Integrated Pest Management
in Greenhouses and Herbaceous Nurseries

Integrated pest management (IPM) involves the use of cultural, physical (or mechanical), biological, and pest control material (insecticides and/or miticides) tactics to manage arthropod (insect and mite) pests. Most greenhouses and nurseries use some IPM practices, which emphasize routine inspection, scouting and monitoring, and the use of pest control materials only when arthropod pest populations are capable of causing significant damage. When pest control is necessary, IPM favors using beneficial insects and mites and products that are less harmful to the environment. This publication is designed to help greenhouse and nursery managers select pest control alternatives compatible with this approach.

Alternative or "Reduced Risk" Pest Control

Pest control material use has changed dramatically over the past 30 years. Organophosphate, carbamate, and chlorinated hydrocarbon classes, once used extensively, are gradually being replaced by pyrethroids, which are deemed less risky by the Environmental Protection Agency (EPA).

These "reduced risk" pest control materials are preferred for use in greenhouses and herbaceous nurseries because they are less persistent in the environment, present less of a health risk to humans, are less directly harmful to natural enemies including parasitoids and predators, and require lower use rates to control arthropod pests. The term reduced risk may not appear on the label but is prevalent in promotional or marketing material.

The primary arthropod pests encountered in Kansas and Missouri greenhouses and herbaceous nurseries include aphids, thrips, fungus gnats, shore flies, spider mites, mealybugs, plant bugs, whiteflies, leafhoppers, leafminers, leaf-feeding beetles, and caterpillars. Table 1 (pages 3-6) presents reduced-risk pest control materials registered for use in greenhouses and/or herbaceous nurseries and certified for use in organic production systems. For more information see *http://www.epa.gov/opprd001/workplan/completionsportrait.pdf.*

Pest control materials that contain microorganisms include spinosad (Conserve), abamectin (Avid), *Bacillus thuringienisis* spp. *kurstaki* (Dipel), and *Bacillus thuringiensis* spp. *israelensis* (Gnatrol). In addition, pest control materials derived from plants — often called botanicals or plant-derived essential oils — are available for use in greenhouses and/or herbaceous nurseries. Examples are the clarified hydrophobic extract from neem oil (Triact) and the product GC-Mite, which contains cottonseed, clove, and garlic oil.

Generally, new pest control materials are registered faster for use on ornamental plants because they are not edible and do not require food safety testing. However, registration for greenhouse-grown vegetables may be delayed or denied. This may be confusing especially with regard to vegetable bedding plants. Several of the pest control materials listed in Table 1 may be used on vegetable bedding plants, but it is critical to read the label to obtain this information. Higher infestations of arthropod pests are more tolerable in vegetable production systems compared to ornamental plants because crops such as tomatoes and cucumbers are grown for fruit production and may even be saleable if plants exhibit damage from insect and/or mite pest feeding. Overall, it is important to read product labels before application to make sure that the arthropod pest and site are designated.

Reducing Use Of Pest Control Materials

Although pest control materials are, in general, effective in killing arthropod pests, relying on them solely may increase resistance in arthropod pest populations. It is important to implement cultural, physical, and biological control strategies as well.

Ladybird beetles, known for their appetite for aphids, occur naturally in Kansas but also can be introduced as biocontrol agents in greenhouses and nurseries.

Practices to reduce the use of pest control materials in greenhouses and/or herbaceous nurseries include the following:

- Start with clean greenhouses and nurseries by removing weeds, plant material, and growing medium debris.
- Maintain adequate sanitation and implement proper cultural practices such as watering and fertility throughout the growing season.
- Scout plants weekly, especially indicator plants, which are plants that typically have or are more susceptible to arthropod pest problems.
- Use colored sticky cards (yellow or blue) and visually inspect plants. Record insect and mite pest information such as abundance (or numbers) and life stages (eggs, nymphs or larvae, pupae, and adults) present.
- Inspect transplants or propagation material carefully. Isolate newly introduced plants and inspect for arthropod pest problems. If arthropod pests are present, treat with an appropriate pest control material.
- Only treat those plants with arthropod pests or localized infested areas with pest control materials.
- If possible, install insect screening over greenhouse openings such as ridge vents, sidewalls, and intake vents. Be sure to compensate for airflow reduction by increasing the screening surface area.

Biological Control

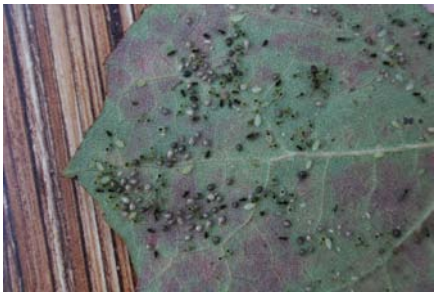
Biological control agents or natural enemies such as parasitoids, predators, and beneficial nematodes may be purchased from commercial suppliers/distributors and released into greenhouses and herbaceous nurseries. This is known as augmentative biological control, and there are two strategies: inoculation and inundation.

Inoculation involves releasing small numbers of natural enemies early in the growing season or cropping cycle with the intent that the natural enemies will establish and reproduce in the greenhouse or herbaceous nursery, providing long-term control. Inundation is the practice of releasing high numbers of natural enemies into a greenhouse or herbaceous nursery with the intent of having the released individuals provide control in the short-term. Additional releases may be required during the growing season or cropping cycle to sustain arthropod pest populations at low levels.

Natural enemies may be purchased from commercial suppliers, which are then released into greenhouses and/or herbaceous nurseries. Refer to the five companies listed under "Biological Control Suppliers." Consult biological control suppliers/distributors for additional information on the use of natural enemies in greenhouses or herbaceous nurseries. Biological control programs tend to be more effective when crops are grown for extended periods (e.g. cut flowers and vegetables) and when environmental conditions (e.g. temperature and relative humidity) are constant. Preventative releases of natural enemies are more efficient and easier in a monoculture (e.g. single crop) cropping system when there is only one arthropod pest compared to polyculture (e.g. multiple crops) cropping systems where there may be a complex (more than three) of different arthropod pests. For example, in spring bedding plant production, a number of insect pests may be present simultaneously including aphids, thrips, whiteflies, and fungus gnats.

The greenhouse environment does not contain the abundance and diversity of natural enemies found in outdoor settings or nurseries. This is primarily due to the lack of natural migration by natural enemies and extensive use of pest control materials. Natural enemy survival in greenhouse environments is influenced by prey abundance and types of prey present.

Aphidius



Parasitized aphids

However, certain parasitoids and predators may occur naturally in greenhouses and/or herbaceous nurseries. For example, parasitoids in the genus *Aphidius*, which prey on many different types of aphids, may inadvertently enter greenhouses through unscreened doors, vents, or sidewalls. Adult females lay eggs into aphids, which hatch into larvae that consume the internal contents. Aphids then harden and turn brown (aphid mummies). Eventually, a new adult parasitoid creates an exit hole and emerges from the dead aphid.

Minute pirate bugs, *Orius spp.* are predatory anthocorid bugs that are black and white and feed on thrips. These predatory bugs may also enter greenhouses through openings, particularly when weeds and field crops start desiccating. Natural enemies that may be present in outdoor nurseries include ladybird beetles, green lacewings, ground beetles, soldier beetles, assassin/ambush bugs, damsel bugs, hover (syrphid) flies, tachinid flies, predatory mites, and spiders.

Biological Control Guidelines

Following are tips for biological control:

- Scout the crop regularly to detect early infestations of arthropod pests before they reach damaging levels.
- Order natural enemies early (at least 3 weeks in advance) and release as soon as possible upon arrival following release instructions by the supplier.
- Install insect or micro-screening over greenhouse openings such as ridge vents, sidewalls, and intake vents. This will reduce the migration of winged aphids, adult whiteflies, thrips, and leafminers into greenhouses. Be sure to compensate for airflow reduction by increasing the screening surface area.
- Avoid overfertilizing plants, particularly with nitrogen-based fertilizers, because this results in the production of soft succulent growth that is more susceptible to aphids and the twospotted spider mite (*Tetranychus urticae*).
- Remove yellow sticky cards before releasing parasitoids because sticky cards may attract and capture parasitoids. Yellow sticky cards can be replaced one week after making releases.
- Reduce pest control material use when bumblebees are used as pollinators, and avoid applying pest control materials with extended residual activity such as those in the organophosphate, carbamate, and pyrethroid chemical classes. Systemic insecticides applied as a drench to the growing medium may be directly less harmful than foliar applications of systemic insecticides.

Table 1. Pest control materials (insecticides and miticides) registered for use on ornamental plants and/or greenhouse-grown vegetables. Numbers and letters in brackets [xx] indicate the IRAC (Insecticide Resistance Action Committee) mode of action designation found on the label. Always read the label to determine if a pest control material can be used in a particular facility and on a specific crop.

Common Name or Active Ingredient (Trade Name)

Abamectin (Avid)
Class: Macrocyclic lactone
Mode of Action: Gamma-aminobutyric acid (GABA) chloride channel activator [6]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites, thrips, and leafminers

Acephate (Orthene/Precise)
Class: Organophosphate
Mode of Action: Acetylcholine esterase inhibitor [1B]
Re-entry Interval (REI): 24 and 12 hours
Labeled Pests: Aphids, whiteflies, scales, mealybugs, and thrips

Acequinocyl* (Shuttle)
Class: Napththoquinone
Mode of Action: Mitochondria electron transport inhibitor [20B]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites

Acetamiprid* (TriStar)
Class: Neonicotinoid
Mode of Action: Nicotinic acetylcholine receptor disruptor [4A]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, whiteflies, mealybugs, and scales

Azadirachtin (Azatin/Ornazin/Aza-Direct/ Neemix[1]/Azatrol[1])
Class: Botanical (insect growth regulator)
Mode of Action: Ecdysone antagonist [18B]
Re-entry Interval (REI): 4 and 12 hours
Labeled Pests: Aphids, fungus gnat larvae, thrips, whiteflies, and caterpillars

Bacillus thuringiensis **spp.** *israelensis* **(Gnatrol[1])**
Class: Microbial
Mode of Action: Midgut membrane disruptor [11A1]
Re-entry Interval (REI): 4 hours
Labeled Pests: Fungus gnat larvae

Bacillus thuringiensis **spp.** *kurstaki* **(Dipel[1])**
Class: Microbial
Mode of Action: Midgut membrane disruptor [11B2]
Re-entry Interval (REI): 4 hours
Labeled Pests: Caterpillars

Beauveria bassiana **(BotaniGard/Naturalis[1]/ Mycotrol[1])**
Class: Microbial (entomopathogenic fungus)
Mode of Action: Direct infection of host by hyphae
Re-entry Interval (REI): 4 hours
Labeled Pests: Aphids, mealybugs, and whiteflies

Bifenazate* (Floramite)
Class: Carbazate
Mode of Action: Gamma-aminobutyric acid (GABA) gated antagonist [25]
Re-entry Interval (REI): 4 hours
Labeled Pests: Spider mites

Bifenthrin (Talstar/Attain)
Class: Pyrethroid
Mode of Action: Sodium channel blocker [3]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, caterpillars, fungus gnat adults, mealybugs, scales, plant bugs, thrips, leafhoppers, and whiteflies

Buprofezin* (Talus)
Class: Benzoylurea (insect growth regulator)
Mode of Action: Chitin synthesis inhibitor [16]
Re-entry Interval (REI): 12 hours
Labeled Pests: Whiteflies, mealybugs, scales, and leafhoppers

Chlorfenapyr* (Pylon)
Class: Pyrrole
Mode of Action: Oxidative phosphorylation uncoupler [13]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites, broad mite, cyclamen mite, fungus gnat larvae, and thrips

Chlorpyrifos (DuraGuard)
Class: Organophosphate
Mode of Action: Acetylcholine esterase inhibitor [1B]
Re-entry Interval (REI): 24 hours
Labeled Pests: Aphids, caterpillars, fungus gnat larvae, leafhoppers, mealybugs, shore fly larvae, and thrips

Clarified hydrophobic extract of neem oil (Triact[1])
Class: Botanical
Mode of Action: Suffocation or membrane disruptor
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, whiteflies, spider mites, and scales

Clofentezine (Ovation)
Class: Tetrazine
Mode of Action: Growth and embryogenesis inhibitor [10A]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites

Cyfluthrin (Decathlon/Tempo)
Class: Pyrethroid
Mode of Action: Sodium channel blocker [3]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, caterpillars, fungus gnat adults, mealybugs, scales, thrips, and whiteflies

Cyromazine (Citation)
Class: Triazine (insect growth regulator)
Mode of Action: Chitin synthesis inhibitor [17]
Re-entry Interval (REI): 12 hours
Labeled Pests: Fungus gnat larvae, shore fly larvae, and leafminers

Diflubenzuron* (Adept)
Class: Benzoylurea (insect growth regulator)
Mode of Action: Chitin synthesis inhibitor [15]
Re-entry Interval (REI): 12 hours
Labeled Pests: Fungus gnat and shore fly larvae

Dinotefuran* (Safari)
Class: Neonicotinoid
Mode of Action: Nicotinic acetylcholine receptor disruptor [4A]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, whiteflies, scales, leafminers, thrips, leafhoppers, and mealybugs

Etoxazole* (TetraSan)
Class: Diphenyloxizoline derivative (mite growth regulator)
Mode of Action: Chitin synthesis inhibitor [10B]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites

Fenbutatin-Oxide (ProMite)
Class: Organotin
Mode of Action: Oxidative phosphorylation inhibitor [12B]
Re-entry Interval (REI): 48 hours
Labeled Pests: Spider mites

Fenoxycarb (Preclude)
Class: Carbamate (insect growth regulator)
Mode of Action: Juvenile hormone mimic [7B]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, caterpillars, leafminers, mealybugs, scales, thrips, and whiteflies

Fenpropathrin (Tame)
Class: Pyrethroid
Mode of Action: Sodium channel blocker [3]
Re-entry Interval (REI): 24 hours
Labeled Pests: Caterpillars, fungus gnat adults, mealybugs, and whiteflies

Fenpyroximate* (Akari)
Class: Phenoxypyrazole
Mode of Action: Mitochondria electron transport inhibitor [21]

Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites

Flonicamid* (Aria)
Class: Trifluoromethylnicotinamide
Mode of Action: Selective feeding blocker [9C]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, thrips, and whiteflies

Fluvalinate (Mavrik)
Class: Pyrethroid
Mode of Action: Sodium channel blocker [3]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, fungus gnat adults, thrips, leafhoppers, caterpillars, plant bugs, and whiteflies

Hexythiazox (Hexygon)
Class: Carboxamide
Mode of Action: Growth and embryogenesis inhibitor [10A]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites

Horticultural oils: petroleum oils (PureSpray Green[1]), plant-based oils (GC-Mite/Golden Pest Spray Oil[1]), and fish-based oils (Organocide[1])
Class: Refined petroleum distillate and botanical
Mode of Action: Suffocation or membrane disruptor (some products have multiple modes of action; refer to label)
Re-entry Interval (REI): 4 hours
Labeled Pests: Aphids, mealybugs, scales, spider mites, and whiteflies

Kaolin clay (Surround[1])
Class: Protectant
Mode of Action: Multiple modes of action (refer to label)
Re-entry Interval (REI): 4 hours
Labeled Pests: Caterpillars, beetles, tarnished plant bug, stink bug, and thrips

Imidacloprid* (Marathon/Merit/Admire/Benefit/Mantra)
Class: Neonicotinoid
Mode of Action: Nicotinic acetylcholine receptor disruptor [4A]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, whiteflies, scales, and mealybugs

Kinoprene (Enstar II)
Class: Insect growth regulator
Mode of Action: Juvenile hormone mimic [7A]
Re-entry Interval (REI): 4 hours
Labeled Pests: Aphids, fungus gnat larvae, mealybugs, scales, thrips, and whiteflies

Methiocarb (Mesurol)
Class: Carbamate
Mode of Action: Acetylcholine esterase inhibitor [1A]
Re-entry Interval (REI): 24 hours
Labeled Pests: Aphids, thrips, and snails/slugs

Milbemectin (Ultiflora)
Class: Macrocyclic lactone
Mode of Action: Gamma-aminobutyric acid (GABA) chloride channel activator [6]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites

Novaluron* (Pedestal)
Class: Benzoylurea (insect growth regulator)
Mode of Action: Chitin synthesis inhibitor [15]
Re-entry Interval (REI): 12 hours
Labeled Pests: Thrips, whiteflies, caterpillars, and leafminers

Paraffinic oil (Ultra-Fine Oil)
Class: Refined petroleum distillate
Mode of Action: Suffocation or membrane disruptor
Re-entry Interval (REI): 4 hours
Labeled Pests: Aphids, mealybugs, scales, spider mites, and whiteflies

Petroleum oil (PureSpray Green)
Class: Refined petroleum distillate
Mode of Action: Suffocation or membrane disruptor
Re-entry Interval (REI): 4 hours
Labeled Pests: Aphids, mealybugs, scales, spider mites, and whiteflies

Potassium salts of fatty acids (Insecticidal Soap/M-Pede[1])
Class: Insecticidal soap
Mode of Action: Desiccation or membrane disruptor
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, caterpillars, fungus gnat adults, leafhoppers, mealybugs, scales, spider mites, and whiteflies

Pymetrozine* (Endeavor)
Class: Pyridine (Azomethine)
Mode of Action: Selective feeding blocker [9B]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids and whiteflies

Pyridaben (Sanmite)
Class: Pyridazinone
Mode of Action: Mitochondria electron transport inhibitor [21]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites and whiteflies

Pyriproxyfen* (Distance)
Class: Pyridine (insect growth regulator)
Mode of Action: Juvenile hormone mimic [7C]
Re-entry Interval (REI): 12 hours
Labeled Pests: Fungus gnat and shore fly larvae, scales, and whiteflies

Pyrethrin (Pyganic[1]/Pyreth-It/Pyrethrum)
Class: Botanical
Mode of Action: Sodium channel blocker [3]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, caterpillars, beetles, mealybugs, thrips, and whiteflies

Pyrethrin and silicon dioxide (Diatect V)
Class: Botanical
Mode of Action: Central nervous system disruptor and desiccant [3]
Re-entry Interval (REI): 12 hours
Labeled pests: Aphids, caterpillars, and whiteflies

Pyridalyl (Overture)
Class: Pyridine
Mode of Action: Unknown (refer to label)
Re-entry Interval (REI): 12 hours
Labeled Pests: Caterpillars and thrips

Spinosad* (Conserve/Entrust[1])
Class: Spinosyn
Mode of Action: Nicotinic acetylcholine receptor agonist and Gamma-aminobutyric acid (GABA) chloride channel activator [5]
Re-entry Interval (REI): 4 hours
Labeled Pests: Caterpillars, thrips, and leafminers

Spiromesifen* (Judo)
Class: Tetronic acid
Mode of Action: Lipid biosynthesis inhibitor [23]
Re-entry Interval (REI): 12 hours
Labeled Pests: Spider mites, broad mite, and whiteflies

Spirotetramat* (Kontos)
Class: Tetronic acid
Mode of Action: Lipid biosynthesis inhibitor [23]
Re-entry Interval (REI): 24 hours
Labeled Pests: Aphids, leafhoppers, mealybugs, spider mites, and whiteflies

Steinernema feltiae **(Nemasys/NemaShield/Scanmask/Entonem)**
Class: Biological control (entomopathogenic nematode)
Mode of Action: Penetrant through insect cuticle and degrades internal contents
Re-entry Interval (REI): 0 hours
Labeled Pests: Fungus gnat larvae

Thiamethoxam* (Flagship)
Class: Neonicotinoid
Mode of Action: Nicotinic acetylcholine receptor disruptor [4A]
Re-entry Interval (REI): 12 hours
Labeled Pests: Aphids, whiteflies, mealybugs, and scales

* Indicates that active ingredient is considered "reduced-risk" or an organophosphate alternative.

[1] Products registered for use in organic production systems (ornamentals, herbs, and vegetables).

Supplemental References

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Biological control suppliers

Green Spot, 93 Priest Road, Nottingham, NH 03290-6204. Phone: 603-942-8925; E-mail: info@greenmethods.com or http://greenmethods.com

IPM Laboratories, PO Box 300, Locke, NY 13092-0300. Phone: 315-497-2063; E-mail: ipminfo@Ipmlabs.com or http:www.ipmlabs.com

Koppert Inc., Romulus, MI. Phone: 734-641-3763; E-mail: info@koppertline.com

Syngenta Bioline, Oxnard, CA. Phone: 805-986-8255; E-mail: info@syngentabioline.com

BioBest Biological Systems. Email: info@biobest.ca or www.biobest.be

Sources of biological control agents are located in the publication, "Suppliers of Beneficial Organisms in North America," by Charles Hunter, which is available online from the California Environmental Protection Agency (CEPA) at http://www.cdpr.ca.gov/docs/pestmgt/ipminov/bensuppl.htm or from reputable suppliers (refer to the contact information of the five biological control suppliers provided above). Consult your biological control supplier to determine the availability of the natural enemy species you are interested in and designated shipping requirements.

Raymond A. Cloyd
Entomologist, Kansas State University,

James Quinn
Research Associate, University of Missouri – Columbia

David Trinklein
Floriculturist, University of Missouri – Columbia

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-2892 **July 2009**

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