Greenhouse Insect and Mite Control

Chemical Control

The following products can be used to control insects attacking vegetables grown inside greenhouses. They have been grouped according to their mode of action (based on the Insecticide Resistance Action Committee, 2007; http://www.irac-online.org/Crop_Protection/MoA.asp). Always remember to **rotate products belonging to different mode of action groups** when establishing a rotation program.

Remember to always read the label before using pesticides and to double check the pH and alkalinity requirements of the solution.

New products available for use in greenhouse vegetables include: Talus (buprofezin) and Pylon (chlorfenapyr).

Note: a ? mark indicates that you should consult with manufacturer. All products are listed starting with their active ingredient. The different trademarks are included at the end of each segment.

Group 25, Neuronal inhibitors (unknown mode of action).

Bifenazate (PHI, 3 days; REI, 12 hrs).
For various mite species.
Registered only on tomato varieties greater than 1 inch in diameter.
Floramite: 4-8 oz/100 gal.

Group 18B, Ecdysone agonists / moulting disruptors, insect growth regulator, neem extract.

Azadirachtin (PHI, 0 days; REI, 4 hours for Azatin XL, and Neemix, 12 hours for Ornazin).
For aphids, whiteflies, thrips, leafminers, fungus gnats, caterpillars.
Registered on all vegetables, herbs and spices.
Azatin XL: 10-16 oz/100 gal.
Neemix: 64-128 oz/100 gal.
Ornazin: 8-10 oz/100 gal.

Group 16, Inhibitors of chitin, Homopteran.

Buprofezin (PHI, 7 days; REI, 12 hrs).
For leafhoppers, mealybugs and whiteflies.
Registered for greenhouse tomatoes. No more than two applications per season, at least 28 days apart.
Talus: 9-13 fl oz/A.

Group 13, Uncouplers of oxidative phosphorylation via disruption of proton gradient.

Chlorfenapyr (PHI, 0 days; REI, 12 hrs).
For caterpillars, two spotted spider mites, broad mites, western flower thrips, melon thrips.
Registered for tomato, tomatillo, ground cherry, peppers, eggplant, pepinos. DO NOT apply more than 39 fl oz (0.6 lb a.i.) per acre, per crop growing cycle.
Pylon: 6.5-13 fl oz/A.

Group 11, microbial disruptors of insect midgut membranes.

Bacillus thuringiensis* subsp. *kurstaki (PHI, 0 days; REI, 4 hours)
For loopers, tomato fruitworms/corn earworms, leafrollers, diamondback moths.
Registered on all greenhouse vegetables, herbs and spices, and watercress.
Biobit HP: 0.5-2.0 lb/A.
DiPel ES: 1-4 pt/A; DiPel DF: 0.5-2.0 lb/A.

Bacillus thuringiensis* subsp. *aizawai (PHI, 0 days; REI, 4 hours).
For loopers, tomato fruitworms/corn earworms, leafrollers, diamondback moths.
XenTari registered on all greenhouse vegetables, herbs and spices; Ketch DF registered on tomatoes, cole crops and peppers.
XenTari: 0.5-2.0 lb/A.

Bacillus thuringiensis* subsp. *israelensis (PHI, 0 days; REI, 4 hours)
For fungus gnat larvae.
Registered on tomato, cucumber, pepper, eggplant, leafy vegetables, cole crops.

Gnatrol: 64-128 oz/100 gal (Depending on infestation level).
Note: Gnatrol can be applied in irrigation systems. See label for details.

Unclassified (products in this category can be used in the same rotation).

Beauveria bassiana, strain GHA (PHI, 0 days; REI, 12 hours)
For whiteflies, aphids, thrips, psyllids.
Registered on all greenhouse vegetables, herbs and spices.
BotaniGard ES: 1.5-3 qt/100 gal.

Neem Oil (PHI, 0 days; REI, 4 hours)
For aphids, mealybugs, rust mites, spider mites, soft scale, whiteflies (suppression), thrips (suppression). Also registered for fungal disease control.
Registered on all vegetables, herbs and spices.
Trilogy 70%: 0.5-2% in 25-100 gal water per acre.

Insecticidal Soap (PHI, 1 day; REI, 12 hours)
For aphids, whiteflies, spider mites, fungus gnats, thrips, caterpillars.
Registered on all vegetables, herbs and spices.
M-Pede: 1-2.5 gal/100 gal.

Paraffinic Oil (PHI, 0 days; REI, 4 hours)
For aphids, beetle larvae, leaf miners, thrips, whiteflies, spider mites.
Registered on all vegetables, herbs and spices.
Prescription Treatment Ultra-Fine Oil: 1-2 gal/100 gal.

Nuclear polyhedrosis virus (PHI, 0 days; REI, 4 hours)
For beet armyworm.
Registered on all tomatoes, lettuce, cabbage, beans, peppers, celery, escarole, sweet corn, peas, asparagus, beets, cauliflower, cucumber, broccoli, onion.
Spod X LC: 1.7-3.4 oz/A.

Metaldehyde (PHI, ? days; REI, 12 hours)
For slugs and snails.
Registered on Artichoke, Asparagus, Beans, Beets, Black-eyed peas, Broccoli, Brussel Sprouts, Cabbage, Cantaloupes, Carrots, Cauliflower, Celery, Collards, Corn, Cowpeas, Cucumbers, Eggplant, Endive, Garlic, Ginseng, Horseradish, Kale, Kohlrabi, Leeks, Lettuce, Melons, Mustard Greens, Okra, Onions, Parsnips, Peas, Peppers, Pimentos, Potatoes, Pumpkins, Radishes, Rhubarb, Rutabagas, Salsify, Shallots, Spinach, Squash, Sweet Potatoes, Swiss Chard, Tomatoes, Turnips, and Watermelons.
Do not contaminate edible parts. Keep bait from coming in contact with plants.
Durham 7.5: 17.5-20 lb/A.

Group 4B, Nicotinic Acetylcholine receptor agonists / antagonists.

Nicotine (PHI: 1 day, tomato and cucumber; 5 days, lettuce; REI: after ventilation criteria* have been met as specified by the Worker Protection Standard). RESTRICTED USE PESTICIDE. For aphids, thrips. Registered on cucumbers, lettuce, tomatoes.
Fulex Nicotine Smoke Fumigator: Use one can (12 oz)/20,000 cu ft.

Group 3, Sodium channel modulators.

Pyrethrins + Piperonyl Butoxide (PHI, 0 days; REI, 12 hours; REI: after ventilation criteria* have been met for total release products).
For aphids, beetles, caterpillars, flies, fungus gnats, mealybugs, whiteflies, thrips, spider mites.
Registered on all vegetables, herbs and spices. See directions on can for area coverage.
Pyreth-It: 2-16 oz/A.
1100 Pyrethrum TR: 2 oz can for 1,500-3,000 sq ft; 6 oz can for 3,000-9,000 sq ft.

Pyrethrum + Rotenone (PHI, 12 hours; REI, 12 hours)
For aphids, loopers, tomato fruitworms, beetles, whiteflies, thrips, fruit flies.
Registered on all vegetables, herbs and spices.
Pyrellin: 1-2 pt/A.

Group 2A, Cyclodiene organochlorines.

Endosulfan (REI, 24 hours)
For aphids, whiteflies, thrips, loopers, tomato fruitworms, flea beetles, tomato russet mites.
Registered on tomatoes (all formulations) and cucumbers (Fulex Thiodan only).
Fulex Thiodan Smoke (PHI: tomato, 4 days; cucumber, 7 days): See label for rates. Note that the 24 hour REI does not begin until after the ventilation criteria* have been met as specified by the Worker Protection Standard. Fulex Thiodan Smoke is registered only for whiteflies and thrips.
Thionex 50WP (PHI: tomato, 2 days): 1.5-2 lb/A for all pests except whiteflies. For whiteflies apply 1 lb/100 gal.
Phaser 3EC, Thionex 3EC (PHI: tomato, 2 days): 0.67-1.3 qt/A for all pests but whiteflies. For whiteflies apply 0.67 qt/100 gal.

* Ventilation criteria for greenhouses: If a pesticide is being applied as a fumigant, smoke, mist, fog or aerosol, one of the following ventilation criteria must be met. The concentration of the pesticide in the air is measured to be less than or equal to any inhalation exposure level required on the labeling. If no inhalation exposure level is listed on the labeling, workers must not enter the treated area until after:

10 air exchanges, or
2 hours of ventilation using fans or other mechanical ventilating systems, or
4 hours of ventilation using vents, windows or other passive ventilation, or
11 hours with no ventilation followed by 1 hour of mechanical ventilation, or
11 hours with no ventilation followed by 2 hours of passive ventilation, or
24 hours with no ventilation.

Integrated Insect Mite and Disease Management Programs on Greenhouse Vegetable Crops

Please refer to the general description of integrated pest management on page 63 in this bulletin. The information below is specific to greenhouse pest management and is supplemental to the general information.

Pest Detection by Traps

Yellow sticky traps in greenhouses will catch winged aphids, leafminers, thrips, whiteflies, fungus gnats and shore flies. Blue traps are sometimes better at detecting western flower thrips, but yellow is satisfactory.

Place traps vertically at or just above plant height. This is where most of the "action" is in insect flight activity. However, fungus gnats, shore flies, thrips, and leafminers can also be trapped quite well just above the growing medium surface. Fungus gnat capture is much better on horizontal traps. Be sure to place some traps near side vents, doors and other areas where pests may be found. Some growers place some traps outside of the greenhouse to help detect insects moving in from outside. The number of traps to use will depend upon your objectives and ability to inspect them. A minimum number should be somewhere around 4-5/acre, but more will be better, especially if using traps to monitor whitefly population trends (1 trap per 1,000 sq ft).

Traps should be inspected at least weekly and counts or estimates made of pest numbers. Estimates are usually sufficient. Some people prefer to deploy traps for shorter periods; for example, a few hours or a day, to get a better picture of insect activity at that moment. Number the traps and have a greenhouse outline map. This should be used to keep records of trap locations and insect infestations.

Pest and Disease Detection Using Indicator Plants

Indicator plants are plants that are more attractive to specific insect or mite pests and/or plants that show feeding injury or virus symptoms sooner than the main crop being grown. The idea is to get an early warning of a pest or disease problem. The most use of this technique for greenhouse crops in the United States is in monitoring western flower thrips and the viruses spread by these insects. Yellow or blue sticky traps are also involved. This is how the method is used. Potted petunia plants (cultivars 'Blue Carpet', 'Burgundy Madness', 'Red Cloud', 'Summer Madness', and 'Super Magic Coral') are placed around and among the crop at about the same density as sticky traps. All petunia flowers should be removed. Non-sticky yellow or blue trap cards are placed near each petunia to attract thrips.

The non-sticky traps can be made by covering sticky traps with clear plastic wrap. Thrips feeding injury is easily visible on the petunia leaves. If any thrips are carrying virus, the petunias will show the symptoms in 3 to 7 days after infection, which is much sooner than most virus-susceptible crops (which include tomato, pepper, lettuce).

Indicator plants, combined with the use of sticky traps to show the direction of thrips movement, are very useful in a thrips and virus management program. For a more complete discussion, color photographs, etc., see GMPRO, March, 1998 (pp. 31-33).

Pest and Disease Detection by Plant Inspection

Sticky traps and/or indicator plants will not replace plant inspection as a pest detection method. Sticky traps are useless for disease detection. Whiteflies occur in localized infestations that traps may not detect. Non-winged aphids and spider mites are not caught on traps. Therefore, plant inspection is a very important part of a pest management program. Inspect plants in all areas of the greenhouse, looking underneath leaves near the top, middle and lower parts of plants. The same hand lens used for trap inspection can be used for plant inspection. Isolated infested plants can be marked with a colored ribbon or flag for later inspection following a pesticide application or release of beneficial insects and mites.

Cultural Control

Destroy crop residues promptly after harvest. The longer these plants remain, the greater the chances are for increased pest and disease problems. Do not place the crop residues outside of the greenhouse; the flying adults from many insect species will simply move back into the greenhouse. Virus-infected plants may serve as a source of virus for the plants remaining in the greenhouse, if pests such as western flower thrips are able to complete their development on them. Do not plant a vegetable garden adjacent to the greenhouse, for these same reasons.

Physical/Mechanical Control

Insect screens can be useful in reducing the movement of some insects into the greenhouse. Whiteflies, leafminers, Lepidoptera (moths), and winged aphids can be excluded relatively easily. Thrips are very difficult to exclude because of the small screen mesh size required. The use of screens will require increasing the screen surface area over openings in the greenhouse to compensate for reduced air flow. The calculations for surface area increase can be made in cooperation with the screen supplier. Greenhouses with mechanical ventilation can be screened more easily than greenhouses with natural ventilation.

Environmental Control

Manipulating the greenhouse environment has long been suggested as a way of preventing the establishment of plant pathogens (e.g., venting and heating at sundown to reduce leaf wetness and prevent fungal spore germination). This is an area that will be more useful as more environmental control computer systems are installed in commercial greenhouses. To date, very little work has been done on manipulating the greenhouse environment to make it less favorable for pest insects and mites and/or more favorable for natural enemies.

Keeping the greenhouse warm between crops (after the greenhouse has been emptied) is a useful method to reduce the carryover of pests from one crop to another. Pests will complete their development, but after emerging as adults will not have any food and should starve. Some growers even "solarize" their greenhouses during warm weather months—a useful technique, but unless greenhouse openings are screened, pests from outdoors will be able to move back in as soon as the vents are opened and any ventilation system is again operated. Heating is much better than cooling the greenhouse. Sticky traps should be placed in the empty greenhouse to help detect pests that emerge and begin to fly.

Biological Control

Biological control of insects and mites on greenhouse vegetable crops is practiced worldwide. There are beneficial insects and mites available from commercial sources for control of nearly every major insect or mite pest. The most difficult pest to control biologically (chemically as well) is the western flower thrips. Many growers are able to use biological control as their primary pest management method. Other growers will try to integrate pesticides with few or no harmful effects on beneficials into their program (see the table), or apply pesticides only to localized areas where pest infestations are higher than desired. Some growers will use biological controls for part of the year, changing to pesticides if pests become too numerous. Even more than when using pesticides, biological control requires that a good pest scouting and monitoring program be in place.

Some Commercially Available Biological Controls		
Common Name	**Scientific Name**	**Pests Attacked**
Whitefly parasitoid	*Encarsia formosa*	Whiteflies, especially the greenhouse whitefly
Whitefly parasitoid	*Eretmocerous eremicus* *Eretmocerus mundus*	Whiteflies, especially the silverleaf whitefly
Whitefly predator	*Amblyseius swirskii*	Whiteflies, greenhouse and silverleaf whitefly, also attacks thrips
Leaf miner parasitoids	*Diglyphus* spp., *Dacnusa* spp.	Leafminers
Mealybug destroyer	*Cryptolaemus montrouzieri*	Citrus mealybugs
Mealybug parasitoid	*Leptomastix dactylopii*	Citrus mealybugs
Aphid midge	*Aphidoletes aphidimyza*	Aphids
Aphid parasitoid	*Aphidius colemani*	Green peach and melon aphids
Aphid parasitoid	*Aphidius ervi, Aphelinus abdomalis*	Potato aphids
Soil insects predator	*Atheta coriaria*	Fungus gnat larvae, shore fly larvae, western flower thrips pupae
Entomopathogenic nematodes for fungus gnats	*Steinernema feltiae,* plus others	Fungus gnat larvae
Fungus gnat and thrips predatory mite	*Hypoaspis miles*	Fungus gnat larvae, thrips prepupae (Also: shore fly larvae)
Spider mite predator	*Phytoseiulus persimilis,* other phytoseiids *Amblyseius californicus*	Spider mites
Green lacewings	*Chrysoperla* sp.	Aphids, whiteflies, mites, caterpillars
Minute pirate bug	*Orius insidiosus*	Thrips, other pests
Thrips predator	*Neoseiulus cucumeris,* *Amblyseius degenerans* *Amblyseius cucumeris*	Thrips
Moth parasitoid	*Trichogramma brassicae*	Moth eggs

Where can information on biological control be obtained? A list of commercial companies that supply beneficial insect and mites can be obtained from:

California Environmental Protection Agency
Department of Pesticide Regulation Environmental Monitoring and Pest Management
P.O. Box 942871
Sacramento, CA 94271-0001

There are many information sources on the World Wide Web. Some excellent ones include the following:

http://www.cdpr.ca.gov/docs/ipminov/ben_supp/ben_sup2.htm
(California Environmental Protection Agency. The same list of companies that supply beneficials as in the printed version listed above.)

http://www.anbp.org/
(Association of Natural Biological Control Producers)

http://www.nysaes.cornell.edu/ent/biocontrol/
(Cornell University's site for general information on biological control)

http://www.ipmlabs.com
(Web site of IPM Laboratories, a major supplier of beneficial insects and mites)

http://www.koppert.nl/e005.shtml
(Web site of the Koppert Company, a major supplier of beneficial insects, nematodes and mites)

http://www.biobest.be/
(Web site of Biobest Company, a major supplier of beneficial insects, nematodes and mites)

Integrating Pesticides with Biological Control

Although there are not many products registered for use on greenhouse vegetables, insecticides, miticides and fungicides are integral parts of a pest and disease management system. Most insecticides and some fungicides are harmful to parasites and predators. These harmful effects can last for weeks following application. Do not use them for at least 30 days before beginning a biological control program, and do not use them anywhere in the greenhouse after beginning a program. Local or "spot" applications generally are less harmful to natural enemies than treating the entire greenhouse.

Some of the newly registered pesticides are "soft" on beneficial insects and mites. *Bacillus thuringiensis* formulations are harmless to natural enemies. Insecticidal soaps, *Beauveria bassiana*, azadirachtin, and pyrethrum + rotenone tend to be less harmful than conventional materials. This does not mean that these materials are harmless, but that natural enemies can be re-introduced soon after an application without any deleterious effects.

Application method and formulation will affect the toxicity, or lack thereof, of pesticides to natural enemies. There are a number of studies that have conflicting information concerning how long a particular pesticide will remain harmful to a natural enemy. When in doubt, be conservative. The effects of specific pesticides on some of the most common natural enemies used in greenhouses are listed in the table below.

Effects of Insecticides Registered on Greenhouse Vegetables, Herbs and Spices on Some Common Biological Control Agents and Bumblebees*

Pesticide Trade Name	Pesticide Common Name	*Encarsia formosa*	*Phytoseiulus persimilis*	*Amblyseius cucumeris*	*Orius insidiosus*	Bumble bees
Azatin	azadirachtin	H (adult)	H (nymph, adult)	?	S	Remove (1.5)
Floramite	*bifenazate*	S	S	S?	?	S
Botanigard	*Beauveria bassiana*	S?	S?	S?	S?	Cover (0)?
DiPel, Gnatrol, etc.	*Bacillus thuringiensis* formulations	S	S	S	S	Cover (0)
M Pede, Olympic	Potassium salts of fatty acids	H (pupa, adult, 0)	H (egg, nymph, adult, 0)	H (egg, nymph, adult, 0)	?	Cover (0)
Ultra Fine Oil	paraffinic oil	S	H (nymph, adult)	H (nymph, adult)	S	Cover (0)
Spod X	Nuclear Polyhedrosis virus	S	S	S	S	S (0)
Fulex Nicotine	nicotine smoke	H (adult, 0.5)	H (nymph, adult, 1)	H (nymph, adult, 1)	?	Remove (0.5)
1100 Pyrethrum TR	pyrethrins + piperonyl butoxide	H (pupa, adult, 2)	H (nymph, adult, 1)	H (nymph, adult, 1)	H (adult, 0)	Remove (1.5)
Thiodan	endosulfan	H (adult, 8-12)	H (egg, nymph, adult, 2)	H (egg, nymph, adult, 6-8)	H (nymph, adult)	H (14)

H-harmful; S-Safe; ?-not known S?-probably safe but few reports are available. Numbers in ( ) following H for the four beneficial insects and mites are the number of **weeks** after application that a material remains harmful to the listed developmental stages. Numbers in ( ) in the bumble bee column are number of **days** that a material is harmful. Also indicated is whether the hives should be covered, removed from the greenhouse, or if the product is simply not compatible with bumble bees.

*Modified from information supplied by Koppert BV, The Netherlands and Biobest, Belgium (see web sites above).

Products Registered for Insect and Mite Control on Greenhouse Vegetables, Herbs and Spices													
Product	**Aphids**	**Beetles**	**Caterpillars**	**Fungus Gnats**	**Fruit Flies**	**Leafhoppers**	**Leafminers**	**Mealybugs**	**Psyllids**	**Thrips**	**Whiteflies**	**Russet Mites**	**Spider Mites**
Azadirachtin (Azatin, Ornazin, Neemix)	X	X	X	X	X	X	X	X	X	X	X		
Floramite													X
Beauveria bassiana (Botanigard)	X	X						X	X	X	X		
Bacillus thuringiensis kurstaki (Biobit, DiPel)			X										
Bacillus thuringiensis aizawai (XenTari)			X										
Bacillus thuringiensis israelensis (Gnatrol)				X									
Insecticidal soap (M-Pede, Olympic)	X		X			X	X	X	X	X	X		
Spray oil (Ultra-Fine Oil)	X	X				X	X			X	X		X
Neem Oil (Trilogy 70%)	X							X		X	X		
Nuclear polyhedrosis virus (Spod X)			X										
nicotine (Fulex Nicotine)	X									X	X		
pyrethrins + piperonyl butoxide (1100 Pyrethrum TR)	X	X	X	X	X	X		X		X	X		X
Endosulfan (Phaser, Thionex)	X	X	X			X				X	X		

*See listing of individual products on pages 282-284 for specific pests within each group (e.g., caterpillars, beetles) and registered crops.