Integrated pest management in ornamentals information kit

Reprint – information current in 2000

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.deedi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2000. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

This publication was last revised in 2000. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

This information has been made available to assist users to identify issues involved in ornamental horticulture. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

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Queensland Government

Know your **Biocontrol Agents**

What can you expect to learn from this section?

Questions and answers outline why biocontrol might be useful to you, which biocontrol agents are commercially available in Australia, where and how to buy them and how to use them. In addition, there are details about different biocontrol agents.

The directory of biocontrol agents (this section page 2) will help you match key pests with biocontrol agents commercially available in Australia. Handy Guide 6, Chemical toxicity to biocontrol agents *will help you select more compatible chemicals for use with biocontrol agents.*

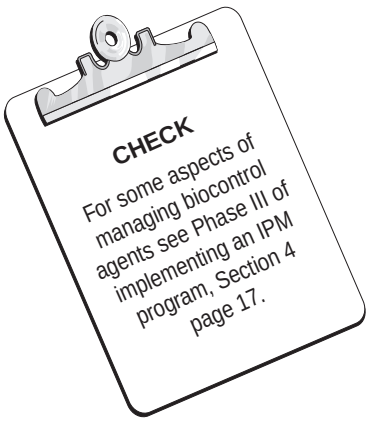
***Coloured photographs** of each of these biocontrol agents can be found in the companion publication* Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide*, see* Section 10, Further reading *page 7.*

Contents

Directory of biocontrol agents

For commercially produced biocontrol agents in Australia and the pests they are used against

Note: Biocontrol agents marked with an asterisk * have not been fully tested under greenhouse conditions, but are known to prey on the pest.



What does biocontrol offer you?

Incorporating biocontrol into a pest management program can be a rewarding experience in terms of better control of pests (if done well), while adding a new dimension of interest for staff. Biocontrol rarely works well if it is done piece-meal without an understanding of the processes involved, and without a plan that considers likely scenarios for managing all the pests and pathogens that might attack a particular crop.

To a beginner, biocontrol may seem like uncharted territory that means relinquishing known methods of pest and disease control. Biocontrol will come together much more easily if all the other elements of a successful IPM program are in place. You need to gather background information on pests and diseases and start experimenting with commercially produced biocontrol agents or friendly microbials so that you have some knowledge of what to expect.

Incorporating biocontrol into your IPM program can be an **active** process, where you are buying and releasing commercial supplies of biocontrol agents. It can also be a **passive** process, where you are manipulating the local natural enemies by restricting the use of toxic pesticides, and providing the best environmental conditions for their survival. A combined approach can also work well.

What are the advantages of using biocontrol in my operation?

The advantages can be significant. They include:

- reduced reliance on pesticides
- no environmental concerns
- no phytotoxicity problems
- longer active life of existing pesticides because of limited usage
- no re-entry delays for staff
- plants available for immediate sale (no withholding periods).

Is biocontrol really feasible in ornamentals?

Yes. There is rapidly increasing use of biocontrol in these crops.

In northern Europe and parts of North America, where biocontrol has been the norm rather than the exception for many years in greenhouse vegetable crops, there was an initial resistance to accepting it in ornamentals because of the perceived zero tolerance for pests and damage. However, many successful biocontrol programs now operate in interior plantscapes, nurseries and greenhouses, including some very 'high tech', sophisticated operations.

The key to successful biocontrol is access to a wide range of relatively inexpensive biocontrol agents that are introduced on a regular basis to excess, much like using a chemical in a preventative manner. In addition, access to highly trained advisers to help growers with IPM programs is also very important. These are generally available through biocontrol suppliers, their agents or government agencies.

Are there circumstances where it is not an option to use biocontrol?

Yes, there are situations where biocontrol is not practical. These are where:

- The tolerance to pests may be very low, for example the crop is highly susceptible to an insect or mite transmitted virus (tomato spotted wilt virus and western flower thrips).
- The environmental conditions may favour the pest or disease at the expense of the biocontrol agent, for example hot dry conditions or cool grown crops.
- There may be a lack of key biocontrol agents or compatible chemicals for the pest complex on the crop being grown.
- It may not be economical to buy the numbers needed to keep the pest in check.
- There may be no effective biocontrol agents for a particular combination of pest and crop stage, for example western flower thrips adults in flowers.
- There may be a lack of technical expertise to assist in setting up programs relevant to the operation.
- High numbers of pests may be migrating into the area (screened structure needed).

Can I apply pesticides if I am using biocontrol agents?

Yes, pesticides and biocontrol agents may be combined under the following circumstances:

- When a pesticide is relatively harmless to the biocontrol agents being used. For example, pirimicarb can be used as a soil drench or foliar spray to control aphids (presuming your aphids aren't resistant to it) without affecting predatory mites, parasitoids or lacewings.
- When biocontrol agents are used early in the crop and pesticides only used when the crop is at a critical stage, for example at coloured bud stage for a crop sold for flower display rather than foliage.
- When a corrective pesticide, though toxic at the time of application, has no residual toxicity so biocontrol agents can be released within a short period after application. Dichlorvos, for example, has a short lived fumigant action.

Can I use biocontrol agents in an open situation?

Yes**,** some biocontrol species can work very well in open situations. Others may leave for better hunting grounds if they are mobile and pest populations are too low to attract and sustain them. Environmental conditions will also affect how well biocontrol agents do.

Open situations can also benefit from natural enemies adapted to local conditions migrating from the surrounding area. These can have a significant impact on pest populations. Lacewings, aphid parasitoids, scale and mealybug parasitoids and spider mite-eating midge larvae or beetles are some of the more frequently encountered natural enemies.

Wayne Bacchi, of Wholesale Indoor Foliage in Queensland, has been practising IPM for 10 years. He says:

"The benefits of IPM include less reliance on chemicals and overcoming chemical resistance. Beneficial insects have better crop penetration than chemicals."

Which biocontrol agents are available commercially in Australia, and for which pests?

Fewer biocontrol agents are available in Australia compared with the Northern Hemisphere, but several key species can be bought here. The directory on page 2 of this section shows commercially produced biocontrol agents in Australia and the pests they are used against. This list will expand as demand increases. Suppliers are given at the end of the details on each biocontrol agent (this section, pages 8 to 21).

What types of biocontrol agents are available?

Biocontrol agents for insects and mites fall into two main categories: **predators** and **parasitoids**. A third category includes **micro-organisms** such as pathogenic fungi and bacteria. These have a useful place in a biocontrol program, but regulatory agencies treat them as insecticides requiring registration, and they are not dealt with in this guide. The exception is entomopathogenic nematodes, which do not require registration and are included in this section.

A **predator** consumes its prey. Examples are the mite *Phytoseiulus persimilis* and the green lacewing *Mallada signata*.

A **parasitoid** lays one or more eggs into a host organism and the immature stages develop within it, killing the host. Examples are the tiny wasps *Encarsia* and *Trichogramma*. **Parasites**, on the other hand, may live in or on their host, but don't necessarily kill it.

Biocontrol agents for plant diseases are also being developed. They act by:

- out-competing the disease organism for nutrients and space
- producing a chemical such as an antibiotic that inhibits or kills the pathogen
- attacking and feeding directly on the pathogen
- being inoculated into the host plant to trigger a disease resistance response.

How many biocontrol agents do I need?

The number of biocontrol agents needed depends on the crop situation, the type of pest, how many there are and the biocontrol agent under consideration. Most biocontrol agents are best introduced when pest numbers are very low. It is much cheaper this way because you need fewer biocontrol agents.

If the biocontrol agent is a generalist feeder that can survive on pollen, nectar and other non-problem invertebrates (for example some predatory mites), you can even establish it before the pest arrives. You might only need one or two introductions (for example *Stratiolaelaps [Hypoaspis] miles*) or you might need a series of regular introductions over several weeks (for example *Encarsia formosa*). Some predators and parasitoids are only effective when there are large numbers of pests at the outset, for example ladybird beetles, some leafminer parasitoids and lacewings.

Seek advice from the supplier on recommended rates and frequency of introduction. After a bit of practice (and good records), you can work out a seasonal program with your supplier that provides good pest and disease control.

If you have a mixed crop, calculate the number of biocontrol agents required per square metre, based on the area of the target crop, not the whole floor area. It will help if targeted plants are grouped and not scattered throughout the production area. Biocontrol agents have little legs and little wings. Your aim is not to improve their fitness.

John Bunker, from Redlands Nursery in Queensland, has been involved in IPM since the mid 1980s. He says:

"Since then we have used Persimilis for two-spotted mite, Cryptolaemus for mealybugs, Encarsia for whitefly, Aphytis for scales, Aphidius for aphids and Leptomastix for citrus mealybug."

Is there any research to fill some of the gaps in the present suite of biocontrol agents?

Yes. Two native phytoseiid mites have been identified through a project funded by the Horticultural Research and Development Corporation. These mites have potential to control western flower thrips, and their commercial development is pending. A soil mite is already commercially available for fungus gnat control. A new project is planned to further identify native beneficials for development as commercially available species. Commercial companies are contributing to this effort as well as studying new species.

How can I find more information on how to use biocontrol agents?

Information on available biocontrol species can be obtained from this section of the information guide, from the companion field guide *Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide*, from literature, and from biocontrol suppliers. The companies selling biocontrol agents are the best source of advice on how to use their products. They can assist you in setting up a program suitable for your particular operation.

Can I rear my own biocontrol agents?

Rearing natural enemies to obtain consistent numbers and quality is not an easy task and is not recommended. However, keen advocates of biocontrol often collect natural enemies such as lacewings, ladybirds and aphid mummies from the wild and release them into their operations. Biocontrol companies are always interested in any promising species that you may find.

In Australia, biocontrol producers are members of Australasian Biological Control Inc. (ABC), which actively promotes biocontrol in commercial horticulture and ensures members meet minimum standards. The association has a web site (http://www.goodbugs.org.au) and their publication, *The Good Bug Book*, has received worldwide acclaim as a quality guide on the use of biocontrol agents. Copies can be obtained from member companies.

Further reading
Section 10 page 5

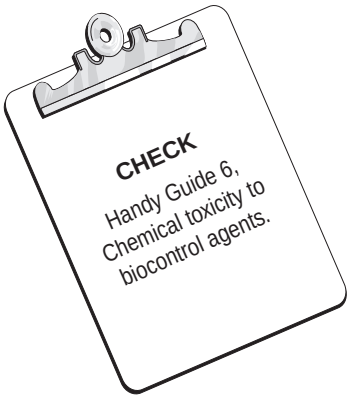
Can I store biocontrol agents?

The general answer is no, though entomopathogenic nematodes are an exception. Most biocontrol agents should be released the same day they are received, though not if it is extremely hot. Hold biocontrol agents at 10° to 20°C until conditions are suitable, and follow instructions on the label or accompanying leaflet.

I released biocontrol agents and never saw them again. Why didn't they work?

There are several reasons why biocontrol agents may fail to perform:

- The temperature and/or humidity were unfavourable. This is one of the most common causes of failure. Most biocontrol agents operate best between 20° and 30°C and between 60 and 80% relative humidity. Plants prefer these conditions too.
- There were pesticide residues on the leaves, in the soil or impregnated in the pots, plastic floor or plastic sheeting; some fungicides are also toxic. Between crops, wash down walls and floors with high phosphate detergent to remove pesticide residues. Put biocontrol agents with suspect leaves in a vented container for a day or two to see if they survive.
- A 'safe' application of pesticide became unsafe because the rate was increased substantially, or a wetting agent was added.
- Pesticide drifted across from another area or was sucked in by fans.
- The biocontrol agents were in poor condition on arrival. Always check to make sure they are active on arrival. For *Encarsia*, check cards against the light a week after receipt to see if there are small round holes in the black scales, indicating successful adult emergence.
- The wrong biocontrol agent was matched with the pest. Make sure pests are identified correctly. For example, *Leptomastix* wasps only attack citrus mealybug, not longtailed mealybug.
- Too few biocontrol agents were released to do the job or they were put in too late to catch up. Most biocontrol agents need to be introduced when pest numbers are very low.
- There were too few pests to encourage the biocontrol agents to stay in the crop. Biocontrol agents have to eat too. If there is no food (pests) or not enough food, they will migrate or die. In this situation you may need to release fewer biocontrol agents more often, or use monitoring to indicate when it is time to order more biocontrol agents.



The Nursery Papers
1998#007, 1996#008
Section 10 page 8

The following information on commercially produced biocontrol agents contains useful advice to help you select, use and identify biocontrol agents. Information on the recommended rates for each biocontrol agent has been provided by the suppliers.

If you are concerned about the correct rates for your crop, please contact your supplier.

Aphytis

Card reference 126 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Aphytis lingnanensis* and *Aphytis melinus.*

Target pest(s): Oleander scale and some other armoured scales.

Description: Aphytis are tiny (less than 1 mm) yellow, parasitoid wasps. They lay their eggs into the second and third instar scales, and their developing young feed upon the scale, eventually killing it. After three weeks the adult parasitoid emerges from the scale.

Aphytis lingnanensis is available in Queensland. It prefers the tropical, warm and wet summers.

Aphytis melinus is available in South Australia and is best suited to warm and dry Mediterranean summers.

Optimal conditions: Optimum temperature for *Aphytis lingnanensis* and *Aphytis melinus* development is 26°C and a relative humidity of 60 to 65%.

How to buy: Aphytis can be ordered by phone and delivered by mail. The parasitoid is supplied in plastic capsules containing a minimum of 1000 wasps, with a drop of honey on the lid for food, or in paper cups containing 10 000 wasps.

How to use: Monitor pest populations and release wasps during early spring and summer before scales become prolific. If scale levels are still high, if pesticides have been used or if summer temperatures have become excessive, an additional late season release is recommended.

The wasps should arrive within one to two days by mail or courier and should be released as soon as possible. In extreme weather conditions such as high temperature (over 35°C) or heavy rainfall, the wasps can be stored for one or two days in a dark room at about 17°C. Honey, for food, should be applied to the lid if storing the wasps. Do not refrigerate them.

The wasps should be active upon arrival. Release the wasps in the morning, before the temperature rises. Attach the capsule to the shady side of a plant and open the lid.

In enclosed situations, 100 to 150 wasps per square metre are recommended. Outdoors, release 25 000 to 50 000 wasps per hectare (25 to 50 capsules). Release up to three times, either monthly or twice a month.

Monitor the crop before and after wasps are released with the aid of an experienced scout. Use a microscope to assess the level of parasitism. Check for small round exit holes in the scales. Continue releases until half the available scales have been parasitised (only second instars and third unmated instars are parasitised).

Compatibility with pesticides: Organophosphate, carbamate and synthetic pyrethroid insecticides are toxic to Aphytis. Most miticides, copper-based products and fertilisers will usually not harm them. If insecticides are required, as a general rule, allow a minimum of four weeks to pass before re-releasing Aphytis.

Supplier:

Aphytis lingnanensis
Bugs for Bugs
Bowen Street
Mundubbera Qld 4626
Ph: (07) 4165 4663
Fax: (07) 4165 4626
E-mail:
sales@bugsforbugs.com.au
Web: www.bugsforbugs.com.au

Aphytis melinus
Biological Services
PO Box 501 Loxton SA 5333
Ph: (08) 8584 6977
Fax: (08) 8584 5057
E-mail: fruitdrs@sa.ozland.net.au

Handy Guide 6, Chemical toxicity to biocontrol agents

Cryptolaemus beetle

Card reference 128 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Cryptolaemus montrouzieri.*

Target pest(s): Citrus mealybugs, longtailed mealybugs and other mealybugs. Cryptolaemus will also eat some soft brown scales.

Description: Cryptolaemus is a ladybird-shaped predatory beetle with an orange head and dark brown wing covers. It can grow up to 4 mm long. The adult lays eggs into the egg mass of the mealybugs and they hatch about five to six days later. Larvae feed on the mealybug eggs and nymphs for 12 to 17 days and go through four stages, reaching 13 mm before pupating. Cryptolaemus larvae look very similar to mealybugs as they are covered in white waxy filaments. Adult Cryptolaemus emerge after 7 to 10 days and feed on all stages of mealybugs. The life cycle of Cryptolaemus takes four to seven weeks.

Optimal conditions: Optimum temperature for Cryptolaemus beetles is about 28°C. Adults are most active in sunny weather. The beetles are active between 16° and 33°C and 70 to 80% humidity. Cryptolaemus will not be as effective in cooler parts of Australia during winter.

How to buy: Cryptolaemus can be ordered by phone and delivered by mail. The predators are supplied in punnets containing a minimum of 40 beetles (home pack) or bulk containers of 500 beetles (commercial pack), in shredded paper, with a drop of honey on the lid for food.

How to use: Release Cryptolaemus early in the season, as soon as mealybugs are present. Initially make a full release (recommended rate) followed by two smaller releases (half recommended rate) at three to six week intervals. The beetles should be active upon arrival. Release beetles in the morning, before the heat rises. Gently tap insects out of the container near mealybug infestations.

The beetles should arrive within one to two days by mail and should be released as soon as possible. In extreme weather conditions such as high temperature or heavy rainfall, the beetles can be stored for one to two days in a dark room at about 17°C. Honey, for food, should be applied to the lid if storing the beetles.

In enclosed situations, one punnet per 20 to 40 square metres is recommended (one to two beetles per square metre). Outdoors use 20 to 50 punnets per hectare (800 to 2000 beetles). Release in the early morning or late evening, and avoid wearing light coloured clothes that may attract the beetles. Temperatures above 30°C are too high for release.

Monitor the crop before and after Cryptolaemus release, noting the incidence of mealybugs and predatory beetles. It can take two to four months to achieve mealybug control, as indicated by the appearance of uninfested new growth. Longtailed mealybug is more difficult to control than citrus mealybug.

Compatibility with pesticides: Organophosphate, carbamate and synthetic pyrethroid insecticides are toxic to the beetles. Some miticides, copper-based products and fertilisers will usually not harm them. If insecticides are required, allow a minimum of four weeks to pass before releasing the beetles again.

Supplier:

Bugs for Bugs
Bowen Street
Mundubbera Qld 4626
Ph: (07) 4165 4663
Fax: (07) 4165 4626
E-mail:
sales@bugsforbugs.com.au
Web: www.bugsforbugs.com.au

Handy Guide 6, Chemical toxicity to biocontrol agents

Encarsia

Card reference 130 in
Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Encarsia formosa.*

Target pest(s): Greenhouse whitefly and silverleaf whitefly. They will also attack ash whitefly, but are not very effective in controlling them.

Description: Encarsia is a parasitoid wasp that is about 0.6 mm long and has a dark head and thorax, and a yellow abdomen. Except for the adult, all stages of Encarsia develop within the whitefly scale. The adult whitefly lays its eggs inside the late third and fourth nymphal stages of the whitefly. The Encarsia larva feeds on the nymph and develops within the scale. Parasitised greenhouse whitefly pupae turn from white to black, while parasitised silverleaf whitefly pupae turn from white to brown before adults emerge two weeks later. Adult Encarsia can act as predators, killing the youngest whitefly nymphs by feeding on them. They also feed on the honeydew secreted by the whiteflies. The adult can live 10 to 30 days and lays up to 300 eggs in that time.

Optimal conditions: Encarsia performs best at temperatures from 27° to 30°C, 50 to 90% relative humidity and with at least 10 hours of light each day. High numbers of whitefly will decrease the movement of the parasitoid wasp. Encarsia are less efficient at temperatures below 18°C and double the recommended rate may be needed. Hairy leaves may also reduce their efficiency.

How to buy: Encarsia can be ordered by phone and delivered by mail. The wasps are sent over an eight-week period or more, in packs from 500 to 10 000 per week. They are transported within parasitised whitefly pupae that are glued to a small card.

Supplier:
Biological Services
PO Box 501 Loxton SA 5333
Ph: (08) 8584 6977
Fax: (08) 8584 5057
E-mail: fruitdrs@sa.ozland.net.au

How to use: Release wasps early in the season, either before or as soon as whitefly are present. Do not try to use Encarsia if whitefly numbers are high. The insects are supplied on cards, each containing at least 100 black, parasitised scales. Few adult Encarsia should be present on or in the package.

Release Encarsia as soon as they arrive. If release is not possible, Encarsia can be stored for one to two days at 10° to 20°C. The estimated emergence date will be written on the back of the card. Do not release Encarsia in temperatures above 35°C.

Release early in the day, before the temperature rises. Open the package of cards within the greenhouse in case some adult Encarsia have already emerged. Place the cards near the middle or bottom of the plants, in the shade, near the whitefly infestation. Do not remove cards from plants for at least 10 days to allow all Encarsia to hatch. Distribute the cards regularly and evenly throughout the greenhouse with extra cards in each whitefly 'hot-spot'.

If you wish to check the quality of Encarsia you receive, place one card in a sealed container and count the number of wasps that emerge. Eighty percent or more of the black scales should yield healthy wasps. Release two cards per 100 square metres per week, for six to eight weeks, or until 80% parasitism of available scales is achieved. Where leaf surfaces are very hairy, or where

whitefly are already established or silverleaf whitefly are present, double to four cards per 100 square metres per week.

Monitor the crop before and after Encarsia release, noting the incidence of black parasitised and white unparasitised whitefly scales. Count whitefly adult numbers on sticky traps. Once the percentage of black parasitised whitefly scales exceeds 80%, whitefly has been controlled. At this point, further Encarsia releases should not be necessary.

If white scales but no black scales are seen in the crop up to four weeks after Encarsia release, check for problems such as failure of adult Encarsia to emerge from cards, or pesticide residues on the crop or the plastic or glass covering of the greenhouse. Excessively high temperatures, constantly over 40°C, may also cause adult Encarsia to die. Identify the cause of poor parasitism and plan to reuse after correcting any problems.

Compatibility with pesticides: Nearly all insecticides are toxic to Encarsia to some degree. If whitefly becomes too numerous, spot-spray with non-residual pesticides such as insecticidal soap or oil. Most fungicides, miticides and fertilisers are not harmful to Encarsia. Wait for a minimum of four weeks before re-introducing Encarsia into the greenhouse after spraying residually toxic pesticides. Some plastic coverings of greenhouses can harbour residues for longer than four weeks. Before using Encarsia, check spray records over the past two months.

Handy Guide 6, Chemical toxicity to biocontrol agents

Entomopathogenic nematodes

Card reference 132 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Steinernema feltiae, S. carpocapsae, Heterorhabditis bacteriophora* and *H. zealandica.*

Target pest(s): *Steinernema feltiae:* Lepidoptera, Diptera such as fungus gnats.

Steinernema carpocapsae: Lepidoptera such as cutworms, *Helicoverpa* and *Spodoptera*.

Heterorhabditis bacteriophora: Coleoptera such as the black vine weevil.

Heterorhabditis zealandica: black vine weevil, garden weevil and scarab beetle.

Description: Entomopathogenic nematodes are microscopic, worm-like and clear-bodied. Juveniles search in the moist soil for a host, then enter the insect through spiracles (breathing holes), mouth or anus into the gut. Once inside, the juvenile nematodes release symbiotic bacteria that kill the insect. They then mature and reproduce, feeding on the remains of the insect from the inside. When the insect has been consumed, thousands of juvenile nematodes move out into the soil in search of more prey.

Optimal conditions: Air and soil temperatures between 15° and 30°C are best. Keep the nematodes out of the sun as they deteriorate under ultraviolet light. Spray nematodes onto slightly moist soil, so they can move about. Spray after watering or rain, making sure that each square centimetre gets its share of nematodes.

Supplier:

Ecogrow
Unit 12
5–11 Hollywood Avenue
Bondi Junction NSW 2022
Ph: (02) 9389 0888
Fax: (02) 9389 2244
E-mail: info@ecogrow.com.au
Web: www.ecogrow.com.au

How to buy: Nematodes can be ordered by phone and delivered by mail. They are protected in an inert, powder-like carrier. Nematodes are provided in packs of no less then 50 million infective juveniles.

How to use: Before use, the nematode powder should be mixed with water and allowed to activate for about 10 minutes. The nematode suspension should be constantly agitated to prevent sedimentation. Nematodes can be applied as a drench, sprayed on the crop or applied through drip irrigation systems (beware of clogging). It is possible to store some nematodes in the refrigerator for some weeks, though particular species cannot be kept in the cold. Consult your supplier before doing so.

Nematodes are barely seen with the unaided eye, but their effectiveness can be measured by recording the number of pests present before and after nematode release.

A release rate of one pack onto 100 to 200 square metres is recommended. Some nematodes for specific pests require different rates and application methods. Consult your supplier to determine the right rate and method for the particular nematodes you need.

Compatibility with pesticides: A few insecticides including organophosphate, carbamate and soap sprays are detrimental to nematodes on contact, yet have little residual effect. Most fungicides will not harm them. If insecticides are required, allow a minimum of one week to pass before releasing nematodes again.

Handy Guide 6, Chemical toxicity to biocontrol agents

Green lacewing

Card reference 134 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Mallada signata*.

Target pest(s): Small caterpillars, two-spotted mite, scales, aphids, thrips, mealybugs, various moth eggs and whitefly. Usually only used commercially for aphids and mealybugs.

Description: Green lacewing is a predator only in the juvenile stages. The eggs of the lacewing are very noticeable, with each egg attached to a long slender stalk. The eggs take four days to hatch. Larvae grow from 1 to 8 mm, are dark brown to black, and impale the remains of their prey on their backs as a form of camouflage. The larvae grow for 12 days before pupating inside a cocoon and emerging as an adult after nine days. The adult lacewings are green with four clear wings showing distinct venation. Adult lacewings feed on nectar and pollen and begin to lay eggs seven days after emerging.

Optimal conditions: Green lacewing performs best at temperatures around 25°C and relative humidity from 60 to 65%. Green lacewings will not be as efficient in cooler parts of Australia during winter. Lacewings prefer a crop with plenty of leaf cover.

How to buy: Lacewings can be ordered by phone and delivered by mail. Eggs are delivered in rice hulls in lots of 100 or 500.

How to use: Release lacewings early in the season, as soon as pests are present. The insects are supplied as eggs, though during transit some may develop and arrive as larvae. Release in the morning, before the heat rises. Shake the container evenly over all plants in the crop. Concentrate on pest 'hot spots.' Temperatures above 30°C are not suitable for lacewing release.

The lacewings should arrive within one to two days by mail and should be released as soon as possible. After the first release follow up with two further introductions, 10 to 14 days apart.

In enclosed situations, one to five lacewings per plant is recommended. Outdoors use 500 to 1000 lacewings per hectare.

Monitor the crop before and after lacewing release, noting the incidence of pests and predators on the plants. For targeted pests with wings, such as aphids, thrips and whitefly, count numbers on sticky traps.

Compatibility with pesticides: Most fungicides high in copper and most insecticides can be toxic to lacewings. Some miticides and other fungicides may be harmless. Wait two to three weeks after spraying before releasing lacewings into a crop.

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Handy Guide 6, Chemical toxicity to biocontrol agents

Hypoaspsis (Stratiolaelaps)

Card reference 136 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Stratiolaelaps (Hypoaspis) miles.*

Target pest(s): Fungus gnat larvae and thrips pupae.

Description: Hypoaspsis are predatory mites. They are less than 1 mm long, light brown and fast moving. The eggs of these mites are hidden in the soil. They are glossy, white, elliptical, and hatch in two to three days. Younger stages of the mite look like a smaller version of the adult but are lighter coloured. The life cycle is completed in about 11 days. All stages of the soil-dwelling mite feed on target pests. Adult mites can live for several weeks in soil with no obvious food supply.

Optimal conditions: Hypoaspis is fairly tolerant of most weather conditions. They become inactive at temperatures below 12°C while prolonged, daily soil temperatures over 30°C are harmful. Hypoaspis prefers highly porous soil and will not do well in total peat or sand.

How to buy: Hypoaspis can be ordered by phone and delivered by mail. Mites are packed in loose compost, in densities of 15 000 mites per litre or larger packs, depending on whether a preventative or curative application is needed.

How to use: Monitor for adult fungus gnats or thrips by using yellow sticky traps and count the numbers caught each week. It is best to apply Hypoaspis at planting to attack the fungus gnat larvae or thrips pupae when numbers are still low. If you have a history of fungus gnat or thrips infestation, release Hypoaspis preventatively. Release the mites during the cooler parts of the day or under cool conditions. Use a shaker to sprinkle the mites over the soil surface.

Mites arrive in a pasteurised compost mix, and should be fast moving. They come with a stored product mite as a food source, but this smaller, slow moving mite will not attack crops. It is recommended that Hypoaspis are used as soon as they arrive by post. If conditions are unfavourable for release, it is possible to store the mites in a dark room at 10° to 20°C for no longer than 48 hours.

Curative applications require two releases at the recommended rate a week or two apart. Preventative applications should be applied at the recommended rate twice a year. If plants are being re-potted, an additional release will be needed to replenish the population.

A release rate of 100 mites per square metre or 25 mites per 10 to 20 cm pot is recommended as a preventative measure when less than 20 fungus gnats per yellow sticky trap per week are recorded. If fungus gnats are present and causing problems, a curative release rate of 200 to 400 mites per square metre or 50 to 100 mites per 10 to 20 cm pot is recommended. Try to concentrate predator numbers in fungus gnat 'hot spots' and spread the remainder evenly throughout the crop. Also treat the ground underneath the benches.

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Monitor the number of fungus gnats and/or thrips before and after release to assess predator establishment and pest control. While some thrips pupae are eaten, total control of thrips should not be expected.

Compatibility with pesticides: Hypoaspis is generally less affected by pesticides sprayed above ground than are other biocontrol agents. Diazinon and fungicides such as benzimidazoles are harmful. The mites should not be applied to soil treated with lime or copper sulfate. As with most beneficials, it is best to wait several weeks after applying synthetic pesticides before releasing the predators into the soil.

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Leptomastix

Card reference 140 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Leptomastix dactylopii.*

Target pest(s): Citrus mealybug **but not** longtailed mealybug.

Description: Leptomastix are small (3 mm) brown, parasitoid wasps with long antennae. The wasps lay eggs into third instar nymphs and adult mealybugs, which hatch and develop fully within the mealybug. After forming a brown pupal case the adult wasp emerges. It takes two to three weeks for the wasp to complete its lifecycle.

Optimal conditions: Optimum temperature for Leptomastix is 25°C and above, and a relative humidity of 60 to 65%.

How to buy: Leptomastix can be ordered by phone and delivered by mail. The parasites are supplied in punnets containing about 250 adult wasps, with a drop of honey on the lid for food.

How to use: Release during early spring and summer before mealybugs become prolific. Two further releases at four to six week intervals will help maintain control. The wasps should be active upon arrival. Release the wasps on a sunny morning, before the temperature rises above 30°C.

The wasps should arrive within one to two days by mail and should be released as soon as possible. In extreme weather conditions such as high temperature or heavy rainfall, the wasps can be stored for one to two days in a dark room at about 17°C. Honey, for food, should be applied to the lid if storing the wasps. Do not refrigerate.

In enclosed situations, one punnet per 125 square metres or five per infested plant is recommended. Outdoors use 20 to 50 punnets per hectare (7500 to 15 000 wasps).

Monitor the crop before and after wasp release, as adult wasps are hard to detect. Check for brown pupal cases amongst the mealybugs. Releases of Leptomastix should continue until at least 30% of mealybug-infested sites contain these pupal cases.

Compatibility with pesticides: Organophosphate, carbamate and synthetic pyrethroid insecticides are all toxic to the wasps. Miticides, fertilisers and copper-based fungicides are generally safe to use. If insecticides are required, as a general rule, allow a minimum of four weeks to pass before re-releasing Leptomastix.

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Persimilis

Card reference 142 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Phytoseiulus persimilis.*

Target pest(s): Two-spotted mite and bean spider mite.

Description: Persimilis is a predatory mite. Adult Persimilis are orange and visible to the unaided eye. Juvenile stages are paler and the light orange eggs are oval and twice the size of spider mite eggs, which are round and clear. Eggs hatch in two to three days. The larval stage takes one to three days to develop and protonymph and deutonymph one to four days each. The total time from egg to adult ranges from 4 to 20 days, depending on temperature. Females can lay up to 60 eggs in a lifetime. Adult predators feed on all life stages of spider mites, while juvenile Persimilis feed on spider mite eggs and juvenile spider mites.

Optimal conditions: Persimilis performs best in warm, humid conditions. It does not do well at temperatures greater than 30°C and with a relative humidity of less than 60% as these conditions are lethal to eggs. It does best on well-foliated plants.

How to buy: Persimilis can be ordered by phone and delivered by mail. Persimilis is packed on bean leaves in small buckets or cardboard tubes. Some two-spotted mite will also be in the container as a food supply. There is a minimum of 10 000 Persimilis adults, nymphs and eggs in each commercial pack.

How to use: Release Persimilis early in the season, either before spider mites are present or at the first signs. Do not expect Persimilis to control an established outbreak without some plant damage. Previous monitoring data can indicate when spider mite infestations can be predicted. Regular monitoring will help in the early identification of new spider mite infestations. Sometimes a pre-release knock down spray with insecticidal oils (petroleum or vegetable), insecticidal soap or fenbutatin oxide is needed if two-spotted mite numbers are too high and/or temperatures too cold.

Release the mites when the plants are dry. If it is raining on an outdoor release site, predators can be kept for one or two days in a cool place away from direct sunlight, but quality cannot be guaranteed after such time. Inside the greenhouse, if the air is dry, wet walkways to increase humidity and encourage Persimilis establishment.

Adult mites should look round and fat and move quickly. Place the carrier bean leaves on infested plants ('hot spots'), around the margins of those 'hot spots', and distribute the remainder of the leaves evenly throughout the crop. After release Persimilis should build up in numbers until the spider mite population is exhausted. If there is no spider mite in the crop, Persimilis will leave the plants in search of mites elsewhere or die. Fresh releases will be needed when a new spider mite outbreak is recorded. It is possible to achieve a low-level population of both pest and predator that will persist for an entire season.

In enclosed situations, release 4 to 10 mites per square metre with 20 to 50 mites per square metre in 'hot spots'. Outdoors, release one pack of 10 000 mites per 1000 to 2000 square metres. At least one extra release is required

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if plants are being removed or changed over, as part of the Persimilis population will have been removed. It is often advisable in these situations to 'trickle-release' mites. Smaller releases (less than half the recommended rate) are introduced monthly into 'hot spots' for the life of the crop. This is where monitoring is essential and can save money.

Where spider mite is frequent, release Persimilis monthly into known trouble spots before the pest is present, as a preventative measure. Monitor the crop before and after release, recording spider mite and Persimilis presence.

Compatibility with pesticides: Persimilis is resistant to several pesticides including some insecticides, miticides and most fungicides. However some insecticides, and a few fungicides (such as benomyl, oxythioquinox, mancozeb and carbendazim) are toxic. Avoid spraying any insecticides for at least two weeks after release until Persimilis has established. If chemicals of medium toxicity are only sprayed on the tops of leaves, Persimilis living underneath the leaf may not be harmed.

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Scale-eating ladybirds

Card reference 138 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific names: *Chilocorus circumdatus* (red chilocorus), *Chilocorus baileyi* (blue chilocorus).

Target pest(s): For red chilocorus—white louse scale (citrus snow scale) and oleander scale.

For blue chilocorus—oleander scale and some other armoured scales.

Description: Blue chilocorus is a ladybird-shaped predator, deep blue and about 3 mm long.

Red chilocorus is a ladybird-shaped predator, red with a black band around the base of the wing shields and 5 mm long.

Adults start laying eggs about 10 days after they emerge. They lay cylindrical eggs beneath the cover of the scale insect. The spiny larvae hatch after one week at 25°C and begin to feed on surrounding scales. After 10 days feeding, the larva pupates and the adult emerges seven to nine days later. Only the larval stages of Chilocorus feed on the scales.

Optimal conditions: Optimum temperature for beetles is about 28°C and relative humidity 60 to 65%. Chilocorus will not be as efficient in cooler parts of Australia during winter.

How to buy: Chilocorus can be ordered by phone and delivered by mail. The beetles are supplied in punnets containing a minimum of 30 beetles (home pack) or in bulk containers of 500 beetles (commercial pack), in shredded paper, with a drop of honey on the lid for food.

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How to use: Release Chilocorus whenever scale insects are present. Chilocorus can predate high numbers of scale insects. Initially make a full release (recommended rate) followed by two smaller releases (half the recommended rate) at three to six week intervals.

The beetles should arrive within one to two days by mail and should be released as soon as possible. They should be active upon arrival. Release the beetles in the morning, before the heat rises. Gently tap them out of the container near scale infestations. In extreme weather conditions such as high temperature (above 30°C) or heavy rainfall, the beetles can be stored for one to two days in a dark room at about 17°C. Honey, for food, should be applied to the lid if storing the beetles.

In enclosed situations, one punnet per 20 to 50 square metres is recommended. Outdoors use 20 to 50 punnets per hectare.

Monitor the crop before and after beetle release, noting the incidence of scale and predatory beetles. It can take up to three months after release to achieve control.

Compatibility with pesticides: Organophosphate, carbamate and synthetic pyrethroid insecticides are toxic to the beetles. Some miticides, copper-based products and fertilisers will usually not harm them. If insecticides are required, as a general rule, allow a minimum of four weeks to pass before re-releasing predatory beetles.

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Trichogramma

Card reference 144 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Trichogramma carvarae, Trichogramma pretiosum.*

Target pest(s): For *Trichogramma carvarae*—lightbrown apple moth eggs.

For *Trichogramma pretiosum*—eggs of *Helicoverpa* (Heliothis), lightbrown apple moth and looper caterpillar.

Description: Trichogramma parasitoid adults are less than 0.5 mm long, have a black body and red eyes. The female wasp lays eggs into the caterpillar eggs. A Trichogramma larva hatches inside the egg and feeds on the contents before pupating inside, turning the egg from white to black. After chewing its way out of the egg, the new wasp finds a mate and is ready to lay eggs. The life cycle of Trichogramma takes 7 to 20 days, depending on temperature. The adult wasp feeds on nectar, so it helps if the crop is flowering.

Optimal conditions: Trichogramma performs best at temperatures from 20° to 27°C and at 60% relative humidity.

How to buy: Trichogramma can be ordered by phone and delivered by mail. The wasps are supplied as 1000 parasitised eggs within a capsule. Each pack contains 60 capsules. The capsule protects the wasps from other predators and weather. Once hatched, adult wasps can emerge from the capsules through escape holes.

How to use: Begin using Trichogramma when light traps or pheromone lure traps detect the first moths or at the first signs of egg-laying in the crop. Check with the supplier that your moth pest is a host for the species of Trichogramma commercially available. You should also receive a small vial of parasitised eggs along with the capsule. These eggs will hatch 24 hours ahead of eggs in the capsules. Use the eggs in the vial as an indicator for development. Wait until the wasps are ready for emergence before releasing them into the field.

Select a shady position for release. In enclosed situations, release 10 to 20 eggs per square metre on two occasions, five to seven days apart, when moth eggs are first discovered. Outdoor release rates vary and it is best to contact your supplier for this information.

Parasitised eggs can be stored at 8° to 10°C for up to a week if the weather is too hot (over 33°C) or wet.

Monitoring is very important as a guide to the numbers of Trichogramma needed to combat the pests. Regular releases ensure constant supplies of females to attack fresh eggs during periods of maximum threat.

Compatibility with pesticides: Most chemical insecticides are toxic to Trichogramma. Miticides are safe to use, however most miticide solvents in liquid formulations are toxic. Fungicides are generally harmless, but there are some exceptions. If harmful pesticides have been used, wait four weeks before re-introducing Trichogramma wasps into the crop.

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Typhlodromus

Card reference 146 in

Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide, see Section 10 page 7

Scientific name: *Typhlodromus occidentalis.*

Target pest(s): Two-spotted mite.

Description: Typhlodromus predatory mite can vary from a yellow-white to clear coloured. They are pear-shaped and similar in size to two-spotted mite. Their eggs are oval and a bit larger than two-spotted mite eggs. The life cycle of Typhlodromus takes seven to eight days, twice as fast as the two-spotted mite.

Optimal conditions: Typhlodromus performs best at 27° to 32°C with low to moderate humidity. In the cooler parts of Australia, Typhlodromus will go into diapause (dormant period) during winter.

How to buy: Typhlodromus can be ordered by phone and delivered by mail. Mites are supplied in small buckets in two sizes, containing bean leaves supporting about 5000 or 10 000 predators in various life stages, as well as a small amount of pest mite for their food.

How to use: Persimilis is the preferred mite for the control of two-spotted mite.

Typhlodromus will not work as fast or spread as quickly as Persimilis, but if the greenhouse environment is hot and dry, or if you intend to use a predatory mite in outdoor crops where these conditions prevail, Typhlodromus may be the more suitable predator. It may also be worthwhile trying both predatory mites together. The mites can be released at any time of year in greenhouse crops where heat is maintained. The mites should be active upon arrival (check with a hand lens) and should be released immediately. Typhlodromus should not be stored for any period of time.

Place the leaves evenly throughout indoor crops with about 10 mites per square metre and 20 to 30 predators per plant in pest 'hot spots.' Outdoors it is suggested that 25 000 to 50 000 predators are released per hectare, depending on the crop. A second release of Typhlodromus is recommended after four weeks.

Monitor the crop before and after release to assess predator establishment and pest control.

Compatibility with pesticides: Most carbamate, organophosphate and pyrethroid chemicals are toxic to Typhlodromus. Miticides are safe to use and Typhlodromus is resistant to azinphos-methyl. As a general rule, wait four weeks for toxic residues to break down before releasing predatory mites and wait two weeks for the predators to establish before spraying any pesticides. Benomyl can decrease the number of eggs Typhlodromus will lay, however most other fungicides and fertilisers are safe to use.

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