

Processes and
Applications of
Commercially Available
Bio-Control Agents.

by



Applied Bio-nomics

Best in first



**The Bio-Control
Handbook** *Second Edition*

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Introduction

The Bio-Control Handbook presented by Applied Bio-Nomics Ltd is an essential text for commercial growers and scouts and is useful for anyone responsible for the success of a plant or crop.

The following processes and applications for use of our bio-control agents only apply to our products. The same species from different producers will have different rates and ranges due to how they are reared, stored and shipped. If using bio-controls from another company, refer to their strategies.

This guide is meant to supplement an established bio-control program.

Should you just be starting down this road of alternatives to chemical bio-control, contact us or your local bio-control distributor for information on getting started.

Our website is a more complete source of information:

www.appliedbio-nomics.com

Forward for the Second Edition

A typical bio-control publication will date itself with reference to obsolete and unavailable pesticides. Fortunately, the bio-control program encouraged by Applied Bio-nomics Ltd. recognizes that while some bio-control agents will survive some chemical treatments, a purely chemical free approach benefits the applied bio-control agents and encourages the arrival of native contributors. Therefore, you will find few changes from the First Edition, other than the massively influential addition of the new bio-control agent: *Anystis baccarum* (The Crazee Mite).

The common foliar pests discussed in this handbook are all harassed, consumed and sometimes outright eliminated by the Crazee mite. Additionally, it can control other pests that have often eluded control by traditional bio-control agents; most important of those being echinothrips and mealybugs. Thus, the Crazee Mite warrants discussion on its own.

However, the strategies discussed for controlling the common greenhouse pests prior to the introduction of the Crazee Mite are still relevant and in many cases preferable both in cost and efficacy. Therefore, this Second Edition will begin with an introduction to *Anystis baccarum* and what you can expect from it, but leave the existing strategies in place.

CHAPTER 1

The Crazee Mite - *Anystis baccharum*



Ch. 1

The Crazee Mite - *Anystis baccharum*

A*nystis baccharum* is a cosmopolitan predatory mite with populations throughout North America, Europe and Asia. It has long been recognized as an effective predator of the European Red Mite in orchards and is known to control various other pests in natural settings.

However, attempts to mass produce and commercialize *Anystis* species have been thwarted by their voracious appetite and tendency to cannibalize with a lack of food. But with the combined research and development with Applied Bio-nomics Ltd. and Vineland Research and Innovation Centre this breakthrough has allowed for growers to try *Anystis baccharum* as a substitute or addition to regular bio-control programs.

These mites are easy to scout and have quickly become favoured by most growers who have tried them. Their large size, hunger, speed and erratic running pattern resulted in their nickname The Crazee Mite, although some are familiar with their other name: "whirligig mites."

Most importantly, their range of prey and compatibility with other bio-control agents is astonishing. They can be added in addition to all strategies and products listed in this handbook, and can also stand alone in some circumstances.

As with all new bio-control agents, research is on-going. Which pests are truly controlled and in what environments as well as the limitations of the Crazee Mite are still being determined. However, as this research continues, the Crazee Mites have already established themselves as the top thrips predator, an essential addition to aphid and spider mite control programs and a welcomed predator of whitefly, mealybugs, echinothrips, psyllids and more. Growers are welcoming this new bio-control agent and eager to try it in crops previously controlled regularly with chemical interventions, like hanging baskets, calibrachoa, gerbera and succulents.

Anystis baccharum

The Crazee Mite, *Anystis baccharum* (also known as the Whirligig Mite) is a cosmopolitan predatory mite found throughout most of the Northern Hemisphere and in select areas of the Southern Hemisphere.

It is easily recognizable as being relatively large, extremely fast and often running in a seemingly erratic pattern. It primarily feeds on foliar pests and is found most often on undersides of leaves where pests are present. It notably controls thrips, aphids and spider mites, but is also a known predator of echinothrips, mealybugs, psyllids, whitefly, and the European Red Mite.

Its lifecycle is relatively long. Eggs hatch into larval stages and then three nymph stages before reaching adult hood 3-4 weeks later. All stages are predatory and all mites are female. Eggs will be laid by adults for three weeks. They are typically laid in loose growing media and in small clusters of 15-30 eggs, several times during the adult stage.



Anystis on lemon

Eggs and larval stages are best suited for moist and consistently warm locations but still develop as low as 10°C.



An adult Crazee Mite

While adults historically cross exposed concrete at impressively high temperatures and are subject to the natural temperature swings of high latitude areas, 25°C and 60%RH is close to their optimum conditions. Therefore, they are well suited for both outdoor applications in gardens and field crops as well as indoor applications like nurseries, house plants, and greenhouses.



A bag of 1000 adults

Applying Anystis

Shipping: Crazee Mites are shipped in various quantities and life stages. A package of 1,000 adults is actually shipped as their last pupal stage so as to emerge as hungry adults upon receipt. So to is the intention of the adult package of 250. The 250 Eggs quantity is several hundred eggs (to account for mortality) and emerge as larval stage upon receipt.

Quality Control: All stages of the *Anystis baccarum* are mobile. The fastest way to determine fitness of the shipped population is to watch emerging Crazees over 1-3 days of receipt. The mites are very fragile, so allow them some time to choose to move. Once mobile, they should be quick and not lethargic.

Release: Tub products may remain as-is to allow voluntary release from the container. The bag product may be sprinkled in desired location. All stages want to disperse, so central releases are appropriate, but so too is pouring out contents in several locations.



Anystis pupa

Scouting: Scouting is famously easy with Crazee Mites, at least initially. They are relatively large, bright orange or red and run at incredible speeds. They are sometimes stationary only when eating, and will be found hidden on undersides of leaves



An adult Anystis eating hop aphids on hops

during this time. Most common they are found running along exposed surfaces like leaf tops, concrete or greenhouse structural components. Nymphs and larval stages are smaller and paler and less likely to be found. Eggs and pupa are often in growing media or other cryptic locations.

Rates: Because of their searching abilities, speed and tendency to disperse to find suitable prey, precise rates are subject to crop, pest and environment. However, the recommended starting point is 250 mites per 1000 square feet for prevention and 1,000 mites or more, for the same space when knock-down is required.

Predators: It is believed spiders are their primary predator.

Anystis at a Glance



Effective Temperature Range: **Unknown**



Eggs laid per female: **45-150** in three weeks



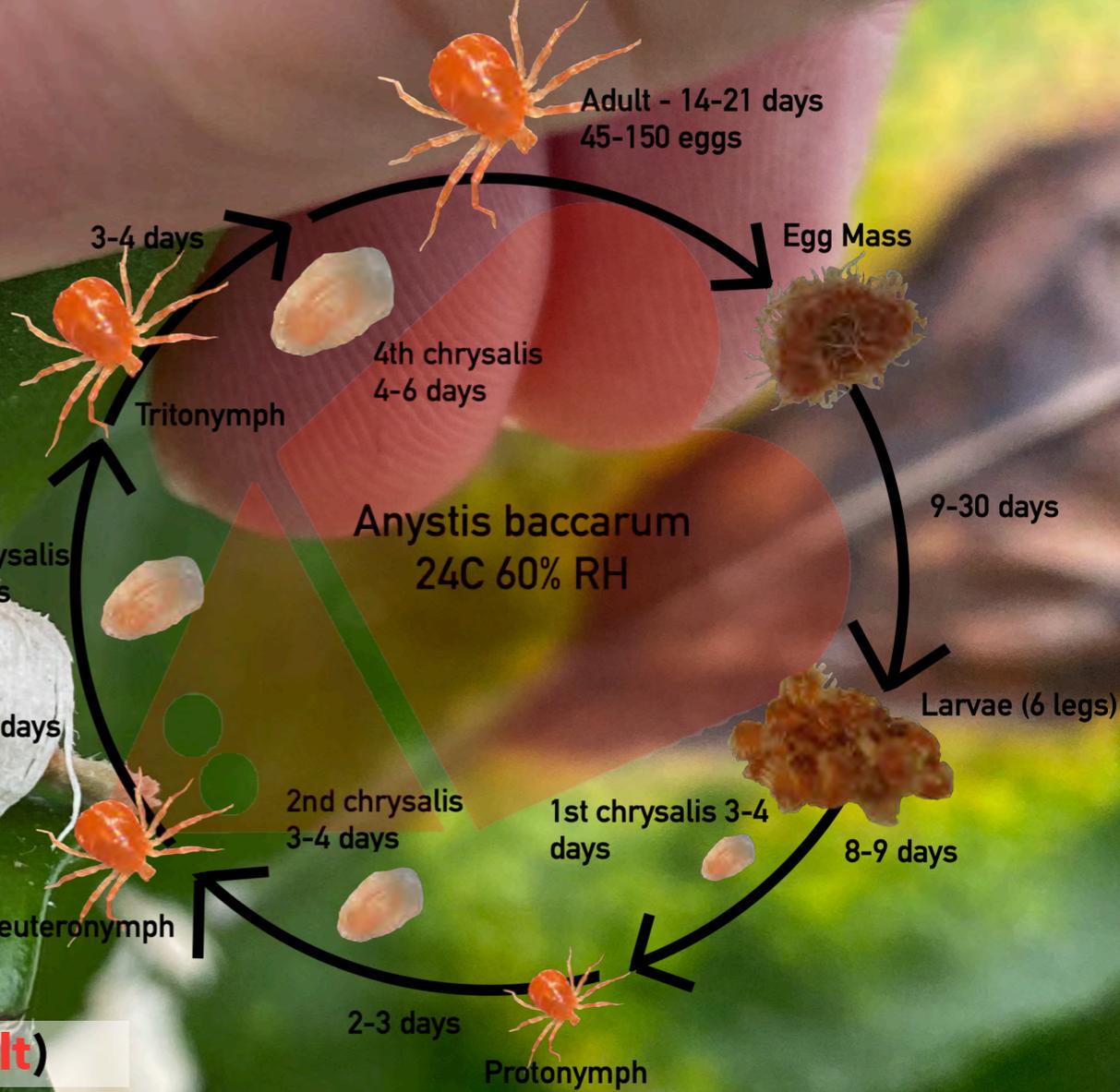
Egg to Adult: **3 weeks (Another 3 weeks as adult)**



Prey eaten per adult: **depends on size of prey**



Known Predators: **Spiders**



Targeted Pests and Species: Aphids, Thrips, Spider mites and European Red Mite. May control mealybugs, echinothrips, pycnophidius and whitefly.

CHAPTER 2

Aphid Control



2

Aphid Control

Aphids cause more costly crop damage than any other pest. Every grower in the world has encountered aphids. Resistance to chemical controls, the restrictions or out-right bans on neonicotinoids, and rapidly developing bacterial resistance to parasitism has lead experts to predict that aphids will continue to be the #1 threat to growers and will continue to get worse.

Unfortunately, aphids are one of the most complicated pests to control.

Aphids are able to surprise even the most keen-eyed scouts with their sudden ability to exponentially increase colony size. Aphids actively defend against predation and receive help doing so by ants who farm them for their honeydew secretions. Their rapid draw of phloem and their promotion of molds and mildew lead to quick plant decline and immediate cosmetic losses.

Fortunately, aphid ubiquity and proliferation also make them a reliable food source for a multitude of predators. Some predators target specific aphid species, while others are more general in their appetite. Some predators are not beholden to

aphids as their only food source. Aphid parasitoids are common and commercially available, but naturally-occurring parasitism resistance has recently made them less suitable for commercial aphid control, and the mummies created and left behind are a serious cosmetic concern, especially for ornamentals.

This chapter will focus on providing quick access to proven, practical control techniques of aphids. We will address the nature of aphids, scouting and monitoring techniques, beneficial cultural practices, our primary aphid predator and two supplementary predators for special situations.

Aphids

Aphid populations increase rapidly due to live-birthing pre-fertilized female clones. High density and other environmental factors can trigger some aphids to become alate (grow wings). And extend their range rapidly. Sexual reproduction and the production of eggs is much more rare.

Aphids feed on the phloem (or sap) in the soft tissue of plants. Rapid plant growth directly correlates with rapid aphid reproduction. When you can, reduce the nitrogen content in your fertilizer and provide calcium-based nitrogen.

Screened air in-takes and entrances restrict aphid infestations. Ultra-violet “bug zappers” may attract alate aphids. Put a bucket of water below to monitor their populations. Many aphids are also repelled by specific colours (like silver) and attracted to others (like orange). Colours, along with the presence of some bio-pesticides are sometimes an additional deterrent from your crop.



Aphidoletes aphidimyza

Aphidoletes aphidimyza is the primary aphid predator for commercial bio-control. It proliferates and consumes aphids at a rate far greater than the aphid reproduction cycle. It will persist as long as there are any aphids, and only once aphids are gone will it turn to other food sources like whitefly. There are few environmental conditions that limit its use and therefore there are almost no applications where growers have failed to control aphids with Aphidoletes.

Aphidoletes is a predatory midge. At the winged adult stage it seeks out and feeds on honeydew secreted by phloem-feeding insects. It lays its hundreds of eggs on or near aphids.



Aphidoletes larva are short-lived: approximately one week. Each will consume 20 or more aphids during this time, but can kill up to 50 per day. They are only easily visible in the last 3 days of their larval stage. Larvae drop to the ground to pupate in soil. Pupation can take over one week. The cycling of Aphidoletes is dependant on a light ratio greater than 13:11 (light to dark). Supplemental light does not need to be intense. Walkway/emergency lighting is often enough.

The temperature range for Aphidoletes when shipped fresh and unrefrigerated is 15 Celsius to just over 30, with the optimum range of 21 to 25 Celsius. Below 18C they are often not fast enough to keep up with some aphid species.

Aphidoletes are not aphid species specific. Like other vermiform (worm like) predators, Aphidoletes larvae do not elicit aphid defences.



(Three Aphidoletes larva fight over a remaining aphid.)

Windspeed must be less than 2mph in order to get the greatest efficiency in predation. High windspeed make all winged-predators ineffective by making them unable to fly, or by disrupting their ability to smell and locate prey. Turn fans off when releasing Aphidoletes for a minimum of 6 hours.

Like most vermiform predators of the Diptera order, Aphidoletes are very susceptible to chemical applications.

Aphidoletes are not effective against low-temperature foxglove aphid, or on calibrachoa. Crops of intensely hairy plants often need increased Aphidoletes application rates.



Adult female Aphidoletes

Applying Aphidoletes

Shipping: Aphidoletes are shipped as pupae, with carefully measured moisture content. Do not open until time of release. Holding temperature is best at room temperature.

Quality Control: Wait 24 hours after adults emerge. Make an estimated count of emergence by utilizing the ribs of the tray as a grid-system.

Release: Fresh, unrefrigerated Aphidoletes have full search capabilities in tact. One release point per hectare is sufficient. Screw a pot to the north side of a central post. Ensure this spot is protected from water. 24 hours after adults began to emerge place the tray in the pot at dusk. Turn off greenhouse fans for at least 6 hours. Open the lid.



Alternatively, a hanging vial can be placed in a protected spot in the crop. The process of hanging opens the vial to emerging adults.

Scouting: At dusk, with fans off, look to see the adult midges flying in random patterns above the crop. 3-5 days after release, a microscope or hand-lens may be required to spot eggs or new larvae. At 5 to 7 days look to existing aphid colonies for Aphidoletes larvae. Aphidoletes often feed protected under their prey. Gently brush aside the aphids to reveal the Aphidoletes below.



Aphidoletes will turn yellow when feeding exclusively on whitefly scale.

Ants: Continuously monitor for and control ants. They will remove the Aphidoletes from aphid colonies.



Rates: Release rates vary. A typical prevention program entails a release of 250 A.a. per acre every week. Typically, to combat an infestation that rate is increased to 1000 A.a. per acre every week. In some out door crops, waiting for aphids to establish, then introducing 1000 A.a. per acre on-

time ensures a season-long cycling of predatory midges. Success depends on matching the release rate to the aphid population. Always aim for more in the beginning, so you need less in the end.

Aphidoletes At a Glance



Effective Temperature Range: **15C to 30C**



Eggs laid per female: **150-250** in one weeks



Egg to Adult: 1-2 weeks (**1 week as predatory larva**)



Aphids consumed per larva: **50-200 daily**



Trigger aphid defences: **No**

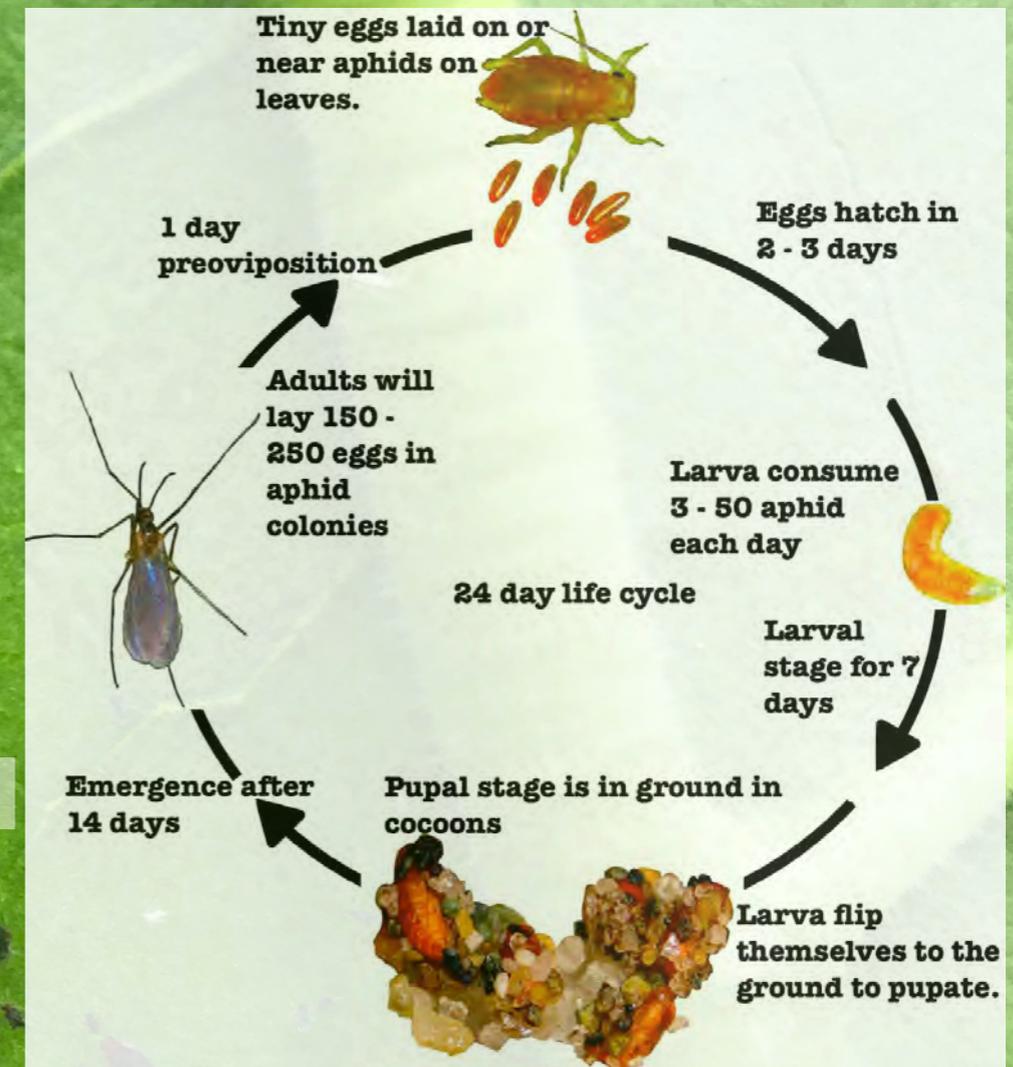


Known Predators: **Ants and swirskii**



Special precautions: Supplemental **light**; reduced **fan** speeds.

Targeted Pests and Species: Aphids (>60 different species) ; Whitefly scale



Prevention Rate:
250-1000 per acre every week.

Reactive Rate: 1,000 to 5,000 in two or more release points per acre once per week.

Micromus variegatus

Our brown lacewing, *Micromus variegatus*, is also a top aphid predator. Until now, brown lacewings have garnered little attention in North America. Part of this is due to the relative fame of its larger cousin - the green lacewing; but also because, being nocturnal, they are seldom seen.

What separates the brown lacewing from the green lacewing, and raises its stature among aphid predators to the liking of beetles and hoverflies is that it is a voracious predator both in the larval and adult stage.



The addition of *Micromus* to our program was intended to fill two important gaps: 1. To provide a hungry generalist (they eat aphids, scale, spider mites, leaf-hoppers, mealybugs and more) and 2. To provide a cold-season aphid predator for control in cool crops and target the foxglove aphid. The lacewing still actively hunts and feeds down to 4 degrees Celsius.

There are some applications where *Micromus* has been successfully used as the only aphid predator, but it still remains primarily a supplement to our *Aphidoletes* program. We have found *Micromus* persisting over a year in ornamental greenhouses where it presumably served as a low-density generalist.

With the successful application of *Micromus variegatus*, you get low-level pollination, a clean-up of honeydew, long-range searching ability, generalist predation, and extreme aphid predation.



Adult brown lacewing, *Micromus variegatus*.

Micromus variegatus lay eggs singularly near aphids. Larva emerge after 5-7 days and immediately begin consuming aphids and any soft-bodied prey by piercing and holding prey in their hollow mandibles and sucking them dry.



After two weeks as larvae, consuming hundreds of aphids, they take to the ground in protected leaf-litter or under pots to pupate. Adults emerge one week later.

Under the right circumstances, adults will live several weeks and lay over one hundred more eggs, typically lower in the canopy than other predators.

Larva of all lacewing species are cannibalistic when food is scarce or when densities are too high.

Applying Micromus

Shipping: Our brown lacewings are shipped as adults with a small amount of “bug food” for transit in quantities of 50 or 100. There is no “storage time” for Micromus. They must be released immediately after one hour of acclimatizing to release temperature. They are also available as eggs, ready to hatch into voracious larva.



Micromus weave a delicate cocoon

Quality Control: Micromus will “play dead” as a defence against predation. Expect to see many that appear dead in the bottle. 24 hours after release, slowly remove the packing paper, shaking any adults back into the container. Wait one more hour then count the dead. Packages are over-packed by 10 percent to account for some mortality.



Release on a hop vine

emergence. Reduce fan speeds to allow them to search for aphids. Because they are most active at night, this is the best time for low wind speeds.

Release: Egg application is easy. Simply drape the contents in an aphid hot spot and remove the media 3-7 days later. Adult lacewing are likely ready to release when they arrive. Find a protected area low in a canopy off the ground and remove the lid. Remove some of the packing from the bottle to ease adults’



Two Micromus variegatus larva fight for food.

Scouting: Micromus are attracted to lights at night. If aphid control is best in night-lighted areas, consider turning off the lights for



A captured aphid

more even spread. Adult populations can be seen when these lights are on. During the day, look for them under leaves. You may find larvae, but moving the leaf often results in the adults “playing dead” and dropping to the ground. Look up into the densest part of the canopy without touching the plants to find adults.

When hungry, adults and larva will also feed during the day. Their natural predators are birds, so the cast of a shadow from you walking-by or a spray-boom passing over the crop is often enough to make lacewings drop from the plant. While this may disrupt their feeding it is seldom enough to reduce efficacy.

Brown lacewing at a Glance



Effective Temperature Range: **4C to 30C**



Eggs laid per female: **100-200** in two or three weeks



Egg to Adult: 3-4 weeks (**2 weeks as predatory larva**)



Aphids consumed per larva: **5-200 daily**



Trigger aphid defences: **Yes**



Known Predators: **Birds**



Special precautions: Reduced **fan** speeds, especially at night.



Prevention Rate: 600 adults per hectare in spring.

Reactive Rate: 100 to 200 adults in a hotspot, once. Eggs are best for knock-down.

Targeted Pests

- **Aphids:**
- **Whitefly:**
- **Leaf hopper**
- **Small caterpillars**
- **Mealybugs**
- **Other soft-bodies prey**

Eupeodes americanus

Eupeodes americanus is the American Hoverfly. Known also as Flowerflies and syrphid flies, these flies are regular and welcome predators. Many species, including ours, feed only on pollen and nectar as adults, but it is the hoverfly larvae that consume aphid colonies.



Like Aphidoletes, hoverfly larvae are vermiform. This worm-like, or slug-like form has evolved to be undetectable to aphids. Thus the predation rate of *Eupeodes americanus* larvae out compete all other predators.

However, because of this intense feeding habit, many hoverflies establish naturally late in the season when aphid populations are at their peak. A preventative release of hoverflies does not guarantee they will cycle. As with our Brown Lacewing, the Hoverfly should only be used as a supplement to Aphidoletes for aphid control, unless under special circumstances.

Hoverfly species are the most likely candidates to have any effective aphid control in caliberchoa, and research continues. Hoverflies are also useful in crops requiring pollination that are subject to aphid infestations, such as peppers. In these crops, the hoverflies can pollinate and protect.

The adult hoverfly needs 5 days of feeding exclusively on pollen and nectar before they are ready to lay eggs. Some growers have taken to releasing the hoverflies in small cages with a potted alyssum and allowing them to feed for 5 days before opening the cage for them to fly out. Adults are oviposition-ready from that point until they die 2-3 weeks later.



An adult hoverfly, *Eupeodes americanus*

Hoverflies are strong fliers, but still require reduced windspeed to detect aphids. Eggs are laid singularly next to feeding aphids. The larvae emerge and begin feeding immediately for the next 7 days. In the last two days (their third instar) each larva will feed on over 100 aphids daily.



Eupeodes americanus is unlikely to pupate on plant material, but instead, burrow into the soil or pupate under pots. Pupation lasts approximately one week.

The release of hoverflies is a favourite for release and sale in garden centres, as customers recognize them as beneficial. They also serve as an excellent example for an alternative to the environmentally-harmful trade of wild ladybugs.

Applying Hoverflies

Shipping: *Eupeodes americanus* is shipped as pupa in moisture-controlled media in packages of 50, with an over-pack of 20%.



Quality Control: After all adults have emerged, sift out the puparium (pupa shells.) Successful emergence is demonstrated by an open and hollow puparium. There is regularly 10% that do not emerge.

Release: Ensure a source of nectar and pollen is present. If releasing into a small cage, simply open the lid as the first adults emerge. If releasing into a broad flowering crop, place a small cotton pad soaked with 50/50 honey and water inside the package and carefully close the lid. Wait another 24 hours before releasing. Males emerge first, so this process allows them to mate in the container (which occurs immediately after emergence).

Scouting: Adults are easy to spot tending to flowers. After 5 days, expect to see them hovering deep in the canopy looking for aphids. Hoverfly eggs look like tiny grains of rice and are laid on the undersides of leaves, most often near the edges. Larva feed heavily and then rest in mid-day. You most often find them resting on the



Hoverfly larva, third instar.

undersides of leaves, often in the protected areas alongside veins or tight leaf folds. Early instar larva are small and pale-coloured. It is often easier to scout 7-10 days after release, when third instar larvae are most likely.



Ants: Ants will actively defend against small larvae and carry-away exposed pupa. Always control ants.

The predation of aphids by the Hoverfly is fast and furious. But, maintaining a population of adults in a greenhouse is difficult. Without adequate nectar, adults will try to leave the greenhouse. Research continues on the best way to supplement cycling adult hoverflies.

Hoverfly at a Glance



Effective Temperature Range: **15C to 35C**



Eggs laid per female: **50-150** in three weeks



Egg to Adult: 16-17 days (**1 week as predatory larva**)



Aphids consumed per larva: **70-100 daily**



Trigger aphid defences: **No**



Known Predators: **Spiders, Ants, birds**



Special precautions: **Provide nectar-heavy flowering plants.**

Prevention Rate: 200 per hectare 3 times, 2 weeks apart in spring.

Reactive Rate: 500 to 1000 per acre one time.

Targeted Pests

- All aphid species, particularly in flowering crops.



CHAPTER 3

Whitefly Control



Ch.3

Whitefly Control

Whitefly are a concern in a wide variety of ornamental and agricultural crops. The relative invisibility of eggs and early-instars allow populations to grow unnoticed.

Two of the most common pests, the greenhouse whitefly and *Bemisia* have now obtained a problematic level of chemical resistance. The cosmetic damage and the promotion of plant pathogens caused by whitefly must now be controlled by their natural predators by preventing large populations from establishing.

Our formula for success in managing whitefly is the most financially efficient strategy available to growers. No truer is the phrase “an ounce of prevention is worth a pound of cure” than in the case of whitefly control. As with all beneficials, the freshness and fitness that comes from no storage and no refrigeration is absolutely essential for whitefly management. The greater range, predation and searching ability that comes with premium products allows for quicker results, fewer release points, and reduced application rates.

Whitefly populations grow rapidly. Prevention of whitefly means starting a bio-control program before you notice whiteflies in your crops and sticking with the program throughout the season.

If you have already noticed whitefly in your crops, then you must move to a reactive bio-control program.

Both preventative and reactive programs use two essential bio-controls: *Encarsia formosa* and *Delphastus catalinae*. Two additional predators are effective as generalists and consume whitefly scale: *Neoseiulus cucumeris* and *Aphidoletes aphidimyza*. They are discussed in more detail elsewhere in this booklet.

Whitefly

The background of the entire page is a close-up photograph of several whiteflies on a green leaf. The whiteflies are small, with two pairs of white wings and a yellowish-brown body. They are scattered across the leaf, some appearing to be feeding or moving. The leaf's texture and veins are visible, providing a naturalistic setting for the insects.

Whitefly larva are soft scales that are fixed after a very short, quasi-mobile stage. Both adults and larva feed on plant phloem and secrete honeydew as a waste-product. Bemisia use their honeydew as a defence against predation by producing dense areas of sticky honeydew.

An adult female whitefly will lay hundreds of eggs that will emerge into new adults just over two weeks later. Whitefly will most often be found on the undersides of leaves and sometimes go unnoticed.

Screened air in-takes and entrances restrict some whitefly species from entering greenhouses. However, most are established by bringing-in contaminated plant material. Dipping cuttings, quarantining new plants or refusing heavily-sprayed or contaminated plants will reduce occurrence.

Encarsia formosa

Encarsia formosa is our primary whitefly control. It can be used both preventatively and as a reaction to increased whitefly pressure.

Encarsia is a tiny parasitic wasp. Its population at any given point is close to 99% female, which, alone, makes it the best choice for whitefly parasitism. Each female will parasitize 5 and consume 3 whitefly scales each day. Eggs are laid inside developing whitefly scale and emerge two weeks later.

Encarsia prefer to parasitize late-instar whitefly. While all instars can be parasitized, the fitness and survival of adults is greatly increased when developed inside the third-instar. For this reason, small amounts of Encarsia released weekly is the best model for prevention.



Freshness is essential for parasitoids. Long or cold-stored Encarsia lose their ability to discriminate between scale-instars. Furthermore, the distance from release points that adults will fly to find whitefly is reduced to several feet because storage removes their ability to search.

Encarsia should not be mixed with other whitefly parasites, as each species will interfere with the other's parasitism. Only in extremely fast growing crops where different leaves will have different instar whiteflies is a mixture effective - but it is still more efficient to use only Encarsia: taking advantage of a reduced release rate.



An adult *Encarsia formosa* parasitizing a whitefly scale

Encarsia formosa are subtropical. They respond best to intense light and warm temperatures. When provided fresh, Encarsia's temperature range is increased from 10 Celsius well into the high 30s allowing for both mid-summer whitefly control and cool, late-season crops like poinsettias.

While Encarsia formosa is traditionally associated with greenhouse whitefly, recent studies have proven that fresh Encarsia is also the parasitoid most suitable for control of Bemisia or silver-winged whitefly.

As with all winged-insects, fan speed must be reduced to less than 2 mph for optimum conditions. Encarsia formosa is small and a weak flier. Ideal searching and mobility occurs when the air is still. Low fan speed also tends to increase humidity at the canopy level, which these wasps prefer.

Applying Encarsia

Shipping: Encarsia formosa are sold as pupae. As they are small, they are shipped either in bulk, or stuck to cards to be hung in the crop to await emergence. Each card is advertised as 100 pupae, but will have close to 125. Cards are sold as a pack of 10, for an advertised total of 1,000. Shipments are not permitted to drop below 8 degrees Celsius and will therefore be vented in warm weather and insulated in cold weather.



Quality Control: Simply collect a card after adults have emerged. Ants may consume the pupae or the puparium so select a card that was kept from ants. With a microscope or hand lens, count the puparium with exit holes to ensure the target of 100 have emerged.

Release: Cards are designed to hang in a crop for easy dispersal. They may also be hung anywhere that is protected from direct sunlight, water and ants. Avoid attaching the card to a stem that has honeydew to avoid detection by ants. Successful prevention programs have been achieved at a release rate of 0.25 / m² (1000 per acre) every week, but the most common prevention rate is 1-2/ m². This rate changes significantly when whitefly are present, with rates as high as 8/m² used. Once again, prevention is not only most effective, but also most efficient.

Scouting: Scouting for Encarsia is satisfying. Simply look for whitefly scale that have turned black. Up to five days before emergence the scale will start to turn black. Before that, use a hand



lens to examine other scale. Prior to turning black, parasitized scale will develop two red "eyes." Often the unparasitized whitefly around a blackened scale will actually be parasitized, but are less developed. Due to size, the adults Encarsia are often difficult to see, but with practice the tiny yellow abdomens will stand-out on the undersides of leaves.



Ants: Once again, ants are problematic, as they may eat Encarsia pupae, although this is not common when other food is around. Encarsia adults will avoid leaves with ants present, so controlling them is an important step in your whitefly control program.

Encarsia at a Glance

Prevention Rate: 0.25 to 2 per m² per week.

Reactive Rate: 4 to 8 per m² per week.



Effective Temperature Range: 10C to 40C



Eggs laid per female: 5 per day



Egg to Adult: 21 days



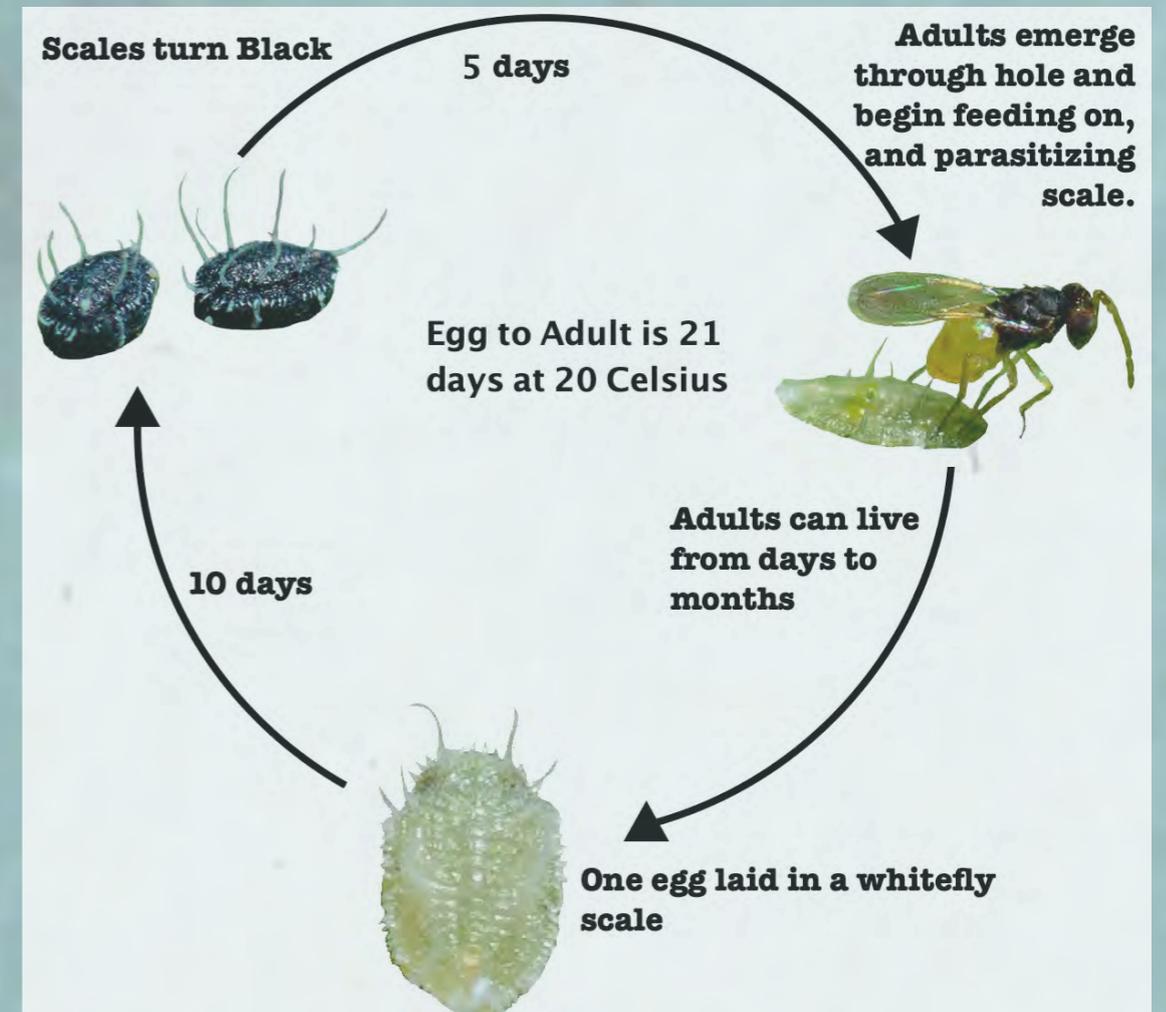
Whitefly killed per adult: 8 daily



Known Predators: Ants



Special precautions: Reduce fan speeds; maintain >70% Rh



Targeted Pests

- Greenhouse whitefly
- Bemisia (silverleaf/sweet potato) whitefly.



Delphastus catalinae

Delphastus catalinae is a small beetle that primarily consumes most species of whitefly. It will eat all life-stages of whitefly with preference in order from eggs to adults. Delphastus adults and their larva prey on whitefly, living their entire life-cycle on the host plant. Eggs are tiny and laid near egg-laying whitefly adults. The larva emerge feeding on the whitefly eggs and scale for 2 weeks before pupating in protected areas on the other side of leaves.



Delphastus is a favourite for growers because of the ease with which they can clean-up and find hotspots. However, because of their need to eat so much, many believed Delphastus was not suitable as a preventative. We have since found the opposite. Both the highly-mobile larva and flying adult stages will survive several weeks searching

for food. Therefore, a level of whitefly prevention can be achieved with a small number of Delphastus.

One grower, having achieved whitefly control with Delphastus, but rarely seeing them, set out to record by mapping any sighting of Delphastus and all hotspots of whitefly. After compiling the data, she found that the sightings of Delphastus were in the same spots that whitefly populations were found a week later. They were feeding on the eggs, but not all of them (as is the behaviour of most Coccinellidae) . She then supplemented with a small amount of Encarsia to further reduce, but not eliminate the whitefly.



Adult female *Delphastus catalinae*

Finding that balance between predator and prey is ideal, but not essential. Most Delphastus applications will match the whitefly potential and eradicate the food source....temporarily. It is then essential to return to, or begin the preventative Encarsia program to prevent further establishment. If Delphastus is the preferred control, then multiple applications should be made with small amounts 2 weeks apart.

Delphastus were first observed and collected in Florida on their native host: Bemisia. Like many tropical/subtropical predators they do not respond to variations in light and temperature. While extremes are harmful, and can inhibit their efficacy, they are practically suitable for any greenhouse application.

Applying Delphastus

Shipping: Delphastus are shipped as adult beetles available in 100 or 1,000 quantities. Both will be overpacked to allow for any natural mortality. The package is a plastic vial with shredded paper for surface area and absorbing condensation.

Quality Control: Inspect the container. Some adults will have died in transit and will be at the bottom. Condensation is formed with temperature changes during transit, but there should not be enough for pooling of water in the vial. After a normal release, re-collect the vial and count any dead adults. There should be no more than approximately 10% mortality.



Release: Allow to gently acclimatize to the release environment. Reduce fan speed and open the lid in a protected, central area, away from direct light or water. Wait an hour, then return and gently tease out the shredded paper, knocking any adults back

into the vial. Some growers leave the paper as indication of release point. After 24 hours, remove the vial for quality control check or leave it as indication of date and place of release.

Scouting: Adults will spread out, graze on whitefly eggs, lay their own and fly to the next egg-laying adult whitefly. This habit along with the low numbers needed for control, the translucent larva and tiny eggs, makes Delphastus famously difficult to scout. If a whitefly



hotspot persists for a week, it is a likely place to see Delphastus in action, otherwise it is most often by chance. But, as scouting for whitefly requires inspecting large numbers of plants in many areas of the greenhouse, the scouting for Delphastus will be done at the



same time. Just keep in mind, the beetles are small and quick to fly, so only gentle handling of the plant will lead to successful scouting. Delphastus eggs are laid in small groups, usually oval, and slightly yellowish.

Delphastus at a Glance



Effective Temperature Range: **5 C to 40 C**



Eggs laid per female: **2-6 per day (over 300 in life time)**



Egg to Adult: **21-25 days (7-10 days as larva)**



Whitefly consumed: **10,000 eggs or 700 scale in lifetime.**



Known Predators: **Cannibalistic with no prey.**



Special precautions: Reduced **fan** speeds for searching.

Prevention Rate: 200 per acre every two weeks

Reactive Rate: 100 per hot spot or 10 per infected plant.

Targeted Pests

- Bemisia (Silverleaf, Sweet Potato whitefly)
- Most species of Whitefly:
- Can survive on spider mite and other invertebrates.

Aphidoletes At a Glance (For Whitefly)



Effective Temperature Range: **15 C to 35 C**



Eggs laid per female: **150-250** in two weeks



Egg to Adult: 1-2 weeks (**1 week as predatory larva**)



Whitefly scale consumed per larva: **30-50 daily**



Known Predators: **Ants**



Special precautions: Supplemental **light**; reduced **fan** speeds.

Prevention Rate: Only used to knock-back established whitefly

Reactive Rate: 5,000 in two or more release points per hectare once per week.

Targeted Pests and Species:

- Aphids: >60 different species
- Whitefly:

See chapter 1 (Aphid Control) for more on Aphidoletes.

CHAPTER 4

Spider Mite Control



Ch.4

Spider mite Control

Spider mite is a term used to describe a variety of plant-feeding mites. While there are several commercially-significant spider mites, the term "spider mite" almost always refers to the Two-Spotted Spider Mite (*Tetranychus urticae*). This document will use "spider mite" when referring to *Tetranychus urticae* unless otherwise specified.

Spider mite feed on plant tissue by piercing the cells. The toxin they produce causes permanent damage to plant tissues with immediate reduction in crop value for ornamentals. Other growers may be more lenient towards spider mite populations, but all know that spider mite will eventually kill plants.

Spider mites have been getting progressively worse year after year because of increasing chemical resistance, and more efficient watering techniques that minimize usage and often never get foliage wet.

Spider mites simply do not like moisture and humidity. Their webbing acts to protect them from predators as well as keep them off the more humid surface of the leaves. The single greatest control technique for spider mite is misting, or otherwise wetting plant leaves continuously over several days.

In some cases, 4 days of being wet results in a naturally-occurring fungus within the gut of spider mite to bloom, thus rupturing spider mites from the inside-out. In other cases, the moisture causes the same fungus to kill them more slowly, and it generally inhibits their movement and reproduction. Furthermore, all commercially available predatory mites, many of which are used for spider mite control, show greater success with increased humidity.

Relative humidity (Rh) is of great concern for growers, but for beneficial insects and mites we have to consider both the Rh of the entire greenhouse and of that within the canopy. While we don't expect this to be measured, it must be understood that healthy plants produce higher humidity on and around their leaves. The surface of damaged plant tissue can often have a lower Rh than the rest of the plant (during the day.) Spider mite will quickly dry out your plant, causing other stresses. Some predators may even recognize a plant that will not survive and will pass over it, to lay eggs in more favourable areas. Prevention is key.

Spider Mite

On most crops, spider mite damage is immediate. Use a potted bean plant to both "sponge-out" spider mite ahead of planting a crop and as a monitoring tool.

Female spider mite will lay 14 eggs each day on average, with that rate decreasing with age. Egg to oviposition-ready adult is only 5 days, so expect populations to increase dramatically.

Winter clean-out should be done with the application of *Stratiolaelaps scimitus* into the building foundation. There, they will predate on over-wintering spider mite and alleviate the pressure next season. See chapter 5 for more.

Spider mites prefer fresh plant tissue. They spread-out more quickly than one might think. Always treat a spider mite hotspot by treating all plants adjacent to the observed spider mite.

Neoseiulus fallacis

Neoseiulus fallacis is a cornerstone product at Applied Bio-Nomics. Our variety shows a preference to spider mite but control is best at low densities of spider mite. Thus, we use it exclusively as a spider mite prevention. Because of its generalist feeding habits, small size and ease crossing non-plant surfaces to find food, we have found a successful preventative application rate can be as low as 2 mites per square meter.

The key to this strategy is small plants. We recommend applying fallacis right after sticking a cutting, or as soon as the first true leaves have appeared after germination. A low application rate is suited for the small amount of surface area, and their population will grow to suit the larger plants.



Fallacis was discovered in Ontario and can survive harsh winters. Field applications are typically done once for the life of the crop, although some growers opt to apply lesser quantities and repeat it in consecutive years. Extreme temperatures do not impede fallacis and it will out-perform and displace other predatory mites at low temperatures.

If applying to larger plants, consider the rate to be in volume: 2 mites per cubic meter.

Fallacis populations develop quickly. It can take 7 days from egg to adult in many greenhouse applications, but that time is shortened to 3 days at 32C. At a typical 26C, fallacis will increase their population 4 times in 4 days. Adults will live anywhere from two weeks to two months, and lay



Neoseiulus fallacis adults

1-5 eggs daily during that time. Adults feed on all stages of prey and will consume 2-16 spider mite each day.

Because of its northern native range, fallacis will enter a diapause when day length shortens towards the winter months. However, this diapause is also triggered by temperature, and studies have found greenhouses kept above 18C will prevent fallacis diapause independent of light.

There is seldom a situation where we don't introduce fallacis and expect it to be the work-horse of the bio-control program. Whether or not your crop is susceptible to spider mite, start all plants with the smallest application of fallacis. For the life of that plant, fallacis will continue to protect against infestations of any mites, and help control most other small plant pests.

Applying fallacis

Shipping: Fallacis is available in two forms; a vial of vermiculite supplemented with pollen in quantities of 500 and 1000; or on bean-leaves supplemented with spider mite in quantities of 1250 and 2500. Vermiculite products are best for broadcasting over small plants. Bean-leaves are best for placing directly onto established plants. The spider mites present in the bean-leaves will not contribute to the spider mite infestation. Fallacis will eat all the packaged spider mite and more shortly after release.



Quality Control: After unpacking, keep a vial of vermiculite upright for several minutes. Inspect (a hand lens might be needed) the inside of the vial above the level of carrier. Ensure there are active adults. Also, after several minutes you could remove the lid and check the underside for active adults. This is best done near the application point, as the fallacis will quickly escape. For the leaf-product, use a hand lens or microscope to check for active adults, nymphs, eggs and spider mite. Numbers vary leaf to leaf.

Release: Very gently rotate the vials of vermiculite to thoroughly mix the adults into the media. Then sprinkle amongst the crop. Mixing it with a greater amount of carrying media may help disperse. For leaf-products, simply remove a leaf and place it on an established plant. If plants are small or a smaller release rate is preferable, divide the leaves by tearing into thirds and place each piece on a plant. If fallacis is not established before you find spider mite, a release of fallacis and persimilis simultaneously is



recommended. Most field crop application rates are 10,000 per acre. Indoors, 2 per m² is sufficient.



Scouting: Adults are half a millimetre long, translucent and tan, which makes them difficult to scout. Furthermore, they tend to hide in tight folds along ribs or under plant hairs. Use a 10-15x hand lens to inspect the crop. Locate your spider mite, then look in surrounding areas for the adults.

Eggs are 0.3mm in length and often hidden in the same areas. They can be distinguished from spider mite eggs, as they are more oval and slightly larger.

Fallacis at a Glance

Prevention Rate: 2 /m2
at earliest vegetative
stage.

Reactive Rate: Not
typically cost efficient.



Optimum Temperature Range: 9C to 32C



Eggs laid per female: 1-5 per day (26-60 in life time)



Egg to Adult: 7 days



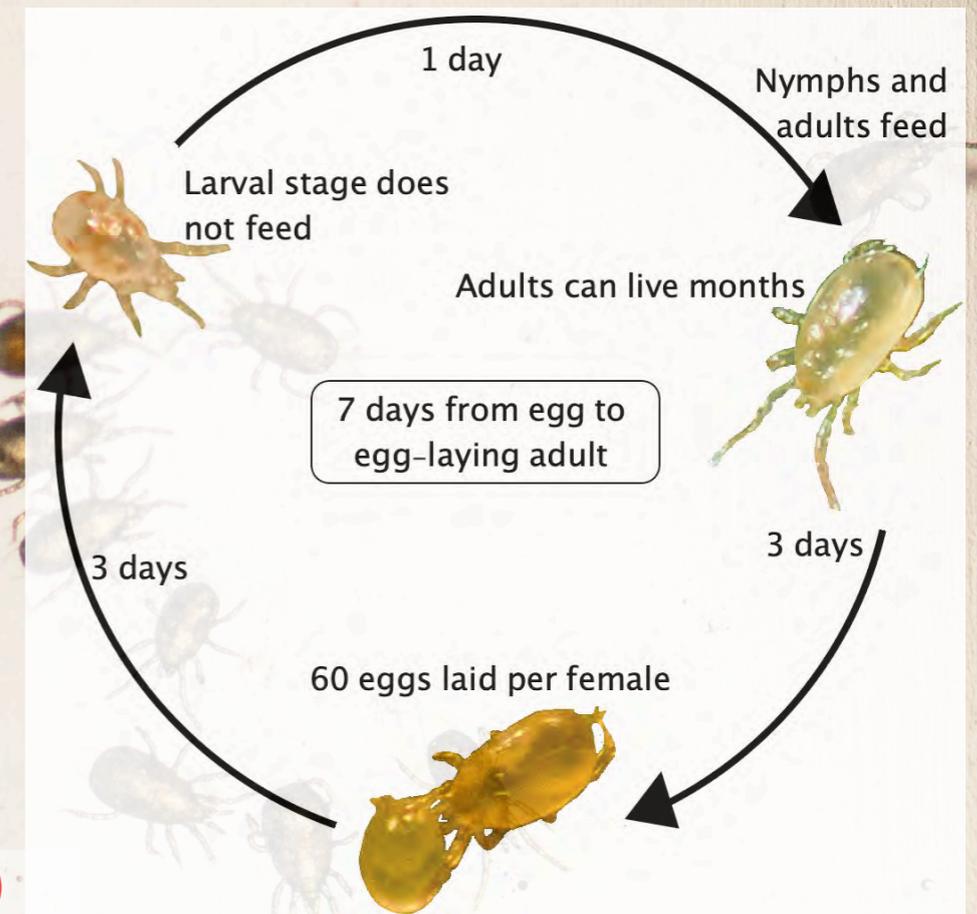
Spider mite killed per adult: 2 - 16 daily



Negative Factors: Fallacis will not control spider mite
where **webbing** is established.



Special precautions: Successful egg laying corresponds
positively with **increased humidity**.



Targeted Pests

- Spider Mite
- Bamboo Mite
- Generalist predation of most mites, including cyclamen, broad mites, and other soft bodied pests, like thrips.

Stethorus punctillum

Stethorus punctillum is quickly becoming the industry standard for spider mite control. It is far more successful than predatory mites in many applications because of its resilience to temperature and humidity ranges. When air movement is reduced, the winged adults search by smell and can detect spider mite colonies anywhere in a greenhouse from a central release point per acre or more. *Stethorus* replaces much of the scouting time finding spider mite hot spots and applying the control.



An early study demonstrated that *Stethorus* was unsuitable as a spider mite prevention because each adult needs to consume 20-40 spider mite daily to lay eggs. But follow-up studies found that adults may live up to two years feeding only when spider mite are available and laying eggs only when they can. Therefore, we have found

Stethorus establishing in crops like peppers at very low densities, and being found wherever spider mites momentarily establish. For this reason, *Stethorus* is used both preventatively and as an efficient reactive control.

Females lay 3 - 13 eggs daily. Eggs hatch within one week and the larva emerge and prey on spider mite consuming 240 spider mite in 10 to 14 days, prior to pupation. Pupation lasts 7 days, and emerged adults may live up to two years.



Adult female *Stethorus punctillum*

Stethorus are perfectly adapted to feed on spider mite. The beetles do not hesitate to walk along spider mite webbing to feed on adults, and even the driest, upper-most infestations are suitable for adult *Stethorus*.

Stethorus are native to Canada and most active in brighter months. A pepper grower in the lower mainland of BC had an established *Stethorus* population one year and found them migrating back into his greenhouse from surrounding areas the next year.

Applying Stethorus

Shipping: Stethorus are shipped as adults in bottles of 50 or 100. Each is packed with shredded paper for moisture control and surface area.

Quality Control: Condensation within the bottles will drown the adults. When receiving your package, ensure it was not damaged or subject to extreme temperature changes. Likewise, allow the Stethorus bottles to gently acclimatize to release temperature. This may take hours. Quickly unpacking the beneficials may result in a rapid temperature change (cool box to warm office, or warm box to



cool receiving area) and this may increase mortality. Mortality rate is determined by the adults that remain in the bottle 24 hour after release - do not rush this measurement, as

Stethorus “play dead” and will not move when disturbed. However, gently blowing on them usually wakes them up. Expect no more than 10% mortality.

Release: Once the bottle has acclimatized, reduce air-speed in your greenhouse and simply open the bottle. For hot-spot control, gently shake some adults out into the desired locations or just place the open bottle in a dry, protected place. Preventatively, simply open the bottle in a central location per acre.



Scouting: Regular scouting will turn-up a spider mite location. Shortly after a release of Stethorus, these spider mite locations will have some sign of Stethorus. You may see the adult (1.5 mm long, all black, with brown legs, face and antenna) or larva (grey, long and thin) or eggs, (yellowish, laid individually.) When spider mite populations are high-enough, the adults will graze, eating enough to lay eggs amongst the reduced spider mite population and then fly off in search of a new spider mite area. Because they fly off, adult Stethorus may be difficult to locate in the first 3 weeks after release and one should use a hand lens to look for eggs. Following the emergence of the next generation, you’ll likely find adults and all stages of Stethorus on the same plants where spider mite are present.

Stethorus at a Glance



Optimum Temperature Range: **16 - 35 Celsius**



Eggs laid per female: **3 - 13 per day (over 1000 in their two year life span)**



Egg to Adult: **21 - 28 days**



Spider mite consumed: **20 - 50 per day**



Known Predators: **Cannibalistic with no prey.**



Special precautions: Reduced **fan** speeds for searching.

Prevention Rate: 100 per acre

Reactive Rate: 100 to 200 per hot spot or 10 per infected plant weekly for 3-4 weeks.

Targeted Pests

- Two spotted spider mite
- Many other spider mites, like red mites and spruce mites.



Phytoseiulus persimilis

Phytoseiulus persimilis has been the primary spider mite control for decades. It eats only Two-spotted spider mite (TSSM) and will eat every last one. Under ideal conditions, persimilis simply out-run spider mite by literally running faster than them, but also with a reproductive rate and feeding rate with which spider mite will not keep up.

This is also a favourite for many growers because when a plant is clean of spider mite, persimilis will gather at the highest point on the plant. This makes it easy to see how well they established, and it also give peace-of-mind that there is not a single spider mite or egg left on that plant.



However, persimilis will not often leave a plant for another. The collection at the upper most tips of the plants is their natural way of dispersal: by climbing on one another, activating a differential in magnetic field, levitating and then being carried off in the breeze. Therefore, the application of persimilis must be directly on any

plant needing spider mite control.

Persimilis may not be used as a preventative when no spider mite are present. They will quickly leave or starve when no TSSM are present. Even though they will eat some whitefly eggs, they cannot survive without TSSM.

Persimilis eggs hatch in two to three days and spend the same time in their nymph stage. After approximately 5 days they become adults that are immediately able to lay eggs, and will lay 2-5 eggs each day. Adults



An adult *Phytoseiulus persimilis*

may live a month laying up to 60 eggs, but the daily rate decreases with age.

Because persimilis are tropical, they have no diapause tendencies related to light or temperature. While they become slower in low light and low temperatures (and spider mite will have the advantage as the 5 day life cycle of persimilis is lengthened to 25 days at just 15C), persimilis will persist in a greenhouse until they freeze to death or take shelter in more humid, cooler locations during extreme heat.

Persimilis is tried and tested. When it does not control spider mite, it is outside of its effective temperature range, or there is chemical residue or another limiting factor.

Applying persimilis

Shipping: Persimilis is available in two forms; in a vial of vermiculite, in quantities of 1,000, 2,000 and 10,000 with an alternative packaging of 2,000 called a "Hot Spot" that has less carrier; or on bean leaves, supplemented with spider mite in quantities of 1,000 and 3,000. Vermiculite products are best for broadcasting over small plants. Bean leaves are best for placing directly onto established plants. The spider mite present in the bean-leaves will not contribute to the spider mite infestation. Persimilis will eat all packaged spider mite and more shortly after release.



Quality Control: After unpacking, keep a vial of vermiculite upright for several minutes. Inspect the inside of the vial above the level of carrier. Ensure there are active adults. After several minutes you could remove the lid and check the underside for active adults. This is best done near the application point, as the

persimilis will quickly escape. For the leaf-product, use a hand lens or microscope to check for active adults, nymphs, eggs and spider mite.

Release: Very gently rotate the vials of vermiculite to thoroughly mix the adults into the media, then sprinkle amongst the crop. Mixing it with a greater amount of carrying media may help disperse. For leaf products, simply remove a leaf and place it on an infected plant and all plants directly around the infected one, even if they are not touching. If plants are small or a smaller release rate



is preferable, divide the leaves by tearing into thirds and place each piece on a plant. Persimilis is applied only when spider mite are present.



Scouting: Eggs are 0.3mm, slightly oval and bigger than TSSM eggs. Nymphs are translucent and cream coloured whereas adults are bigger and orange, turning opaque reddish orange when pregnant. They are easy to distinguish from TSSM because they will be moving faster. When feeding, persimilis are motionless and usually found on the undersides of leaves. They are distinguished from the prey by colour, although some TSSM can turn red

with age or in winter.

Persimilis at a Glance



Effective Temperature Range: **5C to 35C**



Eggs laid per female: **2-3 per day** (60 in 35 day lifetime)



Egg to Adult: **5 days at 30C**



Spider mite killed per adult: **5-30 daily**



Known Predators: **Swirskii**



Special precautions: **Wait for any chemical residues to wear-off before application.**

Prevention Rate: n/a

Reactive Rate: 5 mites per m², weekly, until control is gained.

Targeted Pests

- Two spotted Spider Mite

CHAPTER 5

Thrips Control



Ch.5

Thrips Control

There are three main reasons why thrips are quickly becoming one of the top pests for growers in North America: 1.) The loss of natural habitat inhibits natural thrips predation. Large monocultures and an overall reduction in large trees cause thrips populations to explode. Thrips are then carried easily to adjacent areas by the wind. 2.) Onion thrips (which can be controlled relatively easily with chemical applications) are nearly identical to the Western Flower Thrips which have near-immunity to chemical interventions. The two species are often misidentified, leading to application of improper control techniques. 3.) Many thrips spend one or multiple life stages protected from predation within the soil and within the plant tissues itself.

There is no perfect Thrips preventative biocontrol agent. Thrips most commonly arrive in droves, carried by wind often in periods of atmospheric convection. A grower could try to maintain high-enough populations of predators within the greenhouse to await their arrival, but it is less expensive and equally effective to simply monitor and react with *Neoseiulus cucumeris* within three days of their arrival.

Monitoring and trapping is an essential part of thrips control. Use yellow sticky cards or tape below benches and along the ground. (Thrips do not fly, but rather tumble along the ground and “hop” up to your plants.) Supplement some sticky cards with floral extracts on cotton balls like peppermint, vanilla or almond and rotate these frequently to enhance trapping. Extract can also be dripped into a bucket of soapy water to trap and monitor. Favourable flowers like yellow “pom-pom” marigolds should be placed near entranceways and “tapped” regularly to check for thrips numbers.

When an influx of thrips is occurring eggs are being laid inside the plant tissue. Cucumeris applied within the next three days will sense the emerging larva and eat them as they appear. One must then disrupt their life cycle further with an application of *Stratiolaelaps scimitus* or *Gaeolaelaps gillespiei* to the soil media or ground to feed upon pupating thrips.

Care should be taken to provide wind breaks to the windward or air intake side of a greenhouse, and thrips screens should be placed on all openings.

Thrips control is multi-faceted, but effective and inexpensive.

Thrips

Eggs are laid within plant tissue. In only a few days they begin to emerge. It is at this time they are most susceptible to predation.

Larva and adults feed on plant tissue but as they grow they are more able to defend against predators.

Larva drop to the soil to pupate. Here they are susceptible to in-soil predatory mites.

Adults use their feather-like wings to reach variations in electromagnetic fields allowing them to levitate during atmospheric convection. They are then carried by the wind to greener pastures, and your crop.

A bucket of soapy water with the addition of a few drops of a common floral or baking extract will attract and kill thrips. Try it out with a bucket under a bench of flowers.

Try the same extracts on cotton balls stuck to yellow sticky tape or cards to increase trapping. Vanilla, almond, peppermint, rosemary and some perfumes will work, but scents must be rotated to remain effective.

Neoseiulus cucumeris

Neoseiulus cucumeris is the industry standard for thrips control. While some predators are more specific to thrips, the exponentially lower cost of cucumeris means dollar-for-dollar nothing compares.

Cucumeris is a generalist predator. It will feed on spider mites, and successfully reduce whitefly populations, it controls broad mites, straw mites and many other tiny pests. Its thrips predation is specialized in that it detects when first instar larva are about to emerge from plant tissue, then wait and feed on it as it pops its head out. They will also run down and feed on second-instar thrips.



Typically, cucumeris will run out of food and begin to disperse more quickly than some other generalist mites. Because of this, we employ slow-release sachets. The sachet is specially formulated to produce and release cucumeris over a 6 week period. This continual release is one of two methods - the other being inundation - to control thrips. As mentioned in the chapter introduction, thrips most commonly infest a greenhouse in waves,

with hundreds of thousands entering the house at once. Sparsely-populated cucumeris applied earlier in the season, (and any predator for that reason) will have a hard-time keeping up. So our slow release cucumeris allows for constant protection from arriving thrips and the inundation of cucumeris is a large release at the first sign of trouble. Both strategies are effective and cost-efficient.

Cucumeris and Fallacis are closely related, and when applied alone as a generalist predator we find they have different strategies or roles. It



Neoseiulus cucumeris adults

seems both have preferences in regard to plant texture or other cues. It is also worth noting that nearly all of the commercially available foliar mites are generalists to some degree. The same study that claims Swirskii is a whitefly predator also found that all the tested mites will prey on whitefly, even the extremely TSSM-specific persimilis. As a generalist mite, it is worth finding which works best for your crop, but one should always begin trialing with cucumeris as it is a fraction of the price of the others.



Applying cucumeris

Shipping: Cucumeris will be shipped as a mix of all life stages in a bran-based carrier with a concentration of 50,000 per litre.

Packages include: A 1/2L pouch; 1L recyclable plastic bottle; 1L compostable pouch; 5L bag; 10L bag; sachet of 1,000; and a slow-release sachet. They are packed with residual food and can be maintained in packaging at 10 Celsius for up to 7 days.

Quality Control: It is challenging to properly check for cucumeris.



Use a 10-15x hand lens and inspect clear packaging for the mobile adults (they are relatively fast). Taking one ml samples, sterilizing in 70% alcohol and counting the concentration is appropriate as long as enough samples are taken to make the observations statistically relevant. (3-5 minimum).

Release: Gently rotate the tube or mix the media in bags and pouches then pour at the base of plants or sprinkle over the canopy. (Care should be taken to rinse or blow-off the bran from leaves the next day). Sachets should be employed on every 5 plants, weekly. The slow release sachets will generate 5,000 mites, on average, over a 6 week period. 500 mites per m² is a standard release rate, but it is sometimes better to calculate the need per plant. Rates of 10 mites per plant all the way to 100 per plant are employed based on the size and type of plants.

Scouting: Cucumeris adults are translucent, cream-coloured, pear shaped and less than 0.5mm in length. They are difficult to spot.



Use a hand lens and look under leaves along ribs, and veins to see adults. Eggs are round, transparent and 0.14mm in diameter.



Cucumeris adults live around 30 days and spend 3 days as egg and 7 as nymph. Adults and late-stage nymphs will feed on one or more thrips/day or several other pest eggs.

Cucumeris at a Glance



Effective Temperature Range: **12C to 35C**



Eggs laid per female: **1-3 eggs daily**



Egg to Adult: **10-12 days**



Thrips consumed per day: **1-2 (and other prey)**



Known Predators: **Dalotia may get into the sachets**



Special precautions: When controlling spider mite, allow your spider mite predators to establish before the addition of cucumeris as they will eat enough spider mite eggs to interfere.

Prevention Rate: 10-100 per plant weekly or one sachet for every 5 plants.

Reactive Rate: 500-1000 per m²

Targeted Pests and Species:

- Thrips
- Whitefly scale, broad mites, cyclamen mites, spider mite eggs, and more.

THIRIPS ELIMINATOR
Neoseiulus cucumeris
These mites are present in the sachet liner to distribute the mites.
www.appliedbio.com
Applied Bio-Nomics Ltd.,
DO NOT C

Fungus Gnat and Soil Pest Control

Stratiolaelaps scimitus

25,000
1 LITRE



PREDATORY SOIL MITE
Stratiolaelaps scimitus (Womersley)

Feeds on fungus gnats, thrips and other small soil organisms.

Contains a minimum of 25,000 predatory mites (all stages) in one litre of peat carrier. Distribute carrier around the root zone of plants at a rate of 125 - 250 predators (5-10 ml) per square metre.

Please see appliedbio-nomics.com for detailed use and application.



HOLD AT ROOM TEMPERATURE
DO NOT CHILL

Applied Bio-Nomics Ltd., North Saanich, B.C., Canada
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Ch.6

Fungus Gnat and Soil Pest Control

This final chapter, ironically, is where most bio-control programs must begin: in the soil. Most in-soil plant pests feed on the smallest filaments of plant roots. While plants can tolerate certain amounts of root damage, they cannot grow at the same rate as a plant without root damage. We have found the application of one or more of our in-soil bio control agents result is more vigorous plant growth.

Many in-soil plant pests do not spend their entire life cycle underground. In fact, many, like beetles, aphids and gnats have winged stages that allow them to spread over great distances. This also makes them important vectors of plant pathogens.

Thus, all bio-control programs must start with a preventative release of an in-soil predatory mite and all infestations must be met with high densities of those mites or our rove beetle.

This chapter will introduce *Dalotia coriaria*, our rove beetle and our two in-soil predatory mites, *Stratiolaelaps* and *Gaeolaelaps*. These mites are so similar that they were once believed to be the same and, later, studies were conducted on one believing it was the other. What we have discovered since, however, is that both behave in different ways, prefer different soil structures,

and while they may control the same pests, the order in which they will control them differs.

Some root pests, like Rice Root Aphid can only be effectively controlled through prevention. As they discover your plant they are easily found and fed upon, but once established, no bio control has been able to keep up with the infestation.

All three of the controls presented are native to North America. Outdoor applications show lasting results with populations remaining well after 20 years. Only *Dalotia* is likely to leave to maintain its preferable low-density, but can be found years after application especially in wet or very loose soil media.

Unlike nematodes, these predators require no special preparation, no specific soil temperature, or time of year, and do not need direct contact with the prey. Some can live months without food and after one application the mite colony will stay with your plant for the plant's entire life.

Fungus Gnats and Soil Pests



A classic soil pest is a winged or "above-ground" adult that lays eggs in the crowns of plants so the larva can emerge and feed upon roots. Often these are susceptible to predation only immediately after hatching.

Some soil pests live entirely underground. While they may always be present to some degree, predation usually occurs regularly, so they never get out of control.

The control of soil pests like fungus gnats improves the health and size of your plants and limits the vectoring of plant pathogens.

Artificial or non-traditional soil or rooting media often favour the pests rather than the predators. When using these media, be sure to test out the various predators available to see which work best.

Stratiolaelaps scimitus

Like *Fallaxis*, *Stratiolaelaps* is a cornerstone of the industry. There are few applications where *Stratiolaelaps* isn't the first bio-control to apply. Not only will it control fungus gnats and thrips pupae, but it is also found to control pathogenic nematodes, spring tails, Black Vine Root Weevil, Strawberry Root Weevil, symphylans and overwintering spider mite. It has been applied in aquariums to control mites in hermit crabs; pet stores to control fleas and mites in tarantula and snake cages and in chicken coops to control phoretic mites. It even had a 99% predation rate (in trial) of varroa mites and has been applied to bee hives.



Stratiolaelaps is simply as close to a "Silver Bullet of Bio-Control" as you can get.

Following the research conducted at Oregon State University, *Stratiolaelaps* were applied in rhododendron gardens to control Black Vine Root Weevil. During subsequent checks, they were found persisting in the same gardens for over 20 years.

We are bombarded with growers happily telling us "*Stratiolaelaps* cured my ____." One researcher even claims *Stratiolaelaps* left the soil at night and fed on whitefly scale, ruining his whitefly experiment. While some of this is not yet validated, there is enough peer-reviewed research to suggest that almost no crop should be without *Stratiolaelaps*. It is such a generalist and so inexpensive that most growers simply broadcast the "stratio" and its carrying media over newly seeded pots and trays allowing equal amounts to fall to



Adult in-soil predatory mite, *Stratiolaelaps scimitus*

the floor knowing they will continue the fight in the greenhouse substructure.

There is no better way to "clean-out" a greenhouse when a crop has been pulled than by pouring "stratio" around posts, plumbing or any cracks that will allow them to find their way underground - this

is where your spider mite have gone, and no chemical applications would otherwise prevent spider mite from returning next season.



Outdoors, *Stratiolaelaps* will continue to multiply as long as any food is present allowing for fewer field applications or a reduced rate.

Applying Stratiolaelaps

Shipping: Stratiolaelaps will be shipped in a carrying media and supplied with enough residual food for comfort in transit. Quantities are all based on the same density of 25,000 mites per litre and consist of: 1/2 litre compostable pouch; 1L compostable pouch or recyclable tube; 5L bulk bag; or a 10L bulk bag. All our products are “best used immediately,” but because of the nature of soil predators and the food available to them, each of these packages can be held for up to 7 days if maintained around 10-15 Celsius.

Quality Control: Gently mix a package and remove a 1ml sample. Either place this sample in a fridge for 30 minutes then pour onto a black surface, or sterilize the sample with 70% alcohol and prepare in a petri dish. In a one ml sample there should be no less than 25 stratiolaelaps in all life stages (including eggs). However, 5 or more 1ml samples are required to have a more appropriate average. A simpler check is to make your own observations and compare them week over week, then do a proper sampling if it looks amiss.

Release: Gently mix the media by rotating the package or gently decanting into another container. Broadcast by hand to achieve the appropriate release rate, or take a measured scoop to apply to each potted plant. Other than frozen soil, direct summer sun or flooded media, the timing of application does not matter. They will immediately move into the soil. Even mites broadcast onto the canopy of plants will immediately find their way into the soil. When inoculating several acres, it may be best to split the order over two or three weeks to aid in prompt application and to ensure product availability.



Adult “Stratio”

Scouting: Stratiolaelaps are fairly well dispersed within the soil. Scraping the top half inch will often expose any pests, and this is the most likely place to find them. They are a translucent cream colour and even paler in nymph and egg stage, so use a 10-15x hand lens. Stratiolaelaps do not like being disturbed and will take cover from your disruption of the soil, so be prepared to spend some time



looking, or take soil samples to examine later at your desk. Adults are 0.8mm long, and have a pointed “shield” on their back.

Stratiolaelaps at a Glance



Optimum Temperature Range: **Same as plant roots**



Eggs laid per female: **1-5 per day**



Egg to Adult: **11 -18 days**



Prey consumed per day: **1-5**



Special precautions: Regular applications should be made when conditions favour fungus gnats (rice hull or wet media).



Prevention Rate: 250 per m² once.

Reactive Rate: Reapply the prevention rate or increase up to 4 x

Targeted Pests

- Fungus gnats
- Pupating thrips
- Overwintering spider mites
- Black Vine Root Weevil
- Other small insects and mites (springtails, root mealybug crawlers, root aphids, symphylans, nematodes)

Gaeolaelaps Gillespiei

Gaeolaelaps gillespiei was first researched for its superior predation of thrips pupae. It was believed to be *Stratiolaelaps* at the time. Years later we collected a wild culture, had it identified and found it was a different species and the same as originally researched by Dr. Dave Gillespie of Ag Canada.

We since had it named after him and have carried it along-side our *Stratiolaelaps* because of its superior predation of thrips. Much more research is being done and needing to be done to find how else it differs from *Stratiolaelaps*.



Gaeolaelaps are more surface-dominant than *Stratiolaelaps*. By disturbing the upper 1/2 inch of soil you are often disrupting the majority of the population. Also, after leaving that disturbed area for a few minutes and returning, you may find them in high numbers directly on the surface.

The densities they reach both in rearing and in applied samples are much higher than *Stratiolaelaps* and the reason for this is unknown.

In most applications *Gaeolaelaps* and *Stratiolaelaps* are interchangeable, with growers more concerned with thrips preferring *Gaeolaelaps*. The rate of control of fungus gnats and other soil pests remains similar, although no studies have been



Adult *Gaeolaelaps gillespiei*

done using *Gaeolaelaps* on larger prey like root weevils, which has been so successful with *Stratiolaelaps*.

Additionally, *Gaeolaelaps* appears more suitable for dense artificial rooting material like rock wool which further gives it a special niche.

Gaeolaelaps is "native," and our colony was collected on Vancouver Island. While the range of *Gaeolaelaps* is wide-spread it is only available commercially in Canada, as it was only recently identified.

Applying Gaeolaelaps

Shipping: Gaeolaelaps will be shipped in carrying media and supplied with enough residual food for comfort in transit. Quantities are all based on the same density of 25,000 mites per litre and consist of: 1L compostable pouch or recyclable tube; 5L bulk bag; 10L bulk bag. All our products are “best used immediately,” but because of the nature of soil predators and the food available to them, each of these packages can be held for up to 7 days, if maintained around 10-15 Celsius.

Quality Control: Gently mix a package and remove a 1ml sample.



Either place this sample in a fridge for 30 minutes then pour onto a black surface or sterilize the sample with 70% alcohol and prepare in a petri dish. In a one ml sample there should be no less than 25 Gaeolaelaps in all life stages (including eggs). However, 5 or more 1ml samples are required to have a more appropriate

average. A simpler check is to make your own observations and compare them week over week, then do a proper sampling if it looks amiss.

Release: Gently mix the media by rotating the package or gently decanting into another container. Broadcast by hand to achieve the appropriate release rate or take a measured scoop to apply to each potted plant. Other than frozen soil, direct summer sun or flooded media, the timing of application does not matter as they will immediately move into the soil. Even mites broadcast onto the



Adult Gaeolaelaps in peat/vermiculite carrier

canopy of plants will immediately find their way into the soil. When inoculating several acres, it may be best to split the order over two or three weeks to aid in prompt application and to ensure product availability.

Scouting: Gaeolaelaps are surface dominant, and while digging down several inches will reveal some, most will be in the upper 1/2 inch. They are a translucent cream colour and even paler in nymph and egg stage, so use a 10-15x hand lens. Gaeolaelaps sometimes congregate en masse where the soil was disturbed. Try making an inch deep scrape of the soil with your finger and waiting until they appear. Adults are 0.8mm long, and have a rounded “shield” on their back which easily differentiates the adults from the “pointed shield” back of the Stratiolaelaps.

Gaeolaelaps at a Glance



Optimum Temperature Range: **Same as plant roots.**



Eggs laid per female: **1-5 Per day**



Egg to Adult: **10-17 days**



Prey consumed per larva: **1-5 daily**

Prevention Rate: 250 per m² once.

Reactive Rate: Reapply prevention rate or up to 4x more.

Targeted Pests

- Thrips
- Fungus gnats
- Likely the same as Stratiolaelaps

Dalotia coriaria

Dalotia is also referred to as “the rove beetle,” and was previously identified as “Atheta.”

Most growers love Dalotia. They are big, fast, hungry and easy to spot. They’ll eat almost anything and wipe out some populations of pests. The adults are winged and flight-capable and may choose to go after soil pests, or fly up into the canopy to feed on thrips, spider mites and more.

While this sounds like the perfect bio-control specimen, most bio-



control programs can achieve what Dalotia will do with a fraction of the price using established bio-control agents in a preventative way.

That being said, some specific situations are perfectly suited for

Dalotia and some growers employ it in weekly releases.

Dalotia will control shoreflies. Not only will it attack them in all life stages, but it will find and establish itself in pipes and drains where the flies can cycle. Dalotia seem exceptionally suited to use in wet fruit-tree propagation, rooting cuttings, and mulched conifer ornamentals because they do well in very wet soil and course media (sawdust/woodchips.)



Adult Dalotia coriaria, the rove beetle

The most common use of Dalotia is to clean up a root-pest problem. Over-watered plants will stress and impede the

effectiveness of Gaeolaelaps and

Stratiolaelaps and cause an increase in fungus gnats or other root pests. This is the time to release Dalotia into the crop.



Dalotia should never be used as a preventative. With little food, it will simply leave and sometimes only

after eating all your other bio-control agents. It is most successful when applied as recommended or when needed to rescue an over-run crop.

Applying Dalotia

Shipping: Rove Beetles will be shipped in quantities of 100 or 1,000 containing all life stages in a carrying media with some residual food. At 10 Celsius, the Dalotia can be held for up to 7 days. The 1,000 unit is available as a recyclable plastic bottle or compostable bag.

Quality Control: Do not open the lid until ready to release. Dalotia are active fliers. In clear packaging, gently warm to room temperature and simply look to see adults moving - they are fast and easy to see. In opaque packaging, simply take a small sample at the time of release to inspect.



Release: Dalotia will disperse quickly so determine your application locations ahead of time and move quickly between them, gently shutting the container lid when not in use. Do not release Dalotia where sachets or slow release pouches have been deployed, as they will feed in these. Avoid releasing where any other bio-control release has been made and is still in the critical stage of establishing.

Applying adjacent to drains is often a sure way of providing them a natural habitat and intended food source as quickly as possible. Release rates are typically 1 beetle per m².

Scouting: Dalotia are slower to establish than the other root-pest predators because of their longer life cycle. When food is available,



Dalotia looking for food

it may still take two or more weeks to see an obvious increase in their population. Larva look similar to adults but are pale in colour. Adults are 3-4 mm long and slender. They are often found curving



their abdomen up like a scorpion. They will run or fly when disturbed, but are seldom found flying. They are most commonly found in wet areas like under pots where fungus gnats are likely or where algae has been left to grow and fly larva are likely.

Dalotia at a Glance



Optimum Temperature Range: **10C to 30C**



Eggs laid per female: **8 per day**



Egg to Adult: **21 days**



Prey consumed per larva: **10-20 daily**



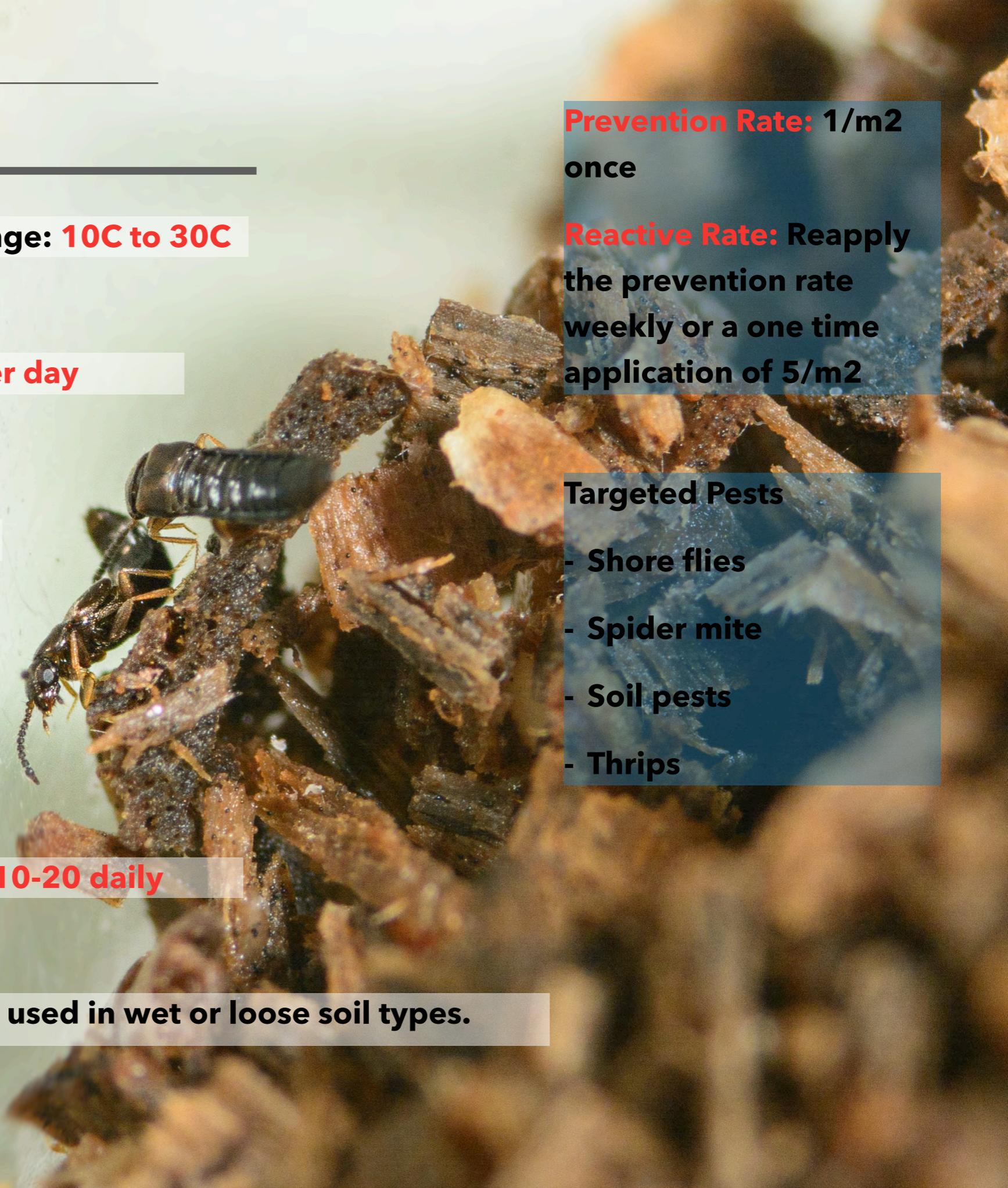
Special precautions: **Best used in wet or loose soil types.**

Prevention Rate: 1/m²
once

Reactive Rate: Reapply
the prevention rate
weekly or a one time
application of 5/m²

Targeted Pests

- Shore flies
- Spider mite
- Soil pests
- Thrips



Get started with these General Rates

All total values represent rates per 100 m2 (1,000 f2)

Pest	Prevention /100m2	Knockdown /100m2	Prevention /100m2	Knockdown /100m2	Prevention /100m2	Knockdown /100m2
Aphids  Totals	Aphidoletes 250 2000		Brown Lacewing 50 200		Hoverfly 25 100	
Spider mite  Totals	Fallacis 200 1000		Persimilis 1,000 100,000		Stethorus 20 100	
Whitefly  Totals	Encarsia 25 400		Delphastus 50 200		Cucumeris 10,000 N/A	
Thrips  Totals	Cucumeris 50,000 200,000		Stratiolaelaps 25,000 100,000		Gaeolaelaps 25,000 100,000	
All soil/root pests  Totals	Stratiolaelaps 25,000 100,000		Gaeolaelaps 25,000 100,000		Dalotia 100 1000	
Caterpillar, mealy bug prevention  Totals	Brown Lacewing 50 N/A					
Generalist predation and control of aphids, thrips and spider mites.	Crazee Mite 250 1000					



Applied Bio-nomics

Best in first

Contact your retailer or distributor to determine application frequency and crop-specific rates.

Acknowledgments

Applied Bio-Nomics Ltd would simply not be where it is without the enormous contributions to our field by many researchers, but none more directly than Dr. David R. Gillespie. In retirement, Dr. Gillespie has taken to professional photography and so we are again thankful for his contributions to our field and our company. Many of our products are the direct result of the research of one or more of the following people:

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Photos by Dr. Dave Gillespie:

Cover photo; page 3; page 6, A.a. eggs, adult and larva; page 9, all photos; page 10, two M.v. larva feeding and pupa; page 11; page 12, both adult E.a; page 13, adult E.a.; page 15; page 18 both photos; page 19, both E.f. scale; page 20, page 21 all photos; page 22 all photos; page 23; page 25; and all photos from pages 27 to 35; page 40, top; page 41, top two; pages 46 to 54, all photos.

Other photos:

Ant and A.a. larva, page 7 by Beth Lounds

All others by David Spencer.

Written and produced by David Spencer