Introduction

What is Integrated Pest Management?

Integrated Pest Management is a pest management strategy that focuses on long-term prevention or suppression of pest problems with minimum impact on human health, the environment and nontarget organisms. Preferred pest management techniques include encouraging naturally occurring biological control; using alternate plant species or varieties that resist pests; selecting pesticides with a lower toxicity to humans or nontarget organisms; adopting cultivating, pruning, fertilizing or irrigation practices that reduce pest problems and changing the habitat to make it incompatible with pest development. Pesticides are used as a last resort when careful monitoring indicates that they are needed according to preestablished guidelines. When treatments are necessary, the least toxic and most target specific pesticides are chosen. Implementing an integrated pest management program requires a thorough understanding of pests, their life histories, environmental requirements and natural enemies, as well as establishment of a regular and systemic program for surveying pests, their damage and other evidence of their presence.

Why use Integrated Pest Management?

As a result of growing concerns about health and environmental problems associated with pesticides, universities are facing increasing demands from their employees, their students and general public to explain and justify their use of these materials. Universities must be able to respond with careful, thoughtful answers. Managing insects, plant pathogens, weeds, rodents and other organisms that become pests is a complex science; applying pesticides safety and effectively in public areas requires substantial expertise and skill. Responses to the public's questions must communicate an understanding of the complexity and a genuine concern for health and environmental problems.

Adoption of written policy and procedures for making pest management decisions provides an agency with an effective way to respond to the questioning public and at the same time improves the Universities internal decision making process, resulting in more efficient, more effective and safer resolution of pest problems.

Benefits of Integrated Pest Management

- Promotes sound structures and healthy plants, which better withstand damage from pests.
- Reduces the need for pesticides by using several pest management methods.
- Reduces excessive or unnecessary pesticide applications, which can negatively affect human health and the environment.
- Promotes clean water. If water leaving your home contains pesticides, these can pollute streams, groundwater, or coastal regions.
- Typically provides long-term control of pests, as opposed to more conventional short-term treatments.
- Usually costs less to use IPM control methods.

Pests of Homes, Structures, People, and Pets

Cockroaches

There are five species of cockroaches in California that can become pests:
German cockroach, brownbanded cockroach, oriental cockroach, smokybrown cockroach, and American cockroach. Of these, the one that has the greatest potential of becoming persistent and troublesome is the German cockroach, which prefers indoor locations. Oriental and American cockroaches occasionally pose problems in moist, humid areas.

Problems Associated with Cockroaches

Cockroaches may become pests in homes, restaurants, hospitals, warehouses, offices, and virtually any structure that has food preparation or storage areas. They contaminate food and eating utensils, destroy fabric and paper products, and impart stains and unpleasant odors to surfaces they contact.

Cockroaches (especially the American cockroach, which comes into contact with human excrement in sewers or with pet droppings) may transmit bacteria that cause food poisoning (*Salmonella* spp. and *Shigella* spp.).
German cockroaches are believed to be capable of transmitting disease causing organisms such as *Staphylo- coccus spp., Streptococcus spp., hepatitis virus, and coliform bacteria.* They also have been implicated in the spread of typhoid and dysentery. Some people, especially those with asthma, are sensitive to the allergens produced by these cockroaches. However, a major concern with cockroaches is that people are repulsed when they find cockroaches in their homes and kitchens.

Identification

Cockroaches are medium-sized to large insects in the order Dictyoptera (formerly Orthoptera). They are broad, flattened insects with long antennae and a prominent pronotum. Some people confuse them with beetles, but adult cockroaches have membranous wings and lack the thick, hardened forewings or elytra of beetles. They are nocturnal and run rapidly when disturbed. Immature cockroaches (nymphs) look like adults, but are smaller and do not have wings.

Of the five common pest species, German and brownbanded cockroaches inhabit buildings, whereas the oriental, smokybrown, and American cockroaches usually live outdoors, only occasionally invading buildings. It is important to correctly identify the species involved in a cockroach infestation so that the most effective control method(s) for the species involved is chosen (Figure 1).

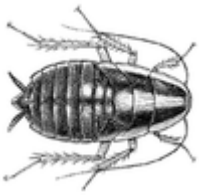
German Cockroach

The German cockroach, Blattella germanica, is the most common indoor species, especially in multiple-family dwellings. They prefer food preparation areas, kitchens, and bathrooms because they favor warm (70° to 75°F), humid areas that are close to food and water. Severe infestations may spread to other parts of buildings. This species reproduces the fastest of the common pest cockroaches: a single female and her offspring can produce over 30,000 individuals in a year, but many succumb to cannibalism and other population pressures. Egg laying occurs more frequently during warm weather. The female carries around a light tan egg case (about 1/4 inch long) until 1 to 2 days before it hatches, when she drops it. Sometimes the egg case hatches while it is still being carried by the female. Each egg case contains about 30 young, and a female may produce a new egg case every few weeks.

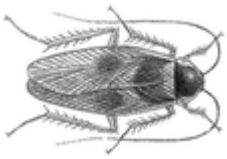
Figure 1: Identifying features of the different species of pest cockroaches

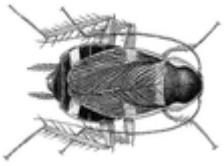
GERMAN
Adult: 0.5 inch; light brown, two dark stripes on pronotum
Preferred location: kitchens, bathrooms, food preparation and storage areas

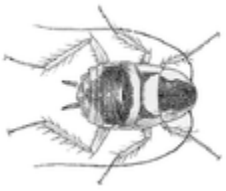

adult


nymph

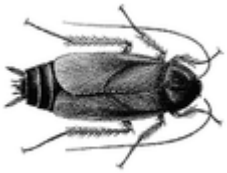
BROWNBANDED
Adult: 0.5 inch; males are golden tan; females are darker brown; both have light-colored bands on abdomen, wings, and sides of pronotum
Preferred location: warm areas indoors

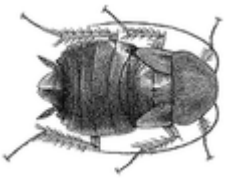

adult male


adult female


nymph

ORIENTAL
Adult: 1.25 inch; almost black; male, wings are shorter than body; female, wings are rudimentary
Preferred location: damp, dark places--woodpiles, garages, basements, and in drains


adult male


adult female

SMOKYBROWN
Adult: 0.5 inch; dark brown to mahogany; almost black pronotum
Nymph: banded pattern on antennae
Preferred location: trees, shrubs, vegetation


adult

AMERICAN
Adult: 2 inches; reddish brown; large body, edges of pronotum are light colored
Preferred location: sewers, steam tunnels, animal-rearing facilities

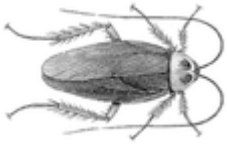

adult

Illustration from U.S. Depts. of Food and Agric. and Health and Human Services. 1991. Insect and Mite Pests in Food, Vol. II. Washington, D.C.: U.S. Government Printing Office, Ag. Handbook No. 655.

Brownbanded Cockroach

The brownbanded cockroach, Supella longipalpa, is not as common as the German cockroach in California and accounts for only about 1% of all indoor infestations. This species seeks out areas that are very warm most of the time, preferring temperatures of about 80°F, about 5° to 10°F warmer than what German cockroaches prefer. Favorite locations include near the warm electrical components of appliances such as radios, televisions, and refrigerators. Brownbanded cockroaches prefer starchy food (e.g., glue on stamps and envelopes), are often found in offices and other places where paper is stored, and are more common in apartments or homes that are not air conditioned. They also infest animal-rearing facilities, kitchens, and

hospitals. Adult males sometimes fly when disturbed, but females do not fly. Females glue light brown egg cases, which are about 1/4 inch long, to ceilings, beneath furniture, or in closets or other dark places where eggs incubate for several weeks before hatching. Each female and her offspring are capable of producing over 600 cockroaches in one year.

Oriental Cockroach

The oriental cockroach, Blatta orientalis, is sometimes referred to as a waterbug or waterbeetle. It lives in dark, damp places like indoor and outdoor drains, water control boxes, woodpiles, basements, garages, trash cans, and damp areas under houses. It is most likely to occur in single-family dwellings that are surrounded by vegetation. It is also common in ivy, ground cover, and outside locations where people feed pets. They prefer cooler temperatures than the other species do, and populations of this species often build to large numbers in masonry enclosures such as water meter boxes. At night, oriental cockroaches may migrate into buildings in search of food. They usually remain on the ground floor of buildings and move more slowly than the other species. Oriental cockroaches do not fly and are unable to climb smooth vertical surfaces; consequently they are commonly found trapped in porcelain sinks or tubs. Females deposit dark red-brown egg cases, which are about 3/8 inch long, in debris or food located in sheltered places. Each female and her offspring can produce nearly 200 cockroaches in one year. Development from a newly emerged nymph to adult can take from 1 to 2 years or more.

Smokybrown Cockroach

The smokybrown cockroach, Periplaneta fuliginosa, is usually found in decorative plantings and planter boxes, woodpiles, garages, and water meter boxes; it may occasionally inhabit municipal sewers. They sometimes invade homes, taking refuge in areas such as the attic. Nymphs are dark brown and have white segments at the end of their antennae and across their backs. Smokybrown cockroaches prefer the upper parts of buildings; they also may live under shingles or siding and sometimes get into trees, shrubs, and other vegetation during summer months. Females carry the dark brown to black egg case, which measures about 3/8 inch long, for about 1 day before dropping it; eggs can hatch in as soon as 24 days after being laid or as long as 70 days after laying, depending on temperature. About 40 to 45 nymphs hatch from a single egg case.

American Cockroach

The American cockroach, Periplaneta americana, prefers warm and humid environments, usually with temperatures in excess of 82°F. Under the right conditions, they readily live outdoors and are common pests in zoos and animal-rearing facilities. They are also common in sewers, steam tunnels, and masonry storm drains. Occasionally they forage from sewers and other areas into the ground floor of buildings. Adult females carry the egg cases around for about 6 days and then cement them to a protected surface where they incubate for about 2 months or longer. The egg cases, which are about 3/8 inch long, are brown when laid but turn black in 1 to 2 days. Each egg capsule contains about 12 young; a female and her offspring can produce over 800 cockroaches in one year.

Life Cycle

An adult female cockroach produces an egg capsule, called an ootheca, which it carries around protruding from the tip of the abdomen. The German cockroach carries the ootheca for most of the 30-day incubation period and then drops it about the time the eggs hatch; the other four species carry it for only about a day before depositing it in a suitable location where it incubates for weeks or months. Young or immature cockroaches undergo gradual metamorphosis, which means they resemble adults and have similar feeding habits, but they do not have fully developed wings and are not reproductively active. Immediately after molting, cockroaches are white, but their outer covering darkens as it hardens, usually within hours.

Cockroaches are nocturnal. They hide in dark, warm areas, especially narrow spaces where surfaces touch them on both sides. Adult German cockroaches can hide in a crack 1/16 inch or 1.6 mm wide. Immature

cockroaches tend to stay in even smaller cracks where they are well protected. Cockroaches tend to aggregate in corners and generally travel along the edges of walls or other surfaces.

Management

Managing cockroaches is not easy. You must first determine where the roaches are located. The more harborages you locate and treat, the more successful your control program will be. Remember that cockroaches are tropical and like warm hiding places with access to water. Some locations will be difficult to get to. If cockroaches have access to food, baits will have limited effect. Sprays alone will not eliminate cockroaches. An approach that integrates several strategies is required.

If you know the species of cockroach, you will be better able to determine where the source of infestation is and where to place traps, baits, or insecticides. Note locations of suspected infestation and concentrate control measures in these areas. The keys to controlling cockroaches are sanitation and exclusion: cockroaches will continue to reinvade as long as a habitat is suitable to them (i.e., food, water, and shelter are available), so the conditions that attracted and favored the infestation must be changed. In addition to sanitation and exclusion, baits and sticky traps can be effective against most species of cockroaches. As a last resort, sprays or dusts that are registered for use on cockroaches may temporarily suppress populations, but they do not provide long-term solutions. Commercially available devices that emit sound to repel cockroaches are not effective.

Monitoring Cockroaches

Traps offer the best way to monitor cockroach populations. By placing traps in several locations and inspecting them regularly, you can identify the areas of most severe infestation and know where to concentrate control efforts. Traps also can be very helpful in evaluating the effectiveness of control strategies.

Traps can be purchased or made. Most commercially available cockroach traps are open-ended and contain an attractant substance along with a sticky material that lines the inside. An alternative is to make a cockroach trap from a quart-sized can. The inside top of the can is coated with a petroleum jelly to prevent the roaches from escaping, and a slice of white bread is placed in the can as bait.

To be effective, traps must be placed where cockroaches are likely to encounter them when foraging. The best places are along the edges of floors and walls and close to sites where cockroaches are numerous; these sites can be determined by accumulations of fecal matter (e.g., dark spots or smears), cast skins, egg cases, and live or dead cockroaches. In the kitchen put traps against walls behind the stove and the refrigerator and in cabinets. Check the traps daily for several days until it is apparent where the greatest number of roaches are caught; usually this is within the first 24 hours of placing a trap--after that cockroaches may become wary of the trap. Trapped cockroaches may be destroyed with hot, soapy water.

You can also monitor a cockroach population at night using a flashlight to inspect cracks, underneath counters, around water heaters, and in other dark locations. Look for live and dead cockroaches, cast skins, egg capsules, and droppings, all of which aid in identification and are evidence of an infestation.

Sticky Traps with Pheromones

Continuous trapping, especially of slow-developing species such as the oriental cockroach, may be helpful. Trapping by itself has not been shown to be effective in controlling German or brownbanded cockroaches because these species have such a high reproductive rate. A recent development in the use of sticky traps, however, has been the addition of an aggregation pheromone attractant. With this development, sticky traps have become more useful as a control tool for German cockroaches. An additional benefit of pheromone sticky traps is that the bodies of trapped roaches are removed with the traps. Dead roaches contain proteins that can cause asthma symptoms when they are inhaled by susceptible individuals, so the removal of dead cockroaches may be beneficial in certain situations. Intensive trapping may provide a reduction in German cockroach populations but the number of traps and their placement are critical: follow the manufacturer's recommendations.

Sanitation

Cockroaches thrive where food and water are available to them. Even tiny amounts of crumbs or liquids caught between cracks provide a food source. Important sanitation measures include the following:

- Store food in insect-proof containers such as glass jars or sealable plastic containers.
- Keep garbage and trash in containers with tight-fitting lids. Remove trash, newspapers, magazines, piles of paper bags, rags, boxes, and other items that provide hiding places and harborage.
- Eliminate plumbing leaks and correct other sources of free moisture. Increase ventilation where condensation is a problem.
- Vacuum cracks and crevices to remove food and debris. Be sure surfaces where food or beverages have been spilled are cleaned up immediately. Vacuuming also removes cockroaches, shed skins, and egg capsules. Removing cockroaches reduces their numbers and slows development. Vacuumed cockroaches and debris should be destroyed. Because bits of cuticle and droppings may be allergenic, it is recommended that the vacuum cleaner have HEPA (high efficiency particulate absorber) or triple filters.
- Trim shrubbery around buildings to increase light and air circulation, especially near vents, and eliminate ivy or other dense ground covers near the house, as these may harbor cockroaches.
- Remove trash and stored items such as stacks of lumber or firewood that provide hiding places for cockroaches from around the outside of buildings.

Exclusion and Removal of Hiding Places

During the day cockroaches hide around water heaters, in cupboard cracks, stoves, crawl spaces, outdoor vegetation, and many other locations. They invade kitchens and other areas at night. Limiting hiding areas or avenues of access to living areas is an essential part of an effective management strategy. False-bottom cupboards, hollow walls, and similar areas are common cockroach refuges. Prevent access to the inside of buildings through cracks, conduits, under doors, or through other structural flaws. If it is not practical to remedy these problem areas, treat them with boric acid powder.

Take the following measures if roaches are migrating into a building from outdoors or other areas of the building:

- Seal cracks and other openings to the outside.
- Look for other methods of entry, such as from items being brought into the building, especially appliances, furniture, and items that were recently in storage.
- Look for oothecae glued to undersides of furniture, in refrigerator and other appliance motors, boxes, and other items. Remove and destroy any that are located.
- Locate and seal cracks inside the treatment area where cockroaches can hide.

Chemical Control

Insecticides are most effective in controlling cockroaches when combined with sanitation and exclusion practices that limit the cockroach's ability to establish or reinvade; chemical control alone will not solve the problem. If insecticides are used, they must always be used with extreme care. Indoor chemical control is warranted only if the cockroach population is established but not for an incidental intruder or two.

Dusts

One effective dust for control of cockroaches is boric acid powder, which is a contact poison. It is the least repellent of all the insecticides for cockroach control, and if it remains dry and undisturbed, it provides control for a very long time. Because it has a positive electrostatic charge, the dust clings to the body of a cockroach as it walks through a treated area and the cockroach ingests small amounts when it grooms itself. Because boric acid powder is fairly slow acting, it may take 7 days or more to have a significant effect on a cockroach population. Because of its toxicity to plants, boric acid is not recommended for outdoor use.

Blow dust into cracks and crevices or lightly spread it in areas where visible residues are not a problem and where people will not contact it. Remove kick panels on refrigerators and stoves and apply a light film of dust throughout the entire area underneath these appliances. A thin film of dust is more effective than a thick layer. Holes that are the same size as the tip of a puff-type applicator can be drilled into the TOP of kick panels beneath cabinets and powder may be applied through the holes to these areas as well as under the sink, in the dead space between the sink and wall, and around utility pipes. Also treat along the back edges and in corners of shelves in cabinets, cupboards, pantries, and closets.

Boric acid powder does not decompose and is effective for as long as it is left in place, if it remains dry. Formulated as an insecticide, boric acid dusts usually contain about 1% of an additive that prevents the powder from caking and improves dusting properties. If it gets wet and then dries and cakes, it loses its electrostatic charge and will not be picked up readily by the cockroach. If this occurs, reapply powder to these areas.

Baits

Baits are formulated as pastes, gels, granules, and dusts. The most popular use of baits in homes is within bait stations, which are small plastic or cardboard units that contain an attractive food base along with an insecticide. Bait gels are placed in small dabs in cracks and crevices where cockroaches will find it. The advantage of bait stations is that insecticides can be confined to a small area rather than being dispersed and they are relatively child resistant. Baits in plastic containers also remain effective for many months whereas the bait gels dehydrate in about 3 days when left in the open air. But while they are fresh, bait gels are very effective when placed in locations where they will be found by cockroaches. To remain effective, however, the gels need to be reapplied frequently.

Most insecticides used in baits are slow acting; cockroaches quickly learn to avoid fast-acting ones. Consequently an effective bait program does not give immediate results, but may take 7 days or longer. Baits can be quite effective for long-term control of cockroaches unless the cockroaches have other food sources available to them.

Baits do not control all cockroaches equally. Female cockroaches with egg cases do very little feeding and avoid open spaces; consequently they are less likely to be immediately affected by a bait.

Commercial baits available (see Table 1) contain abamectin, boric acid, fipronil, hydramethylnon, or sulfluramid mixed with a food base. Sulfluramid is not as effective as the other materials because it is somewhat volatile and there has been some development of resistance to it.

As with sticky traps, baits do not attract cockroaches so place them near hiding spaces or where roaches are likely to encounter them when foraging. When placed next to a sticky trap that contains an attractant pheromone, bait consumption by the roaches is reported to increase. Bait stations can also be placed next to fecal specks and droppings of cockroaches, which contain a natural aggregation pheromone. Look for these fecal specks and droppings under kitchen counters, behind kitchen drawers, and in the back of cabinets.

Insect Growth Regulators

The insect growth regulator (IGR) hydroprene prevents immature cockroaches from becoming sexually mature. It also has the added advantage of stimulating cockroaches to feed. When placed next to bait it can increase bait consumption. Under normal circumstances an adult female cockroach carrying an egg case doesn't feed much, but exposure to an IGR will induce her to feed.

TABLE 1. Baits Currently Available for Use in Homes.

Active ingredient	Brand name	Formulation	Where to get product
abamectin	Avert	gel, powder	pest control company
abamectin plus hydroprene	Raid Max Plus Egg Stoppers	bait station	retail stores
boric acid	Stapleton's Magentic	paste	Blue Diamond Phone: (800) 237-5705
	Niban and others	granules	pest control company
fipronil	Maxforce	bait station	pest control supply store
	Maxforce	gel	pest control supply store
hydramethylnon	Combat	bait station	retail stores
	Combat	granules	retail stores
	Maxforce	gel	pest control supply store
	Siege	gel	pest control company

Sprays and Aerosols

Applying low-residual insecticides to get a quick knockdown of cockroaches in an infested area can provide immediate relief from a cockroach infestation but generally does not give long-term control. Common home use insecticides include combinations of pyrethrin and piperonyl butoxide or pyrethroids such as cyfluthrin, cypermethrin, and permethrin. The safest application method for home users is the crack-and-crevice spray used in combination with sanitation and exclusion. Avoid the use of insecticide aerosol sprays, bombs, or foggers, as these will just disperse the cockroaches and may actually increase problems.

The faster the knockdown activity of an insecticide, the quicker cockroaches learn to avoid it. Cockroaches are repelled by deposits of residual insecticides such as synergized pyrethrins and emulsifiable concentrate formulations of pyrethroids such as cyfluthrin, cypermethrin, and permethrin. Wettable powder formulations are generally less repellent and more effective on a wide range of surfaces; however, they may be unsightly.

It should be noted that many cockroach populations, especially the German cockroach, have developed resistance (or tolerance) to many insecticides used for their control. Resistance has been documented with allethrin, chlorpyrifos, cyfluthrin, cypermethin, fenvalerate, and others. Do not expect instant results from an insecticide spray application, but if the cockroaches seem to be unaffected the following day, a different material or strategy may be required.

Under extreme circumstances when professional pest control services are warranted to alleviate a persistent cockroach infestation, everything should be removed from kitchen drawers, cabinets, cupboards, and closets and stacked in out-of-the-way places and covered to prevent their contamination with the spray. This also allows for thorough coverage of surfaces. Do not replace these items until the spray is dry. Treated surfaces should not be washed or the effectiveness of the treatment will be reduced.

Always combine the use of insecticides with sanitation and exclusion, apply dusts or use bait stations, alternate the types of active ingredients and formulations that are used, or use insecticides, such as boric acid, that do not repel cockroaches or for which cockroaches have not developed resistance.

If you wish to avoid sprays and aerosols completely, a thorough vacuuming with a HEPA or triple filter vacuum cleaner followed by the use of boric acid dust in cracks and crevices and a baiting program can effectively control severe infestations.

Follow-Up

After a cockroach control program has been started, evaluate the effectiveness of the methods that are being used. Use traps or visual inspections to help determine if further treatment is necessary.

If populations persist, reevaluate the situation. Look for other sources of infestations, make sure that all possible entryways are blocked, be certain that food and water sources are eliminated as much as possible, and continue sealing and eliminating hiding places.

When cockroach populations are under control, continue monitoring with traps on a regular basis to make sure reinfestation is not taking place. Maintain sanitation and exclusion techniques to avoid encouraging a new infestation. If severe reinfestations continue to recur, consider having the infested areas modified or remodeled to reduce the amount of suitable habitat for cockroaches.

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Flies

Of the thousands of species of flies, only a few are common pests in and around the home. Some of the more common nuisance flies are the house fly *(Musca domestica),* the face fly *(Musca autumnalis),* the stable fly *(Stomoxys calcitrans),* the little house fly *(Fannia canicularis),* and several species of garbage fly (especially in the genus *Phaenicia).* These pests breed in animal wastes and decaying organic material from which they can pick up bacteria and viruses that may cause human diseases. In addition, adult stable flies (sometimes called "biting flies") feed on mammalian blood and can give a painful bite.

All flies undergo complete metamorphosis with egg, larva, pupa, and adult stages in their development. The female fly deposits her eggs in animal waste or moist organic material where the larvae, or "maggots," complete their development, feeding on bacteria associated with their developmental site. When the maggots have completed their development and are ready to undergo the next step in their metamorphosis, they convert their last larval skin into a puparium, a hardened shell within which the pupa develops. Within the puparium, the pupa transforms into an adult fly, which pops off the end of the puparium and emerges. Body fluids pump into the fly's veins, causing the wings to unfold and expand and allowing them to dry and harden so that the adult can fly. The rate of fly development is dependent upon temperature, and under optimal summertime conditions flies may develop from egg to adult in as little as 7 days. Once the female fly has mated, she can lay several batches of eggs, typically containing over 100 eggs each.

While humans commonly find adult flies to be the most bothersome, the larval stage should be the prime target for control efforts. Elimination of larval habitat is the preferred method of pest fly suppression. By removing material in which the larvae develop, the life cycle of the fly can be broken, preventing subsequent production of adult flies. While chemical pesticides may be effective for suppressing adult fly populations in some situations, they are not a substitute for proper sanitation and aggressive elimination of nuisance fly developmental sites. Because flies can quickly develop resistance to insecticides, use them only as a last resort to obtain immediate control of adult flies.

House Fly

Identification and Life Cycle

The house fly *(Musca domestica)* is a cosmopolitan companion of humans and domestic animals. House flies are generally found in greatest numbers during the hotter summer months. House flies are less than 3/8 inch in length and have four dark stripes down the back of their thorax. House flies have sponging mouthparts and eat solid food by first liquefying it with their saliva.
Under favorable conditions house flies can reproduce prodigiously because of their rapid developmental time and the large number of eggs produced by each female—several batches of about 100 to 150 eggs. Eggs are laid in warm, moist, organic materials such as manure, garbage, lawn clippings, decaying vegetables and fruits, or soils contaminated with any of these materials. Larvae of the house fly are cream colored, have a blunt posterior end and taper to a point at the head. Young larvae respond negatively to light and will burrow into the organic material in which they are developing. Older larvae respond positively to light and will emerge from their organic habitat to seek drier and cooler areas to transform into pupae. Under optimal summertime conditions, house flies can complete their development from egg to adult in as little as 7 days.

Damage

Because they have sponging mouthparts, house flies cannot bite; however, they may play an important role in disease transmission to humans and animals. House flies serve as carriers of disease agents due to their predilection for feeding on animal wastes, garbage, and human foods. House flies are known to carry bacteria and viruses that cause conditions such as diarrhea, cholera, food poisoning, yaws, dysentery, and eye infections.

Management of House Flies

Flies found inside a building have entered from the outside in almost all cases. Therefore, barriers preventing access to the building are the first line of defense. Cracks around windows and doors where flies may enter should be sealed. Well-fitted screens will also limit their access to buildings. Outdoors, regular removal (at least once a week) and disposal of organic waste, including dog feces and rotting fruit, reduces the attractiveness of the area to adult flies and limits their breeding sites. Garbage should not be allowed to accumulate and should be placed in plastic bags and held in containers with tight-fitting lids. Garbage should also be placed as far from a building entrance as is practicable. In general, poor exclusion and lack of sanitation are the major contributors to fly problems.

Sticky fly papers or ribbons are effective at eliminating a few flies in relatively confined areas, but are not effective enough to manage heavy infestations or to provide control in an outdoor setting. Inverted cone traps containing fly food attractants can be readily purchased commercially and are effective when they are not competing with nearby garbage or animal wastes. The fly food attractants used in these inverted cone traps will be quite foul smelling, so the traps should be placed at some distance from occupied structures.

Fly traps using ultraviolet light may be effective when used indoors where they are not competing with daytime sunlight. For control of just a few flies, the time-tested fly swatter is appropriate. Don't use fly swatters near food preparation areas because they may result in contaminating food with insect body parts.

Selective use of insecticides against house flies is one component of a total fly management program, but should only be used after all possible nonchemical strategies have been employed. In most home situations, pesticides are not needed or recommended. Sanitation methods along with screens to keep flies out of the home should be sufficient. If sanitation efforts are not possible, a nonresidual pyrethrin aerosol may be used. Outside, a professional pest control company can be hired to apply residual insecticides to surfaces such as walls and overhangs that are being used by the flies as resting areas. Fly baits used in trash areas may be effective in reducing the number of adult flies if proper sanitation practices are followed. However, when flies have access to garbage, baits will not control them.

Little House Fly

Identification and Life Cycle

Little house flies *(Fannia canicularis)* is generally most numerous during the cooler spring and fall months. As temperatures rise in summer, populations of *Fannia* diminish.
Adults are approximately two-thirds the size of the house fly and lack the house fly's distinctive thoracic stripes. *Fannia* at rest hold their wings over the back more than the house fly does, creating a narrower V-shape to the wing outline. Flying clusters of male *Fannia* typically form in areas with still air such as breezeways and porch areas of residential homes, maintaining a position 5 or 6 feet above the ground. Strong air currents tend to disperse these male aggregations.

Larval *Fannia* are adapted to tolerate a wide moisture range at their developmental sites, making them a particularly difficult nuisance fly to control. Egg laying and larval development frequently occur in animal wastes (especially chicken manure), but various moist organic materials can serve as suitable substrates. Poultry manure in inland areas of southern California can have abundant coastal fly, *F. femoralis.* This fly looks much like *F. canicularis,* especially in the immature stages, but is not a pest affecting humans. Unlike house fly larvae, Larvae of *Fannia* are brown in color, more flat than round, and have numerous fleshy spines. The developmental time from egg to adult is somewhat longer for little house fly than for the house fly at all temperatures.

Damage

Little house flies are more reluctant to enter homes than are house flies; instead, they tend to congregate in outdoor areas such as patios, entryways, and garages. As temperatures decline, they seek cover in buildings or protective vegetation. They seldom land on human foods and are not considered a significant carrier of human disease agents. However, their habit of hovering at face height makes them annoying, though they move readily out of the way when approached.

Management of Little House Flies

As with all nuisance flies, eliminating breeding sites is the preferred method of controlling *Fannia.* Accumulations of manure (especially poultry) or other decaying organic matter are ideal developmental sites. These developmental sites must be removed or spread thin to fully dry. *Fannia* are not attracted to the same fly baits or traps that collect house flies. Some relief can be obtained by placing fans in areas where male *Fannia* tend to swarm, as the increased air movement will make the site less attractive to them.

Face Fly

Identification and Life Cycle

Face flies *(Musca autumnalis)* are a problem particularly in rural areas of northern and coastal California where livestock are present. The hotter, drier weather in southern California and the southern San Joaquin Valley is not conducive to their development. Face flies require fresh cattle or horse manure for development. The face fly looks virtually identical to the house fly but is somewhat larger and darker in color and male face flies have a distinctive orange-yellow-colored abdomen. Like the house fly, it also has sponging mouthparts and cannot bite. However, face fly behavior is distinctive because they are specifically attracted to the eyes, nose, and mouth of cattle and horses.

Damage

Face flies feed on the secretions of cattle and horses in the summer months. Their habit of feeding around the eyes makes them capable of transmitting pinkeye to livestock, and they are a much more successful pinkeye vector than the closely related house fly. In fall, swarms of face flies may enter buildings or similar structures to hibernate through the winter months. On warm days, these hibernating flies can become active resulting in nuisance to homeowners. When active, face flies are attracted to light, so they are frequently found flying inside homes near windows.

Management of Face Flies

To control adult face flies within the home, locate the area where the flies are hibernating and then treat them directly. Begin searching for resting sites on the southern and western sides of the building because in fall and winter these walls receive the most sun and therefore are usually the warmest parts of the building. The flies are attracted to these warm areas when searching for protective wintertime harborage. Face flies seeking shelter will often enter cracks and crevices that lead to structural voids in a building, such as crawl spaces, attics, or false ceilings. These structural voids may need to be inspected if the presence of adult face flies persists throughout the winter.

Flies can be vacuumed off the surfaces on which they are hibernating; in areas inaccessible to vacuuming, a residual insecticide such as a pyrethroid can be applied. For application of residual insecticides, contact a reputable pest control company. To prevent future infestations, cracks on the outside of the building structure that may serve as entry points for flies should be sealed.

For most fly species, the best control is achieved by removing larval developmental sites. Because face flies develop in fresh, undisturbed cattle manure (intact manure pats), removal of larval developmental sites (i.e., removal of intact manure pats) may be very difficult and probably impractical in most circumstances. However, by increasing the density of cattle (generally accomplished by restricting their pasture area), the manure pats will be disturbed, allowing few flies to develop. Also, removal of cattle from nearby fields or pastures may help to reduce the problem.

Stable Fly

Identification and Life Cycle

The stable fly *(Stomoxys calcitrans),* sometimes called the "biting fly," is a common fly that attacks people living in neighborhoods where livestock animals (e.g., horses, cattle, and sheep) are present or that are close to livestock facilities.

Stable flies typically appear in midspring, become severe in early summer, and decrease in numbers throughout the remaining summer months. These flies are similar in appearance to house flies, except that stable flies have a bayonetlike mouthpart (proboscis) protruding from the front of the head and they lack the four dark stripes on the thorax indicative of house flies.

Under optimal temperatures, the stable fly can develop from egg to adult in 12 days. Piles of moist, decaying plant material (e.g., grass clippings, hay, and silage) should be considered potential sources of stable flies, especially when this material is mixed with animal manure and urine. Backyard compost and piles of grass clippings are ideal breeding sites for stable fly larvae and may serve as the production source for an entire neighborhood.

Damage

Both sexes of stable flies feed about once per day on the blood of animals (and sometimes people) and are known to give a painful bite. Although they are blood feeders and capable of transmitting some viruses, stable flies are not known to be significant carriers of disease agents in the U.S. Stable flies prefer to feed on the legs and lower body of large animals such as cattle and horses. On dogs, stable flies typically feed around the periphery of the ears. Undisturbed, the stable fly can fully engorge with blood in less than 5 minutes. Fully fed stable flies will move to a suitable resting site (e.g., a wall or fence) while the blood meal is digested.

Management of Stable Flies

The most effective and economical method for reducing stable fly numbers is to eliminate their developmental sites. To prevent larval development, moist grass clippings should be removed or incorporated into compost piles. Compost piles must be properly maintained to prevent them from becoming breeding areas for stable flies. Proper maintenance includes periodically turning the pile, which promotes rapid decomposition of heat-producing organic matter.

To protect dogs and horses that are bothered by stable flies, insect repellents containing permethrin or pyrethrins are effective, but neither provides long-term control; repeated applications every other day are necessary. Because the stable fly season is relatively short, this chemical repellent approach may be the most economical method to control stable flies on companion animals

Garbage Flies

Identification and Life Cycle

Garbage flies are a group of fly species with similar life histories and behaviors. Adult flies in this group can be readily differentiated from other flies discussed in this publication by their coloration, which is a shiny, metallic green or blue often mixed with some copper color.
Under ideal temperatures, garbage flies can develop from egg to adult in as little as 7 days. Eggs are usually laid in decaying meats (carrion), garbage, or dog feces. Similar to other nuisance flies, garbage fly larvae leave their developmental site to seek out drier and more protected areas for pupation. This behavior is responsible for the mass emergence of maggots from trash cans that have been sitting with garbage for too long. Garbage fly larvae and house fly larvae look and behave similarly, making identification difficult for the untrained.

Damage

Like house flies, garbage flies have sponging mouthparts and do not bite or feed on blood. They are, however, strongly attracted to human foods and garbage and can make cooking outdoors difficult due to the nuisance they pose. As with house flies, they may be involved in the transmission of disease agents picked up from garbage or animal feces and subsequently carried to human foods.

Management of Garbage Flies

As with the other nuisance fly species, eradication of larval developmental sites is the most efficient means of control. Household garbage and pet feces should be placed in plastic garbage bags and sealed with ties. Garbage bags should be removed from the home at least weekly and placed in a covered garbage can for pickup by a refuse collection service. Garbage cans should be set out for pickup at least once each week even if they are not full because garbage that sits for more than one week allows for the development of adult garbage flies. Finally, garbage cans should be regularly washed out with soap and water to remove any garbage residues that might attract garbage flies or allow for their development.

Vertically hanging, sticky fly ribbons used to reduce adult house fly numbers will not work to control adult garbage flies; unlike house flies, garbage flies do not rest on vertical surfaces. Adult garbage flies can be controlled using inverted cone traps, as for house flies, but traps should be placed at some distance from the home or structure due to their foul odor.

Selective use of insecticides may be considered when sanitation measures fail. Fly baits used for control of house flies are not likely to provide good control of garbage flies because the attractants present in fly baits were designed to attract house flies rather than garbage flies, and therefore may not be very attractive to them. However, when placed on the ground or in containers where garbage has accumulated, some control may be obtained.

Summary

Almost all nuisance fly species are best controlled by eliminating larval developmental sites and reducing adult attractants in the vicinity of buildings or other areas of concern. Attractive material (such as garbage cans) should always be placed at some distance from a building entrance, and barriers such as screens, doors, and air curtains should be used to prevent flies from entering buildings.

Chemicals are only rarely required in residential situations. Their use generally leads only to short-term control because they target adult flies and leave the larval fly stages intact and capable of producing

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Rats

Rats are some of the most troublesome and damaging rodents in the United States. They consume and contaminate food, damage structures and property, and transmit parasites and diseases to other animals and humans. Rats live and thrive under a wide variety of climates and conditions; they are often found in and around homes and other buildings, farms, gardens, and open fields.

Identifying the Rat

People do not often see rats, but signs of their presence are easy to detect (see sidebar). In California the most troublesome rats are two introduced species: the roof rat and the Norway rat. It is important to know which species of rat is present in order to place traps or baits in the most effective locations.

Norway Rats

Norway rats (Rattus norvegicus), sometimes called brown or sewer rats, are stocky burrowing rodents that are larger than roof rats. Their burrows are found along building foundations, beneath rubbish or woodpiles, and in moist areas in and around gardens and fields. Nests may be lined with shredded paper, cloth, or other fibrous material. When Norway rats invade buildings, they usually remain in the basement or ground floor. The Norway rat occurs throughout the 48 contiguous United States. Generally it is founds at lower elevations but may occur wherever people live.

Roof Rats

Roof rats (Rattus rattus), sometimes called black rats, are slightly smaller than Norway rats. Unlike Norway rats, their tails are longer than their heads and bodies combined. Roof rats are very agile climbers and usually live and nest above ground in shrubs, trees, and dense vegetation such as ivy. In buildings, they are most often found in enclosed or elevated spaces in attics, walls, false ceilings, and cabinets. The roof rat has a more limited geographical range than the Norway rat, preferring ocean-influenced, warmer climates. In areas where the roof rat occurs, the Norway rat may also be present. If you are unsure of the species, look for rats at night with a strong flashlight or trap a few. There are several key physical differences between the two species of rats; Table 1 summarizes identifying characteristics.

Table 1. Identifying Characteristics of Adult Rats.

Characteristic	Roof rat	Norway rat
general appearance	sleek, agile	large, robust
color of belly	gray to white	mostly grayish
body weight	5 to 10 ounces	7 to 18 ounces
tail	extends at least to snout; black, fine scales	shorter than body; dark above; pale below; scales
head	muzzle pointed	muzzle blunt
ears	long enough to reach eyes if folded over	do not reach eyes

While rats are much larger than the common house mouse or meadow vole, a young rat is occasionally confused with a mouse. In general, very young rats have large feet and large heads in proportion to their bodies, whereas those of adult mice are much smaller in proportion to their body size. While both rats and mice gnaw on wood, rats leave much larger tooth marks than those of a mouse. For additional information on mice, see Pest Notes: House Mouse and Pest Notes: Voles (Meadow Mice) listed in References.

How to Spot a Rat Infestation

Because rats are active throughout the year, periodically check for signs of their presence. Once rats have invaded your garden or landscaping, unless your house is truly rodent proof, it is only a matter of time before you find evidence of them indoors. Experience has shown it is less time consuming to control rodents before their numbers get too high, and fewer traps and less bait will be required if control is started early.

Inspect your yard and home thoroughly. If the answer to any of the following questions is yes, you may have a rat problem.

Do you find rat droppings around dog or cat dishes or pet food storage containers?
Do you hear noises coming from the attic just after dusk?
Have you found remnants of rat nests when dismantling your firewood stack?
Does your dog or cat bring home dead rat carcasses?
Is there evidence rodents are feeding on fruit/nuts that are in or falling from the trees in your yard?
Do you see burrows among plants or damaged vegetables when working in the garden?
Do you see rats traveling along utility lines or on the tops of fences at dusk or soon after?
Have you found rat nests behind boxes or in drawers in the garage?
Are there smudge marks caused by the rats rubbing their fur against beams, rafters, pipes, and walls?
Do you see burrows beneath your compost pile or beneath the garbage can?
Are there rat or mouse droppings in your recycle bins?
Have you ever had to remove a drowned rat from your swimming pool or hot tub?
Do you see evidence of something digging under your garden tool shed or doghouse?

Biology and Life Cycle of the Rat

Rats, like house mice, are mostly active at night. They have poor eyesight, but they make up for this with their keen senses of hearing, smell, taste, and touch. Rats constantly explore and learn about their environment, memorizing the locations of pathways, obstacles, food and water, shelter, and other elements in their domain. They quickly detect and tend to avoid new objects placed into a familiar environment. Thus, objects such as traps and baits often are avoided for several days or more following their initial placement. While both species exhibit this avoidance of new objects, it is usually more pronounced in roof rats than in Norway rats.

Both Norway and roof rats may gain entry to structures by gnawing, climbing, jumping, or swimming through sewers and entering through the toilet or broken drains. While Norway rats are more powerful swimmers, roof rats are more agile and are better climbers.

Norway and roof rats do not get along. The Norway rat is larger and the more dominant species; it will kill a roof rat in a fight. When the two species occupy the same building, Norway rats will dominate the basement and ground floors, with roof rats occupying the attic or second and third floors. Contrary to some conceptions, the two species cannot interbreed. Both species may share some of the same food resources but do not feed side-by-side. Rats may grab food and carry it off to feed elsewhere.

Rats of either species, especially young rats, can squeeze beneath a door with only a 1/2-inch gap. If the door is made of wood, the rat may gnaw to enlarge the gap, but this may not be necessary.

Norway Rats

Norway rats eat a wide variety of foods but mostly prefer cereal grains, meats, fish, nuts, and some fruits. When searching for food and water, Norway rats usually travel an area of about 100 to 150 feet in diameter; seldom do they travel any further than 300 feet from their burrows or nests. The average female Norway rat has four to six litters per year and may successfully wean 20 or more offspring annually.

Roof Rats

Like Norway rats, roof rats eat a wide variety of foods, but their food preferences are primarily fruits, nuts, berries, slugs, and snails. Roof rats are especially fond of avocados and citrus and often eat fruit that is still on the tree. When feeding on a mature orange, they make a small hole through which they completely remove the contents of the fruit, leaving only the hollowed out rind hanging on the tree. The rind of a lemon is often eaten, leaving the flesh of the sour fruit still hanging. Their favorite habitats are attics, trees, and overgrown shrubbery or vines. Residential or industrial areas with mature landscaping provide good habitat, as does riparian vegetation of riverbanks and streams. Roof rats prefer to nest in locations off the ground and rarely dig burrows for living quarters if off-the-ground sites exist.
Roof rats routinely travel up to 300 feet for food. They may live in the landscaping of one residence and feed at another. They can often be seen at night running along overhead utility lines or fence tops. They have an excellent sense of balance and use their long tails for balance while traveling along overhead utility lines. They move faster than Norway rats and are very agile climbers, which enables them to quickly escape predators. They may live in trees or in attics and climb down to a food source. The average number of litters a female roof rat has per year depends on many factors, but generally is three to five with from five to eight young in each litter.

Damage caused by rats

Rats consume and contaminate foodstuffs and animal feed. They also damage containers and packaging materials in which foods and feed are stored. Both species of rats cause problems by gnawing on electrical wires and wooden structures (doors, ledges, in corners, and in wall material) and tearing up insulation in walls and ceilings for nesting.

Norway rats may undermine building foundations and slabs with their burrowing activities. They may also gnaw on all types of materials, including soft metals such as copper and lead as well as plastic and wood. If roof rats are living in the attic of a residence, they can cause considerable damage with their gnawing and nest-building activities. They also damage garden crops and ornamental plantings.

Among the diseases rats may transmit to humans or livestock are murine typhus, leptospirosis, trichinosis, salmonellosis (food poisoning), and ratbite fever. Plague is a disease that can be carried by both roof and Norway rats, but in California it is more commonly associated with ground squirrels, chipmunks, and native wood rats.

Managing a rat problem

Three elements are necessary for a successful rat management program: sanitation measures, building construction and rodent proofing, and, if necessary, population control.

Sanitation

Sanitation is fundamental to rat control and must be continuous. If sanitation measures are not properly maintained, the benefits of other measures will be lost, and rats will quickly return. Good housekeeping in and around buildings will reduce available shelter and food sources for Norway and, to some extent, roof

rats. Neat, off-the-ground storage of pipes, lumber, firewood, crates, boxes, gardening equipment, and other household goods will help reduce the suitability of the area for rats and will also make their detection easier. Garbage, trash, and garden debris should be collected frequently, and all garbage receptacles should have tight-fitting covers. Where dogs are kept and fed outdoors, rats may become a problem if there is a ready supply of dog food. Feed your pet only the amount of food it will eat at a feeding, and store pet food in rodent-proof containers.

For roof rats in particular, thinning dense vegetation will make the habitat less desirable. Climbing hedges such as Algerian or English ivy, star jasmine, and honeysuckle on fences or buildings are very conducive to roof rat infestations and should be thinned or removed if possible, as should overhanging tree limbs within 3 feet of the roof. Separate the canopy of densely growing plants such as pyracantha and juniper from each other and from buildings by a distance of 2 feet or more to make it more difficult for rats to move between them.

Building Construction and Rodent Proofing

The most successful and long lasting form of rat control in buildings is to "build them out." Seal cracks and openings in building foundations, and any openings for water pipes, electric wires, sewer pipes, drain spouts, and vents. No hole larger than 1/4 inch should be left unsealed to exclude both rats and house mice. Make sure doors, windows, and screens fit tightly. Their edges can be covered with sheet metal if gnawing is a problem. Coarse steel wool, wire screen, and lightweight sheet metal are excellent materials for plugging gaps and holes. Plastic sheeting, wood, caulking, and other less sturdy materials are likely to be gnawed away.
Because rats (and house mice) are excellent climbers, openings above ground level must also be plugged. Rodent proofing against roof rats usually requires more time to find entry points than for Norway rats because of their greater climbing ability. Roof rats often enter buildings at the roof line area so be sure that all access points in the roof are sealed. If roof rats are traveling on overhead utility wires, contact a pest control professional or the utility company for information and assistance with measures that can be taken to prevent this.

Rodent Proofing Your Structure

Repair or replace damaged ventilation screen around the foundation and under eaves.
Provide a tight fitting cover for the crawl space.
Seal all openings around pipes, cables, and wires that enter through walls or the foundation.
Be sure all windows that can be opened are screened and that the screens are in good condition.
Cover all chimneys with a spark arrester.
Make sure internal screens on roof and attic air vents are in good repair.
Cover rooftop plumbing vent pipes in excess of 2 inches in diameter with screens over their tops.
Make sure all exterior doors are tight fitting and weatherproofed at the bottom.
Seal gaps beneath garage doors with a gasket or weather-stripping.
Install self-closing exits or screening to clothes dryer vents to the outside.
Remember that pet doors into the house or garage provide an easy entrance for rodents.
Keep side doors to the garage closed, especially at night.

Population Control

When food, water, and shelter are available, rat populations can reproduce and grow quickly. While the most permanent form of control is to limit food, water, shelter, and access to buildings, direct population control is often necessary.
For controlling rats indoors, use traps. Baiting is best done outdoors only; otherwise rats may die behind a wall. In hot weather, the stench of a dead rat can be unbearable and may necessitate cutting a hole in the wall to remove the carcass. Also, ectoparasites such as fleas and mites often leave dead rat carcasses and may infest the entire house if the carcass is not removed promptly.

Trapping

Trapping is the safest and most effective method for controlling rats in and around homes, garages, and other structures. Because traps can be used over and over again, trapping is less costly than poison baits but more labor intensive. Traps can be set and left indefinitely in areas where rats have been a problem in the past, such as an attic. The simple wooden rat-size snap trap is commonly used for rats, and the newer rat traps with large plastic treadles are especially effective. Generally young rats cannot be trapped until they are about a month old, which is when they leave the nest to venture out for food.
The kind of bait used for the trap is important. Nut meat, dried fruit, or bacon makes excellent baits for rats. The bait should be fastened securely to the trigger of the trap with light string, thread, or fine wire so the rodent will spring the trap in attempting to remove the food. Even glue can be used to secure the bait to the trigger. Soft baits such as peanut butter and cheese can be used, but rats sometimes take soft baits without setting off the trap. Leaving traps baited but unset until the bait has been taken at least once improves trapping success by making the rodents more accustomed to the traps. Set traps so the trigger is sensitive and will spring easily.

The best places to set traps are in secluded areas where rats are likely to travel and seek shelter. Droppings, gnawings, and damage indicate the presence of rodents, and areas where such evidence is found are usually the best places to set traps, especially when these areas are located between their nests and food sources. Place traps in natural travel ways, such as along walls, so the rodents will pass directly over the trigger of the trap. If a rat sets off a trap without getting caught, it will be very difficult to catch the rat with a trap again.

For Norway rats, set traps close to walls, behind objects, in dark corners, and in places where rat signs, such as droppings, have been seen. Position traps along a wall so that they extend from the wall at right angles, with the trigger end nearly touching the wall. If traps are set parallel to the wall, they should be set in pairs to intercept rodents traveling from either direction.

For roof rats, the best places for traps are off the ground in locations where rats may be coming down from their nests to find food such as on ledges, shelves, branches, fences, pipes, or overhead beams where they can be fastened with screws or wire. In homes, the attic and garage rafters close to the infestation are good trapping sites. In areas where children, pets, or birds might contact traps, place the trap in a box or use a barrier to keep them away.

Use as many traps as are practical so trapping time will be short and decisive. A dozen or more traps for a heavily infested home may be necessary. Place rat traps about 10 to 20 feet apart. Dispose of dead rats by burying or placing them in plastic bags, sealing, and putting them in the trash. Do not touch the rodent with bare hands and wash thoroughly after handling traps.

Glue Board

One of the alternatives to a snap trap is a glue board. Glue boards work on the same principle as flypaper: when a rat or mouse attempts to cross the glue board, the rodent gets stuck. Glue boards are much more effective for mice than for rats. Also, one of the major drawbacks with glue boards (and other live-catch type traps) is that the trapped rat may not die quickly, and you will need to kill it. For this reason, glue boards are not a good alternative for many people and their use is not recommended. Also, cats and dogs may get into the glue and track it around the house, creating additional problems.

Live Trap

Live traps are not recommended because trapped rats must either be killed or released elsewhere. Releasing rats outdoors is not recommended because of health concerns to people, pets, and other domestic animals. Because neither the roof nor Norway rat is native to this country, their presence in the wild is very detrimental to native ecosystems. They have been known to decimate some bird populations.

Toxic Bait

While trapping is generally recommended for controlling rats indoors, when the number of rats around a building is high, you may need to use toxic baits to achieve adequate control, especially if there is a continuous reinfestation from surrounding areas. If this is the case, consider hiring a licensed pest control applicator, who is trained to use rodenticides safely.
Toxic baits contain active ingredients that work as either an anticoagulant, causing death by internal bleeding or as a direct toxin (Table 2).

Table 2. Types of Baits Used in Rat Control and Their Active Ingredients.

Type of bait	Active ingredients	Use restrictions
multiple-feeding anticoagulant	warfarin, chlorophacinone, diphacinonene	for use in and around buildings and in gardens and landscaped areas
single-feeding anticoagulant	brodifacoum, bromadiolone, difethialone	for use in and around buildings only
nonanticoagulant	bromethalin, cholecalciferol	for use in and around buildings only
nonanticoagulant	zinc phosphide	for use in and around buildings and in gardens and landscaped areas

It is important to note that some of the baits on the market may only be used in and around buildings and are not registered for use in the garden and landscape. These include the newer, single-feeding anticoagulants (brodifacoum, bromadiolone, and difethialone) and two of the nonanticoagulants (bromethalin and cholecalciferol). The multiple-feeding anticoagulant baits and zinc phosphide may be used both in and around structures as well as in gardens and landscapes.

Anticoagulant Baits

Anticoagulant baits used to be thought of as relatively safe baits to use around the house and garden because they required multiple feedings to be effective. Newer anticoagulant baits, however, have been developed that only require a single feeding to be effective and are, therefore, more hazardous than the older type of anticoagulant bait to pets and children. Baits that require multiple feedings over a period of several days contain warfarin, chlorophacinone, or diphacinone as their active ingredient, whereas the single-feeding anticoagulants contain brodifacoum, bromadiolone, or difethialone. Whether a bait actually requires multiple feedings or not depends on how much is consumed at each feeding—even the newer, single-feeding baits must be consumed in adequate amounts to be effective. With all anticoagulants, death is generally delayed 2 to 6 days after a lethal dose of bait has been consumed. While both types of anticoagulant toxicants are effective against Norway and roof rats when formulated in acceptable baits, roof rats tend to need a few more feedings to obtain a lethal dose than Norway rats do. This is particularly true with the multiple-feeding anticoagulants, as compared to the single-feeding ones.

Anticoagulant baits are available in meal, pellet, kernel, or block form. Pelleted or meal baits are frequently sold in small packets called "place packs." Also, a wide variety of paraffin block baits are marketed and convenient to use. Most of these blocks must be placed in a tamper-resistant bait station to prevent dogs and other animals from chewing on them.

Nonanticoagulant Baits

Nonanticoagulant baits are usually lethal after one feeding if the rat ingested an adequate amount of toxin. Bromethalin, cholecalciferol, and zinc phosphide are common active ingredients in this group of baits used for rats. These baits are placed in runways or next to burrows where rats will find them. Nonanticoagulant baits are generally more rapid acting than anticoagulant baits and you may find dead rodents within 12 hours of baiting. Because the toxins in these baits do not accumulate in the tissue of the rodent, predators or scavengers such as dogs and cats are not likely to be adversely affected by eating poisoned carcasses (see

sidebar, Pets and Rat Control). However, they, as well as other animals and children, can be affected by eating the bait so it must be stored and used carefully.

Bait Stations

Bait stations or boxes are often used with baits of all kinds. These enclosures protect the bait from weather and restrict accessibility to rodents, providing a safeguard for people, pets, and other animals. Bait stations should be large enough to accommodate several rats at a time and should contain a bait-holding compartment. Each station should have at least two openings for rats to enter and exit. Place bait stations next to walls or in places where rats will encounter them. Commercial bait stations are available in a variety of sizes and shapes. Stations that may be accessible to children or pets must be made of sturdy, tamper-resistant material and be secured in a way that they cannot be tipped. See the product label for additional information. All bait stations should be clearly labeled.

Bait Placement

It is best to place bait in a bait station. In addition to increasing the safety of the bait, the use of bait stations also helps the rats to feel secure while feeding. Place all bait stations in rat travel-ways or near their burrows and harborage. Do not expect rats to go out of their way to find the bait. For Norway rats, place bait stations near rodent burrows or suspected nest sites, against walls, or along travel routes. For roof rats, place baits in elevated locations, such as in the crotch of a tree, on top of a fence, or high in a vine. If you place bait stations above ground level, take care that they are securely fastened and will not fall to the ground where children or pets could find them.

Because rats are often suspicious of new or unfamiliar objects, it may take several days for them to enter and feed in bait stations. For best results, make sure there is a continuous supply of bait until feeding stops. With the older anticoagulant baits it usually takes 5 days or more once the rats start feeding for them to succumb.

During the baiting process, dispose of dead rodents by burying them or placing them in plastic bags and putting them in the trash. Use gloves and wash hands thoroughly after handling dead rodents, traps, or bait stations. Additionally, poisoned rats often die in inaccessible locations within a building, leading to persistent and unpleasant odors, so rodent-proof the building before you use toxic baits outside.

Other Control Methods

Rats are wary animals, easily frightened by unfamiliar or strange noises. However, they quickly become accustomed to repeated sounds, making the use of frightening sounds, including high frequency and ultrasonic sounds, ineffective for controlling rats in home and garden situations.

Traps that kill rats by electrocution are available on the market. These traps are considerably more expensive than the common snap trap and can be used safely and effectively only in limited situations. Like the snap traps, these traps catch only one rat at a time and then must be emptied. Twenty or more snap traps can be purchased and put to use for the price of one of the electrocution units. When compared with snap traps, electrocution traps have not shown sufficient advantages to promote their use.

Rats have an initial aversion to some odors and tastes, but no repellents have been found to solve a rat problem for more than a very short time. There are no truly effective rat repellents registered for use in California.

Smoke or gas cartridges are registered and sold for the control of burrowing rodents. When placed into the burrows and ignited, these cartridges produce toxic and suffocating smoke/gases. Norway rat burrows may extend beneath a residence and have several open entrances, however, permitting toxic gases to permeate the dwelling. For this reason and because some fire hazard is associated with their use, smoke and gas cartridges are not recommended for rat control around homes.

Norway rats may be drowned or flushed from their burrows by flooding them out with water from a garden hose and then closing the holes with dirt.

Predators, especially cats and owls, eat rats and mice. However, much of the time these predators are unable to keep rodent numbers below levels that are acceptable to most people.

Compiled From

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California Ground Squirrel

The California ground squirrel, *Spermophilus beecheyi,* is one of the most troublesome pests to homeowners and gardeners. It is found in nearly all regions of California except for the Owens Valley southward into the desert regions.

Identification

Ground squirrels are easily identified as they forage aboveground near their burrows. The ground squirrel's body measures 9 to 11 inches and its semi-bushy tail adds another 5 to 9 inches in length. The fur is brownish gray and speckled with off-white along the back; the sides of the head and shoulders are light gray to whitish. One subspecies that occupies most of northern California has a dark, triangular-shaped patch on its back between the shoulders; this patch is missing from other species. While ground squirrels are similar in appearance to tree squirrels and may climb trees, when frightened they will always retreat to a burrow, whereas tree squirrels will climb a tree or tall structure and never use a burrow.

Biology and Behavior

Ground squirrels live in a wide variety of natural habitats but usually avoid thick chaparral, dense woods, and wet areas. Populations may be particularly high in grazed rangelands and in areas disturbed by humans such as road or ditchbanks, fence rows, around buildings, and in or bordering many crops.

Ground squirrels live in a burrow system where they sleep, rest, rear young, store food, and avoid danger. The burrow openings are about 4 inches in diameter, but can vary considerably. The burrows may be 5 to 30 feet or more in length and may go 2 to 4 feet below the soil surface. Often there is more than one opening in a burrow system. Ground squirrels live in colonies that may include several dozen animals in a complex of burrows. More than one squirrel may live in a burrow.

Ground squirrels are active during the day, mainly from mid-morning through late afternoon, especially on warm, sunny days. Ground squirrels have two periods of dormancy during the year. During winter months most ground squirrels hibernate, but some young may be active at this time, especially in areas where winters are not severe. During the hottest times of the year most adults go into a period of inactivity, called estivation, that may last a few days to a week or more. During these periods, the burrow appears open at the entrance but the squirrel plugs it with soil near the nest.

Ground squirrels breed once a year, averaging seven to eight per litter. Timing of breeding varies with location: in southern California breeding begins in December, in the Central Valley in February through April, and somewhat later in the mountain ranges. Aboveground activity by adults is at a maximum at the height of the breeding season. The young are born in the burrow and grow rapidly; by about 6 weeks of age they usually emerge from the burrow. At 6 months of age they resemble adults.

Ground squirrels are primarily herbivorous. Their diet changes with the season. After emergence from hibernation, they feed almost exclusively on green grasses and herbaceous plants. When annual plants begin to dry and produce seed, squirrels switch to seeds, grains, and nuts, and begin to store food. Ground squirrels usually forage close to their burrows. Their home range typically is within a 75-yard radius of their burrow.

Damage

Ground squirrels damage many food-bearing and ornamental plants. Particularly vulnerable are grains and nut and fruit trees such as almond, apple, apricot, orange, peach, pistachio, prune, and walnut. Ground squirrels will enter gardens and devour vegetables in the seedling stage. They may damage young shrubs, vines, and trees by gnawing bark, girdling trunks, eating twigs and leaves, and burrowing around roots.

Ground squirrels will gnaw on plastic sprinkler heads and irrigation lines. They also eat the eggs of ground-nesting birds and may limit attempts to attract quail to the yard.

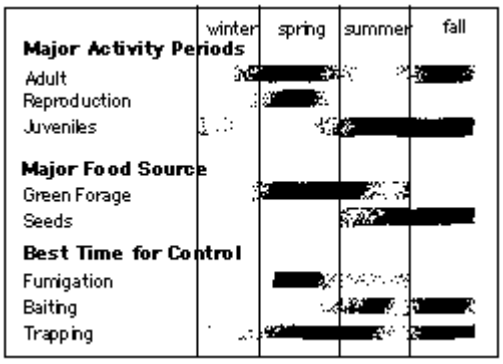
Burrowing can be quite destructive. Burrows and mounds make it difficult to mow, and they present hazards to machinery, pedestrians, and livestock. Burrows around trees and shrubs can damage and desiccate roots, and sometimes topple trees. Burrows beneath buildings and other structures sometimes necessitate repair.

Ground squirrels can harbor diseases harmful to humans, particularly when squirrel populations are dense. A major concern is bubonic plague transmitted to humans by fleas carried on the squirrels. Ground squirrels are susceptible to plague, which has wiped out entire colonies. If you find unusual numbers of squirrels or other rodents dead for no apparent reason, notify public health officials. Do not handle dead squirrels under these circumstances.

Legal Status and Considerations

Ground squirrels are classified as nongame mammals by the California Fish and Game Code. Nongame mammals injuring growing crops or other property may be controlled in any legal manner by the owner or tenant; tree squirrels, on the other hand, are classified as game animals and have a hunting season.
Note that the Mohave ground squirrel *(S. mohavensis)* and the San Joaquin antelope squirrel *(Ammospermophilus nelsoni)* are classified as *threatened* by the U.S. Fish and Wildlife Service and are protected. Although neither of these relatively small squirrels is likely to be misidentified as the much larger California ground squirrel, their ranges could overlap in some areas. The endangered San Joaquin kit fox *(Vulpes macrotis mutica)*, several endangered species of kangaroo rats, the riparian brush rabbit *(Sylvilagus bachmani riparius)*, riparian wood rat *(Neotoma fuscipes riparia)*, as well as some endangered amphibians and reptiles, are also found within California ground squirrels' range and could be impacted by some squirrel control techniques. Before using pesticides for ground squirrel control, *read the product label* to determine if any restrictions exist on rodent control within the ranges of these and other endangered and protected animals. Also, if the kit fox is found in your county (for a range map, see the California Department of Pesticide Regulation's Web site listed in "References"), contact your county agricultural commissioner for additional information

Management



The selection of control procedures is heavily influenced by the unique life cycle and behavior of the ground squirrel. For example, baiting with treated grain is effective in summer and fall because squirrels primarily feed on seeds during this period. Fumigation is most effective in spring when soil is moist, which helps seal gasses in the burrow system. Fumigating at this time also is more effective because squirrels are removed before they can reproduce. The best time for baiting, trapping, and fumigation depends on the activity periods and food sources of the ground squirrel.

Trapping

Traps are practical for control when squirrel numbers are low to moderate. Live-catch traps are not recommended because they present the problem of how to dispose of the live animals. Because ground squirrels carry diseases and are agricultural pests, the California Fish and Game Code specifies that it is illegal to release them elsewhere without a written permit.

There are several types of traps that kill ground squirrels, including box traps, Conibear traps, and tunnel traps. Box traps should be placed on the ground near squirrel burrows or runways. Bait these traps with walnuts, almonds, oats, barley, or melon rinds. Place the bait well behind the trigger or tied to it. Bait the traps but do not set them for several days so the squirrels become accustomed to them. After the squirrels are used to taking the bait, rebait and set the traps.

To reduce hazards to children, pets, poultry, and nontarget wildlife, place box-type traps in a covered box with a 3-inch diameter entrance. Put the box near active burrows with signs of recent diggings. Inactive burrows will be filled with leaves, old straw, or have cobwebs across the entrance.

The Conibear trap (No. 110) with a 4-1/2 by 4-1/2-inch jaw spread is also an effective kill trap. The wire trigger can be baited but is usually left unbaited. Place the trap directly in the burrow opening so the squirrel must pass through it, tripping the trigger. It may be necessary to partially fill in the burrow entrance around the outer edges of the trap with soil to prevent the squirrel from slipping around the outside of the trap. Closing all other burrows with soil may hasten success by directing the squirrel to the remaining open burrow with the trap. Attach the Conibear trap to a stake to prevent a scavenger from carrying off the trap and squirrel. With this type of trap, leaving the trap baited but unset has little effect on trapping success.

Inspect traps at least once a day and remove dead squirrels. Do not handle the carcasses without protective gear. Use a plastic bag slipped over each hand and arm as a glove. Once the squirrel is removed from the trap, hold the animal with one hand and turn the bag inside out while slipping it off your arm and hand. If possible, keep small children and pets out of the area while traps are in use. In kit fox areas, spring all Conibear traps before nightfall and reset them the following morning.

Fumigation

Fumigation is a relatively safe method of control. As with any pesticide, *read and follow label instructions* with particular regard for nontarget species and safety factors. With some fumigants, flames may be produced, creating a fire danger. Do not use such fumigants where a significant fire hazard exists, such as near buildings, dry grass, or other flammable materials. To avoid the accumulation of fumes in enclosed areas, never fumigate beneath buildings or in burrows that may open under occupied buildings.
Be aware of the signs of nontarget species inhabiting inactive ground squirrel burrows. Kit foxes will use an old burrow, enlarging the opening, often creating a keyhole-shaped entrance. Active pupping dens may be littered with prey remains, droppings, and matted vegetation, and show signs of fresh paw prints. The burrowing owl *(Athene cunicularia)* is another potential occupant of abandoned ground squirrel burrows. Only fumigate active ground squirrel burrows; county agricultural commissioners can provide additional information on how to recognize these. Do not treat a burrow if you suspect a nontarget animal is present.

Many county agricultural commissioners' offices sell USDA gas cartridges, which are designed for fumigating burrowing rodents. Other types of fumigation cartridges are also available at retail outlets. Fumigation is most effective in spring or other times when soil moisture is high, which helps to contain the gas within the burrow system. Do not fumigate in summer or when the soil is dry because the gas more readily diffuses into small cracks present in dry soil. Do not fumigate during hibernation because the squirrel plugs its burrow with soil, preventing fumes from reaching the nest chamber. The plug cannot be seen by examining the burrow entrance.

Treat all active burrow systems when fumigating. When using a USDA gas cartridge, puncture the end with a nail or screwdriver at the points marked and rotate the nail to loosen the material inside. Insert the fuse into the center hole. Place the cartridge in the burrow as far as possible and light the fuse. With a shovel handle or stick, push the lighted cartridge down the burrow and quickly seal the opening with soil, tamping it down. Fill in connected burrows if smoke is seen escaping. Larger burrow systems usually require two or more cartridges placed in the same or connecting burrow openings. After 24 hours, check for reopened burrows and re-treat as needed.

Toxic Baits

Anticoagulant baits, available at county agricultural commissioners' offices, are recommended for controlling ground squirrels. To be effective, anticoagulants must be consumed in several feedings over a period of 5 or more days. These features, as well as an antidote (vitamin K1), make anticoagulant baits relatively safe for humans and pets. Keep pets out of treated areas, check the areas daily, and remove and dispose of any carcasses. Dogs are more likely to consume the pelletized cereal-based baits than the loose grain baits. Pelletized baits are prohibited in kit fox areas.

Anticoagulant baits can be used in bait boxes or by repeated spot baiting. Bait boxes are small structures that the squirrel must enter to eat the bait. Boxes contain sufficient bait for repeated feedings. They are the preferred baiting method around homes and other areas where children, pets, and poultry are present. Unless a bait label specifies otherwise, bait boxes can be constructed from any durable material and in a variety of designs. If you design a bait box, make the entrance hole(s) about 3 inches across to allow access to squirrels but not to larger animals. Construct a lip to prevent bait from spilling out of the box when squirrels exit. Provide a lock on the box or devise some other method that will make it difficult for children to open. Secure the bait box so it cannot be turned over or easily removed. A self-feeding arrangement insures that the pest gets a continuous supply of bait. Never fill a bait box with more than 5 pounds of bait.

Place bait boxes near runways or burrows. If squirrels are present over a large area, space the boxes at 100- to 200-foot intervals. Initially, inspect bait stations daily and add bait as needed. Increase the amount of bait if all is eaten by the end of the day. Fresh bait is important; replace moldy or old bait. Do not use old, leftover bait. It may take a number of days before squirrels become accustomed to the bait box and enter it. Anticoagulant bait generally requires 2 to 4 weeks or more to be effective. Continue baiting until all feeding ceases and no squirrels are observed. While few ground squirrels will die aboveground, those that do should be picked up and disposed of as described in the section above on *Trapping* and in accordance with label directions. Also, pick up and dispose of unused bait (according to label instructions) upon completion of the control program.

Habitat Modification

Ground squirrels generally are found in open areas, although they sometimes use available cover. Remove brush piles and debris to make an area less desirable to ground squirrels. This also aids in detection of squirrels and their burrows, and improves access during control operations.
Ground squirrels can reinvade a site by moving into vacant burrows. Destroy old burrows by deep ripping them to a depth of at least 20 inches, using a tractor and ripping bar(s). Simply filling in the burrows with soil does not prevent reinvasion as ground squirrels easily find and reopen old burrows.

Other Control Techniques

Shooting squirrels with a .22 rifle may provide some control but is very time-consuming. Shooting is recommended only when it can be safely done in rural locations where squirrel numbers are very low. There are no effective frightening devices or repellents that will cause ground squirrels to leave their burrows or avoid an area or crop.

Natural Control

Many predators, including hawks, eagles, rattlesnakes, and coyotes, eat ground squirrels. In most cases, predators are not able to keep ground squirrel populations below the level at which they become pests for the home gardener. Dogs may prevent squirrels from entering small areas, but they cannot control established squirrel populations.

Follow-up

For those who live next to wildlands or other areas where squirrels are common, an ongoing control program will be necessary. Squirrels will reinvade over time. Once ground squirrels have been controlled, periodically monitor the area for reinfestation. Check for new burrows. Start control actions as soon as new squirrels are noticed. It is easier and less expensive to control a small population.

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Ants

Ants are among the most prevalent pests in households. They are also found in restaurants, hospitals, offices, warehouses, and other buildings where they can find food and water. On outdoor (and sometimes indoor) plants, ants protect and care for honeydew-producing insects such as aphids, soft scales, whiteflies, and mealybugs, increasing damage from these pests. Ants also perform many useful functions in the environment, such as feeding on other pests (e.g., fleas, caterpillars, and termites), dead insects, and decomposing tissue from dead animals.

There are over 12,000 species of ants throughout the world. In California, there are about 200 species but fewer than a dozen are important pests. The most common ant occurring in and around the house and garden in California is the Argentine ant, *Linepithema humile* (formerly *Iridomyrmex humilis).* Other common ant pests include the pharaoh ant *(Monomorium pharaonis),* the odorous house ant *(Tapinoma sessile),* the thief ant *(Solenopsis molesta),* and the southern fire ant *(Solenopsis xyloni).* The velvety tree ant, *Liometopum occidentale,* nests in old wood and is a common outdoor species in landscapes.

Less common, but of great importance, is the red imported fire ant, *Solenopsis invicta,* which has recently gained a foothold in southern California. In some areas, the spread of the fire ant has been slowed by competition from the Argentine ant. Carpenter ants, *Camponotus* spp., also invade buildings in California. Although they do not eat wood as termites do, they hollow it out to nest and may cause considerable damage.

Identification

Ants belong to the insect order Hymenoptera and are close relatives of bees and wasps. They are familiar insects that are easily recognized, especially in their common wingless adult forms, known as workers. However, winged forms of ants, which leave the nest in large numbers in warm weather to mate and establish new colonies, are often mistaken for winged termites, which also leave their nests to mate. Ants and termites can be distinguished by three main characteristics:

- The ant's body is constricted, giving it the appearance of having a thin waist; the termite's body is not constricted.
- The ant's hind wings are smaller than its front wings; the termite's front and hind wings are about the same size. (Shortly after their flights, both ants and termites lose their wings, so wings may not always be present.)
- Winged female and worker ants have elbowed antennae; the termite's antennae are not elbowed.

Ants undergo complete metamorphosis, passing through egg, larval, pupal, and adult stages. Larvae are immobile and wormlike and do not resemble adults. Ants, like many other hymenopterans, are social insects with duties divided among different types, or castes, of adult individuals. Queens conduct the reproductive functions of a colony and are larger than other ants; they lay eggs and sometimes participate in the feeding and grooming of larvae. Female workers, who are sterile, gather food, feed and care for the larvae, build tunnels, and defend the colony; these workers make up the bulk of the colony. Males do not participate in colony activities; their sole purpose is to mate with the queens. Few in number, males are fed and cared for by workers.

Damage

Inside buildings, household ants feed on sugars, syrups, honey, fruit juice, fats, and meat. Long trails of thousands of ants may lead from nests to food sources, causing considerable concern among building occupants. Outdoors they are attracted to honeydew, produced by soft scales, mealybugs, and aphids. This liquid excrement contains sugars, and other nutrients. Frequently outbreaks of scales and aphids occur when ants tend them for honeydew because the ants protect scales and aphids from their natural enemies.

Ants can bite with their pincerlike jaws, although most species rarely do. The velvety tree ant, however, is an aggressive biter. A few ants sting, including native fire ants and harvester ants, which are primarily outdoor species, and are the most common stinging ants in California. An aggressive stinging ant, the red imported fire ant *(S. invicta)*, has recently been found in various southern California counties.

Life Cycle and Habits

Ants usually nest in soil; nest sites vary with species but are often found next to buildings, along sidewalks, or in close proximity to food sources such as trees or plants that harbor honeydew-producing insects. They also construct nests under boards, stones, tree stumps or plants, and sometimes under buildings or other protected places. In temperate climates the pharaoh ant nests indoors preferring warm, moist locations, often in wall voids, under flooring, or near hot water pipes or heating systems but is also found nesting outdoors in warmer parts of California. Ant food includes fruits, seeds, nuts, fatty substances, dead or live insects, dead animals, and sweets. Food preferences vary among ant species.

Ants often enter buildings seeking food and water, warmth and shelter, or a refuge from dry, hot weather or flooded conditions. They may appear suddenly in buildings if other food sources become unavailable or weather conditions change.

A new colony is typically established by a single newly mated queen. After weeks or months of confinement underground, she lays her first eggs. After the eggs hatch, she feeds the white, legless larvae with her own metabolized wing muscles and fat bodies until they pupate. Several weeks later, the pupae transform into sterile female adult workers, and the first workers dig their way out of the nest to collect food for themselves, for the queen (who continues to lay eggs), and for subsequent broods of larvae. As numbers increase, new chambers and galleries are added to the nest. After a few years, the colony begins to produce winged male and female ants, which leave the nest to mate and form new colonies.

Argentine ants differ from most other ant species in California in that their nests are often shallow, extending just below the soil surface. However, under dry conditions they will nest deeper in the soil. In addition, Argentine ant colonies are not separate but linked to form one large supercolony with multiple queens. When newly mated queens disperse to found new colonies, they are accompanied by workers rather than going out on their own as most other species do.

Management

Ant management requires diligent efforts and the combined use of mechanical, cultural, sanitation, and often chemical methods of control. It is unrealistic and impractical to attempt to totally eliminate ants from an outdoor area. Focus your management efforts on excluding ants from buildings or valuable plants and eliminating their food and water sources. Reducing outdoor sources of ants near buildings may reduce the likelihood of ants coming indoors. Remember that ants play a beneficial role in the garden in some cases. Become aware of the seasonal cycle of ants in your area and be prepared for annual invasions by caulking and baiting before the influx. Different species of ants respond to management practices differently. For management information specific to a particular species, see the online *Key to Identifying Common Household Ant* at http://www.ipm.ucdavis.edu/TOOLS/ANTKEY/

Monitoring and Inspection

Monitor for ants near attractive food sources or areas of moisture. Ants may invade kitchens, bathrooms, offices, or bedrooms. Inspect under sinks, in cupboards, along pipes, and along electrical wires. Look for large trails of ants or for just a few stragglers. Straggling ants are scouts randomly searching for food or nesting sites. When you spot ant trails, try to follow the ants to where they are entering the building and to the nest if possible. Look for holes or cracks in foundations or walls that provide entry points to buildings.

Exclusion and Sanitation

To keep ants out of buildings, caulk cracks and crevices around foundations that provide entry from outside. Some caulking products available to professionals contain silica aerogel for long-term control combined with pyrethrins for more immediate effects. Ants prefer to make trails along structural elements, such as wires and pipes, and frequently use them to enter and travel within a structure to their destination. Indoors, eliminate cracks and crevices wherever possible, especially in kitchens and other food preparation and storage areas.

Store attractive food items such as sugar, syrup, honey, and pet food in closed containers that have been washed to remove residues from outer surfaces. Rinse out empty soft drink containers or remove them from the building. Thoroughly clean up grease and spills. Remove garbage from buildings daily and change liners frequently. Look for indoor nesting sites, such as potted plants. If ants are found in potted plants, remove the containers from the building, then place the pots for 20 minutes or more in a solution of insecticidal soap and water at a rate of one to two tablespoons of insecticidal soap per quart of water. Submerge so the surface of the soil is just covered by the water-soap solution.

Outdoor ant nests may be associated with plants that support large populations of honeydew-producing insects such as aphids, soft scales, mealybugs or whiteflies. Avoid planting such trees and shrubs next to buildings, or manage honeydew producing insects. Keep plants, grass, and mulch several inches away from the foundation of buildings because they provide nesting sites for ants.

Management on Trees and Shrubs

When numerous ants are found on plants, they are probably attracted to the sweet honeydew deposited on the plants by honeydew-producing insects such as aphids or soft scales. Ants may also be attracted up into trees or shrubs by ripening or rotten sweet fruit or floral nectar. These ants can be kept out by banding tree trunks with sticky substances such as Tanglefoot. Trim branches to keep them from touching structures or plants so that ants are forced to climb up the trunk to reach the foliage.

Protect young or sensitive trees from possible injury by wrapping the trunk with a collar of heavy paper, duct tape, or fabric tree wrap and coating this with the sticky material. Check the sticky material every 1 or 2 weeks and stir it with a stick to prevent the material from getting clogged with debris and dead ants, which will allow ants to cross. Ant stakes with bait can also be used around trees. In landscapes, some mulches can repel ants and discourage nesting. For example, aromatic pencil cedar mulch repels Argentine ants, whereas pine straw provides an ideal nesting site. Be aware that not all types of cedar chips repel ants: the effectiveness of red cedar chips found in California has not been verified.

Baits

Baits are insecticides mixed with materials that attract worker ants looking for food. They are a key tool for managing ants and the only type of insecticide recommended in most situations. Ants are attracted to the bait and recruit other workers to it. Workers carry small portions of the bait back to the nest where it is transferred mouth-to-mouth to other workers, larvae, and queens and other reproductive forms to kill the entire colony. Bait products must be slow-acting so that the foraging ants have time to make their way back to the nest and feed other members of the colony before they are killed. When properly used, baits are more effective and safer than sprays.

What to Do If You Have an Ant Emergency
• Determine what the ants are attracted to and remove the food source • Vacuum trails, wipe them with soapy water, or spray with window cleaner • Locate entry points and caulk openings or plug with petroleum jelly • Put out bait stations or apply gel bait at entry points • Baits take time to work so continue to clean up trails • Indoor sprays are not usually necessary

Baits are available in several different forms. For residential users, the most readily available forms are solids or liquids that are prepackaged into ant stakes or small plastic bait station containers. These products are easy to use and are quite safe if kept away from children or pets. Some products dry up rapidly and must be frequently replaced to control a large population. A few boric acid products are liquids that are poured into containers or applied as drops on cards.

Reusable bait stations, which are primarily available to pest control professionals, are more useful than prepackaged baits for difficult ant problems. Reusable stations can be opened, checked and refilled as needed. This is particularly important for liquid baits, which may be rapidly consumed or dry out. Some of these stations have removable cups that can be filled with two or more types of baits to offer ants a choice. Bait stations protect baits from photodegradation and disturbance by children. Some types of bait stations can be permanently installed into the ground or attached to outside walls or pavement in areas around schools or other buildings where ants are a frequent problem. They may be hidden in mulch so they are not immediately visible to children or pets.

Gel formulations of pesticide baits are packaged in small tubes. They are applied in small cracks and crevices where ants are entering. Gel products are now available to home users as well as professionals. Ant baits contain either carbohydrates (e.g., sugars), proteins, or oils, or some combination of these as attractants along with an active ingredient (toxicant). Different attractants are more effective against different species of ants and at different times of the year. In the case of Argentine ants, sweet baits are attractive year-round. Protein baits are attractive primarily in the spring because they are brought back to the colony to feed the developing brood. In the case of fire ants, they prefer baits containing oils. Offering a small quantity of each kind of bait and observing which one the ants prefer is a good way to determine what to use.

Look for the active ingredient listed on the label of bait products. Some examples of active ingredients include hydramethylnon, fipronil, arsenic trioxide, boric acid (borax), avermectin B (abamectin), and n-ethyl perfluorooctane-sulfonamide (sulfluramid). Table 1 lists some common ant bait products organized by active ingredient. Bait products are constantly being improved. Look out for new active ingredients and improvements to current products. Avoid products packaged as granules that contain the active ingredients cyfluthrin or permethrin. Although these products may be mistaken for baits, they are actually contact insecticides that rapidly kill foragers and do not control the colony. Likewise, bait stations with propoxur are not very effective because the active ingredient is too fast-acting.

Table 2. Common Ant Bait Products Available in 2004. Effectiveness varies.

Active Ingredient	Example product name	Formulation: application/bait
Arsenic trioxide	Grant's Kills Ants*	Solid: bait discs/sugar
Avermectin B (Abamectin)	381B Advance Select Granular Ant Bait	Solid: scatter or use bait station/protein
Borate-based products	Drax Ant Kil Gel[1] Advance liquid ant bait[1] Terro Ant Killer II Liquid Ant Baits[2]	Gel: apply in cracks/sugar Liquid: bait station/sugar Liquid: bait containers/sugar
Fipronil	Combat ant killing gel* Combat Quick Kill* Maxforce FC Ant Killer Bait Gel Maxforce FC Ant Bait Stations	Gel: apply in cracks/protein Solid: bait discs/protein Gel: apply in cracks/sugar Solid: bait discs/protein
Hydramethylnon	Combat Source Kill* Maxforce Ant Killer Bait Stations Maxforce granular insect bait	Solid: bait discs/protein Solid: bait discs/protein Solid: scatter or use bait station/protein
Sulfluramid (N-ethyl Perfluorooctane-sulfonamide)	Advance Dual Choice ant bait stations FMC FluorGuard Ant Control Baits Hotshot MaxAttrax ant bait* Raid Double Control Ant Baits* Zep ant bait stations*	Solid: bait discs/protein or sugar Solid: bait discs/protein or sugar Solid: bait discs/protein or sugar Solid: bait discs/protein or sugar

*Available for nonprofessionals in retail outlets. [1]Orthoboric acid [2]Sodium tetraborate decahydrate (borax)

To improve bait effectiveness, be sure to remove any particles of food or other attractive material from cracks around sinks, pantries, and other ant-infested areas. For the most effective and economical control, use baits only when there is an ant problem. Treatments made in late winter and early spring when ant populations are just beginning to grow will be most effective. Ant preferences can change throughout the year; to increase your success rate, set out different formulations of various bait products in a single baiting station, giving ants a choice. Do not use any insecticide sprays while you are using baits. Check and refresh bait stations regularly. Baits can dry up or become rancid and unattractive over time.

Use baits primarily outdoors. Use indoors only if there is a serious infestation and you can't find the spot where they are entering the building, otherwise you could actually attract ants indoors. Outdoor baits draw ants out of buildings. Place bait stations where ants can easily find them, but avoid placing them in areas that are accessible to small children and pets. Place baits near nests, on ant trails beneath plants, or along edges where ants travel. Space them every 10 to 20 feet outside around the foundation and at nest openings if they can be found. Effectiveness of baits will vary with ant species, bait material, and availability of alternative food. To achieve wide distribution of the bait so the entire colony will be killed, the bait toxicant must be slow acting. Control with baits is not immediate and may take several weeks or more to be complete.

Indoor Treatments

If ants can be thoroughly washed away and excluded from an area, an insecticide is probably not necessary. Vacuuming up ant trails or sponging or mopping them with soapy water may be as effective as an insecticide spray in temporarily removing foraging ants in a building because it removes the ant's scent trail, especially if thorough cleaning is done at the entry points. Some soap products such as window

cleaners can kill ants on contact but leave no residual toxicity. Certain plant-based oils are also applied for this purpose, but their odor can be offensive.

Outdoor Treatments

A common method used to prevent ants from coming indoors is to apply a perimeter treatment of residual sprays around the foundation. Commonly used insecticides include the pyrethroids bifenthrin and lambda-cyhalothrin. Both are available in retail products, but products available to professionals provide a longer residual control than home-use products. Spraying around the foundation will not provide long-term control because it kills only foraging ants without killing the colony. Perimeter treatments may appear to knock down the population, but ants will quickly build back up and invade again. To try to achieve long-term control, some pest control companies offer monthly perimeter spray programs. Perimeter treatments pose more risk of environmental upset than baits in bait stations and are less effective than a bait-based IPM program.

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Yellowjackets and Other Social Wasps

Only a few of the very large number of wasp species in California live a social life; these species are referred to as social wasps. Some social wasps are predators for most or all of the year and provide a great benefit by killing large numbers of plant-feeding insects and nuisance flies; others are exclusively scavengers. Wasps become a problem only when they threaten to sting humans. One of the most troublesome of the social wasps is the yellowjacket. Yellowjackets, especially ground- and cavity-nesting ones such as the western yellowjacket, tend to defend their nests vigorously when disturbed. Defensive behavior increases as the season progresses and colony populations become larger while food becomes scarcer. In fall, foraging yellowjackets are primarily scavengers and they start to show up at picnics, barbecues, around garbage cans, at dishes of dog or cat food placed outside, and where ripe or overripe fruit are accessible. At certain times and places, the number of scavenger wasps can be quite large.

Identification and Life Cycle

In western states there are two distinct types of social wasps: yellowjackets and paper wasps. Yellowjackets are by far the most troublesome group. Paper wasps are much less defensive and rarely sting humans. They tend to shy away from human activity except when their nests are located near doors, windows, or other high traffic areas.

Nests of both yellowjacket and paper wasps typically are begun in spring by a single queen who overwinters and becomes active when the weather warms. She emerges in late winter/early spring to feed and start a new nest. From spring to midsummer nests are in the growth phase, and the larvae require large amounts of protein. Workers forage mainly for protein at this time (usually in the form of other insects) and for some sugars. By late summer, however, the colonies grow more slowly or cease growth and require large amounts of sugar to maintain the queen and workers. So foraging wasps are particularly interested in sweet things at this time.

Normally, yellowjacket and paper wasp colonies only live one season. In very mild winters or in coastal California south of San Francisco, however, some yellowjacket colonies survive for several years and become quite large.

Yellowjackets

The term yellowjacket refers to a number of different species of wasps in the genera *Vespula* and *Dolichovespula* (family Vespidae). Included in this group of ground-nesting species are the western yellowjacket, *Vespula pensylvanica,* which is the most commonly encountered species and is sometimes called the "meat bee," and seven other species of *Vespula. Vespula vulgaris* is common in rotted tree stumps at higher elevations and *V. germanica* (the German yellowjacket) is becoming more common in many urban areas of California, where it frequently nests in houses. These wasps tend to be medium sized and black with jagged bands of bright yellow (or white in the case of the aerial-nesting *Dolichovespula [=Vespula] maculata)* on the abdomen, and have a very short, narrow waist (the area where the thorax attaches to the abdomen).

Nests are commonly built in rodent burrows, but other protected cavities, like voids in walls and ceilings of houses, sometimes are selected as nesting sites. Colonies, which are begun each spring by a single reproductive female, can reach populations of between 1,500 and 15,000 individuals, depending on the species. The wasps build a nest of paper made from fibers scraped from wood mixed with saliva. It is built as multiple tiers of vertical cells, similar to nests of paper wasps, but enclosed by a paper envelope around the outside that usually contains a single entrance hole. If the rodent hole is not spacious enough, yellowjackets will increase the size by moistening the soil and digging. Similar behavior inside a house sometimes leads to a wet patch that develops into a hole in a wall or ceiling.

Immature yellowjackets are white, grublike larvae that become white pupae. The pupae develop adult coloring just before they emerge as adult wasps. Immatures are not normally seen unless the nest is torn open or a sudden loss of adult caretakers leads to an exodus of starving larvae.

Aerial-nesting yellowjackets, *Dolichovespula arenaria* and *D. maculata*, build paper nests that are attached to the eaves of a building or are hanging from the limb of a tree. The entrance is normally a hole at the bottom of the nest. These aerial nesters do not become scavengers at the end of the season, but they are extremely defensive when their nests are disturbed. Defending *D. arenaria* sometimes bite and/or sting, simultaneously. Wasp stingers have no barbs and can be used repeatedly, especially when the wasp gets inside clothing. As with any stinging incident, it is best to leave the area of the nest site as quickly as possible if wasps start stinging.

Paper Wasps

Paper wasps such as *Polistes fuscatus aurifer*, *P. apachus*, and *P. dominulus* are large (1-inch long), slender wasps with long legs and a distinct, slender waist. Background colors vary, but most western species tend to be golden brown, or darker, with large patches of yellow or red. Preferring to live in or near orchards or vineyards, they hang their paper nests in protected areas, such as under eaves, in attics, or under tree branches or vines. Each nest hangs like an open umbrella from a pedicel (stalk) and has open cells that can be seen from beneath the nest. White, legless, grublike larvae sometimes can be seen from below. Paper wasp nests rarely exceed the size of an outstretched hand and populations vary between 15 to 200 individuals. Most species are relatively unaggressive, but they can be a problem when they nest over doorways or in other areas of human activity, such as fruit trees.

Mud Daubers

Mud daubers are black and yellow, thread-waisted, solitary wasps that build a hard mud nest, usually on ceilings and walls, attended by a single female wasp. They belong to the family Sphecidae and are not social wasps but may be confused with them. They do not defend their nests and rarely sting. During winter, you can safely remove the nests without spraying.

Injury or Damage

Concern about yellowjackets is based on their persistent, pugnacious behavior around food sources and their aggressive colony defense. Stinging behavior is usually encountered at nesting sites, but scavenging yellowjackets sometimes will sting if someone tries to swat them away from a potential food source. When scavenging at picnics or other outdoor meals, wasps will crawl into soda cans and cause stings on the lips, or inside the mouth or throat.

Responses to wasp stings vary from only short-term, intense sensations to substantial swelling and tenderness, some itching, or life-threatening allergic responses. Of specific concern is a condition that results from multiple-sting encounters, sometimes unfamiliar to attending health professionals, that is induced by the volume of foreign protein injected and the tissue damage caused by destructive enzymes in wasp venom. Red blood cells and other tissues in the body become damaged; tissue debris and other breakdown products are carried to the kidneys, to be eliminated from the body. Too much debris and waste products can cause blockages in the kidneys, resulting in renal insufficiency or renal failure. Patients in this condition require medical intervention, even dialysis.

Management

Most social wasps provide an extremely beneficial service by eliminating large numbers of other pest insects through predation and should be protected and encouraged to nest in areas of little human or animal activity. Although many animals prey on social wasps (including birds, reptiles, amphibians, skunks, bears, raccoons, spiders, preying mantids, and bald-faced hornets), none provides satisfactory biological control in home situations.

The best way to prevent unpleasant encounters with social wasps is to avoid them. If you know where they are, try not to go near their nesting places. Wasps can become very defensive when their nest is disturbed. Be on the lookout for nests when outdoors. Wasps that are flying directly in and out of a single location are probably flying to and from their nest.

Scavenging wasps will not usually become a problem if there is no food around to attract them. When nuisance wasps are present in the outdoor environment, keep foods (including pet food) and drinks covered or inside the house and keep garbage in tightly sealed garbage cans. Once food is discovered by wasps, they will continue to hunt around that location long after the source has been removed.

If wasp nests must be eliminated, it is easiest and safest to call for professional help. In some areas of California, personnel from a local Mosquito and Vector Control District may be available to remove nests. To determine if this service is available in your area, call the California Mosquito and Vector Control Association at (916) 440-0826.

If a rapid solution to a severe yellowjacket problem is essential, seek the assistance of a professional pest control operator who can use microencapsulated baits to control these pests. Do-it-yourself options include trapping wasps in a baited trap designed for that purpose, early-season removal of nests, or spraying the nest or nesting site with an insecticide labeled for that use.

Trapping Wasps

Trapping wasps is an ongoing effort that needs to be initiated in spring and continued into summer and fall, especially when the yellowjacket population was large the previous year. In spring there is a 30- to 45-day period when new queens first emerge before they build nests. Trapping queens during this period has the potential to provide an overall reduction in the yellowjacket population for the season, and a study is currently underway to test this theory in some California Mosquito and Vector Control districts. The more traps put out in spring on an area-wide basis to trap queens, the greater the likelihood of reducing nests later in the summer. Usually one trap per acre is adequate in spring for depletion trapping of queens; in fall, more traps may be necessary to trap scavenging wasps, depending on the size of the population. There are two types of wasp traps: lure and water traps.

Lure Traps

Lure traps are available for purchase at many retail stores that sell pest control supplies and are easiest to use. They work best as queen traps in late winter and spring. In summer and fall they may assist in reducing localized foraging workers, but they do not eliminate large populations. Lure traps contain a chemical that attracts yellowjackets into the traps, but common lures such as heptyl butyrate are not equally attractive to all species. Proteins such as lunchmeat can be added as an attractant and are believed to improve catches.

During spring, baited lure traps should have the chemical bait changed every 6 to 8 weeks. In summer, change the bait every 2 to 4 weeks; change bait more frequently when temperatures are high. Meats must be replaced more frequently because yellowjackets are not attracted to rotting meat. Also, periodically check the trap to remove trapped yellowjackets and make sure workers are still attracted to the trap.

Water Traps

Water traps are generally homemade and consist of a 5-gallon bucket, string, and protein bait (turkey ham, fish, or liver works well; do not use cat food because it may repel the yellowjackets after a few days). The bucket is filled with soapy water and the protein bait is suspended 1 to 2 inches above the water. (The use of a wide mesh screen over the bucket will help prevent other animals from reaching and consuming the bait.) After the yellowjacket removes the protein, it flies down and becomes trapped in the water and drowns. Like the lure trap, these traps also work best as queen traps in late winter to early spring. In

summer and fall they may assist in reducing localized foraging workers but usually not to acceptable levels. Place them away from patio or picnic areas so wasps aren't attracted to your food as well.

Discouraging or Eliminating Nests

Early in the season, knocking down newly started paper wasp nests will simply cause the founding female to go elsewhere to start again or to join a neighboring nest as a worker. As there is little activity around wasp nests when they are first starting, they are very hard to find. Wasps are more likely to be noticed later after nests and populations grow. Nest removal for controlling subterranean or cavity-dwelling yellowjackets is not practical because the nests are underground or otherwise inaccessible.

Nest Sprays

Aerosol formulations of insecticides on the market labeled for use on wasp and hornet nests can be effective against both yellowjackets and paper wasps, but they must be used with extreme caution. Wasps will attack applicators when sensing a poison applied to their nests, and even the freeze-type products are not guaranteed to stop all wasps that come flying out. It is prudent to wear protective clothing that covers the whole body, including gloves and a veil over the face. In addition, you need to wear protective eyewear and other clothing to protect yourself from pesticide hazards. Wasps are most likely to be in the nest at night. But even after dark and using formulations that shoot an insecticide stream up to 20 feet, stinging incidents are likely. Underground nests can be quite a distance from the visible entrance and the spray may not get back far enough to hit the wasps. Partially intoxicated, agitated wasps are likely to be encountered at some distance from the nest entrance, even on the day following an insecticidal treatment. Hiring a pest control professional will reduce risks to you and your family; in some areas of California, this service may be available through your local Mosquito and Vector Control District.

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Pests in Landscapes, Gardens and Turf

Aphids

Aphids are small, soft-bodied insects with long, slender mouth parts that they use to pierce stems, leaves, and other tender plant parts and suck out plant fluids. Almost every plant has one or more aphid species that occasionally feeds on it. Many aphid species are difficult to distinguish; however, identification to species is not necessary to control them in most situations.

Identification

Aphids may be green, yellow, brown, red, or black depending on the species and the plants they feed on. A few species appear waxy or woolly due to the secretion of a waxy white or gray substance over their body surface. All are small, pear-shaped insects with long legs and antennae. Most species have a pair of tubelike structures called cornicles projecting backwards out of the hind end of their bodies. The presence of cornicles distinguishes aphids from all other insects.

Generally adult aphids are wingless, but most species also occur in winged forms, especially when populations are high or during spring and fall. The ability to produce winged individuals provides the pest with a way to disperse to other plants when the quality of the food source deteriorates.

Although they may be found singly, aphids often feed in dense groups on leaves or stems. Unlike leafhoppers, plant bugs, and certain other insects that might be confused with them, most aphids do not move rapidly when disturbed.

Life Cycle

Aphids have many generations a year. Most aphids in California's mild climate reproduce asexually throughout most or all of the year with adult females giving birth to live offspring (often as many as 12 per day) without mating. Young aphids are called nymphs. They molt, shedding their skins about four times before becoming adults. There is no pupal stage. Some species mate and produce eggs in fall or winter, which provides them a more hardy stage to survive harsh weather. In some cases, these eggs are laid on an alternative host, usually a perennial plant, for winter survival.

When the weather is warm, many species of aphids can develop from newborn nymph to reproducing adult in 7 to 8 days. Because each adult aphid can produce up to 80 offspring in a matter of a week, aphid populations can increase with great speed.

Damage

Low to moderate numbers of leaf-feeding aphids are usually not damaging in gardens or on trees. However, large populations cause curling, yellowing, and distortion of leaves and stunting of shoots; they can also produce large quantities of a sticky exudate known as honeydew, which often turns black with the growth of a sooty mold fungus. Some aphid species inject a toxin into plants, which further distorts growth. A few species cause gall formations.

Aphids may transmit viruses from plant to plant on certain vegetable and ornamental plants. Squashes, cucumbers, pumpkins, melons, beans, potatoes, lettuces, beets, chards, and bok choy are crops that often have aphid-transmitted viruses associated with them. The viruses cause mottling, yellowing, or curling of leaves and stunting of plant growth. Although losses can be great, they are difficult to prevent through the control of aphids because infection occurs even when aphid numbers are very low: it only takes a few minutes for the aphid to transmit the virus while it takes a much longer time to kill the aphid with an insecticide.

A few aphid species attack parts of plants other than leaves and shoots. The lettuce root aphid is a soil dweller that attacks lettuce roots during most of its cycle, causing lettuce plants to wilt and occasionally die if populations are high. The lettuce root aphid overwinters as eggs on poplar trees, where it produces leaf galls in spring and summer. The woolly apple aphid infests woody parts of apple roots and limbs, often near pruning wounds, and can cause overall tree decline if roots are infested for several years.

Management

Although aphids seldom kill a mature plant, the damage and unsightly honeydew they generate sometimes warrant control. Consider the nonchemical controls discussed below; most insecticides, if used, will destroy beneficial insects along with the pest. On mature trees, such as in citrus orchards, aphids and the honeydew they produce can provide a valuable food source for beneficial insects.

Monitoring

Check your plants regularly for aphids--at least twice weekly when plants are growing rapidly. Many species of aphids cause the greatest damage when temperatures are warm but not hot (65° to 80°F). Catch infestations early. Once aphid numbers are high and they have begun to distort and curl leaves, it is often hard to control them because the curled leaves shelter aphids from insecticides or natural enemies.

Aphids tend to be most prevalent along the upwind edge of the garden and close to other sources of aphids, so make a special effort to check these areas. Many aphid species prefer the undersides of leaves, so turn them over to check them. On trees, clip off leaves from several areas of the tree to check for aphids. Also check for evidence of natural enemies such as lady beetles, lacewings, syrphid fly larvae, and the mummified skins of parasitized aphids. Look for disease-killed aphids as well: they may appear off-color, bloated, or flattened. Substantial numbers of any of these natural control factors can mean that the aphid population may be reduced rapidly without the need for treatment.

Ants are often associated with aphid populations, especially on trees and shrubs, and often are a tip-off that an aphid infestation is present. If you see large numbers of ants climbing up your tree trunks, check for aphids (or other honeydew-producing insects) on limbs and leaves above. To protect their food source, ants ward off many predators and parasites of aphids. Management of ants is a key component of aphid management and is discussed under cultural controls.

In landscape settings, aphids can be monitored by using water-sensitive paper to measure honeydew dripping from the tree. This type of monitoring is of particular interest where there is a low tolerance for dripping honeydew, such as in groups of trees along city streets or in parks and for tall trees where aphid colonies may be located too high to detect. See Dreistadt et al. (1994) in "Suggested Reading" for more details on honeydew monitoring.

Biological Control

Natural enemies can be very important in the control of aphids, especially in gardens not sprayed with broad-spectrum pesticides (organophosphates, carbamates, and pyrethroids) that kill natural enemy species as well as pests. Usually natural enemy populations do not appear in significant numbers until aphids begin to be numerous.

Among the most important natural enemies are various species of parasitic wasps that lay their eggs inside aphids. The skin of the parasitized aphid turns crusty and golden brown, a form called a mummy. The generation time of most parasites is quite short when the weather is warm, so once you begin to see mummies on your plants, the aphid population is likely to be reduced substantially within a week or two.

Many predators also feed on aphids. The most well known are lady beetle, lacewing, and syrphid fly. Naturally occurring predators work best, especially in a small backyard situation. Commercially available

lady beetles may give some temporary control when properly handled, although most of them will disperse away from your yard within a few days.

Aphids are very susceptible to fungal diseases when it is humid. Whole colonies of aphids can be killed by these pathogens when conditions are right. Look for dead aphids that have turned reddish or brown; they have a fuzzy, shriveled texture unlike the shiny, bloated, tan-colored mummies that form when aphids are parasitized.

Weather can also impact aphids. Populations of many species are reduced by summer heat in the Central Valley and desert areas, and aphid activity is also limited during the coldest part of the year. However, some aphids may be active year round, especially in the milder, central coastal areas of California.

Cultural Control

Before planting vegetables, check surrounding areas for sources of aphids and remove them. Aphids often build up on weeds such as sowthistle and mustards, moving onto crop seedlings after they emerge. Check transplants for aphids and remove them before planting.

Where aphid populations are localized on a few curled leaves or new shoots, the best control may be to prune these areas out and dispose of them. In large trees, some aphids thrive in the dense inner canopy; pruning these areas out can make the habitat less suitable.

In some situations ants tend aphids and feed on the honeydew aphids excrete. At the same time, they protect the aphids from natural enemies. If you see ants crawling up aphid-infested trees or woody plants, put a band of sticky material (Tanglefoot, etc.) around the trunk to prevent ants from getting up. Teflon products, which are too slippery for ants to climb up, have also been used. (Note: Do not apply sticky material directly to the bark of young or thin-barked trees or to trees that have been severely pruned; the material may have phytotoxic effects. Wrap the trunk with fabric tree wrap or duct tape and apply sticky material to the wrap.) Alternatively, ant stakes or baits may be used on the ground to control the ants without affecting the aphids or their natural enemies. Prune out other ant routes such as branches touching buildings, the ground, or other trees.
High levels of nitrogen fertilizer favor aphid reproduction. Never use more nitrogen than necessary. Use less soluble forms of nitrogen and apply it in small portions throughout the season rather than all at once. Or better yet, use a urea-based, time-release formulation (most organic fertilizers can be classified as time-release products as compared to synthetically manufactured fertilizers).

Because many vegetables are primarily susceptible to serious aphid damage during the seedling stage, losses can be reduced by growing seedlings under protective covers in the garden, in a greenhouse, or inside and then transplanting them when they are older and more tolerant of aphid feeding. Protective covers will also prevent transmission of aphid-borne viruses.

Aluminum foil mulches have been successfully used to reduce transmission of aphid-borne viruses in summer squashes, melons, and other susceptible vegetables. They repel invading aphid populations, reducing numbers on seedlings and small plants. Another benefit is that yields of vegetables grown on aluminum foil mulches are usually increased by the greater amount of solar energy reflecting on leaves.

To put an aluminum mulch in your garden, remove all weeds and cover beds with aluminum-coated construction paper, which is available in rolls from Reynolds Aluminum Company. Bury the edges of the paper with soil to hold them down. After the mulch is in place, cut or burn 3- to 4-inch diameter holes and plant several seeds or single transplants in each one. You may furrow irrigate or sprinkle your beds; the mulch is sturdy enough to tolerate sprinkling. In addition to repelling aphids, leafhoppers, and some other insects, the mulch will enhance crop growth and control weeds. When summertime temperatures get high, however, remove mulches to prevent overheating plants. An alternative to aluminum-coated construction paper is to spray clear plastic mulch with silver paint. Reflective plastic mulches are also available in many garden stores.

Another way to reduce aphid populations on sturdy plants is to knock them off with a strong spray of water. Most dislodged aphids will not be able to return to the plant, and their honeydew will be washed off as well. Using water sprays early in the day allows plants to dry off rapidly in the sun and be less susceptible to fungal diseases.

Chemical Control

Insecticidal soap, neem oil, and narrow-range oil (e.g., supreme or superior parafinic-type oil) provide temporary control if applied to thoroughly cover infested foliage. To get thorough coverage, spray these materials with a high volume of water and target the underside of leaves as well as the top. Soaps, neem oil, and narrow range oil only kill aphids present on the day they are sprayed, so applications may need to be repeated. Predators and parasites often become abundant only after aphids are numerous, so applying nonpersistent insecticides like soap or oil may provide more effective long-term control. Although these materials do kill natural enemies that are present on the plant and hit by the spray, because they leave no toxic residue, they do not kill natural enemies that migrate in after the spray. These and other insecticides with only contact activity are generally ineffective in preventing damage from aphids such as the woolly apple aphid or the woolly ash aphid that are protected by galls or distorted foliage. Do not use soaps or oils on water-stressed plants or when the temperature exceeds 90°F. These materials may be phytotoxic to some plants, so check labels and test them out on a portion of the foliage several days before applying a full treatment.

Supreme- or superior-type oils will kill overwintering eggs of aphids on fruit trees if applied as a delayed dormant application just as eggs are beginning to hatch in early spring. These treatments will not give complete control of aphids and are probably not justified for aphid control alone. Earlier applications will not control aphids. Common aphid species controlled include the woolly apple aphid, green apple aphid, rosy apple aphid, mealy plum aphid, and black cherry aphid.

Many other insecticides are available to control aphids in the home garden and landscape, including foliar-applied formulations of malathion, permethrin and acephate (nonfood crops only). While these materials may kill higher numbers of aphids than soaps and oils, their use should be limited because they also kill the natural enemies that provide long-term control of aphids and other pests. Repeated applications of these materials may also result in the development of resistance to the material by the aphid. Insecticides such as oils and soaps are also safer to use when children and pets may be present. Formulations combining insecticidal soaps and pyrethrins may provide slightly more knockdown than soaps alone, yet have fewer negative impacts on natural enemies than malathion, permethrin, and acephate, because pyrethrins break down very quickly. Avoid the use of diazinon and chlorpyrifos; urban garden use of these materials has been identified as a source of pollution in California’s creeks and rivers. Carbaryl is not recommended because it is not very effective against aphids. Acephate has systemic activity, which means it moves through leaves, thus it can be effective where aphids are hidden beneath curling foliage. Acephate is not registered for use on food crops in the garden because it can break down to a much more toxic material. The soil-applied systemic pesticide disulfoton is sometimes applied in roses for aphid control, but it is a highly toxic material to people.

Professional applicators can make soil injections of the systemic insecticide imidacloprid, which is quite effective against aphids infesting large street trees and not very harmful to beneficial soil organisms. Because it takes a substantial time for the product to get from the soil to the growing points of trees, applications must be made up to 2 months before problems are expected.

When considering application of pesticides for aphid control, remember that moderate populations of many aphids attacking leaves of fruit trees or ornamental trees and shrubs do not cause long-term damage. Low populations can be tolerated in most situations and aphids will often disappear when natural enemies or hot temperatures arrive. Often a forceful spray of water or water-soap solution, even on large street trees, when applied with appropriate equipment, will provide sufficient control.

Suggested Reading

Dreistadt, S. H., J. K. Clark, and M. L. Flint. 1994. *Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide.* Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3359.

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Snails and Slugs

Snails and slugs are among the most bothersome pests in many garden and landscape situations. The brown garden snail *(Helix aspersa)* is the most common snail causing problems in California gardens; it was introduced from France during the 1850s for use as food.

Several species of slugs are frequently damaging, including the gray garden slug *(Agriolimax reticulatus),* the banded slug *(Limax marginatusi),* the tawny slug *(Limax flavus),* and the greenhouse slug *(Milax gagates).* Both snails and slugs are members of the mollusk phylum and are similar in structure and biology, except slugs lack the snail's external spiral shell.

Identification and Biology

Snails and slugs move by gliding along on a muscular "foot." This muscle constantly secretes mucus, which later dries to form the silvery "slime trail" that signals the presence of either pest. Slugs and snails are hermaphrodites, so all have the potential to lay eggs. Adult brown garden snails lay about 80 spherical, pearly white eggs at a time into a hole in the topsoil. They may lay eggs up to six times a year. It takes about 2 years for snails to mature. Slugs reach maturity after about 3 to 6 months, depending on species, and lay clear oval to round eggs in batches of 3 to 40 under leaves, in soil cracks, and in other protected areas.

Snails and slugs are most active at night and on cloudy or foggy days. On sunny days they seek hiding places out of the heat and bright light; often the only clues to their presence are their silvery trails and plant damage. In mild-winter areas such as southern coastal locations, young snails and slugs can be active throughout the year.

During cold weather, snails and slugs hibernate in the topsoil. During hot, dry periods or when it is cold, snails seal themselves off with a parchmentlike membrane and often attach themselves to tree trunks, fences, or walls.

Damage

Snails and slugs feed on a variety of living plants as well as on decaying plant matter. On plants they chew irregular holes with smooth edges in leaves and flowers and can clip succulent plant parts. They can also chew fruit and young plant bark. Because they prefer succulent foliage or flowers, they are primarily pests of seedlings and herbaceous plants, but they are also serious pests of ripening fruits, such as strawberries, artichokes, and tomatoes, that are close to the ground. However, they will also feed on foliage and fruit of some trees; citrus are especially susceptible to damage. Look for the silvery mucous trails to confirm damage was caused by slugs or snails and not earwigs, caterpillars, or other chewing insects.

Management

A good snail and slug management program relies on a combination of methods. The first step is to eliminate, to the extent possible, all places where snails or slugs can hide during the day. Boards, stones, debris, weedy areas around tree trunks, leafy branches growing close to the ground, and dense ground covers such as ivy are ideal sheltering spots. There will be shelters that are not possible to eliminate—e.g., low ledges on fences, the undersides of wooden decks, and water meter boxes. Make a regular practice of trapping and removing snails and slugs in these areas. Also, locate vegetable gardens or susceptible plants as far away as possible from these areas. Reducing hiding places allows fewer snails and slugs to survive. The survivors congregate in the remaining shelters, where they can more easily be located and removed. Switching from sprinkler irrigation to drip irrigation will reduce humidity and moist surfaces, making the habitat less favorable for these pests. Choose snail-proof plants for areas where snails and slugs are dense. Copper barriers can be useful for protecting especially susceptible plants. Though baits can be part of a management program for snails and slugs, by themselves they don't provide adequate control in gardens that contain plenty of shelter, food, and moisture.

Choice of plant can greatly affect how difficult your battle with snails and slugs will be. Snails and slugs favor seedlings and plants with succulent foliage and these plants must be vigilantly protected. Some plants that are seriously damaged include basil, beans, cabbage, dahlia, delphinium, hosta, lettuce, marigolds, strawberries, and many vegetable plants. On the other hand, many plants resist damage from snails and slugs including begonias, California poppy, fuchias, geraniums, impatiens, lantana, nasturtiums, and purple

robe cup flower, and many plants with stiff leaves and highly scented foliage like lavender, rosemary, and sage. Most ornamental woody plants and ornamental grasses are also not seriously affected. If you design your landscape using plants like these, you are likely to have very limited damage from snails and slugs.

Handpicking

Handpicking can be very effective if done thoroughly on a regular basis. At first it should be done daily. After the population has noticeably declined, a weekly handpicking may be sufficient. To draw out snails, water the infested area in the late afternoon. After dark, search them out using a flashlight, pick them up (rubber gloves are handy when slugs are involved), place them in a plastic bag, and dispose of them in the trash; or they can be put in a bucket with soapy water and then disposed of in your compost pile. Alternatively, captured snails and slugs can be crushed and left in the garden. Household ammonia diluted to a 5 to 10% solution in water can also be sprayed on collected slugs to kill them.

Traps

Snails and slugs can be trapped under boards or flower pots positioned throughout the garden and landscape. Inverted melon rinds make good traps. You can make traps from 12" x 15" boards (or any easy-to-handle size) raised off the ground by 1-inch runners. The runners make it easy for the pests to crawl underneath. Scrape off the accumulated snails and slugs daily and destroy them. Crushing is the most common method of destruction. Do not use salt to destroy snails and slugs; it will increase soil salinity. Beer-baited traps have been used to trap and drown slugs and snails; however, they are not very effective for the labor involved. Beer traps attract slugs and snails within an area of only a few feet, and must be refilled every few days to keep the level deep enough to drown the mollusks. Traps are buried at ground level, so the mollusks easily fall into them. It is the fermented product that attracts them and a sugar-water and yeast mixture can be used in place of beer. Traps must have deep, vertical sides to keep the snails and slugs from crawling out and a top to reduce evaporation. Snail and slug traps can also be purchased at garden supply stores.

Barriers

Several types of barriers will keep snails and slugs out of planting beds. The easiest to maintain are those made with copper flashing and screen. Copper barriers are effective because it is thought that the copper reacts with the slime that the snail or slug secretes, causing a flow of electricity. Vertical copper screens can be erected around planting beds. The screen should be 6 inches tall and buried several inches below the soil to prevent slugs from crawling through the soil beneath the barrier.

Copper foil (for example, Snail-Barr) can be wrapped around planting boxes, headers, or trunks to repel snails for several years. When banding trunks, wrap the copper foil around the trunk, tab side down, and cut it to allow an 8-inch overlap. Attach one end or the middle of the band to the trunk with one staple oriented parallel to the trunk. Overlap and fasten the ends with one or two large paper clips to allow the copper band to slide as the trunk grows. Bend the tabs out at a 90° angle from the trunk. The bands need to be cleaned occasionally with a vinegar solution. When using copper bands on planter boxes, be sure the soil within the boxes is snail-free before applying bands. If it is not, handpick the snails and slugs from the soil after applying the band until the box is free of these pests.

Instead of copper bands, Bordeaux mixture (a copper sulfate and hydrated lime mixture) or copper sulfate alone can be brushed on trunks to repel snails. One treatment should last about a year. Adding a commercial spreader or white latex paint may increase the persistence of Bordeaux mixture through two seasons. Barriers of dry ashes or diatomaceous earth, heaped in a band 1 inch high and 3 inches wide around the garden, have also been shown to be effective. However, these barriers lose their effectiveness after becoming damp and are therefore difficult to maintain and not very useful in most garden situations.

Natural Enemies

Snails and slugs have many natural enemies, including ground beetles, pathogens, snakes, toads, turtles, and birds, but most are rarely effective enough to provide satisfactory control in the garden. An exception is the use of domesticated fowl—ducks, geese, or chickens—kept penned in infested areas. (Be careful, though, as these birds may also eat seedlings.) The predaceous decollate snail *(Rumina decollata)* has been released in southern California citrus orchards for control of the brown garden snail and is providing very effective biological control. It feeds only on small snails, not full-sized ones. Because of the potential impact of the decollate snail on certain endangered mollusk species, it cannot be released in California outside of Fresno, Imperial, Kern, Los Angeles, Madera, Orange, Riverside, Santa Barbara, San Bernardino, San Diego, Ventura, or Tulare counties. Also, decollate snails may feed on seedlings, small plants, and flowers as well as be a nuisance when they cover the back patio on a misty day. Decollate snails will be killed by snail baits.

Baits

Snail and slug baits can be effective when used properly in conjunction with a cultural program incorporating the other methods discussed above. However, baits alone will not effectively control snails or slugs. Several types of snail and slug bait products are available. Baits containing the active ingredient metaldehyde are most common. Metaldehyde baits are particularly poisonous to dogs and cats, and the pelleted form is especially attractive to dogs. Metaldehyde snail baits should not be used where children and pets cannot be kept away from them. Some metaldehyde products are formulated with carbaryl, partly to increase the spectrum of pests controlled to include soil and debris-dwelling insects, spiders, and sowbugs. However, carbaryl is toxic to soil-inhabiting beneficials like ground beetles and earthworms and should be avoided if snail and slug management is all that is required. Metaldehyde baits containing 4% metaldehyde are significantly more effective than those products containing only 2% metaldehyde; however, they are also more toxic to dogs and wildlife. Most currently available 4% products are formulated for use in enclosed bait stations to minimize their hazard.

Avoid getting metaldehyde bait on plants, especially vegetables. Baits containing only metaldehyde are most reliable when temperatures are warm or following a rain when snails and slugs are active. Metaldehyde does not kill snails and slugs directly unless they eat a substantial amount; rather, it stimulates their mucous-producing cells to overproduce mucous in an attempt to detoxify the bait. The cells eventually fail and the snail dies. When it is sunny or hot, they die from desiccation. If baiting is followed by cool and wet weather, they may recover if they ingest a sublethal dose. Do not water heavily for at least 3 or 4 days after bait placement; watering will reduce effectiveness and snails may recover from metaldehyde poisoning if high moisture conditions occur. Most metaldehyde baits break down rapidly when exposed to sunlight; however, some paste or bullet formulations (such as Deadline) hold up somewhat longer under conditions of sunlight and moisture.

A recently registered snail and slug bait, iron phosphate (available under many trade names including Sluggo and Escar-Go), has the advantage of being safe for use around domestic animals, children, birds, fish, and other wildlife and is a good choice for a garden IPM program. Ingestion of the iron phosphate bait, even in small amounts, will cause snails and slugs to cease feeding, although it may take several days for the snails to die. Iron phosphate bait can be scattered on lawns or on the soil around any vegetables, ornamentals, or fruit trees to be protected. Iron phosphate baits may be more effective against snails than slugs.

Sprinkle baits in areas that snails and slugs regularly frequent such as areas around sprinkler heads. Placing baits repeatedly in the same areas maximizes control because molluscs tend to return to food source sites. Never pile bait in mounds or clumps, especially those baits that are hazardous, because piling makes a bait attractive to pets and children. Placement of the bait in a commercial bait trap reduces hazards to pets and children and can protect baits from moisture, but may also reduce their effectiveness. Thick liquid baits may persist better under conditions of rain and sprinklers.

The timing of any baiting is critical; baiting is less effective during very hot, very dry, or cold times of the year because snails and slugs are less active during these periods. Irrigate before applying a bait to promote snail activity and apply the bait in the late afternoon or evening. Application on a warm, humid evening is

ideal. Apply bait in a narrow strip around sprinklers, close to walls and fences or in other moist and protected locations, or scatter it along areas that snails and slugs cross to get from sheltered areas to the garden.

References

Dreistadt, S. H., J. K. Clark, and M. L. Flint. 1994. *Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide.* Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3359.

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Weed Management in Landscapes

Weed management in landscape plantings is often made difficult by the complexity of many plantings: usually more than one species is planted in the landscaped area and there is a mix of annual and perennial ornamentals. The great variety of ornamental species, soil types, slopes, and mulches creates the need for a variety of weed management options. There are also considerations regarding public concern about the use of chemicals to control weeds. The choice of a specific weed management program depends on the weeds present and the types of turf or ornamentals planted in the area. Because of the many variables, weeds in landscape plantings are controlled by a combination of nonchemical and chemical methods.

Most landscape plantings include turfgrass, bedding plants, herbaceous perennials, shrubs, and trees. Use this publication as a practical review and guide to weed management options suited to general types of landscape plantings.

Weed Management Before Planting

An integrated approach, utilizing several options, is the most economical and effective means of controlling weeds. Begin your weed management plan for landscapes before planting by following these five basic steps:

1. *Site assessment.* Before soil preparation and when the weeds are visible, evaluate the soil, mulch, and slope of the site. Identify the weed species in the area, with particular emphasis on perennial weeds. The best time to look for winter annual weeds is mid- to late winter; perennials and summer annuals are easiest to identify in mid- to late summer.
2. *Site preparation.* The most often overlooked aspect of a landscape maintenance program is site preparation. Control existing weeds, especially perennials, before any grading and development are started. Glyphosate (Roundup, etc.) can be used to kill existing annual and perennial weeds. Preplant treatment with fumigants (available to licensed pesticide applicators only) or soil solarization can be used if time allows; however, 6 weeks are required for solarization to work and it is most effective when done during the time of highest sun radiation—from June to August in California.
3. *Define the type of planting.* There are more weed control options if the planting consists entirely of woody plants as opposed to herbaceous annuals or perennial plants, or a mixture of all three.
4. *Don't introduce weeds.* Weeds are sometimes introduced in the soil brought to the landscape site either when amending the soil or in the potting mix of transplants.
5. *Encourage rapid establishment of desired plants.* Use the best management practices to get the plants established as quickly as possible so that they become competitive with weeds and more tolerant of herbicides applied to the site. Hand-weeding and keeping weeds from producing seeds in the landscape will greatly reduce overall weed populations.

Weed Management After Planting

When developing a weed management plan for an existing planting or after an installation is in place, consider the types of plants present and the weeds present and their life cycles.

Weed control options in the landscape include hand-weeding and cultivation, mowing, mulching, hot water treatments, and chemical control. All of these methods are used at one time or another in landscape maintenance operations (Table 2). After elimination by hand-pulling, cultivation, or a postemergent herbicide application, the subsequent growth of annual weeds can be discouraged with mulches and/or preemergent herbicides.

TABLE 1. How to Manage Weeds in Five Types of Landscape Plantings.

Type of planting and comments	Recommendations
Woody Trees and Shrub Beds. Densely shaded plantings reduce weeds. Preplant weed control is not as critical as in other types of plantings. It is often necessary to combine treatments for complete weed control.	Control perennial weeds before planting (although control may be possible after planting); use geotextile fabrics with a shallow layer of mulch or use a thick layer of mulch without a geotextile base; use a preemergent herbicide, if needed, and supplement with spot applications of postemergent herbicides and/or hand-weeding. Perennial weeds may be controlled by manual removal, spot applications of glyphosate or glufosinate, or, in some instances, dormant-season applications of preemergent herbicides. Escaped weeds may be controlled manually or with spot applications of postemergent herbicides.
Woody Ground Cover Beds. Woody ground covers should exclude most weeds; however, weed encroachment during establishment is likely.	Control perennial weeds before planting, although perennial grasses may be selectively controlled after planting with fluazifop (Fusilade, Ornamec), clethodim (Envoy), or other selective grass herbicides. Annual weeds may be controlled with mulch plus a preemergent herbicide, supplemented with some hand-weeding. Use geotextiles where possible but do not use them where ground covers are expected to root and spread. After planting, it is difficult to make spot applications of nonselective herbicides without injuring desirable plants. Postemergent control of most annual and perennial grasses is possible.
Annual Flower Beds. A closed canopy will help shade out many weeds. Periodic cultivations (at 3- to 4-week intervals and between display rotations) will suppress many weeds.	Control perennial weeds before planting and carefully select flower species for weed management compatibility. Annual weeds may be controlled with mulches, preemergent herbicides, frequent cultivation, and/or hand-weeding. Perennial grasses can be selectively controlled with clethodim or fluazifop, or other grass-selective herbicides, but other perennial weeds cannot be selectively controlled after planting. Geotextiles generally are not useful because of the short-term nature of the planting. Avoid nonselective herbicides after planting.
Herbaceous Perennial Beds. Weed management options in herbaceous perennial beds are similar to those for annual flowers, except (1) it is more important to eradicate perennial weeds as there will be no opportunity to cultivate or renovate the bed for several years; and (2) fewer species are included on herbicide labels.	Control perennial weeds before planting; use geotextiles where possible; use mulches with a preemergent herbicide; and supplement with hand-weeding.
Mixed Plantings of Woody and Herbaceous Plants. Weed management is complex because of the diversity of species. Different areas of the bed could receive different treatments. Site preparation is critical because postplant herbicide choices are few.	Plant the woody species first; control perennial weeds in the first two growing seasons, then introduce the herbaceous species. Plant close together to shade the entire area. Another option may be to define use-areas within the bed that will receive similar weed management programs.

Cultivation and Hand-weeding

Cultivation (hoeing) and hand-weeding selectively remove weeds from ornamental plantings. These methods are time-consuming, expensive, and must be repeated frequently until the plantings become established. Cultivation can damage ornamentals with shallow roots, bring weed seeds to the soil surface, and propagate perennial weeds. When cultivating, avoid deep tilling, as this brings buried weed seeds to the soil surface where they are more likely to germinate. Perennial weeds are often spread by cultivation and should be controlled or removed by other methods.

Frequent hand-removal of weeds when they are small and have not yet set seed will rapidly reduce the number of annual weeds. If weeds are scattered at a site, hand-weeding may be the preferred management method. Hand-weeding can be time consuming and costly but should be included in all weed management programs to keep weeds from seeding.

Young weeds in open areas also can be controlled with small flaming units. Propane burners are available to rapidly pass over young weeds to kill them. A quick pass over the plant is all that is necessary; do not burn the weed to the ground. Flaming is more effective on broadleaf weeds than grasses. Be careful not to flame over dry vegetation and dry wood chips or near buildings and other flammable materials, and don't get the flame near desired plants.

The top growth of older weeds can be controlled by using a string trimmer. Annual broadleaf weeds are more effectively controlled than annual grasses because the growing points of grasses are usually below ground. Perennial weeds regrow rapidly after using a string trimmer. Be careful not to girdle and kill desirable shrubs and trees with repeated use of a string trimmer.

Mowing

Mowing be used to prevent the formation and spread of weed seeds from many broadleaf weeds into cultivated areas by cutting off flower heads. However, weeds that flower lower than the mowing blade are not controlled. Repeated mowing tends to favor the establishment of grasses and low-growing perennial weeds. Mowing of some ground covers can rejuvenate them and make them more competitive against weeds.

Mulches

A mulch is any material placed on the soil to cover and protect it. Mulches suppress annual weeds by limiting light required for weed establishment. Many types of landscape mulches are available. The most common are bark and other wood products and black plastic or cloth materials. Other products that are used include paper, yard compost, hulls from nuts (pecans) or cereals (rice), municipal composts, and stones.

Organic mulches

Organic mulches include wood chips, sawdust, yard waste (leaves, clippings, and wood products), and hardwood or softwood bark chips or nuggets. Bark chips are moderate-sized particles (1/5 to 1/2-inch) and have moderate to good stability, while bark nuggets are larger in size (1/2 to 2-1/2 inches) and have excellent stability over time. These materials can be used in landscape beds containing herbaceous or woody ornamentals.

The thickness or depth of a mulch necessary to adequately suppress weed growth depends on the mulch type and the weed pressure. The larger the particle size of the mulch, the greater the depth required to exclude all light from the soil surface. Coarse-textured mulches can be applied up to 4-inches deep and provide long-term weed control. Fine-textured mulches pack more tightly and should only be applied to a depth of about 2 inches. If the mulch is too decomposed, it may serve better as a weed propagation medium rather than a means of prevention. Plan to periodically replenish landscape mulches, regardless of particle

size, because of decomposition, movement, or settling. If seedlings germinate in mulches, a light raking, hoeing, or hand-weeding will remove the young weeds.

Inorganic mulches

Inorganic mulches, which include both natural and synthetic products, are generally more expensive and less widely used in the landscape. Natural inorganic mulches are stable over time and include materials such as sand, gravel, or pebbles. Most of these products are used in public and commercial plantings. If using a rock mulch, consider placing a landscape fabric underneath it. The fabric creates a layer between the mulch and soil, preventing rock pieces from sinking into the soil. The fabric prevents soil from moving above the rock layer, which would bring weed seed to the surface.
Black plastic (solid polyethylene) can be used underneath mulches to improve weed control. It provides excellent control of annual weeds and suppresses perennial weeds, but lacks porosity and restricts air and water movement. For this reason, black plastic may not be the preferred long-term weed control method in landscape beds.

Synthetic mulches

Synthetic mulches, which are manufactured materials that are called geotextile or landscape fabrics, have been developed to replace black plastic in the landscape. Geotextiles are porous and allow water and air to pass through them, overcoming the major disadvantage of black plastic. Although these materials are relatively expensive and time-consuming to install, they become cost-effective if the planting is to remain in place for 4 or more years. Geotextiles are used mainly for long-term weed control in woody ornamental trees and shrubs. Geotextiles should not be used where the area is to be replanted periodically, such as in annual flower beds or in areas where the fabric would inhibit the rooting and spread of ground covers. Tree and shrub roots can penetrate the materials and if the material is removed, damage can occur to the plant's root system. This might be a concern if a fabric has been in place longer than 5 years. At least one geotextile fabric (BioBarrier) has an herbicide encapsulated in nodules on the fabric that reduces root penetration problems.

Placing a landscape fabric under mulch results in greater weed control than mulch used alone. There are differences in the weed-controlling ability among the geotextiles: fabrics that are thin, lightweight, or have an open mesh allow for greater weed penetration than more closely woven or nonwoven fabrics.

To install a landscape fabric, you can plant first and then install the fabric afterwards using U-shaped nails to peg it down. After laying the cloth close to the ground, cut an "X" over the plant and pull it through the cloth. If laying down a fabric before planting, cut an "X" through the fabric and dig a planting hole. Avoid leaving soil from the planting hole on top of the fabric because this could put weed seeds above the material. Fold the "X" back down to keep the geotextile sheet as continuous as possible. Weeds will grow through any gap in the landscape fabric, so it is important to overlap pieces of fabric and tack them down tightly. Apply a shallow mulch layer (about 1-inch deep) to thoroughly cover the fabric and prevent photodegradation. If weeds grow into or through the geotextile, remove them when they are small to prevent them from creating holes in the fabric. Maintain a weed-free mulch layer on top of the fabric by hand-weeding or by applying herbicides. Use of a rock mulch above a landscape fabric can have greater weed control than fabric plus organic mulch combinations.

Yellow nutsedge grows through all geotextiles but some fabrics are better at suppressing yellow nutsedge than others.

Problems with Organic and Natural Inorganic Mulches

There are several problems associated with the use of organic and inorganic mulches. Perennial weeds such as field bindweed and nutsedges often have sufficient root reserves to enable them to penetrate even thick layers of mulches. Some annual weeds will grow through mulches, while others may germinate on top of them as they decompose. Weeds that are a particular problem are those that have windborne seeds such as

common groundsel, prickly lettuce, and common sowthistle. Applying mulches at depths of greater than 4 inches may injure plants by keeping the soil too wet and limiting oxygen to the plant's roots. Disease incidence, such as root or stem rot, may increase when deep mulches are maintained.

When mulches are too fine, applied too thickly, or begin to decompose, they stay wet between rains and allow weeds to germinate and grow directly in the mulch. For best weed control, use a coarse-textured mulch with a low water-holding capacity. When used alone, mulches rarely provide 100% weed control. To improve the level of weed control, apply preemergent herbicides at the same time as the mulch (see Table 2). Supplemental hand-weeding or spot spraying may also be needed.

TABLE 2. Suggestions for Placement of Herbicide with an Organic Mulch.

Herbicide	**Application**
Devrinol (napropamide)	under the mulch
Gallery (isoxaben)	best under the mulch, moderate control when applied on top of mulch
OHII (pendimethalin plus oxyfluorfen)	works well both under or over mulch
Pennant (metolachlor)	under the mulch
Ronstar (oxadiazon)	over the mulch
Rout (oryzalin plus oxyfluorfen)	works well both under or over mulch
Surflan (oryzalin)	best under the mulch but provides some control when applied on top of mulch
Surflan plus Gallery	under the mulch but will give a fair amount of control even when applied on top of mulch
Treflan (trifluralin)	under the mulch
XL (oryzalin/benefin)	under the mulch

Avoid mulches with a pH less than 4 or that have an "off odor" such as ammonia, vinegar, or rotten egg smell. These mulches were stored incorrectly and contain chemical compounds that may injure plants, especially herbaceous plants.

If using a composted mulch, temperatures achieved during the composting process should have killed most weed seeds. However, if the compost was stored uncovered in the open, weed seeds may have been blown onto the mulch. Be sure the mulch is not contaminated with weed seeds or other propagules such as nutsedge tubers.

Hot Water or Steam Treatments

There are several machines currently available that use hot water or steam to kill weeds. These machines are most effective on very young annual weeds or perennials that have recently emerged from seeds. The effect is similar to that of a nonselective, postemergent herbicide. Hot water and steam are not very effective on perennial weeds with established storage organs, such as rhizomes and bulbs, nor do they control woody plants. In general, broadleaf weeds are more easily controlled by this method than grasses. The equipment is expensive to purchase and maintain, so these machines are not appropriate for home use. However, commercial landscapers may find them useful in certain situations where the use of herbicides is not desired such as when line-marking playing fields, in playgrounds, around woody plants, for edging, and for weeds growing along fence lines. Some brands of equipment travel slowly (about 2 mile/hour) and are probably not cost-effective for weed control along roadsides. Because these methods employ boiling water or steam, workers must be adequately trained in the use of the machines to prevent severe burns.

Herbicides for Landscape Plantings

Herbicides have been effectively used in many types of landscape plantings and are most often integrated with the cultural practices discussed above. Generally, home gardeners should not need to apply herbicides to existing landscape plantings. Hand-weeding and mulching should provide sufficient control and avoid hazards to desirable plants associated with herbicide use. Many herbicides listed here are for use by professional landscape pest managers and are not available to home gardeners. To determine which herbicide(s) are in a product, look at the active ingredients on the label.

Preemergent Herbicides

When weeds have been removed from an area, preemergent herbicides can then be applied to prevent the germination or survival of weed seedlings. Preemergent herbicides must be applied before the weed seedlings emerge. Examples of preemergent herbicides include: DCPA (Dacthal), dithiopyr (Dimension), isoxaben (Gallery), metolachlor (Pennant), napropamide (Devrinol), oryzalin (Surflan, Weed Stopper), oxadiazon (Ronstar), oxyfluorfen (Goal), pendimethalin (Pendulum, Pre-M), and prodiamine (Barricade). DCPA, dithiopyr, oryzalin, napropamide, pendimethalin, and prodiamine control annual grasses and many broadleaf weeds and can be used safely around many woody and herbaceous ornamentals. Metolachlor has become popular because it controls yellow nutsedge as well as most annual grasses. Isoxaben is used for control of broadleaf weeds.

Timing of a preemergent herbicide application is determined by when the target weed germinates, or by when the weed is in the stage that is most sensitive to the herbicide. In general, late summer/early fall applications of preemergent herbicides are used to control winter annuals, while late winter/early spring applications are used to control summer annuals and seedlings of perennial weeds. If heavy rainfall occurs after preemergent herbicide application or if a short residual product was applied, a second preemergent herbicide application may be needed. Generally, herbicides degrade faster under wet, warm conditions than under dry, cool conditions.

No cultivation should occur after an application of oxyfluorfen; however, shallow cultivation (1 to 2 inches) will not harm napropamide, pendimethalin, or oryzalin. Also, soil type and pH can affect the activity of some herbicides. Use the information contained in herbicide labels and from your local county Cooperative Extension office to determine the tolerance of an ornamental plant species to a given herbicide.

Match herbicides with weeds present, and consider using herbicide combinations. Combinations of herbicides increase the spectrum of weeds controlled and provide effective control of grasses and many broadleaf weeds. Commonly used combinations include tank mixes of the materials listed above or isoxaben/trifluralin (Snapshot), oryzalin/benefin (XL), oxyfluorfen/oryzalin (Rout), and oxyfluorfen/pendimethalin (Ornamental Herbicide II). Check the label to determine which ornamental species the material can safely be used around and which species of weeds are controlled.

Postemergent Herbicides

When weeds escape preemergent herbicides or geotextile fabrics, postemergent herbicides can be used to control established weeds. Postemergent herbicides control existing plants only and do not give residual weed control. Their primary function is to control young annual species, but they are also used to control perennial species. Clethodim and fluazifop selectively control most annual and perennial grasses.

Glufosinate (Finale), diquat (Reward), and pelargonic acid (Scythe) are nonselective, contact herbicides that kill or injure any vegetation they contact. They kill annual weeds, but only "burn off" the tops of perennial weeds. Glyphosate (Roundup Pro and others) is a systemic herbicide. It is translocated to the roots and growing points of mature, rapidly growing plants and kills the entire plant. It is effective on most annual and perennial weeds.

Mulch and Herbicide Placement

The placement of an herbicide in relation to an organic mulch can affect the herbicide's performance. Additionally, the characteristics of organic mulches can affect how herbicides work. A mulch that primarily consists of fine particles can reduce the availability of some herbicides. The finer the organic material (compost or manure, compared to bark), the greater the binding of the herbicide. Most herbicides are tightly bound by organic matter, and while the binding minimizes leaching, it can also minimize an herbicide's activity. Mulch that is made up of coarse particles will have little effect on herbicide activity.

Another important factor is the depth of the mulch. An herbicide applied on top of a thin mulch may be able to leach through to where the weed seeds are germinating, but when applied to the top of a thick layer of mulch it may not get down to the zone of weed seed germination. Products like oxadiazon (Ronstar) and oxyfluorfen (Goal) that require a continuous surface layer must be placed on the soil surface under the mulch. Suggestions for use of mulch with herbicides are given in Table 2.

Avoiding Herbicide Injury

Because of the close proximity of many different species of plants in the landscape, herbicide injury may occur, resulting in visual plant damage. Herbicide injury symptoms vary according to plant species and the herbicide and can include yellowing (chlorosis), bleaching, root stunting, distorted growth, and the death of leaves. Granular formulations of preemergent herbicides are less likely to cause injury than sprayable formulations. Using a granular formulation reduces the potential for foliar uptake, but granules of oxadiazon (Ronstar) or oxyfluorfen (Goal) mixtures will injure plants if they collect in the base of leaves or adhere to wet leaves. Apply nonselective herbicides such as diquat, pelargonic acid, or glyphosate with low pressure and large droplets on a calm day. Use shielded sprayers when making applications around ornamentals to avoid contact with nontarget plants.

Herbicide injury to established plants from soil-applied chemicals is often temporary but can cause serious growth inhibition to newly planted ornamentals. Herbicides that contain oryzalin or isoxaben are more likely to cause this injury. Injury may result when persistent herbicides are applied to surrounding areas for weed control in turf, agronomic crops, or complete vegetative control under pavement. Activated charcoal incorporated into the soil may adsorb the herbicide and minimize injury. Usually it just takes time for herbicide residues to completely degrade. To speed degradation, supplement the organic content of the soil and keep it moist but not wet during periods of warm weather.

References

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