1%	92	27.1%
Herbicide	8	12.7%	15	13.6%	18	8.6%	26	7.7%
Fungicide	2	3.2%	5	4.5%	7	3.3%	18	5.3%
Snake Repellents	0		0		1	0.5%	6	1.8%
Antimicrobial Agent	2	3.2%	1	0.9%	2	1.0%	5	1.5%
Plant Growth Regulator	1	1.6%	3	2.7%	3	1.4%	6	1.8%
Algaecide	1	1.6%	1	0.9%	1	0.5%	1	0.3%

Although our greatest concerns with EPA's minimum risk exemption is with products claiming to control or repel disease vectors, we have also found some examples of products that comply with EPA's minimum risk exemption, but may present a significant risk to applicators or the environment. For example, we have registered products for potato sprout removal composed of 100% clove oil, with label requirements that applicators wear respirators, goggles, and chemical-resistant gloves. We have also seen products listing the surfactant sodium lauryl sulfate as the active ingredient with instructions to apply to aquatic sites (including bird baths) as a mosquito larvicide. USDA used to have a registered pesticide labeled to kill birds whose active ingredient was a surfactant. The use directions and mode of action of this EPA-registered avicide involved spraying birds with surfactant and water prior to a cool evening, with death resulted from hypothermia.

In 2006, the Consumer Specialty Products Association petitioned EPA to modify the minimum risk exemption, to exclude pesticides claiming to control pests of significant public health importance. By July of 2007, EPA had publically agreed with some of the concerns in this petition. EPA has initiated the rule-making process, and may have a proposed rule or rule(s) published by 2011. The highest priority will be to remove skin-applied insect repellents from exemption.

More information can be found at the following EPA website:
http://www.epa.gov/pesticides/biopesticides/regtools/25b_list.htm

SYMPOSIUM

THE CHANGING FACE OF URBAN PEST MANAGEMENT

Organizers:
Ron Harrison and Pat Copps (Orkin, Inc.)

CHANGING FACE OF URBAN PEST MANAGEMENT: IMPORTANCE OF PRODUCT INNOVATION

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Urban insect pests can present severe hazards to human health and to our dwellings. Sickness and lethality to humans combined with the billions of dollars annually in structural damage caused by these pests require innovation in treatment products and methodology. At the same time, insecticide manufacturers must develop new technologies that provide a significant contribution to the control of pests while reducing the overall threat to the environment. This balancing act forces true innovation.

DuPont has been on the forefront of bringing innovation to the urban pest management industry. Specifically, there are three areas in which we have been focused in order to deliver improved management tools to pest management professionals (PMPs): 1) active ingredient (AI), 2) formulation, and 3) packaging.

For the first 50 years of modern active ingredient development, manufacturers were working in the same three basic target areas: sodium channel, chloride channel, and acetylcholine esterase (Nauen 2006). For the last 15 years or so, manufacturers have broadened the search to now include at least 15 different target sites (Nauen 2006, Lahm et al. 2009). Part of what drives this pursuit of more diversity in mode-of-action is to narrow the spectrum on which the insecticide is active and thereby improve selectivity--essentially precision targeting. New target areas typically lead to new classes of chemistry. Successful discovery and development efforts lead to introduction of new compounds with novel modes of action. This occurs infrequently. This is an increasingly expensive enterprise (~\$250-\$300 million per compound) and is now performed at just a handful of companies.

DuPont has continued to be active in insecticide screening and, after major overhauls conducted in the late 1990s, has introduced the two most recent new classes of chemistry: oxadiazines (indoxacarb) and anthranilic diamides (chlorantraniliprole), with both AI's receiving "reduced risk" designation by the U.S. Environmental Protection Agency (EPA) for the requested uses (U.S. EPA 2000, 2008). Indoxacarb is a pro-insecticide requiring activation by insect-specific enzymes. Once converted, the active metabolite binds to the voltage-gated sodium channels of nerve axons and shuts them down resulting in paralysis and eventual death of the insect (Wing et al. 2000). Chlorantraniliprole was designed by DuPont scientists but inspired by the defense compounds of the plant *Ryania speciosa*. Extremely specific in activity, chlorantraniliprole binds to ryanodine receptors in insect muscle cells causing uncontrolled release of calcium into the cell cytoplasm leading to complete muscle paralysis (Cordova et al. 2006, Lahm et al. 2009). Insects affected by this compound stop feeding very soon after exposure, followed by decreased movement and eventual death (Hannig et al. 2009, Quarcoo et al. 2010). Two examples of DuPont products based on these new AIs follows.

Advion® Fire Ant Bait (0.045% indoxacarb) was introduced in 2005 and immediately became popular among users as it provided complete colony kill within 1-3 days of application (Oi and Oi 2006). This type of speed from a bait product was truly innovative as it was previously accepted that no insecticidal bait could control entire ant colonies that fast due to transfer requirements within the colony (Stringer et al. 1964, Oi and Oi 2006). Prior to the introduction of Advion®, users typically had to allow 7-14 days after application of bait to achieve control of fire ant colonies. The combination of superior performance and its reduced risk status has led Advion® Fire Ant Bait to be among the most popular choices for School IPM programs across the southern U.S.

Altriset™ Termiticide (chlorantraniliprole) was designated "reduced risk" by the EPA in March 2010 and was granted full registration in May 2010. As the first and only reduced-risk liquid termiticide, which also lacks any signal word on the label, this is a paradigm shift in termite management tools for professional users. Altriset™ offers excellent performance (as represented by U.S. Forest Service trials, laboratory studies, and field studies) and an excellent toxicological profile from an insecticidal product (Anonymous 2010). Although this new insecticide earned reduced risk status due to its extremely favorable toxicological and environmental profile, it has also proven to be very effective in controlling structure-infesting termites (Yeoh and Lee 2007, Quarcoo et al. 2010).

The second area that DuPont has focused on is formulation. Two additional product innovations will be discussed. By the early to mid 2000's, there was considerable concern within the pest management industry regarding failures of bait products to control German cockroaches (*Blatella germanica*) (Harbison et al. 2003). It was determined that some product failures could be linked to behavioral resistance or "gel aversion" (Silverman and Ross 1994, Wang et al. 2004) along with possible physiological resistance in the case of fipronil (Holbrook et al. 2003, Wang et al.

2004). In 2006 DuPont introduced Advion® Cockroach Gel which combined a unique formulation specifically targeting behavioral resistant populations along with a powerful new blatticide, indoxacarb. Early commercial users reported to DuPont that this new product performed beyond their expectations of a bait, quickly cleaning up very serious infestations. Further research into the potential source of this superior performance led to the discovery of tertiary transfer of AI within the cockroach population. It was determined that lethal residues of indoxacarb could be transferred from a single male cockroach that fed on an Advion® deposit to a second cohort of cockroaches, and then yet again to a third cohort of cockroaches (Buczowski et al. 2008). This mechanism could partially explain the improved performance observed by PMPs relative to other products as no other product has been demonstrated to offer tertiary kill.

With the introduction of Arilon™ Insecticide (20% indoxacarb WG) in 2009, PMPs now have a non-repellent liquid spray insecticide that meets most of their performance needs. Arilon™ Insecticide is labeled for indoor (including food handling areas) and outdoor applications. The formulation (20WG) was designed specifically to allow crawling insects to readily pick up the AI from the treated surface, whether that surface is tile, steel, brick, concrete, wood, vinyl, etc. In addition, due to indoxacarb's photostability and low water solubility, sprayed residues stay put and provide long lasting control even in outdoor and weathered environments (DuPont 2009). Arilon™, which provides the reduced toxicity/hazard of indoxacarb, is the first non-repellent insecticide labeled for indoor and outdoor applications--a result of innovative formulation.

Packaging or presentation of the product is the third area in which DuPont has invested considerable resources. After evaluating several possibilities for years, DuPont introduced Terrene™ packaging in combination with its Arilon™ Insecticide in 2009 as the first outcome of its Sustainable Packaging Initiative. Terrene™ offers PMPs the option of biofilm packaging (DuPont 2009). Several advantages can be utilized with this packaging system. The product is pre-packaged in single packets with a pre-measured quantity to mix 1 gallon of spray, thereby significantly reducing spills, waste, under-application, and other measurement errors. Once the dry contents are poured into the spray tank, the empty packet can be disposed of in the trash without triple rinsing. In addition the packet is made from material that is biodegradable and compostable (breaking down to humus) helping to reduce the waste stream of PMPs.

In conclusion, the three technology areas where DuPont has been actively working to provide innovation are AI, formulation, and packaging; we continue to research improvements in these three areas. Product application technology is another area that will be added to our portfolio. In the near future we hope to introduce yet additional innovations for PMPs.

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LOW-IMPACT TERMITE TREATMENT

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Low-impact termite treatment is now possible due to the materials and equipment currently available. Combining foam technologies with the newer non-repellent termiticides makes spot treatment very possible and successfully controls termites in structures.

Foam History. The use of foam as a means of getting termiticide to termites has been around for many years. Foam was used in 1965, if not before, in China for the control of Formosan subterranean termites by completely filling the void space under houses. This treatment targeted the tunneling of termites and was called ‘tunnel killer’.

In 1975, Orkin® started testing foam treatment for controlling termites using a foaming machine that was made by Fulton Exterminators, Little Rock, Arkansas; this machine worked, but very poorly. After making modifications to the foaming machine, we tested it in Florida using chlordane from 1976 until 1981. We had great success using this tool, with the exception of one major problem, ODOR, which forced us to stop using it.

After chlordane was removed from the market, we needed something to help against termites, so in 1987, Orkin® began redeveloping foam technology with Foam Innovations, San Jose, California. This company made foaming equipment to use in city drains for root control.

In 1990, Orkin® started their foam program in the southeastern United States, where termite occurrences are the greatest. Delivering Dursban® TC as the primary termiticide in combination with foam proved to be very successful in knocking out tunnels and giving better distribution of diluted termiticide. Re-treats were reduced by more than 15% in the test area. In 1991, foam as a part of subterranean termite treatment was made available to all of Orkin® and the industry.

Working with Formosan subterranean termites in carton located in structures, dry foam machines and specifications were introduced in 1992. Great progress was

made at getting at the termites via a contact termiticide rather than a soil barrier type termiticide.

Foam Treatments. Recent tests to evaluate foaming, foam agent, water and air indicate success in controlling many insects, including ants, bees, wasps, flies, and termites. Additional testing is needed to verify success against many other insects. Foam mixed with a pesticide seems to work as a synergist. Direct application of pesticides is enabled using foam in voids, cracks, and insect galleries. Pesticide life is much longer when pesticides are applied inside protected areas that shield them from light, sun, temperature, air, and disturbance.

Using a wet foam mixed with pesticide to treat one-foot- up and one- foot-out on exterior foundation walls has shown great results in controlling ant infestations. Foaming through and under mulch has shown good insect control using foam alone or foam mixed with pesticide; fire ants are a good example where good control has been obtained without the use of pesticide, just foam.

Termiticides applied in foam have shown great success in controlling subterranean and drywood termites when applied directly to the areas where the termites are located, such as under slab voids, bath traps, behind brick veneer, in wall voids above slabs, wall voids above the floor, door frames, and window cases. Treatment in these areas using non-repellent termiticides has shown good results in controlling infestations, both inside and outside of structures. Colony elimination has not been substantiated, but structural control of termites has been achieved.

CASE HISTORIES FROM A 10-YEAR PROGRAM AIMED AT DEVELOPING AN INTEGRATED PEST MANAGEMENT APPROACH FOR SUBTERRANEAN TERMITES

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The Household and Structural Entomology Research Program at the University of Georgia has conducted all termite treatments on the main campus in Athens, GA, since 2000. There have been 57 interventions conducted at 43 building in the nine years of data compiled for this report. Ninety-three percent of the infestations were identified by a swarming event and the remaining 7% were noticed during repairs/remodeling. *Reticulitermes flavipes* were responsible for 92% of infestations, with 7% for *R. virginicus*, and the remainder *R. hageni*. Expansion joints provided entry into the structure in 89% of the infestations with both gaps in stone foundation and wood-to-ground contact providing 5% each. Interventions included, doing nothing, landscape alterations, construction alterations/repairs, baits and liquid termiticide

applications as well as combinations of several intervention types. Measures of success, using the terminology of Greene and Breisch (2002), ranged from 100% for the methodological approach and 72-95% depending on the ideological definition. This effort has demonstrated acceptable management of subterranean termites using 99% less active ingredient compared to what is required by Georgia Department of Agriculture Regulatory Standards.

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SYMPOSIUM

SOIL ENVIRONMENT AFFECTING EFFECTIVENESS OF TERMITICIDES

Organizer:

Shripat Kamble (University of Nebraska)

TERMITICIDE ANALYSIS: FROM CHLORINATED HYDROCARBONS AND BEYOND

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Termiticide analysis has been of interest to scientists for more than five decades. The desire to detect, quantify, and confirm these pesticides in the environment has been the goal of chemists and biologists alike. While the technologies associated with such analyses have made the process somewhat easier, correctly interpreting the results of this work has become increasingly more difficult. The beauty of mathematics, chemistry, and biology are based on the pure simplicity of accurate data, while the reality of reporting the same results has unfortunately become subjected to political meddling, and perceived misuse of the information from organizations with an agenda. The effective use of the equipment involves a skill set that includes chemistry, physics, mathematics, heating/air conditioning, plumbing, and electrical knowhow. In addition, according to some students, religion plays a role because, "It is a miracle!" if the instruments work well throughout the entire project.

No one is advocating that we return to the procedures and equipment of the past such as having to do hand calculations, frequent calibrations and dilutions, and weighing out the peaks from a chromatogram, but such exercises do instill a certain understanding and appreciation for what the instruments and detectors actually are doing. Present day automated chem-stations with attenuations and integrators can produce estimates of the amounts of pesticides in a sample, but it takes a "gut" feeling from the chemist to sense that the data are realistic and accurate.

Proper environmental sampling for termiticides is as important as proper calibration of the chem-station. Sampling must be representative of the application, and samples must be properly cared for at all stages in the analytical process. Sampling is actually an “art form”, and collection and preservation of samples should follow the rule of many, which states “It is better to have 1,000 too many samples rather than one too few.”

The methods development aspect of termiticide analysis is best initiated by a thorough literature review. The manufacturers of the chemicals generally have been very helpful in making suggestions in terms of extractions and the parameters for actual analysis. Regulatory agencies are also invaluable when preparing for a project, as are the manufacturers of the instruments that are to be used. The most efficient system for the development of project methods is to take the best advice available, and then modify it for a specific instrument, and the capabilities of the operator. When it comes to methods development, the “principle of parsimony” should be followed. That is, the more steps there are in any process, the higher the probability of errors.

While it is sometimes misunderstood by the general public, and some researchers, the analytical instrument does not give the concentration of the termiticide directly. It is only through serial dilutions of standards that the comparison between a known concentration of a specific chemical is made with the unknown sample. Stated another way, every response in pesticide analysis is proportional to something that is assumed to be correct, i.e., a standard. Because of this concept, when data sets are reviewed for validation of accuracy, the number, concentration, and linearity of the standard are very important. There sometimes has been a tendency to reduce analytical costs by limiting the number of standards. This practice could adversely affect the validity of the analysis.

The instrument used for the termiticide analysis must be correct for the chemical composition of the pesticide as well as the solvents used to separate the chemical from any substrate. There are several excellent instruments available to do termiticide analysis, but thought needs to be given to the level of detection desired as compared to the cost of the equipment and the abilities of the technicians doing the work. It is possible to spend more money than is needed to get a specific range of results. Every instrument and method will have a “limit of detection”. Regardless of the price, that limit must be determined at the initiation of the study.

What has been learned through practical experience with termiticide analysis is that it can be expected that all insecticides degrade through time. There are many factors that affect this degradation, but termiticides do not increase in efficacy after initial application. The mean number of years of effectiveness under Texas soil and temperature conditions is five. The minimum concentration of termiticide that will be effective in either killing or repelling termites is dependent upon the chemical structure, mode of action, and formulation of the product. It is not determined by marketing or enforcement strategies. The value is what it is, not what someone wants or claims it

to be. The best estimate of the minimum concentration should be based on chemical analysis coupled with bioassays using termites. It is possible to measure the amount of termiticide in soil, but that amount may not be biologically important, particularly if the concentration is below the minimum concentration needed, or if the residue is so tightly bound to the soil that it is not available to foraging termites.

There are many challenges associated with extracting termiticides from complex substrates, but with enough resources, it can be done...even if the results are not biologically important. The interpretation of analytical results can be debated, but the outcome of the research should be independent of the contractor. The essence of science is to discover and report accurate data; the political ramifications should be left to others. Integrity is something that out-lasts the most recent marketing or enforcement program. Stated another way, data should be of pure intent; politics is what gums it up.

RE-EVALUATING INSECTICIDES APPLIED TO SOILS TO CONTROL SUBTERRANEAN TERMITES

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The use of chemicals applied to soil has been the primary recommendation for controlling subterranean termites for the past 100 years (Peterson et al. 2008, Potter 1997). For nearly a half century, the application of organochlorine insecticides such as chlordane, heptachlor, aldrin, and dieldrin to soil provided an inexpensive and persistent barrier to protect structures from subterranean termites (Potter 1997, Su and Scheffrahn 1998). With the loss of organochlorine termiticides in the U.S. in 1988, there has been a continuous evolution of insecticides registered for subterranean termite control (partially reviewed by Rust 2001, 2010; Kard 2003).

Insecticides used to control termites have been placed into three distinct categories by Su et al. (1982, 1987). Soils treated with Type I insecticides (fenvalerate, permethrin, resmethrin, and pyrethrins) are repellent and only small numbers of termites die because of exposure. Type II insecticides (diazinon, chlorpyrifos, chlordane, and carbaryl) quickly kill termites entering the treated zones with some individuals dying and being sealed off in the treated tunnels. Termites continually entered soils treated with Type III insecticides (hydramethylnon, avermectin B₁) and died in areas away from the treated soil. Since Su's publications, many additional active ingredients have been registered for subterranean termite control (Table 1). Type III insecticides with delayed toxicity can be further divided into two groups: those displaying dose-independent and dose-dependent toxicity (Table 2) (Rust and Saran 2008). The dose-

independent toxicants (diflubenzuron, hexaflumuron, and noviflumuron) are the most effective baits because mortality is dependent upon the amount of active ingredient present only when termites molt. The slow-acting toxicants such as chlorfenapyr, fipronil, imidacloprid, and indoxacarb provide dose-dependent mortality, but at low concentrations they allow for the possibility of horizontal transfer of the toxicant.

The physical attributes of insecticides applied to soils are extremely important because they affect their bioavailability to termites. The water solubility and the topical contact toxicity (Rust and Saran 2008) of many of the recently registered insecticides against subterranean termites have increased compared with organochlorine chemistry. In general, the octanol-water partition coefficients (K_{ow}), soil absorption coefficients (K_d , K_{oc}), and soil half-lives have decreased. Higher water solubility and decreased K_{oc} increase the likelihood the active ingredients will move thorough soil. However, factors such as soil type and aging may affect the K_{oc} . Hydrophilic insecticides with low K_{ow} values are less likely to bind to lipid surface layers of insects such as termites.

Table 1. Insecticides (chemical class) registered for termite control in the U.S. since 1988^a

Type I		Type II		Type III	
Acetamiprid	(NE)	Chlorpyrifos	(OP)	Diflubenzuron	(CSI)
Bifenthrin	(PY)	Isofenphos	(OP)	Disodium octaborate tetrahydrate	(I)
λ -Cyhalothrin	(PY)			Chlorfenapyr	(CP)
Cypermethrin	(PY)			Fipronil	(PP)
Esfenvalerate	(PY)			Hexaflumuron	(CSI)
<i>d</i> -Limonene	(OT)			Hydramethylnon	(AH)
Permethrin	(PY)			Imidacloprid	(NE)
				Noviflumuron	(CSI)
				Sulfluramid	(FS)

^aAdapted from Su et al. (1982, 1987). AH = amidinohydrazone, CSI = chitin synthesis inhibitor, CP = cyanopyrrole, FS = fluorinated sulfonamide, I = inorganic, NE = neonicotinoid, OP = organophosphate, OT = orange terpene, PP = phenylpyrazole, PY = pyrethroid.

Table 2. Type III slow-acting insecticides (chemical class) with dose dependent and dose independent activity^a

Dose dependent	Dose independent
Disodium octaborate tetrahydrate (I)	Diflubenzuron (CSI)
Sulfluramid (FS)	Hexaflumuron (CSI)
Chlorfenapyr (CP)	Noviflumuron (CSI)
Fipronil (PP)	
Hydramethylnon (AH)	
Imidacloprid (NE)	
Indoxacarb (OX)	

^aAH = amidinohydrazones, CSI = chitin synthesis inhibitor, CP = cyanopyrrole, FS = fluorinated sulfonamide, I = inorganic, NE = neonicotinoid, OX = oxadiazine, PP = phenylpyrazole.

Studies conducted by Potter and Hillery (2001, 2002) suggested that fipronil and possibly imidacloprid exhibited area-wide effects on subterranean termites. Observations by Kard (2003) of decreased termite activity in control plots adjacent to fipronil-treated plots may lend creditability to claims of area-wide effects. It has been suggested that the horizontal transfer of the toxicant is responsible for this effect. The transfer of toxicant is due to direct contact during grooming and mutual interactions (Haagsma and Rust 2007; Rust and Saran 2006, 2008; Saran and Rust 2007). However, this effect is limited to a distance of 1-6 m from the treated structure (Saran and Rust 2007, Su 2005). As Kuriachan and Gold (1998) reported, it is probably the non-repellent nature of the treatment and the delayed toxicity that contribute to the effectiveness of these barriers. Termites actively tunnel and acquire lethal doses of toxicant. Consequently, workers continue to encounter lethal barriers and populations are dramatically affected.

The new Type III termiticides exhibit dose-dependent toxicity, but have delayed activity at lower concentrations. Delayed toxicity was responsible for the increased mortality in tunneling studies with fipronil and thiamethoxam (Remmen and Su 2005). Researchers have reported on the ability of Type III termiticides to affect locomotion, tunneling, grooming, and other social interactions. For example, exposure to imidacloprid-treated soils inhibits feeding and locomotion in termite workers (Haagsma and Rust 2007, Ramakrishnan et al. 2000, Thorne and Breisch 2001). At low concentrations (1-5 ppm), fipronil is transferred from exposed workers to unexposed nestmates (Ibrahim et al. 2003, Tsunoda 2006, Saran and Rust 2007).

Remedial soil treatments with insecticides will continue to be an important element in the pest management of subterranean termites. Environmental concerns and the public's interest in so-called "green pest control," will stimulate the continued development and registration of "reduced risk insecticides." Their incorporation will necessitate changes in termite integrated pest management (IPM) control strategies in the future.

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SORPTION AND DESORPTION OF FIPRONIL IN MIDWESTERN SOILS

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Fipronil, {5-amino-1-[2, 6-dichloro-4-(trifluoromethyl)phenyl]-4-[(trifluoromethyl)sulfinyl]-1H-pyrazole-3-carbonitrile} is commonly applied to soil to protect structures against termite infestations. The fate and bioavailability of fipronil in soil is dependent upon the variability of sorption processes and will differ from soil to soil. Adsorption of fipronil to three Nebraska soils with varying organic matter (OM) content was determined. At the concentrations tested (0.025, 0.1, 0.25, 0.5, 1.0, 1.5, and 2.0 mg L⁻¹), adsorption curves showed constant partitioning of fipronil to the soil matrices ($r^2 = 0.998-0.999$). Calculated organic carbon partitioning coefficients (K_{oc}) ranged from 244 to 628 with a mean of 396. Reported K_d and K_f values increased with increasing organic matter content. Desorption hysteresis was observed as fipronil has a propensity to stay in the adsorbed state. After five soil washes with 0.003 M CaCl₂, ~30% of adsorbed fipronil residues were desorbed. Reported K_{oc} values for fipronil suggest that it has intermediate mobility in the field-collected soils utilized in this study. These K_{oc} values were derived from technical grade fipronil at much lower concentrations than those of the formulated product commonly used for termite control.

SUBTERRANEAN TERMITE-SOIL PATHOGENS INTERACTIONS

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Biological control in subterranean termites has long been considered as a suitable measure for managing these structural pests. A wide range of microorganisms such as fungi, bacteria, and nematodes were tested against subterranean termite for pathogenicity but despite many promising laboratory results, biological control for subterranean termites was never achieved in the field. One of the reasons for such failure is that, in natural conditions, subterranean termites coexist with a wide range of soil microbial organisms and appear to be adapted to the presence of soil entomopathogens.

Our recent work showed that termites evolved disease resistance mechanisms to prevent the occurrence of epizootics in the colony, and it now appears obvious that the soil microenvironment in the termite gallery is not conducive for pathogens to disperse, replicate and survive within the colony. Because subterranean termites have the ability to manipulate their soil environment to a highly modified ecosystem, express behavioral, chemical and immunological response to disease agents, there is a need to bypass these defense mechanisms for successful biological control with entomopathogens.

SOIL/CHEMICAL INTERACTIONS AFFECTING TERMITICIDE PERFORMANCE

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Interactions of a termiticide with constituents of the soil environment affect the distribution of the chemical in the soil profile, its lifetime, and its availability for control of termites. While soil is a complex, inhomogeneous mixture of inorganic substrate and organic matter mixed with water and air, the chemical and physical properties affecting the mobility and degradation are usually measured by methods that lump together several processes. The key properties describe the sorption of the termiticide as a partition coefficient, i.e., the soil sorption coefficient, and the degradation rate of the termiticide by a half-life. Sorption and degradation have been shown to be linked, and the development of kinetic models based on distribution of chemicals between protected and bioavailable compartments has accompanied observations of non-linear sorption and biphasic degradation, suggesting that degradation of the chemical by microbes may become less significant as the residues age in soil. Sorption and degradation properties may be used in models that combine hydrology and chemical fate to predict mobility, patterns of residue decline and formation of metabolic products. Combining predicted concentrations with effects endpoints allows predictions of the duration of termite control and the potential for termites to avoid exposure. While chemical and physical properties and environmental fate models have great power to describe general patterns of mobility and degradation, the limitations of the modeling illustrate why understanding the effect of site specific factors, application methods and mechanisms of termite exposure are essential to developing effective termite control products.

MOBILITY OF FIVE TERMITICIDES IN SOIL COLUMNS

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The objective of this study was to evaluate the mobility of five termiticides, imidacloprid, chlorpyrifos, permethrin, fipronil, and chlorfenapyr, upward through packed soil columns, which stood upright in the termiticide solutions. The upward movement of a termiticide through a soil column provides information on the capacity for the termiticide to move with water laterally through soil. The insecticides were applied at specified

commercial application rates. Imidacloprid was the only compound detectable at a concentration of more than 1 mg kg⁻¹ at a 30-cm distance from the treatment source. Relative concentrations, based on percent extracted from the column, indicated that imidacloprid was distributed throughout the first 20 cm of the column and maintained moderate concentrations through the remainder of the column. Chlorpyrifos distributed well through the first 12.5 cm, and then decreased to very low levels at distances further than 12.5 cm. Chlorfenapyr and fipronil concentrations decreased rapidly in the first 10 cm, maintained moderate concentrations from 15 and 20 cm, respectively, and then fell below detectable limits. Permethrin demonstrated the least mobility.

Introduction

Subterranean termites cause extensive damage and repair costs to wooden structures. To protect wooden structural materials, termiticides are applied to the surface and/or injected into soil to form a chemical barrier. The extent of coverage of the chemical barrier against termites in the soil depends on the lateral movement of a termiticide active ingredient (AI) through soil. The objective of this research was to measure the movement of five termiticides: imidacloprid (AI in Premise® termiticide), chlorpyrifos (AI in Dursban®), permethrin (AI in Dragnet®), fipronil (AI in Regent®), and chlorfenapyr, through soil as measured by movement upward with water through soil columns. Upward movement of imidacloprid, chlorpyrifos, permethrin, fipronil, and chlorfenapyr by capillary action through packed soil columns provides basic information on their mobility through soil, but also sheds considerable light on the capacity for the five insecticides to move with water laterally through soil.

The mobility of a termiticide laterally is important to the establishment of the chemical barrier against termites. Researchers have conducted some investigations on the mobility of imidacloprid, chlorpyrifos, permethrin and fipronil. Imidacloprid was classified to have a medium to slight mobility (McCall et al. 1980). Chlorpyrifos was classified as being “immobile” (McCall et al. 1980). Permethrin was immobile in the soil columns (Smith and Willis 1985). Fipronil was reported to not move beyond 10 cm (Bebé et al. 1998). However, there has not been a study focused directly on the comparative mobility of the five major termiticides in a single soil type. Knowledge of their relative mobility may help explain efficacy and help predict environmental fate of these insecticides.

Materials and Methods

Chemicals. Formulated products Premise® 75 WP, Fipronil 80 WP, Chlorfenapyr 10% EC, and Dragnet® were provided by Bayer Corporation (Stilwell, KS). Dursban® TC was purchased from Dow Agroscience Corporation (Indianapolis, IN). ¹⁴C-imidacloprid was also obtained from Bayer Corporation. The percentages of active ingredient were 75% imidacloprid for Premise® 75 WP, 80% fipronil for Fipronil 80 WP, 10% chlorfenapyr for Chlorfenapyr 10% EC, 38% permethrin for Dragnet®, and 42.8% chlorpyrifos for Dursban® TC.

Analytical standards of fipronil (98.0% purity), chlorpyrifos (99.2% purity), and permethrin (99.0% purity) were purchased from ChemService Corporation (West Chester, PA). The analytical standard of chlorfenapyr was purified from formulated Chlorfenapyr 10% EC, and the purity of the standard was greater than 95% based on proton nuclear magnetic resonance analysis. Premise® 75 WP was prepared as 0.05% solution by adding 1.348 g of the formulated product to two liters of ultrapure water. Then the solution was spiked with 8.71 μCi of the ^{14}C -imidacloprid (purity of 98.0%) to obtain a radioactive concentration of 0.0044 $\mu\text{Ci/mL}$. Fipronil 80 WP was prepared as 0.06% solution by adding 1.498 g of the formulated product to two liters of ultrapure water. Chlorfenapyr 10% EC was prepared as 0.0625% solution by adding 12.1 mL of the formulated product to two liters of ultrapure water. Dragnet® was prepared as 0.5% solution by adding 26.0 mL of the formulated product to two liters of ultrapure water. Dursban® TC was prepared as 1% solution by adding 40.8 mL of the formulated product to two liters of ultrapure water. The concentration of each compound was based on the active ingredient. The calculated concentrations of imidacloprid, fipronil, chlorfenapyr, permethrin, and chlorpyrifos in the water were 506, 599, 624, 4990, and 9783 mg L^{-1} , respectively.

Soil. The soil was collected from the top 15 cm of an agricultural soil, a sandy clay loam, from a control plot at the Iowa State University Ag Engineering/Agronomy Farm (Boone County, IA). The soil for this study was classified as Nicollett Webster. It contained 52% sand, 26% silt, and 22% clay. The organic matter content was 2.7%, and the pH was 5.7. Each soil column was prepared by packing 7.0-cm diameter by 38-cm length clear acrylic tubes with 30 cm of soil, packed at a density of 1.3 g cm^{-1} . The bottoms of the soil columns were fit with a fine-mesh screen to hold the soil in the tube. The columns were stood upright in glass dishes of the prepared termiticide solutions, and a magnetic stirring bar was added to each dish to keep the chemical solution as uniformly distributed as possible for the duration of the experiment. Four replicate columns were used for each insecticide.

Analysis. The frozen columns were sawed into 2.5-cm sections such that the solid columns were divided into 12 sub-sections (i.e., the bottom and the top section of a column was defined as section 1st and 12th, respectively). The soil from each 2.5-cm section was removed from the section of the acrylic tube. After it thawed, the soil was dried at room temperature until the moisture was below 16.6%. Two 20-g (wet weight) subsamples were taken from each section for extraction. Optimization of extraction efficiency for the five insecticides resulted in the following methods. Imidacloprid, permethrin, and chlorpyrifos were extracted with acetone; fipronil was extracted with acetone + acetonitrile (3 + 7 by volume); and chlorfenapyr was extracted with ethyl acetate. After shaking, the solvent was removed from the soil by vacuum filtration through a glass micro-fiber filter. All three extracts were pooled and concentrated with a rotary evaporator. Extraction efficiencies (\pm standard deviation) for imidacloprid, chlorpyrifos, permethrin, fipronil, and chlorfenapyr were 96 ± 1.5 , 103 ± 5.8 , 101 ± 5.4 , 100 ± 8.7 , and $105 \pm 8.2\%$, respectively, for laboratory-fortified samples. An aliquot from each ^{14}C -imidacloprid-extract was added to scintillation cocktail and was

radioassayed. Fipronil extracts were solvent-exchanged to isooctane by addition of ethyl acetate + isooctane (2 + 1 by volume) and evaporation of lighter solvents using a stream of nitrogen. Solvent exchange was performed to remove acetonitrile, which interferes with the detection technique used.

A Shimadzu GC-9A gas chromatograph equipped with a flame-thermionic detector, a nitrogen and phosphorus-specific detector (NPD), was used for the analysis of fipronil, chlorpyrifos, and chlorfenapyr. GC conditions were as follows: column, glass packed with 80/100 mesh 3% OV-17 (Supleco Inc., Bellefonte, PA), 1.2 m length x 3 mm i.d.; column temperature, 220°C; injector temperature, 250°C; detector temperature, 250°C; carrier gas, helium; flow rate 60 mL min⁻¹. The quantitation limit = (the concentration (µg mL⁻¹) of the standards required to give a signal-to-noise ratio of 5:1) x (10 ml of the soil extract)/20 g soil. The limit of quantitation for fipronil, chlorpyrifos, and chlorfenapyr was 0.5, 0.2, and 1.3 mg Kg⁻¹ soil, respectively. Permethrin extracts from sections 1-5 were analyzed using a Hewlett Packard 1100 liquid chromatograph equipped with a C₁₈ µ-Bondapak column (Waters) and a Spectroflow 757 absorbance detector set at 225 nm. The limit of quantitation for permethrin by the HPLC was 5.8 mg kg⁻¹ soil; then samples of section 6 and 7 were analyzed using a Tracor 540 gas chromatograph equipped with a ⁶³Ni electron-capture detector (ECD). The data were statistically analyzed by analysis of variance (ANOVA) and least significant differences (LSD) at 5%.

Results

The concentration of each chemical at each section of each soil columns is shown in Table 1. Imidacloprid was more mobile than the other four compounds as indicated by the significantly greater concentrations in section 9 and higher. Imidacloprid was detectable throughout the column and maintained a mean concentration of 3.0 mg kg⁻¹ at the top section of the columns. Since each termiticide was applied at recommended concentrations and therefore differing rates, relative concentrations were also determined by dividing the concentration in each section by the total amount found in the column. The termiticides were concentrated toward the bottom of the column, as would be expected. Compared to the other four insecticides, imidacloprid distributed more evenly throughout the column, as indicated by lower percentages in the first sections and higher percentages through much of the remainder of the column. Chlorpyrifos only distributed well through the first four sections (10 cm). Chlorfenapyr and fipronil concentrations decreased rapidly in the first several sections, maintained good relative concentrations from the fifth through eighth sections (12.5 to 20 cm), then fell below detectable limits. Permethrin demonstrated the least mobility and was mostly found in the bottom of the column.

Table 1. Mean (\pm SD) concentration (mg kg⁻¹) of each termiticide per section^{a,b}

Section	Height, cm	Imidacloprid	Fipronil	Chlorfenapyr	Chlorpyrifos	Permethrin
12 th	27.5-30.0	3.0 ^B (1.4)	<QL ^A	<QL ^A	<QL ^A	<QL ^A
11 th	25.0-27.5	1.3 ^B (0.7)	<QL ^A	<QL ^A	<QL ^A	<QL ^A
10 th	22.5-25.0	2.6 ^B (0.6)	0.2 ^A (0.1)	<QL ^A	0.1 ^A (0.2)	<QL ^A
9 th	20.0-22.5	2.3 ^B (1.3)	0.1 ^A (0.1)	<QL ^A	0.2 ^A (0.1)	<QL ^A
8 th	17.5-20.0	1.9 ^{AB} (0.3)	3.3 ^B (2.8)	<QL ^A	0.8 ^A (0.8)	<QL ^A
7 th	15.0-17.5	1.1 ^A (0.7)	4.8 ^B (2.3)	<QL ^A	0.9 ^A (0.5)	0.3 ^A (0.2)
6 th	12.5-15.0	11 ^A (15)	10 ^A (3.1)	12 ^A (10)	2.6 ^A (2.1)	0.6 ^A (0.2)
5 th	10.0-12.5	53 (15)	17 (1.0)	25 (19)	155 (112)	25 (13)
4 th	7.5-10.0	196 (5.6)	24 (6.0)	40 (6.0)	1275 (496)	457 (284)
3 rd	5.0-7.5	335 (9.9)	55 (10)	58 (16)	3484 (592)	728 (162)
2 nd	2.5-5.0	449 (25)	159 (73)	98 (31)	6517 (524)	1944 (600)
1 st	0-2.5	558 (21)	1068 (334)	473 (203)	10573 (1401)	11227 (2679)

^aMean of four replicates.^bMeans in each row followed by a different letter are statistically different ($P < 0.05$).

Discussion

Adsorption and water solubility are the principal factors that affect the mobility of organic compounds (Kaufman et al. 1981, Sharom et al. 1980). The higher the adsorption of a compound is, the less mobile it is (Sharom et al. 1980, Laabs et al. 2000). Generally speaking, if a compound has a relatively high water solubility, it is likely that the compound is weakly adsorbed to soil and is somewhat mobile in soil. All the five termiticides except imidacloprid have a low water solubility, ranging from 0.1 to 2 mg L⁻¹. Imidacloprid has a higher water solubility (510 mg L⁻¹). The organic carbon normalized soil adsorption coefficients (K_{oc}) of imidacloprid, chlorpyrifos, permethrin, fipronil, and chlorfenapyr are 259, 8498, 81600, 825, and 11500 mL g⁻¹, respectively. The water solubility and K_{oc} of the five compounds would predict a higher mobility potential of imidacloprid and lower mobility potential of the other four termiticides in soil. Our results showed that imidacloprid distributed most thoroughly through the soil column. González-Pradas et al. (1999) reported that 82.3% of the applied imidacloprid was recovered in the leachate of their 20-cm soil columns. The movement of chlorpyrifos in the current study is greater than that in previous research, which showed that the majority of chlorpyrifos did not leach more than 2.5 cm (Fermanich and Daniel 1991). Permethrin distributed the least well through the soil columns, similar to earlier studies (Smith and Willis 1985, Kaufman et al. 1981). Fipronil moved 25 cm in the current study. Others reported that fipronil did not move beyond 10 cm (Bebé et al. 1998).

Mobility of chlorpyrifos, permethrin, and fipronil in the current study was higher than that previously reported in the literature. One possible reason is that different soils have different organic matter contents and clay contents, which influence the adsorption of the chemicals to the soils. A second reason is that the concentrations of the applied chemicals were very high in this study. Adjuvants in the formulated commercial products

can also play a role in influencing mobility of the treatment solution and the active ingredient. A concentration of 1 mg kg⁻¹ of each of the five insecticides can inhibit the tunneling of some termite species in soil or kill certain termite species. Therefore, the data in Table 1 indicates that imidacloprid may provide better termite-protection than the other four insecticides at distances further from the treatment source. Under conditions of upward mobility investigated in this experiment, imidacloprid showed the greatest mobility.

Conclusions

Imidacloprid, the active ingredient in Premise® termiticide, was demonstrated to be distributed through the soil to a greater distance than the four other termiticide Als tested in this study. Although the experiment monitored upward mobility of the Als, the results also would reflect the relative mobility of the insecticides laterally through the soil.

Acknowledgements

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FACTORS AFFECTING THE INITIAL DISTRIBUTION OF TERMITICIDES IN SOIL

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The initial penetration of termiticide formulations into soil determines the thickness and concentration of the active ingredient in a chemical barrier, which affects the barrier's efficacy and longevity.

The first of the two studies reported here examined the effects of soil type and soil moisture on initial active ingredient penetration. This study was based on the hypothesis that a pesticide solution should penetrate differently in soils that differ in silt, sand, clay, and organic matter content. In addition, it was supposed that the application solution would penetrate more deeply in soils with higher moisture content. Both of these factors affect the thickness of the chemical barrier. Suspensions of termiticide were applied at the recommended label rate to soil of known texture and moisture. Soil samples were then taken at 1-cm intervals and analyzed for active ingredient content. There were no qualitative differences in initial penetration between active ingredients (fipronil and imidacloprid) and few qualitative differences based on soil type. In each case, the active ingredient in the top 1 cm of soil was highest in the drier soils, while the active ingredient penetrated more deeply in moister soil (Peterson 2009).

The second study reported the effects of suspension concentration and application volume on initial penetration. Three suspensions of each product were prepared, the first at one-half the labeled rate to be applied at double the labeled application volume, the second at the labeled rate to be applied at the labeled volume, and the third at twice the active ingredient concentration but applied at one-half the application volume. The suspensions were applied to different soil types of uniform soil moisture and then the soil was sampled at 1-cm intervals and analyzed for active ingredient concentration. The active ingredient concentration in the top 1 cm of soil was highest when the application suspension was more concentrated but applied at a lower volume. Penetration was deeper, however, when the active ingredient concentration was reduced but the suspension was applied at a higher volume (Peterson 2010).

Thinner barriers of higher initial concentration were formed either in dry soil or when a more-concentrated suspension was applied at a lower volume. Thicker barriers of lower initial concentration were formed either in moist soil or when higher volumes of less-concentrated suspensions were applied.

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DISTRIBUTION OF TERMITICIDES FOLLOWING SUB-SOIL APPLICATION AS AFFECTED BY SOIL TYPE

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The effects of soil type (sandy loam and silty clay loam), and rodding tool tip (straight, 360°, 180° [3.8 and 7.6 liters/min]) on the distribution of Dursban® TC (chlorpyrifos), Dragnet® FT (permethrin) and Premise® 75 (imidacloprid) were studied. Water diluted Dursban (1.0% active ingredient [AI], 6.06 l), Dragnet (Permethrin 0.5% AI, 6.06 l) or Premise 75 (0.05% AI, 6.06 l) were applied to soils per rodding point with a B&G® rodding application tool (1.22 m) using a constant application pressure (172.4 kPa). No significant differences in termiticide distribution resulted from the rodding tip or soil type. In all applications, the largest termiticide concentrations were located within 0.15 m of the injection site 0-1.22 m below the soil surface. Generally, lesser termiticide quantities were detected in the soil with an increase in distance from the injection point. Based on these results, rodding hole spacing 15 cm apart will provide sufficient termiticide overlap. This will create a continuous soil termiticide barrier from 0.0-1.22 m beneath the soil surface along a structure's foundation for protection from subterranean termites. Rodding spacing of 30 cm will provide a continuous barrier 0.61-1.22 m below the surface, but may result in untreated soil areas between the soil surface and the treated soil (0.0-61.0 m). Important differences in initial insecticide distribution are not expected regardless of the rodding tip selection or within these soil types.

Validity of using a water soluble fluorescent dye to estimate distribution patterns of termiticide in Nebraska soils after rodding was investigated. Each of the three termiticides at finished solutions and Pylam® D&C Green #8 (hidacid uranine 0.5% AI) were concurrently applied. The dye was easier to visually detect in the sandy loam (>83 ppm @ 90% probability) than in the silty clay loam (>143 ppm @ 90% probability). Dye distribution patterns in soils were similar to those observed for the termiticides.

For example, in the sandy loam, visual dye (>83 ppm) and imidacloprid (>1.00 µg/g) were distributed similarly in 88.8% of the soil samples. In the silty clay loam, visual dye (>143 ppm) and imidacloprid (>1.00 µg/g) were distributed similarly in 83.7% of the soil samples. Visual dye may be used as a conservative estimator of termiticide distribution in the silty clay loam. However, caution should be exercised when using dye in predicting termiticide distribution in sandy loam soils since it may overestimate initial insecticide lateral dispersion.

SYMPOSIUM

VESPID PESTS IN THE URBAN ENVIRONMENT: THREATS AND OPPORTUNITIES

Organizer:

**ElRay Roper (Syngenta Professional
Pest Management)**

EVALUATIONS OF COMMERCIAL TRAPS AND BAITS FOR VESPID WASPS IN COLORADO

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Seven commercially available traps marketed for control of yellowjackets were tested for ability to collect pest vespids in Colorado and to note captures of non-target organisms. Highest numbers of vespids (*Vespula atropilosa*, *V. pensylvanica*) were captured in the Safer® Brand Deluxe Yellowjacket/Wasp™ Trap. In contrast, the Raid® Disposable Yellow Jacket Trap was completely ineffective. Comparison of three reusable traps using identical heptyl butyrate lures showed a range in vespid captures: Sterling Rescue!® Yellowjacket Trap > Safer® Brand Deluxe Yellowjacket/Wasp™ Trap > Victor® Yellow Jacket Trap. Comparison of the attractiveness of lures provided with these same traps, but used in a standard trap (Sterling Rescue! Yellowjacket Trap), showed a similar range in vespid capture: Sterling Rescue! > Safer® Brand Deluxe > Victor® Yellow Jacket Trap. The use of the Waspinator®, a purported mimic of a *Dolichovespula* nest, did not deter recruitment to yellowjacket traps. None of the traps was effective for the European paper wasp, *Polistes dominula*, which has rapidly emerged as a dominant and ecologically significant species since it colonized Colorado approximately a decade ago.

TOWARDS THE DEVELOPMENT OF A READY-TO-USE YELLOWJACKET BAIT

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Yellowjackets are a significant pestiferous species, causing painful and sometimes deadly stings in humans and causing ecological damage in places where they are invasive. Traps are commonly used to control these pests, but they do not effectively reduce the foraging population and do not kill the nest. Baits are easy to use, ecologically friendly, and are more effective at killing the nest, but there have been difficulties in their development. Our aim was to develop a highly palatable and attractive bait that is easy to manufacture and use. We screened different meat products for their palatability and attractiveness and selected a meat product to use in our bait base. We also examined how bait texture, sugar, and chemical attractants affect the palatability and attractiveness of the bait, and we present results showing the promise of this new bait matrix for effective yellowjacket control.

LABORATORY AND FIELD EFFICACY OF PRESSURIZED AEROSOL PRODUCTS AGAINST *POLISTES DOMINULUS* AND *VESPULA PENNSYLVANICA*

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Laboratory “knockdown” studies were conducted using several commercially available wasp & hornet aerosol products against caged *Polistes dominulus* and *Vespula pensylvanica*. Lethal time (LT) evaluations were utilized to determine how quickly these products immobilized and killed these stinging Hymenoptera. Product performance aspects of the aerosol application devices were investigated to determine effective and maximum distance of the product stream and coverage based on stated label claims. Field efficacy studies were also conducted to determine efficacy against these two species when treating nests in their natural environment. Colony behaviors were recorded immediately after treatment and up to three month post-treatment to determine efficacy against adult wasps and re-colonization of the nests or the sites.

CONTROLLING YELLOWJACKETS IN SOUTHERN CALIFORNIA

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We researched control of the western yellowjacket, *Vespula pensylvanica*, in southern California with baiting. Foragers take tainted meat back to their colony to feed the larvae with the result that the entire colony is killed. The bait needs to have delayed toxicity so that it doesn't kill foragers before they have a chance to make multiple trips between the colony and bait station. Fipronil (0.25%) mixed with cooked canned chicken works very well in this regard as an effective toxicant at low dose. We tested other compounds to determine if alternates could be found. Dinotefuron (0.05%, 0.025%, or 0.0125%) decreased populations 50 to 75% in the first week after deployment, but wasp populations recovered to that of the control within 1 or 2 weeks. Chlorfenapyr (0.05%) reduced the number of foragers by 18 to 28% for 2 weeks, but control was not nearly as effective as fipronil.

We also attempted virtual baiting in which wasps entered traps with the attractant (heptyl butyrate) that lacked collection jars but had a strip of cardboard treated with fipronil. The wasp enters the trap, flies around inside, contacts the treated cardboard, and eventually flies out of the holes in the trap. The contaminated wasps eventually fly back to their nest and transfer fipronil to nestmates, effecting control. Virtual baiting caused a 44% reduction in subsequent trap catch compared to controls after 3 weeks but not nearly as large as with the most successful toxic meat baiting.

OPTIGARD® FLEX LIQUID INSECTICIDE AS A CONTROL FOR VESPID WASPS

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Optigard® Flex Liquid Insecticide (thiamethoxam) was investigated as a control product against vespid wasps. Three trials (Vero Beach, FL; Provo, UT; and Modesto, CA) were conducted against paper wasps (*Polistes* spp.) and two trials (northern Florida and Greensboro, NC) against yellowjackets (*Vespula* spp.).

The *Polistes* trials used a 0.1% dilution of Optigard® Flex Liquid Insecticide and a water-only control. Nests were sprayed to run-off. Pre-counts of living adults on the nests were taken prior to treatment and post-counts were made 1, 3, and 7 d after

application. The *Polistes* trials showed comprehensive mortality of adults on the nests. Twenty-four hours after application, no living *Polistes* adults were present on the nests across the three trials. The 3-day and 7-day assessments also showed a complete lack of live adults on the nests.

The *Vespula* trials used a finished foam concentration of 0.1% of Optigard® Flex Liquid Insecticide at an expansion ratio of 10 (± 3) to 1. Prior to application, foraging activity at the nests was assessed by counting the numbers of yellowjacket foragers entering and exiting the nests. Optigard® Flex Liquid Insecticide foam was injected into the entry holes of the nests. Control nests were not treated. Twenty-four hours after application, no foraging activity was evident at Optigard® Flex Liquid Insecticide-treated nests across both field sites; all treated nests were then excavated to confirm mortality of the colonies. Nest excavation confirmed that none of the treated nests was active.

Optigard® Flex Liquid Insecticide was confirmed to be a very effective control product for vespid wasps as a 0.1% liquid formulation applied as a spray and a 0.1% finished foam solution injected into the nest.

THIAMETHOXAM FOR CONTROL OF EUROPEAN PAPER WASPS

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Wasps are common stinging pests in the urban environment that pose a serious health threat to individuals sensitive to their stings. Treatment of nests of these pests can be hazardous due to the risk of being stung while making treatments. Thiamethoxam is a neonicotinoid insecticide in the thianicotinyl subclass. In the professional pest control market, thiamethoxam is registered as Optigard® Flex Liquid Insecticide. It is currently labeled for control of ants and a variety of other nuisance pests.

A field study was conducted to evaluate its potential for control of European paper wasps. Twenty-two active paper wasp nests were identified on 10 homes in Smithfield, UT. Three treatments were compared: untreated control (sprayed with water), Optigard® Flex 0.1% applied as a low pressure spray, Optigard® Flex 0.1% applied as a foam (15:1 expansion ratio). Nests that were located in voids such as within soffits were treated with foam. Open nests were treated with a low pressure spray from a backpack sprayer.

Two hours after application, untreated nests had no reduction in numbers of active adults. Nests sprayed with 0.1% Optigard® had a 71% reduction in adult wasps. Nests foamed with 0.1% Optigard® had an 83% reduction in adult wasps.

Ten hours after application, untreated nests had no reduction in the number of active adults. Nests sprayed with 0.1% Optigard® had a 100% reduction in adult wasps. Nests foamed with 0.1% Optigard® also had a 100% reduction in adult wasps.

Fourteen days after application, all treated and untreated nests were removed and examined for the presence of viable immature wasps. All untreated nests contained viable larvae and pupae. There were no viable larvae or pupae in any of the Optigard®-treated nests.

Optigard® Flex provided excellent control of European paper wasps when applied either as a 0.1% spray or a 0.1% foam. Treated wasps did not display aggressive defensive behavior during any of the treatments.

SYMPOSIUM

**BED BUGS: NEW LESSONS ON
AN OLD PEST – WHAT HAVE WE
LEARNED**

Organizer:
Ellen M. Thoms (Dow AgroSciences)

**MORE THAN A NUISANCE:
MEDICAL AND SOCIETAL IMPACTS OF BED BUGS**

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The bed bug, *Cimex lectularius* L., has quickly become the most problematic indoor pest in the United States. Although bed bugs are unproven as disease vectors, their bites cause itching, pain and allergic reactions in sensitive individuals, which we believe comprise about 70% of the general population (Potter et al. 2010). No significant differences in reactivity were observed among people whose homes were infected relative to infestation level, gender, or ethnicity, but elderly individuals were less reactive than those who were younger. Infection may occur as a result of bed bug bites, and at least one lawsuit in California has been filed claiming a connection between the bites and methicillin-resistant *Staphylococcus aureus* (MRSA). Sleeplessness, stress, anxiety and depression are additional symptoms frequently mentioned by those we have surveyed afflicted with bed bugs.

Societal impacts range from economic hardship to embarrassment and social stigma. In a growing number of cities, agencies are receiving more complaints about bed bugs than all other pests combined, depleting municipal and state resources for other health issues. Based on a recent survey of the U.S. pest control industry (Potter et al. 2010), 95% of firms encountered bed bugs in the past year. Although incidence was most common in homes and hotels, infestations were also encountered in dormitories (mentioned by 35% of respondents), nursing homes (by 24%), office buildings (17%),

hospitals (12%), primary/secondary schools (10%), public transportation (9%), laundries (5%), and movie theaters (4%).

More than half (51%) of companies surveyed estimated that the majority of their clients had attempted to treat their bed bug problem themselves before calling a professional. Materials used included ammonia, bleach, fire, smoke, kerosene, wasp spray, bug bombs, and professional-use pesticides purchased on the internet. Besides being ineffective, such actions may cause serious injury and indicate an urgent need for public education by universities and government agencies.

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WHO IS LIVING WITH BED BUGS IN 2010?

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As bed bug infestations continue to spread, so has the public outcry for bed bug control. State and federal agencies are grappling with how to deal with this pest. Several states have recently appealed to the EPA requesting that they grant a Section 18 emergency use permit (EUP) for propoxur. The EPA's risk assessment for propoxur is not favorable, and EPA is concerned that if propoxur were granted an EUP that it would be used, or overused, in locations where children or other sensitive individuals might be placed at risk. But what about the risks associated with living with bed bugs? No one has yet attempted to conduct a bed bug risk analysis. One of the problems is that we have not yet identified those individuals or groups of individuals that are the most at risk for prolonged bed bug exposure. This presentation focuses on some preliminary data gathered from Virginia housing authorities and the public health departments to identify those demographic groups most at risk for bed bug infestations.

INSIGHTS ON BED BUG BIOLOGY AND CONTROL

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The current resurgence of bed bugs (*Cimex lectularius* L.) in the U.S. has brought significant challenges to the pest management industry. This pest is more common in multi-unit dwellings than single family buildings based on our field observations. Our studies showed that in a high-rise apartment building, bed bugs frequently dispersed into hallways with adults being nine times more likely to disperse than nymphs (Wang et al. 2010). From discovery of the first infestation, it took only 41 months for the bed bug to spread into 45% of the apartments in the building. Lack of awareness and cooperation from residents, acceptance of infested second-hand furniture, and ineffective control service contributed to the rapid spread and chronic bed bug infestations in the building. These findings along with reports from other researchers highlight the need for developing and adopting more effective community-wide integrated pest management (IPM) programs. These may include, but are not limited to, proactive building-wide monitoring, educating residents and management staff, maximizing the use of nonchemical tools, and proper application of residual insecticides. Without concerted IPM efforts, bed bugs may continue to expand in our society and become even more wide-spread, particularly in low-income communities.

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Wang, C., K. Saltzmann, E. Chin, G. W. Bennett, and T. Gibb. 2010. Characteristics of *Cimex lectularius* (Hemiptera: Cimicidae) infestation and dispersal in a high-rise apartment building. *Journal of Economic Entomology* 103: 172-177.

POTENTIAL OF CHLORFENAPYR TO CONTROL BED BUGS

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Recently, the bed bug, *Cimex lectularius* L. (Heteroptera: Cimicidae), has reemerged as a serious and growing problem, not only in North America, but globally (Krueger 2000, Boase 2001, Doggett et al. 2004, Potter 2006, Kilpinen et al. 2008). The bed bug resurgence has renewed interest in effective control tactics. Chemical options for bed bug management, however, are limited because of precautions and regulatory

restriction pertaining to insecticide treatment in areas where human exposure is possible. Furthermore, the near disappearance of bed bugs in many parts of the world reduced the interest of industry for registering insecticide products against this pest. The most commonly used insecticides for bed bug control today in the USA are pyrethroids (Potter 2008). Recent laboratory studies reported that some bed bug populations have become highly resistant to this class of insecticides (Boase 2006, Romero et al. 2007ab, Kilpinen et al. 2008, Yoon et al. 2008, Lilly et al. 2009). Molecular and synergism studies suggest that target site insensitivity and metabolic detoxification are involved as resistance mechanisms to pyrethroids in some bed bug populations (Yoon et al. 2008, Romero et al. 2009a, Zhu et al. 2010). Failure to eliminate resistant bed bugs could be a contributing factor for the spread of this pest (Romero et al. 2007a). Therefore, alternative effective insecticides for bed bug control are of great importance.

Chlorfenapyr (Phantom® SC Termiticide-Insecticide, BASF), is one of the few current insecticides with a different mode of action against bed bugs. Chlorfenapyr is a halogenated pyrrole that disrupts mitochondrial oxidative phosphorylation (Hollingworth and Gadelhak 1998). It is a pro-insecticide that must be activated by cytochrome P450 monooxygenases to its more active metabolite (Black et al. 1994). Chlorfenapyr has proved to be an effective non-repellent insecticide against a variety of medically important household insects, e.g., cockroaches, ants, horn flies, and mosquitoes (Ameen et al. 2000, Guglielmone et al. 2000, Buczkowski et al. 2005, N'Guessan et al. 2007) and structural insects, e.g., subterranean termites (Rust and Saran 2006).

Phantom® formulated as a liquid or aerosol is labeled for indoor use as a “low-pressure spot or crack-and-crevice spray that can be applied to places where pests are found or are likely to infest” (BASF 2010). Sprays of mattresses, a common location for bed bugs, are restricted to seams, folds and edges. Although chlorfenapyr is being used commercially (Potter 2008, Moore and Miller 2009, Wang et al. 2009), its effect on pyrethroid-resistant bed bugs has not been fully investigated under laboratory conditions. The only report on the efficacy of chlorfenapyr on bed bugs was conducted with a susceptible laboratory strain that had not been exposed to insecticides for more than two decades (Moore and Miller 2006). Another study showed that bed bugs did not avoid resting on chlorfenapyr-treated surfaces (Romero et al. 2009b). The objective of the current study was to evaluate the effectiveness of chlorfenapyr against both susceptible and pyrethroid-resistant strains of bed bugs. We also examined the toxicity of aged residues of chlorfenapyr to bed bugs and compared the effectiveness of two chlorfenapyr-based formulations.

Bed bugs: Insects were obtained from field-collected bed bugs maintained at 26°C, 65 ± 5% RH, and a photoperiod of 12:12 (L:D) h. Two strains used were highly resistant to deltamethrin (Romero et al. 2007ab, Romero et al. 2009a): CIN-1 (collected in 2005 in Cincinnati, OH) and WOR-1 (collected in 2007 in Worcester, MA); and two were susceptible (Romero et al. 2007ab): LA-1 (collected in 2006 in Los Angeles, CA) and Fort Dix which has not been exposed to insecticides for more than 30 years (Bartley

and Harlan 1974). Insects were fed in the laboratory through a parafilm–membrane feeder with citrated rabbit blood that was heated to 39°C with a circulating water bath (Montes et al. 2002). Evaluations began 7–12 d after adult emergence, and insects had not been fed as adults.

Evaluations with chlorfenapyr technical grade: Insects were continuously exposed to dry deposits of chlorfenapyr (0.5%) that corresponded to the label rate of the commercial formulations. Mortality was assessed daily for at least one week. Mortality of >50% was recorded after three days of continuous exposure, and no significant differences of LT_{50} s were detected among the Fort Dix susceptible strain and the three field strains, two of which were highly resistant to pyrethroids (CIN-1 and WOR-1). The similar rate of mortality caused by chlorfenapyr in all strains, regardless of their pyrethroid susceptibility status, suggests that the occurrence of pyrethroid resistance in bed bugs might not limit (or enhance) the effectiveness of chlorfenapyr.

Evaluations with aged residues of Phantom® SC: Adult bed bugs were continuously exposed to filter papers that were treated with Phantom® SC (same concentration as above). Treated discs were allowed to dry in room conditions ($24 \pm 2^\circ\text{C}$; $50 \pm 10\%$ RH) for three hours (referred to as fresh dry residue hereafter) or for one, two or four months. Dry residues of Phantom® aged indoors for one, two or four months remained as toxic as fresh deposits when evaluated against susceptible and pyrethroid-resistant bed bugs. Overall, mortalities of >50% or >90% were recorded after three days or seven days of continuous exposure to dry deposits of Phantom® SC, respectively. The ability of chlorfenapyr to remain effective over an extended period of time is encouraging because bed bugs that are not sprayed directly may still succumb after residing on treated surfaces. Most insecticides available today have limited potency as a dry deposit against pyrethroid-resistant bed bugs. Dry residual action of chlorfenapyr might also aid in preventing new infestations if likely areas of infestation are pretreated. Further study is warranted on the longevity and availability of chlorfenapyr on wood, fabric, and similar substrates commonly occupied by bed bugs and the suitability of prophylactic applications in bed bug management programs.

Comparison of efficacy of two chlorfenapyr formulations: We compared the effectiveness of Phantom® SC and an aerosol formulation (0.5% chlorfenapyr; Phantom® Pressurized Insecticide) with direct contact and dry residue assays. In direct contact assays, a group of ten male (or female) bed bugs from the CIN–1 and WOR–1 strains were directly sprayed with Phantom® SC or the aerosol formulation. Groups treated with Phantom® SC received two pumps with a fine mist sprayer (0.28 ml of insecticide solution; ca. 0.0014 g AI), which was adequate to wet each of the ten individuals. Other groups of bed bugs received two brief discharges (about 0.5 sec) with the Phantom® aerosol formulation (0.1 ml; 0.0005 g AI). Controls consisted of sprays of distilled water or the aerosol without active ingredient (blank formulation). Treated individuals were immediately transferred into individual wells of a 24–well cell culture plate lined with filter paper. Insect mortality was recorded 4 h post–spray and then daily for at least seven days. In residual assays, discs of filter paper were treated

with 50 µl of Phantom® SC, or two 0.5 sec discharges from Phantom® aerosol or aerosol blank. These discs were allowed to dry for 3 h before they were inserted into the 24-well cell culture plate. Observations of mortality were the same as above.

Direct sprays with aerosol had significantly shorter LT_{50} s than dry residues of the same formulation in evaluations with CIN-1 (1.5 vs. 2.5 days) and WOR-1 (0.9 vs. 2.0 days). Similar mortality rates were observed when individuals from CIN-1 were sprayed directly with Phantom® SC (LT_{50} = 5.6 days) or when they were exposed continuously to dry residues of the same formulation (LT_{50} = 4.6 days). In assays with WOR-1 with Phantom® SC, no significant differences were observed between LT_{50} s of direct sprays (LT_{50} = 3.1 days) and exposure to dry residues (LT_{50} = 3.3 days). The difference in mortality rate between the two formulations could be due to greater bioavailability of the active ingredient or synergism with other ingredients in the aerosol formulation. Insecticides that kill bed bugs upon contact are widely used by pest control companies because they can quickly suppress populations and provide some relief to their customers (Pinto et al. 2007).

Bed bug behavioral responses to surfaces treated with chlorfenapyr aerosol:

We evaluated responses of bed bugs to Phantom® aerosol with a two-choice test. Bugs from CIN-1 or WOR-1 were offered one tent treated with a 0.5 sec discharge of Phantom® aerosol while the other remained untreated and served as a blank. The treated tent was allowed to dry for 3 h before being placed in an arena. Behavioral assays lasted about 16 h and at the end of each assay it was noted whether the test individual was resting on a treated or untreated tent or wandering in the arena. Bed bugs from both strains showed no avoidance of surfaces treated with the chlorfenapyr aerosol. Similar responses had been seen with these strains in previous evaluations with chlorfenapyr technical grade and Phantom® SC (Romero et al. 2009b). Continued occupancy of harborages treated with chlorfenapyr enhances exposure to the insecticide and presumably lessens the potential spread of bed bugs to adjoining areas, which may occur with some pyrethroids and insecticides that bed bugs tend to avoid (Romero et al. 2009b).

In conclusion, chlorfenapyr is an option for controlling pyrethroid-resistant bed bugs. While it does not cause quick knockdown, chlorfenapyr is suitable for bed bug control due to its long residual activity and bed bugs' lack of avoidance of dry residues. A faster insecticidal effect is obtained with the aerosol formulation than the suspension concentrate, suggesting greater bioavailability of the toxicant.

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FUMIGATION – AN OVERLOOKED TOOL FOR CONTROL OF A RE-EMERGING PEST, THE BED BUG

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Vikane® gas fumigant (99.8% sulfuryl fluoride, Dow AgroSciences, Indianapolis, IN) has been used for nearly 50 years in the U.S. to fumigate more than 2 million buildings for control of structure-infesting pests (Dow AgroSciences, unpublished data). The global pandemic of bed bugs (*Cimex lectularius*) has resulted in renewed commercial applications of sulfuryl fluoride for control of this cryptic pest. Past research, summarized

by Thoms and Scheffrahn (1994), and recent research (D. Miller, unpublished data) have confirmed that all life stages of bed bugs, including the egg stage, are effectively controlled by label-prescribed dosage rates.

Sulfuryl fluoride has multiple benefits for bed bug control. It results in no persistent residues of toxicological concern in fumigated items. Sulfuryl fluoride can be used to fumigate items, including mattresses, clothing, toys, and electronics (Bell et al. 2002), which other treatments may damage or may not be approved for application. There is no known resistance of any insects to sulfuryl fluoride (Thoms and Phillips 2004), whereas bed bug populations have been documented to have high levels of resistance to pyrethroid insecticides (Moore and Miller 2006, Romero et al. 2007), which are commonly used for indoor pest control. Concentrations of sulfuryl fluoride can be easily measured using a Fumiscope (Key Chemical and Equipment Co., Clearwater, FL) or an SF-ReportIR (Spectros Instruments, Hopewell, MA) to ensure a lethal dosage is obtained during the fumigation. Sulfuryl fluoride has not been documented to stimulate insect movement from fumigated areas, an issue for heat treatment (Potter et al. 2008) and pyrethroids (Romero et al. 2009) when applied to control bed bugs. Clutter, which has been documented to be an important factor hindering treatment efficacy (Wang et al. 2009), does not affect the efficacy of sulfuryl fluoride, which will penetrate throughout the fumigated space to control bed bugs.

In spite of the efficacy of Vikane® gas fumigant for bed bug control, regulators did not discuss fumigation as a control option during the 2009 U.S. EPA Bed Bug Summit (www.regulations.gov, docket number EPA-HQ-OPP-2009-0190). A summary of participant recommendations following the Bed Bug Summit stated that “reduced-risk pesticides” should be developed for bed bug control. Regulators often confuse “high toxicity” with “high risk”. Speakers at the Bed Bug Summit (Tom Nelter, National Center for Health Housing) and the author’s personal observations have documented low toxicity pesticides, such as DEET and boric acid, being misapplied by occupants in bed bug-infested buildings to create high risk situations. Sulfuryl fluoride, which is highly toxic, is low risk to the public when applied according to the product label. Its use is highly regulated by numerous federal and state government agencies. In addition, applicators must pass a state certification exam for fumigation and attend annual stewardship training programs to be able to apply Vikane®.

Whole-structure fumigations using Vikane® gas fumigant to eliminate bed bug infestations are being conducted throughout the U.S. in many types of buildings, including single family homes (Dow AgroSciences 2004), multi-unit dwellings (Dow AgroSciences 2007, 2010; Miller and Fisher 2008) and hotels (Dow AgroSciences 2008). In addition, containerized fumigation of furnishings has been conducted in conjunction with steam and localized insecticide application in the building to eliminate bed bugs infesting single units in which whole-structure fumigation of the multi-unit dwelling is not practical (Walker et al. 2008). In conclusion, research and commercial practices to date have validated the value of Vikane® as an important tool for control of bed bugs.

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BED BUGS: TEN YEARS LATER, HAVE WE MADE ANY PROGRESS?

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The resurgence of bed bugs in the United States began in the late 1990's. Since that time, a great deal of emphasis has been placed on educating the pest management industry about bed bugs and their management. Many tools and methods have been created to help improve our ability to control this difficult pest, and research is beginning to yield important information from both an applied and basic science perspective. Still bed bugs continue to spread in what could be described as an unrestricted fashion. Ten years have gone by, but have we made progress?

Just six years ago there were no urban entomology departments studying bed bugs from an urban pest perspective. Now there are at least nine research programs dedicated to bed bug research and several symposia have been held dedicated to the topic of bed bugs as an urban pest. The attention of the research community is providing us insight into pesticide resistance (Moore and Miller 2006, Romero et al. 2007, Romero et al. 2009, Potter 2010), the latency of bite reactions (Reinhardt et al. 2009, Potter et al. 2010), movement of bed bugs in multi-occupancy structures (Doggett and Russel 2008, Pinto et al. 2008) as well as a number of other important aspects of behavioral ecology.

The pest management industry has also placed an emphasis on educating its membership about bed bugs. In addition to education, pest management professionals have gained much needed field experience that was previously lacking due to the nearly five decade absence of the blood-sucking pest. Today, many pest management firms have become very effective at eliminating infestations once they are reported. Modern-day tools include the use of encasements, vacuums, steam, freezing, structural heat treatments, and detailed applications of insecticides.

Despite the great strides that have been made, we are losing the war at the community and societal level as bed bugs continue to weave their way into the fabric of American society, showing up in nonresidential environments as well as infesting office buildings, movie theaters, and retail stores (Pinto et al. 2010). Public awareness is lacking and the cost of treatment is prohibitive for many, particularly those in the lower socioeconomic sector. As a result, bed bugs are now beginning to reservoir in our cities and will continue to do so unless we are able to develop effective national public awareness campaigns, fund much needed research, develop more affordable control methods, and assist those who still cannot afford the costs associated with bed bug eradication. Thus while we have made much progress over the past six years, unless there is a shift in focus to affordable community-based control efforts, it is unlikely that the spread of bed bugs will be stemmed.

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PROGRAM



2010 National Conference on Urban Entomology



May 16–19, 2010
Portland, Oregon

<http://ncue.tamu.edu>

National Conference on Urban Entomology *at a glance*

For locations, see the detailed program on the following pages

SUNDAY, MAY 16

- 8:00 – 4:00** eXtension Work Group Meeting
2:30 Registration open
6:00 – 8:00 Welcome reception (free hors d'oeuvres and cash bar)

MONDAY, MAY 17

- 6:30 – 8:00** Breakfast
7:00 Registration open
7:45 – 10:00 Opening session
10:00 – 10:30 BREAK
10:30 – 12:00 Student paper presentations
Submitted papers, general
12:00 – 1:30 Awards luncheon
1:30 – 3:30 **SYMPOSIUM** Molecular techniques and urban entomology — the why and the how
Submitted papers, Termites
3:30 – 4:00 BREAK
4:00 – 5:10 Student paper presentations
4:00 – 5:30 Submitted papers, Termites
6:00 Dinner on your own

TUESDAY, MAY 18

- 6:30 – 8:00** Breakfast
7:00 Registration open
8:00 – 10:00 Submitted papers, ants
Submitted papers, public health and general
10:00 – 10:30 BREAK
10:30 – 12:30 **SYMPOSIUM** Green pest management
SYMPOSIUM The changing face of urban pest management
12:30 Lunch on your own
1:30 – 4:05 **SYMPOSIUM** Soil environment affecting effectiveness of termiticides
2:00 – 4:05 **SYMPOSIUM** Vespoid pests in the urban environment: threats and opportunities
4:05 – 4:15 BREAK
4:15 – 5:05 **SYMPOSIUM** Soil environment affecting effectiveness of termiticides (cont.)
4:15 – 5:00 Submitted papers, general
6:00 – 9:30 **EVENING RECEPTION**
The Portland Spirit dinner cruise, boarding at 6 pm, student competition awards presented

WEDNESDAY, MAY 19

- 7:00 – 8:30** Breakfast
7:00 Registration open
8:30 – 10:30 **SYMPOSIUM** Bed bugs: new lessons on an old pest — What have we learned?
8:30 – 9:45 Submitted papers, general and ants
9:45 – 10:30 BREAK
10:30 Business Meeting
11:15 Executive Committee Business Meeting

National Conference on Urban Entomology

SUNDAY, MAY 16

- 8:00 – 4:00** eXtension Work Group Meeting — MORRISON
2:30 Registration open — PORTLAND
6:00 – 8:00 Welcome reception (free hors d'oeuvres and cash bar)
 MT. HOOD / MT. ST. HELENS

MONDAY, MAY 17

- 6:30 – 8:00** Breakfast — HOLLADAY / BROADWAY
7:00 Registration open — PORTLAND

CASCADE BALLROOM

- 7:45** **Welcome and Orientation**
 Conference Chair KAREN VAIL, UNIVERSITY OF TENNESSEE
 President of the Oregon Pest Control Association, BILL LARSEN, and STEVE FISHER
 Local Arrangements Committee, LAUREL HANSEN and TOM NISHIMURA
Conference Overview
 ROGER GOLD, TEXAS A&M UNIVERSITY
 DANIEL R. SUTTER, UNIVERSITY OF GEORGIA
8:15 **Distinguished Achievement Award in Urban Entomology**
 The Arnold Mallis Memorial Award Lecture:
 If you come to a fork in the road, take it
 DONALD A. REIERSON, UNIVERSITY OF CALIFORNIA, RIVERSIDE
9:15 **Student Scholarship Award Presentations**
 RICHARD M. HOUSEMAN, UNIVERSITY OF MISSOURI
9:15 – 9:30 **Bachelor of Science Award**
 Raft behavior of red imported fire ants
 BENJAMIN ADAMS, Rachel Strecker, Daniel O'Brien and Linda Hooper-Bui
 LOUISIANA STATE UNIVERSITY
9:30 – 9:45 **Master of Science Award**
 Occasional invaders in the suburban landscape
 CHRISTOPHER SCOCCO
 UNIVERSITY OF GEORGIA
9:45 – 10:00 **Ph.D. Award**
 Investigations of the gut chitinase gene-enzyme system in the eastern subterranean termite
 TIMOTHY J. HUSEN, Shripat T. Kamble and Julie Stone
 UNIVERSITY OF NEBRASKA, LINCOLN
10:00 – 10:30 **BREAK**

THREE SISTERS / MT BACHELOR STUDENT PAPER PRESENTATIONS

- 10:30 – 10:40** **Imidacloprid with minimum invasive treatment controlled subterranean termites in Malaysia**
 (Isoptera: Rhinotermitidae)
 ABDUL HAFIZ AB MAJID
 UNIVERSITY OF NEBRASKA, LINCOLN
10:40 – 10:50 **Laboratory trial of fate of imidacloprid in soil and field evaluation of imidacloprid granules against *Reticulitermes flavipes* (Kollar) subterranean termites in Texas**
 CHRIS KEEFER and Roger Gold
 TEXAS A&M UNIVERSITY

- 10:50 – 11:00** **Comparative study of tunneling and feeding preferences of *Coptotermes formosanus* Shiraki and *Coptotermes gestroi* Wasmann (Blattodea: Rhinotermitidae) in foraging arenas**
 NIRMALA HAPUKOTUWA and J. Kenneth Grace
 UNIVERSITY OF HAWAII, MANOA
11:00 – 11:10 **The relationship between subterranean termite (Isoptera: Reticulitermes) infestation frequency and historical landscape**
 PAUL S. BOTCH and Richard Houseman
 UNIVERSITY OF MISSOURI
11:10 – 11:20 **Origin of the infestation by the West Indian drywood termite *Cryptotermes brevis* (Walker) in the Azores Islands**
 MARIA TERESA FERREIRA, Seemanti Chakrabarti and Rudolph H. Scheffrahn
 UNIVERSITY OF FLORIDA, FT. LAUDERDALE REC
11:20 – 11:30 **Species distributions and phylogenetic relationships of *Reticulitermes* spp. found in Georgia, USA**
 SU YEE LIM, Joseph V. McHugh, Tracie M. Jenkins and Brian T. Forschler
 UNIVERSITY OF GEORGIA
11:30 – 11:40 **Variability of salivary reservoirs among *Reticulitermes flavipes* castes**
 NICOLA T. GALLAGHER and Susan C. Jones
 THE OHIO STATE UNIVERSITY
11:40 – 11:50 **Eastern subterranean termite gut chitinase activity in response to pentoxifylline treated diet**
 TIMOTHY J. HUSEN, Shripat T. Kamble and Julie Stone
 UNIVERSITY OF NEBRASKA, LINCOLN

MT HOOD / MT ST HELENS SUBMITTED PAPERS

- General**
10:30 – 10:45 **Control and web management of a long-legged cellar spider, *Holocnemus pluchei*, in Southern California**
 RICHARD S. VETTER, Donald A. Reiersen and Michael K. Rust
 UNIVERSITY OF CALIFORNIA, RIVERSIDE
10:45 – 11:00 **The activity of insecticides against urban spiders: methods and implications**
 DONALD A. REIERSON, R.S. Vetter and M.K. Rust
 UNIVERSITY OF CALIFORNIA, RIVERSIDE
11:00 – 11:15 **Persistence of outdoor spider control using a single application of Temprid™ or Transport GHP®**
 WILLIAM H. KERN
 UNIVERSITY OF FLORIDA, FT. LAUDERDALE REC
11:15 – 11:30 **A review of nuisance invader household pests of the United States**
 WHITNEY CRANSHAW
 COLORADO STATE UNIVERSITY
11:30 – 11:45 **Arlon: A new residual spray insecticide with unique formulation and wide spectrum of activity on key urban pests**
 RAJ K. SARAN
 DUPONT PROFESSIONAL PRODUCTS
11:45 – 12:00 **Formulation of a highly palatable granular housefly bait**
 VY NGUYEN and Dangsheng Liang
 APEX BAIT TECHNOLOGIES, INC
12:00 – 1:30 **Awards luncheon — HOLLADAY/BROADWAY**

**THREE SISTERS / MT BACHELOR
SYMPOSIUM**

**Molecular techniques and urban entomology
— the why and the how**

Organizers and Moderators

Mike Scharf, *University of Florida*

Grzegorz Buczkowski, *Purdue University*

- 1:30 – 1:54** How molecular systematics provides insights into the complexity of urban pest biology nucleotide by nucleotide
TRACIE M. JENKINS
UNIVERSITY OF GEORGIA, GRIFFIN
- 1:54 – 2:18** What can molecular markers tell us about urban pest populations that we didn't already know?
WARREN BOOTH, Edward L. Vargo and Coby Schal
NORTH CAROLINA STATE UNIVERSITY
- 2:18 – 2:42** Symbiosis in urban pest termites and its disruption for control
CLAUDIA HUSSENER, Amit Sethi and Jennifer Delatte
LOUISIANA STATE UNIVERSITY AGRICULTURAL CENTER
- 2:42 – 3:06** High throughput DNA sequencing: advances and applications
SRINI KAMBHAMPATI
KANSAS STATE UNIVERSITY
- 3:06 – 3:30** Translational genomics: genes to function to pest control
MICHAEL E. SCHARF
UNIVERSITY OF FLORIDA, GAINESVILLE

**MT HOOD / MT ST HELENS
SUBMITTED PAPERS**

- 1:30 – 1:45** Dispersal of the exotic arboreal termite *Nasutitermes corniger*: population dynamics study using microsatellite markers
SEEMANTI CHAKRABARTI and Rudolf H. Scheffrahn
UNIVERSITY OF FLORIDA, FT. LAUDERDALE REC
- 1:45 – 2:00** Spatial association of marine dockage with land-borne infestations of invasive termites in urban South Florida
RUDOLF H. SCHEFFRAHN and Hartwig H. Hochmair
UNIVERSITY OF FLORIDA, FT. LAUDERDALE REC
- 2:00 – 2:15** Persistent Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae) infestations in New Orleans' French Quarter
FRANK S. GUILLOT¹, Dennis R. Ring², Alan R. Lax¹ and Alan Morgan²
¹SOUTHERN REGIONAL RESEARCH CENTER, USDA-ARS, NEW ORLEANS
²LOUISIANA STATE UNIVERSITY AGRICULTURAL CENTER
- 2:15 – 2:30** Interactions of the Formosan subterranean termite (Isoptera: Rhinotermitidae) with a brown rot and a white rot fungus
MARY L. CORNELIUS, Kelley S. Williams,

- 2:30 – 2:45** Altriset: A new generation non-repellent termiticide with new mode of action and its effect on termite tunneling and horizontal transfer
RAJ K. SARAN
DUPONT PROFESSIONAL PRODUCTS
- 2:45 – 3:00** Evaluation of small IMPASSE TERMITE BARRIER[®] plots around utility penetrations and vertical walls against two subterranean termites, *Heterotermes aureus* and *Gnathamitermes perplexus* (Isoptera) in Southern Arizona
PAUL B. BAKER^{1,2}, Ruben Marchosky¹, David L. Cox² and ElRay M. Roper²
¹UNIVERSITY OF ARIZONA
²SYNGENTA CROP PROTECTION, INC.
- 3:00 – 3:15** Preventing decay in termite monitoring stations
Adam Taylor¹, Lina Nunes², Jeff Lloyd³ and JANET KINTZ-EARLY³
¹UNIVERSITY OF TENNESSEE
²LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL (LNEC), LISBOA, PORTUGAL
³NISUS CORPORATION
- 3:15 – 3:30** Orientation and navigational strategies in the trail-following response of termite
XING PING HU and Brittany Wall
AUBURN UNIVERSITY
- 3:30 – 4:00** BREAK

**THREE SISTERS / MT BACHELOR
STUDENT PAPER PRESENTATIONS**

- 4:00 – 4:10** Assessment of violations in Georgia public schools
SONJA L. BRANNON and Brian T. Forschler
UNIVERSITY OF GEORGIA, ATHENS
- 4:10 – 4:20** Biogeography of *Triatoma sanguisuga* on two barrier islands off the coast of Georgia, USA
ASHLEY RODEN and Brian T. Forschler
UNIVERSITY OF GEORGIA, ATHENS
- 4:20 – 4:30** Life tables and mathematical models: a contribution to the life history of *Cimex lectularius* (L.)
ANDREA POLANCO and Dini Miller
VIRGINIA TECH
- 4:30 – 4:40** Quantitative differences in bed bug, *Cimex lectularius* (L.) response to topical versus injection insecticide assays
REINA K. KIM, MARU, Dini M. Miller, Jeffery R. Bloomquist and Zach N. Adelman
VIRGINIA TECH
- 4:40 – 4:50** The genetic variation of thief ants, *Solenopsis molesta* (Say) (Hymenoptera: Formicidae)
RALPH NARAIN, Shripat T. Kamble and Thomas O. Powers
UNIVERSITY OF NEBRASKA, LINCOLN
- 4:50 – 5:00** The repellency of five essential oils against Argentine ants
CHRISTOPHER M. SCOCCO and Daniel R. Suiter
UNIVERSITY OF GEORGIA, GRIFFIN
- 5:00 – 5:10** Effect of broadcast fire ant control products on non-target ant species in Virginia
HAMILTON R. ALLEN and Dini Miller
VIRGINIA TECH

**MT HOOD / MT ST HELENS
SUBMITTED PAPERS**

Termites

- 4:00 – 4:15** Predicting the likelihood of treatment for subterranean termites (*Reticulitermes*) in Missouri neighborhoods
RICHARD M. HOUSEMAN
UNIVERSITY OF MISSOURI
- 4:15 – 4:30** Innovation history of the Sentricon® Termite Colony Elimination System
MIKE P. TOLLEY
DOW AGROSCIENCES
- 4:30 – 4:45** Recruit® HD, a new termite bait from Dow AgroSciences: laboratory performance characterization
JOE DeMARK, Ronda L. Hamm, Eva Chin-Heady, Mike Tolley and Joe Eger
DOW AGROSCIENCES
- 4:45 – 5:00** Does previous feeding by *Reticulitermes* spp. (Isoptera: Rhinotermitidae) on blank Recruit® HD bait preclude subsequent feeding by other colonies of the same or different species?
RHONDA HAMM and Eva Chin-Heady
DOW AGROSCIENCES
- 5:00 – 5:15** Preliminary field evaluation of Recruit® HD: a new durable termite bait from Dow AgroSciences
J.A. McKERN, J.E. Eger, Joe J. DeMark, M.P. Tolley, M.D. Lees, M.L. Fisher, R.L. Hamm, M.W. Melichar, M. Messenger¹ and E.M. Thoms
DOW AGROSCIENCES
¹USDA, APHIS, VS, NCAHP
- 5:15 – 5:30** Field validation of subterranean termite (Isoptera, Rhinotermitidae) control with Recruit® HD, a new termite bait from Dow AgroSciences
JOE EGER, Joe J. DeMark, J.A. McKern, M.P. Tolley, M.D. Lees, M.L. Fisher, R.L. Hamm, M.W. Melichar, M. Messenger¹ and E.M. Thoms
DOW AGROSCIENCES
¹USDA, APHIS, VS, NCAH
- 6:00** Dinner (on your own)

TUESDAY, MAY 18

- 6:30 – 8:00** Breakfast — HOLLADAY / BROADWAY
- 7:00** Registration open — PORTLAND

**THREE SISTERS / MT BACHELOR
SUBMITTED PAPERS**

Ants

- 8:00 – 8:15** Pacific Northwest ant survey
ROCHELLE V. HOEY-CHAMBERLAIN^{1,2} and Laurel D. Hansen²
¹UNIVERSITY OF CALIFORNIA, RIVERSIDE
²SPOKANE FALLS COMMUNITY COLLEGE
- 8:15 – 8:30** Who's nesting in my house?
LAUREL D. HANSEN¹, Rochelle Hoey-Chamberlain^{1,2} and Arlana Nielsen¹
¹SPOKANE FALLS COMMUNITY COLLEGE
²UNIVERSITY OF CALIFORNIA, RIVERSIDE
- 8:30 – 8:45** Old ants, new problem; new ants, old problem: leaf-cutting ants and crazy ants in Louisiana
LINDA M. HOOPER-BÚI¹, R. Strecker¹, J. Moser²,

N. Nagendra¹, M. Adams¹, X. Chen¹ and G. Henderson¹

¹LOUISIANA STATE UNIVERSITY

²USDA-FOREST SERVICE, ALEXANDRIA FORESTRY CENTER, PINEVILLE, LA

- 8:45 – 9:00** Identification of two exotic ant species, *Odontomachus haematodus* and *Paratrechina pubens*, in Louisiana
K.S. BROWN¹, C. Riegel¹, E.G. Guidry¹, T.H. Madere¹ and AJ Mullins²
¹CITY OF NEW ORLEANS MOSQUITO AND TERMITE CONTROL BOARD
²VIRGINIA TECH
- 9:00 – 9:15** *Escherichia coli* transmission by Raspberry crazy ants (*Nylanderia* sp. nr *pubens*) in Texas
ROBERT T. PUCKETT, Danny McDonald and Roger Gold
TEXAS A&M UNIVERSITY
- 9:15 – 9:30** Is the Raspberry crazy ant the new red imported fire ant?
JASON M. MEYERS
BASF CORPORATION
- 9:30 – 9:45** Development of a new broad-spectrum granular bait formulation for the control of ants and other indoor and perimeter pests
THOMAS MACOM, Nonggang Bao, Deborah Koufas, John Paige and Byron Reid
BAYER ENVIRONMENTAL SCIENCE
- 9:45 – 10:00** Maxforce Quantum: A better “mousetrap” for ant management
JOHN PAIGE, Byron Reid, Joe Hope and Tom Macom
BAYER ENVIRONMENTAL SCIENCE

**MT HOOD / MT ST HELENS
SUBMITTED PAPERS**

Public Health and General

- 8:00 – 8:15** Time to aggregation in fed and starved bed bugs, *Cimex lectularius* (L.)
MATTHEW D. REIS and Dini Miller
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
- 8:15 – 8:30** Knockdown, residual and larvicide efficacy of Temprid SC Insecticide against susceptible & resistant strains of the common bed bug, *Cimex lectularius* (L.)
BYRON L. REID, John H. Paige, Eric Snell¹ and Guenther Nentwig
BAYER ENVIRONMENTAL SCIENCE
¹SNELL SCIENTIFICS, MEANSVILLE, GA
- 8:30 – 8:45** Evaluation of a bed bug control program used in residential properties
DINA RICHMAN¹ and Jim Ballard²
¹FMC CORPORATION
²BALLARD PEST MANAGEMENT CONSULTING, MEDFORD, NJ
- 8:45 – 9:00** Gene discovery in bed bugs (*Cimex lectularius*)
OMPRAKASH MITTAPALLI¹, Xiaodong Bai¹ and Susan C. Jones²
THE OHIO STATE UNIVERSITY
¹OARDC, WOOSTER, OH
²COLUMBUS, OH
- 9:00 – 9:15** Bed bug (*Cimex lectularius*) life stages and adult sex ratios in a multi-story apartment complex: dispersal implications
SUSAN C. JONES, Benjamin R. Diehl and George Keeney
THE OHIO STATE UNIVERSITY

PROCEEDINGS OF THE 2010 NCUE, PORTLAND, OR

9:15 – 9:30	Piloting IPM at public housing authorities Nationwide ALLISON TAISEY CORNELL UNIVERSITY
9:30 – 9:45	Starting a professional association for school IPM coordinators in Texas JANET HURLEY and Michael E. Merchant TEXAS AGRI LIFE EXTENSION, DALLAS
9:45 – 10:00	iPestManager—A web-based pest reporting system for improving efficacy of a school integrated pest management program: a case study of the Salt Lake City school district RYAN S. DAVIS ¹ , Gregg Smith ² , Ricardo Zubiate ² and Robin Anderson ² ¹ UTAH STATE UNIVERSITY EXTENSION ² SALT LAKE CITY SCHOOL DISTRICT
10:00 – 10:30	BREAK
	THREE SISTERS / MT BACHELOR SYMPOSIUM
	Green pest management <i>Organizer and Moderator</i> <i>Daniel R. Suiter, University of Georgia, Griffin</i>
10:30 – 10:47	The pest management community needs to define green pest management B.T. FORSCHLER UNIVERSITY OF GEORGIA, ATHENS
10:47 – 11:04	Effects of essential oils and blends on urban pests A.G. APPEL AUBURN UNIVERSITY
11:04 – 11:21	Repellency and topical toxicity of various plant oils to various pest ants D.R. SUITER UNIVERSITY OF GEORGIA, GRIFFIN
11:21 – 11:38	Green urban pest management: where did it come from and is there anything to it? D.A. REIERSON and M.K. Rust UNIVERSITY OF CALIFORNIA, RIVERSIDE
11:38 – 11:55	Shades of green: opportunities for the pest management industry J. BRUESCH PLUNKETT'S PEST CONTROL, INC., MINNEAPOLIS, MN
11:55 – 12:12	Reduced risk products for urban pest control: past, present and future S.R. SIMS BASF CORPORATION
12:12 – 12:29	A state regulatory perspective on "minimum risk" pesticides L. QUAKENBUSH PESTICIDE REGISTRATION COORDINATOR, COLORADO DEPARTMENT OF AGRICULTURE, LAKEWOOD, CO
	MT HOOD / MT ST HELENS SYMPOSIUM
	The changing face of urban pest management <i>Organizers and Moderators</i> <i>Ron Harrison and Pat Copps, Orkin</i>
10:30 – 10:35	Introduction PATT COPPS and Ron Harrison ORKIN PEST CONTROL

10:35 – 10:47	Residential pest control RUSS HORTON Director of Technical Service HOME TEAM
10:47 – 10:59	Training RON HARRISON Director of Technical Service ORKIN PEST CONTROL
10:59 – 11:11	Sophisticated pest problems PAT COPPS Division Technical Manager ORKIN PEST CONTROL
11:11 – 11:23	Technology ZIA SIDDIQI Director of Quality Systems ORKIN COMMERCIAL SERVICES
11:23 – 11:35	Product innovation CLAY SCHERER Product Development DuPONT PROFESSIONAL PRODUCTS
11:35 – 11:47	Termite PAUL HARDY Senior Technical Director (49 years) ORKIN PEST CONTROL
11:47 – 11:59	Regulation: A Canadian prospective KATHY CANO Manager, Quality Assurance and Government Relations ORKIN, CANADA
11:59 – 12:11	International pest control FRANK MEEK ORKIN PEST CONTROL
12:11 – 12:23	Academia, research, funding BRIAN FORSCHLER Professor of Entomology UNIVERSITY OF GEORGIA, ATHENS
12:30	Lunch on your own
	THREE SISTERS / MT BACHELOR SYMPOSIUM
	Soil environment affecting effectiveness of termiticides <i>Organizer and Moderator</i> <i>Shripat Kamble, University of Nebraska</i>
1:30 – 1:55	Termiticide analysis: from chlorinated hydrocarbons and beyond ROGER E. GOLD TEXAS A&M UNIVERSITY
1:55 – 2:20	Re-evaluating insecticides applied to soils to control subterranean termites MICHAEL K. RUST and R. Saran UNIVERSITY OF CALIFORNIA, RIVERSIDE
2:20 – 2:45	Sorption and desorption of fipronil in Midwestern soils Neil A. Spomer ¹ and SHRIPAT T. KAMBLE ² ¹ DOW AGROSCIENCES ² UNIVERSITY OF NEBRASKA
2:45 – 3:10	Subterranean termite – soil pathogens interactions THOMAS CHOUVENC and Nan-Yao Su UNIVERSITY OF FLORIDA, FT. LAUDERDALE REC

3:10 – 3:35 **Soil/chemical interactions affecting termiticide performance**

ALDOS C. BAREFOOT
DuPont Crop Protection, STINE HASKELL RESEARCH
CENTER, NEWARK, DE

3:35 – 4:05 **Mobility of five termiticides in soil columns**
JOEL COATS, Shaohan Zhao, Jason B. Belden and
James Cink¹

IOWA STATE UNIVERSITY
¹BASF CORPORATION

4:05 – 4:15 **BREAK**

4:15 – 4:40 **Factors affecting the initial distribution of termiticides in soil**
CHRIS PETERSON
USDA FOREST SERVICE, INSECTS, DISEASES AND INVASIVE
PLANTS UNIT, STARKVILLE, MS

4:40 – 5:05 **Distribution of termiticides following sub-soil application as affected by soil type**
ROBERT W. DAVIS¹ and Shripat T. Kamble²
¹BASF PEST CONTROL SOLUTIONS
²UNIVERSITY OF NEBRASKA

MT HOOD / MT ST HELENS SYMPOSIUM

Vespid pests in the urban environment: threats and opportunities

Organizer and Moderator
ElRay Roper, Syngenta Professional Pest Management

2:00 – 2:05 **Introduction**
ELRAY ROPER
SYNGENTA PROFESSIONAL PEST MANAGEMENT

2:05 – 2:25 **Evaluations of commercial traps and baits for vespid wasps in Colorado**
WHITNEY CRANSHAW
COLORADO STATE UNIVERSITY

2:25 – 2:45 **Toward the development of a ready-to-use yellowjacket bait**
JADE MCGILL and Dangsheng Liang
APEX BAIT TECHNOLOGIES SANTA CLARA, CA

2:45 – 3:05 **Laboratory and field efficacy studies against *Polistes dominulus* and *Vespula pensylvanica* evaluating pressurized aerosol products**
WILLIAM A. DONAHUE, Jr.
SIERRA RESEARCH LABORATORIES, MODESTO, CA

3:05 – 3:25 **Controlling yellowjackets in Southern California**
MICHAEL K. RUST, Richard S. Vetter and
Donald A. Reiersen
UNIVERSITY OF CALIFORNIA, RIVERSIDE

3:25 – 3:45 **Optigard Flex Liquid Insecticide as a control for vespid wasps**
CLARK LOVELADY¹, Catherine Long¹,
Bill Donohue² and David Cox³
¹SYNGENTA BR&D, VERO BEACH, FL
²SIERRA RESEARCH LABS, MODESTO, CA
³SYNGENTA BR&D, MADERA, CA

3:45 – 4:05 **Thiamethoxam for control of yellowjackets, paper wasps, and bald faced hornets**
ELRAY M. ROPER
SYNGENTA PROFESSIONAL PEST MANAGEMENT

4:05 – 4:15 **BREAK**

MT HOOD / MT ST HELENS SUBMITTED PAPERS

General

4:15 – 4:30 **Conducting efficacy studies (GLP & non-GLP) against urban pest species for EPA pesticide product registrations**
WILLIAM A. DONOHUE, JR.
SIERRA RESEARCH LABORATORIES, MODESTO, CA

4:30 – 4:45 **Discovery and distribution of the bean plataspid in Northeast Georgia**
D.R. SUITER¹, J.E. Eger², L.M. Ames¹, R.C. Kemerait³,
G.D. Buntin¹ and T.M. Jenkins¹
¹UNIVERSITY OF GEORGIA ENTOMOLOGY, GRIFFIN
²DOW AGROSCIENCES
³UNIVERSITY OF GEORGIA, TIFTON

4:45 – 5:00 **The first New World record of *Megacopta cribraria* (Fabricius) (Heteroptera: Plataspidae) from Georgia: a serious home invader and potential legume pest**

J.E. EGER¹, L. Ames², D.R. Suiter³, D.A. Rider³
S.E. Halbert⁴, T.M. Jenkins² and T.J. Henry⁵
¹DOW AGROSCIENCES
²UNIVERSITY OF GEORGIA, GRIFFIN
³NORTH DAKOTA STATE UNIVERSITY
⁴FLORIDA STATE COLLECTION OF ARTHROPODS, FLORIDA
DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES,
GAINESVILLE, FL
⁵USDA-ARS, SYSTEMATIC ENTOMOLOGY LABORATORY,
WASHINGTON, DC

6:00 – 9:30 **EVENING RECEPTION**
The Portland Spirit dinner cruise, boarding at 6 PM
student competition awards presented

WEDNESDAY, MAY 19

Breakfast — HOLLADAY / BROADWAY
Registration open — PORTLAND

THREE SISTERS / MT BACHELOR SYMPOSIUM

Bed bugs: new lessons on an old pest — What have we learned?

Organizer and Moderator
ELLEN M. THOMS, Dow AgroSciences

8:30 – 8:50 **More than a nuisance: medical and societal impacts of bed bugs**
MICHAEL F. POTTER and Ken F. Haynes
UNIVERSITY OF KENTUCKY

8:50 – 9:10 **Who is living with bed bugs in 2010?**
DINI MILLER
VIRGINIA TECH

9:10 – 9:30 **Insights on bed bug biology and control**
CHANGLU WANG
RUTGERS UNIVERSITY

9:30 – 9:50 **Potential of chlorfenapyr to control bed bugs**
ALVARO ROMERO¹, Michael Potter¹,
Robert Hickman² and Ken F. Haynes¹
¹UNIVERSITY OF KENTUCKY
²BASF CORPORATION

9:50 – 10:10 Fumigation — an overlooked tool for control of a re-emerging pest, the bed bug
ELLEN THOMS
DOW AGROSCIENCES

10:10 – 10:30 Bed bugs: Ten years later, have we made any progress?
RICK COOPER
COOPER PEST SOLUTIONS, LAWRENCEVILLE, NJ

**MT HOOD / MT ST HELENS
SUBMITTED PAPERS**

8:30 – 8:45 **General and Ants**
Development of an improved integrated pest management program to protect retail and distribution facilities
STEPHEN A. KELLS¹, Kim Kemp² and Robert M. Corrigan³

¹UNIVERSITY OF MINNESOTA

²NESTLE PURINA PETCARE

³RMC PEST MANAGEMENT CONSULTING

8:45 – 9:00 Native “invasive” ants: a novel evolutionary trend in the age of global change?
GRZEGORZ BUCZKOWSKI
PURDUE UNIVERSITY

9:00 – 9:15 Perimeter treatments around homes or simulated structures for odorous house ant management
KAREN VAIL, Jennifer Chandler, Patricia Barnwell and Joseph Maples
UNIVERSITY OF TENNESSEE

9:15 – 9:30 Effect of broadcast fire ant control products on non-target ant species in Virginia
HAMILTON R. ALLEN and Dini M. Miller
VIRGINIA TECH

9:30 – 9:45 Arilon for Argentine ants in Atlanta
DANIEL R. SUITER
UNIVERSITY OF GEORGIA, GRIFFIN

9:45 – 10:30 BREAK

MT HOOD / MT ST HELENS

10:30 Business Meeting

11:15 Executive Committee Business Meeting

**Past Recipients of the
Distinguished Achievement Award in Urban Entomology**

1986 Walter Ebeling, James Grayson
1988 John V. Osmun, Eugene Wood
1990 Francis W. Leichleitner
1992 Charles G. Wright
1994 Roger D. Akre, Harry B. Moore, Mary H. Ross
1996 Donald G. Cochran
1998 Gary W. Bennett
2000 Michael K. Rust
2004 Roger E. Gold
2006 Coby Schal
2008 Nan-Yao Su

Past Conference Chairs

1986 Patricia A. Zungoli
1988 William H. Robinson
1990 Michael K. Rust
1992 Gary W. Bennett
1994 Roger E. Gold, Judy K. Bertholf
1996 Donald A. Reiersen
1998 Brian T. Forschler, Shripat Kamble
2000 Shripat Kamble
2004 Daniel R. Suiter
2006 Dini Miller, Bob Kopanic
2008 Richard Houseman, Bob Cartwright

**2010 National Conference on
Urban Entomology Planning Committee**

Conference chair, KAREN VAIL, University of Tennessee
Queen of the conference, LAURA NELSON, Texas A&M University
Program chair, FAITH OI, University of Florida
Proceedings chair, SUSAN JONES, The Ohio State University
(jones.1800@osu.edu)
Local arrangements co-chairs
LAUREL HANSEN, Spokane Falls Community College
TOM NISHIMURA, BASF Corporation

Sponsorship

DANIEL R. SUITER, University of Georgia, Chair
GARY BENNETT, Purdue University
GRZEGORZ BUCZKOWSKI, Purdue University
SHRIPAT KAMBLE, University of Nebraska

Awards

RICHARD HOUSEMAN, University of Missouri, Chair
BOB CARTWRIGHT, Syngenta Professional Products
DINI MILLER, Virginia Tech
GRZEGORZ BUCZKOWSKI, Purdue University
BOB KOPANIC, S.C. Johnson

Secretary, DINI MILLER, Virginia Tech
Treasurer, ROGER GOLD, Texas A&M University
Student Paper Competition Chair, JOE DeMARK, Dow AgroSciences

Corporate Sponsors
2010 National Conference on Urban Entomology

To be a Corporate Sponsor of the National Conference on Urban Entomology is to be a supporter of current activities in the area of urban entomology and a partner in promoting a better understanding of the science of urban entomology. The following are the National Conference on Urban Entomology Corporate Sponsors for 2010.


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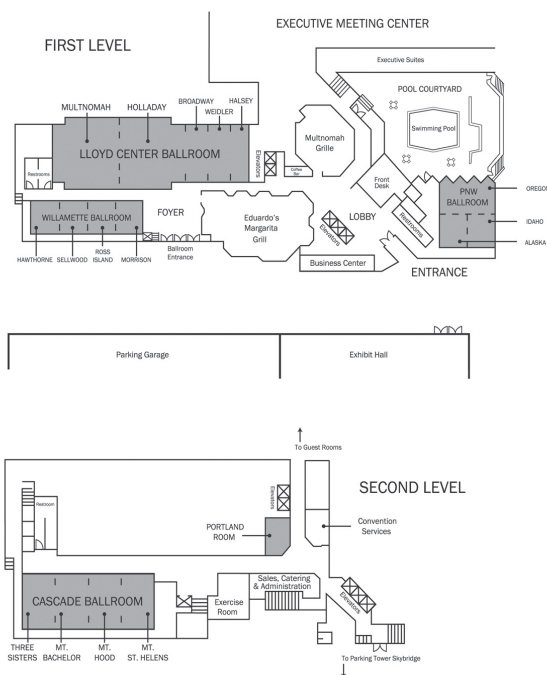
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2010 National Conference on Urban Entomology Planning Committee

Karen M. Vail (University of Tennessee), Conference Chair

Laura Nelson (Texas A&M University), Conference Assistant

Faith M. Oi (University of Florida), Program Chair

Susan C. Jones (Ohio State University), Proceedings Chair

Laurel D. Hansen (Spokane Falls Community College), Local Arrangements
Co-chair

Tom Nishimura (BASF), Local Arrangements Co-chair

Daniel R. Suiter (University of Georgia), Sponsorship Chair

Gary W. Bennett (Purdue University), Sponsorship

Shripat T. Kamble (University of Nebraska), Sponsorship

Grzegorz Buczkowski (Purdue University), Sponsorship
Awards

Joe DeMark (Dow AgroSciences), Student Paper Competition, Chair

Richard M. Houseman (University of Missouri), Awards Chair

Bob Kopanic (S.C. Johnson & Son), Awards

Bob Cartwright (Syngenta), Awards

Dini M. Miller (Virginia Tech), Awards
Secretary

Roger E. Gold (Texas A&M University), Treasurer

2012 National Conference on Urban Entomology Planning Committee

Faith Oi (University of Florida), Conference Chair

Grzegorz Buczkowski (Purdue University), Program and Proceedings

Dan Suiter (University of Georgia), Local Arrangements

Tracie Jenkins (University of Georgia), Local Arrangements

Kyle Jordan (BASF), Local Arrangements

Dini Miller (Virginia Tech), Secretary

Roger Gold (Texas A&M University), Treasurer

Laura Nelson (Texas A&M University), Assistant to Roger Gold

Dan Suiter (University of Georgia), Sponsorship

Karen Vail (University of Tennessee), Awards

Recipients Of The Distinguished Achievement Award In Urban Entomology

- 1986 Dr. Walter Ebeling (University of California, Los Angeles)
Dr. James Grayson (Virginia Polytechnic Institute & State University)
- 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 Dr. Coby Schal (North Carolina State University)
- 2008 Dr. Nan-Yao Su (University of Florida)
- 2010 Dr. Donald A. Reiersen (University of California, Riverside)

NCUE Conference Chairs

- 1986 Patricia A. Zungoli (Clemson University)
- 1988 William H. Robinson (Virginia Polytechnic Institute & State University)
- 1990 Michael K. Rust (University of California, Riverside)
- 1992 Gary W. Bennett (Purdue University)
- 1994 Roger E. Gold (Texas A&M University)
Judy K. Bertholf (DowElanco)
- 1996 Donald A. Reiersen (University of California, Riverside)
- 1998 Brian T. Forschler (University of Georgia)
Shripat T. Kamble (University of Nebraska)
- 2000 Shripat T. Kamble (University of Nebraska)
- 2004 Daniel R. Suiter (University of Georgia)
- 2006 Dini M. Miller (Virginia Tech University)
Bob Kopanic (S.C. Johnson and Son)
- 2008 Richard Houseman (University of Missouri)
Bob Cartwright (Syngenta)
- 2010 Karen Vail (University of Tennessee)

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 scholarships.

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, teaching and extension programs related to urban and structural entomology.
3. To prepare a written/electronic 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. Three levels of scholarships will be offered: the first level is for Bachelor students; the second level is for Masters students; and the third level is for Ph.D. candidates. These students must register for, and attend, the conference and present the paper in order to receive funding. 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. The student will receive funding only if they are currently enrolled in a university at the time that the conference is held.
6. There may also be first, second, and third place recipients of an onsite student competition for students who are currently involved in their undergraduate or graduate programs. These students can compete for scholarship funds; however, if any student has already been awarded a scholarship for the current meeting, and wishes to participate in this onsite competition, their presentation must be completely separate, and they must be properly registered in advance for this competition.

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, preparation/printing of proceedings and the offering of scholarships. All persons with an interest in urban entomology are invited to attend the conferences and associated events.

ARTICLE VI-OFFICERS

Leadership for the Conference will be provided by the Chair of the Conference Committee. The Executive committee will be composed primarily of representatives from academia, industry and government. There will be seven officers of the Executive Committee and will include the following:

- Chair of the Conference Committee
- Chair of the Program Committee
- Chair of the Awards Committee
- Secretary to the Conference
- Treasurer to the Conference
- Chair of the Sponsorship Committee
- Chair of the Local Arrangements Committee

The Chair of the Conference Committee will preside at all Committee meetings, and will be the Executive Officer for the organization, and will preside at meetings. In the absence of the Chair of the Conference Committee, the Chair of the Program Committee may preside. The voting members for executive decisions for the conference will be by a 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 oversee the printing of announcements, programs and proceedings.

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

Secretary: To take notes and provide minutes of meetings.

Treasurer: Provide documentation of expenditures, and the collection and disbursement of funds. To act on behalf of the executive committee in making arrangements with hotels, convention centers and other facilities in which conferences are held.

Chair For Sponsorship: This committee will be involved in fund raising and in seeking sponsorship for various aspects of the conference. It will also contact contributors and potential contributors to seek donations and support for the conference and associated events. It is anticipated that the committee will be composed of at least one member representing academia, and one member representing industry.

Chair For Local Arrangements: To gather information on behalf of the executive committee for hotels, convention centers and other facilities in which the conference is to be held. To arrange for audio/visual equipment, and to oversee the general physical arrangements for the conference.

ARTICLE VII-TERMS OF OFFICE & SUCCESSION OF OFFICERS:

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 Awards Chair is the last position to be served, and may be relieved from NCUE officer duties unless asked or willing to serve NCUE in another capacity.

The Conference Chair may serve for one conference after which time they will become the Chair of the Awards Committee.

The Program Chair may serve for one conference term after which time they will become the Conference Chair.

The Secretary may serve for one conference term, after which time they will become the Program Chair.

The Chair for Local Arrangements should change with each conference unless the meetings are held in the same location.

The Chair the Sponsorship Committee (to include both an academic and industry representative) will serve for two conferences.

The Treasurer will serve for two conference cycles, unless reappointed by the Executive Committee.

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 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 Conference. In the event that there are no nominations, the existing Chair may remain in office with a majority vote of the Executive 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 Conference on Urban Entomology", and may be subjected to annual audits. Expenditures may be made in support of the conference, for scholarships and other reasonable costs; however, funds may not be used to pay officers', or their staff's salaries, or for officers' travel 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.

Modified: 5/19/10-passed

2010 NCUE Closing Business Meeting Minutes

**May 19th 10:30am – 11:40 am
Double Tree Hotel, Portland, OR**

Members of the planning committee in attendance: Karen Vail, Roger Gold, Laura Nelson, Dini Miller, Faith Oi, Bob Kopanic, Bob Cartwright, Richard Houseman, Dan Suiter, Shripat Kamble, Joe DeMark, Laurel Hansen, Tom Nishamura, Grzegorz Buczkowski, and Gary Bennett.

1. Meeting Summary:

Total Registrants for the 2010 meeting of the NCUE was 208.

There were 102 presentations total:

Award presentations including Mallis Distinguished Achievement award-4
Student paper competition presentations-14
Submitted papers-43
Symposium presentations-41

All abstracts or extended abstracts will be published in the 2010 NCUE Proceedings. Any additions that are to be made to the proceedings need to be sent to Susan Jones (jones.1800@osu.edu) at Ohio State University by July 1st, 2010.

The conference made all room night obligations with the Double Tree Hotel and the necessary “carry-over” funds (~\$40,000) to initiate conference in 2012. We thank the members and particularly the Sponsors of the NCUE conference for their continued support.

2. Final Business Meeting

Karen Vail (2010 NCUE Conference Chair) called the meeting to order. A total of 25 NCUE members participated in the final business meeting including those members of the planning committee listed above.

a. The first item of business raised by Dr. Roger Gold was to discuss if the NCUE conference was to continue in 2012. A motion was made that the conference would continue into 2012 and the motion was unanimously approved.

b. The second item of business was to determine where the conference was to be held and who would be in charge of local arrangements. The locations suggested by meeting participants were:

Ft. Lauderdale, FL- no specific local arrangements committee suggested
Lincoln, NE- Shripat Kamble volunteered to handle local arrangements
Albuquerque, NM- Bob Davis volunteered to handle local arrangements
San Antonio, TX- Roger Gold and Laura Nelson expressed some willingness to handle local arrangements (in 2014)
New Orleans, LA- Claudia Reigel was volunteered to handle local arrangements
Atlanta, GA- Dan Suiter, Tracy Jenkins and Kyle Jordan volunteered to handle local arrangements.

Clay Scherer of DuPont Professional Products made a motion to have the 2012 meeting in Atlanta, Georgia. The motion was unanimously approved.

c. The officers (listed below) for the 2012 NCUE conference planning meeting were discussed and voted into office.

Chair of the Conference Committee: Faith Oi
Chair of the Program Committee: Grzegorz Buczkowski
Chair of the awards Committee: Karen Vail
Secretary to the Conference: Dini Miller
Treasurer to the Conference: Roger Gold (Laura Nelson)
Chair of the Sponsorship Committee: Dan Suiter (his 2nd term of 2)
2012 Local Arrangements Committee: Dan Suiter, Tracy Jenkins, and Kyle Jordan

d. It was decided that continuing to hold the NCUE conference during the 3rd week of May still worked the best for most participants.

e. All amendments to the NCUE by-laws were passed, with the exception of the proposed change that would prevent scholarship winners from participating in the student paper competition. This particular change to the by-laws was eliminated at the request of the membership so that by-laws still allow all students to participate in the paper competition.

There was also discussion regarding the succession of officers. Robert Kopanic made a motion that an amendment be made to the by-laws which stated that "If an officer could not serve in their next position (in the succession), a replacement would be elected by the membership via electronic vote." The motion was passed unanimously, and the by-laws regarding the succession of officers were passed, as amended.

f. Roger Gold has again exceeded the number of years (2 years) that by-laws allow for holding a single office (NCUE Treasure). At the request of the membership, he agreed to serve another two years. The motion was made for Roger to serve another two years as treasurer. The motion was passed unanimously.

Roger Gold also expressed to the membership that he could not be the NCUE treasurer forever, and that a replacement would have to be found within the next four years. Bob Kopanic (of S. C. Johnson) expressed interest in taking the position. Bob suggested that he may have

PROCEEDINGS OF THE 2010 NCUE, PORTLAND, OR

the staff and potential support of S.C. Johnson to take over the position (which requires some administrative support). Bob also stated that if S.C. Johnson was not supportive, he might still be willing to take on the position and seek out his own administrative help. It was decided that Bob Kopanic would attend the hotel negotiations (for the 2012 meeting) with Roger Gold and Laura Nelson to see what is involved.

g. New business- It was suggested from the floor that NCUE look into the possibility of on-line registration. Michelle Smith of Dow AgroSciences volunteered to contact the Pacific Branch of the ESA, which now has on-line registration, to see what would be required to make the NCUE conference registration available on-line.

H. There was no additional new business and the business meeting was adjourned by Karen Vail at 11:40am.

Letter Certifying Compliance with IRS Filing Requirements

Thompson, Derrig & Craig, P.C.

CERTIFIED PUBLIC ACCOUNTANTS

Woody Thompson, CPA/CFP
Ronnie Craig, CPA
Dillard Leverkuhn, CPA

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Gay Vick Craig, CPA
Kay Dobbins, CPA
Lyn Kuclemba, CPA
Alice Monroe, CPA
Jamie Reeves, CPA
Marian Rose Varisco, CPA


March 1, 2010

National Conference of Urban Entomology
Board of Directors
c/o Texas A&M University
Center for Urban and Structural Entomology
2143 TAMU
College Station, TX 77843-2143

Dear Board of Directors,

For the 2009 tax year a Form 990-EZ will not be required to be filed for the organization. The organization's average annual gross receipts for the three-year period of 2007, 2008, and 2009 is less than the \$25,000 threshold that requires a return to be filed. A Form 990-N (the e-Postcard) has been electronically filed with the IRS for the 2009 tax year to notify the IRS that the organization's average gross receipts are under the \$25,000 threshold.

Sincerely,



Dillard Leverkuhn, CPA

List of Attendees
2010 National Conference on Urban
Entomology
May 16-19, 2010
Portland, Oregon

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PROCEEDINGS OF THE 2010 NCUE, PORTLAND, OR

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