BIOLOGICAL CONTROL AND NATURAL ENEMIES OF INVERTEBRATES

Integrated Pest Management for Home Gardeners and Landscape Professionals

Biological control is the beneficial action of parasites, pathogens, and predators in managing 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 (Figure 1). Use of natural enemies for biological control of rangeland and wildland weeds (e.g., Klamath weed, St. Johnswort) is also effective. Plant pathogens, nematodes, and vertebrates also have many natural enemies, but this biological control is often harder to recognize, less well understood, and/or more difficult to manage. Conservation, augmentation, and classical biological control are tactics for harnessing natural enemies' benefits.

Figure 1. Adult convergent lady beetle feeding on aphids.

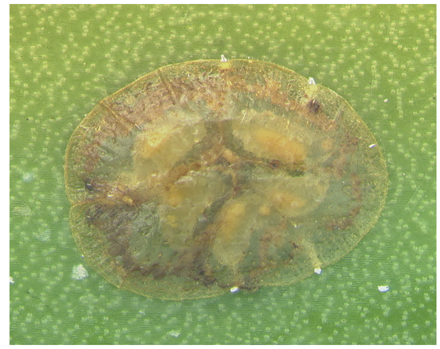

Figure 2. Parasitic wasp larvae (*Metaphycus*) visible through the surface of their scale insect host.

Figure 3. Aphid mummies and a parasitic wasp (*Lysiphlebus testaceipes*).

Figure 4. Entomopathogenic nematodes emerging from a root weevil larva they killed.

TYPES OF NATURAL ENEMIES

Parasites, pathogens, and predators are the primary groups used in biological control of insects and mites (Table 1). Most parasites and pathogens, and many predators, are highly specialized and attack a limited number of closely related pest species. Learn how to recognize natural enemies by consulting resources such as the *Natural Enemies Handbook* and the Natural Enemies Gallery.

Parasites

A parasite is an organism that lives and feeds in or on a host (Figure 2). Insect parasites can develop on the inside or outside of the host's body. Often only the immature stage of the parasite feeds on the host. However, adult females of certain parasites (such as many wasps that attack scales and whiteflies) feed on and kill their hosts (Figure 8), providing an easily overlooked but important source of biological control in addition to the host mortality caused by parasitism.

Although the term "parasite" is used here, true parasites (e.g., fleas and ticks) do not typically kill their hosts. Species useful in biological control, and discussed here, kill their hosts; they are more precisely called "parasitoids."

Most parasitic insects are either flies (Order Diptera) or wasps (Order Hymenoptera). Parasitic wasps occur in over three dozen Hymenoptera families. For example, Aphidiinae (a subfamily of Braconidae) attack aphids (Figure 3). Trichogrammatidae parasitize insect eggs. Aphelinidae, Encyrtidae, Eulophidae, and Ichneumonidae are other groups that parasitize insect pests. It's important to note that these tiny to medium-sized wasps are incapable of stinging people. The most common parasitic flies are the typically hairy Tachinidae. Adult tachinids often resemble house flies. Their larvae are maggots that feed inside the host.

Pathogens

Natural enemy pathogens are microorganisms including certain bacteria, fungi, nematodes, protozoa, and viruses that can infect and kill the host (Figure 4). Populations of some aphids, caterpillars, mites, and other invertebrates

PEST NOTES Publication 74140

University *of* California
Agriculture and Natural Resources
Statewide Integrated Pest Management Program

December 2014

high humidity or dense pest populations. In addition to a naturally occurring disease outbreak (epizootic), 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.

Predators

Predators kill and feed on several to many individual prey during their lifetimes. Many species of amphibians, birds, mammals, and reptiles prey extensively on insects. Predatory beetles, flies, lacewings, true bugs (Order Hemiptera), and wasps feed on various pest insects or mites (Figures 5 and 6). Most spiders feed entirely on insects. Predatory mites that feed primarily on pest 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 natural enemies, is essential for effective biological control. Carefully observe the mites and insects on your plants to help discern their activity. For example, some people may mistake syrphid fly larvae for caterpillars. However, syrphid fly larvae are found feeding on aphids and not chewing on the plant itself. If you find mites on your plants, observe them with a good hand lens. Predaceous mites appear more active than plant-feeding species. In comparison with pest mites, predaceous mites are often larger and do not occur in large groups.

Consult publications listed in the References to learn more about the specific pests and their natural enemies in your gardens and landscapes. Take unfamiliar organisms you find to your local University of California (UC) Cooperative Extension office, UC Master Gardener Program, or agricultural commissioner office in your county for aid in identification.

CONSERVATION: PROTECT YOUR NATURAL ENEMIES

Preserve existing natural enemies by choosing cultural, mechanical, or selective chemical controls that do not harm beneficial species. Remember, only about 1% of all insects and mites are harmful. Most pests are attacked by multiple species of natural enemies, and their conservation is the primary way to successfully use biological control. Judicious (e.g., selective, timing) pesticide use, ant control, and habitat manipulation are key conservation strategies.

Pesticide Management

Biological control's importance often becomes apparent when broad-spectrum, residual pesticides (those that persist for days or weeks) cause secondary pest outbreaks or pest resurgence. An example is the dramatic increase in spider mite populations (flaring) that sometimes results after applying a carbamate (e.g., carbaryl or Sevin) or organophosphate (malathion) to control caterpillars or other insects.

Eliminate or reduce the use of broad-spectrum, persistent pesticides whenever possible. Carbamates, organophosphates, and pyrethroids kill natural enemies that are present at the time of spraying and for days or weeks afterwards their residues kill predators and parasites that migrate in after spraying (Figure 7). Neonicotinoids (e.g., dinetofuran, imidacloprid) and other systemic insecticides that translocate (move) into blossoms can poison natural enemies and honey bees that feed on nectar and pollen. Even if beneficials survive an application, low levels of

Figure 5. An adult assassin bug (*Zelus renardii*) eating a lygus bug.

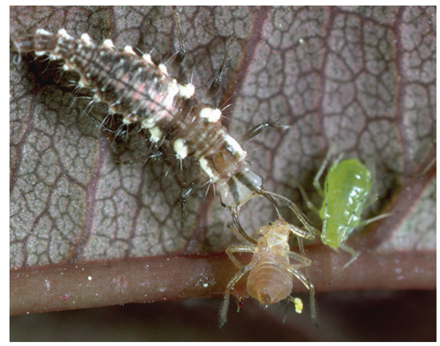

Figure 6. An alligatorlike green lacewing larva eating a rose aphid.

	TOXICITY TO PARASITES AND PREDATORS [1]	
INSECTICIDE	Direct	Residual
microbial (*Bacillus thuringiensis*)	no	no
botanicals (pyrethrins)	yes/no[2]	no
oil (horticultural), soap (potash soap)	yes	no
microbial (spinosad)	yes/no[2]	yes/no[2]
neonicotinoids (imidacloprid)	yes/no[2]	yes
carbamates (carbaryl), organophosphates (malathion), pyrethroids (bifenthrin)	yes	yes

1. 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 ability to locate and kill pests) due to residues that persist.
2. Toxicity depends on the specific material and how it is applied and the species and life stage of the natural enemy.
See the active ingredients database at www.ipm.ucanr.edu/PMG/menu.pesticides.php for more information about specific pesticides.

Figure 7. Relative toxicity of insecticides to natural enemies.

pesticide residues can interfere with natural enemies' reproduction and their ability to locate and kill pests.

When pesticides are used, apply them in a selective manner. Treat only heavily infested areas with "spot" applications 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 consume treated foliage.

For most other types of exposed-feeding insects, rely on contact insecticides with little or no persistence, including azadirachtin, insecticidal soap, narrow-range oil (horticultural oil), neem oil, and pyrethrins, which are often combined with the synergist piperonyl butoxide.

In situations where you wish to foster biological control, use of nonpersistent pesticides can provide better long-term control of the pest because they do less harm to natural enemies that migrate in after the application. To obtain adequate control, thoroughly wet the

Table 1. Some Pests and Their Common Natural Enemies.

	Natural Enemies					
Pests	**Lacewings**	**Lady beetles**	**Parasitic flies**	**Parasitic wasps**	**Predatory mites**	**Other Groups and Examples**
aphids	X	X		X		entomopathogenic fungi, soldier beetles, syrphid fly larvae
carpenterworm, clearwing moth larvae				X		entomopathogenic nematodes
caterpillars (e.g., California oakworm)	X		X	X		*Bacillus thuringiensis*, birds, entomopathogenic fungi and viruses, predaceous bugs and wasps, *Trichogramma* spp. (egg parasitic wasps), spiders
cottony cushion scale		X	X			*Cryptochaetum iceryae* (parasitic fly), vedalia beetle
elm leaf beetle			X	X		*Erynniopsis antennata* (parasitic fly), *Oomyzus* (=*Tetrastichus*) spp. (parasitic wasps)
eucalyptus longhorned borers				X		*Avetianella longoi* (egg parasitic wasp)
eucalyptus redgum lerp psyllid				X		*Psyllaephagus bliteus* (parasitic wasp)
giant whitefly	X	X		X		*Encarsia hispida*, *Encarsia noyesi*, *Entedononecremnus krauteri*, and *Idioporus affinis* (parasitic wasp), syrphid fly larvae
glassy-winged sharpshooter	X			X		assassin bugs, *Gonatocerus* spp. (egg parasitic wasps), spiders
lace bugs	X	X		X		assassin bugs and pirate bugs, spiders
mealybugs	X	X		X		mealybug destroyer lady beetle
mosquitoes						*Bacillus thuringiensis* spp. *israelensis*, mosquito-eating fish
psyllids	X	X		X		pirate bugs
scales	X	X		X	X	*Aphytis*, *Coccophagus*, *Encarsia*, and *Metaphycus* spp. parasitic wasps
slugs, snails			X			*Rumina decollata* (predatory snail), predaceous ground beetles, birds, snakes, toads, and other vertebrates
spider mites	X	X			X	bigeyed bugs and minute pirate bugs, *Feltiella* spp. (predatory cecidomyiid fly larvae), sixspotted thrips, *Stethorus picipes* (spider mite destroyer lady beetle)
thrips	X			X	X	minute pirate bugs, predatory thrips
weevils, root or soil-dwelling				X		*Steinernema carpocapsae* and *Heterorhabditis bacteriophora* (entomopathogenic nematodes)
whiteflies	X	X		X		bigeyed bugs and minute pirate bugs, *Cales*, *Encarsia*, and *Eretmocerus* spp. parasitic wasps, spiders

infested plant parts with spray beginning in spring when pests become abundant. To provide sustained control, repeated applications may be needed.

For certain harder-to-control pests where contact-only insecticides are inadequate, other choices include spinosad, a fermentation product of a naturally occurring bacterium. This insecticide persists about 1 week and it has translaminar activity (is absorbed short distances into plant tissue). Spinosad can be toxic to certain natural enemies (e.g., predatory mites, *Trichogramma* wasps, and syrphid fly larvae) and bees when sprayed and for about 1–4 days afterwards; do not apply spinosad to plants that are flowering.

Ant Control and Honeydew Producers

The Argentine ant and certain other ant species are considered pests primarily because they feed on honeydew produced by insects that suck phloem sap, such as aphids, mealybugs, soft scales, psyllids, 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 (called "farming"). 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 of sticky material, and applying insecticide baits near plants. See *Pest Notes: Ants* for more information.

Habitat Manipulation

Plant a variety of species that flower at different times 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 supplement their diet. To retain predators and parasites, grow diverse plant species well adapted to the local conditions and that tolerate low populations of plant-feeding insects and mites so that some food is always available.

Other cultural controls that can help natural enemies include reducing dust and properly fertilizing and irrigating. Dust can interfere with natural enemies and may cause outbreaks of pests such as spider mites. Reduce dust by planting ground covers and windbreaks and hosing off small plants that become excessively covered with dust. 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. Many natural enemies are generalist predators and are cannibalistic and feed indiscriminately on pest and beneficial species, thereby reducing their effectiveness.

Only a few natural enemies can be effectively augmented in gardens and landscapes. For example, entomopathogenic nematodes can be applied to control certain tree-boring and lawn-feeding insects. Convergent lady beetles (*Hippodamia convergens*) purchased in bulk through mail order, stored in a refrigerator, 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. Situations where pests or damage are already abundant are not good opportunities for augmentation.

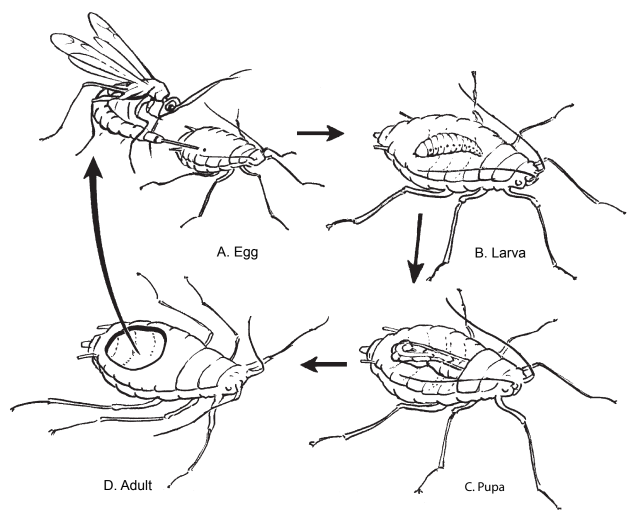

Figure 8. In many cases, only the immature stage of a parasite feeds on the host, as illustrated here with a species that attacks aphids. A. An adult parasite lays an egg inside a live aphid. B. The egg hatches into a parasite larva that grows as it feeds on the aphid's insides. C. After killing the 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.

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, 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.

By law, natural enemy importation 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.

It is important for landscape managers to recognize imported natural enemies and conserve them whenever possible. Because classical biological control can provide long-term benefits over a large area and is conducted by agencies and institutions funded through taxes, public support is critical to the continued success of classical biological control.

Is Biological Control "Safe"?

A great benefit of biological control is its relative safety for human health and the environment, compared to widespread use of broad-spectrum pesticides. Most negative impacts from exotic species have been caused by undesirable organisms contaminating imported goods, by travelers carrying in pest-infested fruit, and from introduced ornamentals that escape cultivation and become weeds. These ill-advised or illegal importations are not part of biological control.

Negative impacts have occurred from poorly conceived, quasi-biological control importations of predaceous vertebrates like frogs, mongooses, and certain fish, often conducted by nonscientists. To avoid these problems, biological control researchers follow government quarantine regulations and work mostly with host-specific natural enemies that pose low risks and can provide great benefits. As a pest comes under biological control, population densities decline for both the pest and the biological control agent because host-specific natural enemies cannot prey or reproduce on other species.

REFERENCES

Dreistadt, S.H., M.L. Flint, and J.K. Clark. 2004. *Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide*. 2nd ed. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3359.

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

Rust, M.K. and D.-H. Choe. 2012. *Pest Notes: Ants*. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 7411. Available online at www.ipm.ucanr.edu/PMG/PESTNOTES/pn7411.html.

IMPORTANT LINKS

Quick Tip Beneficial Predators: http://www.ipm.ucanr.edu/QT/beneficialpredatorscard.html.

Quick Tip Common Garden Spiders: http://www.ipm.ucanr.edu/QT/commongardenspiderscard.html.

Quick Tip Lady Beetles: http://www.ipm.ucanr.edu/QT/ladybeetlescard.html.

Quick Tip Parasites of Insect Pests: http://www.ipm.ucanr.edu/QT/parasitesinsectcard.html.

Natural Enemies Gallery: http://www.ipm.ucanr.edu/PMG/NE/index.html.

Narrated presentation on biological control (24 minutes): http://stream.ucanr.org/biocontrol_final/index.htm.

More biological control resources: www.ipm.ucanr.edu/PMG/menu.biocontrol.html.

AUTHORS: S. H. Dreistadt, UC Statewide IPM Program, Davis.

TECHNICAL EDITOR: K. Windbiel-Rojas
EDITOR: K. Beverlin

ILLUSTRATIONS: Figs. 1, 3–6. J. K. Clark; **Fig 2**. A. Kapranas; **Fig 8**. D. Kidd.

This and other Pest Notes are available at www.ipm.ucanr.edu.

For more information, contact the University of California Cooperative Extension office in your county. See your telephone directory for addresses and phone numbers, or visit http://ucanr.edu/County_Offices/.

University of California scientists and other qualified professionals have anonymously peer reviewed this publication for technical accuracy. The ANR Associate Editor for Pest Management managed this process.

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.

This material is partially based upon work supported by the Extension Service, U.S. Department of Agriculture, under special project Section 3(d), Integrated Pest Management.

Produced by:
Statewide Integrated Pest Management Program
University of California
2801 Second St.
Davis, CA 95618-7774

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 the 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.