

Integrated Pest Management

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(updated January 2009)

An integrated pest management (IPM) program (or total plant management) takes into account all factors which influence plant health and vigour as well as those factors that affect the health and reproductive capacity of various pests. Typically, an IPM program will attempt to optimize growing conditions for the crop while minimizing the conditions for pest development. The keys to planning a strategy for pest management in the greenhouse are:

- sanitation,
- control of the greenhouse environment,
- monitoring for pests,
- understanding the life cycle of pests, and
- timely use of biological and chemical pest control agents.

Sanitation

Growers with clean greenhouses have fewer pest problems. Greenhouse sanitation includes the removal or exclusion of factors that allow pests to gain access to the greenhouse, survive from crop to crop, or spread from plant to plant. Good crop hygiene focuses on starting clean and preventing the introduction of pathogens or insects to the crop. If possible, growers should empty the greenhouse entirely between crops and sanitize the facility.

A factsheet titled *On-Farm and Greenhouse Sanitation and Disinfection Practices* is available on-line from the BC Ministry of Agriculture and Lands.

Start with Clean Plants

Ensure that trays and wagons/carts with propagation material are clean before coming into your greenhouse.

If your new plant material originated off site, check for evidence of pests and diseases when plants arrive from the propagator. Inspect plants upon arrival and remove diseased, insect or mite infested product.

Install a foot bath. A container with a foam mat is effective. Use a labelled disinfectant (See the section on *Disinfectants and Algicides* in Chapter 10). Change solutions every two weeks and ensure the footbath is used. Post strict signage on use. Control visitor access and require them to use disposable coveralls when entering sensitive areas. Insects and disease organisms can be carried on clothing.

Meet with staff to discuss pest management. Discuss the importance of early pest and disease detection. Explain the early symptoms caused by specific pests and diseases.

Install sticky traps to monitor for certain insect pests. See the *Crop Monitoring and Scouting* section in this chapter.

Keep the growing area for growing. Do your container filling and transplanting in a non-growing area of the greenhouse.

Sanitation During the Crop

Sanitize cutting tools between cuttings or when moving to a new stock plant. There are several disinfectants available and different products have different properties and uses. See Table 1.1 for a list of disinfectants and treatment times. For more information on disinfectant products, refer to Chapter 10. Do not dip cuttings in disinfectant. Chlorine bleach is very corrosive and may damage cutting tools over time. Keep ethanol containers away from flames.

Avoid putting “pet” house plants or vegetable plants in the greenhouse. These are often a source of disease and insects.

Table 1.1: Disinfectant Treatments for Cutting Knives

Disease	Disinfectants	Treatment Time
Bacterial Blight of Geranium	5% Virkon 10% Bleach* DCD Floralife (16 mL/L) Ethanol 70%	Quick Dip Quick Dip Quick Dip 20 seconds
<i>Penicillium</i>	10% Bleach* 70% Ethanol	10 seconds 10 seconds
Fusarium wilt of cyclamen	5% Virkon 10% Bleach* DCD Floralife (16 mL/L) Ethanol 70%	Quick Dip Quick Dip 20 seconds Quick Dip
*Household strength (5.25% sodium hypochlorite) Note: The phytotoxicity of disinfectant residues on cutting knives was not evaluated. USE WITH CAUTION.		

Plant Residues

Promptly remove plant residues, and diseased and dead plants. In general, eliminating 90% of the disease inoculum reduces the incidence of disease from 60% down to 10%. Remove plant residues from the greenhouse site, or dispose of them by burying, pasteurizing, or burning. Open refuse piles near a greenhouse are a source of re-infestation for a variety of diseases and insects. If you must have a cull pile, locate it as far away from the greenhouse as possible, downwind, and not close to your water source. Pathogens such as *Pythium* and tobacco mosaic virus can be spread in the water. The pile should be covered with plastic sheets or a soil layer after each deposit to prevent the release of spores and the build up of insects feeding on plant tissue. The best solution is to remove all cull material from the greenhouse site. Recycling is fine, but don't recycle your pests.

Weeds

There should be no weeds in the greenhouse. Weeds are a feeding and breeding site for many pests including whiteflies, thrips, and spider mites. Keep a one to three metre weed-free zone outside the perimeter of the greenhouse. The weed-free zone should be at least three metres near doorways and vents.

Screening

Pests that fly such as thrips, aphids, and moths can be excluded from greenhouses by covering vents

with screens. Several materials of various mesh sizes are available. Screens reduce airflow into greenhouses, which is usually compensated for by increasing the surface area of the vent opening or by installing pleated screens into the vent opening. For exclusion of thrips, the increase in surface area needs to be 2 to 5 times larger than the unscreened vent area.

Algae Control

Algae build-up should be minimized in the greenhouse because it encourages and harbours fungus gnats and shore flies and can pose a safety hazard due to its slippery nature. Avoid over-watering and provide good drainage under the greenhouse. Fix any broken or improperly functioning drains as quickly as possible to prevent wet areas in the greenhouse. Algae can be controlled by following disinfection procedures.

Cleaning Up After the Crop

“One gram of dirt or just a pinch, can contain over 10,000 Fusarium spores. Only one spore is needed for infection” Jarvis, 1997.

During crop production infectious microbes, pathogens, and algae can accumulate. Disinfecting the growing area and greenhouse system components of both the visible and invisible accumulations can be done through the use of chemicals labelled for that purpose. In addition to managing algae, disinfectants can control specific plant pathogens. Disinfecting should be done

routinely during the cropping cycle and, if possible, growers should empty the greenhouse entirely between crops and sanitize the facility.

Between crops and before a crop goes in, disinfect all benches, equipment, flats, and tanks. Pressure wash with a mild soap detergent followed by a disinfectant at label rates. **Never mix bleach and ammonia compounds together as hazardous gases may form.**

Remove debris on walkways and header-house floors. Wash down with a disinfectant. Note: If high levels of organic debris are present on surfaces being treated with products that work through oxidation such as bleach or hydrogen peroxide, their efficacy is significantly reduced. Mineral deposits can also be safe havens for pathogens. Remove as much debris with detergents and water before applying disinfectants.

Whenever the Greenhouse is Empty

Take the opportunity to clean out irrigation lines when the greenhouse is empty. The following steps outline the process:

- Keep lines charged at a low rate prior to cleaning to prevent drying out. Once they dry out, it is difficult to remove dried salts and other debris.
- Remove EC and pH electrodes.
- Divert cleaning solutions away from slow sand filters. Keep the slow sand filter units charged with old solution.
- Pressure-flush the irrigation lines with air or water before acid or bleach treatment.
- Flush lines with nitric or phosphoric acid at a pH of 1.6 to 1.7 for 24 hours if there is scale in the lines. This is prepared by adding 1 part 60 to 70% acid concentrate to 50 parts water. Apply twice if you have older lines or narrow orifice capillary lines. CAUTION, some lines have neoprene diaphragms that can be damaged with exposure to solutions with a pH less than 3.0 or buffered bleach. Consult your supplier for information on compatible disinfectants.
- RINSE WELL. When acid contacts bleach, dangerous chlorine gas may form.
- Flush lines and tanks with a disinfectant. NOTE: disinfectant disposal recommendations have not been developed. Contact the BCMAL office in Abbotsford for further information.

- It is more effective to flush the lines as a ‘pulse charge’ four times with one hour intervals than to flush with one pulse charge and leave the solution in the line for four hours. Do not drop the pH below 5.0 when using buffered bleach. Target your pH for 6.5 to 7 and follow all safety recommendations on the label. Use a non-phytotoxic surfactant such as Super Spreader* at the rate of 1 L/1,000 L of water solution. Used buffered bleach solution must be collected and disposed of in accordance with Ministry of Environment guidelines. It can be used for other disinfection purposes. It can also be dechlorinated.
- Rinse with fresh water.
- Disinfect regular sand filters with bleach. Do not treat slow sand filtration (biological) systems with bleach.
- Power wash the structure and glass with water to remove larger pieces of debris. Then power wash the structure with a cleaner. Use registered products and follow label directions. If you have had a virus problem, use Virkon*. Apply Virkon with LVM or mist after the plastic is down. If using ammonium bifluoride, remove it within 5 minutes or it will damage glass. **AVOID MIXING BLEACH AND AMMONIA COMPOUNDS –HAZARDOUS CHLORINE GAS COULD BE PRODUCED.**

For more information on greenhouse sanitation and clean-up: a factsheet [Greenhouse Vegetable Crop Clean-Up](#) is available from the BC Ministry of Agriculture and Lands.

Environmental Control

Light, temperature, water, and air quality are climatic factors that influence plant growth. When any of these factors are more or less than optimum, there are stresses placed on the plants. Actively growing root systems will often ‘out grow’ root rot organisms. Stressed plants tend to grow slower and are more susceptible to pest damage.

Precise climate control is important. Large swings in the greenhouse climate can produce an environment that is ideal for disease development. Remember, strong and healthy plants have the best chance to fight pests and resist infections. For more information, see the *Managing the Plant Environment* section in Chapter 3.

Crop Monitoring and Scouting

Monitoring and scouting are essential to insect and disease management. In order for an integrated pest management program to be effective, it is necessary to detect pests early when their population levels are low. A successful program requires commitment and time must be allowed for crop monitoring. Inspect plants regularly for signs of pests. Workers are in close contact with the crop. Inform them about symptoms to look for so they can spot problems early. Examine all new material before it is brought into the greenhouse. It is easier to prevent new insect and pathogen outbreaks than to control established ones.

It is usually best to have one person assigned to maintain a scouting and monitoring program. However, everyone should be trained to be on the

lookout for signs of insect activity. Use Tables 1.2 & 1.3 to detect insect problems early. Table 5.1 should be used for early disease diagnosis.

Yellow sticky cards or strips are available and are excellent for early detection of whiteflies, fungus gnats, and thrips. Blue sticky traps are particularly attractive to Western flower thrips, but they don't provide the broad pest attraction that yellow traps have. Place one trap in each 100 m² of greenhouse area close to the crop canopy. Check the traps for pests twice a week. More traps should be placed close to doorways and vents. Generally, you'll need six to eight per monitoring area. Evaluate the stickiness of traps after 3 to 4 weeks and replace if necessary. Keep an on-going record of trap-catch numbers. When a pest is detected, have it accurately identified and begin control measures as soon as possible after the action threshold has been reached.

Table 1.2: Scouting Methods	Aphid	Caterpillar	Fungus Gnat	Leafhopper	Leafminer	Mealybug	Midge, Gall Fly	Cyclamen Mite	Spider Mite	Plant Bug	Scale	Shore Fly	Slug, Snail	Thrips	Weevil	Whitefly
Flower/Shoot Tip Damage	✓	✓						✓	✓	✓				✓		
Leaf/Stem Damage																
Galls	✓						✓									
Holes		✓								✓			✓			
Lineal mines					✓											
Notches on margins															✓	
Skeletonization		✓											✓		✓	
Speckling				✓					✓					✓		
Signs of a Pest																
Dark fecal spots on leaf		✓										✓	✓	✓		
Honeydew/sooty mould	✓					✓					✓					✓
Insects clustered on stems or leaves	✓	✓				✓			✓		✓					
Insects fall out of flowers when tapped										✓				✓		
Insects seen to move in flowers when blown on														✓		
Insects or eggs on underside of leaf	✓	✓							✓					✓		✓
Insect skins on leaf	✓			✓							✓					
Pests hide under objects													✓		✓	
Slime trails													✓			
Small black flies			✓				✓					✓				
Webbing		✓							✓							

Table 1.3: Monitoring Methods	Aphid	Fungus Gnat	Leafhopper	Leafminer	Mite	Moth	Plant Bug	Shore Fly	Thrips	Whitefly
Yellow sticky cards at top of plant canopy	✓	✓	✓	✓			✓	✓	✓	✓
Blue sticky cards at top of plant canopy									✓	
Trap crops/catch plants	✓								✓	✓
Potato sections on soil surface		✓								
Light traps						✓				
Visual Inspection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Understand the Pest

It is important to know the life cycle of the pest as some control methods will be specific to certain stages of the insect. Often the egg or pupal stages of insects and the spores of pathogens are resistant to pesticides. Many chemicals used against whiteflies will control the adults but are not effective against the pupal stages. These types of sprays must be timed to coincide with periods of high adult populations. Some insects live part of their lives in the soil (thrips and fungus gnats). At such times pest control applications to the leaf area of the plant will be ineffective, whereas treating the soil will control the pest and avoid possible plant injury from sprays on the foliage.

When pest control is required, time the applications to control the stage of the pest for which the control agent is recommended and monitor its effect afterwards. Knowledge of a pest's life cycle will help determine the best time for control methods. Keep dated records of pest problems and the stages of crops attacked, and any treatments done and their level of effectiveness (efficacy). Use this information to anticipate and prepare for future pest problems.

For some pests, monitoring techniques using the ratio between a pest and its natural enemies have been developed as a measure of whether more biologicals need to be added or if the system is keeping the pest in check. For example, the ratio of *Encarsia*-parasitized (black) whitefly scales (larvae) compared to un-parasitized (white) scales.

Biological Control

The term “biological control” refers to the use of natural enemies to suppress pests. Biological control tactics include both recognizing and conserving naturally occurring beneficial organisms as well as introducing commercially produced biological control agents in a timely and effective manner.

Many beneficial organisms will occur naturally in field grown flower crops and greenhouses, particularly when the use of insecticides is minimized. It is important to understand and recognize the natural predators and parasites since they can often limit the growth of a pest population or even control a pest outbreak and keep pest numbers below economic thresholds.

The successful use of introduced biological control agents in ornamental crops is dependent on a number of factors. The pest level that can be tolerated in a crop is important because a biological control program seldom eliminates all the pests. The range of insects, mites, and diseases that a crop is susceptible to must be considered as compatible control methods must be available for all potential pest problems. The use of biological control is most suitable to long-term crops because the predators and the parasitoids must go through at least one generation to build-up to effective levels and establish a dynamic equilibrium with the pests.

If chemical controls are required, try to choose a selective pesticide that will have the least impact on beneficial insects. Table 1.5, which is at the end of this chapter, contains information on the toxicity of pesticides and PGRs to biological control agents. Generally, old broad spectrum insecticides (e.g. organophosphates) are not compatible with

biocontrol agents, as they kill them outright as well as impede re-establishment for several weeks. Newer insecticides tend to be more compatible with biocontrol agents. “Spot spraying” is a useful approach to limit pest hotspots and allow biocontrol agents to ‘catch up’, however, pesticide toxicity and persistence still needs to be considered or the biological control agents will not establish in the hotspot.

Getting Started With Biologicals

The following section, “Getting Started with Biologicals”, is based on a presentation at the CanWest Horticulture Show, September 26, 1996, by James A. Matteoni, British Columbia Horticulture Centre at Kwantlen University College.

Switching to biologicals can’t be implemented overnight and should be started on a small scale to minimize potential risks. The transition process is smoother and often more effective if it’s carried out in several phases. The three phases are: monitoring and recording; modifying your pesticide program; and implementing biological control.

Table 1.4: The Three Phases of Getting Started with Biologicals

Phase I – Monitoring and Recording	
<ul style="list-style-type: none"> ✓ make a commitment ✓ research and choose methods ✓ allow time for them to work ✓ involve staff in the program ✓ keep good records (avoid last year’s mistakes!) 	<p>The crucial step is to make the commitment to the program, and even more important, to make the commitment to the time involved. Monitoring isn’t something that is only done when you have the time and is discontinued during busy periods. It has to be the primary duty of one or more workers that is carried out a specified number of times a week. Involving the rest of the staff is as easy as putting up a “pest alert” board in the lunch or shipping area. Staff can mark on the site or greenhouse plan where and what pests they saw. You don’t have to give awards for “sightings”, but get staff involved.</p>
Phase II – Modifying Your Pesticide Use	
<ul style="list-style-type: none"> ✓ continue to monitor ✓ determine pest threshold levels ✓ eliminate ineffective pesticides ✓ time your pesticide sprays (i.e. when your neighbour cuts his hay) ✓ stop unnecessary sprays ✓ spray only hot spots 	<p>This is the phase where pesticide use is scrutinized. Start evaluating whether the spray is needed or if there are other options. Check your records to see if the pesticide actually was effective or if there was any phytotoxicity. It’s up to you to determine your own threshold levels for your different crops; they’re not conveniently listed in a table</p>
Phase III – Introducing the Biological Control Agents	
<ul style="list-style-type: none"> ✓ identify the pest and choose the biocontrol agent(s) ✓ reduce use of toxic pesticides (avoid broad spectrum, long residual, especially pyrethroids) ✓ identify the biocontrol suppliers and their routes ✓ calculate rates and timing (think big!) ✓ inspect biologicals upon arrival ✓ correct any imbalances ✓ adjust your expectations 	<p>Phase III involves long-term planning that must start months before the biologicals are released. Many commonly used pesticides must be discontinued one to two months before biologicals are introduced. See Table 1.5. Don’t hesitate to involve experts in pest identification and biocontrol strategies. Often biologicals are pest specific and a wrong identification can mean that the program is doomed from the start.</p>

Using the three phases for implementing a biological control program breaks the process into smaller, more easily managed steps. Proceeding one phase at a time allows you and your staff to become familiar with each step before moving onto the next phase. Despite everyone's good intentions, the program may fail because of some of the following reasons:

- the pest was incorrectly identified,
- environmental conditions weren't suitable for the biological agent,
- host plant interference (the biological didn't like the taste of the crop),
- pesticide residue (see Table 1.5),
- wrong biological agent was used,
- too few biologicals and too late,
- biologicals were sick or dead upon arrival,
- unexpected pests interfered with control, or
- your goals and expectations of the program were not appropriate.

Biologicals may not be a "silver bullet" to solve all your pest management problems, so don't give up on using them. But then, no control tool should be relied on exclusively, including pesticides.

Biological control agents might effectively control pests in certain stages or areas of production. Successful biological control means no more problems with pesticide phytotoxicity and resistance, improved worker safety and access (no re-entry intervals), and it can be used as a public relations tool.

Biological Control Agents – Listed by Pest

Aphids

Aphids have several natural enemies; two of these are commonly used as biological control agents in greenhouse crops. *Aphidius colemani*, a small wasp that parasitizes aphids, and *Aphidoletes aphidimyza*, a predatory fly (midge), have been shown to be reliable aphid control agents and are widely available. They are most effective when used together because *Aphidoletes* provides a rapid reduction of aphid numbers and *Aphidius* seeks out and attacks the remaining aphids.

Aphidius and *Aphidoletes* should be released while aphid populations are low; weekly or bi-weekly checks of new foliage are needed to monitor aphid

population levels. The two are capable of seeking out 'hot-spots' to lay their eggs. Heavy aphid infestations should be treated with a pesticide.

Aphidoletes adults are small, about 2 - 3 mm in size, and delicate flyers. It is the larval stage that feeds on aphids. They're orange and grow to about 3 mm long, and eat over 60 species of aphids. Females are active at night, searching for aphids and laying up to 250 eggs over their 10-day lifespan. Eggs are laid singly or in small groups near aphids, and hatch in 2 to 3 days. Larvae attack nearby aphids and suck them dry. High aphid population levels cause larvae to kill more aphids than they can eat. Depending upon temperature, the larval stage lasts 4 to 7 days. They drop to the ground and burrow 2 to 4 cm into the growing medium to pupate. Adults emerge 2 weeks later. The life cycle takes 3 to 4 weeks.

High relative humidity increases adult longevity. If the greenhouse floor is covered with cement or plastic, population build-up cannot occur because this eliminates pupation sites. Areas of bare soil or sawdust are required to complete the life cycle. As the days shorten in fall, *Aphidoletes* go into diapause and stop reproducing. This can be prevented by using lights in the greenhouse.

Aphidoletes are purchased as pupae in moist vermiculite. They should be applied in small piles (10 mL minimum) in shaded, humid areas. To control low infestations apply 2 to 3 midges per square metre. Because the predatory larval stage lasts for only 4 to 7 days and the pupal stage lasts for 2 weeks, it is important to do staggered releases. Make 2 to 3 releases at 2-week intervals. Protect cocoons from ants. *Aphidoletes* will not establish in low aphid populations and is not recommended for preventive use.

Aphidius are tiny, black parasitic wasps that are less than 2 mm long. They lay their eggs inside aphids. As the wasp larva develops, it kills the aphid and then uses the mummified body as its pupal case. The rigid, light brown or bronze aphid mummies show up on leaves 7 to 10 days after the aphids are parasitized and the adults emerge in 5 days by chewing an exit hole in the mummy.

Aphidius is purchased as pupae inside aphid cases. Some adults will be present by the time they are used in the greenhouse. Application rates for low infestations are 2 to 4 per square metre, applied 2 to 3 times a week apart. Naturally occurring *Aphidius* may also enter greenhouses during the summer provided insecticide usage is minimal.

Banker plants are used in the greenhouse as a rearing system for biocontrol agents. When used properly, they keep a high level of parasites present in the greenhouse on an ongoing basis with limited cost and effort. Cereal host plants infested with cereal aphids is a well studied banker plant system for *Aphidius colemani*. Other types of banker plant systems that have proven useful include the use of pepper plants to support growth of *Orius insidiosus*, and mullen and eggplants to support *Dicyphus hesperus*.

During late summer, *Aphidius* itself often become parasitized (hyper-parasitism) by naturally occurring parasites. In addition, high summer temperatures may reduce its efficacy, so aphid populations should be monitored carefully during hot spells and in late summer.

Aphidius colemani is the most effective parasite for green peach aphids. However other *Aphidius* species are more effective for other aphids. Suppliers of biological agents can recommend the correct parasite. Other species include *Aphidius ervi* and *Aphelinus abdominalis*; both are bigger parasites that will control larger aphid species such as foxglove or potato aphid.

Other beneficial agents that can contribute to aphid control in greenhouses are ladybug beetles and lacewings. However these have not been found to reduce aphid numbers to acceptable levels exclusively; *Aphidius* and *Aphidoletes* must be part of the aphid control program.

Note that if your crop is susceptible to aphid transmitted viruses, using biological control agents exclusively may not be advisable because there will likely be a low level of aphids present that are capable of transmitting viruses.

Fungus Gnats (Sciaridae)

Biological control for fungus gnats relies primarily on *Hypoaspis miles*, a predatory mite, *Steinernema feltiae*, an insect-parasitizing nematode, and *Bacillus thuringiensis* subspecies *israelensis*, a bacterial larvicide.

The predatory mite is golden to reddish-brown and about 0.5 mm long. It's easily seen without magnification. Both immatures and adults feed on small soil dwelling insects, including fungus gnat eggs and young larvae. The mites live and feed on the surface and upper 2 cm of growing media. For successful control, the soil should be moist, but not overly wet, and the soil temperature must be at least

15°C. They should be introduced to the crop as early as possible in production at the preventive rate of 100/m². When they are applied to potted crops, the rate should be determined on the basis of how much area the pots occupy. Ideally, they should be applied at the plug stage to allow easy dispersal through the media and early establishment. If the greenhouse has exposed soil or other media under the tables, then *Hypoaspis* should also be applied to these areas. These mites do not diapause so will remain active in the fall and winter as long as the soil temperature is high enough.

Hypoaspis are general feeders; in addition to feeding on fungus gnats, they will also feed on thrips nymphs that drop to the soil to pupate. They must not be used as the sole thrips control measure however; they can be part of an overall thrips control program.

The insect parasitic nematodes (Trade name: Nemasys) are applied to the growing media in water to attack the larval stages of fungus gnats. Mortality usually occurs within 48 hours. These nematodes require adequate soil moisture for survival and mobility, so make sure the soil is quite wet at the time of application. This can be accomplished by applying it as a drench or by pre-wetting the soil/media if the nematodes are to be applied as a spray or through the irrigation system. Soil temperature should be 15 to 28°C. Though there is some reproduction of nematodes within the soil, this should not be relied upon for ongoing fungus gnat control. A second application should be made in 10 to 14 days, and ongoing monitoring should occur over the life of the crop.

VectoBac, a product containing the insect pathogenic bacteria, *Bacillus thuringiensis* subspecies *israelensis*, can be applied to the soil to kill fungus gnat larvae. Apply as a drench in adequate water to wet the soil surface. The larvae must ingest the bacteria, and this requires the product be applied over the entire surface and to a depth of 2 cm. VectoBac must not be applied in combination with fertilizer or fungicides containing copper or chloride. For ongoing regular maintenance of low populations, use the low rate: mix 200 - 400 mL of product in 100 L of water and apply as a drench at weekly intervals if monitoring indicates fungus gnats are present. If a high population with all life stages is present, the initial treatment should be with the high rate of 400 – 800 mL, followed by weekly treatments with the lower rate of 200 - 400 mL per 100 L water.

Atheta coriaria, a predatory rove beetle, can be used for fungus gnats and shore flies. For more information, see the *Shore Flies* section in this chapter.

Leafminers (*Liriomyza* spp.)

Parasitic wasps are commercially available as biological control agents for leafminers. *Opius pallipes* (a braconid wasp, is not as commonly used and may not be locally available), *Dacnusa sibirica*, and *Diglyphus isaea* parasitize and kill leafminer larvae. *Dacnusa* lays eggs within the tunneling leafminer larva. But it does not immediately kill the larva, so it continues to feed and expand mines within the leaf. The larva may drop to the ground and pupate, but an adult *Dacnusa* will emerge. In contrast, *Diglyphus* paralyzes leafminer larvae, larvae stop feeding, and therefore mines are not expanded. This difference between the two should be kept in mind when evaluating their control efficacy. When using them you must be able to tolerate some leafminer damage (mines) to the crop because they will not eradicate the pest. Therefore, it is not suitable for crops where there is a zero tolerance of mine damage, for example, some export markets.

Parasites should be applied at a rate of at least 2 per m², three times at 2-week intervals. Initial introductions should be done when the number of mines is low. *Dacnusa* should be used during the cooler months, and their use should be discontinued once temperatures exceed 25°C. This is a good agent to use early in the season. *Diglyphus* works well when leafminer populations are moderate to high, during the warmer spring and summer months. The parasites, purchased as adults, should be applied in the morning or evening when the greenhouse is cooler. Biocontrol with parasites cannot be used as the sole control agents once the leafminer population is well established or when there are large numbers of adult leafminers present.

Parasitic nematodes (*Nemasys*), applied for fungus gnat control, will parasitize leafminer pupae in the soil. Nematodes applied as a foliar spray will enter tunnels and parasitize mining larvae, so can be a useful tool in some crops.

Mealybugs (primarily citrus mealybug, *Planococcus citri*)

The Australian ladybug beetle, *Cryptolaemus montrouzieri*, is the most successful and commonly used biological control agent for mealybugs. This

predator, called the mealybug destroyer, feeds on all stages of mealybugs. The 4 mm long adult beetle is shaped like a ladybug, while the larvae are “cotton” covered and resemble mealybugs. Adults are most active in sunny conditions and temperatures greater than 20°C.

The parasitic wasp, *Leptomastix dactylopii*, can be an effective control agent for citrus mealybugs. The adults are good flyers and have excellent searching ability. Because it is effective at low densities, *L. dactylopii* can be used to supplement *C. montrouzieri*, which works best at high host densities.

Green lacewings, *Chrysopa carnea*, also feed on mealybugs, but they do not disperse well in greenhouses.

Mites – Two-Spotted Spider Mites (*Tetranychus urticae*)

The most effective biological control agent for two-spotted mites for most greenhouse crops is the predatory mite *Phytoseiulus persimilis*. This mite is widely available from producers of biological control agents. Tropical in origin, this predator is well adapted to greenhouse conditions. It is not effective outdoors in BC. Adult *P. persimilis* are shiny orange, while immature stages are a pale salmon colour. They can be distinguished from the ‘red’ phase of the two-spotted spider mite by the lack of spots, smooth pear shaped body, and their faster movement over leaf surfaces.

To be most effective, *P. persimilis* should be introduced at the first sign of spider mites or their feeding (stippling on leaves). Predatory mites are most effective at greater than 70% RH and from 20 to 30°C. Very hot, bright conditions favour spider mites and can result in pest outbreaks. Ideally, the plants should be in close contact, allowing the predators to move easily through the crop from one plant to another. Each female lays about 50 eggs. At favourable temperatures the life cycle is about a week, twice as fast as the two-spotted spider mite. *Phytoseiulus persimilis* consume 5 to 20 eggs or adults a day. They are not affected by day length, do not diapause, and will remain in the crop as long as pest mites are present and temperatures are adequate. The *P. persimilis* will not survive between crops in an empty greenhouse. They do not eat pollen.

Introduction rates range from 2 to 30 per plant, depending upon infestation levels and the crop

involved. Suppliers can usually suggest more precise rates based on your crop and situation. The most effective and economical introduction system is to apply at least two *P. persimilis* to all infested plants and to every fifth plant in the rest of the crop. Subsequently, treat any “hot-spots” that develop. Be sure to release some *P. persimilis* into areas outside any outbreaks to encourage the predators to disperse and look for food. At very high spider mite levels it is often advisable to apply insecticidal soap or other non-residual miticides before releasing *P. persimilis*. Successful spider mite biological control programs are based on releasing predators every two to four weeks, starting early, on the assumption that there will be low levels of mites from the start of the crop.

For outdoor crops, *Amblyseius (Neoseiulus) fallacis*, a predatory mite of temperate origin, is promising for two-spotted mite control, but it has not been fully evaluated in ornamentals. Use of *A. fallacis* has been primarily in berry crops. It occurs naturally in areas with habitual two-spotted spider mite populations.

Other biocontrol agents for mites include *Feltiella acarisuga*, a predatory gall midge, *Amblyseius californicus*, a predatory mite that eats pollen, other mite species and thrips, and *Amblyseius swirskii* which feeds secondarily on spider mites. These can be used in conjunction with *P. persimilis* for season long mite control.

Scales

There are several species of scales that can impact floriculture crops. It is important to know the type of scale or species of concern in order to successfully implement a biological control program for scales. Scales are divided into soft and armoured scales, and each requires a different parasite. Armoured scales develop a waxy covering over their bodies, but it is not attached to the insects' bodies. They do not secrete honeydew. Soft scales also develop a waxy covering, but it is attached to their bodies. Soft scales produce honeydew.

Commercially available parasites are *Aphytis melinus* for armoured scales and *Metaphycus helvolus* for soft scales. These require high release rates, and even then control is variable. Some commercially available predators can contribute to scale control. The predatory ladybug beetle, *Cryptolaemus montrouzieri*, which is primarily used to control mealybugs, will feed on soft scales if food is scarce. Other commercially available ladybug beetles, including *Hippodamia convergens*, may

provide some control if released in large numbers. The green lacewing, *Chrysopa carnea*, feeds on immature scales and may contribute to control.

Shore Flies (*Scatella* spp.)

Shore flies do not feed directly on plants. They feed sometimes on rotting plant material, but mostly on bacteria and other small organisms within algal communities that develop on continually wet surfaces. Shore flies deposit black ‘fly specks’ (excrement) on plant leaves. They are generally a nuisance pest and an indicator of wet areas in the greenhouse. They are often found in association with fungus gnats. *Atheta coriaria*, a predatory rove beetle of soil insects, is available for management of fungus gnats and shore flies. It can be released into any type of growing media, including rockwool, coconut coir, sawdust, and soil. Both adults and larvae are highly voracious and mobile, so will move around the greenhouse in search of prey.

Thrips (most common species is *Frankliniella occidentalis*, Western Flower Thrips)

Several biological control agents are available to manage thrips. Some predatory mites, predatory pirate bugs, *Orius* spp., and nematodes can be part of an effective thrips biological control program under greenhouse conditions. Biological control agents should not be used exclusively if impatiens necrotic spot virus (INSV) is a concern. Biocontrol agents do not totally eliminate thrips, so the low level of thrips that are not killed by the agents will continue to transmit the virus throughout the crop.

It is most efficient and effective to introduce predatory mites before thrips populations reach damaging levels. They will not control large populations of well established thrips, nor will they control large numbers of adult thrips migrating into greenhouses. Their use requires a thrips monitoring program entailing sticky traps and crop examination. *Amblyseius* do best at temperatures from 20 to 25°C and relative humidities above 70%. Lower humidities result in high egg mortality and can prevent establishment of *Amblyseius*. Females lay one to two eggs per day over a 10 to 20 day lifespan. *Amblyseius* kill only about 6 first instar thrips per day, so large numbers are needed for control. Rates range from 10 to 50 predatory mites per plant per week, plus 25 to 100 predators for every infested plant. Ideally a ratio of one predator per two thrips should be achieved. It will also feed on spider mites, but it cannot be relied to bring about any degree of control.

Amblyseius degenerans controls thrips in flowers better than *A. cucumeris*, is less sensitive to low humidity, has a faster population growth rate, and is more mobile than *A. cucumeris*. It also feeds on pollen. It is best to introduce *A. degenerans* early in the season, as with all predatory mites.

Amblyseius swirskii has recently become available. It has similar characteristics to *A. cucumeris* (feeds on pollen), as well as significant advantages including: *A. swirskii* is more effective at high temperatures, and also feeds on whitefly eggs and larvae. Secondly, it will feed on other mite species.

The predatory mite, *Hypoaspis miles*, will feed on thrips larvae that drop to the soil to pupate. They should not be used as the sole thrips control measure; but are useful in an overall thrips control program.

Orius feeds on all thrips stages and actively searches them out. *Orius* will also feed on pollen if few prey are available, so *Orius* numbers will build up and remain high even if thrips numbers are low. Successful use of *Orius* on ornamental crops largely depends on the presence of pollen in the crop. After hatching, all stages of *Orius* are predatory. The nymphs are amber coloured, while the adults are black and white and about 3 mm long. The life cycle is about 20 days under greenhouse conditions. *Orius* reproduction is affected by day length and some species stop laying eggs when days are less than 12 hours long, limiting their use to spring and summer. In addition to thrips, they will also feed on small aphids, caterpillars, and spider mites. They will also prey on beneficial mites such as *A. cucumeris*, but the rapid movement of these predatory mites makes them more difficult to capture. On cut flowers, the tendency of *Orius* to frequent flowers may result in a large part of the population being removed with each harvest causing poor establishment. Introduction rates and number of releases vary by crop and pest level. Contact a supplier for recommended release rates. *Orius* adults will often fly to the greenhouse roof during the heat and brightness of the afternoon, so it is best to apply them in early morning or late afternoon.

The insect parasitic nematode *Steinernema feltiae* is available in a gel formulation that can be sprayed directly on the plants and flowers, where the nematodes infest and kill thrips. No residue remains from the gel.

A Western flower thrips pheromone is now available. It can be used in conjunction with sticky cards (blue or yellow) to increase trap sensitivity for monitoring purposes, which enables growers to detect thrips earlier than with only the sticky traps. Pheromones plus traps can be used for mass trapping. Some growers have experimented with releasing pheromone into the greenhouse shortly before pesticide sprays which appears to result in better pesticide efficacy. Thrips commonly stay hidden within flowers, so coverage is often an issue with pesticide applications. The pheromone appears to draw the thrips out of their hiding places by agitating and causing them to be more active and exposed.

Weevils (primarily *Otiorynchus sulcatus*, Black Vine Weevil)

Insect parasitic nematodes such as *Steinernema kraussei*, *Heterorhabditis bacteriophora*, and *H. megidis* are commercially available. Nematodes are added to water and drenched into the soil/media. They kill weevil larvae within a few days, and a new generation of nematodes are released from the host larvae. Still, a second and likely subsequent applications are recommended to keep the pest population under control. Small larvae are more susceptible to nematode attack.

A fungal entomopathogen, *Metarhizium anisopliae* strain F52, is expected to be registered in Canada soon. This generalist insect-infesting fungus has shown promise particularly in container stock. *Metarhizium* is applied to the soil as a drench. The fungal spore germinates on the insect surface and enters the soil-inhabiting larvae and grows within it, killing it within several days. There is evidence that *Metarhizium* remains present and active in soil or media for 1-2 years.

Whiteflies (*Trialeurodes vaporariorum*, Greenhouse Whitefly and *Bemisia* spp., Sweet Potato and Silverleaf Whiteflies)

Encarsia formosa is a parasitic wasp that is commercially available for biological control of greenhouse whiteflies. The adult wasp is about the size of a spider mite, with a dark head and thorax and yellow abdomen. It makes short hopping flights, attracted by honeydew or a scent given off by the whitefly. Almost the entire population is female. Adult females lay eggs in the third and early fourth larval growth stages of the whitefly. They will also kill the first, second, and late fourth stages by feeding on them. The parasite larvae feed within the scale.

The scales turn black within two weeks, which provides a convenient way of assessing the success of the *Encarsia* introductions. Development time, adult life span, and numbers of eggs laid are dependent upon temperature. The threshold for development is 13°C. Females live 15 to 30 days and can lay up to 400 eggs. The wasp larvae go through three larval and one pupal stage before the adult stage. The emerging wasp adult cuts a small exit hole in the top of the black scale.

At its optimum development temperature of 27°C, the egg laying capacity of *Encarsia* is twice that of the greenhouse whitefly. However, the wasp is more sensitive to cold than are whiteflies and the whitefly lays ten times as many eggs as *Encarsia* below 21°C. The critical average temperature for good control is approximately 23°C, however, a minimum night temperature of 15°C is satisfactory as long as the day temperature is sufficient to raise the average daily temperature to 23°C. A daily average temperature of 18°C will hold the status quo. (See Table 3.1, Day and Night Temperatures Needed to Produce Various Average Daily Temperatures.) *Encarsia* is impeded by hairy-leaved plants and by honeydew. *Encarsia* has been reported to be fully reproductive at light intensities of only 7300 lux, and intensities below 4200 lux cause high mortality. This, together with the fact that they do not become active until four hours after sunrise, probably explains the poor control sometimes obtained during the dark winter months. Supplementary lighting helps achieve better control.

Trying to control a severe whitefly infestation with *Encarsia* is unlikely to succeed, and is not cost effective because of the large number of *Encarsia* required. Chemical insecticides may be necessary to reduce heavy infestations to low levels prior to releasing *Encarsia*. A chemical with little or no persistence and minimal effect on other biological agents in the crop should be used.

Encarsia should be released preventively, before the first whiteflies are seen, at a rate of 0.5/m² per week. Use yellow sticky traps to detect the first whiteflies and then increase the release rate to 3/m² each week. Monitor the lower leaves for the presence of black (parasitized) scales, and when 90% of the scales are black the application rate can be reduced.

Encarsia are purchased as parasitized whitefly scales on thick paper cards which are placed in the crop for adult emergence. The cards should be placed in a shady position on the lower part of the

plant. In potted plants, do not let the card contact the growing medium. Avoid handling the scales. Distribute the cards uniformly throughout the crop.

A few *Encarsia* adults and other predators and parasites will be trapped on yellow stick traps, but most will remain in the crop searching for whitefly scales.

Eretmocerus eremicus, another small wasp-like whitefly parasite is available for both *Trialeurodes* spp. and *Bemisia* spp. It kills whiteflies by parasitizing larvae as well as directly feeding on the whitefly. *Eretmocerus* is more effective than *Encarsia* at high temperatures (> 30°C), and is more effective than *Encarsia* against *Bemisia* spp., an occasional pest of poinsettias. *Eretmocerus mundus* is available specifically as a *Bemisia* spp. parasite. It is effective at both higher and lower temperatures than *E. eremicus*, so is well-suited to early season releases, warm mid summer temperatures, and cool fall temperatures.

Dicyphus hesperus, a plant bug, and generalist predator, feeds on whitefly nymphs. Because it has a relatively long generation time (5 to 8 weeks), *Dicyphus* can take at least 10 weeks before significantly affecting whitefly levels. It must be introduced as soon as whiteflies are found to be economical. Release at a rate of 0.25 to 0.5 *Dicyphus*/m² and repeat in 2 to 3 weeks. *Dicyphus* needs high levels of prey to reproduce, however they can survive without food for a long time. It is useful to release *Dicyphus* in hotspots. This predator is fast moving and highly mobile. It will also feed on thrips and spider mites, but should not be relied on for control. *Dicyphus* will feed on plants to obtain water, but feeding damage is usually superficial and not noticeable. However caution is advised in ornamentals, for example, *Dicyphus* should not be used on gerbera due to damage to stems.

Additional Reading on Biological Control Agents

Ball Identification Guide to Greenhouse Pests and Beneficials, Stanton Gill and John Sanderson, Ball Publishing, Batavia Illinois, USA, ISBN 1-883052-17-3, 1998.

Ball Pest and Disease Manual, Disease, Insect, and Mite Control on Flower and Foliage Crops, Charles C. Powell and Richard K. Lindquist, Ball Publishing, Batavia Illinois, USA, ISBN 0-9626796-4-X, 1992.

Knowing and Recognizing, The Biology of Glasshouse Pests and their Natural Enemies, M. Malais and W. J. Ravensberg, Koppert B.V., Berkel en Rodenrijs, the Netherlands, First Edition, 1992. Translated from *Kennen en herkennen, levenswijzen van kasplagen en hun natuurlijke vijanden*. (Contact your Koppert representative for a copy.)

Pasteurization and Fumigation of Soil

Soil pasteurization or fumigation can be an effective treatment for controlling soil-borne diseases, insects, weeds, and nematodes. Observe the following rules to achieve satisfactory results.

- The soil temperature at 15 cm depth must be 13°C or higher for successful treatment with chemicals.
- The soil must be in a loose condition to allow gas penetration. Sods, lumps, and organic materials must be thoroughly broken up.
- If organic materials (manure, compost, etc.) are to be used, they must be incorporated before treatment in order to prevent recontamination.
- The soil must be moist, but not wet.

When soil is pasteurized with steam or fumigated with chemicals, the number of soil micro-organisms is greatly reduced for the first few days, then it rises and eventually exceeds that of untreated soil.

Pasteurization or fumigation destroys a large part of the dense population of soil microbes, and the first organisms to return after treatment meet no competition. Thus, if plant pathogens are among the first to recolonize the soil, they may develop rapidly and cause severe disease losses. Therefore, it is important that the grower make every effort to prevent recontamination. Pathogens can gain entrance to the soil by:

- splashing of rain or watering,
- contaminated cuttings,
- soil in water hoses,
- infested containers,
- infested tools and equipment,
- growers' hands and footwear,
- placing containers on the ground,
- unsterilized tarps, and
- infected plants or seeds.

Soil Pasteurization

Steam is the most common form of heat used for soil pasteurization. For potting mixes it can be injected into the media pile. Old truck boxes are often good containers. Ground beds can be steamed through underground tile drainage pipes or through canvas hoses covered by tarps. In either case, the soil should be heated to 70°C, measured at points farthest from the source of steam and maintained for 30 minutes.

Above 82°C beneficial soil organisms are destroyed and excess manganese may be released. Aerated steam should be used to prevent overheating. This allows the soil to be pasteurized without the problems associated with over-steaming such as excessive ammonia release, manganese toxicity, higher salt levels, and destruction of organic matter and beneficial organisms. Unless there are specific problems, a pasteurization time of 30 minutes at 70°C should eliminate most pathogens and all but the most heat-resistant weed seeds, while leaving some beneficial, heat-tolerant organisms to compete with the re-colonization attempts of disease organisms.

Manganese Toxicity

Manganese toxicity may occur on acid mineral soils or on steamed soils with a pH below 6.0. Symptoms of toxicity include:

- root browning,
- brown spotting of the stem, petioles and veins of the lower leaves,
- yellowing of the leaf starting at the veins, and/or
- premature loss of lower leaves.

This problem may be avoided by liming the soil, by pasteurizing at a lower temperature, using a steam-air mixture, and by increasing the application of super-phosphate.

Soil Fumigation

Some fumigants control fungi, bacteria, nematodes, insects, and weeds, whereas others, that are more specific in their action, control only nematodes or fungi. Soil fumigation is not always an adequate substitute for soil steaming. Fumigants may not destroy all soil-borne pathogens harboured in root debris and other plant parts.

The soil must be prepared properly before treatment. It must be tilled and kept moist for at least two

weeks after removing the plants to allow the roots to rot before treatment. Cultivate the area thoroughly, breaking up lumps and loosening the soil deeply and thoroughly. The soil should be moist before treatment; cultivate lightly if the soil has crusted. Seal the soil with a plastic cover after the chemical is injected. An approved respirator must be used during treatment and at any time when fumes remain.

After an area has been fumigated, care must be taken to avoid contaminating it with nematodes, seeds, or soil pathogens. Don't add any untreated soil, manures, or mulches. Use clean tools and check for soil adhering to workers' footwear. As much as possible, use certified, disease-free seeds or transplants.

Use one of the following treatments:

Basamid (dazomet) - Apply 3.25 - 5 kg/100 m² evenly on the soil surface. This may be done by hand when wearing rubber gloves or by means of a fertilizer spreader. Immediately after application, incorporate to a depth of 15 to 23 cm and seal the soil by irrigation, compacting, or covering with plastic sheets. The amount of time for fumigation and aeration depends on soil temperatures. The soil must be aerated before planting. Fumes are harmful to plants; all traces must disappear from the treated soil before planting or sowing is undertaken or extreme plant damage may result. **Do not use treated soil until the safety germination test has been carried out and has shown the soil to be safe to use.** See the label for complete instructions. Do not use when soil temperatures are below 6°C. Basamid controls nematodes (except encysted phases), soil fungi, soil insects, and germinating weed seeds.

Telone C-17 (1,3-dichloropropene + chloropicrin) - Use as a preplant treatment to control soilborne nematodes and diseases. Apply in the spring when soil moisture is at 50% of field capacity and soil temperature is between 5 to 27°C at a depth of 20 cm. Apply at a rate of 2 L per 100 m² for greenhouse beds. Seal the soil immediately following application. At the end of the exposure period, allow the soil to aerate completely before planting the crop.

Vapam (metam-sodium) - See the label for rate and application methods. Do not apply to the soil surface if air temperatures are above 32°C or when strong winds would cause the loss of Vapam before it can be sealed into the soil. Do not use in

greenhouses where plants are present. Vapam controls germinating weed seeds, nematodes, and soil-borne fungal diseases such as damping-off and root rot. It is toxic to fish.

Weed Control

Keep the interior of the greenhouse weed-free. Weeds in the greenhouse and in the area surrounding the greenhouse are a continuous source of mite, aphid, whitefly, and thrips re-infestation. **Never use the same sprayer for herbicides and other pesticides.** Many growers have suffered economic losses from herbicide damage by using non-registered herbicides or herbicide contaminated sprayers in the greenhouse.

To kill weeds outside, surrounding the greenhouse, use a contact weed killer such as Gramoxone Ⓢ (paraquat) for annual weeds, or Roundup (glyphosate) for perennial weeds. A 1 to 5 metre weed-free zone around the greenhouse is recommended. Do not use hormone-type herbicides such as 2,4-D or MCPA for weed control adjacent to greenhouses. Use low pressure (less than 275 kPa) to avoid misting and drift into the greenhouse.

For more information, see Chapter 8, *Weed Control*.

Table 1.5: The Relative Toxicity of Pesticides to Beneficial Organisms

The data represent the number of **weeks** a pesticide remains harmful to a beneficial organism. The beneficial organism can only be successfully introduced to a crop after the stipulated time period. A product with no residual period still may be harmful at the time of application. When there was no residual data for a pesticide, the product is classified as being **safe**, or **slightly**, **moderately**, or **highly** harmful to the beneficial organism, which relates primarily to the effect after direct spray. In general, fungicides have little effect on beneficial organisms.

Active Ingredient	Trade Name	Aphid Midge	Hypoaspis	Lacewing	Lady Beetle	Orius spp.	Predatory Mites ²	Aphid Parasites ¹	Whitefly Parasites ¹¹	Parasitic Nematodes
Fungicides										
azoxystrobin ⁵	Heritage	safe	safe	safe	safe	safe	safe	safe	safe	safe
captan	Captan, Maestro	0	0	0	-	0	safe ⁴	safe ⁴	safe	-
chlorothalonil	Bravo, Daconil	0	0	0	-	0	safe ⁴	0	safe	0
copper oxychloride	Copper Spray	0	safe ⁴	-	-	safe ⁴	safe ⁴	safe ⁴	mod	0
fosetyl-al	Aliette (spray)	-	0	-	-	-	-	-	safe	0
fosetyl-al	Aliette (drench)	-	-	-	-	-	-	-	-	0
iprodione	Rovral (spray)	0	0	0	-	0	safe ⁴	0	safe	0
iprodione	Rovral (drench)	-	-	-	-	-	-	-	-	0
mancozeb	Dithane, Manzate	mod ⁴	0	-	-	0	safe ⁴	0	slight	0
metalaxyl	Subdue	mod ⁴	0	-	-	-	mod ⁴	mod ⁴	safe	0
myclobutanil	Eagle, Nova	-	0	0	-	0	-	-	safe	-
propiconazole	Topas	-	0	0	-	-	-	0	safe	0
sulfur	Sulphur	safe ⁴	0	0	high ³	mod ⁴	1 ⁴	0	1-4, slight-high ¹²	0
thiophanate-methyl	Senator	0	0	0	-	-	2-3	0	½, high	-
trifloxystrobin ⁵	Compass	safe	safe	safe	safe	slight	safe	safe	safe	safe
Insecticides										
acephate	Orthene	8-12	0	6-8	-	high ⁴	4 ⁴	12 ⁴	6-8, high	0
acetamiprid ⁵	Tristar	high	1, high	mod	mod	2, high	1, mod	mod	2, high	-
<i>Bacillus thuringiensis</i>	DiPel, VectoBac	0	safe ⁴	0	0	0	0	0	safe	0
carbaryl	Sevin	4 ⁴	0	4	high ³	8	2-4 ⁴	4 ⁴	4, high	0
chlorpyrifos	Dursban	2 ⁴	0	8-12	-	5	½-6 ⁴	6 ⁴	8, high	-
cyromazine	Citation	½, high	safe	high	½, mod	slight	1, slight	slight	safe	0
deltamethrin	Decis	8-12	0	8-12	8-12	8-12	8-12	8-12	8, high	0
diazinon	Diazinon	6-8	1 ⁴	4	high ³	high ³	1 ⁴	2 ⁴		-
diflubenzuron	Dimilin	0	0	-	-	-	-	0	safe	0
dimethoate	Cygon, Lagon	2 ⁴	0	8-12	high ³	high ⁴	≥8	8 ⁴	8, high	-
☞ endosulfan	Endosulfan☞, Thiodan☞, Thionex☞	2 ⁴	½ ⁴	-	high ³	high ⁴	½ ⁴	1-2	6, high	0
imidacloprid	Intercept, Merit (drench, drip ⁹)	0	0	0	-	4-6	0	0		0
kinoprene	Enstar II	safe ⁴	0	-	-	safe ⁴	safe ⁴	safe ⁴	½, slight-high	-

Table 1.5: The Relative Toxicity of Pesticides to Beneficial Organisms (continued)

Active Ingredient	Trade Name	Aphid Midge	Hypoaspis	Lacewing	Lady Beetle	<i>Orius</i> spp.	Predatory Mites ²	Aphid Parasites ¹	Whitefly Parasites ¹¹	Parasitic Nematode
Insecticides (cont.)										
malathion	Malathion	2	0	high ³	>2	high ⁴	2 ⁴	8-12	8, high	0
permethrin	Pounce	8-12	0	8-12	high ³	8-12	8-12	8-12	8, high	-
petroleum oil	Dormant Oil	safe ³	-	0	-	safe ³	mod ³	0	-	0
pyrethrins	Pyrethrins	-	-	0	0	-	-	½	2, high	-
pymetrozine ⁵	Endeavor	mod	slight	safe	-	slight	safe-slight	safe-slight	safe	-
salts of fatty acids	Insecticidal Soap	0 ⁴	0 ⁴	safe ³	-	mod ⁴	0 ⁴	0 ⁴	-	-
spinosad ⁵	Success	safe	safe	safe	safe	slight-mod	safe	mod	1, mod	-
tebufenozide	Confirm	-	-	0	-	-	-	-	safe	-
trichlorfon	Dylox	-	0	-	-	-	2	-	mod	0
Miticides										
abamectin	Avid	2 ⁴	2 ⁴	-	-	3	2	1	1, high	0
acequinocyl ⁵	Shuttle, Kanemite	-	safe	-	-	-	safe-high ⁶	-	-	-
bifenazate ⁵	Floramite	high	safe	safe	safe	safe	safe-mod ⁸	mod	safe	-
dicofol	Kelthane	½ ⁴	0	1	-	mod ⁴	2-4 ⁴	2 ⁴	1, high	0
fenbutatin-oxide	Vendex	0	0	0	-	0	mod ⁴	0	safe	-
pyridaben	DYNO-Mite	3½ ⁴	2 ⁴	-	-	safe ⁴	2 ⁴	>4 ⁴	2, high	-
pyriproxyfen ⁵	Distance	safe	safe	safe	mod	safe	safe-slight	safe	mod	-
spiromesifen ⁵	Forbid	high	safe	-	safe	safe	safe-mod ⁷	safe	slight	-

Sources: *Side Effects Guide*, Koppert Biological Systems, unless stated otherwise. The data was collected from greenhouse-grown crops in northwest Europe. Under warmer and brighter conditions, or in the field, a pesticide's residual effect is often shorter.

¹ Data for *Aphidius* spp.

² Applies to *Amblyseius cucumeris*, *A. californicus*, *A. degenerans* and *Phytoseiulus persimilis*

³ From: *A Field Guide to Beneficial Insects and Arachnids in British Columbia Seed Orchards*, 1996, BC Ministry of Forests

⁴ From: *Floriculture Production Guide*, 1999, British Columbia Ministry of Agriculture, Food and Fisheries

⁵ From: *Side Effects Manual*, BioBest Biological Systems, www.biobest.ca, based on results obtained under Western European horticultural and climatic conditions.

⁶ Non-toxic to *Amblyseius swirskii* nymphs, but highly toxic to *Phytoseiulus persimilis* nymphs. Unknown on other *Amblyseius* species.

⁷ Non-toxic to *Amblyseius degenerans* and *A. swirskii* nymphs, slightly toxic to *A. cucumeris* nymphs, and moderately toxic to *A. californicus* and *Phytoseiulus persimilis* nymphs.

⁸ Non-toxic to *Amblyseius cucumeris*, *A. californicus*, and *A. degenerans* nymphs, moderately toxic to *A. swirskii* nymphs, and slightly toxic to *Phytoseiulus persimilis* nymphs.

⁹ Imidacloprid is toxic to many biocontrol agents if sprayed directly. Drip/drench applications are safer, however persistence can limit re-introduction of biocontrols.

¹⁰ Only *Amblyseius swirskii* was tested.

¹¹ Whitefly parasites are *Encarsia formosa* and *Eretmocerus* spp. For many pesticides, both were tested, but for some only *E. formosa* was tested. From www.biobest.ca

¹² Highly toxic to *Encarsia formosa* adults; do not reintroduce for 4 weeks after treatment. Slightly toxic to *Eretmocerus* spp. adults; can reintroduce after 1 week.