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Orange Oil for Drywood Termites: Magic or Marketing Madness?

By Bill Mashek and
William Quarles

There is a thriving market for reduced-risk pesticides. Many pesticides containing conventional active ingredients such as chlorpyrifos and diazinon have been phased out of urban markets. Their widespread use in both agriculture and urban areas had led to increased exposures and unacceptable risks (FQPA 1996; NRC 1993; Wright et al. 1994). They were also a threat to water quality in many areas (Johnson 2004).

A rich source of new pesticides is plant essential oils. Some of these occur in food and are even exempted from pesticide registration by the EPA. Active ingredients in the new products include oils of clove, rosemary, mint, and oranges. Large corporations such as EcoSmart, Woodstream, and Whitmire have made these pesticides readily available (Quarles 1999a; Isman 2006) (see Resources).

Orange oil has attracted a lot of media interest because it is a natural product and has low toxicity to mammals. It is a by-product of orange juice processing, and is extracted from orange peels. Orange oil is currently available as an insecticide (Orange Guard™; ProCitra®) and as an herbicide (Green Match™) (see Resources). It has been registered in California under the brandname XT-2000™ for control of drywood termites. If all the claims are true, it is the holy grail of pest control—an effective natural product with low toxicity and no toxic residuals; a green product obtained by utilization of waste. The purpose of this article is



Photo courtesy USDA

Termites like these are vulnerable to desiccation. Contact with orange oil kills termites by damaging their exoskeleton, causing loss of water and protein.

to present what is currently known about orange oil for termite control so that possible customers will have better information to evaluate the treatment. For comparison, we will summarize some of the other methods used in California for drywood termite control.

What is Orange Oil?

Orange oil should not be confused with orange juice. Orange juice is basically a water extract; orange oil is insoluble in water. Though orange oil has low toxicity, it is irritating to eyes and skin, and drinking it would cause vomiting. Repeated exposure could cause allergic sensitivity in some individuals (MSDS 2006).

Orange oil is an oily mixture extracted from orange peels, and the major components are chemicals called terpenes or terpenoids. It is a volatile liquid and has a strong odor of oranges. A chemical relative of orange oil is turpentine. Both food grade and technical grade orange oil are available. According to Jeff Chang of Florida Chemical, a major supplier of orange oil, there

In This Issue

Orange Oil	1
ESA	10
Calendar	15
Books	16
Ask the Expert	17

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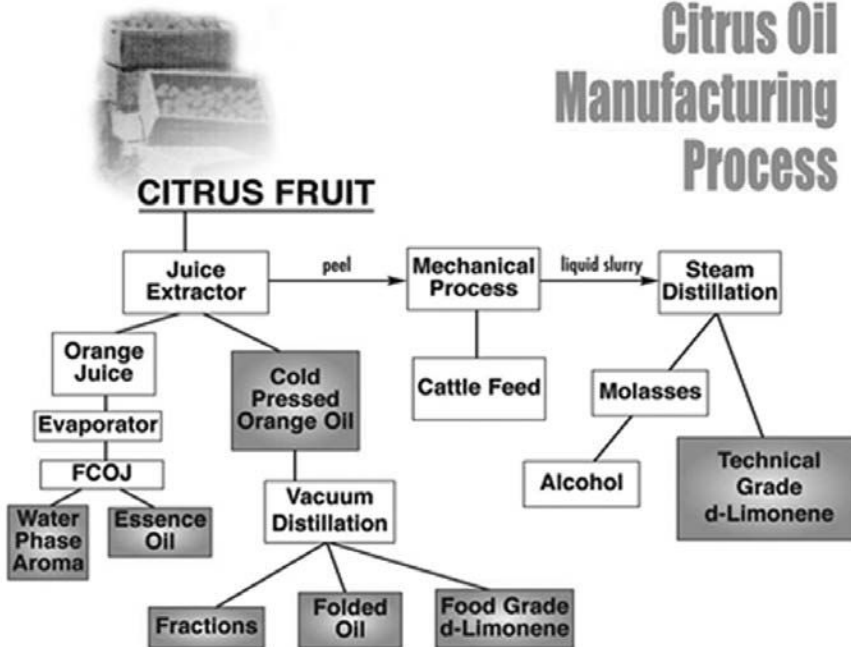
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Update

Citrus Oil Manufacturing Process



Orange oil is extracted from orange peels. It contains terpenes and terpenoids, and the major component is d-limonene.

Schematic courtesy Florida Chemical Company

is very little chemical difference between the two. Food grade is obtained by cold pressing the peels to remove the oil, technical grade is mostly obtained by steam distillation.

There is a lot of misinformation on the internet about termites and orange oil. Some companies say that termites are killed by the citric acid in the oil. According to Chang, this is unlikely, because the orange oil they supply has less than 0.1% citric acid. Although their orange oil contains 5% of other terpenes, alcohols, ketones, and aldehydes that may have some activity, the major active ingredient is about 95% d-limonene. D-limonene (92%) is the registered active ingredient of the termiticide XT-2000, and d-limonene termiticidal activity is consistent with its known insecticidal properties against a variety of flies, mosquitoes, ants, weevils, fleas, wasps, crickets, mealybugs, scales, ticks, mites, and wood beetles (Taylor and Vickery 1974; Styer and Greany 1983; Sheppard 1984; Hink and Fee 1986; Coyne and Lott 1976; Karr and Coats 1988; Karr et al. 1990; Vogt et al. 2002;

Hollingsworth 2005; Quarles 2006a).

Chang believes that d-limonene kills termites through its solvent activity. It actually “melts” or dissolves their chitinous exoskeleton. This is consistent with the known exoskeleton damage produced in the Formosan subterranean termite by a related chemical, *cis*-nerol. Damage to the exoskeleton and cell membranes causes lethal loss of proteins and water (Zhu et al. 2003).

Orange oil is sold as a cleaning agent, and it is a good solvent. Because it is a good solvent, it can cause paint damage if used on painted surfaces. It is flammable, but relatively small amounts of orange oil are used in a termite treatment (MSDS 2006).

Drywood Termite Treatments

Drywood termites are found along the southern border of the U.S., and they are major pests in California and Florida. With global warming, their range is likely to extend northward (Quarles 2007). Treatment costs may exceed \$500 million each year (Su and Scheff-

Update

rahn 1990; Su and Scheffrahn 2000). Drywood termites are either built into new structures, or they invade by flying in from outside. Unlike subterranean termites that live in the ground, drywood termites spend most of their life cycle inside a piece of wood. They live in hollowed out spaces called galleries (see Box A).

In California, drywood termite treatments are either whole house treatments or local treatments. Local treatments include non-chemical methods such as heat, electro-gun or microwaves or injections of chemicals directly into termite galleries. Whole house treatments may

be either a heat treatment or a chemical fumigation, usually with sulfuryl fluoride (Vikane®). Local treatments are done with minimal disruption. Whole house treatments require that occupants move out of the house for about 3 days in the case of a fumigant, or leave for 4-8 hours during a heat treatment (Quarles 2006b).

If there are a limited number of accessible colonies of known location, a local treatment is often used. In California, about 70% of the time, customers choose chemical injections, about 10% of the time, they choose non-chemical methods, and about 20% of the time a struc-

tural fumigant is used (Lewis 2003; Potter 1997).

Key to success with local treatments is detection. Termite inspection involves a trained and experienced inspector. Inspectors are limited to accessible areas and rely mostly on their eyes to find termite signs such as damaged wood, flying termites (swarmers), discarded wings, and fecal pellets. Tools of the trade include a flashlight and wood probe such as an icepick, knife, or screwdriver (see Box A).

Over the years additional tools have been developed. Since termites are encouraged by moisture, finding moist areas can help with the ter-

Box A. Biology of Drywood Termites

Pest termites can be roughly divided into two kinds, subterranean and drywood. Subterranean termites live in the ground and forage in wood beneath and above the ground. The most economically important species are the eastern and western subterranean termite, *Reticulitermes flavipes* and *R. hesperus*, and the Formosan subterranean termite, *Coptotermes formosanus*. Subterranean colonies usually maintain ground contact and commute back and forth between soil and structure through mud tubes. When there is a source of water such as a leaking pipe inside a building, a complete colony may reside inside a structure. Subterranean colonies are large, ranging in size from 50,000 to a few million, and a Formosan colony can do significant damage within 6 months (Su and Scheffrahn 1990; Potter 1997).

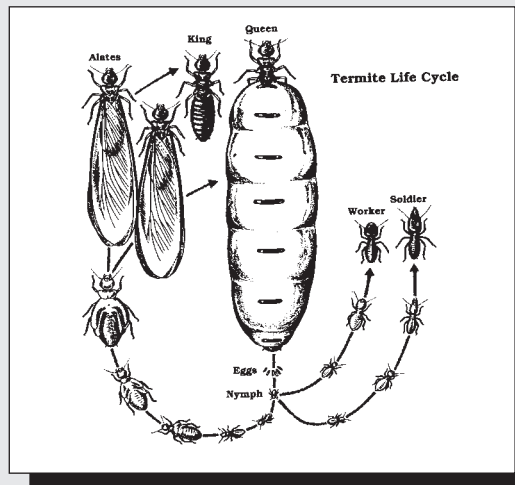
Colonies of drywood termites, such as *Incisitermes* spp. or *Cryptotermes* spp., tend to be small, often containing fewer than 1,000 individuals. They live their entire life cycle inside of wood, except for time spent in reproductive swarming. Swarming drywood termites generally leave the colony between August and November. Reproductive swarms mate, fly around structures looking for cracks or holes, then lose their wings. King and queen crawl into cracks and small holes, excavate further, and start laying eggs that eventually turn into workers, soldiers or reproductives. Termites continue eating, producing hollow spaces called galleries. After 2-3 years annual swarming begins, and the termites infest other wood throughout the structure. A typical colony of drywood termites takes about

four years to mature, and a colony of 1000 might take 7 years to develop. To eradicate, colonies might have to be reduced to less than 20 termites (Lewis 2003; Lewis 2002; Ebeling 1975; Smith 1995; Kofoid et al. 1946).

Signs of Drywood Termites

Current IPM programs for termites are based on regular inspections and early detection. If they can be detected early enough, infested wood can be physically removed, repaired, or treated without great cost. Wings, flying termites, kick-out holes in wood, and especially piles of hexagonal shaped, small BB sized fecal pellets sometimes resembling piles of sawdust are signs of drywood termites. Blisters on paint could hide a colony just underneath. Inspection is a laborious process because all exposed wood on the inside and the outside of the building should be inspected. Frames of doors and windows, eaves, soffits, fascia boards and dormers should receive attention. An infested board has a hollow sound when tapped with a screwdriver or probe (Potter 1997).

Inside, horizontal surfaces should be checked for pellets, window and door frames, doors, baseboards, moldings, paneling, flooring, shelves, bookcases, ceiling beams and even wooden furniture should be inspected. Drywood colonies have even been found in woody plants. In attics, "infestations are commonly found around vents, in rafters, ridgepoles, plates, ceiling joists, roof sheathing, and in general, around the perimeter" (Potter 1997).



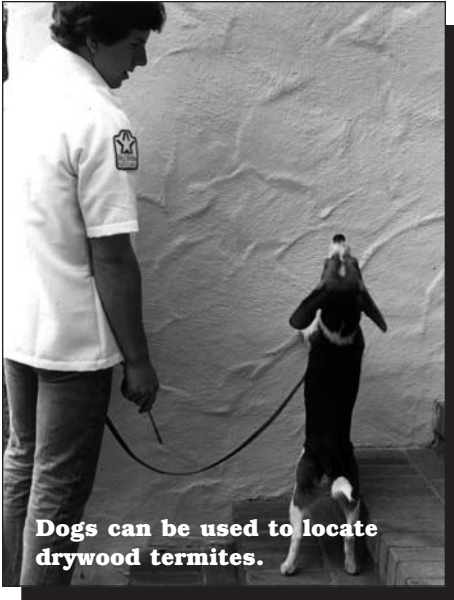


Photo courtesy TADD Dogs

Dogs can be used to locate drywood termites.

mite search. Moisture can be sensed by moisture meters, and these are readily available (see Resources). Another useful tool is the borescope. By drilling holes and inserting a flexible, lighted probe, inspectors can see signs of termites in wall voids without removing the drywall (see Resources).

Other tools include termite-sniffing dogs, and “sniffers”—devices that detect characteristic gases emitted by a termite colony (Brooks et al. 2003; Quarles 2004; Lewis et al. 1997). Acoustic detectors have been developed that can “hear” termites feeding (Quarles 2004; Lemaster et al. 1997; Scheffrahn et al. 1993; Thoms 2000; Dunegan 2001; Lewis et al. 2004). In the last few years, there has been a surge in new detection methods. Detectors using microwave, infrared, lasers, and even X-rays have been commercially developed. Most termite companies do not invest in this technology because of excessive costs and lack of proven efficacy. Most use conventional visual inspection, sometimes augmented with a borescope, an acoustic detector, or a dog (Quarles 2004).

Orange Oil Treatment Method

Orange oil is a local treatment method. When a drywood colony is infested wood, and orange oil is

injected. According to one company’s website, “drill in a staggered pattern from the point of the infestation out 30 inches (76 cm) in all directions.” The schematic on the website shows drill holes about every 5 inches (12.7 cm). If the holes and injections coincide with an active gallery, laboratory efficacy studies suggest (see below) termites in the gallery will be killed by contact. The problem with this method is finding the galleries, one cannot drill and inject into solid wood. Orange oil must be pumped into the hollow spaces where termites are feeding.

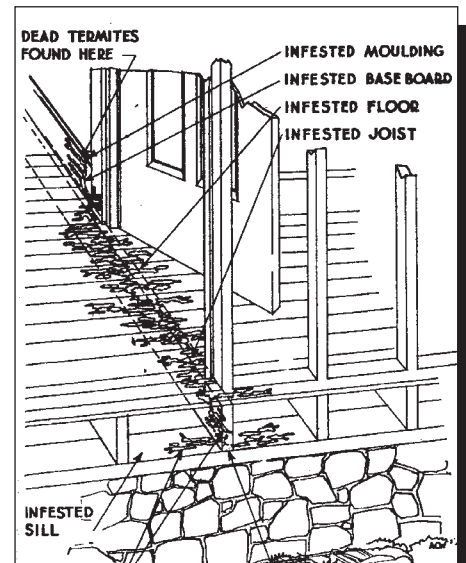
There are anecdotal claims that orange oil “wicks through wood,” and it may do so. However, there are no published studies that show termites can be killed in this way. Orange oil vapor moves by diffusion out of the injected gallery, through the wood and off-gasses into the air. This movement accounts for the odor of oranges in the air that lingers after a treatment. But there is no published evidence that shows this movement produces concentrations large enough to kill termites by fumigant action in a gallery at an appreciable distance from an injection site. From laboratory studies with the Formosan subterranean termite, *Coptotermes formosanus*, orange oil fumigant concentrations of about 5 ppm would have to be maintained for about 5 days (Raina et al. 2007). Professor Rudolf Scheffrahn, who did some of the laboratory efficacy studies believes, “any fumigant action is over a short distance” (Scheffrahn 2008). Further research may be needed to clarify this point. Orange oil research is currently being conducted by Prof. Michael Rust at the University of California (UC) Riverside.

Like a structural fumigation, orange oil does not leave a residual, so once the material has diffused and evaporated, it is no longer effective. One study showed that it dissipates within a week, the orange oil companies say the smell of oranges lingers from three days to two weeks (Raina et al. 2007).

Efficacy of Orange Oil

Despite widespread publicity and promotion, very little has been published in peer reviewed journals on the efficacy of orange oil for termite control. Orange oil will kill termites by contact in laboratory situations. Dr. Rudolph Scheffrahn was hired by XT-2000 to test the efficacy of orange oil injections into infested trunks and branches of Brazilian pepper trees with active galleries of the drywood termite, *Incisitermes synderi*. Infested pieces were 82-144 cm long (32.8-57.6 in) and ranged from about 1-5 liters (approx. 1-5 quarts) in volume. Injections were made about every 5 inches (12.7 cm). Termite mortality ranged from about 48 to 100%. Lowest percent mortalities were in larger pieces that had lower termite densities. Injection volumes of XT-2000 were about 3% of the total wood volume. Termites in pieces injected with water showed no mortality (XT-2000).

Though published experiments with drywood termites are sparse, USDA researchers have recently published experiments with orange oil and the Formosan subterranean termite, *Coptotermes formosanus*. They found that 96% of termites



Orange oil must be injected into active termite galleries. If the injection misses a gallery, termites will not be killed.

Drawing from Kofoid 1946

Update

sealed in a 1.9 liter (0.5 gal) plastic container containing 5 parts-per-million (ppm) of orange oil died within 5 days. Lower concentrations tested showed reduced mortality, but caused termites to reduce feeding. Orange oil vapors came from a filter paper saturated with orange oil suspended from the top of the container. Termites were not in contact with the source, and thus they were killed by fumigant action (Raina et al. 2007).

However, when a wooden mockup of a wall void was used as a test platform, twice as much, or 10 ppm of orange oil, caused only 15% mortality. The researchers believe that the wet wood used in this test absorbed orange oil, making it less effective as a fumigant. Thus, ability of wood to soak up orange oil, may actually work against its action as a fumigant. For fumigant action, enough orange oil must be used to overcome wood absorption and dissipation into ambient air.

Finally, termites were added to glass tubes filled with treated sand containing 0.2% and 0.4% orange oil by weight. All termites were killed by contact with the orange oil within 72 hours. The orange oil was not persistent, and about half of the oil from the 0.4% treatment was gone within a week, and most of it had volatilized within 3 weeks (Raina et al. 2007).

So laboratory experiments show that orange oil is a fumigant, kills by contact, and acts as an antifeedant. Other essential oils have similar properties. Clove oil can kill termites by fumigant action (Park and Shen 2005). Basil and citronella oils kill by contact, act as antifeedants, and are repellent to termites (Sbeghan et al. 2002). Though no tests are available, orange oil may also be repellent.

Field Efficacy of Drywood Termite Treatments

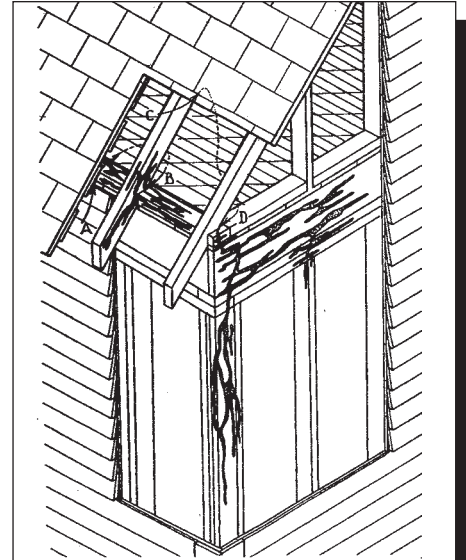
It is not easy to completely rid a structure of drywood termites. Most treatments properly applied lead to a significant reduction of colony numbers, but complete eradication in all cases just does not happen

(Lewis 2003). Even with structural fumigation, some termites may be left alive (Lewis and Haverty 1996), especially if termites are in areas where the wood has high moisture content, because water acts as a barrier to sulfuryl fluoride (Vikane) penetration (Su and Scheffrahn 1986). It may not be necessary to kill all the termites to destroy a drywood colony. If the queen and most of them are killed that may be enough. However, supplementary reproductives can be produced from a queenless colony as small as 20 termites (Smith 1995).

But how can we rate the field efficacy of any particular treatment? There are four possible methods: the termite company can visually reinspect some time after treatment, some kind of instrument can be used to measure termite activity before and after treatment; the treated wood can be removed and destructively sampled; or the customer can act as a quality control agent by calling the termite company back when fresh signs of termites are seen.

The first method is rarely used. Companies usually treat on a one-time basis and do not return unless called back. Acoustic detectors have been used to evaluate field efficacy. Termites make sounds when they feed, and the number of feeding sounds per minute is a measure of activity. Activity is measured before and after treatment to get a measure of field efficacy (Thoms 2000). Because of cost and the technical expertise needed to operate the detector, this method is rarely used (see below).

Destructive sampling is also rarely used. Although infested wood is sometimes removed and replaced, seldom is the wood treated before replacement. So most of the time, field efficacy assessments rely on the customer. Customers see fresh evidence of termite excretions or swarming, and the company is called back for further work. These "callbacks" can be a practical measure of treatment effectiveness, and are often the only measure. A survey of pest control operators (PCOs) by the Bio-Integral Resource Center



Local treatments require that galleries be accessible. Each active gallery must be injected with orange oil to kill termites.

(BIRC) found callbacks on structural fumigations to be 5-15% (Quarles and Bucks 1995). Consistent with this callback estimate of efficacy, Ebeling and Wagner (1964) found that 26 to 37% of all structures fumigated for drywood termites in Los Angeles showed evidence of active infestations within 3 to 5 years. Some of these were reinfestations, but some of this activity undoubtedly reflected a fumigation failure (Ebeling 1975).

Callback rates for treatments other than fumigation are more heavily dependent on the skill of the operator. John Lemm of Cal Western Pest Control in Los Angeles treated over 1200 structures with heat in the 1990s, and had a callback rate of less than 1%. Other heat treatment operators have higher callback rates. According to Phil Holt, former president of Etex, Ltd., the manufacturer of the Electrogun, "the callback rate for Electrogun treatments done properly is probably about 5%. However, companies that do not adhere to treatment guidelines may have a failure rate of up to 25% (Quarles 1999b). This estimation is consistent with a study by Ebeling (1983), who found an Electrogun callback rate of 3 out of 35 or 9%.

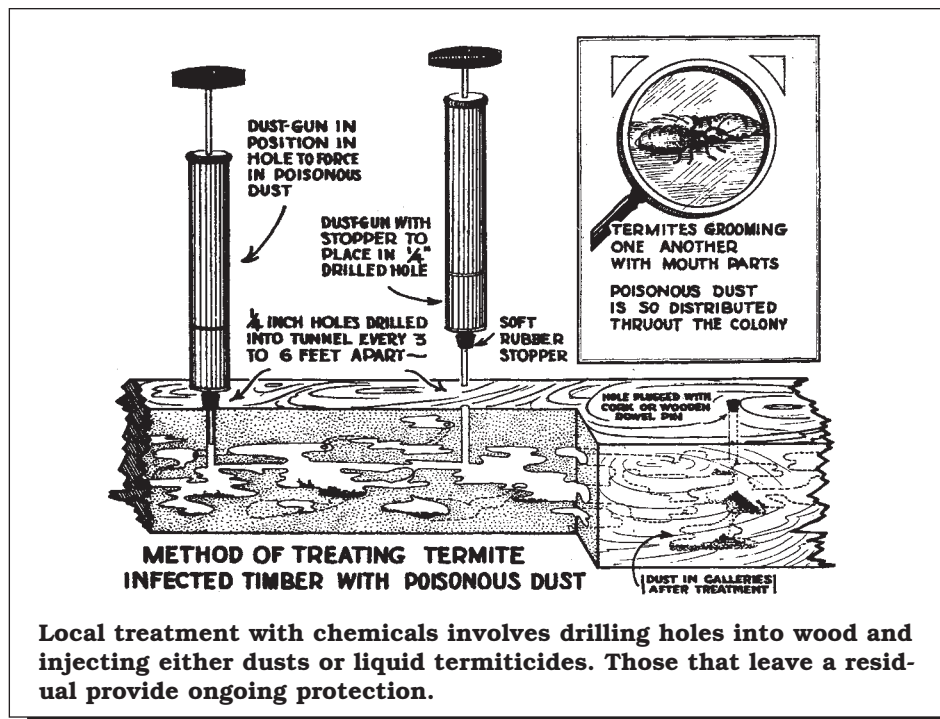
Drawing from Kofoid 1946

Efficacy of Local Injections

The local treatment method of injecting chemicals to kill drywood termites was developed by University of California researchers in the 1930s (Light et al. 1930; Ebeling 1975). Dusts containing arsenic salts or other chemicals were injected into active galleries. Any termites that did not encounter the material initially were exposed to toxic residues as they blundered through the treatment area. There was also transfer of active residues between termites (Randall and Doody 1946; Kofoid and Williams 1946). Many current researchers believe that local treatments work better if termites are presented with lingering toxic residuals. In case an active gallery is missed, surviving termites may encounter lethal residues later (Ferster et al. 2001; Scheffrahn et al. 1997; 1998).

As mentioned earlier, 70% of the time customers choose chemical injections for treatment of drywood termites. Colonies must be accessible, and field efficacy of local chemical treatments depend on the skill of the operator, skill of the termite inspector, and to some degree on the specific treatment chemical (Lewis 2003; Thoms 2000; Scheffrahn et al. 1997, 1998). A number of materials have been tested in the past (Lewis 2003), some of these were very toxic and only a few are currently registered. There are very few published studies covering the field efficacy of chemical injection for drywood termite control that directly compares currently registered materials.

Scheffrahn et al. (1997) found field efficacy measured with an acoustic detector at 1 month after treatment ranged from 22-90% for a number of materials they tested. Thoms (2000) and cooperating PCOs used an acoustic detector to monitor efficacy of spinosad injections for drywood termite control. All colonies tested were totally accessible. Infestations were monitored, then treated. Then effects were checked 1-2 months later with the acoustic detector. Colonies were



Drawing from Kofoid 1946

completely eliminated at 61% of the treated sites, and 90% or better reduction of activity was seen at 89% of the sites. At 11% of the sites, mortality was less than 90%, and these sites required further treatment. These results are probably as good as it gets with local injections.

Woodrow et al. (2006) did a field efficacy simulation by injecting various products into infested loading pallets. Some of the active galleries were part of several interlocking boards. Each board received only one injection of either spinosad, chlorpyrifos, disodium octaborate tetrahydrate (DOT), or resmethrin. Spinosad showed the largest mortality with rates of 53-59%. Because of the limited number of injection sites, some galleries were missed. Thoms (2000) probably obtained better results with spinosad because a larger number of injection sites were used near signs of infestation.

Another experiment by Woodrow and Grace (2005) with imidacloprid, DOT, and spinosad, showed best results with DOT, about 63% mortality. Again, only one injection site per board was used, and some galleries missed treatment. Orange oil practitioners saturate galleries near

signs of infestation with injection holes every 5 inches (12.7 cm).

Sometimes laboratory efficacy studies show good results, but field efficacy is poor. Scheffrahn et al. (1997) found that injections of DOT dust in the laboratory killed more than 80% of termites. Injections in the field killed very few, because "dust applications, which are difficult to inject into wood, yielded sparse coverage in natural gallery systems." Conversely, surface applications of DOT liquid did not kill any termites in the laboratory, because galleries were deeper in the wood than the penetration distance of the borate. Termites were killed in the field with surface applications because colonies were near the surface. The great value of DOT comes as a treatment to prevent termite infestations (Scheffrahn et al. 2001).

Field Efficacy of Orange Oil

Since there are no published studies of orange oil field efficacy, we have to rely on callback estimates given by the practitioners. One of the major orange oil companies is X-Termite, which is owned by Mike Folkins. According to Mike,

Update

X-Termite has treated 15,000 structures with orange oil in the last 9 years. He believes that a fair estimate of the callback rate on orange oil treatments is 5-15%. He believes that success with orange oil depends on intensive structural inspections and extensive treatment of areas adjacent to active infestations. He agrees that there is a lot of misinformation about orange oil, including the claims that termites are killed by citric acid. The registered active ingredient in XT-2000, which is technical grade orange oil, is d-limonene.

According to Nathan Vogel of Orange-X Termite, his company has about a 5% callback rate from orange oil treatments. Most important on keeping callbacks low is treatment of a large enough area so that all active galleries are saturated with orange oil. Vogel believes

are not killed immediately will likely persist.

According to Joseph Grande of Pacific Coast Termite, his company has about a 15% callback rate from orange oil treatments. Inspections rely on standard visual techniques. When a colony is found, orange oil is injected into the active gallery. Since orange oil is not persistent, Pacific Coast uses Boracare® foam as a supplemental treatment in areas near the active infestation. After treatment, any infestations found by the customer anywhere in the structure within a two-year period are treated without charge.

Marketing Claims

Controversies surrounding orange oil treatments are centered on possibly misleading marketing claims. Termite treatments in California are either local treatments such as chemical injections into active termite galleries, or whole structure treatments such as heat or chemical fumigation where all elements of the structure are actually in contact with the lethal agent. According to one company's website, orange oil is a "full structure treatment."

Actually, an entire structure is not treated with orange oil. Standard inspection techniques and an optical instrument called the borescope are used in an intensive visual inspection of all areas that are accessible by these techniques. Any accessible colonies detected receive a local treatment with orange oil. The borescope can increase the efficacy of an inspection by viewing some inaccessible areas, such as wall voids, but whole house termite-free guarantees with a borescope seem optimistic. Accessing some areas, such as behind tile walls or stucco may involve substantial renovation and might be expensive.

In fact, companies usually do not warranty a whole house to be free of termites from a local orange oil treatment. Instead, they offer to come back and locally treat any accessible infestation found upon inspection anywhere in the structure within a one or two year guarantee period (Vogel 2008).

Conclusion

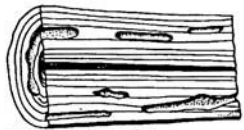
Orange oil is not magic, but it may represent a reasonable local treatment method that can compete with other chemical injection techniques. However, there is some uncertainty, because field, or even laboratory studies directly comparing orange oil efficacy with other products for drywood termite control have not been published. The only field efficacy estimations available are the callback rates given by the termite companies. Based on our limited sampling, orange oil callbacks compare favorably with other options.

Advantages of orange oil are that it has low toxicity and is perceived as a green product. Disadvantages of orange oil are that, like structural fumigation, electrogun, microwave, or heat treatments, it does not leave a residue, and provides no ongoing protection. Other disadvantages are that some people may react to the strong smell of oranges; it is flammable; and care must be used not to damage paint jobs.

The good news is that Californians now have a number of options for treating drywood termites. None of them are magic, none of them are perfect. Non-chemical options, botanicals, and conventional methods are all available. The larger number of choices make it more likely customers can find one that fits their special needs and personal preferences.

Bill Mashek is a licensed California Pest Control Operator (PCO), and is a graduate of the Advanced Urban IPM Program at Purdue University. He is the owner of Northwest Termite and Pest Control in Santa Rosa, CA.

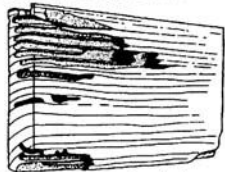
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Drywood, *Kaloterms* sp.



Subterranean, *Reticulitermes* sp.



Subterranean, *Coptotermes* sp.

Damage caused by drywood termites has a different appearance than that caused by subterraneans.

termites are killed by contact, by fumigation action from orange oil vapors, and by eating the treated wood. Typically, about a gallon of orange oil is used in a local treatment. Orange oil does not leave a residue, and according to Vogel, the smell lingers from 3 to 10 days, depending on temperature. When the smell has disappeared, it is likely that any insecticidal action also disappears. So termites that

Drawing from Kofoid 1946