IPM and the Nolen Greenhouses

An exploration of best practices in pest control.

A report prepared by

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Above: *Coccinellidae* (lady bug) larvae.

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Introduction

During the summer of 2020 I had the unique opportunity to engage as a student intern in a research project at The New York Botanical Garden. My area of study was Integrated Pest Management (IPM), with a close look at biological controls agents (BCAs). After months of reading, interviewing, listening, and writing, the project came together in this document: a deeply-researched compendium of pest and control information (roughly 130 pages, covering 8 key pests), written specifically with the production zones of a botanical garden in mind.

The document covers eight common production house pests, addressed in the attached reports. Each report is broken into two parts.

Part one contains detailed information on the pest's life cycle and optimal conditions for population explosions. This includes climate requirements, timing and stages of development, as well as vulnerable and protected stages. All reports contain an analysis of pest numbers for production houses at NYBG (Zones 1, 2, and 3) over a year-long period. Discussion of monitoring best practices are tailored for each pest and include several methods that are already in use at the greenhouse. Likewise, key actions for sanitation and cultural interventions are included, again, many of which are already in use.

Part two begins to unpack opportunities for greater use of BCAs as part of the garden's IPM programming. This section draws on the work of NYBG staff over the past several years, along with other sources. A summary is offered that synthesizes information from several experts and relevant literature.

A deep dive into the use of pesticides and other chemical treatments was out of scope for this project.

The pests covered are:

- *Bemisia tabaci* MED and MEAM1 (sweet potato and silverleaf whitefly)
- *Frankliniella occidentalis* (western flower thrips)
- *Gynaikothrips ficorum* (Cuban laurel thrips)
- *Myzus persicae* (green peach aphid)
- *Planococcus citri* (citrus mealy)
- *Polyphagotarsonemus latus* (broad mite)
- *Pseudococcus longispinus* (long-tailed mealy)
- *Tetranychus urticae* (two-spotted spider mite)

As a whole, the entire report (and supporting documents) draws on the vast depth of knowledge of garden staff, outside experts, and various forms of written scholarship. Ultimately, it explores conditions under which key pests flourish, best practices for controlling pest presence, and what might occur in order to include BCAs as part IPM programming.

Pest monitoring

Each pest report includes a detailed section about scouting best-practices. This information was compiled for reference purposes (and this compilation was of significant pedagogical benefit to the present author), and much of it will not be revelatory for long-time gardeners.

Monitoring summaries are also tailored to the specific pest. Whenever possible, these sections cover how to look for the pests (visual inspection, tapping, trapping, plant part sampling, and use of indicator plants), where to look (terminal buds, whorls, top of plant, bottom of plant, roots, soil), and if the use of indicator plants is recommended or not.

Cultural and sanitation controls

Cultural and sanitation controls are the most important non-chemical interventions for pest management. They are crucial tools for pest control and are the foundation of any effective Integrated Pest Management program. A summary of best practices, tailored to each pest, is included in each Pest Report.

BCAs

One of the most exciting prospects of this project was the opportunity to (hopefully) contribute to further use of Biological Control Agents in greenhouse production areas.

Specifics regarding curative and preventative applications, as well as population rearing and reapplication — are discussed in part two of each pest report. These should not be mistaken for expert analysis or prescription. But they can be used as a launch point for future conversations with experts and vendors as an official plan or pilot project is formulated.

Using both pesticides and BCAs hand-in-hand can be done and should be done because one or the other, alone, may not give good control of pests, especially where pest populations have achieved resistance. This is especially true of the priority pests reported on here. Interdependence of all tools available is a crucial component of pest control and no IPM program is truly complete without the inclusion of Biological Control Agents.

How to use the document

Each report that follows is a summary about the pests they cover. The reports can be used as a starting point, or quick reference.

Vendors of BCAs should be willing to send a consultant to help with onboarding and technical support. But overcoming the learning curve and training staff takes time, just as trialing beneficials and finding the correct fit for each house, zone or crop, takes time.

If just starting out with BCAs, “start small” was the advice of several peers in greenhouses and institutions alike during interviews. Inherent in this advice is an equal measure of “be patient” — both with results and with internal stakeholders.

My hope is that this document is useful on your journey. It is an ongoing work, so if you have questions, comments, or even anecdotes, please reach out to me. I look forward to your insights.

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PEST REPORT

Aphids

Myzus persicae
green peach aphid

As with many insect pests, the green peach aphid prefers feeding on new growth, which has the highest concentration of amino acids and provides a healthy and balanced diet.

Photo via Science Direct. Photograph by Sébastien Boquel.

Feeding + vulnerable stages.

All stages of the hatched pest are feeding. Eggs, nymphs and adults are susceptible to various BCAs. Nymphs and adults are the most susceptible to pesticides.

Reproduction + life cycle.

Sexual and parthenogenic reproduction.
Matures in an average of **11 days**.
Lifespan of **23 – 41 days**.
Lifestages are: eggs, 4 instar nymphs, adults.
Females produce **30 – 80** young each.

Optimal climate.

Total development range of **39° – 86° F**.
Optimal temperature is **80° F**.

Severity + speed of damage.

Damage can be quick and severe if a population explosion is underway. Plants are sapped of vigor and death is possible.

In this report:

1. Pest overview

Summary

Green peach aphid populations are a near-constant presence in production greenhouses. Their populations are often notable during the winter, explode readily in the spring, recede a bit over the summer and remain a nuisance into the fall.

Myzus persicae is a small aphid type, and the most common aphid found in greenhouses. Able to winter outdoors as an egg in northern climates, it is also an outdoor pest in our area, compounding existing problems when they come indoors. During the summer months, it is mostly parthenogenic in the landscape. Since greenhouses mimic warm summer weather, asexual reproduction may be favored by the pest and a real factor in the exponential growth of greenhouse-dwelling populations, giving rise quickly to large infestations.

There are many commercial means of combating aphids with biological control agents. They all must be implemented preventatively, early in the season before the green peach aphid populations become overwhelming. Spot treating with insecticides early in the season may keep populations in check before application of BCAs (Mahr, et. al., 2001.).

As noted above, *Myzus persicae* reproduces both sexually and via parthenogenesis. All stages of the hatched pest are feeding. Nymphs and adults are susceptible to BCAs and pesticides. Eggs, when they are present, are protected from most types of pesticides.

Damage to plants

This pest is a phloem-feeder (Cloyd, 2016.) and it is highly polyphagous. In the landscape it has over 40 summer hosts (CABI, 2020.). Outdoor summer conditions are readily mimicked by greenhouses, making parthenogenesis possible and the need of locating host-plants for egg laying less important; this results in the species having a very wide host range in greenhouse environments.

Of note is the fact that these pests are ready vectors for several viruses: potato leaf roll virus (PLRV), beet yellows viruses (BYV, BYDV, BWYV), and many mosaic viruses (CABI, 2020.). More than 100 viruses are vectored by the green peach aphid (Casuso and Smith, 2017.).

Like other phloem-feeders, *Myzus persicae* produces honeydew that decreases photosynthesis by encouraging the growth of sooty-mold. Honeydew also attracts ants and wasps that can attack beneficial insects (predators, etc.), protecting aphid populations.

Temperatures + climate

Myzus persicae has a total development range of **39º - 86º F** (Capinera, 2020), with an optimal development temperature of **80º F** (Davis, 2006). Growth slows around **50º F**, and ceases under **39º** (Capinera, 2020) and over **86º F** (Davis, 2006).

The green peach aphid thrives during periods of fluctuating temperatures, such as spring with its warm days and cool nights.

Its eggs can overwinter outdoors on host species (such as peach trees).

Pest monitoring

Population triggers


Image via University of Florida. Photograph by Luis F. Aristizábal.

Myzus persicae numbers can be expected to rise when a combination of these factors is optimal:

Optimal climate. Temperatures that hover around **80°F** during the day and cool down during the night are best (Davis, et. al., 2006.). This fluctuation is preferred in part because of a symbiotically-obligated bacteria in *Myzus persicae's* stomach that facilitates digestion. The bacteria dislikes heat, recovering from hot days during cool nights. In turn, the pests are better at digesting food and develop faster (Davis, et. al., 2006.).

Protectors present, predators and parasitoids absent. Protectors such as ants and wasps attracted by honeydew may protect against natural enemies.

Food sources are present. This species is highly polyphagous in greenhouses. As with many insects, it prefers feeding on new growth, as this has the highest concentrations of amino acids, providing a healthy and balanced diet for many pests. This is of special importance in the production houses, where new growth is pushed. Likewise, plants coming out of winter dormancy may be targets. Outdoor broadleaf weeds can be a suitable host for green peach aphid, which then come inside the greenhouse when temperatures warm and outdoor overwintering populations hatch (Capinera, 2020.).

All of these factors lead to exponential growth. The pest develops from egg to adult in an average of **10.8 days** (Capinera, 2020.). Adults live anywhere from **23 – 41 days** (Capinera, 2020.). Wingless parthenogenetic females produce **30 – 80 young** each (CABI, 2020.), over a **20-day** period (Capinera, 2020.).

Suboptimal growth can still take place at temperatures between **39° – 50° F**, although growth persists at a slower rate, this range enables populations to continue when other pests have gone into diapause or died. The species' cold hardiness is of special note. Even at overnight temperatures of **23° F**, acclimated populations were shown to survive without too much mortality for **7 – 10 days** (CABI, 2020.). Overwintering eggs are able to withstand temperatures of **-50° F** (CABI, 2020.). This makes them well-equipped to spend the winter outdoors and come inside from the landscape as soon as the spring arrives, adding to populations that might be year-round in greenhouses.

Monitoring

Visual inspection is the most important way to get a sense of populations of green peach aphids in greenhouses. Sticky traps can also be used to detect winged females, though their presence in a closed greenhouse can often indicate a far-reaching problem (Mahr, et. al., 2001.).

Scouting. Due to the localized nature of outbreaks, visual inspection should be non-random and performed on as many plants as possible, rather than a sampling (Mahr, et. al., 2001.). Green peach aphids will occur all over the plant, so entire plants must be checked with special attention paid to terminal buds and the undersides of leaves. This includes tall specimens, such as containerized trees. Signs such as cast skins, honeydew, and sooty mold also indicate infestations.

Predatory *Hippodamia convergens* feeding on green peach aphid. Photo by Luis F. Aristizábal, via University of Florida.

Scouting should happen at least once a week at first detection, as the pest can multiply very quickly. Reproduction can happen in as little as 6 days under perfect conditions, and even under suboptimal conditions it can take place within 10 days.

Winged females on plants (rather than only on sticky cards) may be worth noting on scouting sheets to help identify and record the first springtime population boom, for future use.

Sticky cards. Sticky cards and traps will catch winged females. In greenhouses, population density forces females to develop wings in order to look for new sources of food. Therefore, if sticky cards catch winged females in a closed greenhouse it is likely a sign that there is a very serious infestation afoot (Mahr, et. al., 2001.).

If the weather is warm and the vents have been open, green peach aphids may come in from outdoors, as they are capable of overwintering as eggs in the landscape. Migration from the outdoors, indoors should be monitored. Aerial travel of winged aphids is the main mode of dispersal early in a new season (CABI, 2020.). Set traps next to windows, doors, vents, and other potential points of entry when the outdoor weather jumps above **40° F** to monitor outdoor populations as they may add to populations already inside the greenhouse.

Water pan traps may also be used to attract and catch winged females (Capinera, 2020.) Their use might be considered if this alate form is a major concern during the springtime, year-after-year.

Environmental management

Sanitation, Physical, and Cultural Controls

Plant sanitation. If fungal infections are not a concern, syringe plants to knock off eggs, juvenile and adult insects (NYBG, *Control*, 2013.), paying particular attention to the undersides of leaves and terminal buds.

Check all incoming plants. Carefully check all stock plants; do not propagate using materials from an infested plant.

On vegetable crops, the use of aluminum or white plastic mulch was shown to repel aphids (Capinera, 2020.).

House sanitation. Overcrowding can lead to a more acute infestation with this species. Touching leaves may encourage population spread. Consider deaccessioning and decreasing production whenever possible on crops or species that are repeat offenders.

Moving plants between production houses can also increase problems throughout growing zones.

Broadleaf weeds can be suitable host plants (Capinera, 2020.). It's important to keep pots, underneath benches and areas immediately outside the greenhouse weed-free. A 15' – 30' weed-free radius around greenhouses may help to keep the pest from coming in from the outdoors (Mahr, et. al., 2001.).

Cultural Controls. If possible, reducing nitrogen fertilizer may make plants less attractive to green peach aphids, as they will produce less tender growth. This may be more feasible in a collections house setting.

2. Introduction of Biological Controls into IPM Programming

Biological Controls

There is a species of aphid for nearly any and all glasshouse crop and collection. Happily, this demand has resulted in ample options for commercially available biological controls. Moreover, greenhouses provide an environment where the climate can be manipulated and the number of predators, parasitoids and pathogens can be increased at will, (Capinera, 2020.), raising the chances of success over landscape interventions.

Lady beetles are the most famous natural enemy of the aphids. However, lacewing larvae, flower or syrphid flies, parasitoid wasps, and pathogenic fungi are all also commonly used for control (Capinera, 2020.).

Pre-conditions. Generally speaking, green peach aphid populations should be lowered before introducing natural enemies. Lacewings, however, are able to quickly reduce large populations (Mahr, et. al., 2001.), and may be released while population numbers are high.

If using parasitoids, reduce populations of *Myzus persicae* if more than **10%** of the plants are infested (Mahr, et. al., 2001.). Be sure to remove all sticky traps before any parasitoid release.

As with all honeydew producing pests, make sure ant or wasp populations that may be attracted to honeydew are killed, they will protect aphids from natural enemies. Use boric acid or bait (Mahr, et. al., 2001.).

For continued use of chemicals with biological control agents, microbial insecticides and insecticidal soaps are usually best for use with most BCAs (Mahr, et. al., 2001.). Obviously, avoid the use of fungicides if using fungal pathogens as a means of control.

As with many releases of predators and parasitoids, stop using residual insecticides one month in advance of release (Mahr, et. al., 2001.).

Introduction of BCAs. Although some natural enemies (such as the green lacewing) are able to control large numbers of aphids, releases of BCAs should be made while numbers are low. Because aphids are able to reproduce so quickly, populations can quickly become too high for many BCAs to control (Mahr, et. al., 2001.).

Summary. A complimentary mix of predators, parasitoids, and fungal applications may be useful.

A one-time curative inundation of the voracious predator *Chrysoperla spp*. will lower numbers during a warm-temperature population surge. If numbers remain high, lacewings could be followed-up with a one-time release of *Hippodamia convergens*.

Once numbers have been reduced, smaller weekly preventive releases of *Chrysoperla spp*. may be used if the house remains warm, which they prefer to cool temperatures. *A. colemani* is a good parasitoid to complement the release of such a predator. If released before the eggs of green lacewing hatch, they have a better chance of making an impact; they should have time to parasitize the pest, and the predators generally do not eat parasitized prey.

The parasitoid *Aphidius matricariae* (optimum temperature is **77° F**; not effective above **82° F**) is active at cooler temperatures and might be worth using on a preventative basis during cooler times when lacewings are less active. Unlike *A. colemani*, *A. matricariae* will not diapause during short days, so it is a good “off-season” choice if green peach aphids are the target, as long as conditions in the greenhouse are not too hot.

Banker plants may be used to rear *A. colemani*. Rich Densel at Grower’s Choice has been successful using the cereal grass and bird cherry oat aphid systems. However, he notes that cereal grasses for this system must be strictly organically raised.

Another cooler temperature option for control may be the fungal pathogen *Lecanicillium lecanii*, which has been shown to be so effective that it may prove chemical interventions unnecessary (Mahr, et. al., 2001.).

Orius insidiosus is a great generalist that will eat aphids and many other prey. In the early spring they may be introduced as a light curative and used throughout the warmer months. They diapause during short-days. They may be reared on banker plants thereafter.

Rich Densel at Grower's Choice uses *Orius insidiosus* for general pest control by making a purchase of around 500 in April or May, (but not earlier because they diapause during short-days and tricking them is difficult). After the initial inundation he uses a banker plant system that keeps their numbers going strong throughout the summer.

Notes. Parasitoids are a good complement to predators but care should be taken to release them if/when they themselves won't be consumed.

Green lacewings seem like a good choice for pest control but they will eat many other species of beneficial insect. Caution must be taken with the timing of their release if other beneficials are present.

Parasitoids

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Parasitoids of Note* section.

Aphidius colemani Parasitic wasp	**Sources:** Miller, et. al, 2018; Mahr, et. al., 2001.; Wollaeger, 2015.; NYBG, *Control*, 2013.
Feeding habits Parasitizes smaller aphid types, such as the green peach aphid and melon aphid *(Aphis gossypii)*.	**Additional details** May come sold as a mixture with *A. ervi*. Parasitizes larger aphids, such as foxglove. Other species, such as *D. rapae* or *A. gifuensis* during short-term applications, such as inoculative releases, and overall, may be a more effective parasitoid in control of green peach aphids. Insecticides to control thrips had no effect on mummy formation.
Habitat requirements Optimal temperature is 86° F. This is too hot for aphid reproduction.	
Life cycle Release 400 – 2,000 per acre.	

	Recommended by Rich Densel at Grower's Choice, who uses a banker plant system to rear them. Recommended by NYBG in the past.

Aphidius matricariae Parasitic wasp	**Sources:** Mahr, et. al., 2001.; Wollaeger, 2015.
Feeding habits Parasitizes green peach aphids only. 50 – 150 eggs laid in aphid nymphs. Also knock adult aphids off plants, which will kill them as they can't climb back up.	**Additional details** Will be killed by *Lecanicillium lecanii.* Most common and effective parasite of green peach aphid. Release 400 – 2,000 per acre.
Habitat requirements Active between 50° F – 85° F. Optimum temperature is 77° F. Active at cooler temperatures than *A. Colmani.*	
Life cycle Good for fall-early spring, because it does not have a diapause when the days are shorter.	

The species *Aphidoletes aphidimyza* may also be a good bet for control, as noted in the book *Biological Control of Insects and Other Pests of Greenhouse Crops* (Mahr, et. al., 2001.). However, to be truly sustainable it needs ground-soil in order to pupate which would be difficult to provide at the Nolen, which uses containers. It may be a candidate for use on the back gravel or in the hoop houses, but more research should be done.

Predators

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Predators of Note* section.

Chrysoperla spp. Lacewing	**Sources:** Mahr, et. al., 2001.; Wollaeger, 2015.; NYBG, Control, 2013.
Feeding habits Voracious, good for rapidly lowering numbers.	**Additional details** *C. carnea* is standard.

Larvae eat up to 425 aphids per week. Major drawback is larvae appetite. Also eat other prey (including beneficials, so be careful). The predacious larval stage lasts roughly 15 – 20 days. Adults eat pollen, nectar and honeydew.	*C. rufilabris* is good in humid conditions. *C. comanche* is good in dry conditions. Numbers do not need to be lowered before the lacewing is introduced. Recommended by NYBG in the past.
Habitat requirements Conditions for optimum performance fall between 67 – 89° F. Relative humidity of 30% or greater.	
Life cycle Females lay up to 300 eggs over 3-4 weeks. Eat for 2-3 weeks, then pupate. Pupation cocoon is above ground.	

Orius insidiosus Insidious flower bug	**Sources:** Mahr, et. al., 2001.
Feeding habits Also feed on spider mites, western flower thrips, whiteflies, caterpillar eggs. Feed on pollen and plant juices when prey is not available. Will also eat predatory mites.	**Additional details** Banker plant system and introduction during springtime covered in summary of western flower thrips. Recommended by Rich Densel at Grower's Choice, for general use; he uses a banker plant system with them after an initial purchase of 500+ in April or May. **Go to the *Western Flower Thrips Report*.**
Habitat requirements Temperatures over 59° F. Greenhouse temperatures of 64-82 ° F. Humidity over 60%.	
Life cycle Diapauses under short days and low temperatures. Blue light will reduce the number of *O. insidiosus* that diapause.	

Hippodamia convergens Ladybird	**Sources:** Mahr, et. al., 2001.; Obrycki, 1982.; Wollaeger, 2015.; NYBG, *Control*, 2013.
Feeding habits Attacks many soft-bodied insects. Consume 500 – 1,000 aphids over 3 – 4 weeks.	**Additional details** Multiple releases are usually required, adults will fly away. Most effective when aphid numbers are high. Need to release more every 2 – 3 weeks. Cost will be ongoing.
Habitat requirements Likes warmer temperatures. Optimal temperature of 84° F.	
Life cycle Females lay up to 1,500 eggs.	

Pathogens

Some pathogens of note are listed below. A full is included in the *Pathogens of Note* section.

> ***Lecanicillium lecanii**, fungal pathogen (syn. *Verticillium lecanii*) (Mahr, et. al., 2001.; CABI, 2020.; Capinera, 2020.) May take away the need for further insecticide applications. Will control most aphids except chrysanthemum aphids. Not compatible with *A.matricariae* and other whitefly parasites. Is compatible with insecticides used against *M. persicae.* Needs high humidity to perform RH must be greater than 95%.

Associated plants

Indicator plants. Infestations tend to be localized (especially early on in the season) and randomized scouting is not encouraged with this species. Therefore, use of indicator plants is not appropriate for aid in scouting.

Banker plants. Banker plants may be used for many BCAs of the green peach aphid. As mentioned in the sections where *Crysoperla carnea* appears, adults will eat pollen and nectar. Therefore, it may be advisable to have flowering plants on-hand for the adulthood of their lives, as it may dissuade them from flying away to find more suitable foraging.

Lobularia maritima has been used by some gardeners to attract syrphid flies, which are a natural enemy.

If using the parasitoid *Aphidius colemani*, barley, wheat, or oats may be grown as a host plant for bird cherry oat aphids. Bird cherry oat aphids (*Rhopalosiphum padi*) are a cereal grass pest that doesn't attack greenhouse bedding plants and can be reared on banker plants to sustain parasites if green peach aphids are not present (Sullivan, 2013.).

It's important to note that these cool-season plants may languish in most growing environments, and will need to be replaced once every 1 – 2 weeks in the summertime. While some grasses may not be preferred hosts for the bird cherry oat aphid, the plants themselves may fare better.

These concepts are better explained here:

> "Greenhouse growers maintain temperate environments all year, causing cool-season banker plant species to decline quickly; while winter wheat and barley used for rearing *R. padi* currently provide the best banker plant material (Jandricic et al. 2014)...These cool-season annual grasses must be replaced every 7 to 14 d, especially during summer months...While R. padi prefers to feed and reproduce on barley, it can also reproduce on sand lovegrass (*Eragrostis trichodes* (Nutt.) (Poales: *Poaceae*)), sideoats grama (*Bouteloua curtipendula* (Michx.) (Poales: Poaceae)), buffalograss (*Buchloe dactyloides* (Nutt.) (Poales: *Poaceae*)), mature switchgrass (*Panicum virgatum* (L.) (Poales: *Poaceae*)), and mature indiangrass (*Sorghastrum nutans* (L.)."
>
> - (Miller, et. al, 2018)

3. Sources

Aristizábal, Luis F. (photographer). University of Florida, IFAS Extension. Accessed September 26, 2020. http://entnemdept.ufl.edu/creatures/BENEFICIAL/convergent_lady_beetle.html

Boquel, Sébastien (photographer). *Myzus Persicae*. Science Direct. Accessed September 26, 2020. https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/Myzus-persicae

CABI. *Invasive Species Compendium: Myzus persicae (green peach aphid)*. Accessed September 26, 2020. https://www.cabi.org/isc/datasheet/35642

Capinera, John L. *Featured Creatures: Green Peach Aphid.* University of Florida, IFAS Extension. Accessed September 27, 2020.
http://entnemdept.ufl.edu/creatures/veg/aphid/green_peach_aphid.htm

Casuso, Nicole, and Smith, Hugh. *Green Peach Aphid Factsheet*. University of Florida, IFAS Extension, 2017. https://edis.ifas.ufl.edu/pdffiles/IN/IN105400.pdf

Cloyd, Raymond A. *Greenhouse Pest Management*. CRC Press, 2016.

Cranshaw, Whitney, and Shetlar, David. *Garden Insects of North America.* Princeton University Press, 2018.

Davis, J. A., et. al. “Effects of High and Fluctuating Temperatures on Myzus persicae (Hemiptera: Aphididae).” *Environmental Entomology*, vol. 35, no. 6, December 2006, p. 1461–1468.
https://doi.org/10.1093/ee/35.6.1461

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Control Handbook.* New York Botanical Garden internal document. 2013.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Identification Handbook Supplement 1.* New York Botanical Garden internal document. 2013.

Mahr, Susan E. Rice, et. al. *Biological Control of Insects and Other Pests of Greenhouse Crops.* University of Wisconsin-Extension, Cooperative Extension, 2001.
https://cdn.shopify.com/s/files/1/0145/8808/4272/files/NCR581.pdf

Miller, Tracey L. Patton, and Rebek, Erik J. “Banker Plants for Aphid Biological Control in Greenhouses.” *Journal of Integrated Pest Management*, vol. 9 no. 1, 2018. p. 1461–1468
https://doi.org/10.1093/jipm/pmy002

Obrycki, John J., and Tauber, Maurice J. “Thermal Requirements for Development of Hippodamia convergens (Coleoptera: Coccinellidae).” Annals of the Entomological Society of America, vol. 75, no. 6, November 1982. p. 678 – 683.
https://academic.oup.com/aesa/article-abstract/75/6/678/20879

Sullivan, Cheryl E. Frank, and Skinner, Margaret. *Plant-Mediated IPM Systems Explained*. University of Vermont, Entomology Research Laboratory. 2013.

http://www.uvm.edu/~entlab/Greenhouse%20IPM/Workshops/2014/PlantMedIIPMSystemsOverviewFinalNov13.pdf

Texas A & M AgriLife Extension, “Green Peach Aphid.” Accessed September 27, 2020. https://texasinsects.tamu.edu/green-peach-aphid/

Wollaeger, Heidi, et. al. *Commercially Available Biological Control Agents for Common Greenhouse Insect Pests*. Michigan State University, 2015.

PEST REPORT

Mealy

Planococcus citri
Citrus mealybug

Photo via the University of Minnesota (*NOTE)

"They live on containers, walls and benches. The day we saw hatched crawlers on stainless steel flashing, we gained a new respect for them."

— Greenhouse Product News (Sclar, 2008)

Feeding + vulnerable stages.

All stages of hatched females are feeding. Adult males have no mouth parts and do not feed. Eggs, nymphs and adult females are susceptible to various BCAs. Young instars are the most susceptible to pesticides.

Reproduction + life cycle.

Sexual and parthenogenic reproduction.
Matures in **5 weeks**.
Lifestages for females are: egg, 3 instars, adult. Lifestages for males: egg, 4 instars, pupa, adult.
Lays **400 – 600 eggs** during their lives.

Optimal climate.

Developmental range is **46° – 86° F**.
Prefer relative humidity greater than **85%**.

Severity + speed of damage.

Damage is not swift but populations are persistent. Plants are rarely killed but are especially compromised aesthetically.

In this report:

1. Pest overview

Summary

Citrus mealy is the most common mealy pest of glasshouses. Although production areas have a less-entrenched mealy population than collections at the Nolen Glasshouses, they nonetheless can become a perennial issue, given the pest's tendency to hide in the soil, cracks and crevices in the ground, on benches and pot rims, and (as growers have observed) in the walls of the houses themselves when conditions become unfavorable.

Thorough sanitation is a crucial partner to any BCA programming that is introduced, this is especially true for mealybugs. Also, with more than 275 species of mealy occurring in the United States alone, it is important to have identification at a species level when introducing BCAs (University of Minnesota Extension, 2020.).

Citrus mealybug reproduction is both parthenogenic and sexual, and males are very, very rare (Martin, 2020.). Like long-tailed mealy, all stages of hatched females actively feed. Adult male mealybugs do not have mouthparts and only live a few days in order to reproduce with females (University of Minnesota Extension, 2020.). Adults, nymphs and eggs are susceptible to various types of BCAs. Citrus mealybug nymphs have much thinner wax coverings than adults and are generally considered to be the most susceptible stage, including their susceptibility to pesticides. Adult females secrete waxy covering that protects them while they feed, and their habits often make them hard to reach with sprays (CABI, 2020.). Egg sacs are protected from chemical treatments by their protective waxy covering.

Damage to plants

This pest is phloem-feeding (Sclar, 2008.). It attacks both plant foliage and roots. Changes in temperature and humidity appear to drive them to the roots where they may feed (CABI, 2020.).

Although it is associated with citrus, its feeding habits are general. In colder regions, *P. citri* mainly occurs on greenhouse plants such as coleus, ferns and gardenias, but also occurs outdoors under summer conditions on citrus, grapes, figs, taro, date palms and potatoes (CABI, 2020.).

Beyond the damage caused by feeding, these pests are also ready vectors for banana streak disease, cacao swollen shoot virus, cucumber mosaic virus (cucumber mosaic), *Dioscorea bacilliform* virus, and Schefflera ringspot virus (CABI, 2020.). Roots that have been attacked can become encrusted with *Polysporus* fungus, capable of killing entire trees (CABI, 2020.).

The pest also produces honeydew which decreases photosynthesis by encouraging sooty-mold, and attracts ants and wasps that will attack beneficial insects.

Temperature + climate

Citrus mealybug has a total development range of **46° – 86° F** (CABI, 2020.), and an optimal range of **68° – 86° F**. It achieves its fastest growth at **86° F**, and has slower growth at **68° F**. Development ceases below **59° F** and above **95° F** (El-Aw, M. et. al., 2016).

Female citrus mealybug will cease to lay eggs below **46° F** (CABI, 2020.). Temperatures above **95° F** will kill nymphs (El-Aw, M. et. al). The pest is susceptible to outdoor winter freezing in the northern U.S.

Citrus mealybug thrives in humidity of **70% – 80%**.

Pest monitoring

Population Triggers

A mealybug and her eggs. Image via University of Wisconsin(*NOTE)

Planococcus citri numbers can be expected to rise when a combination of these factors is optimal:

Optimal climate. Citrus mealy reproduces and develops faster at warmer temperatures. The higher developmental threshold temperature is **86° F**, (CABI, 2020.). (Below **46° F** and nymphs and adults cease development (CABI, 2020.). This makes a range of developmental temperatures spanning **46°– 86° F**, which is very broad. Death occurs over **95° F** (El-Aw, M. et. al., 2016). **77° F** is optimal for egg-laying (El-Aw, M. et. al., 2016). Relative humidity below **85%** drives the citrus mealy from the top of the plant to the soil where it feeds on roots (CABI, 2020.).

Presence of protectors, absence of predators and parasites. As with all honeydew producers, ants and wasps drawn will protect citrus mealybugs from natural enemies. *Cryptolaemus montrouzieri*, a natural enemy of the mealybug, has been observed in the houses at NYBG, and may have survived from BCA releases long ago in the Conservatory. This predator lays its eggs in citrus mealybug egg masses, so it needs this pest to be present and laying eggs in order to sustain its numbers.

Food sources are present. This pest is associated with citrus, but is a generalist when it comes to feeding.

All of these factors lead to exponential growth. Nymphs mature in **5 weeks** under optimal conditions, (otherwise taking **6 – 10 weeks** to reach maturity), (Gill, 2020.). Females lay **400 – 600 eggs**. The average is **29 eggs per day / per female** (Gill, 2020.). Under optimal conditions, the eggs hatch in **6 – 10 days** (Gill, 2020.).

Monitoring

Visual inspection of plants is the best way to get a sense of citrus mealybug populations. However, the species is often hidden, sometimes migrating to the roots of plants, or even cracks in the walls, so this type of scouting must be thorough -- and may not always be constrained to plants.

Mealybug destroyer larvae (large and white) hanging out with various aphids. Image via Bug Guide.(*NOTE)

Scouting. Visual inspection should be undertaken once a week for production houses. Check as many plants as possible, rather than a randomized sample; the pest is relatively non-mobile and therefore infestations tend to be localized. Look for signs of the pest such as honeydew and wax secretions.

They prefer humid and shaded conditions (Martin, 2020.). Especially check hard to-see-areas on plants but also under benches and pot rims. They may also be found in cracks and drains. In cooler, drier houses or climates, check pot drainage holes for signs that the pest has migrated to the roots (Mahr, et. al., 2001.).

Mealybugs should be identified on a species level. Although there is much crossover for environmental management (sanitation practices, cultural measures, etc.), as well as in BCA controls, some differences do exist that would change treatment courses if the species was identified, and in what quantities.

For example, citrus mealy is able to hide in soil and feed on roots, meaning they can go undetected for a period of time. Different scouting measures would need to be taken and more attention would need to be paid to treating those mealy in the soil. BCA applications (especially parasites and predators that are host-specific for regeneration) are based on a species level in order to be fully effective. Identifying mealy at the species level would help surmise the ratio of citrus mealy to long-tailed mealy for purposes of counter-attack.

Sticky cards. Sticky cards are able to catch male citrus mealy. However, because their numbers tend to be so variable, careful inspection of plants is a better way to gauge outbreak numbers.

Environmental management

Sanitation, Physical, and Cultural Controls

Plant sanitation. Remove or spot treat heavily infested plants (Mahr, et. al., 2001.). Space plants so leaves are not touching, unless using a BCA that prefers contact between plants. Infestations are relatively localized, so moving plants away from one another may help to keep them from spreading. This is a concern in collections houses but is perhaps not as much of a problem in production, because gardeners are more able to move plants around.

Syringe infested plants regularly to dislodge adults and nymphs (Tenbrink, 2020.). Mealy that has been knocked off may come back, however, and this species is known to hide in soil and eat roots, on pots, etc., as has been seen by gardeners at NYBG. Horticulturalists at Longwood Gardens observed that mealy is capable of living without host plants for **10 – 19 days**, and are even able to produce crawlers more than a month after migrating to off-plant habitat (Sclar, 2008.).

Volunteers at the Denver Botanical Garden, armed with toothbrushes and rubbing alcohol, are often deployed to rid infested plants of mealy and scale. Although rubbing alcohol used this way may not be allowed at NYBG (unless wielded by someone holding a certified pesticide applicator's license), a toothbrush alone may be a legally admissible weapon for volunteers to use against the pest.

Do not use infested stock in propagation. If a stock plant is too rare to be disposed of, and is a bit cold-hardy, exposing cuttings to low temperatures may significantly reduce mealybug survival. This may be done with entire plants, if they can withstand it. Growers at Longwood Gardens noted that “several subtropical plant species can tolerate ‘chilling’ for short periods — more than **36 hours** at **36° F** — with no damage and superior mealybug control,” (Sclar, 2008.).

Check all incoming plants carefully (Cloyd, 2016.). Reject any infested materials, do not try to clean them up (Sclar, 2008.). Check roots carefully for signs of infestations, as well as foliage.

If root-dwelling mealy is discovered, identify species in order to dictate a clear course of action. If the root-dwelling mealy is identified as citrus mealy, pots should be washed well with soap and water. Do not reuse growing mediums. Ensure that water from root-infested plants is not allowed to drain into areas that are uninfested — mealybugs can be transported in the runoff. Gardeners working in many zones should clean up their clothes after grooming infested plants as they may transfer from one area to another (Mahr, et. al., 2001.).

House sanitation. Plants should be moved so their leaves are not touching (Cloyd, 2016.), unless you have just released BCAs that require plants to be close together. If houses are overfull and citrus mealy is a perennial issue, consider culling or decreasing production so plants may be spaced further apart. This pest also prefers humid and shaded conditions (Martin, 2020.) so increased space could mean better airflow and light, making a less hospitable environment for reproduction.

Check the house for evidence of ants and eradicate whenever possible; ants and wasps protect mealy from beneficial predators (Martin, 2020.).

Setting house temperatures below **55° F** during the day and lower at night, if possible, will slow mealy growth to a crawl (Sclar, 2008.).

Hot water drips can kill mealybugs (Tenbrink, 2020.).

Annual Sanitation Controls. Since this pest has the ability to hide in cracks so well, extra care should be taken cleaning houses before new crops are planted, or during times when the houses are not in use.

2. Introduction of Biological Controls into IPM Programming

Biological Controls

In nature, citrus mealy is regulated by parasitic fungi and insect predators (Gill, 2020), as well as inundative rains that fall during summer months. First instar crawlers tend to hide immediately in cracks and crevices, making effective pesticide control difficult. Staff at the Nolen has commented on long-term difficulties in gaining control of the pest using pesticides alone.

Used in crowded areas where foliage is touching and populations are high, mealybug destroyers provide good control. It is important to note that mealybug destroyers will not work on citrus mealy located on the roots of plants (or other root-dwelling mealy species). This beneficial insect also needs citrus mealy eggs in order to propagate and sustain populations without re-introduction.

Not many parasitoids are available to control citrus mealy. However, there are a few and they are a good compliment for mealybug predators.

Although numbers do not always need to be reduced before the introduction of some BCAs, sanitation measures should be taken before BCAs are introduced into the environment (Mahr, et. al., 2001.).

Pre-conditions. Spot-treat female mealy bugs when egg masses are present and natural enemies are not (Mahr, et. al., 2001.). Cease using residual pesticides one month before releasing BCAs (Mahr, et. al., 2001.). If using mealybug destroyers (*Cryptolaemus montrouzieri*), levels of mealy do not need to be lowered with chemicals first. Syringe to clean sooty mold and honeydew that may attract ants and wasps, and to dislodge visible mealy. Clean up benches, under pot lips and drains.

Make sure ant or wasp populations that may have been attracted to honeydew are killed. Use boric acid or bait (Mahr, et. al., 2001.).

Remove sticky traps before releasing parasitoids. Microbial insecticides and insecticidal soaps are usually best for use with most BCAs (Mahr, et. al., 2001.).

Introduction of BCAs. For use of mealybug destroyers, pots that do not move for long periods of time have been found to provide a more hospitable environment. Gardeners at Longwood

Gardens noted, “where new plants are constantly being removed or replaced, large portions of the display lack ecological stability and success with biocontrol is lessened. However, removing plants is in itself a great cultural control,” (Sclar, 2008.).

Because citrus mealy in the soil is so difficult to control, interventions through the soil may need to be given more attention.

Summary. Treatment for citrus mealybug is very much the same for long-tailed mealybug in these two pest reports. The only major difference is between their parasitoids, which are generally more host-specific (See *Long-Tailed Mealy Report* for any differences). For citrus mealybugs, the parasitoid *Anagyrus pseudococci* may be used as a preventative between predator releases in warm houses. This beneficial will also parasitize long-tailed mealybugs.

Depending on the ratio of long-tailed mealybugs to citrus mealybugs, consider initially treating both with *Cryptolaemus montrouzieri*, the mealybug destroyer. Mealybug destroyers will eat both types of mealybugs but need citrus mealybug eggs in order to reproduce. They are more effective when released in higher populations of citrus mealy. If you want them to regenerate, do not release adults unless citrus mealy eggs are present.

This is a good option for houses with large and lasting infestations. It is not recommended to use as a preventative, but instead as a curative (Koppert, 2020.). This could be done in warmer houses at any time as that is what the predator and prey both favor (optimal temperatures are **72° - 77 ° F**).

If citrus mealybug is eradicated, mealybug destroyers will not be able to persist past one generation because of its reliance on the eggs of citrus mealybug in order to propagate.

Applications of *Beauveria bassiana* may provide protection during cooler temperatures and shorter days when many beneficials diapause.

Parasitoids

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Parasitoids of Note* section.

Anagyrus pseudococci encyrtid parasitoid	**Sources:** Arbico, 2020.; Mahr, et. al., 2001;. Wollaeger, 2015.

Feeding habits Feeds on citrus mealy and vine mealy. Attacks all stages of nymphs.	**Additional details** Internal parasite, solitary.
Habitat requirements Optimal temperature of 86° F. Active range of 57° – 93°F. Humidity has “limited effect.”	
Life cycle Lays approximately 45 eggs. Eggs hatch within 5 days.	

Leptomastix dactylopii Parasitoid wasp	**Sources:** Mahr, et. al., 2001.; Wollaeger, 2015.
Feeding habits Prefers third-instar nymphs	**Additional details** Able to control citrus mealy within 3 months. Populations must be reduced before introduction. Use mealybug destroyers to reduce populations, then introduce.
Habitat requirements 75 – 81° F.	
Life cycle Females lay 18-20 eggs a day. Oviposit in young adult citrus mealy. Life cycle takes 18 days in warm temperatures (81° F). In cooler temperatures (64° F), 35 days.	

Predators

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is provided in the *Predators of Note* section.

Cryptolaemus montrouzieri Cryptobug, Mealybug Destroyer	**Sources:** Mahr, et. al., 2001.; NYBG, *Control*, 2013.
Feeding habits	**Additional details**

Adult and larvae are both feeding Adults and young beetle larvae prefer mealy eggs and young instars. Older larvae feed on all stages of the mealybug. They also consume mealy, aphid, immature scales**.** Because LTM don't lay eggs, this could mean there needs to be an alternate *food source* (such as citrus mealy eggs).	Pest population does not need to be lowered before using. Eat up to 1,400 mealybugs in 12 – 20 days. Periodic releases may be needed if other natural enemies are not being used. Recommended by NYBG in the past.
Habitat requirements Temperatures of 72 – 77° F. Humidity of 70 – 80%	
Life cycle Needs citrus mealybug to hatch young.	

Chrysoperla carnea Green lacewing	**Sources:** Mahr, et. al., 2001.; NYBG, *Control*, 2013.
Feeding habits Will feed on mealy, will also feed on their BCAs if present**.**	**Additional details** Used with success in NYBG glasshouses to control this pest. **See the *Aphid Report* for more information.**

Pathogens

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Pathogens of Note* section.

Steinernema feltiae. A beneficial nematode, sold as Nemasys, (Recommended for use by the Denver Botanical Garden).

*** Beauveria bassiana.*** Sold as BotaniGard or Naturalis-L. It must be used in tandem with predators (such as Orius spp. in order to provide good control), (Mahr, et. al., 2001.).

Isaria fumosorosea. This entomopathogenic fungus was given as a possible solution by Koppert under the name NOFLY WP. It is unclear how well it would work for mealybugs.

Associated plants

Indicator plants. Infestations tend to be localized, and randomized scouting is not encouraged with this species. Therefore, use of indicator plants is not appropriate for aid in scouting.

Trap plants. No information was found on any trap plants that may be used for mealybugs.

Banker plants. Although there are no official banker plants for *Crysoperla carnea*, adults will eat pollen and nectar. Therefore, it may be advisable to have flowering plants on-hand for the adulthood of their lives.

3. Sources

Arbico Organics. *Mealybug Parasite, Anagyrus pseudococci*. Accessed September 27, 2020. https://www.arbico-organics.com/product/anagyrus-system-anagyrus-pseudococci/vine-mealybug-control

CABI. *Invasive Species Compendium: Planococcus citri (citrus mealybug)*. Accessed September 26, 2020. https://www.cabi.org/isc/datasheet/45082

Cloyd, Raymond A. *Greenhouse Pest Management*. CRC Press, 2016.

El-Aw, M. et. al. “Laboratory Studies on the Development and Life Table Parameters of Planococcus citri (Risso) (Hemiptera , Pseudococcidae) at Different Temperatures.” *International Journal of Research Studies in Biosciences*, vol. 4 no. 5. May 2016. p. 16 – 25. https://www.arcjournals.org/pdfs/ijrsb/v4-i5/3.pdf

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Control Handbook.* New York Botanical Garden internal document. 2013.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Identification Handbook Supplement 1.* New York Botanical Garden internal document. 2013.

Gill, Harisman K., et. al. *Citrus Mealybug Planococcus citri (Risso) (Insecta: Hemiptera: Pseudococcidae)*. University of Florida IFAS Extension. Accessed September 27, 2020. https://edis.ifas.ufl.edu/in947

Koppert Biological Systems. *Cryptobug*. Accessed September 27, 2020. https://www.koppertus.com/cryptobug-l/

Martin, K.W. et. al. *Citrus mealybug*. IDTools.org: Citrus Pests. Accessed September 27, 2020. https://idtools.org/id/citrus/pests/factsheet.php?name=Citrus%20mealybug

Osborne, Lance S. *Mealybugs*. University of Florida, MREC. Accessed September 27, 2020. https://mrec.ifas.ufl.edu/lso/Mealybugs.htm

Sclar, Casey. *Targeting the White Menace: Mealybug*." Greenhouse Product News, April 2008. https://gpnmag.com/article/targeting-white-menace-mealybugs/

Tenbrink, Victoria L. and Hara, Arnold H. *Pseudococcus longispinus (Targioni-Tozzetti)*. University of Hawai'i Beaumont Research Center. 1993. Accessed September 27, 2020. http://www.extento.hawaii.edu/kbase/crop/Type/p_longis.htm

University of Minnesota Extension. *Introduction to Mealybugs*. Accessed September 27, 2020. http://cues.cfans.umn.edu/old/inter/inmine/Mbugs.html

Wikipedia. *Planococcus citri*. Accessed September 27, 2020. https://en.wikipedia.org/wiki/Planococcus_citri

Wollaeger, Heidi, et. al. *Commercially Available Biological Control Agents for Common Greenhouse Insect Pests*. Michigan State University, 2015.

PEST REPORT

Mealy

Pseudococcus longispinus
long-tail mealybug

Mealy feeds on phloem, a food source that is plentiful but diluted, meaning phloem feeders must take in a fair amount plant sap in order to get adequate nutrition.

Photo via Koppert.

Feeding + vulnerable stages.

All stages of hatched females are feeding, only male nymphs are feeding.
Eggs, nymphs, and adult females are susceptible to various BCAs. Young nymphs are the most susceptible to pesticides.

Reproduction + life cycle.

Parthenogenic and sexual reproduction.
Matures in **30 – 45 days**.
Females live for **2 – 3 months**.
Female life stages: egg, 3 instars, adult.
Male life stages:: egg, 4 instars, pupa, adult
Lays **100 – 200 nymphs** over **2 – 3 weeks**.

Optimal climate.

Optimal temperature is **70° – 77º F**.
77º F is optimal for reproduction.
Optimal humidity is **70%**.

Severity + speed of damage.

Damage is not swift but populations are persistent. Plants are rarely killed but are compromised aesthetically.

In this report:

1. Pest overview

Summary

Long-tailed mealy prefers not-too-hot, not-too-cool temperatures around **70° - 77° F** (Tenbrink, 2020.). If hoping to use BCAs, there are fewer parasitoids exist for long-tailed mealy, making it somewhat harder to control than citrus mealy and making identification on a species level very important. Despite fewer perfect fits, there are still opportunities to obtain good control of long-tailed mealybugs using BCAs.

Reproduction is both parthenogenic and sexual (Koppert, 2020.). Unlike citrus mealy, long-tailed mealy females do not produce an egg sac. Instead, the young remain under the mother until she releases them as 1st instar nymphs, which makes her look as if she is birthing live young (Sullivan, 2010). Pupa and adult stages of males are non-feeding, though male nymphs do feed; all stages of hatched females are feeding (Tenbrink, 2020.). First instar male and female crawlers lack protective waxy secretions; older instars begin to secrete the coating soon after they start feeding (Tenbrink, 2020.). This interplay between feeding and non-feeding, protected from sprays and not protected, likely makes pesticide interventions kill some, but never all, of the stages of an infestation.

Damage to plants

This pest is phloem-feeding (Cloyd, 2016.) and it attacks plant foliage.

The long-tailed mealy has a smaller range of host plants than the citrus mealy but is nonetheless very widespread (Koppert, 2020.). It has been found on many plants, including air plant, asparagus, avocado, banyan, begonia, betel-nut, caladium, coconut and other palms, coffee, citrus, cycads, dracaena, gardenia, floral ginger, guava, heliconia, hibiscus, kamani, lilies, macadamia, mango, orchids, philodendron, pigeon pea, pineapple and other bromeliads, potato, sugar cane, and soybeans (Tenbrink, 2020.).

While feeding it injects a toxin while it feeds that can cause malformation (Mahr, et. al., 2001.), and grapevine leafroll-associated virus 3 (GLRaV-3) (Osborne, 2020.), which has not generally been a problem at the Nolen.

The pest also produces honeydew which decreases photosynthesis by encouraging sooty-mold, and attracts ants and wasps that attack beneficial insects (predators, etc.).

Temperature + climate

Long-tailed mealybugs have an optimal development range of **70° – 77º F** (Tenbrink, 2020.). **77° F** is the optimal temperature for long-tailed mealybug reproduction, while **70° F** is optimal for development into adulthood (Tenbrink, 2020.). Growth slows below **55° F** (Santa-Cecilia, 2011). The pest dies below **36° F** and above **95° F** (Santa-Cecilia, 2011), and is susceptible to outdoor winter freezing.

The pest thrives in humidity of around **70%** (Santa-Cecilia, 2011).

Pest monitoring

Population Triggers

Long-tailed mealy on cycad. Image via Center for Invasive Species and Ecosystem Health[2]

Pseudococcus longispinus numbers can be expected to rise when a combination of these factors is optimal:

Optimal climate. The optimal range for development and reproduction is **70° – 77º F.** (Tenbrink, 2020.)**.**

Presence of protectors, absence of predators and parasites. As with all honeydew producers, ants and wasps will protect long-tailed mealybugs from natural enemies.

Cryptolaemus montrouzieri, a natural enemy of the mealybug has been observed in the production houses at NYBG, and may have survived from BCA releases long-ago. This predator lays its eggs in citrus mealybug egg masses, and cannot sustain its numbers if only long-tailed mealybugs are present.

Food sources are present. The pest has a wide host range, but is said to be especially fond of succulent plants (coleus, fuchsia, croton, and cactus) (Mahr, et. al., 2001.).

All of these factors lead to exponential growth. Individuals mature in **30 – 45 days**. Females produce less young than citrus mealy, hatching **100 – 200 nymphs** over **2 – 3 weeks** (Koppert, 2020.). The female does not lay eggs but harbors them beneath her body. She lives for **2 – 3 months**; males only live a few days after reaching adulthood (Tenbrink, 2020.).

Monitoring

Like citrus mealy, visual inspection of plants is the best way to get a sense of citrus mealybug populations. However, the species is often hidden, so this type of inspection must be thorough.

Scouting. As with citrus mealy, visual inspection should be undertaken once a week for production houses. As many plants as possible should be checked, rather than a randomized sample; the pest is relatively non-mobile and therefore infestations tend to be localized. Signs of the pest include honeydew and wax secretions.


Long-tailed mealy infestation. Image via Center for Invasive Species and Ecosystem Health.[3]

Especially check hard-to-see-areas on plants, under benches, and pot rims, gardeners at NYBG have especially found them to hide in many places. The pest is known to hide inside leaf whorls (Sullivan, 2010).

Sticky cards. Sticky cards are able to catch male long-tailed mealybugs, however, because there tend to be so few males, careful inspection of plants is a better way to gauge outbreak numbers.

Environmental management

Sanitation, Physical, and Cultural Controls

Many practices that are recommended for long-tailed mealy are also recommended for citrus mealy, so the two have been combined and addressed in the citrus mealy report. It is worth noting however, that long-tailed mealy likely never migrate to roots of plants. Therefore, there is a chance that any recommendations pertaining to soil treatments may be disregarded if long-tailed mealy are the target pest.

Refer to the *Citrus Mealybug Report* for more information about environmental management.

2. Introduction of Biological Controls into IPM Programming

Biological Controls

Before biological controls can be introduced, it is vital that identification be made at the species level. Available parasitoids are closely matched to their hosts, and the mealybug destroyer (*Cryptolaemus montrouzieri*) is far more effective on obscure and citrus mealybugs than on long-tailed mealybugs. They will eat long-tailed mealy, but require the cottony masses of eggs of former for their own egg-laying and continuance in a greenhouse environment (Sullivan, 2010), (long-tailed mealy females do not produce eggs.).

Parasitoids are not widely available, but those that do exist are considered a crucial component for mealybug control (Mahr, et. al., 2001.). Predators such as *Diomus flavifrons*, *Scymnus* (*Nephus*) *reunioni*, and *S. bipunctatus* may be worth looking into if control with predators alone is fleeting.

Microbial insecticides and insecticidal soaps are usually best for use with most BCAs (Mahr, et. al., 2001.).

Introduction of BCAs. It is best to introduce most BCAs while numbers are low, before the warming air encourages population booms. Because mealybugs are so hidden, there's often more than meets the eye in an infestation.

Pre-conditions. Pest levels do not need to be reduced if using the mealybug destroyer (Mahr, et. al., 2001.). If releasing adult mealybug destroyers, make sure the egg masses of citrus mealy are present.

Make sure ant or wasp populations that may have been attracted to honeydew are killed, as they will protect mealy from natural enemies. Use boric acid or bait traps (Mahr, et. al., 2001.).

Summary. Treatment for citrus mealybug is very much the same for long-tailed mealybug in these two pest reports. The only major difference is between their parasitoids, which are generally more host-specific. For long-tailed mealybugs, the parasitoid *Pauridia peregrina* may be used as a preventative between predator releases in warm houses. This beneficial *will not* parasitize citrus mealybugs. Consider using if longtailed mealybug populations are not dented by other BCA interventions.

See the *Citrus Mealybug Report* for a detailed summary.

Parasitoids

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is available in the *Parasitoids of Note* section.

Anagyrus pseudococci *encyrtid parasitoid*	**Sources:** Osborne, 2020.
Feeding habits Singularly parasitizes older nymphs and adults. The larger the host, the better. Host is completely mummified by the 8th day at optimal temperatures.	**Additional details** Capable of ovipositing unfertilized eggs.
Habitat requirements Developmental range between 57 – 93 °F. Optimal temperature is 77 °F.	
Life cycle Adults emerge after 12 days.	

Pauridia peregrina *(syn. Hungariella peregrina)* *parasitic wasp*	**Sources:** Mahr, et. al., 2001.
Feeding habits Attacks first instar and second instars Will not attack citrus mealy.	**Additional details**
Habitat requirements Tolerant of high temperatures. More humidity is better for it at high temps and will increase longevity.	
Life cycle Lifecycle completed in 13 – 22 days. Does not diapause.	

Predators

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is available in the *Predators of Note* section.

Chrysoperla carnea Green Lacewing	**Sources:** Mahr, et. al., 2001.; Wollaeger, 2015.; NYBG, *Control*, 2013.
Feeding habits Will feed on mealy, will also feed on their BCAs if present**.**	**Additional details** Recommended by NYBG in the past. **See the *Green Peach Aphid Report* for more information.**

Cryptolaemus montrouzieri Mealybug destroyer	**Sources:** Mahr, et. al., 2001.**;** NYBG, Control, 2013.
Feeding habits Adult and larvae are both feeding Adults and young beetle larvae prefer mealy eggs and young instars. Older larvae feed on all stages of the mealybug. They also consume mealy, aphid, immature scales**.** Because LTM don't lay eggs, this could mean there needs to be an alternate *food source* (such as citrus mealy eggs).	**Additional details** Pest population does not need to be lowered before using. Eat up to 1,400 mealybugs in 12 – 20 days**.** Must hold off on using residual pesticides for one month before using**.** Recommended by NYBG in the past. **See the *Citrus Mealybug Report* for more information.**
Habitat requirements Use when temperatures are above 70° F. 72 – 77° F is best. Relative humidity of 70 – 80%. This happens to be the optimal range for long-tailed mealy, so these two appear to be well-paired.	
Life cycle	

Cannot complete lifecycle if only long-tailed mealy is present. This is because it lays its eggs in citrus mealy egg masses; long-tailed mealy do not lay eggs. Females lay up to 500 eggs (10 eggs per day) Eggs hatch in 7 days at 75° F. Generation is 25 days at 86° F; 72 days at 65° F. Short days lessen activity. Inactive below 50° F.	

Pathogens
Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Pathogens of Note* section.

* **Beauveria bassiana.** Sold as BotaniGard or Naturalis-L, used in tandem with predators (such as *Orius spp*.) in order to provide good control (Mahr, et. al., 2001.).

Steinernema feltiae. This is a beneficial nematode, sold as Nemasys (Recommended by the Denver Botanical Garden).

Associated plants

Indicator plants. Infestations tend to be localized and randomized scouting is not encouraged with this species. Therefore, use of indicator plants is not appropriate for aid in scouting.

Trap plants. *Dracaena sp.* is a preferred host and could perhaps be used as a trap plant. The pest is not very mobile, and information on trap plants has been difficult to find.

Threshold

Action thresholds for this pest are being revisited and will be updated if the information becomes available.

3. Sources

Byron, Morgan A., and Gillett-Kaufman, Jennifer L. *Featured Creatures: Longtailed mealybug.* University of Florida, IFAS Extension. Accessed September 27, 2020. http://entnemdept.ufl.edu/creatures/fruit/MEALYBUGS/longtailed_mealybug.htm

Cloyd, Raymond A. *Greenhouse Pest Management*. CRC Press, 2016.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Control Handbook.* New York Botanical Garden internal document. 2013.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Identification Handbook Supplement 1.* New York Botanical Garden internal document. 2013.

Koppert Biological Systems. *Long-tailed mealybug*. Accessed September 27, 2020. https://www.koppertus.com/challenges/mealybugs-and-scales/long-tailed-mealybug/

Martin, N. A. *Long-tailed mealybug — Pseudococcus longispinus*. New Zealand Arthropod Factsheet Series Number 160. Accessed September 27, 2020. https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Long-tailed-mealybug---Pseudococcus-longispinus.html

Santa-Cecilia, Lenira Viana Costa, et. al. “Effect of temperature on development and survival of the mealybug cochineal Pseudococcus longispinus (Targioni Tozzetti, 1867) (Hemiptera: Pseudococcidae) in coffee.” *Coffee Science*, vol. 6 no. 2. May / August 2011. http://sbicafe.ufv.br/bitstream/handle/123456789/7882/Coffee%20Science_v6_n2_pxx-xx_2011.pdf

Sclar, Casey. *Targeting the White Menace: Mealybugs.* Greenhouse Product News, April 2008. https://gpnmag.com/article/targeting-white-menace-mealybugs/

Sullivan, Cheryl E. Frank, and Skinner, Margaret. *Common greenhouse pests: Mealybug*. University of Vermont, Entomology Research Laboratory. 2010. https://www.uvm.edu/~entlab/Greenhouse%20IPM/Pests&Beneficials/Mealybugs.pdf

Tenbrink, Victoria L. and Hara, Arnold H. *Pseudococcus longispinus (Targioni-Tozzetti)*. University of Hawai’i Beaumont Research Center. 1993. Accessed September 27, 2020. http://www.extento.hawaii.edu/kbase/crop/Type/p_longis.htm

PEST REPORT

Mites

Polyphagotarsonemus latus
broad mite

Broad mites are half the size of two-spotted spider mites — meaning they can hide in the tiniest cracks of the tightest growth.

Photo by Erbe and Pooley, via Wikipedia

Feeding + vulnerable stages.

All stages of hatched mites are feeding except a pre-adult nymph. Mites are often hidden in the tight buds of new growth, protecting them from some types of pesticides.

Reproduction + life cycle.

Reproduction is sexual.
Matures in **4 days** (average).
Lifestages are eggs, nymphs, adults.
Lays **30 – 75 eggs**.

Optimal climate.

Optimal for development: **61° – 70° F**.
Relative humidity of **60% – 80%**.
Prefers cool and moist conditions.

Severity + speed of damage.

Feeding causes major deformation and stunting of terminal buds and meristems. Plants may not die, but growers may wish to destroy infested plants to control populations.

In this report:

1. Pest overview

Summary

Broad mites often go undetected, hiding in very tight new growth. Because of their size they can go unnoticed until extensive feeding causes visible signs of damage (Mahr, et. al., 2001.). *Polyphagotarsonemus latus* tend to be found in meristematic tissues and populations may be difficult to suppress with contact miticides alone (Cloyd, 2010.).

Because of the pests' hidden nature, problematic houses and mature plant specimens that have repeat infestations, should be watched closely year-over-year to pre-empt population explosions. Early action is best taken in susceptible production crops; once damage is evident it is often too late to suppress populations, even through chemical means (Cloyd, 2010.). If using predatory mites for control it is best to introduce them early in the crop cycle, before damage appears (Cloyd, 2010.).

Reproduction is sexual and males are widely responsible for distribution of the species, carrying females and eggs off to new plants and leaves in a "frenzy" (Fasulo, 2020.). All hatched stages of this pest are feeding, except the eggs and a pre-adult nymph, which is inactive (Mahr, et. al., 2001.).

Damage to plants

Broad mites feed on the epidermis of plants, feeding on the cells and damaging the meristematic tissues (Cloyd, 2010.). They are described as "broadly polyphagous" and have been found in over 60 different plant families (CABI, 2020.). Greenhouse favorites include: *Acalypha*, *Begonia*, *Calendula*, *Celosia*, *Fuchsia*, Geranium, Gerbera, *Hedera*, *Hydrangea*, *Jasminum*, New Guinea and standard *Impatiens*, *Plectranthus*, and *Salvia*.

Aside from feeding damage, the mite has toxic saliva that can cause twisted, hardened, and distorted growth in the terminal of the plant (Fasulo, 2020.). Even when the mites have been eradicated new growth may still be deformed (Blalock, 2013.).

Temperature + climate

Broad mites have a developmental range of **61° – 80° F**, with optimal temperatures falling between **61° – 70° F** (Cloyd, 2010.). Growth slows at **80° F**. Even when slowed by temperature, development only takes between **4 – 10 days** (Blalock, 2013.). Detailed information on the preferred temperatures for this pest varies widely between sources.

Broad mites thrive at a humidity of **60% – 80%**. Unlike spider mites, broad mites prefer cool and moist habitats (Mahr, et. al., 2001.).

It's difficult to kill broad mites with cold. The "supercooling threshold" of adults is **2° F**. Even temperatures as low as **44° F** will not kill or reduce reproductive rates (Luypaert, 2015.), though it will significantly slow them down.

Pest monitoring

Population Triggers

Polyphagotarsonemus latus numbers can be expected to rise when a combination of these factors is optimal:

Broad mite damage. Image via Greenhouse Product News[2]

Optimal climate. Prefers cool and moist conditions, with temperatures around **61 – 70°F** (Mahr, et. al., 2001.). Insects mature in **5 – 10 days** (Cloyd, 2010.). They prefer a relative humidity of **80%**.

Predators absent. Need more information. Food sources are present. This species is highly polyphagous (CABI, 2020.). Weeds may serve as alternate host plants or food (NYBG, Identification, 2013.).

All of these factors lead to exponential growth. The pest develops from egg to adult in an average of **4.1 days** (CABI, 2020.). Adults live **8 – 13 days** and then die (NYBG, *Identification*, 2013.). Females lay **30 – 75 eggs** (an average of **5 per day**) during their lifetime (NYBG, *Identification*, 2013.).

Suboptimal growth is also quick, happening in as little as 10 days (Fasulo, 2020.). They are able to develop down to very cool temperatures but are far less prolific below 44°F. Temperatures below freezing sustained for days or weeks, depending on their lifecycle, will kill them (Luypaert, 2015.).

Monitoring

A combination of visual inspection (for signs of feeding and symptoms of infestation), use of indicator plants, and perhaps even plant-part sampling should be used to monitor for broad mites.

The pest is exceptionally small and cannot be seen with the naked eye. It is difficult to identify without a microscope. Fallbacks such as looking for the pest itself, or tapping, will not help monitor populations. Scouting closely in houses that are problematic, or on specimens with a history of infestation is important.

Broad mite eggs are quite distinct. Image via ResearchGate[3]

Monitoring should begin as soon as plants begin to push new growth, and continue on a weekly basis (NYBG, *Identification*, 2013.), with special attention paid to repeat offenders.

Inspection. Visual inspection can be difficult because this species is so small, use of a 10x or stronger hand lens (or a dissecting microscope) is necessary (Fasulo, 2020.). Especially check developing terminal foliage and leaf buds (Mahr, et. al., 2001.), or the undersides of leaves (NYBG, *Identification*, 2013.).

A better indicator of infestation is to look for the signs of feeding. Damage from this pest can easily be mistaken for herbicide injury, nutritional (boron) deficiencies, or physiological disorders (Fasulo, 2020.). One difference between broad mite damage and abiotic damage is that broad mite damage tends to be patchy throughout the greenhouse (Mahr, et. al., 2001.). Closely inspect between the densely packed young leaves of the leaf bud (Mahr, et. al., 2001.). The mites avoid light, prefer relatively high humidity, and tend to be found in the crown of hosts (Mahr, et. al., 2001.). The dark, warm, moist conditions of unfurling growth is very attractive to them and the mites might crowd into crevices and buds (Fasulo, 2020.).

Keep a close eye for dispersal in houses that have whitefly populations. This pest is known to hitch rides on the legs and antennae of whiteflies to travel to greener pastures once populations become dense. They will not attach to aphids or thrips (Cloyd, 2010).

Plant part sampling. Because of the hidden nature of this pest, it may be useful to use plant part sampling if an infestation is suspected. Eggs are the clearest distinguishing feature of the broad mite and can be seen under a microscope (Blalock, 2013.).

Indicator plants. Beans are a favorite host of this pest and could possibly make a good indicator plant. Trial and error will tell.

Environmental management

Sanitation, Physical, and Cultural Controls

Plant sanitation. Some sources recommend that infested plants be immediately removed and destroyed, along with adjacent plants (Cloyd, 2010.). At NYBG problematic foliage is simply pruned from infested plants. This seems to work as part of a program of control as the pests pose little problem in the production houses. All tools should be cleaned thoroughly to avoid spreading after working with infested plants (Mahr, et. al., 2001.).

Check all incoming plants carefully for signs of feeding (Mahr, et. al., 2001.). Quarantine plants if infestation is suspected and sample parts of the plant to inspect. Be suspicious of anything appearing to have abiotic damage as outlined in the previous section (Mahr, et. al., 2001.).

If pruning does not help and removing a plant is not a viable option, consider hot water treatment. The University of Florida describes this as "lowering the plant into water held at **109.4 – 120.2° F** for **15 – 45 minutes**" and notes that it "may be used to control the mites without injuring the plants" (Fasulo, 2020.).

As noted by Kansas State University, "plants must be immersed in the hot water long enough to allow penetration into areas such as the meristematic tissues where mites are located, but not so long as to damage plants. Producers may consider implementing this procedure as a short-term solution. Plants placed back among crops can be infested," (Cloyd, 2010)**.**

House sanitation. Regularly clean the house of infested plants. Remove weeds that may serve as alternate host plants or food sources (NYBG, *Control*, 2013.).

If possible, consider manipulating environmental controls to achieve unfavorable climatic conditions (NYBG, *Control*, 2013.). Broad mites generally like cool and moist conditions, so hotter and drier air should slow them down. Do not try to kill with cold, it will not work.

If broad mites have been an issue on a particular bench, disinfect the bench and surrounding areas to alleviate future problems (Cloyd, 2010).

Annual Sanitation Controls. If broad mites (or cyclamen) have been a widespread issue in a particular house, consider disinfecting the entire house (Cloyd, 2010).

2. Introduction of Biological Controls into IPM Programming

Biological Controls

Monitoring, plant and house sanitation, as well as drawing on past experience are all important tools in combating broad mites. If use of BCAs is desired, these routines must be in place before any biologicals are introduced or they will quickly be overwhelmed. Predatory mites appear to be the most commonly employed for this pest. However, solid research in glasshouse use is limited (Mahr, et. al., 2001.).

Pre-conditions. Do not use residual pesticides for one month before the release of predators (Mahr, et. al., 2001.); after release, do not use sulfur-containing fungicides, as they are very toxic to predatory mites (Mahr, et. al., 2001.). High populations generally need to be reduced before predator introduction and infested plants should be spot-sprayed with selective chemicals (Mahr, et. al., 2001.).

As noted throughout, microbial insecticides and insecticidal soaps are usually best for use with most BCAs (Mahr, et. al., 2001.). In the case of broad mites, insecticidal soap may be just as effective as miticides that are labeled for control of the pest (Fasulo, 2020.).

Summary. Gardeners often control broad mites with mechanical means at the Nolen Greenhouses— cutting off disfigured and infested growth. If this intervention is the sole means of control and it is working, the production houses will probably not need to utilize targeted beneficials for this pest.

If more control is needed predatory mites are the most commonly recommended course of treatment.

In houses with an annual occurrence of outbreaks, *Neoseiulus cucumeris* could be used as a continued preventative in areas with continued populations. Another predatory mite, *N. barkeri* has been shown to target the pest more specifically and could be as a heavy or light curative for new outbreaks. *N. barkeri* is now considered “a strain of *N. cucumeris*” (Mahr, et. al., 2001.), so working closely with a vendor to sort through any differences will be important.

N. cucumeris will consume broad mites and is widely available, although it is unclear how voracious of a predator it is against *Polyphagotarsonemus latus*, specifically. Because it may prefer other prey (such as thrips and two-spotted spider mites), it may not favor eating broad mites. If this is the case, consider augmenting with something such as *N. californicus*, testing it for use as a light curative.

Parasitoids

No species worthy of recommendation were found. A full list of *Parasitoids of Note* for all other pests may be found here.

Predators

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list of *Predators of Note* may be found here.

Neoseiulus californicus Predatory mite	**Sources:** Mahr, et. al., 2001.; Schwartz
Feeding habits Able to survive long periods without food, so may be good for feeble populations	**Additional details** Easily established on peppers, even if prey is absent. Needs pollen to reproduce.

Neoseiulus cucumeris Predatory mite	**Sources:** Anatis Bioprotection, 2020.; CABI, 2020.
Feeding habits In greenhouses in China, the release of predatory mites of *Neoseiulus cucumeris* successfully controlled *P. latus* on sweet pepper. Also effective against western flower thrips and two-spotted spider mites.	**Additional details** Will feed on other biological controls. “In absence of prey, *Neoseiulus cucumeris* feed on eggs and immature stages of *Phytoseiulus persimilis*. It can be used with the soil mite *Stratiolaelaps scimitus*, *Dalotia (Atheta) coriaria* and with *Orius insidiosus*.” **See the *Western Flower Thrips Report*.**

Pathogens

No species worthy of recommendation were found. A full list of *Pathogens of Note* for all other pests may be found here.

Associated plants

Indicator plants. The pest is highly mobile via wind currents, peppers and beans could possibly be used as they are favored by the pest.

Trap plants. No information. Preferred hosts such as peppers and beans might make good candidates for experimentation.

Banker plants. *Neoseiulus cucumeris* is easily established on *Capsicum sp.*, even if prey is absent. Needs pollen to reproduce.

3. Sources

Anatis Bioprotection. Neoseiulus cucumeris. Accessed September 27, 2020. https://anatisbioprotection.com/en/biological-control-products/neoseiulus-cucumeris-thrips-mites.html

Blalock, Adam and Addesso, Karla. *Broad Mites Factsheet.* Tennessee State University College of Agriculture, Human And Natural Science Cooperative Extension. 2013. http://www.tnstate.edu/extension/documents/Broad%20Mites%20-%20TSUNRC%20Fact%20Sheet-1.pdf

CABI. *Invasive Species Compendium: Polyphagotarsonemus latus(broad mite)*. Accessed September 27, 2020. https://www.cabi.org/isc/datasheet/26876

Cloyd, Raymond A. *Broad Mite and Cyclamen Mite: Management in Greenhouses and Nurseries.* Kansas State University Agricultural Experiment Station and Cooperative Extension Service. November 2010.
https://bookstore.ksre.ksu.edu/pubs/MF2938.pdf

Fan, Y. Q., and Petitt F. L. "Biological Control of Broad Mite, *Polyphagotarsonemus latus* (Banks), by *Neoseiulus barkeri* Hughes on Pepper." Biological Control, vol. 4 no. 4, 1994. https://www.sciencedirect.com/science/article/abs/pii/S1049964484710498

Fasulo, Thomas R. *Broad Mite, Polyphagotarsonemus latus (Banks) (Arachnida: Acari: Tarsonemidae).* University of Florida IFAS Extension. Accessed September 27, 2020. https://edis.ifas.ufl.edu/in340

Luypaert, Gil et. al. "Cold hardiness of the broad mite Polyphagotarsonemus latus (Acari: Tarsonemidae)." *Experimental & applied acarology*, vol. 66, no. 1, 2015. https://pubmed.ncbi.nlm.nih.gov/25758635/

Texas A & M AgriLife Extension, "Broad Mite." Accessed September 27, 2020. https://texasinsects.tamu.edu/broad-mite/

Wollaeger, Heidi, et. al. *Commercially Available Biological Control Agents for Common Greenhouse Insect Pests*. Michigan State University, 2015. https://www.bioworksinc.com/wp-content/uploads/products/nemashield-hb/BCA_greenhouse-Insect-Pests.pdf

PEST REPORT

Mites

Tetranychus urticae
two-spotted spider mite

This mite produces exceptionally quick generations, going from egg to adult in as little as 8 days. It overwinters in greenhouse cracks and crevices, making it the first to the party on new crops.

Photo via University of Wisconsin.

Feeding + vulnerable stages.

All stages of hatched mites are feeding.
All stages of these mites are susceptible to various BCAs; nymphs and non-diapausing adults are the most susceptible to pesticides. Prone to arachnicide resistance.
Most miticides aren't effective against eggs.

Reproduction + life cycle.

Reproduction is sexual.
Matures in **8 – 12 days**.
Lives up to **30 days**.
Lifestages are: egg, 2 instars, adult.
Lays **90 – 110 eggs** during their lifetime.

Optimal climate.

Optimal temperature is **86 – 89° F**.
Development ceases below **54° F**.
Prefers low humidity.
Generally like hot and dry conditions.
Diapauses in cold weather.

Speed + severity of damage.

Damage is swift and difficult to stop. Can severely defoliate and kill plants.

In this report:

1. Pest overview

Summary

The two-spotted spider mite is a serious greenhouse pest. With a wide host range, short generation time, and continual production of young, populations can quickly explode (CABI, 2020.). Since the mites are able to crawl into cracks in the floor and diapause when days shorten, the temperatures cool, or food is scarce, they are able to return the moment more favorable conditions prevail. Predators (usually other mites) are an important component of two-spotted mite control (Fasulo, 2020.), and they should be looked for, identified, and protected on plants whenever possible. Early (or even pre-emptive) action is crucial if using BCAs to help control this pest as they can only be regulated when levels are low. In the case of predatory mites in a house with a history of infestation, application is recommended a full week before plants begin to emerge (Mahr, et. al., 2001.).

Reproduction is sexual. All stages of the hatched pest are feeding (CABI, 2020.). Adult females diapause and overwinter when day length and temperatures fall. When temperatures fall below **54° F**, adult females drop from plants into the cracks and crevices to hibernate until conditions become more favorable (CABI, 2020.). Aside from mites within the greenhouse, it is possible that mites from the outdoors may come in from the cold and take refuge inside the house as well. This period gives them protection from interventions that may otherwise knock their numbers down year-after-year.

Damage to plants

Two-spotted spider mites are chlorophyll feeders and have a very wide host range (CABI, 2020.). It may be found on tomatoes, cucumbers and peppers and, in greenhouses, on flowers such as chrysanthemums and orchids (CABI, 2020.).

Feeding reduces chlorophyll content, which results in reduced photosynthesis, carbon dioxide assimilation and transpiration, weakening the plant overall (CABI, 2020.). The function of the stomatal apparatus is also affected, so that the stomata remain closed (CABI, 2020.), that affects transpiration.

Alarmingly, plants can be killed rapidly by this pest.

Temperature + climate

Two-spotted spider mites have a development range of **54° – 89° F**, with an optimal range of **86° – 89° F** (CABI, 2020.). Development ceases below **54° F**, suggesting that greenhouses may get a slight break from spider mites if it's cool enough for them to enter diapause from September – February (Mahr, et. al., 2001.).

This mite hibernates during cold temperatures **(below 54° F)**, and is not susceptible to hard winter freezing.

They thrive in low humidity.

Pest monitoring

Population Triggers

Two-spotted spider mite damage on soybean. Image via University of Minnesota.(*NOTE)

Tetranychus urticae numbers can be expected to rise when a combination of these factors is optimal:

Optimal climate. Temperatures between **86-89° F** (CABI, 2020.). The total life cycle takes only **8 – 12 days** (CABI, 2020.). The pest likes low humidity.

Predators absent. No naturally occurring predators of *Tetranychus urticae* have been observed in NYBG's greenhouses.

Food sources are present. Weeds may serve as an alternate host plant and food source (NYBG, *Control*, 2013.).

A few of the plants that two-spotted spider mites have been found on in the past year are listed in the section *Damage to Plants*.

All of these factors lead to exponential growth. The pest rapidly develops from egg to adult in **8 – 12 days** (CABI, 2020.). Egg stage lasts from **3 – 5 days** (CABI, 2020.). Pre-oviposition period is

1 – 2 days (CABI, 2020.). Adults live around **30 days** (CABI, 2020.), with females laying **90 – 110 eggs** during their lifetimes (CABI, 2020.).

Monitoring

A combination of visual inspection, tapping, and use of indicator plants is necessary to get an accurate sense of two-spotted spider mite populations.

Scouting. Visual inspection is recommended, with scouts searching a randomized sampling (Mahr, et. al., 2001.). Tapping will help with this. Gently tap foliage over a sheet of white paper and, using a hand lens, count the individuals that fall. Especially check older and middle-age leaves, around the midrib (Mahr, et. al., 2001.).

Image via University of Florida.

Inspect the undersides of the leaves for mites, cast skins, and webbing (Fasulo, 2020.). This mite produces abundant amounts of webbing, but if it's visible, it's usually a sign that an infestation is out of control.

Indicator plants. The species is mobile enough on wind currents that indicator plants may be used. Lima beans are recommended (Mahr, et. al., 2001.). Monitor indicator plants next to doors, vents and windows as temperatures warm up, as the mites may come in from the outdoors.

Environmental management

Sanitation, Physical, and Cultural Controls

Plant sanitation. Syringe to dislodge all stages of pest — eggs, juvenile and adult insects (NYBG, *Control*, 2013.). Mist plants to increase moisture and make an unfavorable environment for the mite (Mahr, et. al., 2001.).

House sanitation. Regularly clean the house of heavily infested plants, destroying or quarantining them. If possible, manipulate greenhouse conditions to achieve unfavorable pest conditions (NYBG, *Control*, 2013.), ie. humid.

If there is an infestation in a house, restrict movement by staff through infested areas until it is brought to heel (Mahr, et. al., 2001.), (NYBG, *Control*, 2013).

Eliminate weeds from greenhouses, and in a **15' – 30' radius** around greenhouses, as the pest may come in from outdoors (Mahr, et. al., 2001.). Rooting out pokeweed, Jerusalem oak, Jimson weed, wild blackberry, wild geranium and others may decrease the numbers of overwintering mites that come inside from the outside (Fasulo, 2020.).

Annual Sanitation Controls. Overwintering females diapause in cracks and crevices and are able to survive very cold temperatures. Likewise, they are able to crawl to safety during production house summer clean-ups by crawling into the floor and away from heat, which can climb to **120° F** during solarization.

Cultural Controls. Hot water treatment may help control this pest (CABI, 2020.). If feasible, reduce fertilization as high nitrogen levels are associated with mite infestation (Mahr, et. al., 2001.). Increase humidity whenever possible to make conditions unfavorable (Mahr, et. al., 2001.).

2. Introduction of Biological Controls into IPM Programming

Biological Controls

The two-spotted spider mite is very difficult to control if BCAs are introduced too late. In fact, the book *Biological Controls of Insects and Other Pests of Greenhouse Crops* advises that, if adequate control is being provided with chemical applications the grower may want to stick with what works (Mahr, et. al., 2001.). This is particularly true if the habitat requirements for the chosen BCAs cannot be maintained (especially temperature and humidity) (Mahr, et. al., 2001.). Low tolerance thresholds due to the rapid aesthetic damage and death this pest deals may dissuade some growers from attempting to control by using beneficial organisms if pesticides are working.

In some specific cases (rose production houses), growers have integrated selective pesticide use on the tops of plants, while using BCAs on the lower sections (Mahr, et. al., 2001.).

Introduction of BCAs. Because this pest can quickly kill plants it is especially important that BCA introduction is preemptive, or introduced immediately after new outbreaks have been discovered. BCA programming fails when BCAs are released too late — mite damage can continue for only **1 – 3 weeks** before BCAs must be released (Mahr, et. al., 2001.). Therefore, if the house or the crop has a history of spider mites, predatory mites should be applied one week before plants emerge (Mahr, et. al., 2001.).

Insecticidal soaps will kill spider mites and their eggs, along with predators themselves. However, soaps have very limited effects on predator eggs (Mahr, et. al., 2001.).

Arranging leaves so plants touch may be advisable for some of the mite's predators. This will need to be figured into plant arrangement, especially if an effort to "de-clutter" and cull has been underway in order to keep plant leaves from touching.

Special attention should be paid to *Phytoseiulus persimilis*, which is used to control mites in glasshouses (CABI, 2020.), and has been used by NYBG in the past. Genera that are used to regulate populations of this pest include *Amblyseius, Euseius, Neoseiulus* and *Phytoseius* (CABI, 2020.). Species of *Stethorus*, a group of small ladybird beetles (*Coccinellidae*), are also important (CABI, 2020.).

Pre-conditions. This mite's population should be lowered before introducing BCAs, especially if the program is using predatory mites (Mahr, et. al., 2001.). Also crucial for meeting the success of predatory mites are pre-adjustments of temperature and humidity requirements.

Do not use residual pesticides for one month before release of predators (Mahr, et. al., 2001.); after release, do not use sulfur-containing fungicides, as they are very toxic to predatory mites (Mahr, et. al., 2001.).

Summary. Emphasis should be on preemptive intervention. Because this pest hibernates in the floors when conditions are unfavorable, growers should assume they will return year-over-year if established in a greenhouse. If BCAs are applied preemptively, there is hope that a single inoculation may give good control (Mahr, et. al., 2001.). Failures in control will occur if predators are released too late (Mahr, et. al., 2001.). Ensure coverage for warm and cool periods. If possible, strains that are non-diapausing and insecticide-resistant should be used (Mahr, et. al., 2001.).

Beneficials must be applied a full week before plants begin to emerge (Mahr, et. al., 2001.). The schedule of production and seed-sewing itself will drive applications of the initial intervention more than the time of year or temperature.

Control ideas here for the two-spotted spider mite are very similar to what was written previously for broad mites; most of the choices for broad mites would very likely rather be eating the two-spotted spider mite.

In houses with an annual occurrence of outbreaks, *Neoseiulus cucumeris* may be used as a continued preventative in areas with consistent populations during warmer temperatures.

Phytoseiulus persimilis was recommended by Rich Densel, who works with Grower's Choice, because it functions in a wide range of temperatures. *N. fallacis* is noted as doing better in higher temps and lower humidities. It may be worth testing either of them as a preventative treatment during cooler temperatures and shorter days.

If using *Phytoseiulus persimilis*, *Feltiella acarisuga* may be a good compliment, released if hotspots emerge. Buckets containing live insects may be placed in houses near the infestation. They begin to work on spider mite populations within a week and may be left in place for at least two weeks (Koppert, 2020.).

During cool temperatures and short days, *Beauveria bassiana* might be used for control.

Parasitoids

No species worthy of recommendation were found. A full list of parasitoids for all pests is included in the *Parasitoids of Note* section.

Predators

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Predators of Note* section.

Amblyseius andersoni predatory mite	**Sources:** Evergreen Growers, 2020.; Wollaeger, 2015.
Feeding habits Feeds on other prey of mites are unavailable.	**Additional details** Active at very low temperatures, unlike other beneficials. Release 10 per square foot.
Habitat requirements Active between 43° – 100°F.	

68° – 77° F may be optimal for development.	Recommended by NYBG in the past.
Life cycle Eggs hatch in 2 – 3 days. Egg to maturity takes 8 – 11 days. Live for about 21 days.	

Chrysoperla carnea Green Lacewing	**Sources:** Wollaeger, 2015.
Feeding habits Will feed on mites, does not appear to be a preferred food. Also feeds on aphids, sweet potato whitefly.	**Additional details** NYBG recommends use. **See *Green Peach Aphids Report* for more information.**

****Feltiella acarisuga*** predatory gall midge	**Sources :** Mahr, et. al., 2001.; Wollaeger, 2015.
Feeding habits Voracious feeder.	**Additional details** Has a low dispersal rate, but if used with another species, can help provide control if used with *P. persimilis*, and can find things the mite cannot be used alone. Good for use on plants with trichomes. A weekly release of one per 10 square feet is recommended, but is expensive. Growers often use one per 40 square feet and encourage numbers to grow over time.
Habitat requirements Optimal temperature range 68 – 81°F. Relative humidity greater than 60%.	
Life cycle High humidity improves emergence.	

Galendromus occidentalis predatory mite	**Sources:** Mahr, et. al., 2001.; Wollaeger, 2015.
Feeding habits Will not control populations quickly. Unclear which it prefers.	**Additional details** Can survive long periods without prey. Some strains are pesticide resistant. Better used in semi-permanent crops, rather than short-term crops, which could make it good for use in collections.
Habitat requirements Works in cooler temperatures, might be a good candidate for cooler houses or months. Wide humidity range 40 – 80%.	

Life cycle Does not diapause during short days or cool temperatures.	

***Neoseiulus californicus** Predatory mite	**Sources:** Mahr, et. al., 2001.
Feeding habits Able to survive long periods without food, so may be good for feeble populations	**Additional details** Recommended by Noah Schwartz, Neal Mast Growers

***Neoseiulus fallacis** (syn. *Neoseiulus*) predatory mite	**Sources:** Arbico Organics, 2020.; Evergreen Growers, 2020.; Wollaeger, 2015.
Feeding habits Voracious eater of mites. Feeds on pollen if mites are unavailable.	**Additional details** Active in cool temperatures. Tolerates higher temps and lower humidities than *Phytoseiulus persimilis*. Can out-reproduce their prey, making them effective at control.
Habitat requirements Wide range of temperatures:48° – 85° F . Relative humidity over 50%.	
Life cycle Lay 60 – 80 eggs. Live 20 days. Can reproduce at low temperatures. Not great for winter months (females diapause during short days).	

Phytoseiulus macropilis predatory mite	**Sources:** Mahr, et. al., 2001.; Wollaeger, 2015.
Feeding habits Prefers immature spider mites. As an adult they eat 6 eggs or nymphs per day.	**Additional details** Builds up quickly and is able to suppress populations. Has been tested on dieffenbachia, dracena, parlor palm, and schefflera. Therefore, might be a good fit for houses 7 and 8. Recommended by NYBG in the past.
Habitat requirements Works well in warm, humid conditions.	
Life cycle Very short lifecycle.	

***Phytoseiulus persimilis** predatory mite	**Sources:** NYBG, *Control*, 2013.; Mahr, et. al., 2001.
Feeding habits Nymphs consume 8 – 12 eggs or nymphs per day. Adults can consume 24 nymphs or 30 eggs per day. Strong preference for immature mites but will feed on all stages of mites.	**Additional details** Humidity below 60% stops oviposition and shortens their lives. Especially good on low-growing plants in humid houses. Trichomes make it hard for them to hunt, carnations are an example of "too slick" to hold on. Recommended by NYBG in the past. Recommended by Rich Densel, Grower's Choice.
Habitat requirements Optimum temperature range is 70° – 81° F. Relative humidity over 60% is crucial. Development can outpace two-spotted mites when heat and humidity are optimal.	
Life cycle Females lay up to 50 eggs. Eggs hatch within 3 days.	

Pathogens
A full list of pathogens for all pests is included in the *Pathogens of Note* section.

* ***Beauveria bassiana,*** a fungi. (CABI, 2020.).

Associated plants
Indicator plants. Lima beans may be used, as they are tall and attract blowing mites (Mahr, et. al., 2001.). If using indicator plants, release predatory mites at the first sign of spider mites on the plant (Mahr, et. al., 2001.). *Salvia* seems to be a favorite plant of the pest and growers might want to consider using it as an early indicator plant if not already doing so.

Trap plants. The bush beans 'Strike' and 'Provider' placed in spider mite prone crops and areas attract spider mites and can then be disposed of (Sullivan, 2010.).

Banker plants. Banker plants, such as cucumbers, could be a good way to "release" BCAs for use against two-spotted spider mites (Mahr, et. al., 2001.). Place cucumber plants at either end of the greenhouses. Plants may then be intentionally infested with spider mites. Release predatory mites when damage begins to show. Within a month, there will be thousands of predatory mites, ready to release onto the main crop (Mahr, et. al., 2001.).

Threshold

Action thresholds for this pest are being revisited and will be updated if the information becomes available.

3. Sources

Arbico Organics. *Amblyseius andersoni: Mite Predator.* Accessed September 27, 2020. https://www.arbico-organics.com/product/mite-predator-amblyseius-andersonii/pest-solver-guide-mites

CABI. *Invasive Species Compendium: Tetranychus urticae (two-spotted spider mite)*. Accessed September 27, 2020. https://www.cabi.org/isc/datasheet/53366

Cloyd, Raymond A. *Greenhouse Pest Management*. CRC Press, 2016.

Evergreen Growers. Accessed September 27, 2020. https://www.evergreengrowers.com

Fasulo, Thomas R. and Denmark, H.A. *Featured Creatures: Twospotted spider mite*. University of Florida, IFAS Extension. Accessed September 27, 2020. http://entnemdept.ufl.edu/creatures/orn/twospotted_mite.htm

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Control Handbook.* New York Botanical Garden internal document. 2013.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Identification Handbook Supplement 1.* New York Botanical Garden internal document. 2013.

Sullivan, Cheryl E. Frank, and Skinner, Margaret. *Plant-Mediated IPM Systems Explained*. University of Vermont, Entomology Research Laboratory. 2013.

http://www.uvm.edu/~entlab/Greenhouse%20IPM/Workshops/2014/PlantMedIIPMSystemsOverviewFinalNov13.pdf

Wollaeger, Heidi, et. al. *Commercially Available Biological Control Agents for Common Greenhouse Insect Pests*. Michigan State University, 2015. https://www.bioworksinc.com/wp-content/uploads/products/nemashield-hb/BCA_greenhouse-Insect-Pests.pdf

PEST REPORT

Thrips

Gynaikothrips ficorum
Cuban laurel thrip

Completely dissimilar from western flower thrips in habit and biology, this species is a strong flier, only feeds on tender green leaves, and lives most of its life in galls.

Photo via the University of Minnesota[1]

Feeding + vulnerable stages.

Nymphs and adults are feeding.
Eggs, nymphs, and adults are susceptible to various BCAs. Adults are susceptible to more types of pesticides than nymphs.

Reproduction & life cycle.

Reproduction is sexual.
Matures in **30 days**.
Lives for an unknown number of days.
Lifestages are: egg, 2 instars, pre-pupa, pupa, and adult. Females lay a large number of eggs.

Optimal climate.

Optimal temperature is **77°** – **86°** F.
Fastest growth at **86° F**.
Development ceases under **53° F** and over **95° F**.

Severity + speed of damage

Damage is severe, but plants are rarely killed. Damage develops slowly.

In this report:

1. Pest Overview

Summary

Unlike western flower thrips, Cuban laurel thrips feed only on foliage. This species is much larger than other types of thrips, and it is very good at flying. Populations are able to disperse readily in warmer temperatures (Texas A & M, 2020.). They may be found living in galls that are created by their feeding. Since *Gynaikothrips ficorum* only eats the tender green leaves, it is possible to mechanically remove sites of oviposition, such as galls and new uninfested growth, until the infestation has ceased (University of Florida, 2020.).

Cuban laurel thrips reproduce sexually, though males make up a much larger portion of the population (University of Florida, 2020.). Instars and adults both actively feed. Pre-pseudo pupa and pseudo pupa develop in the galls. All stages of thrips may be found in these galls, which may have up to 500 individuals in them, of overlapping generations (Paine, 1991.). The gall protects the pest from foliar pesticide applications, though systematics can provide some control (Funderburk, 2020.). However, systemic insecticides are not as readily absorbed by slow-growing indoor plants when compared to outdoor or production specimens. Furthermore, there is significant difficulty getting systemic insecticides into dead or dying leaves (Texas A & M, 2020.).

In general, adults leave the galls after pupation and are therefore less protected from a range of interventions than younger stages (Paine, 1991.).

Damage to plants

This pest is phloem-feeding (Cloyd, 2016). Unlike western flower thrips, it never feeds on pollen, but only on tender pale, green leaves (Funderburk, 2020.). It is polyphagous but has a more limited host range than most other thrips (Texas A & M, 2020.). Their primary host is *Ficus nitida* and *F. onocarpa* (Cranshaw, 2018.). Secondary hosts are *F. azillaria, F. aurea, F. benjamina, F. elastica, F. retusa, Viburnum,* citrus, *Eucalyptus, Gliricidia*, and orchids (Texas A & M, 2020.), along with various shrubs and herbs (Funderburk, 2020.).

Temperatures + climate

Cuban laurel thrips have an estimated development range of **53° – 95° F**, with an optimal range of **77° – 86° F.** Their growth is fastest at **86° F**, and slows in temperatures under **59° F.** Development ceases below **53°** and above **95° F** (Paine, 1991.).

As a pantropical species, Cuban laurel thrips are likely susceptible to hard winter freezing.

More information is needed about humidity conditions under which Cuban laurel thrips thrive and struggle.

Pest monitoring

Population triggers

Family time in the leaf gall. Image via University of Florida[4]

Gynaikothrips ficorum numbers can be expected to rise when a combination of these factors is optimal:

Optimal climate. 77° – 86° F (Paine, 1991.), **22 days** at **77° F**, fastest growth at **86° F** (**16 days**) (Paine, 1991.).

Food sources are present. This species needs pale, young, green leaves to set up its home (Funderburk, 2020.). It is polyphagous but *strongly* prefers *Ficus spp*.

Leaves roll after 2-3 days of feeding, and provide a gall that the Cuban laurel thrips live and breed inside (Funderburk, 2020.).

All of these factors lead to exponential growth. At **86° F** the pest undergoes rapid development, maturing in **16 days** from egg to adult (CABI, 2020.). Females lay large numbers of eggs during their lifetime (Texas A & M, 2020.). Eggs hatch after **2 – 4 days**, when warmer (**76° F**); up to **10 days** when cooler (**59° F**) (CABI, 2020.).

Development during suboptimal temperatures is far slower, taking up to **50 days** at **59° F** to mature (CABI, 2020.). Pantropical species are assumed to be susceptible to outdoor winter weather and do not diapause.

Monitoring

A combination of visual inspection, trapping, use of indicator plants, and plant-part sampling may help get an accurate sense of Cuban laurel thrips populations. Monitoring should begin early in the production cycle and happen on a weekly basis.

Scouting. Visual scouting is easier with Cuban laurel thrips when compared to western flower thrips due to their size, though they do hide in galls and leaf rolls. Especially check developing terminal foliage, terminal buds where galls are likely to form rolled leaves (Mahr, et. al., 2001.).

Feeding damage. Image via Flickr (Scot Nelson, plant pathologist)(NOTE)

Feeding results in a very specific growth, causing the leaf to roll, or to fold along the midrib (Funderburk, 2020.). Leaves begin to roll 2 – 3 days after feeding has begun (Texas A & M, 2020.). All stages of development may be found living in the protection of the pocket galls and several generations can develop within a single gall at once (Funderburk, 2020.).

Sticky cards. Blue or yellow sticky cards may be used. Increase monitoring with traps as warmer temperatures approach, adults are active fliers on hot days and migrate rapidly when it is hot (Funderburk, 2020.). While it is not likely that these pests come in from the outdoors, it is possible for them to fly between zones, as they are active and strong fliers. Traps should be placed 1" – 2" above the crop canopy (Mahr, et. al., 2001.).

Plant part sampling. Sample galls to get an accurate sense of population (Mahr, et. al., 2001.).

Indicator plants. With *Ficus* as a host species and the Cuban laurel thrips ability to fly, it may be possible to use the thrips' natural primary host plant as an indicator.

Environmental management

Sanitation, Physical, and Cultural Controls

Plant sanitation. Prune away all infested leaves (Funderburk, 2020.). If feasible, cut back any new growth suitable for feeding or oviposition, even if it is uninfested, as this will starve *Gynaikothrips ficorum* and disrupt their egg-laying (Texas A+M, 2020.).

Preventative measures should be taken whenever possible; sprays should be made before a leaf rolls (Texas A & M, 2020.).

Carefully check all plants coming out of collections houses, or propagation specimens, for signs of infestation. Check all incoming plants from outside vendors carefully.

Cultural controls. Replace *Ficus microcarpa* and *F. benjamina* with a resistant species of *Ficus* (Funderburk, 2020.). If feasible, limit the use of nitrogen fertilizers that will push new growth during infestations.

2. Introduction of Biological Controls into IPM Programming

Biological Controls

Cuban laurel thrips are not easily controlled by pesticides alone, given the protection afforded to them by the galls they brood in. Moreover, their hidden nature likely makes them impervious to parasitoids and their lifecycle makes soil predators moot, unlike other common thrips species that pupate in the soil.

As with pesticides, BCAs often have a difficult time getting at insects within the galls themselves. *Macrotracheliella nigra* (minute pirate bug) and *Chrysoperla carnea* (green lacewing) have both been found inside the rolled leaves, feeding. They will eat all stages of the thrips but both insect-predators prefer to eat adults (Paine, 1991.). Conversely, some sources note that *Orius insidiosus* have shown some difficulty getting into the galls to consume young Cuban laurel thrips.

Pre-conditions. Reduce populations of Cuban laurel thrips through mechanical means and spot treatment with pesticides. Stop use of residual pesticides one month before releasing parasites or predators.

Microbial insecticides and insecticidal soaps are generally best for use with most BCAs (Mahr, et. al., 2001.).

Introduction of BCAs. Introduce BCAs at the first sign of leaf galls.

Summary. The predators listed below are purported to be able to infiltrate leaf galls in order to get at developing Cuban laurel thrips. Many of them are also known to control other pests. It stands to reason that some combination along with mechanical removal would give good control. Because Cuban laurel thrips have not been an issue in production areas experimentation should begin in the Collections areas.

Parasitoids

No species worthy of recommendation were found. However, a full list of *Parasitoids of Note* for all other pests is available.

Predators

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list of *Predators of Note* is available.

Chrysoperla carnea Green Lacewing	**Sources:** NYBG, *Control*, 2013.; Paine, 1991.; University of California, 2020.
Feeding habits Often found within leaf rolls feeding on this pest. Larvae are voracious feeders. Adults eat pollen, nectar and honeydew.	**Additional details** Able to get into galls. Recommended by NYBG in the past. **See the *Green Peach Aphid Report* for more information.**
Habitat requirements Range 77-87°F for development. Eggs like it warm, but not more than 80°F. Relative humidity of 70% for egg development.	
Life cycle Females lay up to 300 eggs over 3-4 weeks. Eat for 2-3 weeks, then pupate. Pupation cocoon is above ground.	

Montandoniola confusa	**Sources:** CABI, 2020.; University of California, 2020.; Tavaresa, 2013.; Funderburk, 2020.

Feeding habits Natural enemy of Cuban laurel thrips. Preys on all life stages of pest Strong preference for eggs over adult/larvae	**Additional details** Reduces populations more than 95%, and leaf galls by 77% Much more fecund than *O. insidiosus* Eats Unclear if commercially available.
Habitat requirements More information is needed.	
Life cycle Lays up to 10 eggs every 2 days.	

Montandoniola moraguesi	**Sources:** Gerson, 2020.
Feeding habits Feeds on several species of gall-forming thrips (as many as 40)	**Additional details** Natural enemy, effectively introduced in HI for control in Ficus. *Macrotracheliella nigra* is also a species of interest. Unclear if commercially available.
Habitat requirements Consume 3-4 adults thrips per day	
Life cycle Females lay 12-24 eggs per day	

Neoseiulus cucumeris + degenerans Predatory mite	**Sources:** Wollaeger, 2015.
Feeding habits only kills first instars **(MSU)**. Also used on western flower thrips.	**Additional details** Possibly more effective against western flower thrips *N. degenerans* may have been recommended by NYBG for use in the past, unverified. **See the *Western Flower Thrips Report* for more information.**
Habitat requirements Needs humidity above 65% to reproduce, eggs will not hatch when drier. Pollen is needed to reproduce, which makes it less able to establish on non-flowering plants.	
Life cycle Adults live up to 30 days. Females lay 2 eggs a day, over a period of 20 days. *N. cucumeris* diapauses when daylight is less than 12.5 hours and temperatures are less than 69°F; though Koppert does not say as much.	

N. degenerans does not diapause.	

Also cited, but less effective:

Orius insidiosus. This predator cannot always get at the thrips inside of galls, and is not as voracious of a feeder on this pest as some other types of minute pirate bugs.

Stratiolaelaps scimitus. A soil-dwelling predatory mite. Not effective for these thrips because they do not pupate in the soil.

Pathogens

Pathogens of note:

Lecanicillium lecanii, a fungal pathogen (Funderburk, 2020.)

Steinernema feltiae, a beneficial nematode (Wollaeger, 2015.)

Associated plants

Indicator plants. The literature reviewed in this survey didn't cite any specific indicator plants. However, *Ficus* may be worth experimenting with as an indicator as it tends to be a preferred plant of Cuban laurel thrips.

Banker plants. *Neoseiulus cucumeris* is easily established on peppers, even if thrips are not available. It is also able to live on 'Hero Yellow' marigolds (though Cuban laurel thrips will not be attracted to this plant).

Flowering plants may be attractive to adult *Chrysoperla carnea*, enticing them and keeping them from flying away.

Threshold

Action thresholds for this pest are being revisited and will be updated if the information becomes available.

3. Sources

CABI. *Invasive Species Compendium: Gynaikothrips ficorum (Cuban laurel thrips)*. Accessed September 27, 2020. https://www.cabi.org/isc/datasheet/26258

Cloyd, Raymond A. *Greenhouse Pest Management*. CRC Press, 2016.

Cranshaw, Whitney, and Shetlar, David. *Garden Insects of North America.* Princeton University Press, 2018.

Evergreen Growers. Accessed September 27, 2020. https://www.evergreengrowers.com

Funderburk, Joseph E. et. al. *Featured Creatures: Leaf-gall thrips of Ficus.* University of Florida, IFAS Extension. Accessed September 27, 2020. http://entnemdept.ufl.edu/Creatures/ORN/THRIPS/Gynaikothrips.htm

Funderburk, Joseph E. et. al. *Leaf-Gall Thrips of Ficus Gynaikothrips ficorum (Marchal) and Gynaikothrips uzeli (Zimmerman) (Insecta: Thysanoptera: Phlaeothripidae).* University of Florida, IFAS Extension. Accessed September 27, 2020. https://edis.ifas.ufl.edu/in599

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Control Handbook.* New York Botanical Garden internal document. 2013.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Identification Handbook Supplement 1.* New York Botanical Garden internal document. 2013.

Gerson, Uri, and Applebaum, Shalom. *Montandoniola moraguesi Puton.* Hebrew University of Jerusalem. Accessed September 27, 2020. http://www.agri.huji.ac.il/mepests/enemy/Montandoniola_moraguesi/

Paine, Timothy D. "Factors Influencing the Development of Cuban Laurel Thrips on *Ficus Retusa*." University of California Division of Agriculture and Natural Resources. 1991. http://slosson.ucdavis.edu/newsletters/Paine_199129109.pdf

Tavaresa, Adauto M. "Behavior of Montandoniola confusa Streito & Matocq (Hemiptera: Anthocoridae) preying upon gall-forming thrips Gynaikothrips ficorum Marchal (Thysanoptera: Phlaeothripidae)" *Biological Control*, vol. 67 no. 3, 2013. p. 328 – 336. https://www.sciencedirect.com/science/article/pii/S1049964413002016

Texas A & M AgriLife Extension. *Cuban Laurel Thrips*. Accessed September 27, 2020. https://landscapeipm.tamu.edu/ipm-for-ornamentals/pests-of-ornamentals/cuban-laurel-thrips/

University of California. *Thrips of California: Gynaikothrips ficorum*. Accessed September 27, 2020. https://keys.lucidcentral.org/keys/v3/thrips_of_california/identify-thrips/key/california-thysanoptera-2012/Media/Html/browse_species/Gynaikothrips_ficorum.htm

University of Florida. *Cuban Laurel Thrips*. Accessed September 27, 2020. https://mrec.ifas.ufl.edu/lso/entomol/ncstate/thrips3.htm

PEST REPORT

Thrips

Frankliniella occidentalis
western flower thrip

North America's very own pest from the southwest is currently the most damaging thrips species in greenhouses and has spread throughout the world.

Photo by Frank Peairs, Colorado State University (*NOTE)

Feeding + vulnerable stages.

Feeding stages are: 1st instars, 2nd instars, adults. Eggs, nymphs, pupa and adults are susceptible to various BCAs. Nymphs and adults are susceptible to pesticides.

Reproduction + life cycle.

Reproduction is parthenogenic and sexual.
Matures in **10 – 15 days**.
Lives for **13 – 75 days**.
Lifestages are: egg, 2 instars, pre-pupa, pupa, adult.
Lays **40 – 250 eggs** during their lifetime.

Optimal climate.

Optimal temperature is **76° – 86° F**.
Fastest growth at **86° F**.
Dislikes high humidity.

Severity + speed of damage.

Reduces plant vigor. Reduces plant's aesthetic appeal. Transmitted viruses can kill plants. Damage is quick.

In this report:

1. Pest overview

Summary

Western flower thrips are a perennial problem in many greenhouses, with constant presence and population explosions throughout the year. Early detection is difficult as the species is often hidden, small, and hard to see. Using past experience as a guide is the best way to combat them (Mahr, et. al., 2001.). Year-over-year experience will point to patterns in population explosions that must be preempted. Once the pest has been discovered only a holistic approach to control will hopefully work, as no one thing will work alone (Mahr, et. al., 2001.). Throw everything at them, including the kitchen sink, and BCAs for good measure.

These thrips reproduce both sexually and via parthenogenesis (Cluever, 2015.). Actively feeding stages are instar I and II (Reitz 2009; CABI 2014) (Cluever, 2015.). Pre-pseudo pupa and pseudo pupa drop to the soil and do not feed for a total of **2 – 5 days** (NYBG, *Identification*, 2013.). These phases can also occur in complex flowers such as chrysanthemum, or perhaps even orchids (Cluever, 2015.). While in the soil or flower, the pre- and pupal- stages are protected from foliar sprays (NYBG, *Identification*, 2013.). This, and the cryptic behavior of instars and adults limits exposure to insecticides (Cluever, 2015.). Eggs are oviposited into the plant tissue or hidden areas that are protected from foliar sprays (NYBG, *Identification*, 2013.). Their tendency to develop pesticide resistance further complicates the problem (Sanderson, 2020.).

Damage to plants

This pest feeds on the mesophyll and pollen-grains of plants, causing cells to collapse (Sanderson, 2020.). Western flower thrips are highly polyphagous and have been found on over 500 species of plants (Cluever, 2015.). They have also been known to eat spider mite eggs (Cluever, 2015.).

Beyond the damage caused by feeding, these pests are also ready vectors for incurable viruses: Tomato spotted wilt virus (TSWV), chlorotic spot virus, impatiens necrotic spot virus (INSV), and groundnut ringspot virus (Sanderson, 2020.). INSV has been shown to impact impatiens, begonia, cyclamen, cineraria and gloxinia, many other plants (Sanderson, 2020.). These viruses are acquired as first instar nymphs and the pests have them for the rest of their lives (Sanderson, 2020.).

Temperature + climate

Western flower thrips have an estimated developmental range of **41° – 86° F**, with an optimal development range of **76° – 86° F** (NYBG, *Identification*, 2013.). They grow fastest at **86° F**

(CABI, 2020.), and their growth slows noticeably below **54° F**. Development ceases *entirely* below **41° F** (Tsumuki, Hisaaki, et. al., 2007).

These pests are susceptible to outdoor winter freezing temperatures but can overwinter in controlled mild environments.

Western flower thrips have a humidity range of **70% – 90%**. Their populations will begin to decrease when humidity exceeds **90%** (Mahr, et. al., 2001.)**.**

Population Triggers

Frankliniella occidentalis numbers can be expected to rise when a combination of these factors is optimal:

Optimal climate. Temperatures between **76° – 86°F**. The greatest population growth rates are seen at temperatures of **86° F** (CABI, 2020.)

Western flower thrips damage. Image via University of Florida.

Food sources are present. This species is highly polyphagous. Pollen is especially nourishing and flowering plants are desirable. Weeds in the greenhouse can allow it to survive during dire times.

A few of the plants that western flower thrips have been found on in the past year are listed in the section *Damage to Plants*.

All of these factors lead to exponential growth. The pest rapidly develops from egg to adult in **10 – 15 days** (NYBG, *Identification*, 2013.) when temperatures are warm **(76° – 86° F).** Adults live anywhere from **13 – 75 days** (Sanderson, 2020.), depending on temperature and development time. At **68° F**, females may hatch an average of **95.5 eggs** (CABI, 2020.), with even greater reproductive rates above **86° F**.

Growth in suboptimal temperatures is still high. Lower temperatures yield lower developmental and reproductive rates. The pest takes up to **57 days** to go from egg to adult at **54° F** (NYBG, *Identification*, 2013.). Females typically hatch **20 – 40 eggs** during their lives (CABI, 2020.). Eggs hatch in **13 days** at **59° F** (CABI, 2020.). Western flower thrips do not undergo reproductive or developmental diapause (CABI, 2020.). instead succumbing to colder temperatures. Western flower thrips survived for about **30 – 40 days** at **32° F**, then perished (Tsumuki, Hisaaki, et. al., 2007).

Monitoring

A combination of visual inspection, tapping, blowing, trapping, use of indicator plants, and plant-part sampling is necessary to get an accurate sense of western flower thrips populations. Monitoring should begin before flower buds start to form (Mahr, et. al., 2001.) and happen on a weekly basis.

Scouting. Visual scouting can be difficult because this species remains so hidden (Mahr, et. al., 2001.). Longtime go-tos like gently tapping flowers over a sheet of white paper and counting the individuals that fall, as well as breathing on flowers to excite hidden thrips, are helpful.

The predator *Orius insidiosus*. Image via University of Florida.[3]

Especially check developing terminal foliage and the base of flower petals (Mahr, et. al., 2001.). For immature thrips, counting the number found on leaf samples is the best indicator of population (Mahr, et. al., 2001.). Once found, assume there are far more than meets the eye (Mahr, et. al., 2001.). For multi-generational infestations, use a wider-range of tactics.

Sticky cards. Sticky cards and traps should be used especially when temperatures are **above 55° F**, as flight activity increases (Sanderson, 2020.). Set traps next to windows, doors, vents, and other potential points of entry when the outdoor weather is optimal for thrips development, because they often come in from outside. Blue traps should be used if exclusively stalking *Frankliniella occidentalis*, as they catch more of this species when compared to yellow traps (Cluever, 2015.). Take note that trap catches are unlikely to reflect population size or predictor damage accurately (Cluever, 2015.).

Plant part sampling. Sampling plant parts is the best way to get an accurate count of western flower thrips (Mahr, et. al., 2001.). Select a set number of flowers, put them in a 1 oz. plastic vial of 70% alcohol and seal immediately. Filter contents and count what is on the filter paper (Mahr, et. al., 2001.). Flowers may also be dissected for a more thorough count (Mahr, et. al., 2001.).

Indicator plants. The species is a poor flier but somewhat mobile, so indicator plants such as yellow marigolds, mums, or gerberas may be used (Sullivan, 2010.). Trap plants, such as peppers, were used at the NYBG in the past and were effective, though a routine "throw out" threshold must be established in order to keep trap plants from becoming sources of infestation.

Environmental management

Sanitation, Physical, and Cultural Controls

"Sanitation is the most important cultural practice in preventing problems with thrips," (Mahr, et. al., 2001.).

Plant sanitation. Destroy (or remove and quarantine) all heavily infested plants. Immediately throw away any plants with signs of virus to quash a potential epidemic (Sanderson, 2020.). If fungal infections are not a concern, syringe the top of the plants to knock the pests off (NYBG, *Identification*, 2013.). Remove buds, blooming flowers and spent flowers; they may harbor several life stages of the pest, including pseudo-pupa if the flower is complicated enough. Pre-emptive disbudding may be advisable if the crop or zone is known to be problematic, as pollen is very nourishing to western flower thrips and populations may explode when it is available as a food source.

Hang blue sticky traps or roller traps just above the soil to capture adults as they emerge (Koppert, 2020).

Check all incoming plants. Because of the hidden nature of this pest, quarantining incoming plants may help. Even if it looks clean, it could be harboring eggs, which are oviposited internally. Carefully check all stock plants; do not propagate using materials from an infested plant.

As a point of protocol to treat incoming plants, Rich Densel dips all incoming plants in a 10-gallon nematode and beneficial bacterial concoction. He uses *Steinernema feltiae* and *Beauveria bassiana*, asserting that this combination will kill several pests, including western flower thrips.

Quarantine all plants coming back into production houses from the back gravel. Gardeners have observed thrips and whitefly populations migrating from the outdoors, indoors.

Set standardized pruning and disposal thresholds for all trap plants.

House sanitation. Regularly clean the house of heavily infested plants, destroying or quarantining them. Eliminate weeds from greenhouses, as they may harbor thrips or viruses, or host thrips. Change patterns of greenhouse gardeners to mitigate movement from thrip-infested areas to non-infested areas as they will often hitch rides from one area to another, especially on people wearing yellow or blue clothing (Sanderson, 2020.).

Steam-treat soil of infested plants to kill pupa (Mahr, et. al., 2001.).

The use of roller tape traps will greatly reduce the movement of any thrips throughout the house (Mahr, et. al., 2001.).

Screening the side of the house that faces prevailing winds might effectively keep outdoor thrips outside (Mahr, et. al., 2001.), but may be prohibitively expensive and reduce air flow, resulting in fungal issues. UV-reflective mulch has been shown to reduce the ability of thrips to find hosts (Cluever, 2015.), (although this is a crop-based intervention perhaps some sort of “collar” could be created for potted specimens).

Annual Sanitation Controls. Western flower thrips may be starved, as outlined by Cornell (Sanderson, 2020.). To summarize: empty greenhouses, keeping them at **60° F**, and remove any nearby plants upon which thrips can feed, including weeds. Emerging pupae starve, breaking the cycle of infestation. This is done during the winter to keep thrips from the outdoors from coming inside (Sanderson, 2020.).

A **15' – 30' weed-free** radius around greenhouses may help to keep the pest from coming in from the outdoors during warmer months (Mahr, et. al., 2001.).

Cultural Controls. A reduction in nitrogen fertilization may result in a decrease in the number of *Frankliniella occidentalis* (Cluever, 2015.), but this might not be possible in a production setting.

Changing house humidity by way of misting could help, too. Relative humidity of **90%** has been shown to reduce thrips population (Mahr, et. al., 2001.).

Nematode drenches in the late winter and early spring of 2020 were observed to be crucial in knocking down numbers of western flower thrips and should continue year-over-year.

2. Introduction of Biological Controls into IPM Programming

Biological Controls

Proper monitoring, plant and house sanitation, as well as cultural controls are all necessary to control western flower thrips. The pest is so problematic that all these controls should be utilized, regardless of the introduction of beneficials. At a minimum, these physical controls must be in place before any BCAs are introduced. Ultimately, if the grower wishes to establish BCAs, they may need to tolerate a high threshold of foliar damage (or flower damage) while thrips are brought under control (Mahr, et. al., 2001.). Spinosad is recommended for use against thrips, with low to moderate impact on beneficials (Mahr, et. al., 2001.).

Microbial insecticides and insecticidal soaps are usually best for use with most BCAs (Mahr, et. al., 2001.).

A solid, detailed, and clear plan for introducing BCAs into the orchids collection house exists from 2015 and should be revisited.

Introduction of BCAs. Cornell suggests that it is crucial for control to begin at the end of the season to avoid carrying large populations from one season to the next (Sanderson, 2020.). In a production greenhouse, this could mean it is best done after “winter starvation” (mentioned in the previous section), when the first plants are just arriving in the house.

Parasitoids are easily overwhelmed by multitudes of thrips entering the greenhouse from outdoors, so pay close attention to cards near doors and vents. If using predatory mites, release them as soon as thrips are detected on sticky cards (Mahr, et. al., 2001.). Predators such as the minute pirate bug should also be released when numbers are low.

Neoseiulus degenerans and *N. cucumeris,* are commonly used (one diapauses, the other does not, so together they provide good coverage), (Mahr, et. al., 2001.). Together, may provide control over a range that is typical of greenhouses (Mahr, et. al., 2001.).

Pre-conditions. In general, thrips populations should be lowered before introducing BCAs. If using parasitoids or predators, residual sprays should be discontinued for one month prior to introduction (Mahr, et. al., 2001.). Sanitation measures mentioned in the previous section should all be met, especially for a pernicious pest such as western flower thrips.

Summary. In addition to throwing any and all sanitation and cultural best-practices at this pest, a complimentary mix of predatory mites and pirate bugs in the foliage, and soil-dwelling mites and predators in the growing medium may be able to control thrips (Mahr, et. al., 2001.). *Orius insidiosus* are the only species detailed here that will consume adults; it will also consume predatory mites if thrips do not provide sufficient food (Mahr, et. al., 2001.).

During cooler times, or shorter days when beneficial insects might be diapausing, a nematode drench with Nemasys was recommended by gardeners at the Denver Botanical Garden. This year, nematode drenches were viewed very favorably by production house gardeners at NYBG. They were applied in February and early March of 2020.

The predatory mite *Neoseiulus cucumeris* is also good for cooler seasons and shorter days. It was recommended for use as a preventative by Rich Densel, from January until May or even early June during a cooler year. It does not do well in temperatures greater than **85° F**. It is broadcast every other week while in use.

Atheta coriaria is very effective against western flower thrips pupae in the soil. It is an aggressive generalist that will eat many pests, has a wide temperature range, overwinters well and can get going early in the season. It is also not cheap. Rich Densel has found a simple way to rear them in order to have them readily available as a preventative treatment.

At the start of the season, Rich buys a batch of 500 and rears the rest. This beneficial insect needs soil in order to pupate and complete its life cycle. This is not readily available in a house with a concrete floor. In order to create a space for pupation, he sets out several 1 – 2 gallon buckets and fills them with soil or some other substrate, such as peat moss. Just above the substrate line he drills a number of ¼" holes, (these will allow the adults that have completed their pupation to escape). He sprinkles water in the mix and puts in trout pellets, which they love to feed on. This smells horrible. But it's what they like to eat and they breed in the buckets. After **5 – 7** weeks, adults emerge from the holes to live their lives and aggressively feed.

As temperatures warm, a constant course of predatory mites such as *Amblyseius californicus*, the soil-dwelling mite *Hypoaspis miles* (*Stratiolaelaps scimitus*) and the predator *Orius insidiosus* may be used as preventatives. The predatory mites must be purchased and applied. *O. insidiosus* must be purchased and applied in the cooler weather of April and May. After initial applications, they may be reared on pepper plants. Once the hot weather gets going, Rich has had a lot of success using banker plants to keep them breeding and their numbers up.

Mites can be released before thrips are detected and pirate bugs work well on hot spots (Mahr, et. al., 2001.). The pirate bugs can be re-purchased and released as a curative if they fail to establish and reproduce on banker plants.

Whatever choice is made, it is best to control western flower thrips with multiple BCAs and strategies (NYBG, *Control*, 2013.).

Parasitoids

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is located in the Parasitoids of Note section.

<table>
<tr><td>Thripobius javae
(syn. T. semiluteus)
Parasitic wasp</td><td>Sources: Mahr, et. al., 2001.</td></tr>
<tr><td>Feeding habits
Attack larvae.</td><td rowspan="3">Additional details
Recommended for use as a compliment to N. cucumeris.</td></tr>
<tr><td>Habitat requirements
Optimal temperature is 65 – 75° F.
Likes RH of 50 – 60%.</td></tr>
<tr><td>Life cycle
Parthenogenic, laying 15 – 20 eggs.

Egg – adult takes about 3 weeks.

Diapauses below 40° F .</td></tr>
</table>

Predators

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Predators of Note* section.

Atheta coriaria Predatory rove beetle	**Sources:** Mahr, et. al., 2001.
Feeding habits Feed on soil-dwelling pupae.	**Additional details** Rich Densel at Growers Choice recommends this generalist predator. A one-time purchase of 500 individuals. Eats "good, bad, pretty, ugly." They will also eat beneficials. NYBG has recommended using in the past.

Hypoaspis miles brown mite (syn. *Stratiolaelaps scimitus*) predatory mite	**Sources:** Mahr, et. al., 2001.; Sanderson, 2020.; Wollaeger, 2015.
Feeding habits Eats the soil-dwelling pre-pupa and pupa of western flower thrips. Consumes 15 – 30 per day. **Habitat requirements** Likes temperatures of at least 59° F and works best when the soil is moist. **Life cycle** Life cycle completed in 13 – 22 days. Does not diapause.	**Additional details** Should not be used as a sole source of control, but when used with other controls can reduce thrips by 70%. Must be applied early in the season to allow establishment before thrips begin to pupate in the soil. Not effective against Cuban flower thrip. Also used against fungus gnats. *Stratiolaelaps scimitus* is another soil dwelling mite that may be useful. Rich Densel at Growers Choice recommends this generalist predator. Recommended by NYBG in the past.

***Neoseiulus cucumeris** predatory mite, (syn. *Amblyseius cucumeris)*	**Sources:** Mahr, et. al., 2001.; Sanderson, 2020.; Wollaeger, 2015.
Feeding habits Only kills first instar thrips. Will also feed on spider mites and eggs; broad mite adults. Eats pollen or resorts to cannibalism when prey is not available.	**Additional details** Recommended for use as a compliment to *N. cucumeris*. Established easily on peppers even without thrips. Does not perform well with trichomes, therefore repeated releases may be necessary, making control more costly. Release rate of 50 mites per plant, plus an extra 100 infested leaf.
Habitat requirements Needs humidity above 65% to reproduce, eggs will not hatch when drier. Pollen is needed to reproduce, which makes it less able to establish on non-flowering plants.	
Life cycle Adults live up to 30 days. Females lay 2 eggs a day, over a period of 20 days. Diapauses when daylight is less than 12.5 hours and temperatures are less than 69° F; Koppert does not note this diapauses, may want to double check.	

Neoseiulus degenerans (syn. Iphiseius, Amblyseius degenerans) Predatory mite	**Sources:** Mahr, et. al., 2001.; Sanderson, 2020.
Feeding habits Only kills first instar thrips.	**Additional details** Recommended for use as a compliment to *N. cucumeris*. May have been recommended by NYBG in the past, unverified.
Habitat requirements Similar to *N.cucumeris*	
Life cycle Do not diapause during winter months.	

***Orius insidiosus + Orius sp.** predatory true bug	**Sources:** Mahr, et. al., 2001.; Evergreen Growers, 2020.; Wollaeger, 2015.; NYBG, *Control*, 2013.
Feeding habits	**Additional details**

Feed on all active stages of thrips. Also feed on spider mites, aphids, whiteflies, and caterpillar eggs. Feed on pollen and plant juices when prey is not available. Will also eat predatory mites.	Species do not reproduce equally well on all plants; all have different preferences. For instance, *O. insidiosus* reproduces best on mums, gerbera, cukes and peppers; whereas *O. laevigatus* and *O. albipennis* are better suited for peppers and strawberries. Recommended by NYBG in the past. Rich Densel at Growers Choice recommends this generalist predator.
Habitat requirements Temperatures over 59° F. Greenhouse temperatures of 64 – 82 °F. Humidity over 60%.	
Life cycle Diapauses under short days and low temperatures. Blue light will reduce the number of *O.insidiosus* that diapause. First instar nymphs are often found in the same place as western flower thrips.	

Pathogens

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is located in the *Pathogens of Note* section.

* ***Beauveria bassiana***, BotaniGard or Naturalis-L, insect-killing fungal pathogen that is also useful against mites (Sanderson, 2020.); must be used in tandem with predators (such as Orius spp. in order to provide good control (Mahr, et. al., 2001.).

* ***Heterorhabditis bacteriophora***, a nematode that reduces the adult emergence of western flower thrips by 40% and reduces young produced by surviving adults. Might be too expensive (Mahr, et. al., 2001.).

* ***Steinernema feltiae***, beneficial nematode, sold as Nemasys (Recommended by the Denver Botanical Garden.)

Unknown strain and brand, nematode drenches were given rave reviews by production house gardeners. Applied in February and early March of 2020, gardeners.

Associated plants

Indicator plants. Yellow marigolds, mums and gerberas can all be used as indicator plants (Sullivan, 2010.).

Trap plants. Peppers have been successfully used at the Nolen in the past and could easily be used in the future, with a plan to throw away infested plants on a regular schedule or when past a certain threshold.

For non-flowering ornamentals and vegetables, flowering 'Hero Yellow' marigolds will be more attractive and draw western flower thrips to them, away from crops (Sullivan, 2010.).

Banker plants. Aside from being excellent trap plants, 'Hero Yellow' marigolds can also sustain *Neoseiulus cucumeris* by providing pollen and attracting thrips as food (Sullivan, 2010.).

Likewise, *Neoseiulus cucumeris* is established easily on peppers, even if thrips are absent. If done correctly, this could be a way to brood a good number and introduce to thrips-prone areas.

When used among non-flowering ornamentals, *Lobularia* 'Snow Crystal' provides pollen to the predatory bug *Orius* and attracts thrips (Sullivan, 2010.).

Threshold

Action thresholds for this pest are being revisited and will be updated if the information becomes available.

3. Sources

CABI. *Invasive Species Compendium: Frankliniella occidentalis (western flower thrips)*. Accessed September 27, 2020. https://www.cabi.org/isc/datasheet/24426

Cluever, Jeffrey D. et. al. Western Flower Thrips (Frankliniella occidentalis [Pergande])." University of Florida, IFAS Extension. 2015. https://edis.ifas.ufl.edu/pdffiles/IN/IN108900.pdf

Cranshaw, Whitney, and Shetlar, David. *Garden Insects of North America.* Princeton University Press, 2018.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Control Handbook.* New York Botanical Garden internal document. 2013.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Identification Handbook Supplement 1.* New York Botanical Garden internal document. 2013.

Koppert Biological Systems. *Horiver-TR*. Accessed September 27, 2020. https://www.koppertus.com/horiver-tr/

Sanderson, John P. *Western Flower Thrips*. Cornell Cooperative Extension. Undated. http://www.greenhouse.cornell.edu/pests/pdfs/insects/WFT.pdf

Sullivan, Cheryl E. Frank, and Skinner, Margaret. *Plant-Mediated IPM Systems Explained*. University of Vermont, Entomology Research Laboratory. 2013. http://www.uvm.edu/~entlab/Greenhouse%20IPM/Workshops/2014/PlantMedIIPMSystemsOverviewFinalNov13.pdf

Tsumuki, Hisaaki, et. al. "Cold hardiness of adult western flower thrips, Frankliniella occidentalis(Pergande) (Thysanoptera: Thripidae)." Applied Entomology and Zoology, vol. 42 no. 2, 2007. p. 223 – 229. https://www.researchgate.net/publication/238440717_Cold_hardiness_of_adult_western_flower_thrips_Frankliniella_occidentalis_Pergande_Thysanoptera_Thripidae

Wikipedia. *Western flower thrips*. Accessed September 27, 2020. https://en.wikipedia.org/wiki/Western_flower_thrips

Wollaeger, Heidi, et. al. *Commercially Available Biological Control Agents for Common Greenhouse Insect Pests*. Michigan State University, 2015. https://www.bioworksinc.com/wp-content/uploads/products/nemashield-hb/BCA_greenhouse-Insect-Pests.pdf

PEST REPORT

Whitefly

Bemisia tabaci (MED, Q-biotype)
sweet potato whitefly

Bemisia tabaci (MEAM1, B-biotype)
silverleaf whitefly

"*Bemisia tabaci* is a complex of 11 genetic groups...These groups are composed of at least 34 morphologically indistinguishable species." - CABI, 2020.

Photo via Wikipedia.

Feeding + vulnerable stages.

All stages of hatched pests are feeding. Eggs, crawlers and early nymphs are susceptible to various BCAs, later nymphs and adults are mostly protected. Young crawlers and nymphs are the most susceptible to pesticides but develop resistance quickly.

Reproduction + life cycle.

Sexual and arrhenotokous parthenogenesis reproduction.
Matures in **12 – 19** days.
Lives for up to **60 days**.
Lifestages are: egg, 3 instars, 4th instar pupa, adult.
Lays up to **160 eggs** during their lifetime.

Optimal climate.

Optimal temperature is **76 – 86° F**.
Prefers temperatures over **81° F**.

Speed + severity of damage.

Damage is swift. Feeding may stunt plants and if the infestation is severe enough it will kill hosts.

In this report:

1. Pest overview

Summary

Sweet potato and silverleaf whitefly are part of the *Bemisia tabaci* species complex, made up of at least 11 genetic groups. Part of this complex are two terrible specimens: the sweet potato and silverleaf whitefly, which are only distinguishable on a molecular level. The silverleaf whitefly is of the most concern to greenhouses in the Northeastern United States (CABI, 2020.), with sweet potato whitefly rating a close second. These two biotypes differ in terms of habit in that the silverleaf whitefly, (*B. tabaci* Middle East-Asia Minor 1 (MEAM1), formerly known as B-biotype), extracts more sap, is more prodigious, spreads more diseases, and is found on more plants (McAuslane, 2020.). They have slight molecular differences but are identical in appearance and environmental preferences (CABI, 2020.). Sweet potato whitefly (*B. tabaci* Mediterranean (MED), formerly known as Q-biotype) has higher resistance to pesticides (McAuslane, 2020.) and more research into its interactions with BCAs has been documented.

They reproduce both sexually and via arrhenotokous parthenogenesis, (meaning that unfertilized eggs develop into males), (Kumar, Vivek et. al., 2020). All stages of the hatched pest are feeding (Kumar, Vivek et. al., 2020). The first nymphal instar "crawler" moves on the plant until it finds a place to feed. Subsequent instars (there are 4), have a scale-like appearance and do not move (Bográn and Heinz, 2012.). The fourth instar, (sometimes called a pupa although it is a pseudo-pupal phase), has large distinctive red eyes (Bográn and Heinz, 2012.). The scale-like coating on the nymphal instars may protect this pest from some types of foliar sprays. Eggs are protected from soap sprays (Mahr, et. al., 2001.). Natural egg mortality is minimal (University of Minnesota Extension, 2020.). Later nymphal stages and adults are protected from predation.

Damage to plants

Both biotypes of pest *Bemisia tabaci* are phloem-feeding (McAuslane, 2020.). Greenhouse ornamentals that are susceptible to whitefly include Poinsettia, *Hibiscus,* ivy, Gerbera daisy, *Lantana, Verbena,* garden chrysanthemum, *Salvia*, and *Mandevilla* (McAuslane, 2020.). Silverleaf whitefly has an even wider host range than sweetpotato whitefly, and has been found on more than 900 plant species (McAuslane, 2020.).

More than damage caused by feeding these pests are by far the most important vectors of geminiviruses, (now called begomoviruses), (CABI, 2020.). These include tomato yellow leaf curl virus (TYLCV), tomato mottle virus (TMoV), and bean golden mosaic virus (BGMV), (McAuslane, 2020.). Silverleaf whitefly alone is a vector of over 100 plant-damaging viruses (McAuslane, 2020.).

Both biotypes of this pest also produce honeydew which decreases photosynthesis by encouraging sooty-mold, and attracts ants and wasps that attack beneficial insects.

Temperature + climate

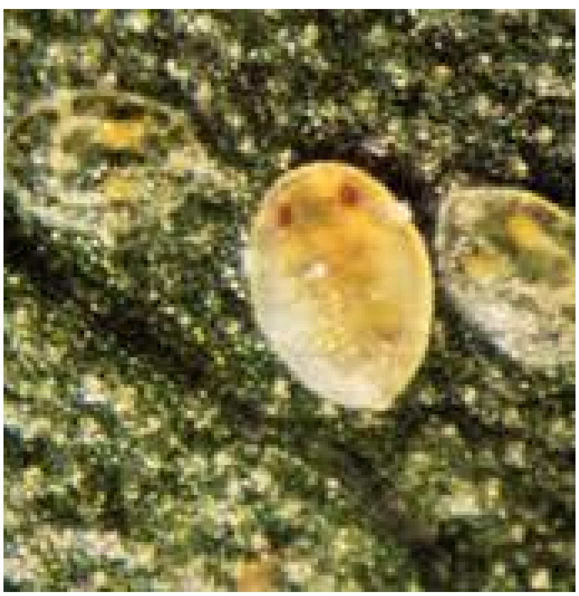
Sweet potato and silver leaf whitefly have a total development range of **50° – 89° F**, with an optimal range of **77° – 86° F** (Bográn and Heinz, 2012.). More information is needed about how temperature affects the pace of whitefly development.

Sweet potato and silver leaf whitefly are not particularly cold tolerant, and cannot overwinter outdoors north of South Carolina (Kumar, Vivek et. al., 2020).

More information is needed about how humidity affects sweet potato and silver leaf whitefly.

Pest monitoring

Population Triggers



The red-eyed and scale-like nymphal stage of the Bemisia tabaci. Image via University of Florida.(*NOTE)

Bemisia tabaci numbers can be expected to rise when a combination of these factors is optimal:

Optimal climate. Hot temperatures are favored, **77 – 86° F** (CABI, 2020.). Lower developmental threshold is around **50° F** (University of Minnesota Extension, 2020.).

Protectors present. As with all honeydew producers, ants and wasps drawn will protect long-tailed mealybugs from natural enemies, if they should appear.

Food sources are present. This species is highly polyphagous. Weeds may also be a source of food (McAuslane, 2020.). Moreover, as noted by the University of Florida, “Sources of infestation may be present (weeds, old plant debris, and growing medium) in and around the greenhouse or nursery that might carry over populations from one season to the next,” (McAuslane, 2020.).

A few of the plants that whitefly was found on in the past year are listed in the section *Damage to Plants* in this pest report.

Monitoring

Use visual inspection and trapping to monitor sweet potato and silverleaf whitefly. Monitoring should begin early, and happen on a weekly basis in production houses. Sticky cards should be checked twice a week for this pest (Mahr, et. al., 2001.).

Scouting. Visual inspection should begin as soon as crops are planted (Mahr, et. al., 2001.) and continue on a weekly basis in order to catch infestations as early as possible (McAuslane, 2020.). Infestations will not be uniform at first but will spread and multiply with time (Mahr, et. al., 2001.).

Chrysoperla spp. feeding on nymphal stages of Bemisia. Image via University of Florida.(*NOTE)

Randomized checks should be executed, with 10 plants examined for every 1,000 square feet (McAuslane, 2020.). Cultivars of repeat offenders should always be monitored more carefully (Mahr, et. al., 2001.).

Especially check the underside of leaves for all stages of pests, including nymphs, and eggs (McAuslane, 2020.). Leaves inspected should be from both the crown and the lower parts of the plant. Eggs are usually found on young, new growth near the top of the plant; nymphs are typically found below. Therefore, sampling different parts of the plant can give a good estimation of the overall population (McAuslane, 2020.).

Eggs are generally laid randomly, in small groups or singly, which makes them difficult to find (Mahr, et. al., 2001.). Eggs are small, so use of a 10 – 15× hand lens is recommended.

Sticky cards. Yellow or blue sticky traps should be checked twice weekly due to this pest's tendency toward population explosion (Mahr, et. al., 2001.). It is recommended that the traps be placed **45 – 60 feet** apart, or about **one per 1,000 square feet** (Mahr, et. al., 2001.). They should be placed within the crop canopy, on the bench, on the ground, near doors, and intake vents.

It may be a good practice to place them in all groups of incoming plants (from other nurseries or even from the back gravel) to monitor for issues before placing them in greenhouses.

Environmental management

Sanitation, Physical, and Cultural Controls

Sanitation is the most important cultural practice to control whitefly infestations (Mahr, et. al., 2001.).

Plant sanitation. Destroy all severely infested plants (Mahr, et. al., 2001.). Check all plants slated for propagation carefully to ensure they are clean as "all stages of the pest are liable to be carried on planting material" (CABI, 2020.), including the difficult-to-see eggs.

When disposing of infested plant materials, place all debris directly into a garbage bag, sealing it tightly, and dispose of it immediately (McAuslane, 2020.).

Heavily spraying infested plants is a tactic that should *not* be underestimated when fighting whitefly infestations. The scale-like pupal stage is especially susceptible to being knocked from the plant with a hard and well-directed stream of water. Gardeners at the Denver Botanical Garden often spray on a daily basis when there is an infestation afoot in their own production houses.

Remove and dispose of any plants displaying symptoms of gemini-viruses, which can spread (McAuslane, 2020.).

Colored plastics on row crops are shown to reduce whitefly populations (McAuslane, 2020.).

Growers at the Nolen speculate that whitefly may flourish on specimens left outdoors on the back gravel, then find their way into the production areas as they are brought back indoors. If this is a concern it may make sense to thoroughly check incoming plants. Establishing a quarantine area could be invaluable, though that would obviously be difficult to find the space. Setting sticky traps within groups of incoming plants may help monitor problems before reintroducing them to the indoor houses.

House sanitation. Immediately destroy all residue from infested plants (Mahr, et. al., 2001.). Immature whitefly can continue to develop on dead and dying plant materials. The use of roller tape traps will greatly reduce the movement of whitefly throughout the house and can be used to contain the pest (Mahr, et. al., 2001.).

As with so many of these priority pests, remove all weeds in and around the greenhouse that could host the pest in the warmer summer months. The very useful *Biological Control of Insects and Other Pests of Greenhouse Crops* suggests a **15' – 30' weed-free strip** surrounding all crops and houses. This would include the back gravel and hoop houses.

Placing row cover or screens over contaminated plants may help to contain the outbreak (Bográn and Heinz, 2012.). BCAs could potentially be trapped-in with their prey.

Infestations may be reduced by using UV-absorbing greenhouse plastic films. “Whiteflies do not enter greenhouses or areas covered with this type of plastic as frequently as they do greenhouses covered in non-UV-absorbing material.” (McAuslane, 2020.).

Annual Sanitation Controls. A crop-free period should break the whitefly cycle within the nursery (McAuslane, 2020.). This may explain why the pests are an erratic presence in production houses, owing to the fact that they are super-heated and emptied annually.

Cultural Controls. Whenever possible, select plants and cultivars that aren’t attractive to the pest. If possible, avoid over-fertilizing (pushing growth attracts the pest) and under-fertilizing (stresses the plant, making it harder to recover from pest damage), (Mahr, et. al., 2001.).

2. Introduction of Biological Controls into IPM Programming

Biological Controls

If planning to use BCAs it’s important to never let whitefly numbers get too high. Any infestations must be reduced prior to the introduction of biological controls. Several of the biological controls listed below are parasitic wasps, and special considerations should be made when using them. For instance, the honeydew excreted by whiteflies can hinder the behavior of smaller wasps. Not only does honeydew slow the movement of wasps down, but they also spend such an excessive amount of time grooming themselves of the sticky substance that they have less time for egg-laying (Mahr, et. al., 2001.). This is true of any wasp used to combat a honeydew producing pest.

Parasitic wasps are also rendered less effective by plant trichomes.

Changing habits during plant and house upkeep after parasitic wasp release is also important. Excessive removal of leaves may rid host plants of parasitized pests. Therefore, it is suggested to leave debris behind for a few days if parasites appear to be unhatched on pruned materials (Mahr, et. al., 2001.). Pruning a little at a time, rather than en mass is another way to ensure parasites are not all removed at the same time (Mahr, et. al., 2001.).

Introduction of BCAs. As discussed above, high numbers of white fly must not be present when releasing BCAs. Moreover, this pest causes significant damage in a short period of time, and must be controlled quickly if plants are expected to thrive. Therefore, pre-emptive preparedness and early detection are crucial to the success of any BCAs added to the program.

Pre-conditions. Reduce pest numbers before releasing BCAs. Consider spot-spraying before release if pests are an issue. Make sure ant or wasp populations that may have been attracted to honeydew are killed, as they will protect whitefly from natural enemies. Remove all sticky traps before releasing any parasites (Mahr, et. al., 2001.).

Summary. A complimentary mix of parasitic wasps and predators may help to curb outbreaks. Fungus can be applied during cooler temperatures or short days. The most effective means of controlling populations of the MEAM1 biotype are predatory mites, as well as nematodes and fungi that are tank mixed with compatible chemical pesticides (CABI, 2020.).

The parasitoid *Encarsia formosa* may be used as a preventative in houses that have an annual occurrence of outbreak, and used as a complement to *Delphastus catalinae*. If greenhouse whitefly is also an issue it can be purchased as a mix with *Eretmocerus eremicus (*sold as Enermix by Koppert).

During the shorter days of late fall and early winter, when insects may diapause, it might be best to turn to beneficial fungi to combat populations. *Beauveria bassiana* and *Isaria fumosoroseus* both may give control.

Beneficials are able to forage and consume stages of the pest that may be impervious to some types of insecticides, such as young crawlers, which may develop chemical resistance.

The predator *Delphastus catalinae* may be introduced as a curative in warm, humid houses.
It is most effective when populations are high.

Parasitoids

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Parasitoids of Note* section.

Encarsia spp. Parasitic wasp	**Sources:** Mahr, et. al., 2001.; CABI, 2020.
Feeding habits Adults generally feed on nymphs. Eggs laid in nymphs.	**Additional details** It is not good at controlling whitefly during cooler temperatures. *Encarsia luteola* (syn. *E.deserti*), is potentially better for *B. tabaci* than *E. formosa*. *E. inaron, E. lutea, E. transversa* are other options.
Habitat requirements Optimal temperature is 61° – 82°F. Likes RH of 50% – 70%. Lays eggs best in warm, bright greenhouses.	
Life cycle They generally like warmer temperatures. At lower temperatures whitefly development will outpace the parasitic wasp, making it ineffective.	

Encarsia formosa Parasitic wasp	**Sources:** Anatis Bioprotection, 2020.; Mahr, et. al., 2001.; Wollaeger, 2015.; University of California, 2020.; Razze, 2020.
Feeding habits Adult females eat immature stages of whitefly, including adults. Eggs are laid in 3rd and 4th instars and feed on them before emerging.	**Additional details** Does not parasitize sweet potato whitefly as readily as greenhouse whitefly, but will eat them.
Habitat requirements Optimum temperatures are above 70 °F. RH 50% – 70%.	
Life cycle 28 days at 70 °F Average of 10 eggs a day, totaling 200 – 350 eggs in their lifetime.	

Adults emerge after 2 weeks.	

Eretmocerus eremicus Parasitic wasp	**Sources:** CABI, 2020.; Wollaeger, 2015.; NYBG, *Identification*, 2013.; Razze, 2020.
Feeding habits Larvae host feed as they develop. Adults do not always host feed, unless they are on *B. tabaci* on poinsettia. Also parasitizes greenhouse whiteflies. Host-feeds more than *Encarsia formosa*.	**Additional details** Will not parasitize sweet potato whitefly as readily as greenhouse whitefly. Often sold as a mix with *Encarsia formosa*. Recommended by NYBG in the past.
Habitat requirements Optimal temperature 80° – 110° F. Tolerates high temperatures. From the desert, it does best under hot conditions. Can survive cooler temperatures, however, development is too slow to control outbreaks at 70 – 75° F.	
Life cycle Females will lay eggs under nymphs, special preference for 2nd and 3rd instars. Reproduces well on sweet potato whitefly EXCEPT on poinsettia. Will not lay eggs next to pupae.	

Predators

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Predators of Note* section.

Most of the predators won't eat the parasitized whitefly, so they are good to use in concert with parasitic wasps (Mahr, et. al., 2001.).

***Delphastus catalinae** Predatory lady beetle	**Sources:** Wollaeger, 2015.; NYBG, Identification, 2013.; Razze, 2020.
Feeding habits Can feed on > 150 whitefly eggs a day, 1,000 eggs total before pupation. And up to 700 larvae. Prefers eggs over nymphs. Effective when populations are high.	**Additional details** May have sensitivity to pesticide residue. Recommended by NYBG in the past.
Habitat requirements Low humidity (RH 10%) negatively impacts survival.	
Life cycle Life cycle from egg to adult takes 21 – 25 days at 77 – 86°F Females can lay 200 – 300 eggs over the course of their lives Females live for 60 days; males for 45 days.	

Chrysoperla carnea Green Lacewing	**Sources:** Mahr, et. al., 2001.; Wollaeger, 2015.; NYBG, *Identification*, 2013.
Feeding habits Will feed on immature whitefly nymphs if other prey is not available. Also feeds on aphids, thrips, two-spotted spider mites, mealybug, beneficial insects. Adults eat pollen, nectar and honeydew.	**Additional details** Leaves of plants should be touching to make it more effective. Recommended by NYBG in the past. **See the *Green Peach Aphid Report* for more information.**
Habitat requirements Conditions for optimum performance fall between 67° – 89°F Relative humidity of 30% or greater.	
Life cycle Develop slowly and rarely reproduce on whiteflies.	

Chrysoperla comanche Comanche lacewing	**Sources:** Mahr, et. al., 2001.
Feeding habits Will “voraciously” feed on whitefly eggs and nymphs if aphids are absent. Primarily feeds on aphids. Occasionally eats adult whiteflies.	**Additional details** Similar details as *C. carnea*. **See the *Green Peach Aphid Report* for more information.**
Habitat requirements Adapted to drier conditions than other *Chrysoperla* species .	

Delphastus pusillus Predatory lady beetle	**Sources:** Mahr, et. al., 2001.
Feeding habits Adult females eat up to 150 eggs or nymphs a day. Larvae are able to eat up to 1,000 eggs during development. Prefers eggs, but will not eat parasitized eggs (which is good). Feeds many different whitefly types: sweetpotato, silverleaf, greenhouse and banded winged whitefly. Will also eat spider mites.	**Additional details** Release rate of 7 per 10 square feet is suggested.
Habitat requirements In order to pupate they need leaf litter to pupate and complete their life cycle. If they pupate in standing water they will drown (when plants are watered).	
Life cycle Live up to 2 months**.**	

Orius spp. predatory true bug	**Sources:** Mahr, et. al., 2001.
Feeding habits Nymphs and adults will eat all stages of whitefly.	**Additional details**

Generalist predator. Also feed on spider mites, aphids, whiteflies, caterpillar eggs and pollen.	**See the *Western Flower Thrips* *Report*.**
Habitat requirements Temperatures over 59° F. Greenhouse temperatures of 64 – 82 °F. Humidity over 60%	
Life cycle Diapauses under short days and low temperatures.	

Pathogens

Species that show the most initial promise are briefly outlined below, those that may be the most promising are marked with an asterisk. A full list is included in the *Pathogens of Note* section.

Beauveria bassiana. This fungus may be able to eliminate the need for insecticides, working at least as well as (if not better than) conventional insecticides (Mahr, et. al., 2001.). Beneficials will not be affected unless they are directly sprayed and can help to reduce populations if introducing BCAs (Mahr, et. al., 2001.). It is not persistent in the environment.

***Isaria fumosorosea* (*syn. Paecilomyces*)**. This is the best fungal killer of sweet potato whitefly, killing all whitefly stages including eggs (unlike conventionals) (Mahr, et. al., 2001.). It is compatible with *Encarsia*, *Eretmocerus* and *Delphastus* (Mahr, et. al., 2001.). It is not persistent in the environment.

***Lecanicillium lecanii*,** a fungal pathogen (syn. Verticillium lecanii).

Associated plants

Banker plants. When used among non-flowering ornamentals, *Lobularia* 'Snow Crystal' provides pollen to the predatory bug *Orius* (Sullivan, 2010.).

As mentioned in the *Citrus Mealybug Report* and *Aphid Report*, *Crysoperla carnea* adults will eat pollen and nectar. Therefore, it may be advisable to have flowering plants on-hand for the adulthood of their lives, as it may dissuade them from flying away to find more suitable foraging.

Thresholds

Action thresholds for this pest are being revisited and will be updated if the information becomes available.

3. Sources

Anatis Bioprotection. *Encarsia formosa*. Accessed September 27, 2020. https://anatisbioprotection.com/en/biological-control-products/encarsia-formosa-whitefly.html

Bográn, Carlos E., and Heinz, Kevin M. *White flies.* Texas A & M AgriLife Extension. 2012. http://counties.agrilife.org/galveston/files/2012/03/Whiteflies-Publ.-E-432.pdf

Brown, J.K. “The Bemisia tabaci Complex: Genetic and Phenotypic Variability Drives Begomovirus Spread and Virus Diversification.” *APSnet Features*. 2007. https://www.apsnet.org/edcenter/apsnetfeatures/Pages/BemisiatabaciComplex.aspx

CABI. *Invasive Species Compendium: Bemisia tabaci (tobacco whitefly)*. Accessed September 27, 2020. https://www.cabi.org/isc/datasheet/8927

Cranshaw, Whitney, and Shetlar, David. *Garden Insects of North America.* Princeton University Press, 2018.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Control Handbook*. New York Botanical Garden internal document. 2013.

Gabel, Don, and Primeau, Christian, et. al. *Glasshouse Pest Identification Handbook Supplement 1*. New York Botanical Garden internal document. 2013.

Kumar, Vivek et. al. *Whitefly (Bemisia tabaci) Management Program for Ornamental Plants*. University of Florida, IFAS Extension. Accessed September 27, 2020. https://edis.ifas.ufl.edu/in1171

McAuslane, Heather J. *Featured Creatures: Sweetpotato whitefly B biotype or silverleaf whitefly.* University of Florida, IFAS Extension. Accessed September 27, 2020.

http://entnemdept.ufl.edu/creatures/veg/leaf/silverleaf_whitefly.htm

Razze, Janine, and Liburd, Oscar E. *Featured Creatures: whitefly predatory lady beetle.* University of Florida, IFAS Extension. Accessed September 27, 2020. http://entnemdept.ufl.edu/creatures/BENEFICIAL/Delphastus_catalinae.htm

Sullivan, Cheryl E. Frank, and Skinner, Margaret. *Plant-Mediated IPM Systems Explained*. University of Vermont, Entomology Research Laboratory. 2013. http://www.uvm.edu/~entlab/Greenhouse%20IPM/Workshops/2014/PlantMedIIPMSystemsOverviewFinalNov13.pdf

University of California, Statewide Integrated Pest Management Program. *Pest Management and Identification: Encarsia formosa*. Accessed September 27, 2020. http://ipm.ucanr.edu/PMG/NE/encarsia_formosa.html

University of Minnesota Extension. *Sweetpotato whitefly*. Accessed September 27, 2020. http://cues.cfans.umn.edu/old/inter/inmine/Whitefsp.html

Wollaeger, Heidi, et. al. *Commercially Available Biological Control Agents for Common Greenhouse Insect Pests*. Michigan State University, 2015. https://www.bioworksinc.com/wp-content/uploads/products/nemashield-hb/BCA_greenhouse-Insect-Pests.pdf

Appendix

Parasites of Note

Aphid

- *Macrosiphum euphorbiae*, potato aphid; *Aulacorthum solani,* foxglove aphids and other "large" aphids
    - *Aphelinus abdominalis*
    - *Aphidius ervi*
- *Myzus persicae,* Green peach Aphid, and other "small" aphids (ex. *Aphis gossypii*, cotton/melon aphid)
    - *Aphidoletes aphidimyza*
    - *Aphidius colemani*
    - *Aphidius matricariae*

Fungus Gnat

- *Bradysia coprophila,* fungus gnat
    - None found in research

Leaf Miner

- *Liriomyza sp*.
    - *Diglyphus sp*.

Mealybugs

- *Planococcus citri*, citrus mealy
    - *Pauridia peregrina*
- *Pseudococcus longispinus*, long-tailed mealy
- listed controls work for both kinds of mealy
    - *Anagyrus fusciventris*
    - *Anagyrus psedudococci*
    - *Leptomastix dactylopii*

Mites

- *Polyphagotarsonemus latus*, Broad Mite
    - None found in research
- *Tetranychus urticae*, Two-spotted Spider Mite
    - None found in research

Scale, soft

- *Ceroplastes floridensis*, Florida Wax Scale
    - *Coccophagus lycimnia*
    - *Metaphycus eruptor*
    - *Scutellista cynea*
- *Coccus hesperidum*, Brown Soft Scale
    - *Metaphycus flavus*
    - *M. luteolus*
    - *Microterys flavus*
    - *Rhyzobius lophanthae*
    - *Coccophagus* spp.

Scale, armored

- *Chrysomphalus dictyospermi*, palm Scale, dictyospermum scale
    - *Aphytis chrysomphalina*
    - *Aphytis melinus*, will often displace *A. chrysomphali*
- *Pinnaspis aspidistrae*, Fern Scale
    - *Ablerus* sp.
    - *Aphelinus* sp.

Thrips

- *Frankliniella occidentalis*, Western Flower Thrip
    - *Thripobius javae*, parasitic wasp
- *Gynaikothrips ficorum*, Cuban Laurel Thrip
    - None found during research

Whitefly

- *Bemisia tabaci*, Sweet Potato Whitefly
    - *Encarsia formosa*
    - *Eretmocerus eremicus*
    - *Encarsia luteola*
- *Trialeurodes vaporariorum*, Greenhouse Whitefly
    - *Encarsia formosa*
    - *Eretmocerus eremicus*

Predators of Note

Aphids

- *Myzus persicae,* Green peach aphid
    - *Adalia bipunctata*, ladybird
    - *Chrysopa carnea,* lacewing
    - *Chrysoperla rufilabris,* lacewing
    - *Hippodamia convergens*, ladybird
    - *Orius insidiosus,* insidious flower bug

Fungus Gnats

- *Bradysia coprophila,* fungus gnat
    - *Dalotia coriaria*, predatory rove beetle
    - *Stratiolaelaps scimitus/Hypoaspis miles*, soil-dwelling predatory mite

Leaf Miners

- *Liriomyza sp*., leaf miner
    - Many of the natural predators of *L. sativae* have been shown to be more susceptible to the insecticides than *L. sativae* itself

Mealy Bugs

- *Planococcus citri*, citrus mealy
- *Pseudococcus longispinus*, long-tailed mealy
- Listed controls work for both species
    - *Chrysoperla carnea*, green lacewing
    - *Cryptolaemus montrouzieri*, predatory beetle

Mites

- *Polyphagotarsonemus latus*, Broad Mite
    - *Amblyseius californicus*, predatory mite
    - *Amblyseius ovalis*
    - *Chrysoperla carnea*, Green Lacewing
    - *Metaseiulus occidentalis*, predatory mite
    - *Neoseiulus barkeri*
    - *Neoseiulus californicus*
    - *Neoseiulus cucumeris,* on sweet potato
    - *Phytoseiulus longipes*, predatory mite
    - *Phytoseiulus persimilis,* predatory mite

  - *Stethorus punctillum*, predatory beetle
- *Tetranychus urticae*, Two-spotted Spider Mite
  - *Amblyseius andersoni,* predatory mite
  - *Amblyseius californicus*, predatory mite
  - *Amblyseius fallacis,* predatory mite
  - *Chrysoperla carnea*, Green Lacewing
  - *Coccinella septempunctata*
  - *Feltiella acarisuga*, predatory gall midge
  - *Galendromus occidentalis*, predatory mite
  - *Mallada basalis* has been used on strawberry in Taiwan
  - *Metaseiulus occidentalis*, predatory mite
  - *Neoseiulus californicus*, predatory mite
  - *Neoseiulus fallacis*, predatory mite
  - *Orius minutus*
  - *Phytoseiulus longipes*, predatory mite
  - *Phytoseiulus macropilis*, predatory mite
  - *Phytoseiulus persimilis,* predatory mite
  - *Stethorus gilvifrons*
  - *Stethorus punctillum*, predatory beetle

Scale, soft

- *Ceroplastes floridensis*, Florida Wax Scale
  - *Chrysoperla carnea*, green lacewing
  - *Metaphycus eruptor*, predatory wasp
- *Coccus hesperidum*, Brown Soft Scale
  - *Chrysoperla carnea*, green lacewing
  - *Metaphycus eruptor*, predatory wasp

Scale, armored

- *Chrysomphalus dictyospermi*, Palm Scale, dictyospermum scale
  - *Chrysoperla carnea*, green lacewing
  - *Metaphycus eruptor*, predatory wasp
- *Pinnaspis aspidistrae*, Fern Scale
  - *Cheletogenes ornatus*
  - *Chrysopa sp.,* lacewing
  - *Chrysoperla carnea*, green lacewing
  - *Metaphycus eruptor*, predatory wasp
  - *Pentilia egena*

Thrips

- *Frankliniella occidentalis*, Western Flower Thrip
    - *Amblydromalus limonicus*, predatory mite
    - *Amblyseius swirskii*, predatory mite
    - *Atheta coriaria*, predatory rove beetle
    - *Chrysoperla carnea*, green lacewing
    - *Hypoaspis miles*, predatory mite that attack pupae in the soil
    - Iphiseius degenerans, predatory mite, (only kill first instar thrips)
    - *Neoseiulus cucumeris*, predatory mite, (only kill first instar thrips)
    - *Neoseiulus degenerans*, predatory mite
    - *Orius sp.*; *orius insidiosus*, minute pirate bug
    - *Stratiolaelaps scimitus*, soil-dwelling predatory mite, useful against pupae

- *Gynaikothrips ficorum*, Cuban Laurel Thrip
    - *Amblydromalus limonicus*, predatory mite
    - *Amblyseius swirskii*, predatory mite
    - *Cardiastethus rugicollis*
    - *Chrysoperla carnea*, green lacewing, often found within leaf rolls, with this pest, feeding
    - *Atheta coriaria,* Greenhouse Rove beetle
    - *Macrotracheliella laevis*
    - *Macrotracheliella nigra,* often found within leaf rolls, feeding
    - *Montandoniola confusa*
    - *Montandoniola moraguesi*
    - *Neoseiulus cucumeris*, predatory mite,

Whitefly

- *Bemisia tabaci*, Sweet Potato Whitefly
    - *Amblyseius swirskii*, predatory mite
    - *Chrysoperla carnea*, green lacewing
    - *Chrysoperla comanche*, Comanche lacewing
    - *Delphastus catalinae*, beetle
    - *Delphastus pusillus*, predatory lady beetle
    - *Dicyphus hesperus*, predatory mirid bug
    - *Orius spp.*, predatory true bug
- *Trialeurodes vaporariorum*, Greenhouse Whitefly
    - *Chrysoperla carnea*, green lacewing
    - *Delphastus catalinae*, beetle

    - *Amblyseius swirskii*, predatory mite
    - *Dicyphus hesperus*, predatory mirid bug

Pathogens of Note

Aphid

- *Myzus persicae,* Green Peach Aphid
    - *Lecanicillium lecanii*, fungal pathogen

Fungus Gnat

- *Bradysia coprophila*, fungus gnat
    - *Steinernema feltiae*, beneficial nematode
    - *Bacillus thuringiensis ssp. Israelensis*, microbial insecticide,

Leaf Miner

- *Liriomyza sp*., Leaf miner
    - Entomogenous fungal strains
    - Release of gamma-irradiated sterile males

Mealybugs

- *Planococcus citri*, citrus mealy (see below)
- *Pseudococcus longispinus*, long-tailed mealy
    - *Beauveria bassiana*
    - *Steinernema feltiae*

Mites

- *Polyphagotarsonemus latus*, Broad Mite
- *Tetranychus urticae*, Two-spotted Spider Mite
    - *Beauveria bassiana,* fungi

Scale, soft

    - *Ceroplastes floridensis*, Florida Wax Scale
    - *Coccus hesperidum*, Brown Soft Scale
        - None found during research

Scale, armored

- *Chrysomphalus dictyospermi*, Palm Scale, dictyospermum scale
    - None found during research

- *Pinnaspis aspidistrae*, Fern Scale
    - None found during research

Thrips

- *Frankliniella occidentalis*, Western Flower Thrips
    - *Beauveria bassiana*, BotaniGard or Naturalis-L, insect-killing fungal pathogen
    - *Heterorhabditis bacteriophora*, nematode
    - *Steinernema feltiae*, beneficial nematode
- *Gynaikothrips ficorum*, Cuban Laurel Thrips
    - *Lecanicillium lecanii*, fungal pathogen
    - *Steinernema feltiae*, beneficial nematode

Whitefly

- *Bemisia tabaci*, Sweet Potato Whitefly
    - *Beauveria bassiana*, fungi
    - *Isaria fumosorosea*
- *Trialeurodes vaporariorum*, Greenhouse Whitefly
    - *Lecanicillium lecanii*, fungus
    - *Paecilomyces fumosoroseus,* entomopathogenic fungus