The IPM Practitioner
Monitoring the Field of Pest Management
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Baits or Barriers? Field Efficacy of Subterranean Termite Treatments

By William Quarles

Termites cause at least $2 billion dollars of damage each year in the U.S. (Su 2003ab; Su 2002). Most of this damage is due to subterranean termites, and discovery of a structural infestation usually leads to some kind of treatment. None of the available treatments are perfect, and efficacy can vary with field conditions (Peterson et al. 2006).

If your home is infested with subterranean termites, commercially available treatments include termite barriers, termite baits, and treatment of the wood. Liquid termiticides are often added to the soil to establish a barrier between foraging termites and your home. Chemical barriers comprise about 70% of the subterranean termite treatment market (Kard 2003; Curl 2004; Saran and Rust 2007).

Termite baits have been commercially available since 1994, and now account for about 30% of the market. Baits have the advantage of low environmental impact and the possibility of longterm protection if a bait maintenance contract is purchased. Baits have the disadvantage that they work slowly and are not 100% reliable. Part of this article is to try to establish what kind of efficacy to expect, both with baits and barriers (Quarles 2003ab).

Another option is treated wood. Treated wood may be combined with either chemical barriers or termite baits. If you have crawlspace construction, the wood can be treated with borates. Termites do not like to eat or tunnel over the treated wood. Treatment protects against termites, woodboring beetles, and some wood damaging fungi. Complete protection is not possible in a remedial application because there are inaccessible areas. Borate treatments and borate treated wood are now available in new construction (Quarles 1998; Kard 2003).


Photo courtesy of Dow Agro

Treatments include baits or barriers. Baits such as Sentricon®, shown here, have a low impact on the environment, eliminate termite colonies, and have efficacy comparable to termiticide barriers.

Prevention and Early Treatments

Early approaches to termite management emphasized prevention. According to Synder (1948), “It is much cheaper to keep termites out of a building than to get rid of them and repair the damage once they are inside.” Building construction techniques included designs to prevent termites, such as no soil-wood contact, proper drainage, and construction standards for foundations. Before 1940, there were few effective treatments once subterranean termites were established (Synder 1956).

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Monitoring the Field of Pest Management

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Update

Efficacy testing of termite treatments started in 1911 at the Forest Products Laboratory and the Federal Bureau of Entomology and Plant Quarantine. Initially, only resistant wood or treated wood was tested. Wood blocks were simply placed on the soil in areas where termites were foraging. Wood was periodically inspected for damage.

After treated wood, there were experiments with soil termiticides, which were originally called soil poisons. One of the earliest was sodium arsenite, an extremely toxic material. During World War II, DDT was dissolved in diesel oil and used as a soil treatment for termites (Synder 1948; 1956). This approach evolved into the chemical barrier concept that has dominated the industry for more than 50 years (Peterson et al. 2006).

Barrier Technology

Chemical barriers are prepared by digging trenches around structural perimeters and adding many gallons of liquid termiticides. Chemicals may also pumped into the soil underneath concrete slabs (Peterson et al. 2006).

Organochlorines such as DDT, chlordane and other such persistent chemicals were used at first. But their toxicity, and environmental problems such as bioaccumulation caused them all to be banned by 1987 (French 1994; Thoms et al. 2009).

Photo courtesy USDA

Chemicals are added to a trench to form a barrier against termites.

Although the chemicals have changed, the techniques have not. Organochlorines were replaced in the 1990s by pyrethroids and organophosphates. Organophosphates have since been banned from structural pest control. Pyrethroids are applied to form a repellent barrier. Unless the active ingredient is applied uniformly, termites find untreated areas and attack the structure (Potter 1994; Kuriachan and Gold 1998).

Repellent barriers of pyrethroids have now been mostly replaced by treatments with non-repellent termiticides. Non-repellent formulations containing imidacloprid (Premise®) or fipronil (Termidor®) have been the industry standard for several years. They have been recently challenged by newly registered materials such as chlorfenapyr (Phantom®), and chlorantraniliprole (Altriset®). Indoxacarb (Arilon®) and thiomethoxam (Optigard®) are under development.

Chemical soil treatments are often applied in new construction. In these cases, it is also possible to install physical barriers of sand or stainless steel mesh as an alternative. These approaches can be effective in new construction, but it is difficult to provide remedial protection with a sand barrier or stainless steel (French 1994; Kard 2003; Ebeling and Pence 1957).

Efficacy of Chemical Barriers

The USDA conducts efficacy tests of termiticide barriers at locations in Arizona, Florida, Mississippi and South Carolina. Tests are of two kinds, wood block and concrete slab. In the wood block test, the soil is treated and a block of wood is dropped onto the surface. In the concrete block test, the soil is treated, then a concrete slab is poured. A hole in the middle of the slab is left to add a test block. Failure of the termiticide occurs when termites penetrate the chemical barrier and feed on the wood. Efficacy tests consist of yearly inspections for barrier failures (Wagner et al. 2011).

Each termiticide has an EPA registered label that specifies application rates. The minimum number of years of protection after application of registered rates is listed in Table 1. As we see in the Table, the best of the barriers tested is Termidor®. It protects a minimum of 8 years in the slab test and 5 years in the wood block test. The worst in the slab test is Phantom® (1 yr), and the worst in the wood block test is Altriset®(<1yr).

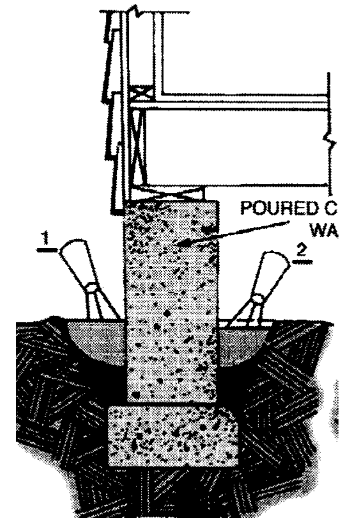
The Table represents the worst case performance, and that was found usually in Mississippi, which has abundant annual rains. All termiticides performed much better in Arizona, where rainfall is limited. This fact is illustrated well with Premise®, which gave a minimum protection of 15 years in Arizona, versus two years in Mississippi. The active ingredient of Premise, imidacloprid, is water soluble, and that may have contributed to the results.

Except for Termidor, repellent barriers (1.5 to 4 yrs; concrete slab) gave about the same worst case protection as non-repellent barriers (1 to 3 yrs; concrete slab) (Wagner et al. 2011).

Worst case results are reported here because remedial treatments of real structures with a variety of construction styles, soil conditions and complicating circumstances may be more challenging than these USDA tests. These small test plots (less than 2ft by 2ft; 0.6m by 0.6m) also may make it easier to apply a repellent barrier uniformly.

How long a chemical provides protection in real situations can vary. In areas with high termite pressure and lots of rainfall, worst case efficacy will probably prevail. In dry areas with low termite pressure, barriers could last for 10 years or more. In most cases, barriers should protect for at least five years (Hu et al 2001).

A barrier treatment may not always be successful in removing termites from a structure (Ripa et al. 2007). An informal measure of efficacy is the callback rate. Callbacks occur when the customer calls the company back because treatment was not 100% effective. A *Pest Management Professional* survey in 2005 found callback rates of about 10%, but in recent years the percentage may have dropped (Whitford 2011).



Courtesy USDA

Soil adjacent to crawlspace foundations is treated with chemicals.

New Materials

The active ingredients of most liquid termiticides, including non-repellent ones, are neurotoxins. Thus, fipronil (Termidor) interacts with GABA receptors and has effects on chloride ion channels in neurons. It is more toxic to insects than mammals and has profound effects on ants and termites (Mao et al. 2011).

Though the name is suggestive, indoxacarb (Arilon) is not a carbamate. It is an oxadiazine, and like pyrethroids and DDT, it acts on neuronal sodium ion channels. But its effects are complicated, and it is not cross resistant. Imidacloprid (Premise) attacks nicotinic receptors. Since there are more of those in insects than mammals, imidacloprid is more toxic to insects than mammals. Thiomethoxam (Optigard) is a neurotoxin with similar actions to imidacloprid. Effects of imidacloprid, thiomethoxam, fipronil or indoxacarb on termites are similar. Termites first become intoxicated, and disoriented. They may initially become more active, but then they slow down and die (Quarcoo et al. 2010).

Chlorfenapyr (Phantom) is not a neurotoxin, but interferes with oxidative metabolism. Poisoned termites cannot generate energy, slow down, and die. Chlorfenapyr has a number of environmental problems, such as persistence, and extreme acute and chronic toxicity to birds. Registration as a termiticide was probably allowed because bird exposure is unlikely (EPA 2001).

The newest termiticide is chlorantraniliprole (Altriset), which has unique activity. It binds to ryanodine receptors leading to calcium ion depletion and muscular paralysis. It is thus a muscle toxicant, not a neurotoxin. It is practically nontoxic to mammals (LD50>5,000 mg/kg). Low toxicity is partly due to low absorption. Only 14% of a large

Table 1. Minimum Number of Years 100% Protection at Label Rates*

Active Ingredient	Formulation	EPA Slab Test	EPA Wood Block Test
Non-Repellent Barriers			
Chlorfenapyr	Phantom®	1	2
Imidacloprid	Premise®	2	1
Chloranthraniliprole	Altriset®	3	0
Fipronil	Termidor®	8	5
Repellent Barriers			
Permethrin	Torpedo®	1.5	1
Bifenthrin	Biflex®	2	--
Cypermethrin	Cypermethrin	3	--
Permethrin	Dragnet®	4	0.5

*Data from Wagner et al. (2011)

oral dose is absorbed by rats. It is not carcinogenic, and has no effects on rat reproduction in laboratory tests. The chronic No Observed Adverse Effect Level (NOAEL) in mammals is an amazing 1000 mg/kg/day. It has a generally benign environmental profile, but negative aspects include persistence, and a moderate tendency to move in soil. When exposed, termites stop eating, slow down, then die of muscular paralysis (Cordova et al. 2006).

Favor With Environmentalists

Due to its low toxicity, and generally benign environmental profile, Altriset may find favor with environmentalists. It also may give longer lasting protection than indoxacarb (Spomer and Kamble 2011). However, the protection of Termidor is well established, and any environmental problems are minimized by low application rates of the active ingredient (0.06% and 0.125%).

Termite baits are also considered to have a low impact on the environment. Active ingredients are targeted to termites, contained within a bait station, and are nearly insoluble in water. Small amounts of active ingredients are deployed, and the likelihood of exposure to mammals is low (Quarles 2003b; MSDS 2009).

Termite baits commercially available contain either chitin synthesis inhibitors (CSIs), or toxicants such as sulfluramid (Terminate®, First Line®) and hydramethylnon (Subterfuge®). The first termite bait registered was the Sentricon System with Recruit bait containing the CSI hexaflumuron. Hexaflumuron has since been replaced by the CSI noviflumuron. Other CSI baits include lufenuron and diflubenzuron (Advance®, Exterra®). These baits and the baiting process are described in detail elsewhere (Quarles 2003ab). Research is being conducted on new active ingredients such as the CSIs bistrifluron and chlorfluazuron (Neoh et al. 2011; Osbrink et al. 2011).

Horizontal Transfer

When non-repellent barriers were first introduced, increased protection was expected due to horizontal transfer. Horizontal transfer occurs when one termite picks up the termiticide and passes it on to others that have not contacted the chemical. The active ingredient is ingested and transferred by trophallaxis (see *IPMP* Jan/Feb 2003) or is adsorbed to the outer cuticle of termites tunneling through treated soil and transferred through grooming and contact. Potentially, non-repellent barriers could have areawide effects on termite populations, killing termites at a distance from the treated zone (Potter and Hillery 2002; Saran and Rust 2007).

Ibrahim et al. (2003), Bagneres et al. (2009) and others were able to show that horizontal transmission does occur. The problem is that it is extremely concentration dependent. Termites must pick up and transfer enough active ingredient to kill another termite. This amount tends to be so toxic that the donor termite is unable to travel very far (Su 2005).

So, horizontal transfer can only occur in areas close to the treated zone. Saran and Rust (2007) found the maximum distance of termite movement away from a fipronil treated area was about 2 m (6.6 ft). In an extended foraging arena, Su (2005) found that dead termites were always found within 5 m (16.4 ft) or less of fipronil treated sand.

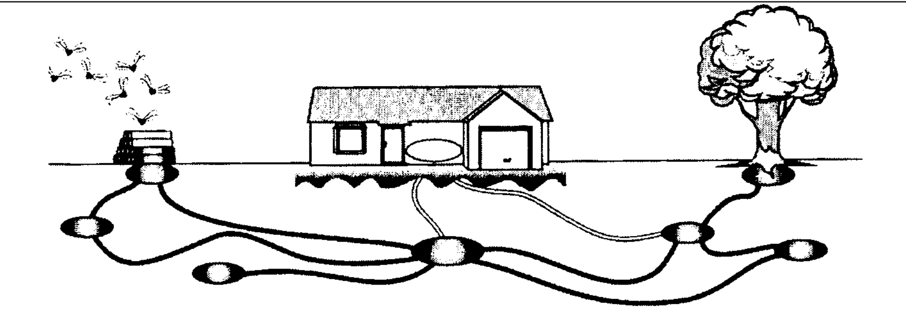
Ripa et al. (2007) found the eastern subterranean termite, *Reticulitermes flavipes*, was unaffected in monitoring stations >2m (6.6 ft) away from a fipronil soil barrier. Osbrink et al. (2005) showed that Formosan subterranean termites, *Coptotermes formosanus*, foraging 1-3 m (3.3-9.8 ft) from imidacloprid (Premise) soil barriers were unaffected by the treatment.

Termites Forage at Will Outside Barriers

New research techniques are casting light on the foraging patterns and colony structure of subterranean termites (see below). In the case of the eastern subterranean termite, *Reticulitermes flavipes,* the good news is the colonies are small—the bad news is that there are a lot of them. When Parman and Vargo (2010) tested the colony level effects of imidacloprid (Premise) at 11 infested structures in North Carolina, they found that each site had about 6 colonies, but only one of them was infesting the structure.

When imidacloprid was applied as a barrier treatment, it eliminated termites from the structures and reduced the numbers of termites foraging within 0.5 m (1.6 ft) of the structure for at least two years. About 75% of the colonies infesting the structures contacted the imidacloprid and disappeared totally within 90 days. About 25% of the infesting colonies left the structure and continued to feed elsewhere.

On the other hand, 75% of untreated colonies more than 2 m (6.6 ft) from the imidacloprid barrier continued to be detected. Untreated colonies continued to thrive, and during the course of the two year study, an average of five new additional colonies appeared at each site. The structures remained pro-

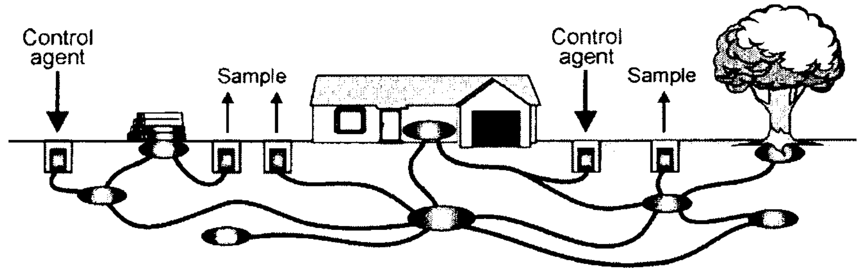


Termiticide barriers have no effect on termites foraging away from the treated area.

Courtesy Professor Nan-Yao Su

tected, but *the number of foraging colonies nearly doubled*.

So although a barrier can protect a structure, termites usually forage at will outside the treated area. Horizontal transfer does not cover a large area, and barriers do not have areawide effects on termite populations. In fact, some researchers believe that use of barrier technology has encouraged the spread of Formosan subterranean termite (Su 2003b).



When a termite colony forages in tunnels connected to active baits, the entire colony can be eliminated.

Courtesy of Professor Non-Yao Su

What is a Termite Colony?

Barriers are meant to repel or kill termites and directly prevent them from attacking a structure. Baits do not repel termites, and unlike barriers, can have areawide effects on termite populations (Ripa et al. 2007). But effective use of baits requires some knowledge of termite colony structure (see Box A).

The definition of a termite colony can be genetic or behavioral. A genetic definition is that new colonies are established by mated queens after a swarm. Queens lay eggs, and all individuals developing from the queen are by definition members of the same colony. Extended colonies occur when the queen produces other reproductives called neotenics that also lay eggs, producing new workers (see Box A). By this definition a termite colony is a set of genetically related individuals (Vargo and Husseneder 2009; Snyder 1948; Pickens 1946).

The behavioral definition is that "a subterranean termite colony is defined as a group of termites sharing interconnected foraging sites" (Su 2003a; Su and Scheffrahn 1998). Colonies are identified by drilling monitoring stations into the soil and observing termites that appear in the stations. To identify a foraging network, termites captured at one station are marked with a dye and then released. All stations where the marked termites appear are part of the same foraging network of the same termite colony. Termite foraging galleries and tunnels of one colony can extend up to 140 m (459 ft)(Su 2003a).

The Sentricon baiting system uses a network of monitoring stations and active feeding stations to eliminate termites feeding within this foraging network. This behavioral definition of a colony provides a way to establish bait efficacy (see below). If marked termites feed on an active bait, then disappear from all monitoring stations, by definition the colony foraging in this network has been eliminated (Su 2003a).

Even Large Colonies Can Be Produced By One Queen

New molecular genetic techniques have shown that the behavioral definition of a colony and the genetic one are consistent. A group of termites foraging in the same network are usually close relatives. In the case of *R. flavipes* in North Carolina, foraging workers in the same network are either directly produced by the same queen (70%), or by related neotenics of an extended family (27%). In a small percentage (3%) of the cases, termites foraging in the same network are part of two genetically different colonies that may have fused (DeHeer and Vargo 2004). In Massachusetts the *R. flavipes* colony distribution is 27% simple families, 59% extended families, and 14% mixed families (Bulmer et al. 2001).

Surprisingly, even large colonies of Formosan subterranean termites, *Coptotermes formosanus*, in 100-185 m (328-607 ft) foraging networks can be simple families headed by a pair of primary reproductives. An analysis of three populations in the U.S. found 48-82% of the huge colonies were simple families produced by a single queen. Others were extended families produced by genetically related neotenics (Vargo et al. 2006).

Baiting efficacy may depend on colony identification. Termites foraging in the same network can be captured and genetically analyzed. These results show that baits can eliminate a genetically distinct colony. Later, another genetically distinct colony can invade the same foraging network (Vargo and Husseneder 2009). Constant reinvasion at some sites may mean that baits have to be maintained for long periods of time (Messenger et al. 2005).

Pest Subterranean Termite Species

There are at least 45 different termite species in the U.S., and about 30 of them are pests (Su and Scheffrahn 1990).There are at least seven native pest species of *Reticulitermes*. In the East, the prevalent species is the eastern subterranean termite, *R. flavipes*. In the West, the western subterranean termite, *R. hesperus* is most likely. In the southern U.S., native pests will be usually *R. flavipes*, *R. hageni*, and *R. virginicus*. Throughout much of the South, and sometimes in Southern California, the exotic invasive Formosan subterranean termite, *C. formosanus*, may also be found (Vargo and Husseneder 2009).

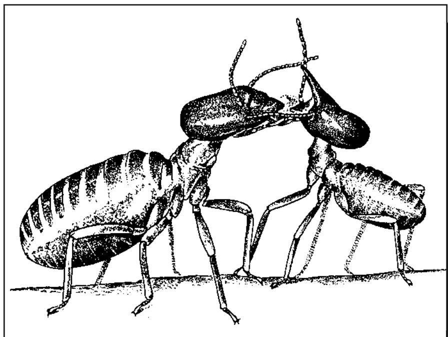
Reticulitermes spp. generally have small colonies (<100,000), but in some areas colony density is high (62/ha; 25/acre). Foraging ranges are usually 1-15 m (3.2-49 ft), sometimes reaching 25 m (82 ft). Colonies tend to be larger in urban areas than wildlands (Parman and

Vargo 2010; Haverty et al. 2000; Haagsma and Rust 1995).

Coptotermes formosanus has less colony density, but colonies are very large. There are often 1-1.5 colonies/ha (1-1.5/2.47 acre) and foraging ranges often exceed 100m (328 ft). Each colony can have a million or more foragers (Su and Tamashiro 1987; Vargo and Husseneder 2009). Because colonies are so large, termiticide barriers only treat part of an infestation, leaving swarmers to spread throughout an area (Su 2003a).

In either case, for a baiting strategy to work, the colony or colonies infesting a structure must encounter the baits and eat them. These colonies are either totally eliminated by the bait, or populations are reduced so that the infested structure is no longer part of the foraging network (Su 2003a; Vargo and Husseneder 2009).

An added complication is that Formosan subterranean termites can form aerial nests. According to Su and Tamashiro (1987), about 25% of the Formosan infestations in Florida are aerial nests. Since they do not require contact with the soil, they cannot be eliminated with a soil barrier. Aerial nests are treated with the same techniques as drywood termites (Quarles 1999; 2001; Mashek and Quarles 2008; Lewis 2002).



Termites share the active ingredient of a bait by trophallaxis.

How to Determine Baiting Success

As a practical matter, a termite treatment is successful when termites are removed from a structure. The informal efficacy standard is no signs of termites, including mud tubes, swarms, frass, and damaged wood. This is established by visual inspection by an experienced inspector, and possibly by use of instruments such as moisture meters, termite scanners, infrared cameras, termite dogs, or other methods. A termite-free structural inspection is an important part of baiting efficacy, and is part of regulatory standards such as the Florida Rule (see below)(Quarles 2004; Thoms et al. 2009).

Baiting meets the commercial standard of efficacy by eliminating the colonies feeding on the structure. Colony elimination is determined by monitoring for termites. The standard baiting technique starts with installation of underground monitoring stations around a building perimeter. When termites start feeding, active baits are installed. In some baiting systems, the monitors also include active baits, but having independent monitors in addition to active baits is considered a better technique (Forschler and Ryder 1996).

In research studies, foraging activity, foraging ranges, and number of foragers are measured with monitoring and mark recapture techniques before and after active baiting (Grace et al. 1989; Grace 1990; Su and Scheffrahn 1996ab). Companies usually do not have the resources to perform these techniques in commercial applications.

But if termites start feeding on an active bait, there is a good chance of success. Termite companies measure activity at bait stations, and the amount of bait consumed. Also, monitoring stations are checked periodically for termites. Thorne and Forschler (2000) suggest a colony is eliminated when swarms disappear, when termites disappear from pre-baiting and post-baiting monitoring stations, and when feeding is vigorous on an active bait, followed by termite inactivity.

The manufacturer of Exterra termite baits uses the following criterion of success: "if all termite feeding and activity in an area has been absent from the area for six consecutive months and termites fed on the bait for three months prior to the cessation of feeding and activity, we presume that colony elimination has occurred" (Quarles 2003b). Again, as a practical matter, termites should no longer be foraging inside the structure or constructing mud tubes.

The Florida Rule

Since Sentricon baits were registered in 1994, the baiting technique has evolved and matured. Standards of efficacy have been defined and formulated into laws such as the Florida Rule. The Rule is meant to define standards of efficacy that new baits must meet before they can be registered in Florida. The Rule requires installation of independent monitoring stations in addition to baiting stations. It requires a structural inspection before baits are installed, after termites are eliminated, and at least one year later. It also sets standards of protection in new construction—buildings not yet infested by termites.

For infested buildings, there must be at least a 90% reduction in termite activity at independent monitors at 90% of buildings within a year after termites start feeding on the baits. If buildings are infested, baits must eliminate termites in at least 90% of buildings within a year after feeding starts. After termites are eliminated, buildings must not show signs of termites for at least a year.

If buildings are not infested, there must be 100% reduction in feeding activity in the independent monitors within a year. If buildings are not infested, 98% of them must remain uninfested within a year after feeding stops in independent monitors (Thoms et al. 2009).

Efficacy of Baits

If termites feed on the baits, colonies can be eliminated and structures can be protected. Companies that make the baits can cite numerous studies showing

Table 2. Bait Efficacy for Subterranean Termites

Bait	Efficacy	Number Colonies or Sites	Reference
hexaflumuron	60%	48	Haagsma and Rust 2005
hexaflumuron, *C. formosanus*	80%	10	Glenn et al. 2008
sulfluramid First Line *R. flavipes*	80%	25	Glenn et al. 2008
sulfluramid Terminate *R. flavipes*	84%	25	Glenn et al. 2008
hexaflumuron *R. flavipes*	88%	25	Glenn et al. 2008
hexaflumuron	91%	23	Potter et al. 2001
hexaflumuron	93%	15	Forschler and Ryder 1996
hexaflumuron	94%	335	Grossman 2000
hexaflumuron	96%	159	Su 2003a
hexaflumuron	98.5%	13,691	Su 2003a
noviflumuron	100%	62	Thoms et al. 2009

their efficacy. Su (2003a) cites 33 studies involving 159 baited termite colonies, and 152 of them were eliminated. If colony elimination is the standard of efficacy, that is an efficacy rate of 96%. At a total of 13,691 commercial sites, baiting was successful in 98.5% of the cases. Failure was defined as termite activity in structures more than 6 months after bait installation, little or no feeding on baits, and lack of activity in monitoring stations. Most the commercial successes reported by Su (2003a) were in Florida and Louisiana.

In Kentucky, when 23 structures were baited with hexaflumuron, termites were eliminated at 21 of them. This is a success rate of about 91% (Potter et al. 2001). Forschler and Ryder (1996) used Sentricon with hexaflumuron on *Reticulitermes* spp. in Georgia. About 93% of baited colonies were eliminated within a year. If the colonies ate the bait, 100% of them were eliminated.

Glenn et al (2008) report an average efficacy of 84% at 75 commercial baiting sites in Texas involving *R. flavipes*. Sentricon (88%), Terminate (84%), and First Line (80%) baits were tested. Terminate and First Line had to be supplemented with liquid termiticides. At 20 structures infested with Formosans, sulfluramid (Terminate, First Line) baits functioned poorly. Sentricon baits at 10 Formosan sites had an average efficacy of 80%. But at 5 of these sites where baiting was aggressive, success rate was 100%.

Robert Davis of ABC Pest and Lawn Service in Austin, TX reported a 94% success rate with hexaflumuron. Of 335 sites treated, only 20 (6%) still had termites one year later (Grossman 2000).

Thoms et al. (2009) installed Sentricon baits containing 0.5% noviflumuron at 24 buildings in 5 Southern States. There were a total of 62 colonies of *Reticulitermes* spp. and *Coptotermes formosanus*, and half of the buildings were infested with termites. Termite colonies were identified by mark recapture techniques and genetic analysis.

All termites (100% success) were eliminated from buildings in an average of 151 days (62-266 days). Structural inspections a year or more later showed the buildings were free of termites. At unifested buildings, termites were eliminated from independent monitors in 29-275 days.

Less Success in the West

Research studies clearly show that hexaflumuron can be effective for the western subterranean termite (Haagsma and Bean 1998; Kistner and Sbragia 2001; Getty et al. 2000; 2007). But Haagsma and Rust (2005) report that hexaflumuron was less successful in early

Resources

Borates

NISUS Corp., 100 Nisus Drive, Rockford, TN 37853; 800/264-0870, 865/577-6119, Fax 865/577-5825; www.nisuscorp.com

Non-Repellent Barriers

Altriset® (0.05% chloranthraniliprole)—Dupont Professional Products, Wilmington, DE 19898; www.pro-products.dupont.com

Arilon® (0.05% and 0.10% indoxacarb, spot treatment)—Dupont, see above

Optigard® (0.05 and 0.10% thiomethoxam, spot treatment)—Syngenta, PO Box 18300, Greensborough, NC 27419-8300; 800/334-9481, 336/632-6000, Fax 336/632-2653; www.syngenta.com

Phantom® (0.125 and 0.25% chlorfenapyr)—BASF, see below

Premise® (0.05% and 0.10% imidacloprid)—Bayer ES (Environmental Science), 2 TW Alexander Drive, Research Triangle Park, NC 27709; 800/331-2867; www.bayeres.com

Termidor® (0.06% and 0.125% fipronil)—BASF Professional Pest Control, 26 Davies Drive, PO Box 13528, Research Triangle Park, NC 27709; 800/327-4645, 919/547-2000; www.basf.com

Baits

Advance® (0.25% diflubenzuron)—BASF, see above

Exterra® (0.25% diflubenzuron)—Ensystex, 2709 Breezewood Avenue; PO Box 2587, Fayetteville, NC 28302; 888/398-3772, Fax 888/368-4749; www.ensystex.com

First Line® (.01% sulfluramid)—FMC Corporation (wholesale), 1735 Market St., Philadelphia, PA 19103; 800/321-1362, 215/299-6000; www.fmcprosolutions.com

Hex-Pro® (0.5% hexaflumuron)—Dow, see below

Subterfuge® (0.3% hydramethylnon)—BASF

Sentricon® (0.5% noviflumuron)—Dow AgroSciences, 9330 Zionsville Road, Indianapolis, IN 46268-1054; 800/255-3726; 800/745-7476, 317/337-4385, Fax 800/905-7326; www.dowagro.com

Terminate® (0.01% sulfluramid)—United Industries, 2520 Northwinds Parkway, Alpharetta, GA 30004; 800/336-1372; www.spectrumproducts.com7

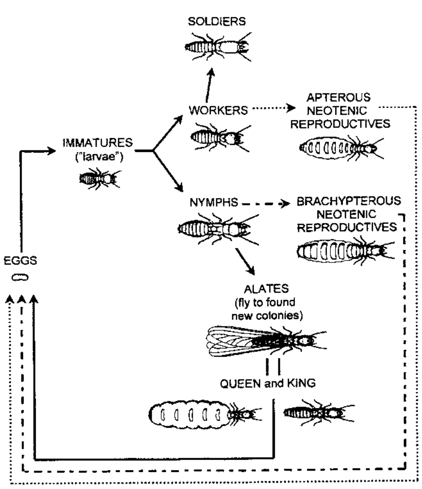
Box A. Termite Life Cycle

Termites can be traced back 50 million years. Like cockroaches, termites practice incomplete metamorphosis, with eggs hatching into larvae resembling adults. Unlike cockroaches, these early larvae molt into a number of different castes.

Eggs hatch into larvae, molt once, then differentiate into two castes, either sterile workers or reproductives called nymphs. Most of the adults are workers. Workers can either continue to molt and grow into larger workers, or they can molt into sterile soldiers or rarely into wingless reproductives.

Nymphs form two kinds of reproductives, primary reproductives that have functional wings (alates) and neotenics that do not (brachyapterous). All reproductive forms are either male or female. So there are three kinds of reproductives: large wings or small wings from nymphs, and those with no wings that develop from workers. Large winged termites are the primary reproductives. Reproductives with small wings or no wings are called neotenic forms (Synder 1948; Thorne et al. 1999).

The most common reproductive strategy involves mating flights. King and queen alates are released by the colony. They fly away from the colony, mate, lose their wings and pairwise start forming new colonies by burrowing into the ground. Most new colonies are of this type. Primary reproductives of *Reticulitermes* live an average of 7-10 years, and a maximum of 18 (Laine and Wright 2003).



From Thorne et al. 1999

Most of the eggs are laid by queens, foraging workers are the most numerous caste.

These primary families either die out or continue to grow. As colonies grow larger, or if one of the primary reproductives is killed, some of the supplementary reproductives (neotenics) may start to reproduce. This may result in inbreeding as the original king or queen may mate with these forms. If both colony founders are killed, reproduction becomes entirely the responsibility of the neotenics.

To make things more complicated, nymphs can regressively molt into worker forms called pseudergates. This regression makes for a very flexible family structure. If needed, pseudergates can develop into alates, neotenics, or soldiers. Pseudergates are found in low numbers, and in some species not at all (Laine and Wright 2003).

The ratios of the different castes vary according to species. *Reticulitermes* spp. have smaller numbers of soldiers (1-3%) than Formosans (10%). Typical laboratory colonies of *R. flavipes* have about 86.9% workers, 9.6% larvae, 2.1% soldiers, and 2.3% eggs. About 17% of *R. flavipes* laboratory colonies contain neotenics (Long et al. 2003).

Both workers and nymphs molt at least 5 times as they grow. Once they reach maturity, workers continue molting even though they remain about the same size. Since termite colonies cannot grow or develop reproductive forms without molting, they are very vulnerable to chitin synthesis inhibitors that stop the molting process (Su 2003a; Laine and Wright 2003).

commercial operations. They report that of 48 commercial field test sites in Southern California in 1996-1998, only 29 (60%) met standards of efficacy defined by Su (2003).

This low efficacy rate in California was thought to be due to sporadic feeding at bait stations, low foraging activity, and low bait fidelity. In addition, donor termites might have eliminated hexaflumuron faster than it could be transferred (Haagsma and Rust 2005).

Improved Baits and Placement

Since those early experiments, hexaflumuron has since been replaced by noviflumuron, which has a slower elimination rate. It also works to eliminate colonies twice as fast as hexaflumuron (Karr et al. 2004). The labor of baiting has been reduced through use of digital technology and introduction of long-lasting noviflumuron (Recruit HD) baits that are inspected only once a year (MSDS 2009; Thoms et al. 2009).

Problems with termite discovery of bait stations and sporadic feeding have been addressed with the use of targeted placements, auxiliary stations and enhanced baits (Jones 2003; Paysen et al. 2004; Cornelius et al. 2009). Targeted placement near areas of moisture or signs of termites can double the number of hits on bait stations from about 10 to 20% (Jones 2003). Placing auxillary stations around active ones improved persistence at feeding stations by 36% and overall consumption of bait by 41% (Paysen et al. 2004). Adding a sports drinks to bait stations increases bait discovery rate, and rate of feeding but not significantly so (Cornelius et al. 2009).

Since termite foraging is seasonal and increases with temperature and moisture, colonies can be eliminated faster if baits are installed when termites are actively foraging in the spring and summer (Getty et al. 2000; Haagsma and Rust 1995; Su et al. 1984; Cornelius and Osbrink 2011).

Ongoing Protection of Baits

According to Grace and Su (2001), "use of the Sentricon system and hexaflumuron baits to eliminate all detectable subterranean termite activity has been demonstrated numerous times ...to the point where citations to the published literature are superfluous."

Though there are numerous published accounts of remedial success, there are fewer published papers about ongoing protection and the likelihood of reinvasion. The cumulative experience of Grace and Su (2001) is that ongoing monitoring over 8 years shows that once termites are eliminated, they may not show up again even after 7 years.

But where the termite pressure is intensive, reinvasion is more or less expected (Messenger et al. 2005). Sometimes new colonies invade during the original baiting process. When Thoms et al. (2009) baited 62 colonies of *Recticulitermes* spp. and *Coptotermes formosanus* with 0.5% noviflumuron, all colonies were destroyed. But monitoring stations showed more than half of the treated properties had new colonies reinvade within 3 months. The new colonies were also eliminated by baits.

Baiting technology is generally effective in eliminating colonies attacking houses. In most cases, there will be a respectable time before reinvasion is seen (Getty et al. 2000). With Formosan termites in Florida, rebaiting is sometimes needed every 3-4 years. The new colonies tend to use the old foraging networks, so repeated colony elimination is relatively easy (Grace and Su 2001).

Conclusion

Nothing is certain. But both baits and barriers can be effective. Barriers should be initially effective in at least 90% of the cases. In areas of average termite pressure and moderate rainfall, they should last at least 5 years.

Drawbacks of baits are that they may take three months to eliminate termites, and are not 100% reliable. Commercial experience and research studies show success rates of about 85-98% in most cases. Effectiveness was originally less than this in California, but may have improved with new techniques. Where termite pressure is intense, an ongoing monitoring contract may be needed, with occasional redeployment of active baits.

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EcoWise News

In October 2011, the California Academy of the Sciences in San Francisco became a U.S. Green Building Council's Double Platinum LEED-Certified Building for sustainability. This high level certification has been achieved by only five buildings in the world. Factors considered are low environmental pollution, energy and water use, recycling, and pest management. Part of the high rating is due to the use of EcoWise Certified pest management professionals.

The California Academy of Sciences is leading the way, but managers of other buildings can also get LEED points by choosing an EcoWise Certified Company. EcoWise certification is now available through BIRC's new EcoWise Online IPM Certification Program (see July/Aug *IPMP*). Pest Management Professionals from Western Exterminators and Applied Pest Management have already enrolled in the Program.

The convenience and low cost of online training and certification will help pest management companies stay competitive as more businesses and government agencies adopt green building standards and ask for EcoWise Certified professionals.

Conference Notes

ESA 2010 Annual Meeting Highlights

By Joel Grossman

These Conference Highlights are from the Dec. 12-15, 2010, Entomological Society of America (ESA) annual meeting in San Diego, California. ESA's next annual meeting is November 13-16, 2011, in Reno, Nevada. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org

Attract-and-kill perimeter trap trees utilizing aggregation pheromones and attractive plant volatiles can reduce pesticide use 90% against plum curculio, *Conotrachelus nenuphar*, a key cherry pest in Michigan that also attacks apples in the Northeast and blueberries in New Jersey, said Tracy Leskey (USDA-ARS, 2217 Wiltshire Rd, Kearneysville, WV 25430; Tracy.Leskey@ars.usda.gov). Attract-and-kill perimeter trap trees on orchard borders can be baited after petal-fall, when fruits naturally produce attractive benzaldehyde scents and male plum curculios produce grandisoic acid aggregation pheromone.

Plum curculios are most active in trees when relative humidity is high and wind flow is low. Leskey increased lab relative humidity to 75%, and found that virgin male plum curculios increased grandisoic acid production.

Electroantennograms (EAG) confirmed the activity of grandisoic acid and synthetic versions of plant volatiles such as trans-2-hexenal, ethyl acetate, ethyl butanoate, and R(+)-limonene. *Trans*-2-hexenal, produced by Stanley plums and attractive to plum curculios at low concentrations, is the standard for comparison. The combination of grandisoic acid aggregation pheromone and attractive plant volatiles can concentrate plum curculios on trap trees. By just spraying perimeter trap trees and a few trees near field borders, pesticide use can be reduced to only 10% of the more costly and ecologically disruptive whole orchard spray regimens.

Psyllid Traps & Photonics

Asian citrus psyllid, *Diaphorina citri*, a vector of citrus greening bacteria that can deform and kill trees, moves between residential backyards and orchards, said Joseph Patt (USDA-ARS, 2413 East Hwy 83, Weslaco, TX 78596; joseph.patt@ars.usda.gov). In Texas' Rio Grande Valley, the psyllid is found on Meyer lemons, orange jasmine, and Rio Red grapefruit. It can be monitored and suppressed by scent-based traps as it moves from tree to tree. Pest movement is likely motivated by the need to reproduce on flush new growth. (See *IPMP* July/Aug 2010)

Sulfur-containing volatiles from guava are among the repellents. A waxy epoxy of SPLAT™ (ISCA, Riverside, CA) with pheromones is sprayed on foliage for mating disruption. Yellow-green color, odor, edges, light, growing shoot characteristics, and female sex pheromone are among the attractants. Plant volatiles attracting *D.citri* include terpenes such as *E-beta*-ocimene, caryophyllene, and linalool.

In lab crawling tests, the pest was very attracted to yellow dispensers; it perceived but was not attracted to gray. With scent added, trap color became a neutral factor. In backyard fungal pathogen transmission tests, *D. citri* transmitted more spores from yellow dispensers with pleated ridges for crawling and probing.

Photonic Fence technology (Intellectual Ventures Lab) utilizes a low-energy laser light source which measures the wing beats of insects flying by and can distinguish males from females and mosquitoes from psyllids, said Patt. High-energy lasers can kill, but removing the killing energies can turn the laser into a device for measuring psyllid movements.

BABA Induces Citrus Psyllid Resistance

"Beta-aminobutyric acid (BABA) is known to broadly induce resistance against several microbial pathogens, nematodes and insects in plants," said Siddharth Tiwari (Citrus Res & Educ Center, 700 Experiment Station Rd, Lake Alfred, FL 33850; stiwari@ufl.edu). BABA induces plant resistance to plant pathogens such as downy mildew, *Bremia lactucae* on lettuce and late blight, *Phytophthora infestans* on tomato. BABA also induces plant resistance to insects.

A non-protein amino acid, BABA was applied as a root-drench in greenhouse experiments. BABA "induced resistance in citrus plants" and suppressed the development of Asian citrus psyllid, *Diaphorina citri*. Leaf-dip bioassays showed that BABA is not toxic to Asian citrus psyllid; confirming that BABA root drenches induced resistance in citrus plants.

"Current experiments are being conducted to determine how BABA-induced resistance compares with use of standard systemic insecticides," said Tiwari. "Also, we are investigating the effect of BABA-induced resistance on other pests of citrus, such as citrus leafminer, *Phyllocnistis citrella*. Induced resistance may be a possible supplement or alternative to the current heavy use of insecticides in Florida pest management."

Lemon Grass Arrests Whitefly

"During the last decades, a worldwide spread of the sweetpotato whitefly, *Bemisia tabaci*, resistant to pesticides has led to local devastation of food and fiber crops, specifically vegetables and ornamentals, resulting in large economic losses," said Francoise Djibode-Favi (Virginia State Univ, Agric Res Stn, 1 Hayden, Petersburg, VA 23803; Ffavi@vsu.edu). "Whiteflies also transmit more than 100 different virus species, of which the majority belong to the genus *Begomovirus*.

A BIRC Archive

BIRC founders Bill and Helga Olkowski have established a website, www.WHO1615.com, describing the early years of BIRC. Along with Olkowski personal information, the website also profiles correspondence and project reports. According to Bill Olkowski, "we thought the whole experience of building this non-profit was worth preserving. People who have pictures and documents from those early years should contact me."—olkowskiw@yahoo.com

Calendar

September 11-16, 2011. IOBC Meeting. 13th Intl. Conf. Biocontrol of Weeds, Honululu, HI. Contact: Dr. Tracy Johnson, email tracyjohnson@fs.fed.us

September 23-24, 2011. PCOC Board of Directors Meeting. Lake Tahoe, CA. Contact: www.pcoc.org

October 19-22,2011. Pestworld, Annual Meeting National Pest Management Association (NPMA), New Orleans, LA. Contact: NPMA, 10460 North St., Fairfax, VA 22031; 800/678-6722; 703/352-6762www.npmapestworld.org

October 27, 2011. Beyond Pesticides 30th Anniversary Meeting. Washington, DC. Contact: Beyond Pesticides, 701 E Street, SE, Washington, DC 20003; 202-543-5450; www.beyondpesticides.org

November 5-8, 2011. 15th Annual Conf. Community Food Security, Oakland, CA. Contact: www.comunityfoodconference.com

November 13-16, 2011. ESA Annual Meeting, Reno, NV. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org

January 3-6, 2012. Advanced Landscape IPM Short Course. U Maryland, College Park. Contact: A. Koieman, U. Maryland, 301-405-3913; akoeiman@umd.edu

February 1-4, 2012. 32th Annual Ecofarm Conference. Asilomar, CA. Contact: Ecological Farming Association, 406 Main St., Suite 313, Watsonville, CA 95076; 831/763-2111; www.eco-farm.org

February 5-7, 2012. Annual Meeting Association Applied IPM Ecologists. Embassy Suites, Oxnard, CA. Contact: www.aaie.net

February 6-12, 2012. Annual Meeting Weed Science Society of America. Big Island, HI. Contact: www.wssa.net

February 23-25, 2012. 23rd Annual Moses Organic Farm Conference. La Crosse, WI. Contact: Moses, PO Box 339, Spring Valley, WI 54767; 715/778-5775; www.mosesorganic.org

March 4-6, 2012. California Small Farm Conference. Valencia, CA. Contact: www.californiafarmconference.com

March 27-29, 2012. 7th Intl. IPM Symposium. Memphis, TN. Contact: E. Wolff, Univ. IL, Urbana. 217/233-2880; email ipmsymposium@ad.uiuc.edu

June 21-23, 2012. 69th Annual Convention, Pest Control Operators of CA. Catamaran Resort, San Diego, CA. Contact: www.pcoc.org

November 11-14, 2012. ESA Annual Meeting Knoxville, TN. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org

Conference Notes

Virus infection ranges from mild symptoms such as leaf discolorations, to overall yield reduction, severe fruit necrosis, flower and fruit abortions, and plant death."

"Intercropping tomato with coriander, *Coriandrum sativum*, reduces the incidence and severity of damage caused by *B. tabaci*," said Djibode-Favi. "Coriander constitutive volatiles have an odor-masking effect on tomato volatiles, thus interfering in the host plant selection of *B. tabaci* (Pedro et al. 2010)."

Visual and olfactory cues guide whiteflies to host plants. Odor probably initiates host plant targeting, while vision increases landing accuracy. Lemongrass, *Cymbopogon citratus*, volatiles repelled adult sweetpotato whitefly and can be lethal. These volatiles produced by an edible plant are apparently harmless and could be used to confer repellency to plants that were otherwise attractive to whitefly.

There are differences between volatiles from fresh plants and old dried plants. Fresh leaf provided 99.5% whitefly mortality in 24 hours, versus 28% for week-old dried ground leaf. Volatiles from dried lemon grass leaves were 30% myrcene and 60% citral. High quality lemon grass essential oil is over 75% citral. Citral has two bioactive isomers, neral and geranial. Citral is lethal to whiteflies.

Isopropanol Lures Green June Beetle

"Green June beetle, *Cotinis nitida*, is native to the southeastern region of the United States from Kansas to Connecticut and south to Texas and northern Florida," attacking turf grass, lawns, figs, grapes, apples, peaches, and other crops, said Brian Cowell (Missouri State Univ, 9740 Red Spring Rd, Mountain Grove, MO 65711: Cowell007@MissouriState.edu).

About 13,100 ha (32,370 acres) suffer yield losses, and chemical control costs can be $260/ha ($105/acre). Pest flights and damage are often near harvest, when alternative control methods are needed because insecticides cannot be used.

An alternative is a modified Baker trap (Oliver et al. 2004; Reut et al. 2010) made from 710 ml (24 oz) transparent polyethylene terephthalate (PET) soda bottles with square openings. PET bottles are available at recycling centers. The lure or bait is a wicked dispenser releasing 50% isopropanol. Isopropanol, also known as rubbing alcohol, is available cheaply in pharmacy and grocery stores. White, blue, or orange strips near the top of the trap increase the GJB catch more than transparency or other colors; though yellow can also be used.

"Improved bottle traps made of 2 liter (68 oz) PET bottles and baited with 50% isopropanol hung at 1.5 or 2 meters (5 to 6.5 ft) caught about 300 GJB per day (73-326). "This trap should fit into the budget of every grower, professional or amateur alike," said Cowell, as the cost is about $5.50 per trap per season.

Lygus Trap Crops Protect Strawberries

"Alfalfa trap crops are used to reduce *Lygus hesperus* damage to strawberries on the California Central Coast," said Sean Swezey (Univ of California, 1156 High St, Santa Cruz, CA 95064; findit@ucsc.edu). "To determine the movement patterns of *L. hesperus* from trap crops onto strawberries or other alfalfa trap crops, a protein mark-capture technique was utilized. The movements of generalist predators were also tracked using this technique."

L. hesperus adults and generalist predators marked with milk or egg white protein sprays "were later captured in alfalfa trap crops, adjacent strawberry rows, and bordering weeds," said Swezey. "On a percentage basis, two weeks after marking (using the egg-white protein), only 2.7% of captured marked *L. hesperus* adults were found in strawberries, while the remaining 97.3% were collected from alfalfa trap crops. But larger proportions of predaceous natural enemies moved into neighboring strawberries from the trap crop.

Organic Soybean Buckwheat Strips

Biological control needs to be boosted to help stop soybean aphid, *Aphis glycines*, in organic soybeans, said Thelma Heidel (Univ of Minnesota, 1980 Folwell Ave, St. Paul, MN 55108; heide067@umn.edu). Buckwheat, *Fagopyrum esculentum*, which can be used a cover crop to slow soil erosion or turned under as a green manure to increase soil biomass, is also a flowering sugar source for beneficial insects;

and growers have observed fewer soybean aphids in the proximity of buckwheat.

At Minnesota's Lamberton Research Center, 5-ft (1.5-m) wide buckwheat border strips were planted around soybeans. At Bob Henneman's organic farm in Evansville, MN, a buckwheat strip was planted down the middle of the soybean field. No trends in natural enemy numbers were noted, but there was a trend towards fewer aphids nearer the buckwheat in a year when soybean aphid numbers were low. Thus, buckwheat may boost aphid biocontrol. Buckwheat strips still need to be tested in a year with high soybean aphid populations.

Microbial Combo Controls Colorado Potato Beetle

"Our previous studies demonstrated synergistic and highly complementary interactions between the fast-acting bacterial pathogen *Bacillus thuringiensis* serovar *tenebrionis* (Bt) and the slow-acting fungus *Beauveria bassiana* strain GHA (Bb)," said Stephen Wraight, (USDA-ARS, Tower Rd, Ithaca, NY 14853; Steve.Wraight@ars.usda.gov). "These findings stimulated development of an experimental Colorado potato beetle, *Leptinotarsa decemlineata*, control program based on three strategically timed applications of these microbial biocontrol agents."

Potato yields after microbial sprays were 67% higher, compared to the controls. Applying the same amount of microbes as two sprays instead of three is equally effective. Defoliation on day 26 was 14%, versus 46% in the controls. Summer CPB adult populations were reduced 90%. Mid- and late-season CPB larvae populations were reduced over 70%.

"This study confirms our previous findings that mid-late instar CPB larvae are highly susceptible to Bb but generally succumb to infection only after entering the soil to pupate," said Wraight. "High efficacy of this program in reducing summer adult (and thus overwintering populations) of CPB suggest it would be an effective long-term control method for area-wide CPB management."

Purple Sticky Trap Botanical Beetle Lures

Purple sticky traps baited with botanical oil lures effectively capture Asian longhorn beetles, *Anoplophora glabripennis*; emerald ash borer, *A. planipennis* and many other wood-boring beetle species in the Buprestidae, Cerambycidae and other families. "Collections of emerald ash borer were significantly increased by manuka and phoebe oils (Crook et al. 2008)," said Nadeer Youssef (Tennessee State Univ, McMinnville, TN 37209; nyoussef@blomand.net). Manuka is the natural oil distillates of New Zealand tea trees, *Leptospermum scoparium.* Phoebe oil is from Brazilian walnut, *Phoebe porosa.*

"These oils contain high concentrations of several compounds found in headspace volatile collections from ash bark, which are antennally active on emerald ash borer," said Youssef. Other compounds in these oils are likely attractive to other wood-boring beetle species, which prompted purple sticky trapping experiments in small Tennessee mixed deciduous woodlots with manuka and phoebe oil baits (AgBio Inc, Westminster, CO).

Sticky traps were made from purple-colored chloroplast corrugated plastic (Champion Box Co, Cedaredge, CO) covered with Pestick™ insect glue said Youssef. All trap treatments were statistically equally effective at capturing Buprestidae and Cerambycidae wood-boring beetles.

Poplar Biocontrol

Caterpillars of the moth *Gluphisia septentrionis* defoliated thousands of acres of hybrid poplars in the Pacific Northwest in June 2009. "Normally there are two generations of this pest each year," said Alejandro Del Pozo (Washington State Univ, Pullman, WA 99163; alejodelpozo@hotmail.com). "However, 25% of the larvae of the first generation were parasitized by *Eulophus orgyiae* and 85% of the eggs of the second generation were parasitized by *Trichogramma* spp." This biocontrol by parasitoids prevented an expected second defoliation.

The parasitoids use speckled green fruitworm, *Orthosia hibisci*, as an intermediate host to increase in May before the first *Gluphisia* generation in June; after increasing on the June generation, the parasitoids attack the second *Gluphisia* generation in August. Tachinidae fly parasitoids and Pentatomidae predators are also part of the natural enemy complex controlling *Gluphisia* on poplars.

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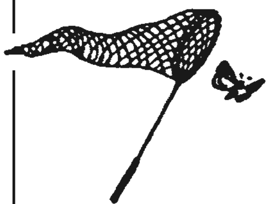

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