Greenhouse IPM Programs

Dr. Vera Krischik, Department of Entomology, University of Minnesota

Information from:
http://www.ipm.ucdavis.edu/PMG/selectnewpest.floriculture.html
http://www.extento.hawaii.edu/kbase/crop/Type/scalemen.htm
http://www.extension.umn.edu/distribution/horticulture/DG7375.html

What is greenhouse IPM?

* A system utilizing multiple methods
* A decision making process
* A risk reduction system
* Information intensive
* Biologically based
* Cost effective
* Site specific
* Multiple tactics:
    legal, cultural, physical,
    genetic, biological, chemical

What is greenhouse IPM?

When developing an IPM program, it is important to know what pests you have. Learn the major characteristics for pest and damage identification and how to monitor for the pests.

Determine threshold levels for each pest. At low densities, biological control and biorational pesticides may be used. High pest densities may call for conventional pesticides, but these should be avoided whenever possible to conserve beneficials.

IPM Program For Aphids

Order Hemiptera
Family Aphididae
Melon/cotton aphid, *Aphis gossypii*
Green peach aphid, *Myzus persicae*

DESCRIPTION OF THE PESTS

Aphids are distinguished from other insects by the presence of cornicles, tubelike appendages that protrude from the rear of the aphid. The two species most commonly encountered are the green peach aphid (pictured) and the cotton or melon aphid. Green peach aphid is characterized by a depression in the front of the head between the antennae and by long thin, translucent cornicles that extend beyond the tip of the body. Green peach aphids vary in color from yellowish green to rose pink. Winged adults have a dark blotch in the middle of the abdomen.

IPM Program For Aphids

DESCRIPTION OF THE PESTS

Melon aphids are typically dark green, but color variations do occur frequently. The cornicles are relatively short, stout, and always dark. Melon aphids have red eyes and antennae that only reach to the middle of the abdomen. Adult aphids may or may not have wings. Winged aphids are produced as a result of crowding. Green peach aphids produce winged adults at lower population densities than the melon aphid. The optional temperature for green peach aphid development is 75°F, whereas optional temperatures for melon aphids are above 75°F.

Melon aphids and mummies

IPM Program For Aphids

DESCRIPTION OF THE PESTS

Adult aphids give birth to live young. Generally, aphids begin giving birth when they are 7 to 10 days old, depending on temperature.

Green peach aphid adult and young

Winged green peach aphid adult

IPM Program For Aphids

DAMAGE

Aphids excrete copious amounts of honeydew, a sweet, sticky substance that they produce as they feed on the plants. The honeydew can cover leaves and other plant parts and cause the plants to become sticky. Black sooty molds then grow on the honeydew. The white shed skins of the aphids frequently are stuck to the plant surfaces by the honeydew and further detract from the plant's appearance. Sufficient feeding can cause foliage to become yellowed, and feeding on newly developing tissues can cause those parts to become twisted as they grow. Melon aphids are known to transmit 44 plant viruses, while green peach aphids are known to transmit more than 100 plant viruses. Aphids have been reported to transmit cucumber mosaic virus which can cause flower break and distortion on cyclamen, lisanthus and vinca.

IPM Program For Aphids

BIOLOGICAL CONTROL

Predators such as lacewings (*Chrysoperla* spp. and midges (*Aphidoletes aphidimyza*) are commercially available. Parasitoids, such as *Aphidius* spp., *Lysiphlebus testaceipes, Diaeretiella rapae, and Aphelinus abdominalis*, are also commercially available. The lady beetle *Hippodamia convergens* is commonly used.

***Aphidoletes aphidimyza* larvae attacking melon aphid**

***Aphidius* sp.**

IPM Program For Aphids

CULTURAL CONTROL

Because aphids feed on a large variety of plant species, keep production areas free of weeds, which can serve as hosts of aphid populations. Exclusion of winged adults can be accomplished by covering openings to the greenhouse with screens that have a pore width of 355 microns or smaller. Before starting a new crop, carefully inspect plants to ensure that they are free of aphids and other pests. Treat or rogue any infested plants.

Green peach aphids

IPM Program For Aphids

MONITORING and WHEN TO TREAT

Yellow sticky cards placed in greenhouses will capture winged adults. However, aphids produce winged individuals in response to crowding so monitoring plants for infestations is an essential component of managing and detecting these pests before populations get too high. Melon aphids tend to have a more uniform vertical distribution on plants than green peach aphids, which tends to be clustered around growing points, meaning that infestations of melon aphids under lower leaves can easily go undetected if these areas are not inspected. Green peach aphids will produce winged individuals at lower densities than melon aphids on crops such as chrysanthemums. Use at least one sticky trap per 10,000 square feet (900 sq m) of growing area for monitoring aphids. Consider treating if an average of 5 to 10 aphids per card per week is present.

IPM Program For Aphids

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
biological	*Beauveria bassiana* (BotaniGard 22 WP) (BotaniGard ES)	4 12	Treat every 7 days while insects are active. Do not tank mix with most fungicides and wait 48 hours after application to apply a fungicide.
botanical	cinnamaldehyde (Cinnacure)	4	After 2 applications, rotate to an insecticide of different chemistry for 2+ applications. Don't apply to stressed/newly transplanted plants. Don't apply with irrigation system.
	pyrethrin/PBO2 (PT 1100 Pyrethrum TR)	12	An aerosol.
	pyrethrin/rotenone (Pyrellin EC)	12	

IPM Program For Aphids

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
carbamate	methiocarb (Mesurol 75W)	24	Apply in 50 gal water. Repeat as necessary up to 4 applications/season. Do not apply with oil or foliar fertilizer. Don't apply with irrigation system
insect growth regulator	azadirachtin (Azatin XL Plus)	4	Must contact insect. Repeated applications as necessary. Aphid suppression only. Label permits low-volume application.
	azadirachtin (Ornazin 3%EC)	12	Do not exceed 22.5 oz/acre/application.
	pyriproxyfen (Distance)	12	Do not apply more than 2 times per cropping cycle or per 6 months. Do not use through any type of irrigation system.
	s-kinoprene (Enstar II)	4	Apply prebloom. Also-labeled for low volume use. Do not apply through any type of irrigation system.

IPM Program For Aphids

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
neonico-tinoid	imidacloprid (Marathon 60 WP)	12	As above, but apply only as a drench.
	imidacloprid (Marathon 1G) (Marathon II)	12	Do not use more than once every 16 weeks. Alternate with insecticides that have a different mode of action to prevent resistance. Do not apply to soils that are water logged. Do not apply to plants intended as food crops.
oil	clarified hydrophobic extract of neem oil (Triact 70)	4	Do not spray plants under stress. Pest must be completely covered with spray-this material may not effectively control melon aphid because it is often on the underside of lower leaves. May cause injury to flowers. Do not use through any type of irrigation system.
	horticultural oil Ultra-Fine Oil SafTSide JMS Stylet Oil	4	Use as above for neem oil. Do not use with sulfur fungicides; check label for tank mix restrictions.

IPM Program For Aphids

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
organo-chlorine	endosulfan (Endosulfan 3EC)	24	Check runoff restrictions. Chrysanthemums may exhibit phytotoxicity. Don't use through irrigation system or more than 3 lb ai/acre/season.
organo-phosphate	acephate (Address)	24	Do not use through any type of irrigation system.
	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don't use through irrigation system.
	acephate (1300 Orthene TR)	24	An aerosol that is only for greenhouse use.
	chlorpyrifos (PT DuraGuard ME)	24	
organo-phosphate/ pyrethroid	chloropyrifos/ cyfluthrin (PT Duraplex TR)	24	An aerosol.

IPM Program For Aphids

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyrethroid	bifenthrin (Attain TR)	12	Check label. Fogger for greenhouse use only.
	bifenthrin (Talstar Flowable)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	cyfluthrin (Decathlon 20 WP)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	deltamethrin (DeltaGard)	12	Do not use through any type of irrigation system.
	fenpropathrin (Tame 2.4 EC)	24	Label permits low-volume application. Do not use through any type of irrigation system.
	fluvalinate (Mavrik Aquaflow)	12	Low-volume application. Also labeled for cutting dip at 5 fl oz/100 gal. Don't use through irrigation system.

IPM Program For Aphids

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyrethroid	lambda-cyhalothrin (Scimitar)	24	Supplemental label for greenhouse and nursery use. Apply at 7-day intervals. Do not apply more than 52.4 fl oz of concentrate/ acre/year. Do not mix with EC's or oils.
	permethrin (Astro)	12	May cause browning of petals. Marginal leaf burn may occur on salvia, diffenbachia and pteris fern. Low-volume application. Do not apply more than 2 lb a.i./acre/year.
pyridine	pymetrozine (Endeavor)	12	Do not use through irrigation system. Apply as foliar spray at 7-14 day intervals. For indoor use, do not use more than 100 oz.
soap	potash soap (Insecticidal soap) (M-Pede)	12	Must contact insect, so thorough coverage is important. Repeat weekly as needed up to 3 times. Test for phytotoxicity. Do not spray new transplants or newly rooted cuttings. Do not add adjuvants.

IPM Program For Foliar-Feeding Mealybugs

Order Hemiptera
Family Pseudococcidae
Citrus mealybug,
Planococcus citri
Longtailed mealybug,
Pseudococcus longispinus

DESCRIPTION OF THE PESTS

Mealybugs are slow-moving sucking insects that have a loose, waxy coating on the body. The citrus mealybug is heavily and evenly covered with white, powdery wax, except for a faint narrow streak down the middle. It has short, wax filaments along the sides and hind filaments that are about one-fourth as long as the body. Both the citrus mealybug and the Mexican mealybug lay eggs in ovisacs (eggs are within masses of cottony wax). Pictured is citrus mealybug ovisac.

IPM Program For Foliar-Feeding Mealybugs

DESCRIPTION OF THE PESTS

The longtailed mealybug has four long terminal wax filaments and it gives birth to live young. Mealybug infestations often occur under foliage and in dense foliage.

DAMAGE

Mealybugs remove sap from plants, which can cause yellowing of leaves and decline in vigor. Mealybug ovisacs and excreted honeydew are unsightly. Honeydew supports the growth of black sooty mold and attracts ants; ants may then carry mealybugs to uninfested plants.

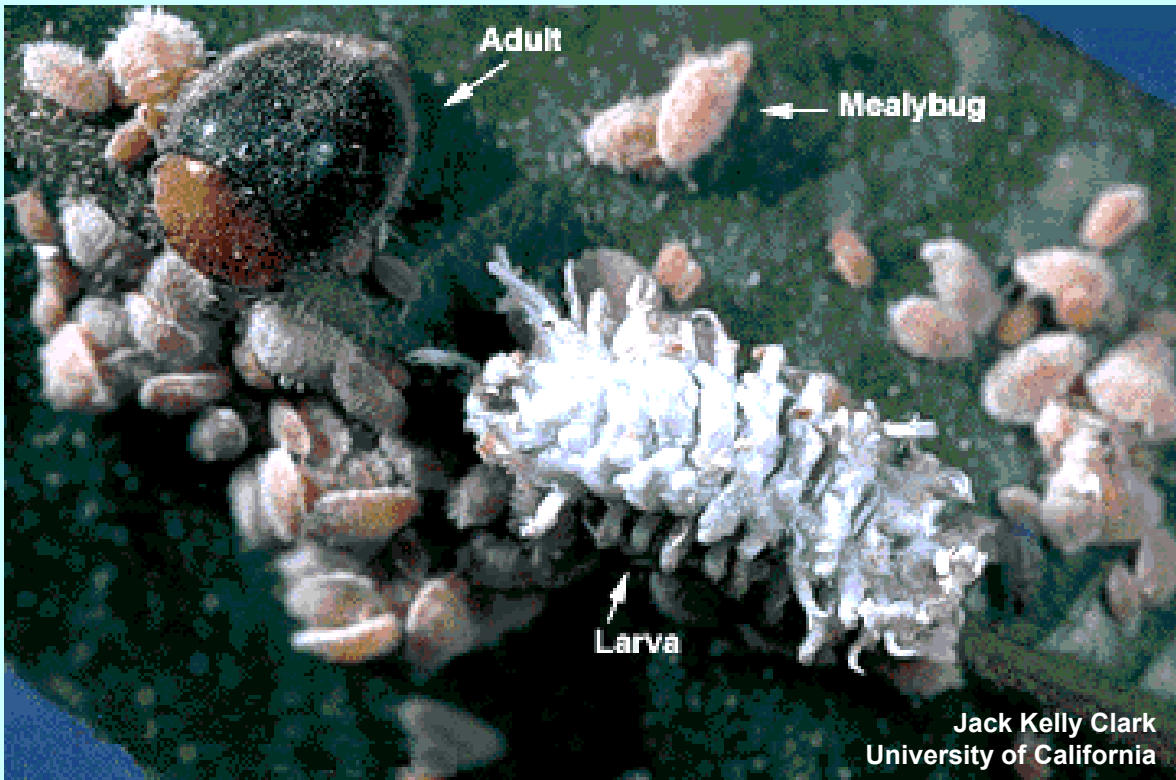
Citrus mealybug (top) and longtailed mealybug (bottom)

IPM Program For Foliar-Feeding Mealybugs

BIOLOGICAL CONTROL

Cryptolaemus montrouzieri, the mealybug destroyer lady beetle, is an effective predator of citrus and Mexican mealybugs and other ovisac-forming sucking insects (such as green shield scale). Larval mealybug destroyers themselves look like large, faster-moving mealybugs, but are readily distinguished by their chewing mouthparts.

L***eptomastix dactylopii*** and ***Anagyrus pseudococci*** are parasitoids of citrus mealybugs.



Cryptolaemus montrouzieri

IPM Program For Foliar-Feeding Mealybugs

MONITORING and WHEN TO TREAT

Carefully inspect plants being brought in to start a new crop to ensure that they are free of mealybugs and other pests. If necessary, treat infested plants. Regularly inspect plants for signs of honeydew (i.e., glistening, sticky leaves) and ant activity. Well-established infestations containing females with ovisacs are much more difficult to control with either systemic or contact insecticides than new infestations because reproducing adults usually stop feeding and the females' body or the wax secretions help protect eggs or crawlers.

Mealybugs on coleus

IPM Program For Foliar-Feeding Mealybugs

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
biological	*Beauveria bassiana* (BotaniGard 22 WP) (BotaniGard ES)	4 12	Treat every 7 days while insects are active. Do not tank mix with most fungicides and wait 48 hours after application to apply a fungicide.
botanical	pyrethrin/PBO2 (PT 1100 Pyrethrum TR)	12	An aerosol.
	pyrethrin/rotenone (Pyrellin EC)	12	

IPM Program For Foliar-Feeding Mealybugs

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
insect growth regulator	azadirachtin (Azatin XL Plus)	4	Must contact insect. Repeated applications as necessary. Only effective on immatures. Label permits low-volume application.
	azadirachtin (Ornazin 3%EC)	12	Do not exceed 22.5 oz/acre/application.
	s-kinoprene (Enstar II)	4	Apply prebloom. Low-volume use. Only effective on immatures. Do not apply through any type of irrigation system.
neonico-tinoid	imidacloprid (Marathon 60 WP)	12	As above, but apply only as a drench.
	imidacloprid (Marathon 1G) (Marathon II)	12	Do not use more than once every 16 weeks. Alternate with insecticides that have a different mode of action to prevent resistance. Do not apply to soils that are water logged. Do not apply to plants intended as food crops.

IPM Program For Foliar-Feeding Mealybugs

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
oil	clarified hydrophobic extract of neem oil (Triact 70)	4	Do not spray plants under stress. Pest must be completely covered with spray. May cause injury to flowers. Do not use through any type of irrigation system.
	horticultural oil Ultra-Fine Oil SafTSide JMS Stylet Oil	4	Use as above for neem oil. Do not use with sulfur fungicides; check label for tank mix restrictions.
organo-phosphate	acephate (Address)	24	Do not use through any type of irrigation system.
	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don’t use through irrigation system.
	acephate (PT 1300 Orthene TR)	24	An aerosol that is only for greenhouse use.
	chlorpyrifos (PT DuraGuard ME)	24	

IPM Program For Foliar-Feeding Mealybugs

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
organo-phosphate/ pyrethroid	chloropyrifos/ cyfluthrin (PT Duraplex TR)	24	An aerosol.
pyrethroid	bifenthrin (Attain TR)	12	Check label. Fogger for greenhouse use only.
	bifenthrin (Talstar Flowable)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	cyfluthrin (Decathlon 20 WP)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	deltamethrin (DeltaGard)	12	Do not use through any type of irrigation system.
	fenpropathrin (Tame 2.4 EC)	24	Label permits low-volume application. Do not use through any type of irrigation system.

IPM Program For Foliar-Feeding Mealybugs

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyrethroid	fluvalinate (Mavrik Aquaflow)	12	Low-volume application. Also labeled for cutting dip at 5 fl oz/100 gal. Don't use through irrigation system.
	permethrin (Astro)	12	May cause browning of petals. Marginal leaf burn may occur on salvia, diffenbachia and pteris fern. Low-volume application. Do not apply more than 2 lb a.i./acre/year.

Longtailed mealybug

IPM Program For Root Mealybugs

Order Hemiptera
Family Pseudococcidae
Root mealybug, *Rhizoecus* spp.

DESCRIPTION OF THE PESTS

Root mealybugs are below-ground dwelling mealybugs that feed on the roots of plants. These mealybugs have a thin, uniform waxy coating and lack the terminal wax filaments typical of their foliar-feeding relatives.

DAMAGE

The only outward sign of root mealybug feeding may be a decline in the health of infested plants. When plants are removed from the pot, the whitish mealybugs feeding on the roots are then observed.

IPM Program For Root Mealybugs

BIOLOGICAL CONTROL

Biological control has not been investigated.

CULTURAL CONTROL

Discard infected and surrounding plants. Control ants.

MONITORING and WHEN TO TREAT

Examine plant root balls when monitoring and when plants are declining. The presence of ants climbing on the plant can also indicate a problem with mealybugs. Rogue and discard infected plants. Treat with a soil drench or discard the surrounding plants.

IPM Program For Root Mealybugs

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
botanical	pyrethrin/PBO2 (PT 1100 Pyrethrum TR)	12	An aerosol.
	pyrethrin/rotenone (Pyrellin EC)	12	
organo-phosphate	acephate (Address)	24	Do not use through any type of irrigation system.
	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don't use through irrigation system.

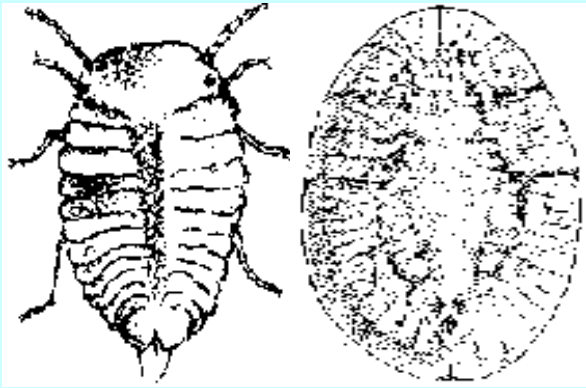
IPM Program For Root Mealybugs

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyrethroid	bifenthrin (Talstar Flowable)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	cyfluthrin (Decathlon 20 WP)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	fenpropathrin (Tame 2.4 EC)	24	Label permits low-volume application. Do not use through any type of irrigation system.
	fluvalinate (Mavrik Aquaflow)	12	Low-volume application. Also labeled for cutting dip at 5 fl oz/100 gal. Don't use through irrigation system.
	permethrin (Astro)	12	May cause browning of petals. Marginal leaf burn may occur on salvia, diffenbachia and pteris fern. Low-volume application. Do not apply more than 2 lb a.i./acre/year.

IPM Program For Soft Scales

Order Hemiptera
Family Coccidae
Brown soft scale, *Coccus hesperidum*
Hemispherical scale, *Saissetia coffeae*
Black scale, *Saissetia oleae*
Green shield scale, *Pulvinaria psidii*



Brown soft scale crawler (L) and adult female

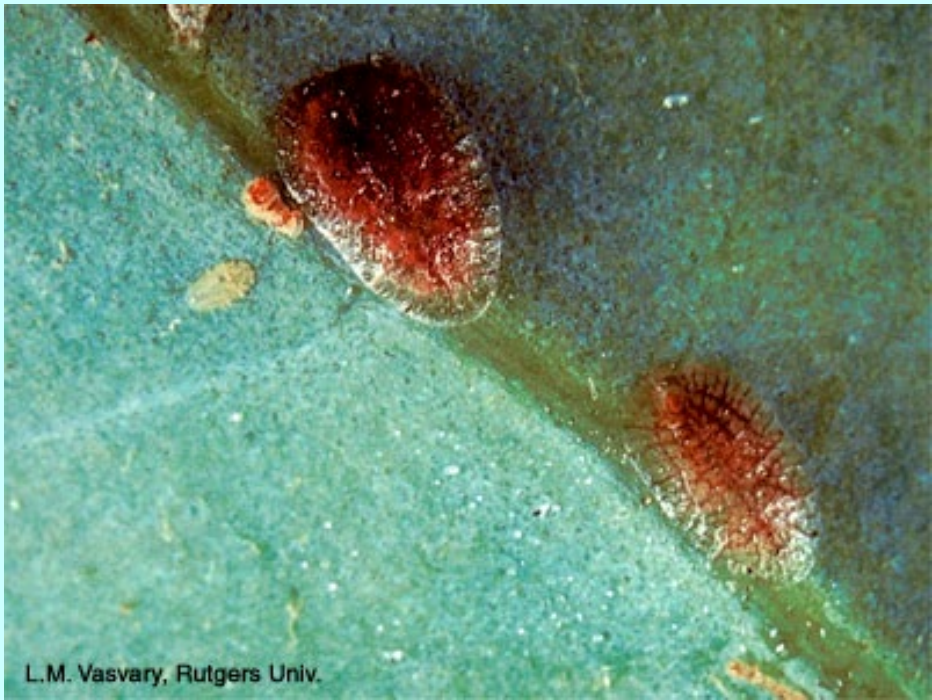
DESCRIPTION OF THE PESTS

Soft scales are typically found on woody and foliage plants. The first nymphal instar is called a crawler and has functional legs. The remaining instars are attached to the leaf or twig and (with the exception of green shield scale) do not move. These scales typically have a more conspicuous profile from the side view compared with armored scales and produce copious honeydew. The protective covering over a soft scale cannot be separated from its body.

IPM Program For Soft Scales

DESCRIPTION OF THE PESTS

Brown soft scale adults are fairly flat in profile, range in color from yellowish green to brown, and are often spotted or mottled to uniform brown. Hemispherical scale adults are round, hard, brown, smooth and shiny. Black scale adults are globular and hardened with ridges on the back that look like the letter "H". Green shield scale, introduced into California in the early 1990s, has a light yellow-green color as an immature. Female green shield scales produce a mass of eggs in a cottony ovisac without mating (there are no males).



Brown soft scale

IPM Program For Soft Scales

DAMAGE

Soft scales remove sap from plants and cause yellowing of leaves and overall plant decline. Green shield scale ovisacs and the honeydew excreted by soft scales disfigure plants. Honeydew allows the growth of black sooty mold and attracts ants, which may then carry scales to uninfested plants.

BIOLOGICAL CONTROL

The black scale parasite, *Metaphycus helvolus,* has controls hemispherical scale. The mealybug destroyer, *Cryptolaemus montrouzieri*, is an effective predator of green shield scale. The lady beetle *Rhyzobius lophanthae* attacks brown soft scale and black scale.

Rhyzobius lophanthae

IPM Program For Soft Scales

CULTURAL CONTROL

Exclusion of windblown crawlers can be accomplished by covering openings to the greenhouse with fine mesh screens. Prune and discard heavily infested plant parts. Control ants.

MONITORING and WHEN TO TREAT

Visual inspection of plants will help locate infestations and may permit treatments of hot spots. The presence of ants on plants can indicate a problem with scales.

Treatment is generally warranted when scales are present. Optimum timing is when crawlers are active; however, this can be difficult. Multiple applications are generally necessary.

Hemispherical scale

IPM Program For Soft Scales

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
insect growth regulator	pyriproxyfen (Distance)	12	Do not apply more than 2 times per cropping cycle or per 6 months. Do not use through any type of irrigation system.
	s-kinoprene (Enstar II)	4	Apply prebloom. Low-volume use. Do not apply through any type of irrigation system.
neonico-tinoid	imidacloprid (Marathon 60 WP)	12	As above, but apply only as a drench.
	imidacloprid (Marathon 1G) (Marathon II)	12	Do not use more than once every 16 weeks. Alternate with insecticides that have a different mode of action to prevent resistance. Do not apply to soils that are water logged. Do not apply to plants intended as food crops.

IPM Program For Soft Scales

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
oil	clarified hydrophobic extract of neem oil (Triact 70)	4	Do not spray plants under stress. Pest must be completely covered with spray. May cause injury to flowers. Do not use through any type of irrigation system.
	horticultural oil Ultra-Fine Oil SafTSide JMS Stylet Oil	4	Use as above for neem oil. Do not use with sulfur fungicides; check label for tank mix restrictions.
organo-chlorine	endosulfan (Endosulfan 3EC)	24	Check runoff restrictions. Chrysanthemums may exhibit phytotoxicity. Don't use through irrigation system or more than 3 lb ai/acre/season.

IPM Program For Soft Scales

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
organo-phosphate	acephate (Address)	24	Do not use through any type of irrigation system.
	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don't use through irrigation system.
	acephate (PT 1300 Orthene TR)	24	An aerosol that is only for greenhouse use.
	chlorpyrifos (PT DuraGuard ME)	12	

Top and side views of hemispherical scale

IPM Program For Armored Scales

Order Hemiptera
Family Diaspididae
Boisduval scale, *Diaspis boisduvali*
Fern Scale, *Pinnaspis aspidistrae*
(pictured)

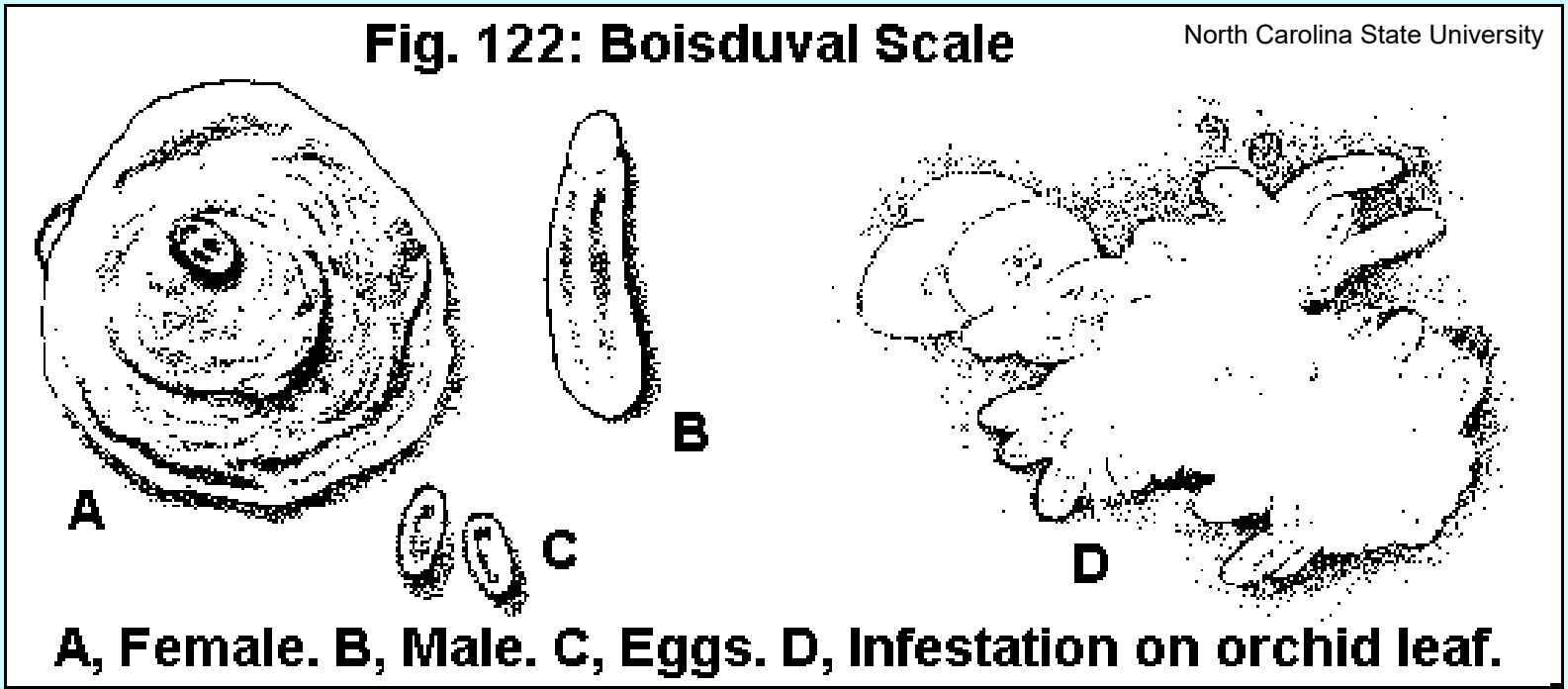
DESCRIPTION OF THE PESTS

Eggs are laid under the armor of the female where they develop and hatch. The first stage after hatching is the nymphal stage with legs, so the insects are called crawlers. Crawlers may stay under the maternal armor several hours until outside conditions are good. After they leave the cover, they wander for minutes to days (usually a few hours). At the end of the wandering period they flatten against the leaf or stem and begin to secrete their armor.

IPM Program For Armored Scales

DESCRIPTION OF THE PESTS

Newly settled nymphs insert their piercing, sucking mouthparts into plant tissue and start feeding on plant juices. Nymphs shed their skin as they grow and develop, and towards the end of development, males do not feed. The cast skins, called exuviae, are incorporated into the armor. The armor is non-living and is made of cast skins, threads, and liquid, all produced by the insect.



IPM Program For Armored Scales

DESCRIPTION OF THE PESTS

Females look like immatures. They remain under armor in one place throughout their lives to feed and reproduce. Males are very different in appearance and behavior from females. They are tiny, winged creatures with eyes and legs.
The armor must be pried off to reveal a female insect attached to the plant by thread-like mouthparts. The adult female insect lacks wings, legs, or eyes. Dead ones are dark brown and are dried rather than plump.

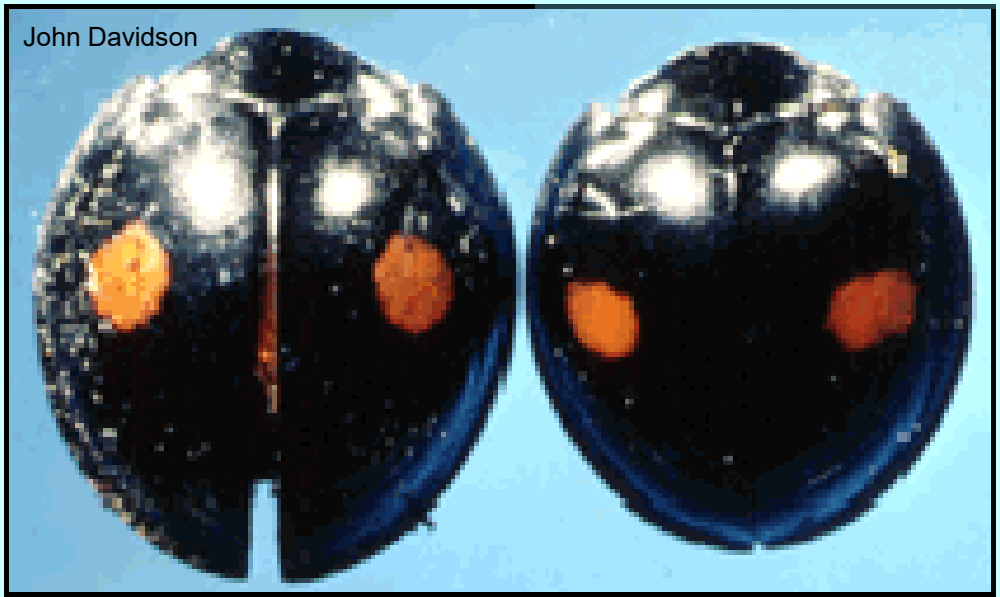
DAMAGE

Armored scales feed on plant juices and cause loss of vigor, deformation of infested plants, yellowish spots on leaves, loss of leaves, and even death. Since scales are spread by introduction of infested material and are difficult to identify to species outside of the lab, they are a quarantine problem on exported potted plants, cut flowers, and cut foliage.

IPM Program For Armored Scales

BIOLOGICAL CONTROL

Lady beetles have been introduced to control armored scales. Species such as *Chilocorus kuwanae* and *C. stigma* are used to control armored scales. Wasp parasitoids lay eggs in developing scales. They are parasites that absorb food from the scale body. Instead of an adult scale under the cover, an adult wasp emerges. The wasp *Coccidencyrtus ochraceipes* (Hymenoptera: Encyrtidae) parasitizes boisduval scale. *Aphytis melinus* attacks several species of armored scales.



C. stigma* (left) and *C. kuwanae

IPM Program For Armored Scales

CULTURAL CONTROL

Since armored scales are spread chiefly through movement of nursery stock, only propagative material that is free of scales should be planted. Adequate plant spacing is important because armored scales seldom spread from plant to plant unless the crowns of the plants are in contact. As plants grow, pruning maintains spacing and allows maximum coverage when using insecticides.

MONITORING and WHEN TO TREAT

Carefully inspect plants being brought in to start a new crop to ensure that they are free of scales. Treatment is generally warranted when scales are present. Optimum timing is when crawlers are active; however, this can be difficult. Multiple applications are generally necessary.

IPM Program For Armored Scales

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
insect growth regulator	pyriproxyfen (Distance)	12	Do not apply more than 2 times per cropping cycle or per 6 months. Do not use through any type of irrigation system.
	s-kinoprene (Enstar II)	4	Apply prebloom. Low-volume use. Do not apply through any type of irrigation system.
oil	clarified hydrophobic extract of neem oil (Triact 70)	4	Do not spray plants under stress. Pest must be completely covered with spray. May cause injury to flowers. Do not use through any type of irrigation system.
	horticultural oil Ultra-Fine Oil SafTSide JMS Stylet Oil	4	Use as above for neem oil. Do not use with sulfur fungicides; check label for tank mix restrictions.

IPM Program For Armored Scales

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
organo-chlorine	endosulfan (Endosulfan 3EC)	24	Check runoff restrictions. Chrysanthemums may exhibit phytotoxicity. Don't use through irrigation system or more than 3 lb ai/acre/season.
organo-phosphate	acephate (Address)	24	Do not use through any type of irrigation system.
	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don't use through irrigation system.
	acephate (PT 1300 Orthene TR)	24	An aerosol that is only for greenhouse use.
	chlorpyrifos (PT DuraGuard ME)	12	

IPM Program For Whiteflies

Order Hemiptera
Family Aleyrodidae
Greenhouse whitefly,
***Trialeurodes vaporariorum* (pictured)**
Silverleaf whitefly,
Benicia argentifolii

DESCRIPTION OF THE PESTS

The greenhouse whitefly adult is 0.9 (male) to 1.1 mm (female) long, with four wings, sucking mouthparts, a powdery waxy coating over the body, and wings that give the otherwise yellow body a white color. The wings are held nearly parallel to the leaf and cover the abdomen when the adult is at rest. There are seven life stages: egg, four nymphal instars, pupal stage, and the adult. Females occasionally lay eggs in circles on the undersides of leaves.

IPM Program For Whiteflies

DESCRIPTION OF THE PESTS

Eggs are partially inserted into the leaf, initially they are yellowish, but close to hatching they turn a purplish brown. The first nympal instar is called a crawler and has functional legs, while the remaining instars are attached to the underside of the leaf and do not move. The end of the fourth instar is called a pupa. The pupal stage is the most important for determining whitefly species identification. Greenhouse whitefly pupae are oval and have vertical sides, giving the pupa a cakelike appearance from the side. Along the perimeter of the upper surface is a fringe of filaments and relatively large wax filaments project above the upper surface of the body. The greenhouse whitefly can complete one generation in 21 to 26 days at 81°F.

IPM Program For Whiteflies

DESCRIPTION OF THE PESTS

The silverleaf whitefly adult is 0.8 (male) to 1.0 mm (female) long, with four wings, and sucking mouthparts. The white, waxy coating is not as thick as it is on the greenhouse whitefly and its yellow body has a whitish hue rather than a white color. Wings are held at the sides of the body, partially exposing the back of the abdomen when the adult is at rest. There are also seven life stages. Eggs are not laid in a circular pattern, are partially inserted into the leaf, and remain yellowish until hatching. The first nymphal instar is called a crawler and has functional legs; the remaining instars are attached to the leaf and do not move. The end of the fourth instar is called a pupa. Silverleaf whitefly pupae are ovoid, with a slightly pointed hind end and red eye spots. The pupa is flat and does not have a marginal fringe of filaments. Silverleaf whiteflies can complete development in 16 (86°F) to 31 (68°F) days.

IPM Program For Whiteflies

DAMAGE

Whitefly adults and immatures feed on sap. As they feed, they excrete honeydew, a sticky substance that causes unsightly glistening and supports the growth of black sooty mold. Very large populations of whiteflies cause stunting of plant growth, and leaves may senesce and die. Physiological abnormalities, such as white stem on poinsettia, may also occur. Usually populations are not high enough to stunt ornamentals, and damage is mostly caused by honeydew, sooty mold, and nuisance populations of flying adults.

Silverleaf whiteflies

IPM Program For Whiteflies

BIOLOGICAL CONTROL

Encarsia formosa, **a tiny, stingless parasitic wasp, is as an effective biological control for greenhouse whiteflies. Wasps are released once a week at a rate of two to five parasites per plant for 8 to 10 weeks of the growing season. This sort of release program can be effective if long residual insecticides have not been applied in advance of the parasite release, and where the initial population of whiteflies is quite low (only a few whiteflies per plant). Greenhouse whitefly pupae turn black when parasitized by *Encarsia,* which emerge as adults through circular exit holes. *Delphastus pusillus,* a whitefly predator, has been used against silverleaf whiteflies. *Eretmocerus eremicus* is a commercially available whitefly parasite for silverleaf whitefly. It will also attack greenhouse whitefly, whereas *Encarsia* is ineffective against silverleaf whitefly.**

IPM Program For Whiteflies

CULTURAL CONTROL

Because whiteflies feed on a large variety of plant species, keep production areas free of weeds. Exclusion of winged adults can be accomplished by covering openings to the greenhouse with screens that have a pore width of 405 microns or smaller. Before starting a new crop, carefully inspect plants to ensure that they are free of whiteflies and other pests. Treat or discard any infested plants.

MONITORING and WHEN TO TREAT

Yellow sticky cards placed in greenhouses will capture adult whiteflies. However, traps need to be used at a greater density, one per 1,000 sq. ft., than for other pests. Trap monitoring should be supplemented with inspection of leaves for nymphs and pupae. When monitoring plant samples, it is imperative to look on the undersides of leaves for adults and nymphs. Treatment thresholds vary with the crop.

IPM Program For Whiteflies

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
biological	*Beauveria bassiana* (BotaniGard 22 WP) (BotaniGard ES)	4 12	Treat every 7 days while insects are active. Do not tank mix with most fungicides and wait 48 hours after application to apply a fungicide.
botanical	pyrethrin/PBO2 (PT 1100 Pyrethrum TR)	12	An aerosol.
	pyrethrin/rotenone (Pyrellin EC)	12	pyrethrin/rotenone (Pyrellin EC)
insect growth regulator	azadirachtin (Azatin XL Plus)	4	Must contact insect. Repeated applications as necessary. Low-volume application.
	azadirachtin (Ornazin 3%EC)	12	Do not exceed 22.5 oz/acre/application.

IPM Program For Whiteflies

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
insect growth regulator	diflubenzuron (Adept 25WP)	12	Whitefly suppression. May damage poinsettias if used over labeled rate. Also effective on fungus gnat larvae and lepidopteran larvae.
	novaluron (Pedestal)	12	Use no more than twice per year and don't exceed 52 oz/acre/year. Don't use on poinsettia.
	pyriproxyfen (Distance)	12	Do not apply more than 2 times per cropping cycle or per 6 months. Do not use through any type of irrigation system.
	s-kinoprene (Enstar II)	4	Apply prebloom. Also-labeled for low volume use. Do not apply through any type of irrigation system.
macrocyclic lactone	abamectin (Avid 0.15EC)	12	Low-volume application. Do not apply through any type of irrigation system.

IPM Program For Whiteflies

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
neonico-tinoid	imidacloprid (Marathon 60 WP)	12	As above, but apply only as a drench.
	imidacloprid (Marathon 1G) (Marathon II)	12	Do not use more than once every 16 weeks. Alternate with insecticides that have a different mode of action to prevent resistance. Do not apply to soils that are water logged. Do not apply to plants intended as food crops.
oil	clarified hydrophobic extract of neem oil (Triact 70)	4	Do not spray plants under stress. Pest must be completely covered with spray-this material may not effectively control melon aphid because it is often on the underside of lower leaves. May cause injury to flowers. Do not use through any type of irrigation system.
	horticultural oil Ultra-Fine Oil SafTSide JMS Stylet Oil	4	Use as above for neem oil. Do not use with sulfur fungicides; check label for tank mix restrictions.

IPM Program For Whiteflies

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
organo-chlorine	endosulfan (Endosulfan 3EC)	24	Check runoff restrictions. Chrysanthemums may exhibit phytotoxicity. Don't use through irrigation system or more than 3 lb ai/acre/season.
organo-phosphate	acephate (Address)	24	Do not use through any type of irrigation system.
	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don't use through irrigation system.
	acephate (1300 Orthene TR)	24	An aerosol that is only for greenhouse use.
	chlorpyrifos (PT DuraGuard ME)	24	
organo-phosphate/ pyrethroid	chloropyrifos/ cyfluthrin (PT Duraplex TR)	24	An aerosol.

IPM Program For Whiteflies

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyrethroid	bifenthrin (Attain TR)	12	Check label. Fogger for greenhouse use only.
	bifenthrin (Talstar Flowable)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	cyfluthrin (Decathlon 20 WP)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	fenpropathrin (Tame 2.4 EC)	24	Label permits low-volume application. Do not use through any type of irrigation system.
	fluvalinate (Mavrik Aquaflow)	12	Low-volume application. Also labeled for cutting dip at 5 fl oz/100 gal. Don't use through irrigation system.
	permethrin (Astro)	12	May cause browning of petals. Marginal leaf burn may occur on salvia, diffenbachia and pteris fern. Low-volume application. Do not apply more than 2 lb a.i./acre/year.

IPM Program For Whiteflies

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyridazinone	pyridaben (Sanmite 75WP)	12	
pyridine	pymetrozine (Endeavor)	12	Do not use through irrigation system. Apply as foliar spray at 7-14 day intervals. For indoor use, do not use more than 100 oz.
soap	potash soap (Insecticidal soap) (M-Pede)	12	Must contact insect, so thorough coverage is important. Repeat weekly as needed up to 3 times. Test for phytotoxicity. Do not spray new transplants or newly rooted cuttings. Do not add adjuvants.

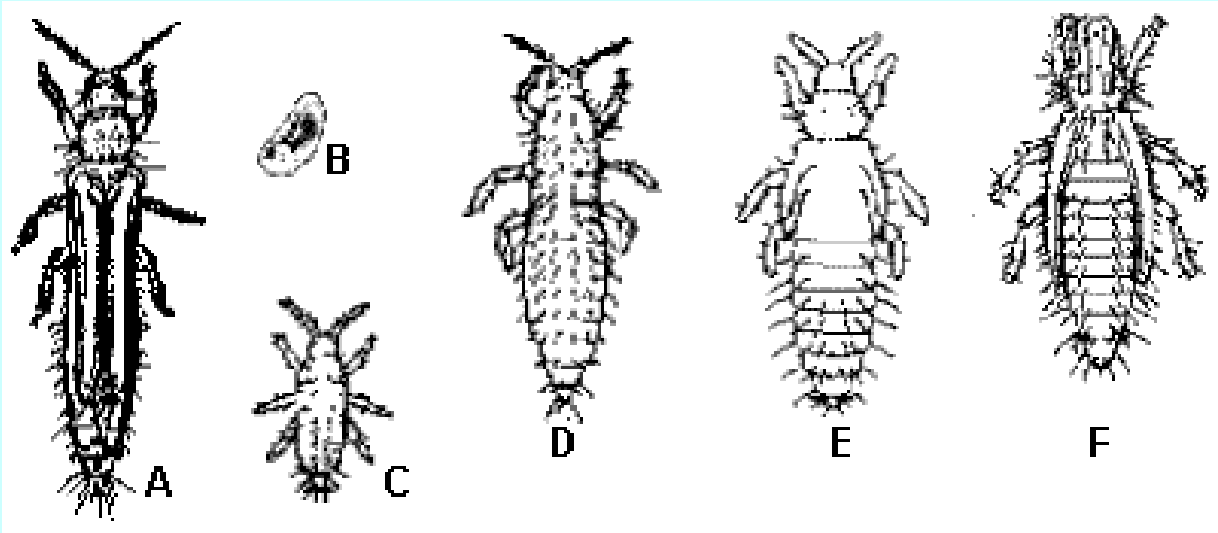
Silverleaf whitefly

IPM Program For Thrips

Order Thysanoptera
Family Thripidae
Western flower thrips, *Frankliniella occidentalis*
Greenhouse thrips, *Heliothrips haemorrhoidalis*

DESCRIPTION OF THE PESTS

Thrips are tiny insects that have four featherlike wings, each consisting of a thick supporting strut with fine hairs on the front and hind edges. Thrips go through six life stages: egg, first instar, second instar, prepupa, pupa, and adult. Thrips insert eggs into plant tissue. The first two instars and adults feed by piercing and removing contents of individual plant cells.



IPM Program For Thrips

DESCRIPTION OF THE PESTS

Western flower thrips (WFT, pictured on right) has three color forms. There is a pale form that is white and yellow, except for slight brown spots or blemishes on the top of the abdomen; an intermediate form with a dark orange thorax and brown abdomen; and a dark form that is dark brown. Western flower thrips usually feed in enclosed tissues such as flowers, buds, or growing tips. Adults also feed on pollen and on spider mites. The prepupa and pupal stages take place in the soil beneath infested plants. Females will lay male eggs if unmated and female eggs are produced once mating has occurred. Development times to complete one generation of western flower thrips varies from 11 days (77° to 87°F), to 44 days (50° to 60°F).

IPM Program For Thrips

DESCRIPTION OF THE PESTS

Adult greenhouse thrips are tiny, black, insects with whitish to translucent wings folded back over their thorax and abdomen. Legs are also a whitish color. Nymphs are whitish to slightly yellowish in color and produce a globule of fecal fluid at the tip of their abdomen. These globules of fluid increase in size until they fall off and another one begins to form, resulting in a characteristic spotting of the infestation area with black specks of fecal material.

Greenhouse thrips

IPM Program For Thrips

DAMAGE

Western flower thrips primarily feeds on flowers but also sometimes on new vegetative growth, whereas greenhouse thrips feeds primarily on foliage. Direct feeding damage includes streaking, spotting, and tissue distortion. On leaves, feeding often occurs along veins and appears as an outlining of the veins. Western flower thrips can vector tomato spotted wilt virus as well as many other viruses. Western flower thrips may cause premature senescence of flowers, such as African violets, because they prematurely pollinate the flowers. On orchids, western flower thrips feeding and egg laying will leave translucent 'pimpling' spots on petals and leaves. Greenhouse thrips stipple the foliage of numerous field and greenhouse grown plants. The stippling damage caused by thrips feeding on individual cells is often confused with mite stippling.

IPM Program For Thrips

BIOLOGICAL CONTROL

Three commercially available predators to help control western flower thrips are the minute pirate bug, *Orius* spp., and two predatory mites, *Amblyseius cucumeris* and *Hypoaspis miles*. *Orius* are released at a rate of 2000 to 4000 per acre, while *Amblyseius cucumeris* are released at a rate of 10 to 50 mites per plant for each of 2 to 3 weeks. *Hypoaspis miles* are soil-inhabiting predators that feed on thrips prepupae and pupae in the soil. These mites are released in the soil at planting and are most successful when plant-to-plant contact facilitates movement of predators between plants. A commercially available parasite of greenhouse thrips is *Thripobius semileteus* (right).

Jack Kelly Clark
University of California

IPM Program For Thrips

CULTURAL CONTROL

Because western flower thrips and greenhouse thrips feed on a large variety of plant species, keep production areas free of weeds, which can serve as hosts for thrips populations. Most commercially available screens have pore sizes slightly larger than the width of the western flower thrips thorax (145 microns), meaning that some winged adults can penetrate these openings. However, covering openings to the greenhouse with fine screens does exclude most thrips. Be sure that the ventilation system on an existing greenhouse can accommodate the reduced flow caused by a fine screen or else the system will need to be modified.

Carefully inspect plants being brought in to start a new crop to ensure that they are free of thrips and other pests. A holding area where plants are kept for about 11 to 12 days is useful so that plants can be inspected for any infestations that may develop. Treat any infested plants if necessary.

IPM Program For Thrips

MONITORING and WHEN TO TREAT

Blue sticky cards are most attractive to western flower thrips. However, yellow cards are easier to count and more commonly used for insect monitoring. Place yellow sticky cards vertically in the crop canopy, with the lower one-third of the trap in the leaves and the upper two-thirds above the leaves. As the crop grows, the traps will need to be raised. Three traps per cultivar is adequate. In greenhouses with many different cultivars, place traps in the most sensitive varieties, usually yellow or white flowers. In large greenhouses of the same or similar cultivars, there should be at least eight traps per 100,000 square feet. The treatment threshold for roses is 25 to 50 thrips per card per week (25 for more sensitive yellow- and white-flowered varieties, 50 for reds). In other crops place one card per 10,000 square feet. Consider treating if an average of 5 to 10 thrips per card per week is present.

IPM Program For Thrips

MONITORING and WHEN TO TREAT

It is important to note that correct identification of pest thrips is essential in a monitoring program. There may be several species of thrips present on a sticky card but only the western flower thrips and greenhouse thrips should be counted when making treatment decisions. Most insecticides must be applied at least two times, 5 to 7 days apart, for efficacy against western flower thrips.

White feeding scars and black excrement from greenhouse thrips

IPM Program For Thrips

MONITORING FOR VIRUSES

It is also important to monitor for viruses that western flower thrips vector, such as impatiens necrotic spot virus (INSV) and tomato spotted wilt virus (TSWV) (both are tospoviruses).

It is difficult to diagnose tospovirus infections of greenhouse plants using visual symptoms alone because symptoms can vary. Tospovirus symptoms often mimic symptoms caused by other problems, such as nutritional deficiencies.

Tospovirus infections may be systemic (i.e., virus symptoms are spread throughout the plant) or non-systemic (i.e., the virus symptoms are confined to a specific part of the plant). Tospoviruses, however, may be present even though the plant shows no symptoms.

IPM Program For Thrips

MONITORING FOR VIRUSES

The symptoms of tospovirus infections in floral crops are:

- **Brown, black, or white spots**
- **Necrosis on the leaf petiole**
- **Yellow mottling or variegation**
- **Death of young plants or terminal meristems of older plants**
- **Brown or black cankers on the stem**
- **Stunting**
- **Veinal necrosis**
- **Concentric ring spots**
- **Mosaics**
- **Line or zonal patterns**

Begonia with tomato spotted wilt virus

IPM Program For Thrips

MONITORING FOR VIRUSES

Early warning is critical to the control of western flower thrips and to the prevention of tospovirus infections. Indicator plants are often used to detect thrips and virus problems. Indicator plants should meet at least one of the following criteria:

- **Indicator plants should be more attractive to pests than the producing crop**
- **Pests or pathogen must develop faster on indicator plants**
- **Indicators must show feeding damage or virus symptoms more readily**
- **Indicator plants should not contribute to the spread of the virus being monitored**

IPM Program For Thrips

MONITORING FOR VIRUSES

Petunia plants (*Petunia* x *hybrida*) are excellent indicators for presence of western flower thrips and transmission of tospoviruses because petunias are not systemically infected with either TSWV or INSV. In response to a tospovirus infection, petunias show a hypersensitive response: rapid death of plant tissues that also kills the invading virus.

The following petunia cultivars are excellent indicator plants:

- **Calypso**
- **Super Blue Magic**
- **Blue Carpet**
- **Cascade Blue**
- **Summer Madness**
- **Burgundy Madness**
- **Red Cloud**
- **Super Magic Coral**

Lesions on petunia leaves caused by feeding of western flower thrips

IPM Program For Thrips

MONITORING FOR VIRUSES

Remove flowers from indicator plants before placing them in greenhouses because petunia flower petals do not express local lesions and attract western flower thrips away from leaves. Flag indicator plants with blue pie pans or metal sheets to increase effectiveness since western flower thrips are most sensitive to blue colors. Look for feeding scars, which are whitish and have an irregular outline. Brown or black-edged lesions will develop on the edges of thrips feeding scars within 3 days if a tospovirus has been transmitted. If a tospovirus outbreak occurs in the greenhouse, look for patterns of injury that correlate with variations in air movement, humidity, and temperature. Control measures include removal of infected plants and controlling or excluding thrips.

IPM Program For Thrips

MONITORING FOR VIRUSES

In addition to the use of indicator plants, there are several kits designed specifically to test for tospoviruses vectored by western flower thrips. The test kits are available from www.agdia.com.

IPM Program For Thrips

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
biological	*Beauveria bassiana* (BotaniGard 22 WP) (BotaniGard ES)	4 12	Treat every 7 days while insects are active. Do not tank mix with most fungicides and wait 48 hours after application to apply a fungicide.
botanical	cinnamaldehyde (Cinnacure)	4	After 2 applications, rotate to an insecticide of different chemistry for 2+ applications. Don't apply to stressed/newly transplanted plants. Don't apply with irrigation system.
	pyrethrin/PBO2 (PT 1100 Pyrethrum TR)	12	An aerosol.
	pyrethrin/rotenone (Pyrellin EC)	12	

IPM Program For Thrips

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
carbamate	methiocarb (Mesurol 75W)	24	Apply in 50 gal water. Repeat as necessary up to 4 applications/season. Do not apply with oil or foliar fertilizer. Don't apply with irrigation system
insect growth regulator	azadirachtin (Azatin XL Plus)	4	Must contact insect. Repeated applications as necessary. Label permits low-volume application.
	azadirachtin (Ornazin 3%EC)	12	Do not exceed 22.5 oz/acre/application.
	novaluron (Pedestal)	12	Use no more than twice per year and don't exceed 52 oz/acre/year. Don't use on poinsettia.
macrocyclic lactone	abamectin (Avid 0.15EC)	12	Label permits low-volume application. Do not use through any type of irrigation system.

IPM Program For Thrips

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
neonico-tinoid	imidacloprid (Marathon 60 WP)	12	As above, but apply only as a drench.
	imidacloprid (Marathon 1G) (Marathon II)	12	Do not use more than once every 16 weeks. Alternate with insecticides that have a different mode of action to prevent resistance. Do not apply to soils that are water logged. Do not apply to plants intended as food crops.
nicotine	nicotine (Nicotine Smoke Generator)	see label	
oil	clarified hydrophobic extract of neem oil (Triact 70)	4	Do not spray plants under stress. Pest must be completely covered with spray-this material may not effectively control melon aphid because it is often on the underside of lower leaves. May cause injury to flowers. Do not use through any type of irrigation system.

IPM Program For Thrips

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
organo-chlorine	endosulfan (Endosulfan 3EC)	24	Check runoff restrictions. Chrysanthemums may exhibit phytotoxicity. Don't use through irrigation system or more than 3 lb ai/acre/season.
organo-phosphate	acephate (Address)	24	Do not use through any type of irrigation system.
	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don't use through irrigation system.
	acephate (1300 Orthene TR)	24	An aerosol that is only for greenhouse use.
	chlorpyrifos (PT DuraGuard ME)	24	
organo-phosphate/ pyrethroid	chloropyrifos/ cyfluthrin (PT Duraplex TR)	12	An aerosol.

IPM Program For Thrips

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
soap	potash soap (Insecticidal soap) (M-Pede)	12	Must contact insect, so thorough coverage is important. Repeat weekly as needed up to 3 times. Test for phytotoxicity. Do not spray new transplants or newly rooted cuttings. Do not add adjuvants.
spinosyn	spinosad (Conserve SC)	4	Do not apply more than 10 times in a 12-month period. Do not apply more than 3 times in a row without rotating to a different chemistry. Compatible with most beneficials, but highly toxic to bees and hymenopteran parasites. Direct contact can cause significant mortality to *Phytoseiulus persimilis.*

Western flower thrips

Jack T. Reed, Mississippi State University, www.insectimages.org

IPM Program For Fungus Gnats

Order Diptera
Family Sciaridae
Darkwinged fungus gnats, *Bradysia* spp.

DESCRIPTION OF THE PEST

Fungus gnats are small (2-5 mm long) mosquito-like flies with dark wings, delicate legs, and long antennae. They lay their eggs in soil, and the eggs hatch about 4 days later. There are four larval instars that increase in size up to about 0.33 inch (8 mm). Larvae are clear, with visible internal organs, and have shiny black head capsules. Initially larvae feed on root hairs and algae; later, larvae may feed on the insides of roots. When populations are high, larvae may bore into larger roots or stems that are in the soil. Larvae will also feed on leaves touching the soil. One generation may complete development in 21 (72°F) to 40 (61°F) days.

IPM Program For Fungus Gnats

DAMAGE

Larvae usually feed on roots and algae within 1 inch of the soil surface. Root feeding by larvae can allow entry of plant pathogens. Direct damage through root feeding can cause wilting even though the plants are being sufficiently watered. Damage is particularly severe in propagation areas, in seedling flats, and with especially sensitive crops. Adult fungus gnats also disseminate soil-inhabiting pathogens on their bodies and in their feces. Fungus gnat adults can be a nuisance when present in large numbers.

BIOLOGICAL CONTROL

Biological control agents include nematodes (*Steinernema feltiae*), soil-inhabiting predaceous mites (*Hypoaspis miles*), and the bacteria *Bacillus thuringiensis* (Gnatrol).

IPM Program For Fungus Gnats

CULTURAL CONTROL

Keep production areas free of weeds and algal scum, which can serve as breeding sites for fungus gnats. Over-watered conditions and using incompletely composted organic matter or manure in potting media provides ideal conditions for fungus gnats. Commercial sources of peat may be infested with fungus gnats and should be steamed before use when growing crops sensitive to fungus gnats. Use hydrated lime under benches to control algal growth and thus reduce populations of fungus gnats. Pictured above are fungus gnat larvae.

IPM Program For Fungus Gnats

MONITORING and WHEN TO TREAT

Yellow sticky cards (right) will capture adult fungus gnats. Small emergence traps can also be used to determine precisely where adults are emerging. Larval populations can be monitored with cubes or slices of potatoes pressed into soil.

Pyrethroids are useful for knocking down adult populations and microencapsulated pesticides (pyriproxyfen and chlorpyrifos both are available in microencapsulated formulations) applied to the soil are effective against larvae. Apply drenches to top 1 inch of soil to kill larvae and use foggers, aerosols, or sprays to control adults.

IPM Program For Fungus Gnats

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
biological	*Bacillus thuringiensis* (Gnatrol)	4	Do not apply with fertilizers or fungicides containing copper or chlorine. Not effective on shore flies.
botanical	pyrethrin/PBO2 (PT 1100 Pyrethrum TR)	12	An aerosol.
	pyrethrin/rotenone (Pyrellin EC)	12	

Darkwinged Fungus Gnat

Gerald J. Lenhard, Louisiana State University, www.insectimages.org

IPM Program For Fungus Gnats

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
insect growth regulator	azadirachtin (Azatin XL Plus)	4	Must contact insect. Repeated applications as necessary. Label permits low-volume application.
	azadirachtin (Ornazin 3%EC)	12	Do not exceed 22.5 oz/acre/application.
	cyromazine (Citation 75 WP)	12	Certification training required to use this product. Also effective against shorefly larvae.
	diflubenzuron (Adept 25WP)	12	Apply as spray or drench to top 2 inches of soil.
	pyriproxyfen (Distance)	12	Do not apply more than 2 times per cropping cycle or per 6 months. Do not apply through any type of irrigation system.
	s-kinoprene (Enstar II)	4	Apply prebloom. Also labeled for low volume use. Do not apply through any type of irrigation system.

IPM Program For Fungus Gnats

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
neonico-tinoid	imidacloprid (Marathon 60 WP)	12	As above, but apply only as a drench.
	imidacloprid (Marathon 1G)	12	Do not use more than once every 16 weeks. Alternate with insecticides that have a different mode of action to prevent resistance. Do not apply to soils that are water logged. Don't apply to food crops.
organo-phosphate	acephate (Address)	24	Do not use through any type of irrigation system.
	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don't use through irrigation system.
	acephate (1300 Orthene TR)	24	An aerosol that is only for greenhouse use.
	chlorpyrifos (PT DuraGuard ME)	24	

IPM Program For Fungus Gnats

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyrethroid	bifenthrin (Attain TR)	12	Check label. Fogger for greenhouse use only.
	bifenthrin (Talstar Flowable)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	cyfluthrin (Decathlon 20 WP)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	deltamethrin (DeltaGard)	12	Do not use through any type of irrigation system.
	fenpropathrin (Tame 2.4 EC)	24	Label permits low-volume application. Do not use through any type of irrigation system.
	fluvalinate (Mavrik Aquaflow)	12	Low-volume application. Also labeled for cutting dip at 5 fl oz/100 gal. Don't use through irrigation system.
	permethrin (Astro)	12	May cause browning of petals. Marginal leaf burn may occur. Low-volume application. Do not apply more than 2 lb a.i./acre/year.

IPM Program For Shore Flies

Order Diptera
Family Ephydridae
Shore flies, *Scatella stagnalis*

DESCRIPTION OF THE PEST

This fly breeds in over-watered conditions in association with algae. The adult is small (2 mm) and dark. The overall appearance is similar to a fruit fly; having short antennae and shorter legs than fungus gnats. The pair of dark wings has three white spots on each wing. When the fly is at rest, there appears to be five spots because the wings overlap. Small, oblong eggs are laid in algal scum where larvae feed. Shore fly larvae have no distinct head capsule, and the body is opaque yellow, white, or brown. Both the dark brown pupa and the larva have a forked air tube at the rear end.

IPM Program For Shore Flies

DAMAGE

Large populations of shore flies can be a nuisance. Neither the adults nor larvae feed on plants. However, adults may spread fungal spores in greenhouses. Fecal spots on leaves produced by resting adults can cause cosmetic damage.

BIOLOGICAL CONTROL

Biological control of shore flies has not been investigated.

CULTURAL CONTROL

Do not overwater. Control algae with hydrated lime.

MONITORING and WHEN TO TREAT

Yellow sticky cards placed will capture adult shore flies. Because these flies do not directly feed on plants, treatment may not be essential unless there is a large nuisance population. Foggers and aerosols may be better than sprays.

IPM Program For Shore Flies

INSECTICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
botanical	pyrethrin/PBO2 (PT 1100 Pyrethrum TR)	12	An aerosol.
	pyrethrin/rotenone (Pyrellin EC)	12	

Pupa (left) and larva of shore fly

IPM Program For Shore Flies

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
insect growth regulator	azadirachtin (Azatin XL Plus)	4	Must contact insect. Repeated applications as necessary. Label permits low-volume application.
	cyromazine (Citation 75 WP)	12	Certification training required to use this product. Also effective against shorefly larvae.
	diflubenzuron (Adept 25WP)	12	Apply as spray or drench to top 2 inches of soil.
	pyriproxyfen (Distance)	12	Do not apply more than 2 times per cropping cycle or per 6 months. Do not apply through any type of irrigation system.
	s-kinoprene (Enstar II)	4	Apply prebloom. Also labeled for low volume use. Do not apply through any type of irrigation system.

IPM Program For Shore Flies

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
neonico-tinoid	imidacloprid (Marathon 60 WP)	12	As above, but apply only as a drench.
	imidacloprid (Marathon 1G)	12	Do not use more than once every 16 weeks. Alternate with insecticides that have a different mode of action to prevent resistance. Do not apply to soils that are water logged. Don't apply to food crops.
organo-phosphate	acephate (Orthene T, T&O Spray) 75WP	24	Chrysanthemums may exhibit phytotoxicity. Can stunt growth in roses. Don't use through irrigation system.
	acephate (1300 Orthene TR)	24	An aerosol that is only for greenhouse use.
	chlorpyrifos (PT DuraGuard ME)	24	

IPM Program For Shore Flies

INSECTICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyrethroid	bifenthrin (Attain TR)	12	Check label. Fogger for greenhouse use only.
	bifenthrin (Talstar Flowable)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	cyfluthrin (Decathlon 20 WP)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	fenpropathrin (Tame 2.4 EC)	24	Label permits low-volume application. Do not use through any type of irrigation system.
	fluvalinate (Mavrik Aquaflow)	12	Low-volume application. Also labeled for cutting dip at 5 fl oz/100 gal. Don't use through irrigation system.
	permethrin (Astro)	12	May cause browning of petals. Marginal leaf burn may occur. Low-volume application. Do not apply more than 2 lb a.i./acre/year.

IPM Program For Spider Mites

Class Arachnida
Order Acari
Family Tetranychidae
Twospotted spider mite, *Tetranychus urticae*

DESCRIPTION OF THE PEST

Twospotted spider mites are web-forming mites that pierce plant cells and remove their contents. All spider mites have two body segments and four pairs of legs as adults. Twospotted spider mite adults, as the name suggests, have two large dark spots on the sides of their yellowish green bodies. These mites lay round eggs that hatch into six-legged larvae. The subsequent stages, the protonymph and deutonymph stages, are eight-legged as are the adults. Since the entire life cycle can take as little as 8 (77° to 95°F) to 28 (50° to 68°F) days, spider mites have many generations per year and can rapidly increase in number.

IPM Program For Spider Mites

DAMAGE

Twospotted mites suck cell contents from leaves, initially stippling leaves with a fine pale green mottling. As feeding continues, the stippling increases and leaves turn yellow with bronze or brown areas; damaged leaves may fall. Undersides of leaves may have many cast skins of mites, and webbing on the foliage is unaesthetic. Plants may become stunted when large mite populations feed and the plants may die.

Infestation

IPM Program For Spider Mites

BIOLOGICAL CONTROL

Many different species of predatory mites are available for control of these mites under different conditions. *Phytoseiulus persimilis* is a commercially available predator of twospotted spider mite, and it has been used to control mite populations in greenhouses and field situations. It can reproduce faster than its prey, yet best results have been obtained when it is released into the crop well before the spider mite populations have built up. The lady beetle, *Stethorus* sp., also attacks spider mites.

CULTURAL CONTROL

Because spider mites feed on a large variety of plants, keep production areas free of weeds, which can serve hosts to the mites. Carefully inspect plants being brought in to start a new crop to ensure that they are free of mites. Rogue or treat infested plants.

IPM Program For Spider Mites

MONITORING and WHEN TO TREAT

Monitor the crop regularly, as indirect sampling methods (such as sticky cards) are ineffective. Observe the undersides of leaves with a 10X hand lens, and watch for changes in plant foliage, which is characteristic of mite feeding. Except as noted, the materials listed on the following slides only kill active stages of mites, so more than one treatment may be necessary to break the life cycle. Follow label directions regarding reapplication times.

IPM Program For Spider Mites

MITICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
botanical	cinnamaldehyde (Cinnacure)	4	After 2 applications, rotate to an insecticide of different chemistry for 2+ applications. Don't apply to stressed/newly transplanted plants. Don't apply with irrigation system.
carbamate	methiocarb (Mesurol 75W)	24	Apply in 50 gal water. Repeat up to 4 applications/season. Don't apply with oil or foliar fertilizer or with irrigation system
carboximide	hexythiazox (Hexygon 50WP)	12	No chemigation. Ovicidal/larvicidal action. Use only 1 time per crop or once a year.
carboxylic acid	bifenazate (Floramite)	12	Apply at least two alternative products between treatments of bifenazate. Primarily effective against motile stages but has some ovicidal activity.

IPM Program For Spider Mites

MITICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
macrocyclic lactone	abamectin (Avid 0.15EC)	12	Label permits low-volume application. Do not use through any type of irrigation system.
oil	clarified hydrophobic extract of neem oil (Triact 70)	4	Do not spray plants under stress. Pest must be completely covered with spray-this material may not effectively control melon aphid because it is often on the underside of lower leaves. May cause injury to flowers. Do not use through any type of irrigation system.
	horticultural oil Ultra-Fine Oil SafTSide JMS Stylet Oil	4	Use as above for neem oil. Do not use with sulfur fungicides; check label for tank mix restrictions.

IPM Program For Spider Mites

MITICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
organochlorine	endosulfan (Endosulfan 3EC)	24	Check runoff restrictions. Chrysanthemums may exhibit phytotoxicity. Don't use through irrigation system or more than 3 lb ai/acre/season.
	dicofol (Kelthane 50WP)	48	Low-volume use. Do not use through any type of irrigation system.
organtin	fenbutatin-oxide (Vendex)	48	
phenoxypyrazole	fenpyroximate (Akari)	12	Do not apply more than 10 gal spray/1000 sq ft/application. Do not exceed 48 oz/crop cycle or growing season, whichever is longer.

IPM Program For Spider Mites

MITICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
pyrethroid	bifenthrin (Attain TR)	12	Check label. Fogger for greenhouse use only.
	bifenthrin (Talstar Flowable)	12	Label permits low-volume application. Do not use through any type of irrigation system.
	fenpropathrin (Tame 2.4 EC)	24	Label permits low-volume application. Do not use through any type of irrigation system.
	fluvalinate (Mavrik Aquaflow)	12	Low-volume application. Also labeled for cutting dip at 5 fl oz/100 gal. Don't use through irrigation system.
pyridazinone	pyridaben (Sanmite 75WP)	12	Use at least 2 different chemicals between applications of Sanmite. Do not use fertilizers containing boron or apply through any type of irrigation system. Do not exceed 10.67 oz/acre/application.

IPM Program For Spider Mites

MITICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
soap	potash soap (Insecticidal soap) (M-Pede)	12	Must contact mite, so thorough coverage is important. Repeat weekly as needed up to 3 times. Test for phytotoxicity. Do not spray new transplants or newly rooted cuttings. Do not add adjuvants.
spinosyn	spinosad (Conserve SC)	4	Miticidal activity is due mainly to surfactants and other inert ingredients. Not recommended for use against mites unless control is also needed for other pests (caterpillars, leafminers, thrips) against which the active ingredient in this product is effective. Do not apply more than 10 times in a 12-month period. Do not apply more than 3 times in a row without rotating to a different chemistry. Compatible with most beneficials, but highly toxic to bees and hymenopteran parasites. Direct contact can cause significant mortality to *Phytoseiulus persimilis.*

IPM Program For Tarsonemid Mites

Class Arachnida
Order Acari
Family Tarsonemidae
Cyclamen mite,
Phytonemus pallidus
Broad mite,
Polyphagotarsonemus latus
Bulb scale mite,
Stenotarsonemus laticeps

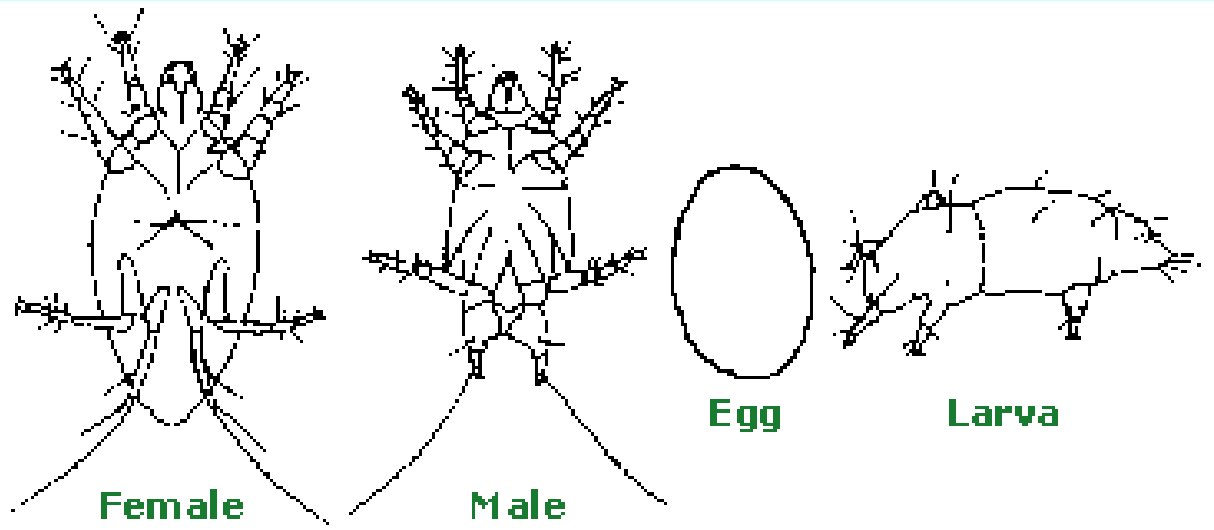
DESCRIPTION OF THE PESTS

Tarsonemid, or thread-footed mites are tiny and cannot be readily seen without magnification (20X to 40X). The life stages of these thread-footed mites are: egg, nymph, pseudopupa, and adult (one less stage than for spider mites).

IPM Program For Tarsonemid Mites

DESCRIPTION OF THE PESTS

Eggs of the cyclamen mite are one-half the length of the adult and are oval shaped. Eggs of the closely related broad mite are distinguishable from cyclamen mite eggs by rows of white pegs on the egg's upper surface. Immature stages of these mites are white. These mites get the name "thread-footed" from the appearance of the hind pair of legs in the adult female, which is threadlike; adult males, on the other hand, have stout legs for clasping the female. Adult males carry female pseudopupae on their back. As soon as the adult female emerges, they mate.



Life cycle of cyclamen mite

IPM Program For Tarsonemid Mites

DESCRIPTION OF THE PESTS

Cyclamen mite (pictured on right) is generally found on growing terminals, in buds, or on unfolding leaflets. Development is optimal under moderately warm (60° to 80°F) temperatures and high humidity (80 to 90%). Broad mite is similar to cyclamen mite, but is found mostly on undersides of plant leaves. Mites disperse between plants on air currents and by mechanical transport such as on clothing. These mites can complete one generation in 7 to 21 days. Female bulb scale mites lay up to 28 eggs. Adults are found between the scales of the bulb and the neck region.

IPM Program For Tarsonemid Mites

DAMAGE

Feeding by cyclamen and broad mites is easily recognized on all hosts because affected leaves become characteristically cupped, dwarfed and thickened, and internodes are greatly shortened. Broad mite damage occurs more generally over the plant than cyclamen mite damage. Bulb scale mites can cause bronze streaks of discoloration, horizontal cracks, distortion, and death of leaves and flowers.

Damage by cyclamen mite (left) and broad mite

IPM Program For Tarsonemid Mites

BIOLOGICAL CONTROL

Neoseiulus californicus **and other species of predatory mites have been used for broad mite and cyclamen mite control.**

N. californicus **attacking mite egg**

IPM Program For Tarsonemid Mites

CULTURAL CONTROL

Keep production areas free of weeds that can serve as hosts for mite populations. Carefully inspect plants being brought in to start a new crop to ensure that they are free of pests, and disinfest the plants if needed. Disinfestation can be accomplished by immersing propagation stock in 110.3°F water for 30 minutes, or treatment at 100% relative humidity and 110.3°F for 1 hour. If hot spots of these mites are found in production areas, consider roguing affected plants and treating the surrounding plants.

MONITORING and WHEN TO TREAT

Visually inspect plants for typical damage symptoms as part of a weekly scouting program.

IPM Program For Tarsonemid Mites

MITICIDES

Read and follow the instructions on the label. Before using a pesticide for the first time or on a new crop or cultivar, treat a few plants and check for phytotoxicity.

Class	Pesticide (commercial name)	R.E.I.	Comments
macrocyclic lactone	abamectin (Avid 0.15EC)	12	Label permits low-volume application. Do not use through any type of irrigation system.
oil	clarified hydrophobic extract of neem oil (Triact 70)	4	Do not spray plants under stress. Pest must be completely covered with spray-this material may not effectively control melon aphid because it is often on the underside of lower leaves. May injury flowers. Don't use through any type of irrigation system.
	horticultural oil Ultra-Fine Oil SafTSide JMS Stylet Oil	4	Use as above for neem oil. Do not use with sulfur fungicides; check label for tank mix restrictions.

IPM Program For Tarsonemid Mites

MITICIDES

Class	Pesticide (commercial name)	R.E.I.	Comments
organochlorine	endosulfan (Endosulfan 3EC)	24	Check runoff restrictions. Chrysanthemums may exhibit phytotoxicity. Don't use through irrigation system or more than 3 lb ai/acre/season.
	dicofol (Kelthane 50WP)	48	Low-volume use. Do not use through any type of irrigation system.
pyridazinone	pyridaben (Sanmite 75WP)	12	Use at least 2 different chemicals between applications of Sanmite. Do not use fertilizers containing boron or apply through any type of irrigation system. Do not exceed 10.67 oz/acre/application.
soap	potash soap (Insecticidal soap) (M-Pede)	12	Must contact mite, so thorough coverage is important. Repeat weekly as needed up to 3 times. Test for phytotoxicity. Do not spray new transplants or newly rooted cuttings. Do not add adjuvants.