Augmentation Biological Control Practices for the Home Landscape

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Gardeners can use many different strategies to manage pests in the garden. An integrated pest management program (IPM) takes advantage of multiple options to create a comprehensive management plan for pests. One tool available to homeowners is biological control, using predators, parasitoids and disease agents (natural enemies) to manage pests. Biological control works to reestablish predator-prey relationships in the garden. Gardeners can practice biological control through augmentation. Augmentation involves the purchase and release of natural enemies into the landscape to manage a pest. This Fact Sheet outlines the goals and approaches to augmentation biological control, including the purchase and release of commercially available natural enemies.

In an augmentation biological control program, gardeners add to the number and/or type of natural enemies in the landscape. This typically involves purchasing natural enemies from a commercial supplier and releasing these into the landscape. The goal is not to replace existing natural enemies, but rather provide an additional source of mortality to help manage a pest population. This may be necessary if existing natural enemies are not present in sufficient numbers to provide control or appear too late in the season to manage the pest effectively.

Augmentation can be labor-intensive and/or expensive. Augmentation strategies have not been developed for all pest situations. The most common application of augmentation biological control is in greenhouses. Augmentation biological control is also commonly applied to manage filth flies in stables and where livestock are raised. In row crops, generalist natural enemies are frequently used, such as the egg parasite, *Trichogramma*, green lacewings and microbial insecticides. Home gardeners are increasingly using natural enemies to protect food crops and landscape plants. Augmentation requires proper pest identification, patience and planning.

Augmentation Approaches

There are two approaches to using augmentation biological control. First, it can be used as a preventive measure to provide long-term control and keep pest populations from reaching excessive numbers. This type of augmentation is called inoculation. With inoculation, small numbers of a natural enemy are released early in the pest cycle to prevent the pest population from building. Ideally, the natural enemies reproduce and build in numbers along with the pest population to provide continued control throughout the season.

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Augmentation also can be used to treat a pest outbreak by overwhelming a pest with the sudden introduction of large numbers of predators. This approach is called inundation, and involves the mass release of large numbers of natural enemies to provide a quick, knockdown effect on the pest population. In this way, augmentation can be used as a remedial treatment to manage a pest problem in the same way chemicals are often used. The use of microbial pesticides such as Bt, *Bacillus thuringiensis*, is also a form of inundation biological control.

In both inundative and inoculative augmentation, the goal is not to permanently establish the natural enemy into the landscape, but rather provide mortality for a short time period, perhaps one growing season or a critical point during the season. Augmentation biological control does not replace natural mortality, but simply provides an additional source of control. It is compatible with conservation biological control as well as cultural, physical and mechanical pest management strategies.

Commercially Available Natural Enemies

Many different types of natural enemies can be purchased commercially including predators, parasitoids, pathogens and nematodes. Knowing which species to purchase begins with proper pest identification. Plants can be damaged by a wide range of environmental factors, disease and insects. Be sure to correctly identify the source of damage before selecting a control agent. Research the proper control species for specific pest situations, as different control agents feed upon different pest species. Table 1 indicates commercially available biological control agents to use against a number of common landscape pests.

Predators

Many predators are generalists, feeding on a wide variety of prey items. For example, praying mantids will eat anything, including pests, other predators and one another. They are not ideal candidates for augmentation. The most effective natural enemies are relatively host specific, feeding on a single pest species or a group of similar pests. Following are some of the more effective commercially available natural enemies for use in the landscape.

Table 1. Common insect pests and associated biological control agents.

	aphid midge	*parasitoids*	*predatory mites*	*green lacewing*	*lady beetle*	*mealybug destroyer*	*Bacillus thuringiensis*	*parasitic nematodes*	*Beauveria bassiana*	*other microbial agents*
aphids	•	•		•	•	•		•	•	•
armyworms		•					•	•	•	
cabbage root maggots								•		
cabbage worm, butterflies		•		•			•		•	•
codling moths		•					•		•	
Colorado potato beetles							•		•	
corn earworms		•		•			•			
cucumber beetles		•						•	•	•
cutworms		•					•	•		
elm leaf beetles					•		•		•	
flea beetles								•		
grubs, white								•	•	•
leaf-hoppers				•					•	
leaf rollers		•					•		•	•
looper caterpillars		•					•		•	•
mealybugs		•		•	•	•			•	
oak moths							•	•		
scales		•		•	•	•				
spider mites			•	•	•				•	•
thrips			•	•				•	•	•
tomato hornworms		•					•			
whiteflies (greenhouse)		•		•	•				•	•
whiteflies (sweet potato)		•		•	•				•	•
wireworms								•	•	•
mosquitos							•			
fungus gnats		•	•				•	•	•	
flies		•								
Japanese beetle								•	•	•
plant-parasitic nematodes								•	•	•

Lacewings

Chrysoperla carnea, the common green lacewing, and *Chrysoperla rufilabris*, an eastern lacewing species, are widely available commercially and also quite prevalent in the landscape. Larvae feed on aphids, mites, insect eggs, thrips, scales, small caterpillars and whiteflies. The larvae are often called aphid lions for their voracious appetites - a single larva can eat 300 aphids to 400 aphids, 11,000 spider mites or 6,000 scale eggs before reaching adulthood. Lacewings can be purchased as larvae or eggs. Eggs are shipped in rice hulls or vermiculite, or sometimes glued to cards. The rice hulls or vermiculite act as a carrier to provide separation among any early-hatching larvae, and also to allow for more even distribution in the garden. Lacewing larvae are shipped in individual cardboard cells to keep them from eating one another during shipping. Release one to five lacewing eggs or larvae per square foot of garden.

Aphid Midge

Larvae of the predatory fly, *Aphidoletes aphidimyza*, feed on more than 60 aphid species. The larvae are orange maggots, about 2 mm to 3 mm long. They are effective both indoors and outdoors for aphid management on food and ornamental crops. Aphid midges are shipped as cocoons. Adults emerge quickly upon receipt and begin laying eggs near aphid infestations. The aphid midge can be used in combination with other sources of mortality, including lacewing larvae and lady beetles. This midge is an important biological control agent for greenhouse crops and is widely available.

Predatory Mites

Several species of predatory mites are commercially available. These are commonly used to manage two-spotted spider mites, although some species manage other pests as well. Some species are used commonly in greenhouses, while others are adaptable for landscape use.

For spider mite management, species of *Amblyseius* and *Phytoseiulus* are available. The species *Phytoseiulus longipes* feeds on spider mites and is tolerant of the high temperatures and low relative humidity common in Oklahoma landscapes. *Amblyseius californicus* also tolerates high temperatures, but feeds at a slower rate than *Phytoseiulus*. Mixes of the two species are commonly available. Also available are *Phytoseiulus persimiliis* and *Amblyseius fallacis*, which both are less tolerant of high temperatures.

Predatory mites are also available for managing thrips and other soft bodied pests. *Hypoaspis miles* feed on fungus gnat larvae, western flower thrips and springtail insects. It is used to manage pests on houseplants as well as commercially for interiorscapes and greenhouses. *Amblyseius cucumeris* also feeds on western flower thrips and onion thrips, but is primarily used in greenhouses.

Mealybug destroyer

Adult and larval stages of the small beetle, *Cryptolaemus montrouzieri*, feed on mealybugs, aphids and immature scales. Mealybug destroyers do not reproduce well in the field and are most commonly used for inundative control of heavy mealybug infestations. Suppliers recommend releasing two beetles to five beetles per infested plant.

Lady beetles

Lady beetles are one of the most commonly released natural enemies. They feed on aphids, mealybugs, whiteflies and scales as well as insect eggs and small larvae. The most commonly available lady beetle is the Convergent Lady Beetle, *Hippodamia convergens*. Most commercially available lady beetles are collected from overwintering. When released, lady beetles have a tendency to disperse. Better success is found with field-collected beetles that have been allowed to fly in captivity. Recommended release rates are one pint to one quart per home garden.

Parasitoids

Parasitoids are specialized natural enemies that develop on or inside a host insect. Several tiny, non-stinging wasps are commonly used for augmentation biological control. Some species of parasitic flies are also commercially available.

Trichogramma

The *Trichogramma* wasp is an almost microscopic wasp that parasitizes the eggs of many common moth pests. The larvae develop within the eggs, killing the embryo. Mature larvae pupate inside the host egg. Most commercially sold *Trichogramma* are shipped in this stage. Adults emerge within 1 day to 3 days and begin laying eggs in hosts. It is important to time releases to correspond with the egg-laying activity of the pest. This is determined by monitoring the pest population. There are many species of *Trichogramma* with varying host ranges; it is important to purchase the proper species for effective pest control.

Trichogramma pretiosum is a generalist parasitoid, using more than 200 host species of moth and butterfly eggs. It is used in row crop settings to manage caterpillar pests. *Trichogramma brassicae* parasitizes cabbage worms, cutworm, earworm and armyworm among others, and also is used in vegetable crops.

Pediobius foveolatus

This parasitoid attacks larvae of the Mexican bean beetle, *Epilachna varivestis*. *Pediobius foveolatus* has been used to successfully manage Mexican bean beetles on soybean crops as well as fresh-market beans. Releases require proper timing to prevent population build-up of the target pest. Order and release wasps as soon as Mexican bean beetles or their eggs are sighted in the garden. *Pediobius foveolatus* does not survive freezing temperatures and will not overwinter in the landscape, thus inoculative releases are required each season.

Encarsia formosa

Encarsia formosa is a great natural enemy of whiteflies and is used extensively in greenhouse flower and food production. Commercial use of *E. formosa* as a biological agent dates back to the 1920s, when it was used widely in Europe. It is used primarily to manage greenhouse whitefly, sweet potato whitefly and silverleaf whitefly on greenhouse tomatoes and cucumbers. Very little is known about the ecology and life history of *E. formosa* in outdoor systems.

Fly Parasitoids

In some settings, such as on farms and in stables, flies can be a major pest. Several fly parasitoids are available for

release against these pests. Often, a combination of several species is released for more effective control. Fly parasitoids can manage fly pests around compost piles, animal cages, garbage cans and farm animals.

Muscidifurax raptorellus is the fly parasitoid most commonly produced for sale in the U.S. It is well adapted to hot climates and parasitizes house flies. Female wasps lay more than one egg per host allowing parasitoid populations to increase quickly.

The aggressive parasitoid wasp, *Muscidifurax raptor,* and the closely related *Muscidifurax zaraptor* attack stable flies, house flies, blow flies and other closely related species. These species perform well both indoors and outdoors.

The hardy species *Spalangia cameroni* and *Spalangia endius* attack house flies and other fly species. These species are generally active in summer through fall and are reliable biological control agents.

Pathogens

A number of pathogens are used for augmentation biological control. These are commonly referred to as microbial pesticides. Some are formulated and applied as living agents, while other microbial pesticides contain products or toxins produced by living agents, although not the entire living organism. Microbial pesticides are sold in formulations that look very similar to chemical pesticide formulations. Most of them can be applied with the same equipment used for insecticide applications.

Several fungi and bacteria have been developed for use as biological control agents (Table 2). Other organisms, including protozoa and viruses have also been evaluated, although applications utilizing these organisms are limited. Microbial pesticides containing these organisms or products produced by microorganisms are regulated by the Environmental Protection Agency and use is governed by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).

Bacillus thuringiensis (Bt)

The bacterium *Bacillus thuringiensis* (Bt) produces a crystalline protein called an endotoxin. When ingested by the target insect, the endotoxin is activated by the alkaline conditions in the insect's stomach where it begins to break down the lining of the host insect's gut. Reproductive spores of Bt then enter the host's blood where the bacterium quickly multiplies. Different species and strains of *Bacillus* are effective against different groups of insect pests. *Bacillus thuringiensis* subsp. *kurstaki* infects the larval stage or caterpillars of moths and butterflies, while *Bacillus thuringiensis* subsp. *israelensis* infects the larvae of flies such as fungus gnats and mosquitoes.

Products containing Bt are most successful when applied early in the host's life cycle, particularly during the actively feeding first and second larval stages. Larvae typically stop feeding soon after ingesting Bt, and may take several days to die. Products containing Bt are formulated in liquid concentrates, wettable powders, dusts and granules. Some products contain the living Bt agent, while others contain Bt endotoxins.

A number of additional *Bacillus* species have been developed for biological control (Table 2). These include species targeting insect pests, such as *Bacillus sphaericus* used against mosquitos, and several species that are pathogenic against plant-infecting fungal pathogens.

Streptomyces

Two soil-dwelling bacterial species of the genus *Streptomyces* are used in commercial formulations of microbial insecticides to manage plant pathogens. *Streptomyces griseoviridis* is used to protect plants from infection by fungal pathogens including *Pythium, Fusarium, Botrytis, Alternaria*, and *Phomosis*. The closely related *Streptomyces lydicus*, also protects plants from root-decaying diseases including *Pythium*, *Phytophthora, Fusarium, Rhizoctonia*, and *Verticillium*. Both species of *Streptomyces* act to protect plants from infection by colonizing the roots and secreting anti-fungal chemicals. Together, these create a defensive barrier around the roots.

Paenibacillus popilliae

This bacterium produces "milky disease" in larvae of the Japanese beetle, *Popillia japonica*. The Japanese beetle was accidently introduced into the eastern U.S. in the early 1900s, and has steadily expanded its range westward. *Paenibacillus popilliae* was the first microbial control agent registered in the U.S. The strains available commercially are highly specific to Japanese beetle grubs.

Beauveria bassiana

Beauveria bassiana is a fungus that causes a disease called white muscadine disease in certain insects. This fungus infects hosts through the cuticle or body lining and does not need to be consumed to be effective. After killing the host, the fungus develops a downy white mold covering the outside of the insect. Susceptible hosts include beetle larvae, lepidopteran larvae (caterpillars), aphids, fungus gnats, leafhoppers, mealybugs, whiteflies and other leaf-feeding insects. Commercial formulations primarily targets and is most effective against foliage-feeding pests.

Metarhizium brunneum

*Metarhizium brunneum (*previously known as *M. anisopliae*) is a soil-borne fungal pathogen commonly found in disturbed sites such as agricultural fields. It infects a variety of arthropods including ticks, whiteflies, thrips, mites, weevils, aphids and grubs. Recent work with the *Metarhizium* genus has identified two species, previously considered the same. *Metarhizium brunneum* had been grouped with *M. anisopliae*, which is pathogenic of grasshoppers and locusts.

Trichoderma

Several species of *Trichoderma* are used for biological control of plant-infecting pathogens. These fungi are prevalent in soils worldwide and commonly colonize plant roots. *Trichoderma* attack, parasitize and feed upon other fungi, including many common plant pathogens. In addition to protecting plants against disease-causing fungi, *Trichoderma* also enhances general plant growth. Several species are available for purchase in Oklahoma to control soil-borne plant pathogens including *Fusarium, Phytophthera, Pythium, Rhizoctonia, Sclerotinia* and *Verticillium*.

Isaria fumosorosea

Isaria fumosorosea is a naturally occurring fungus that attacks and kills several insect species including aphids, spider mites, thrips, weevils, leafminers and whiteflies. Like *Beaveria*, *Isaria* penetrates insects through the cuticle of the

Table 2. Microbial pesticides available in Oklahoma for insect and pathogen control.

Active Ingredient	*Type of Agent*	*Trade Name(s)*	*Target Pest(s)*
Bacillus licheniformis	Bacterium	EcoGuard	dollar spot
Bacillus thuringiensis subsp. *Israelensis*	Bacterium	numerous products available	mosquitos, black flies, drain flies, fungus gnats
Bacillus thuringiensis subsp. *Kurstaki*	Bacterium	numerous products available	lepidopteran larvae (caterpillars)
Bacillus pumilus	Bacterium	Yield Shield, Pro-Mix	*Fusarium, Rhizoctonia, Alternaria, Aspergillus, Pythium*
Bacillus sphaericus	Bacterium	Vectolex	mosquitos
Bacillus subtilis	Bacterium	Integral, Kodiak, Serenade, Taegro	*Rhizoctonia, Pythium, Fusarium, Aspergillus, Botrytis Phytophthora,* powdery mildew
Beauveria bassiana	Fungus	BotaniGard, Naturalis, Mycotrol	beetle larvae, lepidopteran larvae (caterpillars), aphids, ants, fungus gnats, grasshoppers, leafhoppers, mealybugs, mites, whiteflies
Isaria fumosorosea	Fungus	Preferal	aphids, leafminers, mites, lepidoptera larvae (caterpillars), plant bugs, mealybugs, whiteflies, beetle larvae
Metarhizium anisopliae	Fungus	Met 52 Bioinsecticide, Tick-EX	ticks, whiteflies, thrips, mites, weevil, aphid, grubs
Myrothecium verrucaria (killed)	Fungus	DiTera	plant-parasitic nematodes
Nosema locustae	Protozoan	Nolo Bait, Semaspore bait	Grasshoppers, Mormon cricket
Spinosad	Bacterial product	numerous products available	caterpillars, leafminers, beetle larvae, thrips, borers, spider mites, fruit flies, fleas
Streptomyces griseoviridis	Bacterium	Mycostop	*Fusarium, Alternaria brassicola, Phomopsis, Botrytis, Pythium, Phytophthora*
Streptomyces lydicus	Bacterium	Actinovate, Actino-Iron	numerous soil-borne fungal and bacterial pathogens
Trichoderma asperellum and T. *gamsii*	Fungus	Tenet	*Fusarium, Phytophthera, Pythium, Rhizoctonia, Sclerotinia, Verticillium*
Trichoderma hamatum	Fungus	Incept	Soil born diseases
Trichoderma harzianum	Fungus	RootShield, T-22	*Pythium, Rhizoctonia, Fusarium, Sclerotinia*

body. It affects both soil-dwelling and foliar-feeding pests and is used in greenhouse, landscape and turf settings.

Myrothecium verrucaria

The killed fungus *Myrothecium verrucaria* is used as a microbial pesticide to manage plant-parasitic nematodes. The microbial agent is highly specific and effective only against plant-pathogenic nematodes. It is harmless against free-living nematodes. *Myrothecium* products are used on food and ornamental crops.

Nosema locustae

This biological control organism is a microsporidium, a type of protozoan. These single-celled life forms infect insect hosts, causing reduced feeding, lower reproduction and moderate rates of mortality. *Nosema* is available in products targeted for management of grasshoppers. The disease agent must be ingested to be effective and is slow to work. Efficacy has not yet been demonstrated for garden settings, as grasshoppers are strong fliers and occupy a large home range. Commercially available products are registered for use throughout the landscape.

Nematodes

Insect-parasitic nematodes, also called *entomogenous* or *entomopathogenic* nematodes, are round worms that carry insect-pathogenic bacteria in their guts. It is actually the symbiotic bacteria that infects and kills insect hosts. Nematodes are mixed with water and applied to the soil around infected plants or directly onto the plants. Once applied, the nematodes seek out insect hosts and the bacteria are injected into the host insect's blood. Parasitic nematodes have been successfully used to control a number of pests including root-feeding weevil larvae, fungus gnat larvae and sod webworms. Parasitic nematodes are non-toxic and non-pathogenic to humans, plants and animals. They are highly host-specific in their activity.

Heterorhabditis bacteriophora

These nematodes naturally occur in the soil, but not at high enough levels to provide effective pest control. Inundative releases are used to reduce populations of soil-dwelling insects. Some pests successfully controlled in field tests include Japanese beetle grubs, black vine and other weevils, Colorado potato beetle, cucumber beetle and corn root worm. *Heterorhabditis* is highly mobile and reaches soil depths of more than seven inches.

Heterorhabditis indica

Heterorhabditis indica is more heat-tolerant than other *Heteorhabditis* species. Like *H. bacteriophora*, it is effective against lepidopteran and beetle larvae. In addition, it is used to manage fire ant infestations. In greenhouses, *H. indica* is used to control fungus gnats and flower thrips. Beekeepers utilize *H. indica* to manage the small hive beetle, *Aethina tumida.*

Steinernema carpocapse

Easily mass produced, this species has been extensively studied and is most effective against highly mobile pests inhabiting the soil surface. It is highly effective against lepidopteran pests including codling moth, cutworm, armyworm, various webworms and corn earworm. It is also used against fleas, mole crickets and some borers.

Steinernema feltiae

This species of *Steinernema* is highly effective against fly pests. It is used to manage fungus gnats in greenhouses, interiorscapes, and houseplants. It is also effective against some caterpillar pests such as armyworm, codling moth and corn earworm. *Steinernema feltiae* is also used to manage plant-parasitic nematodes including root nematodes.

Many additional biological control agents are commercially available to manage common greenhouse pests. Fact Sheet HLA-6710 "Integrated Pest Management in Commercial Greenhouses: An Overview of Principles and Practices" lists common greenhouse pests and associated biological control agents.

Purchasing Biological Control Agents

There are several items to consider when purchasing natural enemies to release in the garden. Biological control agents are often highly specific in their mode of action. They attack a very narrow range of hosts and sometimes, a specific life stage of that host, such as eggs or larvae. Research the pest and associated natural enemies to identify the most appropriate control agent as well as the proper time for release, based on the pest and natural enemy life cycles.

Purchase natural enemies from a reputable company. Several resources are available to help locate suppliers of biological control agents. The Association of Natural Biocontrol Producers maintains a list of suppliers at www.anbp.org. This website also contains general information on biological control. Another good resource is the booklet "Suppliers of Beneficial Organisms in North America" produced by the California Environmental Protection Agency: http://www.cdpr.ca.gov/docs/pestmgt/ipminov/bensup.pdf. Feel free to call the suppliers with questions. They are very knowledgeable about handling and suggesting release rates.

It is important to remember biological control agents are living organisms. They must be handled carefully and protected from environmental extremes. Have your shipment delivered to a location where the insects can be cared for upon arrival. Insects can quickly die inside a box sitting on a porch in the sun. It is ideal to release and distribute biological control agents as soon as they arrive, but this is not always possible. If you cannot release agents right away, many organisms can be stored in the refrigerator for a few days. Read the information accompanying your biological control organism carefully, as some agents will perish under refrigeration.

Understand proper release practices, so preparation has been made when the shipment arrives. Suppliers of natural enemies provide detailed information regarding agent release, both on-line and in printed material shipped with the control agent. Evening and early morning are the best times to release mobile insect biological control agents. Mist the area prior to release to encourage the natural enemies to remain in the landscape or garden. Select several infested plants for release points, evenly distributing the biological control agent throughout the treatment area.

Adults of many insect biological control agents are not predaceous. Encourage adults to remain in the landscape and reproduce by providing a source of nectar and pollen in the

form of nectar-rich flowering plants throughout the garden. Extension Circular E-1023, "Conserving Beneficial Arthropods in Residential Landscapes" identifies specific habitat and feeding practices of common natural enemies. It is available online at: http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-7426/E-1023.pdf. Fact Sheet HLA-6447 "Conservation Biological Control for the Home Landscape" also includes practices for protecting beneficial insects.

It is also important to be careful with insecticides. Consider the compatibility of chemical control strategies when using natural enemies. Some of the chemicals used to treat pests can also harm beneficial insects, including certain organic and microbial compounds. Always read product labels carefully and research the product before treating a crop intended for releasing natural enemies.

Successful augmentation generally requires advanced planning, biological understanding, careful monitoring and optimal release timing. It is a control strategy that requires patience and realistic expectations. Augmentation is most appropriate for situations where low levels of pests and damage can be tolerated.

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