PROCEEDINGS OF THE NATIONAL CONFERENCE ON URBAN ENTOMOLOGY 1996

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Edited by: *Arthur G. Appel*
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NATIONAL CONFERENCE ON URBAN ENTOMOLOGY

HISTORICAL PERSPECTIVE AND GOALS OF THE NATIONAL CONFERENCE ON URBAN ENTOMOLOGY

In the spring of 1985 individuals representing urban entomology and the pest control industry came together to organize a national conference on urban entomology. They agreed the conference could open channels of communication and information exchange between scientists in industry, academia, and government, and foster interest and research in this important discipline of entomology.

The primary scope of the National Conference will be areas of urban entomology other than ornamental, stored products, medical and veterinary, and industrial pest control. Focus and emphasis will be given to innovation and research on household and structural insect pests. However, flexibility remains to include peripheral topics that pertain to the general discipline of urban entomology.

Leadership for the Conference will be provided by a Steering Committee composed primarily of representatives from academia, but including pest control professionals from industry and government. The 5-8 positions on the Committee will be selected from academia (4-5), industry (1-2), and government (0-1). These members of the Committee will serve a maximum of four Conference terms (8 years). New members of the Committee will be invited by the Chairperson to serve, after discussions on potential new members by the Steering Committee. The Committee will include two titled positions: Committee Chairperson, and Committee Treasurer.

> Chairperson of Steering Committee-The individual in this position will be selected from the existing Committee by the Committee members, and will serve one two-year term (one conference).
>
> Committee Treasurer-This individual will be selected from the Steering Committee and will serve a minimum of two terms (two conferences).

There will be an ad hoc Awards Subcommittee chaired by the immediate-past Chair of the Steering Committee. The remaining people on the committee will be appointed for a one-Conference term by the Subcommittee Chair. The Chair will report directly to the Steering Committee.

National Conference on Urban Entomology

1996 Planning Committee

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ARNOLD MALLIS MEMORIAL LECTURE

THE FUTURE OF RESEARCH

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INTRODUCTION

I am honored by the invitation to present a lecture memorializing the name of Arnold Mallis. I count myself fortunate to have known this pioneer in the field of urban entomology. I am delighted that his name is being kept alive in this manner, and I commend the National Conference Organizing Committee for doing so. I am grateful to this year's Planning Committee for the invitation.

As most of you know, I retired from VPI&SU about one year ago. Let me assure you, first of all, that my retirement hasn't improved my vision or wisdom. I am still the same person I was previously. It is unlikely that I will say anything new today. All I really hope to do is to make you focus on urban entomology, especially urban entomology research.

My comments will be critical at times. Please don't take them personally, because they are intended to be general in nature. I understand, of course, that urban entomology is a broad field. I will not try to address specific areas, except as examples of research.

MY BASIC PREMISE

I want to begin my discussion from a point of view that I have maintained throughout my career. I believe strongly that research in entomology, or any sub-discipline of entomology, must have two main components. They are basic research and applied research. Put another way, they are the science and the practice of entomology.

If you view entomology as a whole, the main reason for its existence as a discipline is to solve practical problems. That is to say, to provide the means to control pest insects. However, a discipline of this nature will soon find itself crippled by a lack of knowledge if it does not have a strong basic research component as well. This is certainly not a new thought, but I intend to couch the rest of my remarks from this perspective.

ARNOLD MALLIS MEMORIAL LECTURE

THE CURRENT STATUS OF URBAN ENTOMOLOGY RESEARCH

It is my contention that urban entomologists have done a creditable job of providing answers to practical problems of insect control in the urban environment. I believe we can be proud of the our research record in the past, at present, and I think that will continue to be the case in the future. That is not to say that we have provided satisfactory solutions to all urban insect problems. Indeed, some of them have not even been addressed.

There are at least two reasons for this situation. First, there are not enough people working in urban entomology to have accomplished that lofty goal. Second, control practices are dynamic in nature. There may never be a "final" solution to some, if not most, control problems. The area in which I have worked is an example. Insecticide resistance in the German cockroach is an ever-changing arena. Continuing research will be necessary to stay abreast of the problem, and we certainly have not solved it. I am sure each of you could point out similar examples from your specific area of work. Nevertheless, I believe the applied research component of our discipline is creditable and compares well with applied research in other sub-disciplines in entomology. Of course, that is also not to say that improvements aren't needed. Again, I am sure that most of you can think of ways in which you could have done a better job in the past.

Now we come to basic research. It is here that I will become somewhat more critical. To be blunt, basic research in urban entomology, as I will define it, is virtually non-existent. That which has been done has often been "bootlegged" on applied research funds. Of course, that goes to the heart of the problem; funding for basic research is in short supply. I will address funding problems later, but here I want to concentrate on basic research itself.

I define basic research as research done for its own sake. It may or may not have practical value now or ever. However, basic research is critical to the long term success of any discipline because out of it will come the basis for practical solutions.

Much of the basic research that has been done in urban entomology has related to the biology of specific pests. Of course, that kind of information is vital because it may point out weaknesses in the biology of specific pests that can be exploited in control operations. What I am more concerned about is the paucity of new information on the physiology, biochemistry, and genetics of urban pests. I believe that future control technologies will come out of basic research in these areas. It is useful to remember that many current insecticides attack the insect nervous system, but the nervous system is only one of many possible physiological systems that can be disrupted. Further research is needed to establish how that can be accomplished.

Furthermore, most urban entomologists have stood by like disinterested spectators and watched as the revolution in molecular biology has swirled around their heads. I am as guilty as anyone else here, but it is my contention that, if urban entomology is to remain a viable science in the long term, some urban entomologists must become more deeply involved in all of the above areas.

I was pleased to hear several papers in the Urban Entomology Formal Conference at the ESA meeting in Las Vegas last December, in which biochemical and molecular techniques were used in basic studies on urban pests. One such paper used the molecular technique called RAPD-PCR to distinguish *Blattella* species at the molecular level. I am also aware of other work being done in these areas. What I am trying to say is that this kind of research can be done by urban entomologists, and I believe it is important for them to do so. For anyone who might be interested, I recommend a book called "Insect Molecular Genetics" by Marjorie Hoy published in 1994 (Academic Press), in which she detailed many molecular techniques and their application to entomological problems.

THE FUNDING OF BASIC RESEARCH

I previously mentioned funding problems in relation to basic research. I now want to address them more specifically here. I will start by reviewing the traditional sources of funding that are available, at least in theory, to urban entomologists. The main ones are federal agencies like NSF, NIH, and USDA, state experiment stations and extension services, industry, and private funding agencies.

I can remember a time, early in my career, when NIH and NSF funding was readily available for research on insects, even cockroaches. That is no longer the case. To be successful now, one has to be at the cutting edge of a discipline like physiology, biochemistry, genetics, or toxicology. Most grant requests that are funded in these areas also involve the use of molecular techniques. Even then, the rejection rate by those agencies is high.

USDA has it's in-house laboratories, in which some of you work, and it's competitive grants programs. In my opinion, the latter offer very limited opportunities for urban entomologists because of the way they are set up. Regional USDA grant programs are also available, but are tried to commodity areas. Only recently has urban been identified as a "commodity" in some, but not all, regions.

State experiment station and extension service funding has never been adequate, and has been squeezed repeatedly in recent years in many states. Private granting agencies have never been a major source of funding for urban research.

Therefore, as most urban entomologists are painfully aware, the principal source of funding for research in this area is industry support. I want to say up front that I, and I am sure most other people who have received such support, are grateful for it. Without it we would have been able to do very little research of any kind in the recent past. However, there are some things about industry support that need to be said; some positive, some negative. On the positive side, industry has supported much of the applied research that has been done over at least the last 20 years. On the negative side, very little basic research, as I have defined it, is supported by industry outside of their own facilities. In addition, the applied research that is funded is mainly designed to support product development. It goes without saying that such applied research must be done if we are to continue to have successful insecticides on the market. I certainly am not suggesting otherwise.

What I am leading up to is, what should and/or can we do to alter or improve the current situation? First, do we want to change current funding arrangements? I believe we should. I think we are mortgaging our future if we don't start placing more emphasis on basic research. To do that will require changes in funding patterns.

I believe there are three approaches that can be taken to improve the situation. They are: individual efforts, collective efforts, and broadening industrial support. I want to briefly discuss each of these points.

As individuals, I am afraid that most urban entomologists have given up on trying to get funding from federal granting agencies like NSF. I know from my own experience that it is tough, frustrating, and time consuming. Yet, I know that many of my former colleagues in other departments at VPI were able to get NSF funding on a continuing basis. What it takes is a good idea on some basic problem, and , if necessary, a tie-in with someone like a biochemist or a molecular biologist to help get started with the technical or technique aspects of the proposal. That is how it is done, and those agencies represent the best source of funding for basic research.

As many of you are aware, a collective effort is under way to try to secure special federal funding to support urban-entomology research. Those of you who attended the ESA meeting in Las Vegas have already heard of that effort. This is not the place to discuss it in detail, but I support that effort wholeheartedly. However, we must be realistic. Even if that effort is successful, it will take a while, perhaps several years, for it to be accomplished. Thus, it offers no immediate increase in funding for any type of urban research.

Perhaps the most promising place for people in academia to look for that kind of support is the USDA Regional Grant Program. It already exists and has an annual request for proposals. As I mentioned earlier, some regions already have urban as one of their "commodity" areas. I am not sure whether what I am going to say next belongs under individual or collective efforts, but what urban entomologists in academia need to do is to get involved on the selection committees for their regions. My impression is that agricultural entomologists have dominated those committees in the past. My feeling is that many of them don't consider urban to be a legitimate USDA commodity area. By getting on those committees, urban entomologists can help change that perspective. Those of you in academic positions can volunteer to serve through your experiment-station directors. I think there is a real hope of getting increased research dollars from that source in the immediate future.

That brings me to industry support. What I want to say here is relatively simple. I know that urban entomologists in industry only have limited funds directly available to them, and that those funds are used mainly for product development. What I am urging on industrial urban entomologists is to try to convince their higher administrators to invest some small percentage of sales or profits or whatever in basic research. I look at it as an investment in the future. I know that may be difficult to justify to hard-nosed business executives, but I believe the benefits to the long-term success of the pest-control industry are enormous. I hope some of you in industry will give it a try, or try again if you have tried and failed in the past.

CONCLUSION

In conclusion, I want to say that I believe urban entomology is a great field in which to work. I am sure that most of you hearing or reading this paper would agree. The opportunities are almost limitless. As you now know, I believe we need to do more and better basic research to ensure continued success in the future. Sadly, insect control and product development efforts are frequently taken for granted. In the long run, urban entomology will be judged by the contributions it makes to the science of entomology. Those contributions will come mainly from or will be fostered by the people hearing or reading this paper. To borrow a phrase from a TV commercial "Be all that you can be." That is how to secure the future of urban entomology.

PAPER 1
A VIEW OF THE FUTURE ISSUES & OPPORTUNITIES

COCKROACHES

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Cockroaches remain one of the most important urban arthropod pests. They are despised by apartment residents and householders alike and, unlike other structural pests, cockroaches are fast moving, odorous, and consume human food and waste. More recently, the association between cockroaches and allergy has become a significant focus of medical research.

Basic and applied research has been conducted with cockroaches for more than a century, but we still know relatively little about the biology of even the most important pest species. Our lack of knowledge can be attributed to several factors that will be discussed in this manuscript, namely the very nature of cockroaches as pests, the paucity of funding for basic and non-product related applied research, and the very limited number of researchers working in the field of urban entomology.

RESEARCH

Typically, most past and present research projects have evaluated the effects of single chemicals, formulations, or control strategies against one species or even one stage of that species. Naturally, for purely basic scientific studies, as many variables should be controlled as possible so that the magnitude of the affect of a treatment can be determined most accurately. However, most cockroach pest population are not homogeneous in terms of age, reproductive status, or sex. There are profound differences in body mass, lipid, and water content among cockroach stages that can affect insecticide toxicity and ultimately insecticide performance. Similarly the behavioral differences among stages and even between gravid and nongravid adult females may also affect insecticide toxicity (Abd-Elghafar et al. 1990) and performance. Thus, experiments with for example 2-3 week old adult males are somewhat, but not absolutely indicative of treatment effects on a population.

Past and present laboratory studies include simple LD_{50} and LT_{50} determinations, various repellency assays including the slant card, treated jar, and Ebeling choice box (Ebeling et al. 1966); and in some studies a mathematical combination of toxicity and repellency, the Performance Index (Rust and Reierson 1978). As mentioned above, most of these previous studies have been conducted with single toxicants or single formulations against, most commonly, male German cockroaches. Field studies have typically compared the effectiveness of several single treatments over a 3 month period. However, there are important methodological problems with many field studies because of insufficient sampling, inadequate experimental design and replication, and lack of 'standards' and experimental controls (see Appel and Reid 1992, Reid and Appel 1994). The issue of experimental controls is particularly important in field studies.

An untreated control group is critical to proper experimental design. The control group "controls" for all factors other than the various insecticide treatments. These factors include, but are not limited to, temperature, humidity, a species intrinsic rate of growth, seasonal variations, etc. Controls are particularly critical in peridomestic cockroach research because cockroach behavior and therefore trap catch is greatly dependent on the weather (e.g., Appel and Rust 1985). A simplistic example of the need for experimental controls is a late season (August or September) German cockroach field experiment that lasts 3 months (ending in November or December). All treatments will show reductions in cockroach trap catch over time, but so does the untreated control. Properly analyzed, insecticide efficacy results must be 'corrected' for natural population decline. This is hardly ever done!

What about the "morality" of allocating apartments into a group that does not receive a treatment (or a treatment 'placebo' that has no chance of working)? This is a real ethical and scientific dilemma. We have attempted to deal with the problem of controls by asking residents if they wish to receive an insecticide treatment to control their cockroaches. A surprising number of residents do not wish to have their apartments sprayed or even baited, but will agree to allow us to trap their apartments with nontoxic sticky traps. We have considered the possibility that cockroaches infesting apartments where residents do not want insecticide treatments are not representative of cockroaches infesting other apartments. Our preliminary studies have shown no difference in insecticide resistance levels between German cockroaches removed from control and insecticide-treated apartments. Apparently routine Housing Authority sprays (twice a year to **every** apartment) and some population movement between apartments (see e.g., Owens and Bennett 1982) is sufficient to maintain a degree of homogeneity.

Future research will include evaluation of non-traditional control agents such as bacteria, fungi, and nematodes, as well as a variety of new insecticide chemistries. Environmental tactics including heat and cold treatments, anoxia, and moving air will all be evaluated as single treatments against male German cockroaches. Hopefully, laboratory experiments will incorporate more stages and even mixed-stage groups for more relevant evaluation of control tactics. Because our current laboratory bioassay methods are relatively simple, results from procedures that incorporate increased habitat complexity will yield better predictions of field results. Finally, better analytical methods need to be developed to provide more accurate predictions of field efficacy from laboratory results.

RESEARCH FUNDING

Past and present funding for cockroach related research has come primarily from chemical manufactures and consumer or professional products companies. Because these funds come from profit oriented companies, the sponsored research projects tend to be goal oriented. Typically, university researchers compare formulations, evaluate repellency and toxicity, and conduct field efficacy trials. University researchers are of value to industry because of their perceived objectivity. More 'basic' research is conducted with the 'profits' obtained from sponsored research. Unfortunately, much of sponsored research is of limited intrinsic value and often can not be published. In addition, the funds obtained for sponsored research projects are relatively small and unstable, especially when compared with the size and duration of major government grants. Thus, 'basic' research ends up poorly funded, at best.

Traditional funds for cockroach research also include Hatch, United States Department of Agriculture (USDA) and various university grants, the National Research Initiative (NRI), National Science Foundation (NSF), and National Institutes of Health (NIH). Unfortunately, basic whole-organism research has not been well funded by NSF or NIH and more applied research is usually tied to a major agricultural crop or commodity. Urban entomologists often find themselves at a disadvantage when applying for competitive grants because they do not have sufficient preliminary data, or lack the grant-writing skills to compete. Their time and research programs have been focused on contract research.

Beginning in the 1980's several USDA regional IPM programs began to list "urban" (in the broad sense) as a priority area. Several sizable grants have been awarded for cockroach research, however, the subject areas for successful proposals are narrow and the proposals must be written for review by non-entomologists. More recently, the National IPM implementation program provided Phase I funds for planning structural urban entomology IPM. Phase II funds are still pending.

Research funding from chemical manufactures and consumer product companies will undoubtedly continue, but can not be expected to fund 'basic' research or even research into management strategies that might use a competing companies products. Unless the urban entomology funding initiative spearheaded by Purdue University is successful, 'basic' research will continue to be either funded by competitive grants (e.g., NRI, UDA, etc.) or bootlegged from sponsored research.

A View Of The Future
Issues & Opportunities

Control Practices

Professional cockroach control has developed significantly from the days of baseboard sprays and other broadcast applications of insecticides. Crack and crevice treatments and containerized baits, together with low-toxicity insect growth regulators have replaced most baseboard, ultra low volume (ULV), and greater-toxicity treatments. However, there are few examples of multi-tactic approaches, especially those that incorporate several toxicants/formulations or 'unconventional' tactics. Smith et al. (1995a) developed a multiple correlation model that related smokybrown cockroach trap catch outdoors to house and landscape characteristics. They (Smith et al. 1995b) used this model to develop and validate a multi-tactic IPM system that reduced cockroach trap catch faster, better, and longer than conventional control methods. Similar correlation models and IPM systems are being developed for German cockroach control.

Future control practices will probably continue the trend of minimizing broadcast use of insecticides for cockroach control. Some companies have begun to offer consumers choices between traditional spray programs and IPM systems. Even if the costs are greater for IPM, many consumers are willing to pay to minimize their exposure to insecticides. More trapping and less insecticide application will continue. New IPM strategies that incorporate multiple insecticides, precision placement of treatments, and construction practices will be developed.

Extension and Teaching

Traditionally, information on identification and control of cockroaches and other urban pests has been distributed in books, extension bulletins and circulars, and yearly state 'pesticide handbooks'. This will continue, but with the growth of information and the Internet, it has been envisioned that most bulletins and circulars will be available online at interactive world wide web (WWW) sights. Most Cooperative Extension Services currently have some of this information available.

Together with on-line keys for pest identification and correlation models, it is now possible for homeowners to evaluate the potential for their home to have large or small cockroach populations. An interactive exchange of information between the homeowner and a computer model will help to identify potential pest harborage sites that can be treated or physically removed. On-line information will also aid in training pest control operators with the latest information, even before it has been published. Training manuals will eventually be on-line. Testing and certification may soon be conducted in computer classrooms. Similarly, student textbooks will exist on-line.

New books (both bound and virtual) on the "Science of Urban Entomology" are needed. There are no graduate-level books that discuss the details of designing and validating IPM systems for management of urban insect pests. Hopefully, such a text will be developed.

CONCLUSIONS

Urban entomology and more specifically cockroach management is gradually becoming more professional and more scientific. I believe that these trends will continue as we adopt the methods of longer-established disciplines and the technologies of the future.

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Paper 2
A View Of The Future Issues & Opportunities

Ants

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In the year 2000, 40% of the world's people will be living in cities and more than 80% of the population growth during this time will occur in urban areas. The impact of household insects such as ants on humans in the urban environment will be even greater than it is today.

There are more than 20 species of ants that will infest households in the United States and probably twice this number throughout the world. However, the pest ants that cause the most problems in the U. S. generally belong to the following genera: *Camponotus, Linepithema [Iridomyrmex] Monomorium, Paratrechina, Pheidole, Solenopsis, Tapinoma, Tetramorium,* and *Wasmannia.*

Ants can cause numerous problems in the urban environment. Their mere presence in peoples homes causes annoyance and undue stress, the possibility of contamination by spreading pathogens and diseases is always present, some can inflict painful stings that can be life-threatening to hypersensitive individuals, and some cause damage to wooden structures, roofs, and electrical equipment.

The habits of many urban pest ants make most control techniques utilizing sprays and dusts ineffective because these treatments usually kill only foraging workers but do not eliminate the colonies. Although the use of toxic baits is one of the best methods to control urban pest ants, there is still a need for developing new and more attractive bait formulations and biorational methods of control.

Future issues that we will certainly face will be to maintain and conduct research with less funds, but continue to find answers to questions in basic research and behavior which will lead to new ideas for control. For example, we need to develop baits that can work against multiple pest ant species, especially those that occur in dwellings, while at the same time develop species-specific ant baits for use against those widespread, damaging outdoor pest ants such as the imported fire ant. The development of biological control and other methods that have less negative impact on the environment should be a high priority. We still have many unanswered questions in areas such as foraging behavior, nutrition, neurohormonal influences, the mode of action of several active ingredients, etc. that will require answers for the future.

The opportunities for us are tremendous. We still have exotic ants being introduced into the U.S. and some will become urban pests which will require new solutions. Also, disturbances in habitat or other changes have elevated some innocuous ants to pest status, and these new pest problems are demanding solutions. Finally, much of the ant bait development in the past was a result of the tremendous amount of basic research expended on the fire ant in the United States. Therefore, in order for us to unlock secrets that will allow us to solve the problems that pest ants present to our urban environment, there will always be a need for basic research if we are to develop safer and less costly methods for ant control.

Paper 3
A View Of The Future
Issues & Opportunities

Modes of Action of Insect Growth Regulators on Fleas

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In addition to their well known effects on gene expression, insect growth regulators (IGRs) have a number of other modes of action on fleas. This presentation will describe current research on the modes of action of IGRs on the adult and egg stages of the cat flea.

Four IGRs are currently registered for flea control in the US, the chitin synthesis inhibitor, lufenuron, and three juvenile hormone mimics, fenoxycarb, methoprene, and pyriproxyfen. Lufenuron is a benzoylphenyl urea derivative which is sold as an oral medication that persists for about a month in the blood of the pet. Lufenuron, ingested with the blood, is incorporated into the eggs of the flea and prevents hatching of the larvae. Fenoxycarb, methoprene, and pyriproxyfen also act on the egg to prevent hatching (Marchiondo et al. 1995) but their modes of action differ from lufenuron and from each other.

Modes of Action of Lufenuron

Data on the modes of action of lufenuron on cat fleas will be presented as a poster paper at this meeting by Susan Pullen and R. Meola. For information on the effects of lufenuron on unhatched larvae and adult fleas, readers are referred to the abstract of this paper.

Mode of Action of Pyriproxyfen on Adult Fleas

Pyriproxyfen is unusual among juvenile hormone mimics because it is toxic to adult fleas (Meola et al. 1993, 1996). Mortality does not occur immediately but instead occurs over a period of days (Fig. 1) when fleas are maintained on treated dog hair and fed blood with an artificial membrane feeding system.

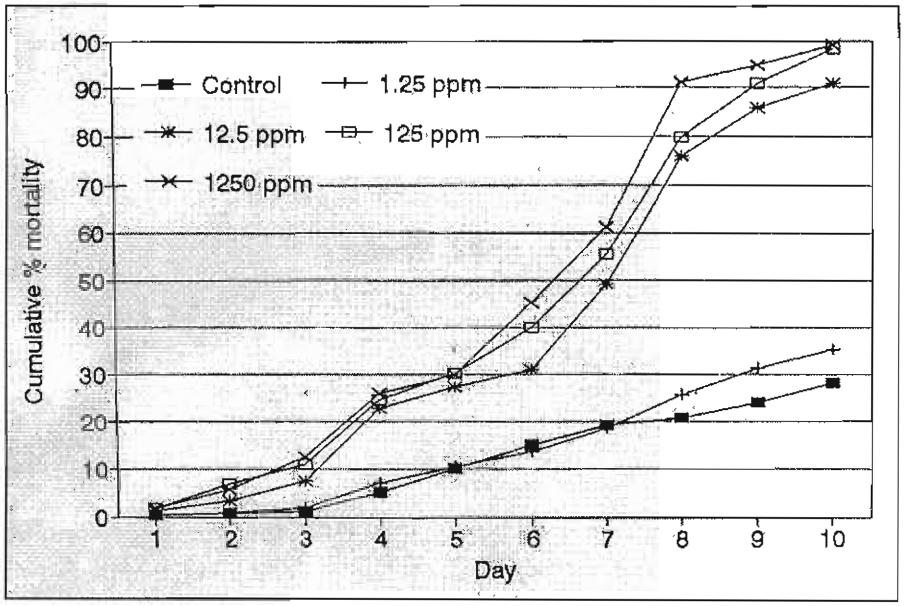

FIGURE 1

To determine why pyriproxyfen was toxic, fleas that had been exposed for 7d to acetone-treated (control) or pyriproxyfen-treated dog hair were preserved in alcoholic Bouin's fixative and prepared for histological study. Paraffin sections, 7µm in thickness, were cut with a microtome, mounted on slides, stained for 1 min according to the Malloy-Heidenhain procedure of Cason (1950) and then photographed though a compound microscope. Examination of the internal tissues indicated that pyriproxyfen-treated fleas were dying due to histopathological damage to their epithelial tissues. Examples of these histological effects are illustrated in the following comparisons of healthy control tissues with the dying cells of pyriproxyfen-treated fleas.

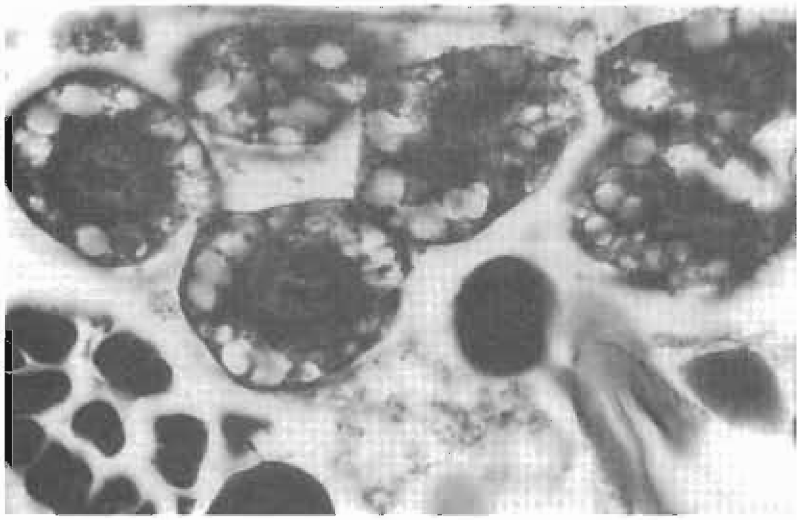

FIGURE 2
NORMAL FAT BODY CELLS OF A CONTROL FLEA FILLED WITH STORAGE VACUOLES. NOTE DISTINCT NUCLEI AND CYTOPLASMIC MEMBRANES. 1075X

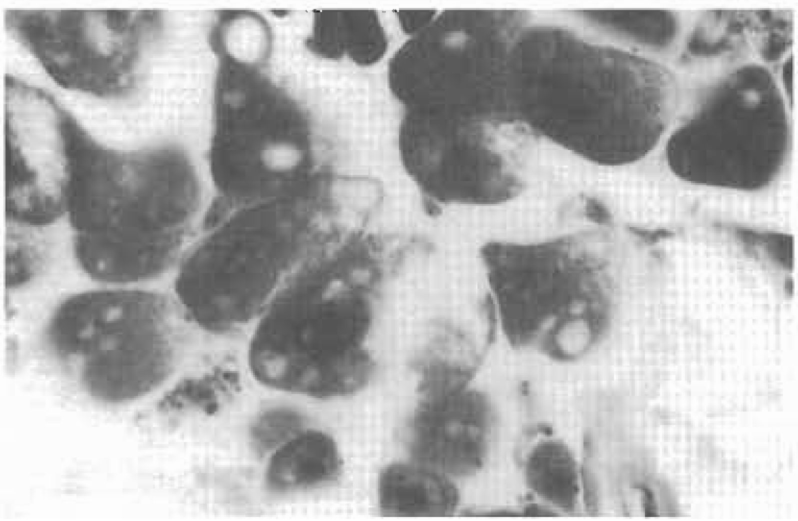

FIGURE 3
FAT BODY CELLS OF PYRIPROXYFEN-TREATED FLEA UNDERGOING AUTOLYSIS. CELL MEMBRANES BREAK DOWN AS THE FAT BODY DISINTEGRATES. 1075X

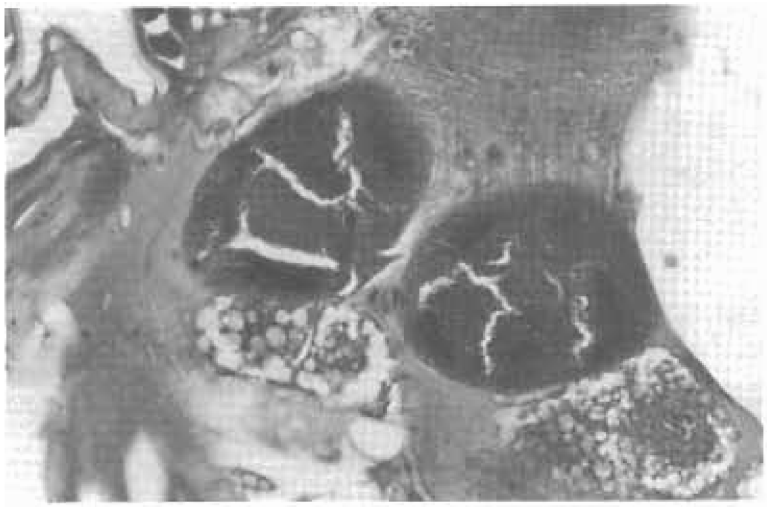

FIGURE 4
SALIVARY GLANDS OF CONTROL FLEA WITH FULLY FORMED EPITHELIAL CELLS AND DISTINCT OVAL NUCLEI SURROUNDING A WELL FILLED SALIVARY RESERVOIR. 484X

FIGURE 5
SALIVARY GLANDS OF PYRIPROXYFEN-TREATED FLEA UNDERGOING AUTOLYSIS. EPITHELIAL CELLS ARE FLATTENED, AND NO LONGER HAVE DISTINCT CELL MEMBRANES OR NUCLEI. SALIVARY RESERVOIR IS ENLARGED AND FILLED WITH PARTIALLY DIGESTED EPITHELIAL TISSUE. 484X

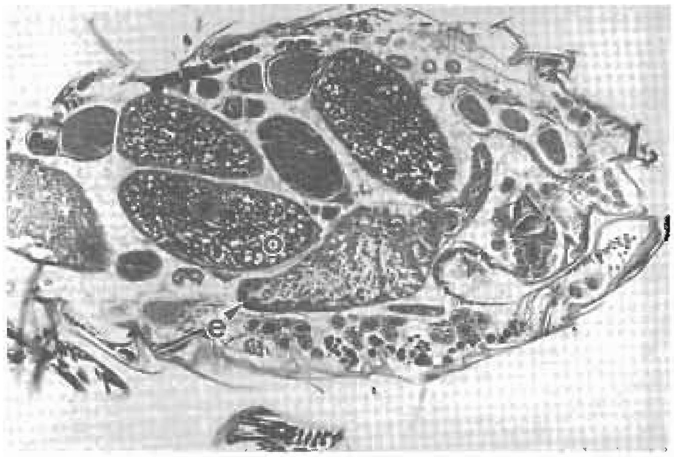

FIGURE 6
SAGITTAL VIEW OF CONTROL FLEA WITH WELL DEVELOPED MIDGUT EPITHELIAL CELLS (E) ENCLOSING REMNANTS OF DIGESTED BLOOD MEAL. NOTE MATURE OOCYTE (O). 107.5X

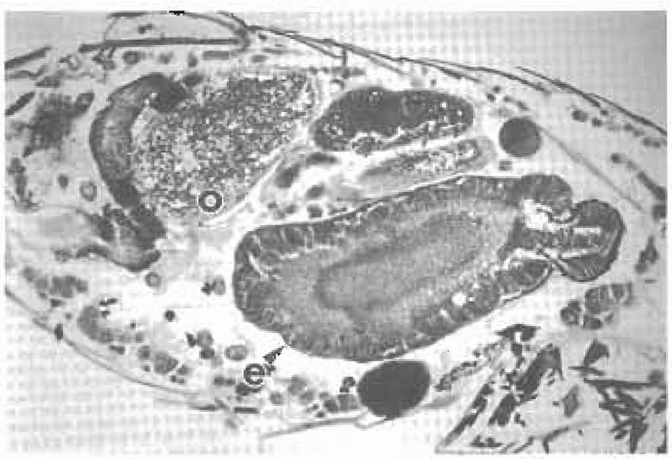

FIGURE 7
SAGITTAL SECTION THROUGH PYRIPROXYFEN-TREATED FLEA ILLUSTRATING HISTOPATHOLOGICAL EFFECTS. UNDIGESTED BLOOD IN MIDGUT IS THE RESULT OF LYSIS OF MIDGUT EPITHELIAL CELLS (E) WHICH HAS DESTROYED THE MIDGUTS DIGESTIVE FUNCTION. OOCYTE (O) IS ALSO UNDERGOING AUTOLYSIS. 107.5X

MODE OF ACTION OF PYRIPROXYFEN ON DEVELOPING EGGS

In addition to pathological effects on epithelial cells, pyriproxyfen also acts internally on developing eggs causing autolysis of maturing oocytes. The resulting damage to the eggs is illustrated in the following comparison of sections through a 7-day-old control versus a 7-day-old pyriproxyfen-treated flea.

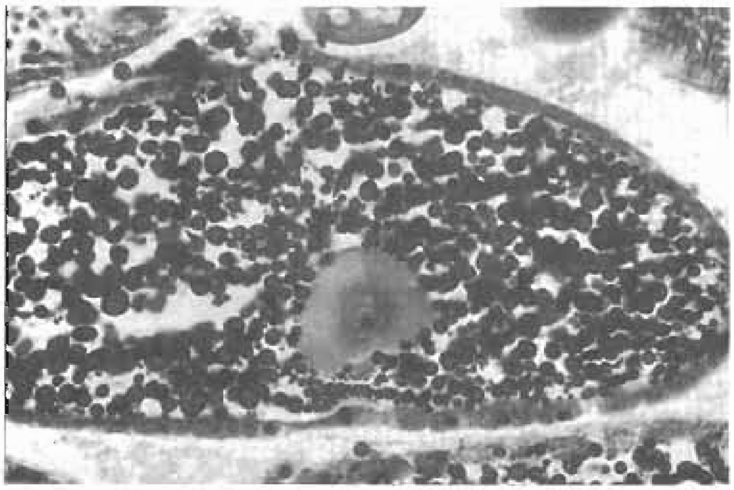

FIGURE 8
MATURING OOCYTE OF A CONTROL FLEA SHOWING ENLARGED OOCYTE FILLED WITH YOLK GRANULES SURROUNDING THE OOCYTE NUCLEUS. NOTE DISTINCT FOLLICULAR EPITHELIAL CELLS SECRETING CHORONIC MEMBRANES AROUND THE PERIPHERY OF THE OOCYTE. 484X

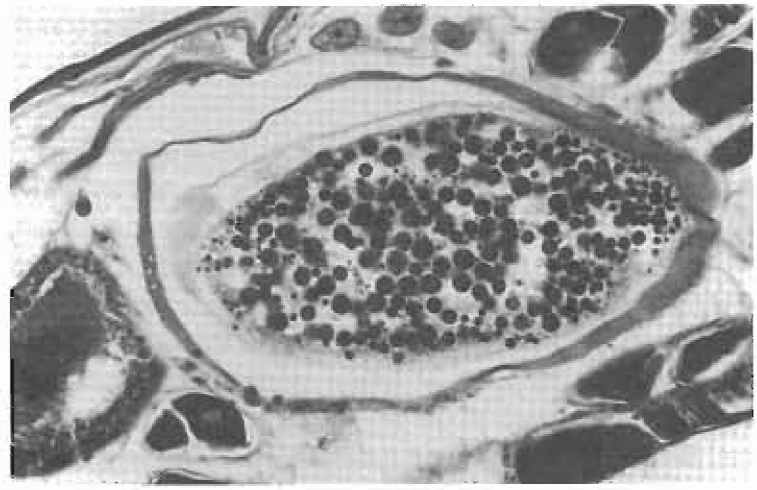

FIGURE 9
MATURING OOCYTE OF PYRIPROXYFEN-TREATED FLEA UNDERGOING AUTOLYSIS. NOTE PARTIALLY COLLAPSED SHAPE OF OOCYTE, AUTOLYTIC VACUOLES DIGESTING YOLK, DESTRUCTION OF THE OOCYTE NUCLEUS, AND DAMAGED CHORION. 484X

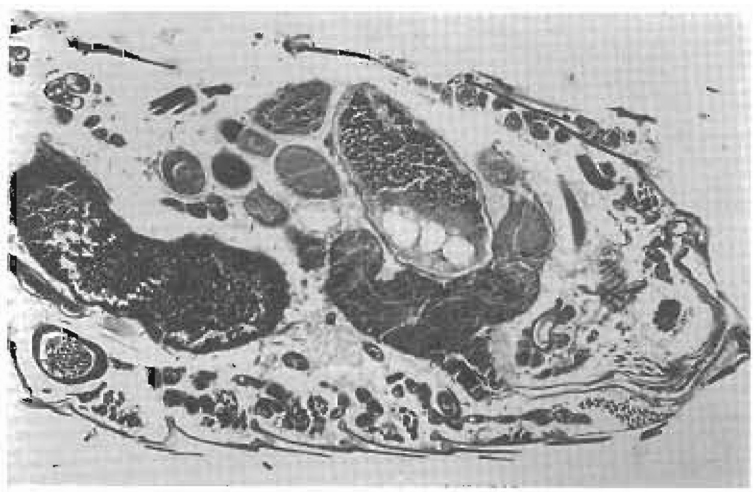

FIGURE 10
MATURE EGG OF A PYRIPROXYFEN-TREATED FLEA ABOUT TO ENTER OVIDUCT. LARGE AUTOLYTIC VACUOLES INDICATE AREA OF YOLK DIGESTION. 145X

COMPARISON OF EFFECTS OF PYRIPROXYFEN AND METHOPRENE ON FLEA EGGS

Damage to the follicular epithelial cells of pyriproxyfen-treated fleas often results in the production of a weak, poorly-formed chorion which is unable to withstand the muscular pressure of the oviducts during ovulation. As a consequence, eggs are crushed releasing their contents into the oviducts which results in the deposition of empty shells (Fig.11). Those eggs that withstand the pressure of the oviducts during oviposition usually lack a nucleus and thus fail to undergo zygote formation. In this respect, the mode of action of pyriproxyfen is different than the mode of action of methoprene which acts on the egg after oviposition to prevent blastokinesis of the segmented embryo (Palma et al. 1993). Eggs of methoprene-treated fleas remain turgid but may eventually become discolored.

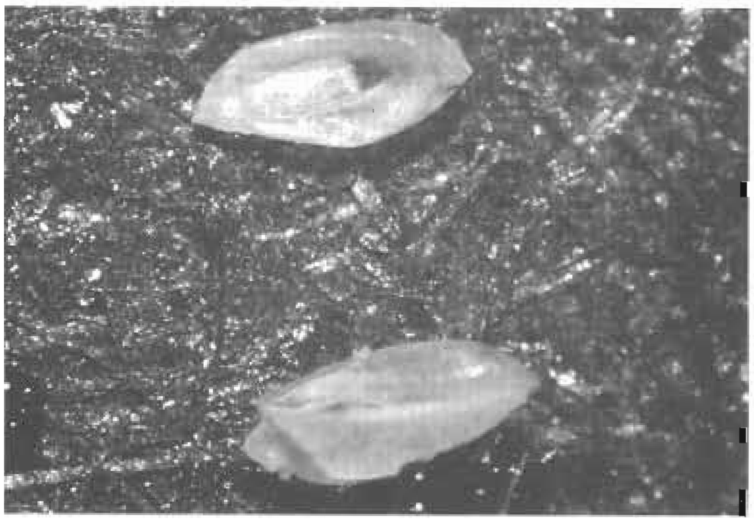

FIGURE 11

COMPARISON OF THE EFFECTS OF PYRIPROXYFEN AND FENOXYCARB ON THE FLEA EGGS

Marchiondo et al. (1990) demonstrated that 1 minute exposures of eggs to fenoxycarb residues on filter paper were highly toxic to cat flea eggs ranging in age from 0 to 48 hours old. To compare the effects of pyriproxyfen and fenoxycarb on flea eggs, Susan Pullen and I conducted similar experiments duplicating the procedures of Marchiondo et al. (1990) as closely as possible. Technical grade samples of pyriproxyfen and fenoxycarb were diluted in 70% isopropyl alcohol and applied to filter paper at the rate of 1.1 µg AI/cm^2 of surface area. Flea eggs of different ages were rolled on the surface of the paper in a circular pattern for 1 minute. Eggs that were to receive a 1 minute exposure were then removed from the paper, whereas eggs that were to be exposed for longer intervals were left on the paper for the allotted time.

Eggs removed from the treated paper were put on clean 1 cm^2 pieces of moist filter paper, and then placed on a mixture of sand and larval diet so that larvae hatching from the eggs could crawl to the diet and begin feeding. All containers seeded with test eggs were maintained in an environmental chamber at 25°C and 80% relative humidity. The number and percentage of larvae hatching from the eggs were determined after 5 days by examining the eggs under a microscope. Numbers of larvae completing development to the adult stage were determined after 4 weeks by counting the adult fleas in each test container.

The results in Table 1 showed that both pyriproxyfen and fenoxycarb substantially reduced percentage hatch in 0-4 hour old and 24-hour-old eggs compared with 80-90% egg hatch in the untreated control eggs. Only 29% of the eggs hatched when they were exposed for 1 minute to the pyriproxyfen-treated papers versus 15% hatch on the fenoxycarb-treated papers. Less than 10% of the 0-4 hour eggs hatched after 1 hour exposure to either of the test chemicals. Emergence of adult fleas reared from larvae that hatched from treated eggs also was reduced.

Overall, fenoxycarb had significantly better ovicidal activity than pyriproxyfen in both the 0-4-hour and 24-hour old egg groups. Evidently the IGR sensitivity of the flea eggs used by Marchiondo et al. (1990) was greater than the Texas A&M University strain used in our tests, because our results showed that fenoxycarb was not toxic to older eggs. They obtained nearly 100% control of eggs or newly hatched larvae by treating 48-to 72-hour-old eggs with 1 minute exposure to fenoxycarb. In contrast, our results showed that 48-hour-old eggs were only slightly affected, if at all, by up to 1 hour exposure to pyriproxyfen or fenoxycarb.

Results presented here suggest that the ovicidal action of pyriproxyfen is more effective during development of the egg in the adult flea than it is as a direct contact spray on the pet, whereas fenoxycarb is more effective by direct contact to eggs deposited on the hair of the pet. However, further studies are needed to test this hypothesis, because there is no published information on the physiological effects of fenoxycarb in adult fleas.

PHARMACOLOGICAL ACTION OF JUVENILE HORMONE AS A BASIS FOR THE HISTOLOGICAL EFFECTS OF PYRIPROXYFEN ON ADULT FLEAS

Preliminary studies currently underway in my laboratory indicate that the histopathological effects of pyriproxyfen can be duplicated by exposing adult fleas to high concentrations of

Juvenile Hormone III. These findings suggest that the juvenile hormone potency of the pyriproxyfen molecule is so great that even at relatively low dosages it causes pharmacological effects in the flea equivalent to a massive overdose of juvenile hormone. This mode of action is different than the effects observed in previous studies with IGRs on larval fleas, and the results suggest that the multiple modes of action of IGRs on fleas may be due to their extreme sensitivity to chemicals that mimic the action of the juvenile hormone molecule.

TABLE 1

PERCENT HATCH AND ADULT EMERGENCE OF CAT FLEAS EXPOSED AS EGGS TO FILTER PAPER TREATED WITH PYRIPROXYFEN OR FENOXYCARB AT A DOSAGE OF 1.1 μG/CM^2.

		Pyriproxyfen		Fenoxycarb	
Age of Eggs	Exposure Interval	Hatch	Emergence	Hatch	Emergence
0-4 h	1 min	29A[3]	86a	15B	84a
	10 min	22A	44a	5B	10b
	60 min	9A	20a	0B	0a
24 h	1 min	60A	79a	20B	45b
	30 min	45A	59a	9B	30a
	60 min	27A	41a	6B	20a
48 h	1 min	83A	92a	85A	96a
	30 min	79A	92a	90B	91a
	60 min	82A	94a	86A	93a
Control[1]		92	94	80	96

1Control eggs 24 h-old were left on alcohol-treated paper for 60 min.

2Numbers above represent means of 5 replicate groups of 20 eggs each for percent hatch or mean adult emergence of larvae hatching from eggs.

3Within a row values followed by different letters are significantly different (two sample t-test, $P \leq 0.05$). Upper case letters refer to comparisons between hatch, lower case letters to emergence.

COLONY DEVELOPMENT AND REPRODUCTIVE DYNAMICS IN THE SUBTERRANEAN TERMITE, *RETICULITERMES FLAVIPES* (KOLLAR)

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Despite their ecological and economic importance, little is known of patterns of colony growth and reproduction in species of *Reticulitermes.* Because field studies of colony foundation and growth are impossible with these cryptic insects, we studied population growth of laboratory colonies initiated from alates of known origin. We report on the results of studies of 55 incipient colonies of *Reticulitermes flavipes* (Kollar) that contained a live primary king and queen at the end of two years.

The total colony size of these two-year-old colonies (sum of all workers, soldiers, immatures, and the reproductives; excluding the number of eggs) ranged from 51 to 984 individuals, with a mean of 387 $\pm$ 226 (standard deviation). The percentage of soldiers (plus presoldiers) per colony ranged from 0.23 to 7.91 percent, with a mean of 2.1 ($\pm$ 1.4) percent.

Previous records of maximum growth rates for incipient termite colonies were substantially lower than in our study. Our colonies were reared under highly favorable conditions and without the interference of periodic censuses. These "best case scenario" colony growth rates combine with other aspects of the life history of *Reticulitermes* colonies to support an emerging concept of the reproductive dynamics and colony structure of natural *Reticulitermes* colonies.

The classic paradigm of the life history of a social insect colony is that colony reproduction occurs with the dispersal flights of fertile offspring. However, the relatively slow growth rates observed, even under the best-case conditions of this study, raise questions concerning the importance of colony founding by dealate pairs as a major means of population expansion in these insects. Colonies appear to grow the most rapidly when headed by multiple brachypterous or apterous neotenic reproductives. Differentiation of numerous neotenic reproductives, in combination with diffuse colony spatial organization and budding, appear to be the predominant modes of population growth and expansion in *Reticulitermes flavipes.*

TERMITES

KEYWORDS

subterranean termites, *Reticulitermes,* Rhinotermitidae, colony growth

MARK-RELEASE-RECAPTURE EXPERIMENTS WITH FIELD POPULATIONS OF *RETICULITERMES* SPP. (ISOPTERA: RHINOTERMITIDAE) IN GEORGIA, USA.

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Three subterranean termite species, *Reticulitermes flavipes, R. virginicus,* and *R. hageni* were included in 67 mark-release-recapture experiments conducted on 57 different colonies in Georgia. Data from 1992-93 were collected under a triple-mark-release protocol and analyzed using two mathematical models; the Lincoln Index and a Weighted Mean Model. Data from 1995 were collected under a single release of marked termites followed by three recapture periods and analyzed using the Lincoln Index for each separate recapture period.

There were no indications of species-dependent trends with the estimates obtained using these techniques therefore the data were combined. Termite foraging population estimates ranged from 106 to 1,453,021 for the Weighted Mean Model and 127 to 384,617 for the Lincoln Index in 1992-93. The 1995 Lincoln Index population estimates ranged from 776 to 3,547,152. Upon comparison, both mathematical models used with the 1992-93 data provided similar population estimates with a median estimate of 28,473 for the Lincoln Index and 36,370 for the Weighted Mean Model. The mean of the Lincoln Index estimates from the 1992-93 data was lower than the 1995 mean, 61,829 ±90,209 to 462,640 ±575,752, respectively (median = 98,202 for 1995).

The data, when examined by recapture cycle, demonstrate that *Reticulitermes* visitation to individual termite monitors is unpredictable. In 23% of our experiments termites were not found in particular monitors during at least one of the recapture cycles. In colonies active in more than one monitor in 1995 no marked termites were recovered from the monitor in which they were released in 29% of the experiments and marked termites were recovered from only 56% of the other monitors visited by those colonies. Of those 1995 colonies in which marked termites were recovered on the final recapture period marked termites were recovered on only the first and third recapture cycles in 25% of the cases. These data indicate that the model assumption of equal mixing of marked and unmarked termites is tenuous in *Reticulitermes* field populations. The premise that numbers derived from mark-release-recapture protocols reflect accurate estimates of true subterranean termite foraging population size must be interpreted with caution and require a better understanding of termite behavior and biology in the field.

KEY WORDS

Subterranean termites, mark-release-recapture, population estimates

TRIAL-FOLLOWING ACTIVITY BY FORMOSAN TERMITE WORKERS AND SOLDIERS ON ARTIFICIAL TRIALS

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Improved and economical attractants appear necessary to increase the acceptance of termite baits. Bait additives that mimic natural trail pheromones are known to enhance bait acceptance by termites. Three chemicals were evaluated at four different concentrations for their trail-following potential against workers and soldiers of the Formosan subterranean termite, *Coptotermes formosanus Shiraki.* The trail-following assay was modified from the assay used by Prestwich et al. (1984) for subterranean termites. Five microliters of a test solution was applied to a 10-cm semicircular pencil line on Consolith paper. Only one termite was tested on each paper and 20 replicates were conducted for each concentration and termite caste. (Z)-4-phenyl-3-buten- 1 -o1 has been reported by some researchers to be an effective trail-following lure of Formosan termites while others have shown poor bioassay results for this termite. A 93% cis isomer of the chemical was synthesized by photoequilibration of isomers using triplet excitation and bioassayed. The two other chemicals evaluated for their trail-following activity against Formosan termites included: 1) 3-phenoxy-1-propanol, which is commercially available but easy to make in high purity and structurally resembles both the termite trail-following component found in Paper Mate® ball-point pens (phenoxyethanol) and (Z)-4-phenyl-3-buten-l-ol; and 2), 2-naphthalenemethanol, which is easily available and appears to fit the model of termite trail pheromone receptor site proposed by Prestwich et al. (1984). Chi-square analysis was used to determine if trail-following by soldiers and workers significantly varied due to concentration. This analysis also was used to determine if soldier responses varied significantly from worker responses. 2-naphthalenemethanol gave results that appear most promising for further consideration as a bait additive.

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HIGH-GRADE STAINLESS-STEEL MESH AND SAND-BARRIER FIELD TESTS FOR CONTROL OF SUBTERRANEAN TERMITES

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Stainless-steel mesh (S-S mesh) tests were installed in Arizona, Florida, Mississippi, and South Carolina during 1993, and on Midway Island during September 1994. The objective of these tests is to evaluate a specific stainless-steel mesh as an exclusion barrier to native *(Reticulitermes flavipes, R. virginicus)* and Formosan *(Coptotermes formosanus)* subterranean termites. The three test methods in use on the mainland are: (1) S-S mesh sleeve, (2) concrete block, and (3) concrete slab. The "mesh-case" method is being used on Midway Island. After 2 years of testing on the U. S. mainland and 1 year on Midway Island, the S-S mesh remained 100% successful.

Basaltic sand barrier tests were installed in the 4 U. S. mainland test sites during 1991, and on Midway Island during 1988, 1989, 1990, and 1991. The two test methods in use against the Formosan termite on Midway Island are: (1) concrete-slab stake, and (2) concrete-block. The concrete-block method is being used against native termites on the mainland. After 4-7 years of testing on Midway Island and 4 years on the mainland, basaltic sand barriers varied in their effectiveness. On Midway, sand barriers placed under concrete slabs remained 100% effective for 6 years, then declined to 80% effectiveness after 7 years. Concrete blocks containing 5-, 10-, or 15-cm thick sand barriers remained 100% effective after 4-6 years (1995), but there was very little termite activity in the control concrete blocks that contained only coral sand. Concrete-block tests on the mainland were 20 to 100% effective after 4 years depending on barrier thickness. Effectiveness of 5- and 10-cm thick barriers ranged from 20-90% and 30-100%, respectively. Fifteen-cm thick barriers were 90-100% effective in AZ, FL, and SC, but only 40-80% effective in MS. Control failures ranged from 70-100%.

KEY WORDS

Reticulitermes flavipes, *Reticulitermes virginicus*, *Coptotermes formosanus*, stainless-steel mesh, basaltic sand barriers

PAPER 5
TERMITES

EFFICACY OF TERMITICIDES IN A THREE-YEAR FIELD STUDY IN HAWAII

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To evaluate efficacy against the Formosan subterranean termite, *Coptotermes formosanus* Shiraki, soil insecticides were applied to locally-obtained soil and to sand at six field sites on the four major Hawaiian islands (Kauai, Oahu, Maui, and Hawaii). The insecticide solutions were applied at the pre-treatment rate of 1 gallon per 10 square feet, and each treated substrate was covered by a polyethylene sheet and a 30 by 30 by 4-inch thick concrete slab. In a modification of the protocol originally developed by M. Tamashiro and J.R. Yates, soil cores were extracted annually at each site, and returned to the laboratory for bioassay. The 4-day bioassay assessed termite mortality and horizontal penetration of 4-cm of the test substrate, held between two agar plugs in a glass tube.

This paper reports results after three years of field exposure with commercial formulations of bifenthrin (0.06% solution concentration), chlorpyrifos (1%, 2%), cyfluthrin (0.25%, 0.50%), and cypermethrin (0.3%); and results after one year of exposure with imidacloprid (0.01%, 0.05%, 0. 1%). This study provides a realistic appraisal of the relative longevity of soil insecticides applied for Formosan subterranean termite control under the diverse environmental conditions found in the Hawaiian islands.

KEY WORDS

Subterranean termites, *Coptotermes*, soil termiticides

THE EFFECTIVENESS OF BORATE TREATED FOAM INSULATION PANELS FOR THE CONTROL OF TERMITES

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Conventional termite control strategies include the use of water-based emulsions of termiticides for structural treatment. Incorporation of the pesticide into the soil or wood provides protection by making such media either repellent or toxic to termites. These measures have in general been quite successful over a range of building construction types. Recently however a new problem in termite control has emerged as a result of the increased use of polystyrene-based foam insulation panels in renovations and new construction. The use of these panels increases the energy efficiency of the structures but also is subject to tunneling activity by various wood-infesting insects such as termites. As a result, some panel manufacturers have incorporated boron containing materials into the insulation with the expectation that the pesticidal residue will effect insects that tunnel into the foam. The purpose of the research presented here was to determine whether such panels would be effective in prevention of termite infestation and the level of boron needed to achieve that effectiveness.

Expanded polystyrene (EPS) panels were manufactured to contain 1, 3, 5, and 10% zinc borate by the Reddi-Form Co. (Oakland, N.J.) The borate was incorporated into the foam panels during the manufacturing process and not applied as a simple surface coating. Mean boron content of the panels determined using inductively coupled plasma spectrometry were 109, 280, 253, and 426 ppm, respectively. For a bioassay, glass tubes were used to hold 2.5 cm of soil and either 2 or 4 cm plugs of EPS. Fifty worker and two soldier termites *(Reticulitermes flavipes)* were placed on the soil. A minimum of three replicates were done for each of the panel concentration. Tubes were examined daily and extent of tunneling and termite mortality were recorded. Results indicated that the tunneling activity of the worker termites was not inhibited regardless of the concentration of borate. There was some amount of tunneling activity in all tubes. At least one replicate from each panel concentration had a foam barrier which was completely tunneled through. In addition, termite mortality was directly linked to boron level and thickness of the foam barrier. The amount of time until 100% mortality decreased in proportion to increasing levels of boron or barrier widths. However, regardless of boron level, 100% mortality was not reached before extensive or complete penetration of the foam had been achieved.

Overall, the use of zinc borate treated EPS panels in building construction apparently offers only limited protection from termite infestation.

KEY WORDS

Subterranean termite, *Reticulitermes*, borates, foam insulation

BORATE AS A DETERRENT TO COLONY FOUNDATION BY THE WEST-INDIAN POWDERPOST TERMITE, *CRYPTOTERMES BREVIS*

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A wood-block bioassay was designed to be an attractive habitat for colony foundation by drywood termite dealates. Fifty units were constructed from "2x2s" surface sprayed with 10% disodium octaborate tetrahydrate (Tim-bor), fifty from untreated wood, and fifteen from commercial CCA-treated lumber. The 115 units were arranged randomly near a 3.9-watt light in a dark room housing wood infested with *Cryptotermes brevis* (Walker). Continuous natural alate dispersal flights were monitored in this room during May and June 1995 and dealates were observed initiating mating behavior and nuptial chamber construction on block surfaces. Four months after flights, the blocks were disassembled and inspected for nuptial chamber location and incipient colony development. Twenty-eight (56%) untreated blocks contained one or more nuptial chambers housing a total of 129 living (72 males and 57 females) and 1 dead dealate. Nuptial chambers were constructed preferentially in crevices built into bioassay units compared to flat outside surfaces. Only two nuptial chambers were constructed in borate-treated units with neither containing dealates. No nuptial chambers were found in CCA-treated units. We conclude that borate and CCA-treatments either deter colony foundation or are unpreferred substrates in comparison to untreated blocks offered as an alternate choice. Treatment effects appeared to be limited to behavior modification as no toxicity was observed as a result of dealate contact with chemical deposits. Of 49 incipient colonies in untreated blocks, 27 were composed of one male and one female with the remaining consisting of various homo- and heterosexual combinations. Brood development was observed almost exclusively in single male/female pairings where 17 of 27 contained eggs and/or larvae.

KEY WORDS

Kalotermitidae, drywood termites, incipient colonies, disodium octaborate tetrahydrate, CCA, alates.

EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON AGGREGATION AND WATER LOSS IN THE WESTERN DRYWOOD TERMITE, *INCISITERMES MINOR* (HAGEN)

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Aggregation is a behavior commonly observed in *Incisitermes minor* (Hagen). Pence (1956) suggested that *I. minor* nymphs aggregate when exposed to arid conditions to conserve and exchange moisture. Aggregated nymphs, he proposed, could effectively reduce cuticular water loss and increase their survival because the individuals in the group would have less exposed surface area. However, this hypothesis was never tested or, at least, published. The purpose of this study was to determine if aggregation of *I. minor* nymphs, as measured by the distance between individuals in a group, is affected by temperature, relative humidity (RH) and saturation deficit (SD) and to compare water loss between grouped and individual termites exposed to different combinations of temperature and RH for 24 h.

MATERIALS AND METHODS

To determine if water loss was affected by the presence of other termites and the distance between them, fifteen *I. minor* nymphs, which had not fed for 36 h, were weighed as a group and placed in a 14-cm diam. petri dish. Five more unfed nymphs were weighed individually and placed in separate 3.5-cm diam. dishes set on a desiccator plate. The larger dish was placed on top of a glass jar so that it rested directly above the smaller dishes in the desiccator. Nymphs were exposed for 24 h to combinations of 10°, 21.1°, or 35°C and 12.5, 33, 52, or 76% RH. Each desiccator had a clear plexiglas lid with a 1-mm hole through which a thermocouple was inserted to monitor the temperature inside. The desiccators were placed on a cart and the grouped termites were videotaped for 5 min at the end of the 24-h exposure by moving the cart slightly so that eventually each desiccator was positioned directly beneath an overhead videocamera. Videotapes were analyzed by pausing the tape at randomly selected times and measuring the distance between the termites as follows: one termite on the screen was picked at random and the remaining 14 termites were numbered in ascending order according to their proximity to the first termite. Six of these numbered termites were randomly chosen and the distances between the first one chosen and the remaining five were measured by placing an acetate sheet over the television screen, circling the randomly selected termites and measuring the distance between the centers of these circles. The nymphs were weighed at the end of each test, dried in desiccators maintained at 0-2% RH at 60°C and reweighed to determine initial and final total body water content and the percent change in total body water content for grouped and individual termites.

Results and Discussion

Weight loss, mostly due to water loss, for grouped and isolated termites was greater in the following order: 35°C > 21.1°C > 10°C. RH did not have a significant effect on weight loss for grouped termites. At 12.5% RH isolated termites lost significantly more weight than at the other three RH's. Weight loss was greater at all three temperatures and at 12.5 and 33% RH in isolated termites. Weight loss was greatest at higher SD's and was significantly greater for individual termites than for grouped termites at the two highest SD's (45 and 35 mmHg). There were more significant differences in weight loss between the different treatments among isolated termites than among grouped termites suggesting that temperature and RH have a greater influence on water loss for isolated termites. Overall, isolated termites consistently lost more water than did termites held in groups, especially at the higher SD's; but these differences were not significant.

SD had no significant effect on the density of aggregations except at 5.6, 5.3 and 13 mmHg where the largest and smallest distances between aggregated termites were 5.1, 1.5 and 1.4 cm, respectively. The smallest distances between termites were found at low SD's rather than at the higher SD's we had expected. This probably reflects the tendency of *I. minor* to aggregate even in the absence of strong external stimuli (Cabrera and Rust 1996). The distance between grouped termites was greater at 35°C than at 10°C, but the distance at 21°C was not significantly different from either of these temperatures. RH did not have a significant effect on aggregation. The greater distance between termites at 35°C indicated the possibility of a thermoregulatory response to prevent overheating (May 1985). *I. minor* nymphs have been shown to avoid temperatures > 44°C and aggregate at lower temperatures on a thermal gradient (Cabrera and Rust 1996). Temperature, more so than RH and SD, seemed to have the greatest effect on aggregation during a 24-h exposure. Future studies will include longer exposure periods (48 - 96 h) which may produce a greater effect on aggregation and more pronounced differences in weight loss between grouped and isolated nymphs.

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KEY WORDS

Kalotermitidae, drywood termite, water relations, desiccation

EFFICACY OF A LAMBDACYHALOTHRIN AND PYRIPROXYFEN MIXTURE ON AN INSECTICIDE RESISTANT FIELD POPULATION OF THE GERMAN COCKROACH (FIELD TRIALS)

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Field trials were conducted to study the effects of a formulated pyrethroid insecticide (lambdacyhalothrin) + synergist (piperonyl butoxide) + juvenoid (pyriproxyfen) mixture on an insecticide-resistant field population of the German cockroach. In a total of 17 apartments, treatments were made at 1 day, and 1-6 months following initiation of the study. Sticky trap catch (an estimator of population size) decreased through the study, and indicated a 91.2% population reduction at 12 months following the initial treatment. Wing twisting of trapped adults (an estimator of juvenoid-induced sterility) continued to be observed through the study. However, wing twist (% of trapped adults) formed a plateau at 65-70% for months 3, 4, and 5, and fell from 90% at month 9 to 70.6% at month 12. The treatment mixture also induced decreases in nymph: adult, and gravid: non-gravid female ratios between 6 and 9 months following the initial treatment. These ratios increased at month 12 in association with the slight recovery of the population from juvenoid effects. The overall high effectiveness of this treatment leads us to suggest that it may have applications for management of German cockroach populations which are resistant to pyrethroid insecticides.

KEY WORDS

Blattella germanica, resistance management, pyrethroids, juvenoids

EFFICACY OF A LAMBDACYHALOTHRIN AND PYRIPROXYFEN MIXTURE ON AN INSECTICIDE RESISTANT FIELD POPULATION OF THE GERMAN COCKROACH (LABORATORY TESTS)

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Combinations of live trapping, toxicity tests and biochemical assays were conducted to study the effects of a formulated pyrethroid insecticide (lambdacyhalothrin) + synergist (piperonyl butoxide) + juvenoid (pyriproxyfen) mixture on an insecticide-resistant field population of the German cockroach. Following initial live-trapping of cockroaches, topical toxicity tests revealed a high level of resistance to the active ingredient used on the population for 8 years previous (cypermethrin; LD_{50} resistance ratio (RR) = 82.2, LD_{95} RR = 136.5). In comparison to a susceptible strain, this resistance was partially reduced by pretreatment with piperonyl butoxide (8.0% at LD_{50}, 14. 1 % at LD_{95}), and cross-resistance to chlorpyrifos was detected at a significant level (LD_{50} RR = 5.22, LD_{95} RR = 9.97). Jar tests using technical grade cypermethrin, chlorpyrifos, and lambdacyhalothrin also indicated resistance and cross-resistance. In cockroaches collected from the field after an 80.3% population reduction and 90.5% level of wing twist, tolerance to lambdacyhalothrin increased significantly over the original population (25.0% at LD_{50}, 31.0% at LD_{95}). Biochemical assays of hydrolytic and oxidative resistance mechanisms for the original and surviving populations found a 3 1 0% increase in 1 -naphthyl acetate hydrolysis, a 191 % increase in 2-naphthyl acetate hydrolysis, a non-significant decrease of 2.5% in *p*-nitrophenyl acetate hydrolysis, and a 141 % increase in total cytochrome P450 monooxygenase content for the surviving population. Results are discussed in terms of the impacts of this management program on resistance levels and resistance mechanisms in survivors, as well as the impacts of these findings in developing resistance management strategies with respect to the chemicals involved.

KEY WORDS

Blattella germanica, resistance management, pyrethroids, juvenoids

THE USE OF HEAT FOR CONTROL OF CHRONIC GERMAN COCKROACH INFESTATIONS IN FOOD SERVICE FACILITIES – A FRESH START

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Chronic, unacceptable, insecticide resistant German cockroach (*Blattella germanica*) populations exist in some U.S. Army's food service facilities. We have conducted 20 field trials using heat to control German cockroaches in food service facilities. The process used involved: caulking holes in walls and floor, disconnecting all electrical equipment, sealing exhaust and other air handling vents, applying an insect growth regulator (IGR), and heating the facility with direct fired propane heaters to a target temperature of 46°C (115°F) for 45 minutes or longer. Temperatures within the heated areas were monitored by placing T-type thermocouples at various levels (ceiling, floor, and in equipment) and recorded by a data logger at 10 min intervals until the heating process was terminated. Heat was applied for 4 to 6 hours or until no cockroach movement was observed. Temperatures frequently reached 65°C (150°F) at the ceiling while some areas at floor level remained below 46°C (115°F). As temperatures rose, the heat forced cockroaches hiding in daytime harborages to become active and leave to seek cooler locations. Those cockroaches which congregated in relatively cool spots were collected with a vacuum during the process. Following heating, a residual insecticide and IGR were applied to control those cockroaches surviving the heat treatment process. In one of the worst infestations treated, the pre-treatment trap index was 46. The trap index 1-week post treatment was 4.1, representing a 91 percent reduction. At 1-month post treatment, it was 0.3, the lowest level recorded in this facility in 1.5 years. The trap index remained well below 2.0 (the threshold for residual pesticide treatment) for 11 months with no additional pesticide applications, other than the placement of one to two dozen bait stations on three separate occasions in the dish washing and serving areas. This process has consistently provided long term (18 months) control of cockroach populations in treated buildings. Food service personnel who constantly battle cockroach infestations are interested in this process since it offers long-term population reduction.

The opinions or assertions contained herein are the views of the author(s) and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

COCKROACHES

KEY WORDS

Blattellidae, *Blattella germanica*, thermal control

PAPER 4
COCKROACHES

CHARACTERIZATION OF THE INSECTICIDAL ACTIVITY OF FRAGRANCE OILS AGAINST THE GERMAN COCKROACH

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Selected aromatic essential oils structurally related to α-terpineol provided knockdown (KD) of the German cockroach, *Blattella germanica* (L.), within 20 min. when applied as a dust. KT was as rapid as with some registered rates of pyrethroid insecticides. Not all fragrance oils were insecticidal. Symptomology suggests involvement with an energy-related system such as octopamine production. An anomaly was that topical application or exposure to pure fragrance oil deposits did not produce rapid KD. This indicated an important role of the diluent for increasing cuticular penetration. The activity of most fragrance oils tended to be short-lived and most were repellent. Efficacy may be enhanced by formulation that masks repellency or by use patterns in which the insect cannot escape exposure. Similar activity was observed with other insects, including other species of cockroaches and cat fleas.

Studies we made in 1994 with a diatomaceous earth-based dust (EcoSmart, Inc., Roswell, GA) indicated exceptional biological activity against the German cockroach; the cat flea, *Ctenocephalides felis (Bouché)*; and the Argentine ant, *Linepithema humile* (Mayr) [formerly *Iridomyrmex humilis (Mayr)*]. KD and mortality were so rapid as to suggest the presence of a nerve-active substance such as a pyrethroid insecticide. Further investigation, however, revealed no such contaminant. We determined that the insecticidal action of the dust was associated with a fragrance oil (FO) that had been added to enhance the odor of the mix. The objective of this study was to determine the biological activity of selected fragrance oils against the German cockroach, with a view to determining their applicability for control of this important pest.

MATERIALS AND METHODS

Insecticidal activity of dry components. Cockroaches were exposed to the dry ingredients listed in a statement of formulation for the EcoSmart dust. An inert diluent was needed in order to determine the activity of FO alone. Related presumably inert diluent dusts also were tested. Dust diluents tested included calcium carbonate ($CaCO_3$), sodium bicarbonate ($NaCHO_3$), pearlite (Hi-Sil 233), and diatomaceous earth. Using German cockroaches as test insects, continuous exposures were made to determine the speed of action (LT) of the dry dusts. For each dust, 3 replicates of 10 ♂♂ German cockroaches (Orlando Normal) were confined to 1.2 cc of dust spread onto Whatman No.1 ashless filter paper in the bottom of covered 9-cm-diam deep glass petri dishes. This quantity of dust assured thorough contact and coverage. Insects used in the study were selected from large, mixed-aged culture. The cockroaches were anesthetized with CO_2, allowed to recover 2h in corked glass shell vials, and then dumped directly onto the deposits. The cockroaches were observed for KD periodically for up to 24 h. The insects were considered KD when they were paralyzed and could not right themselves within at least 2 minutes of being turned over. KT_{50} and KT_{90} was calculated by interpolation and a mean KT value for each treatment was determined.

Activity of Fragrance Oils. The insecticidal activity of ingredients of selected commercial fragrance oils (Arylessence, Inc., Marietta, GA) was determined from the LT of cockroaches confined to mixtures of FO in $CaCO_3$. Calcium carbonate was used as the diluent because it had the least toxic effect on cockroaches of several supposedly inert dusts tested. Each oil was formulated at 5% (wt/wt). Mixes of 100 g dust mix were prepared by shaking together weighed quantities of $CaCO_3$ and pipetted quantities of FO or other test liquid. A good blend was ensured by vigorously shaking the mix with metal machine nuts by hand for 5 min. in a capped glass specimen jar. The oil ingredients tested included amyl cinnamic aldehyde, benzyl acetate, diethyl phthlate, phenyl ethyl alcohol, dipropylene glycol, and α-terpineol. Benzyl alcohol and benzyl benzoate were tested separately to determine possible relationships between chemical structure and biological activity.

Adult cockroaches were confined to 1.2 cc of each mixture on filter paper in petri dishes, as described above for exposures to the dry dust ingredients. KT was calculated by interpolating periodic KD data gathered every few minutes (up to 1.0-h intervals) over a maximum exposure period of 24 h. Differences among mean KT values was analyzed by analysis of variance (ANOVA) and overall means were compared using Tukey studentized range test, critical $P = 0.05$.

Food additives. To determine if common aromatics might also be insecticidal, several commercial natural food products were mixed into $CaCO_3$ and evaluated for insecticidal activity against cockroaches. Foods with potent odors were mixed, as per the FO mix, at 10% (wt/wt) into $CaCO_3$ and cockroaches (n = 30) were confined to 1.2 cc of the mixture spread onto filter paper in petri dishes. Some of the foods tested have been purported in popular literature to kill or ward off various insects. The foods included in the study included black pepper, chili powder, curry powder, garlic powder, and onion powder. Observations of KD were made every 30 min for the first 8 h, then intermittently for up to 48 h.

RESULTS AND DISCUSSION

Dust Diluents. As shown in Table 1, the least active dust diluent was calcium carbonate, ($CaCO_3$). The activity of $CaCO_3$ was not statistically difference from the untreated control. Hi-Sil 231, on the other hand, is a potent desiccant and was the most active of the dry ingredients, providing an average KT_{90} of 6.7 hours. Obviously, the addition of Hi-Sil to $CaCO_3$ proportionately increased the activity of the $CaCO_3$ because of the sorptive qualities of the Hi-Sil. Diatomaceous earth and sodium bicarbonate were not highly insecticidal but they did provide significant KD within 24 h. These data suggested that $CaCO_3$ was the most inert ingredient with which to determine the relative effects of FO in dust formulation. Other diluents may mask the effects of FO, especially if the FO produces effects slowly, perhaps over several hours. Therefore, $CaCO_3$ was subsequently used as the inert diluent in tests to determine FO activity.

TABLE 1
AVERAGE HOURS (± SD) FOR 50% AND 90% KNOCKDOWN OF ADULT MALE GERMAN COCKROACHES, *BLATTELLA GERMANICA*, CONTINUOUSLY CONFINED TO DUST DEPOSITS

	KT_{50}	KT_{90}
Dust or dust mix	Hours ± SD	Hours ± SD
Calcium carbonate ($CaCO_3$)	--	(10% KD at 24 h)
Hi-Sil 231	4.9 ± 0.38c	6.7 ± 1.38c
Diatomaceous Earth (DE)	11.8 ± 1.44ab	16.8 ± 3.03ab
Sodium bicarbonate ($NaHCO_3$)	16.5 ± 0.48a	20.9 ± 0.10a
$CaCO_3$ + 30% Hi-Sil 231	6.5 ± 1.00c	9.3 ± 1.53c
$CaCO_3$ + 30% Hi-Sil + 5% DE	6.3 ± 1.19c	10.8 ± 3.70c
$CaCO_3$ + 36% $NaHCO_3$	19.5 ± 0.50a	(80% KD at 24 h)
$CaCO_3$ + 5% Hi-Sil	13.7 ± 3.44ab	19.4 ± 1.52a
Untreated control	--	(0% KD at 24 h)

Average values based on 3 replicates, each with 10 cockroaches. SD = standard deviation. Exposures at 76°F, 55% relative humidity. In a column, values followed by different letter are significantly different ($P<0.05$, Tukey studentized range test).

Fragrance Oils. Fragrance oils have specific odor characteristics and low mammalian toxicity. Although high concentrations of some chemicals in these oils may irritate mucous membranes or cause intestinal discomfort if ingested, many are used extensively in products for humans and pets. Several of the tested FO components are used as food flavorings, and in pharmaceuticals, perfumes, and soaps.

Cockroaches were not visibly irritated by the FO mix. They remained relatively immobile during most of their exposure, and often succumbed standing upright, similar to symptoms observed when cockroaches are exposed to pyrethroid insecticide or treated with a metabolic inhibitor such as hydramethylnon. The insecticidal activity of the FO ingredients tested against cockroaches is summarized in Table 2. It was presumed in these bioassays that fastest KT was indicative of the most active FO or constituent. The most active FO components included benzyl acetate, phenyl ethyl alcohol, and α-terpineol. Each of these substances provided 90% KD of cockroaches in approximately 1 h. Amyl cinnamic aldehyde was much slower, about as active as diatomaceous earth. Although they impart a pleasant odor, diethyl phthlate and dipropylene glycol were not insecticidal. Interestingly, the complete EcoSmart formula provided fastest KD, the KT_{90} for it being only 0.5 h. Perhaps physical characteristics of formulation, a higher % of actives, or additive effects of ingredients in the complete formula contributed to more rapid effects.

TABLE 2
AVERAGE HOURS (± SD) FOR 50% AND 90% KNOCKDOWN OF GERMAN COCKROACHES CONTINUOUSLY CONFINED TO CALCIUM CARBONATE + 5% INGREDIENTS OF FRAGRANCE OILS

	KT_{50}	KT_{90}
Dust or mix	Hours ± SD	Hours ± SD
Calcium carbonate (dust)	--	(3.3% KD at 24 h)
Sodium bicarbonate (dust)	9.7 ± 0.48a	16.0 ± 0.88a
Diatomaceous earth (dust)	9.4 ± 0.00a	15.5 ± 0.00a
Amyl cinnamic aldehyde	9.4 ± 0.00a	15.5 ± 0.00a
Benzyl acetate	0.7 ± 0.05b	1.0 ± 0.18b
Diethyl phthlate	--	(0% KD at 18 h)
Phenyl ethyl alcohol	0.7 ± 0.09b	1.0 0.25b
Dipropylene glycol	--	(23% KD at 18 h)
∝-Terpineol	0.7 ± 0.08b	1.1 ± 0.17b
EcoSafe dust	0.2 ± 0.06c	0.5 ± 0.03c

Average values based on 3 replicates, each with 10 cockroaches. SD = standard deviation. Exposures at 78 ± 4°F, 55 ± 6% relative humidity. In a column, values followed by different letter are significantly different ($P<0.05$, Tukey studentized range test).

Although FO constituents in a dust mix provided rapid KD, pure FO or 10 % FO in acetone applied topically to the ventral sternites of German cockroaches (1 µl per insect) had no observable effect within 24 h. Similarly, residual deposits of pure FO on glass had no effect. Dust diluent apparently synergizes or otherwise enhances FO activity. This suggests that aerosol or contact spray formulations of FO may not be highly effective.

Table 3 shows that structurally related FO ingredients provide dissimilar effects on cockroaches, probably because of differential binding activity. Based on structure-activity comparisons, it has been postulated that a hydroxyl group at the end of a side chain attached to the benzene moiety causes binding *in vivo* that results in the observed biological activity. Good activity of some FO constituents may be derived from an aldehyde group being hydrolyzed to an hydroxyl end group. Research done elsewhere suggests that binding may occur at an energy-producing site rather than at a nerve site. The importance of isomeric configuration and the effect of various side chain substitutions (e.g. of benzyl acetate) on biological activity have yet to be determined.

TABLE 3
ACTIVITY AGAINST GERMAN COCKROACHES OF STRUCTURALLY SIMILAR CONSTITUENTS OF SOME FRAGRANCE OILS

	KT_{50}	KT_{90}
Dust or mix	Hours ± SD	Hours ± SD
Benzyl alcohol	1.5 ± 0.46	2.7 ± 0.29
Benzyl benzoate	(6.7% at 18 h)	
$CaCO_3$ (inert)	(0% at 18 h)	
∝-Terpineol	1.4 ± 0.36	1.9 ± 0.12

Average values based on 3 replicates, each with 10 cockroaches. SD = standard deviation. Exposures at 78°F, 28% relative humidity

Food additives. Each food-$CaCO_3$ mix had a characteristic, potent odor but none provided any KD of cockroaches (3 replicates of 10 ♂♂) within 30 hours. At 48 hr, KD was: 30% with onion powder, 23% on garlic powder, 10% on black pepper, 7% on curry powder, and 0% on black pepper. Obviously, none of these potent substances was insecticidal at the rates tested. Higher concentrations may be more active or repellent. These findings highlight the dramatic activity of the FO dust mix, and show that effects are not merely attributable to virtually any aromatic material formulated as a dust.

In summary, German cockroaches were killed within 20 min when exposed to a 5% mix of certain fragrance oils + an inert dust diluent. The most active substances tested included α-terpineol, benzyl acetate, and phenyl ethyl alcohol. Constituents such as amyl cinnamic aldehyde and benzyl alcohol also were active but provided KD more slowly. Dust mixes provided good activity, but FO applied topically or as a residue did not. A diluent may be a requisite for good activity. Potent aromatic food additives were not insecticidally active. Additional studies with various configurations and substitutions of FO constituents should be undertaken.

KEY WORDS

Blattellidae, *Blattella germanica*, insecticidal properties of fragrance oils

PAPER 5
COCKROACHES

COPROPHAGY AND DELAYED TOXICANT ACTIVITY OF COMMERCIAL BAITS IN *B. GERMANICA*: SEX AND STAGE DIFFERENCES

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Coprophagy occurs in both social and eusocial insects. It provides a means for redistribution of nutrients and symbiotic organisms among colony members. Coprophagous behavior like trophalaxis, is exploited in the control of urban pests, such as ants and termites; delayed activity bait products are consumed by foragers, transported to the colony, and redistributed via feces among feeding individuals. Coprophagy has been reported in cockroaches, but its significance in facilitating growth and enhancing fitness has not been studied. We quantified the amount of adult *B. germanica* feces ingested by first, second, and last instars. Only first instars accrue benefits from ingesting feces. Significant increase in longevity of otherwise starved nymphs occurs in first instars but not in other instars. This result indicates that the benefit of coprophagy is a stage specific phenomenon. The effects of type of feces (pellets, smears, or feces resulting from adults on different diets) on longevity of first instars are also reported. The diet of insects contributing feces to nymphs has an effect on nymphal longevity. In laboratory assays, first instar nymphs exposed to feces collected from conspecifics on a high protein diet survived longer than those on other lower protein treatments. These data suggest that coprophgy can provide nutrients to 1st instars during periods of food scarcity.

Nine commercial baits and defined diets (with insecticides added) were evaluated in laboratory assays for secondary kill of different life stages of the *B. germanica. S*econdary kill was observed in all stages tested but first instar nymphs were most affected when exposed to contaminated feces while last instar nymphs were the least affected. Thus far all cockroach baits tested in the laboratory show positive results although different active ingredients behave differently. Preliminary results support the idea that coprophagy is a promising target behavior to study for ways to improve toxic baits.

KEY WORDS

Blattellidae, *Blattella germanica*, coprophagy, secondary kill

PAPER 6
COCKROACHES

HISTORY OF CYPERMETHRIN AND CHLORPYRIFOS RESISTANCE IN A FIELD POPULATION OF THE GERMAN COCKROACH

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The majority of information on insecticide resistance in the German cockroach, *Blattella germanica* (L.), consists of one-time profiles for several chemicals based on laboratory colonies and often without background information on insecticide use or efficacy. Long-term studies of resistance in field populations of the German cockroach are few. The Urban Pest Control Research Center has been monitoring the field efficacy of insecticides in the German cockroach population (RHA) in the Lincoln Terrace apartments of the Roanoke, VA for 20 years, and has evaluated the efficacy (percentage reduction) and resistance ratios (RR) of chlorpyrifos and cypermethrin in this location for > 10 years.

One of the objectives of this monitoring program is to link insecticide use patterns and percentage reduction with resistance ratios for several key insecticides. This paper reports the gradual decline in efficacy of a pyrethroid (cypermethrin) against RHA in Lincoln Terrace apartments, control-failure resistance is documented at RR 180 at LC_{50}; the remediation of resistance in the RHA population, and the prospects for sustaining susceptibility are also presented.

The 25-year history of insecticide treatment for the 340 Lincoln Terrace apartments is summarized as follows: from 1970-1975 cockroach control was unscheduled and based on the use of chlorpyrifos; from 1975 to mid-1985 chlorpyrifos was used on a scheduled basis (1-3 times/yr.); from 1985 to mid-1990 cypermethrin was used exclusively (1-3 times yr.). From 1990-1993 the apartments were treated exclusively with chlorpyrifos, an no pyrethroids; from 1994-1996 they were treated once every 3-4 months with either chlorpyrifos or cypermethrin.

Cypermethrin was used experimentally in the apartments in 1981, and provided > 90% reduction of the pest population. Following exclusive use (1985-90), RHA susceptibility to cypermethrin (and other pyrethroids) gradually declined. In 1988 cypermethrin provided about 70% reduction; by 1989 a loss of flushing action and control failure occurred. High-level resistance (RR 180 at LC_{50}) was confirmed in 1990. During this time

(1981-1990) the efficacy of chlorpyrifos in the apartments fluctuated between 54% and 63%, and the RR at LT_{50} was 1.7-1.8.

From 1990-1993 all use of pyrethroids in the apartments was stopped, and control was provided by chlorpyrifos. During this 3-yr period the cypermethrin susceptibility in RHA returned, so that by late 1993 the RR at LC_{50} was 3. The remediation of cypermethrin resistance in generations of RHA was documented periodically. The return of susceptibility was confirmed in 1993 by the 76% reduction provided by applying cypermethrin in apartments. From 1990-1993 the level of chlorpyrifos resistance increased to RR 2.2 at LT_{50}.

Control-failure cypermethrin resistance in Lincoln Terrace was accomplished in about 13 RHA generations, and with only limited selection pressure. It may be difficult to design a IRM program for cypermethrin based on rotation of < 3 applications/yr. and still utilize the benefits of this chemical. There is considerable client satisfaction and incentive for the applicator to use this and other pyrethroids, and little incentive to restrict usage to preserve susceptibility. The restoration of susceptibility in RHA was accomplished in about 13 RHA generations; with this came moderate effectiveness and a return of the flushing action that characterizes pyrethroids. However, periodic (once every 3 months) use of cypermethrin resulted in a percentage reduction that ranges from 54 to 62%, and a RR at LC_{50} that ranges from 20 to 33.

The desirable characteristics of pyrethroids for household pest control will insure their popularity and probably their continued use by professionals and homemakers. It is inevitable that control-failure resistance will develop in some populations, but to date there has not been the widespread resistance predicted, nor the loss of this entire class of insecticides for German cockroach control. Resistance remediation may be effective for some populations, and may restore limited use of the insecticide.

KEY WORDS

Resistance, *Blattella germanica,* cypermethrin, chlorpyrifos

LONGEVITY OF FIELD-COLLECTED FEMALES OF THE SMOKYBROWN COCKROACH AND IMPLICATIONS FOR FIELD FECUNDITY

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Outdoor populations of smokybrown cockroaches, *Periplaneta fuliginosa* (Serville), are difficult to monitor. Quantitative records of oviposition from the field are unknown. This data is critical in determining the normal pattern of ootheca deposition in the field. and finding out if this pattern varies from year to year.

Ten females were collected field sites on 12 separate occasions in jar traps in 1994. The females were placed in individual jars with water food, and harborage. Females were checked daily for oviposition and death. Other females gathered from the field and dissected were used to determine the percentage of prereproductives (ovaries undeveloped prior to oogenesis). We used laboratory longevity and egg hatch to estimate the reproductive ability of trapped females.

Cumulative mortality from each trapping date allowed us to show that on some days old females predominated, while on others young females predominated. We interpret these data as the changing age structure of the population. The longevity of individual females fell into 3 broad classes : 220+ days, 150 days, and 50 days. The first category represented prereproductives and new reproductives, the second category represented older reproductives, and the last category, females which had passed most of their reproductive life in the field. Means of longevity were much longer that previously reported for laboratory reared females, perhaps indicating the vigor of individuals in the field.

Peak reproduction, as determined by high percentages of prereproductives and new reproductives peaked in June and in late August and September. Perhaps chemical controls timed to these peaks, would have the greatest effect on future population development, by greatly reducing the reproductive potential of population. We still need data to show whether this is a yearly pattern.

COCKROACHES

KEY WORDS

Blattidae, *Periplaneta fuliginosa*, longevity, population dynamics

PAPER 1
ANTS

THE CONTROL OF *SOLENOPSIS XYLONI* (MCCOOK) IN A COLONY OF ENDANGERED CALIFORNIA LEAST TERNS, *STERNA ANTILLARUM BROWNI* (MEARNS)

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The southern fire ant, *Solenopsis xyloni* (McCook), coexists with the endangered California least tern, *Sterna antillarum browni* (Mearns) at the Naval Air Station, North Island (NASNI) in San Diego, CA. *Solenopsis xyloni* is an omnivorous ant that damages crops and attacks wildlife, especially ground nesting birds (Stoddard 1931, Delnicki and Bolen 1977, Zalom and Bentley 1985). Successful nesting and fledgling production of the California least tern are adversely affected in some coastal nesting areas by *S. xyloni*. In fact, 78.7% (48 of 61) of chicks and eggs present at the NASNI colony in 1989 were killed by southern fire ants (D.A. Reierson unpubl. data). We developed an ecologically sound and sensitive strategy to protect the California least terns from predation by southern fire ants by using an attractive and efficacious bait and implementing and evaluating area-wide and strategic baiting.

Coturnix quail eggs, *Coturnix coturnix,* which are similar in size and eggshell thickness to California least tern eggs, were provided to laboratory and field colonies of southern fire ants. In the laboratory, quail eggs were presented to starved and unstarved southern fire ant colonies to determine if the eggs were readily attacked, if the ants were capable of breaching and foraging on the contents of the eggs, and how long it took for this to occur. In the field, Coturnix eggs were placed under wooden shelters and monitored for attack. A young sparrow chick was placed in starved and unstarved laboratory colonies and attractiveness to southern fire ants was investigated. California least tern chicks and eggs were monitored for southern fire ant attack

In the laboratory and field, *S. xyloni* was capable of breaching and foraging on *Coturnix* quail eggs (Table 1). Ants from starved laboratory colonies more readily attacked eggs than did ants from fed colonies. In the laboratory, ants immediately attacked a house sparrow chick of a size comparable to California least tern nestlings (Table 2). *Solenopsis xyloni* sometimes attacked California least tern eggs and chicks at field sites. In the field, pipped least tern eggs were attacked more frequently than unpipped eggs. *Solenopsis xyloni* attacked and killed newly hatched California least terns.

TABLE 1
RECRUITMENT OF SOUTHERN FIRE ANTS TO COTURNIX QUAIL EGGS

		Avg. No. Ants (± SE)		
Colony	No. Colonies	30 s	60 s	Time to Breach
Starved	6	36.3 ± 4.11	222.5 ± 8.65	30 - 60 min
Unstarved	3	7.7 ± 2.41 *	16.3 ± 6.72 *	22 h - 7 wks *

* Denotes significant differences of means within a column.

TABLE 2
RECRUITMENT OF SOUTHERN FIRE ANTS TO THE HOUSE SPARROW CHICK

	Avg. No. Ants (±SE)			
Colony	30 s	45 s	60 s	120 s
Starved	1.4 ± 0.76	21.6 ± 4.03	34.8 ± 7.15	52.6 ± 11.1
Unstarved	0.6 ± 0.47 *	4.8 ± 2.34 *	28.4 ± 3.03 *	48.4 ± 4.22
Starved (FF)	12.2 ± 2.34 *	33.8 ± 3.48 *	65.2 ± 1.0 *	145.4 + 7.0 *

FF = Fish fed sparrow/starved ants
*denotes significant differences among means

To reduce *S. xyloni* attacks, we prepared an attractive bait and performed area-wide and strategic baiting. *Solenopsis xyloni* in the laboratory readily took granular anchovy bait-base prepared with 1.0% hydramethylnon and Max Force. In the laboratory, hydramethylnon anchovy bait and Max Force each killed 100% of the colonies in 7d. In the field, hydramethylnon reduced the number of above ground foragers and suppressed the ant colonies for 6 months. In 1989, *S. xyloni* attacked and killed 48 of 61 (78.7%) of eggs and chicks present (Table 3). When M.K. Rust and D.A. Reierson scattered bait over the 8.9-ha site (area-wide baiting) in 1990 and 1991, 63 of 83 (75.9%) and 41 of 61, (67.2%), respectively, of eggs and chicks present were preyed upon. When we implemented strategic baiting or strategic placement of baits in a circle (radius 1m) around tern nests in 1993, only 11 of 88 (12.5%) of the eggs and chicks were killed by *S. xyloni* compared with 28 of 73 (38.3%) of the eggs and chicks in 1992 when no strategic baiting was conducted. In 1995, when we initiated both area-wide and strategic baiting of ant colonies, no least tern chick deaths were attributed to *S. xyloni*.

TABLE 3
PREVENTATIVE BAITING FOR SOUTHERN FIRE ANTS IN THE CALIFORNIA LEAST TERN COLONY AT NASNI.

	Eggs and Chicks		
Year	No. present	No. Killed (%)	Baiting Method
1989	61	48 (78.7%)	None
1990	83	63 (75.9)	Area-Wide
1991	61	41 (67.2)	Area-Wide
1992	73	28 (38.3)	Area-Wide
1993	88	11 (12.5)	Strategic
1995	97	0 (0)	Area-Wide & Strategic

We documented in the laboratory and the field that *Solenopsis xyloni* was capable of breaching and foraging on quail eggs that have similar size and eggshell thickness to California least tern eggs. Sparrow and California least tern chicks were also readily attacked by southern fire ants, especially when ants are food stressed. Because of heavy losses of California least terns to southern fire ants, it was important to initiate a control program that was ecologically and environmentally sensitve. Together, area-wide baiting and strategic baiting with hydramethylnon increased tern survival as well as the percentage of birds successfully fledging.

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COMPARISON OF POLYGYNE AND MONOGYNE FIRE ANT POPULATION DENSITIES (HYMENOPTERA: FORMICIDAE: *SOLENOPSIS INVICTA*)

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Polygyne or multiple-queen fire ant colonies (*Solenopsis invicta* Buren) are reported to be a substantially greater environmental and economic problem than monogyne or single-queen fire ants because of much higher population densities associated with polygyny. This study compared population densities of polygyne and monogyne fire ant colonies using measures of mound density, worker number, ant biomass, metabolic consumption and standing caloric energy of ant biomass. We began the experiment by counting and measuring mounds at 14 polygyne and 14 monogyne sites located within a 35-km radius of Gainesville, Florida. Average mound densities were 3.03 times larger at polygyne sites than at monogyne sites (470 verses 155 mounds/ha). To adjust for differences in mound size, 22 monogyne and 21 polygyne mounds of various sizes were excavated from 16 of the experimental sites. Colony size and biomass were regressed on mound volume. These regressions were then used to estimate colony size and colony biomass from the mound volumes measured at the 28 field sites. The estimated colony size and colony biomass at each site were summed and used to estimate field population densities. Polygyne populations contained 1.94 times more workers per unit area (35 million versus 18 million workers/ha) and 1.86 times more biomass (27.7 versus 14.9 kg wet weight/ha) than monogyne populations. Energy usage and standing energy of the ants per hectare were respectively 2.30 times and 1.90 times higher in polygyne populations. Overall, this study indicates that polygyne population densities are about two times larger on average than monogyne population densities.

KEY WORDS

colony size, respiration, polygyny, metabolism, mounds, Florida

THE ROLE OF FIRE ANT QUEEN PHEROMONES IN REGULATING REPRODUCTION AND POTENTIAL FOR THEIR USE IN CONTROL

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Queens of social insects produce a variety of primer pheromones which regulate the development and reproduction of other individuals in the colony. These important semiochemicals represent a promising and untapped avenue for control of social insect pests, such as fire ants. With the development of new bioassays, research over the last decade and a half has documented three ways fire ant queens use pheromones to regulate reproduction in the colony: 1) inhibition of egg laying by female sexuals (virgin queens), 2) suppression of egg laying by mature queens, and 3) inhibition of the production of new female and male sexuals. It is not yet clear whether a single pheromone produces an of these effects, or whether multiple effects might achieved by a single pheromone.

Of these effects, pheromonal control of egg laying by female sexuals is the best studied. The pheromone is produced by the poison gland whose products consist primarily of alkaloids. Most of the activity appears to reside in the minor non alkaloid components, although some degree of synergy between these components and one or more compounds in the basic alkaloid-containing fraction may occur. Physiological studies indicate that the pheromone is perceived by the antennae and acts on the endocrine system by inhibiting the production of juvenile hormone by the corpora allata. Pheromonal suppression of egg laying in mature queens also appears to occur by suppression of juvenile hormone titers, suggesting that this effect is regulated by the same pheromone that inhibits egg laying in female sexuals.

The development of new reproductive forms is controlled by affecting the behavior of workers toward the developing larvae. Early in development, female larvae can be prevented from developing into new queens by restricting food and channeling their development into workers. Late in larval development, workers can respond to the queen pheromone by killing larvae destined to develop into male or female reproductive forms.

The Pheromones responsible for these effects have obvious implications for controlling populations of this pest species. For example, it may be possible to shut down egg laying by all queens in a colony or suppress the production of new reproductive forms through application of synthetic pheromone. In addition, studies of the physiological effects of the queen primer pheromones may reveal other avenues that could be exploited for control.

Successful development of this approach depends on continued progress in the identification and mode of action of these semiochemicals.

KEY WORDS

Hymenoptera, fire ant, pheromones

SEASONAL FEEDING PREFERENCES OF THE ARGENTINE ANT

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The Argentine ant, *Linepithema humile* (Mayr), is the most important urban ant pest species in California (Knight and Rust 1990). Even though barrier sprays are widely used by pest control operators, their efficacy is generally limited to less than 30 days (Rust et al. 1996). Baits may provide a more effective means of controlling Argentine ant. However, little is known about their feeding preferences or the repellency of toxicants added to bait substances (Baker et al. 1985). Observed differences in feeding behavior over time may relate to differential effects of bait administered at different times of the year. The seasonal feeding preference of the Argentine ant was studied by providing representative foods to Argentine ants throughout 1994 -95 in choice tests.

Carbohydrate and protein substances were provided near nests twice monthly in a citrus grove on the UCR campus. Five trees with extensive foraging columns of *L. humile* were selected as permanent test sites. Heavy trailing into the trees suggests that the ants were feeding on sugary exudates produced by homopterans. Argentine ants are polydomous and polygynous (Passera and Keller 1990). To minimize intracolony movement, the trees selected as test sites were at least 18 m (60 ft) from one another. Ant activity was determined at each tree by the average number of ants crossing a line on the trunk of the tree per minute. Each of 10 food substances were placed in polystyrene weighing dishes in circular choice arenas near the base of the trees. One-gram aliquots were used in the spring and winter. In the summer, 2-gram aliquots were provided because intense foraging resulted in > 1 g being taken within the test period. The foods consisted of various solid protein and carbohydrate baits and granular Tahara (Maxforce bait blank without toxicant), two liquids, 20% sucrose, and 20% honey. An arena was placed at the base of each tree for 24 hrs. The arenas were returned to laboratory where the amount of bait taken was determined. Exposures were repeated approximately bi-weekly. The amount of food taken for each food substance and date was ranked for non-parametric statistical analysis.

TABLE 1
THE RELATIVE AMOUNT OF FOOD TAKEN BY ARGENTINE ANTS (RANKED DATA) DURING EACH SEASON OF THE YEAR

	Relative amount of food taken (Ranks)[a]			
Food material	Winter	Spring	Summer	Fall
Protein solid	40	178	202	170
Carbohydrate solid	19	16	104	119
Maxforce blank	182	201	241	169
Hi protein solid	17	33	146	99
Mid Protein solid	23	41	137	79
Hi Carbohydrate solid	20	108	61	30
Liquid 1	45	145	123	93
Liquid 2	28	72	122	117
Sucrose	163	195	232	221
Honey	37	120	190	129

[a] Amount of feeding ranked from low to high (highest possible rank = 240)

The number of ants trailing in citrus trees between January and March ranged from 66 to 184 ants min^{-1}. Activity increased to 224 to 304 ants min^{-1} in June and July, and increased dramatically between August and September to a peak of 594 ants min^{-1} in October. Argentine ants were most active when afternoon temperatures ranged from 32.2-39.4°C (90-103° F). Ant activity declined in November to between 118 to 223 ants min^{-1}, the afternoon temperatures at 1530 hours averaging about 16°C (61° F).

Based on weighed amounts taken, the most accepted food substances (potential bait materials) were 20% solutions of sucrose and honey (Table 1). Acceptance dropped only slightly from December through February when trailing activity in the trees was below 200 ants min^{-1}. Of the solid foods presented, the Maxforce blank was foraged nearly as well as the sucrose and honey solutions from April to October. However, the amount taken from November to February was about half of that taken during the summer. Significantly less of the solid baits containing either medium or high protein and low or high carbohydrate were taken by ants in the spring and summer. All of the other solid or liquid foods showed the same cyclic pattern of acceptance, with minimal acceptance during the winter months.

The two factors that influence the amount of food taken by *L. humile* throughout the year were the composition of the food and the daily temperatures. The number of ants foraging in the trees dramatically decreased when temperatures fell below 16°C. Both of these will impact the development of bait for Argentine ant control.

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PAPER 5
ANTS

COLONY SIZE, QUEEN NUMBER, AND QUEEN RECRUITMENT IN CARPENTER ANTS (*CAMPONOTUS SPP.*)

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While estimates of the average colony size in carpenter *ants (Camponotus)* are given as 3000 to 6000, few colonies have actually been tabulated for total population. These numbers are probably underestimated because of the problems associated in collecting all the individuals from the parent colony plus the satellite colonies. Populations have been reported over 12,000 for *C. herculeanus,* over 50,000 for *C. modoc,* and over 100,000 for *C. vicinus.* In June and July, 1995, three nests of *C. modoc* were collected; each contained over 25,000 individuals in the main colony alone. A *C. modoc* colony commonly consists of a main colony and six to ten satellite colonies.

Several possible explanations for the large population size of colonies found in and around structures are proposed. Colony foundation in *Camponotus* has generally been accepted as haplometrotic (founding by a single queen) because of the aggressiveness of inseminated queens toward one another. However, polygyny reported in field-collected colonies of *C. herculenaus, C. ligniperda, and C. vicinus* may indicate pleometrosis (founding by multiple queens) or secondary polygyny. Another explanation is queen recruitment by workers in queenless colonies or in satellite colonies. Current investigations suggest that queen recruitment may be a factor in colony growth for *C. modoc.* Inseminated queens were readily accepted into queenless colonies during laboratory experiments in June and July, 1995.

KEY WORDS

Camponotus, carpenter ants, queen recruitment, colony size

FIRE ANTS REDUCE INDOOR POPULATIONS OF PHARAOH ANTS

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Pharaoh ant, *Monomorium pharaonis* (L.), nests are difficult to locate without causing damage to a structure. Buildings (2.4 m wide x 3.0 m long x 2.4 m high) were constructed with modifications (hinged paneling and attic hatches) to allow observation of hidden nests. Large Pharaoh ant colonies ranging from 32,000 to 74,000 workers per colony were introduced into these buildings. Buildings were inspected every 2 - 4 weeks to determine the following: (1) the size and composition of satellite colonies, (2) Pharaoh ant nest sites indoors and outdoors, and (3) the effects of imported fire ants, *Solenopsis invicta* Buren, on Pharaoh ant nest composition and location. Fire ants severely limited Pharaoh ant colonization and establishment in some of the buildings. The indoor presence of fire ants at food cups ranged from 9 - 72% of the observation days. On several occasions, fire ants caused the formation of small, ephemeral nests on the paneling facing the interior of the room. These nests averaged (±SD) 47.3 ± 59.6 workers and 0.4 ± 0.6 queens and female alates compared to the average nest found within the walls or attic with 1,556 ± 1,121 workers, 16.0 ± 1.8 queens and female alates, and 1.4 ± 1.2 g brood. Fire ants decreased the biomass, brood, number of females, and number of workers per colony and per building. Fire ants also decreased the mean number of nests per building. Several Pharaoh ant nests, as indicated by the movement of queens, brood, and workers, were located in the soil under the slab of the buildings. Pharaoh ant colonies would persist outdoors under the slab until they encountered fire ants. Fire ants also caused nests to be located further from the food provided. Pharaoh ants will return to a previous nest site after a disturbance or they will occupy previously used nest sites on average (±SD) 56.7 ± 6.5% of the time. Fire ants also reduced the percentage of nest sites previously occupied. Could fire ants control Pharaoh ants in structures? Because of the fire ants ability to sting and recruit effectively, it is unlikely their presence in structures would be tolerated.

KEY WORDS

Monomorium pharaonis, Pharaoh ant, nest location, *Solenopsis invicta*, Imported fire ant

LABORATORY AND FIELD EVALUATION OF A LIQUID BORIC ACID ANT BAIT

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A boric acid - sucrose water bait was evaluated for efficacy against five species of urban pest ants: *Camponotus abdominalis floridanus* (Buckley), *Solenopsis invicta* Buren, *Tapinoma melanocephalum* (F.), *Linepithema humile* (Mayr), and *Monomorium pharaonis* (L.). LC_{50}s for *C. Abdominalis floridanus* and LC_{90}s for *S. invicta* showed a delayed toxicity to boric acid over a 10-fold range of concentration.

A continuous exposure to 0.25, 0.5, 0.75, and 1% boric acid - sucrose water bait was effective in reducing large laboratory colonies (60,000-75,000) of *S. invicta*. By the 6th wk there was a 90% reduction in population index at all four concentrations. A faster kill was obtained with smaller laboratory colonies (250-500 workers) of *T. melanocephalum, L. humile,* and *M. pharaonis* feeding continuously on a 1% boric acid-sucrose water bait. All colonies were completely eliminated by 10 wk. Only partial elimination of colonies was achieved when they were exposed to the boric acid bait for 3 d.

A bait application of a 1% boric acid in 10% sucrose water against infestations of *M. pharaonis* in an apartment complex achieved control within the 1st wk. In laboratory tests

with *S. invicta*, there was a negative correlation with bait consumption and boric acid concentration. As concentration increased, consumption decreased.

A bait application of a 1% boric acid in 10% sucrose water against infestations of *M. pharaonis* in an apartment complex achieved control within the 1st wk. In laboratory tests with *S. invicta*, there was a negative correlation with bait consumption and boric acid concentration. As concentration increased, consumption decreased.

Our research results show that low concentration (≤1%) of boric acid are capable of eliminating ant colonies and that at these rates there is reduced repellency.

KEY WORDS

Ants, insecticidal bait, boric acid

IN VITRO EVALUATION FOR REPELLENTS OF ADULT CAT FLEAS, *CTENOCEPHALIDES FELIS* (BOUCHE´), USING AN ARTIFICIAL MEMBRANE FEEDING SYSTEM

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Methods for the evaluation of repellency of external parasites on hosts have consisted mostly of estimates or enumeration of the parasite on treated animals compared with untreated control animals. Specific aspects of repellency may be undetected especially with a relatively cryptic ectoparasite such as the cat flea.

The artificial membrane feeding system described by Wade and Georgi (1988) may come close in simulating a canine or feline host of the cat flea and still allow detailed observations of behavior. This system has been used extensively for rearing fleas as well as evaluation of contact and systemic compounds for their control. Data obtained from the artificial system has proven similar to that obtained from on-animal studies regarding biology and effects of control agents.

Clipped dog hair was treated with the repellent formulations (McLaughlin Gormley King Co.) at a rate of 5 ml per gram of clean hair and allowed to dry thoroughly. The hair was placed in specially designed repellency chambers to be used with an artificial membrane feeding system. Citrated porcine blood warmed by a jacketed waterbath was then placed on a parafilm membrane as a food source and stimuli for adult fleas. Treated and placebo hair samples were placed in their respective side of the repellency chambers. Chambers with untreated hair were set-up as controls.

Approximately 100 unfed adult cat fleas, *C. felis* were placed in the open bottom portion of the repellency chamber and allowed to acclimate. The entire chamber was assembled and placed onto the artificial membrane feeding system. The fleas were observed and the number of fleas ascending each side of the repellency chamber recorded. Observations were conducted hourly for the first 8 hours and at 24 hours. After 24 hours a plexiglass panel was inserted beneath the divided chamber to retain the adult fleas in each side, the replicates were frozen and final flea counts determined.

Adult cat fleas were evenly distributed on both sides of the control repellency chambers with an average of 49.4% and 50.6% for sides A and B, respectively. Adult cat fleas in the DEET treated chambers were distributed with an average of 95.2% on the untreated side

(A) and 4.8% on the treated side (B). Repellent-11 (R-11) had similar results with 97.4% of the fleas on the untreated side (A) and 2.6% on the treated side (B). Both DEET and R-11 demonstrated a high degree of repellency (>95%) for at least 24 hours against adult cat fleas using the in vitro evaluation technique. Future work includes the evaluation of other candidate repellents and their effects on behavior and reproduction of cat fleas.

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KEY WORDS

Siphonaptera, cat flea, repellents

PAPER 2

FLEAS AND OTHERS

NATURAL PRODUCTS AS ECTOPARASITICIDES

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Control of ectoparasites of animals, especially food animals and pets, is a sensitive area for two reasons. For food animals there is concern about chemical residues in meat, milk, and eggs. With companion animals (especially dogs, cats, and horses) there is significant opportunity for human insecticidal exposure because of the intimacy with which owners share the pet's environment. For this reason, there is considerable interest in the development of safer chemicals for use in these niche markets, and plant by-products have been targeted. In fact, application of plant products for suppression of ectoparasites is the second most common use of botanical insecticides. Because of their production from plants, these "natural" insecticides are perceived as less toxic to humans and other vertebrates.

Use of insecticides on pets presents the problems of applicator exposure when the pet-owner treats the animal, sustained release from the pet and consequent human exposure, and direct effects of the insecticide on the treated animal. For both medical and veterinary reasons, compounds used on companion animals need to have minimal toxicity.

There are a variety of flea products, including collars, dips, and sprays, containing "natural" compounds such as extracts of pennyroyal, eucalyptus, rosemary, and citronella. Cases have been reported of dogs being treated with pennyroyal oil (typically obtained from health food stores), resulting in acute illness, vomiting, and death. Pennyroyal contains the hepatotoxic monoterpene, pulegone. In addition to damaging the liver, pulegone significantly depletes glutathione, thereby increasing the animal's susceptibility to other toxicants, including many insecticides. Eucalyptus appears to be toxic mainly when ingested. Even the ubiquitous oil of citronella can be toxic at high doses.

Flea dips containing d-limonene, when not adequately diluted, have produced necrotizing dermatitis with sloughing of the skin. Cats are particularly susceptible to poisoning by crude citrus extracts, as well as the refined linalool and d-limonene, with toxicosis resulting in hypersalivation, muscle tremors, ataxia, depression, and hypothermia. Limonene and its derivatives have high sensitizing potential, producing allergic responses upon repeated exposure.

Another botanical ectoparasiticide appearing in the popular press is "tea tree" or Melaleuca oil. Melaleuca oil toxicosis is characterized by depression, weakness, incoordination and muscle tremors. In addition to being toxic, melaleuca oil contains a number of sensitizing components, producing contact dermatitis in susceptible individuals.

Many aromatic compounds produced by plants are hepatotoxic. Though they may have some repellent and insecticidal properties, as well, they certainly have no advantage over synthetic insecticides when considered on a mammalian health basis.

While there is certainly a need for continued investigation and development of safer, more effective means of controlling pests, the tendency to equate "natural" with "better" or "safer" must be avoided. Natural products are not necessarily safer or more efficacious than their synthetic alternatives.

KEY WORDS

Siphonaptera, natural products, natural control

Paper 3
Fleas and Others

Comparative Activity of Insecticides Applied to Turfgrass Against Adult Cat Fleas, *Ctenocephalides felis* (Bouche´)

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Current control methods for cat flea infestations consist of applying contact or residual insecticides and IGRs (insect growth regulators) in and around homes and on animals. Effective control not only depends to a large extent on the insecticide selected, but also on the amount applied and the areas where it is applied. Outdoor treatments may involve application of insecticides to a variety of different substrates such as concrete, soil, and turfgrass, each which may affect the availability of the insecticide to fleas (Ebeling and Wagner 1965, Chadwick 1985, Rust 1995). Even though a wide variety of insecticides are currently registered and used for outdoor flea control, very few insecticide evaluations against adult cat fleas have been conducted (Wilson et al. 1957; Cilek and Knapp 1988a,b; Palma and Meola 1990; Henderson and Foil 1993). The objective of this study was to develop a simple bioassay for testing insecticides on turf against adult cat fleas.

A total of 10 different insecticides and several formulations were applied to fescue turfgrass which is a common lawn grass in southern California. To compare activity directly, each insecticide was applied at three rates (1,135, 568, and 284 g AI/ha) with a 3.8-liter hand-held compression sprayer. Formulations with label recommendation rates higher than 1,135 g AI/ha were also tested at the higher rate. Treated turfgrass was watered and maintained in a greenhouse (Meyer and Gibeault 1986). Residual activity was assessed by exposing adult fleas for 24 hrs to treated and untreated disks of turfgrass, 1 day and 7 days after treatment. Of the 10 insecticides tested, three formulations of chlorpyrifos (Dursban 50WP, 2E, and Pro) provided the highest percent kill on both day 1 and 7. Pyrethroid insecticides such as cyfluthrin, fluvalinate, and permethrin, and microencapsulated insecticides such as diazinon, generally provided poor residual activity.

TABLE 1
RESIDUAL ACTIVITY OF INSECTICIDES APPLIED TO TURFGRASS AT A RATE OF 10 GAL /1000 FT^2 (1 LB [AI]/ ACRE)

	% mortality ± SEM on turf deposits aged	
Insecticide	24 hours	7 days
Chlorpyrifos (Dursban 50 WP)	100 ± 0.0	99 ± 0.8
Cyfluthrin (Tempo 20WP)	95 ± 1.5	65 ± 7.8
Diazinon (50WP)	79 ± 5.1	28 ± 2.6
Chlorpyrifos (Dursban 2E)	100 ± 0.0	100 ± 0.0
Chlorpyrifos (Dursban Pro)	100 ± 0.0	100 ± 0.0
Diazinon (4E)	100 ± 0.0	33 ± 5.6
Fluvalinate (Yardex)	86 ± 2.4	51 ± 4.2
Permethrin (Dragnet FT)	86 ± 3.7	42 ± 7.1
Diazinon (Knox Out 2FM)	61 ± 7.0	17 ± 5.6
Chlorpyrifos (Empire 20)	64 ± 11.0	60 ± 7.2

Flea mortality figure based on 5 replicates of 25 adult fleas. Untreated control mortality averaged 3.0% (0.8-8%).

The effect of spraying adult fleas directly with insecticides was not addressed in this study. Although contact sprays may suppress a population of fleas, eclosion of preemerged adults from cocoons represents a continuing problem. Residual activity for days or weeks would help provide control of new adults. Thus, proper selection and application of insecticide is important in a flea control program especially with the many factors possibly affecting insecticide performance outdoors. Results from this study indicate that present recommended rates do not necessarily represent the optimal dose on turfgrass. For example, most formulations of chlorpyrifos performed very well on turf at 1/2 or 1/4 the recommended rate, whereas others such as permethrin and fluvalinate performed poorly even at higher-than-recommended rates. The development of this bioassay provides a novel method for evaluating the performance of chemicals on surfaces such as turfgrass which in turn may improve outdoor flea control methods.

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Key Words

Siphonaptera, cat flea, outdoor control

PAPER 4
FLEAS AND OTHERS

PROTEASES ASSOCIATED WITH THE CAT FLEA MIDGUT

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To investigate blood meal processing in *Ctenocephalides felis,* the cat flea, various classes of protease inhibitors were added to *in vitro* blood meals. Adult survival and fecundity of the female fleas were evaluated over a 7 day period. Zymogram analyses were done using soluble extracts of unfed and fed flea guts to demonstrate *in vitro* inhibition of protoolytic activity by the same inhibitors.

Results indicated that the vast majority of blood digestion in cat fleas is accomplished by serine proteases. Addition of 5 mM Pefabloc to the blood meals caused a statistically significant reduction in adult flea viability, killing 100% of males and 95% of females and causing a 98% decrease in the fecundity of surviving females.

Autoradiographic analyses of soluble extracts from flea guts labeled with tritiated diisopropylfluorophosphate, which covalently binds serine proteases at the catalytic site, allowed the qualitative and quantitative assessment of the expression of gut serine proteases. There was a significant increase in the levels of serine proteases in the flea guts within hours after initiation of feeding. Protease levels were maintained for as long as the fleas continued to feed. The temporal increase in number of eggs laid per hour by blood fed female cat fleas was linearly correlated to the levels of serine proteases in the flea guts.

Using affinity chromatography several serine proteases from cat flea guts have been purified and N-terminally sequenced. Additionally, several serine protease clones have been isolated from a fed flea cDNA library by both PCR and immunoscreening. The proteases identified by these techniques represent several subclasses of serine proteases including trypsins, chymotrypsins, collagenases, furins, vitellin-degrading proteases, and blood coagulation factors.

The only other protease inhibitor tested that showed any effect was bestatin at 1.3 and 13 mM. Bestatin, an aminopeptidase inhibitor, had no effect on adult viability, but significantly decreased female fecundity in a dose-dependent manner when added to blood meals. An aminopeptidase activity in fed midgut extracts was identified using a fluorescence based assay. Both soluble and membrane-bound forms have been partially purified and are inhibited by bestatin. Attempts to obtain N-terminal sequence from purified peptides displaying this activity indicate that these proteins are apparently N-terminally blocked, and further purification of internal peptide fragments for sequencing is on-going. In addition, a clone having significant homology with mammalian leucine aminopeptidases was PCR amplified from a fed flea cDNA library.

Key Words

Siphonaptera, cat flea, blood digestion, gut proteases

PAPER 1
NEW TECHNOLOGIES

VICTOR ROACH PHEROMONE TRAPS

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The efficacy of the Victor Roach Pherornone Trap against the German cockroach, *Blattella germanica,* was determined in both the laboratory and field. Laboratory tank tests were completed to determine the effectiveness of the pheromone in attracting German cockroaches. Victor roach traps with and without pheromone were set up on opposite sides of the tank to determine their relative attractiveness. Traps with pheromone were found to capture 2.65 times as many cockroaches as traps without pheromone. Field evaluations were completed in public housing and apartment complexes to determine if the trap can be used as an effective control device. The first test was completed by Dr. Austin Frishman. Five apartments were used as test sites. Results showed a total of 2,877 cockroaches captured after a period of 6 weeks. A second field evaluation was completed by Purdue University. In this test, 11 apartments were, treated with the Victor Roach Pheromone Trap. Sticky trap monitors were used to determine initial and subsequent reductions in cockroach populations. After four weeks, Victor Roach Pheromone traps were found to significantly reduce the population of cockroaches by 79.3%. A total of 7,543 cockroaches was caught from the 11 apartments. Of these 7,543 cockroaches, 6,437 were found to be nymphs and 1,106 adults (6:1 ratio). This ratio was found to differ significantly from that of sticky trap monitors used in the test which averaged only a 1.5:1 ratio of nymphs to adults. The number of cockroaches captured varied from 2,497 in the heaviest populated apartment to 199 in the least populated apartment. These results indicate that the Victor Pheromone Roach Trap can be used as an effective tool in controlling German cockroach populations.

KEY WORDS

Cockroach, *Blattella germainca*, sticky traps, control

PREMISE - THE NEW PARADIGM

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Imidacloprid, the active ingredient in Premise 75, brings to the pest control industry a new method of termite control utilizing a combination of two modes of action. First, imidacloprid works by attaching to specific acetylcholine (ACH) binding sites called nicotinergic receptors on the post synaptic side of nerve cells. This mode of action prevents ACH from binding and transmitting information. This leads to lasting impairment of the nervous system and eventual death of the insect. The chemical mode of action provides effective termite control with low toxicity to people, animals, and the environment.

In addition to the chemical mode of action, exposure to Premise dramatically increases the susceptibility of termites to naturally occurring insect pathogens. Premise has no direct affect on insect pathogens but alters termite behavior. Symptoms in termites exposed to Premise include cessation of feeding and tunneling; disorientation; and cessation of foraging, grooming, and caring for other colony members. Through specific behavior changes, termites lose the ability to survive among naturally occurring levels of pathogens in the soil. The consistent synergistic interaction of Premise and nature takes place across various soil types, pathogen levels in the soil and with different species of termites. Research on this interesting mode of action is continuing at Bayer and at several cooperating universities.

KEY WORDS

Imidacloprid, termite, nicotinergic, behavior, pathogen

EVALUATION OF SIX METHODS FOR CONTROLLING DRYWOOD TERMITES IN STRUCTURES

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Nonchemical and chemical methods for control of drywood termites were evaluated under simulated field conditions. Specifically, we assessed the efficacy of four methods currently marketed as alternatives to whole-structure fumigation for control of drywood termites: excessive heat, excessive cold, electrocution, and microwaves. In addition, we evaluated a reduced dosage of methyl bromide synergized with carbon dioxide, as well as standard fumigation treatment with sulfuryl fluoride.

Tests were conducted using *Incisitermes minor* (Hagen) in artificially infested or naturally infested boards of various dimensions used in construction. Infested boards were placed into the attic, drywalls, or subarea of the *Villa Termiti*, a symmetrical building constructed specifically for these tests. Commercial pest control operators performed 5 of 6 control methods; liquid nitrogen was applied by University of California personnel. For artificially infested boards, mortality was measured 3 d and 4 wk post-treatment. For naturally infested boards, mortality was evaluated only 4 wk post-treatment. Efficacy performance of all treatments was compared to 90% and 99% levels of mortality.

Termite mortality in artificial boards was 100% at 3 d and 4 wk post-treatment for both fumigant gases. Heating the whole-structure or spot-applications using microwaves resulted in 96% and 90% mortality, respectively, 3 d post-treatment. Mortality levels 4 wk post-treatment increased to 98% for heating and 92% for microwaves. Spot-applications of liquid nitrogen at the 30-min@ 1.4 kg/min dose (highest dose tested) achieved 100% mortality 3 d post-treatment. However, for the 15-min@ 0.9 kg/min and 7-min@ 0.9 kg/min dosages, 4 wk post-treatment mortality were 99% and 87%, respectively. Mortality

by electrocution of termites in artificially infested boards was 44% 3 d post-treatment in the first test. Four weeks post-treatment drywood termite mortality increased to 82%. In a second electrocution test, using spot-application techniques infrequently used in structures, mortality levels increased to 93% 3 d and 98% 4 wk post-treatment.

For naturally infested board, both fumigants exceeded the 99% level of mortality. Nonchemical applications of heat for whole-structure and spot-applications with microwaves resulted in 100% and 99% mortality levels for naturally infested boards. Chemical applications of liquid nitrogen were at or near 100% for naturally infested boards tested at the 30-min@ 1.4 kg/min and 15 min@ 0.9 kg/min dosages. However, mortality was significantly lower (74%) for the 7 min@ 0.9 kg/min dose. Mortality levels from electrocution were 89% and 95% 4 wk post-treatment, respectively, in the two tests.

The distribution of termite survivors varied for some techniques by: 1) location within the test structure and 2) galleries within test boards. Visual signs of damage to test boards, drywall, and the *Villa Termiti* were noted for some treatment techniques. This study provides information for evaluation of the relative efficacy of nonchemical alternatives and fumigation technology for the eradication/elimination of drywood termite infestations in structures.

Several published documents now exist on the findings reported at the National Urban Entomology Conference. The citation for the complete State of California report is:

Lewis, V. R. and M. I. Haverty. 1996. Simulated field evaluation of six techniques for controlling the drywood termite *Incisitermes minor* (Isoptera: Kalotermitidae) in residences. Report prepared for the California Structural Pest Control Board. Division of Insect Biology, University of California, Berkeley, 91 pp.

A refereed journal version of the study has been published:

Lewis, V. R. and M. I. Haverty. 1996. Evaluation of six techniques for control of the western drywood termite (Isoptera: Kalotermitidae) in structures. J. Econ. Entomol. 89: 922-934.

An industry trade magazine version also has been published.

Lewis, V. R. and M. I. Haverty. 1996. Long awaited nonchemical alternative to drywood termite control study completed. The Voice of PCOC, Summer 1996, pp. 20-22, 24, 26, 28-29.

Finally, a short 4-page homeowner version of the study is also available: **UC IPM Pest Notes: Drywood Termites. 1997.** Oakland: Univ. Calif. Agric. and Nat. Resources, Publication 7440 (written by V. R. Lewis). This document is also available on the World Wide Web at **http://www.ipm.ucdavis.edu.**

KEY WORDS

Termite, Fumigation, heat and cold treatment, control

A NEW TERMITE BAIT APPARATUS AND METHOD

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Termites facilitated other termites of the same colony or an amicable one to find food by initiating and participating in making a shelter tube which connected to the food source. Based on these experimental results, a compartmentalized preconditioning bait system (CPBS) was developed. The CPBS bait system has two compartments: a non-toxic preconditioning compartment (P-compartment) and a toxicant compartment. Termites from the targeted colony or from a amicable colony are placed in the P-compartment and allowed to feed on non-toxic food. Termites from the P-compartment build a new shelter tube to the targeted colony. Termites from the targeted colony then travel through the new shelter tube to the P-compartment where they feed on the non-toxic food. After a time, the termites eat through a cellulose block between the two compartments and begin feeding on the toxicant-laced food in the T-compartment. The CPBS bait has several beneficial characteristics, such as: (1) CPBS bait does not disturb the targeted colony; (2) termites in a CPBS bait have access to the toxicant only after the targeted colony has established feeding at the bait, because the passage between the two compartments is initially blocked; the time required to eat through the block allows construction of the connecting shelter tube before termites can enter the T-compartment, (3) both nestmates and amicable non-nestmates can be used in the bait, (4) The CPBS system does not require prior activity at a bait station. (5) the T-compartment is replaceable. Data need to be collected in the field.

KEY WORDS

Termite, bait, behavior

PAPER 5
NEW TECHNOLOGIES

ANOXIA: PROVEN TECHNOLOGY FOR PEST MANAGEMENT IN SPECIALTY SITUATIONS

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The use of modified or controlled atmospheres to control stored product pests has been studied for many years using various combinations of nitrogen, carbon dioxide, and oxygen (reviews by Calderon and Barkai-Golan 1990, Jay et al. 1990). Modified atmospheres are all cases where the atmospheric gas composition in a container has been changed. Controlled atmospheres are special situations where the composition is usually changed artificially by generating the desired gases such as carbon dioxide or nitrogen or by purging from pressurized cylinders (Calderon 1990). In the United States, carbon dioxide concentrations ranging from 40 to 70% have been tested because private corporations are reluctant to construct storage vessels suitable to use nitrogen (Jay et al. 1990).

The potential use of controlled atmospheres to control pests associated with museums and archives has been reviewed by Daniel and Hanlon (1995). In studies with pests frequently encountered in museums, Gilberg (1989) found that 1-week exposures to 0.4% O_2 killed adult webbing clothes moth, cigarette and drugstore beetles, brown lyctid beetle, and a carpet beetle. Gilberg (1990) confirmed his findings using Ageless™ oxygen scavenger to reduce the oxygen to <0.1% in sealed plastic bags. Purging plastic bags with nitrogen and using Ageless™, Valentine (1990) killed all stages of the furniture beetle, *Anobium punctatum*, infesting books and bundles of paper. An extensive series of tests with all stages of 12 different pests commonly associated with museums was conducted in chambers maintained at <0.1% O_2 (Rust and Kennedy 1993, Rust et al. 1996). Each developmental stage of each species required different exposure times to provide 100% kill. In general, the egg and pupal stages were the most difficult stages to kill, especially the cigarette beetle (Fig. 1). Some insects such as the German cockroach, *Blattella germanica*, and the firebrat, *Thermobia domestica*, were killed by exposures of less than 24 hrs.

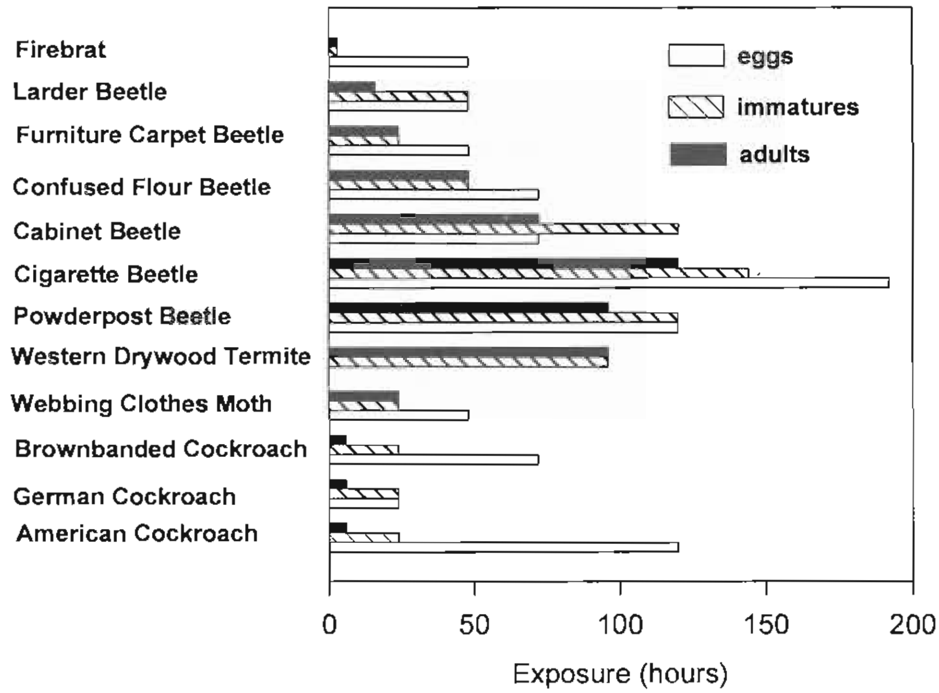

FIGURE 1
EXPOSURE PERIOD REQUIRED TO PROVIDE 100% KILL OF REPRESENTATIVE MUSEUM PESTS IN <0.1% O_2 AND 55% RH (RUST ET AL. 1996).

Several possible mechanisms to explain the lethal action of controlled atmospheres (i.e. low % O_2) have been proposed. Oxygen atmospheres < approximately 18% O_2 retard development and metabolic processes, eventually killing insects (Fleurat-Lessard 1990). In many stored product insect pests, an associated loss of water is strongly correlated with mortality. Low O_2 atmospheres affect the spiracular muscles of insects causing the muscles to open the spiracle, thereby resulting in increased, unregulated water loss (Navarro 1978). Table 1 shows the mortality and percent body water lost for three stages of confused flour beetle, *Tribolium confusum*, exposed to <0.1% O_2 (Rust and Kennedy unpublished data). Mortality dramatically increased as the total body water lost approached 30%. As little as a 3-hour exposure killed 100% of *Thermobia domestica* (Rust et al. 1996). Noble-Nesbitt (1989) found that the spiracles of *T. domestica* closed when the insects were anaesthetized with carbon dioxide, thereby reducing water loss, the opposite reaction of many other insects. It is therefore unlikely that desiccation kills firebrats exposed to low O_2 atmospheres. The brief exposure period required to kill firebrats suggests that metabolic anoxia may be a relevant mode of action for some insects. In addition, low O_2 may have lethal chronic effects. For example, sublethal exposures of the western drywood termite, *Incisitermes minor*, resulted in latent mortality (Rust et al. 1996). Exposures for 24 hrs provided 48, 75 and 95 % kill of *I. minor* nymphs at 1, 2 and 3 weeks post-treatment, respectively. Exposure to low oxygen atmosphere may have killed or affected the intestinal fauna of the termite, resulting in starvation.

For most applications, it is unlikely that bags or chambers can maintain <0.1% oxygen for extended exposures of several weeks. Even minute leakage results in higher O_2 concentrations. A second series of studies was performed with two of the most resistant insects in the Rust et al. (1996) study to determine if higher, more easily attainable concentrations (0.32 and 0.64% O_2) were lethal to the insects and if lower relative humidity (33%) would reduce the time required to kill more tolerant stages. The time required to kill all stages of cigarette beetle, *Lasioderma serricorne,* and furniture carpet beetle, *Anthrenus flavipes*, were similar when those insects were exposed to 0.32 and 0.1% O_2 atmospheres. Significantly longer exposures at 0.62 and 0.95% O_2 were

TABLE 1
PERCENT BODY WATER LOSS OF CONFUSED FLOUR BEETLES, *TRIBOLIUM CONFUSUM*, EXPOSED TO <0.1% O_2 AT 55% RH (RUST AND KENNEDY UNPUBLISHED DATA)

Exposure	Egg[a]		Larva		Pupa		Adult	
(hrs)	% H_2O	% Kill	% H_2O	% Kill	% H_2O	% Kill	% H_2O	% Kill
6	--	15.0	9.2	0	2.4	0	11.8	0
18	--	12.1	49.9	67.5	4.0	15.1	22.8	77.7
48	--	30.6	53.7	100	21.7	70.1	29.7	90.7
72	--	100	44.5	100	20.1	100	72.7	100

[a] Percent water content not determined.

required to kill either cigarette or carpet beetles. Lowering the RH to 33% in 0.32% and 0.64% O_2 atmospheres resulted in consistently greater kill at 24- and 48-h exposures than did similar exposures at 55 and 75% RH, but the time required to provide 100% kill did not significantly decrease (Rust and Kennedy 1995, unpublished data). Jay et al. (1990) reported that increasing the temperature from 32° to 43°C in 0.03% CO_2 + 99% N_2 atmospheres decreased the exposure time required to kill 100% of *L. serricorne* eggs from 96 to 24 hrs. Similarly, we found that increasing the temperature from 25.6° to 30°C reduced the exposure period eggs of *L. serricorne* held at 0.62% O_2 and 55% RH from 10 to 6 days. This study clearly demonstrated the good potential for using chambers and bags that allowed slightly higher oxygen concentrations (0.32% O_2) to control urban pests.

The two most common laminated plastic films used by conservators to make enclosures to maintain low oxygen atmospheres are Aclar™ poly (chloro-fluorethylene) and Cryovac™ poly (vinyladine chloride) (Daniel and Hanlon 1995). These films are relatively impervious to O_2 and moisture. The films consist of four layers: polyethylene (heat seal), an aluminum or Alcar layer, polyethylene, and a nylon or polypropylene layer (Burke 1992). These two laminated films are resistant to water vapor and oxygen transmission. Depending upon the type of film, temperatures of 176 to 252 °C (350-485°F) for 1 sec at 40-50 PSI can be used to seal the films together. Ready-to-use bags may be purchased or sheets of the films may be used to construct custom bags for larger objects.

Packets of an oxygen scavenger (Ageless™) placed inside before sealing the chambers or bags to effectively reduce the concentration of oxygen and maintain low % oxygen for long periods of time. Ageless™ consists of finely divided moist iron oxide and potassium chloride. Because Ageless™ removes O_2 by exothermic reaction, the packets should not be placed directly on heat-sensitive objects. Ageless™ will also absorb an

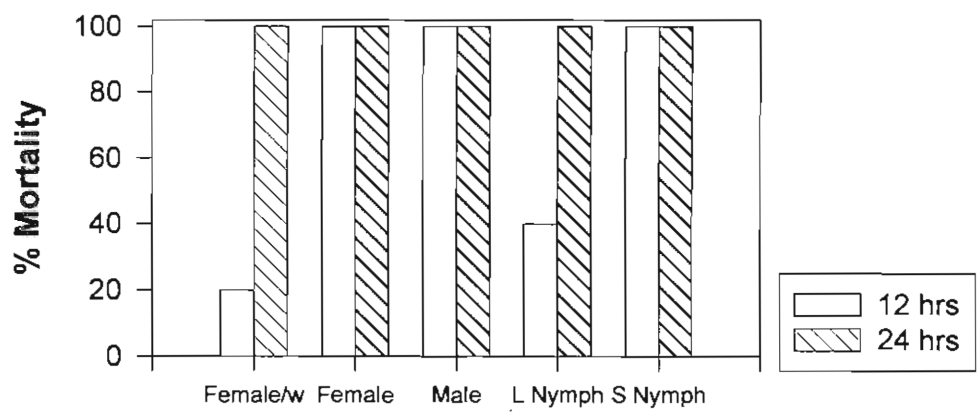

FIGURE 2
EFFICACY OF LOW O_2 ATMOSPHERES IN CRYOVAC BAGS AGAINST GERMAN COCKROACHES.

equal amount of gaseous CO_2. Ageless™ is recommended for use when the RH is > 55%. However, the reaction rate reportedly remained constant at 33% RH for 4 months, permitting its use at lower RH (Daniel and Lambert 1993).

In some preliminary tests, exposures in sealed bags provisioned with Ageless™ provided complete kill of all stages of the German cockroach, within 24 h (Fig. 2). Excess oxygen was removed from the bags with a small portable vacuum pump prior to sealing. The simplicity and lack of potential chemical exposure makes this a practical technique for IPM programs in food preparation facilities, nursing homes, and hospitals or other chemical-sensitive areas.

Modified atmospheres have been used to control insects associated with stored foods and only recently have they been explored for controlling insect pests of museums. However, the ease and flexibility in making enclosures with laminated films and the availability of Ageless™ to remove oxygen make this a viable pest management alternative the pest control industry.

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KEY WORDS

Anoxia, modified atmospheres, pest control

INTER AND INTRASPECIFIC AGONISTIC BEHAVIOR ASSAYS USING *RETICULITERMES FLAVIPES* (KOLLAR) AND *R. VIRGINICUS* (BANKS) WORKERS: EFFECTS OF ARENA SIZE AND NUMBER OF TERMITES PER ARENA

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Two colony sources for each of two subterranean termite species, *Reticulitermes flavipes* and *R. virginicus* were examined for displays of agonistic behavior in assays conducted using all possible combinations of one of four arena sizes 1.3, 3.5, 6.5, or 8.5-cm diam arenas and different numbers, 2, 4, 10, or 20 termites per arena. Worker termites from each source colony were simultaneously placed in an arena containing only a moistened filter paper disk. The number of termites alive after 24 was recorded for each arena. Agonistic behavior was scored positive in those arenas which contained half or less than the starting number of termites. Each species, arena size, and number of termites per arena combination was replicated at least 16 times and data analyzed using analysis of variance and protected least significant difference mean separation technique.

Arena size was the only variable that provided significantly different agonistic behavior ratings. The two larger arena sizes showed significantly more positive agonistic behavior scores than the two smaller arena sizes ($P < 0.01$). The number of termites per arena did not provide evidence it had an effect in provoking aggressive behavior. Only 66% of the interspecific pairings provided positive agonistic behavior scores in all of the combinations tested. One particular interspecific pairing provided scores which were not statistically different than the intraspecific combinations. Aggressive behavior was scored positive in 3.5% (n=288) of the intraspecific assays.

These assays indicate that displays of agonistic behavior between worker termites from the two species tested are not a reliable indicator of species difference. They also suggest that kin recognition, as evidenced by agonistic behavior, in *Reticulitermes* is governed by a series of cues. The variability in aggressive behavior was relegated to specific individuals within the colony rather than being a generic behavioral expression in worker termites.

KEY WORDS

Subterranean termites, agonistic behavior, bioassay

THE USE OF HEAT TO CONTROL *CRYPTOTERMES BREYIS* (WALKER) (ISOPTERA: KALOTERMITIDAE) IN HAWAII

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Research was focused on assessing the use of thermal pest eradication (TPE) against *Cryptotermes brevis* (Walker). Preliminary experiments revealed that gradual temperature increase rates may allow termites to acclimate to increasing temperature extremes. Field studies were carried out to determine the variation in temperature increase rates present during TPE procedures. These field conditions were modeled in the lab. Groups of late instar *C. brevis* nymphs were placed in an oven at room temperature and raised at 0.6 and 1.2°C/min until knock-down was achieved. Mortality was assessed at 24 hours. Upper lethal limits (ULL) determined according to the standardized procedure produced mortality at temperatures as high as 64°C; far in access of suggested treatment temperatures. Subsequent tests which held final test temperatures demonstrated that the extremely high ULLs were the result of a time lag between the body temperature of the test organisms and that of the test chamber. The results from these later tests produced total mortality when suggested treatment temperatures were held for a minimum of 15 minutes.

KEY WORDS

Powderpost termite, heat, temperature, control

TERMITICIDE BAITING GOES TO THE MALL

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University researchers, PCOS, the chemical industry, and building management are cooperating to control the Formosan termite *(Coptotermes formosanus* Shiraki) using baits within a large hotel/mall in the French Quarter of New Orleans, Louisiana. The program integrates inspection, baiting with a cardboard formulation of the toxicant, sulfluramid, and monitoring. Baits are frequently placed in high profile, sensitive locations which are monitored for evidence of termite activity and for termite bait consumption. At the end of the first year we have controlled the termites in a number of locations that continue to be monitored, we have identified additional source locations for termites that have been included into the baiting program, and we have reduced the number of complaints by merchants of termites.

KEY WORDS

Formosan termites, sulfluramid, bait

EFFECTS OF APPLICATION TIPS ON DURSBAN TC DISTRIBUTION IN SOILS FOLLOWING RODDING AND THE VALIDITY OF USING A FLUORESCEIN DYE TO ESTIMATE SOIL INSECTICIDE DISTRIBUTION

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Tip effects on chlorpyrifos (Dursban® TC) distribution in soils after rodding and the validity of using dye to estimate termiticide distribution were investigated. Dursban TC (chlorpyrifos, 1.0% AI) and Pylam D&C Green #8 dye (0.5% AI) (6.06 1) were applied at 172.4 kPa. Treatments varied by soil [silty clay loam (SCL) and sandy loamy (SL)] and tip [straight, 360°. and 180° (3.8 and 7.6 Lpm)].

Soil samples were taken one week after insecticide plus dye application. Each soil sample was air-dried, homogenized, weighed and observed for visual dye levels. Chlorpyrifos and dye were extracted from the soil samples, and then quantified by gas chromatography or spectrophotometry, respectively.

According these data, neither the type of soil, application tip, nor the soil by tip interaction provided for significant differences in distribution of chlorpyrifos in soil. However, significant differences were observed due to soil depth, lateral distance from the injection point and the depth by lateral distance interaction. Larger amounts of chlorpyrifos were observed proximal to the rodding point (> 100 µg/g) and in the soil 0.91-1.22 cm (0- > 500 µg/g) below the soil surface in all treatments. Minimal chlorpyrifos residues were detected in the soil more laterally distant from the rodding point and closer to the soil surface (0-50 µg/g). An inverted 'T' treated soil pattern was common to all treatments. Based on these results, rod spacings of approximately 30 cm should provide a continuous insecticide barriers in soil around a foundation. Increased spacing will allow for untreated soil regions 0-61 cm from the soil surface and 15-40 cm laterally distant from the injection point.

The dye was easier to visually detect in the SL than in the SCL (> 83 and > 143 ppm at 90% probability, respectively). Dye (visual amounts) overestimated insecticide distribution in the SL. However, dye (visual amounts) underestimated SCL insecticide distribution. Due to these differences, care should be taken when using dye as a predictor of insecticide distribution in soils.

KEY WORDS

Subterranean termites, chlorpyrifos, dye, distribution, soil

COMPARATIVE ACCEPTANCE AND CONSUMPTION OF BAIT MATRIX CANDIDATES BY SUBTERRANEAN TERMITES *(RETICULITERMES* SPP.) IN LABORATORY AND FIELD CHOICE TESTS

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Research is ongoing at DowElanco to optimize and enhance current bait technology for all regions of the country. In this paper we summarize two studies which examined subterranean termite *(Reticulitermes* spp.) preference for selected bait matrices.

Laboratory choice feeding tests with *Reticulitermes flavipes* (Kollar) and *Reticulitermes virginicus* (Banks) were conducted to determine termite worker preference with four cellulosic bait matrix candidates. Termite workers of both species consumed a significantly higher amount of the bait matrix NAF-165 when compared in a four-way choice test with the standard NAF-46 (previously proven attractive to termites) and two other experimental bait matrices.

Field tests were conducted in Endeavor, WI and Indianapolis, IN which compared termite consumption of NAF-165 and NAF-46 in above-ground baiting situations. At both sites, termite workers *(R. flavipes)* clearly preferred NAF-165 over NAF-46. Further field testing with NAF-165 is planned in 1996, in both above-ground and below-ground baiting situations.

KEY WORDS

Subterranean termites, cellulosic, bait matrix

EFFECTS OF THE CHITIN SYNTHESIS INHIBITOR, LUFENURON, ON THE CUTICLE OF THE CAT FLEA, *CTENOCEPHALIDES FELIS* (BOUCHE´)

Susan Pullen and **Roger Meola**
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When 0.5 ppm lufenuron was fed to adult fleas in blood using an artificial membrane system, significant mortality resulted after 8 days. Light and electron micrographs reveal that new endocuticle is produced in these treated adults. However, the new endocuticle appears amorphous, lacking the regular lamellae of chitin microfibrils and it is much thinner than that of control fleas. Protein inclusions not seen in controls are also present, confirming that lufenuron interferes with formation of normal endocuticle.

A significantly greater number of eggs from control fleas hatched compared to those from lufenuron-fed fleas. Eggs from lufenuron-fed fleas complete embryogenesis within the chorion but do not hatch in spite of having an egg tooth. Electron micrographs reveal that procuticle formed in these larvae is abnormal. Mortality of these first instar larvae is probably due to tearing of the cuticle as the larvae attempt to emerge from eggs.

KEY WORDS

Cat flea, lufenuron, chitin, endocuticle

PAPER 7
POSTERS

SYSTEMIC EFFECTS OF NYLAR IN THE BLOOD DIET ON ADULTS, EGGS AND LARVAE OF THE CAT FLEA, *CTENOCEPHALIDES FELIS* (BOUCHE´)

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The success of lufenuron, a chitin synthesis inhibitor (CSI), and its ease of application as an oral systemic has created a demand for other oral formulations of insecticides for flea control. In this investigation, we tested the hypothesis that a juvenile hormone mimic such as Nylar may also work systemically as a blood additive to control fleas using an artificial membrane system. The results demonstrated that concentrations of Nylar in blood as low as 0.01 ppm suppressed egg hatch. Not only did Nylar act as an ovicide, it also acted as an adulticide. Using a 10 ppm blood-Nylar mixture, over half of the adult fleas were killed within 5 days.

Like lufenuron, Nylar is highly lipophilic and provides long-term flea control when sprayed on animals. Thus there is a good possibility that it may also accumulate in the blood of pets and act systemically when ingested by fleas. Indeed, Nylar may be very effective for flea control as an oral systemic because it is a juvenoid with a broad spectrum of activity against larvae, is know to remain active for a year or more when sprayed on pests and is effective on both the immature and adult stages of the cat flea.

KEY WORDS

Cat flea, Nylar, systemic, ovicide, larvicide, adulticide

CONTROLLING STORED-PRODUCT INSECTS IN WHEAT-BASED CAT LITTER WITH DIATOMACEOUS EARTH DUSTS IN URBAN ENVIRONMENT

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A natural cat litter made from cracked wheat and semolina is being sold by a rural business in Minnesota. This wheat-based cat litter is susceptible to infestation by several stored-product insects. A mixture of diatomaceous earth dusts with the cat litter is being explored as a natural control measure. A preliminary laboratory test has shown that the diatomaceous earth Insecto at 1 g per kg of cat litter was effective in killing all adults of the merchant grain beetle and suppressing egg-to-adult emergence of the Indianmeal moth. In the laboratory, two diatomaceous earth dusts — Insecto and Dryacide — have been incorporated at the rate of 1, 3, 5, 10, and 20 g per kg of the cat litter to control six stored-product insects. The insects tested were the red flour beetle, rusty grain beetle, sawtoothed grain beetle, lesser grain borer, rice weevil, and Indian meal moth. The insect response was monitored weekly for five weeks. All insects were killed at the highest rate within seven days. Longer exposures were necessary to control insects at the lower rates (3 and 5 g per kg). In general, Insecto performed well against the insects than Dryacide at all rates. A rate of 20 g of Insecto or Dryacide per kg of cat litter is recommended for killing all stored-product insects and for preventing their population growth. The susceptibility of the cat litter + diatomaceous earth mixture to stored-product insects remains to be tested under field (warehouse, grocery store, etc.) conditions.

KEY WORDS

Diatomaceous earth, red flour beetle, sawtoothed grain beetle, lesser grain borer, rice weevil, rusty grain beetle, merchant grain beetle, Indianmeal moth, cat litter

IPM GOES TO SCHOOL IN TEXAS

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Since 1995, public schools in Texas are required to have a policy stating that all pest control operations on school facilities will be conducted according to IPM principles. In addition to requiring an IPM policy, the Texas law requires: (1) that each school district appoint an IPM coordinator; (2) that all pest control activities be conducted by a licensed certified applicator; (3) that a 12-hour child re-entry period be observed for all pesticide applications; and (4) pesticide selection be based on a pesticide classification system set up by the state.

The Texas law is one of the most comprehensive and wide-ranging state laws regarding IPM in the nation. A number of other states are considering similar regulations in an attempt to reduce possible risks posed by pesticides to children.

The Texas Agricultural Extension Service has responded to the need for more information on IPM among school districts by developing live satellite broadcasts, a resource guide for pest control operators and school pest control staff, and one-day training conferences for school IPM coordinators. A videotape training set is currently under production and should be available by late 1996.

While Texas schools maintain access to all pesticides under the new regulations, use of less toxic products is encouraged through a pesticide classification scheme whereby pesticides are classified as either Red, Yellow, or Green List. Green List products include EPA Category III and IV pesticides that are also: botanical insecticides, insect growth regulators, microbials, low-toxicity inorganics (i.e., silica gels, boric acid, diatomaceous earth), or containerized baits. Yellow List products include the remaining Category III and IV pesticides that do not belong to one of the Green List groups. Red List products include pesticides with Danger or Warning signal words. Red and Yellow List products require written justification and prior approval by the IPM coordinator before use.

KEY WORDS

IPM, public schools, less toxic pesticides, pest control

SPECIES DETERMINATION IN *RETICULITERMES:* CORRELATION OF CUTICULAR HYDROCARBONS AND SOLDIER DEFENSE SECRETIONS

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In studies of the foraging ecology of *Reticulitermes* in California, the first obstacle we encountered was the identity of our "colonies." Only *P, hesperus,* should occur on our sites. Available keys to soldiers were not helpful. Alates are rarely found in foraging groups. Studies *of Reticulitermes* populations in Georgia are similarly hampered by inadequate keys. In short, determination of species of *Reticulitermes* based on morphology or geographic origin of the sample is difficult and often equivocal. We decided to try to resolve some of the taxonomic problems in *Reticulitermes* by characterizing cuticular hydrocarbons and soldier defense secretions. Our primary goal is to make the initial separations based on chemical characters then search for useful morphological characters for future separations.

Near our Placerville, CA site, we have found three very distinct hydrocarbon patterns and three soldier defense secretion patterns that correlate with the hydrocarbon phenotypes. Two additional hydrocarbon phenotypes and corresponding defense secretion mixtures have been characterized from samples collected in Marine County. We have seen eight different cuticular hydrocarbon phenotypes from collections of *Reticulitermes* from the four disparate sites and soil provinces in Georgia: Atlantic Coast Flatwoods. Blue Ridge, Piedmont, and Coastal Plain. Three hydrocarbon phenotypes key to R *flavipes.* Only one phenotype keys to R *virginicus.* Two phenotypes key to *R. hageni,* while two more phenotypes do not key to any known species and probably represent two separate, undescribed species. Hydrocarbon phenotypes from Georgia did not all have unique terpene phenotypes. Our collections in Arizona are relatively limited. The current taxonomy of *Reticulitermes* recognizes only one species in Arizona: *R. tibialis.* Three different cuticular hydrocarbon phenotypes of *Reticulitermes* have been identified so far from Arizona.

We have many additional ecological units or soil provinces to examine, and will likely discover additional hydrocarbon phenotypes. Our results indicate that there are at least four "species" of *Reticulitermes* in California. The fifth hydrocarbon phenotype may represent intraspecific variation or a sub-species. Samples from Georgia indicate six species based on hydrocarbon and terpene phenotypes. In Arizona there are at least two, and most likely three or more species. Soldier defense secretions appear to be more conservative characters than cuticular hydrocarbons. Measurements of the soldier head (length v. width) separate the California samples into two groups, and the Georgia samples into five groups. Cuticular hydrocarbons and soldier defense secretions will enhance further discrimination of the morphotypes and should lead to identification of discrete character states for unequivocal species determination.

KEY WORDS

Subterranean termites, cuticular hydrocarbons, taxonomy

AQUAPY: ADVANCED WATER-BASED FORMULATION TECHNOLOGY FOR THE CONTROL OF URBAN INSECT PESTS

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AquaPy® is a water-based emulsion of 3% pyrethrins and 15% piperonyl butoxide, for use in urban and industrial pest control. Aquapy uses patented anti-evaporant, low solvent aqueous spray technology. It can be diluted with water and applied through conventional equipment, or undiluted for use in ultra low volume (ULV) applications.

Laboratory trials demonstrated high levels of efficacy of AquaPy against a range of stored product insects, cockroaches and cat fleas. A mechanical aerosol generator was used to apply undiluted AquaPy as a combination of crack and crevice and space sprays. At a rate of 0.1 fl. oz/1000 ft^3 (3.2 mg pyrethrins/m^3), AquaPy achieved excellent control of insecticide susceptible German and American cockroaches, susceptible and resistant lesser grain borers, cigarette beetles and maize weevils. It achieved 76% control of flour beetles. An application rate of 0.2 fl. oz/1000 ft^3 (6.4 mg pyrethrins/m^3) achieved 89% and 96% control of resistant German cockroaches and cat fleas, respectively.

AquaPy was also evaluated against field populations of German and American cockroaches, and cat fleas in urban environments. Application rates of 0.2 fl. oz/1000 ft^3 to 0.3 fl. oz/1000 ft^3 provided 83% to 99% control of German cockroaches. An application rate of 0.2 fl. oz/1000 ft^3 achieved 94% and 100% control of cat fleas and American cockroaches, respectively.

KEY WORDS

AquaPy, pyrethrins, piperonyl butoxide, anti-evaporant

DIFFERENTIAL LEVELS OF EXPRESSED CYTOCHROME P450 IN A FIELD POPULATION OF GERMAN COCKROACH FOLLOWING DIFFERENT INSECTICIDE TREATMENTS

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Recently, we collected a field strain of German cockroach *(Munsyana)* from a public housing site. This strain has 82x resistance to the cypermethrin (pyrethroid) in comparison to a susceptible strain *(Johnson Wax).* In addition, we have determined this field-collected strain to have both elevated cytochrome P450 content and elevated esterase activity, which are likely responsible for cypermethrin resistance. In order to obtain information on resistance management from the field, we have tracked the esterase activity and cytochrome P450 content in the *Munsyana* strain following three separate treated sub-populations in the field. Here, we report the preliminary results of the cytochrome P450 examinations for this study. Our principal hypothesis was that cytochrome P450 content would be elevated in survivors of the three insecticide + IGR treatments. Our results support this hypothesis, and indicate that cytochrome P450-inhibiting synergist (i.e., PBO and MGK-264) could be used as part of mixtures in follow-up treatments to control survivors of neurotoxic insecticide + IGR treatments. Implementing a management strategy which includes synergists can have a direct impact on reducing management costs by reducing the number of re-treatments necessary to achieve a satisfactory level of control.

KEY WORDS

Blattella gerinanica, resistance management, synergists

NATIONAL CONFERENCE ON URBAN ENTOMOLOGY

February 18-20, 1996

Marriott Hotel • Arlington, Texas

PROGRAM OF THE
NATIONAL CONFERENCE ON URBAN ENTOMOLOGY

February 18-20, 1996
Champion's Ballroom I & II
Arlington Marriott
Arlington, TX

Sunday, February 18, 1996

1:00 p.m.	INTRODUCTION AND WELCOME **Donald A. Reierson-Conference Chair**, Department of Entomology, University of California, Riverside, CA.
1:30 p.m.	ARNOLD MALLIS MEMORIAL LECTURE *The Future of Research.* **Donald G. Cochran**, Professor Emeritus, Department of Entomology, Virginia Polytechnic Institute & State University, Blacksburg, VA.
2:30 p.m.	**Break** -- Champion's Ballroom Foyer
	A VIEW OF THE FUTURE – Issues and Opportunities
2:45 p.m.	*Termites.* **Roger E. Gold**, Department of Entomology, Texas A&M University, College Station, TX.
3:15 p.m.	*Cockroaches.* **Arthur G. Appel**, Department of Entomology, Auburn University, Auburn, AL.
3:45 p.m.	*Ants.* **David F. Williams**, USDA-ARS MAVERL, Gainesville, FL.
4:15 p.m.	*Modes of Action of Insect Growth Regulators on Fleas.* **Roger W. Meola**, Department of Entomology, Texas A&M University, College Station, TX.
4:45 p.m.	**Adjourn**
5:30 p.m.	RECEPTION -- Champion's Ballroom III

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Monday, February 19, 1996

TERMITES

Moderator: *Michael F. Potter, Department of Entomology, University of Kentucky, Lexington, KY.*

8:15 a.m. *Colony development and reproductive dynamics in the subterranean termite, Reticulitermes flavipes (Kollar).* **Barbara L. Thorne** and N. L. Breisch, Department of Entomology, University of Maryland, College Park, MD.

8:40 a.m. *Mark-release-recapture experiments with field populations of Reticulitermes spp. (Isoptera: Rhinotermitidae) in Georgia, USA.* **Brian T. Forschler**, Department of Entomology, University of Georgia Experiment Station, Griffin, GA; B. L. Thorne, Department of Entomology, University of Maryland, College Park, MD; and M. L. Townsend, Department of Entomology, University of Georgia Experiment Station, Griffin, GA.

9:05 a.m. *Trail-following activity by Formosan termite workers and soldiers on artificial trails.* **Gregg Henderson**, Department of Entomology, Louisiana State University, Baton Rouge, LA; J. C. Stowell, Department of Chemistry, University of New Orleans, New Orleans, LA; S. Gatti, Department of Entomology, Louisiana State University, Baton Rouge, LA; and R. S. Geralds, Department of Chemistry, University of New Orleans, New Orleans, LA.

9:30 a.m. *High-grade stainless-steel mesh and sand-barrier field tests for control of subterranean termites.* **Brad Kard**, USDA Forest Service, Gulfport, MS.

9:55 a.m. **Break and Poster Displays** – Champion's Ballroom III (for a listing of poster displays see pages 8 and 9).

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TERMITES (continued)

10:20 a.m. *Efficacy of termiticides in a three-year field study in Hawaii.* **J. Kenneth Grace**, Department of Entomology, University of Hawaii, Honolulu, HI .

10:45 a.m. *The effectiveness of borate treated foam insulation panels for the control of termites.* **Robert A. Barlow**, Department of Entomology, Virginia Polytechnic Institute & State University, Blacksburg, VA.

11:10 a.m. *Borate as a deterrent to colony foundation by the West Indian powderpost termite, Cryptotermes brevis.* **Rudolf H. Scheffrahn**, J. Krecek, and N. Su, Ft. Lauderdale Research & Education Center, University of Florida, Ft. Lauderdale, FL.

11:35 a.m. *Effect of temperature and relative humidity on aggregation and water loss in the Western drywood termite, Incisitermes minor (Hagen).* **Brian J. Cabrera** and M. K. Rust, Department of Entomology, University of California, Riverside, CA.

12:00 p.m. Lunch (on your own).

COCKROACHES

Moderator: *William H. Robinson, Department of Entomology, Virginia Polytechnic Institute & State University, Blacksburg, VA.*

1:30 p.m. *Efficacy of a lambdacyhalothrin and pyriproxyfen mixture on an insecticide resistant field population of the German cockroach (field trials).* **Walid Kaakeh**, M. E. Scharf and G. W. Bennett, Center for Urban and Industrial Pest Management, Department of Entomology, Purdue University, W. Lafayette, IN.

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1:45 p.m. *Efficacy of a lambdacyhalothrin and pyriproxyfen mixture on an insecticide resistant field population of the German cockroach (laboratory tests).* **Michael E. Scharf**, W. Kaakeh and G. W. Bennett, Center for Urban and Industrial Pest Management, Department of Entomology, Purdue University, W. Lafayette, IN.

2:00 p.m. *The use of heat for control of chronic German cockroach infestations in food service facilities -- A fresh start.* **Brian C. Zeichner**, D. W. Wood Jr. and A. L. Hoch, U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD.

2:25 p.m. *Characterization of the insecticidal activity of fragrance oils against the German cockroach.* **Donald A. Reierson** and M. K. Rust, Department of Entomology, University of California, Riverside, CA.

2:50 p.m. *Coprophagy and delayed toxicant activity of commercial baits in B. germanica: Sex and stage differences.* **Robert J. Kopanic** and C. Schal, Department of Entomology, North Carolina State University, Raleigh, NC.

3:15 p.m. **Break** -- Champion's Ballroom III.

3:35 p.m. *History of cypermethrin and chlorpyrifos resistance in a field population of the German cockroach.* **William H. Robinson**, Urban Pest Control Research Center, Department of Entomology, Virginia Polytechnic Institute & State University, Blacksburg, VA.

4:00 p.m. *Longevity of field-collected females of the smoky brown cockroach and implications for field fecundity.* **Lane M. Smith** and A. G. Appel, Department of Entomology, Auburn University, Auburn, AL.

4:25 p.m. Adjourn

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5:00 p.m. RECEPTION -- 2nd Floor Lobby

6:00 p.m. BANQUET -- Hall of Fame Exhibit Hall
Master of Ceremonies -- **Phil Hamman**, Department of Entomology, Texas A&M University, College Station, TX.
Awards Presentation -- **Gary W. Bennett**, Department of Entomology, Purdue University, Purdue, IN.

Tuesday, February 20, 1996

ANTS

Moderator: *John H. Klotz, Department of Entomology, University of California, Riverside, CA.*

8:15 a.m. *The control of Solenopsis xyloni (McCook) in a colony of endangered California least terns, Sterna antillarum browni (Mearns).* **Linda M. Hooper** and M. K. Rust, Department of Entomology, University of California, Riverside, CA.

8:40 a.m. *Comparison of polygyne and monogyne fire ant population densities (Hymenoptera: Formicidae: Solenopsis invicta).* **Tom Macom**, Department of Entomology, Texas A&M University, College Station, TX.

9:05 a.m. *The role of fire ant queen pheromones in regulating reproduction and potential for their use in control.* **Edward L. Vargo**, Department of Zoology, University of Texas, Austin, TX.

9:30 a.m. **Break** -- Champion's Ballroom Foyer

9:50 a.m. *Seasonal feeding preferences of the Argentine ant.* **Michael K. Rust**, D. A. Reierson, E. Paine, J. Hampton-

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Beesley, Department of Entomology, University of California, Riverside, CA; and L. J. Brecher, The Clorox Co., Pleasanton, CA.

10:15 a.m. *Colony size, queen number, and queen recruitment in carpenter ants (Camponotus spp.).* **Laurel D. Hansen**, Spokane Falls Community College, Spokane, WA.

10:40 a.m. *Fire ants reduce indoor populations of pharaoh ants.* **Karen M. Vail**, Department of Entomology and Plant Pathology, University of Tennessee, Knoxville, TN; and D. F. Williams, USDA-ARS MAVERL, Gainesville, FL.

11:05 a.m. *Laboratory and field evaluation of a liquid boric acid ant bait.* **John H. Klotz**, Department of Entomology, University of California, Riverside, CA; D. F. Williams, USDA-ARS MAVERL, Gainesville, FL; K. M. Vail, Department of Entomology and Plant Pathology, University of Tennessee, Knoxville, TN; D. Oi, Department of Entomology, Auburn University, Auburn, AL; and J. Moss, Gainesville, FL.

11:30 a.m. Lunch (on your own).

FLEAS AND OTHERS

Moderator: *Roger W. Meola, Department of Entomology, Texas A&M University, College Station, TX*

1:00 p.m. *In vitro evaluation for repellents of adult cat fleas, Ctenocephalides felis (Bouche), using an artificial membrane feeding system.* **William A. Donahue**, Sierra Research Laboratories, Modesto, CA.

1:25 p.m. *Natural products as ectoparasiticides.* **Nancy C. Hinkle**, Department of Entomology, University of California, Riverside, CA.

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1:50 p.m. *Comparative activity of insecticides applied to turfgrass against adult cat fleas, Ctenocephalides felis (Bouche).* **Marco Metzger**, M. K. Rust and D. A. Reierson, Department of Entomology, University of California, Riverside, CA.

2:15 p.m. *Proteases associated with the cat flea midgut.* **Rex Thomas**, G. Silver, S. Hunter, G. Steigler, N. Wisnewski and K. Rushlow, Heska Corporation, Fort Collins, CO.

2:40 p.m. **Break** – Champion's Ballroom Foyer

NEW TECHNOLOGIES

Moderator: *Pat Zungoli, Department of Entomology, Clemson University, Clemson, SC.*

3:00 p.m. *Victor roach pheromone traps.* **Michael Goldstein** and M. Gehret, Woodstream Corporation, Lititz, PA.

3:25 p.m. *PREMISE – The new paradigm.* **Greggory K. Storey** and A. L. Anderson, Bayer Corporation, Kansas City, MO.

3:50 p.m. *Evaluation of six methods for controlling drywood termites in structures.* **Vernard R. Lewis**, Structural Pest Research and Education Center, University of California, Berkeley, CA.

4:15 p.m. *A new termite bait apparatus and method.* **Jian Chen** and G. Henderson, Department of Entomology, Louisiana State University, Baton Rouge, LA.

4:40 p.m. *Anoxia: Proven technology for pest management in specialty situations.* **Michael K. Rust**, D. A. Reierson and J. M. Kennedy, Department of Entomology, University of California, Riverside, CA

5:05 p.m. BUSINESS MEETING

7

POSTERS

Monday, February 19, 1996
Champion's Ballroom III

Organizer: *Shripat T. Kamble, Department of Entomology, University of Nebraska, Lincoln, NE.*

1. *Inter and intraspecific agonistic behavior assays using Reticulitermes flavipes (Kollar) and R. virginicus (Banks) workers: Effects of arena size and number of termites per arena.* Janine M. Polizzi and B. T. Forschler, Department of Entomology, Georgia Experiment Station, Griffin, GA.

2. *The use of heat to control Cryptotermes brevis (Walker) (Isoptera: Kalotermitidae) in Hawaii.* R. J. Woodrow and J. K. Grace, Department of Entomology, University of Hawaii, Honolulu, HI.

3. *Termiticide baiting goes to the mall.* Kathleen Sharpe-McCollum and G. Henderson, Department of Entomology, Louisiana State University, Baton Rouge, LA.

4. *Effects of application tips on Dursban TC distribution in soils following rodding and the validity of using a fluorescein dye to estimate soil insecticide distribution.* Robert W. Davis and S. T. Kamble, Department of Entomology, University of Nebraska, Lincoln, NE.

5. *Comparative acceptance and consumption of bait matrix candidates by subterranean termites (Reticulitermes spp.) in laboratory and field choice tests.* J. Edward King, I. J. DeMark, D. G. Wujek and A. S. Robertson, DowElanco Research & Development, Indianapolis, IN.

6. *Effects of the chitin synthesis inhibitor, lufenuron, on the cuticle of the cat flea, Ctenocephalides felis (Bouche).* Susan Pullen and R. W. Meola, Department of Entomology, Texas A&M University, College Station, TX.

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7. *Systemic effects of Nylar in the blood diet on adults, eggs and larvae of the cat flea, Ctenocephalides felis (Bouche).* Kristin Meier and R. W. Meola, Department of Entomology, Texas A&M University, College Station, TX.

8. *Controlling stored-product insects in wheat-based cat litter with diatomaceous earth dusts in urban environment.* B. Subramanyam, Department of Entomology, University of Minnesota, St. Paul, MN.

9. *IPM goes to school in Texas.* Mike Merchant, P. Hamman, D. Ronchie and S. Hyden, Department of Entomology, Texas A&M University, College Station, TX.

10. *Species determination in Reticulitermes: Correlation of cuticular hydrocarbons and soldier defense secretions.* Mike I. Haverty, B. T. Forschler, L. J. Nelson, L. G. Cool and M. Page, Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA.

11. *Aquapy: Advanced water-based formulation technology for the control of urban insect pests.* Jing Zhai, AgrEvo Environmental Health, Montvale, NJ.

12. *Differential levels of expressed Cytochrome P450 in a field population of German cockroach following different insecticide treatments.* Michael E. Scharf, Center for Urban and Industrial Pest Management, Department of Entomology, Purdue University, West Lafayette, IN; J. J. Neal, Department of Entomology, Purdue University, West Lafayette, IN; and G. W. Bennett, Center for Urban and Industrial Pest Management, Department of Entomology, Purdue University, West Lafayette, IN.

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