Pest Management Assessment

LEAST-TOXIC ALTERNATIVES FOR ARGENTINE ANTS, FLEAS, AND WHITE GRUBS OF LAWNS

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California Environmental Protection Agency

JANUARY 2001

Report Number PM–01–02

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Acknowledgments

Thanks to Lyn Hawkins, Bob Hobza, Nan Gorder, John Sanders and David Supkoff of the Department of Pesticide Regulation (DPR) for critical review and discussion. Candace Miller, formerly of DPR, helped by assembling a list of active ingredients used for the pests covered by this report. Dennis Kelly of Novartis and Bryan Stuart and Ray Brinkmeyer, both of DowElanco, helped with information requests about specific products. Tom Leffingwell and Lyn Emery of DPR answered questions about active ingredients and located product data volumes, respectively. The following provided some of the literature I reviewed: Kelly Moran, TDC Environmental, San Mateo; John Skarstad, Special Collections, Shields Library, UC Davis; and Charlie Hunter and Lyn Hawkins, DPR. Special gratitude to Kelly Moran, who offered support and encouragement to persevere. Finally, I thank the members of the Urban Pesticide Committee for the impetus to complete this report.

INTRODUCTION

This document presents pest management alternatives to organophosphate insecticides for controlling Argentine ants, fleas, and white grubs of lawns. In California, pesticides used around the home and garden may be released to the environment during handling, mixing, loading, and applying activities. Users may improperly dispose organophosphates such as diazinon and chlorpyrifos if they pour leftover products down drains or into gutters. After application, rainwater may convey pesticides from lawns and other landscaping, outdoor hardscape (e.g., patios, paths, sidewalks, streets, driveways, curbs, and gutters), and other structures into storm drains, which in most of California drain untreated directly to surface waters. For pesticides such as organophosphates that take a few weeks or longer to degrade, entry into sewers or storm drains may lead to contamination of sewage effluent and storm water—and ultimately creeks, rivers, and bays in California (Bailey et al., 2000; Scanlin and Gosselin, 1997) and in other parts of the United States (Kimbrough and Litke, 1996).

The U.S. Environmental Protection Agency (U.S. EPA) has listed 53 waterbodies in California as impaired due to diazinon in urban runoff and seven waterbodies as impaired due to chlorpyrifos in urban runoff as part of the final 1998 section 303(d) (Clean Water Act) list of impaired water bodies in California. As a result of the 303(d) listings and other legal actions, eight Total Maximum Daily Loads (TMDLs) for diazinon and four chlorpyrifos TMDLs have been initiated in California, including at least one in every major urban area of the state. (A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.)

The Bay Area Stormwater Management Agencies Association (BASMAA), a consortium of seven municipal storm water programs in the San Francisco Bay Area, has agreed that diazinon, at extremely low concentrations, is a major cause of toxicity to test organisms (BASMAA, 2000). When diazinon—one of the most popular home and garden insecticides nationwide—is applied outdoors, only 0.3% need run off to be measurable (Cooper, 1996). Diazinon also has a relatively long half-life (40 days) in surface water. In December 2000, U.S. EPA announced an agreement to phase out diazinon for indoor uses beginning in March 2001, and for all lawn, garden, and turf uses by December 2003 (U.S. EPA, 2000).

In California, scientists frequently detect chlorpyrifos used in urban and suburban areas in creeks, streams, and rivers throughout the state (Kratzer, in press). In June 2000, Dow AgroSciences, the registrant of chlorpyrifos-containing products and other registrants agreed to remove certain uses from the label based on health and safety data; by the end of 2001, sales of most home-use chlorpyrifos-containing products will be phased out.

Carbamate insecticides, which include the pesticides bendiocarb, carbaryl, fenoxycarb, and propoxur, are frequently used as alternatives to organophosphates. Carbamates are very water soluble, and like diazinon, commonly detected in runoff, especially in urban areas, and have been found in fog (Schomburg et al., 1991).

Pyrethroid insecticides, currently the most widely used organophosphate alternatives, are synthetic compounds based on pyrethrum, a compound derived from chrysanthemum flowers. Pyrethrin, the naturally derived insecticide, is often combined with piperonyl butoxide (PBO), a synergist. Pyrethrins are unstable in light or air, and are rapidly degraded in sunlight and in water. However, the toxicity of pyrethroids in waterbodies is of great concern—aquatic concentrations in the part-per-trillion range have been identified for several pyrethroids (the U.S. EPA ECOTOX Database System summarizes and references studies showing such toxicity). In November 1997, U.S. EPA granted conditional three-year re-registrations for ten common pyrethroids and required manufacturers to conduct detailed studies of their toxicity to aquatic invertebrates and fish. Environmental persistence and surface water runoff potential may be of concern as well—although available data are limited, runoff at one agricultural site was found to contain pyrethroids at detectible levels 45 days after application (Antonious et al., 1997.)

Because organophosphates, carbamates, and pyrethroids potentially contaminate surface water, we recommend the following decision-making process based on principles of integrated pest management (IPM) to manage Argentine ants, fleas, and white grubs of lawns in and around the home.

- Identify the pest correctly and monitor for its presence.
- Modify the pest habitat (e.g., caulking; sanitation; planting native trees and shrubs, or plants without major pest problems).
- Use non-chemical practices (e.g., trapping, baiting, biological control) that pose the least possible hazard.
- If pesticides are necessary, use effective, registered pesticides that pose the least possible hazard (low toxicity and minimal exposure).

We believe following this IPM decision-making process will lead to using the least-toxic pest management practices to manage these pests.

LEAST-TOXIC ALTERNATIVES FOR ARGENTINE ANTS

In California, the Argentine ant, *Linepithema humile* (formerly *Iridomyrmex humilis*), is the most common ant found in urban areas (Powell and Hogue, 1979). Argentine ants travel toward food sources and nesting sites in trails marked by pheromones (ant-specific olfactory attractants). They prefer sweet foods; 99 percent of their diet is made up of honeydew and nectar. When honeydew—the sweet excretion produced by some insects—is in short supply, Argentine ants seek out almost anything else, often entering buildings in their search. Although Argentine ants displace native ant species, they also kill various insect pests (including flea larvae and subterranean termites), help aerate soil, and aid in breaking up dead animal and vegetable material.

Argentine ants arrived in Louisiana from South America in the 1890s and soon made their way to California, quickly out-competing native ants in disturbed areas (Ward, 1987). Unlike most other ant species, Argentine ants form extended, coalesced colonies with multiple egg-laying queens, often encompassing tens of thousands of individuals. The expansiveness of Argentine ant colonies often makes eradication unfeasible; persistent management is usually the only option.

Ant populations build up in spring and early summer coinciding with high populations of honeydew-producing insects such as aphids, mealybugs, psyllids, and scale insects. During late summer and fall, the dwindling supply of honeydew and nectar can no longer support the expanded Argentine ant population, and the ants become invasive (A. Slater, pers. comm.). Colonies are relocated when disrupted by flooding, drought, or other disturbances.

Monitoring for ants indoors requires being watchful for one to a few scout ants foraging on counters, around garbage receptacles, or anywhere food is available (Olkowski et al., 1991). Once a scout senses food, other ant workers are alerted and follow the scout's pheromone trail to the food source; killing scouts or eliminating the pheromone trail prevents invasion by the rest of the colony.

Physical and Cultural Practices

Sanitation—Argentine ants are primarily attracted to sugary food, but will often seek protein-containing food and water. To stem huge aggregations of ants, food should be transferred to glass jars or plastic containers with tight-fitting lids. Boxes of sugar, jars of honey, and anything sweet should be placed in the refrigerator or freezer. Teflon-coated pet bowls prevent ants from crawling into pet food. Ants traveling in trails can be squirted with soapy water and wiped up (Daar et al., 1997). Soapy water alone will effectively dissolve pheromone trails and is sufficient for containing small infestations. Mass-marketed aerosol insecticide sprays kill workers, but rarely get carried back to the colony to kill queens.

Barriers—Possible entry points should be closed off and access to food and garbage eliminated, although these strategies do not always solve the problem. Also, ants sometimes enter through spaces that are not easily sealed. Cracks or holes can be caulked with silicone seal. Two caulking products contain both silica aerogel for long-term control and pyrethrins for quick knockdown (Whitmire PT 230 Tri-Die® and Drione®).

Preventing access to honeydew-producing insects (aphids, mealybugs, psyllids, and scale insects)— During spring, Argentine ant populations build up in direct response to the availability of honeydew. Many of the honeydew producers such as aphids that attract ants are found on common landscape trees and shrubs such as Chinese elm, citrus, deodar cedar, European white birch, linden, Monterey pine, oleander, rose, and tulip tree (Steve Suoja, pers. comm).

Argentine ants often aggravate biological control efforts of honeydew-producing insects because they deter natural enemies. A band of sticky barrier material or Teflon banding can be placed around tree trunks, after trimming branches that serve as bridges for the ants. If ants have access to hummingbird feeders or hanging plants, using a Teflon spray is recommended. Pests of some plants such as black scale on citrus can be managed by simply banding the tree and excluding Argentine ants. In many landscapes, homopterous insects infest an assortment of plants, and ant exclusion is unfeasible. Strategically placing ant baits around these plants may attract workers who will spread the poison around the nest and help eliminate queens during the critical population-buildup phase.

Chemical Control

Sprays—Perimeter treatments every 2–4 weeks using either a wettable powder or microencapsulated insecticide (usually an organophosphate or pyrethroid) is still advocated by many pest control operators (PCOs) to prevent foraging worker ants from entering homes (Hedges, 1994). These insecticides poison some foraging workers, but not the queens. The colonies in the treated area may seemingly disappear, only to reappear intact a few weeks later.

Most diazinon products used for Argentine ants are formulated as sprays for perimeter treatments. Many of the products contain 0.5% diazinon plus 0.052% pyrethrins and 0.26% piperonyl butoxide (PBO). Dusts and microencapsulated products are also available. Although diazinon is highly toxic to ants, it fails to reach most of the queens and workers.

Pyrethroids quickly kill ants upon contact, but are not recommended for long-term control of ant colonies (Tucker, 1996). Examples of pyrethroids used for rapid-knockdown perimeter treatments include cypermethrin, deltamethrin, and tralomethrin.

Organophosphate and pyrethroid sprays are also used for soil drenches, although outdoor colonies can be flooded with a potash-based insecticidal soap solution. Argentine ant colonies usually move after one or more floods.

Aerosols—At least one hundred aerosol products for ants are registered in California (DPR, 2000). Aerosols are primarily used by the general public, rather than by PCOs. Most aerosol products (various formulations of Raid® or Black Flag®, for instance) contain mixtures of pyrethroids such as cypermethrin, permethrin, or tetramethrin. Some products also contain pyrethrins or the carbamate propoxur.

Baits—In recent years, rapid-knockdown sprays have lost favor to slow-acting baits containing avermectin (abamectin), boric acid, fipronil, hydramethylnon, and sulfluramid. Baits with small amounts of toxicant increase the likelihood that foraging worker ants survive long enough to transfer the poison to their nestmates—other workers and queens. Within two to three weeks the poison weakens nearby colonies, greatly reducing the number of workers. Surviving workers often narrow their foraging range and no longer enter structures. One disadvantage of slow-acting baits is that Argentine ants are not instantly killed. Because the bait offers a reliable food source, both workers and queens may forage together, and the numbers of ants may suddenly seem to increase. However, once the queens assist in foraging, the entire satellite colony is probably feeding on the bait, and ant numbers taking the bait will soon dwindle (pers. obs.).

Baits are available in gel, granular, or liquid forms and are often housed in plastic disc stations, thus preventing children and pets from contacting the pesticide. The stations must allow ants easy access to feed on the bait, must be child- and pet-resistant, and at the same time, must prevent liquid bait solutions from evaporating. PCOs often purchase bait and stations separately because prefilled stations are more expensive. Some do-it-yourself bait stations have two compartments to accommodate an additional type of bait, ensuring that ants will feed on at least one bait. PCOs can also inject gel baits into cracks and crevices.

Avermectin-containing baits come in both gel and granular forms (e.g., Prescription Treatment Advance® and Raid® Granular Ant Bait), both 0.011% avermectin. Most boric acid baits are formulated as gels and contain 4–5% boric acid; some also combine 4–5% borax (e.g., Drax® and Niban®), and are available as either sugar or protein attractants, or both combined. Several products contain 1% or less boric acid. The lower concentration decreases the possibility of poisoning worker ants before they transfer the bait to the queens. Fipronil, a relatively new active ingredient with a unique mode of action, is found in two bait products for ants (Maxforce® FC Professional Insect Control Ant Bait Stations and Combat Outdoor Ant Stakes®) at a 0.01% concentration. Baits containing hydramethylnon, a delayed-action metabolic insecticide, include Maxforce® (available in gel or granular forms, or as bait stations—all 1% hydramethylnon) and Combat® also in various formulations at 1% hydramethylnon. About a dozen sulfluramid-containing ant bait products are registered, all with 0.5% active ingredient. Baits enclosed in metal stakes are also available to the public—two ant stake products are formulated with 0.46% arsenic trioxide (Grant’s Ant Control™ and Grant’s Kills Ants™).

Baits containing chlorpyrifos (e.g., Affront™) come in both granular and gel forms for spot and crack and crevice treatments, but because chlorpyrifos is a contact poison, worker ants may die before transferring the poison to the queens.

Bait in stations or stakes that becomes too concentrated may repel ants or kill foraging workers before the poison is transferred to the queens. Liquid organophosphate or pyrethroid insecticides sprayed near the bait will also repel ants, rendering the bait useless.

Dusts—Dusts are dry formulations applied ready to use out of the container to inaccessible areas such as cracks and voids. (Dusts are not the same as caulks, which are described earlier under *Physical and Cultural Control*.) Insects contact the dust by crawling through it. Dusts combine active ingredients such as pyrethrins plus an activator, piperonyl butoxide (PBO), and an inert carrier; often the carrier also has insecticidal properties (Hedges, 1996). Carriers include the abrasives and desiccants silica aerogel and diatomaceous earth (DE), and boric acid, which is both an abrasive and a stomach poison. Dusts are generally not recommended for use in damp areas such as crawl spaces, although one pyrethroid-containing product, DeltaDust®, claims to be relatively waterproof.

Dusts containing DE take several days to kill ants. DE, the fossilized remains of silicaceous plankton, is nontoxic to mammals but can irritate the lungs if inhaled. Boric acid dusts, which also should not be inhaled, are also slow acting. Ants disperse the dust over their body and pass it on to other colony members through grooming.

Repellents—Ideal repellents keep areas free of ants, and can be used around food-preparation areas, garbage cans, and floors. One product sold as a repellent, Orange Guard®, contains 5.8% of the active ingredient d-limonene, an extract of citrus. (D-limonene also appears in flea and tick shampoos—see page 9 for more information about these products.) According to one study, Orange Guard repels ants for at least three days (Donahue, 1997).

Unregistered home remedies, such as insecticidal chalk, are often used indoors and outdoors, but these may be dangerous or ineffective.

Biological Control

Argentine ants originated in a part of South America that includes southern Brazil. There, the ants are parasitized by small flies in the family Phoridae. Adult phorids in the genus *Pseudacteon* directly attack foraging worker ants, actively preventing the ants from gathering food (Orr and Seike, 1998). The ants abandon food such as honeydew and return to their nest underground. Although studies show that *Pseudacteon* effectively limits Argentine ant populations in Brazil, the flies may be too host-specific to attack the somewhat genetically different populations in the U.S. (M. Orr, pers. comm.). In Brazil *Pseudacteon* does not inhabit disturbed areas, so it is not known whether the phorids would do well in the U.S. in areas where Argentine ants are normally found.

Conclusion

One of the most important ways to manage Argentine ants is by limiting access to honeydew-producing insects and using well-placed baits outdoors. Indoors, sanitation and slow-acting baits will help prevent or shrink an active infestation. Useful baits incorporate avermectin, boric acid, fipronil, hydramethylnon, and sulfluramid. Chlorpyrifos-containing baits kill workers before the poison is transferred to the queens and are therefore not as effective as slow-acting baits.

Perimeter sprays containing organophosphates or pyrethroids may kill foraging workers quickly, but do not reach the queens. Because organophosphates and pyrethroids applied as liquids or aerosols often repel workers, they are a poor choice to use with baits, and are not recommended for long-term control of ant colonies. Limiting the use of these pesticides to manage ants also reduces the potential for surface water contamination.

Least-toxic Alternatives for Fleas

The cat flea *(Ctenocephalides felis)* is the most common flea found on cats and dogs. Cat fleas attack people and wild animals when feline or canine hosts are unavailable, or when flea populations build up to enormous levels. They can spread the dog tapeworm and their bites may lead to allergic dermatitis. People who develop allergies to flea saliva may experience itchiness and red, swollen welts. Animals lose hair and aggravate the condition further by biting and scratching the itchy, inflamed area.

Eggs of fleas resemble grains of salt, and are usually deposited around the pet's sleeping area, carpeting, and furniture. After 2–12 days, they hatch into tiny, whitish, wormlike larvae measuring 1/16 to 1/5 inch in length, which feed on organic debris and on the blood-rich feces of adult fleas. Larval development takes 8–24 days, but under adverse conditions the larvae may not spin a cocoon for six months or longer. The larvae require relative humidity of 50 percent or higher. The filmy, silken cocoons (or pupae) are often camouflaged by particles of dirt and dried blood. The pupae remain inert for one to two weeks until the warmth and movement of a host is detected—if the pupae are not stimulated by temperature or vibration, they can remain dormant for almost a year. Adult fleas may survive several months without a blood meal, prefer temperatures ranging from 65°F–80°F, and relative humidity of 70 percent or higher. The adults are nest parasites, spending the majority of their time on the host or in the host's bedding. Under ideal conditions, female fleas can lay up to 1,000 eggs.

Monitoring

Bathing a pet using a non-insecticidal pet shampoo is a way to estimate the flea population and gives the pet relief during severe infestations. Combing pets with a metal flea comb, available at pet supply stores, also provides a baseline for determining whether the flea population is rising or declining. While combing, fleas become entrapped between the tines and drown after the contents of the comb are dipped into a container of soapy water. (A few drops of soap added to the water breaks the surface tension; otherwise the fleas can escape. The water does not have to be sudsy.) The comb should be wiped off between immersions to avoid getting the pet's coat soapy. (See *Bathing and grooming* below for information about bathing and combing to reduce the number of fleas on the pet.) Areas where fleas are concentrated, both indoors and outdoors, can be determined by walking around in ordinary white socks. Light traps effectively monitor flea populations (Dryden and Broce, 1993). Pulsating light traps that emit greenish-yellow light attract more adult fleas than those using incandescent bulbs or nonpulsating green lights. The light traps, which include directions explaining monitoring strategies, attract adult fleas from carpeting and upholstery up to 20 feet away. When bathing, combing, or trapping, numbers of fleas can be recorded to estimate the flea population.

Prevention

If there is a history of large infestations an early start with an insect growth regulator (IGR) is recommended (see discussion on page 8). Indoor treatment in early spring with an IGR product containing methoprene or pyriproxyfen will prevent juvenile fleas from maturing.

Cultural Practices

Sanitation—During a major infestation, carpets and floors should be vacuumed daily, making sure areas under furniture are reached, crevices of couches and chairs, and anywhere the pet has slept. The vacuum bag should be wrapped in a plastic bag and either placed in the freezer until the next vacuuming, or out in direct sunlight for a few hours. (Cat flea larvae die if exposed to heat over 102°F for one hour.) Vacuuming will rid the house of organic debris, flea feces, and flea eggs. Rugs covering wooden floors should be laundered, or steam or dry cleaned, rolled up, and stored until the worst of the flea infestation is over. Bare floors are easier to keep clean—otherwise flea larvae cling to the carpet fibers and cannot be pried loose with vacuuming. If carpets cannot be removed, steam cleaning will kill most of the larvae, pupae, and adults. However, the warmth and humidity of the steam often sets off a mass hatching of remaining flea eggs, requiring another steam cleaning.

Pets should sleep on washable bedding, washed once weekly, to kill flea eggs before they hatch. Pet owners should note any other out-of-the-way resting places of pets (Hedges, 1991). Cats frequently crawl under beds, into closets, and on top of bookcases, and these areas should be vacuumed or wiped down.

Bathing and grooming—Dogs and willing cats should be bathed with a mild pet shampoo to dislodge and drown fleas. It is recommended that pets be thoroughly rinsed and irritation of sore spots avoided. Shampooing alone will not remove all fleas; regular flea combing is essential. The pet should be relaxed when combing, avoiding abrasion of scabs or sore spots. Combing also removes flea feces and eggs that provide food for flea larvae. When pets are combed often, the flea population may be kept under control.

Chemical Control

Quick-knockdown materials—Products designed to kill fleas rapidly are formulated as liquids, aerosols foggers, collars, and shampoos. They contain various active ingredients such as organophosphates, carbamates, pyrethroids and pyrethrins. Liquids and aerosols, sprayed indoors or outdoors, can thoroughly cover an area. Foggers, which are pressurized cans that release the product in a mist, allow only minimal coverage of carpeting or furniture, areas preferred by fleas. Collars do not kill all fleas on an animal and, depending on the active ingredient and its concentration, can be hazardous to people and pets. Ultrasound collars, or ultrasound devices of any type, do not repel fleas (Noxon, 1998). Shampoos can pose problems to the environment because the waste water runs down bathtub drains, or—if a pet is bathed outdoors—into storm drains. The waste water then enters sewers or creeks untreated.

Organophosphate insecticides such as chlorpyrifos, propetamphos, and diazinon—and the carbamate bendiocarb—have been favored by PCOs because these materials are relatively odorless, non-staining, and persistent against flea larvae and adults for up to 30 days (Jones, 1993), but these insecticides can contaminate surface water. In California, only one propetamphos product remains registered. Bendiocarb-containing products such as Ficam® have not been registered since 1993.

Over 60 shampoos, sprays, collars, and other pyrethrin-containing products are registered in California for use on dogs and about 20 products are registered for cats (DPR Product Label Database, 2000).

Several pyrethroids, synthetic versions of pyrethrins, are used for all stages of fleas, and especially adults. Pyrethroids, also combined with PBO, are gaining favor in management programs used by PCOs, most notably permethrin, cyfluthrin (Tempo®), tralomethrin (Saga®), and deltamethrin. Although pyrethroids have low mammalian toxicity, they may contaminate water before degrading. However, most are formulated at low concentrations (tralomethrin in Saga is 0.05%) and used at low rates.

Slower-acting materials (including repellents)—Borax or boric acid, formulated as dusts or liquids, desiccates flea larvae. Fleabusters®, a national flea control company, uses sodium polyborate on carpeting to kill flea larvae, guaranteeing effectiveness for one year. Fleabusters also sells three-pound containers of the product it uses commercially, Rx for Fleas Plus®, for home use. Biotrol™ Carpet Powder also contains 64% boric acid and is formulated to minimize inhalation and exposure to skin or eyes. Although boric acid has low mammalian toxicity, one of its potential drawbacks is the amount of dislodgeable residue in the form of dust when used at the directed rate (Kramer, 1996).

Citrus oil extracts include D-limonene and linalool. D-limonene in low concentrations is a food additive; at higher concentrations it kills larval and adult stages of fleas. One product, VIP Pet Spray®, can be applied directly to the pet or sprayed on animal bedding. Demize® E.C. contains 37% linalool with 40% PBO; label directions advise mixing it with IGRs. If used above suggested label rates, citrus oil extracts can harm cats (Bio-Integral Resource Center, 1996).

Oil of citronella is derived from a grass (*Cymbopogon nardus*) native to Southern Asia and used as a repellent and insecticide. Most of the 22 citronella-containing repellents registered for use on the human body mention activity against fleas on their labels (DPR Product Label Database, 2000). Most Avon Skin-So-Soft® products contain 0.05% citronella oil, Buzz Away® contains 5%, and two Natrapel® repellents with aloe contain 10%.

Insecticidal soaps are useful for spot treatments of areas indoors and outdoors where pets rest. When used outdoors, soap should be directed toward areas of intense infestation (hotspots); otherwise, beneficial insects will be affected (Bio-Integral Resource Center, 1996).

A recently registered active ingredient in California (1997), spinosad, is produced from fermentation products derived from *Saccharopolyspora spinosa*, a newly discovered species of actinomycete bacterium. Conserve™ SC, the turf and ornamental product, is primarily effective against moth larvae, gall midges, and some beetles (DowElanco, 1997). According to the label, Conserve can be used on turf to control adult and larval cat fleas, and again seven to 14 days later to control newly emerged adults. It cannot be used directly on pets.

Diatomaceous earth (DE), described in the ant section, kills fleas in any stage through dehydration. The agricultural or food grade DE should be used; DE used for pool filters is too coarse and contains toxic impurities (Olkowski et al., 1991) and is not registered for use against fleas. The concentration of DE varies among products from 75% to 100%. Product labels suggest wearing a mask and goggles when applying DE; the food grade DE is not orally toxic, but can irritate lungs and eyes. DE is easily vacuumed up from carpeting but should not be applied directly to carpeting underneath furniture.

The IGRs methoprene (Precor®, FleaTrol®, Ovitrol®, Siphotrol®, Petcor®), fenoxycarb (Torus®), and pyriproxyfen (Nylar®, EctoKyl®) prevent larval fleas from becoming adults. Adult fleas remain untouched, which is why many IGR products are formulated with an insecticide (usually a pyrethroid or OP) that targets adult fleas. IGRs are best used indoors preventively—early spring in California, for instance—and when used with sanitation and good grooming practices. IGRs are available in several formulations, including liquids, foggers, and collars; liquid versions have been shown to last longer than foggers. IGR products may be used on carpets and pet bedding. Fleas develop resistance to IGRs, so these materials should be used sparingly. Also, because IGRs have broad-specrum activity, using IGR products outdoors may kill beneficial insects (see *Biological Control* below).

Long-lasting Topical Flea Adulticides—Advantage™, a product used directly on dogs and cats once a month, was introduced in the mid-1990s. The concentrated imidacloprid penetrates the animal's skin, entering the hair follicle. Because Advantage is an insecticide that kills adult fleas, it does not have to be used preventively. According to the manufacturers, Advantage kills almost 90 percent of the adult fleas on the animal in 8 hours, and 98–100 percent within 24 hours. Like Advantage, fipronil-containing Frontline® or Top Spot™ can be used monthly on dogs and cats, and remain effective even after bathing or swimming. The products are applied between the shoulder blades, as is Advantage.

Systemic Insect Growth Regulators—Program® is a type of IGR known as a chitin synthesis inhibitor or more broadly, insect development inhibitor. The active ingredient, lufenuron, is absorbed into fat and slowly leaches out for 30 days, preventing flea eggs from hatching and larvae from molting (R. Lynn, pers. comm.). Pets are given one pill per month during flea season, preferably starting in early spring, or one injection every six months. Program does not kill adult fleas; its use must be combined with good sanitation and grooming. Program and Advantage became available through veterinarians around the same time. According to one veterinarian, Advantage is now preferred by most pet owners in her practice because it also kills adult fleas (K. True, pers. comm.).

Biological control

Flea-attacking nematodes, *Steinernema carpocapsae*, are soil-dwelling roundworms that are used outdoors for flea hotspots. The nematodes do not harm mammals or beneficial soil organisms such as earthworms (Daar et al., 1997). They supposedly control 99 percent of the flea larvae and pupae within two days and are effective for up to three months with adequate irrigation. Nematode-containing products can be applied by pet owners or PCOs.

Conclusion

In the past, pest management of fleas by PCOs and pet owners relied heavily on rapid-knockdown products used on pets and inside houses, especially aerosols, shampoos, and foggers. Monitoring was not part of the pest management scheme. When insect growth regulators (IGRs) were first introduced, they freed pet owners from relying primarily on chemical control. The availability of topically used imidacloprid, which is absorbed into the pet's hair follicles and kills fleas for a month, drastically changed pest management practices for fleas. Use of less toxic pesticides such as borates should accompany the sanitation, bathing, and grooming practices described above to reduce the potential of surface water contamination through disposal of unused products or outdoor treatments. IGRs should be used sparingly to prevent flea resistance and avoid killing nontarget beneficial insects.

LEAST-TOXIC ALTERNATIVES FOR WHITE GRUBS OF LAWNS

In California, lawn grubs, which are larvae of scarab beetles, can cause major damage to lawns in late spring by destroying grass roots. Once feeding damage is severe, the grass dies back and brown spots appear. Lawns can also be damaged indirectly by hungry raccoons that dig up lawns in search of grubs (Ali and Harivandi, 1987). Once the raccoons find a good source of grubs, they often return and tear up the lawn looking for food.

The different grub species resemble each other—all are white to gray with brown head capsules, ½–1 inch long when fully grown, and often curled in a C shape. Masked chafers (*Cyclocephala* spp.) are the most common white grubs in California (Ali and Harivandi, 1987). *Cyclocephala hirta* occurs throughout California; *C. pasadenae* is found in Southern California (University of California Statewide IPM Project [UC IPM], 1997). Masked chafers and the less-common May and June beetles (*Phyllophaga* spp.) have similar life cycles. In late spring to early summer the adult beetles mate and lay eggs in soil. The beetles can often be seen at night when males are attracted to lights and buzz around porches or enter houses (Powell and Hogue, 1979). The grubs hatch during summer, feeding on roots and thatch, the layer of dead grass roots and stems. Damage from feeding becomes most noticeable during the late summer and early fall as irregular brown patches (UC IPM, 1997). During winter the nearly mature grubs burrow deep in the soil to hibernate, pupating in spring, and emerging as adults in late spring. The adults live for only one or two months. In other parts of the U.S., May and June beetles have three- and four-year cycles, remaining grubs for most of that time (Davidson and Lyon, 1979).

Although masked chafer grubs damage all turf species, rye and bluegrass mixtures are more susceptible than fescue or Bermuda grass (Ali and Harivandi, 1987; UC IPM, 1997). As the grubs destroy the root layer, the turf becomes spongy and can be rolled back like a carpet (Ali and Harivandi, 1987). Besides attracting hungry raccoons, other animals such as skunks, moles, crows, and blackbirds dig up lawns searching for the grubs.

Monitoring

Mammals or birds digging up the lawn in late spring are an indication that grubs are feeding below the surface. If present, grubs can often be found by digging around the grass roots. If the lawn can be easily rolled back, grubs will be exposed along the soil surface (Bone, 1996). One grub per square foot indicates that treatment is needed. However, the grubs are not evenly distributed, so several locations of turf must be sampled.

A commonly used method for detecting a number of turf pests, the pyrethrum test, does not work for lawn grubs (Bone, 1996). To test for cutworms, skipper larvae, and sod webworms, one tablespoon of 1–2% pyrethrum insecticide is added to one gallon of water and, using a sprinkling can, applied evenly to one square yard of turf. The pyrethrum solution irritates most of the insects in the thatch and root zones, causing them to surface, which allows proper identification and appropriate treatment.

Proper identification of turf pests is critical because brown patches can be caused by chemical, physical, or mechanical agents, or by pests or disease. Possibly 85 percent or more of turf problems arise from improper watering (Bone, 1996).

Chemical Control

In their most recent (1987) advisory leaflet, U.C. Cooperative Extension recommends chlorpyrifos (Dursban) or diazinon (Ali and Harivandi, 1987). The UC IPM Pest Management Guidelines list imidacloprid (Merit), carbaryl (Sevin), chlorpyrifos, diazinon, and trichlorfon (Dylox). Merit, a systemic, is frequently used preventively in the Bay Area in late May to early June, while in inland areas such as the Sacramento Valley infrequent grub problems are treated when they arise in late summer with granular diazinon or chlorpyrifos (C. Smith, pers. comm.).

Organophosphates such as diazinon and chlorpyrifos, and carbamates such as carbaryl have been detected in creeks in the San Francisco Bay Area and Denver, Colorado (Scanlin and Gosselin, 1997; Kimbrough and Litke, 1996). If applied to turf, these compounds (and the organophosphate–organochlorine compound trichlorfon) could potentially run off into storm drains and contaminate creeks. Of the synthetic pesticides registered for use on lawns for white grubs—diazinon, chlorpyrifos, carbaryl, trichlorfon, and the nicotinoid compound imidacloprid—the latter is selective (Kenney et al., 1998) with low toxicity to fish, although it is fairly toxic to aquatic invertebrates (Extension Toxicology Network, 1998).

As mentioned in the section on fleas, a new reduced-risk product, Conserve SC, containing the active ingredient spinosad is registered for use on turf. Although effective only against some lawn pests (cutworms, sod webworms, and armyworms), these pests are often responsible for the symptoms blamed on white grubs.

Biological control

Tiphiid wasps commonly parasitize masked chafers, but do not help reduce grub populations below damaging levels. White grubs are not infected by the nematode, *Steinernema carpocapsae*, which control sod webworm, billbugs, cutworms, armyworms, and other turf pests (UC IPM, 1997). Two other commercially available nematode species, *Steinernema glaseri* and *Heterorhabditis bacteriophora*, infect chafers. The nematodes should be applied in late spring to early summer before adult beetles emerge, or early fall when most chafers are susceptible to infection. The nematodes easily become desiccated, so are best applied to irrigated—not waterlogged—turf. The lawn should be watered regularly for two weeks after the application to keep soil moist, and nematodes applied during the morning or evening in hot areas.

Bacillus popilliae, a bacterium that causes milky spore disease among scarab grubs, is most effective against the Japanese beetle, a damaging pest occasionally introduced into California (Parrella, 1986). When detected, the beetles are immediately eradicated by the California Department of Food and Agriculture. Evidence to date does not indicate that *B. popillae* affects white grubs, and products containing the bacterium are not registered in California.

Cultural practices

Proper watering helps prevent excessive buildup of the thatch layer. Watering should be uniform and long enough in duration so the water percolates 6 to 8 inches below the soil surface. To prevent fungal diseases, the optimal time for watering in California is 2:00 AM to 4:00 AM (Steve Zien, pers. comm.).

Aeration of the soil during the peak growth period—either with a foot- or gas-powered coring tool—improves drainage and allows soil-dwelling microbes and arthropods to decompose the dead grass in the thatch layer (Olkowski et al., 1991). The decomposition process reduces the thickness of the thatch layer. When the thatch becomes impenetrable, moisture becomes entrapped, encouraging disease organisms to thrive. A well-aerated thatch layer permits grass to grow more vigorously and tolerate some feeding by white grubs.

When used during the summer, spiked sandals (e.g., Spikes O' Death®) serve two purposes—aerating the turf and jabbing white grubs feeding near the surface. The sandals are available by catalog and at some nurseries.

Conclusion

Proper watering and adequate aeration and fertilization are essential for healthy turf. Together, these cultural practices discourage infestations of white grubs of lawns. The use of organophosphates and carbamates to manage grubs is unnecessary given the potential for contamination of surface water and the availability of effective alternatives such as nematodes.

Active ingredients found in products registered in California for control of ants (A), fleas (F), and/or white grubs of lawns (G). Common names are listed alphabetically; trade names, if they exist, follow in parentheses.

Active Ingredient	Pest(s)	Comments
Acephate[a] (Orthene)	A	Organophosphate. Systemic broad-spectrum insecticide with contact and stomach action.[2]
Allethrin (Pynamin)	A	Pyrethroid. First synthetic pyrethroid developed (1949).[1] Nonsystemic insecticide with contact, stomach, and respiratory action; rapid knockdown. Usually formulated as an aerosol for ants. Low solubility in water.[2] (See also *d-trans* allethrin and S-bioallethrin, which are allethrin stereoisomers.)
Arsenic trioxide	A	Inorganic.
Avermectin or abamectin	A	Antibiotic. Contact and stomach action. Natural product of the soil microorganism *Streptomyces avermitilis*.[2] No bioaccumulation; rapid degradation in soil.[2]
Azadirachtin or neem	G	Botanical (derived from seeds of the neem tree). Disrupts insect molting and deters feeding. Shows residual insecticidal activity for 7 to 10 days.[1]
Bendiocarb (Ficam®)	A, F	Carbamate. Systemic insecticide with contact and stomach action; rapid knockdown; residual activity.[2] Toxic to fish; label cautions against contaminating water bodies with product.[1] Half-life in soil: several days to a few weeks.[2] *(No products currently registered.)*
Bifenthrin (Talstar®)	A, F	Pyrethroid. Contact and stomach action. Half-life in soil: 7–62 days.[2] Toxic to *Daphnia* at 0.0016 mg/L.[2]
S-bioallethrin	A, F	Pyrethroid. Nonresidual insecticide with rapid knockdown action. Introduced in 1972; several times more effective than allethrin against insects.[1] Formulated as aerosols and sprays.
Borax and boric acid	A, F	Inorganic. Persistence in soil ≤ 2 yrs.[2] Stomach poison and abrasive.
Carbaryl (Sevin®)	A, F, G	Carbamate. Insecticide with contact and stomach action and slight systemic properties. Half-life in soil: 7 to 28 days.[2] Toxic to nontarget species (e.g., honey bees). Found in surface water.[6]
Chlorpyrifos[a] (Dursban®)	A, F, G	Organophosphate. Broad-spectrum, nonsystemic insecticide with contact, stomach, and respiratory action. Half-life in soil: 60–120 days.[2]
Cyfluthrin (Cy-kick®, Tempo®)	F	Pyrethroid. Nonsystemic insecticide with contact and stomach action.[2] Various formulations. Exceptionally toxic to *Daphnia magna* (LC_{50} = 0.14 ng/L).[2]

Cypermethrin (Demon®, Suspend®, Ammo®)	A, F	Pyrethroid. Broad-spectrum, nonsystemic insecticide with contact and stomach action; some anti-feedant activity. Various formulations. Toxic to *Daphnia magna* at low concentrations (0.2 ppb).[2] Extremely toxic to fish. Typical half-life in soil is 30 days, although can be longer. Rapidly broken down by soil microbes. Extremely low potential to move into soil. Unlikely to contaminate ground water because it binds tightly to soil particles. Stable in sunlight.
Cyphenothrin	A, F	Pyrethroid. Nonsystemic insecticide with contact and stomach action. Usually formulated as aerosols and sprays. Used for flying and crawling household insect control.
d-trans allethrin (bioallethrin)	A	Pyrethroid. Nonsystemic, nonresidual insecticide with contact and stomach action; rapid knockdown. Usually formulated as aerosols and sprays. Introduced in 1969.[1] The *d-trans* isomer is more toxic than the allethrin or S-bioallethrin forms.
DDVP[a] (dichlorvos, Vapona®)	A, F	Organophosphate. Broad-spectrum nonsystemic insecticide with contact, stomach, and respiratory action; rapid knockdown. Formulated as aerosols, soluble concentrates, and no-pest strips. Half-life in water: 19–79 hrs.[2]
DEET	F	Used as a repellent, especially in situations where there are high flea populations.
Deltamethrin (Suspend®)	A, F	Pyrethroid. Nonsystemic insecticide with contact and stomach action. Household and public health uses for flying and crawling insects. In soil, undergoes microbial degradation in 1–2 wks.[2] Extremely toxic to fish.
Diatomaceous earth (DE)	A, F	Silicon dioxide. Abrasive and desiccant. Non-toxic, but dust mask should be worn when applying.
Diazinon[a]	A, F, G	Organophosphate. Broad-spectrum nonsystemic insecticide with contact, stomach, and respiratory action
Disodium octaborate tetrahydrate	F	Inorganic. Boron salt applied to carpeting. Poor water solubility.
D-limonene	A, F	See *Limonene*.
Esbiothrin	—	Discontinued name. See *S-bioallethrin*.
Esfenvalerate	A, F	Pyrethroid. Broad-spectrum nonsystemic insecticide with contact and stomach action. Extremely toxic to aquatic animals.[2]
Ethoprop[a] (= ethoprophos)	G	Organophosphate. Nonsystemic soil insecticide with contact action.
Fenoxycarb (Torus®)	A, F	Carbamate. Insect growth regulator for wide range of insects. Relatively fast degradation in soil and water.[2]
Fenvalerate	A, F	Pyrethroid. Broad-spectrum nonsystemic insecticide with contact and stomach action.

Fipronil (Maxforce®, Frontline®)	A, F	Pyrazole. Broad-spectrum contact and stomach insecticide. Formulated as ant bait; slow action allows it to be carried into ant nests where it can kill reproductives. Low soil mobility; little potential for ground water contamination. Its tendency to bind to sediments and low water solubility may reduce the potential hazard to aquatic wildlife.[4]
tau-Fluvalinate (Mavrik®)	A	Trifluoromethyl /pyrethroid. Broad-spectrum insecticide with contact and stomach action. Rapidly degrades in soil.[2]
Fonofos[a]	G	Organophosphate. Soil insecticide with contact and stomach action.
Garlic	A, F, G	Botanical.
Hydramethylnon	A	Trifluoromethyl. Formulated as bait in gel or granular forms, or in bait stations (all are 1% hydramethylnon); slow action allows it to be carried into ant nests where it can kill reproductives.[2] Half-life in sunlight: 1 hr; water @ pH 7.0: 10–11 days.[2]
Hydroprene	F	Isoprenoid. Insect growth regulator; juvenile hormone mimic, preventing larval to adult metamorphosis. Rapidly degrades in soil.[2]
Imidacloprid (Advantage®, Merit®)	F, G	Nitroguanidine. Broad-spectrum systemic insecticide with contact and stomach action.
D-limonene	A, F	Botanical. Citrus oil extract. Repellent action. Some cats may show sensitivity to citrus-based products. Eye irritant. Food-grade ingredient; component of oils of lemon, orange, caraway, dill, and bergamot.
Linalool	F	Botanical. Citrus oil extract. Repellent action. Toxic to all stages of flea; no residual activity. Eye irritant. Food-grade ingredient; component of cinnamon, sassafras, orange flower, bergamot, and ylang ylang.
Lufeneron (Program®)	F	Chitin synthesis inhibitor. Prevents flea eggs from hatching and larvae from molting. Highly toxic to aquatic invertebrates, but is highly insoluble in water. Rapidly broken down by microbial activity under normal soil conditions and binds tightly to soil particulate matter.[5]
Malathion[a]	A, F	Organophosphate. Broad-spectrum nonsystemic insecticide with contact, stomach, and respiratory action.
Methoprene (Precor®, FleaTrol®, Petcor®)	F	Terpenoid. Insect growth regulator; juvenile hormone mimic, preventing larval to adult metamorphosis. Rapidly degraded in soil.[2]
Mineral oil	A, F	Carrier for other pesticides. Respiratory action. Nonresidual activity.
Naled	F	Organophosphate. Broad-spectrum nonsystemic insecticide with contact, stomach, and some respiratory action.
Octyl bicycloheptene–dicarboximide	F	Insecticidal synergist. Combined with other active ingredients in sprays, foggers, shampoos, and lotions.

Oil of citronella	F	Botanical. Extract of a grass (*Cymbopogon nardus*) native to Southern Asia.
Permethrin	F, G	Pyrethroid. Broad-spectrum nonsystemic insecticide with contact and stomach action; some repellent effect. Various formulations. Rapid degradation in soil and water.[2]
— Petroleum distillates — Aromatic petroleum distillates — Petroleum hydro-carbons	A, F, G	Carrier for other pesticides.
d-Phenothrin	A, F	Pyrethroid. Nonsystemic insecticide with contact and stomach action; rapid knockdown. Household flying and crawling insects.
Phorate[a]	G	Organophosphate. Broad-spectrum systemic insecticide with contact and stomach action. Half-life in soil: 2–14 days.[2]
Phosmet[a] (Imidan®)	F	Organophosphate. Broad-spectrum nonsystemic insecticide with contact action. Rapidly broken down in soil.[2]
Piperonyl butoxide (PBO)	A, F	Synergist. Prevents insects from breaking down pyrethrins and pyrethroids.
Potash soap (insecticidal soap)	A, F	Aliphatic acid. Potassium salts of fatty acids. Used to control adult and larval fleas in lawns.
Propetamphos[a] (Safrotin®)	A, F	Organophosphate. Insecticide with contact and stomach action; long residual activity (2–3 months indoors).[2] Household and public health pests.
Propoxur (Baygon®)	A, F	Carbamate. Nonsystemic insecticide with contact and stomach action. Rapid knockdown; long residual activity. Household pests. Highly soluble in water: 2,000 µg/mL.[2]
Pyrethrins (pyrethrums)	A, F, G	Botanical. Nonsystemic insecticide with contact action. Various components derived from chrysanthemum flowers. Pyrethrins are unstable in light or air and are rapidly degraded in sunlight at the soil surface and in water.[4]
Pyriproxifen (Frontline®, Nylar®)	F	Alkoxypyrimidine. Juvenile hormone mimic.
Resmethrin	A, F, G	Pyrethroid. Nonsystemic insecticide with contact action. Household flying and crawling insects.
Rotenone	F	Botanical. Selective nonsystemic insecticide with contact and stomach action. Very toxic to fish. Residual insecticidal activity for 7 days.[1]
Silica aerogel	A	Caulking-type products with insecticidal properties. Abrasive and desiccant.
Sodium lauryl sulfate	F	Botanical. Derived from coconut. Foaming agent.

Spinosad (Conserve™)	F	Naturalyte™. Produced from fermentation products derived from *Saccharopolyspora spinosa*, a recently discovered actinomycete bacterium. (The term *naturalyte* was coined by DowElanco to describe a new category of active ingredients.)[1] Used to control Lepidoptera and some Diptera. Aqueous photolysis in < 1 day.[3]
Sulfluramid	A	Metabolic inhibitor.
Tetrachlorvinphos[a b]	F	Organophosphate/organochlorine. Nonsystemic insecticide with contact and stomach action.
Tetramethrin	A, F	Pyrethroid. Nonsystemic insecticide with contact action; rapid knockdown. Flying insects and garden pests.
Tralomethrin	A, F, G	Pyrethroid. Nonsystemic insecticide with contact and stomach action.
Trichlorfon[a b] (Dylox®)	A, G	Organophosphate/organochlorine. Nonsystemic insecticide with contact and stomach action.

a Organophosphates—Acephate (systemic), chlorpyrifos, diazinon, malathion, tetrachlorvinphos, and trichlorfon. Improper disposal results in water pollution.

b Organochlorines—Lindane, tetrachlorvinphos, and trichlorfon. Persistent fat-soluble insecticides. Improper disposal results in water pollution.

References:

1 Meister, R.T. (ed.). 2000. Farm Chemicals Handbook 2000. Meister Publishing Company, Willoughby, Ohio.

2 The Agrochemicals Handbook, 3rd edition. 1994. Royal Society of Chemistry Information Systems, Unwin Brothers Ltd. Surrey, England.

3 Ray Brinkmeyer, DowElanco. Personal communication, October 6, 1997.

4 National Pesticide Telecommunications Network. 1999. Factsheets. http://ace.orst.edu/info/nptn/factsheets

5 Feinman, J. 1997. HomeVet® Natural Pet Care Web site. http://www.homevet.com

6 Ross, L.J., R. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California—Winter 1991–92 and 1992–93. Environmental Hazards Assessment Program Environmental Monitoring and Pest Management Branch, California Department of Pesticide Regulation. EH 96–02.

REFERENCES

Ali, A.D. and M.A. Harivandi. 1987. White grubs in lawns. Biology and Insect Management Series. Cooperative Extension, University of California. Leaflet 21442, 1 p.

Antonious, G.F., M.E. Byers, and W.C. Kerst. 1997. Residue levels of pyrethrins and piperonyl butoxide in soil and runoff water. J. Environ. Sci. Health. B 32:621–644.

Bailey, H.C., L. Deanovic, E. Reyes, T. Kimball, K. Larson, K. Cortright, V. Connor, and D.E. Hinton. 2000. Diazinon and chlorpyrifos in urban waterways in Northern California, USA. Environmental Toxicology and Chemistry 19:82–87.

Bio-Integral Resource Center. 1996. IPM action plans for pests at the Presidio of San Francisco, National Park Service. Prepared for the Golden Gate Natural Resource Area, National Park Service, San Francisco, Calif.

Bone, P.S. 1996. Diagnosing turf disorders. Cooperative Extension, University of California, Sacramento County. 3 p.

Cooper, A. 1996. Diazinon in urban areas. Palo Alto Regional Water Quality Control Plant.

Daar, S, T. Drlik, H. Olkowski, and W. Olkowski. 1997. IPM for schools: A how-to manual. (Prepared for U.S. EPA, Region IX.) EPA 909–B–97–001.

Davidson, R.H. and W.F. Lyon. 1979. Insect pests of farm, garden, and orchard, 7th ed. John Wiley & Sons, New York City, New York.

Department of Pesticide Regulation, Sacramento, Calif. 2000. Product Label Database. www.cdpr.ca.gov/docs/label/labelque.htm

Donahue, W.A., Jr. 1997. Laboratory evaluation of d-limonene applied as a contact insecticide to Argentine ants, *Iridomyrmex humilis*. Sierra Research Laboratories, Modesto, California.

DowElanco. 1997. Conserve™ SC Turf and Ornamental. Proposed labeling for Section 3 registration. Indianapolis, Ind.

Dryden, M.W. and A.B. Broce.1993. Development of a trap for collecting newly emerged *Ctenocephalides felis* (Siphonaptera: Pulicidae) in homes. J. Med. Entomol. 30:901–906.

Extension Toxicology Network.(Extoxnet). 1998. Imidacloprid. Pesticide Information Project of cooperative extension offices of Cornell University, Michigan State University, Oregon State University, and UC Davis. http://ace.orst.edu/info/extoxnet/

Hedges, S.A. 1996. Ashes to ashes…Using dust insecticides effectively. Pest Control Technology 24(5):82, 86, 88, 92.

Hedges, S.A. 1994. Ant inspection and treatment tips. Pest Control Technology 22(5):72, 74–75, 78, 112.

Hedges, S.A. 1991. Flea control: Actual case histories from the field highlight the key elements of a successful flea management program. Pest Control Technology 19(8):50–52, 56.

Hinkle, N.C. 1991. Flea control: Attitudes and experiences of PCOs. Pest Management 19(8):15.

Jones, David. 1993. Fleas are no laughing matter. Pest Control Technology 21(7):26–28,30.

Kenney, J.M., E. Groth III, and C.M. Benbrook. 1998. Worst first: High-risk insecticide uses, children's foods and safer alternatives. Consumers Union of U.S., Washington D.C.

Kimbrough, R.A. and D.W. Litke. 1996. Pesticides in streams draining agricultural and urban areas in Colorado. Environ. Sci. Technol. 30:908–916.

Kramer, R. 1996. Flea control using boric acid: how safe is it? Pest Control Technology 24(5):75, 76, 78.

Kratzer, C.R., in press, Pesticides in storm runoff from agricultural and urban areas in the Tuolumne River Basin in the vicinity of Modesto, California: U.S. Geological Survey Water—Resources Investigations Report 98–4017.

Noxon, J.O. 1998. Fleas and flea control: A lesson on flea control from Companion Animal Dermatology. http://www.vetmed.iastate.edu/units/vth/noxon/flea.html.

Olkowski, W., S. Daar, and H. Olkowski. 1991. Common-sense pest control: least-toxic solutions for your home, garden, pets and community. The Taunton Press, Newtown, Conn.

Orr, M.R. and S.H. Seike. 1998. Parasitoids deter foraging by Argentine ants (*Linepithema humile*) in their native habitat in Brazil. Oecologia 117:420–425.

Parrella, M.P. 1986. Biological control of white grubs in California turfgrass. Minimal maintenance landscaping: A report of the Elvenia J. Slosson Fund for Ornamental Horticulture: 1983–1986. p. 45–46. University of California, Division of Agriculture and Natural Resources, Berkeley, Calif.

Powell, J.A. and C.L Hogue. 1979. California insects. University of California Press, Berkeley, Calif.

Regional Water Quality Control Board [California]. 1998. California 303(d) list and TMDL priority schedule. http://www.swrcb.ca.gov/plnspols/wqplans/303d98.pdf

Ross, L.J., R. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and mass loading of insecticides in the San Joaquin River, California—Winter 1991–92 and 1992–93. Environmental Hazards Assessment Program Environmental Monitoring and Pest Management Branch, California Department of Pesticide Regulation. EH 96–02.

Scanlin, J. and S. Gosselin. 1997. Strategy to reduce diazinon levels in creeks in the San Francisco Bay Area. Alameda County Flood Control and Water Conservation District. Hayward, Calif.

Schomburg, C.J., D.E. Glotfelty, and J.N. Seiber. 1991. Pesticide occurrence and distribution in fog collected near Monterey, California. Environmental Science and Technology 25:155–160.

Tucker, J. 1996. Why customers shouldn't meddle with bait stations. Pest Control Technology 24(5):78.

United States Environmental Protection Agency. 2000. EPA announces elimination of all indoor uses of widely used pesticide diazinon; begins phase-out of lawn and garden uses. Press release, Dec. 5, 2000. www.epa.gov/pesticides

United States Environmental Protection Agency. 1998. California list of impaired waters for 1998. Office of Water, Total Maximum Daily Load Program. http://www.epa.gov/owow/tmdl/states/catmdltables.html

University of California Statewide IPM Project. 1997. UC IPM Pest Management Guidelines: Turfgrass. Landscape and Ornamental Series, #1.

Ward, P.S. 1987. Distribution of the introduced Argentine ant (*Iridomyrmex humilis*) in natural habitats of the Lower Sacramento Valley and its effects on the indigenous ant fauna. Hilgardia 55:1–16.

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