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Bed Bugs Bounce Back

By William Quarles

Bed bug bites are not new, since bed bugs lived with us in caves back in the ice ages. They have been persistent pests throughout at least 4000 years of recorded history, and they will probably never disappear. Populations do wax and wane with time. In the early 20th century, bed bugs were biting four million inhabitants of London, and one-third of the dwellings in Stockholm were infested. In the second half of the 20th century populations declined, perhaps due to better building practices, better education, emphasis on prevention, and widespread use or overuse of insecticides (Usinger 1966; Potter 2005).

For the last few years, however, there has been a minor resurgence. About 67% of recently surveyed pest control companies nationwide have reported increases in bed bug calls (Gangloff-K et al. 2006). Homes, apartments, hotels, college dormitories, laundries, homeless shelters, and other places have been treated. No one knows why the number of infestations have increased. Speculations include increased travel and immigration, reduced applications of residual pesticides, and pesticide resistance (Hwang et al. 2005; Potter 2005).

Resistance may be part of the problem. Bed bugs started showing up again in 1999 at large hotels in major cities (Cooper 2006). These are exactly the kind of structures that encourage resistance, since they are often treated with pesticides on a regular basis. Bed bugs were resistant to DDT when it was banned in the U.S., and they became resistant in Africa as a result of house-to-house DDT sprays for malaria. Pyrethroids and DDT act by the same neurochemical mechanism, and resistance is now building to pyrethroids. Lack of awareness, carelessness, and no efforts for prevention could also be factors in resurgence (Mallis and Miller 1964; Usinger 1966; Bloomquist 1996; Moore and Miller 2006; Myamba et al. 2002).

Photo courtesy of Carlos Agurto of Pestec

Bed bug sniffing dogs are invaluable allies in the fight against bed bugs. Shown here is Ladybug, the bed bug hound for Pestec IPM Providers in San Francisco.

To put this problem in perspective, Toronto, which has a population of over 2 million, reported only 847 infestations in 2003 (Hwang et al. 2005). Though total numbers are still low, numbers are increasing each year. Since bed bugs are easy to spread and difficult to eradicate, this fact is bad news. According to Luis Agurto of Pestec IPM Providers in San Francisco, “we never had a bed bug call before 2002. Now we have a bed bug crew working on a daily basis.” About 300 bed bug infestations were reported in San Francisco in 2006, almost double that of 2004. Many

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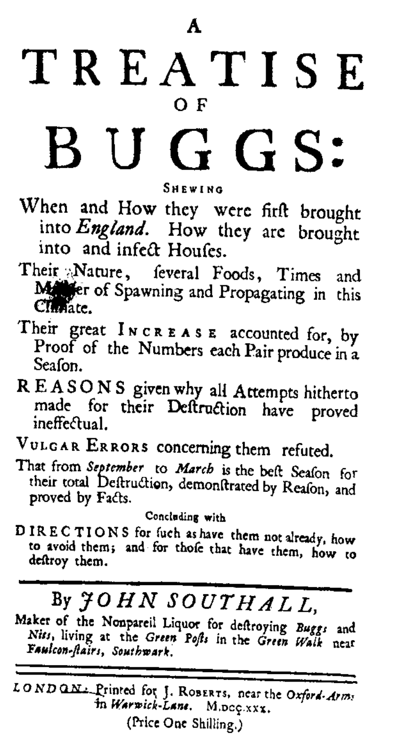
of the cases involved travelers reporting bites at upscale hotels (Reinhardt and Sivva-Jothy 2007; May 2007).

Worldwide Pest

Bed bugs are a worldwide pest, and there is a word for them in nearly every language. In middle English, the word *bugge* means ghost or wraith. Since bed bugs appear only at night to do undesirable things, they were called *bugges*. The insects are sometimes called *buks* in the Middle East, and that is another possible origin of the English word (Schaefer 2000; Usinger 1966; Thomas et al. 2004; Ebeling 1975). (see Box A. Biology of Bed Bugs)

Bed bugs are a dreaded pest because of the anxiety, social stigma, and irritations they cause. As part of the social stigma, friends may decide not to visit, and landlords may put you on a blacklist. Other species that infest birds and chickens can cause economic damage by destroying nestlings, slowing growth, and damaging eggs with blood spots (Schaefer 2000).



A
TREATISE
OF
BUGGS:
SHEWING
When and How they were firſt brought into *England*. How they are brought into and infect Houſes.
Their Nature, ſeveral Foods, Times and Manner of Spawning and Propagating in this Climate.
Their great INCREASE accounted for, by Proof of the Numbers each Pair produce in a Seaſon.
REASONS given why all Attempts hitherto made for their Deſtruction have proved ineffectual.
VULGAR ERRORS concerning them refuted.
That from *September* to *March* is the beſt Seaſon for their total Deſtruction, demonſtrated by Reaſon, and proved by Facts.
Concluding with
DIRECTIONS for ſuch as have them not already, how to avoid them; and for thoſe that have them, how to deſtroy them.

By *JOHN SOUTHALL*,
Maker of the Nonpareil Liquor for deſtroying *Buggs* and *Nits*, living at the *Green Poſts* in the *Green Walk* near *Faulcon-ſtairs, Southwark*.

LONDON: Printed for J. ROBERTS, near the *Oxford-Arms* in *Warwick-Lane*. M.DCC.XXX.
(Price One Shilling.)

Title page from a book on bed bugs, about 1730. From Usinger 1966

Start of an Industry

Bed bugs and rats laid the foundations of the pest control industry. The largest pest control company in Sweden is called Cimex, which is the Latin name for bed bug. In 18th century England, "professional exterminators concocted secret formulas to destroy bugs" (Usinger 1966). No one was immune, even royalty was infested. One company was known as "bug-destroyers to Her Majesty and the Royal Family." Traps were devised and room temperatures raised above 45°C (113°F) to kill bugs. Prevention was stressed and building codes were revised to eliminate harborages (Usinger 1966; Schaefer 2000).

Bed bugs are extremely difficult to eliminate once they are established. Before World War II the primary treatment was either heat or fumigation. In some countries, drastic measures were used. Since bed bugs tend to crawl upward after feeding, buildings were constructed with barriers in the middle of the wall that bed bugs were unable to cross. Wire mesh was attached below the barriers to encourage harborage, then the mesh was flamed with a blow torch on a regular basis. Bed bugs drove many people to switch to iron bedsteads, which are less attractive to bed bugs than wooden ones. DDT was the pesticide of choice in the 1940s and 1950s until bed bugs became resistant (Usinger 1966, Blacklock 1912; Ross 1916; Mossop 1940).

The Bite

Increased attention to bed bugs in the media has led to some mass hysteria. Now, when someone feels a bite, and is unable to immediately determine the cause, the first thought may be bed bug. This hysteria has caused some false alarms. To some degree, the creature biting can be deduced from the bite patterns. Bed bugs tend to bite on the face, neck, and arms (Quarles 2005; Ebeling 1975).

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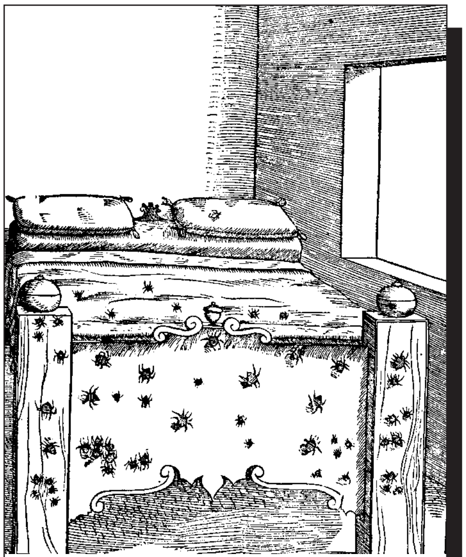


Bed bug illustration from about 1568. From Usinger 1966.

Bed bugs do not bite right away. They wander about looking for just the right place. If you are awake, a slight tickling sensation may be the only clue that you are being bitten. Bed bugs have a beak with mouthparts that saw through the skin, and a proboscis with two tubes. One injects saliva containing anticoagulants and painkillers, the other sucks up the blood directly out of capillaries. There is a range of host sensitivity from an extreme allergic reaction to no reaction at all. About 20% of humans show no reaction to the bite. Some show delayed reactions or an itching sensation that may persist for several hours (Usinger 1966; Schaefer 2000).

According to Ebeling (1975), "the bite ordinarily produces a lump or swelling with no red spot or other distinguishing characteristics... when many bugs feed on a small area, reddish spots caused by hemorrhage may appear after the swelling has disappeared. Swelling is severe with some highly allergic persons, and may not be confined to the immediate area that was bitten."

Cockroaches produce allergens, and there is some anecdotal evidence for contact sensitivity to bed bugs. Bed bugs molt through 5 stages, sloughing off shells made of chitin. Field observers have noticed that mere contact with bed bugs in some people may cause itching, perhaps because of sensitization to chitin (Cain 2007). According to Luis Agurto of Pestec IPM, "I have had one client try the sensitization test, which is to leave a dead bed bug on

A. Biology of the Bed Bug

Bed bugs are a worldwide pest, and are members of the family Cimicidae. There are over 100 species in this family of blood sucking bugs. They include bed bugs, bat bugs, chicken bugs, swallow bugs, pigeon bugs and others. Two species live almost exclusively on human hosts. *Cimex lectularius* is the major pest in temperate areas, and probably originated in caves of the Middle East. *C. hemipterus* is found mostly in tropical areas, although ranges overlap and hybridization can occur. In the laboratory and sometimes in the field these species will also feed on a wide variety of other mammals and birds. In addition, human dwellings are sometimes invaded by bat bugs and swallow bugs (Usinger 1966; Schaefer 2000).

The only food of the bed bug is blood. Blood is needed to live, to produce eggs and sperm, and to moult. The behavior of the bed bug can be described as feed and hide. They feed quickly, usually in about 10 minutes, then hide close to the host for a week or two before feeding again. They aggregate in tight spaces, such as cracks, crevices, underneath wall paper, and other out of the way places. Feeding is usually noctural and takes place after midnight, and especially near 3 AM. Relatively large amounts of blood are taken. According to life stage, bugs can ingest 3-6 times their body weight. A female can ingest about 8 mls of blood in a single feeding (Usinger 1966).

Reproduction is sexual and insemination is traumatic. Males pierce the body walls of females and inject sperm directly into the body cavity. Both males and females feed before reproduction. After she feeds, a female will typically mate about 5 times. The damage done by mating causes about a 30% decrease in her lifespan. Due to female selection, paternity is usually determined by the last male to mate. Females store sperm and are able to fertilize eggs from 5-7 weeks after mating. They lay about 3 eggs a day, but stop after 11 days unless they feed (Schaefer 2000).

Bed bugs practice incomplete metamorphosis and there are eggs, 5 nymphal stages, and adults. Every stage except the egg bites. *C. lectularius* and *C. hemipterus* lay eggs mostly in and about their harborage. Eggs are laid invidually and glued to the substrate. Eggs are yellowish-white capsules about 1 mm long (1/25th in) and 0.44 mm (1/50th in) wide. Rate of development increases with temperature. *C. lectularius* takes about 128 days to develop from egg to adult at 18°C (64.4°F) and about 24 days at 30°C (86°F). At 22°C (71.6°F), eggs take about two weeks to hatch, and bugs spend about one week in each of the 5 instars. Instars grow from about 1.5 mm (1/25th in) long (1st instar) to 4.5 mm (1/5th in) (last instar).

It is easier to kill them with heat than with cold. Freezing temperatures do not kill them. All stages can survive for at least five days at -10°C (14°F), but all stages are killed by 15 minutes exposure to -32°C (-25.6°F). The thermal death point is 45°C (113°F), and all stages are killed by 7 minutes of exposure to 46°C (114.8°F). Longevity after feeding is greatest at low temperatures: at 10°C (50°F) the average for *C. lectularius* adults is about 413 days at 27°C (80.6°F), it is 65 days (Usinger 1966; Sokolova 1956).

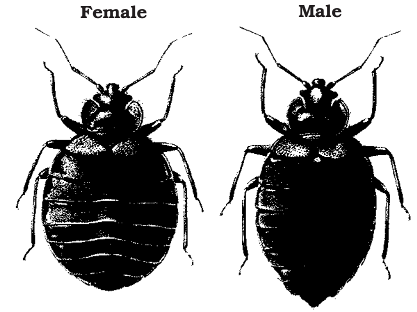
A bed bug cannot detect a host at greater distances than 5 ft (1.5 m). Bed bugs can run at 126 cm/min (4 ft/min; 1 in/sec). They can climb walls and cling to ceilings. Activity ceases at low temperature (12°C; 53.6°F). They are attracted to their hosts by heat, CO_2, pheromones, and perhaps other cues. Rodents will eat bed bugs, but bats will not (Schaefer 2000).

their skin for about 15 minutes. He broke out with what he called bites. This might be the reason that people continue to feel bites after bed bugs are gone." The possibility of allergic sensitivity to chitin, bed bug feces, or other bed bug components deserves further research.

Disease

An adult female will drink about 8 ml of blood. That is a significant amount compared to a mosquito. Since mosquitoes can vector diseases, how about bed bugs? Though at least 32 pathogens, including those for plague, yellow fever, typhus, HIV, and tularemia have been found in bed bugs, there is no evidence that bed bugs transmit diseases to humans through their bite. Diseases have been transmitted to mice that ate infected bugs. HIV and hepatitis B virus can persist in a bug's gut for several weeks. The viruses do not replicate, and no direct transmission to humans has been observed. Hepatitis B persists as bugs molt from one stage to another and infective amounts of virus have been found in bed bug feces. The chance of mechanical transmission from feces or crushed bugs is low, but not impossible (Reinhardt and Siva-Jothy 2007; Blow et al. 2001).

Though potential for infection is very low, Luis Agurto of Pestec believes that pest management professionals should exercise care. According to Agurto, "we handle bed bugs as part of our trade, and we may be more exposed to the potential infections that can occur."



Common bed bugs,
Cimex lectularius

Do You Have Bed Bugs?

Before you treat for them, you should make sure you have bed bugs. Bed bugs react to air currents, so hitting suspected harborages with sprays from compressed air cannisters will flush them from hiding. They also are attracted to darkness and avoid the light, so a flashlight with an intense beam will help with detection. Bugs hide "in crevices and corners of wooden bedboards, behind loose wallpaper, in nail holes and cracks in the walls, behind pictures, conduits, light switches, wall panels, baseboards, door and window frames, floor crevices and in furniture and mattresses"(Usinger 1966). They can also hide in smoke detectors and electronics. Bed bugs are usually spread by humans, but they can be harbored and possibly spread by cats and rodents (Clark et al. 2002; Potter 2005; Usinger 1966).

Bed bugs are noctural, so they are usually seen in open spaces only at night. They are flat and thin before feeding, then become plump with blood. The adults are red-brown, oval or elliptical in shape and about 1/5 of an inch (5 mm) long. But look for small bugs as well as large. Since all stages except eggs feed on blood, you might find a small (1 mm) 1st instar bed bug biting you (Ebeling 1975).

Another sign of bed bugs is black spots of dried blood, or clusters of yellowish-white, elongated eggs and empty egg cases (Snetsinger 1997). Females lay about 10-50 of these yellow-white (1/25th inch; 1 mm) eggs usually on mattresses or in cracks and crevices. Bed bugs tend to aggregate on rough surfaces, and "prefer wood or paper surfaces to stone, plaster, metal or even textiles" for harborages. Sometimes they leave blood stains on walls, bedding and curtains. Cast skins are "thin, white, and translucent" (Ebeling 1975).

Bed Bug Dogs

Since bed bugs are so hard to remove, you may want to call a professional. Companies such as Pestec IPM have bed bug sniffing

Photo courtesy of Carlos Agurto of Pestec

Ladybug, the bed bug hound, alerts her handler to the location of bed bugs.

dogs. These bed bug hounds make it possible to find bugs with a minimal disruption. The dogs are very popular with hotels, because if the dog quickly finds the room is clean, expensive treatment can be avoided. The hotel can rent the room with confidence, knowing their guests are protected. According to Luis Agurto of Pestec, "a trained dog is an indispensable tool. Hotel owners can demonstrate that they are doing everything possible to keep the bed bugs under control" (Agurto 2007).

A trained dog can inspect a hotel room for bed bugs within minutes with 90% accuracy. A lone pest management professional would need an hour for this job. Dogs detect low levels of infestation, before guests get bitten and complain. If bugs are present, the dog can narrow the focus of the search by alerting to their location. Dogs can also be used to inspect after treatment, to determine if bugs have been eradicated (Grossman 2007).

Trapping, Pheromones, Repellents

A recent survey of pest control professionals showed that 67% of them tried to catch bed bugs in sticky traps. For some reason, there has been a general lack of success. One speculation is that bed bugs are flat before feeding, so they may

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crawl underneath them (Gangloff-K et al. 2006). However, Agurto of Pestec says, "we have had great success with sticky traps. Our monitoring program uses about 12 traps per room, against walls, and under bed and nightstands. Perhaps success is directly related to the number of traps and their placement."

Practitioners in the older literature reported success with corrugated cardboard traps. A number of researchers are now working on traps that use attractants. Bed bugs are attracted to heat, carbon dioxide, and components of human sweat (Potter 2006; Usinger 1966). Bed bug pheromones could also be useful. They have aggregation pheromones, and secrete 6- and 8-carbon unsaturated aldehydes that act as alarm pheromones (Levinson and Bar Ilan 1971; Levinson et al. 1974ab; Schaefer 2000).

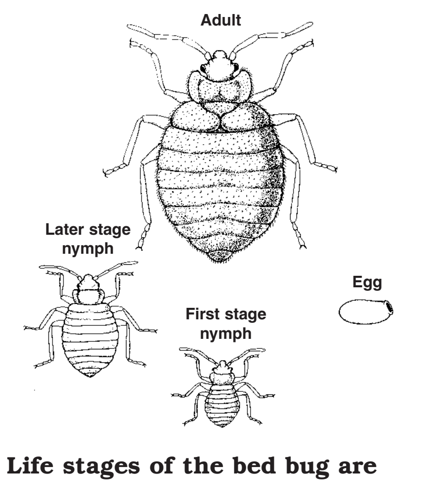
Luis Agurto of Pestec believes, "the best bait for a bed bug trap is the host. In fact, there is a trap that was used many years ago consisting of a wooden tube drilled with holes and capped on both ends with cork. This trap was placed under the pillows, and in the morning the user would unplug the tube and shake out the bed bugs."

It is very difficult to repel a hungry bed bug. Much of the folklore is not very useful. Such as hang a rabbit's foot at the foot of the bed. Or spread bug bane, *Actaea cimicifuga*, around your bed. In Africa foliage from the bushes *Pseudarthna hookeri* or *Laggera alata* placed under bedding is reputed to stop bed bugs. But, even pesticides such as pyrethroids will not repel them. Some of the materials that do repel them are too toxic to use on skin. Deet (15%) gives some protection, but you have to apply it to your whole body (Mossop 1940; Usinger 1966; Moore and Miller 2006). Eucalyptus oil from *E. saligna* will kill them, so lemon eucalyptus mosquito repellent might be effective (Schaefer 2000). (see Resources)

For treatment of harborages, diatomaceous earth should act as a repellent. Many insects are repelled by DE, and there is a history of mineral dust repellency for bed bugs that probably goes back to the days they lived in caves. According to Levinson et al. (1974a), in caves where bed bugs evolved, "powders harmful to the assembled insects often crumble from the corroded walls." Contact with powdered quartz in the laboratory caused bed bugs to "move rapidly and release their alarm pheromone," effectively repelling and dispersing them (Levinson et al. 1974a).

Prevention

Key to prevention is getting what entomologist Michael Potter calls a "bed bug state of mind" (Potter 2005). Bed bugs cannot fly. They get to where they are going by walking or passive transport. "Bed bugs are transmitted from infested house to unifested house on furniture, baggage, boxes, in suitcases, packed clothing, and bedding" (Snetsinger 1997). So it is important to think that any item you bring into your house could be infested with bed bugs. The attractive curbside couch left "free" for pickup should be avoided. Rent-to-use items such be regarded with suspicion. Caution should be your companion on trips to the thrift store. Flip pages of used books to make sure there are no bugs or eggs glued to pages. Reduce clutter around the home. Get rid of picture frames and other hiding places near your bed. Caulk all cracks and crevices and easy hiding places. When traveling, keep luggage off the floor. When you return, vacuum your suitcase, and wash your clothes. Bed bugs can be killed by heat, and an ordinary clothes dryer can do the job (Usinger 1966; Potter 2005).



Life stages of the bed bug are egg, nymph, and adult. There are five nymphal stages.

Biology

If you have just brought a bed bug back from your travels, it will most likely be a mated female (Reinhardt and Siva-Jothy 2007; Schaefer 2000). She would most likely bite right away, and then you would notice nothing until the next bite, about two weeks later (see Biology Box A). After biting, she would immediately start laying about 3 eggs a day, and the eggs would either die or hatch within two weeks. At 18-20°C (64.4-68°F) eggs would become adults in about four months. At these temperatures, there could be three generations a year. Moving out and hoping they die without food would do no good, since they can live more than a year without feeding. Normally, adults live about 10-12 months. Populations can increase quickly, infestations of 4-200 are the norm, but in one case 5000 were found just on one bed (Usinger 1966; Schaefer 2000; Reinhardt and Siva-Jothy 2007). See Biology Box A.

Biological Control

Bed bugs have a number of natural enemies including ants, spiders, mites, centipedes, and predatory bugs, such as the masked bed bug hunter, *Reduvius personatus*. Pharoah ants kill them with venom. An attack of ants and other predators causes release of bed bug alarm pheromone. Rodents will eat bed bugs, but bats will not, since they do not like the taste of alarm pheromone. This bat taste aversion probably allowed bed bugs to survive as a species, since they sheltered in caves along with bats and humans (Usinger 1966; Schaefer 2000). Altogether, it seems that bio-

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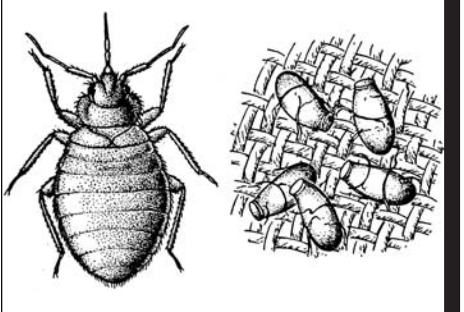

Bed bug, *C. lectularius* and eggs.

controls are not practical for bed bugs in structural pest control.

IPM Program

The best way to get rid of bed bugs is a complete IPM program involving inspection and monitoring, prevention, physical controls, sanitation, exclusion from harborage, and insecticides as a last resort. Steam, vacuuming, treatment of cracks and crevices with diatomaceous earth, and caulking may be warranted. You can try to do it yourself, or hire a company. A pesticide-only approach is seldom used by professionals, but some companies rely more on pesticides than others (Potter 2005; Gangloff-K. et al. 2006)

A recent survey of pest companies nationwide found that about 42% of companies use physical controls such as heat, steam, or freezing for bed bugs. Steam is applied in cracks, crevices, door and window moldings or other hiding places. Steam has also been used to decontaminate mattresses and box springs (Gangloff-K. et al. 2006). Though Pestec IPM uses steam, Luis Agurto advises caution, "at Pestec we have a strong concern about steam. We believe that steam can volatilize some compounds from treated objects. We recommend our operators use respirators with carbon and particulate filters."

Hot air was used in the past to kill bed bugs, and convective heater technology is available today. Rooms are heated a minimum of 3 hrs at 140°F (60°C) (Ross 1916; Gunn 1933; Miller 2002; Quarles 2006). Heat can reach lethal levels inside mattresses, pillows, wall voids, books and all contents within a given habitation. According to Linford and Currie (2006), "Because bed bugs typically migrate upward, rooms on several floors can be treated simultaneously within 4 to 8 hours depending on the number of heaters and the size of the treatment. What that means is that rooms can be rented out by 6 PM if treatment commences in the morning hours. The loss of revenue is minimized, or eliminated altogether..."

Though it is harder to kill bed bugs with cold than with heat (see Box A), Luis Agurto says, "for Pestec, the freeze treatment is more efficient than heat treatment. We do not freeze an entire room, but we treat personal belongings in thermal containers with dry ice overnight to achieve ultra-low temperatures. This treatment destroys eggs and all stages of the bed bugs."

About 70-80% of pest companies throw away contaminated items such as mattresses or use a vacuum cleaner. When pesticides are used, the focus of treatment is the bed frame and headboard (94%), boxsprings (87%), and mattresses (75%). Pesticides used are mostly pyrethroids such as deltamethrin or cyfluthrin. Insect growth regulators such as hydroprene (Gentrol) are sometimes applied to kill the eggs. Bed bugs are rarely eliminated on the first visit. Two or three times is typical, but five or more visits have been reported (Gangloff-K. et al. 2006; Potter 2005).

Treatment of mattresses with pesticides is controversial. Many companies prefer to toss them out rather than treat them. In any event, zippered enclosures are available for mattresses and box springs that deny bed bugs harborage (see Resources). If the mattress or other things are thrown away, it is a good idea to enclose them in plastic before they are moved, to prevent spreading bed bugs as the items are moved through the structure (Potter 2005).

Self Help

You can help with control by making sure that bedding and mattress is not harboring them. Bedding can be washed in hot water and dried in a hot drier. Check the seams of the mattress

Resource Box

Bed Bug Dogs—American K-9 Team**,** PO Box 425, Tarpon, FL 34688; 866/615-2662, 727/781-7879; Fax 727/781-1537; www.k9teams.com. Florida Canine Academy**,** www.termitedogs.com; www.allprok9training.com

Diatomaceous Earth—Perma-Guard, 2430 Alamo SE, Suite 102, Albuquerque, NM 87106; 505/243-1460, Fax 505/243-8878; www.perma-guard.com; Pristine Products, 4526 N 57th Ave., Phoenix, AZ 85031; 800/266-4968, 623/846-0204; Whitmire Microgen Inc**.**, 3568 Tree Court Industrial Blvd., St. Louis, MO 63122; 800/777-8570, 636/225-5371, Fax 636/225-3739; www.wmmg.com; Woodstream, 69 N. Locust St., Lititz, PA 17543-0327; 800/800-1819, 717/626-2125, Fax 717/626-1912; www.woodstream-pro.com

Heat Treatment—Thermapure/TPE Associates, 180 Canada Largo Road, Ventura, CA 03001; 800/873-2912, Fax 805/648-6999; www.thermapure.com

Lemon Eucalyptus Repellents—WPC Brands, 1 Repel Rd., PO Box 198, Jackson, WI 53037; 800/558-6614, 262/677-4121, Fax 262/677-9006

Mattress, Bedspring Covers—Protect A Bed, Chicago, IL. 847/998-6901; www.cooperpest.com

Mattress, Bedspring Covers—Residex, 800/998-2847; www.cooperpest.com

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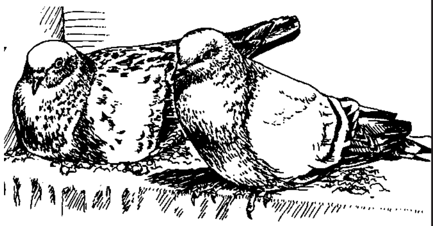

Pigeons also carry bloodsucking bugs of the Cimicidae.

for eggs and feces. If you see evidence of bed bugs, use the vacuum cleaner. Once you are done vacuuming, remove the bag, seal in a plastic bag, and discard outside in the trash. Then, you must make sure they are not hiding in the cracks and crevices of the bed. You can inspect with a strong flashlight and use pressurized air to flush them out of harborage.

If bed bugs are found in the mattress or box springs, you do not have to use a conventional pesticide. You can either throw them out, treat them with vacuum, or use a steam cleaner. Once you are done, zippered enclosures are available for mattresses and boxsprings that will exclude bed bugs (see Resources) (Potter 2005).

If they are inside the box springs, you can repel them with diatomaceous earth (DE). When you use DE, use a rubber bulb duster to apply small amounts of it to areas where it can be contained (Olkowski et al. 1991). One entomologist suggests using homemade sprays of 40% alcohol, 40% water, 20% dish soap, and as much DE as will remain suspended in the solution. When the spray dries, a layer of DE is left that is repellent to bed bugs (Fagerlund 2007). But dried DE residues are probably not lethal to them. Luis Agurto of Pestec says, "when we put bed bugs into a glass container that had been sprayed with soap, water, and DE, they did not die. We should try again to test for repellency."

Once the bed is decontaminated, to get some relief from biting, you can then isolate the bed from the surroundings. If it is supported by legs, for instance, you can use a sticky tape barrier. Alternately, you can use a barrier of vaseline, but that is somewhat messy (Olkowski et al. 1991). This approach may help, but is not foolproof because there are reports of bed bugs dropping onto beds from the ceiling (Usinger 1966).

If the infestation is severe, they may have found their way into the cracks and crevices along the baseboard and intersections of the wall with the floor. Large infestations sometimes produce a "bed bug smell." Bed bugs emit characteristic odors that have been described as "fresh, red raspberries" or "an obnoxious sweetness" (Ebeling 1975). Pestec IPM has found that presence of the characteristic smell is inconsistent. Sometimes it is missing in large infestations "where lots of them are crawling around in plain sight." But sometimes the smell is there in small infestations.

Cracks and crevices can be treated with DE and caulked (Olkowski et al. 1991). Pull up the edges of the carpet and see if you see signs of them. Small amounts of DE could be applied underneath the edge of the carpet. Do not use large amounts of DE in open areas, because you could contaminate the air of your living space with dust. You want to apply it in out-of-the-way places where it will be undisturbed by air. Use freshwater DE that has low crystalline silica content (Olkowski et al. 1991; Snetsinger 1997; Quarles 2007). (see Resources)

Bed bugs also hide behind electrical outlets. You can remove the faceplate and use diatomaceous earth (DE) dust to treat those areas. You might have to look behind picture frames and in the cracks and crevices of the frame (Olkowski et al. 1991).

Bed bugs can spread through a structure in the same way as cockroaches. Luis Agurto of Pestec IPM says, "I have observed that bed bugs have excellent mobility. They are capable of traveling long distances at very fast paces. If an infested building mostly becomes vacant, bed bugs move to the last occupied apartment. They can move from the fifth floor to the first, or from the end of a corridor to the front." If you have a multiunit infestation, you should try to find out how they are getting from apartment to apartment. Check where pipes are going through walls and caulk around those areas. Wall voids might have to be treated with diatomaceous earth or silica gel (Ebeling 1975).

Bats carry bloodsucking bugs of the Cimicidae.

Bed Bugs or Bat Bugs?

Sometimes, bat bugs will invade human dwellings. Bed bugs and bat bugs are difficult to tell apart. Bat bugs have longer body hairs, that is the main difference. There are two species of bat bugs in the U.S. There is an eastern species, *C. adjunctus* and a western one, *C. pilosellus*. The eastern species is more of a human pest. Lifecycle of the bat bug is very similar to that of *C. lectularius*.

Normally, bat bug infestations are treated in a slightly different way than those of bed bugs. Bat bugs migrate into a structure from a bat roosting point. So the strategy is to get rid of the bats, and then treat the general roosting area with an insecticide. Attic areas and other areas adjacent to the roost are treated to prevent the bugs from entering the structure (Snetsinger 1997).

Conclusion

In the past few years bed bugs have shown a minor resurgence. Since bed bugs are carried into dwellings on people and their belongings, prevention is the best remedy for them. When returning from trips, vacuum out suitcases, wash and dry clothing. If your house becomes infested, do not panic and overuse pesticides. You will have to deny bed bugs hiding places. Cracks and crevices should be caulked. Mattresses and boxsprings can vacuumed, or steam cleaned and then encased in zippered enclosures. Belongings can be treated with dry ice to freeze the bugs. Possible harborages such as cracks and crevices in bed frames, electrical outlets, and other areas can be treated with diatomaceous earth. Spot treatments with residual pesticides may be needed as a last resort. If the infestation is severe, a heat treatment may be necessary.

Acknowledgement

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Conference Notes

ESA 2006 Annual Meeting Highlights– 2nd Part

By Joel Grossman

These Conference Highlights are from the annual meeting of the Entomological Society of America (ESA), Dec. 10-13, 2006, in Indianapolis, Indiana. ESA's next annual meeting is December 9-12, 2007, in San Diego, California. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org).

Termite research is always a big topic at the ESA Conference, and this year was no exception. Termite baits have continued to draw attention, and a number of new products containing IGRs as active ingredients are being commercialized. The Dow Sentricon® system has a new active called noviflumuron that works faster than the old active, hexaflumuron. Whitmire is commercializing Advance® baits based on diflubenzuron, and Syngenta is developing SecureChoice® baits with lufenuron as the active ingredient. Several of the reports below discuss these developments.

California Condos Baited

For several years prior to 2001, the RockPointe Condominium Complex (Chatsworth, CA) had frequent complaints and extensive damage from the western subterranean termite, *Reticulitermes* spp. "Failed treatments were the norm," said Gail Getty (Univ of California Berkeley, ESPM, PO Box 1557, Blue Jay, CA 92317; ggetty@berkeley.edu). Rather than spot treating individual buildings with liquid termiticides, management decided to use the Sentricon® baiting system to monitor and reduce termite activity throughout the 90-acre (36-ha) complex.

Photo courtesy of the USDA

A termite bait is being planted in soil.

A total of 7,327 Sentricon® stations were installed along the perimeter of 134 buildings between October and December 2001. For a baiting strategy to work, termites must find and feed on termite baits. Baits were inspected monthly, and within two months of installation, termites were feeding on bait stations at 41% of the buildings. After 6 months 90% of the 134 buildings had active stations, and within one year, 95% of the buildings had termites feeding on bait stations.

"This site has served as a case study for the Sentricon® Termite Colony Elimination System in large scale housing," said Getty. Thanks to successful baiting, only 12% of the 7,327 bait stations in the condo complex had termite activity one year later. Compared to 2002, 70% fewer Sentricon® stations had new termite activity in 2003. Since 2004, very few new termite infestations have been detected. Once baiting was implemented, "a reduction in termite related complaints from residents paralleled the reduction of termites in stations at the site," said Getty.

New Sentricon Bait

Recruit® IV (0.5% noviflumuron), the new Sentricon® bait, utilizes a highly refined briquette formulation of cellulose to attract western, *Reticulitermes hesperus*, and eastern subterranean termites, *Reticulitermes flavipes*. Recruit IV "recruits" four times as many termites as Recruit® III bait, allowing more accurate prediction and monitoring of termite populations and lower service costs, said J.E. Eger (Dow AgroSciences, 2606 S. Dundee St, Tampa, FL 33269; jeeger@dow.com). The bait is designed for monthly inspections and quarterly replacement.

Tested in 14 U.S. states against several termite species, Recruit IV used with Dow's Baitube™ device eliminated 125 termite colonies. From May 2004 to October 2005, termite species were identified and the DNA analyzed. Termites eliminated included colonies of western subterranean termite, *R. hesperus*; West Indian subterranean termite, *Heterotermes aureus*, 70 *R. flavipes* colonies and 21 light southern subterranean termite, *R. hageni*, colonies. *R. hageni* was the most difficult termite species to eliminate, requiring from 20 days to one year.

Hex-Pro™ Baits

In 2005, Dow replaced hexaflumuron with noviflumuron in its Sentricon system, said Michael Lees (5200 Parkford Circle, Granite Bay, CA 95746; mdlees@dow.com). Dow is marketing a new in-ground bait station called Hex-Pro™ that uses 0.5% hexaflumuron as the active ingredient in the bait, which is trademarked Shatter™.

Hex-Pro requires an average of 169 days and 4 bait cartridges to eliminate termite colonies. The number of bait cartridges ranges from 1.1 to 10.6 and days to elimination ranges from 60 to 353. But many termite colonies are eliminated in under three months.

However, besides primary bait stations, auxiliary bait stations are an important factor in termite colony elimination.

Advance® in Ohio

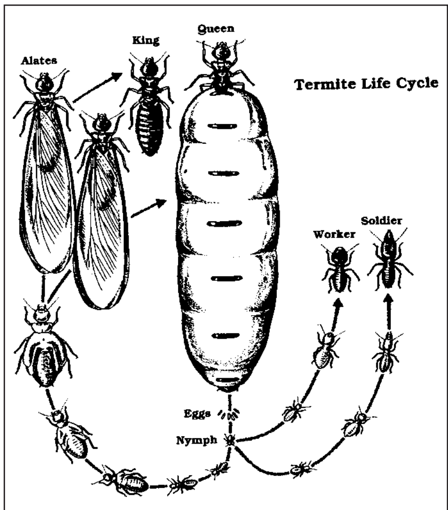
The Advance® termite bait system (Whitmire Micro-Gen) is being used at 23 sites in Columbus, Ohio, said Susan Jones (Ohio State Univ, 1991 Kenny Rd, Columbus, OH 43210; jones.1800@osu.edu). The monitoring base of the Advance bait station has horizontal grooves for termite access to 63 g (2.2 oz) of aspen wood. When termites get inside, the inspection cartridge is replaced with a bait cartridge containing 0.25% diflubenzuron active ingredient.

Columbus, Ohio, termites began finding bait stations within one month (4 of 19 stations); termites were numerous and feeding heavily. Baiting with active ingredient began on May 20, 2005, and within three months (August 24) two eastern subterranean termite, *Reticulitermes flavipes*, colonies were eliminated from one site by one bait cartridge. At another site, termites swarmed for five years before the owners called in pest control professionals; baiting eliminated the termites from the structure in five months and 2006 was the first time in several years without swarming.

Lufenuron Baits

Lufenuron, a benzoylurea chitin synthesis inhibitor originally registered for flea control, was used to assess termite populations established near infested wood in Ohio, said Nicola Gallagher (Ohio State Univ, 1991 Kenny Rd, Columbus, OH 43210; gallagher.155@osu.edu). Monitoring was either biweekly or monthly, except in inclement weather when termite activity is negligible in Ohio.

SecureChoice™ (Syngenta) bait stations at four sites were "hit" by termites within one month. At a residential structure, 11 bait tubes with 86 grams (3 oz) of lufenuron bait eliminated eastern subterranean termites in 10.5 months. In a commercial building (High Street Animal Hospital), 26.5 g (0.9 oz) of bait eliminated termites in 3.5 months. At another site, 8.5 months and 10 bait tubes with 127 g (4.5 oz) of bait were needed to eliminate the termites.



Life stages of the western drywood termite, *Reticulitermes hesperus.*

Lufenuron in the Wildlands

Robin Taylor (Univ of California, 1301 South 46th St, bldg 478, Richmond, CA 94804; rtaylor@-nature.berkeley.edu) tested baits against western subterranean termites, *Reticulitermes hesperus*, in a 4-ha (10-acre) field site near Placerville, CA. The wildland location was chosen because of prior studies on the biology and ecology of subterranean termites, high species diversity and colony density, and to simplify logistics, "We installed wooden stakes on a 2-m (6.6-ft) grid. Once fed upon by termites, independent monitoring stations (IMs) were installed adjacent to stakes" and monitored "monthly for termite activity and wood consumption." After IMs were selected to "represent the species demographic local to the site, 8 monitoring stations (MSs) were then installed at 1-m (3-ft) intervals in a 90 degree radial pattern around the original IMs."

Half the termite colonies were assigned to bait treatments and half were untreated controls. "Seven of the 12 sites had two or more colonies operating within an area of 13 to 48 m^2 (140-517 ft^2)," said Taylor. "We found a total of 30 colonies operating at the 12 sites. At least 6 colonies were completely controlled by lufenuron" with 2-3 months necessary for enough insecticide to be delivered to kill the termite colony.

"Two of the unbaited colonies were displaced by carpenter ants or [they] simply abandoned the IMs," said Taylor. "Additional colonies were found at each baited site but did not feed on the bait... With the densities of colonies at this study site, many colonies in a baited area may never encounter the bait and would escape control. The MSs should be installed early in the spring and the bait placed in the MSs early in the feeding cycle, late spring or early summer."

Larger Baits More Effective

"Recent increases in the use of more directed termite control techniques such as baiting systems have helped to renew an interest in basic termite ecology," said Greg Broussard (Oklahoma State Univ, 127 Noble Res Center, Stillwater, OK 74078; osubroo@yahoo.com). Termites are known to play an important role in ecosystems. A more complete understanding of their behavior could lead to improved control strategies and techniques.

Termite baiting systems rely on effective monitoring. Although eastern subterranean termites, *Reticulitermes flavipes*, are abundant in Oklahoma's native tallgrass prairies, there have been few studies of baiting stations in this habitat, which exists undisturbed inside the Nature Conservancy's Tallgrass Prairie Preserve in Osage County. Hence, a native tallgrass prairie experiment was designed "to investigate termite foraging behavior relative to moni-

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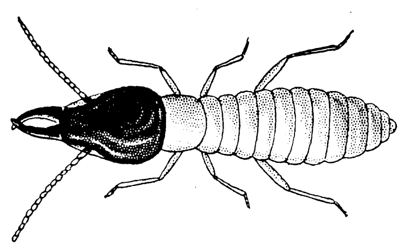
toring station diameter and food source volumes."

Broussard found that regardless of station diameter, termites locate larger volume food sources more quickly and more often than smaller volume food sources. "Of the 115 stations installed in areas known to have termites, 78 became active," said Broussard. When food source volumes were compared: 90% (18 0f 20) of the maximum volume food source stations detected termite activity, versus 35% (7 of 20) of the minimum volume food source stations. In the first 27 days, 11 maximum volume food source stations detected termites, versus only one minimum volume food source station. Most minimum volume food source stations did not detect termite activity until after day 50.

Areawide Termite IPM in New Orleans

"The Formosan subterranean termite, *Coptotermes formosanus*, was first discovered in New Orleans in 1966 and has caused serious losses in the New Orleans area for 30 years," said Dennis Ring (Louisiana State Univ, 404 Life Sci Bldg, Baton Rouge, LA 70803; dring@agctr.lsu.edu). It is a devastating pest in several parishes with estimates of losses reaching $300 million in the New Orleans area and $500 million in Louisiana. Losses include the collapse and demolition of structures and defaults on loans. The termite will eat the center of creosote treated wood and attack live trees.

A pilot areawide IPM program began in New Orleans in 1996 with "all properties in a contiguous 15 block area in the French Quarter" and was expanded in 2002, 2003 and again in June 2006 to include more surrounding neighborhoods. "Glue boards were used to estimate alate (winged) numbers and in-ground monitors for foraging activity," said Ring. Alates were sampled once a week in April and 2-3 times weekly during the flight season (May-July 15) in 1998 through



Formosan soldier, *Coptotermes formosanus*

2006. Since 1999, bait stations have been monitored monthly to determine termite foraging activity. The areawide approach resulted in "an overall 50% reduction in termite numbers and activity," though areas of "high termite activity remain inside the test area."

"Inspections of properties using infrared and acoustic detection technologies and visual inspections of courtyards and trees are being conducted to detect and treat termites," said Ring. The number of alates decreased in most of the areas in 2006 following Hurricane Katrina. The decrease in alate numbers in 2006 could possibly be due to the severe drought experienced in the area. Another possible reason might be the decreased Formosan subterranean termite population along the levee area of the French Quarter.

Act of Congress

The New Orleans areawide IPM program got underway via a directive from the U.S. Congress in 1998, said Frank Guillot (USDA-ARS, 1100 Robert E. Lee Blvd, New Orleans, LA 70124; fguillot@srrc.ars.usda.gov). The IPM strategy was decreasing the insect population size by taking out termite colonies with baits. Termite levels stabilized in the French Quarter, with no changes from 1998 to 2006, and a 95% decrease in activity on levees.

The original 15 areawide IPM blocks in the French Quarter and the 15 block expansion both had significant decreases in alate termites, with a plateau in 2000 and a decrease between 2005 and 2006. In 2006, 6% of Area One structures were infested; that represented a significant 22% decrease since 2003. However, there are still isolated areas with high levels of alate Formosan subterranean termites captured in traps, particularly along the Mississippi River. Many areas have escaped treatment; and there are still infestations from railroad crossties, levees and other sources.

Formosan subterranean termite, *Coptotermes formosanus*, colonies showed periods of expansion and contraction over time in Louis Armstrong Park in New Orleans, said Sang He Lee (Univ of Florida, 3205 College Ave, Davie, FL 33317; sunchaos@ufl.edu). For example, winter territory size shrank compared to summer territory size. However, the trend, which is being modeled, was for colony size to grow over time, reaching a stable state at about 20 years.

Termidor® and Temperature

"Soil termiticides have traditionally been the primary control option for termites," said Neil Spomer (Univ of Nebraska, 202 Plant Industry Bldg, Lincoln, NE 68583; nspomer@-unlserve.unl.edu). Newer formulations of termiticides have non-repellent active ingredients such as fipronil. Termites forage in treated zones, and the toxicant is transfered from one termite to another by grooming and contact (horizontal transfer). According to Spomer, "the rate and amount of horizontal transfer is dependent on the chemistry of the termiticide, activity of the termite, speed of kill, and soil/ termiticide interaction. Temperature fluctuations can significantly impact some of these factors."

Fipronil (C14 radioisotope) uptake by eastern subterranean termite, *Reticulitermes flavipes*, increases with soil temperature. The uptake was highest at 22-32°C (72-90°F), moderate at 17°C (63°F) and lowest at 12°C (54°F). As soil temperatures decrease in the fall, so does

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the rate of short-term acquisition of fipronil from soil and subsequent horizontal transfer to nestmates. When soil temperatures reach 17-19°C (63-66°F) termite activity slows, resulting in reduced uptake and transfer of termiticides.

Fipronil is commonly formulated as Termidor® and applied as a liquid barrier. Fipronil is slow-acting, and its effectiveness depends upon horizontal transfer of residues from treated termites to untreated nestmates in the same social group, said Jody Green (Purdue Univ, 915 W State St, West Lafayette, IN 47907; jaleong@purdue.edu).

Reticulitermes flavipes poisoned with topically-applied fipronil in laboratory assays shake, tightly curl their legs and exhibit uncoordinated movement. The 24 hour LD50 is 2.5 nanograms per termite, with death within 16 hours. However, a high number of termites need to be treated; at a 1:3 ratio of donor to recipient termites, mortality is 25%.

U.S. Forest Service (2006) studies show fipronil can provide 100% control of eastern subterranean termite for over 11 years, said Xing Ping Hu (Auburn Univ, 363 Funchess Hall, Auburn, AL 36849; huxingp@auburn.edu). There is no sign of repellency, as termites pick up treated soil particles and continue tunneling. However, 7 days after treatment few termite workers are traveling the tunnels; 45 days later there are no live termites. Successful destruction of a colony of 8,000 termites includes disruption of reproduction, as there are no eggs or larvae produced. Future studies will examine distance effects such as control of satellite colonies, and the influence of other food sites.

Orange Oil and Termites

Orange oil extract, a 92% d-limonene citrus by-product formulated into numerous cleaning and household products, is also well known as an insecticide. Orange oil extract (XT2000 Inc, 6328 Riverdale St, suite A, San Diego, CA 92120) "was tested by Dr. Scheffrahn against drywood termites and found to be very effective and is registered for use in California," said Ashok Raina (USDA-ARS, 1100 Robert E. Lee Blvd, New Orleans, LA 70124; araina@srrc.ars.usda.gov).

Five sets of orange oil extract experiments were conducted using Formosan subterranean termites, *Coptotermes formosanus*, collected from tree colonies. In one experiment, 50 worker and 5 soldier Formosan subterranean termites were placed in plastic containers with a choice between filter paper treated with orange oil extract (2.5 or 5.0 ppm) or acetone (control). The termites were checked daily for 5 days and the filter paper was weighed to measure termite consumption.

At 5 ppm, orange oil extract provided 96% termite mortality in 5 days, and filter paper consumption was almost negligible. At 2.5 ppm, orange oil extract provided 49% mortality, which was significantly better than the 6% mortality for the acetone control. "Even the termites that had not died had barely consumed any filter paper," said Raina.

In another experiment monitored with a video probe, a plywood and pine wall was constructed and placed in moist sand inside a glass cylinder with 5,000 Formosan termite workers and 500 soldiers. The treated filter paper had 10 ppm (v/v) of orange oil extract. "After 3 days, there was only 15.4% mortality, and in fact the surviving termites had started tunneling through the wood," said Raina. Most likely the moist wood absorbed the orange oil extract and kept it from having the desired termiticidal effect. Orange oil extract would likely work better injected into holes drilled into voids in dry walls (not moist wood).

In 3-day Formosan termite tunneling tests, plastic cups with moist sand (treated with 0%, 0.2% or 0.4% orange oil extract) were connected by glass tubes with sand inside. In the untreated controls, worker termites crossed half the length of the glass tube in 4 hours and tunneled all the way to the other side within 24 hours. No termites tunneled across the tubes in orange oil extract treatments: "After tunneling about 3 cm (1.2 inches), the termites died in a bunch together," said Raina.

However, persistence is a factor when treating sand to prevent termite tunneling. When sand was treated with 5.0 ppm orange oil extract as a barrier against termite tunneling and sampled weekly for eight weeks, GC-MS revealed no detectable amounts of d-limonene left in the sand after three weeks.

"We don't need actually direct contact with orange oil to kill the termites, as the vapor is fairly toxic and it also prevents the termites from feeding," said Raina. "The orange oil treated sand prevented termites from tunneling through it, but the effect did not persist for more than three weeks."

Borate-Treated Lumber

On-going replicated field trials for 8 years in Hawaii and 10 years in Japan show that borates and pressure treatment can provide longterm preventive protection of wood and lumber products from Formosan, *Coptotermes formosanus*, and Japanese subterranean termites, *Reticulitermes speratus*, said J. Kenneth Grace (Univ of Hawaii - Manoa, 3050 Maile Way, Gilmore Hall 310, Honolulu, HI 96822; kennethg@hawaii.edu). To further Hawaiian exports of treated lumber to Japan, the field tests used products such as the 4x4 meter (13x13 ft) timber and hinoki (sill plates) found in Japanese homes.

Treated woods included hemlock, white fir, Douglas fir and plywood. Disodium octaborate tetrahydrate (Tim-Bor®) was used at 2% boric acid equivalents (BAE). Didecyl dimethyl ammonium chloride (DDAC) was used as an anti-mold and anti-sap stain treatment. Chromated copper arsenate (CCA) was tested at the start of the experiments, but is no longer in use.

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Ammoniacal copper zinc arsenate (ACZA) was tested on Douglas fir.

In aboveground tests on infested sites in Japan, lumber was placed atop hollow concrete or tile blocks leading Formosan subterranean termites upwards. After one year, many termites were active in the untreated control. But borate treated wood was repellent for 2-3 years. In Kagoshima in southern Japan at a site with both *C. formosanus* and *R. speratus*, untreated hinoki had surface feeding after 8 years exposure. Surprisingly, hemlock and fir was attacked much less in Hawaii than in Japan.

Using the American Wood Preservers' Association scale of 0 to 10, treated timber in Japan had a very good 9 rating after 10 years. Treated hinoki did not do as well. In Hawaii, termite activity was 300% higher than in Japan. Borates (2% BAE) and ACZA both performed well, and in spring 2006 were approved as standard methods.

Termite-Resistant Particleboard

Eastern red cedar, *Juniperus virginiana*, a native North American juniper with male and female trees, is often treated like a weed to be removed for pastures, though its fleshy seeds feed birds and extracts contain essential oils like cedrene, thujopsene, cedrol and widdrol. Termite research showing that eastern subterranean termite, *Reticulitermes flavipes*, avoids eastern red cedar in favor of other woods, such as pine, led to the idea of turning this unwanted plant into a value-added product, namely termite-resistant wood panels, said Brad Kard (Oklahoma State Univ, 127 Noble Res Center, Stillwater, OK 74078; kard@okstate.edu).

Applying temperature and pressure to eastern red cedar chips (including needles) turns these "waste products" into particleboard products, including triple layer panels with termite resistance. Triple and single layer panel boards and *Juniperus virginiana* chips (with and without foliage) were tested against *R. flavipes*. Foliage played no role in termite resistance; since it is more costly to delimb and remove foliage, the whole tree can be chipped for particleboard manufacture.

Interestingly, the raw tree materials are more resistant than the manufactured panels; termites fed on the light-colored raw wood chips and left the darker material behind. In no-choice feeding tests, triple layer eastern red cedar particleboard panels showed the most termite resistance, and were more effective than standard products with urea or formaldehyde protectants.

Termite Fungal Ecology

"The good the bad the ugly: Fungal associates of Formosan subterranean termites" was the title of a talk by Poornima Jayasimha (Louisiana State Univ, 404 Life Sci Bldg, Baton Rouge, LA 70803; pjayas1@lsu.edu). Fungi can attack termites or compete with them for cellulose resources. They make wood more attractive to termites by destroying toxic chemicals that would otherwise inhibit termite reproduction and survival. Fungi breaks down the wood fiber structure, making it easier for termites to remove wood fibers. Fungi can also supply termites with vitamins and essential nutrients. Termites can be expected to have a mutualistic relationship and spread or transport spores of fungi that make termite life better.

Jayasimha established wood chip cultures of the brown rot fungus, *Gloeophyllum trabeum*, which benefits subterranean termite species by increasing wood nutrition. Besides being more nutritious, decayed wood infested with *G. trabeum* contains the chemical (Z,Z,E)-3,6,8-docecatrien-1-ol, a trail pheromone of Formosan subterranean termites, *Coptotermes formosanus*, that makes the wood more attractive.

Termite dispersal of *G. trabeum*, an indicator of termite-fungus mutualism, was measured in a 20-day experiment using six-chambered containers with or without termites. Wood chips infested with *G. trabeum* were placed in the first chamber and uninfested chips in the sixth.

Surprisingly, Formosan subterranean termites did not carry the fungus or transfer it to unifested wood. Hence, there is no mutualism between the termites and brown rot fungus. Though the lack of mutualism was "very surprising, it makes sense because these two organisms are competing for the same resource, cellulose," said Jayasimha.

Termites did carry green spores that were deadly to *G. trabeum*. The green-spore fungi, which included *Trichoderma harzianum, T. virens, T. ghanaense, T. asperellum* and *Aspergillus flavus,* were isolated from termite guts and external surfaces. *A. flavus*, which is associated with "weak and declining" termite colonies, was found in all three laboratory termite colonies, but in only one of three Formosan subterranean termite colonies freshly collected in the field from New Orleans.

In laboratory cultures *Aspergillus flavus* and *Trichoderma harzianum* completely killed *G. trabeum*. *T. asperellum* and *T. ghanaense* significantly reduced *G. trabeum* growth compared to the control. *T. harzianum* did not affect Formosan termite survival. *A. flavus* at 10(5) and 10(6) spores per ml (but not at 10(4) spores/ml) reduced Formosan subterranean termite survival.

"There was mutualism between Formosan subterranean termites and *Trichoderma harzianum,*" concluded Jayasimha. "*Aspergillus flavus* was pathogenic to Formosan termites, but it also kills the brown rot fungus, *G. trabeum*. So it has potential to be biocontrol agent for both of them."

Interestingly, *T. harzianum* is nontoxic to many insects, including honey bees, which have been used to disperse *T. harzianum* as a biological control agent for flower-infecting plant pathogens on crops.

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Microbial Termite Control

Biological control organisms are another weapon in the IPM arsenal, and microbes living in association with termites in the soil can be selected for success in the same way as slow-acting, non-repellent chemicals. Indeed, termite IPM programs can use chemicals and microbes in partnership, said Maureen Wright (USDA-ARS, 1100 Robert E. Lee Blvd, New Orleans, LA 70124; mswright@srrc.ars.usda.gov). For example, destructins, which are cyclic peptides produced by the insect pathogen *Metarhizium anisopliae*, can help break down insect immune systems leading to increased infections and death.

Termite nest temperature and humidity are important variables for the survival of insect pathogens; human pathogens do not survive under the environmental conditions in termite nests. Termite adaptive behaviors, such as grooming, avoidance of infected nestmates and walling off of infected nest areas, limit the spread of pathogens. Repellency and inadequate sporulation in *in vivo* termite ecosystems also limits pathogen effectiveness. Microbes are more effective against termites in laboratory tests where there is no competition, than in the field. Getting the same good laboratory results against termites in the field remains a major challenge for microbial termite control.

Successful biological termite control requires slow-acting pathogens, so that termites can contact the pathogen and survive long enough to spread it in the nest via social behaviors such as grooming, said Wright. *Metarhizium anisopliae*, which lives in soil with termites, has been found in small populations of swarming termites caught for lab use. Rapid molecular isolation techniques can identify particular strains.

Serratia marcescens has a red-pigment version infecting insects such as *Reticulitermes* termites, as well as non-pigmented versions infecting humans. It is possible to get insect-to-insect transfer of *Serratia* in termite nests. When eicosanoids (oxygenated metabolites of C20 fatty acids) that protect insects from bacterial infection are disrupted by drugs, Formosan subterranean termite infections are increased.

Paecilomyces fumosoroseus, a fungal pathogen used in IPM programs against whiteflies, can be used against subterranean termites. Indeed, there is a patent for delivering *Paecilomyces fumosoroseus* with foam into tree voids to kill termites. The fungi *Beauveria bassiana* and *Metarhizium anisopliae*, as well as entomopathogenic nematodes, show laboratory potential against termites; but much more work is needed, as epizootics do not develop in the field.

Wright collected samples of infected Formosan subterranean termites, and in isolating all the fungi from alates and dead insects recovered a new strain of *Metarhizium anisopliae*, C4B, from dead alates. When reintroduced to termite populations, *M. anisopliae* strain C4B had 50% pathogenicity, indicating it was passed from termite to termite. By day 14 termite mortality was 100%. Strain C4B was equal to *M. anisopliae* strain ESC1 (Bio-Blast) on day 1 and produced better results by day 2, even when diluted with silica. The dose needed to kill termite workers is higher than for alates. Wright foresees the development of novel delivery formulations such as foams and gel agents for *M. anisopliae* C4B, and says that microbes, enzymes and even termite cuticular extracts might be combined in Formosan subterranean termite IPM programs.

Metarhizium for Tick & Mite Biocontrol

Anuja Bharadwaj (Connecticut Agric Exper Stn, 123 Huntington St, Box 1106, New Haven, CT 06504; Anuja.Bharadwaj@po.state.ct.us) talked about fungi for tick control. Entomopathogenic fungi such as *Metarhizium anisopliae* and *Beauveria bassiana* are potential biocontrols of the blacklegged tick, *Ixodes scapularis*, which "transmits the agents of Lyme disease, babesiosis and human granulocytic anaplasmosis." *M. anisopliae* survives and persists in soil, and that could be an important factor in its use as a biopesticide against ticks.

According to Bharadwaj, *M. anisopliae* is pathogenic to both nymphal and adult *I. scapularis* and percent mortality of an emulsifiable concentrate formulation increased with rate of application and time of exposure. "Commercial use of *M. anisopliae* for tick control will be influenced by formulated product costs, feasibility/ease in application, reasonable mortality with minimum time exposure, survival of spores in field, and the optimum rate, time and frequency of application."

The fungus may also control honey bee pests. According to Lambert Kanga (Florida A&M Univ, 406 Perry-Paige Bldg, Tallahassee, FL 32307; lambert.kanga@famu.edu), dust or strip applications of *M. anisopliae* to honey bee, *Apis mellifera*, hives provided satisfactory control (>90%) of Varroa mite, *Varroa destructor*, under field conditions. Since strip applications require more labor, "a user-friendly, cost effective, environmentally sound" method of *M. anisopliae* application was developed using "a mixture of fungal spores, vegetable oil and granular sugar formulated into a patty" with a 15 day shelf life (95% spore germination) at 33ºC (91ºF).

Plant Virus and Ants

"Plants have evolved the ability to respond to herbivory with the production and emission of volatile compounds that attract predators and parasitoids," said Svjetlana Vojvodic (Auburn Univ, 301 Funchess Hall, Auburn, AL 36849;

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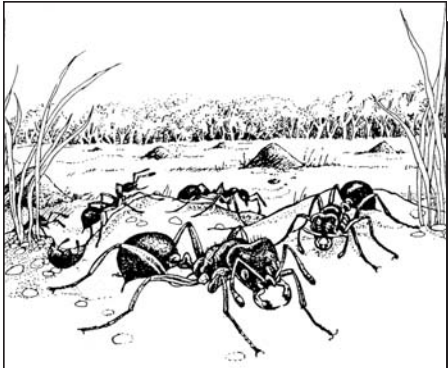

Red imported fire ant, *Solenopsis invicta*

vojvosv@auburn.edu). "Other insects, however, may use herbivore-induced volatiles in ways that do not benefit the plant. For example, some insects use induced volatiles to find herbivore-damaged plants or potential mates." Vojvodic studied the possibility that red imported fire ants, *Solenopsis invicta*, are attracted to virus-induced plant volatiles.

Previous observations of fire ants foraging on tomato plants suggested that fire ants may be more likely to forage on virus-infected plants than uninfected plants. According to Vojvodic, "fire ant workers may be using virus-induced plant volatiles to find plants that are more likely to host honeydew-producing aphids." If this occurs, then attraction of ants may indirectly benefit the virus because "ants protect aphids from natural enemies resulting in larger aphid populations, increased alate production, and potentially higher virus dispersal."

In 2005, plants in nine Alabama tomato fields in a region with a cucumber mosaic virus (CMV) epidemic were randomly searched for fire ants. At the end of the season, tomato leaf CMV levels were estimated using the ELISA test. "We found a strong, positive relationship between virus accumulation and the number of fire ant workers foraging on tomato plants," said Vojvodic. Laboratory studies supported this result, as fire ants chose tomato leaves infected with CMV significantly more than leaves from sham-inoculated plants. Ants must use plant volatiles not only to detect aphids, but also to find plants that are infected with aphid transmitted virus, increasing their chance of finding aphids. So, "fire ants have evolved more than one way of detecting the presence of aphids on the plants."

This work is consistent with recent studies showing ants use plant volatiles as foraging cues. For example, Cordova-Yamauchi et al. (1998) found that Argentine ants searching for honeydew-producing aphids responded positively to volatiles produced by aphid-infected plants. *Azteca* and *Allomerus* ants "use plant volatiles to find mutualistic 'ant plant' partners while dispersing from natal plants" (Edwards et al. 2006).

Areawide Fire Ant IPM

"The Areawide Suppression of Fire Ants program was initiated in 2001. Participants include USDA-ARS, USDA-APHIS, as well as landgrant universities within Florida, Mississippi, South Carolina, Oklahoma and Texas," said Matthew Aubuchon (USDA-ARS, 1600 SW 23rd Drive, Gainesville, FL 32608; aubuchon@gainesville.usda.ufl.edu). Program objectives include reducing red imported fire ant populations by integrating baits and biological controls.

IPM has reduced fire ant populations at least 80%. In each state in the areawide program, 300-acre (121 ha) grazed pasture sites are set aside for aerial bait broadcasting and release of natural enemies, including 3 phorid fly, *Pseudacteon*, species and the pathogen *Thelohania solenopsae*. Two phorid fly species are established and spreading in the IPM program states. *Thelohania solenopsae* is established in Texas, Oklahoma, South Carolina and Florida.

Each state also has three IPM demonstration sites, including golf courses, quail ranches, county and state parks, public schools, and cemeteries. "The USDA is working

Calendar

March 4-6, 2007. 20th Annual CA Farm Conference. Monterey, CA. Contact: www.californiafarmconference.com

March 14, 2007. Invasive Species Conference. Shippenburg Unversity, Carlisle, PA. Contact: C. Smith, Kings Gap Environmental, 500 Kings Gap Rd., Carlisle, PA 17015.

March 21-25, 2007. San Francisco Flower and Garden Show. Contact: www.gardenshow.com

March 29, 2007. UC Riverside 16th Annual Urban Pest Management Conference. Contact: Dept. Entomol., UC Riverside, 3401 Watkins Drive, Riverside, CA 92521.

April 1-5, 2007. 73rd Annual Meeting American Mosquito Control Association, Orlando, FL. Contact: J. Conlon, AMCA, 15000 Commerce Parkway, Suite C., Mt. Laurel, NJ 08054; 856/439-9222; Fax 856/439-0525; email amca@mosquito.org; www.mosquito.org

May 7-9, 2007. Invasive Arthropod Conference. Clemson, SC. Contact: Amanda Hodges, achodges@ufl.edu, 352/392-1901, Extn. 199; http://conference.ifas.ufl.edu/arthropod/

May 23, 2007. EcoWise IPM Training Session. Alameda County, Hayward, CA. Contact: L. Speare 510/622-2452 or lspeare@waterboards.ca.gov

June 1-3, 2007. 25th Annual Meeting National Pesticide Forum, Loyola University, Chicago, IL. www.beyondpesticides.org

June 11-July 16, 2007. Integrated Pest Management for Museums, Libraries and Archives. Northern States Conservation Center. Online Course. Contact: Gretchen Anderson, www.museumclasses.org. BIRC members get 10% discount.

July 18-19, 2007. IPM Water Quality Summit. Penn State Conference Center. Contact: Northeastern IPM Center, M.K. Malinoski, mkmal@umd.edu or L. Braband, lab45@cornell.edu

July 21-25, 2007. Ann. Conf. Soil Water Cons. Soc. Tampa, FL. Contact: www.swcs.org

July 28-August 1, 2007. Annual Meeting American Phytopathological Society. San Diego, CA. Contact: APS, 3340 Pilot Knob Rd., St. Paul, MN 55121; www.apsnet.org

September 17-21, 2007. 9th International Conference on Ecology and Management of Alien Plant Invasions. Perth, WA, Australia. Contact: M. Sheehan, 12 Thelma St., Suite 3, West Perth, WA 6005, Australia. www.congresswest.com.au/emapi9/

October 15-18, 2007. 16th International Plant Protection Congress, Glasgow, UK. Contact: C. Todd, BCPC, 7 Omni Biz. str., Omega Park, Alton Hampshire GlU34 2QD, UK. www.bcpc.org

December 9-13, 2007. Annual Meeting Entomological Society of America. San Diego, CA. Contact: ESA, 9301 Annapolis Rd., Lanham, MD 20706; Fax 301/731-4538; www.entsoc.org

December 7-11, 2008. Annual Meeting Entomological Society of America. Charlotte, NC. Contact: ESA, 9301 Annapolis Rd., Lanham, MD 20706; Fax 301/731-4538; www.entsoc.org

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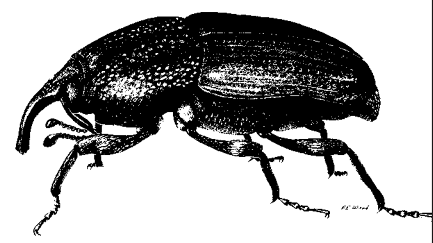

Hunting billbug, *Sphenophorus sp.*

with the Alachua County Public Works Dept to develop a cohesive fire-ant management plan for Kanapaha park, which is one of the most popular parks in Gainesville," said Aubuchon. The IPM plan, which includes broadcasting bait on soccer fields, "may be adapted and applied to 26 other parks that Alachua County manages." Similarly, an IPM program broadcasting bait in picnic areas at Itchetucknee Springs State Park could be adapted for 67 other Florida state parks.

Golf Course IPM in Florida

Ta-i Huang (Univ of Florida, 970 Natural Area Drive, Gainesville, FL 32611; dai7030@ufl.edu).talked about billbugs, *Sphenophorus* spp. Florida has 25 billbug species feeding on the stems and roots of turfgrass, particularly zoysiagrass, *Zoysia japonica*, and bermudagrass, *Cynodon dactylon*. Damage is difficult to diagnose because it resembles drought stress or dollarspot disease.

"Florida turfgrass managers experiencing billbug outbreaks have been struggling to obtain satisfactory control using conventional insecticide applications," said Huang. "Thus, we have sought to identify the billbug species complex, describe the adult and larval activity periods, and develop an IPM program for Florida golf courses."

Every week four large linear pitfall traps were monitored in roughs and monthly soil core samples were collected at bermudagrass golf courses in Gainesville, Miami Beach, and Key Largo, Florida. The large linear pitfall traps consisted of a 19 liter (5 gal) bucket placed in a hole, "and one end of four 3-meter (9.8 ft) long PVC pipes (7.6 cm (3.0 in) in diameter, with a 2.5 cm (1.0 in) slit cut lengthwise) was inserted into the bucket," said Huang. "The other pipe end was capped. A 4 liter (1 gal) bucket was placed inside the 19 liter (5 gal) bucket to collect insects within 24 hour sampling periods, once a week."

Of the 6 *Sphenophorus* species collected, 95% were hunting billbugs, *S. venatus vestitus*, and uneven billbugs, *S. inaequalis*. "The hunting billbug is considered the most damaging billbug in the southern U.S., especially on sites containing bermudagrass and zoysiagrass," said Huang. Typically, fewer than 150 adult billbugs were collected during 24-hour peak periods in April, though one golf course had almost 700 billbugs during a peak 24-hour period.

"The effect of two rates of two commercial varieties of overseeded endophyte-enhanced perennial ryegrass on billbug survival, the susceptibility of various zoysiagrass cultivars to billbug damage, as well as control using entomopathogenic nematodes and various insecticides, will be examined" as the research continues, said Huang.

BT Synergizes *Beauveria*

According to Stephen Wraight (USDA-ARS, Tower Rd, Ithaca, NY 14853; spw4@cornell.edu), there are "low levels of synergism between *Beauveria bassiana* (Botanigard®) and *Bacillus thuringiensis* serovar *tenebrionis* (Novodor®)" when these biopesticides are applied together in potato fields against larval populations of Colorado potato beetle (CPB), *Leptinotarsa decemlineata*. "It indicates an exceptionally high level of compatibility and underscores the potential for integrated use of these microbial biocontrol agents for potato beetle management." The combination of Botanigard and Novodor provided 80% Colorado potato beetle control, versus 43.7% for Novodor alone and 26.6% for Botanigard alone.