BIOLOGICAL CONTROL AND NATURAL ENEMIES

Integrated Pest Management for Home Gardeners and Landscape Professionals

Biological control is the beneficial action of predators, parasites, pathogens, and competitors in controlling pests and their damage. Biocontrol provided by these living organisms (collectively called "natural enemies") is especially important for reducing the numbers of pest insects and mites (Table 1). Natural enemies also control certain rangeland and wildland weeds, such as Klamath weed (St. Johnswort). Plant pathogens, nematodes, and vertebrates also have many natural enemies, but this biological control is often harder to recognize, less-well understood, or more difficult to manage. Conservation, augmentation, and classical biological control (also called importation) are tactics for harnessing the effects of natural enemies.

TYPES OF NATURAL ENEMIES

Predators, parasites, and pathogens are the primary groups used in biological control of insects. Most parasites and pathogens, and many predators, are highly specialized and attack only one or several closely related pest species. Learn how to recognize natural enemies by consulting resources such as the *Natural Enemies Handbook* and the Natural Enemies Gallery online at http://www.ipm.ucdavis.edu.

Pathogens

Pathogens are microorganisms including certain bacteria, fungi, nematodes, protozoa, and viruses that can infect and kill the host. Populations of some aphids, caterpillars, mites, and other invertebrates are sometimes drastically reduced by naturally occurring pathogens, usually under conditions such as prolonged high humidity or dense pest populations. In addition to naturally occurring disease outbreaks, some beneficial pathogens are commercially available as biological or microbial pesticides. These include *Bacillus thuringiensis* or Bt, entomopathogenic nematodes, and granulosis viruses. Additionally, some microorganism by-products such as avermectins and spinosyns are used in certain insecticides, but applying these products is not considered to be biological control.

Parasites

A parasite is an organism that lives and feeds in or on a larger host. Insect parasites (more precisely called parasitoids) are smaller than their host and develop inside, or attach to the outside, of the host's body. Often only the immature stage of the parasite feeds on the host, and it kills only one host individual dur-

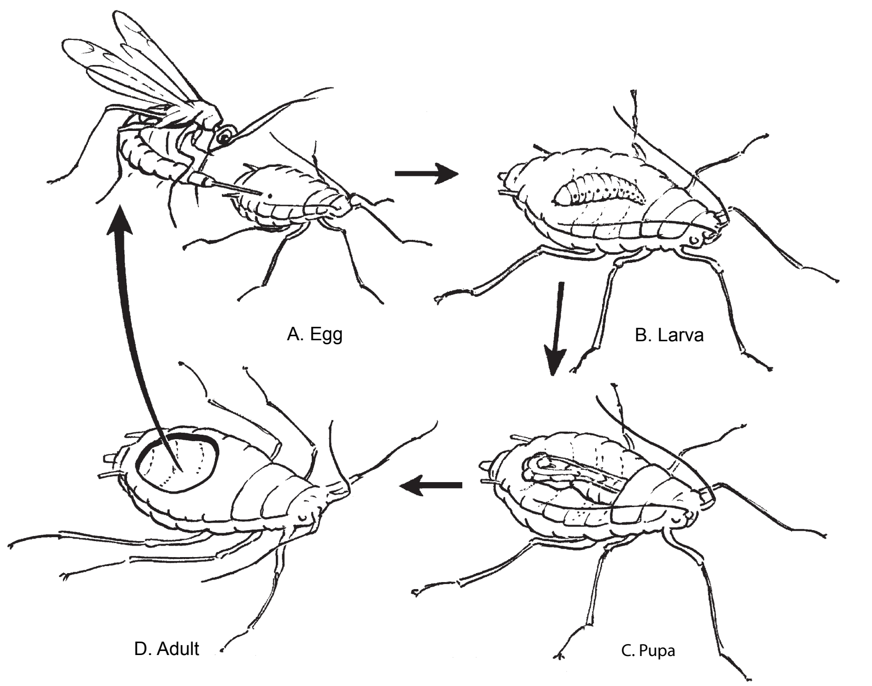

Figure 1. In many cases, only the immature stage of a parasite feeds on the host, as illustrated here with a species that attacks aphids. A. An adult parasite lays an egg inside a live aphid. B. The egg hatches into a parasite larva that grows as it feeds on the aphid's insides. C. After killing the aphid, the parasite pupates. D. The wasp chews a hole and emerges from the dead aphid, then flies off to find and parasitize other aphids.

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Table 1. Some pests and their common natural enemies.

Pests	Natural Enemies					
	Lacewings	Lady beetles	Parasitic flies	Parasitic wasps	Predatory mites	**Other groups and examples**
aphids	•	•		•		entomopathogenic fungi syrphid fly larvae
carpenterworm, clearwing moth larvae				•		entomopathogenic nematodes
caterpillars (e.g., California oakworm)	•		•	•		*Bacillus thuringiensis* birds pathogenic fungi and viruses predaceous wasps *Trichogramma* spp.(egg parasitic wasps) spiders
cottony cushion scale		•	•			*Cryptochaetum iceryae* (parasitic fly) vedalia beetle
elm leaf beetle			•	•		*Erynniopsis antennata* (parasitic fly) *Oomyzus* (=*Tetrastichus*) spp. (parasitic wasps)
eucalyptus longhorned borers				•		*Avetianella longoi* (egg parasitic wasp) *Syngaster lepidus* (larval parasitic wasp)
eucalyptus redgum lerp psyllid		•		•		*Psyllaephagus bliteus* (parasitic wasp)
giant whitefly	•	•		•	•	*Entedononecremnus krauteri, Encarsiella noyesii,* and *Idioporus affinis* (parasitic wasp)
glassy-winged sharpshooter				•		*Gonatocerus* spp. (egg parasitic wasps)
lace bugs	•	•		•		pirate bugs spiders
mealybugs	•	•		•	•	mealybug destroyer lady beetle
mosquitoes						*Bacillus thuringiensis* ssp. *israelensis*
psyllids	•	•		•		pirate bugs
scales	•	•		•	•	*Aphytis* spp. (armored scale parasites)
slugs, snails			•			*Rumina decollata* (predatory snail) predaceous ground beetles vertebrates
spider mites	•	•			•	sixspotted thrips *Stethorus picipes* (spider mite destroyer lady beetle)
thrips	•				•	predatory thrips
weevils, root or soil-dwelling						*Steinernema carpocapsae* and *Heterorhabditis bacteriophora* (entomopathogenic nematodes)
whiteflies	•	•		•		*Encarsia formosa* (greenhouse whitefly parasite) pirate bugs

ing its development (Figure 1). However, adult females of certain parasites (such as many wasps that attack scales and whiteflies) feed on their hosts, providing an easily overlooked but important source of biological control in addition to the host mortality caused by parasitism.

Most parasitic insects are either flies (Diptera) or wasps (Hymenoptera). Parasitic Hymenoptera occur in over three dozen families. For example, Aphidiinae (a subfamily of Braconidae) attack aphids. Trichogrammatidae parasitize insect eggs. Aphelinidae, Encyrtidae, Eulophidae, and Ichneumonidae are other groups of tiny size to medium-sized wasps that parasitize pests but do not sting people. The most common parasitic flies are Tachinidae. Adult tachinids often resemble house flies. Their larvae are maggots that feed inside the host.

Predators

Insects are important food for many amphibians, birds, mammals, and reptiles. Many beetles, true bugs (Hemiptera or Heteroptera), flies, and lacewings are predators of various pest mites and insects (Table 2). Most spiders feed entirely on insects. Predatory mites that prey primarily on spider mites include *Amblyseius* spp., *Neoseiulus* spp., and the western predatory mite (*Galendromus occidentalis*).

Recognizing Natural Enemies. Proper identification of pests, and distinguishing pests from their natural enemies, are essential to effectively using biological control. For example, some people may mistake aphid-eating syrphid fly larvae for caterpillars. The adult syrphid, commonly also called a flower fly or hover fly, is sometimes mistaken for a honey bee. Consult publications such as the UC Statewide Integrated Pest Management Program *Pest Notes* series listed in Suggested Reading to learn more about the specific pests and their natural enemies in your gardens and landscapes. Take unfamiliar organisms you find to your Cooperative Extension office or county agriculture commissioner for an expert identification. Carefully observe the creatures on your plants to help discern their activity. For example, to distinguish plant-feeding mites from predaceous mites, observe them on your plants with a good hand lens. Predaceous species appear more active than plant-feeding species. In comparison with pest mites, predaceous mites are often larger and do not occur in large groups.

Table 2. Some important predaceous insects.

Common name	Examples
aphid flies	*Chamaemyia* spp., *Leucopis* spp.
assassin bugs	*Zelus renardii*
brown lacewings	*Hemerobius* spp.
green lacewings	*Chrysopa* spp., *Chrysoperla* spp.
ground beetles	*Calosoma* spp., *Calathus* spp.
lady beetles	convergent lady beetle, mealybug destroyer, multicolored Asian lady beetle
minute pirate bugs	*Orius* spp., *Anthocoris* spp.
predaceous midges (aphid midges)	*Aphidoletes aphidimyza*
predaceous thrips	black hunter thrips, sixspotted thrips
soldier beetles	*Cantharis* spp.
syrphid flies (flower flies, hover flies)	*Metasyrphus* spp., *Scaeva* spp.

CONSERVATION: PROTECT YOUR NATURAL ENEMIES

Preserve naturally occurring beneficial organisms whenever possible. Most pests are attacked by several different types and species of natural enemies, and their conservation is the primary way to successfully use biological control in gardens and landscapes (Figure 2). Ant control, habitat manipulation, and selective pesticide use are key conservation strategies.

Pesticide Management

Broad-spectrum pesticides often kill a higher proportion of predators and parasites than of the pest species they are applied to control. In addition to immediately killing natural enemies that are present (contact toxicity), many pesticides are persistent materials that leave residues that kill natural enemies that migrate in after spraying (residual toxicity). Residues often are toxic to natural enemies long after pests are no longer affected. Even if beneficials survive an application, low levels of pesticide residues can interfere with natural enemies' reproduction and their ability to locate and kill pests.

Biological control's importance often becomes apparent when broad-spectrum, persistent pesticides cause secondary pest outbreaks or pest resurgence. A secondary outbreak of a different species occurs when pesticides applied against a target pest kill natural enemies of other species, causing the formerly innocuous species to become pests (Figure 3). An example is the dramatic increase in spider mite populations that sometimes results after applying a carbamate (e.g., carbaryl or Sevin) or organophosphate (malathion) to control caterpillars or other pests.

Eliminate or reduce the use of broad-spectrum, persistent pesticides whenever possible. Carbamates, organophosphates, and pyrethroids are especially toxic to natural enemies (Table 3). When pesticides

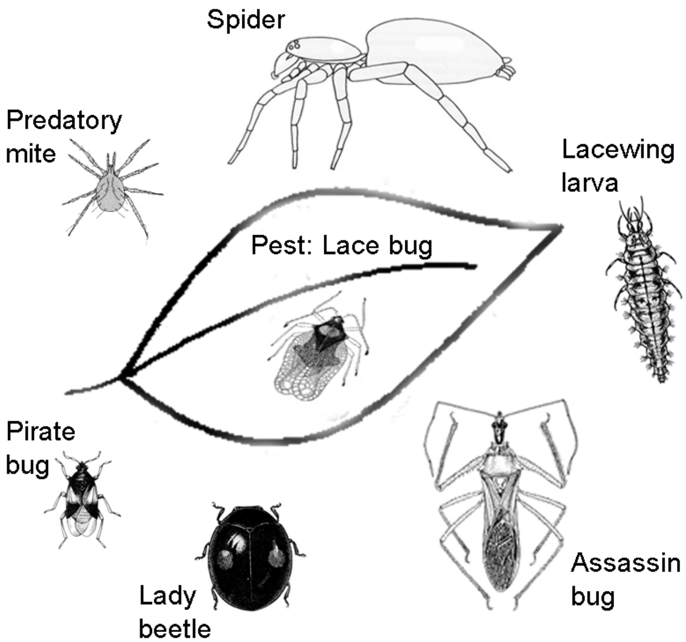

Figure 2. Most pests are attacked by a complex of natural enemies. Shown here is a lace bug surrounded by its common predators. Conserving these beneficial species is the primary way to successfully use biological control in gardens and landscapes. Each pest life stage can be killed by various other species of parasites, pathogens, and predators not illustrated here.

Table 3. Relative toxicity to natural enemies of certain insecticide groups.

Insecticide	Toxicity
Bacillus thuringiensis (Bt)	No contact—No residual
botanicals (e.g., azadirachtin, pyrethrins), oils, soaps, spinosad	Moderate to high contact—No residual to short residual
chloronicotinyls (imidacloprid, Bayer Advanced Tree & Shrub or Merit)	Low to high[1]
carbamates (carbaryl or Sevin), organophosphates (malathion), pyrethroids (permethrin)	High contact—Long residual

Direct contact toxicity is killing within several hours from spraying the beneficial or its habitat.
Residual toxicity is killing or sublethal effects (such as reduced reproduction or impaired ability to locate and kill pests) due to residues that persist.

[1] Toxicity and persistence are highly variable, depending partly on the application method (foliar spray vs. soil drench) and the life stage and species of the natural enemy.

are used, apply them in a selective manner. Treat only heavily infested spots instead of entire plants. Choose insecticides that are more specific in the types of invertebrates they kill, such as *Bacillus thuringiensis* (Bt) that kills only caterpillars that eat treated foliage. Rely on insecticides with little or no persistence, including insecticidal soap, horticultural or narrow-range oil, and pyrethrins.

A less-persistent pesticide can result in longer control of the pest in situations where biological control is important because the softer pesticide will not keep killing natural enemies. One soft pesticide spray plus natural enemies can be effective for longer than the application of one hard spray.

Ant Control and Honeydew Producers

Ants are beneficial as consumers of weed seeds, predators of many insect pests, soil builders, and nutrient cyclers. Ants may attack people and pets or are direct pests of crops, feeding on nuts or fruit (See *Pest Notes: Red Imported Fire Ants*). The Argentine ant and certain other species are pests primarily because they feed on honeydew produced by Homopteran insects such as aphids, mealybugs, soft scales, and whiteflies. Ants protect honeydew producers from predators and parasites that might otherwise control them. Ants sometimes move these honeydew-producing insects from plant to plant. Where natural enemies are present, if ants are controlled, populations of many pests will gradually (over several generations of pests) be reduced as natural enemies become more abundant. Control methods include cultivating soil around ant nests, encircling trunks with ant barriers, and applying insecticide baits near plants. See *Pest Notes: Ants* for more information.

Habitat Manipulation

Manage gardens and landscapes by using cultural and mechanical methods that enhance natural enemy effectiveness. Grow diverse plant species and tolerate low populations of plant-feeding insects and mites so that some food is always available to retain predators and parasites. Plant a variety of sequentially flowering species to provide natural enemies with nectar, pollen, and shelter throughout the growing season. The adult stage of many insects with predaceous larvae (such as green lacewings and syrphid flies) and many adult parasites feed only on pollen and nectar. Even if pests are abundant for the predaceous and parasitic stages, many beneficials will do poorly unless flowering and nectar-producing plants are available to adult natural enemies. Reduce dust, for example, by planting ground covers and windbreaks. Dust can interfere with natural enemies and may cause outbreaks of pests such as spider mites. Avoid excess fertilization and irrigation, which can cause phloem-feeding pests such as aphids to reproduce more rapidly than natural enemies can provide control.

AUGMENTATION

When resident natural enemies are insufficient, their populations can sometimes be increased (augmented) through the purchase and release of commercially available beneficial species. However, there has been relatively little research on releasing natural enemies in gardens and landscapes. Releases are unlikely to provide satisfactory pest control in most situations. Some marketed natural enemies are not effective. Praying mantids, often sold as egg cases, make fascinating pets. But mantids are cannibalistic and feed indiscriminately on pest and beneficial species. Releasing mantids does not control pests.

Only a few natural enemies can be effectively augmented in gardens and landscapes. These include entomophagous nematodes, predatory mites, and perhaps a few other species. For example, convergent lady beetles (*Hippodamia convergens*) purchased in bulk through mail order and released in very large numbers at intervals can temporarily control aphids; however, lady beetles purchased through retail outlets are unlikely to be sufficient in numbers and quality to provide control.

Successful augmentation generally requires advanced planning, biological expertise, careful monitoring, optimal release timing, patience, and situations where certain levels of pests and damage can be tolerated. Desperate problems where pests or damage are already abundant are not good opportunities for augmentation.

CLASSICAL BIOLOGICAL CONTROL OR IMPORTATION

Classical biological control, also called importation, is primarily used against exotic pests that have inadvertently been introduced from elsewhere. Many organisms that are not pests in their native habitat become unusually abundant after colonizing new locations without their natural controls. Researchers go to the pest's native habitat, study and collect the natural enemies that kill the pest there, and then ship promising natural enemies back for testing and possible release. Many insects and some weeds that were widespread pests in California are now partially or completely controlled by introduced natural enemies, except where these natural enemies are disrupted, such as by pesticide applications or honeydew-seeking ants.

Natural enemy importation by law must be done only by qualified scientists with government permits. Natural enemies are held and studied in an approved quarantine facility to prevent their escape until research confirms that the natural enemy will have minimal negative impact in the new country of release. Because classical biological control can provide long-term benefits over a large area and is funded through taxes, public support is critical for continued success. Consult *Natural Enemies*

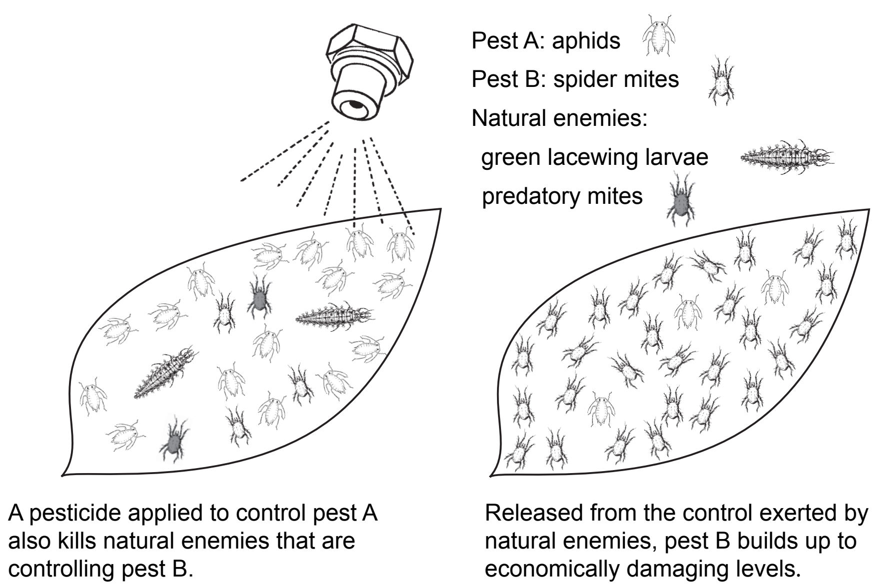

Figure 3. Killing natural enemies often results in secondary outbreaks of insects and mites. For example, spider mites are often present on plants at low densities but become excessively abundant and cause damage when pesticides applied against other species kill the natural enemies of the spider mites. Here a pesticide applied to kill aphids (Pest A) not only killed aphids but also killed predaceous green lacewing larvae and predatory mites, leading to a secondary outbreak of spider mites (Pest B). Insecticides applied during hot weather appear to have the greatest effect on mites, sometimes causing dramatic mite outbreaks within a few days after spraying.

Handbook and *Pests of Landscape Trees and Shrubs* to learn about situations where imported natural enemies are important and conserve them whenever possible.

Is Biological Control "Safe"?

One of the great benefits of biological control is its relative safety for human health and the environment. Most negative impacts from exotic species have been caused by undesirable organisms contaminating imported goods, by travelers carrying in pest-infested fruit, by introduced ornamentals that escape cultivation and become weeds, and by poorly conceived importations of predatory vertebrates like mongooses. These ill-advised or illegal importations are not part of biological control. To avoid these problems, biological control researchers follow regulations and work with relatively host-specific insects.

Help preserve our environment and avoid introducing exotic new pests.

Do not bring uncertified fruit, plants, or soil into California. Take unfamiliar pests to your county agricultural commissioner or Cooperative Extension office for identification.

WHAT MAKES AN EFFECTIVE NATURAL ENEMY?

Although many animals prey on pest insects or mites, not all can be relied upon to reduce a pest population enough to protect plants. The most effective natural enemies are often relatively host specific, feeding on a single pest species or a group of similar pests such as aphids or scales. Good examples include predatory mites, most parasitic wasps, and syrphid flies. Very general predators such as praying mantids are often likely to kill as many beneficials as pests and thus rarely provide effective control.

Synchronization of the life cycle and environmental requirements of the pest and natural enemy also determine the effectiveness of biological control. Natural enemies that do not arrive or become abundant until after pests are very abundant may not prevent serious damage to plants. Conversely, a parasite or predator with multiple annual generations, that can attack a broad range of life stages of the pest and can feed and reproduce when pest populations are low or moderate, will likely be a more effective natural enemy.

SUGGESTED READING

[1]*Natural Enemies Handbook: The Illustrated Guide to Biological Pest Control*. 1998. M. L. Flint and S. H. Dreistadt. Univ. Calif. Div. Agric. Nat. Res. Publ. 3386. Oakland.

[1]*Pest Notes: Ants*. Feb. 2007. M. K. Rust and J. H. Klotz. Oakland. Univ. Calif. Agric. Nat. Res. Publ. 7411. Also available online, http://www.ipm.ucdavis.edu/PMG/menu.invertebrate.html

[1]*Pest Notes: Red Imported Fire Ant.* Sept. 2007. L. Greenberg, J. H. Klotz, and J. N. Kabashima. Oakland. Univ. Calif. Agric. Nat. Res. Publ. 7487. Also available online, http://www.ipm.ucdavis.edu/PMG/menu.invertebrate.html

[1]*Pest Notes: Spiders.* In press. R. S. Vetter. Oakland. Univ. Calif. Agric. Nat. Res. Publ. 7442. Also available online, http://www.ipm.ucdavis.edu/PMG/menu.invertebrate.html

[1]*Pest Notes: Spider Mites.* Dec. 2000. B. Ohlendorf and M. L. Flint, eds. Oakland. Univ. Calif. Agric. Nat. Res. Publ. 7405. Also available online, http://www.ipm.ucdavis.edu/PMG/menu.invertebrate.html

[1]*Pests of Landscape Trees and Shrubs.* 2004. S. H. Dreistadt, M. L. Flint, and J. K. Clark. Univ. Calif. Agric. Nat. Res. Publ. 3359. Oakland.

WORLD WIDE WEB SITES

Biological Control: A Guide to Natural Enemies in North America. Cornell University. www.nysaes.cornell.edu/ent/biocontrol

Biological Control Information Center North Carolina State Univ. http://cipm.ncsu.edu/ent/biocontrol

Biological Control News, Midwest University of Wisconsin-Madison, Dept. of Entomology. www.entomology.wisc.edu/mbcn/mbcn.html

Center for Biological Control, www.cnr.berkeley.edu/biocon

UC Statewide IPM Program Natural Enemies Gallery, an online photographic reference, www.ipm.ucdavis.edu/PMG/NE/index.html ❖

[1] University of California Agriculture and Natural Resource publications may be ordered online or via telephone.

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Fig. 2: assassin bug: Zimmerman, E. C. 1948. *Insects of Hawaii.* Volume 3: Heteroptera. Honolulu: University of Hawaii Press; lacewing larva and pirate bug: by Celeste Green in Smith, R. F., and K. S. Hagen. 1956. Enemies of spotted alfalfa aphid. *Calif. Agric.* 10(4):8–10; lady beetle: Simanton, F. L. 1916. *Hyperaspis binotata,* a predatory enemy of the terrapin scale. *J. Agric. Res.* 6:197–204; spider: Costello, M. J., M. A. Mayse, K. M. Daane, W. A. O'Keefe, and C. B. Sisk. 1995. *Spiders in San Joaquin Valley Grape Vineyards.* Oakland. Univ. Calif. Div. Agric. Nat. Res. Leaflet 21530; predatory mite: Denmark, H. A., and E. Schicha. 1983. Revision of the genus *Phytoseiulus* Evans (Acarina: Phytoseiidae). *Internat. J. Acarol.* 9:27–35;. **Fig. 3:** V. Winemiller.

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To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products that are not mentioned.

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WARNING ON THE USE OF CHEMICALS

Pesticides are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label. Store all chemicals in the original labeled containers in a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, pets, and livestock.

Pesticides applied in your home and landscape can move and contaminate creeks, rivers, and oceans. Confine chemicals to the property being treated. Avoid drift onto neighboring properties, especially gardens containing fruits or vegetables ready to be picked.

Do not place containers containing pesticide in the trash or pour pesticides down sink or toilet. Either use the pesticide according to the label or take unwanted pesticides to a Household Hazardous Waste Collection site. Contact your county agricultural commissioner for additional information on safe container disposal and for the location of the Household Hazardous Waste Collection site nearest you. Dispose of empty containers by following label directions. Never reuse or burn the containers or dispose of them in such a manner that they may contaminate water supplies or natural waterways.